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Contents

Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physical layer procedures for control operations in 5G-NR.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TS 38.201: "NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.211: "NR; Physical channels and modulation"

[5] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8-1] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[8-2] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[8-3] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios"

[8-4] 3GPP TS 38.101-4: "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[10] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[13] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"

[14] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"

[15] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access"

[16] 3GPP TS 38.473: "F1 application protocol (F1AP)"

[17] 3GPP TS 38.304: "NR; User Equipment (UE) procedures in Idle mode and RRC Inactive state"

[18] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities"

[19] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description"

[20] 3GPP TS 38.106: "NR; NR Repeater Radio Transmission and Reception"

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms and definitions given in [1, TR 21.905] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1, TR 21.905]. A parameter referenced in *italics* is provided by higher layers.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in [1, TR 21.905].

BPRE	Bits Per Resource Element
BWP	Bandwidth Part
CB	Code Block
CBG	Code Block Group
CBR	Channel Busy Ratio
CCE	Control Channel Element
CORESET	Control Resource Set
CP	Cyclic Prefix
CRC	Cyclic Redundancy Check
C-RNTI	Cell RNTI
CS-RNTI	Configured Scheduling RNTI
CSI	Channel State Information
CSS	Common Search Space
DAI	Downlink Assignment Index
DAPS	Dual Active Protocol Stack
DC	Dual Connectivity
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
EPRE	Energy Per Resource Element
EN-DC	E-UTRA NR Dual Connectivity with MCG using E-UTRA and SCG using NR
FR1	Frequency Range 1
FR2	Frequency Range 2
G-CS-RNTI	Group Configured Scheduling RNTI
G-RNTI	Group RNTI
GSCN	Global Synchronization Channel Number
HARQ-ACK	Hybrid Automatic Repeat reQuest Acknowledgement
MBS	Multicast Broadcast Services
MCG	Master Cell Group
MCS	Modulation and Coding Scheme
NCR	Network-controlled Repeater
NCR-Fwd	NCR Forwarding
NCR-MT	NCR Mobile Termination
NDI	New Data Indicator
NE-DC	NR E-UTRA Dual Connectivity with MCG using NR and SCG using E-UTRA
NR-DC	NR NR Dual Connectivity
PBCH	Physical Broadcast Channel

PCell	Primary Cell
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PO	Paging Occasion
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
PRG	Physical Resource block Group
PSCell	Primary Secondary Cell
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSFCH	Physical Sidelink Feedback Channel
PSS	Primary Synchronization Signal
PSSCH	Physical Sidelink Shared Channel
PUCCH	Physical Uplink Control Channel
PUCCH-SCell	PUCCH SCell
PUCCH-sSCell	PUCCH switching SCell
PUSCH	Physical Uplink Shared Channel
QCL	Quasi Co-Location
RB	Resource Block
RE	Resource Element
RLM	Radio Link Monitoring
RRM	Radio Resource Management
RS	Reference Signal
RSRP	Reference Signal Received Power
SCG	Secondary Cell Group
SCI	Sidelink Control Information
SCS	Subcarrier Spacing
SFCI	Sidelink Feedback Control Information
SFN	System Frame Number
SL	Sidelink
SLIV	Start and Length Indicator Value
SL PRS	Sidelink Positioning Reference Signal
SPS	Semi-Persistent Scheduling
SR	Scheduling Request
SRI	SRS Resource Indicator
SRS	Sounding Reference Signal
SSS	Secondary Synchronization Signal
SSSG	Search Space Set Group
TA	Timing Advance
TAG	Timing Advance Group
TB	Transport Block
TBG	Transport Block Group
TCI	Transmission Configuration Indicator
TO	Transmission Occasion
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
USS	UE-specific Search Space
UTO-UCI	Unused Transmission Occasion - UCI

4 Synchronization procedures

4.1 Cell search

Cell search is the procedure for a UE to acquire time and frequency synchronization with a cell and to detect the physical layer Cell ID of the cell.

A UE receives the following synchronization signals (SS) in order to perform cell search: the primary synchronization signal (PSS) and secondary synchronization signal (SSS) as defined in [4, TS 38.211].

A UE assumes that reception occasions of a physical broadcast channel (PBCH), PSS, and SSS are in consecutive symbols, as defined in [4, TS 38.211], and form a SS/PBCH block. The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE. The UE may assume that the ratio of PSS EPRE to SSS EPRE in a SS/PBCH block is either 0 dB or 3 dB. If the UE has not been provided dedicated higher layer parameters, the UE may assume that the ratio of PDCCH DMRS EPRE to SSS EPRE is within -8 dB and 8 dB when the UE monitors PDCCHs for a DCI format 1_0 with CRC scrambled by SI-RNTI, P-RNTI, or RA-RNTI, or for a DCI format 2_7, or for a DCI format 4_0.

For a half frame with SS/PBCH blocks, the first symbol indexes for candidate SS/PBCH blocks are determined according to the SCS of SS/PBCH blocks as follows, where index 0 corresponds to the first symbol of the first slot in a half-frame.

- Case A - 15 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes of $\{2,8\} + 14 \cdot n$.
  - For operation without shared spectrum channel access:
    - For carrier frequencies smaller than or equal to 3 GHz, $n = 0,1$.
    - For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1,2,3$.
  - For operation with shared spectrum channel access, as described in [15, TS 37.213], $n = 0, 1, 2, 3, 4$.
- Case B - 30 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{4,8,16,20\} + 28 \cdot n$. For carrier frequencies smaller than or equal to 3 GHz, $n = 0$. For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1$.
- Case C - 30 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2,8\} + 14 \cdot n$.
  - For operation without shared spectrum channel access
    - For paired spectrum operation
      - For carrier frequencies smaller than or equal to 3 GHz, $n = 0,1$. For carrier frequencies within FR1 larger than 3 GHz, $n = 0,1,2,3$.
    - For unpaired spectrum operation
      - For carrier frequencies smaller than 1.88 GHz, $n = 0,1$. For carrier frequencies within FR1 equal to or larger than 1.88 GHz, $n = 0,1,2,3$.
  - For operation with shared spectrum channel access, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9$.
- Case D - 120 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{4,8,16,20\} + 28 \cdot n$. For carrier frequencies within FR2, $n = 0, 1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18$.
- Case E - 240 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{8,12,16,20,32,36,40,44\} + 56 \cdot n$. For carrier frequencies within FR2-1, $n = 0, 1, 2, 3, 5, 6, 7, 8$.
- Case F – 480 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2, 9\} + 14 \cdot n$. For carrier frequencies within FR2-2, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31$.

- Case G – 960 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes $\{2, 9\} + 14 \cdot n$. For carrier frequencies within FR2-2, $n = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31$.

From the above cases, if the SCS of SS/PBCH blocks is not provided by *ssbSubcarrierSpacing*, the applicable cases for a cell depend on a respective frequency band, as provided in [8-1, TS 38.101-1] and [8-2, TS 38.101-2]. A same case applies for all SS/PBCH blocks on the cell. If a 30 kHz SS/PBCH block SCS is indicated by *ssbSubcarrierSpacing*, Case B applies for frequency bands with only 15 kHz SS/PBCH block SCS as specified in [8-1, TS 38.101-1], and the case specified for 30 kHz SS/PBCH block SCS in [8-1, TS 38.101-1] applies for frequency bands with 30 kHz SS/PBCH block SCS or both 15 kHz and 30 kHz SS/PBCH block SCS as specified in [8-1, TS 38.101-1]. For a UE configured to operate with carrier aggregation over a set of cells in a frequency band of FR2 or with frequency-contiguous carrier aggregation over a set of cells in a frequency band of FR1, if the UE is provided SCS values by *ssbSubcarrierSpacing* for receptions of SS/PBCH blocks on any cells from the set of cells, the UE expects the SCS values to be same.

The candidate SS/PBCH blocks in a half frame are indexed in an ascending order in time from 0 to $\overline{L}_{max} - 1$, where $\overline{L}_{max}$ is determined according to SS/PBCH block patterns for Cases A through G. L_{max} is a maximum number of SS/PBCH block indexes in a cell, and the maximum number of transmitted SS/PBCH blocks within a half frame is L_{max}.

- For operation without shared spectrum channel access in FR1 and FR2, and for operation with shared spectrum channel access in FR2-2, $L_{max} = \overline{L}_{max}$
- For operation with shared spectrum channel access in FR1, $L_{max} = 8$ for $\overline{L}_{max} = 10$ and 15 kHz SCS of SS/PBCH blocks and for $\overline{L}_{max} = 20$ and 30 kHz SCS of SS/PBCH blocks

For $\overline{L}_{max} = 4$, a UE determines the 2 LSB bits of a candidate SS/PBCH block index per half frame from a one-to-one mapping with an index of the DM-RS sequence transmitted in the PBCH as described in [4, TS 38.211].

For $\overline{L}_{max} > 4$, a UE determines the 3 LSB bits of a candidate SS/PBCH block index per half frame from a one-to-one mapping with an index of the DM-RS sequence transmitted in the PBCH as described in [4, TS 38.211]

- for $\overline{L}_{max} = 10$, the UE determines the 1 MSB bit of the candidate SS/PBCH block index from PBCH payload bit $\bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]
- for $\overline{L}_{max} = 20$, the UE determines the 2 MSB bits of the candidate SS/PBCH block index from PBCH payload bits $\bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]
- for $\overline{L}_{max} = 64$, the UE determines the 3 MSB bits of the candidate SS/PBCH block index from PBCH payload bits $\bar{a}_{\bar{A}+5}, \bar{a}_{\bar{A}+6}, \bar{a}_{\bar{A}+7}$ as described in [5, TS 38.212]

A UE can be provided per serving cell by *ssb-periodicityServingCell* a periodicity of the half frames for reception of the SS/PBCH blocks for the serving cell. If the UE is not configured a periodicity of the half frames for receptions of the SS/PBCH blocks, the UE assumes a periodicity of a half frame. A UE assumes that the periodicity is same for all SS/PBCH blocks in the serving cell.

For initial cell selection, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames.

For operation without shared spectrum channel access, an SS/PBCH block index is same as a candidate SS/PBCH block index.

For operation with shared spectrum channel access, a UE assumes that transmission of SS/PBCH blocks in a half frame is within a discovery burst transmission window that starts from the first symbol of the first slot in a half-frame. The UE can be provided per serving cell by *discoveryBurstWindowLength* a duration of the discovery burst transmission window. If *discoveryBurstWindowLength* is not provided, the UE assumes that the duration of the discovery burst transmission window is a half frame. For a serving cell, the UE assumes that a periodicity of the discovery burst transmission window is same as a periodicity of half frames for receptions of SS/PBCH blocks in the serving cell. The UE assumes that one or more SS/PBCH blocks indicated by *ssb-PositionsInBurst* may be transmitted within the discovery burst transmission window and have candidate SS/PBCH blocks indexes corresponding to SS/PBCH block indexes provided by *ssb-PositionsInBurst*. If MSB k, $k \geq 1$, of *ssb-PositionsInBurst* is set to 1, the UE assumes that SS/PBCH block(s) within the discovery burst transmission window with candidate SS/PBCH block index(es) corresponding to SS/PBCH block index equal to $k-1$ may be transmitted; if MSB k is set to 0, the UE assumes that the SS/PBCH block(s) are not transmitted. If MSB k, $k \geq 1$, of *inOneGroup* is set to 1, and MSB m, $m \geq 1$, of *groupPresence* is set to 1, the UE assumes that SS/PBCH block(s) within the discovery burst transmission window with candidate SS/PBCH block index(es) corresponding to SS/PBCH block index determined by k and m may be transmitted; otherwise, the UE assumes that the SS/PBCH block(s) are not transmitted.

For operation with shared spectrum channel access in FR1, a UE assumes that SS/PBCH blocks in a serving cell that are within a same discovery burst transmission window or across discovery burst transmission windows are quasi co-located with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable [6, TS 38.214], if a value of $\left(N_{DM-RS}^{PBCH} \bmod N_{SSB}^{QCL}\right)$ is same among the SS/PBCH blocks. N_{DM-RS}^{PBCH} is an index of a DM-RS sequence transmitted in a PBCH of a corresponding SS/PBCH block, and N_{SSB}^{QCL} is either provided by *ssb-PositionQCL* or, if *ssb-PositionQCL* is not provided, obtained from a *MIB* provided by a SS/PBCH block according to Table 4.1-1 with $k_{SSB} < 24$ [4, TS 38.211]. The UE can determine an SS/PBCH block index according to $\left(N_{DM-RS}^{PBCH} \bmod N_{SSB}^{QCL}\right)$, or according to $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$ where $\bar{\imath}$ is the candidate SS/PBCH block index. The UE assumes that within a discovery burst transmission window, a number of transmitted SS/PBCH blocks on a serving cell is not larger than N_{SSB}^{QCL} and a number of transmitted SS/PBCH blocks with a same SS/PBCH block index is not larger than one.

Table 4.1-1: Mapping between the combination of *subCarrierSpacingCommon* and LSB of *ssb-SubcarrierOffset* to N_{SSB}^{QCL} for operation with shared spectrum channel access in FR1

subCarrierSpacingCommon	LSB of *ssb-SubcarrierOffset*	N_{SSB}^{QCL}
scs15or60	0	1
scs15or60	1	2
scs30or120	0	4
scs30or120	1	8

For operation with shared spectrum channel access in FR2-2, a UE assumes that SS/PBCH blocks in a serving cell that are within a same discovery burst transmission window or across discovery burst transmission windows are quasi co-located with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable, if a value of $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$ is same among the SS/PBCH blocks, where $\bar{\imath}$ is the candidate SS/PBCH block index. N_{SSB}^{QCL} is either provided by *ssb-PositionQCL* or, if *ssb-PositionQCL* is not provided, obtained from a *MIB* provided by a SS/PBCH block according to Table 4.1-2. The UE can determine an SS/PBCH block index according to $\left(\bar{\imath} \bmod N_{SSB}^{QCL}\right)$. The UE assumes that within a discovery burst transmission window, a number of transmitted SS/PBCH blocks on a serving cell is not larger than N_{SSB}^{QCL} and a number of transmitted SS/PBCH blocks with a same SS/PBCH block index is not larger than one.

Table 4.1-2: Mapping between *subCarrierSpacingCommon* to N_{SSB}^{QCL} for operation with shared spectrum channel access in FR2-2

subCarrierSpacingCommon	N_{SSB}^{QCL}
scs15or60	32
scs30or120	64

For operation without shared spectrum channel access in FR2-2, a UE expects a MIB in a SS/PBCH block to provide *subCarrierSpacingCommon* = 'scs30or120'.

Upon detection of a SS/PBCH block, the UE determines from *MIB* that a CORESET for Type0-PDCCH CSS set, as described in clause 13, is present if $k_{SSB} < 24$ [4, TS 38.211] for FR1 or if $k_{SSB} < 12$ for FR2. The UE determines from *MIB* that a CORESET for Type0-PDCCH CSS set is not present if $k_{SSB} > 23$ for FR1 or if $k_{SSB} > 11$ for FR2; the CORESET for Type0-PDCCH CSS set may be provided by *PDCCH-ConfigCommon*.

For a serving cell without transmission of SS/PBCH blocks, a UE acquires time and frequency synchronization with the serving cell based on receptions of SS/PBCH blocks on the PCell, or on the PSCell, or on an SCell if applicable as described in [10, TS 38.133], of the cell group for the serving cell.

4.2 Transmission timing adjustments

A UE can be provided a value $N_{\text{TA,offset}}$ of a timing advance offset for a serving cell by *n-TimingAdvanceOffset* for the serving cell. If for a serving cell the UE is provided two *coresetPoolIndex* values 0 and 1 for first and second CORESETs, or is not provided *coresetPoolIndex* value for first CORESETs and is provided *coresetPoolIndex* value of 1 for second CORESETs, the UE can be provided first and second $N_{\text{TA,offset}}$ values by *n-TimingAdvanceOffset* and *n-TimingAdvanceOffset2* for transmissions with first and second spatial filters associated with first and second TCI states for the first and second CORESETs, respectively. A UE can be provided a second $N_{\text{TA,offset}}$ value for transmissions with second spatial domain filters corresponding to second TCI states or to second SS/PBCH block receptions associated with *physCellId* different from *physCellId* for the serving cell in addition to a first $N_{\text{TA,offset}}$ value for transmissions with first spatial domain filters corresponding to first TCI states or to first SS/PBCH block receptions associated with *physCellId* for the serving cell. The first and second $N_{\text{TA,offset}}$ values correspond to first and second TAGs indicated in respective MAC RARs [11, TS 38.321] having an association indicated by *tag-Id-ptr* with first and second joint TCI states provided by *dl-OrJointTCI-StateList* or first and second UL TCI states provided by *ul-TCI-State-List*. If the UE is not provided *n-TimingAdvanceOffset* for a serving cell, the UE determines a default value $N_{\text{TA,offset}}$ of the timing advance offset for the serving cell as described in [10, TS 38.133].

If a UE is configured with two UL carriers for a serving cell, a same timing advance offset value $N_{\text{TA,offset}}$ applies to both carriers for transmissions on the serving cell that are associated with a same TAG. The UE does not expect to apply two $N_{\text{TA,offset}}$ values for transmissions on the SUL carrier.

Upon reception of a timing advance command for a TAG, the UE adjusts uplink timing for PUSCH/SRS/PUCCH transmission on all the serving cells in the TAG based on a value $N_{\text{TA,offset}}$ that the UE expects to be same for all the serving cells in the TAG and based on the received timing advance command where the uplink timing for PUSCH/SRS/PUCCH transmissions is the same for all the serving cells in the TAG.

For a band with synchronous contiguous intra-band EN-DC in a band combination with non-applicable maximum transmit timing difference requirements as described in Note 1 of Table 7.5.3-1 of [10, TS 38.133], if the UE indicates *ul-TimingAlignmentEUTRA-NR* as 'required' and uplink transmission timing based on timing adjustment indication for a TAG from MCG and a TAG from SCG are determined to be different by the UE, the UE adjusts the transmission timing for PUSCH/SRS/PUCCH transmission on all serving cells part of the band with the synchronous contiguous intra-band EN-DC based on timing adjustment indication for a TAG from a serving cell in MCG in the band. The UE is not expected to transmit a PUSCH/SRS/PUCCH in one CG when the PUSCH/SRS/PUCCH is overlapping in time, even partially, with random access preamble transmitted in another CG.

For a SCS of $2^{\mu} \cdot 15$ kHz, the timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG in multiples of $16 \cdot 64 \cdot T_c/2^{\mu}$. The start timing of the random access preamble is described in [4, TS 38.211].

A timing advance command [11, TS 38.321] in case of random access response or in an absolute timing advance command MAC CE or in a cell switch command, T_A, for a TAG indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 3846, where an amount of the time alignment for the TAG with SCS of $2^{\mu} \cdot 15$ kHz is $N_{\text{TA}} = T_A \cdot 16 \cdot 64/2^{\mu}$. N_{TA} is defined in [4, TS 38.211] and is relative to the SCS of the first uplink transmission from the UE after the reception of the random access response or absolute timing advance command MAC CE or the cell switch command.

In other cases, a timing advance command [11, TS 38.321], T_A, for a TAG indicates adjustment of a current N_{TA} value, $N_{\text{TA\_old}}$, to the new N_{TA} value, $N_{\text{TA\_new}}$, by index values of T_A = 0, 1, 2,..., 63, where for a SCS of $2^{\mu} \cdot 15$ kHz, $N_{\text{TA\_new}} = N_{\text{TA\_old}} + (T_A - 31) \cdot 16 \cdot 64/2^{\mu}$.

If a UE has multiple active UL BWPs, as described in clause 12, in a same TAG, including UL BWPs in two UL carriers of a serving cell, the timing advance command value is relative to the largest SCS of the multiple active UL BWPs. The applicable $N_{\text{TA\_new}}$ value for an UL BWP with lower SCS may be rounded to align with the timing advance granularity for the UL BWP with the lower SCS while satisfying the timing advance accuracy requirements in [10, TS 38.133].

Adjustment of an N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a corresponding amount, respectively.

For a timing advance command received on uplink slot n and for a transmission other than a PUSCH scheduled by a RAR UL grant or a fallbackRAR UL grant as described in clause 8.2A or 8.3, or a PUCCH with HARQ-ACK information in response to a successRAR as described in clause 8.2A, the corresponding adjustment of the uplink transmission timing applies from the beginning of uplink slot $n + k + 1 + 2^{\mu} \cdot K_{\text{offset}}$ where $k = \lceil N_{\text{slot}}^{\text{subframe},\mu} \cdot$

$\left(N_{\mathrm{T},1}+N_{\mathrm{T},2}+N_{\mathrm{TA,max}}+0.5\right)/T_{\mathrm{sf}}\rceil$, $N_{\mathrm{T},1}$ is a time duration in msec of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured, $N_{\mathrm{T},2}$ is a time duration in msec of N_2 symbols corresponding to a PUSCH preparation time for UE processing capability 1 [6, TS 38.214], $N_{\mathrm{TA,max}}$ is the maximum timing advance value in msec that can be provided by a TA command field of 12 bits, $N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ is the number of slots per subframe, T_{sf} is the subframe duration of 1 msec, and $K_{\mathrm{offset}}=K_{\mathrm{cell,offset}}-K_{\mathrm{UE,offset}}$, where $K_{\mathrm{cell,offset}}$ is provided by *cellSpecificKoffset* and $K_{\mathrm{UE,offset}}$ is provided by a Differential Koffset MAC CE command [11, TS 38.321]; otherwise, if not respectively provided, $K_{\mathrm{cell,offset}}=0$ or $K_{\mathrm{UE,offset}}=0$. N_1 and N_2 are determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG and of all configured DL BWPs for the corresponding downlink carriers. For $\mu=0$, the UE assumes $N_{1,0}=14$ [6, TS 38.214]. Slot n and $N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ are determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG. $N_{\mathrm{TA,max}}$ is determined with respect to the minimum SCS among the SCSs of all configured UL BWPs for all uplink carriers in the TAG and for all configured initial UL BWPs provided by *initialUplinkBWP*. The uplink slot n is the last slot among uplink slot(s) overlapping with the slot(s) of PDSCH reception assuming $T_{TA}=0$, where the PDSCH provides the timing advance command and T_{TA} is defined in [4, TS 38.211].

If a UE changes an active UL BWP between a time of a timing advance command reception and a time of applying a corresponding adjustment for the uplink transmission timing, the UE determines the timing advance command value based on the SCS of the new active UL BWP. If the UE changes an active UL BWP after applying an adjustment for the uplink transmission timing, the UE assumes a same absolute timing advance command value before and after the active UL BWP change.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as described in [10, TS 38.133], the UE changes N_{TA} accordingly. If a UE operates with two TAGs on an active UL BWP of a serving cell, the UE expects that a difference between a first downlink timing associated with a first TAG and a second downlink timing associated with a second TAG is not larger than the CP length for the active UL BWP unless the UE indicates *larger-thanCP-capability*. If a UE indicates *XYZ_capability*, and transmits SRS based on a configuration by *SRS-PosResourceSet* in *SRS-PosRRC-InactiveConfig-ValidityArea* in RRC_INACTIVE state,

- if the UE is provided *SRS-autonomousTAupdate*, the UE may autonomously update N_{TA} at cell reselection as described in [10, TS 38.133]

- if the UE is not provided *SRS-autonomousTAupdate*, the UE maintains the N_{TA} of a last serving cell prior to the release of a dedicated RRC connection [11, TS 38.321].

For operation with single TAG on a serving cell, if two adjacent slots overlap due to a TA command or due to update of $N_{\mathrm{TA,adj}}^{\mathrm{UE}}$ or $N_{\mathrm{TA,adj}}^{\mathrm{common}}$, when applicable, the latter slot is reduced in duration relative to the former slot. The UE does not change N_{TA} during an actual time domain window for a PUSCH or a PUCCH transmission [6, TS 38.214]. If the UE is not provided *enableSTx2PofMDCI* and operates with two TAGs on a serving cell, the UE does not expect transmissions associated with different TAGs to overlap unless the UE indicates *XYZ*; if the UE indicates *XYZ*, the UE reduces in duration a latter transmission using a first TAG to avoid overlapping with a former transmission using a second TAG.

Using higher-layer ephemeris parameters for a serving satellite, if provided, a UE pre-compensates the two-way transmission delay on the service link based on $N_{\mathrm{TA,adj}}^{\mathrm{UE}}$ that the UE determines using the serving satellite position and its own position. To pre-compensate the two-way transmission delay between the uplink time synchronization reference point and the serving satellite, the UE determines $N_{\mathrm{TA,adj}}^{\mathrm{common}}$ [4, TS 38.211] based on one-way propagation delay $\mathrm{Delay}_{\mathrm{common}}(\mathrm{t})$ that the UE determines as:

$$\mathrm{Delay}_{\mathrm{common}}(t)=\frac{TA_{\mathrm{Common}}}{2}+\frac{TA_{\mathrm{CommonDrift}}}{2}\times\left(t-t_{\mathrm{epoch}}\right)+\frac{TA_{\mathrm{CommonDriftVariant}}}{2}\times\left(t-t_{\mathrm{epoch}}\right)^2$$

where TA_{Common}, $TA_{\mathrm{CommonDrift}}$, and $TA_{\mathrm{CommonDriftVariant}}$ are respectively provided by *ta-Common*, *ta-CommonDrift*, and *ta-CommonDriftVariant* and t_{epoch} is provided by *epochTime* which is the epoch time of *ta-Common*, *ta-CommonDrift*, and *ta-CommonDriftVariant* [12, TS 38.331]. $Delay_{common}(t)$ provides a distance at time t between the serving satellite and the uplink time synchronization reference point divided by the speed of light. The uplink time synchronization reference point is the point where DL and UL are frame aligned with an offset given by $N_{\mathrm{TA,offset}}$.

4.3 Timing for secondary cell activation / deactivation

With reference to slots for PUCCH transmissions, when a UE receives in a PDSCH an activation command [11, TS 38.321] for a secondary cell ending in slot *n*, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133] and no earlier than slot $n+k$, except for the following:

- the actions related to CSI reporting on a serving cell that is active in slot $n+k$
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [11, TS 38.321] that the UE applies in slot $n+k$
- the actions related to CSI reporting on a serving cell which is not active in slot $n+k$ that the UE applies in the earliest slot after $n+k$ in which the serving cell is active.

The value of k is $m + 3\,N_{\text{slot}}^{\text{subframe},\mu} + 1$ where slot *n*+*m* is a slot indicated for PUCCH transmission with HARQ-ACK information for the PDSCH reception as described in clause 9.2.3 and $N_{\text{slot}}^{\text{subframe},\mu}$ is a number of slots per subframe for the SCS configuration μ of the PUCCH transmission as defined in [4, TS 38.211].

With reference to slots for PUCCH transmissions, if a UE receives a deactivation command [11, TS 38.321] for a secondary cell ending in slot n, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133], except for the actions related to CSI reporting on an activated serving cell which the UE applies in slot $n+k$.

If the *sCellDeactivationTimer* associated with the secondary cell expires in slot n, the UE applies the corresponding actions in [11, TS 38.321] no later than the minimum requirement defined in [10, TS 38.133], except for the actions related to CSI reporting on an activated serving cell which the UE applies in the first slot that is after slot $n+3\cdot N_{\text{slot}}^{\text{subframe},\mu}$ where μ is the SCS configuration for PDSCH reception on the secondary cell.

5 Radio link monitoring

The downlink radio link quality of the primary cell is monitored by a UE for the purpose of indicating out-of-sync/in-sync status to higher layers. The UE is not required to monitor the downlink radio link quality in DL BWPs other than the active DL BWP, as described in clause 12, on the primary cell unless the UE indicates a capability *rlm-BM-BFD-L3-IntraFreq-CD-SSB-MeasWithoutInterrupt* [18, TS 38.306]. If the active DL BWP is the initial DL BWP and for SS/PBCH block and CORESET multiplexing pattern 2 or 3, as described in clause 13, the UE is expected to perform RLM using the associated SS/PBCH block when the associated SS/PBCH block index is provided by *RadioLinkMonitoringRS*.

If the UE is configured with a SCG, as described in [12, TS 38.331], and the parameter *rlf-TimersAndConstants* is provided by higher layers and is not set to release, the downlink radio link quality of the PSCell of the SCG is monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers. The UE is not required to monitor the downlink radio link quality in DL BWPs other than the active DL BWP on the PSCell unless the UE indicates a capability *rlm-BM-BFD-L3-IntraFreq-CD-SSB-MeasWithoutInterrupt* [18, TS 38.306].

A UE can be configured for each DL BWP of a SpCell [11, TS 38.321] with a set of resource indexes, through a corresponding set of *RadioLinkMonitoringRS*, for radio link monitoring by *failureDetectionResources*. The UE is provided either a CSI-RS resource configuration index, by *csi-RS-Index*, or a SS/PBCH block index, by *ssb-Index*. The UE can be configured with up to $N_{\text{LR}-\text{RLM}}$ *RadioLinkMonitoringRS* for link recovery procedures, as described in clause 6, and for radio link monitoring. From the $N_{\text{LR}-\text{RLM}}$ *RadioLinkMonitoringRS*, up to N_{RLM} *RadioLinkMonitoringRS* can be used for radio link monitoring depending on L_{max} as described in Table 5-1, wherein L_{max} is as defined in clause 4.1, and up to two *RadioLinkMonitoringRS* can be used for link recovery procedures.

For operation with shared spectrum channel access, when a UE is provided a SS/PBCH block index by *ssb-Index*, the UE is expected to perform radio link monitoring using SS/PBCH block(s) in the discovery burst transmission window as described in clause 4.1, where the SS/PBCH block(s) have candidate SS/PBCH block index(es) corresponding to SS/PBCH block index provided by *ssb-Index*.

If the UE is not provided *RadioLinkMonitoringRS* and the UE is provided for PDCCH receptions TCI states that include one or more of a CSI-RS

- the UE uses for radio link monitoring the RS provided for the active TCI state for PDCCH reception if the active TCI state for PDCCH reception includes only one RS
- if the active TCI state for PDCCH reception includes two RS, the UE expects that one RS is configured with *qcl-Type* set to 'typeD' [6, TS 38.214] and the UE uses the RS configured with *qcl-Type* set to 'typeD' for radio link monitoring; the UE does not expect both RS to be configured with *qcl-Type* set to 'typeD'
- the UE is not required to use for radio link monitoring an aperiodic or semi-persistent RS
- For $L_{max} = 4$, the UE selects the N_{RLM} RS provided for active TCI states for PDCCH receptions in CORESETs associated with the search space sets in an order from the shortest monitoring periodicity. If more than one CORESETs are associated with search space sets having same monitoring periodicity, the UE determines the order of the CORESET from the highest CORESET index as described in clause 10.1.

A UE does not expect to use more than N_{RLM} *RadioLinkMonitoringRS* for radio link monitoring when the UE is not provided *RadioLinkMonitoringRS*.

Values of $N_{\mathrm{LR-RLM}}$ and N_{RLM} for different values of L_{max} are given in Table 5-1.

Table 5-1: $N_{\mathrm{LR-RLM}}$ and N_{RLM} as a function of maximum number L_{max} of SS/PBCH blocks per half frame

L_{max}	$N_{\mathrm{LR-RLM}}$	N_{RLM}
4	2	2
8	6	4
64	8	8

For a CSI-RS resource configuration, *powerControlOffsetSS* is not applicable and a UE expects to be provided only 'noCDM' from *cdm-Type,* only 'one' and 'three' from *density*, and only '1 port' from *nrofPorts* [6, TS 38.214].

If a UE is configured with multiple DL BWPs for a serving cell, the UE performs RLM using the RS(s) corresponding to resource indexes provided by *RadioLinkMonitoringRS* for the active DL BWP or, if *RadioLinkMonitoringRS* is not provided for the active DL BWP, using the RS(s) provided for the active TCI state for PDCCH receptions in CORESETs on the active DL BWP.

In non-DRX mode operation, the physical layer in the UE assesses once per indication period the radio link quality, evaluated over the previous time period defined in [10, TS 38.133] against thresholds (Q_{out} and Q_{in}) configured by *rlmInSyncOutOfSyncThreshold*. The UE determines the indication period as the maximum between the shortest periodicity for radio link monitoring resources and 10 msec.

In DRX mode operation, the physical layer in the UE assesses once per indication period the radio link quality, evaluated over the previous time period defined in [10, TS 38.133], against thresholds (Q_{out} and Q_{in}) provided by *rlmInSyncOutOfSyncThreshold*. The UE determines the indication period as the maximum between the shortest periodicity for radio link monitoring resources and the DRX period.

The physical layer in the UE indicates, in frames where the radio link quality is assessed, out-of-sync to higher layers when the radio link quality is worse than the threshold Q_{out} for all resources in the set of resources for radio link monitoring. When the radio link quality is better than the threshold Q_{in} for any resource in the set of resources for radio link monitoring, the physical layer in the UE indicates, in frames where the radio link quality is assessed, in-sync to higher layers.

6 Link recovery procedures

A UE can be provided, for each BWP of a serving cell, a set $\bar{q}_0$ of periodic CSI-RS resource configuration indexes by *failureDetectionResourcesToAddModList* and a set $\bar{q}_1$ of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by *candidateBeamRSList* or *candidateBeamRSListExt* or *candidateBeamRSSCellList* for radio link quality measurements on the BWP of the serving cell. Instead of the sets $\bar{q}_0$ and $\bar{q}_1$, for each BWP of a serving cell, the UE can be provided respective two sets $\bar{q}_{0,0}$ and $\bar{q}_{0,1}$ of periodic CSI-RS resource configuration indexes by *failureDetectionSet1* and *failureDetectionSet2* that can be activated by a MAC CE [11 TS 38.321] and corresponding two sets $\bar{q}_{1,0}$ and $\bar{q}_{1,1}$ of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by *candidateBeamRS-List* and *candidateBeamRS-List2*, respectively, for radio link quality measurements on the BWP of the serving cell. The set $\bar{q}_{0,0}$ is associated with the set $\bar{q}_{1,0}$ and the set $\bar{q}_{0,1}$ is associated with the set $\bar{q}_{1,1}$.

If the UE is not provided $\bar{q}_0$ by *failureDetectionResourcesToAddModList* for a BWP of the serving cell, the UE determines the set $\bar{q}_0$ to include periodic CSI-RS resource configuration indexes with same values as the RS indexes in the RS sets indicated by *TCI-State* for respective CORESETs that the UE uses for monitoring PDCCH. If the UE is not provided $\bar{q}_{0,0}$ and $\bar{q}_{0,1}$ for a BWP of the serving cell, the UE determines the set $\bar{q}_{0,0}$ and $\bar{q}_{0,1}$ to include periodic CSI-RS resource configuration indexes with same values as the RS indexes in the RS sets indicated by *TCI-State* for first and second CORESETs that the UE uses for monitoring PDCCH, respectively, where the UE is provided two *coresetPoolIndex* values 0 and 1 for the first and second CORESETs, or is not provided *coresetPoolIndex* value for the first CORESETs and is provided *coresetPoolIndex* value of 1 for the second CORESETs, respectively. If there are two RS indexes in a TCI state, the set $\bar{q}_0$ or $\bar{q}_{0,0}$, or $\bar{q}_{0,1}$ includes RS indexes configured with *qcl-Type* set to 'typeD' for the corresponding TCI states. If a CORESET that the UE uses for monitoring PDCCH includes two TCI states and the UE is provided *sfnSchemePdcch* set to 'sfnSchemeA' or 'sfnSchemeB', the set $\bar{q}_0$ includes RS indexes in the RS sets associated with the two TCI states.

The UE expects the set $\bar{q}_0$ to include up to two RS indexes. If the UE is provided $\bar{q}_{0,0}$ or $\bar{q}_{0,1}$, the UE expects the set $\bar{q}_{0,0}$ or the set $\bar{q}_{0,1}$ to include up to a number of N_{BFD} RS indexes indicated by *maxBFD-RS-resourcesPerSetPerBWP*. If the UE is not provided $\bar{q}_{0,0}$ or $\bar{q}_{0,1}$, and if a number of active TCI states for PDCCH receptions in the first or second CORESETs is larger than N_{BFD}, the UE determines the set $\bar{q}_{0,0}$ or $\bar{q}_{0,1}$ to include periodic CSI-RS resource configuration indexes with same values as the RS indexes in the RS sets associated with the active TCI states for PDCCH receptions in the first or second CORESETs corresponding to search space sets according to an ascending order for PDCCH monitoring periodicity. If more than one first or second CORESETs correspond to search space sets with same monitoring periodicity, the UE determines the order of the first or second CORESETs according to a descending order of a CORESET index.

If a UE

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on an active DL BWP of a serving cell,
- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on the active DL BWP of the serving cells, and
- is provided *SSB-MTCAdditionalPCI*

SS/PBCH block indexes associated with a physical cell identity other than the one provided by *physCellId* in *ServingCellConfigCommon* can be provided in $\bar{q}_{1,1}$ set and the corresponding $\bar{q}_{0,1}$ set is associated with the physical cell identity.

The UE expects single port RS in the set $\bar{q}_0$, or $\bar{q}_{0,0}$, or $\bar{q}_{0,1}$. The UE expects single-port or two-port CSI-RS with frequency density equal to 1 or 3 REs per RB in the set $\bar{q}_1$, or $\bar{q}_{1,0}$, or $\bar{q}_{1,1}$. The thresholds $Q_{\mathrm{out,LR}}$ and $Q_{\mathrm{in,LR}}$ correspond to the default value of *rlmInSyncOutOfSyncThreshold*, as described in [10, TS 38.133] for Q_{out}, and to the value provided by *rsrp-ThresholdSSB* or *rsrp-ThresholdBFR*, respectively.

The physical layer in the UE assesses the radio link quality according to the set $\bar{q}_0$, $\bar{q}_{0,0}$, or $\bar{q}_{0,1}$, of resource configurations against the threshold $Q_{\mathrm{out,LR}}$. For the set $\bar{q}_0$, the UE assesses the radio link quality only according to SS/PBCH blocks on the PCell or the PSCell or periodic CSI-RS resource configurations that are quasi co-located, as described in [6, TS 38.214], with the DM-RS of PDCCH receptions by the UE. The UE applies the $Q_{\mathrm{in,LR}}$ threshold to the L1-RSRP measurement obtained from a SS/PBCH block. The UE applies the $Q_{\mathrm{in,LR}}$ threshold to the L1-RSRP measurement obtained for a CSI-RS resource after scaling a respective CSI-RS reception power with a value provided by *powerControlOffsetSS*.

In non-DRX mode operation, the physical layer in the UE provides an indication to higher layers when the radio link quality for all corresponding resource configurations in the set $\bar{q}_0$, or in the set $\bar{q}_{0,0}$ or $\bar{q}_{0,1}$, that the UE uses to assess the radio link quality is worse than the threshold $Q_{\mathrm{out,LR}}$. The physical layer informs the higher layers when the radio link quality is worse than the threshold $Q_{\mathrm{out,LR}}$ with a periodicity determined by the maximum between the shortest periodicity among the SS/PBCH blocks on the PCell or the PSCell and/or the periodic CSI-RS configurations in the set $\bar{q}_0$, $\bar{q}_{0,0}$, or $\bar{q}_{0,1}$ that the UE uses to assess the radio link quality and 2 msec. In DRX mode operation, the physical layer provides an indication to higher layers when the radio link quality is worse than the threshold $Q_{out,LR}$ with a periodicity determined as described in [10, TS 38.133].

For the PCell or the PSCell, upon request from higher layers, the UE provides to higher layers the periodic CSI-RS configuration indexes and/or SS/PBCH block indexes from the set $\bar{q}_1$, or $\bar{q}_{1,0}$, or $\bar{q}_{1,1}$ and the corresponding L1-RSRP measurements that are larger than or equal to the $Q_{in,LR}$ threshold.

For the SCell, upon request from higher layers, the UE indicates to higher layers whether there is at least one periodic CSI-RS configuration index or SS/PBCH block index from the set $\bar{q}_1$, or $\bar{q}_{1,0}$, or $\bar{q}_{1,1}$ with corresponding L1-RSRP measurements that is larger than or equal to the $Q_{in,LR}$ threshold, and provides the periodic CSI-RS configuration indexes and/or SS/PBCH block indexes from the set $\bar{q}_1$, or $\bar{q}_{1,0}$, or $\bar{q}_{1,1}$ and the corresponding L1-RSRP measurements that are larger than or equal to the $Q_{in,LR}$ threshold, if any.

For the PCell or the PSCell, a UE can be provided a CORESET through a link to a search space set provided by *recoverySearchSpaceId*, as described in clause 10.1, for monitoring PDCCH in the CORESET. If the UE is provided *recoverySearchSpaceId*, the UE does not expect to be provided another search space set for monitoring PDCCH in the CORESET associated with the search space set provided by *recoverySearchSpaceId*.

For the PCell or the PSCell, the UE can be provided, by *PRACH-ResourceDedicatedBFR*, a configuration for PRACH transmission as described in clause 8.1. For PRACH transmission in slot n and according to antenna port quasi co-location parameters associated with periodic CSI-RS resource configuration or with SS/PBCH block associated with index q_{new} provided by higher layers [11, TS 38.321], the UE monitors PDCCH in a search space set provided by *recoverySearchSpaceId* for detection of a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI starting from slot $n + 4 + 2^{\mu} \cdot k_{\mathrm{mac}}$, where μ is the SCS configuration for the PRACH transmission and k_{mac} is a number of slots provided by *kmac* [12, TS 38.331] or $k_{\mathrm{mac}} = 0$ if *kmac* is not provided, within a window configured by *BeamFailureRecoveryConfig*. For PDCCH monitoring in a search space set provided by *recoverySearchSpaceId* and for corresponding PDSCH receptions, the UE assumes the same antenna port quasi-collocation parameters as the ones associated with index q_{new} until the UE receives by higher layers an activation for a TCI state or any of the parameters *tci-StatesPDCCH-ToAddList* and/or *tci-StatesPDCCH-ToReleaseList*. After the UE detects a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI in the search space set provided by *recoverySearchSpaceId*, the UE continues to monitor PDCCH candidates in the search space set provided by *recoverySearchSpaceId* until the UE receives a MAC CE activation command for a TCI state or *tci-StatesPDCCH-ToAddList* and/or *tci-StatesPDCCH-ToReleaseList*.

For the PCell or the PSCell, after 28 symbols from a last symbol of a first PDCCH reception in a search space set provided by *recoverySearchSpaceId* for which the UE detects a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI and until the UE receives an activation command for *PUCCH-SpatialRelationInfo* [11, TS 38.321] or is provided *PUCCH-SpatialRelationInfo* for PUCCH resource(s), the UE transmits a PUCCH on a same cell as the PRACH transmission using

- a same spatial filter as for the last PRACH transmission
- a power determined as described in clause 7.2.1 with $q_u = 0$, $q_d = q_{\mathrm{new}}$, and $l = 0$

For the PCell or the PSCell and for sets $\bar{q}_0$ and $\bar{q}_1$, after 28 symbols from a last symbol of a first PDCCH reception in a search space set provided by *recoverySearchSpaceId* where a UE detects a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI, the UE assumes same antenna port quasi-collocation parameters as the ones associated with index q_{new} for PDCCH monitoring in a CORESET with index 0.

If a UE is provided *dl-OrJointTCI-StateList* or *ul-TCI-StateList* and is indicated one or two TCI state(s) for the PCell or the PSCell [6, TS 38.214] associated with $\bar{q}_0$ and $\bar{q}_1$, after 28 symbols from a last symbol of a first PDCCH reception in a search space set provided by *recoverySearchSpaceId* where the UE detects a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI, the UE

- if *SSB-MTC-AdditionalPCI* is not provided, monitors PDCCH in all CORESETs, and receives PDSCH and aperiodic CSI-RS resource in a CSI-RS resource set with same indicated TCI state as for the PDCCH and PDSCH, using the same antenna port quasi co-location parameters as the ones associated with the corresponding index q_{new}, if any
- transmits PUSCH, PUCCH and SRS that uses a same spatial domain filter with same indicated TCI state as for the PUSCH and the PUCCH, using a same spatial domain filter as for the last PRACH transmission using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1
  - the RS index $q_d = q_{\mathrm{new}}$ for obtaining the downlink pathloss estimate

  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell
  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell
  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell

For the remaining of this clause, if a PDCCH reception includes two PDCCH candidates from two linked search space sets based on *searchSpaceLinkingId*, as described in clause 10.1, the last symbol of the PDCCH reception is the last symbol of the PDCCH candidate that ends later. The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

For the PCell or the PSCell, if BFR MAC CE [11, TS 38.321] is provided in Msg3 or MsgA of contention based random access procedure, and if a PUCCH resource is provided with *PUCCH-SpatialRelationInfo*, after 28 symbols from the last symbol of the PDCCH reception that determines the completion of the contention based random access procedure as described in clause 5.1.4a or in clause 5.1.5 of [11, TS 38.321], the UE transmits the PUCCH on a same cell as the PRACH transmission using

- a same spatial filter as for the last PRACH transmission
- a power determined as described in clause 7.2.1 with $q_u = 0$, $q_d = q_{\mathrm{new}}$, and $l = 0$, where q_{new} is the SS/PBCH block index selected for the last PRACH transmission.

If a UE is provided *dl-OrJointTCI-StateList* or *ul-TCI-StateList* and is indicated one or two TCI state(s) for the PCell or the PSCell associated with $\bar{q}_0$ and $\bar{q}_1$, and the UE provides BFR MAC CE in Msg3 or MsgA of contention based random access procedure, after 28 symbols from the last symbol of the PDCCH reception that determines the completion of the contention based random access procedure as described in [11, TS 38.321], the UE

- if *SSB-MTC-AdditionalPCI* is not provided, monitors PDCCH in all CORESETs, and receives PDSCH and aperiodic CSI-RS resource in a CSI-RS resource set with same indicated TCI state as for the PDCCH and PDSCH using the same antenna port quasi co-location parameters as the ones associated with the corresponding index q_{new}, if any
- transmits PUSCH, PUCCH and SRS that uses a same spatial domain filter with same indicated TCI state as for the PUSCH and PUCCH, using a same spatial domain filter as for the last PRACH transmission using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1
  - the RS index $q_d = q_{\mathrm{new}}$ for obtaining the downlink pathloss estimate
  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell
  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell
  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the PCell or the PSCell

A UE can be provided, by *schedulingRequestID-BFR-SCell*, a configuration for PUCCH transmission with a link recovery request (LRR) as described in clause 9.2.4 for the UE to transmit PUCCH [11, TS 38.321]. If the PCell or the PSCell is associated with sets $\bar{q}_{0,0}$ and $\bar{q}_{1,0}$, and with sets $\bar{q}_{0,1}$ and $\bar{q}_{1,1}$, the UE can be provided by *schedulingRequestID-BFR* a first configuration for PUCCH transmission with a LRR and, if the UE provides *twoLRRcapability*, the UE can be provided by *schedulingRequestID-BFR2* a second configuration for PUCCH transmission with a LRR. If the UE is provided only the first configuration, the UE transmits a PUCCH with LRR for either set $\bar{q}_{0,0}$ or $\bar{q}_{0,1}$. If the UE is provided both the first and second configurations, the UE uses the first configuration to transmt a PUCCH with LRR associated with set $\bar{q}_{0,0}$ and the second configuration to transmit a PUCCH with LRR associated with set $\bar{q}_{0,1}$ [11, TS 38.321].

The UE can provide in a first PUSCH MAC CE index(es) for at least corresponding SCell(s) with radio link quality worse than $Q_{\mathrm{out,LR}}$, indication(s) of presence of q_{new} for corresponding SCell(s), and index(es) q_{new} for a periodic CSI-RS configuration or for a SS/PBCH block provided by higher layers, as described in [11, TS 38.321], if any, for corresponding SCell(s). After 28 symbols from a last symbol of a PDCCH reception with a DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the first PUSCH and having a toggled NDI field value, the UE

- monitors PDCCH in all CORESETs on the SCell(s) indicated by the MAC CE using the same antenna port quasi co-location parameters as the ones associated with the corresponding index(es) q_{new}, if any
- transmits PUCCH on a PUCCH-SCell using a same spatial domain filter as the one corresponding to q_{new}, if any, for periodic CSI-RS or SS/PBCH block reception, as described in clause 9.2.2, and using a power determined as described in clause 7.2.1 with $q_{\mathrm{u}} = 0$, $q_{\mathrm{d}} = q_{\mathrm{new}}$, and $l = 0$, if
  - the UE is provided *PUCCH-SpatialRelationInfo* for the PUCCH,
  - a PUCCH with the LRR was either not transmitted or was transmitted on the PCell or the PSCell, and
  - the PUCCH-SCell is included in the SCell(s) indicated by the MAC-CE

where the SCS configuration for the 28 symbols is the smallest of the SCS configurations of the active DL BWP for the PDCCH reception and of the active DL BWP(s) of the at least one SCell.

For serving cells associated with $\bar{q}_0$ and $\bar{q}_1$, if a UE is provided *dl-OrJointTCI-StateList* or *ul-TCI-StateList* and is indicated one or two TCI state(s), after 28 symbols from a last symbol of a PDCCH reception with a DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the first PUSCH and having a toggled NDI field value, the UE

- if *SSB-MTC-AdditionalPCI* is not provided, monitors PDCCH in all CORESETs, on the SCell (s) indicated by the MAC CE, and receives PDSCH and aperiodic CSI-RS resource in a CSI-RS resource set using the same antenna port quasi co-location parameters as the ones associated with the corresponding index q_{new}, if any
- transmits PUSCH, PUCCH and SRS that uses a same spatial domain filter with same indicated TCI state as for the PUSCH and PUCCH, using a same spatial domain filter as the one corresponding to q_{new}, if any, and using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1
  - the RS index $q_d = q_{\mathrm{new}}$ for obtaining the downlink pathloss estimate
  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the corresponding SCell
  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the corresponding SCell
  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the corresponding SCell

If there is at least one serving cell associated with sets $\bar{q}_{0,0}$ and $\bar{q}_{1,0}$, and with sets $\bar{q}_{0,1}$ and $\bar{q}_{1,1}$, the UE can provide in a second PUSCH MAC CE index(es) for cell(s) with $\bar{q}_0$ and/or with at least one of $\bar{q}_{0,0}$ and $\bar{q}_{0,1}$ having radio link quality worse than $Q_{\mathrm{out,LR}}$, the index(es) of those $\bar{q}_{0,0}$ and/or $\bar{q}_{0,1}$, and indication(s) of presence of q_{new} and of index(es) q_{new}, if any, from $\bar{q}_1$ and/or corresponding sets $\bar{q}_{1,0}$ and/or $\bar{q}_{1,1}$ for the serving cells.

For serving cells associated with sets $\bar{q}_{0,0}$ and $\bar{q}_{1,0}$, and with sets $\bar{q}_{0,1}$ and $\bar{q}_{1,1}$, and having radio link quality worse than $Q_{\mathrm{out,LR}}$, after 28 symbols from a last symbol of a first PDCCH reception with a DCI format scheduling a PUSCH transmission with a same HARQ process number as for transmission of the second PUSCH and having a toggled NDI field value, the UE assumes antenna port quasi-collocation parameters

- corresponding to q_{new} from $\bar{q}_{1,0}$, if any, for the first CORESETs,
- corresponding to q_{new} from $\bar{q}_{1,1}$, if any, for the second CORESETs

where the SCS configuration for the 28 symbols is the smallest of the SCS configurations of the active DL BWP for the PDCCH reception and of the active DL BWP(s) of the serving cells.

For a serving cell associated with sets $\bar{q}_{0,0}$ and $\bar{q}_{1,0}$, and with sets $\bar{q}_{0,1}$ and $\bar{q}_{1,1}$, and having radio link quality worse than $Q_{\mathrm{out,LR}}$, and if a UE is provided *dl-OrJointTCI-StateList* or *TCI-UL-State* and is indicated a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, after 28 symbols from a last symbol of a first PDCCH reception with a

DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the second PUSCH and having a toggled NDI field value, the UE

- monitors PDCCH that applies the first *TCI-State* state, and receives PDSCH and aperiodic CSI-RS resource that apply the first *TCI-State*, using same antenna port quasi co-location parameters as the ones associated with a corresponding index q_{new} from $\bar{q}_{1,0}$, if any, on the serving cell

- monitors PDCCH that applies the second *TCI-State*, and receives PDSCH and aperiodic CSI-RS resource that apply the second *TCI-State*, on the serving cell using same antenna port quasi co-location parameters as the ones associated with a corresponding index q_{new} from $\bar{q}_{1,1}$, if any, on the serving cell

- transmits PUSCH, PUCCH, and SRS that apply the first *TCI-State* or *TCI-UL-State* using a same spatial domain filter as the one corresponding to q_{new} from $\bar{q}_{1,0}$, if any, on the serving cell and using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1

  - the RS index $q_d = q_{\mathrm{new}}$ from $\bar{q}_{1,0}$, if any, for obtaining a corresponding downlink pathloss estimate for the serving cell

  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the serving cell

  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the serving cell

  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the serving cell

- transmits PUSCH, PUCCH, and SRS that apply the second *TCI-State* or *TCI-UL-State* using a same spatial domain filter as the one corresponding to q_{new} from $\bar{q}_{1,1}$, if any, on the serving cell and using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1

  - the RS index $q_d = q_{\mathrm{new}}$ from $\bar{q}_{1,1}$, if any, for obtaining a corresponding downlink pathloss estimate for the serving cell

  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the serving cell

  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the serving cell

  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the serving cell

where the SCS configuration for the 28 symbols is the smallest of the SCS configurations of the active DL BWP for the PDCCH reception and of the active DL BWP(s) of the serving cells.

For a serving cell associated with sets $\bar{q}_{0,0}$ and $\bar{q}_{1,0}$, and with sets $\bar{q}_{0,1}$ and $\bar{q}_{1,1}$, and having radio link quality worse than $Q_{\mathrm{out,LR}}$, and if a UE is provided two *coresetPoolIndex* values 0 and 1 for the first and second CORESETs, or is not provided *coresetPoolIndex* value for the first CORESETs and is provided *coresetPoolIndex* value of 1 for the second CORESETs, respectively, and the UE is provided *dl-OrJointTCI-StateList* or *TCI-UL-State*, after 28 symbols from a last symbol of a first PDCCH reception with a DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the second PUSCH and having a toggled NDI field value, the UE

- monitors PDCCH in the first CORESETs, and receives PDSCH scheduled/activated by PDCCH in the first CORESETs, and aperiodic CSI-RS resource that apply a *TCI-State* specific to the first CORESETs, using same antenna port quasi co-location parameters as the ones associated with a corresponding index q_{new} from $\bar{q}_{1,0}$, if any, for the serving cell

- monitors PDCCH in the second CORESETs, and receives PDSCH scheduled/activated by PDCCH in the second CORESETs, and aperiodic CSI-RS resource that apply a *TCI-State* specific to the second CORESETs, using the same antenna port quasi co-location parameters as the ones associated with the corresponding index q_{new} from $\bar{q}_{1,1}$, if any, for the serving cell

- transmits PUSCH, PUCCH, and SRS that apply *TCI-State* or *TCI-UL-State* specific to the first CORESETs using a same spatial domain filter as the one corresponding to q_{new} from $\bar{q}_{1,0}$, if any, for the serving cell and using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1
  - the RS index $q_d = q_{\mathrm{new}}$ from $\bar{q}_{1,0}$, if any, for obtaining a corresponding downlink pathloss estimate for the serving cell
  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the serving cell
  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the serving cell
  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the serving cell
- transmits PUSCH, PUCCH, and SRS that apply *TCI-State* or *TCI-UL-State* specific to the second CORESETs using a same spatial domain filter as the one corresponding to q_{new} from $\bar{q}_{1,1}$, if any, for the serving cell and using the following parameters for determination of a corresponding power as described in clauses 7.1.1, 7.2.1, and 7.3.1
  - the RS index $q_d = q_{\mathrm{new}}$ from $\bar{q}_{1,1}$, if any, for obtaining a corresponding downlink pathloss estimate for the serving cell
  - the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l provided by *p0AlphaSetforPUSCH* associated with the smallest value of *ul-powercontrolId* for the serving cell
  - the value of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)(q_u)$ and the PUCCH power control adjustment state l provided by *p0AlphaSetforPUCCH* associated with the smallest value of *ul-powercontrolId* for the serving cell
  - the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and the SRS power control adjustment state l provided by *p0AlphaSetforSRS* associated with the smallest value of *ul-powercontrolId* for the serving cell

where the SCS configuration for the 28 symbols is the smallest of the SCS configurations of the active DL BWP for the PDCCH reception and of the active DL BWP(s) of the serving cells.

7 Uplink Power control

Uplink power control determines a power for PUSCH, PUCCH, SRS, and PRACH transmissions.

A UE does not expect to simultaneously maintain more than four pathloss estimates per serving cell for all PUSCH/PUCCH/SRS transmissions as described in clauses 7.1.1, 7.2.1, and 7.3.1, except for SRS transmissions configured by *SRS-PosResourceSet* as described in clause 7.3.1. If the UE is provided a number of RS resources for pathloss estimation for PUSCH/PUCCH/SRS transmissions that is larger than 4, the UE maintains for pathloss estimation RS resources corresponding to RS resource indexes q_d as described in clauses 7.1.1, 7.2.1, and 7.3.1. If an RS resource updated by MAC CE, as described in clauses 7.1.1, 7.2.1 and 7.3.1, is one from the RS resources the UE maintains for pathloss estimation for PUSCH/PUCCH/SRS transmissions, the UE applies the pathloss estimation based on the RS resources starting from the first slot that is after slot $k + 3 \cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu} + 2^{\mu} \cdot k_{\mathrm{mac}}$ where k is the slot where the UE would transmit a PUCCH or PUSCH with HARQ-ACK information for the PDSCH providing the MAC CE, μ is the SCS configuration for the PUCCH or PUSCH, respectively, that is determined in the slot when the MAC CE command is applied and k_{mac} is a number of slots for SCS configuration $\mu = 0$ provided by *kmac* or $k_{\mathrm{mac}} = 0$ if *kmac* is not provided.

A PUSCH/PUCCH/SRS/PRACH transmission occasion i is defined by a slot index $n_{s,f}^{\mu}$ within a frame with system frame number SFN, a first symbol S within the slot, and a number of consecutive symbols L. For a PUSCH transmission with repetition Type B, a PUSCH transmission occasion is a nominal repetition [6, TS 38.214].

In the remaining of this clause, if a UE is provided *TCI-State* in *dl-OrJointTCI-StateList* or *TCI-UL-State*, and for each indicated one or two *TCI-State* or *TCI-UL-State* of a PUSCH, PUCCH, or SRS transmission occasion as described in [6, TS 38.214]

- in clauses 7.1.1, 7.2.1, and 7.3.1, the RS index q_d for obtaining the downlink pathloss estimate for PUSCH, PUCCH, and SRS transmission is provided by *pathlossReferenceRS-Id-r17* associated with or included in the indicated *TCI-State* or *TCI-UL-State* except for SRS transmission that is not provided *followUnifiedTCI-StateSRS*

- in clause 7.1.1, if *p0AlphaSetforPUSCH* is provided, the values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$, and the PUSCH power control adjustment state l are provided by *p0AlphaSetforPUSCH* associated with the indicated *TCI-State* or *TCI-UL-State*

- in clause 7.2.1, if *p0AlphaSetforPUCCH* is provided, the values of $P_{\mathrm{O\_UE\_PUCCH}}(q_u)$ and the PUCCH power control adjustment state l are provided by *p0AlphaSetforPUCCH* associated with the indicated *TCI-State* or *TCI-UL-State*

- in clause 7.3.1, if *p0AlphaSetforSRS* is provided,

  - if *followUnifiedTCI-StateSRS* is provided for a SRS resource set, the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and SRS power control adjustment state l are provided by *p0AlphaSetforSRS* associated with the indicated *TCI-State* or *TCI-UL-State*

  - else, if *followUnifiedTCI-StateSRS* is not provided for a SRS resource set and for a SRS resource from the SRS resource set, the values of $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and SRS power control adjustment state l are provided by *p0AlphaSetforSRS* associated with *TCI-State* or *TCI-UL-State* of an SRS resource with lowest *SRS-ResourceId* in the SRS resource set and a RS index q_d for obtaining a pathloss estimate for the SRS transmission is provided by *pathlossReferenceRS-Id-r17* associated with or included in the *TCI-State* or *TCI-UL-State* of an SRS resource with lowest *SRS-ResourceId* in the SRS resource set

  $P_{\mathrm{O\_SRS},b,f,c}(q_s)$ is the sum of the component $P_{\mathrm{O\_UE\_SRS},b,f,c}(q_s)$ and a component *p0* provided by *SRS-ResourceSet* corresponding to the SRS resource set.

In the remaining of this clause, if a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1

- a PDCCH monitoring occasion is the union of the PDCCH monitoring occasions for the two PDCCH candidates

- the end of the PDCCH reception is the end of the PDCCH candidate that ends later

The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

7.1 Physical uplink shared channel

For a PUSCH transmission on active UL BWP b, as described in clause 12, of carrier f of serving cell c, a UE first calculates a linear value $\hat{P}_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$ of the transmit power $P_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$, with parameters as defined in clause 7.1.1. For a PUSCH transmission scheduled by a DCI format other than DCI format 0_0, or configured by *ConfiguredGrantConfig* or *semiPersistentOnPUSCH*, if *txConfig* in *PUSCH-Config* is set to 'codebook',

- if *ul-FullPowerTransmission* in *PUSCH-Config* is provided, the UE scales $\hat{P}_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$ by s where:

  - if *ul-FullPowerTransmission* in *PUSCH-Config* is set to *fullpowerMode1*, and each SRS resource in the *SRS-ResourceSet* with *usage* set to 'codebook' has more than one SRS port, s is the ratio of a number of antenna ports with non-zero PUSCH transmission power over the maximum number of SRS ports supported by the UE in one SRS resource

  - if *ul-FullPowerTransmission* in *PUSCH-Config* is set to *fullpowerMode2,*

    - $s = 1$ for full power TPMIs reported by the UE [18, TS 38.306], and s is the ratio of a number of antenna ports with non-zero PUSCH transmission power over a number of SRS ports for remaining TPMIs, where the number of SRS ports is associated with an SRS resource indicated by an SRI field in a DCI format scheduling the PUSCH transmission if more than one SRS resource is configured in the *SRS-ResourceSet* with *usage* set to 'codebook', or indicated by Type 1 configured grant, or the number of SRS ports is associated with the SRS resource if only one SRS resource is configured in the *SRS-ResourceSet* with *usage* set to 'codebook',

- $s = 1$, if an SRS resource with a single port is indicated by an SRI field in a DCI format scheduling the PUSCH transmission when more than one SRS resource is provided in the *SRS-ResourceSet* with *usage* set to 'codebook', or indicated by Type 1 configured grant, or if only one SRS resource with a single port is provided in the *SRS-ResourceSet* with *usage* set to 'codebook', and

- if *ul-FullPowerTransmission* in *PUSCH-Config* is set to *fullpower*, $s = 1$

- else, if each SRS resource in the *SRS-ResourceSet* with *usage* set to 'codebook' has more than one SRS port, the UE scales the linear value by the ratio of the number of antenna ports with a non-zero PUSCH transmission power to the maximum number of SRS ports supported by the UE in one SRS resource.

The UE splits the power equally across the antenna ports on which the UE transmits the PUSCH with non-zero power.

7.1.1 UE behaviour

If a UE transmits a PUSCH on active UL BWP b of carrier f of serving cell c using parameter set configuration with index j and PUSCH power control adjustment state with index l

- if the UE is indicated a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, and is configured with *multipanelScheme,* and the UE determines to apply both the first *TCI-State* or *TCI-UL-State* and the second *TCI-State* or *TCI-UL-S*tate in PUSCH transmission occasion i, the UE determines the PUSCH transmission power $P_{\mathrm{PUSCH},b,f,c,k}(i,j,q_d,l)$ for the k-th indicated *TCI-State* or *TCI-UL-State* as

$$P_{\mathrm{PUSCH},b,f,c,k}(i,j,q_d,l) = \min\begin{Bmatrix} P_{\mathrm{CMAX},f,c,k}(i) \\ P_{\mathrm{O\_PUSCH},b,f,c}(j) + 10\log_{10}\left(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i)\right) + \alpha_{b,f,c}(j)\cdot PL_{b,f,c}(q_d) + \Delta_{\mathrm{TF},b,f,c}(i) + f_{b,f,c}(i,l) \end{Bmatrix} [\mathrm{dBm}]$$

- else, the UE determines the PUSCH transmission power $P_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$ in PUSCH transmission occasion i as

$$P_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l) = \min\begin{Bmatrix} P_{\mathrm{CMAX},f,c}(i) \\ P_{\mathrm{O\_PUSCH},b,f,c}(j) + 10\log_{10}\left(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i)\right) + \alpha_{b,f,c}(j)\cdot PL_{b,f,c}(q_d) + \Delta_{\mathrm{TF},b,f,c}(i) + f_{b,f,c}(i,l) \end{Bmatrix} [\mathrm{dBm}]$$

where,

- $P_{\mathrm{CMAX},f,c,k}(i)$ is the UE configured maximum output power for the k-th indicated *TCI-State* or *TCI-UL-State* defined in [8-2, TS 38.101-2] for carrier f of serving cell c in PUSCH transmission occasion i .

- $P_{\mathrm{CMAX},f,c}(i)$is the UE configured maximum output power defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3] for carrier f of serving cell c in PUSCH transmission occasion i.

- $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ is a parameter composed of the sum of a component $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(j)$ and a component $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ where $j \in \{0,1,\ldots,J-1\}$.

  - If a UE established dedicated RRC connection using a Type-1 random access procedure, as described in clause 8, and is not provided *P0-PUSCH-AlphaSet* or for a PUSCH (re)transmission corresponding to a RAR UL grant as described in clause 8.3,

    $j = 0$, $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(0) = 0$, and $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0) = P_{\mathrm{O\_PRE}} + \Delta_{\mathrm{PREAMBLE,Msg3}}$,

    where $P_{\mathrm{O\_PRE}}$ is provided by *preambleReceivedTargetPower* [11, TS 38.321] and $\Delta_{PREAMBLE\_Msg3}$ is provided by *msg3-DeltaPreamble* or *deltaPreamble*, or $\Delta_{\mathrm{PREAMBLE,Msg3}} = 0$ dB if *msg3-DeltaPreamble* and *deltaPreamble* are not provided, for carrier f of serving cell c

  - If a UE established dedicated RRC connection using a Type-2 random access procedure, as described in clause 8, and is not provided *P0-PUSCH-AlphaSet*, or for a PUSCH transmission for Type-2 random access procedure as described in clause 8.1A,

    $j = 0$, $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(0) = 0$, and $P_{\mathrm{O\_NOMINAL\_PUSCH},f,c}(0) = P_{\mathrm{O\_PRE}} + \Delta_{MsgA\_PUSCH}$, where $P_{\text{O\_PRE}}$ is provided by *msgA-preambleReceivedTargetPower*, or by *preambleReceivedTargetPower* if *msgA-preambleReceivedTargetPower* is not provided and Δ_{MsgA_PUSCH} is provided by *msgA-DeltaPreamble* or *deltaPreamble*, or $\Delta_{MsgA\_PUSCH} = \Delta_{PREAMBLE\_Msg3}$ dB if *msgA-DeltaPreamble* and *deltaPreamble* are not provided, for carrier f of serving cell c

- For a PUSCH (re)transmission configured by *ConfiguredGrantConfig*, $j = 1$, $P_{\text{O\_NOMINAL,PUSCH},f,c}(1)$ is provided by *p0-NominalWithoutGrant*, or $P_{\text{O\_NOMINAL,PUSCH},f,c}(1) = P_{\text{O\_NOMINAL,PUSCH},f,c}(0)$ if *p0-NominalWithoutGrant* is not provided.
  - If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format that includes a SRS resource set indicator field, and for active UL BWP b of carrier f of serving cell
    - If the SRS resource set indicator value is 00, first $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha* in *ConfiguredGrantConfig*.
    - If the SRS resource set indicator value is 01, second $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig*.
    - If the SRS resource set indicator value is 10 or 11, first and second $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ values that are respectively associated with the first and second SRS resource set are respectively provided by the values of *p0-PUSCH-Alpha* and by *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig*.
  - else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a transmission of a configured grant Type 1 PUSCH and for active UL BWP b of carrier f of serving cell
    - a first $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* that is associated with the first *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*
    - a second $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig* that is associated with the second *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*
  - else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format 0_0, and for active UL BWP b of carrier f of serving cell
    - a first $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha* in *ConfiguredGrantConfig*
  - else, $P_{\text{O\_UE\_PUSCH},b,f,c}(1)$ is provided by *p0* obtained from *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* that provides an index *P0-PUSCH-AlphaSetId* to a set of *P0-PUSCH-AlphaSet*, or by *sdt-P0-PUSCH* for a PUSCH (re)transmission as described in clause 19.1, for active UL BWP b of carrier f of serving cell c
- For $j \in \{2, \dots, J-1\} = S_J$, a $P_{\text{O\_NOMINAL,PUSCH},f,c}(j)$ value, applicable for all $j \in S_J$, is provided by *p0-NominalWithGrant*, or $P_{\text{O\_NOMINAL,PUSCH},f,c}(j) = P_{\text{O\_NOMINAL,PUSCH},f,c}(0)$ if *p0-NominalWithGrant* is not provided, for each carrier f of serving cell c and a set of $P_{\text{O\_UE\_PUSCH},b,f,c}(j)$ values are provided by a set of *p0* in *P0-PUSCH-AlphaSet* indicated by a respective set of *p0-PUSCH-AlphaSetId* for active UL BWP b of carrier f of serving cell c
  - If the UE is provided by *SRI-PUSCH-PowerControl* more than one values of *p0-PUSCH-AlphaSetId* and if a DCI format scheduling the PUSCH transmission includes an SRI field, the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field in the DCI format [5, TS 38.212] and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values and determines the value of $P_{\text{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-*

AlphaSetId value that is mapped to the SRI field value. If the UE is provided by *SRI-PUSCH-PowerControl* more than one values of *p0-PUSCH-AlphaSetId*

- if the DCI format scheduling the PUSCH transmission includes two SRI fields and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook', the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the two SRI fields and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values, and determines first and second values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* values that are mapped to the values of the first and second SRI fields, respectively.

- if the DCI format scheduling the PUSCH transmission includes two SRI fields and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook', the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between

  - a set of values for the first SRI field value and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values, and determines the first value of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* value that is mapped to the first SRI field value, and

  - a set of values associated with the second SRI field value for a same number of layers as indicated by the first SRI field [5, TS 38.212], and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values, and determines the second value of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* value that is mapped to the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212].

- If the DCI format also includes an open-loop power control parameter set indication field and a value of the open-loop power control parameter set indication field is '1' and if the DCI format scheduling the PUSCH transmission includes an SRI field, the UE determines a value of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from a first value in *P0-PUSCH-Set* with a *p0-PUSCH-SetId* value mapped to the SRI field value.

- If the UE is provided by *SRI-PUSCH-PowerControl* more than one values of *p0-PUSCH-AlphaSetId*

  - if a DCI format scheduling the PUSCH transmission includes two SRI fields and an open-loop power control parameter set indication field and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook'

    - if a value of the open-loop power control parameter set indication field is '0', the UE determines two values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* values in *SRI-PUSCH-PowerControl* that are mapped to the two SRI values corresponding to each SRS resource set with *usage* set to 'codebook'.

    - if a value of the open-loop power control parameter set indication field is '1', the UE determines two values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from first values in *P0-PUSCH-Set* in *P0-PUSCH-SetList* and *P0-PUSCH-Set* in *P0-PUSCH-SetList*2 with *p0-PUSCH-SetId* values mapped to the two SRI values corresponding to each SRS resource set with *usage* set to 'codebook', respectively.

  - if a DCI format scheduling the PUSCH transmission includes two SRI fields and an open-loop power control parameter set indication field and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook',

    - if a value of the open-loop power control parameter set indication field is '0', the UE determines two values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* values in *SRI-PUSCH-PowerControl* that are mapped to the first SRI field value corresponding to the first SRS resource set with *usage* set to 'nonCodebook' and to a second value, that is associated with the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value, corresponding to the second SRS resource set with *usage* set to 'nonCodebook'.

    - if a value of the open-loop power control parameter set indication field is '1', the UE determines two values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from first values in *P0-PUSCH-Set* in *P0-PUSCH-SetList* and

P0-PUSCH-Set in *P0-PUSCH-SetList*2 with *p0-PUSCH-SetId* values mapped to the first SRI field value corresponding to the first SRS resource set with *usage* set to 'nonCodebook, and a second value, that is associated with the second SRS field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value, corresponding to the second SRS resource set with *usage* set to 'nonCodebook', respectively.

- if the UE is not provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and if the PUSCH transmission, except for the PUSCH retransmission corresponding to a RAR UL grant, is scheduled by a DCI format that does not include an SRI field, or if *SRI-PUSCH-PowerControl* is not provided to the UE, $j = 2$,
    - if *P0-PUSCH-Set* is provided to the UE and the DCI format includes an open-loop power control parameter set indication field, the UE determines a value of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from
        - a first *P0-PUSCH-AlphaSet* in *p0-AlphaSets* if a value of the open-loop power control parameter set indication field is '0' or '00'
        - a first value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value if a value of the open-loop power control parameter set indication field is '1' or '01'
        - a second value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value if a value of the open-loop power control parameter set indication field is '10'
- else, the UE determines $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ from the value of the first *P0-PUSCH-AlphaSet* in *p0-AlphaSets*
- if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and the PUSCH transmission is scheduled by a DCI format that does not include an SRI field and includes an SRS resource set indicator field with value 10 or 11
    - if *P0-PUSCH-Set* is provided to the UE and the DCI format includes an open-loop power control parameter set indication field, the UE determines first and second values of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ respectively associated with the first and second SRS resource set as
        - first and second *P0-PUSCH-AlphaSet* in *p0-AlphaSets* if the open-loop power control parameter set indication value is '0' or '00'
        - first value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList* and first value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList2*, respectively, if the open-loop power control parameter set indication value is '1' or '01'
        - second value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList* and second value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* in *p0-PUSCH-SetList2*, respectively, if the open-loop power control parameter set indication value is '10' or '11'
    - else, the UE determines first and second values $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ respectively associated with the first and second SRS resource set from the values of the first and second *P0-PUSCH-AlphaSet* in *p0-AlphaSets*, respectively
- if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', and the PUSCH transmission is scheduled by a DCI format that does not include an SRI field and includes an SRS resource set indicator field with value '00'
    - if the UE is provided *P0-PUSCH-Set* and the DCI format includes an open-loop power control parameter set indication field, the UE determines a value of $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ as
        - first *P0-PUSCH-AlphaSet* in *p0-AlphaSets* if the open-loop power control parameter set indication value is '0' or '00'
        - first value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList*, if the open-loop power control parameter set indication value is '1' or '01'

- second value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList*, if the open-loop power control parameter set indication value is '10' or '11'

- else, the UE determines a value of $P_{\text{O\_UE\_PUSCH},b,f,c}(j)$ from the value of the first *P0-PUSCH-AlphaSet* in *p0-AlphaSets*

- if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', and the PUSCH transmission is scheduled by a DCI format that does not include an SRI field and includes an SRS resource set indicator field with value '01'

  - if *P0-PUSCH-Set* is provided to the UE and the DCI format includes an open-loop power control parameter set indication field, the UE determines a value of $P_{\text{O\_UE\_PUSCH},b,f,c}(j)$ as

    - second *P0-PUSCH-AlphaSet* in *p0-AlphaSets* if the open-loop power control parameter set indication value is '0' or '00'

    - first value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* value in *p0-PUSCH-SetList2*, if the open-loop power control parameter set indication value is '1' or '01'

    - second value in *P0-PUSCH-Set* with the lowest *p0-PUSCH-SetID* in *p0-PUSCH-SetList2*, if the open-loop power control parameter set indication value is '10' or '11'

  - else, the UE determines a value of $P_{\text{O\_UE\_PUSCH},b,f,c}(j)$ from the value of the second *P0-PUSCH-AlphaSet* in *p0-AlphaSets*

- For $\alpha_{b,f,c}(j)$

  - For $j = 0$,

    - if $P_{\text{O\_NOMINAL\_PUSCH},f,c}(0) = P_{\text{O\_PRE}} + \Delta_{MsgA\_PUSCH}$ and *msgA-Alpha* is provided, $\alpha_{b,f,c}(0)$ is the value of *msgA-Alpha*

    - elseif $P_{\text{O\_NOMINAL\_PUSCH},f,c}(0) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$ or *msgA-Alpha* is not provided, and *msg3-Alpha* is provided, $\alpha_{b,f,c}(0)$ is the value of *msg3-Alpha*

    - else, $\alpha_{b,f,c}(0) = 1$

  - For $j = 1$,

    - if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format that includes an SRS resource set indicator field, and for active UL BWP b of carrier f of serving cell

      - if the SRS resource set indicator value is '00', first $\alpha_{b,f,c}(1)$ value is provided by *p0-PUSCH-Alpha* in *ConfiguredGrantConfig*

      - if the SRS resource set indicator value is '01', first $\alpha_{b,f,c}(1)$ value is provided by *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig*

      - if the SRS resource set indicator value is '10' or '11', first and second $\alpha_{b,f,c}(1)$ values associated with the first and second SRS resource set are respectively provided by *p0-PUSCH-Alpha* and *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig*

    - else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a transmission of a configured grant Type 1 PUSCH and for active UL BWP b of carrier f of serving cell

      - a first $\alpha_{b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* that is associated with the first *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*.

  - a second $\alpha_{b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig* that is associated with the second *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*.

- else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format 0_0 and for active UL BWP b of carrier f of serving cell

  - a first $\alpha_{b,f,c}(1)$ value is provided by the value of *p0-PUSCH-Alpha* in *ConfiguredGrantConfig*.

- else $\alpha_{b,f,c}(1)$ is provided by *alpha* obtained from *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* providing an index *P0-PUSCH-AlphaSetId* to a set of *P0-PUSCH-AlphaSet*, or by *sdt-Alpha* for a PUSCH (re)transmission as described in clause 19.1, for active UL BWP b of carrier f of serving cell c

- For $j \in S_J$, a set of $\alpha_{b,f,c}(j)$ values are provided by a set of *alpha* in *P0-PUSCH-AlphaSet* indicated by a respective set of *p0-PUSCH-AlphaSetId* for active UL BWP b of carrier f of serving cell c

  - If the UE is provided *SRI-PUSCH-PowerControl* and more than one values of *p0-PUSCH-AlphaSetId* in *p0-AlphaSets*,

    - if a DCI format scheduling the PUSCH transmission includes two SRI fields and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook', the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for

      - the two SRI fields and a set of indexes provided by *P0-PUSCH-AlphaSetId* that map to *P0-PUSCH-AlphaSet* values, and determines first and second values of $\alpha_{b,f,c}(j)$ from the *P0-PUSCH-AlphaSetID* values that are mapped to the values of the first and second SRI field values, respectively.

    - if a DCI format scheduling the PUSCH transmission includes two SRI fields and the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook', the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for

      - the first SRI field and a set of indexes provided by *P0-PUSCH-AlphaSetId* that map to *P0-PUSCH-AlphaSet* values, and determines first value of $\alpha_{b,f,c}(j)$ from the *P0-PUSCH-AlphaSetID* value that is mapped to the first SRI field value, and

      - the second value, associated with the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value, and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values, and determines the second value of $\alpha_{b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* value that is mapped to the second SRI field value

    - if a DCI format scheduling the PUSCH transmission includes one SRI field, the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field in the DCI format [5, TS 38.212] and a set of indexes provided by *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values and determines the values of $\alpha_{b,f,c}(j)$ from the *p0-PUSCH-AlphaSetId* value that is mapped to the SRI field value

  - If the UE is not provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and if the PUSCH transmission except for the PUSCH retransmission corresponding to a RAR UL grant is scheduled by a DCI format that does not include an SRI field, or if *SRI-PUSCH-PowerControl* is not provided to the UE, $j = 2$, and the UE determines $\alpha_{b,f,c}(j)$ from the value of the first *P0-PUSCH-AlphaSet* in *p0-AlphaSets*

  - If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and the PUSCH transmission is scheduled by a DCI format that does not include an SRI field and includes an SRS resource set indicator field with value '10' or '11', the UE determines $\alpha_{b,f,c}(j)$ respectively associated with the first and second SRS resource set from first and second *P0-PUSCH-AlphaSet* in *p0-AlphaSets*

- If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', and the PUSCH transmission is scheduled by a DCI format that does not include an SRI field and includes an SRS resource set indicator field with value '00' or '01', the UE determines $\alpha_{b,f,c}(j)$ from first *P0-PUSCH-AlphaSet* or second *P0-PUSCH-AlphaSet* in *p0-AlphaSets*, respectively.

- $M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c and μ is a SCS configuration defined in [4, TS 38.211]

- $PL_{b,f,c}(q_d)$ is a downlink pathloss estimate in dB calculated by the UE using reference signal (RS) index q_d for the active DL BWP, as described in clause 12, of carrier f of serving cell c

  - If the UE is not provided *PUSCH-PathlossReferenceRS* and *enableDefaultBeamPL-ForSRS*, or before the UE is provided dedicated higher layer parameters, the UE calculates $PL_{b,f,c}(q_d)$

    - using a RS resource from an SS/PBCH block with same SS/PBCH block index as the one the UE uses to obtain *MIB*, or using the SS/PBCH block the UE acquired the time and frequency synchronization for a secondary cell.

    - if the UE is provided *ntn-RACH-LessHO* in *ReconfigurationWithSync* [12. TS 38.331], using a RS resource from an SS/PBCH block with same SS/PBCH block index as the one with same quasi co-location properties as for PDCCH receptions for scheduling an initial PUSCH transmission, as described in Clause 10.1, in *controlResourceSetZero* provided in *ServingCellConfigCommon* of *ReconfigurationWithSync*

  - If the UE is configured with a number of RS resource indexes, up to the value of *maxNrofPUSCH-PathlossReferenceRSs*, and a respective set of RS configurations for the number of RS resource indexes by *PUSCH-PathlossReferenceRS*, the set of RS resource indexes can include one or both of a set of SS/PBCH block indexes, each provided by *ssb-Index* when a value of a corresponding *pusch-PathlossReferenceRS-Id* maps to a SS/PBCH block index, and a set of CSI-RS resource indexes, each provided by *csi-RS-Index* when a value of a corresponding *pusch-PathlossReferenceRS-Id* maps to a CSI-RS resource index. The UE identifies a RS resource index q_d in the set of RS resource indexes to correspond either to a SS/PBCH block index or to a CSI-RS resource index as provided by *pusch-PathlossReferenceRS-Id* in *PUSCH-PathlossReferenceRS*

  - If the PUSCH transmission is scheduled by a RAR UL grant as described in clause 8.3, or for a PUSCH transmission for Type-2 random access procedure as described in clause 8.1A, the UE uses the same RS resource index q_d as for a corresponding PRACH transmission

  - If the UE is provided *SRI-PUSCH-PowerControl* and more than one values of *PUSCH-PathlossReferenceRS-Id*, the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field, or for first and second SRI fields if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook', or values for a first SRI field and values associated with a second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook', in a DCI format scheduling the PUSCH transmission and a set of *PUSCH-PathlossReferenceRS-Id* values and determines the RS resource index q_d, or respective first and second RS resource indexes q_d, from the value of *PUSCH-PathlossReferenceRS-Id* that is mapped to the SRI field value, or from the values of *PUSCH-PathlossReferenceRS-Id* that are mapped to respective first and second SRI field values if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook', or from the values of *PUSCH-PathlossReferenceRS-Id* that are mapped to respective first SRI field value and a value associated with the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook',

  where the RS resource is either on serving cell c or, if provided, on a serving cell indicated by a value of *pathlossReferenceLinking*

  - If the PUSCH transmission is scheduled by DCI format 0_0, and

- if two spatial settings from *PUCCH-SpatialRelationInfo* are activated for a PUCCH resource with a lowest index for active UL BWP b of each carrier f and serving cell c, the UE uses the same RS resource index q_d as for a PUCCH transmission with a spatial setting from the two spatial settings with lowest index in the PUCCH resource with the lowest index for active UL BWP b of each carrier f and serving cell c

- else, if the UE is provided a spatial setting by *PUCCH-SpatialRelationInfo* for a PUCCH resource with a lowest index for active UL BWP b of each carrier f and serving cell c, as described in clause 9.2.2, the UE uses the same RS resource index q_d as for a PUCCH transmission in the PUCCH resource with the lowest index

- If the PUSCH transmission is not scheduled by DCI format 0_0, and if the UE is provided *enableDefaultBeamPL-ForSRS* and is not provided *PUSCH-PathlossReferenceRS* and *PUSCH-PathlossReferenceRS-r16,* the UE uses the same RS resource index q_d as for an SRS resource set with an SRS resource associated with the PUSCH transmission

- If

  - the UE is not provided *enableDefaultBeamPL-ForPUSCH0-0* and the PUSCH transmission is scheduled by DCI format 0_0 and the UE is not provided a spatial setting for a PUCCH transmission, or

  - the PUSCH transmission is scheduled by DCI format 0_1 or DCI format 0_2 that does not include an SRI field, or

  - *SRI-PUSCH-PowerControl* is not provided to the UE,

  the UE determines a RS resource index q_d with a respective *PUSCH-PathlossReferenceRS-Id* value being equal to zero where the RS resource is either on serving cell c or, if provided, on a serving cell indicated by a value of *pathlossReferenceLinking*

- If

  - the PUSCH transmission is scheduled by DCI format 0_0 on serving cell c,

  - the UE is not provided PUCCH resources for the active UL BWP of serving cell c, and

  - the UE is provided *enableDefaultBeamPL-ForPUSCH0-0*

  the UE determines a RS resource index q_d providing a periodic RS resource configured with *qcl-Type* set to 'typeD' in the TCI state or the QCL assumption of a CORESET with the lowest index in the active DL BWP of the serving cell c. If the CORESET has two activated TCI states, as described in clause 10.1, the UE determines the RS resource index q_d based on the first TCI state.

- If

  - the PUSCH transmission is scheduled by DCI format 0_0 on serving cell c,

  - the UE is not provided a spatial setting for PUCCH resources on the active UL BWP of the primary cell [11, TS 38.321], and

  - the UE is provided *enableDefaultBeamPL-ForPUSCH0-0*

  the UE determines a RS resource index q_d providing a periodic RS resource configured with *qcl-Type* set to 'typeD' in the TCI state or the QCL assumption of a CORESET with the lowest index in the active DL BWP of the serving cell c. If the CORESET has two activated TCI states, as described in clause 10.1, the UE determines the RS resource index q_d based on the first TCI state.

- For a PUSCH transmission configured by *ConfiguredGrantConfig*, if *rrc-ConfiguredUplinkGrant* is included in *ConfiguredGrantConfig*,

  - if the UE is provided *enablePL-RS-UpdateForType1CG-PUSCH*, the UE determines a RS resource index q_d from the value of *PUSCH-PathlossReferenceRS-Id* that is mapped to the *sri-PUSCH-PowerControlId* indicated by the *srs-ResourceIndicator* value included in *rrc-ConfiguredUplinkGrant*

  - if the UE is not provided *enablePL-RS-UpdateForType1CG-PUSCH*, a RS resource index q_d is provided by a value of *pathlossReferenceIndex* included in *rrc-ConfiguredUplinkGrant* where the RS resource is either on serving cell c or, if provided, on a serving cell indicated by a value of *pathlossReferenceLinking*. If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and for configured grant Type 1 PUSCH, first and second RS resource indexes q_d that are respectively associated with the first and second *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant* are provided by respective values of *pathlossReferenceIndex* and *pathlossReferenceIndex2* in *rrc-ConfiguredUplinkGrant*.

- For a PUSCH transmission configured by *ConfiguredGrantConfig* that does not include *rrc-ConfiguredUplinkGrant*, the UE determines a RS resource index q_d from a value of *PUSCH-PathlossReferenceRS-Id* that is mapped to a SRI field value in a DCI format activating the PUSCH transmission.

  - If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' and the DCI format activating the PUSCH transmission includes two SRI fields, the UE determines first and second RS resource indexes q_d from respective first and second values of *PUSCH-PathlossReferenceRS-Id* that are mapped to the first and second SRI values corresponding to each SRS resource set with *usage* set to 'codebook', respectively.

  - If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook' and the DCI format activating the PUSCH transmission includes two SRI fields, the UE determines first and second RS resource indexes q_d from respective first and second values of *PUSCH-PathlossReferenceRS-Id* that are mapped to the first SRI value corresponding to the first SRS resource set with *usage* set to 'nonCodebook', and the value, associated with the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value, corresponding to the second SRS resource set with *usage* set to 'nonCodebook'.

  - If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and the DCI format activating the PUSCH transmission does not include an SRI field, the UE determines first and second RS resource indexes q_d respectively associated with the first and second SRS resource set with respective first and second *PUSCH-PathlossReferenceRS-Id* value being equal to zero and one.

  - If the DCI format activating the PUSCH transmission does not include an SRI field, the UE determines a RS resource index q_d with a respective *PUSCH-PathlossReferenceRS-Id* value being equal to zero

  where the RS resources are either on serving cell c or, if provided, on a serving cell indicated by a value of *pathlossReferenceLinking*

- If the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, a mapping between *sri-PUSCH-PowerControlId* and *PUSCH-PathlossReferenceRS-Id* values can be updated by a MAC CE as described in [11, TS 38.321]

  - For a PUSCH transmission scheduled by a DCI format that does not include an SRI field, or for a PUSCH transmission configured by *ConfiguredGrantConfig* and activated, as described in clause 10.2, by a DCI format that does not include an SRI field, the UE determines a RS resource index q_d from the *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0. If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', the UE determines first and second RS resource indexes q_d from respective *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList* and *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList2*, respectively.

- If the UE is not provided *enablePL-RS-UpdateForPUSCH-SRS*

  - For a PUSCH transmission scheduled by a DCI format that does not include an SRI field, if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', the UE determines first and second RS resource indexes q_d respectively associated with the first and second SRS resource set with respective first and second *PUSCH-PathlossReferenceRS-Id* values being equal to 0 and 1.

$PL_{b,f,c}(q_d)$ = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [7, TS 38.215] for the reference serving cell and the higher layer filter configuration provided by *QuantityConfig* is defined in [12, TS 38.331] for the reference serving cell

If the UE is not configured periodic CSI-RS reception, *referenceSignalPower* is provided by *ss-PBCH-BlockPower*. If the UE is configured periodic CSI-RS reception, *referenceSignalPower* is provided either by *ss-PBCH-BlockPower* or by *powerControlOffsetSS* providing an offset of the CSI-RS transmission power relative to the SS/PBCH block transmission power [6, TS 38.214]. If *powerControlOffsetSS* is not provided to the UE, the UE assumes an offset of 0 dB.

- $\Delta_{\mathrm{TF},b,f,c}(i) = 10log_{10}\left((2^{\mathrm{BPRE}\cdot K_s} - 1) \cdot \beta_{\mathrm{offset}}^{\mathrm{PUSCH}}\right)$ for $K_s = 1.25$ and $\Delta_{\mathrm{TF},b,f,c}(i) = 0$ for $K_s = 0$ where K_s is provided by *deltaMCS* for each UL BWP b of each carrier f and serving cell c. If the PUSCH transmission is over more than one layer [6, TS 38.214], $\Delta_{\mathrm{TF},b,f,c}(i) = 0$. BPRE and $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}$, for active UL BWP b of each carrier f and each serving cell c, are computed as below
  - $\mathrm{BPRE} = \sum_{r=0}^{C-1} K_r / N_{RE}$ for PUSCH with UL-SCH data and $\mathrm{BPRE} = Q_m \cdot R / \beta_{\mathrm{offset}}^{\mathrm{PUSCH}}$ for CSI transmission in a PUSCH without UL-SCH data, where
    - C is a number of transmitted code blocks, K_r is a size for code block r, and N_{RE} is a number of resource elements determined as $N_{\mathrm{RE}} = N \cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i) \cdot \sum_{j=0}^{N_{\mathrm{symb},b,f,c}^{\mathrm{PUSCH}}(i)-1} N_{\mathrm{sc,data}}^{\mathrm{RB}}(i,j)$, where $N \geq 1$ is provided by *numberOfSlotsTBoMS* as described in [6, TS 38.214] and $N = 1$ if *numberOfSlotsTBoMS* is not provided, $N_{\mathrm{symb},b,f,c}^{\mathrm{PUSCH}}(i)$ is a number of symbols for PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c, $N_{\mathrm{sc,data}}^{\mathrm{RB}}(i,j)$ is a number of subcarriers excluding DM-RS subcarriers and phase-tracking RS samples [4, TS 38.211] in PUSCH symbol j and assuming no segmentation for a nominal repetition in case the PUSCH transmission is with repetition Type B, $0 \leq j < N_{\mathrm{symb},b,f,c}^{\mathrm{PUSCH}}(i)$, and C, K_r are defined in [5, TS 38.212]
  - $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}} = 1$ when the PUSCH includes UL-SCH data and $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}} = \beta_{\mathrm{offset}}^{\mathrm{CSI},1}$, as described in clause 9.3, when the PUSCH includes CSI and does not include UL-SCH data
  - Q_m is the modulation order and R is the target code rate, as described in [6, TS 38.214], provided by the DCI format scheduling the PUSCH transmission that includes CSI and does not include UL-SCH data
- For the PUSCH power control adjustment state $f_{b,f,c}(i,l)$ for active UL BWP b of carrier f of serving cell c in PUSCH transmission occasion i
  - $\delta_{\mathrm{PUSCH},b,f,c}(i,l)$ is a TPC command value included in a DCI format that schedules the PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c or jointly coded with other TPC commands in a DCI format 2_2 with CRC scrambled by TPC-PUSCH-RNTI, as described in clause 11.3
    - $l \in \{0,1\}$ if the UE is configured with *twoPUSCH-PC-AdjustmentStates* and $l = 0$ if the UE is not configured with *twoPUSCH-PC-AdjustmentStates* or if the PUSCH transmission is scheduled by a RAR UL grant as described in clause 8.3
      - if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format that includes a SRS resource set indicator field, and for active UL BWP b of carrier f of serving cell
        - if the SRS resource set indicator value is 00, l is equal to the value of *powerControlLoopToUse* in *ConfiguredGrantConfig*
        - if the SRS resource set indicator value is 01, l is equal to the value of *powerControlLoopToUse2* in *ConfiguredGrantConfig*
        - if the SRS resource set indicator value is 10 or 11, a first l and a second l respectively associated with the first and second SRS resource set are respectively equal to *powerControlLoopToUse* and *powerControlLoopToUse2* in *ConfiguredGrantConfig*
      - else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a transmission of a configured grant Type 1 PUSCH and for active UL BWP b of carrier f of serving cell

    - a first l is equal to the value of *powerControlLoopToUse* in *ConfiguredGrantConfig* that is associated with the first *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*
    - a second l is equal to the value of *powerControlLoopToUse2* in *ConfiguredGrantConfig* that is associated with the second *srs-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*
- else if the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' and is provided *p0-PUSCH-Alpha2*, for a retransmission of a configured grant Type 1 PUSCH, or for activation or retransmission of a configured grant Type 2 PUSCH, scheduled by a DCI format 0_0 and for active UL BWP b of carrier f of serving cell
    - l is equal to the value of *powerControlLoopToUse* in *ConfiguredGrantConfig*
- else, for a PUSCH (re)transmission configured by *ConfiguredGrantConfig*, the value of $l \in \{0,1\}$ is provided to the UE by *powerControlLoopToUse* in *ConfiguredGrantConfig*.
- If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook', is provided *SRI-PUSCH-PowerControl*, and a DCI format scheduling the PUSCH transmission includes two SRI fields, the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the first and second SRI fields and the l values provided by *sri-PUSCH-ClosedLoopIndex*, and determines the l values mapped to the values of the first and second SRI fields corresponding to each SRS resource set with *usage* set to 'codebook', respectively
- If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'nonCodebook', is provided *SRI-PUSCH-PowerControl*, and a DCI format scheduling the PUSCH transmission includes two SRI fields, the UE obtains a mapping from *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for
    - the first SRI field value and the l values provided by *sri-PUSCH-ClosedLoopIndex*, and determines the l value that is mapped to the first SRI field value corresponding to the first SRS resource set with *usage* set to 'nonCodebook', and
    - the value, associated with the second SRI field value corresponding to Tables 7.3.1.1.2-28/29/30/31 of [5, TS 38.212] for a same number of layers as indicated by the first SRI field value, and the l value(s) provided by *sri-PUSCH-ClosedLoopIndex*, and determines the l value that is mapped to the value corresponding to the second SRS resource set with *usage* set to 'nonCodebook'
- If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', is provided *SRI-PUSCH-PowerControl*, and a DCI format scheduling the PUSCH transmission does not include an SRI field
    - If the UE is provided twoPUSCH-PC-AdjustmentStates
        - the UE determines $l = 0$ for the PUSCH transmission corresponding to the first SRS resource set with usage set to 'codebook' or 'nonCodebook', and $l = 1$ for the PUSCH transmission corresponding to the second SRS resource set with usage set to 'codebook' or 'nonCodebook'
    - else
        - the UE determines $l = 0$ for the PUSCH transmission
- If the UE is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook', and is provided *twoPUSCH-PC-AdjustmentStates*
    - If the DCI format includes two TPC command values and the PUSCH transmissions are associated with $l = 0$ and $l = 1$, the UE applies the first TPC command value for $l = 0$ and applies the second TPC command value for $l = 1$

- If the DCI format includes two TPC command values and the PUSCH transmissions are associated with $l = 0$, the UE applies the first TPC command value for $l = 0$ and ignores the second TPC command value

- If the DCI format includes two TPC command values and the PUSCH transmissions are associated with $l = 1$, the UE applies the second TPC command value for $l = 1$ and ignores the first TPC command value

- If the DCI format includes one TPC command value, the UE applies the TPC command value for all l associated with the PUSCH transmission

- If the UE is provided *SRI-PUSCH-PowerControl*, the UE obtains a mapping between a set of values for the SRI field in a DCI format scheduling the PUSCH transmission and the l value(s) provided by *sri-PUSCH-ClosedLoopIndex* and determines the l value that is mapped to the SRI field value

- If the PUSCH transmission is scheduled by a DCI format that does not include an SRI field, or if an *SRI-PUSCH-PowerControl* is not provided to the UE, $l = 0$

- If the UE obtains one TPC command from a DCI format 2_2 with CRC scrambled by a TPC-PUSCH-RNTI, the l value is provided by the closed loop indicator field in DCI format 2_2

- $f_{b,f,c}(i,l) = f_{b,f,c}(i - i_0, l) + \sum_{m=0}^{\mathcal{C}(D_i)-1} \delta_{\mathrm{PUSCH},b,f,c}(m,l)$ is the PUSCH power control adjustment state l for active UL BWP b of carrier f of serving cell c and PUSCH transmission occasion i if the UE is not provided *tpc-Accumulation*, where

  - The $\delta_{\mathrm{PUSCH},b,f,c}$ values are given in Table 7.1.1-1

  - $\sum_{m=0}^{\mathcal{C}(D_i)-1} \delta_{\mathrm{PUSCH},b,f,c}(m,l)$ is a sum of TPC command values in a set D_i of TPC command values with cardinality $\mathcal{C}(D_i)$ that the UE receives between $K_{\mathrm{PUSCH}}(i - i_0) - 1$ symbols before PUSCH transmission occasion $i - i_0$ and $K_{\mathrm{PUSCH}}(i)$ symbols before PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c for PUSCH power control adjustment state l, where $i_0 > 0$ is the smallest integer for which $K_{\mathrm{PUSCH}}(i - i_0)$ symbols before PUSCH transmission occasion $i - i_0$ is earlier than $K_{\mathrm{PUSCH}}(i)$ symbols before PUSCH transmission occasion i

  - If a PUSCH transmission is scheduled by a DCI format, $K_{\mathrm{PUSCH}}(i)$ is a number of symbols for active UL BWP b of carrier f of serving cell c after a last symbol of a corresponding PDCCH reception and before a first symbol of the PUSCH transmission

  - If a PUSCH transmission is configured by *ConfiguredGrantConfig*, $K_{\mathrm{PUSCH}}(i)$ is a number of $K_{\mathrm{PUSCH,min}}$ symbols equal to the product of a number of symbols per slot, $N_{\mathrm{symb}}^{\mathrm{slot}}$, and the minimum of the values provided by *k2* in *PUSCH-ConfigCommon* for active UL BWP b of carrier f of serving cell c

    - If the first symbol of the PUSCH transmission occasion occurs within $T_{\mathrm{proc},2}$ after a last symbol of a PDCCH reception where the UE detects the DCI format providing the TPC command, the UE may postpone the application of the TPC command until the above condition is not valid. $T_{\mathrm{proc},2}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 0$, and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the PUSCH.

  - If the UE has reached maximum power for active UL BWP b of carrier f of serving cell c at PUSCH transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(D_i)-1} \delta_{\mathrm{PUSCH},b,f,c}(m,l) \geq 0$, then $f_{b,f,c}(i,l) = f_{b,f,c}(i - i_0, l)$

  - If UE has reached minimum power for active UL BWP b of carrier f of serving cell c at PUSCH transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(D_i)-1} \delta_{\mathrm{PUSCH},b,f,c}(m,l) \leq 0$, then $f_{b,f,c}(i,l) = f_{b,f,c}(i - i_0, l)$

  - A UE resets accumulation of a PUSCH power control adjustment state l for active UL BWP b of carrier f of serving cell c to $f_{b,f,c}(k,l) = 0,\ k = 0,1,\ldots,i$

    - If a configuration for a corresponding $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ value is provided by higher layers

    - If a configuration for a corresponding $\alpha_{b,f,c}(j)$ value is provided by higher layers where l is determined from the value of j as

- If $j > 1$ and the UE is provided higher *SRI-PUSCH-PowerControl*, l is the *sri-PUSCH-ClosedLoopIndex* value(s) configured in any *SRI-PUSCH-PowerControl* with the *sri-P0-PUSCH-AlphaSetId* value corresponding to j

- If $j > 1$ and the UE is not provided *SRI-PUSCH-PowerControl* or $j = 0$, $l = 1$ if $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are provided by the second $P0 - PUSCH - AlphaSet$ in $p0 - AlphaSets$; otherwise, $l = 0$

- If $j = 1$,

  - l is provided by the value of *powerControlLoopToUse* if $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(1)$ and $\alpha_{b,f,c}(1)$ are provided by *p0-PUSCH-Alpha* in *ConfiguredGrantConfig*

  - l is provided by the value of *powerControlLoopToUse2* if $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(1)$ and $\alpha_{b,f,c}(1)$ are provided by *p0-PUSCH-Alpha2* in *ConfiguredGrantConfig*

- $f_{b,f,c}(i,l) = \delta_{\mathrm{PUSCH},b,f,c}(i,l)$ is the PUSCH power control adjustment state for active UL BWP b of carrier f of serving cell c and PUSCH transmission occasion i if the UE is provided *tpc-Accumulation*, where

  - $\delta_{\mathrm{PUSCH},b,f,c}$ absolute values are given in Table 7.1.1-1

If the UE transmits a PUSCH associated with the first RS resource index q_d, the UE applies the first $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ value, the first $\alpha_{b,f,c}(j)$ value, and $f_{b,f,c}(i,l)$ for determining $P_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$. If the UE transmits a PUSCH associated with the second RS resource index q_d, the UE applies the second $P_{\mathrm{O\_UE\_PUSCH},b,f,c}(j)$ value, the second $\alpha_{b,f,c}(j)$ value, and $f_{b,f,c}(i,l)$ or $f_{b,f,c}(i,0)$ if *twoPUSCH-PC-AdjustmentStates* is provided or not provided, respectively, for determining $P_{\mathrm{PUSCH},b,f,c}(i,j,q_d,l)$.

- If the UE receives a random access response message in response to a PRACH transmission or a MsgA transmission on active UL BWP b of carrier f of serving cell c as described in clause 8

  - $f_{b,f,c}(0,l) = \Delta P_{\mathrm{rampup},b,f,c} + \delta_{\mathrm{msg2},b,f,c}$, where $l = 0$ and

    - $\delta_{\mathrm{msg2},b,f,c}$ is a TPC command value indicated in a random access response grant of the random access response message corresponding to a PRACH transmission according to Type-1 random access procedure, or in a random access response grant of the random access response message corresponding to a MsgA transmission according to Type-2 random access procedure with RAR message(s) for fallbackRAR, on active UL BWP b of carrier f of serving cell c, and

    - $$\Delta P_{rampup,b,f,c} = \min\left[\left\{\max\left(0, P_{\mathrm{CMAX},f,c} - \begin{pmatrix} 10\log_{10}(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(0)) \\ + P_{\mathrm{O\_PUSCH},b,f,c}(0) + \alpha_{b,f,c}(0)\cdot PL_c \\ + \Delta_{\mathrm{TF},b,f,c}(0) + \delta_{msg2,b,f,c} \end{pmatrix}\right)\right\}, \quad \Delta P_{rampuprequested,b,f,c}\right]$$

    and $\Delta P_{\mathrm{rampup\_requested},b,f,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last random access preamble for carrier f in the serving cell c, $M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(0)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for the first PUSCH transmission on active UL BWP b of carrier f of serving cell c, and $\Delta_{\mathrm{TF},b,f,c}(0)$ is the power adjustment of first PUSCH transmission on active UL BWP b of carrier f of serving cell c.

- If the UE transmits the PUSCH in PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c as described in clause 8.1A, $f_{b,f,c}(0,l) = \Delta P_{rampup,b,f,c}$, where

  - $l = 0$, and

  - $$\Delta P_{rampup,b,f,c} = \min\left[\left\{\max\left(0, P_{\mathrm{CMAX},f,c} - \begin{pmatrix} 10\log_{10}(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i)) \\ + P_{\mathrm{O\_PUSCH},b,f,c}(0) + \alpha_{b,f,c}(0)\cdot PL_c(i) \\ + \Delta_{\mathrm{TF},b,f,c}(i) \end{pmatrix}\right)\right\}, \quad \Delta P_{rampuprequested,b,f,c}\right]$$

  and $\Delta P_{rampup\_requested,b,f,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers, $M_{\mathrm{RB},b,f,c}^{\mathrm{PUSCH}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks, and $\Delta_{\mathrm{TF},b,f,c}(i)$ is the power adjustment of the PUSCH transmission in PUSCH transmission occasion i.

Table 7.1.1-1: Mapping of TPC Command Field in a DCI format scheduling a PUSCH transmission, or in DCI format 2_2 with CRC scrambled by TPC-PUSCH-RNTI, or in DCI format 2_3, to absolute and accumulated $\delta_{\mathrm{PUSCH},b,f,c}$ values or $\delta_{\mathrm{SRS},b,f,c}$ values

TPC Command Field	Accumulated $\delta_{\mathrm{PUSCH},b,f,c}$ or $\delta_{\mathrm{SRS},b,f,c}$ [dB]	Absolute $\delta_{\mathrm{PUSCH},b,f,c}$ or $\delta_{\mathrm{SRS},b,f,c}$ [dB]
0	-1	-4
1	0	-1
2	1	1
3	3	4

7.2 Physical uplink control channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG.

- When the procedures are applied for MCG, the term 'serving cell' in this clause refers to serving cell belonging to the MCG.

- When the procedures are applied for SCG, the term 'serving cell' in this clause refers to serving cell belonging to the SCG. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group.

- When the procedures are applied for the primary PUCCH group, the term 'serving cell' in this clause refers to serving cell belonging to the primary PUCCH group.

- When the procedures are applied for the secondary PUCCH group, the term 'serving cell' in this clause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group. If *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16* is provided, *pdsch-HARQ-ACK-Codebook* is replaced by *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16*.

For unpaired spectrum operation, if the UE is provided a PUCCH-sSCell by *pucch-sSCell* as described in clause 9.A, the UE shall apply the procedures described in this clause for both the primary cell and the PUCCH-sSCell.

7.2.1 UE behaviour

If a UE transmits a PUCCH on active UL BWP b of carrier f in the primary cell c using PUCCH power control adjustment state with index l

- if the UE is indicated a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, and is configured with *multipanelScheme*, and the UE determines to apply both the first *TCI-State* or *TCI-UL-State* and the second *TCI-State* or *TCI-UL-S*tate in PUCCH transmission occasion i, the UE determines the PUCCH transmission power $P_{\mathrm{PUCCH},b,f,c,k}(i,j,q_d,l)$ for the k-th indicated *TCI-State* or *TCI-UL-State* as

$$P_{\mathrm{PUCCH},b,f,c,k}(i,q_u,q_d,l) = \min\begin{Bmatrix} P_{\mathrm{CMAX},f,c,k}(i) \\ P_{\mathrm{O\_PUCCH},b,f,c}(j) + 10\log_{10}\left(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUCCH}}(i)\right) + PL_{b,f,c}(q_d) + \Delta_{\mathrm{F\_PUCCH}}(F) + \Delta_{\mathrm{TF},b,f,c}(i) + g_{b,f,c}(i,l) \end{Bmatrix} \text{[dBm]}$$

- else, the UE determines the PUCCH transmission power $P_{\mathrm{PUCCH},b,f,c}(i,q_u,q_d,l)$ in PUCCH transmission occasion i as

$$P_{\mathrm{PUCCH},b,f,c}(i,q_u,q_d,l) = \min\begin{Bmatrix} P_{\mathrm{CMAX},f,c}(i) \\ P_{\mathrm{O\_PUCCH},b,f,c}(q_u) + 10\log_{10}\left(2^{\mu}\cdot M_{\mathrm{RB},b,f,c}^{\mathrm{PUCCH}}(i)\right) + PL_{b,f,c}(q_d) + \Delta_{\mathrm{F\_PUCCH}}(F) + \Delta_{\mathrm{TF},b,f,c}(i) + g_{b,f,c}(i,l) \end{Bmatrix}$$
[dBm]

where

- $P_{\mathrm{CMAX},f,c,k}(i)$ is the UE configured maximum output power for the k-th indicated *TCI-State* or *TCI-UL-State* defined in [8-2, TS 38.101-2] for carrier f of serving cell c in PUCCH transmission occasion i .

- $P_{\mathrm{CMAX},f,c}(i)$ is the UE configured maximum output power defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3] for carrier f of primary cell c in PUCCH transmission occasion i

- $P_{\mathrm{O\_PUCCH},b,f,c}(q_u)$ is a parameter composed of the sum of a component $P_{\mathrm{O\_NOMINAL,PUCCH}}$, provided by *p0-nominal*, or $P_{\mathrm{O\_NOMINAL,PUCCH}} = 0$ dBm if *p0-nominal* is not provided, for carrier f of primary cell c and, if provided, a component $P_{\mathrm{O\_UE\_PUCCH}}(q_u)$ provided by *p0-PUCCH-Value* in *P0-PUCCH* for active UL BWP b of carrier f of primary cell c, where $0 \le q_u < Q_u$. Q_u is a size for a set of $P_{\mathrm{O\_UE\_PUCCH}}$ values provided by *maxNrofPUCCH-P0-PerSet*. The set of $P_{\mathrm{O\_UE\_PUCCH}}$ values is provided by *p0-Set*. If *p0-Set* is not provided to the UE, $P_{\mathrm{O\_PUCCH},b,f,c}(q_u) = 0$, $0 \le q_u < Q_u$

  - If the UE is provided *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by an index provided by *p0-PUCCH-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of *p0-PUCCH-Value* values. If the UE is provided more than one values for *pucch-SpatialRelationInfoId* and the UE receives an activation command [11, TS 38.321] indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the *p0-PUCCH-Value* value through the link to a corresponding *p0-PUCCH-Id* index. The UE applies the activation command in the first slot that is after slot $k + 3 \cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information for the PDSCH providing the activation command and μ is the SCS configuration for the PUCCH

  - If the UE is provided more than one sets of power control parameters for operation in FR1, and the UE receives an activation command [11, TS 38.321] indicating one or two of the more than one sets of power control parameters, the UE determines *p0-PUCCH-Value* value according to the corresponding one or two sets of power control parameters. The UE applies the activation command in the first slot that is after slot $k + 3 \cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information for the PDSCH providing the activation command and μ is the SCS configuration for the PUCCH.

  - If the UE is not provided *PUCCH-SpatialRelationInfo* and is not provided more than one sets of power control parameters for operation in FR1, the UE obtains the *p0-PUCCH-Value* value from the *P0-PUCCH* with *p0-PUCCH-Id* value equal to the minimum *p0-PUCCH-Id* value in *p0-Set*

- $M_{\mathrm{RB},b,f,c}^{\mathrm{PUCCH}}(i)$ is a bandwidth of the PUCCH resource assignment expressed in number of resource blocks for PUCCH transmission occasion i on active UL BWP b of carrier f of primary cell c and μ is a SCS configuration defined in [4, TS 38.211]

- $PL_{b,f,c}(q_d)$ is a downlink pathloss estimate in dB calculated by the UE using RS resource index q_d as described in clause 7.1.1 for the active DL BWP b of carrier f of the primary cell c as described in clause 12

  - If the UE is not provided *pathlossReferenceRSs* and *enableDefaultBeamPL-ForPUCCH*, or before the UE is provided dedicated higher layer parameters, the UE calculates $PL_{b,f,c}(q_d)$ using a RS resource obtained from an SS/PBCH block with same SS/PBCH block index as the one the UE uses to obtain *MIB*, or using the SS/PBCH block the UE acquired the time and frequency synchronization for a secondary cell.

  - If the UE is provided a number of RS resource indexes, the UE calculates $PL_{b,f,c}(q_d)$ using RS resource with index q_d, where $0 \le q_d < Q_d$. Q_d is a size for a set of RS resources provided by *maxNrofPUCCH-PathlossReferenceRSs*. The set of RS resources is provided by *pathlossReferenceRSs*. The set of RS resources can include one or both of a set of SS/PBCH block indexes, each provided by *ssb-Index* in *PUCCH-PathlossReferenceRS* when a value of a corresponding *pucch-PathlossReferenceRS-Id* maps to a SS/PBCH block index, and a set of CSI-RS resource indexes, each provided by *csi-RS-Index* when a value of a corresponding *pucch-PathlossReferenceRS-Id* maps to a CSI-RS resource index. The UE identifies a RS resource in the set of RS resources to correspond either to a SS/PBCH block index or to a CSI-RS resource index as provided by *pucch-PathlossReferenceRS-Id* in *PUCCH-PathlossReferenceRS*

- If the UE is provided *pathlossReferenceRSs* and *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by indexes provided by corresponding values of *pucch-PathlossReferenceRS-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of *referenceSignal* values provided by *PUCCH-PathlossReferenceRS*. If the UE is provided more than one values for *pucch-SpatialRelationInfoId* and the UE receives an activation command [11, TS 38.321] indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the *referenceSignal* value in *PUCCH-PathlossReferenceRS* through the link to a corresponding *pucch-PathlossReferenceRS-Id* index. The UE applies the activation command in the first slot that is after slot $k + 3 \cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information for the PDSCH providing the activation command and μ is the SCS configuration for the PUCCH

- If *PUCCH-SpatialRelationInfo* includes *servingCellId* indicating a serving cell, the UE receives the RS for resource index q_d on the active DL BWP of the serving cell

- If the UE is provided *pathlossReferenceRSs* and more than one sets of power control parameters for operation in FR1, and the UE receives an activation command [11, TS 38.321] indicating one or two of the more than one sets of power control parameters, the UE determines the *referenceSignal* values in *PUCCH-PathlossReferenceRS* that are indicated in the one or two sets of power control parameter

- If the UE is provided *pathlossReferenceRSs* and is not provided *PUCCH-SpatialRelationInfo* and is not provided more than one sets of power control parameters for operation in FR1, the UE obtains the *referenceSignal* value in *PUCCH-PathlossReferenceRS* from the *pucch-PathlossReferenceRS-Id* with index 0 in *PUCCH-PathlossReferenceRS* where the RS resource is either on the primary cell or, if provided, on a serving cell indicated by a value of *pathlossReferenceLinking*

- If the UE

  - is not provided *pathlossReferenceRSs*, and

  - is not provided *PUCCH-SpatialRelationInfo*, and

  - is provided *enableDefaultBeamPL-ForPUCCH*, and

  - is not provided *coresetPoolIndex* value of 1 for any CORESET, or is provided *coresetPoolIndex* value of 1 for all CORESETs, in *ControlResourceSet* and no codepoint of a TCI field, if any, in a DCI format of any search space set maps to two TCI states [5, TS 38.212]

  the UE determines a RS resource index q_d providing a periodic RS resource configured with *qcl-Type* set to 'typeD' in the TCI state or the QCL assumption of a CORESET with the lowest index in the active DL BWP of the primary cell. If the CORESET has two activated TCI states, as described in clause 10.1, the UE determines the RS resource index q_d based on the first activated TCI state. For a PUCCH transmission over multiple slots, a same q_d applies to the PUCCH transmission in each of the multiple slots.

- The parameter $\Delta_{\mathrm{F\_PUCCH}}(F)$ is a value of *deltaF-PUCCH-f0* for PUCCH format 0, *deltaF-PUCCH-f1* for PUCCH format 1, *deltaF-PUCCH-f2* for PUCCH format 2, *deltaF-PUCCH-f3* for PUCCH format 3, and *deltaF-PUCCH-f4* for PUCCH format 4, if provided; otherwise $\Delta_{\mathrm{F\_PUCCH}}(F) = 0$.

- $\Delta_{\mathrm{TF},b,f,c}(i)$ is a PUCCH transmission power adjustment component on active UL BWP b of carrier f of primary cell c

  - For a PUCCH transmission using PUCCH format 0 or PUCCH format 1, $\Delta_{\mathrm{TF},b,f,c}(i) = 10log_{10}\left(\frac{N_{\mathrm{ref}}^{\mathrm{PUCCH}}}{N_{\mathrm{symb}}^{\mathrm{PUCCH}}(i)}\right) + \Delta_{\mathrm{UCI}}(i)$ where

    - $N_{\mathrm{symb}}^{\mathrm{PUCCH}}(i)$ is a number of PUCCH format 0 symbols or PUCCH format 1 symbols for the PUCCH transmission as described in clause 9.2.

    - $N_{\mathrm{ref}}^{\mathrm{PUCCH}} = 2$ for PUCCH format 0

    - $N_{\mathrm{ref}}^{\mathrm{PUCCH}} = N_{\mathrm{symb}}^{\mathrm{slot}}$ for PUCCH format 1

    - For PUCCH format 0, $\Delta_{\mathrm{UCI}}(i) = 0$

    - For PUCCH format 1

- if the PUCCH transmission provides multicast HARQ-ACK information according to the second HARQ-ACK reporting mode as described in clause 18, $\Delta_{\mathrm{UCI}}(i) = 0$
- otherwise, $\Delta_{\mathrm{UCI}}(i) = 10log_{10}(O_{\mathrm{UCI}}(i))$, where $O_{\mathrm{UCI}}(i)$ is a number of UCI bits in PUCCH transmission occasion i

- For a PUCCH transmission using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and for a number of UCI bits smaller than or equal to 11, $\Delta_{\mathrm{TF},b,f,c}(i) = 10log_{10}\left(K_1 \cdot \left(n_{\mathrm{HARQ-ACK}}(i) + O_{\mathrm{SR}}(i) + O_{\mathrm{CSI}}(i)\right)/N_{\mathrm{RE}}(i)\right)$, where
  - $K_1 = 6$
  - $n_{\mathrm{HARQ-ACK}}(i)$ is a number of HARQ-ACK information bits that the UE determines as described in clause 9.1.2.1 or 16.5.1.1 for Type-1 HARQ-ACK codebook and as described in clause 9.1.3.1 or 9.1.3.3 or 16.5.2.1 for Type-2 HARQ-ACK codebook, or as described in clause 9.1.5 for HARQ-ACK codebook retransmission, or as described in clause 9.2.5.4 for deferring HARQ-ACK for SPS PDSCH. $n_{\mathrm{HARQ-ACK}}(i)$ is the same as $O_{\mathrm{ACK}}(i)$ as described in clause 9.1.4 for Type-3 HARQ-ACK codebook. If the UE is not provided any of *pdsch-HARQ-ACK-Codebook*, *pdsch-HARQ-ACK-Codebook-r16*, or *pdsch-HARQ-ACK-OneShotFeedback*, $n_{\mathrm{HARQ-ACK}}(i) = 1$ if the UE includes a HARQ-ACK information bit in the PUCCH transmission; otherwise, $n_{\mathrm{HARQ-ACK}}(i) = 0$
  - $O_{\mathrm{SR}}(i)$ is a number of SR information bits that the UE determines as described in clause 9.2.5.1
  - $O_{\mathrm{CSI}}(i)$ is a number of CSI information bits that the UE determines as described in clause 9.2.5.2
  - $N_{\mathrm{RE}}(i)$ is a number of resource elements determined as $N_{\mathrm{RE}}(i) = M_{\mathrm{RB},b,f,c}^{\mathrm{PUCCH}}(i) \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}(i) \cdot N_{\mathrm{symb-UCI},b,f,c}^{\mathrm{PUCCH}}(i)$, where $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}(i)$ is a number of subcarriers per resource block excluding subcarriers used for DM-RS transmission, and $N_{\mathrm{symb-UCI},b,f,c}^{\mathrm{PUCCH}}(i)$ is a number of symbols excluding symbols used for DM-RS transmission, as defined in clause 9.2.5.2, for PUCCH transmission occasion i on active UL BWP b of carrier f of primary cell c

- For a PUCCH transmission using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and for a number of UCI bits larger than 11, $\Delta_{\mathrm{TF},b,f,c}(i) = 10log_{10}(2^{\mathrm{BPRE}\cdot K_2} - 1)$, where
  - $K_2 = 2.4$
  - $\mathrm{BPRE(i)} = \left(O_{\mathrm{ACK}}(i) + O_{\mathrm{SR}}(i) + O_{\mathrm{CSI}}(i) + O_{\mathrm{CRC}}(i)\right)/N_{RE}\,(i)$
  - $O_{\mathrm{ACK}}(i)$ is a number of HARQ-ACK information bits that the UE determines as described in clause 9.1.2.1 or 16.5.1.1 for Type-1 HARQ-ACK codebook and as described in clause 9.1.3.1 or 9.1.3.3 or 16.5.2.1 for Type-2 HARQ-ACK codebook, or as described in clause 9.1.4 for Type-3 HARQ-ACK codebook, or as described in clause 9.1.5 for HARQ-ACK codebook retransmission, or as described in clause 9.2.5.4 for deferring HARQ-ACK for SPS PDSCH. If the UE is not provided any of *pdsch-HARQ-ACK-Codebook*, *pdsch-HARQ-ACK-Codebook-r16*, or *pdsch-HARQ-ACK-OneShotFeedback*, $O_{\mathrm{ACK}} = 1$ if the UE includes a HARQ-ACK information bit in the PUCCH transmission; otherwise, $O_{\mathrm{ACK}} = 0$
  - $O_{\mathrm{SR}}(i)$ is a number of SR information bits that the UE determines as described in clause 9.2.5.1
  - $O_{\mathrm{CSI}}(i)$ is a number of CSI information bits that the UE determines as described in clause 9.2.5.2
  - $O_{\mathrm{CRC}}(i)$ is a number of CRC bits that the UE determines as described in clause 9.2
  - $N_{\mathrm{RE}}(i)$ is a number of resource elements that the UE determines as $N_{\mathrm{RE}}(i) = M_{\mathrm{RB},b,f,c}^{\mathrm{PUCCH}}(i) \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}(i) \cdot N_{\mathrm{symb-UCI},b,f,c}^{\mathrm{PUCCH}}(i)$, where $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}(i)$ is a number of subcarriers per resource block excluding subcarriers used for DM-RS transmission, and $N_{\mathrm{symb-UCI},b,f,c}^{\mathrm{PUCCH}}(i)$ is a number of symbols excluding symbols used for DM-RS transmission, as defined in clause 9.2.5.2, for PUCCH transmission occasion i on active UL BWP b of carrier f of primary cell c.

- For the PUCCH power control adjustment state $g_{b,f,c}(i,l)$ for active UL BWP b of carrier f of primary cell c and PUCCH transmission occasion i

- $\delta_{\mathrm{PUCCH},b,f,c}(i,l)$ is a TPC command value included in a DCI format associated with the PUCCH transmission for active UL BWP b of carrier f of the primary cell c that the UE detects for PUCCH transmission occasion i, or is jointly coded with other TPC commands in a DCI format 2_2 with CRC scrambled by TPC-PUCCH-RNTI [5, TS 38.212], as described in clause 11.3
  - $l \in \{0,1\}$ if the UE is provided *twoPUCCH-PC-AdjustmentStates* and *PUCCH-SpatialRelationInfo*, or more than one sets of power control parameters for operation in FR1, $l = 0$ if the UE is not provided *twoPUCCH-PC-AdjustmentStates* or *PUCCH-SpatialRelationInfo* and more than one sets of power control parameters, and $l = 0$ if the PUCCH transmission provides only multicast HARQ-ACK information
  - If the UE obtains a TPC command value from a DCI format associated with the PUCCH transmission and if the UE is provided *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by an index provided by *p0-PUCCH-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of values for *closedLoopIndex* that provide the l value(s). If the UE receives an activation command indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the value *closedLoopIndex* that provides the value of l through the link to a corresponding *p0-PUCCH-Id* index
  - If the UE obtains a TPC command value from a DCI format associated with the PUCCH transmission, and if the UE is provided more than one sets of power control parameters for operation in FR1, and if the UE receives an activation command [11, TS 38.321] indicating one or two sets of the more than one sets of power control parameters, the UE determines the value of l based on the *closedLoopIndex* value in the one or two sets of power control parameters
  - If the UE obtains a TPC command from a DCI format 2_2 with CRC scrambled by a TPC-PUCCH-RNTI, the l value is provided by the closed loop indicator field in DCI format 2_2
  - If the UE transmits the PUCCH with $N_{\mathrm{PUCCH}}^{\mathrm{repeat}} > 1$ repetitions, as described in clause 9.2.6, and the UE is provided *twoPUCCH-PC-AdjustmentStates* by *pucch-PowerControl*
    - If the DCI format includes two TPC command values and the PUCCH resource of the PUCCH transmission is associated with $l = 0$ and $l = 1$, the UE applies the first TPC command value for $l = 0$ and applies the second TPC command value for $l = 1$
    - If the DCI format includes two TPC command values and the PUCCH resource of the PUCCH transmission is associated with $l = 0$, the UE applies the first TPC command value for $l = 0$ and ignores the second TPC command value
    - If the DCI format includes two TPC command values and the PUCCH resource of the PUCCH transmission is associated with $l = 1$, the UE applies the second TPC command value for $l = 1$ and ignores the first TPC command value
    - If the DCI format includes one TPC command value, the UE applies the TPC command value for all l associated with the PUCCH resource of the PUCCH transmission
- $g_{b,f,c}(i,l) = g_{b,f,c}(i-i_0,l) + \sum_{m=0}^{\mathcal{C}(C_i)-1} \delta_{\mathrm{PUCCH},b,f,c}(m,l)$ is the current PUCCH power control adjustment state l for active UL BWP b of carrier f of primary cell c and PUCCH transmission occasion i, where
  - The $\delta_{\mathrm{PUCCH},b,f,c}$ values are given in Table 7.1.2-1
  - $\sum_{m=0}^{\mathcal{C}(C_i)-1} \delta_{\mathrm{PUCCH},b,f,c}(m,l)$ is a sum of TPC command values in a set C_i of TPC command values with cardinality $\mathcal{C}(C_i)$ that the UE receives between $K_{\mathrm{PUCCH}}(i-i_0)-1$ symbols before PUCCH transmission occasion $i-i_0$ and $K_{\mathrm{PUCCH}}(i)$ symbols before PUCCH transmission occasion i on active UL BWP b of carrier f of primary cell c for PUCCH power control adjustment state, where $i_0 > 0$ is the smallest integer for which $K_{\mathrm{PUCCH}}(i-i_0)$ symbols before PUCCH transmission occasion $i-i_0$ is earlier than $K_{\mathrm{PUCCH}}(i)$ symbols before PUCCH transmission occasion i
  - If the PUCCH transmission is in response to a detection by the UE of a DCI format, $K_{\mathrm{PUCCH}}(i)$ is a number of symbols for active UL BWP b of carrier f of primary cell c after a last symbol of a corresponding PDCCH reception and before a first symbol of the PUCCH transmission
  - If the PUCCH transmission is not in response to a detection by the UE of a DCI format, $K_{\mathrm{PUCCH}}(i)$ is a number of $K_{\mathrm{PUCCH,min}}$ symbols equal to the product of a number of symbols per slot, $N_{\mathrm{symb}}^{\mathrm{slot}}$, and the

minimum of the values provided by *k2* in *PUSCH-ConfigCommon* for active UL BWP b of carrier f of primary cell c

- If the first symbol of the PUCCH transmission occasion occurs within $T_{\text{proc},2}$ after a last symbol of a PDCCH reception where the UE detects the DCI format providing the TPC command, the UE may postpone the application of the TPC command until the above condition is not valid. $T_{\text{proc},2}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 0$, and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the PUCCH.

- If the UE has reached maximum power for active UL BWP b of carrier f of primary cell c at PUCCH transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(C_i)-1} \delta_{\text{PUCCH},b,f,c}(m,l) \geq 0$, then $g_{b,f,c}(i,l) = g_{b,f,c}(i - i_0, l)$
- If UE has reached minimum power for active UL BWP b of carrier f of primary cell c at PUCCH transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(C_i)-1} \delta_{\text{PUCCH},b,f,c}(m,l) \leq 0$, then $g_{b,f,c}(i,l) = g_{b,f,c}(i - i_0, l)$
- If a configuration of a $P_{\text{O\_PUCCH},b,f,c}(q_u)$ value for a corresponding PUCCH power control adjustment state l for active UL BWP b of carrier f of primary cell c is provided by higher layers,
  - $g_{b,f,c}(k,l) = 0,\ k = 0,1,\dots,i$
    - if the UE is provided *PUCCH-SpatialRelationInfo*, the UE determines the value of l from the value of q_u based on a *pucch-SpatialRelationInfoId* value associated with the *p0-PUCCH-Id* value corresponding to q_u and with the *closedLoopIndex* value corresponding to l;
    - else, if the UE is provided more than one sets of power control parameters for operation in FR1, and if the UE receives an activation command for a PUCCH resource that indicates one or two sets of the more than one sets of power control parameters, the UE determines the value of l based on the *closedLoopIndex* value in the one or two sets of power control parameters;
    - else, $l = 0$
- Else,
  - $g_{b,f,c}(0,l) = \Delta P_{\text{rampup},b,f,c} + \delta_{b,f,c}$, where $l = 0$, and $\delta_{b,f,c}$ is
    - the TPC command value indicated in a random access response grant corresponding to a PRACH transmission according to Type-1 random access procedure, or in a random access response grant corresponding to MsgA transmissions according to Type-2 random access procedure with RAR message(s) for fallbackRAR, or
    - the TPC command value indicated in a successRAR corresponding to MsgA transmissions for Type-2 random access procedure, or
    - the TPC command value in a DCI format with CRC scrambled by C-RNTI or MCS-C-RNTI that the UE detects in a first PDCCH reception in a search space set provided by *recoverySearchSpaceId* if the PUCCH transmission is a first PUCCH transmission after 28 symbols from a last symbol of the first PDCCH reception,

  and, if the UE transmits PUCCH on active UL BWP b of carrier f of primary cell c,

  $$\Delta P_{\text{rampup},b,f,c} = min\left[max\left(0, P_{\text{CMAX},f,c} - \left(P_{\text{O\_PUCCH},b,f,c} + PL_{b,f,c}(q_d) + \Delta_{\text{F\_PUCCH}} + \Delta_{TF,b,f,c} + \delta_{b,f,c}\right)\right), \Delta P_{\text{rampup\_requested},b,f,c}\right];$$

  otherwise,

  $$\Delta P_{\text{rampup},b,f,c} = min\left[max\left(0, P_{\text{CMAX},f,c} - \left(P_{\text{O\_PUCCH},b,f,c} + PL_{b,f,c}(q_d)\right)\right), \Delta P_{\text{rampup\_requested},b,f,c}\right]$$

  where $\Delta P_{\text{rampup\_requested},b,f,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble for active UL BWP b of carrier f of primary cell c, and $\Delta_{\text{F\_PUCCH}}$ corresponds to PUCCH format 0 or PUCCH format 1

Table 7.2.1-1: Mapping of TPC Command Field in a DCI format to accumulated $\delta_{\mathrm{PUCCH},b,f,c}$ values

TPC Command Field	Accumulated $\delta_{\mathrm{PUCCH},b,f,c}$ [dB]
0	-1
1	0
2	1
3	3

7.3 Sounding reference signals

For SRS,

- if a UE is provided *nrofSRS-Ports-n8* = 'ports8tdm' for an SRS resource with 8 ports in an SRS resource set with usage 'codebook' or 'antennaSwitching', the UE splits a linear value $\hat{P}_{\mathrm{SRS},b,f,c}(i,q_s,l)$ of the transmit power $P_{\mathrm{SRS},b,f,c}(i,q_s,l)$ on active UL BWP b of carrier f of serving cell c equally across the configured antenna ports on each symbol for SRS transmission.

- else, a UE splits a linear value $\hat{P}_{\mathrm{SRS},b,f,c}(i,q_s,l)$ of the transmit power $P_{\mathrm{SRS},b,f,c}(i,q_s,l)$ on active UL BWP b of carrier f of serving cell c equally across the configured antenna ports for SRS.

7.3.1 UE behaviour

If a UE transmits SRS based on a configuration by *SRS-ResourceSet* on active UL BWP b of carrier f of serving cell c using SRS power control adjustment state with index l, the UE determines the SRS transmission power $P_{\mathrm{SRS},b,f,c}(i,q_s,l)$ in SRS transmission occasion i as

$$P_{\mathrm{SRS},b,f,c}(i,q_s,l)=\min\begin{Bmatrix}P_{\mathrm{CMAX},f,c}(i),\\ P_{\mathrm{O\_SRS},b,f,c}(q_s)+10\log_{10}(2^{\mu}\cdot M_{\mathrm{SRS},b,f,c}(i))+\alpha_{\mathrm{SRS},b,f,c}(q_s)\cdot PL_{b,f,c}(q_d)+h_{b,f,c}(i,l)\end{Bmatrix}\ \text{[dBm]}$$

where,

- $P_{\mathrm{CMAX},f,c}(i)$ is the UE configured maximum output power defined in [8, TS 38.101-1], [8-2, TS 38.101-2] and [TS 38.101-3] for carrier f of serving cell c in SRS transmission occasion i

- $P_{\mathrm{O\_SRS},b,f,c}(q_s)$ is provided by *p0* for active UL BWP b of carrier f of serving cell c and SRS resource set q_s provided by *SRS-ResourceSet* and *SRS-ResourceSetId*

- $M_{\mathrm{SRS},b,f,c}(i)$ is a SRS bandwidth expressed in number of resource blocks for SRS transmission occasion i on active UL BWP b of carrier f of serving cell c and μ is a SCS configuration defined in [4, TS 38.211]

- $\alpha_{\mathrm{SRS},b,f,c}(q_s)$ is provided by *alpha* for active UL BWP b of carrier f of serving cell c and SRS resource set q_s

- $PL_{b,f,c}(q_d)$ is a downlink pathloss estimate in dB calculated by the UE using RS resource index q_d as described in clause 7.1.1 for the active DL BWP of serving cell c and SRS resource set q_s [6, TS 38.214]. The RS resource index q_d is provided by *pathlossReferenceRS* associated with the SRS resource set q_s and is either an *ssb-Index* providing a SS/PBCH block index or a *csi-RS-Index* providing a CSI-RS resource index. If the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, a MAC CE [11, TS 38.321] can provide by *SRS-PathlossReferenceRS-Id* a corresponding RS resource index q_d for aperiodic or semi-persistent SRS resource set q_s

  - If the UE is not provided *pathlossReferenceRS* or *SRS-PathlossReferenceRS-Id* and if the UE is not provided *enableDefaultBeamPL-ForSRS*, or before the UE is provided dedicated higher layer parameters, the UE calculates $PL_{b,f,c}(q_d)$ using a RS resource obtained from an SS/PBCH block with same SS/PBCH block index as the one the UE uses to obtain *MIB*, or using the SS/PBCH block the UE acquired the time and frequency synchronization for a secondary cell.

  - If the UE is provided *pathlossReferenceLinking*, the RS resource is on a serving cell indicated by a value of *pathlossReferenceLinking*

  - If the UE

- is not provided *pathlossReferenceRS* or *SRS-PathlossReferenceRS-Id*,
- is not provided *spatialRelationInfo*, and
- is provided *enableDefaultBeamPL-ForSRS*, and
- is not provided *coresetPoolIndex* value of 1 for any CORESET, or is provided *coresetPoolIndex* value of 1 for all CORESETs, in *ControlResourceSet* and no codepoint of a TCI field, if any, in a DCI format of any search space set maps to two TCI states [5, TS 38.212]

the UE determines a RS resource index q_d providing a periodic RS resource configured with *qcl-Type* set to 'typeD' in

- the TCI state or the QCL assumption of a CORESET with the lowest index in the active DL BWP, if CORESETs are provided in the active DL BWP of serving cell c. If the CORESET has two activated TCI states, as described in clause 10.1, the UE determines the RS resource index q_d based on the first TCI state.
- the active PDSCH TCI state with lowest ID [6, TS 38.214] in the active DL BWP, if CORESETs are not provided in the active DL BWP of serving cell c

- For the SRS power control adjustment state for active UL BWP b of carrier f of serving cell c and SRS transmission occasion i
  - $h_{b,f,c}(i,l) = f_{b,f,c}(i,l)$, where $f_{b,f,c}(i,l)$ is the current PUSCH power control adjustment state as described in clause 7.1.1, if *srs-PowerControlAdjustmentStates* indicates a same power control adjustment state for SRS transmissions and PUSCH transmissions; or
  - $h_{b,f,c}(i) = h_{b,f,c}(i-i_0) + \sum_{m=0}^{\mathcal{C}(S_i)-1} \delta_{\mathrm{SRS},b,f,c}(m)$ if the UE is not configured for PUSCH transmissions on active UL BWP b of carrier f of serving cell c, or if *srs-PowerControlAdjustmentStates* indicates separate power control adjustment states between SRS transmissions and PUSCH transmissions, and if *tpc-Accumulation* is not provided, where
    - The $\delta_{\mathrm{SRS},b,f,c}$ values are given in Table 7.1.1-1
    - $\delta_{\mathrm{SRS},b,f,c}(m)$ is jointly coded with other TPC commands in a PDCCH with DCI format 2_3, as described in clause 11.4
    - $\sum_{m=0}^{\mathcal{C}(S_i)-1} \delta_{\mathrm{SRS},b,f,c}(m)$ is a sum of TPC command values in a set S_i of TPC command values with cardinality $\mathcal{C}(S_i)$ that the UE receives between $K_{\mathrm{SRS}}(i-i_0)-1$ symbols before SRS transmission occasion $i-i_0$ and $K_{\mathrm{SRS}}(i)$ symbols before SRS transmission occasion i on active UL BWP b of carrier f of serving cell c for SRS power control adjustment state, where $i_0 > 0$ is the smallest integer for which $K_{\mathrm{SRS}}(i)$ symbols before SRS transmission occasion $i-i_0$ is earlier than $K_{\mathrm{SRS}}(i-i_0)$ symbols before SRS transmission occasion i
    - if the SRS transmission is aperiodic, $K_{\mathrm{SRS}}(i)$ is a number of symbols for active UL BWP b of carrier f of serving cell c after a last symbol of a corresponding PDCCH triggering the SRS transmission and before a first symbol of the SRS transmission
    - if the SRS transmission is semi-persistent or periodic, $K_{\mathrm{SRS}}(i)$ is a number of $K_{\mathrm{SRS,min}}$ symbols equal to the product of a number of symbols per slot, $N_{\mathrm{symb}}^{\mathrm{slot}}$, and the minimum of the values provided by *k2* in *PUSCH-ConfigCommon* for active UL BWP b of carrier f of serving cell c
      - If the first symbol of the SRS transmission occasion occurs within $T_{\mathrm{proc,2}}$ after a last symbol of a PDCCH reception where the UE detects the DCI format providing the TPC command, the UE may postpone the application of the TPC until the above condition is not valid. $T_{\mathrm{proc,2}}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 0$, and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the SRS.

- If the UE has reached maximum power for active UL BWP b of carrier f of serving cell c at SRS transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(S_i)-1} \delta_{\mathrm{SRS},b,f,c}(m) \geq 0$, then $h_{b,f,c}(i) = h_{b,f,c}(i - i_0)$
- If UE has reached minimum power for active UL BWP b of carrier f of serving cell c at SRS transmission occasion $i - i_0$ and $\sum_{m=0}^{\mathcal{C}(S_i)-1} \delta_{\mathrm{SRS},b,f,c}(m) \leq 0$, then $h_{b,f,c}(i) = h_{b,f,c}(i - i_0)$
- If a configuration for a $P_{\mathrm{O\_SRS},b,f,c}(q_s)$ value or for a $\alpha_{\mathrm{SRS},b,f,c}(q_s)$ value for a corresponding SRS power control adjustment state l for active UL BWP b of carrier f of serving cell c is provided by higher layers
  - $h_{b,f,c}(k) = 0, k = 0,1, \ldots, i$
- else
  - $h_{b,f,c}(0) = \Delta P_{rampup,b,f,c} + \delta_{b,f,c}$

  where

  $\delta_{b,f,c}$ is

  - the TPC command value indicated in the random access response grant corresponding to a PRACH transmission according to Type-1 random access procedure, or in a random access response grant corresponding to MsgA transmissions according to Type-2 random access procedure with RAR message(s) for fallbackRAR, or
  - the TPC command value indicated in a successRAR corresponding to MsgA transmissions for Type-2 random access procedure,

  and

  $$\Delta P_{\mathrm{rampup},b,f,c} = \min\left[\max\left(0, P_{\mathrm{CMAX},f,c} - \left(P_{\mathrm{O\_SRS},b,f,c}(q_s) + 10log_{10}\left(2^{\mu} \cdot M_{\mathrm{SRS},b,f,c}(i)\right) + \alpha_{SRS,b,f,c}(q_s) \cdot PL_{b,f,c}(q_d)\right)\right), \Delta P_{\mathrm{rampup\_requested},b,f,c}\right];$$

  where $\Delta P_{\mathrm{rampup\_requested},b,f,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble for active UL BWP b of carrier f of serving cell c.

- $h_{b,f,c}(i) = \delta_{\mathrm{SRS},b,f,c}(i)$ if the UE is not configured for PUSCH transmissions on active UL BWP b of carrier f of serving cell c, or if *srs-PowerControlAdjustmentStates* indicates separate power control adjustment states between SRS transmissions and PUSCH transmissions, and *tpc-Accumulation* is provided, and the UE detects a DCI format 2_3 $K_{\mathrm{SRS,min}}$ symbols before a first symbol of SRS transmission occasion i, where absolute values of $\delta_{\mathrm{SRS},b,f,c}$ are provided in Table 7.1.1-1
- if *srs-PowerControlAdjustmentStates* indicates a same power control adjustment state for SRS transmissions and PUSCH transmissions, the update of the power control adjustment state for SRS transmission occasion i occurs at the beginning of each SRS resource in the SRS resource set q_s; otherwise, the update of the power control adjustment state SRS transmission occasion i occurs at the beginning of the first transmitted SRS resource in the SRS resource set q_s.

If a UE transmits SRS based on a configuration by *SRS-PosResourceSet* on active UL BWP b of carrier f of serving cell c, the UE determines the SRS transmission power $P_{SRS,b,f,c}(i, q_s)$ in SRS transmission occasion i as

$$P_{\mathrm{SRS},b,f,c}(i,q_s) = \min\begin{Bmatrix} P_{\mathrm{CMAX},f,c}(i), \\ P_{\mathrm{O\_SRS},b,f,c}(q_s) + 10\log_{10}(2^{\mu} \cdot M_{\mathrm{SRS},b,f,c}(i)) + \alpha_{\mathrm{SRS},b,f,c}(q_s) \cdot PL_{b,f,c}(q_d) \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\mathrm{O\_SRS},b,f,c}(q_s)$ and $\alpha_{\mathrm{SRS},b,f,c}(q_s)$ are provided by *p0-r16* and *alpha-r16* respectively, for active UL BWP b of carrier f of serving cell c, and SRS resource set q_s is indicated by *SRS-PosResourceSetId* from *SRS-PosResourceSet*, and

- $PL_{b,f,c}(q_d)$ is a downlink pathloss estimate in dB calculated by the UE, as described in clause 7.1.1 in case of an active DL BWP of a serving cell c, using RS resource indexed q_d in a serving or non-serving cell for SRS resource set q_s [6, TS 38.214]. A configuration for RS resource index q_d associated with SRS resource set q_s is provided by *pathlossReferenceRS-Pos*

  - if a *ssb-IndexServing* is provided, *referenceSignalPower* is provided by *ss-PBCH-BlockPower*

  - if a *ssb-Ncell* is provided, *referenceSignalPower* is provided by *ss-PBCH-BlockPower-r16*

  - if a *dl-PRS* is provided, *referenceSignalPower* is provided by *dl-PRS-ResourcePower*

  If the UE is in the RRC_CONNECTED state and determines that the UE is not able to accurately measure $PL_{b,f,c}(q_d)$, or the UE is not provided with *pathlossReferenceRS-Pos*, the UE calculates $PL_{b,f,c}(q_d)$ using a RS resource obtained from the SS/PBCH block of the serving cell that the UE uses to obtain *MIB*. If the UE is in the RRC_INACTIVE state, is not provided *SRS-PosRRC-InactiveConfig-ValidityArea*, and determines that the UE is not able to accurately measure $PL_{b,f,c}(q_d)$, the UE does not transmit SRS for the SRS resource set.

  The UE may indicate a capability for a number of pathloss estimates that the UE can simultaneously maintain for all SRS resource sets provided by *SRS-PosResourceSet* in addition to the up to four pathloss estimates that the UE maintains per serving cell for PUSCH/PUCCH transmissions and for SRS transmissions configured by *SRS-Resource*.

If a UE transmits SRS based on a configuration by *SRS-PosResourceSet* outside initial UL BWP of carrier *f* of serving cell *c* in RRC_INACTIVE state, the active UL BWP *b* refers to the BWP configuration provided by *bwp-NUL* or *bwp-SUL* in *SRS-PosRRC-InactiveConfig* for the corresponding carrier.

If a UE transmits SRS on multiple SRS resources for positioning bandwidth aggregation according to *linkage* [6, TS 38.214], the UE calculates $P_{SRS,b,f,c}(i,q_s)$ using the same values of $P_{\mathrm{O\_SRS},b,f,c}(q_s)$, $\alpha_{\mathrm{SRS},b,f,c}(q_s)$, and $PL_{b,f,c}(q_d)$ for each of the multiple SRS resources.

If a UE transmits SRS based on a configuration by *SRS-PosResourceSet* in *SRS-PosRRC-InactiveValidityAreaConfig* in RRC_INACTIVE state [12, TS 38.331], the active UL BWP *b* refers to the BWP provided by *bwp* in *SRS-PosRRC-InactiveValidityAreaConfig*. If the UE is not provided *pathlossReferenceRS-Pos* in *SRS-PosResourceSet*, or if the UE is provided *pathlossReferenceRS-Pos* in *SRS-PosResourceSet* and the UE cannot accurately measure a pathloss, the UE calculates $PL_{b,f,c}(q_d)$ using an RS resource from an SS/PBCH block with same index as the one the UE used to obtain *MIB*; otherwise, the UE uses the RS indicated by *pathlossReferenceRS-Pos* to calculate $PL_{b,f,c}(q_d)$.

If a RedCap UE transmits SRS with frequency hopping outside the active UL BWP of carrier f of serving cell c in RRC_CONNECTED state based on an indication by *SRS-PosResourceSet* in *XYZ*, the active UL BWP b refers to the BWP provided by *bwp* in *XYZ*.

If a RedCap UE transmits SRS with frequency hopping outside the initial UL BWP of carrier f of serving cell c in RRC_INACTIVE state based on an indication by *SRS-PosResourceSet* in *XYZ*, the active UL BWP b refers to the BWP provided by *bwp* in *XYZ*.

7.4 Physical random access channel

A UE determines a transmission power for a physical random access channel (PRACH), $P_{\mathrm{PRACH},b,f,c}(i)$, on active UL BWP b of carrier f of cell c based on DL RS for cell c in transmission occasion i as

$$P_{\mathrm{PRACH},b,f,c}(i) = min\{P_{\mathrm{CMAX},f,c}(i), P_{\mathrm{PRACH,target},f,c} + PL_{b,f,c}\} \text{ [dBm]},$$

where

- $P_{\mathrm{CMAX},f,c}(i)$ is the UE configured maximum output power defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3] for carrier f of cell c within transmission occasion i,

- $P_{\mathrm{PRACH,target},f,c}$ is the PRACH target reception power *PREAMBLE_RECEIVED_TARGET_POWER* provided by higher layers [11, TS 38.321] for the active UL BWP b of carrier f of cell c, and

- $PL_{b,f,c}$ is a pathloss for the active UL BWP b of carrier f based on the DL RS associated with the PRACH transmission on the active DL BWP of cell c and calculated by the UE in dB as *referenceSignalPower* – higher layer filtered RSRP in dBm, where RSRP is defined in [7, TS 38.215] and the higher layer filter configuration is defined in [12, TS 38.331]. If the active DL BWP is the initial DL BWP and for SS/PBCH block and CORESET multiplexing pattern 2 or 3 as described in clause 13, or for a non-serving cell, the UE determines $PL_{b,f,c}$ based on the SS/PBCH block associated with the PRACH transmission.

If a PRACH transmission from a UE is not in response to a detection of a PDCCH order by the UE, or is in response to a detection of a PDCCH order by the UE that triggers a contention based random access procedure, or is associated with a link recovery procedure where a corresponding index q_{new} is associated with a SS/PBCH block, as described in clause 6, *referenceSignalPower* is provided by *ss-PBCH-BlockPower*.

If a PRACH transmission from a UE is in response to a detection of a PDCCH order by the UE that triggers a contention-free random access procedure and depending on the DL RS that the DM-RS of the PDCCH order is quasi-collocated with as described in clause 10.1

- when the PRACH association indicator is not present in the PDCCH order, or
- when the cell indicator field in the PDCCH order is not present or has value 0, or
- when a value of a PRACH association indicator field in the PDCCH order is 0 if the UE is not provided *SSB-MTC-AdditionalPCI*, or
- when the PRACH association indicator field in the PDCCH order indicates a *physCellId* associated with the cell of the PDCCH order reception,

or depending on an indicated SS/PBCH block

- when the PRACH transmission is on a non-serving cell indicated by the cell indicator field in the PDCCH order, or
- when a value of a PRACH association indicator field in the PDCCH order is 1 if the UE is not provided *SSB-MTC-AdditionalPCI*, or
- when the PRACH association indicator field in the PDCCH order indicates a *physCellId* that is different that the *physCellId* associated with the cell of the PDCCH order reception,

referenceSignalPower is provided by a corresponding *ss-PBCH-BlockPower*.

When a value of a PRACH association indicator field in the PDCCH order is 1 if the UE is not provided *SSB-MTC-AdditionalPCI*, or when the PRACH association indicator field in the PDCCH order indicates a *physCellId* that is different that the *physCellId* associated with the cell of the PDCCH order reception, the UE expects that the indicated SS/PBCH block in the PDCCH order is configured as *pathlossReferenceRS-Id* of an active TCI state.

If the UE is configured resources for a periodic CSI-RS reception or the PRACH transmission is associated with a link recovery procedure where a corresponding index q_{new} is associated with a periodic CSI-RS configuration as described in clause 6, *referenceSignalPower* is obtained by *ss-PBCH-BlockPower* and *powerControlOffsetSS* where *powerControlOffsetSS* provides an offset of CSI-RS transmission power relative to SS/PBCH block transmission power [6, TS 38.214]. If *powerControlOffsetSS* is not provided to the UE, the UE assumes an offset of 0 dB. If the active TCI state for the PDCCH that provides the PDCCH order includes two RS, the UE expects that one RS is configured with *qcl-Type* set to 'typeD' and the UE uses the one RS when applying a value provided by *powerControlOffsetSS*.

If within a random access response window, as described in clause 8.2, the UE does not receive a random access response that contains a preamble identifier corresponding to the preamble sequence transmitted by the UE, or when a random access response does not exist, the UE determines a transmission power for a subsequent PRACH transmission, if any, as described in [11, TS 38.321].

If prior to a PRACH retransmission, a UE changes the spatial domain transmission filter, Layer 1 notifies higher layers to suspend the power ramping counter as described in [11, TS 38.321].

If due to power allocation to PUSCH/PUCCH/PRACH/SRS transmissions as described in clause 7.5, or due to power allocation in EN-DC or NE-DC or NR-DC operation, or due to slot format determination as described in clause 11.1, or due to the PUSCH/PUCCH/PRACH/SRS transmission occasions are in the same slot or the gap between a PRACH transmission and PUSCH/PUCCH/SRS transmission is small as described in clause 8.1, or due to DAPS operation as described in clause 15, or due to HD-UE operation in paired spectrum as described in clause 17.2, the UE does not transmit a PRACH in a transmission occasion, or does not transmit any of $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions of a PRACH as described in Clause 8.1, Layer 1 notifies higher layers to suspend the corresponding power ramping counter.

If due to power allocation to PUSCH/PUCCH/PRACH/SRS transmissions as described in clause 7.5, or due to power allocation in EN-DC or NE-DC or NR-DC operation, the UE transmits a PRACH with reduced power in a transmission occasion, or transmits one or more of $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions of a PRACH with reduced power or transmits less than $N_{\text{preamble}}^{\text{rep}}$ preamble repetitions of a PRACH, Layer 1 may notify higher layers to suspend the corresponding power ramping counter.

7.5 Prioritizations for transmission power reductions

For single cell operation with two uplink carriers or for operation with carrier aggregation, if a total UE transmit power for PUSCH or PUCCH or PRACH or SRS transmissions on serving cells in a frequency range in a respective transmission occasion i would exceed $\hat{P}_{\text{CMAX}}(i)$, where $\hat{P}_{\text{CMAX}}(i)$ is the linear value of $P_{\text{CMAX}}(i)$ in transmission occasion i as defined in [8-1, TS 38.101-1] for FR1 and [8-2, TS 38.101-2] for FR2, the UE allocates power to PUSCH/PUCCH/PRACH/SRS transmissions according to the following priority order (in descending order) so that the total UE transmit power for transmissions on serving cells in the frequency range is smaller than or equal to $\hat{P}_{\text{CMAX}}(i)$ for that frequency range in every symbol of transmission occasion i. If the UE transmits SRS on multiple SRS resources according the *XYZ* [6, TS 38.214], the UE allocates power so that all REs of the SRS transmission have same power.

For the purpose of power allocation in this clause, if a UE is provided *uci-MuxWithDiffPrio* and the UE multiplexes HARQ-ACK information in a PUSCH, a priority index of the PUSCH is the larger of (a) the priority index of the PUSCH according to clause 9 and (b) the larger priority index of the HARQ-ACK information. When determining a total transmit power for serving cells in a frequency range in a symbol of transmission occasion i, the UE does not include power for transmissions starting after the symbol of transmission occasion i. The total UE transmit power in a symbol of a slot is defined as the sum of the linear values of UE transmit powers for PUSCH, PUCCH, PRACH, and SRS in the symbol of the slot.

- PRACH transmission on a candidate cell, if any, as described in Clause 21
- PRACH transmission on the PCell
- PUCCH or PUSCH transmissions with larger priority index
- For PUCCH or PUSCH transmissions with same priority index
  - PUCCH transmission with HARQ-ACK information, and/or SR, and/or LRR, or PUSCH transmission with HARQ-ACK information of the priority index
  - PUCCH transmission with CSI or PUSCH transmission with CSI
  - PUSCH transmission without HARQ-ACK information of the priority index or CSI and, for Type-2 random access procedure, PUSCH transmission on the PCell
- If the UE is configured with prioSCellPRACH-OverSP-PeriodicSRS-r17
  - Aperiodic SRS transmission or PRACH transmission on a serving cell other than the PCell
  - Semi-persistent and/or periodic SRS transmission
- otherwise,
  - SRS transmission, with aperiodic SRS having higher priority than semi-persistent and/or periodic SRS, or PRACH transmission on a serving cell other than the PCell

In case of same priority order and for operation with carrier aggregation, the UE prioritizes power allocation for transmissions on the primary cell of the MCG or the SCG over transmissions on a secondary cell. In case of same priority order and for operation with two UL carriers, the UE prioritizes power allocation for transmissions on the carrier where the UE is configured to transmit PUCCH. If PUCCH is not configured for any of the two UL carriers, the UE prioritizes power allocation for transmissions on the non-supplementary UL carrier.

7.6 Dual connectivity

7.6.1 EN-DC

If a UE is configured with a MCG using E-UTRA radio access and with a SCG using NR radio access, the UE is configured a maximum power P_{LTE} for transmissions on the MCG by *p-MaxEUTRA* and a maximum power P_{NR} for transmissions in FR1 on the SCG by *p-NR-FR1*.

The UE determines a transmission power for the MCG as described in [13, TS 36.213] using P_{LTE} as the maximum transmission power. The UE determines transmission power for the SCG in FR1 as described in clauses 7.1 through 7.5 using P_{NR} as the maximum transmission power. The UE determines transmission power for the SCG in FR2 as described in clauses 7.1 through 7.5.

A UE does not expect to be configured for operation with shortened TTI and/or processing time [13, TS 36.213] on a cell that is included in an EN-DC configuration.

If a UE is configured with $\hat{P}_{\text{LTE}} + \hat{P}_{\text{NR}} > \hat{P}_{\text{Total}}^{\text{EN-DC}}$, where $\hat{P}_{\text{LTE}}$ is the linear value of P_{LTE}, $\hat{P}_{\text{NR}}$ is the linear value of P_{NR}, and $\hat{P}_{\text{Total}}^{\text{EN-DC}}$ is the linear value of a configured maximum transmission power for EN-DC operation as defined in [8-3, TS 38.101-3] for FR1, the UE determines a transmission power for the SCG as follows.

- If the UE is configured with reference TDD configuration for E-UTRA (by *tdm-PatternConfig* or by *tdm-PatternConfig2* in [13, TS 36.213])
  - If the UE does not indicate a capability for dynamic power sharing between E-UTRA and NR for EN-DC, the UE does not transmit in a slot on the SCG in FR1 when a corresponding subframe on the MCG is an UL subframe in the reference TDD configuration.
  - If the UE indicates a capability for dynamic power sharing between E-UTRA and NR for EN-DC, and does not indicate a capability *tdm-restrictionDualTX-FDD-endc-r16* in [18, TS 38.306], and is configured with *tdm-PatternConfig2*, the UE does not transmit on the SCG in FR1 when the UE has overlapped transmission on a subframe on the MCG.
- If the UE indicates a capability for dynamic power sharing between E-UTRA and NR for EN-DC and
  - if UE transmission(s) in subframe i_1 of the MCG overlap in time with UE transmission(s) in slot i_2 of the SCG in FR1, and
  - if $\hat{P}_{\text{MCG}}(i_1) + \hat{P}_{\text{SCG}}(i_2) > \hat{P}_{\text{Total}}^{\text{EN-DC}}$ in any portion of slot i_2 of the SCG,

    the UE reduces transmission power in any portion of slot i_2 of the SCG so that $\hat{P}_{\text{MCG}}(i_1) + \hat{P}_{\text{SCG}}(i_2) \le \hat{P}_{\text{Total}}^{\text{EN-DC}}$ in any portion of slot i_2, where $\hat{P}_{\text{MCG}}(i_1)$ and $\hat{P}_{\text{SCG}}(i_2)$ are the linear values of the total UE transmission powers in subframe i_1 of the MCG and in slot i_2 of the SCG in FR1, respectively. The UE is not required to transmit in any portion of slot i_2 of the SCG if $\hat{P}_{\text{SCG}}(i_2)$ would need to be reduced by more than the value provided by *X*X_{SCALE} in order for $\hat{P}_{\text{MCG}}(i_1) + \hat{P}_{\text{SCG}}(i_2) \le \hat{P}_{\text{Total}}^{\text{EN-DC}}$ in any portion of slot i_2 of the SCG. The UE is required to transmit in slot i_2 of the SCG if $\hat{P}_{\text{SCG}}(i_2)$ would not need to be reduced by more than the value provided by X_{SCALE} in order for $\hat{P}_{\text{MCG}}(i_1) + \hat{P}_{\text{SCG}}(i_2) \le \hat{P}_{\text{Total}}^{\text{EN-DC}}$ in all portions of slot i_2.
- If the UE does not indicate a capability for dynamic power sharing between E-UTRA and NR for EN-DC, the UE expects to be configured with reference TDD configuration for E-UTRA by *tdm-PatternConfig* in [13, TS 36.213].

7.6.1A NE-DC

If a UE is configured with an MCG using NR radio access and with a SCG using E-UTRA radio access, the UE is configured a maximum power P_{NR} for transmissions in FR1 on the MCG by *p-NR-FR1* and a maximum power P_{LTE} for transmissions on the SCG by *p-MaxEUTRA*.

The UE determines transmission power for the MCG in FR1 as described in clauses 7.1 through 7.5 using P_{NR} as the maximum transmission power for $P_{\mathrm{CMAX}} \leq P_{\mathrm{NR}}$. The UE determines transmission power for the MCG in FR2 as described in clauses 7.1 through 7.5.

If the UE is not provided *tdd-UL-DL-ConfigurationCommon* for the MCG, the UE determines a transmission power for the SCG as described in [13, TS 36.213] using P_{LTE} as the maximum transmission power.

If at least one symbol of slot i_1 of the MCG that is indicated as uplink or flexible by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* overlaps with subframe i_2 of the SCG

- for subframe i_2, the UE determines a transmission power for the SCG as described in [13, TS 36.213] using P_{LTE} as the maximum transmission power

otherwise

- the UE determines a transmission power for the SCG as described in [13, TS 36.213] without considering P_{LTE} as the maximum transmission power

If a UE is configured with $\hat{P}_{\mathrm{LTE}} + \hat{P}_{\mathrm{NR}} > \hat{P}_{\mathrm{Total}}^{\mathrm{NE\text{-}DC}}$, where $\hat{P}_{\mathrm{LTE}}$ is the linear value of P_{LTE}, $\hat{P}_{\mathrm{NR}}$ is the linear value of P_{NR}, and $\hat{P}_{\mathrm{Total}}^{\mathrm{NE\text{-}DC}}$ is the linear value of a configured maximum transmission power for NE-DC operation as defined in [8-3, TS 38.101-3] for FR1, the UE determines a transmission power for the MCG as follows

- If the UE is configured with reference TDD configuration for E-UTRA (by *tdm-PatternConfigNE-DC-r15* in [13, TS 36.213])
  - If the UE does not indicate a capability for dynamic power sharing between E-UTRA and NR for NE-DC, the UE does not expect to transmit in a slot on the MCG in FR1 when a corresponding subframe on the SCG is an UL subframe in the reference TDD configuration.
- If the UE indicates a capability for dynamic power sharing between E-UTRA and NR for NE-DC and
  - if the UE transmission(s) in slot i_1 of the MCG in FR1 overlap in time with UE transmission(s) in subframe i_2 of the SCG, and
  - if $\hat{P}_{\mathrm{MCG}}(i_1) + \hat{P}_{\mathrm{SCG}}(i_2) > \hat{P}_{\mathrm{Total}}^{\mathrm{NE\text{-}DC}}$ in any portion of slot i_1 of the MCG,

    the UE reduces transmission power in any portion of slot i_1 of the MCG so that $\hat{P}_{\mathrm{MCG}}(i_1) + \hat{P}_{\mathrm{SCG}}(i_2) \leq \hat{P}_{\mathrm{Total}}^{\mathrm{NE\text{-}DC}}$ in all portions of slot i_1, where $\hat{P}_{\mathrm{MCG}}(i_1)$ and $\hat{P}_{\mathrm{SCG}}(i_2)$ are the linear values of the total UE transmission powers in slot i_1 of the MCG in FR1 and in subframe i_2 of the SCG, respectively.
- If the UE does not indicate a capability for dynamic power sharing between E-UTRA and NR for NE-DC, the UE expects to be configured with reference TDD configuration for E-UTRA (by *tdm-PatternConfigNE-DC-r15* in [13, TS 36.213]).

7.6.2 NR-DC

The UE procedures described in this clause are not applicable if the UE is provided *scg-State* [12, TS 38.331].

If a UE is configured with an MCG using NR radio access in FR1 or in FR2 and with a SCG using NR radio access in FR2 or in FR1, respectively, the UE performs transmission power control independently per cell group as described in clauses 7.1 through 7.5.

If a UE is configured with an MCG and a SCG using NR radio access in FR1 and/or in FR2, the UE is configured a maximum power P_{MCG} for transmissions on the MCG by *p-NR-FR1* and/or by *p-NR-FR2* and a maximum power P_{SCG} for transmissions on the SCG by *p-NR-FR1* and/or by *p-NR-FR2* and with an inter-CG power sharing mode by *nrdc-PCmode-FR1* for FR1 and/or by *nrdc-PCmode-FR2* for FR2. The UE determines a transmission power on the MCG and a transmission power on the SCG per frequency range.

If a UE is provided *semi-static-mode1* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2*, or *semi-static-mode2* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2*, the UE does not expect P_{MCG} and P_{SCG} to be configured such that $\hat{P}_{\mathrm{MCG}} +$

$\hat{P}_{SCG} > \hat{P}_{Total}^{NR-DC}$, where $\hat{P}_{\text{MCG}}$ is the linear value of P_{MCG}, $\hat{P}_{SCG}$ is the linear value of P_{SCG}, and $\hat{P}_{Total}^{NR-DC}$ is the linear value of a configured maximum transmission power for NR-DC operation in FR1 or FR2 as defined in [8-3, TS 38.101-3].

If a UE is provided *semi-static-mode1* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2*, the UE determines a transmission power for the MCG or for the SCG as described in clauses 7.1 through 7.5 using P_{MCG} or P_{SCG} as the maximum transmission power, respectively.

If a UE is provided *semi-static-mode2* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2*

- if the UE is not provided *tdd-UL-DL-ConfigurationCommon* for the MCG or SCG, the UE determines a transmission power for the MCG or for the SCG as described in clauses 7.1 through 7.5 using P_{MCG} or P_{SCG} as the maximum transmission power, respectively
- if at least one symbol of slot i_1 of the MCG or of the SCG that is indicated as uplink or flexible to a UE by *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated*, if provided, overlaps with a symbol for any ongoing transmission overlapping with slot i_2 of the SCG or of the MCG, respectively, the UE determines a power for the transmission on the SCG or the MCG overlapping with slot i_2 as described in clauses 7.1 through 7.5 using P_{SCG} or P_{MCG}, respectively, as the maximum transmission power
- otherwise, the UE determines a power for the transmission on SCG or the MCG overlapping with slot i_2, as described in [8-3, TS 38.101-3] and in clauses 7.1 through 7.5 without considering P_{SCG} or P_{MCG} respectively

The UE expects to be provided *semi-static-mode2* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2* only for synchronous NR-DC operation [10, TS 38.133].

If a UE

- is provided *dynamic* for *nrdc-PCmode-FR1* or for *nrdc-PCmode-FR2*, and
- indicates a capability to support dynamic power sharing for intra-FR NR DC,

the UE determines a maximum transmission power on the SCG at a first symbol of a transmission occasion on the SCG by determining transmissions on the MCG that

- are scheduled by DCI formats in PDCCH receptions with a last symbol that is earlier by at least T_{offset} from the first symbol of the transmission occasion on the SCG, or are configured by higher layers, and
- overlap with the transmission occasion on the SCG

the maximum transmission power on the SCG is determined as

- $min\left(\hat{P}_{\text{SCG}}, \hat{P}_{\text{Total}}^{\text{NR-DC}} - \hat{P}_{\text{MCG}}^{\text{actual}}\right)$, if the UE determines transmissions on the MCG with a $\hat{P}_{\text{MCG}}^{\text{actual}}$ total power
- $\hat{P}_{\text{Total}}^{\text{NR-DC}}$, if the UE does not determine any transmissions on the MCG

where

- $T_{\text{offset}} = \max\{T_{proc,MCG}^{max}, T_{proc,SCG}^{max}\}$,
- $T_{proc,MCG}^{max}$ and $T_{proc,SCG}^{max}$ is the maximum of $T_{proc,2}$, $T_{proc,CSI}$, $T_{proc,release}^{mux}$, $T_{proc,2}^{mux}$, and $T_{proc,CSI}^{mux}$ based on the configurations on the MCG and the SCG, respectively, when the UE indicates the value of 'long' for the capability,
- $T_{proc,MCG}^{max}$ and $T_{proc,SCG}^{max}$ is the maximum of $T_{proc,2}$, $T_{proc,release}^{mux}$, $T_{proc,2}^{mux}$ based on the configurations on the MCG and the SCG, respectively, when the UE indicates the value of 'short' for the capability, and
- $\hat{P}_{\text{MCG}}^{\text{actual}}$ is the total power for the transmissions on the MCG that overlap with the transmission occasion on the SCG where $\hat{P}_{\text{MCG}}^{\text{actual}}$ is determined based on transmissions configured by higher layers and on transmissions scheduled by DCI formats in PDCCH receptions with a last symbol that is at least T_{offset} before the first symbol of the transmission occasion on the SCG.

The UE does not expect to have PUSCH, PUCCH, PRACH, or SRS transmissions on the MCG that

- are scheduled/triggered by DCI formats in PDCCH receptions with a last symbol that is earlier by less than T_{offset} from the first symbol of the transmission occasion on the SCG, and

- overlap with the transmission occasion on the SCG

The UE does not expect to receive a positive TPC command value in a DCI format 2_2 or a DCI format 2_3 in a PDCCH reception with a last symbol that is less than T_{offset} before the first symbol of the transmission occasion on the SCG, if the transmission on the MCG overlaps with the transmission occasion on the SCG.

The UE is not required to apply a TPC command the UE receives in a DCI format 2_2 or a DCI format 2_3 in a PDCCH reception with a last symbol that is less than T_{offset} before the first symbol of the transmission occasion on the SCG, if the transmission on the MCG overlaps with the transmission occasion on the SCG.

7.7 Power headroom report

The types of UE power headroom reports are the following. A Type 1 UE power headroom PH that is valid for PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c. A Type 3 UE power headroom PH that is valid for SRS transmission occasion i on active UL BWP b of carrier f of serving cell c.

A UE determines whether a power headroom report for an activated serving cell [11, TS 38.321] is based on an actual transmission or a reference format based on the higher layer signalling of configured grant and periodic/semi-persistent sounding reference signal transmissions and downlink control information the UE received until and including the PDCCH monitoring occasion where the UE detects the first DCI format scheduling an initial transmission of a transport block since a power headroom report was triggered if the power headroom report is reported on a PUSCH triggered by the first DCI format. Otherwise, a UE determines whether a power headroom report is based on an actual transmission or a reference format based on the higher layer signalling of configured grant and periodic/semi-persistent sounding reference signal transmissions and downlink control information the UE received until the first uplink symbol of a configured PUSCH transmission minus $T'_{proc,2}=T_{proc,2}$ where $T_{proc,2}$ is determined according to [6, TS 38.214] assuming $d_{2,1} = 1$, $d_{2,2}=0$, and with μ_{DL} corresponding to the subcarrier spacing of the active downlink BWP of the scheduling cell for a configured grant if the power headroom report is reported on the PUSCH using the configured grant.

If a UE

- is configured with two UL carriers for a serving cell, and
- determines a Type 1 power headroom report and a Type 3 power headroom report for the serving cell

the UE

- provides the Type 1 power headroom report if both the Type 1 and Type 3 power headroom reports are based on respective actual transmissions or on respective reference transmissions
- provides the power headroom report that is based on a respective actual transmission if either the Type 1 report or the Type 3 report is based on a respective reference transmission

If a UE is configured with a SCG and if *phr-ModeOtherCG* for a CG indicates 'virtual' then, for power headroom reports transmitted on the CG, the UE computes *PH* assuming that the UE does not transmit PUSCH/PUCCH on any serving cell of the other CG. For NR-DC when both the MCG and the SCG operate either in FR1 or in FR2 and for a power headroom report transmitted on the MCG or the SCG, the UE computes *PH* assuming that the UE does not transmit PUSCH/PUCCH on any serving cell of the SCG or the MCG, respectively.

If the UE is configured with a SCG,

- For computing power headroom for cells belonging to MCG, the term 'serving cell' in this clause refers to serving cell belonging to the MCG.
- For computing power headroom for cells belonging to SCG, the term 'serving cell' in this clause refers to serving cell belonging to the SCG. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell,

- For computing power headroom for cells belonging to primary PUCCH group, the term 'serving cell' in this clause refers to serving cell belonging to the primary PUCCH group.

- For computing power headroom for cells belonging to secondary PUCCH group, the term 'serving cell' in this clause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

For a UE configured with EN-DC/NE-DC and capable of dynamic power sharing, if E-UTRA Dual Connectivity PHR [14, TS 36.321] is triggered and,

- if the duration of NR slot on active UL BWP is different from that of E-UTRA subframe carrying the Dual Connectivity PHR, the UE provides power headroom of the first NR slot that fully overlaps with the E-UTRA subframe;

- if the duration of NR slot on active UL BWP is the same as that of E-UTRA subframe carrying the Dual Connectivity PHR for asynchronous EN-DC/NE-DC [10, TS 38.133], the UE provides power headroom of the first NR slot that overlaps with the E-UTRA subframe.

7.7.1 Type 1 PH report

If a UE determines that a Type 1 power headroom report for an activated serving cell is based on an actual PUSCH transmission then, for PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c, the UE computes the Type 1 power headroom report as

$$PH_{\text{type1},b,f,c}(i,j,q_d,l) = P_{\text{CMAX},f,c}(i) - \left\{P_{\text{O\_PUSCH},b,f,c}(j) + 10log_{10}\left(2^{\mu}\cdot M_{\text{RB},b,f,c}^{\text{PUSCH}}(i)\right) + \alpha_{b,f,c}(j)\cdot PL_{b,f,c}(q_d) + \Delta_{\text{TF},b,f,c}(i) + f_{b,f,c}(i,l)\right\} \text{ [dB]}$$

where $P_{\text{CMAX},f,c}(i)$, $P_{\text{O\_PUSCH},b,f,c}(j)$, $M_{\text{RB},b,f,c}^{\text{PUSCH}}(i)$, $\alpha_{b,f,c}(j)$, $PL_{b,f,c}(q_d)$, $\Delta_{\text{TF},b,f,c}(i)$ and $f_{b,f,c}(i,l)$ are defined in clause 7.1.1.

If a UE is configured with multiple cells for PUSCH transmissions, where a SCS configuration μ_1 on active UL BWP b_1 of carrier f_1 of serving cell c_1 is smaller than a SCS configuration μ_2 on active UL BWP b_2 of carrier f_2 of serving cell c_2, and if the UE provides a Type 1 power headroom report in a PUSCH transmission in a slot on active UL BWP b_1 that overlaps with multiple slots on active UL BWP b_2, the UE provides a Type 1 power headroom report for the first PUSCH, if any, on the first slot of the multiple slots on active UL BWP b_2 that fully overlaps with the slot on active UL BWP b_1. If a UE is configured with multiple cells for PUSCH transmissions, where a same SCS configuration on active UL BWP b_1 of carrier f_1 of serving cell c_1 and active UL BWP b_2 of carrier f_2 of serving cell c_2, and if the UE provides a Type 1 power headroom report in a PUSCH transmission in a slot on active UL BWP b_1, the UE provides a Type 1 power headroom report for the first PUSCH, if any, on the slot on active UL BWP b_2 that overlaps with the slot on active UL BWP b_1.

If a UE is configured with multiple cells for PUSCH transmissions and provides a Type 1 power headroom report in a PUSCH transmission with PUSCH repetition Type B having a nominal repetition that spans multiple slots on active UL BWP b_1 and overlaps with one or more slots on active UL BWP b_2, the UE provides a Type 1 power headroom report for the first PUSCH, if any, on the first slot of the one or more slots on active UL BWP b_2 that overlaps with the multiple slots of the nominal repetition on active UL BWP b_1.

For a UE configured with EN-DC/NE-DC and capable of dynamic power sharing, if E-UTRA Dual Connectivity PHR [14, TS 36.321] is triggered, the UE provides power headroom of the first PUSCH, if any, on the determined NR slot as described in clause 7.7.

If a UE is configured with multiple cells for PUSCH transmissions, the UE does not consider for computation of a Type 1 power headroom report in a first PUSCH transmission that includes an initial transmission of transport block on active UL BWP b_1 of carrier f_1 of serving cell c_1, a second PUSCH transmission on active UL BWP b_2 of carrier f_2 of serving cell c_2 that overlaps with the first PUSCH transmission if

- the second PUSCH transmission is scheduled by a DCI format in a PDCCH received in a second PDCCH monitoring occasion, and

- the second PDCCH monitoring occasion is after a first PDCCH monitoring occasion where the UE detects the earliest DCI format scheduling an initial transmission of a transport block after a power headroom report was triggered

or

- the second PUSCH transmission is after the first uplink symbol of the first PUSCH transmission minus $T'_{\mathrm{proc},2} = T_{\mathrm{proc},2}$ where $T_{\mathrm{proc},2}$ is determined according to [6, TS 38.214] assuming $d_{2,1} = 1$, $d_{2,2} = 0$, and with μ_{DL} corresponding to the subcarrier spacing of the active downlink BWP of the scheduling cell for a configured grant if the first PUSCH transmission is on a configured grant after a power headroom report was triggered.

If the UE determines that a Type 1 power headroom report for an activated serving cell is based on a reference PUSCH transmission then, for PUSCH transmission occasion i on active UL BWP b of carrier f of serving cell c, the UE computes the Type 1 power headroom report as

$$PH_{\mathrm{type1},b,f,c}(i,j,q_d,l) = \tilde{P}_{\mathrm{CMAX},f,c}(i) - \left\{P_{\mathrm{O\_PUSCH},b,f,c}(j) + \alpha_{b,f,c}(j) \cdot PL_{b,f,c}(q_d) + f_{b,f,c}(i,l)\right\} \text{ [dB]}$$

where $\tilde{P}_{\mathrm{CMAX},f,c}(i)$ is computed assuming MPR=0 dB, A-MPR=0 dB, P-MPR=0 dB. ΔT_C = 0 dB. MPR, A-MPR, P-MPR and ΔT_C are defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3]. The remaining parameters are defined in clause 7.1.1 and, if *ul-powerControl* is not provided, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are obtained using $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0)$ and *p0-PUSCH-AlphaSetId* = 0, $PL_{b,f,c}(q_d)$ is obtained using *pusch-PathlossReferenceRS-Id* = 0, and $l = 0$. If *ul-powerControl* is provided, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$, $\alpha_{b,f,c}(j)$ and l are obtained by *p0AlphaSetforPUSCH* associated with the indicated *TCI-State* or *TCI-UL-State*, $PL_{b,f,c}(q_d)$ is obtained by PL-RS associated with the indicated *TCI-State* or *TCI-UL-State*. If the activated serving cell is an SCell and parameter *preambleReceivedTargetPower* is not configured for the cell, then the parameter *preambleReceivedTargetPower* configured for the primary cell is applied, where the parameter refers to the one configured for the non-supplementary uplink carrier if the primary cell is configured with two uplink carriers.

If a UE is configured with two UL carriers for a serving cell and the UE determines a Type 1 power headroom report for the serving cell based on a reference PUSCH transmission, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the UL carrier provided by *pusch-Config*. If the UE is provided *pusch-Config* for both UL carriers, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the UL carrier provided by *pucch-Config*. If *pucch-Config* is not provided to the UE for any of the two UL carriers, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the non-supplementary UL carrier.

If a UE is not provided *twoPHRMode*, and is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' on active UL BWP b of carrier f of serving cell c, the UE provides one Type 1 power headroom report in a slot n. If the Type 1 power headroom report is for an actual PUSCH repetition, the Type 1 power headroom report is for the first PUSCH repetition associated with the first SRS resource set or the second SRS resource set that overlaps with slot n.

If a UE is provided *twoPHRMode*, and is provided two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with *usage* set to 'codebook' or 'nonCodebook' on active UL BWP b of carrier f of serving cell c, the UE provides two Type 1 power headroom reports in a slot n, where

- if the UE provides a first Type 1 power headroom report for an actual PUSCH repetition of a PUSCH transmission starting earliest in slot n that is associated with one SRS resource set,
    - if the UE transmits PUSCH repetitions associated with the other SRS resource set in slot n, the UE provides a second Type 1 power headroom report for a first actual PUSCH repetition associated with the other SRS resource set that overlaps with slot n
    - else, the UE provides a second Type 1 power headroom report for a reference PUSCH transmission associated with the other SRS resource set, where
        - if the other SRS resource set is the first SRS resource set, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are obtained using $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0)$ and *p0-PUSCH-AlphaSetId* = 0, $PL_{b,f,c}(q_d)$ is obtained using *pusch-PathlossReferenceRS-Id* = 0 if the UE is not provided *enablePL-RS-UpdateForPUSCH-SRS* or is obtained from *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList* if the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, and $l = 0$. If the UE is provided *dl-OrJointTCI-StateList* or *TCI-UL-State* that indicate a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, the UE provides the second Type 1 power headroom report using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the first *TCI-State* or *TCI-UL-State.*
        - else, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are obtained using $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0)$ and *p0-PUSCH-AlphaSetId = 1*, $PL_{b,f,c}(q_d)$ is obtained using *pusch-PathlossReferenceRS-Id* = 1 if the UE is not

provided *enablePL-RS-UpdateForPUSCH-SRS* or is obtained from *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList2* if the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, and $l = 1$ if the UE is provided *twoPUSCH-PC-AdjustmentStates*, or $l = 0$ if the UE is not provided *twoPUSCH-PC-AdjustmentStates*. If the UE is provided *dl-OrJointTCI-StateList* or *TCI-UL-State* that indicate a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, the UE provides the second Type 1 power headroom report using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the second *TCI-State* or *TCI-UL-State.*

- else, if the UE provides a Type 1 power headroom report for a reference PUSCH transmission associated with the first SRS resource set, the UE provides a Type 1 power headroom report for a reference PUSCH transmission associated with the second SRS resource set, where

  - for the first Type 1 power headroom report, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are obtained using $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0)$ and *p0-PUSCH-AlphaSetId* = 0, $PL_{b,f,c}(q_d)$ is obtained using *pusch-PathlossReferenceRS-Id* = 0 if the UE is not provided *enablePL-RS-UpdateForPUSCH-SRS*, or is obtained from the *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList* if the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, and $l = 0$.

  - for the second Type 1 power headroom report, $P_{\mathrm{O\_PUSCH},b,f,c}(j)$ and $\alpha_{b,f,c}(j)$ are obtained using $P_{\mathrm{O\_NOMINAL,PUSCH},f,c}(0)$ and *p0-PUSCH-AlphaSetId = 1*, $PL_{b,f,c}(q_d)$ is obtained using *pusch-PathlossReferenceRS-Id = 1* if the UE is not provided *enablePL-RS-UpdateForPUSCH-SRS*, or is obtained from the *PUSCH-PathlossReferenceRS-Id* mapped to *sri-PUSCH-PowerControlId* = 0 of *sri-PUSCH-MappingToAddModList2* if the UE is provided *enablePL-RS-UpdateForPUSCH-SRS*, and $l = 1$ if the UE is provided *twoPUSCH-PC-AdjustmentStates* or $l = 0$ if the UE is not provided *twoPUSCH-PC-AdjustmentStates*

  - if a UE is provided *dl-OrJointTCI-StateList* or *TCI-UL-State* and is indicated a first *TCI-State* or *TCI-UL-State* and a second *TCI-State* or *TCI-UL-State*, the UE provides the first or the second Type 1 power headroom reports using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the first *TCI-State* or *TCI-UL-State* or with the second *TCI-State* or *TCI-UL-State*, respectively, if the reference PUSCH transmission is associated with the first *TCI-State* or *TCI-UL-State* or with the second *TCI-State* or *TCI-UL-State*, respectively

If a UE is provided, for active UL BWP b of carrier f of serving cell c,

- *twoPHRMode*,

- two SRS resource sets in *srs-ResourceSetToAddModList* or *srs-ResourceSetToAddModListDCI-0-2* with usage set to 'codebook' or 'nonCodebook',

- *dl-OrJointTCI-StateList* or *TCI-UL-State* and is indicated a first TCI-State or TCI-UL-State and a second TCI-State or TCI-UL-State, and

- *multipanelScheme*

the UE provides

- a first Type 1 power headroom report and a first configured maximum output power associated with the first *TCI-State* or *TCI-UL-State* for an actual PUSCH transmission using a spatial domain filter corresponding only to the first *TCI-State* or *TCI-UL-State*, and a second Type 1 power headroom report and a second configured maximum output power associated with the second *TCI-State* or *TCI-UL-State* for a reference PUSCH transmission using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the second *TCI-State* or *TCI-UL-State*

- a second Type 1 power headroom report and a configured maximum output power associated with the second *TCI-State* or *TCI-UL-State* for an actual PUSCH transmission using a spatial domain filter corresponding only to the second *TCI-State* or *TCI-UL-State*, and a first Type 1 power headroom report and a first configured maximum output power associated with the first *TCI-State* or *TCI-UL-State* for a reference PUSCH transmission using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the first *TCI-State* or *TCI-UL-State*

- a first Type 1 power headroom report and a first configured maximum output power associated with the first *TCI-State* or *TCI-UL-State*, and a second Type 1 power headroom report and a second configured maximum output power associated with the second *TCI-State* or *TCI-UL-State*, for an actual PUSCH transmission using a spatial domain filter corresponding to the first *TCI-State* or *TCI-UL-State* and using a spatial domain filter corresponding to the second *TCI-State* or *TCI-UL-State*.

- a first Type 1 power headroom report and a first configured maximum output power associated with the first *TCI-State* or *TCI-UL-State* for a reference PUSCH transmission using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the first *TCI-State* or *TCI-UL-State*, and a second Type 1 power headroom report and a second configured maximum output power associated with the second *TCI-State* or *TCI-UL-State* for another reference PUSCH transmission using the *p0AlphaSetforPUSCH* and *pathlossReferenceRS-Id-r17* values associated with the second *TCI-State* or *TCI-UL-State*

If a UE provides a Type 1 power headroom report for an activated serving cell based on an actual PUSCH transmission, is provided *assumedPUSCHInfo*, and *dynamicTransformPrecoderIndicationDCI-0-1* or *dynamicTransformPrecoderIndicationDCI-0-2* is set to enabled for the active UL BWP of the serving cell, the UE provides

- $P_{\text{CMAX},f,c}(i)$ based on any applicable maximum output power reduction for an assumed PUSCH transmission with transform precoder enabled, if supported, if transform precoder is disabled for the actual PUSCH transmission, or

- $P_{\text{CMAX},f,c}(i)$ based on any applicable maximum output power reduction for an assumed PUSCH transmission with transform precoder disabled, if supported, if the transform precoder is enabled for the actual PUSCH transmission,

where all other parameters used for the calculation of $P_{\text{CMAX},f,c}(i)$ of the assumed PUSCH transmission are same as for the actual PUSCH transmission.

7.7.2 Type 2 PH report

This clause is reserved.

7.7.3 Type 3 PH report

If a UE determines that a Type 3 power headroom report for an activated serving cell is based on an actual SRS transmission then, for SRS transmission occasion i on active UL BWP b of carrier f of serving cell c and if the UE is not configured for PUSCH transmissions on carrier f of serving cell c and the resource for the SRS transmission is provided by *SRS-Resource*, the UE computes a Type 3 power headroom report as

$$PH_{\text{type3},b,f,c}(i,q_s) = P_{\text{CMAX},f,c}(i) - \left\{ P_{\text{O\_SRS},b,f,c}(q_s) + 10\log_{10}(2^{\mu} \cdot M_{\text{SRS},b,f,c}(i)) + \alpha_{\text{SRS},b,f,c}(q_s) \cdot PL_{b,f,c}(q_d) + h_{b,f,c}(i) \right\} \quad \text{[dB]}$$

where $P_{\text{CMAX},f,c}(i)$, $P_{\text{O\_SRS},b,f,c}(q_s)$, $M_{\text{SRS},b,f,c}(i)$, $\alpha_{\text{SRS},b,f,c}(q_s)$, $PL_{b,f,c}(q_d)$ and $h_{b,f,c}(i)$ are defined in clause 7.3.1 with corresponding values provided by *SRS-ResourceSet*.

If the UE determines that a Type 3 power headroom report for an activated serving cell is based on a reference SRS transmission then, for SRS transmission occasion i on UL BWP b of carrier f of serving cell c, and if the UE is not configured for PUSCH transmissions on UL BWP b of carrier f of serving cell c and a resource for the reference SRS transmission is provided by *SRS-Resource*, the UE computes a Type 3 power headroom report as

$$PH_{\text{type3},b,f,c}(i,q_s) = \tilde{P}_{\text{CMAX},f,c}(i) - \left\{ P_{\text{O\_SRS}b,f,c}(q_s) + \alpha_{\text{SRS},b,f,c}(q_s) \cdot PL_{b,f,c}(q_d) + h_{b,f,c}(i) \right\} \quad \text{[dB]}$$

where q_s is an SRS resource set corresponding to *SRS-ResourceSetId = 0* for UL BWP b and $P_{\text{O\_SRS}b,f,c}(q_s)$, $\alpha_{\text{SRS},f,c}(q_s)$, $PL_{b,f,c}(q_d)$ and $h_{b,f,c}(i)$ are defined in clause 7.3.1 with corresponding values obtained from *SRS-ResourceSetId = 0* for UL BWP b . $\tilde{P}_{\text{CMAX},f,c}(i)$ is computed assuming MPR=0 dB, A-MPR=0 dB, P-MPR=0 dB and ΔT_C =0 dB. MPR, A-MPR, P-MPR and ΔT_C are defined in [8-1, TS 38.101-1], [8-2, TS 38.101-2] and [8-3, TS 38.101-3].

If a UE is configured with two UL carriers for a serving cell and the UE determines a Type 3 power headroom report for the serving cell based on a reference SRS transmission and a resource for the reference SRS is provided by *SRS-Resource*, the UE computes a Type 3 power headroom report for the serving cell assuming a reference SRS transmission on the UL carrier provided by *pucch-Config*. If *pucch-Config* is not provided to the UE for any of the two UL carriers, the UE computes a Type 3 power headroom report for the serving cell assuming a reference SRS transmission on the non-supplementary UL carrier.

8 Random access procedure

Prior to initiation of the physical random access procedure, Layer 1 receives from higher layers a set of SS/PBCH block indexes and provides to higher layers a corresponding set of RSRP measurements.

Prior to initiation of the physical random access procedure, Layer 1 may receive from higher layers an indication to perform a Type-1 random access procedure, as described in clauses 8.1 through 8.4, or a Type-2 random access procedure as described in clauses 8.1 through 8.2A.

Prior to initiation of the physical random access procedure, Layer 1 receives the following information from the higher layers:

- Configuration of physical random access channel (PRACH) transmission parameters (PRACH preamble format, time resources, and frequency resources for PRACH transmission).
- Parameters for determining the root sequences and their cyclic shifts in the PRACH preamble sequence set (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted, restricted set A, or restricted set B)).

From the physical layer perspective, the Type-1 L1 random access procedure includes the transmission of random access preamble (Msg1) in a PRACH, random access response (RAR) message with a PDCCH/PDSCH (Msg2), and when applicable, the transmission of a PUSCH scheduled by a RAR UL grant, and PDSCH for contention resolution.

From the physical layer perspective, the Type-2 L1 random access procedure includes the transmission of random access preamble in a PRACH and of a PUSCH (MsgA) and the reception of a RAR message with a PDCCH/PDSCH (MsgB), and when applicable, the transmission of a PUSCH scheduled by a fallback RAR UL grant, and PDSCH for contention resolution.

If a random access procedure is initiated by a PDCCH order to the UE, a PRACH transmission is with a same SCS as a PRACH transmission initiated by higher layers.

If a UE is configured with two UL carriers for a serving cell and the UE detects a PDCCH order, the UE uses the UL/SUL indicator field value from the detected PDCCH order to determine the UL carrier for the corresponding PRACH transmission.

8.1 Random access preamble

Physical random access procedure for a UE is triggered upon request of a PRACH transmission by higher layers or by a PDCCH order for a cell. A configuration by higher layers for a PRACH transmission includes the following:

- A configuration for PRACH transmission on the cell [4, TS 38.211].
- A preamble index, a preamble SCS, $P_{\mathrm{PRACH,target}}$, a corresponding RA-RNTI when applicable [11, TS 38.321], and a PRACH resource for the cell.
- A number of $N_{\mathrm{preamble}}^{\mathrm{rep}} > 1$ preamble repetitions for the PRACH transmission if the UE would transmit the PRACH with repetitions.

A UE transmits a PRACH on a cell using the selected PRACH format with transmission power $P_{\mathrm{PRACH},b,f,c}(i)$, as described in clause 7.4, on the indicated PRACH resource or on a determined set of $N_{\mathrm{preamble}}^{\mathrm{rep}}$ resources using a same spatial filter in case of $N_{\mathrm{preamble}}^{\mathrm{rep}}$ preamble repetitions.

For Type-1 random access procedure, a UE is provided a number N of SS/PBCH block indexes associated with one PRACH occasion and a number R of contention based preambles per SS/PBCH block index per valid PRACH occasion by *ssb-perRACH-OccasionAndCB-PreamblesPerSSB*.

For Type-2 random access procedure with common configuration of PRACH occasions with Type-1 random access procedure, a UE is provided a number N of SS/PBCH block indexes associated with one PRACH occasion by *ssb-perRACH-OccasionAndCB-PreamblesPerSSB* and a number Q of contention based preambles per SS/PBCH block index per valid PRACH occasion by *msgA-CB-PreamblesPerSSB-PerSharedRO*. The PRACH transmission can be on a subset of PRACH occasions associated with a same SS/PBCH block index within an SSB-RO mapping cycle for a UE provided with a PRACH mask index by *msgA-SSB-SharedRO-MaskIndex* according to [11, TS 38.321].

For Type-2 random access procedure with separate configuration of PRACH occasions with Type-1 random access procedure, a UE is provided a number N of SS/PBCH block indexes associated with one PRACH occasion and a number R of contention based preambles per SS/PBCH block index per valid PRACH occasion by *msgA-SSB-PerRACH-OccasionAndCB-PreamblesPerSSB* when provided; otherwise, by *ssb-perRACH-OccasionAndCB-PreamblesPerSSB*.

For a random access procedure associated with a feature combination indicated by *FeatureCombinationPreambles*, a UE is provided a number N of SS/PBCH block indexes associated with one PRACH occasion by *ssb-perRACH-OccasionAndCB-PreamblesPerSSB* or *msgA-SSB-PerRACH-OccasionAndCB-PreamblesPerSSB* when provided and a number S of contention based preambles per SS/PBCH block index per valid PRACH occasion by *startPreambleForThisPartition* and *numberOfPreamblesPerSSB-ForThisPartition*. The PRACH transmission can be on a subset of PRACH occasions associated with a same SS/PBCH block index within an SSB-RO mapping cycle for a UE provided with a PRACH mask index by *ssb-SharedRO-MaskIndex* according to [11, TS 38.321].

For Type-1 random access procedure, or for Type-2 random access procedure with separate configuration of PRACH occasions from Type 1 random access procedure, if $N < 1$, one SS/PBCH block index is mapped to $1/N$ consecutive valid PRACH occasions and R contention based preambles with consecutive indexes associated with the SS/PBCH block index per valid PRACH occasion start from preamble index 0. If $N \geq 1$, R contention based preambles with consecutive indexes associated with SS/PBCH block index n, $0 \leq n \leq N-1$, per valid PRACH occasion start from preamble index $n \cdot N_{\text{preamble}}^{\text{total}}/N$ where $N_{\text{preamble}}^{\text{total}}$ is provided by *totalNumberOfRA-Preambles* for Type-1 random access procedure, or by *msgA-TotalNumberOfRA-Preambles* for Type-2 random access procedure with separate configuration of PRACH occasions from a Type 1 random access procedure, and is an integer multiple of N.

For Type-2 random access procedure with common configuration of PRACH occasions with Type-1 random access procedure, if $N < 1$, one SS/PBCH block index is mapped to $1/N$ consecutive valid PRACH occasions and Q contention based preambles with consecutive indexes associated with the SS/PBCH block index per valid PRACH occasion start from preamble index R. If $N \geq 1$, Q contention based preambles with consecutive indexes associated with SS/PBCH block index n, $0 \leq n \leq N-1$, per valid PRACH occasion start from preamble index $n \cdot N_{\text{preamble}}^{\text{total}}/N + R$, where $N_{\text{preamble}}^{\text{total}}$ is provided by *totalNumberOfRA-Preambles* for Type-1 random access procedure.

For link recovery, a UE is provided N SS/PBCH block indexes associated with one PRACH occasion by *ssb-perRACH-Occasion* in *BeamFailureRecoveryConfig*. For a dedicated RACH configuration provided by *RACH-ConfigDedicated*, if *cfra* is provided, a UE is provided N SS/PBCH block indexes associated with one PRACH occasion by *ssb-perRACH-Occasion* in *occasions*. If $N < 1$, one SS/PBCH block index is mapped to $1/N$ consecutive valid PRACH occasions. If $N \geq 1$, all consecutive N SS/PBCH block indexes are associated with one PRACH occasion.

SS/PBCH block indexes provided by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* are mapped to valid PRACH occasions in the following order where the parameters are described in [4, TS 38.211].

- First, in increasing order of preamble indexes within a single PRACH occasion

- Second, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions

- Third, in increasing order of time resource indexes for time multiplexed PRACH occasions within a PRACH slot

- Fourth, in increasing order of indexes for PRACH slots

An association period, starting from frame 0, for mapping SS/PBCH block indexes to PRACH occasions is the smallest integer number in the set determined by the PRACH configuration period according Table 8.1-1 such that $N_{\mathrm{Tx}}^{\mathrm{SSB}}$ SS/PBCH block indexes are mapped at least once to the PRACH occasions within the association period, where a UE obtains $N_{\mathrm{Tx}}^{\mathrm{SSB}}$ from the value of *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon*. If after an integer number of SS/PBCH block indexes to PRACH occasions mapping cycles within the association period there is a set of PRACH occasions or PRACH preambles that are not mapped to $N_{\mathrm{Tx}}^{\mathrm{SSB}}$ SS/PBCH block indexes, no SS/PBCH block indexes are mapped to the set of PRACH occasions or PRACH preambles. An association pattern period includes one or more association periods and is determined so that a pattern between PRACH occasions and SS/PBCH block indexes repeats at most every 160 msec. PRACH occasions not associated with SS/PBCH block indexes after an integer number of association periods, if any, are not used for PRACH transmissions.

For a PRACH transmission by a UE triggered by a PDCCH order, the PRACH mask index field, if the value of the random access preamble index field is not zero, indicates the PRACH occasion for the PRACH transmission where the PRACH occasions are associated with the SS/PBCH block index indicated by the SS/PBCH block index field of the PDCCH order and, if any, a cell indicator field indicates a cell for the PRACH transmission [5, TS 38.212]. If the UE is provided $K_{\mathrm{cell,offset}}$ by *cellSpecificKoffset*, the PRACH occasion is after slot $n + 2^{\mu} \cdot K_{\mathrm{cell,offset}}$ where n is the slot of the UL BWP for the PRACH transmission that overlaps with the end of the PDCCH order reception assuming $T_{\mathrm{TA}} = 0$, and μ is the SCS configuration for the PRACH transmission. If the PDCCH reception for the PDCCH order includes two PDCCH candidates from two linked search space sets based on *searchSpaceLinkingId*, as described in clause 10.1, the last symbol of the PDCCH reception is the last symbol of the PDCCH candidate that ends later. The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

For a PRACH transmission triggered by higher layers, if *ssb-ResourceList* is provided, the PRACH mask index is indicated by *ra-ssb-OccasionMaskIndex* which indicates the PRACH occasions for the PRACH transmission where the PRACH occasions are associated with the selected SS/PBCH block index.

The PRACH occasions are mapped consecutively per corresponding SS/PBCH block index. The indexing of the PRACH occasion indicated by the mask index value is reset per mapping cycle of consecutive PRACH occasions per SS/PBCH block index. The UE selects for a PRACH transmission the PRACH occasion indicated by PRACH mask index value for the indicated SS/PBCH block index in the first available mapping cycle.

For the indicated preamble index, the ordering of the PRACH occasions is

- First, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions
- Second, in increasing order of time resource indexes for time multiplexed PRACH occasions within a PRACH slot
- Third, in increasing order of indexes for PRACH slots

For a PRACH transmission with $N_{\mathrm{preamble}}^{\mathrm{rep}}$ preamble repetitions, a set consists of $N_{\mathrm{preamble}}^{\mathrm{rep}}$ valid PRACH occasions that are consecutive in time, use same frequency resources, and are associated with same one or more SS/PBCH block index(es), and each SS/PBCH block index is associated with same preamble indexes in all valid PRACH occasions within the set.

For a PRACH transmission with preamble repetitions, a time period, starting from frame 0, is the smallest integer number of association pattern periods such that at least one set of valid PRACH occasions for each of the $N_{\mathrm{Tx}}^{\mathrm{SSB}}$ SS/PBCH block indexes can be determined within the time period for all configured number of preamble repetitions. The set(s) of valid PRACH occasions for each configured number of preamble repetitions repeats every time period.

Within a time period, for set(s) of $N_{\mathrm{preamble}}^{\mathrm{rep}}$ valid PRACH occasions for a PRACH transmission with $N_{\mathrm{preamble}}^{\mathrm{rep}}$ preamble repetitions

- the first valid PRACH occasion of the first set is the first valid PRACH occasion
- the first valid PRACH occasion of subsequent sets, if any, is determined according to an ordering of valid PRACH occasions
  - first, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions
  - second, in increasing order of time resource indexes for time multiplexed PRACH occasions

where, for each frequency resource index for frequency multiplexed PRACH occasions

- the first valid PRACH occasion of the first set is the first valid PRACH occasion
- the first valid PRACH occasion of subsequent sets, if any,
  - is after *msg1-RepetitionTimeOffsetROGroup* consecutive valid PRACH occasions in time from the first valid PRACH occasion of the previous set, where each PRACH occasion is associated with same SS/PBCH block index(es) and each SS/PBCH block index is associated with same preambles, if *msg1-RepetitionTimeOffsetROGroup* is provided
  - is after the PRACH occasions for the previous set, if *msg1-RepetitionTimeOffsetROGroup* is not provided

For a PRACH transmission triggered upon request by higher layers, a value of *ra-OccasionList* [12, TS 38.331], if *csirs-ResourceList* is provided, indicates a list of PRACH occasions for the PRACH transmission where the PRACH occasions are associated with the selected CSI-RS index indicated by *csi-RS*. The indexing of the PRACH occasions indicated by *ra-OccasionList* is reset per association pattern period.

Table 8.1-1: Mapping between PRACH configuration period and SS/PBCH block to PRACH occasion association period

PRACH configuration period (msec)	Association period (number of PRACH configuration periods)
10	{1, 2, 4, 8, 16}
20	{1, 2, 4, 8}
40	{1, 2, 4}
80	{1, 2}
160	{1}

For paired spectrum or supplementary uplink band all PRACH occasions are valid.

For unpaired spectrum,

- if a UE is not provided *tdd-UL-DL-ConfigurationCommon*, a PRACH occasion in a PRACH slot is valid if it does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last SS/PBCH block reception symbol, where N_{gap} is provided in Table 8.1-2 and, if *channelAccessMode* = "*semiStatic*" is provided, does not overlap with a set of consecutive symbols before the start of a next channel occupancy time where the UE does not transmit [15, TS 37.213].
  - the candidate SS/PBCH block index of the SS/PBCH block corresponds to the SS/PBCH block index provided by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon*, as described in clause 4.1
- If a UE is provided *tdd-UL-DL-ConfigurationCommon*, a PRACH occasion in a PRACH slot is valid if
  - it is within UL symbols, or
  - it does not precede a SS/PBCH block in the PRACH slot and starts at least N_{gap} symbols after a last downlink symbol and at least N_{gap} symbols after a last SS/PBCH block symbol, where N_{gap} is provided in Table 8.1-2, and if *channelAccessMode* = "*semiStatic*" is provided, does not overlap with a set of consecutive symbols before the start of a next channel occupancy time where there shall not be any transmissions, as described in [15, TS 37.213]
    - the candidate SS/PBCH block index of the SS/PBCH block corresponds to the SS/PBCH block index provided by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon*, as described in clause 4.1.

For preamble format B4 [4, TS 38.211], $N_{\text{gap}} = 0$.

Table 8.1-2: N_{gap} values for different preamble SCS μ

Preamble SCS	N_{gap}
1.25 kHz or 5 kHz	0
15 kHz or 30 kHz or 60 kHz or 120 kHz	2
480 kHz	8
960 kHz	16

If a random access procedure is initiated by a PDCCH order, the UE, if requested by higher layers, transmits a PRACH in the selected PRACH occasion, as described in [11, TS 38.321], for which a time between the last symbol of the PDCCH order reception and the first symbol of the PRACH transmission is larger than or equal to $N_{T,2} + T_{\text{BWPswitchDelay}} + \Delta_{\text{Delay}} + T_{\text{switch}} + T_{\text{SSB}} + \Delta_{\text{RF/BB preparation}}$ msec, where

- $N_{T,2}$ is a time duration of N_2 symbols corresponding to a PUSCH preparation time for UE processing capability 1 [6, TS 38.214] assuming μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH order and the SCS configuration of the corresponding PRACH transmission

- $T_{\text{BWPswitchDelay}} = 0$ if the active UL BWP does not change, or if a cell indicator field in the PDCCH order indicates a non-serving cell [5, TS 38.212], and $T_{\text{BWPswitchDelay}}$ is defined in [10, TS 38.133] otherwise

- $\Delta_{\text{Delay}} = 0.5$ msec for FR1 and $\Delta_{\text{Delay}} = 0.25$ msec for FR2

- T_{switch} is a switching gap duration as defined in [6, TS 38.214]

- $T_{\text{SSB}} = 0$ if a cell indicator field in the PDCCH order indicates a serving cell or if cell indicator field is not present, and T_{SSB} is defined in [10, TS 38.133] otherwise

- $\Delta_{\text{RF/BB preparation}} = 0$ if a cell indicator field in the PDCCH order indicates a serving cell or if cell indicator field is not present, and $\Delta_{\text{RF/BB preparation}}$ is defined in [10, TS 38.133] otherwise

For a PRACH transmission using 1.25 kHz or 5 kHz SCS, the UE determines N_2 assuming SCS configuration $\mu = 0$.

For single cell operation or for operation with contiguous carrier aggregation in a same frequency band or for operation with non-contiguous carrier aggregation in a same frequency band if the UE is not provided with *intraBandNC-PRACH-simulTx-r17*, a UE

- does not transmit PRACH and PUSCH/PUCCH/SRS in a same slot with respect to the smallest SCS configuration between the SCS configuration for the UL BWP with the PRACH and the SCS configuration for the UL BWP with the PUSCH/PUCCH/SRS transmissions

- does not transmit PRACH and PUSCH/PUCCH/SRS when a first or last symbol of a PRACH transmission in a first slot is separated by less than N symbols from the last or first symbol, respectively, of a PUSCH/PUCCH/SRS transmission in a second slot; for a PRACH transmission with $N_{\text{preamble}}^{\text{rep}} > 1$ preamble repetitions, this applies to each preamble repetition

- for a PRACH transmission with $N_{\text{preamble}}^{\text{rep}} > 1$ preamble repetitions, if the UE does not indicate *capability-XYZ*, the UE does not transmit a first repetition of the PRACH and a second repetition of the PRACH when a first or last symbol of the first repetition of the PRACH in a first slot is separated by less than N symbols from the last or first symbol, respectively, of the second repetition of the PRACH in a second slot; otherwise, the UE transmits the first repetition of the PRACH and the second repetition of the PRACH

where $N = 2$ for $\mu = 0$ or $\mu = 1$, $N = 4$ for $\mu = 2$ or $\mu = 3$, $N = 16$ for $\mu = 5$, $N = 32$ for $\mu = 6$, and μ is the smallest SCS configuration between the SCS configuration for the UL BWP with the PRACH and the SCS configuration for the UL BWP with the PUSCH/PUCCH/SRS transmissions. For a PUSCH transmission with repetition Type B, this applies to each actual repetition for PUSCH transmission [6, TS 38.214].

8.1A PUSCH for Type-2 random access procedure

For a Type-2 random access procedure, a UE transmits a PUSCH, when applicable, after transmitting a PRACH. The UE encodes a transport block provided for the PUSCH transmission using redundancy version number 0. The PUSCH transmission is after the PRACH transmission by at least N symbols where $N = 2$ for $\mu = 0$ or $\mu = 1$, $N = 4$ for $\mu = 2$ or $\mu = 3$, $N = 16$ for $\mu = 5$, $N = 32$ for $\mu = 6$, and μ is the SCS configuration for the active UL BWP.

A UE does not transmit a PUSCH in a PUSCH occasion if the PUSCH occasion associated with a DMRS resource is not mapped to a preamble of valid PRACH occasions or if the associated PRACH preamble is not transmitted as described in clause 7.5 or clause 11.1 or clause 15 or clause 17.2. A UE can transmit a PRACH preamble in a valid PRACH occasion if the PRACH preamble is not mapped to a valid PUSCH occasion.

A mapping between one or multiple PRACH preambles and a PUSCH occasion associated with a DMRS resource is per PUSCH configuration provided by *MsgA-PUSCH-Resource*.

A UE determines time resources and frequency resources for PUSCH occasions in an active UL BWP from *msgA-PUSCH-Config* or *separateMsgA-PUSCH-Config* for the active UL BWP. If the active UL BWP is not the initial UL BWP and *msgA-PUSCH-Config* or *separateMsgA-PUSCH-Config* is not provided for the active UL BWP, the UE uses the *msgA-PUSCH-Config* or *separateMsgA-PUSCH-Config* provided for the initial UL BWP.

A UE determines a first interlace or first RB for a first PUSCH occasion in an active UL BWP respectively from *interlaceIndexFirstPO-MsgA-PUSCH* or from *frequencyStartMsgA-PUSCH* that provides an offset, in number of RBs in the active UL BWP, from a first RB of the active UL BWP. A PUSCH occasion includes a number of interlaces or a number of RBs provided by *nrofInterlacesPerMsgA-PO* or by *nrofPRBs-perMsgA-PO*, respectively. Consecutive PUSCH occasions in the frequency domain of an UL BWP are separated by a number of RBs provided by *guardBandMsgA-PUSCH*. A number N_f of PUSCH occasions in the frequency domain of an UL BWP is provided by *nrofMsgA-PO-FDM*.

For operation with shared spectrum channel access, if the PUSCH occasion is provided by higher layer parameters *frequencyStartMsgA-PUSCH* and *nrofPRBs-perMsgA-PO*, the UE expects a PUSCH occasion to be confined within the same RB set as the corresponding PRACH transmission.

For operation with shared spectrum channel access, if the PUSCH occasion is provided by higher layer parameters *interlaceIndexFirstPO-MsgA-PUSCH* and *nrofInterlacesPerMsgA-PO*, the RB set for the PUSCH occasion in the active UL BWP is the same RB set as the corresponding PRACH transmission. The UE assumes that the RB set is defined as when the UE is not provided *intraCellGuardBandsPerSCS* for an UL carrier as described in clause 7 of [6, TS 38.214].

If a UE does not have dedicated RRC configuration, or has an initial UL BWP as an active UL BWP, or is not provided *startSymbolAndLengthMsgA-PO*, *msgA-PUSCH-timeDomainAllocation* provides a SLIV and a PUSCH mapping type for a PUSCH transmission by indicating

- one of the first *maxNrofUL-Allocations* values from *PUSCH-TimeDomainResourceAllocationList*, if *PUSCH-TimeDomainResourceAllocationList* is provided in *PUSCH-ConfigCommon*

- one of the entries from table 6.1.2.1.1-2 or table 6.1.2.1.1-3 in [6, TS 38.214], if *PUSCH-TimeDomainResourceAllocationList* is not provided in *PUSCH-ConfigCommon*

else, the UE is provided a SLIV by *startSymbolAndLengthMsgA-PO*, and a PUSCH mapping type by *mappingTypeMsgA-PUSCH* for a PUSCH transmission.

For mapping one or multiple preambles of a PRACH slot to a PUSCH occasion associated with a DMRS resource, a UE determines a first slot for a first PUSCH occasion in an active UL BWP from *msgA-PUSCH-TimeDomainOffset* that provides an offset, in number of slots in the active UL BWP, relative to the start of a PUSCH slot including the start of each PRACH slot. The UE does not expect to have a PRACH preamble transmission and a PUSCH transmission with a msgA in a PRACH slot or in a PUSCH slot, or to have overlapping msgA PUSCH occasions for a MsgA PUSCH configuration. The UE expects that a first PUSCH occasion in each slot has a same SLIV for a PUSCH transmission that is provided by *startSymbolAndLengthMsgA-PO* or *msgA-PUSCH-timeDomainAllocation* [6, TS 38.214].

Consecutive PUSCH occasions within each slot are separated by *guardPeriodMsgA-PUSCH* symbols and have same duration. A number N_t of time domain PUSCH occasions in each slot is provided by *nrofMsgA-PO-perSlot* and a number N_s of consecutive slots that include PUSCH occasions is provided by *nrofSlotsMsgA-PUSCH*.

A UE is provided a DMRS configuration for a PUSCH transmission in a PUSCH occasion in an active UL BWP by *msgA-DMRS-Config*.

A UE is provided an MCS for data information in a PUSCH transmission for a PUSCH occasion by *msgA-MCS*.

For a PUSCH transmission with frequency hopping in a slot, when indicated by *msgA-intraSlotFrequencyHopping* for the active UL BWP, the frequency offset for the second hop [6, TS 38.214] is determined as described in clause 8.3,

Table 8.3-1 using *msgA-HoppingBits* instead of $N_{\mathrm{UL,hop}}$. If *guardPeriodMsgA-PUSCH* is provided, a first symbol of the second hop is separated by *guardPeriodMsgA-PUSCH* symbols from the end of a last symbol of the first hop; otherwise, there is no time separation of the PUSCH transmission before and after frequency hopping. If a UE is provided with *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*, the UE shall transmit PUSCH without frequency hopping. A PUSCH transmission uses a same spatial filter as an associated PRACH transmission.

A UE determines whether or not to apply transform precoding for a PUSCH transmission as described in [6, TS 38.214].

A PUSCH occasion for PUSCH transmission is defined by a frequency resource and a time resource, and is associated with a DMRS resource. The DMRS resources are provided by *msgA-DMRS-Config*.

Each consecutive number of N_{preamble} preamble indexes from valid PRACH occasions in a PRACH slot

- first, in increasing order of preamble indexes within a single PRACH occasion
- second, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions
- third, in increasing order of time resource indexes for time multiplexed PRACH occasions within a PRACH slot

are mapped to a valid PUSCH occasion and the associated DMRS resource

- first, in increasing order of frequency resource indexes f_{id} for frequency multiplexed PUSCH occasions
- second, in increasing order of DMRS resource indexes within a PUSCH occasion, where a DMRS resource index $DMRS_{id}$ is determined first in an ascending order of a DMRS port index and second in an ascending order of a DMRS sequence index [4, TS 38.211]
- third, in increasing order of time resource indexes t_{id} for time multiplexed PUSCH occasions within a PUSCH slot
- fourth, in increasing order of indexes for N_s PUSCH slots

where $N_{\mathrm{preamble}} = ceil\left(T_{\mathrm{preamble}}/T_{\mathrm{PUSCH}}\right)$, T_{preamble} is a total number of valid PRACH occasions per association pattern period multiplied by the number of preambles per valid PRACH occasion provided by *rach-ConfigCommonTwoStepRA*, and T_{PUSCH} is a total number of valid PUSCH occasions per PUSCH configuration per association pattern period multiplied by the number of DMRS resource indexes per valid PUSCH occasion provided by *msgA-DMRS-Config*.

A PUSCH occasion is valid if it does not overlap in time and frequency with any valid PRACH occasion associated with either a Type-1 random access procedure or a Type-2 random access procedure. Additionally, for unpaired spectrum and for SS/PBCH blocks with indexes provided by *ssb-PositionsInBurst* in *SIB1* or by *ServingCellConfigCommon*

- if a UE is not provided *tdd-UL-DL-ConfigurationCommon*, a PUSCH occasion is valid if the PUSCH occasion
  - does not precede a SS/PBCH block in the PUSCH slot, and
  - starts at least N_{gap} symbols after a last SS/PBCH block symbol, where N_{gap} is provided in Table 8.1-2 and, if *channelAccessMode* = "*semiStatic*" is provided, does not overlap with a set of consecutive symbols before the start of a next channel occupancy time where the UE does not transmit [15, TS 37.213].
- if a UE is provided *tdd-UL-DL-ConfigurationCommon*, a PUSCH occasion is valid if the PUSCH occasion
  - is within UL symbols, or
  - does not precede a SS/PBCH block in the PUSCH slot, and
  - starts at least N_{gap} symbols after a last downlink symbol and at least N_{gap} symbols after a last SS/PBCH block symbol, where N_{gap} is provided in Table 8.1-2 and, if *channelAccessMode* = "*semiStatic*" is provided, does not overlap with a set of consecutive symbols before the start of a next channel occupancy time where the UE does not transmit [15, TS 37.213].

8.2 Random access response - Type-1 random access procedure

In response to a PRACH transmission, a UE attempts to detect a DCI format 1_0 with CRC scrambled by a corresponding RA-RNTI during a window controlled by higher layers [11, TS 38.321] if the PRACH transmission is not triggered by a PDCCH order that includes a Cell Indicator field with non-zero value; otherwise, the UE does not attempt to detect the DCI format 1_0. The window starts at the first symbol of the earliest CORESET the UE is configured to receive PDCCH for Type1-PDCCH CSS set, as defined in clause 10.1, that is at least one symbol, after the last symbol of the last PRACH occasion corresponding to the PRACH transmission, where the symbol duration corresponds to the SCS for Type1-PDCCH CSS set as defined in clause 10.1. If $N_{\text{TA,adj}}^{\text{UE}}$ or $N_{\text{TA,adj}}^{\text{common}}$, as defined in [4, TS 38.211], is not zero, the window starts after an additional $T_{\text{TA}} + k_{\text{mac}}$ msec where T_{TA} is defined in [4, TS 38.211] and k_{mac} is provided by *kmac* or $k_{\text{mac}} = 0$ if *kmac* is not provided. The length of the window in number of slots, based on the SCS for Type1-PDCCH CSS set, is provided by *ra-ResponseWindow*.

If the UE detects the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI and LSBs of a SFN field in the DCI format 1_0, if included and applicable, are same as corresponding LSBs of the SFN where the UE transmitted PRACH, and the UE receives a transport block in a corresponding PDSCH within the window, the UE passes the transport block to higher layers. The higher layers parse the transport block for a random access preamble identity (RAPID) associated with the PRACH transmission. If the higher layers identify the RAPID in RAR message(s) of the transport block, the higher layers indicate an uplink grant to the physical layer. This is referred to as random access response (RAR) UL grant in the physical layer.

If the UE does not detect the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI within the window, or if the UE detects the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI within the window and LSBs of a SFN field in the DCI format 1_0, if included and applicable, are not same as corresponding LSBs of the SFN where the UE transmitted PRACH, or if the UE does not correctly receive the transport block in the corresponding PDSCH within the window, or if the higher layers do not identify the RAPID associated with the PRACH transmission from the UE, the higher layers can indicate to the physical layer to transmit a PRACH. If requested by higher layers, the UE shall be ready to transmit a PRACH no later than $N_{T,1} + 0.75$ msec after the last symbol of the window, or the last symbol of the PDSCH reception, where $N_{T,1}$ is a time duration of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 assuming μ corresponds to the smallest SCS configuration among the SCS configurations for the PDCCH carrying the DCI format 1_0, the corresponding PDSCH when additional PDSCH DM-RS is configured, and the corresponding PRACH. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214]. For a PRACH transmission using 1.25 kHz or 5 kHz SCS, the UE determines N_1 assuming SCS configuration $\mu = 0$.

If the UE detects a DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI and LSBs of a SFN field in the DCI format 1_0, if included and applicable, are same as corresponding LSBs of the SFN where the UE transmitted the PRACH, and the UE receives a transport block in a corresponding PDSCH, the UE may assume same DM-RS antenna port quasi co-location properties, as described in [6, TS 38.214], as for a SS/PBCH block or a CSI-RS resource the UE used for PRACH association, as described in clause 8.1, regardless of whether or not the UE is provided *TCI-State* for the CORESET where the UE receives the PDCCH with the DCI format 1_0.

If the UE attempts to detect the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI in response to a PRACH transmission initiated by a PDCCH order that triggers a contention-free random access procedure for the SpCell [11, TS 38.321], the UE may assume that the PDCCH that includes the DCI format 1_0 and the PDCCH order have same DM-RS antenna port quasi co-location properties. If the UE attempts to detect the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI in response to a PRACH transmission initiated by a PDCCH order that triggers a contention-free random access procedure for a secondary cell, or if the UE is configured with *twoTAGs* for the SpCell and the CORESET where the UE receives the PDCCH order that triggers a contention-free random access procedure for the SpCell is not associated with the physical cell ID for the serving cell, the UE may assume the DM-RS antenna port quasi co-location properties of the CORESET associated with the Type1-PDCCH CSS set for receiving the PDCCH that includes the DCI format 1_0 and the PDSCH scheduled by the DCI format 1_0.

A RAR UL grant schedules a PUSCH transmission from the UE. The contents of the RAR UL grant, starting with the MSB and ending with the LSB, are given in Table 8.2-1.

If the value of the frequency hopping flag is 0, the UE transmits the PUSCH without frequency hopping; otherwise, the UE transmits the PUSCH with frequency hopping.

The UE determines the MCS of the PUSCH transmission from the first sixteen indexes of the applicable MCS index table for PUSCH as described in [6, TS 38.214].

The TPC command value $\delta_{\text{msg2},b,f,c}$ is used for setting the power of the PUSCH transmission, as described in clause 7.1.1, and is interpreted according to Table 8.2-2.

The CSI request field is reserved.

The ChannelAccess-CPext field indicates a channel access type and CP extension for operation with shared spectrum channel access [15, TS 37.213] in FR1 as defined in Table 7.3.1.1.1-4 in [5, TS 38.212] or Table 7.3.1.1.1-4A in [5, TS 38.212] if *channelAccessMode* = "*semiStatic*" is provided. The ChannelAccess-CPext field indicates a channel access type for operation with shared spectrum channel access [15, TS 37.213] in FR2-2 as defined in Table 7.3.1.1.1-4B in [5, TS 38.212] if *ChannelAccessMode2-r17* is provided.

Table 8.2-1: Random Access Response Grant Content field size

RAR grant field	Number of bits
Frequency hopping flag	1
PUSCH frequency resource allocation	12, for operation with shared spectrum channel access in FR1 or for FR2-2 when *ChannelAccessMode2-r17* is provided 14, otherwise
PUSCH time resource allocation	4
MCS	4
TPC command for PUSCH	3
CSI request	1
ChannelAccess-CPext	2, for operation with shared spectrum channel access in FR1 or for FR2-2 when *ChannelAccessMode2-r17* is provided 0, otherwise

Table 8.2-2: TPC Command $\delta_{\text{msg2},b,f,c}$ for PUSCH

TPC Command	Value (in dB)
0	-6
1	-4
2	-2
3	0
4	2
5	4
6	6
7	8

Unless the UE is configured a SCS, the UE receives subsequent PDSCH using same SCS as for the PDSCH reception providing the RAR message.

If the UE does not detect the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI within the window, or if the UE detects the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI within the window and the LSBs of a SFN field in the DCI format 1_0, if included and applicable, are not same as corresponding LSBs of the SFN where the UE transmitted the PRACH, or the UE does not correctly receive a corresponding transport block within the window, the UE procedure is as described in [11, TS 38.321].

8.2A Random access response - Type-2 random access procedure

In response to a transmission of a PRACH and a PUSCH, or to a transmission of only a PRACH if the PRACH preamble is mapped to a valid PUSCH occasion, a UE attempts to detect a DCI format 1_0 with CRC scrambled by a corresponding MsgB-RNTI during a window controlled by higher layers [11, TS 38.321]. The window starts at the first symbol of the earliest CORESET the UE is configured to receive PDCCH for Type1-PDCCH CSS set, as defined in clause 10.1, that is at least one symbol, after the last symbol of the PUSCH occasion corresponding to the PRACH transmission, where the symbol duration corresponds to the SCS for Type1-PDCCH CSS set. If $N_{\text{TA,adj}}^{\text{UE}}$ or $N_{\text{TA,adj}}^{\text{common}}$, as defined in [4, TS 38.211], is not zero, the window starts after an additional $T_{\text{TA}} + k_{\text{mac}}$ msec where T_{TA} is defined in [4, TS 38.211] and k_{mac} is provided by *kmac* or $k_{\text{mac}} = 0$ if *kmac* is not provided. The length of the window in number of slots, based on the SCS for Type1-PDCCH CSS set, is provided by *msgB-ResponseWindow*.

In response to a transmission of a PRACH, if the PRACH preamble is not mapped to a valid PUSCH occasion, a UE attempts to detect a DCI format 1_0 with CRC scrambled by a corresponding MsgB-RNTI during a window controlled by higher layers [11, TS 38.321]. The window starts at the first symbol of the earliest CORESET the UE is configured to receive PDCCH for Type1-PDCCH CSS set, as defined in clause 10.1, that is at least one symbol, after the last symbol of the PRACH occasion corresponding to the PRACH transmission, where the symbol duration corresponds to the SCS for Type1-PDCCH CSS set. The length of the window in number of slots, based on the SCS for Type1-PDCCH CSS set, is provided by *msgB-ResponseWindow*.

If the UE detects the DCI format 1_0, with CRC scrambled by the corresponding MsgB-RNTI and LSBs of a SFN field in the DCI format 1_0, if applicable, are same as corresponding LSBs of the SFN where the UE transmitted PRACH, and the UE receives a transport block in a corresponding PDSCH within the window, the UE passes the transport block to higher layers. The higher layers indicate to the physical layer

- an uplink grant if the RAR message(s) is for fallbackRAR and a random access preamble identity (RAPID) associated with the PRACH transmission is identified, and the UE procedure continues as described in clauses 8.2, 8.3, and 8.4 when the UE detects a RAR UL grant, or

- transmission of a PUCCH with HARQ-ACK information having ACK value if the RAR message(s) is for successRAR, where

  - a PUCCH resource for the transmission of the PUCCH is indicated by PUCCH resource indicator field of 4 bits in the successRAR from a PUCCH resource set that is provided by *pucch-ResourceCommon*

  - a slot for the PUCCH transmission is indicated by a HARQ Feedback Timing Indicator field of 3 bits in the successRAR having a value k from {1, 2, 3, 4, 5, 6, 7, 8} for $\mu \leq 3$, from {7, 8, 12, 16, 20, 24, 28, 32} for $\mu = 5$, and from {13, 16, 24, 32, 40, 48, 56, 64} for $\mu = 6$ and, with reference to slots for PUCCH transmission having duration T_{slot}, the slot is determined as $n + k + \Delta + 2^{\mu} \cdot K_{\text{cell,offset}}$, where n is the last slot that overlaps with the DL slot for the PDSCH reception, Δ is as defined for PUSCH transmission in Table 6.1.2.1.1-5 of [6, TS 38.214], μ is the SCS configuration of the active UL BWP, and $K_{\text{cell,offset}}$ is provided by *cellSpecificKoffset*; otherwise, if not provided, $K_{\text{cell,offset}} = 0$

    - the UE does not expect the first symbol of the PUCCH transmission to be after the last symbol of the PDSCH reception by a time smaller than $N_{T,1} + 0.5$ msec where $N_{T,1}$ is the PDSCH processing time for UE processing capability 1 [6, TS 38.214]

  - for operation with shared spectrum channel access in FR1, a channel access type and CP extension [15, TS 37.213] for a PUCCH transmission is indicated by a ChannelAccess-CPext field in the successRAR as defined in Table 7.3.1.1.1-4 in [5, TS 38.212] or Table 7.3.1.1.1-4A in [5, TS 38.212] if *channelAccessMode* = "*semiStatic*" is provided

  - for operation with shared spectrum channel access in FR2-2, a channel access type [15, TS 37.213] for a PUCCH transmission is indicated by a ChannelAccess-CPext field in the successRAR as defined in Table 7.3.1.1.1-4B in [5, TS 38.212] if *ChannelAccessMode2-r17* is provided

  - the PUCCH transmission is with a same spatial domain transmission filter and in a same active UL BWP as a last PUSCH transmission

If the UE detects the DCI format 1_0 with CRC scrambled by a C-RNTI and a transport block in a corresponding PDSCH within the window, the UE transmits a PUCCH with HARQ-ACK information having ACK value if the UE correctly detects the transport block or NACK value if the UE incorrectly detects the transport block and the time alignment timer is running [11, TS 38.321].

If the UE detects a DCI format 1_0 with CRC scrambled by the corresponding MsgB-RNTI and receives a transport block within the window in a corresponding PDSCH, the UE may assume same DM-RS antenna port quasi co-location properties, as described in [6, TS 38.214], as for a SS/PBCH block the UE used for PRACH association, as described in clause 8.1, regardless of whether or not the UE is provided *TCI-State* for the CORESET where the UE receives the PDCCH with the DCI format 1_0.

The UE does not expect to be indicated to transmit the PUCCH with the HARQ-ACK information at a time that is prior to a time when the UE applies a TA command that is provided by the transport block. If the UE does not detect the DCI format 1_0 with CRC scrambled by the corresponding MsgB-RNTI within the window, or if the UE detects the DCI format 1_0 with CRC scrambled by the corresponding MsgB-RNTI within the window and LSBs of a SFN field in the DCI format 1_0, if applicable, are not same as corresponding LSBs of the SFN where the UE transmitted the PRACH, or if the UE does not correctly receive the transport block in the corresponding PDSCH within the window, or if the higher layers do not identify the RAPID associated with the PRACH transmission from the UE, the higher layers can indicate to the physical layer to transmit only PRACH according to Type-1 random access procedure or to transmit both PRACH and PUSCH according to Type-2 random access procedure [11, TS 38.321]. If requested by higher layers, the UE shall be ready to transmit a PRACH no later than $N_{\mathrm{T},1} + 0.75$ msec after the last symbol of the window, or the last symbol of the PDSCH reception, where $N_{\mathrm{T},1}$ is a time duration of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214].

Unless the UE is configured a SCS, the UE receives subsequent PDSCH using same SCS as for the PDSCH reception providing the RAR message.

If the UE does not detect the DCI format 1_0 with CRC scrambled by the corresponding MsgB-RNTI within the window, or if the UE detects the 1_0 with CRC scrambled by the corresponding MsgB-RNTI within the window and LSBs of a SFN field in the DCI format 1_0, if applicable, are not same as corresponding LSBs of the SFN where the UE transmitted the PRACH, or the UE does not correctly receive a corresponding transport block within the window, the UE procedure is as described in [11, TS 38.321].

8.3 PUSCH scheduled by RAR UL grant

An active UL BWP with SCS configuration μ, as described in clause 12 and in [4, TS 38.211], for a PUSCH transmission scheduled by a RAR UL grant is indicated by higher layers.

If *useInterlacePUCCH-PUSCH* is not provided by *BWP-UplinkCommon* and *BWP-UplinkDedicated*, for determining the frequency domain resource allocation for the PUSCH transmission within the active UL BWP

- if the active UL BWP and the initial UL BWP have same SCS and same CP length and the active UL BWP includes all RBs of the initial UL BWP, or the active UL BWP is the initial UL BWP, the initial UL BWP is used
- else, the RB numbering starts from the first RB of the active UL BWP and the maximum number of RBs for frequency domain resource allocation equals the number of RBs in the initial UL BWP

The frequency domain resource allocation is by uplink resource allocation type 1 [6, TS 38.214]. For an initial UL BWP size of $N_{\mathrm{BWP}}^{\mathrm{size}}$ RBs, a UE processes the frequency domain resource assignment field as follows

- if $N_{\mathrm{BWP}}^{\mathrm{size}} \leq 180$, or for operation with shared spectrum channel access in FR1 or for FR2-2 when *ChannelAccessMode2-r17* is provided if $N_{\mathrm{BWP}}^{\mathrm{size}} \leq 90$
  - truncate the frequency domain resource assignment field to its $\left\lceil \log_2\left(N_{\mathrm{BWP}}^{\mathrm{size}} \cdot \left(N_{\mathrm{BWP}}^{\mathrm{size}} + 1\right)/2\right) \right\rceil$ least significant bits and interpret the truncated frequency resource assignment field as for the frequency resource assignment field in DCI format 0_0 as described in [5, TS 38.212]
- else
  - insert
    - $\left\lceil \log_2\left(N_{\mathrm{BWP}}^{\mathrm{size}} \cdot \left(N_{\mathrm{BWP}}^{\mathrm{size}} + 1\right)/2\right) \right\rceil - 12$ most significant bits, for operation with shared spectrum channel access in FR1 or for FR2-2 when *ChannelAccessMode2-r17* is provided;
    - $\left\lceil \log_2\left(N_{\mathrm{BWP}}^{\mathrm{size}} \cdot \left(N_{\mathrm{BWP}}^{\mathrm{size}} + 1\right)/2\right) \right\rceil - 14$ most significant bits, otherwise;

    with value set to '0' after the $N_{\mathrm{UL,hop}}$ bits to the frequency domain resource assignment field, where $N_{\mathrm{UL,hop}} = 0$ if the frequency hopping flag is set to '0' and $N_{\mathrm{UL,hop}}$ is provided in Table 8.3-1 if the hopping flag bit is set to '1', and interpret the expanded frequency resource assignment field as for the frequency resource assignment field in DCI format 0_0 as described in [5, TS 38.212]
- end if

If *useInterlacePUCCH-PUSCH* is provided by *BWP-UplinkCommon* or *BWP-UplinkDedicated*, the frequency domain resource allocation is by uplink resource allocation type 2 [6, TS 38.214]. A UE processes the frequency domain resource assignment field as follows

- truncate the frequency domain resource assignment field to the $X = 6$ LSBs if $\mu = 0$, or to the $X = 5$ LSBs if $\mu = 1$

- for interlace allocation of a PUSCH transmission, interpret the X MSBs of the truncated frequency domain resource assignment field for the active UL BWP as for the X MSBs of the frequency domain resource assignment field in DCI format 0_0 [6, TS 38.214]

- for RB set allocation of a PUSCH transmission, the RB set of the active UL BWP is the RB set of the PRACH transmission associated with the RAR UL grant. The UE assumes that the RB set is defined as when the UE is not provided *intraCellGuardBandsUL-List* [6, TS 38.214].

A UE determines whether or not to apply transform precoding as described in [6, TS 38.214].

For a PUSCH transmission with frequency hopping scheduled by RAR UL grant or for a Msg3 PUSCH retransmission, the frequency offset for the second hop [6, TS 38.214] is given in Table 8.3-1.

Table 8.3-1: Frequency offset for second hop of PUSCH transmission with frequency hopping scheduled by RAR UL grant or of Msg3 PUSCH retransmission

Number of PRBs in initial UL BWP	Value of $N_{\mathrm{UL,hop}}$ Hopping Bits	Frequency offset for 2nd hop
$N_{\mathrm{BWP}}^{\mathrm{size}} < 50$	0	$\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/2 \rfloor$
	1	$\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/4 \rfloor$
$N_{\mathrm{BWP}}^{\mathrm{size}} \geq 50$	00	$\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/2 \rfloor$
	01	$\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/4 \rfloor$
	10	$-\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/4 \rfloor$
	11	Reserved

A SCS for the PUSCH transmission is provided by *subcarrierSpacing* in *BWP-UplinkCommon*. A UE transmits PRACH and the PUSCH on a same uplink carrier of a same serving cell.

A UE transmits a transport block in a PUSCH scheduled by a RAR UL grant in a corresponding RAR message using redundancy version number 0, if the PUSCH transmission is without repetitions. If a TC-RNTI is provided by higher layers, the scrambling initialization of the PUSCH corresponding to the RAR UL grant in clause 8.2 is by TC-RNTI. Otherwise, the scrambling initialization of the PUSCH corresponding to the RAR UL grant in clause 8.2 is by C-RNTI.

If a UE is provided *tag2-Id*, the UE transmits a transport block in a PUSCH scheduled by a RAR UL grant in a corresponding RAR message with timing advance corresponding to a TAG indicated by the RAR message.

Msg3 PUSCH retransmissions, if any, of the transport block, are scheduled by a DCI format 0_0 with CRC scrambled by a TC-RNTI provided in the corresponding RAR message [11, TS 38.321].

With reference to slots for a PUSCH transmission scheduled by a RAR UL grant, if a UE receives a PDSCH with a RAR message ending in slot n for a corresponding PRACH transmission from the UE, the UE transmits the PUSCH in slot $n + k_2 + \Delta + 2^{\mu} \cdot K_{\mathrm{cell,offset}}$, where k_2 and Δ are provided in [6, TS 38.214] and $K_{\mathrm{cell,offset}}$ is provided by *cellSpecificKoffset*; otherwise, if not provided, $K_{\mathrm{cell,offset}} = 0$.

A UE can be provided in *BWP-UplinkCommon* a set of numbers of repetitions for a PUSCH transmission with PUSCH repetition Type A that is scheduled by a RAR UL grant or by a DCI format 0_0 with CRC scrambled by a TC-RNTI. If the UE requests repetitions for the PUSCH transmission [11, TS 38.321], the UE transmits the PUSCH over $N_{\mathrm{PUSCH}}^{\mathrm{repeat}}$ slots, where $N_{\mathrm{PUSCH}}^{\mathrm{repeat}}$ is indicated by the 2 MSBs of the MCS field in the RAR UL grant or in the DCI format 0_0 from a set of four values provided by *numberOfMsg3-RepetitionsList* or from {1, 2, 3, 4} if *numberOfMsg3-RepetitionsList* is not provided. The UE determines an MCS for the PUSCH transmission by the 2 LSBs of the MCS field in the RAR UL grant or by the 3 LSBs of the MCS field in the DCI format 0_0, and determines a redundancy version and RBs for each repetition as described in [6, TS 38.214]. For unpaired spectrum operation, the UE determines the $N_{\mathrm{PUSCH}}^{\mathrm{repeat}}$ slots as the first $N_{\mathrm{PUSCH}}^{\mathrm{repeat}}$ slots starting from slot $n + k_2 + \Delta$ where a repetition of the PUSCH transmission does not include a symbol indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or indicated as a symbol of an SS/PBCH block with index provided by *ssb-PositionsInBurst*.

The UE may assume a minimum time between the last symbol of a PDSCH reception conveying a RAR message with a RAR UL grant and the first symbol of a corresponding PUSCH transmission scheduled by the RAR UL grant is equal to $N_{T,1} + N_{T,2} + 0.5$ msec, where $N_{T,1}$ is a time duration of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured, $N_{T,2}$ is a time duration of N_2 symbols corresponding to a PUSCH preparation time for UE processing capability 1 [6, TS 38.214] and, for determining the minimum time, the UE considers that N_1 and N_2 correspond to the smaller of the SCS configurations for the PDSCH and the PUSCH. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214].

8.4 PDSCH with UE contention resolution identity

In response to a PUSCH transmission scheduled by a RAR UL grant when a UE has not been provided a C-RNTI, the UE attempts to detect a DCI format 1_0 with CRC scrambled by a corresponding TC-RNTI scheduling a PDSCH that includes a UE contention resolution identity [11, TS 38.321]. In response to the PDSCH reception with the UE contention resolution identity, the UE transmits HARQ-ACK information in a PUCCH. The PUCCH transmission is within a same active UL BWP as the PUSCH transmission. A minimum time between the last symbol of the PDSCH reception and the first symbol of the corresponding PUCCH transmission with the HARQ-ACK information is equal to $N_{T,1} + 0.5$ msec. $N_{T,1}$ is a time duration of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214].

When detecting a DCI format in response to a PUSCH transmission scheduled by a RAR UL grant, as described in [11, TS 38.321], or corresponding PUSCH retransmission scheduled by a DCI format 0_0 with CRC scrambled by a TC-RNTI provided in the corresponding RAR message [11, TS 38.321], the UE may assume the PDCCH carrying the DCI format has the same DM-RS antenna port quasi co-location properties, as described in [6, TS 38.214], as for a SS/PBCH block the UE used for PRACH association, as described in clause 8.1, regardless of whether or not the UE is provided TCI-State for the CORESET where the UE receives the PDCCH with the DCI format.

9 UE procedure for reporting control information

If a UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG.

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.

- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If a UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the primary PUCCH group respectively.

- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group. If *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16* is provided, *pdsch-HARQ-ACK-Codebook* is replaced by *pdsch-HARQ-ACK-Codebook-secondaryPUCCHgroup-r16*. If *harq-ACK-SpatialBundlingPUCCH-secondaryPUCCHgroup* is provided, *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUCCH-secondaryPUCCHgroup*. If *harq-ACK-SpatialBundlingPUSCH-secondaryPUCCHgroup* is provided, *harq-ACK-SpatialBundlingPUSCH* is replaced by *harq-ACK-SpatialBundlingPUSCH-secondaryPUCCHgroup*. If *uci-MuxWithDiffPrioSecondaryPUCCHgroup* is provided, *uci-MuxWithDiffPrio* is replaced by *uci-MuxWithDiffPrioSecondaryPUCCHgroup*. If *simultaneousPUCCH-PUSCH-secondaryPUCCHgroup* is provided, *simultaneousPUCCH-PUSCH* is replaced by *simultaneousPUCCH-PUSCH-SecondaryPUCCHgroup*. If *simultaneousPUCCH-PUSCH-SamePriority-secondaryPUCCHgroup* is provided, *simultaneousPUCCH-PUSCH-SamePriority* is replaced by *simultaneousPUCCH-PUSCH- SamePriority-SecondaryPUCCHgroup*. If *pucch-sSCellSecondaryPUCCHgroup* is provided, *pucch-sSCell* is replaced by *pucch-*

sSCellSecondaryPUCCHgroup. If *pucch-sSCellPatternSecondaryPUCCHgroup* is provided, *pucch-sSCellPattern* is replaced by *pucch-sSCellPatternSecondaryPUCCHgroup*. If *pucch-sSCellDynSecondaryPUCCHgroup* is provided, *pucch-sSCellDyn* is replaced by *pucch-sSCellDynSecondaryPUCCHgroup*. If *pdsch-HARQ-ACK-EnhType3SecondaryToAddModList* is provided, *pdsch-HARQ-ACK-EnhType3ToAddModList* is replaced by *pdsch-HARQ-ACK-EnhType3SecondaryToAddModList*. If *pdsch-HARQ-ACK-RetxSecondaryPUCCHgroup* is provided, *pdsch-HARQ-ACK-Retx* is replaced by *pdsch-HARQ-ACK-RetxSecondaryPUCCHgroup*.

If a UE is provided *MC-DCI-SetofCells* for scheduling by a DCI format PDSCH receptions or PUSCH transmissions on serving cells from a set of more than one serving cells, the UE expects the more than one serving cells to be in a same PUCCH group. The UE provides HARQ-ACK information in a same HARQ-ACK codebook for sets of serving cells that are associated with a same PUCCH group. The UE does not expect to be configured to receive multicast PDSCH on serving cells of the same PUCCH group as serving cells from the sets of serving cells.

For unpaired spectrum operation, if a UE is provided a PUCCH-sSCell as described in clause 9.A, the UE shall apply the procedures described in this clause for both the primary cell and the PUCCH-sSCell.

If a UE is provided *pdsch-HARQ-ACK-CodebookList-r16*, *pdsch-HARQ-ACK-Codebook* is replaced by the relevant entry in *pdsch-HARQ-ACK-CodebookList-r16*.

In the remaining of this clause, when a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1

- a PDCCH monitoring occasion is the union of the PDCCH monitoring occasions for the two PDCCH candidates
- the start of the PDCCH reception is the start of the earlier PDCCH candidate
- the end of the PDCCH reception is the end of the PDCCH candidate that ends later

The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

In the remaining of this clause, a last DCI format is from a set of detected DCI formats for which the UE would provide HARQ-ACK information in a PUCCH in a same slot. Detected DCI formats are first indexed in ascending order across indexes of respective scheduled cells for a same PDCCH monitoring occasion, and are then indexed in ascending order across indexes of PDCCH monitoring occasions. For indexing a detected DCI format associated with two or more scheduled cells, a respective scheduled cell is the one with the smallest index among the two or more scheduled cells. For a PDCCH monitoring occasion and a scheduled cell, if a UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs on an active DL BWP of a serving cell, and is provided *ackNackFeedbackMode* = *joint* for the active UL BWP, detected DCI formats from PDCCH receptions in the first CORESETs are indexed prior to detected DCI formats from PDCCH receptions in the second CORESETs.

For the purpose of determining timeline conditions in this clause,

- if a UE would transmit a PUCCH with HARQ-ACK information in response to a first SPS PDSCH reception after an activation of SPS PDSCH receptions, the PUCCH is considered as a PUCCH transmission in response to a DCI format detection;
- if a UE would transmit a configured grant Type 2 PUSCH in the first transmission occasion after an activation of configured grant Type 2 PUSCH transmissions, the PUSCH is considered as a PUSCH transmission in response to a DCI format detection.

If a UE

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on active DL BWPs of serving cells, and
- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on active DL BWPs of the serving cells, and
- is provided *ackNackFeedbackMode* = *separate*

the UE shall separately apply the procedures described in clauses 9.1 and 9.2.3 for reporting HARQ-ACK information associated with the first CORESETs on active DL BWP of the serving cells and for reporting HARQ-ACK information associated with the second CORESETs on active DL BWP of the serving cells, and the UE does not expect to be provided with *subslotLengthForPUCCH* or to be indicated by *pdsch-HARQ-ACK-CodebookList* to generate two HARQ-ACK codebooks on active DL BWP of the serving cells. HARQ-ACK information reporting is associated with a CORESET through a reception of a PDCCH with a DCI format triggering the reporting of the HARQ-ACK information by the UE.

For NR-DC when both the MCG and the SCG operate either in FR1 or in FR2 and for a power headroom report transmitted on the MCG or the SCG, the UE computes *PH* assuming that the UE does not transmit PUSCH/PUCCH on any serving cell of the SCG or the MCG, respectively.

If a UE is configured for NR-DC operation, the UE does not expect to be configured with a PUCCH-SCell.

A PUSCH or a PUCCH transmission other than PUCCH transmissions with SL HARQ-ACK reports, including repetitions if any, can be of priority index 0 or of priority index 1. For a configured grant PUSCH transmission, a UE determines a priority index from *phy-PriorityIndex*, if provided. For a PUCCH transmission with HARQ-ACK information corresponding to a SPS PDSCH reception or a SPS PDSCH release, a UE determines a priority index from *harq-CodebookID*, if provided. For a PUCCH transmission with SR, a UE determines the corresponding priority as described in clause 9.2.4. For a PUSCH transmission with semi-persistent CSI report, a UE determines a priority index from a priority indicator field, if provided, in a DCI format that activates the semi-persistent CSI report. If a priority index is not provided to a UE for a PUSCH or a PUCCH transmission other than PUCCH transmissions with SL HARQ-ACK reports, the priority index is 0.

If a UE is provided one *PUCCH-Config*

- if the UE is provided *subslotLengthForPUCCH* in the *PUCCH-Config*, the PUCCH resource for any SR configuration with priority index 0 or any CSI report configuration in the *PUCCH-Config* is within the *subslotLengthForPUCCH* symbols in the *PUCCH-Config*

If a UE is provided two *PUCCH-Config*

- if the UE is provided *subslotLengthForPUCCH* in the first *PUCCH-Config*, the PUCCH resource for any SR configuration with priority index 0 or any CSI report configuration in any *PUCCH-Config* is within the *subslotLengthForPUCCH* symbols in the first *PUCCH-Config*

- if the UE is provided *subslotLengthForPUCCH* in the second *PUCCH-Config*, the PUCCH resource for any SR configuration with priority index 1 in any *PUCCH-Config* is within the *subslotLengthForPUCCH* symbols in the second *PUCCH-Config*

If a UE is provided *subslotLengthForPUCCH* in a *PUCCH-Config* of a given priority index, in a slot of $N_{\mathrm{sym}}^{\mathrm{slot}}$ symbols [4, TS 38.211] with HARQ-ACK, the UE does not expect that HARQ-ACK information in response to SPS PDSCH reception(s) only (if any) or SR (if any) of the given priority index in a slot of *subslotLengthForPUCCH* symbols is moved to a different slot of *subslotLengthForPUCCH* symbols after multiplexing overlapping PUCCHs.

If in an active DL BWP a UE monitors PDCCH for detection of DCI format that includes a priority indicator field, a priority index can be provided by the priority indicator field. If a UE indicates a capability to monitor, in an active DL BWP, PDCCH for detection of DCI format that includes a priority indicator field, the DCI format can schedule PUSCH transmissions of any priority, or PDSCH receptions and/or trigger a PUCCH transmission with corresponding HARQ-ACK information of any priority, and DCI format 1_1 or DCI format 1_2 with a Transmission Configuration Indication field can indicate a TCI state update and trigger a PUCCH transmission with corresponding HARQ-ACK information of any priority.

A DCI format indicating a SPS PDSCH release, or SCell dormancy without scheduling a PDSCH reception, or indicating a TCI state update without scheduling PDSCH reception, is referred to as a DCI format having associated HARQ-ACK information without scheduling a PDSCH reception.

For the remaining of this clause, when a UE

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs, and is provided *coresetPoolIndex* with a value of 1 for second CORESETs, on active DL BWPs of serving cells, and

- is provided *enableSTx2PofmDCI*

the UE separately determines and resolves time overlapping among first PUSCH transmissions that use respective first spatial domain filters corresponding to first *TCI-State* or *TCI-UL-State* associated with the first CORESETs, and among second PUSCH transmissions that use respective second spatial domain filters corresponding to second *TCI-State* or *TCI-UL-State* associated with the second CORESETs.

When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of larger and/or smaller priority index, the UE resolves the overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUCCH of each priority index as described in clause 9.2.5 and 9.2.6 before resolving the overlapping for PUCCH transmissions without SL HARQ-ACK or the overlapping for PUCCH transmissions and PUSCH transmissions.

When a UE determines overlapping for PUCCH and/or PUSCH transmissions of the same priority index other than PUCCH transmissions with SL HARQ-ACK reports before considering limitations for UE transmission due to cell DRX operation [11, TS 38.321] or as described in clauses 11.1, 11.1.1, 11.2A, 15 and 17.2 including repetitions if any,

- first, the UE resolves the overlapping for PUCCHs with repetitions as described in clause 9.2.6, if any
- second, the UE resolves the overlapping for PUCCHs without repetitions as described in clauses 9.2.5
- third, the UE resolves the overlapping for PUSCHs and PUCCHs with repetitions as described in clause 9.2.6
- fourth, the UE resolves the overlapping for PUSCHs and PUCCHs without repetitions as is subsequently described in this clause.

After resolving the overlapping for PUCCH and/or PUSCH transmissions, and if cell DRX is activated for a serving cell and a PUCCH or PUSCH transmission would overlap with the non-active period of cell DRX of the serving cell, the UE does not transmit the PUCCH if HARQ-ACK information is not multiplexed in the PUCCH, or does not transmit the PUSCH if HARQ-ACK information is not multiplexed in the PUSCH and the PUSCH is not associated with a corresponding PDCCH, respectively.

If a UE

- is provided *simultaneousPUCCH-PUSCH* and would transmit a PUCCH with a first priority index and PUSCHs with a second priority index that is different than the first priority index, where the PUCCH and the PUSCHs overlap in time on different respective cells
- can simultaneously transmit the PUCCH and the PUSCHs with different priority indexes [18, TS 38.306],

the UE excludes the PUSCHs for resolving the time overlapping between the PUCCH and PUSCHs with different priority indexes, where the timeline conditions for resolving the overlapping PUCCH and PUSCHs are not required for the excluded PUSCHs.

If a UE

- is provided *simultaneousPUCCH-PUSCH-SamePriority* and would transmit a PUCCH and PUSCHs with same priority index, where the PUCCH and the PUSCHs overlap in time on different respective cells,
- can simultaneously transmit the PUCCH and the PUSCHs with same priority index [18, TS 38.306],

the UE excludes the PUSCHs for resolving the time overlapping between the PUCCH and PUSCHs with same priority index, where the timeline conditions for resolving the overlapping PUCCH and PUSCHs are not required for the excluded PUSCHs.

When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes, other than PUCCH transmissions with SL HARQ-ACK reports, before considering limitations for transmission due to cell DRX operation or as described in clauses 11.1, 11.1.1, 11.2A, 15 and 17.2 including repetitions if any, if the UE is provided *uci-MuxWithDiffPrio* and the timeline conditions in clause 9.2.5 for multiplexing UCI in a PUCCH or a PUSCH are satisfied

- first, the UE resolves overlapping for PUCCH and/or PUSCH transmissions of a same priority index as described in clauses 9.2.5 and 9.2.6
- second, the UE resolves the overlapping for PUCCH transmissions of different priority indexes, and
  - if the UE is provided *subslotLengthForPUCCH* in the second *PUCCH-Config*, a PUCCH transmission of smaller priority index is associated with the first overlapping slot with *subslotLengthForPUCCH* symbols of larger priority index; otherwise, the PUCCH transmission of smaller priority index is associated with the overlapping slot with $N_{\mathrm{sym}}^{\mathrm{slot}}$ symbols [4, TS 38.211] of larger priority index.
  - the UE first resolves the overlapping for PUCCH transmissions, where at least one of the PUCCH transmissions is with $N_{\mathrm{PUCCH}}^{\mathrm{repeat}} > 1$ repetitions, within a slot of larger priority index as is subsequently

described in this clause, if any, and then the UE resolves the overlapping for PUCCH transmissions without repetitions within the slot using the pseudo-code in clause 9.2.5

- if the UE determines that a first PUCCH transmission of the smaller priority index is not dropped and the UCI of the first PUCCH transmission is not multiplexed in a second PUCCH transmission of larger priority index in an overlapping slot with *subslotLengthForPUCCH* symbols, the first PUCCH transmission is associated with the next overlapping slot with *subslotLengthForPUCCH* symbols for PUCCH transmissions with the larger priority index

- the UE does not expect a PUCCH transmission that includes UCI of different priority indexes to overlap with a PUCCH transmission with $N_{\mathrm{PUCCH}}^{\mathrm{repeat}} > 1$ repetitions after resolving the overlapping for PUCCH transmissions without repetitions within a slot

- the UE does not expect a PUCCH transmission with UCI of first and second priority indexes to overlap with a PUCCH transmission with HARQ-ACK information of the first priority index, or with a PUCCH transmission or with a PUSCH transmission of the second priority index when the second priority index is larger than the first priority index

- the UE does not expect a PUCCH transmission with HARQ-ACK information of larger priority index to overlap with more than one PUCCH transmissions with HARQ-ACK information of smaller priority index

- third, the UE resolves the overlapping for PUCCH and PUSCH transmissions of different priority indexes

  - the UE drops PUSCH transmissions of smaller priority index that overlap with a PUCCH transmission with positive SR of larger priority index prior to multiplexing UCI in a PUSCH transmission of smaller priority index, if any

  - the UE drops PUSCH transmissions of smaller priority index that overlap with a PUCCH transmission with $N_{\mathrm{PUCCH}}^{\mathrm{repeat}} > 1$ repetitions of larger priority index prior to multiplexing UCI in a PUSCH transmission of smaller priority index, if any

  - the UE multiplexes HARQ-ACK information in a PUSCH transmission, as is subsequently described in this clause for multiplexing HARQ-ACK information from a PUCCH transmission in a PUSCH transmission of a same priority index, if a PUCCH transmission with HARQ-ACK information of a first priority index overlaps with one or more PUSCH transmissions of a second priority index that is different than the first priority index

- if // this is for cases the UE supports multiplexing information of different priorities in a PUCCH/PUSCH transmission

  - a PUCCH transmission with HARQ-ACK information, without repetitions, with smaller priority index overlaps with a PUCCH transmission only with HARQ-ACK information, without repetitions, with larger priority index, or

  - a PUCCH transmission without repetitions that includes HARQ-ACK information of smaller priority index overlaps with a PUCCH transmission without repetitions using a PUCCH resource with PUCCH format 2/3/4 with HARQ-ACK information and SR of larger priority index, or

  - a PUCCH transmission with HARQ-ACK information, without repetitions, with smaller or larger priority index overlaps, respectively, with a PUSCH transmission with larger or smaller priority index

  the UE

  - multiplexes HARQ-ACK information of different priority indexes and SR information of larger priority index, if any, in a same PUCCH transmission of larger priority index, or multiplexes HARQ-ACK information the UE would provide in a PUCCH transmission of smaller or larger priority index in a PUSCH transmission of larger or smaller priority index, respectively, and applies the procedures in clause 9.2.5.3 or 9.3, respectively, and

  - drops CSI and/or SR carried in the PUCCH transmission of smaller priority index, if any

  - drops negative SR carried in the PUCCH transmission of larger priority index, if any, if the UE would multiplex the HARQ-ACK information of larger priority index in a PUSCH transmission of smaller priority index

    - drops HARQ-ACK information of smaller priority index if the UE would multiplex the HARQ-ACK information of smaller priority index in a PUSCH transmission where the UE multiplexes Part 1 CSI reports and Part 2 CSI reports of larger priority index

    - drops Part 2 CSI reports of smaller priority index if the UE would multiplex the HARQ-ACK information of smaller and larger priority indexes in a PUSCH transmission where the UE multiplexes Part 1 CSI reports and Part 2 CSI reports of smaller priority index

    - drops HARQ-ACK information of smaller priority index if the UE would multiplex the HARQ-ACK information of smaller priority index in a PUCCH transmission of larger priority index using a PUCCH resource provided by *n1PUCCH-AN*

    - drops Part 2 CSI reports of smaller priority index if the UE would multiplex the HARQ-ACK information of larger priority index in a PUSCH transmission where the UE multiplexes CG-UCI, or UTO-UCI, Part 1 CSI reports and Part 2 CSI reports of smaller priority index

- else

    - if the UE would transmit the following channels that would overlap in time where, if a channel transmission is with repetitions, the following are applicable per repetition

        - a first PUCCH transmission of larger priority index and a second PUCCH transmission of smaller priority index

        - a first PUCCH transmission of larger priority index and a second PUSCH transmission of smaller priority index when the UE cannot simultaneously transmit the first PUCCH and second PUSCH

        - a first PUCCH transmission of smaller priority index and a second PUSCH transmission of larger priority index when the UE cannot simultaneously transmit the first PUCCH and second PUSCH

    the UE

        - transmits the PUCCH or the PUSCH of the larger priority index subject to the limitations for UE transmissions due to cell DRX operation or as described in clauses 11.1, 11.1.1, 11.2A, and 15 and

        - does not transmit a PUCCH or a PUSCH of smaller priority index

When a UE determines overlapping for PUCCH and/or PUSCH transmissions of different priority indexes, other than PUCCH transmissions with SL HARQ-ACK reports, before considering limitations for transmissions including with repetitions, if any, due to cell DRX operation or as described in clauses 11.1, 11.1.1, 11.2A, 15 and 17.2, if the UE is not provided *uci-MuxWithDiffPrio*, the UE first resolves overlapping for PUCCH and/or PUSCH transmissions of smaller priority index as described in clauses 9.2.5 and 9.2.6. Then,

- if a transmission of a first PUCCH of larger priority index scheduled by a DCI format in a PDCCH reception would overlap in time with a repetition of a transmission of a second PUSCH or a second PUCCH of smaller priority index, the UE cancels the repetition of a transmission of the second PUSCH or the second PUCCH before the first symbol that would overlap with the first PUCCH transmission

- if a transmission of a first PUSCH of larger priority index scheduled by a DCI format in a PDCCH reception would overlap in time with a repetition of the transmission of a second PUCCH of smaller priority index, the UE cancels the repetition of the transmission of the second PUCCH before the first symbol that would overlap with the first PUSCH transmission

where

- the overlapping is applicable before or after resolving overlapping among channels of larger priority index, if any, as described in clauses 9.2.5 and 9.2.6

- any remaining PUCCH and/or PUSCH transmission after overlapping resolution is subjected to the limitations for UE transmission due to cell DRX operation or as described in clauses 11.1, 11.1.1, 11.2A, 15 and 17.2

- the UE expects that the transmission of the first PUCCH or the first PUSCH, respectively, would not start before $T_{proc,2}$ after a last symbol of the corresponding PDCCH reception

- $T_{proc,2}$ is the PUSCH preparation time for a corresponding UE processing capability assuming $d_{2,1} = d_1$ [6, TS 38.214], based on μ and N_2 as subsequently defined in this clause, and d_1 is determined by a reported UE capability

If a UE is scheduled by a DCI format in a first PDCCH reception to transmit a first PUCCH or a first PUSCH of larger priority index that overlaps with a second PUCCH or a second PUSCH transmission of smaller priority index that, if any, is scheduled by a DCI format in a second PDCCH

- $T_{proc,2}$ is based on a value of μ corresponding to the smallest SCS configuration of the first PDCCH, the second PDCCHs, the first PUCCH or the first PUSCH, and the second PUCCHs or the second PUSCHs
  - if the overlapping group includes the first PUCCH
    - if *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for the serving cell where the UE receives the first PDCCH and for all serving cells where the UE receives the PDSCHs corresponding to the second PUCCHs, and if *processingType2Enabled* of *PUSCH-ServingCellConfig* is set to *enable* for the serving cells with the second PUSCHs, N_2 is 5 for $\mu = 0$, 5.5 for $\mu = 1$ and 11 for $\mu = 2$
    - else, N_2 is 10 for $\mu = 0$, 12 for $\mu = 1$, 23 for $\mu = 2$, 36 for $\mu = 3$, 144 for $\mu = 5$, and 288 for $\mu = 6$;
  - if the overlapping group includes the first PUSCH
    - if *processingType2Enabled* of *PUSCH-ServingCellConfig* is set to *enable* for the serving cells with the first PUSCH and the second PUSCHs and if *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for all serving cells where the UE receives the PDSCHs corresponding to the second PUCCHs, N_2 is 5 for $\mu = 0$, 5.5 for $\mu = 1$ and 11 for $\mu = 2$
    - else, N_2 is 10 for $\mu = 0$, 12 for $\mu = 1$, 23 for $\mu = 2$, 36 for $\mu = 3$, 144 for $\mu = 5$, and 288 for $\mu = 6$;

If a PUSCH of larger priority index scheduled by a DCI format overlaps in time with a PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH in one or more symbols on the same carrier, and if the earliest symbol of these PUSCH channels starts no earlier than $N_2+d_{2,1}$ symbols after the last symbol of the DCI scheduling the PUSCH of larger priority index where $d_{2,1}$ is the maximum of the $d_{2,1}$ associated with PUSCH of larger priority index scheduled by a DCI format and the PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH, the PUSCH of smaller priority index with SP-CSI report(s) shall not be transmitted by the UE. Otherwise, if the timeline requirement is not satisfied this is an error case.

If a UE would transmit the following channels, including repetitions if any, that would overlap in time

- a first PUCCH of larger priority index with SR and a second PUCCH or PUSCH of smaller priority index, or
- a configured grant PUSCH of larger priority index and a PUCCH of smaller priority index, or
- a first PUCCH of larger priority index with HARQ-ACK information only in response to PDSCH(s) reception without corresponding PDCCH(s) and a second PUCCH of smaller priority index with HARQ-ACK information only in response to PDSCH(s) reception without corresponding PDCCH(s), or a second PUCCH of smaller priority index with SR and/or CSI, or a configured grant PUSCH with smaller priority index, or a PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH, or
- a PUSCH of larger priority index with SP-CSI report(s) without a corresponding PDCCH and a PUCCH of smaller priority index with SR, or CSI, or HARQ-ACK information only in response to PDSCH(s) reception without corresponding PDCCH(s), or
- a configured grant PUSCH of larger priority index and a configured grant PUSCH of smaller priority index or a PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH on a same serving cell
- a PUSCH of larger priority index with SP-CSI report(s) without a corresponding PDCCH and a configured grant PUSCH of smaller priority index or a PUSCH of smaller priority index with SP-CSI report(s) without a corresponding PDCCH on a same serving cell
- a PUSCH of smaller priority index scheduled by a DCI format and a configured grant PUSCH of larger priority index on a same serving cell if the UE is provided *prioLowDG-HighCG*

- a PUSCH of larger priority index scheduled by a DCI format and a configured grant PUSCH of smaller priority index on a same serving cell if the UE is provided *prioHighDG-LowCG*

the UE is expected to cancel a repetition of the PUCCH/PUSCH transmissions of smaller priority index before the first symbol overlapping with the PUCCH/PUSCH transmission of larger priority index if the repetition of the PUCCH/PUSCH transmissions of smaller priority index overlaps in time with the PUCCH/PUSCH transmissions of larger priority index. In case of a PUSCH of larger priority index scheduled by a DCI format in a PDCCH reception and a configured grant PUSCH of smaller priority index on a same serving cell and the UE is provided *prioHighDG-LowCG*

- the UE expects that the transmission of the PUSCH of larger priority index would not start before $T_{proc,2}$ after a last symbol of the corresponding PDCCH reception
- $T_{proc,2}$ is the PUSCH preparation time for a corresponding UE processing capability assuming $d_{2,1} = d_1 + d_3$ [6, TS 38.214], based on μ and N_2 as subsequently defined in this clause, and d_1 and d_3 are determined by a reported UE capability

When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUSCH of smaller priority index, including repetitions if any, after resolving the overlapping PUCCH other than PUCCH transmissions with SL HARQ-ACK reports and/or PUSCH transmissions, if the PUSCH includes no UCI, the UE resolves the overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUSCH of smaller priority index as described in clauses 9.2.5 and 9.2.6.

When a UE determines overlapping for PUCCH transmissions with SL HARQ-ACK reports and PUSCH of larger priority index only, including repetitions if any, after resolving the overlapping PUCCH other than PUCCH transmissions with SL HARQ-ACK reports and/or PUSCH transmissions, the UE does not transmit the PUCCH with SL HARQ-ACK reports

where

- the UE expects that the transmission of the PUSCH would not start before $T_{proc,2} + d_1$ after a last symbol of the corresponding PDCCH reception;
- $T_{proc,2}$ is the PUSCH preparation time for a corresponding UE processing capability assuming $d_{2,1} = 0$ [6, TS 38.214], based on μ and N_2 as subsequently defined in this clause, and d_1 is determined by a reported UE capability.

The UE expects the PUCCH and PUSCH transmissions to fulfill the conditions in clause 9 and clause 9.2.5 for UCI multiplexing replacing the reference time of "end of PDSCH" with "end of the last symbol of a last PSFCH reception occasion" as described in 16.5 and $T_{proc,1}$ with T_{prep}.

A UE does not expect that a PUCCH carrying SL HARQ-ACK reports overlaps with PUSCH with aperiodic or semi-persistent CSI reports.

A UE does not expect to be scheduled to transmit a PUCCH or a PUSCH with smaller priority index that would overlap in time with a PUCCH of larger priority index with HARQ-ACK information only in response to a PDSCH reception without a corresponding PDCCH unless the UE is provided *uci-MuxWithDiffPrio*. A UE does not expect to be scheduled to transmit a PUCCH of smaller priority index that would overlap in time with a PUSCH of larger priority index with SP-CSI report(s) without a corresponding PDCCH unless the UE is provided *uci-MuxWithDiffPrio*.

In the remaining of this clause, a UE multiplexes UCIs with same priority index in a PUCCH or a PUSCH before considering limitations for UE transmission due to cell DRX operation or as described in clauses 11.1, 11.1.1, 11.2A, 15 and 17.2. A PUCCH or a PUSCH is assumed to have a same priority index as a priority index of UCIs a UE multiplexes in the PUCCH or the PUSCH.

In the remaining of this clause, the multiplexing or prioritization for overlapping channels are for overlapping channels with same priority index or for overlapping channels with a PUCCH carrying SL HARQ-ACK information unless stated otherwise.

In the remaining of this clause, if a UE is provided *subslotLengthForPUCCH* for a cell for PUCCH transmission, a slot for an associated PUCCH resource of a PUCCH transmission with HARQ-ACK information on the cell includes a number of symbols indicated by *subslotLengthForPUCCH*, unless stated otherwise.

If a UE would transmit on a serving cell a PUSCH without UL-SCH that overlaps with a PUCCH transmission on a serving cell that includes positive SR information, the UE does not transmit the PUSCH.

If a UE would transmit CSI reports on overlapping physical channels, the UE applies the priority rules described in [6, TS 38.214] for the multiplexing of CSI reports.

If a UE

- would multiplex UCI in a PUCCH transmission that overlaps with a PUSCH transmission, and
- the PUSCH and PUCCH transmissions fulfil the conditions in clause 9.2.5 for UCI multiplexing,

the UE

- multiplexes only HARQ-ACK information, if any, from the UCI in the PUSCH transmission and does not transmit the PUCCH if the UE multiplexes aperiodic or semi-persistent CSI reports in the PUSCH;
- multiplexes only HARQ-ACK information and CSI reports, if any, from the UCI in the PUSCH transmission and does not transmit the PUCCH if the UE does not multiplex aperiodic or semi-persistent CSI reports in the PUSCH.

A UE does not expect to multiplex in a PUSCH transmission in one slot with SCS configuration μ_1 UCI of same type that the UE would transmit in PUCCHs in different slots with SCS configuration μ_2 if $\mu_1 < \mu_2$.

A UE does not expect to multiplex in a PUSCH transmission or in a PUCCH transmission HARQ-ACK information that the UE would transmit in different PUCCHs of a same priority index.

A UE does not expect a PUCCH resource that results from multiplexing overlapped PUCCH resources, if applicable, to overlap with more than one PUSCHs if each of the more than one PUSCHs includes aperiodic CSI reports.

A UE does not expect to detect a first DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with a HARQ-ACK codebook that would include the HARQ-ACK information in a slot if the UE

- detects a second DCI format in a PDCCH monitoring occasion, that starts before a PDCCH monitoring occasion for the first DCI format, that schedules a PUSCH transmission in the slot, and
- multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.

If a UE

- is not provided any of enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant, or enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant, or enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant, or
- is provided uci-MuxWithDiffPrio, or
- transmits a PUSCH without repetitions or transmits a first repetition of a PUSCH transmission,

the UE does not expect to detect a first DCI format scheduling a PDSCH reception and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information that would be included in a HARQ-ACK codebook in a slot if the UE

- previously detects a second DCI format scheduling the PUSCH transmission in the slot, and
- multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot.

If a UE

- is provided enable-Type1-HARQ-ACK-mux-forDLassignmentafterULgrant, or enable-Type2-HARQ-ACK-mux-forDLassignmentafterULgrant, or enable-Type3-HARQ-ACK-mux-forDLassignmentafterULgrant, and
- is not provided uci-MuxWithDiffPrio, and
- transmits a repetition of a PUSCH transmission other than a first repetition,

the UE includes, in a HARQ-ACK codebook, HARQ-ACK information associated with a PDSCH reception scheduled by a first DCI format indicating a resource for a PUCCH transmission in a slot, when

- the UE detects a second DCI format, in a PDCCH monitoring occasion that starts before the PDCCH monitoring occasion for the first DCI format, scheduling a PUSCH transmission in the slot, and
- the UE multiplexes the HARQ-ACK codebook in the PUSCH transmission in the slot, and
- the timeline conditions in clause 9.2.3 for PUCCH resource determination and the timeline conditions of $T_{proc,1}^{mux}$ and $T_{proc,2}^{mux}$ for multiplexing the HARQ-ACK information in the PUSCH, as described in clause 9.2.5, are satisfied, and
- the UE does not determine a different PUCCH resource in time domain for the PUCCH transmission with the HARQ-ACK information in the slot if the UE is not provided *enable-different-PUCCHresource*, and
- the UE does not determine a different size for the HARQ-ACK codebook after including the HARQ-ACK information if the UE is not provided *enable-different-CBsize*.

If a UE multiplexes aperiodic CSI in a PUSCH and the UE would multiplex UCI that includes HARQ-ACK information in a PUCCH that overlaps with the PUSCH and the timing conditions for overlapping PUCCHs and PUSCHs in clause 9.2.5 are fulfilled, the UE multiplexes only the HARQ-ACK information in the PUSCH and does not transmit the PUCCH.

When a UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the multiple PUSCHs overlap with a PUCCH carrying UCI in the slot, the UE selects all the PUSCHs overlapping with the PUCCH as the candidate PUSCHs for UCI multiplexing within the slot.

If a UE would transmit a single PUSCH scheduled by a DCI format that includes a DAI field on a serving cell in a slot with reference to slots for PUCCH transmissions without any other PUSCH that would be transmitted on any serving cell in the slot and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot, or if the UE indicates the corresponding capability *mux-HARQ-ACK-withoutPUCCH-onPUSCH* and the UE transmits multiple PUSCHs on respective serving cells in a slot with reference to slots for PUCCH transmissions and the UE does not determine any PUCCH carrying HARQ-ACK information in the slot and at least one of the multiple PUSCHs is scheduled by a DCI format that includes a DAI field, the UE selects the single PUSCH or all the multiple PUSCHs in the slot as the candidate PUSCHs for HARQ-ACK multiplexing within the slot except for any PUSCH among the multiple PUSCHs that is scheduled by a DCI format that includes a DAI field that is equal to 4 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*, or is equal to 0 in case the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*.

The UE determines the PUSCH for UCI multiplexing by applying the following procedure on the candidate PUSCHs as described in this clause:

- If the UE is provided *enableSTx2PofmDCI*, is provided *ackNackFeedbackMode* = *separate*, and would multiplex UCI that includes HARQ-ACK information in a PUSCH, candidate PUSCHs for the UCI multiplexing are the ones associated with same *coresetPoolIndex* value as for a PUCCH transmission with the HARQ-ACK information.
- If the candidate PUSCHs that include first PUSCHs that are scheduled by DCI formats and second PUSCHs configured by respective *ConfiguredGrantConfig* or *semiPersistentOnPUSCH*, and the UE would multiplex UCI in one of the candidate PUSCHs, and the candidate PUSCHs fulfil the conditions in clause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in a PUSCH from the first PUSCHs.
- If the UE would multiplex UCI in one of the candidate PUSCHs and the UE does not multiplex aperiodic CSI in any of the candidate PUSCHs, the UE multiplexes the UCI in a PUSCH of the serving cell with the smallest *ServCellIndex* subject to the conditions in clause 9.2.5 for UCI multiplexing being fulfilled. If the UE transmits more than one PUSCHs in the slot on the serving cell with the smallest *ServCellIndex* that fulfil the conditions in clause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in the earliest PUSCH that the UE transmits in the slot. If the UE is provided *enableSTx2PofmDCI*, is provided *ackNackFeedbackMode* = *joint* or the UCI does not include HARQ-ACK information, and the UE would transmit two PUSCHs in the slot that start at a same symbol on the serving cell with smallest *ServCellIndex* and fulfil the conditions in clause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in the PUSCH from the two PUSCHs associated with CORESETs that the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0.

If a UE transmits a PUSCH over one or more slots or multiple PUSCHs over one or more slots that are scheduled by a DCI format, and the UE would transmit a PUCCH with HARQ-ACK and/or CSI information over a single slot that overlaps with the PUSCH transmission in the one or more slots, and the PUSCH transmission in the one or more slots fulfills the conditions in clause 9.2.5 for multiplexing the HARQ-ACK and/or CSI information, the UE multiplexes the HARQ-ACK and/or CSI information in the PUSCH transmission in the one or more slots. The UE does not multiplex HARQ-ACK and/or CSI information in the PUSCH transmission in a slot from the one or more slots if the UE would not transmit a single-slot PUCCH with HARQ-ACK and/or CSI information in the slot in case the PUSCH transmission was absent.

If a UE transmits a PUSCH with repetition Type B and the UE would transmit a PUCCH with HARQ-ACK and/or CSI information over a single slot that overlaps with the PUSCH transmission in one or more slots, the UE expects all actual repetitions of the PUSCH transmission [6, TS 38.214] that would overlap with the PUCCH transmission to fulfill the conditions in clause 9.2.5 for multiplexing the HARQ-ACK and/or CSI information, and the UE multiplexes the HARQ-ACK and/or CSI information in the earliest actual PUSCH repetition of the PUSCH transmission that would overlap with the PUCCH transmission and includes more than one symbol. The UE does not expect that all actual repetitions that would overlap with the PUCCH transmission do not include more than one symbol.

If the PUSCH transmission over the one or more slots is scheduled by a DCI format that includes a DAI field, or if the multiple PUSCH transmissions over the one or more slots are scheduled by a DCI format that includes a DAI field, the value of the DAI field is applicable for multiplexing HARQ-ACK information in any PUSCH transmission in any slot from the one or more slots where the UE multiplexes HARQ-ACK information.

When a UE would multiplex HARQ-ACK information in a PUSCH transmission that is configured by a *ConfiguredGrantConfig*, and includes CG-UCI [5, TS 38.212], the UE multiplexes the HARQ-ACK information in the PUSCH transmission if the UE is provided *cg-UCI-Multiplexing*; otherwise, if the HARQ-ACK information and the PUSCH have same priority index, the UE does not transmit the PUSCH and multiplexes the HARQ-ACK information in a PUCCH transmission or in another PUSCH transmission; if the HARQ-ACK information and the PUSCH have different priority indexes, the UE does not transmit the channel with the smaller priority index.

In the following, DCI formats with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI are also referred to as unicast DCI formats and DCI formats with CRC scrambled by multicast-MCCH-RNTI, G-RNTI for multicast or G-CS-RNTI are also referred to as multicast DCI formats. Corresponding unicast DCI formats are DCI formats 0_0/0_1/0_2/0_3/1_0/1_1/1_2/1_3 and multicast DCI formats are DCI formats 4_0/4_1/4_2 [4, TS 38.212]. PDSCH receptions scheduled by unicast or multicast DCI formats are referred as unicast or multicast PDSCH receptions. HARQ-ACK information associated with unicast or multicast DCI formats for PDCCH receptions in RRC_CONNECTED state are also respectively referred as unicast or multicast HARQ-ACK information.

For the remaining of this clause, if a UE is provided $K_{\text{cell,offset}}$ by *cellSpecificKoffset* or $K_{\text{UE,offset}}$ by a MAC CE command, reference to a slot $n+k$ for a PUCCH transmission or PUSCH transmission corresponds to a slot $n+k+2^{\mu-\mu_{K_{\text{offset}}}}\cdot K_{\text{offset}}$ for the PUSCH or the PUCCH transmission, and reference to a slot $n_U - K_{1,k}$ corresponds to slot $n_U - K_{1,k} - 2^{\mu-\mu_{K_{\text{offset}}}}\cdot K_{\text{offset}}$, where μ is the SCS configuration for the PUCCH transmission or PUSCH transmission, K_{offset} is defined in clause 4.2, and $\mu_{K_{\text{offset}}}=0$ in FR1. If *cellSpecificKoffset* or if the MAC CE command is not provided, $K_{\text{cell,offset}}=0$ or $K_{\text{UE,offset}}=0$, respectively. If the PUCCH or PUSCH transmission is scheduled by a DCI format, or if SRS transmission is triggered by a DCI format, the value of $K_{\text{UE,offset}}$ is the one that is applicable at the slot overlapping with the last symbol of the PDCCH reception providing the DCI format. If the PUCCH transmission or the PUSCH transmission is scheduled by a DCI format with CRC scrambled by TC-RNTI, $K_{\text{UE,offset}}=0$. If the UE is provided a $K_{\text{UE,offset}}$ value by a MAC CE command, the UE applies the MAC CE command in the first slot that is after slot $k+3N_{\text{slot}}^{\text{subframe},\mu}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information for the PDSCH providing the MAC CE command, μ is the SCS configuration for the PUCCH transmission that is determined in the slot when the MAC CE command is applied.

9.A PUCCH cell switching

This clause is applicable when a UE is provided a PUCCH-sSCell by *pucch-sSCell* and the PUCCH-sSCell is activated and does not have a dormant UL/DL active BWP. This clause is not applicable for slots with $N_{\text{sym}}^{\text{slot}}$ symbols [4, TS 38.211] of a reference SCS configuration provided by *tdd-UL-DL-ConfigurationCommon* for the PCell where the UE would transmit a PUCCH with $N_{\text{PUCCH}}^{\text{repeat}}>1$ repetitions of any priority, starting from the slot following the slot indicated to the UE as described in clause 9.2.3 for HARQ-ACK reporting, or following the slot determined as described in clause 9.2.4 for SR reporting, or in clause 5.2.1.4 of [6, TS 38.214] for CSI reporting, until the slot of the last repetition of the PUCCH transmission, as described in clause 9.2.6 if the UE is provided *PUCCH-sSCellPattern*.

A UE can be provided a periodic cell switching pattern for PUCCH transmissions by *pucch-sSCellPattern.* Each bit of the pattern corresponds to a slot with $N_{\text{sym}}^{\text{slot}}$ symbols [4, TS 38.211] for a reference SCS configuration provided by *tdd-UL-DL-ConfigurationCommon* for the PCell with a value of '0' or a value of '1' indicating, respectively, the PCell or the PUCCH-sSCell as the cell for PUCCH transmissions during the slot with $N_{\text{sym}}^{\text{slot}}$ symbols of the reference SCS configuration. The UE does not transmit a PUCCH in a slot on a cell if the pattern indicates a different cell for PUCCH transmission during the slot. A slot on the active UL BWP of the PUCCH-sSCell does not overlap with more than one slot on the active UL BWP of the PCell. If a slot for the active UL BWP of the PCell overlaps with more than one slot on the active BWP of the PUCCH-sSCell and the UE would transmit a PUCCH on the PUCCH-sSCell, the UE considers the first of the overlapping slots for the PUCCH transmission on the PUCCH-sSCell.

If a UE is provided *pucch-sSCellDyn* or *pucch-sSCellDynDCI-1-2* or *pucch-sSCellDynDCI-1-3*, a corresponding DCI format associated with generation of HARQ-ACK information by the UE can include a PUCCH cell indicator field [5, TS 38.212] with a value of '0' or a value of '1' indicating, respectively, whether a PUCCH transmission with the HARQ-ACK information by the UE is on the PCell or on the PUCCH-sSCell. When the UE transmits a PUCCH with HARQ-ACK information that is associated only with SPS PDSCH receptions, the UE transmits the PUCCH on the PCell. The UE does not expect the PUCCH cell indicator field to indicate the PUCCH-sSCell for a PUCCH transmission in a slot that overlaps with a slot on the PCell where the UE would transmit another PUCCH of same or different priority index.

A UE transmits a PUCCH on a PUCCH-sSCell with a power that the UE determines as described in clause 7.2.1, where the UE applies

- a *p0-PUCCH-Value* from *pucch-PowerControl* in *PUCCH-Config* for the PUCCH-sSCell for the determination of $P_{O,PUCCH,b,f,c}(q_u)$
- a *pucch-PathlossReferenceRS-Id* from *pucch-PowerControl* in *PUCCH-Config* for the PUCCH-sSCell for the determination of $PL_{b,f,c}(q_d)$
- a PUCCH power control adjustment state $g_{b,0,c}(i,0)$ for active UL BWP b of the UL carrier of PUCCH-sSCell c and PUCCH transmission occasion i where $\delta_{\text{PUCCH},b,0,c}(i,0)$ is a TPC command value included in a DCI format associated with generation of HARQ-ACK information for multiplexing in a PUCCH transmission on the PUCCH-sSCell as indicated either by a *pucch-sSCellPattern* or by a PUCCH cell indicator field in the DCI format, or provided by DCI format 2_2 with CRC scrambled by TPC-PUCCH-RNTI for the PUCCH-sSCell as described in clause 11.3

9.1 HARQ-ACK codebook determination

If a UE is provided *pdsch-HARQ-ACK-CodebookList*, the UE can be indicated by *pdsch-HARQ-ACK-CodebookList* to generate one or two HARQ-ACK codebooks. If the UE is indicated to generate one HARQ-ACK codebook, the HARQ-ACK codebook is associated with a PUCCH of priority index 0. If a UE is provided *pdsch-HARQ-ACK-CodebookList*, the UE multiplexes in a same HARQ-ACK codebook only HARQ-ACK information associated with a same priority index. If the UE is indicated to generate two HARQ-ACK codebooks

- a first HARQ-ACK codebook is associated with a PUCCH of priority index 0 and a second HARQ-ACK codebook is associated with a PUCCH of priority index 1
- the UE is provided first and second for each of {*PUCCH-Config*, *UCI-OnPUSCH*, *PDSCH-codeBlockGroupTransmission*} by {*PUCCH-ConfigurationList*, *UCI-OnPUSCH-ListDCI-0-1*, *PDSCH-CodeBlockGroupTransmissionList*} or {*PUCCH-ConfigurationList*, *UCI-OnPUSCH-ListDCI-0-2*, *PDSCH-CodeBlockGroupTransmissionList*}, respectively, for use with the first and second HARQ-ACK codebooks, respectively

If a UE receives a PDSCH without receiving a corresponding PDCCH, or if the UE receives a PDCCH indicating a SPS PDSCH release, the UE generates one corresponding HARQ-ACK information bit. If the UE generates two HARQ-ACK codebooks, the UE is indicated by *harq-CodebookID*, per SPS PDSCH configuration, a HARQ-ACK codebook index for multiplexing the corresponding HARQ-ACK information bit.

If a UE is provided *pdsch-HARQ-ACK-OneShotFeedback* and the UE detects a DCI format in any PDCCH monitoring occasion that includes a One-shot HARQ-ACK request field with value 1

- the UE includes the HARQ-ACK information in a Type-3 HARQ-ACK codebook, as described in clause 9.1.4
- the UE does not expect that the PDSCH-to-HARQ_feedback timing indicator field of the DCI format provides an inapplicable value from *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17*

In the remaining of this clause, reference is to one HARQ-ACK codebook and to DCI formats that schedule PDSCH reception, or have associated HARQ-ACK information without scheduling a PDSCH reception and are associated with the HARQ-ACK codebook.

If a UE is required to receive SPS PDSCHs in a slot according to Clause 5.1 of [6] and Clause 11.1 for SPS configurations that are indicated to be released by a DCI format, the UE is not expected to receive the DCI format in the slot if the end of the last symbol of the PDCCH reception is after the end of a last symbol of any of the SPS PDSCH receptions. For a SPS configuration subject to *pdsch-AggregationFactor* or *pdsch-AggregationFactor-r16*, the UE is not expected to receive the DCI format in a slot containing a SPS PDSCH transmission occasion other than the first transmission occasion required to be received by the UE for a TB.

If a UE is configured to receive SPS PDSCHs in a slot for SPS configurations that are indicated to be released by a DCI format, and if the UE receives the PDCCH providing the DCI format in the slot, and if HARQ-ACK information for the SPS PDSCH release and the SPS PDSCH receptions would be multiplexed in a same PUCCH, the UE does not expect to receive the SPS PDSCHs, does not generate HARQ-ACK information for the SPS PDSCH receptions, and generates a HARQ-ACK information bit for the SPS PDSCH release.

If a UE is configured to receive SPS PDSCH(s) in a slot for SPS configuration(s), the UE does not expect to receive a PDCCH providing a DCI format in the slot to indicate SPS PDSCH release of these SPS configuration(s), if HARQ-ACK information for the SPS PDSCH release and the SPS PDSCH reception(s) would map to different PUCCHs.

If a UE detects a DCI format 1_1 or a DCI format 1_3 indicating

- SCell dormancy without scheduling a PDSCH reception, as described in clause 10.3, and
- is provided *pdsch-HARQ-ACK-Codebook = dynamic* or *pdsch-HARQ-ACK-Codebook-r16*

the UE generates a HARQ-ACK information bit as described in clause 9.1.3 for a DCI format 1_1 or a DCI format 1_3 indicating SCell dormancy without scheduling a PDSCH reception and the HARQ-ACK information bit value is ACK.

If a UE is not provided *PDSCH-CodeBlockGroupTransmission*, the UE generates one HARQ-ACK information bit per transport block.

For a HARQ-ACK information bit, a UE generates a positive acknowledgement (ACK) if the UE detects a DCI format that provides a SPS PDSCH release or detects a DCI format that does not schedule PDSCH reception and indicates a TCI state update or correctly decodes a transport block, and generates a negative acknowledgement (NACK) if the UE does not correctly decode the transport block. A HARQ-ACK information bit value of 0 represents a NACK while a HARQ-ACK information bit value of 1 represents an ACK.

In the following, the CRC for a DCI format is scrambled with a C-RNTI, an MCS-C-RNTI, or a CS-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI.

In the following, if the value of *maxNrofCodeWordsScheduledByDCI* is not provided, the value of *maxNrofCodeWordsScheduledByDCI* equals one.

9.1.1 CBG-based HARQ-ACK codebook determination

If a UE is provided *PDSCH-CodeBlockGroupTransmission* for a serving cell, the UE receives a PDSCH scheduled by DCI format 1_1, that includes code block groups (CBGs) of a transport block. The UE is also provided *maxCodeBlockGroupsPerTransportBlock* indicating a maximum number $N_{\mathrm{HARQ-ACK}}^{\mathrm{CBG/TB,max}}$ of CBGs for generating respective HARQ-ACK information bits for a transport block reception for the serving cell.

For a number of C code blocks (CBs) in a transport block, the UE determines a number of CBGs M according to clause 5.1.7.1 of [6, TS 38.214] and determines a number of HARQ-ACK bits for the transport block as $N_{\mathrm{HARQ-ACK}}^{\mathrm{CBG/TB}} = M$.

The UE generates an ACK for the HARQ-ACK information bit of a CBG if the UE correctly received all code blocks of the CBG and generates a NACK for the HARQ-ACK information bit of a CBG if the UE incorrectly received at least one code block of the CBG. If the UE receives two transport blocks, the UE concatenates the HARQ-ACK information bits for CBGs of the second transport block after the HARQ-ACK information bits for CBGs of the first transport block.

The HARQ-ACK codebook includes the $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ HARQ-ACK information bits in ascending order of CBG index and, if $N_{\text{HARQ-ACK}}^{\text{CBG/TB}} < N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ for a transport block, the UE generates a NACK value for the last $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}} - N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ HARQ-ACK information bits for the transport block in the HARQ-ACK codebook.

If the UE generates a HARQ-ACK codebook in response to a retransmission of a transport block, corresponding to a same HARQ process as a previous transmission of the transport block, the UE generates an ACK for each CBG that the UE correctly decoded in a previous transmission of the transport block.

If a UE correctly detects each of the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs and does not correctly detect the transport block for the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs, the UE generates a NACK value for each of the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs.

9.1.2 Type-1 HARQ-ACK codebook determination

This clause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*. In clauses 9.1.2, 9.1.2.1, and 9.1.2.2, if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static* for only one of unicast or multicast HARQ-ACK codebook, the Type-1 HARQ-ACK codebook is generated considering only one of respective unicast or multicast configurations for PDSCH receptions or for PDCCH monitoring for detection of DCI formats.

A UE does not provide a Type-1 HARQ-ACK codebook if the Type-1 HARQ-ACK codebook would include only HARQ-ACK information for transport blocks associated with HARQ processes with disabled HARQ-ACK information.

If a UE is provided *downlinkHARQ-FeedbackDisabled* indicating disabled HARQ-ACK information for a HARQ process associated with a transport block in PDSCH reception occasion m on serving cell c, the UE reports a NACK value for a HARQ-ACK information bit corresponding to the transport block in a Type-1 HARQ-ACK codebook and does not consider the transport block as received in the determination of $N_{m,c}^{\text{received}}$ in clause 9.1.2.1. If the UE is also provided *PDSCH-CodeBlockGroupTransmission*, the UE reports NACK values for HARQ-ACK information bits corresponding to CBGs of the transport block in the Type-1 HARQ-ACK codebook and does not consider the CBGs as received in the determination of $N_{m,c}^{\text{received,CBG}}$ in clause 9.1.2.1. If the UE is also provided *harq-feedbackEnablingforSPSactive* = '*enabled'*, the UE considers a HARQ process associated with a transport block in a first SPS PDSCH reception, after an activation of SPS PDSCH receptions, to have enabled HARQ-ACK information and the UE provides a HARQ-ACK information bit according to a decoding outcome for the transport block in the first SPS PDSCH reception.

If a UE reports HARQ-ACK information associated with a G-RNTI for multicast or a G-CS-RNTI with disabled HARQ-ACK information, as described in clause 18, a value of the HARQ-ACK information is a UE implementation choice.

A UE reports HARQ-ACK information for a corresponding PDSCH reception or SPS PDSCH release or TCI state update only in a HARQ-ACK codebook that the UE transmits in a slot indicated by a value of a PDSCH-to-HARQ_feedback timing indicator field in a corresponding DCI format or provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in the DCI format as described in clause 9.2.3. The UE reports NACK value(s) for HARQ-ACK information bit(s) in a HARQ-ACK codebook that the UE transmits in a slot not indicated by a value of a PDSCH-to-HARQ_feedback timing indicator field in a corresponding DCI format.

If a UE is not provided *pdsch-HARQ-ACK-OneShotFeedback*, the UE does not expect to receive a PDSCH scheduled by a DCI format that the UE detects in any PDCCH monitoring occasion and includes a PDSCH-to-HARQ_feedback timing indicator field providing an inapplicable value from *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17*.

If the UE is provided *pdsch-AggregationFactor-r16* in *SPS-Config*, or *pdsch-AggregationFactor* in *PDSCH-Config* and no entry in *pdsch-TimeDomainAllocationList* and *pdsch-TimeDomainAllocationListDCI-1-2* includes *repetitionNumber* in *PDSCH-TimeDomainResourceAllocation-r16*, $N_{\text{PDSCH}}^{\text{repeat,max}}$ is a maximum value of *pdsch-AggregationFactor-r16* in *SPS-Config*, or *pdsch-AggregationFactor* in *PDSCH-Config*; otherwise $N_{\text{PDSCH}}^{\text{repeat,max}} = 1$. The UE reports HARQ-ACK information for a PDSCH reception

- from DL slot $n_D - N_{\text{PDSCH}}^{\text{repeat}} + 1$ to DL slot n_D, if $N_{\text{PDSCH}}^{\text{repeat}}$ is provided by *pdsch-AggregationFactor* or *pdsch-AggregationFactor-r16* [6, TS 38.214], or

- from DL slot $n_D - repetitionNumber + 1$ to DL slot n_D, if the time domain resource assignment field in the DCI format scheduling the PDSCH reception indicates an entry containing *repetitionNumber*, or

- in DL slot n_D, otherwise

only in a HARQ-ACK codebook that the UE includes in a PUCCH or PUSCH transmission in slot $n + k$, where n is

- an UL slot overlapping with the end of the PDSCH reception in DL slot n_D if the UE is provided *subslotLengthForPUCCH* for the HARQ-ACK codebook

  - the UL slot is on the primary cell if the UE is provided *pucch-sSCellPattern*; otherwise, the UL slot is on the serving cell of the PUCCH transmission

- the last UL slot for PUCCH transmission overlapping with DL slot n_D if the UE is not provided *subslotLengthForPUCCH* for the HARQ-ACK codebook

  - the last UL slot is on the primary cell if the UE is provided *pucch-sSCellPattern*; otherwise, the last UL slot is on the serving cell of the PUCCH transmission

and k is a number of slots indicated by the PDSCH-to-HARQ_feedback timing indicator field in a corresponding DCI format, or provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in the DCI format. If the UE reports HARQ-ACK information for the PDSCH reception in a slot other than slot $n + k$, the UE sets a value for each corresponding HARQ-ACK information bit to NACK.

If a UE is provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* for unicast or multicast HARQ-ACK information, the UE reports HARQ-ACK information in a PUCCH only for one of

- a SPS PDSCH release indicated by DCI format 1_0 or by DCI format 4_1, with counter DAI field value of 1, or

- a PDSCH reception providing a transport block having enabled HARQ-ACK information report and scheduled by DCI format 1_0 or by DCI format 4_1, with counter DAI field value of 1 on the PCell, or

- SPS PDSCH receptions with transport blocks having enabled HARQ-ACK information reports,

in the $M_{A,c}$ occasions for candidate PDSCH receptions as determined in clause 9.1.2.1, in which case the UE generates a HARQ-ACK information only for the SPS PDSCH release, or only for the PDSCH reception, or only for SPS PDSCH receptions according to corresponding $M_{A,c}$ occasions on respective serving cells, where the value of counter DAI in DCI format 1_0 or in DCI format 4_1 is according to Table 9.1.3-1 and HARQ-ACK information bits in response to more than one SPS PDSCH receptions that the UE is configured to receive are ordered according to the following pseudo-code; otherwise, the procedures in clause 9.1.2.1 and clause 9.1.2.2 for a HARQ-ACK codebook determination apply.

In the following pseudo-code, SPS PDSCH receptions associated with a SPS PDSCH configuration are activated by a DCI format with CRC scrambled by a CS-RNTI or by a DCI format with CRC scrambled by a G-CS-RNTI.

Set $N_{\text{cells}}^{\text{DL}}$ to the number of serving cells configured to the UE

Set $N_{\text{c}}^{\text{SPS}}$ to the number of SPS PDSCH configurations configured to the UE for serving cell c

Set N_{c}^{DL} to the number of DL slots for SPS PDSCH receptions on serving cell c with HARQ-ACK information multiplexed on the PUCCH

Set $j = 0$ – HARQ-ACK information bit index

Set $c = 0$ – serving cell index: lower indexes correspond to lower RRC indexes of corresponding cell

while $c < N_{\text{cells}}^{\text{DL}}$

Set $s = 0$ – SPS PDSCH configuration index: lower indexes correspond to lower RRC indexes of corresponding SPS configurations while $s < N_{\mathrm{c}}^{\mathrm{SPS}}$

Set $n_D = 0$ – slot index

while $n_D < N_{\mathrm{c}}^{\mathrm{DL}}$

if {

a UE is configured to receive SPS PDSCHs from slot $n_D - N_{PDSCH}^{repeat} + 1$ to slot n_D for SPS PDSCH configuration s on serving cell c, excluding SPS PDSCHs that are not required to be received in any slot among overlapping SPS PDSCHs, if any according to [6, TS 38.214], or based on a UE capability for a number of PDSCH receptions in a slot according to [6, TS 38.214], or due to overlapping with a set of symbols

- indicated as uplink by tdd-UL-DL-ConfigurationCommon or by tdd-UL-DL-ConfigurationDedicated, and/or
- determined as non-active period of cell DTX [11, TS 38.321]

where, for unicast SPS PDSCHs, N_{PDSCH}^{repeat} is provided by *pdsch-AggregationFactor-r16* in *SPS-Config* or, if *pdsch-AggregationFactor-r16* is not included in *SPS-Config*, by *pdsch-AggregationFactor* in *PDSCH-config* and, for multicast SPS PDSCHs, N_{PDSCH}^{repeat} is provided by $repetitionNumber$ if contained in an entry indicated by the time domain resource assignment field in the DCI format scheduling the PDSCH repetition, or provided by *pdsch-AggregationFactor-r16* if included in *SPS-Config* or, otherwise, $N_{PDSCH}^{repeat} = 1$, and

HARQ-ACK information for the SPS PDSCH is associated with the PUCCH

}

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for this SPS PDSCH reception

$j = j + 1$;

end if

$n_D = n_D + 1$;

end while

$s = s + 1$;

end while

$c = c + 1$;

end while

9.1.2.1 Type-1 HARQ-ACK codebook in physical uplink control channel

For a serving cell c, an active DL BWP, and an active UL BWP, as described in clause 12, the UE determines a set of $M_{A,c}$ occasions for candidate PDSCH receptions for which the UE can transmit corresponding HARQ-ACK information in a PUCCH in slot n_U. If serving cell c is deactivated, the UE uses as the active DL BWP for determining the set of $M_{A,c}$ occasions for candidate PDSCH receptions a DL BWP provided by *firstActiveDownlinkBWP-Id*. The determination is based:

a) on a set of slot timing values K_1 associated with the active UL BWP on the primary cell or, if the PUCCH transmission is indicated by a DCI format to be on the PUCCH-sSCell as described in clause 9A, on a set of slot timing values K_1 associated with the active UL BWP on the PUCCH-sSCell

   - If the UE is configured to monitor PDCCH for DCI format 1_0 and is not configured to monitor PDCCH for DCI format 1_1/1_2/1_3 for serving cell c, or the active DL BWP for serving cell c is dormant BWP, K_1 is provided by the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$, {7, 8, 12, 16, 20, 24, 28, 32} for $\mu = 5$, and {13, 16, 24, 32, 40, 48, 56, 64} for $\mu = 6$

- If the UE is configured to monitor PDCCH for DCI format 1_1/1_3 and is not configured to monitor PDCCH for DCI format 1_2 for serving cell c, K_1 is provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700*

- If the UE is configured to monitor PDCCH for DCI format 1_2 and is not configured to monitor PDCCH for DCI format 1_1/1_3 for serving cell c, K_1 is provided by *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-DCI-1-2-r17*

- If the UE is configured to monitor PDCCH for DCI format 1_1/1_3 and DCI format 1_2 for serving cell c, K_1 is provided by the union of *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* and *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-DCI-1-2-r17*

- If an inapplicable value in *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17* is provided, the value is excluded from K_1

- If the UE is configured to monitor PDCCH for multicast DCI formats for serving cell c

  - if the UE is provided *fdmed-ReceptionMulticast* or if the UE is not provided *type1CodebookGenerationMode* = 'mode1'

    - if the UE is configured to monitor PDCCH for DCI format 4_2, *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* is provided by *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1* if provided; otherwise, by *pucch-Config/pucch-ConfigurationList*

      - if UE is configured to monitor PDCCH for DCI format 4_1, K_1 for multicast, $K_{1,\mathrm{M}}$, is provided by the union of *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* and *dl-DataToUL-ACK-MulticastDCI-Format4-1*, if provided; otherwise, by the union of *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* and the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$

      - otherwise, $K_{1,\mathrm{M}}$ is provided by *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700*

    - otherwise, $K_{1,\mathrm{M}}$ is provided by *dl-DataToUL-ACK-ForDCI Format4-1* if provided; otherwise, by the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$

  - else, if the UE is provided *type1CodebookGenerationMode* = 'mode1', the UE

    - determines a first $K_{1,\mathrm{UM}}$ set as $K_1 \cap K_{1,\mathrm{M}}$, a second $K_{1,\mathrm{U}\backslash\mathrm{M}}$ set as $K_1 \backslash K_{1,\mathrm{UM}}$, and a third $K_{1,\mathrm{M}\backslash\mathrm{U}}$ set as $K_{1,\mathrm{M}} \backslash K_{1,\mathrm{UM}}$

    - if the UE is configured to monitor PDCCH for DCI format 4_2, *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* is provided by *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1* if provided; otherwise, by *pucch-Config/pucch-ConfigurationList*

      - if UE is configured to monitor PDCCH for DCI format 4_1, $K_{1,\mathrm{M}}$ is provided by the union of *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* and *dl-DataToUL-ACK-MulticastDCI-Format4-1*, if provided; otherwise, by the union of *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700* and the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$

      - otherwise, $K_{1,\mathrm{M}}$ is provided by *dl-DataToUL-ACK* or *DL-DataToUL-ACK-v1700*

    - otherwise, $K_{1,\mathrm{M}}$ is provided by *dl-DataToUL-ACK-ForDCI Format4-1* if provided; otherwise, by the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$

b) on a set of row indexes R of a table that is associated with the active DL BWP and defining respective sets of slot offsets K_0, start and length indicators *SLIV*, and PDSCH mapping types for PDSCH reception as described in [6, TS 38.214], where the row indexes R of the table are provided by

  - the union of row indexes of time domain resource allocation tables for DCI formats the UE is configured to monitor PDCCH for serving cell c if the UE is not configured to monitor PDCCH for multicast DCI formats for serving cell c, or is not provided *type1CodebookGenerationMode* = 'mode1' and is not provided *fdmed-ReceptionMulticast*, or, if any, for the first $K_{1,\mathrm{UM}}$ set

- the union of row indexes of time domain resource allocation tables for DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2 for serving cell c if UE is provided *fdmed-ReceptionMulticast*, or for the second $K_{1,\mathrm{U}\setminus\mathrm{M}}$ set, if any

- the union of row indexes of time domain resource allocation tables for multicast DCI formats the UE is configured to monitor PDCCH for serving cell c if UE is provided *fdmed-ReceptionMulticast*, or for the third $K_{1,\mathrm{M}\setminus\mathrm{U}}$ set, if any

- if the UE is provided *referenceOfSLIVDCI-1-2*, for each row index with slot offset $K_0 = 0$ and PDSCH mapping Type B in a set of row indexes of a table for DCI format 1_2 [6, TS 38.214], for any PDCCH monitoring occasion in any slot where the UE monitors PDCCH for DCI format 1_2 and with starting symbol $S_0 > 0$, if $S + S_0 + L \leq 14$ for normal cyclic prefix and $S + S_0 + L \leq 12$ for extended cyclic prefix, add a new row index in the set of row indexes of the table by replacing the starting symbol S of the row index by $S + S_0$

c) on the ratio $2^{\mu_{\mathrm{DL}}-\mu_{\mathrm{UL}}}$ between the downlink SCS configuration μ_{DL} and the uplink SCS configuration μ_{UL} provided by *subcarrierSpacing* in *BWP-Downlink* and *BWP-Uplink* for the active DL BWP and the active UL BWP, respectively

d) if provided, on *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* as described in clause 11.1

e) if *ca-SlotOffset* is provided, on $N_{\mathrm{slot,offset,c}}^{\mathrm{DL}}$ and $\mu_{\mathrm{offset,DL,c}}$ provided by *ca-SlotOffset* for serving cell c, or on $N_{\mathrm{slot,offset}}^{\mathrm{UL}}$ and $\mu_{\mathrm{offset,UL}}$ provided by *ca-SlotOffset* for the primary cell, as described in [4, TS 38.211].

If a UE

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on active DL BWPs of serving cells, and

- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on active DL BWPs of the serving cells, and

- is provided *ackNackFeedbackMode* = *joint*

where

- a serving cell is placed in a first set S_0 of $N_{\mathrm{cells}}^{\mathrm{DL},0}$ serving cells if the serving cell includes a first CORESET, and

- a serving cell is placed in a second set S_1 of $N_{\mathrm{cells}}^{\mathrm{DL},1}$ serving cells if the serving cell includes a second CORESET, and

- serving cells are placed in a set according to an ascending order of a serving cell index

the UE generates a Type-1 HARQ-ACK codebook for the set S_0 and the set S_1 of serving cells separately by setting $N_{\mathrm{cells}}^{\mathrm{DL}} = N_{\mathrm{cells}}^{\mathrm{DL},0}$ and $N_{\mathrm{cells}}^{\mathrm{DL}} = N_{\mathrm{cells}}^{\mathrm{DL},1}$ in the following pseudo-code. The UE concatenates the HARQ-ACK codebook generated for the set S_0 followed by the HARQ-ACK codebook generated for the set S_1 to obtain a total number of O_{ACK} HARQ-ACK information bits.

If a UE is provided *fdmed-ReceptionMulticast* and the UE is configured to monitor PDCCH for detection of unicast DCI formats and to monitor PDCCH for detection of multicast DCI formats

- a serving cell is placed in a first set S_{U} of $N_{\mathrm{cells}}^{\mathrm{DL,U}}$ serving cells if the UE is configured to monitor PDCCH for DCI formats 1_0/1_1/1_2 for scheduling on serving cell c, and

- a serving cell is placed in a second set S_{M} of $N_{\mathrm{cells}}^{\mathrm{DL,M}}$ serving cells if the UE is configured to monitor PDCCH for detection of DCI format 4_1/4_2 for scheduling on serving cell c, and

- serving cells are placed in a set according to an ascending order of a serving cell index

the UE generates a Type-1 HARQ-ACK codebook for the set S_{U} and the set S_{M} of serving cells separately by setting $N_{\mathrm{cells}}^{\mathrm{DL}} = N_{\mathrm{cells}}^{\mathrm{DL,U}}$ and using the *maxNrofCodeWordsScheduledByDCI* provided in *PDSCH-config* for the set S_{U} and setting $N_{\mathrm{cells}}^{\mathrm{DL}} = N_{\mathrm{cells}}^{\mathrm{DL,M}}$, *maxCodeBlockGroupsPerTransportBlock* to 1, and using the *maxNrofCodeWordsScheduledByDCI* provided in *PDSCH-configMulticast* for the set S_{M} in the following pseudo-code. The UE concatenates the HARQ-

ACK codebook generated for the set S_{U} followed by the HARQ-ACK codebook generated for the set S_{M} to obtain a total number of O_{ACK} HARQ-ACK information bits.

If the UE is configured to monitor PDCCH for DCI formats with CRC scrambled by G-RNTI for multicast or G-CS-RNTI and is provided *type1-Codebook-Generation-Mode* = 'mode1', the UE separately applies the following pseudo-code for each of the first $K_{1,\mathrm{UM}}$ set, the second $K_{1,\mathrm{U}\setminus\mathrm{M}}$ set, and third $K_{1,\mathrm{M}\setminus\mathrm{U}}$ set as the set of slot timing values K_1, and for the corresponding sets of row indexes as R to obtain first, second, and third Type-1 HARQ-ACK sub-codebooks, and concatenates the first, second, and third, Type-1 HARQ-ACK sub-codebooks to obtain the Type-1 HARQ-ACK codebook. The UE sets *maxCodeBlockGroupsPerTransportBlock* to 1 for determining the third Type-1 HARQ-ACK sub-codebook.

If the UE is configured to monitor PDCCH for DCI formats with CRC scrambled by G-RNTI for multicast or G-CS-RNTI and is not provided *fdmed-ReceptionMulticast*, the UE generates a Type-1 HARQ-ACK codebook using the maximum value of *maxNrofCodeWordsScheduledByDCI* in *PDSCH-config* and *PDSCH-configMulticast* in the following pseudo-code.

If *timeDomainHARQ-BundlingType1* is provided

- set $R'_T = R$
- set R_T to the set of row indexes that include the last SLIV of each row of set R'_T

If the set of rows R includes a row with more than one SLIV entry as described in [6, TS 38.214] and *timeDomainHARQ-BundlingType1* is not provided, the set of rows R and the set of slot timing values K_1 are updated in this clause according to the following pseudo-code.

set R to the set of rows

set $\mathcal{C}(R)$ to the cardinality of R

set $r = 0$ – index of row in set R

set $R_T = \emptyset$

set $K_{1,T} = \emptyset$

while $r < \mathcal{C}(R)$

  set P_r to the set of entries for row r

  set $K_{0,r}$ to the set of K_0 values of entries for row r

  set $\Delta K_{0,r} = \max_{K_0}(K_{0,r}) - K_{0,r}$

  set $\mathcal{C}(P_r)$ to the cardinality of P_r

  set $\mathcal{C}(\Delta K_{0,r})$ to the cardinality of $\Delta K_{0,r}$

  set $p = 0$ – index of element in $P_r$set $d = 0$ – index of element in $\Delta K_{0,r}$

  while $p < \mathcal{C}(P_r)$

    $R_T = R_T \cup P_r(p);$

    $p = p + 1;$

  end while

  while $d < \mathcal{C}(\Delta K_{0,\mathrm{r}})$

    $K_{1,T} = K_{1,T} \cup \left(K_1 + \left\lceil \Delta K_{0,\mathrm{r}}(d) \cdot 2^{\mu_{\mathrm{UL}}-\mu_{\mathrm{DL}}} \right\rceil\right) \cup \left(K_1 + \left\lfloor \Delta K_{0,\mathrm{r}}(d) \cdot 2^{\mu_{\mathrm{UL}}-\mu_{\mathrm{DL}}} \right\rfloor\right);$

    $d = d + 1;$

  end while

$r = r + 1$;

end while

$K_1 = K_{1,T}$;

For the set of slot timing values K_1, the UE determines a set of $M_{A,c}$ occasions for candidate PDSCH receptions or SPS PDSCH releases or TCI state update according to the following pseudo-code. A location in the Type-1 HARQ-ACK codebook for HARQ-ACK information corresponding to a single SPS PDSCH release is same as for a corresponding SPS PDSCH reception. A location in the Type-1 HARQ-ACK codebook for HARQ-ACK information corresponding to multiple SPS PDSCH releases by a single DCI format is same as for a corresponding SPS PDSCH reception with the lowest SPS configuration index among the multiple SPS PDSCH releases. If a UE provides HARQ-ACK information corresponding to detection of a DCI format that provides TCI state update without scheduling PDSCH reception, as described in [6, TS 38.214], a location in the Type-1 HARQ-ACK codebook for the HARQ-ACK information is same as when the DCI format schedules a PDSCH reception with CBGs or with transport blocks that are correctly decoded.

In the following pseudo-code, the *subslotLengthForPUCCH* is for the primary cell if the UE is provided *pucch-sSCellPattern*; otherwise, *subslotLengthForPUCCH* is for the serving cell of the PUCCH transmission.

Set $j = 0$ - index of occasion for candidate PDSCH reception or SPS PDSCH release or TCI state update

Set $B = \emptyset$

Set $M_{A,c} = \emptyset$

Set $\mathcal{C}(K_1)$ to the cardinality of set K_1

Set $k = 0$ – index of slot timing values $K_{1,k}$, in descending order of the slot timing values, in set K_1 for serving cell c

If a UE is not provided *ca-SlotOffset* for any serving cell of PDSCH receptions and for the serving cell of corresponding PUCCH transmission with HARQ-ACK information

while $k < \mathcal{C}(K_1)$

if $\mathrm{mod}\left(n_{\mathrm{U}} - K_{1,k} + 1, \max(2^{\mu_{\mathrm{UL}}-\mu_{\mathrm{DL}}}, 1)\right) = 0$ or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook

Set $n_{\mathrm{D}} = 0$ – index of a DL slot overlapping with an UL slot

Set N_k to a number of DL slots overlapping with UL slot $n_U - K_{1,k}$ if *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook; otherwise, $N_k = \max(2^{\mu_{DL}-\mu_{UL}}, 1)$

while $n_D < N_k$

if *pdsch-TimeDomainAllocationListForMultiPDSCH* and *timeDomainHARQ-BundlingType1* are provided for serving cell c

$R = R_{\mathrm{T}}$;

$R' = R'_T$;

elseif *pdsch-TimeDomainAllocationListForMultiPDSCH* is provided and *timeDomainHARQ-BundlingType1* is not provided for serving cell c

$R = R_{\mathrm{T}}$;

else

Set R to the set of rows

end if

Set $\mathcal{C}(R)$ to the cardinality of R

Set $r = 0$ – index of row in set R

if slot n_{U} starts at a same time as or after a slot for an active DL BWP change on serving cell c or an active UL BWP change on the serving cell of PUCCH transmission if the UE is provided *pucch-sSCellDyn* or *pucch-sSCellDynDCI-1-2* or *pucch-sSCellDynDCI-1-3*, or an active UL BWP change on the PCell if the UE is not provided *pucch-sSCellDyn* and *pucch-sSCellDynDCI-1-2* and *pucch-sSCellDynDCI-1-3*, and slot $n_{0,k} + n_D$ is before the slot for the active DL BWP change on serving cell c or the active UL BWP change on the serving cell of PUCCH transmission, or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook and slot $n_{0,k} + n_D$ overlaps with UL slot $n_U - K_{1,k-1}$, $k > 0$, where $n_{0,k}$ is a DL slot with a smallest index among DL slots overlapping with UL slot $n_U - K_{1,k}$,

$n_D = n_D + 1$;

else

while $r < \mathcal{C}(R)$

if the UE is not provided *timeDomainHARQ-BundlingType1* and is provided *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* and, for each slot from slot $n_{0,k} + n_D - N_{\mathrm{PDSCH}}^{\mathrm{repeat,max}} + 1$ to slot $n_{0,k} + n_D$, at least one symbol of the PDSCH time resource derived by row r is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* where $K_{1,k}$ is the k-th slot timing value in set K_1, where $n_{0,k}$ is a DL slot with a smallest index among DL slots overlapping with UL slot $n_U - K_{1,k}$, or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook and the end of the PDSCH time resource for row r is not within any UL slot $n_U - K_{1,l}$, $0 \le l < \mathcal{C}(K_1)$, or if *pdsch-TimeDomainAllocationListForMultiPDSCH* is provided and HARQ-ACK information for PDSCH time resource derived by row r in slot $n_{0,k} + n_D$ cannot be provided in slot n_U

$R = R \backslash r$;

elseif the UE is provided *timeDomainHARQ-BundlingType1* and *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* and, for each slot $n_{0,k} + n_D - \Delta K_{0,r}(d)$, at least one symbol of each PDSCH time resource derived by row r of set R' is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, and for each slot from $n_{0,k} + n_D - N_{\mathrm{PDSCH}}^{\mathrm{repeat,max}} + 1$ to slot $n_{0,k} + n_D$ at least one symbol of the PDSCH time resource derived by row r of set R is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if the row r of set R belongs to time domain resource allocation table configured for DCI format 1_2, where $d = 0,1,\ldots,\mathcal{C}(\Delta K_{0,r}) - 1$, $\Delta K_{0,r} = \max_{K_0}(K_{0,r}) - K_{0,r}$, and $\mathcal{C}(\Delta K_{0,r})$ is the cardinality of $\Delta K_{0,r}$.

$R = R \backslash r$;

$R' = R' \backslash r$;

else

$r = r + 1$;

end if

end while

if the UE is not provided with *multiPDSCH-perSlotType1-CB* and the UE does not indicate a capability to receive more than one unicast PDSCH or multicast PDSCH per slot and $R \neq \emptyset$, or if the UE is provided with *multiPDSCH-perSlotType1-CB* = 'disabled' and $R \neq \emptyset$,

$M_{A,c} = M_{A,c} \cup j$;

$j = j + 1$;

else

Set $\mathcal{C}(R)$ to the cardinality of R

Set m to the smallest last OFDM symbol index, as determined by the *SLIV*, among all rows of R

while $R \neq \emptyset$

Set $r = 0$

while $r < \mathcal{C}(R)$

if $S \leq m$ for start OFDM symbol index S for row r

$b_{r,k,n_D} = j$; - index of occasion for candidate PDSCH reception, or SPS PDSCH release, or TCI state update associated with row r

$R = R \backslash r$;

$B = B \cup b_{r,k,n_D}$;

else

$r = r + 1$;

end if

end while

$M_{A,c} = M_{A,c} \cup j$

$j = j + 1$;

Set m to the smallest last OFDM symbol index among all rows of R;

end while

end if

$n_D = n_D + 1$;

end if

end while

end if

$k = k + 1$;

end while

else

while $k < \mathcal{C}(K_1)$

if $\mathrm{mod}\left(n_U - K_{1,k} + \left\lfloor \left(\frac{N_{slot,offset}^{UL}}{2^{\mu_{offset,UL}}} - \frac{N_{slot,offset,c}^{DL}}{2^{\mu_{offset,DL,c}}}\right) \cdot 2^{\mu_{UL}} \right\rfloor + 1, \max(2^{\mu_{UL}-\mu_{DL}}, 1)\right) = 0$ or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook

Set $n_{\mathrm{D}} = 0$ – index of a DL slot overlapping with an UL slot

Set N_k to a number of DL slots overlapping with UL slot $n_U - K_{1,k}$ if *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook; otherwise, $N_k = \max(2^{\mu_{DL}-\mu_{UL}}, 1)$

while $n_D < N_k$

if *pdsch-TimeDomainAllocationListForMultiPDSCH* and *timeDomainHARQ-BundlingType1* are provided for serving cell c

$R = R_{\mathrm{T}}$;

$R' = R'_T$;

elseif *pdsch-TimeDomainAllocationListForMultiPDSCH* is provided and *timeDomainHARQ-BundlingType1* is not provided for serving cell c

$R = R_{\mathrm{T}}$;

else

Set R to the set of rows

end if

Set $\mathcal{C}(R)$ to the cardinality of R

Set $r = 0$ – index of row in set R

if slot n_{U} starts at a same time as or after a slot for an active DL BWP change on serving cell c or an active UL BWP change on the serving cell of PUCCH transmission if the UE is provided *pucch-sSCellDyn* or *pucch-sSCellDynDCI-1-2* or *pucch-sSCellDynDCI-1-3*, or an active UL BWP change on the PCell if the UE is not provided *pucch-sSCellDyn* and *pucch-sSCellDynDCI-1-2* or *pucch-sSCellDynDCI-1-3,* and slot $n_{0,k} + n_D$ is before the slot for the active DL BWP change on serving cell c or the active UL BWP change on the serving cell of PUCCH transmission where $n_{0,k}$ is a DL slot with a smallest index among DL slots overlapping with UL slot $n_U - K_{1,k}$, or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook and slot $n_{0,k} + n_D$ overlaps with UL slot $n_U - K_{1,k-1}$, $k > 0$,

$n_D = n_D + 1$;

else

while $r < \mathcal{C}(R)$

if the UE is not provided *timeDomainHARQ-BundlingType1* and is provided *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* and, for each slot from slot $n_{0,k} + n_D - N_{PDSCH}^{repeat,max} + 1$ to slot $n_{0,k} + n_D$, at least one symbol of the PDSCH time resource derived by row r is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* where $K_{1,k}$ is the *k*-th slot timing value in set K_1, where $n_{0,k}$ is a DL slot with a smallest index among DL slots overlapping with UL slot $n_U - K_{1,k}$, or *subslotLengthForPUCCH* is provided for the HARQ-ACK codebook and the end of the PDSCH time resource for row r is not within any UL slot $n_U - K_{1,l}$, $0 \le l < \mathcal{C}(K_1)$ or if *pdsch-TimeDomainAllocationListForMultiPDSCH* is provided and HARQ-ACK information for PDSCH time resource derived by row r in slot $n_{0,k} + n_D$ cannot be provided in slot n_U

$R = R \backslash r$;

elseif the UE is provided *timeDomainHARQ-BundlingType1* and *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* and, for each slot $n_{0,k} + n_D - \Delta K_{0,r}(d)$, at least one symbol of each PDSCH time resource derived by row r of set R' is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, and for each slot from $n_{0,k} + n_D - N_{\mathrm{PDSCH}}^{\mathrm{repeat,max}} + 1$ to slot $n_{0,k} + n_D$ at least one symbol of the PDSCH time resource derived by row r of set R is configured as UL by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if the row r of set R belongs to time domain resource allocation table configured for DCI format 1_2, where d = 0,1,…,$\mathcal{C}(\Delta K_{0,r}) - 1$.

$R = R \backslash r$;

$R' = R' \backslash r$;

else

$r = r + 1$;

end if

end while

if the UE is not provided with *multiPDSCH-perSlotType1-CB* and the UE does not indicate a capability to receive more than one unicast PDSCH or multicast PDSCH per slot and $R \neq \emptyset$, or if the UE is provided with *multiPDSCH-perSlotType1-CB* = 'disabled' and $R \neq \emptyset$,

$M_{A,c} = M_{A,c} \cup j$;

$j = j + 1$;

else

Set $\mathcal{C}(R)$ to the cardinality of R

Set m to the smallest last OFDM symbol index, as determined by the *SLIV*, among all rows of R

while $R \neq \emptyset$

Set $r = 0$

while $r < \mathcal{C}(R)$

if $S \leq m$ for start OFDM symbol index S for row r

$b_{r,k,n_D} = j$; - index of occasion for candidate PDSCH reception, or SPS PDSCH release, or TCI state update associated with row r

$R = R \backslash r$;

$B = B \cup b_{r,k,n_D}$;

else

$r = r + 1$;

end if

end while

$M_{A,c} = M_{A,c} \cup j$;

$j = j + 1$;

Set m to the smallest last OFDM symbol index among all rows of R;

end while

end if

$n_D = n_D + 1$;

end if

end while

end if

$k = k + 1$;

end while

end if

If the UE indicates a capability to receive more than one PDSCH per slot, for occasions of candidate PDSCH receptions corresponding to rows of R associated with a same value of b_{r,k,n_D}, where $b_{r,k,n_D} \in B$, the UE does not expect to receive more than one PDSCH in a same DL slot associated with a same *coresetPoolIndex* value if provided, or if *coresetPoolIndex* is not provided.

If a UE receives a SPS PDSCH, or a SPS PDSCH release, or TCI state update, or a PDSCH that is scheduled by a DCI format that does not support CBG-based PDSCH receptions and if

- the UE is configured with one serving cell, and
- $\mathcal{C}(M_{A,c}) = 1$, and
- *PDSCH-CodeBlockGroupTransmission* is provided to the UE

the UE generates HARQ-ACK information only for the transport block in the PDSCH, or only for the SPS PDSCH release, or only for the TCI state update.

If a UE receives a SPS PDSCH, or a SPS PDSCH release, or TCI state update, or a PDSCH that is scheduled by a DCI format that does not support CBG-based PDSCH receptions and if

- the UE is configured with more than one serving cells, or
- $\mathcal{C}(M_{A,c}) > 1$, and
- *PDSCH-CodeBlockGroupTransmission* is provided to the UE

the UE repeats $N_{\mathrm{HARQ-ACK}}^{\mathrm{CBG/TB,max}}$ times the HARQ-ACK information for the transport block in the PDSCH, or for the SPS PDSCH release, or for the TCI state update.

A UE does not expect to detect a DCI format switching a DL BWP within N_3 symbols prior to a first symbol of a PUCCH transmission where the UE multiplexes HARQ-ACK information, where N_3 is defined in clause 9.2.3.

If a UE is provided *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* or *dl-DataToUL-ACK-DCI-1-2-r17*, the UE does not expect to be indicated by DCI format 1_0 a slot timing value for transmission of HARQ-ACK information that does not belong to the intersection of the set of slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \leq 3$, {7, 8, 12, 16, 20, 24, 28, 32} for $\mu = 5$, and {13, 16, 24, 32, 40, 48, 56, 64} for $\mu = 6$, and the set of slot timing values provided by K_1 for the active DL BWP of a corresponding serving cell for unicast.

If *maxNrofCodeWordsScheduledByDCI* indicates reception of two transport blocks, when the UE receives a PDSCH with one transport block or a SPS PDSCH release or a TCI state update, the HARQ-ACK information is associated with the first transport block and the UE generates a NACK for the second transport block if *harq-ACK-SpatialBundlingPUCCH* is not provided and generates HARQ-ACK information with value of ACK for the second transport block if *harq-ACK-SpatialBundlingPUCCH* is provided.

A UE determines $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK},...,\tilde{o}_{O_{ACK}-1}^{ACK}$ HARQ-ACK information bits, for a total number of O_{ACK} HARQ-ACK information bits, of a HARQ-ACK codebook for transmission in a PUCCH according to the following pseudo-code. In the following pseudo-code, if the UE does not receive a transport block or a CBG, due to the UE not detecting a corresponding DCI format, the UE generates a NACK value for the transport block or the CBG. The cardinality of the set $M_{A,c}$ defines a total number M_c of occasions for PDSCH reception or SPS PDSCH release or TCI state update for serving cell c corresponding to the HARQ-ACK information bits.

Set $c = 0$ – serving cell index: lower indexes correspond to lower RRC indexes of corresponding cells including, when applicable, cells in the set S_0 and the set S_1

Set $j = 0$- HARQ-ACK information bit index

Set $N_{\mathrm{cells}}^{\mathrm{DL}}$ to the number of serving cells configured by higher layers for the UE

while $c < N_{\mathrm{cells}}^{\mathrm{DL}}$

Set $m = 0$ – index of occasion for candidate PDSCH reception, or SPS PDSCH release, or TCI state update

while $m < M_c$

if *timeDomainHARQ-BundlingType1* is provided for serving cell c and a PDSCH associated with occasion m is scheduled by a DCI format indicating a TDRA row that includes more than one SLIV entry if *harq-ACK-SpatialBundlingPUCCH* is not provided and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell c

if the PDSCH is associated with the last SLIV in the TDRA row

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK information bits corresponding to first transport blocks in PDSCH receptions, that do not overlap with an uplink symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, scheduled by the DCI format on serving cell c;

$j = j + 1$;

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK information bits corresponding to second transport blocks in PDSCH receptions, that do not overlap with an uplink symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, scheduled by the DCI format on serving cell c;

else

$\tilde{o}_j^{ACK}$ = NACK;

$j = j + 1$;

$\tilde{o}_j^{ACK}$ = NACK;

end if

$j = j + 1$;

elseif *harq-ACK-SpatialBundlingPUCCH* is provided and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell c

if the PDSCH is associated with the last SLIV in the TDRA row;

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK information bits corresponding to all transport blocks in PDSCHs, that do not overlap with an uplink symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, scheduled by the DCI format of serving cell c

if the UE receives one transport block, the UE assumes ACK for the second transport block;

else

$\tilde{o}_j^{ACK}$ = NACK;

end if

$j = j + 1$;

else

if the PDSCH is associated with the last SLIV in the TDRA row;

$\tilde{o}_j^{ACK}$ =binary AND operation of the HARQ-ACK information bits corresponding to all transport blocks in PDSCHs, that do not overlap with an uplink symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, scheduled by the DCI format of serving cell c

else

$\tilde{o}_j^{ACK}$ = NACK;

end if

$j = j + 1$;

end if

else

if *harq-ACK-SpatialBundlingPUCCH* is not provided, *PDSCH-CodeBlockGroupTransmission* is not provided, and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell c,

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit corresponding to a first transport block of this cell;

$j = j + 1$;

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit corresponding to a second transport block of this cell;

$j = j + 1$;

elseif *harq-ACK-SpatialBundlingPUCCH* is provided, and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell c,

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK information bits corresponding to first and second transport blocks of this cell

if the UE receives one transport block, the UE assumes ACK for the second transport block;

$j = j + 1$;

elseif *PDSCH-CodeBlockGroupTransmission* is provided, and $N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$ CBGs are indicated by *maxCodeBlockGroupsPerTransportBlock* for serving cell c,

Set $n_{\mathrm{CBG}} = 0$- CBG index

while $n_{\mathrm{CBG}} < N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$

$\tilde{o}_{j+n_{\mathrm{CBG}}}^{ACK}$ = HARQ-ACK information bit corresponding to CBG n_{CBG} of the first transport block;

if the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell c

$\tilde{o}_{j+n_{\mathrm{CBG}}+N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}}^{ACK}$ = HARQ-ACK information bit corresponding to CBG n_{CBG} of the second transport block;

end if

$n_{\mathrm{CBG}} = n_{\mathrm{CBG}} + 1$;

end while

$j = j + N_{\mathrm{TB},c}^{\mathrm{DL}} \cdot N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$, where $N_{\mathrm{TB},c}^{\mathrm{DL}}$ is the value of *maxNrofCodeWordsScheduledByDCI* for the active DL BWP of serving cell c;

else

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit of serving cell c;

$j = j + 1$;

end if

end if

$m = m + 1$;

end while

$c = c + 1;$

end while

If $O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CSI}} \leq 11$, the UE determines a number of HARQ-ACK information bits $n_{\mathrm{HARQ-ACK}}$ for obtaining a transmission power for a PUCCH, as described in clause 7.2.1, as $n_{\mathrm{HARQ-ACK}} = \sum_{c=0}^{N_{\mathrm{cells}}^{\mathrm{DL}}-1} \sum_{m=0}^{M_c-1} N_{m,c}^{\mathrm{received}} + \sum_{c=0}^{N_{\mathrm{cells}}^{\mathrm{DL}}-1} \sum_{m=0}^{M_c-1} N_{m,c}^{\mathrm{received,CBG}}$ where

- $N_{\mathrm{cells}}^{\mathrm{DL}}$ are all DL cells where the UE is configured to receive unicast or multicast PDSCHs
- M_c is the cardinality for the union of all sets $M_{A,c}$ of occasions for unicast or multicast PDSCH receptions or SPS PDSCH releases for serving cell c
- $N_{m,c}^{\mathrm{received}}$ is the number of transport blocks the UE receives in PDSCH reception occasion m for serving cell c if *harq-ACK-SpatialBundlingPUCCH* and *PDSCH-CodeBlockGroupTransmission* are not provided, or the number of transport blocks the UE receives in PDSCH reception occasion m for serving cell c if *PDSCH-CodeBlockGroupTransmission* is provided and the PDSCH reception is scheduled by a DCI format that does not support CBG-based PDSCH receptions, or the number of PDSCH receptions if *harq-ACK-SpatialBundlingPUCCH* is provided or SPS PDSCH release or TCI state update in PDSCH reception occasion m for serving cell c and the UE reports corresponding HARQ-ACK information in the PUCCH.
  - If *timeDomainHARQ-BundlingType1* is provided for serving cell c and for a DCI format indicating a TDRA row that includes more than one SLIV entry on the serving cell c, the UE considers as received only a PDSCH associated with the last SLIV.
- $N_{m,c}^{\mathrm{received,CBG}}$ is the number of CBGs the UE receives in a PDSCH reception occasion m for serving cell c if *PDSCH-CodeBlockGroupTransmission* is provided and the PDSCH reception is scheduled by a DCI format that supports CBG-based PDSCH receptions and the UE reports corresponding HARQ-ACK information in the PUCCH.

9.1.2.2 Type-1 HARQ-ACK codebook in physical uplink shared channel

If a UE is not provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* for unicast or multicast HARQ-ACK information, the UE does not multiplex the unicast or multicast HARQ-ACK information in the PUSCH transmission, respectively.

If a UE is provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* for unicast and/or multicast HARQ-ACK information, and would multiplex HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by a DCI format that does not include a DAI field, then

- if the UE has not received any PDSCH providing a transport block having enabled HARQ-ACK information report or SPS PDSCH release or TCI state update that the UE multiplexes corresponding HARQ-ACK information in the PUSCH, based on a value of a respective PDSCH-to-HARQ_feedback timing indicator field in a DCI format scheduling the PDSCH reception or the SPS PDSCH release or the TCI state update, or on the value of *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* if the PDSCH-to-HARQ_feedback timing indicator field is not present in DCI format 1_1 or DCI format 1_3, or on the value of *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in DCI format 1_2, or on the value of *dl-DataToUL-ACK* if the PDSCH-to-HARQ_feedback timing indicator field is not present in DCI format 4_2, in any of the M_c occasions for candidate PDSCH receptions by a DCI format or SPS PDSCH on any serving cell c, as described in clause 9.1.2.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission
- else the UE generates the HARQ-ACK codebook as described in clause 9.1.2.1, except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*, unless the UE receives only one of
  - a SPS PDSCH release indicated by DCI format 1_0 or by DCI format 4_1, with counter DAI field value of 1, or
  - SPS PDSCH(s) with transport blocks having enabled HARQ-ACK information report, or

- a PDSCH providing a transport block having enabled HARQ-ACK information report and scheduled by a DCI format 1_0 or by DCI format 4_1 with a counter DAI field value of 1, on the PCell

in the M_c occasions for candidate PDSCH receptions in which case the UE generates HARQ-ACK information only for the SPS PDSCH release or only for the PDSCH reception as described in clause 9.1.2.

A UE sets to NACK value in the HARQ-ACK codebook any HARQ-ACK information corresponding to

- PDSCH reception scheduled or activated by a DCI format that the UE detects in a PDCCH monitoring occasion that starts after a PDCCH monitoring occasion where the UE detects a DCI format scheduling the PUSCH transmission, if the corresponding conditions in Clause 9 for multiplexing associated HARQ-ACK information in a HARQ-ACK codebook in the PUSCH are not valid

- SPS PDSCH release or TCI state update that the UE detects in a PDCCH monitoring occasion that starts after a PDCCH monitoring occasion where the UE detects a DCI format scheduling the PUSCH transmission.

A UE does not expect to detect a DCI format switching a DL BWP within N_2 symbols prior to a first symbol of a PUSCH transmission where the UE multiplexes HARQ-ACK information, where N_2 is defined in [6, TS 38.214].

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by DCI format that includes a DAI field, and

- is not provided *fdmed-ReceptionMulticast* and is provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* for both unicast and multicast HARQ-ACK information, or

- is provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* only for one of unicast and multicast HARQ-ACK information

the UE generates the HARQ-ACK codebook as described in clause 9.1.2.1 when a value of the DAI field is $V_{\text{T-DAI}}^{\text{UL}} = 1$ except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*. The UE does not generate a HARQ-ACK codebook for multiplexing in the PUSCH transmission when $V_{\text{T-DAI}}^{\text{UL}} = 0$ unless the UE receives only one of

- a SPS PDSCH release indicated by DCI format 1_0 or by DCI format 4_1, with counter DAI field value of 1, or

- SPS PDSCH(s) with transport blocks having enabled associated HARQ-ACK information reports,

- a PDSCH providing a transport block having enabled HARQ-ACK information report and scheduled by a DCI format 1_0 or by DCI format 4_1, or only a TCI state update, with counter DAI field value of 1 on the PCell,

in the M_c occasions for candidate PDSCH receptions in which case the UE generates HARQ-ACK information only for the SPS PDSCH release or only for the PDSCH reception as described in clause 9.1.2.

$V_{\text{T-DAI}}^{\text{UL}} = 0$ if the PUSCH is scheduled by a DCI format that includes a DAI field and the DAI field is set to '0'; otherwise, $V_{\text{T-DAI}}^{\text{UL}} = 1$.

If a UE is provided *fdmed-ReceptionMulticast* and is provided *pdsch-HARQ-ACK-Codebook = 'semi-static'* for both unicast and multicast HARQ-ACK information, the UE generates the HARQ-ACK codebook as described in clause 9.1.2.1, except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*

- for the first set S_{U} of $N_{\text{cells}}^{\text{DL,U}}$ serving cells if a value $V_{\text{T-DAI}}^{\text{UL,U}}$ of the DAI field associated with unicast HARQ-ACK information is $V_{\text{T-DAI}}^{\text{UL,U}} = 1$ [5, TS 38.212]

- for the second set S_{M} of $N_{\text{cells}}^{\text{DL,M}}$ serving cells if a value $V_{\text{T-DAI}}^{\text{UL,M}}$ of the DAI field associated with multicast HARQ-ACK information is $V_{\text{T-DAI}}^{\text{UL,M}} = 1$ [5, TS 38.212]

The UE does not generate unicast or multicast HARQ-ACK information for multiplexing in the PUSCH transmission when $V_{\text{T-DAI}}^{\text{UL,U}} = 0$ and $V_{\text{T-DAI}}^{\text{UL,M}} = 0$, unless the UE receives only one of

- either a unicast SPS PDSCH release indicated by DCI format 1_0, or a multicast SPS PDSCH release indicated by DCI format 4_1, with counter DAI field value of 1, or

- unicast SPS PDSCH(s) or multicast SPS PDSCH(s) having enabled associated HARQ-ACK information reports, or

- either a PDSCH providing a transport block having enabled HARQ-ACK information report and scheduled by either a DCI format 1_0 or a DCI format 4_1 with counter DAI field value of 1, on the PCell,

in the M_c occasions for candidate PDSCH receptions in which case the UE generates only the corresponding unicast or multicast HARQ-ACK information only for the SPS PDSCH release or only for the PDSCH reception as described in clause 9.1.2.

$V_{\text{T-DAI}}^{\text{UL,U}} = 0$ if the corresponding value of the DAI field is set to '0'; otherwise, $V_{\text{T-DAI}}^{\text{UL,U}} = 1$. $V_{\text{T-DAI}}^{\text{UL,M}} = 0$ if the corresponding value of the DAI field is set to '0'; otherwise, $V_{\text{T-DAI}}^{\text{UL,M}} = 1$ [5, TS 38.212].

9.1.3 Type-2 HARQ-ACK codebook determination

This clause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic* or with *pdsch-HARQ-ACK-Codebook-r16*. Unless stated otherwise, a PDSCH-to-HARQ_feedback timing indicator field provides an applicable value. In clauses 9.1.3, 9.1.3.1, 9.1.3.2 and 9.1.3.3, if the UE is provided for only one of *pdsch-HARQ-ACK-Codebook = dynamic* or *pdsch-HARQ-ACK-Codebook-r16* for unicast HARQ-ACK-ACK codebook, or *pdsch-HARQ-ACK-Codebook = dynamic* for multicast HARQ-ACK codebook, the Type-2 HARQ-ACK codebook is generated considering only one of respective unicast or multicast configurations for PDSCH receptions or for PDCCH monitoring for detection of DCI formats.

A UE does not expect to multiplex in a Type-2 HARQ-ACK codebook HARQ-ACK information that is in response to a detection of a DCI format that does not include a counter DAI field.

If a UE is provided *downlinkHARQ-FeedbackDisabled* indicating disabled HARQ-ACK information for a HARQ process associated with a transport block for PDCCH monitoring occasion m or for SPS PDSCH receptions on serving cell c, the UE does not multiplex a HARQ-ACK information bit corresponding to the transport block in a Type-2 HARQ-ACK codebook and does not consider the transport block as received in the determination of $N_{m,c}^{\text{received}}$ or of $N_{\text{SPS},c}$ in clause 9.1.3.1. If the UE is also provided *PDSCH-CodeBlockGroupTransmission*, the UE does not multiplex HARQ-ACK information bits corresponding to CBGs of the transport block in the Type-2 HARQ-ACK codebook and does not consider the CBGs as received in the determination of $N_{m,c}^{\text{received,CBG}}$ in clause 9.1.3.1. If the UE is also provided *harq-feedbackEnablingforSPSactive* = '*enabled*', the UE considers a HARQ process associated with a transport block in a first SPS PDSCH reception, after an activation of SPS PDSCH receptions, to have enabled HARQ-ACK information and the UE provides a HARQ-ACK information bit according to a decoding outcome for the transport block in the first SPS PDSCH reception.

If a UE is indicated to not provide multicast HARQ-ACK information, as described in clause 18, associated with PDCCH monitoring occasion m or for SPS PDSCH receptions on serving cell c, the UE does not multiplex corresponding HARQ-ACK information bits in a Type-2 HARQ-ACK codebook and does not consider any transport blocks as received in the determination of $N_{m,c}^{\text{received}}$ or of $N_{\text{SPS},c}$ in clause 9.1.3.1.

If a UE receives a first DCI format that the UE detects in a first PDCCH monitoring occasion and includes a PDSCH-to-HARQ_feedback timing indicator field providing an inapplicable value from *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17*,

- if the UE detects a second DCI format, the UE multiplexes the corresponding HARQ-ACK information in a PUCCH or PUSCH transmission in a slot that is indicated by a value of a PDSCH-to-HARQ_feedback timing indicator field in the second DCI format, where
  - if the UE is not provided *pdsch-HARQ-ACK-Codebook-r16*, the UE detects the second DCI format in any PDCCH monitoring occasion after the first one, and where the slot indicated by the value of the PDSCH-to-HARQ_feedback timing indicator field in the second DCI format is no later than a slot for HARQ-ACK information in response to a SPS PDSCH reception, if any, received after the PDSCHs scheduled by the first DCI format.
  - if the UE is provided *pdsch-HARQ-ACK-Codebook-r16*, the UE detects the second DCI format in any PDCCH monitoring occasion after the first one, and the second DCI format indicates a HARQ-ACK information report for a same PDSCH group index as indicated by the first DCI format as described in clause 9.1.3.3, and where the slot indicated by the value of the PDSCH-to-HARQ_feedback timing indicator field in the second DCI format is no later than a slot for HARQ-ACK information in response to a SPS PDSCH reception, if any, received after the PDSCHs scheduled by the first DCI format.

  - if the UE is provided *pdsch-HARQ-ACK-Codebook-r16*, the UE receives the second DCI format later than the slot for HARQ-ACK information in response to a SPS PDSCH reception received after the PDSCHs scheduled by the first DCI format, and the second DCI format indicates a HARQ-ACK information report for a same PDSCH group index as indicated by the first DCI format as described in clause 9.1.3.3.
  - if the UE is provided *pdsch-HARQ-ACK-OneShotFeedback*, the first DCI format does not have associated HARQ-ACK information without scheduling a PDSCH reception or TCI state update, the UE detects the second DCI format in any PDCCH monitoring occasion after the first one, and the second DCI format includes a One-shot HARQ-ACK request field with value 1, the UE includes the HARQ-ACK information in a Type-3 HARQ-ACK codebook, as described in clause 9.1.4, and where the slot indicated by the value of the PDSCH-to-HARQ_feedback timing indicator field in the second DCI format is no later than a slot for HARQ-ACK information in response to a SPS PDSCH reception, if any, received after the PDSCHs scheduled by the first DCI format.
  - if the UE is provided *pdsch-HARQ-ACK-OneShotFeedback-r16*, the first DCI format does not have associated HARQ-ACK information without scheduling a PDSCH reception or TCI state update, and the UE receives the second DCI format later than the slot for HARQ-ACK information in response to a SPS PDSCH reception received after the PDSCHs scheduled by the first DCI format, and the second DCI format includes a One-shot HARQ-ACK request field with value 1, the UE includes the HARQ-ACK information in a Type-3 HARQ-ACK codebook, as described in clause 9.1.4.
- otherwise, the UE does not multiplex the corresponding HARQ-ACK information in a PUCCH or PUSCH transmission.

9.1.3.1 Type-2 HARQ-ACK codebook in physical uplink control channel

If a UE is configured to monitor PDCCH for multicast DCI formats with CRC scrambled by one or more G-RNTIs for multicast or G-CS-RNTIs that the UE generates a Type-2 HARQ-ACK codebook, the UE separately applies the procedures in this clause per G-RNTI for multicast or per G-CS-RNTI using *maxNrofCodeWordsScheduledByDCI* in *pdsch-ConfigMulticast* except the procedures for SPS PDSCHs and applies the procedures in this clause using *maxNrofCodeWordsScheduledByDCI* provided in *pdsch-Config* for unicast DCI formats excluding the unicast DCI format activating SPS PDSCH receptions, and determines the Type-2 HARQ-ACK codebook by concatenating the Type-2 HARQ-ACK codebook for unicast DCI formats excluding the unicast DCI format activating SPS PDSCH receptions, followed by the HARQ-ACK codebooks for the multicast DCI formats in ascending order of the corresponding G-RNTI values, followed by the HARQ-ACK codebooks for the multicast DCI formats in ascending order of the corresponding G-CS-RNTI values excluding the multicast DCI format activating SPS PDSCH receptions, followed by the HARQ-ACK codebooks for unicast and multicast SPS PDSCH receptions.

A UE determines monitoring occasions for PDCCH with DCI format scheduling PDSCH receptions, or having associated HARQ-ACK information without scheduling PDSCH reception, on an active DL BWP of a serving cell c, as described in clause 10.1, and for which the UE transmits HARQ-ACK information in a same PUCCH in slot n based on

- PDSCH-to-HARQ_feedback timing indicator field values, or a *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* or *dl-DataToUL-ACK-DCI-1-2-r17* value if the PDSCH-to-HARQ_feedback timing indicator field is not present in a DCI format, for PUCCH transmission with HARQ-ACK information in slot n, as described in clause 9.2.3, in response to PDSCH receptions, or in response to a DCI format having associated HARQ-ACK information without scheduling PDSCH reception
- slot offsets K_0 [6, TS 38.214] provided by time domain resource assignment field in a DCI format scheduling PDSCH receptions and by *pdsch-AggregationFactor*, or *pdsch-AggregationFactor-r16*, or *repetitionNumber*, when provided.

The set of PDCCH monitoring occasions for DCI formats scheduling PDSCH receptions, or having associated HARQ-ACK information without scheduling PDSCH reception, is defined as the union of PDCCH monitoring occasions across active DL BWPs of configured serving cells. PDCCH monitoring occasions are indexed in an ascending order of their start times. The cardinality of the set of PDCCH monitoring occasions defines a total number M of PDCCH monitoring occasions. PDCCH monitoring occasions are separately counted for a DCI format scheduling a PDSCH reception on a single serving cell and for a DCI format scheduling PDSCH receptions on more than one serving cells and corresponding values of M can be different.

A value of the counter downlink assignment indicator (DAI) field in DCI formats, each scheduling PDSCH receptions on respective single serving cells with associated HARQ-ACK information, or having associated HARQ-ACK information without scheduling a PDSCH reception, in a same HARQ-ACK codebook denotes the accumulative number of {serving cell, PDCCH monitoring occasion}-pairs in which PDSCH receptions that provide transport blocks with enabled HARQ-ACK information report, or HARQ-ACK information bits that are not in response for PDSCH receptions, associated with the DCI formats, excluding the SPS activation DCI, is present up to the current serving cell and current PDCCH monitoring occasion,

- first, if the UE indicates by *type2-HARQ-ACK-Codebook* support for more than one PDSCH reception on a serving cell that are scheduled from a same PDCCH monitoring occasion, in increasing order of the PDSCH reception starting time for the same {serving cell, PDCCH monitoring occasion} pair,
- second in ascending order of serving cell index, and
- third in ascending order of PDCCH monitoring occasion index m, where $0 \leq m < M$.

A value of the counter DAI field in DCI formats, each scheduling PDSCH receptions on respective more than one serving cells with associated HARQ-ACK information in a same HARQ-ACK codebook, denotes the accumulative number of {serving cell with smallest index from the more than one serving cells, PDCCH monitoring occasion}-pairs in which PDSCH receptions are present up to the current more than one serving cells and current PDCCH monitoring occasion,

- first, if the UE indicates by *type2-HARQ-ACK-Codebook* support for more than one PDSCH receptions on a serving cell that are scheduled from a same PDCCH monitoring occasion, in increasing order of the PDSCH reception starting time for the same {serving cell with smallest index from the more than one serving cells, PDCCH monitoring occasion} pair,
- second in ascending order of the smallest serving cell index from the more than one serving cells, and
- third in ascending order of PDCCH monitoring occasion index m, where $0 \leq m < M$.

If, for an active DL BWP of a serving cell, the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode = joint*, the value of the counter DAI is in the order of the first CORESETs and then the second CORESETs for a same serving cell index and a same PDCCH monitoring occasion index.

The value of the total DAI, when present [5, TS 38.212], in a DCI format denotes the total number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH reception(s) that provide transport blocks with enabled HARQ-ACK information report, or HARQ-ACK information that does not correspond to PDSCH receptions, associated with DCI formats, excluding the SPS activation DCI, is present, up to the current PDCCH monitoring occasion m and is updated from PDCCH monitoring occasion to PDCCH monitoring occasion. If, for an active DL BWP of a serving cell, the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode = joint*, the total DAI value counts the {serving cell, PDCCH monitoring occasion}-pair(s) for both the first CORESETs and the second CORESETs.

Denote by $N_{C-\mathrm{DAI}}^{\mathrm{DL}}$ the number of bits for the counter DAI and set $T_D = 2^{N_{C-\mathrm{DAI}}^{\mathrm{DL}}}$. Denote by $V_{\mathrm{C-DAI},c,m}^{\mathrm{DL}}$ the value of the counter DAI in a DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling PDSCH reception, on serving cell c in PDCCH monitoring occasion m according to Table 9.1.3-1 or Table 9.1.3-1A. Denote by $V_{\mathrm{T-DAI},m}^{\mathrm{DL}}$ the value of the total DAI in a DCI format in PDCCH monitoring occasion m according to Table 9.1.3-1. The UE assumes a same value of total DAI in all DCI formats that include a total DAI field in PDCCH monitoring occasion m. A UE does not expect to multiplex, in a same Type-2 HARQ-ACK codebook, HARQ-ACK information that is in response to detection of DCI formats with different number of bits for the counter DAI field.

If the UE transmits HARQ-ACK information in a PUCCH in slot n and for any PUCCH format, the UE determines the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \cdots, \tilde{o}_{O_{\mathrm{ACK}}-1}^{ACK}$, for a total number of O_{ACK} HARQ-ACK information bits, according to the following pseudo-code:

Set $m = 0$ – PDCCH, with DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling a PDSCH reception, monitoring occasion index: lower index corresponds to earlier PDCCH monitoring occasion

Set $j = 0$

Set $V_{temp} = 0$

Set $V_{temp2} = 0$

Set $V_s = \emptyset$

Set $N_{\text{cells}}^{\text{DL}}$ to the number of serving cells configured by higher layers for the UE

- if, for an active DL BWP of a serving cell, the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode = joint*, the serving cell is counted two times where the first time corresponds to the first CORESETs and the second time corresponds to the second CORESETs
- if the UE indicates *type2-HARQ-ACK-Codebook* and receives a number $N_{\text{PDSCH},c}^{m} > 1$ of PDSCHs on a serving cell c that are scheduled by DCI formats in PDCCH receptions at a same PDCCH monitoring occasion m, the serving cell c is counted $N_{\text{PDSCH},c}^{m}$ times for PDCCH monitoring occasion m in increasing order of the PDSCH reception starting time

Set M to the number of PDCCH monitoring occasion(s)

while $m < M$

Set $c = 0$ – serving cell index: lower indexes correspond to lower RRC indexes of corresponding cell

while $c < N_{\text{cells}}^{\text{DL}}$

if PDCCH monitoring occasion m is before an active DL BWP change on serving cell c or an active UL BWP change on the serving cell of PUCCH transmission if the UE is provided *pucch-sSCellDyn* or *pucch-sSCellDynDCI-1-2*, or an active UL BWP change on the PCell if the UE is not provided *pucch-sSCellDyn* and *pucch-sSCellDynDCI-1-2*, and an active DL BWP change is not triggered in PDCCH monitoring occasion m

$c = c + 1$;

else

if there is a PDSCH providing a transport block for a HARQ process with enabled HARQ-ACK information on serving cell c associated with PDCCH in PDCCH monitoring occasion m, or there is a PDCCH providing a DCI format associated with HARQ-ACK information without scheduling PDSCH reception on serving cell c

if $V_{C-\text{DAI},c,m}^{\text{DL}} \leq V_{temp}$

$\mathrm{j} = \mathrm{j} + 1$

end if

$V_{temp} = V_{C-\text{DAI},c,m}^{\text{DL}}$

if $V_{\text{T-DAI},m}^{\text{DL}} = \emptyset$

$V_{temp2} = V_{C-\text{DAI},c,m}^{\text{DL}}$

else

$V_{temp2} = V_{T-\text{DAI},m}^{\text{DL}}$

end if

if *harq-ACK-SpatialBundlingPUCCH* is not provided and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for at least one configured DL BWP of at least one serving cell,

$\tilde{o}_{2\cdot T_D\cdot j+2(V_{C-DAI,c,m}^{DL}-1)}^{ACK}$ = HARQ-ACK information bit corresponding to the first transport block of this cell

$\tilde{o}^{ACK}_{2\cdot T_D \cdot j+2(V^{DL}_{C-DAI,c,m}-1)+1}$ = HARQ-ACK information bit corresponding to the second transport block of this cell

$V_s = V_s \cup \{2 \cdot T_D \cdot j + 2(V^{\mathrm{DL}}_{C-\mathrm{DAI},c,m} - 1),\ 2 \cdot T_D \cdot j + 2(V^{\mathrm{DL}}_{C-\mathrm{DAI},c,m} - 1) + 1\}$

elseif *harq-ACK-SpatialBundlingPUCCH* is provided to the UE and m is a monitoring occasion for PDCCH with a DCI format that supports PDSCH reception with two transport blocks and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks in at least one configured DL BWP of at least one serving cell,

$\tilde{o}^{ACK}_{T_D \cdot j+V^{\mathrm{DL}}_{C-\mathrm{DAI},c,m}-1}$ = binary AND operation of the HARQ-ACK information bits corresponding to the first and second transport blocks of this cell

$V_s = V_s \cup \{T_D \cdot j + V^{\mathrm{DL}}_{C-\mathrm{DAI},c,m} - 1\}$

else

$\tilde{o}^{ACK}_{T_D \cdot j+V^{DL}_{C-DAI,c,m}-1}$ = HARQ-ACK information bit of this cell

$V_s = V_s \cup \{T_D \cdot j + V^{\mathrm{DL}}_{C-\mathrm{DAI},c,m} - 1\}$

end if

end if

$c = c + 1$

end if

end while

$m = m + 1$

end while

$V_{temp} = \left(j \bmod \left(\frac{4}{T_D}\right)\right) \times \left(\frac{4}{T_D}\right) + V_{temp}$

if UE does not set $V_{temp2} = V^{UL}_{\mathrm{T}-DAI}$ and $T_D = 2$

$V_{temp2} = V_{temp}$

end if

$j = \left\lfloor \frac{j \times T_D}{4} \right\rfloor$

if $V_{temp2} < V_{temp}$

$j = j + 1$

end if

if *harq-ACK-SpatialBundlingPUCCH* is not provided to the UE and the UE is configured by *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for at least one configured DL BWP of a serving cell,

$O^{ACK} = 2 \cdot (4 \cdot j + V_{temp2})$

else

$O^{ACK} = 4 \cdot j + V_{temp2}$

end if

$\tilde{o}_i^{ACK} = \text{NACK for any } i \in \{0,1,\cdots,O^{ACK}-1\}\backslash V_s$

If a UE is configured to receive SPS PDSCH, the SPS PDSCH does not overlap with a non-active period of cell DTX for a serving cell of the SPS PDSCH reception if cell DTX is activated for the serving cell, and the UE multiplexes HARQ-ACK information for one activated SPS PDSCH reception that provides transport block with enabled HARQ-ACK information report, including the ones associated with the corresponding activation DCI, in the PUCCH in slot n, the UE generates one HARQ-ACK information bit associated with the SPS PDSCH reception and appends it to the O^{ACK} HARQ-ACK information bits.

If a UE is configured to receive SPS PDSCH and the UE multiplexes HARQ-ACK information for multiple activated SPS PDSCH receptions, including the ones associated with the corresponding activation DCI and excluding the ones that provide only transport blocks with disabled HARQ-ACK information report, in the PUCCH in slot n, the UE generates the HARQ-ACK information as described in clause 9.1.2 and appends it to the O^{ACK} HARQ-ACK information bits.

The UE generates HARQ-ACK information with ACK value in response to a detection of a DCI format that does not trigger a Type-3 HARQ-ACK codebook report and has associated HARQ-ACK information without scheduling a PDSCH reception.

For a PDCCH monitoring occasion with DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling a PDSCH reception, in the active DL BWP of a serving cell, when a UE receives a PDSCH with one transport block, or detects a DCI format having associated HARQ-ACK information without scheduling PDSCH reception, and the value of *maxNrofCodeWordsScheduledByDCI* is 2 for at least one configured DL BWP of at least one serving cell, the HARQ-ACK information is associated with the first transport block and the UE generates a NACK for the second transport block if *harq-ACK-SpatialBundlingPUCCH* is not provided and generates HARQ-ACK information with value of ACK for the second transport block if *harq-ACK-SpatialBundlingPUCCH* is provided.

If a UE is

- not provided *PDSCH-CodeBlockGroupTransmission* for any serving cell, and
- not provided *pdsch-TimeDomainAllocationListForMultiPDSCH* for any serving cell, or provided *nrofHARQ-BundlingGroups* with value of 1 for any serving cell provided *pdsch-TimeDomainAllocationListForMultiPDSCH*

or

- for PDSCH receptions scheduled by a DCI format that does not support CBG-based PDSCH receptions and does not schedule more than one PDSCH reception, or
- for PDSCH receptions scheduled by a DCI format on a serving cell when the UE is provided *nrofHARQ-BundlingGroups* with value of 1, or
- for SPS PDSCH reception, or
- for a DCI format having associated HARQ-ACK information without scheduling PDSCH reception, and

if $O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} \leq 11$, the UE determines a number of HARQ-ACK information bits $n_{\text{HARQ-ACK}}$ for obtaining a transmission power for a PUCCH, as described in clause 7.2.1, as

$$n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK,TB}} = \left(\left(V_{\text{DAI},m_{\text{last}}}^{\text{DL}} - \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1} U_{\text{DAI},c}\right) mod(T_D)\right) N_{\text{TB},max}^{\text{DL}} + \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1}\left(\sum_{m=0}^{M-1} N_{m,c}^{\text{received}} + N_{\text{SPS},c}\right) + \sum_{g=0}^{G-1}\left(\left(\left(V_{\text{DAI},m_{\text{last}},g}^{\text{DL}} - \sum_{c=0}^{N_{\text{cells},g}^{\text{DL}}-1} U_{\text{DAI},c,g}\right) mod\left(T_{D,g}\right)\right) N_{\text{TB},max,g}^{\text{DL}} + \sum_{c=0}^{N_{\text{cells},g}^{\text{DL}}-1}\left(\sum_{m=0}^{M_g-1} N_{m,c,g}^{\text{received}} + N_{\text{SPS},c,g}\right)\right)$$

where

- $N_{\text{cells}}^{\text{DL}}$ is a number of serving cells where the UE is configured to receive unicast PDSCHs
- $N_{\text{cells},g}^{\text{DL}}$ is a number of serving cells where the UE is configured to receive multicast PDSCHs for a G-RNTI g for multicast or a G-CS-RNTI g
- G is a total number of G-RNTIs for multicast or G-CS-RNTIs configured to the UE

- M is the number of PDCCH monitoring occasions for unicast DCI formats

- M_g is the number of PDCCH monitoring occasions for multicast DCI formats with CRC scrambled by G-RNTI g for multicast or G-CS-RNTI g

- $T_D = 2^{N_{C-\mathrm{DAI}}^{\mathrm{DL}}}$ where $N_{C-\mathrm{DAI}}^{\mathrm{DL}}$ the number of bits for the counter DAI field in unicast DCI formats

- $T_{D,g} = 2^{N_{C-\mathrm{DAI},g}^{\mathrm{DL}}}$ where $N_{C-\mathrm{DAI},g}^{\mathrm{DL}}$ the number of bits for the counter DAI field in multicast DCI formats with CRC scrambled by G-RNTI g for multicast or G-CS-RNTI g

- if $N_{\mathrm{cells}}^{\mathrm{DL}} = 1$, $V_{\mathrm{DAI},m_{\mathrm{last}}}^{\mathrm{DL}}$ is the value of the counter DAI in the last DCI format scheduling PDSCH reception or having associated HARQ-ACK information without scheduling PDSCH reception, that the UE detects within the M PDCCH monitoring occasions.

- if $N_{\mathrm{cells},g}^{\mathrm{DL}} = 1$, $V_{\mathrm{DAI},m_{\mathrm{last},g}}^{\mathrm{DL}}$ is the value of the counter DAI in the last multicast DCI format with G-RNTI g for multicast, or G-CS-RNTI g, scheduling PDSCH reception or having associated HARQ-ACK information without scheduling a PDSCH reception, that the UE detects within the M_g PDCCH monitoring occasions

- if $N_{\mathrm{cells}}^{\mathrm{DL}} > 1$ or if $N_{\mathrm{cells},g}^{\mathrm{DL}} > 1$

  - if the UE does not detect any DCI format that includes a total DAI field in a last PDCCH monitoring occasion within the M or M_g PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling PDSCH reception, for any serving cell c, $V_{\mathrm{DAI},m_{\mathrm{last}}}^{\mathrm{DL}}$ or $V_{\mathrm{DAI},m_{\mathrm{last},g}}^{\mathrm{DL}}$, respectively, is the value of the counter DAI in a last DCI format the UE detects in the last PDCCH monitoring occasion

  - if the UE detects at least one DCI format that includes a total DAI field in a last PDCCH monitoring occasion within the M or M_g, for G-RNTI g for multicast or G-CS-RNTI g, PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling PDSCH reception, for any serving cell c, $V_{\mathrm{DAI},m_{\mathrm{last}}}^{\mathrm{DL}}$ or $V_{\mathrm{DAI},m_{\mathrm{last},g}}^{\mathrm{DL}}$, respectively, is the value of the total DAI in the at least one DCI format that includes a total DAI field

- $V_{\mathrm{DAI},m_{\mathrm{last}}}^{\mathrm{DL}} = 0$ or $V_{\mathrm{DAI},m_{\mathrm{last},g}}^{\mathrm{DL}} = 0$ if the UE does not detect any DCI format scheduling PDSCH reception, or having associated HARQ-ACK information without scheduling PDSCH reception, for any serving cell c in any of the M or M_g PDCCH monitoring occasions, respectively.

- $U_{\mathrm{DAI},c}$ or $U_{\mathrm{DAI},c,g}$, for G-RNTI g for multicast or G-CS-RNTI g, is the total number of DCI formats scheduling PDSCH receptions providing transport blocks with enabled HARQ-ACK information, or having associated HARQ-ACK information without scheduling a PDSCH reception, that the UE detects within the M or M_g PDCCH monitoring occasions, respectively, for serving cell c. $U_{\mathrm{DAI},c} = 0$ or $U_{\mathrm{DAI},c,g} = 0$ if the UE does not detect any DCI format scheduling PDSCH reception providing a transport block with enabled HARQ-ACK information, or having associated HARQ-ACK information without scheduling PDSCH reception, for serving cell c in any of the M or M_g, respectively, PDCCH monitoring occasions.

- $N_{\mathrm{TB,max}}^{\mathrm{DL}} = 2$ if the value of *maxNrofCodeWordsScheduledByDCI* is 2 for any serving cell c and *harq-ACK-SpatialBundlingPUCCH* is not provided; otherwise, $N_{\mathrm{TB,max}}^{\mathrm{DL}} = 1$.

- $N_{\mathrm{TB,max},g}^{\mathrm{DL}} = 2$ if the value of *maxNrofCodeWordsScheduledByDCI* is 2 for any serving cell c and *harq-ACK-SpatialBundlingPUCCH* is not provided for G-RNTI g for multicast or G-CS-RNTI g; otherwise, $N_{\mathrm{TB,max},g}^{\mathrm{DL}} = 1$.

- $N_{m,c}^{\mathrm{received}}$ or $N_{m,c,g}^{\mathrm{received}}$, for G-RNTI g for multicast or G-CS-RNTI g, is

  - if *harq-ACK-SpatialBundlingPUCCH* is not provided, the number of transport blocks the UE receives in a PDSCH, or the number of transport block groups the UE receives in PDSCHs if *nrofHARQ-BundlingGroups* with $N_{\mathrm{HARQ-ACK}}^{\mathrm{TBG,max}} = 1$ is provided, scheduled by a DCI format that the UE detects in PDCCH monitoring occasion m for serving cell c, or

- if *harq-ACK-SpatialBundlingPUCCH* is provided, the number of PDSCHs, or the number of PDSCH groups if *nrofHARQ-BundlingGroups* with $N_{\text{HARQ-ACK}}^{\text{TBG,max}} = 1$ is provided, scheduled by a DCI format that the UE detects in PDCCH monitoring occasion m for serving cell c, or

- the number of DCI formats that the UE detects and have associated a HARQ-ACK information without scheduling PDSCH reception in PDCCH monitoring occasion m for serving cell c.

- $N_{\text{SPS},c}$ or $N_{\text{SPS},c,g}$, for G-RNTI g for multicast or G-CS-RNTI g, is the number of SPS PDSCH receptions by the UE on serving cell c for which the UE transmits corresponding HARQ-ACK information in the same PUCCH as for HARQ-ACK information corresponding to PDSCH receptions within the M or M_g PDCCH monitoring occasions, respectively.

If a UE

- is provided *PDSCH-CodeBlockGroupTransmission* for $N_{\text{cells}}^{\text{DL,CBG}}$ serving cells; and

- is not provided *PDSCH-CodeBlockGroupTransmission*, for $N_{\text{cells}}^{\text{DL,TB}}$ serving cells where $N_{\text{cells}}^{\text{DL,TB}} + N_{\text{cells}}^{\text{DL,CBG}} = N_{\text{cells}}^{\text{DL}}$

the UE determines the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \cdots, \tilde{o}_{O_{\text{ACK}}-1}^{ACK}$ according to the previous pseudo-code with the following modifications

- $N_{\text{cells}}^{\text{DL}}$ is used for the determination of a first HARQ-ACK sub-codebook for

  - SPS PDSCH reception,

  - a DCI format having associated HARQ-ACK information without scheduling PDSCH reception,

  - TCI state update, and

  - TB-based PDSCH receptions on the $N_{\text{cells}}^{\text{DL,CBG}}$ serving cells and on the $N_{\text{cells}}^{\text{DL,TB}}$ serving cells,

- $N_{\text{cells}}^{\text{DL}}$ is replaced by $N_{\text{cells}}^{\text{DL,CBG}}$ for the determination of a second HARQ-ACK sub-codebook corresponding to the $N_{\text{cells}}^{\text{DL,CBG}}$ serving cells for CBG-based PDSCH receptions, and

- if, for an active DL BWP of a serving cell, the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode* = *joint*, the serving cell is counted as two times where the first time corresponds to the first CORESETs and the second time corresponds to the second CORESETs, and

  - instead of generating one HARQ-ACK information bit per transport block for a serving cell from the $N_{\text{cells}}^{\text{DL,CBG}}$ serving cells, the UE generates $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$ HARQ-ACK information bits, where $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$ is the maximum value of $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ across all $N_{\text{cells}}^{\text{DL,CBG}}$ serving cells and $N_{\text{TB},c}^{\text{DL}}$ is the value of *maxNrofCodeWordsScheduledByDCI* for serving cell c. If for a serving cell c it is $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}} < N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$, the UE generates NACK for the last $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}} - N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ HARQ-ACK information bits for serving cell c

  - the pseudo-code operation when *harq-ACK-SpatialBundlingPUCCH* is provided is not applicable

- The counter DAI value and the total DAI value apply separately for each HARQ-ACK sub-codebook

- The UE generates the HARQ-ACK codebook by appending the second HARQ-ACK sub-codebook to the first HARQ-ACK sub-codebook

If $O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} \leq 11$, the UE also determines $n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK,TB}} + n_{\text{HARQ-ACK,CBG}}$ for obtaining a PUCCH transmission power, as described in clause 7.2.1, with

$$n_{\text{HARQ-ACK,CBG}} = \left(\left(V_{\text{DAI},m_{\text{last}}}^{\text{DL}} - \sum_{c=0}^{N_{\text{cells}}^{\text{DL,CBG}}-1} U_{\text{DAI},c}^{\text{CBG}}\right) mod(T_D)\right) N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}} + \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1} \sum_{m=0}^{M-1} N_{m,c}^{\text{received,CBG}}$$

where

- if $N_{\text{cells}}^{\text{DL}} = 1$, $V_{\text{DAI},m_{\text{last}}}^{\text{DL}}$ is the value of the counter DAI in the last DCI format scheduling CBG-based PDSCH reception that the UE detects within the M PDCCH monitoring occasions
- if $N_{\text{cells}}^{\text{DL}} > 1$, $V_{\text{DAI},m_{\text{last}}}^{\text{DL}}$ is the value of the total DAI in the last DCI format scheduling CBG-based PDSCH reception for any serving cell c that the UE detects within the M PDCCH monitoring occasions
- $V_{\text{DAI},m_{\text{last}}}^{\text{DL}} = 0$, if the UE does not detect any DCI format scheduling CBG-based PDSCH reception for any serving cell c in any of the M PDCCH monitoring occasions
- $U_{\text{DAI},c}^{\text{CBG}}$ is the total number of DCI formats scheduling CBG-based PDSCH receptions that the UE detects within the M PDCCH monitoring occasions for serving cell c. $U_{\text{DAI},c}^{\text{CBG}} = 0$ if the UE does not detect any DCI format scheduling CBG-based PDSCH reception for serving cell c in any of the M PDCCH monitoring occasions
- $N_{m,c}^{\text{received,CBG}}$ is the number of CBGs the UE receives in a PDSCH scheduled by a DCI format that supports CBG-based PDSCH reception that the UE detects in PDCCH monitoring occasion m for serving cell c and the UE reports corresponding HARQ-ACK information in the PUCCH

If a UE is provided *nrofHARQ-BundlingGroups* and is not provided *harq-ACK-SpatialBundlingPUCCH* for a serving cell c, the UE generates HARQ-ACK information over transport block groups (TBGs) for PDSCH receptions where, for a maximum number of $N_{\text{PDSCH}}^{\text{max}}$ PDSCH receptions scheduled by a DCI format on the serving cell, a maximum number of TBGs $N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ is provided by *nrofHARQ-BundlingGroups*. If the UE detects a DCI format scheduling $N_{\text{PDSCH},c}$ PDSCH receptions on the serving cell c, the UE generates $N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ HARQ-ACK information bits for the first TBs and, if applicable, generates $N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ HARQ-ACK information bits for the second TBs as described in clause 9.1.1 by setting $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}} = N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ and $C = N_{\text{PDSCH},c}$. For a TBG associated with at least one PDSCH that does not overlap with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE assumes that TB(s) provided by a PDSCH that overlaps with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, are correctly received. For a TBG associated only with PDSCHs that overlap with UL symbols indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE generates a NACK value for the TBG.

If a UE is provided *nrofHARQ-BundlingGroups* and *harq-ACK-SpatialBundlingPUCCH* for a serving cell c, the UE generates HARQ-ACK information over PDSCH reception groups for PDSCH receptions scheduled by a DCI format on the serving cell c where a maximum number of PDSCH reception groups, $N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$, is provided by *nrofHARQ-BundlingGroups*. If the UE detects a DCI format scheduling $N_{\text{PDSCH},c}$ PDSCH receptions on the serving cell c, the UE generates $N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ HARQ-ACK information bits for the $N_{\text{PDSCH},c}$ PDSCH receptions as described in clause 9.1.1 by setting $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}} = N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ and $C = N_{\text{PDSCH},c}$, after binary AND operation of the HARQ-ACK information bits corresponding to the first and second transport blocks of each PDSCH reception. For a PDSCH reception group associated with at least one PDSCH that does not overlap with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE assumes that TBs provided by a PDSCH that overlaps with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, are correctly received. For a PDSCH reception group associated only with PDSCHs that overlap with UL symbols indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE generates a NACK value for the PDSCH reception group.

If a UE is provided *pdsch-TimeDomainAllocationListForMultiPDSCH* and neither provided *nrofHARQ-BundlingGroups* nor *harq-ACK-SpatialBundlingPUCCH* for a serving cell c, the UE generates HARQ-ACK information over transport blocks for PDSCH receptions. If the UE detects a DCI format scheduling $N_{\text{PDSCH},c}$ PDSCH receptions on the serving cell c, the UE generates $N_{\text{PDSCH},c}$ HARQ-ACK information bits for the first TBs in the ascending order of the starting of PDSCH receptions and, if applicable, generates $N_{\text{PDSCH},c}$ HARQ-ACK information bits for the second TBs in the ascending order of the starting of PDSCH receptions. For a PDSCH reception that overlaps with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE generates a NACK value for the first TB and, if applicable, generates a NACK value for the second TB in the PDSCH reception. If $N_{\text{PDSCH},c} < N_{\text{PDSCH},c}^{\text{max}}$, the UE generates a NACK value for the last $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{PDSCH},c}^{\text{max}} - N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{PDSCH},c}$ HARQ-ACK information bits where $N_{\text{TB},c}^{\text{DL}}$ is the value of *maxNrofCodeWordsScheduledByDCI* for serving cell c and $N_{\text{PDSCH},c}^{\text{max}}$ is determined by the maximum number of SLIVs amongst all rows of the TDRA table configured by *pdsch-TimeDomainAllocationListForMultiPDSCH*.

If a UE is provided *pdsch-TimeDomainAllocationListForMultiPDSCH* and *harq-ACK-SpatialBundlingPUCCH* and not provided *nrofHARQ-BundlingGroups* for a serving cell c, the UE generates HARQ-ACK information over PDSCH receptions for PDSCH receptions scheduled by a DCI format on the serving cell c. If the UE detects a DCI format scheduling $N_{\text{PDSCH},c}$ PDSCH receptions on the serving cell c, the UE generates $N_{\text{PDSCH},c}$ HARQ-ACK information bits for the PDSCH receptions in the ascending order of the starting of PDSCH receptions after binary AND operation of the HARQ-ACK information bits corresponding to the first and second transport blocks of each PDSCH reception. For a PDSCH reception that overlaps with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, the UE generates a NACK value for the PDSCH reception. If $N_{\text{PDSCH},c}<N_{\text{PDSCH},c}^{\max}$, the UE generates a NACK value for the last $N_{\text{PDSCH},c}^{\max} - N_{\text{PDSCH},c}$ HARQ-ACK information bits.

If a UE

- is provided *pdsch-TimeDomainAllocationListForMultiPDSCH* and, if provided, *nrofHARQ-BundlingGroups* with value $N_{\text{HARQ-ACK}}^{\text{TBG,max}} > 1$ for $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells; and

- is not provided *pdsch-TimeDomainAllocationListForMultiPDSCH* or is provided *nrofHARQ-BundlingGroups* with value $N_{\text{HARQ-ACK}}^{\text{TBG,max}} = 1$, for $N_{\text{cells}}^{\text{DL,TB}}$ serving cells where $N_{\text{cells}}^{\text{DL,TB}} + N_{\text{cells}}^{\text{DL,TBG}} = N_{\text{cells}}^{\text{DL}}$

the UE determines the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \cdots, \tilde{o}_{O_{\text{ACK}}-1}^{ACK}$ according to the previous pseudo-code with the following modifications

- $N_{\text{cells}}^{\text{DL}}$ is used for the determination of a first HARQ-ACK sub-codebook for
  - SPS PDSCH reception,
  - any DCI format having associated HARQ-ACK information without scheduling PDSCH reception, and
  - PDSCH reception scheduled by a DCI format scheduling one PDSCH
  - PDSCH reception with $N_{\text{HARQ-ACK}}^{\text{TBG,max}} = 1$ for TBG-based HARQ-ACK information on the $N_{\text{cells}}^{\text{DL,TB}}$ serving cells,
- $N_{\text{cells}}^{\text{DL}}$ is replaced by $N_{\text{cells}}^{\text{DL,TBG}}$ for the determination of a second HARQ-ACK sub-codebook corresponding to the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells for TBG-based HARQ-ACK information, or for TB-based HARQ-ACK information corresponding to multiple PDSCH receptions scheduled by a single DCI format, and
- if, for an active DL BWP of a serving cell, the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with value 0 for one or more first CORESETs and is provided *coresetPoolIndex* with value 1 for one or more second CORESETs, and is provided *ackNackFeedbackMode* = *joint*, the serving cell is counted as two times where the first time corresponds to the first CORESETs and the second time corresponds to the second CORESETs, and
  - instead of generating one or two HARQ-ACK information bits per PDSCH for a serving cell from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells, the UE generates $N_{\text{HARQ-ACK,max}}^{\text{TBG,max}}$ HARQ-ACK information bits for the PDSCH receptions scheduled by a DCI format, where $N_{\text{HARQ-ACK,max}}^{\text{TBG,max}}$ is the maximum value between $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ across all $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells if the UE is provided *nrofHARQ-BundlingGroups*, and $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{PDSCH},c}^{\max}$ across all $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells where the UE is not provided *nrofHARQ-BundlingGroups*, and $N_{\text{TB},c}^{\text{DL}}$ is the value of *maxNrofCodeWordsScheduledByDCI* for serving cell c if *harq-ACK-SpatialBundlingPUCCH* is not provided; else, $N_{\text{TB},c}^{\text{DL}} = 1$. If for a serving cell c where the UE is provided *nrofHARQ-BundlingGroups*, it is $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{TBG,max}} < N_{\text{HARQ-ACK,max}}^{\text{TBG,max}}$, the UE generates NACK for the last $N_{\text{HARQ-ACK,max}}^{\text{TBG,max}} - N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{HARQ-ACK},c}^{\text{TBG,max}}$ HARQ-ACK information bits for serving cell c. If for a serving cell c where the UE is not provided *nrofHARQ-BundlingGroups*, it is $N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{PDSCH},c}^{\max} < N_{\text{HARQ-ACK,max}}^{\text{TBG,max}}$, the UE generates NACK for the last $N_{\text{HARQ-ACK,max}}^{\text{TBG,max}} - N_{\text{TB},c}^{\text{DL}} \cdot N_{\text{PDSCH},c}^{\max}$ HARQ-ACK information bits for serving cell c.
  - The pseudo-code operation when *PDSCH-CodeBlockGroupTransmission* is provided is not applicable.
- The counter DAI value and the total DAI value apply separately for each HARQ-ACK sub-codebook.
- The UE generates the HARQ-ACK codebook by appending the second HARQ-ACK sub-codebook to the first HARQ-ACK sub-codebook.

If $O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} \leq 11$ and $N_{\text{cells}}^{\text{DL,TBG}} > 0$, the UE also determines $n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK,TB}} + n_{\text{HARQ-ACK,TBG}}$ for obtaining a PUCCH transmission power, as described in clause 7.2.1, with

$$n_{\text{HARQ-ACK,TBG}} = \left(\left(V_{\text{DAI},m_{\text{last}}}^{\text{DL}} - \sum_{c=0}^{N_{\text{cells}}^{\text{DL,TBG}}-1} U_{\text{DAI},c}^{\text{TBG}}\right) mod(T_D)\right) N_{\text{HARQ-ACK,max}}^{\text{TBG,max}} + \sum_{c=0}^{N_{\text{cells}}^{\text{DL,TBG}}-1} \sum_{m=0}^{M-1} N_{m,c}^{\text{received,TBG}}$$

where

- if $N_{\text{cells}}^{\text{DL}} = 1$, $V_{\text{DAI},m_{\text{last}}}^{\text{DL}}$ is the value of the counter DAI in the last DCI format scheduling more than one PDSCH receptions for any serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells with TBG-based HARQ-ACK information or with TB-based HARQ-ACK information that the UE detects within the M PDCCH monitoring occasions
- if $N_{\text{cells}}^{\text{DL}} > 1$, $V_{\text{DAI},m_{\text{last}}}^{\text{DL}}$ is the value of the total DAI in the last DCI format scheduling more than one PDSCH receptions with TBG-based HARQ-ACK information or with TB-based HARQ-ACK information for any serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells that the UE detects within the M PDCCH monitoring occasions
- $V_{\text{DAI},m_{\text{last}}}^{\text{DL}} = 0$, if the UE does not detect any DCI format scheduling more than one PDSCH receptions with TBG-based HARQ-ACK information or with TB-based HARQ-ACK information for any serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells in any of the M PDCCH monitoring occasions
- $U_{\text{DAI},c}^{\text{TBG}}$ is the total number of DCI formats scheduling more than one PDSCH receptions with TBG-based HARQ-ACK information or with TB-based HARQ-ACK information for any serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells that the UE detects within the M PDCCH monitoring occasions for serving cell c. $U_{\text{DAI},c}^{\text{TBG}} = 0$ if the UE does not detect any DCI format scheduling more than one PDSCH receptions for serving cell c in any of the M PDCCH monitoring occasions
- if *harq-ACK-SpatialBundlingPUCCH* is provided,
  - if *nrofHARQ-BundlingGroups* is provided, $N_{m,c}^{\text{received,TBG}}$ is the number of PDSCH groups that include at least one PDSCH not overlapping with a UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* if provided, that the UE receives in serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells in PDCCH monitoring occasion m and the UE reports corresponding HARQ-ACK information in the PUCCH
  - if *nrofHARQ-BundlingGroups* is not provided, $N_{m,c}^{\text{received,TBG}}$ is the number of PDSCHs that the UE receives in serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells in PDCCH monitoring occasion m and the UE reports corresponding HARQ-ACK information in the PUCCH
- if *harq-ACK-SpatialBundlingPUCCH* is not provided,
  - if *nrofHARQ-BundlingGroups* is provided, $N_{m,c}^{\text{received,TBG}}$ is the number of TBGs including at least one PDSCH not overlapping with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* if provided, that the UE receives in serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells in PDCCH monitoring occasion m and the UE reports corresponding HARQ-ACK information in the PUCCH
  - if *nrofHARQ-BundlingGroups* is not provided, $N_{m,c}^{\text{received,TBG}}$ is the number of transport blocks in PDSCHs that the UE receives in serving cell c from the $N_{\text{cells}}^{\text{DL,TBG}}$ serving cells in PDCCH monitoring occasion m and the UE reports corresponding HARQ-ACK information in the PUCCH.

If a UE is provided by *MC-DCI-SetofCellsToAddModList* a number of sets of serving cells and is provided USS sets to monitor PDCCH for detection of DCI format 1_3, the UE separately applies the following procedures for determining a corresponding second Type-2 HARQ-ACK sub-codebook for scheduling cells associated with DCI format 1_3 that

- schedules PDSCH receptions on more than one serving cells from a set of serving cells, and/or
- does not include a SCell dormancy indication field or the SCell dormancy indication field is reserved, indicates SCell dormancy, and schedules PDSCH reception on one or more serving cells from the set of serving cells
  - in the following, and for the purpose of providing HARQ-ACK information corresponding to SCell dormancy indication, the UE assumes that the UE receives a PDSCH on the serving cell associated with

fields in DCI format 1_3 used for SCell dormancy indication, as described in Clause 10.3, and that the PDSCH provides one transport block that the UE correctly decodes

from the procedures for determining a first Type-2 HARQ-ACK sub-codebook that is associated with unicast SPS PDSCH receptions or with any unicast DCI format scheduling a PDSCH reception on a single serving cell, or has associated HARQ-ACK information without scheduling a PDSCH reception as described in this clause. The UE appends the second Type-2 HARQ-ACK sub-codebook to the first Type-2 HARQ-ACK sub-codebook.

Denote by $N_{C-\mathrm{DAI}}^{\mathrm{DL}}$ the number of bits for the counter DAI field in DCI format 1_3 and set $T_D = 2^{N_{C-\mathrm{DAI}}^{\mathrm{DL}}}$. Denote by $V_{\mathrm{C-DAI},c,m}^{\mathrm{DL}}$ the value of the counter DAI in a DCI format 1_3 scheduling PDSCH receptions on more than one serving cells among the more than one serving cells, in PDCCH monitoring occasion m according to Table 9.1.3-1. Denote by $V_{\mathrm{T-DAI},m}^{\mathrm{DL}}$ the value of the total DAI in DCI format 1_3 scheduling PDSCH receptions on more than one cells in PDCCH monitoring occasion m according to Table 9.1.3-1. The UE assumes a same value of total DAI in all DCI formats 1_3 in PDCCH monitoring occasion m that schedule more than one PDSCH receptions on respective more than one serving cells from a set of serving cells.

The UE determines the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \cdots, \tilde{o}_{O_{\mathrm{ACK}}-1}^{ACK}$, for a total number of O_{ACK} HARQ-ACK information bits in the second Type-2 HARQ-ACK sub-codebook according to the following pseudo-code.

Set $N_{\mathrm{cells,set}}^{\mathrm{DL,max}}$ to the maximum number of serving cells in *ScheduledCell-ListDCI-1-3* of a set of serving cells provided by *MC-DCI-SetofCells*, across the number of sets of serving cells, that can be scheduled PDSCH receptions by DCI format 1_3

Set $N_{\mathrm{sets}}^{\mathrm{TB,max}}$ to the maximum total number of TBs in PDSCH receptions that can be scheduled by a DCI format 1_3 over more than one serving cells in a set of serving cells across the number of sets of serving cells

Set $N_{\mathrm{sets}}^{\mathrm{DL}}$ to the number of sets of serving cells *MC-DCI-SetofCells* in a PUCCH group

Set $N_{\mathrm{cells}}^{\mathrm{DL}}$ to the number of serving cells, across $N_{\mathrm{sets}}^{\mathrm{DL}}$ sets of serving cells in the PUCCH group

Set c to the index of serving cells, $c = 0, \ldots, N_{\mathrm{cells}}^{\mathrm{DL}} - 1$, a lower index corresponds to a lower RRC index of a corresponding serving cell

Set mc to the index of a serving cell, in a set of indexes of serving cells arranged in ascending order, from the set of $N_{\mathrm{cells,set}}^{\mathrm{DL,max}}$ serving cells, $mc = 0, \ldots, N_{\mathrm{cells,set}}^{\mathrm{DL,max}} - 1$

Set $m = 0$ – PDCCH monitoring occasion index for detection of a DCI format 1_3 scheduling PDSCH receptions on more than one serving cells from a set of serving cells: lower index corresponds to earlier PDCCH monitoring occasion

Set $j = 0$

Set $V_{temp} = 0$

Set $V_{temp2} = 0$

Set $V_s = \emptyset$

Set M to the number of PDCCH monitoring occasions

while $m < M$

$c = 0$

if *harq-ACK-SpatialBundlingPUCCH* is not provided,

while $c < N_{\mathrm{cells}}^{\mathrm{DL}}$

if PDCCH monitoring occasion m is before an active UL BWP change on the serving cell of PUCCH transmission if the UE is provided *pucch-sSCellDyn*, or an active UL BWP change on the PCell if the UE is not provided *pucch-sSCellDyn*

$c = c + 1;$

else

if there is a PDSCH reception on serving cell c that is scheduled by a DCI format scheduling more than one PDSCHs that provide respective more than one transport blocks with enabled HARQ-ACK information on respective more than one serving cells, where the DCI format is associated with a PDCCH reception in PDCCH monitoring occasion m and c is the smallest serving cell index among the more than one serving cells

if $V_{C-\mathrm{DAI},c,m}^{\mathrm{DL}} \leq V_{temp}$

$j = j + 1;$

end if

$V_{temp} = V_{C-\mathrm{DAI},c,m}^{\mathrm{DL}};$

if $V_{\mathrm{T\text{-}DAI},m}^{\mathrm{DL}} = \emptyset$

$V_{temp,2} = V_{C-\mathrm{DAI},c,m}^{\mathrm{DL}};$

else

$V_{temp,2} = V_{T-\mathrm{DAI},m}^{\mathrm{DL}};$

end if

$cnt = 0;$

$mc = 0;$

while $mc < N_{\mathrm{cells,set}}^{\mathrm{DL,max}}$

if the UE is scheduled PDSCH reception on serving cell mc, if any, from the more than one serving cells

if *maxNrofCodeWordsScheduledByDCI* is 2 for serving cell mc, if any, from the more than one serving cells

$\tilde{o}^{ACK}_{N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot T_D \cdot j + N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot (V_{C-DAI,c,m}^{DL} - 1) + cnt}$ = HARQ-ACK information bit corresponding to the first transport block of this cell

$\tilde{o}^{ACK}_{N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot T_D \cdot j + N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot (V_{C-DAI,c,m}^{DL} - 1) + 1 + cnt}$ = HARQ-ACK information bit corresponding to the second transport block of this cell

$cnt = cnt + 2;$

else

$\tilde{o}^{ACK}_{N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot T_D \cdot j + N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot (V_{C-DAI,c,m}^{DL} - 1) + cnt}$ = HARQ-ACK information bit corresponding to the transport block of this cell

$cnt = cnt + 1;$

end if

end if

$mc = mc + 1;$

end while

while $cnt < N_{\mathrm{sets}}^{\mathrm{TB,max}}$

$\tilde{o}^{ACK}_{N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot T_D \cdot j + N_{\mathrm{sets}}^{\mathrm{TB,max}} \cdot V_{C-DAI,c,m}^{DL} - 1 + cnt}$ = NACK;

$cnt = cnt + 1;$

end while

$V_s = V_s \cup \{N_{\text{sets}}^{\text{TB,max}} \cdot T_D \cdot j + N_{\text{sets}}^{\text{TB,max}} \cdot (V_{C\text{-DAI},c,m}^{\text{DL}} - 1), \ldots, N_{\text{sets}}^{\text{TB,max}} \cdot T_D \cdot j + N_{\text{sets}}^{\text{TB,max}} \cdot (V_{C\text{-DAI},c,m}^{\text{DL}} - 1) + N_{\text{sets}}^{\text{TB,max}} - 1\};$

end if

$c = c + 1;$

end if

end while

else

while $c < N_{\text{cells}}^{\text{DL}}$

if PDCCH monitoring occasion m is before an active UL BWP change on the serving cell of PUCCH transmission if the UE is provided *pucch-sSCellDyn*, or an active UL BWP change on the PCell if the UE is not provided *pucch-sSCellDyn*

$c = c + 1;$

else

if there is a PDSCH reception on serving cell c that is scheduled by a DCI format scheduling more than one PDSCHs that provide respective more than one transport blocks with enabled HARQ-ACK information on respective more than one serving cells, where the DCI format is associated with a PDCCH reception in PDCCH monitoring occasion m and c is the smallest serving cell index among the more than one serving cells

if $V_{C-\text{DAI},c,m}^{\text{DL}} \leq V_{temp}$

$j = j + 1;$

end if

$V_{temp} = V_{C-\text{DAI},c,m}^{\text{DL}};$

if $V_{\text{T-DAI},m}^{\text{DL}} = \emptyset$

$V_{temp,2} = V_{C-\text{DAI},c,m}^{\text{DL}};$

else

$V_{temp,2} = V_{T-\text{DAI},m}^{\text{DL}};$

end if

$cnt = 0;$

$mc = 0;$

while $mc < N_{\text{cells,set}}^{\text{DL,max}}$

if the UE is scheduled PDSCH reception for transport blocks with enabled HARQ-ACK information on serving cell mc, if any, from the more than one serving cells

if *maxNrofCodeWordsScheduledByDCI* is 2 for serving cell mc

if the PDSCH reception provides two transport blocks

$\tilde{o}^{ACK}_{N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot V^{\text{DL}}_{C\text{-DAI},c,m} - 1 + cnt}$ = binary AND operation of the HARQ-ACK information bits corresponding to the first and second transport blocks of this cell

else

$\tilde{o}^{ACK}_{N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot V^{\text{DL}}_{C\text{-DAI},c,m} - 1 + cnt}$ = HARQ-ACK information bit corresponding to the first transport block of this cell

end if

else

$\tilde{o}^{ACK}_{N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot V^{\text{DL}}_{C\text{-DAI},c,m} - 1 + cnt}$ = HARQ-ACK information bit of this cell

end if

$cnt = cnt + 1;$

end if

$mc = mc + 1;$

end while

while $cnt < N^{\text{DL,max}}_{\text{cells,set}}$

$\tilde{o}^{ACK}_{N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot V^{\text{DL}}_{C\text{-DAI},c,m} - 1 + cnt}$ = NACK;

$cnt = cnt + 1;$

end while

$V_s = V_s \cup \{N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot (V^{\text{DL}}_{C\text{-DAI},c,m} - 1), N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot (V^{\text{DL}}_{C\text{-DAI},c,m} - 1) + 1 \ldots, N^{\text{DL,max}}_{\text{cells,set}} \cdot T_D \cdot j + N^{\text{DL,max}}_{\text{cells,set}} \cdot (V^{\text{DL}}_{C\text{-DAI},c,m} - 1) + N^{\text{DL,max}}_{\text{cells,set}} - 1\};$

end if

$c = c + 1;$

end if

end while

end if

$m = m + 1;$

end while

$V_{temp} = \left(j \bmod \left(\frac{4}{T_D}\right)\right) \times \left(\frac{4}{T_D}\right) + V_{temp};$

if UE does not set $V_{temp2} = V^{UL}_{\text{T}-DAI}$ and $T_D = 2$

$V_{temp2} = V_{temp};$

end if

$j = \left\lfloor \frac{j \times T_D}{4} \right\rfloor;$

if $V_{temp2} < V_{temp}$

$j = j + 1;$

end if

if *harq-ACK-SpatialBundlingPUCCH* is not provided,

$$O^{ACK} = N_{\text{sets}}^{\text{TB,max}} \cdot \left(4 \cdot j + V_{temp2}\right)$$

else

$$O^{ACK} = N_{\text{cells,set}}^{\text{DL,max}} \cdot \left(4 \cdot j + V_{temp2}\right)$$

end if

$\tilde{o}_i^{ACK} = \text{NACK}$ for any $i \in \{0,1,\cdots,O^{ACK}-1\} \backslash V_s$.

If $O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} \leq 11$ and $N_{\text{sets}}^{\text{DL}} > 0$, for obtaining a PUCCH transmission power as described in clause 7.2.1, the UE determines $n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK,0}} + n_{\text{HARQ-ACK,1}}$, where $n_{\text{HARQ-ACK,0}}$ is the value of $n_{\text{HARQ-ACK}}$ for the first Type-2 HARQ-ACK sub-codebook and $n_{\text{HARQ-ACK,1}}$ is the value of $n_{\text{HARQ-ACK}}$ for the second Type-2 HARQ-ACK sub-codebook that is determined as

$$n_{\text{HARQ-ACK}} = \left(\left(V_{\text{DAI},m_{\text{last}}}^{\text{DL}} - \sum_{s=0}^{N_{\text{sets}}^{\text{DL}}-1} U_{\text{DAI},s}\right) mod(T_D)\right) N_{\text{TB,max}}^{\text{DL,MC}} + \sum_{s=0}^{N_{\text{sets}}^{\text{DL}}-1} \sum_{m=0}^{M-1} N_{m,s}^{\text{received}}$$

where

- in the following
  - a DCI format 1_3 schedules more than one PDSCH receptions providing transport blocks with enabled HARQ-ACK information
  - a dormancy indication is considered as a PDSCH reception providing a single transport block with enabled HARQ-ACK information
- $V_{\text{DAI},m_{\text{last}}}^{\text{DL}}$ is the value of the total DAI field in a last DCI format 1_3 the UE detects in a last PDCCH monitoring occasion within the M PDCCH monitoring occasions where the UE detects at least one DCI format 1_3. $V_{\text{DAI},m_{\text{last}}}^{\text{DL}} = 0$ if the UE does not detect any DCI format 1_3 in any of the M PDCCH monitoring occasions.
- $U_{\text{DAI},s}$ is the total number of DCI format 1_3 that the UE detects within the M PDCCH monitoring occasions for the set s of serving cells. $U_{\text{DAI},s} = 0$ if the UE does not detect any DCI format 1_3 associated with scheduling on set s of serving cells in any of the M PDCCH monitoring occasions.
- $N_{\text{TB,max}}^{\text{DL,MC}} = N_{\text{sets}}^{\text{TB,max}}$ if *harq-ACK-SpatialBundlingPUCCH* is not provided; otherwise, $N_{\text{TB,max}}^{\text{DL,MC}} = N_{\text{cells,set}}^{\text{DL,max}}$.
- $N_{m,s}^{\text{received}}$ is
  - the number of transport blocks, in PDSCH receptions not overlapping with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon* or by *tdd-UL-DL-ConfigurationDedicated* if provided, associated with a DCI format 1_3 that the UE detects in PDCCH monitoring occasion m for set s of serving cells, if *harq-ACK-SpatialBundlingPUCCH* is not provided
  - the number of more than one PDSCHs, not overlapping with an UL symbol indicated by *tdd-UL-DL-ConfigurationCommon* or by *tdd-UL-DL-ConfigurationDedicated* if provided, scheduled by a DCI format 1_3 that the UE detects in PDCCH monitoring occasion m for set s of serving cells, if *harq-ACK-SpatialBundlingPUCCH* is provided

Table 9.1.3-1: Value of counter DAI for $N_{C-\mathrm{DAI}}^{\mathrm{DL}} = 2$ and of total DAI

DAI MSB, LSB	$V_{\mathrm{C\text{-}DAI}}^{\mathrm{DL}}$ or $V_{\mathrm{T\text{-}DAI}}^{\mathrm{DL}}$	Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH generating a HARQ-ACK information bit without scheduling a PDSCH reception or providing TCI state update is present, or number of PDCCH monitoring occasions associated with PDCCH for scheduling PDSCH receptions on more than one cells, denoted as Y and $Y \geq 1$
0,0	1	$(Y-1)\, mod\, T_D + 1 = 1$
0,1	2	$(Y-1)\, mod\, T_D + 1 = 2$
1,0	3	$(Y-1)\, mod\, T_D + 1 = 3$
1,1	4	$(Y-1)\, mod\, T_D + 1 = 4$

Table 9.1.3-1A: Value of counter DAI for $N_{C-\mathrm{DAI}}^{\mathrm{DL}} = 1$

DAI	$V_{\mathrm{C\text{-}DAI}}^{\mathrm{DL}}$	Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH generating a HARQ-ACK information bit without scheduling a PDSCH reception or providing TCI state update is present, denoted as Y and $Y \geq 1$
0	1	$(Y-1)\, mod\, T_D + 1 = 1$
1	2	$(Y-1)\, mod\, T_D + 1 = 2$

9.1.3.2 Type-2 HARQ-ACK codebook in physical uplink shared channel

In this clause, a DAI field is either the one corresponding to unicast HARQ-ACK information and associated PDSCH receptions or DCI formats, or is the one corresponding to multicast HARQ-ACK information and associated PDSCH receptions or DCI formats, as described in [5, TS 38.212].

If a UE would multiplex HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by a DCI format that does not include a DAI field, then

- if the UE has not received any PDCCH within the monitoring occasions for DCI formats scheduling PDSCH receptions, or providing a DCI format having associated HARQ-ACK information without scheduling a PDSCH reception, on any serving cell c and the UE does not have HARQ-ACK information in response to a SPS PDSCH reception to multiplex in the PUSCH, as described in clause 9.1.3.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission;
- else, the UE generates the HARQ-ACK codebook as described in clause 9.1.3.1, except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by a DCI format that includes a DAI field, the UE generates the HARQ-ACK codebook as described in clause 9.1.3.1, with the following modifications:

- For the pseudo-code for the HARQ-ACK codebook generation in clause 9.1.3.1, after the completion of the c and m loops, the UE sets $V_{temp2} = V_{\mathrm{T-DAI}}^{\mathrm{UL}}$ where $V_{\mathrm{T-DAI}}^{\mathrm{UL}}$ is the value of the DAI field according to Table 9.1.3-2
  - if the UE multiplexes HARQ-ACK information associated with more than one G-RNTIs for multicast or G-CS-RNTIs, the value of the DAI field $V_{\mathrm{T-DAI}}^{\mathrm{UL}}$ is applicable to each of the more than one G-RNTIs for multicast or each of the G-CS-RNTIs.
- For the case of first and second HARQ-ACK sub-codebooks, the DCI format includes a first DAI field corresponding to the first HARQ-ACK sub-codebook and a second DAI field corresponding to the second HARQ-ACK sub-codebook
- *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

If a UE is not provided *PDSCH-CodeBlockGroupTransmission* and the UE is scheduled for a PUSCH transmission by DCI format that includes a DAI field for unicast PDSCH receptions with value $V_{\mathrm{T\text{-}DAI}}^{\mathrm{UL}} = 4$ and the UE has not received any PDCCH within the monitoring occasions for a unicast DCI format scheduling PDSCH receptions providing transport blocks with enabled HARQ-ACK information or having associated HARQ-ACK information without scheduling PDSCH receptions on any serving cell c, and the UE does not have HARQ-ACK information in response to a SPS PDSCH reception to multiplex in the PUSCH as described in clause 9.1.3.1, the UE does not multiplex HARQ-ACK information associated with unicast DCI format and HARQ-ACK information for SPS PDSCH reception in the PUSCH transmission.

If a UE is provided *PDSCH-CodeBlockGroupTransmission* and the UE is scheduled for a PUSCH transmission by DCI format that includes a DAI field for unicast PDSCH receptions with first value $V_{\text{T-DAI}}^{\text{UL}} = 4$ or with second value $V_{\text{T-DAI}}^{\text{UL}} = 4$ and the UE has not received any PDCCH within the monitoring occasions for a unicast DCI format scheduling PDSCH reception providing a transport block with enabled HARQ-ACK information or having associated HARQ-ACK information without scheduling PDSCH reception on any serving cell c, and the UE does not have HARQ-ACK information in response to a SPS PDSCH reception to multiplex in the PUSCH, as described in clause 9.1.3.1, the UE does not multiplex HARQ-ACK information associated with unicast DCI format and HARQ-ACK information for SPS PDSCH reception for the first sub-codebook or for the second sub-codebook, respectively, in the PUSCH transmission.

If a UE is scheduled for a PUSCH transmission by DCI format that includes a DAI field for multicast PDSCH receptions with value $V_{\text{T-DAI}}^{\text{UL}} = 4$ and the UE has not received any PDCCH within the monitoring occasions for a multicast DCI format scheduling PDSCH reception providing a transport block with enabled HARQ-ACK information or having associated HARQ-ACK information without scheduling PDSCH receptions on any serving cell c, to multiplex in the PUSCH as described in clause 9.1.3.1, the UE does not multiplex multicast HARQ-ACK information associated with a multicast DCI format in the PUSCH transmission.

Table 9.1.3-2: Value of DAI

DAI MSB, LSB	$V_{\text{T-DAI}}^{\text{UL}}$	Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH indicating SPS PDSCH release or providing TCI state update or DCI format 1_1 or DCI format 1_3 indicating SCell dormancy without scheduling a PDSCH reception is present, or number of PDCCH monitoring occasions associated with PDCCH for scheduling PDSCH receptions on more than one cells, denoted as X and $X \geq 1$
0,0	1	$(X-1)\,mod\,4+1=1$
0,1	2	$(X-1)\,mod\,4+1=2$
1,0	3	$(X-1)\,mod\,4+1=3$
1,1	4	$(X-1)\,mod\,4+1=4$

9.1.3.3 Type-2 HARQ-ACK codebook grouping and HARQ-ACK retransmission

If a UE is provided *pdsch-HARQ-ACK-Codebook-r16*, the UE determines HARQ-ACK information for multiplexing in a PUCCH transmission occasion according to the following procedure.

Set g to the value of a PDSCH group index field in a last DCI format that provides a value of g and indicates a PUCCH transmission occasion.

Set $i(g)$ to denote a PUCCH transmission occasion for multiplexing HARQ-ACK information

Set k to the value of a PDSCH-to-HARQ_feedback timing field, if any, in a DCI format providing a value of g

- If the DCI format does not include a PDSCH-to-HARQ_feedback timing field, set k to the value provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16*

Set $h(g)$ to the value of the New feedback indicator field in the last DCI format providing the value of g if the New feedback indicator field includes 1 bit, or to the MSB of the New feedback indicator field in the last DCI format providing the value of g if the New feedback indicator field includes 2 bits

Set $h^{(g+1)mod2}(g)$ to a value of the LSB of the New feedback indicator field in the last DCI format providing the value of g if the New feedback indicator field includes 2 bits, or to $\emptyset$ otherwise

Set $V_{DAI}^{(g+1)mod2}$ to the value of a total DAI field for group $(g+1)mod2$ in the last DCI format providing the value of g

- If $g = 1$ and the UE detects a DCI format that does not include a PDSCH group index field in a PDCCH reception that is after the PDCCH reception for the last DCI format detection providing the value of g and indicating a same slot for a PUCCH transmission occasion, set $V_{\text{DAI}}^{(g+1)mod2} = \emptyset$

Set q to the value of a number of requested PDSCH group(s) field in the last DCI format providing the value of g

A UE does not expect to detect DCI formats with respective

- Number of requested PDSCH group(s) field values of 0, and
- PDSCH-to-HARQ_feedback timing field values that indicate a same PUCCH transmission occasion, and
- PDSCH group index field values that are different

Generate first HARQ-ACK information for PUCCH transmission occasion $i(g)$ in a slot, as described in clause 9.1.3.1, where

- the first HARQ-ACK information corresponds only to detections of DCI formats each providing a same value of g, of $h(g)$, and to detections of DCI formats that do not provide a value of g and $h(g)$ and are associated with a same value of g, of $h(g)$, and at least one of the DCI formats providing a value of k indicating the slot
- at least one of the DCI formats provides a $h(g)$ value
- $m = 0$ corresponds to a PDCCH monitoring occasion, where the UE detects a DCI format that provides a value of g or is associated with a value of g, that is the first PDCCH monitoring occasion after a PDCCH monitoring occasion where the UE detects another DCI format that provides a value different than $h(g)$

The generation of the first HARQ-ACK information for PUCCH transmission occasion $i(g)$ in a slot, as described in clause 9.1.3.1, excludes the generation of HARQ-ACK information for SPS PDSCH receptions.

If $h^{(g+1)mod2}(g) = \emptyset$ or $h^{(g+1)mod2}(g) = h((g+1)mod2)$, generate second HARQ-ACK information for PUCCH transmission occasion $i((g+1)mod2)$ in a slot, as described in clause 9.1.3.1, where

- the second HARQ-ACK information corresponds to detections of DCI formats each providing a same value of $(g+1)mod2$, of $h((g+1)mod2)$ and to detections of DCI formats that do not provide a value of $(g+1)mod2$, of $h((g+1)mod2)$, but are associated with a same value of $(g+1)mod2$, of $h((g+1)mod2)$
- at least one of the DCI formats provides a $h((g+1)mod2)$ value
- $m = 0$ corresponds to a PDCCH monitoring occasion, where the UE detects a DCI format that provides a value of $(g+1)mod2$ or that is associated with a value of $(g+1)mod2$, that is the first PDCCH monitoring occasion after a PDCCH monitoring occasion where the UE detects another DCI format that provides a value different than $h((g+1)mod2)$
- the PUCCH transmission occasion $i((g+1)mod2)$ is a last one for multiplexing second HARQ-ACK information and it is not after PUCCH transmission occasion $i(g)$
- if $V_{\mathrm{DAI}}^{(g+1)mod2} \neq \emptyset$, after the completion of the c and m loops for the pseudo-code for the second HARQ-ACK codebook generation in clause 9.1.3.1, set $V_{temp2} = V_{DAI}^{(g+1)mod2}$. If the UE is provided *PDSCH-CodeBlockGroupTransmission* for $N_{\mathrm{cells}}^{\mathrm{DL,CBG}}$ serving cells, set $V_{temp2} = V_{DAI}^{(g+1)mod2}$ for both sub-codebooks before appending the second sub-codebook to the first sub-codebook.

If $h^{(g+1)mod2}(g) \neq \emptyset$ and $h^{(g+1)mod2}(g) \neq h((g+1)mod2)$, generate second HARQ-ACK information as described in clause 9.1.3.1 by setting $M = 0$ and, after the completion of the c and m loops for the pseudo-code for the second HARQ-ACK codebook generation in clause 9.1.3.1, setting $V_{temp2} = V_{DAI}^{(g+1)mod2}$.

The generation of the second HARQ-ACK information for PUCCH transmission occasion $i((g+1)mod2)$ in a slot, as described in clause 9.1.3.1, excludes the generation of HARQ-ACK information for SPS PDSCH receptions.

If $q = 0$, the UE

includes only the first HARQ-ACK information for multiplexing in PUCCH transmission occasion $i(g)$

elseif $q = 1$

if g = 1

appends the first HARQ-ACK information to the second HARQ-ACK information for multiplexing in PUCCH transmission occasion $i(g)$

else

append the second HARQ-ACK information to the first HARQ-ACK information for multiplexing in PUCCH transmission occasion $i(g)$

end if

end if

The UE appends the HARQ-ACK information corresponding to SPS PDSCH receptions, if any, as described in clause 9.1.3.1, after the first and second, if any, HARQ-ACK information.

If the HARQ-ACK information is multiplexed in a PUSCH transmission, the HARQ-ACK information is determined as

- for multiplexing in PUCCH transmission occasion $i(g)$, if the PUSCH transmission is not scheduled by a DCI format or is scheduled by a DCI format that does not include a DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$

- for multiplexing in PUCCH transmission occasion $i(g)$, if the PUSCH transmission is scheduled by a DCI format without *ul-TotalDAI-Included* configured except that for PDSCH group g, the DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$ in the DCI format is used after the completion of the c and m loops for the pseudo-code for the HARQ-ACK codebook generation in clause 9.1.3.1, and when the HARQ-ACK information multiplexed in the PUCCH transmission occasion $i(g)$ does not include HARQ-ACK information for PDSCH group $(g+1)mod2$

- for multiplexing in PUCCH transmission occasion $i(g)$, if the PUSCH transmission is scheduled by a DCI format without *ul-TotalDAI-Included* configured except that for PDSCH group $g=0$, the DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$ in the DCI format is used after the completion of the c and m loops for the pseudo-code for the HARQ-ACK codebook generation in clause 9.1.3.1, and when the HARQ-ACK information multiplexed in the PUCCH transmission occasion $i(g)$ includes HARQ-ACK information for PDSCH groups g and $(g+1)mod2$

- for multiplexing in PUCCH transmission occasion $i(g)$, if the PUSCH transmission is scheduled by a DCI format without *ul-TotalDAI-Included* configured except that for PDSCH group $g=0$, the DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$ in the DCI format is used after the completion of the c and m loops for the pseudo-code for the HARQ-ACK codebook generation in clause 9.1.3.1, and when the UE has not detected any DCI format scheduling PDSCH receptions, and the UE has not detected any DCI format with a request for HARQ-ACK information for any PDSCH group

- for multiplexing in PUCCH transmission occasion $i(g)$, if the PUSCH transmission is scheduled by a DCI format with *ul-TotalDAI-Included* configured except that MSBs of the DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$ in the DCI format are used for PDSCH group $g=0$, and LSBs of DCI field with value $V_{\mathrm{DAI}}^{\mathrm{UL}}$ in the DCI format are used for PDSCH group $g=1$, after the completion of the c and m loops for the pseudo-code for the HARQ-ACK codebook generation in clause 9.1.3.1.

If a UE is scheduled a PUSCH transmission by DCI format 0_1 having a DAI field value $V_{\mathrm{DAI}}^{\mathrm{UL}}=4$ for a PDSCH group index, and the UE has not detected any DCI format scheduling PDSCH receptions for the PDSCH group index, and the UE has not detected any DCI format with a request for HARQ-ACK information for the PDSCH group index, the UE does not multiplex HARQ-ACK information in the PUSCH transmission for the PDSCH group index.

If a UE detects DCI formats with respective PDSCH-to-HARQ_feedback timing field values indicating a same PUCCH transmission occasion and none of the DCI formats that the UE detects after a last PUCCH transmission occasion for $g=0$ includes a New feedback indicator field for $g=0$, and at least one of the DCI formats is DCI format 1_0, the UE generates HARQ-ACK information only for PDSCH receptions scheduled by detections of DCI format 1_0 and SPS PDSCH releases indicated by detections of DCI format 1_0, as described in clause 9.1.3.1 or 9.1.3.2 for multiplexing in the PUCCH transmission occasion.

If a DCI format indicating a slot for a PUCCH transmission occasion does not include a New feedback indicator field, a PDSCH reception scheduled by the DCI format or a SPS PDSCH release indicated by the DCI format is associated with PDSCH group 0 and a value of $h(g)$ associated with the DCI format is set only if $h(g)$ is provided by another DCI format that provides a value of $h(g)$ for PDSCH group 0 and indicates the slot for the PUCCH transmission occasion.

For PUCCH transmission occasion $i(g)$, the UE determines a PUCCH or a PUSCH transmission to multiplex the HARQ-ACK information according to the procedures in clauses 9.2.3 and 9.2.5.

If $O_{\mathrm{ACK}}+O_{\mathrm{SR}}+O_{\mathrm{CSI}}\leq 11$, the UE determines a number of HARQ-ACK information bits $n_{\mathrm{HARQ-ACK},g}$ for group g and a number of HARQ-ACK information bits $n_{\mathrm{HARQ-ACK},(g+1)mod2}$ for group $(g+1)mod2$ as described in clause 9.1.3.1 where $N_{\mathrm{SPS},c}$ is included in $n_{\mathrm{HARQ-ACK},g}$ and, if $q=1$ and $V_{\mathrm{DAI}}^{(g+1)mod2}\neq\emptyset$, the UE determines

$n_{\text{HARQ-ACK},(g+1)mod2}$ by setting $V_{\text{DAI,m}_{\text{last}}}^{\text{DL}} = V_{DAI}^{(g+1)mod2}$. For obtaining a PUCCH transmission power, if $q = 0$, $n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK},g}$; else, $n_{\text{HARQ-ACK}} = n_{\text{HARQ-ACK},g} + n_{\text{HARQ-ACK},(g+1)\text{mod}2}$.

9.1.4 Type-3 HARQ-ACK codebook determination

If a UE is provided *pdsch-HARQ-ACK-OneShotFeedback* or *pdsch-HARQ-ACK-EnhType3ToAddModList*, the UE determines $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O_{ACK}-1}^{ACK}$ HARQ-ACK information bits, for a total number of O_{ACK} HARQ-ACK information bits, of a Type-3 HARQ-ACK codebook according to the following procedure. If the UE is provided *pdsch-HARQ-ACK-EnhType3ToAddModList* and a DCI format scheduling PDSCH reception and triggering the Type-3 HARQ-ACK codebook includes an enhanced Type 3 codebook indicator field that provides a value for *pdsch-HARQ-ACK-EnhType3Index*, the UE determines a size of a set of indicated serving cells $N_{\text{cells}}^{\text{DL,ind}}$ and a size of a set of indicated HARQ process numbers $N_{\text{HARQ},c}^{\text{DL,ind}}$ for each indicated serving cell and each indicated HARQ process number from the entry in *pdsch-HARQ-ACK-EnhType3ToAddModList* corresponding to the *pdsch-HARQ-ACK-EnhType3Index* value. Each bit from MSB to LSB provided by *perCC* corresponds to a serving cell in ascending order of serving cell index, where value '1' or value '0' indicate HARQ-ACK for the corresponding serving cell is included or not included in the Type 3 HARQ-ACK codebook, respectively. Each bit string provided by *perHARQ* corresponds to a serving cell in ascending order of serving cell index, and each bit from MSB to LSB within a bit string corresponds to a HARQ process number on a corresponding serving cell in ascending order of HARQ process number, where value '1' or value '0' indicate HARQ-ACK for the corresponding HARQ process number on the corresponding serving cell is included or not included in the Type 3 HARQ-ACK codebook, respectively. If the DCI format does not include the enhanced Type 3 codebook indicator field, the *pdsch-HARQ-ACK-EnhType3Index* value is zero.

Set $N_{\text{cells}}^{\text{DL}}$ to the number of configured serving cells or, when applicable, to $N_{\text{cells}}^{\text{DL,ind}}$.

Set $N_{\text{HARQ},c}^{\text{DL}}$ to the value of *nrofHARQ-ProcessesForPDSCH* or *nrofHARQ-ProcessesForPDSCH-v1700* for serving cell c, if provided; else, set $N_{\text{HARQ},c}^{\text{DL}} = 8$. When applicable, set $N_{\text{HARQ},c}^{\text{DL}}$ to $N_{\text{HARQ},c}^{\text{DL,ind}}$.

Set $N_{\text{TB},c}^{\text{DL}}$ to the maximum value of *maxNrofCodeWordsScheduledByDCI* in *PDSCH-config* and *PDSCH-configMulticast* for serving cell c if *harq-ACK-SpatialBundlingPUCCH* is provided and $NDI_{\text{HARQ}} = 0$, or if *harq-ACK-SpatialBundlingPUCCH* is not provided, or if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell c; else, set $N_{\text{TB},c}^{\text{DL}} = 1$.

Set $N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ to the number of HARQ-ACK information bits per TB for PDSCH receptions on serving cell c as described in clause 9.1.1 if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell c and *pdsch-HARQ-ACK-OneShotFeedbackCBG* or *pdsch-HARQ-ACK-EnhType3CBG* corresponding to the *pdsch-HARQ-ACK-EnhType3Index* value is provided; else, set $N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}} = 0$. A UE provided with *pdsch-HARQ-ACK-OneShotFeedbackCBG* or *pdsch-HARQ-ACK-EnhType3CBG* does not expect to be provided with different values of *maxCodeBlockGroupsPerTransportBlock* for different priority indexes in *pdsch-CodeBlockGroupTransmissionList* for serving cell c.

Set $NDI_{\text{HARQ}} = 0$ if *pdsch-HARQ-ACK-OneShotFeedbackNDI* or *pdsch-HARQ-ACK-EnhType3NDI* is provided; else set $NDI_{\text{HARQ}} = 1$.

Set $c = 0$ – serving cell index in the set of serving cells

Set $h = 0$ – HARQ process number index in the set of numbers of HARQ processes

Set $t = 0$ – TB index

Set $g = 0$ – CBG index

Set $j = 0$

while $c < N_{\text{cells}}^{\text{DL}}$

while $h < N_{\text{HARQ},c}^{\text{DL}}$

if *downlinkHARQ-FeedbackDisabled* is not provided, or is provided and indicates enabled HARQ-ACK information for h, or *harq-feedbackEnablingforSPSactive* is provided and enabled and h corresponds to a transport block in a first SPS PDSCH reception after an activation of SPS PDSCH receptions if $NDI_{\mathrm{HARQ}} = 0$

if $N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}} > 0$

while $t < N_{\mathrm{TB},c}^{\mathrm{DL}}$

while $g < N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for CBG g of TB t for HARQ process number index h in the set of numbers of HARQ processes of serving cell c, if any; else, $\tilde{o}_j^{ACK} = 0$

$j = j + 1$

$g = g + 1$

end while

$\tilde{o}_j^{ACK}$ = NDI value indicated in the DCI format corresponding to the HARQ-ACK information bit(s) for TB t for HARQ process number index h in the set of numbers of HARQ processes on serving cell c, if any; else, $\tilde{o}_j^{ACK} = 0$

$g = 0$

$j = j + 1$

$t = t + 1$

end while

else

while $t < N_{\mathrm{TB},c}^{\mathrm{DL}}$

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for TB t for HARQ process index h in the set of numbers of HARQ processes of serving cell c, if any; else, $\tilde{o}_j^{ACK} = 0$

$j = j + 1$

$\tilde{o}_j^{ACK}$ = NDI value indicated in the DCI format corresponding to the HARQ-ACK information bit(s) for TB t for HARQ process number index h in the set of numbers of HARQ processes on serving cell c, if any; else, $\tilde{o}_j^{ACK} = 0$

$j = j + 1$

$t = t + 1$

end while

end if

$t = 0$

else

if $N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}} > 0$

while $t < N_{\mathrm{TB},c}^{\mathrm{DL}}$

if UE has obtained HARQ-ACK information for TB t for HARQ process number index h in the set of numbers of HARQ processes on serving cell c corresponding to a PDSCH reception and has not reported the HARQ-ACK information corresponding to the PDSCH reception

while $g < N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for CBG g of TB t for HARQ process number index h in the set of numbers of HARQ processes of serving cell c

$j = j + 1$

$g = g + 1$

end while

else

while $g < N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$

$\tilde{o}_j^{ACK} = \text{NACK}$

$j = j + 1$

$g = g + 1$

end while

end if

$g = 0$

$t = t + 1$

end while

else

while $t < N_{\text{TB},c}^{\text{DL}}$

if UE has obtained HARQ-ACK information for TB t for HARQ process number index h in the set of numbers of HARQ processes on serving cell c corresponding to a PDSCH reception and has not reported the HARQ-ACK information corresponding to the PDSCH reception

if *harq-ACK-SpatialBundlingPUCCH* is not provided

$\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for TB t for HARQ process number index h in the set of numbers of HARQ processes of serving cell c

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK information bits corresponding to first and second transport blocks for HARQ process number index h in the set of numbers of HARQ processes of serving cell c. If the UE receives one transport block, the UE assumes ACK for the second transport block

end if

$j = j + 1$

$t = t + 1$

else

$\tilde{o}_j^{ACK} = \text{NACK}$

$j = j + 1$

$t = t + 1$

end if

end while

end if

$t = 0$

end if

end if

$h = h + 1$

end while

$h = 0$

$c = c + 1$

end while

If $N_{\mathrm{TB},c}^{\mathrm{DL}} > 1$, when a UE receives a PDSCH with one transport block, the HARQ-ACK information is associated with the first transport block.

If a UE receives a SPS PDSCH, or a PDSCH that is scheduled by a DCI format that does not support CBG-based PDSCH receptions for a serving cell c, and if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell c, and *pdsch-HARQ-ACK-OneShotFeedbackCBG* or *pdsch-HARQ-ACK-EnhType3CBG* corresponding to the *pdsch-HARQ-ACK-EnhType3Index* value is provided, the UE repeats $N_{\mathrm{HARQ-ACK},c}^{\mathrm{CBG/TB,max}}$ times the HARQ-ACK information for the transport block, if any, in the PDSCH.

If a UE detects a DCI format that includes a One-shot HARQ-ACK request field with value 1, the UE determines a PUCCH or a PUSCH to multiplex a Type-3 HARQ-ACK codebook for transmission in a slot as described in clauses 9.2.3 and 9.2.5. If the UE is provided a periodic cell switching pattern for PUCCH transmissions by *pucch-sSCellPattern*, the UE determines the slot and a corresponding cell based on the periodic cell switching pattern as described in clause 9.A. The UE multiplexes only the Type-3 HARQ-ACK codebook in the PUCCH or the PUSCH for transmission in the slot. If the UE is provided *pdsch-HARQ-ACK-EnhType3ToAddModList*, the UE expects that HARQ-ACK information in a Type-1 or Type-2 HARQ-ACK codebook in a slot is associated with HARQ process(es) of the Type-3 HARQ-ACK codebook in the slot.

If

- a UE detects a DCI format that includes a One-shot HARQ-ACK request field with value 1, and
- the CRC of the DCI is scrambled by a C-RNTI or an MCS-C-RNTI, and

if for one or more serving cells

- *resourceAllocation* = *resourceAllocationType0* and all bits of the frequency domain resource assignment field in the DCI format are equal to 0, or
- *resourceAllocation* = *resourceAllocationType1* and all bits of the frequency domain resource assignment field in the DCI format are equal to 1, or
- *resourceAllocation = dynamicSwitch* and all bits of the frequency domain resource assignment field in the DCI format are equal to 0 or 1

the DCI format provides a request for a Type-3 HARQ-ACK codebook report and does not schedule a PDSCH reception on the one or more serving cells. If the UE is provided *pdsch-HARQ-ACK-EnhType3ToAddModList* and the DCI format includes an enhanced Type 3 codebook indicator field that provides a value for *pdsch-HARQ-ACK-EnhType3Index*, the UE determines a size of a set of indicated serving cells $N_{\mathrm{cells}}^{\mathrm{DL,ind}}$ and a size of a set of indicated HARQ process numbers $N_{\mathrm{HARQ},c}^{\mathrm{DL,ind}}$ for each indicated serving cell and each indicated HARQ process number from the entry in *pdsch-HARQ-ACK-EnhType3ToAddModList* corresponding to the *pdsch-HARQ-ACK-EnhType3Index* value. If the DCI format does not include the enhanced Type 3 codebook indicator field, the *pdsch-HARQ-ACK-EnhType3Index* value is provided by the value of

- the MCS field for transport block 1 if the DCI format is DCI format 1_1,
- the MCS field if the DCI format is DCI format 1_2,

- the MCS field for transport block 1 of a serving cell with smallest index among the one or more serving cells if the DCI format is DCI format 1_3.

The UE is expected to provide HARQ-ACK information in response to the request for the Type-3 HARQ-ACK codebook after N symbols from the last symbol of a PDCCH providing the DCI format, where the value of N is provided in clause 10.2 by replacing "SPS PDSCH release" with "DCI format".

If a UE multiplexes HARQ-ACK information in a PUSCH transmission, the UE generates the HARQ-ACK codebook as described in this clause except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

9.1.5 HARQ-ACK codebook retransmission

With reference to slots of PUCCH transmissions on the primary cell and for Type-1 or Type-2 HARQ-ACK codebooks, a UE that transmitted or would transmit a PUCCH or a PUSCH with a first HARQ-ACK codebook in slot m can be indicated by a DCI format with CRC scrambled by a C-RNTI or a MCS-C-RNTI that does not schedule a PDSCH reception [4, TS 38.212] and is received in a PDCCH ending in slot n, to transmit a PUCCH with the first HARQ-ACK codebook in slot $n+k$, where slot $n+k$ is after slot m. The UE determines k and a resource for the PUCCH transmission as described in clauses 9.2.3 and 9.2.5. If the UE is provided a periodic cell switching pattern for PUCCH transmissions by *pucch-sSCellPattern*, the UE further determines a corresponding cell based on the periodic cell switching pattern as described in clause 9.A.

If the HARQ-ACK retransmission indicator field value in a DCI format is '1', the UE determines slot m as $m = n - l$ where l is determined by a one-to-one mapping in ascending order among the values from -7 to 24 and the values of

- the MCS field for transport block 1 if the DCI format is DCI format 1_1
- the MCS field if the DCI format is DCI format 1_2
- the MCS field for transport block 1 for a serving cell if the DCI format is DCI format 1_3, where the serving cell is the one with smallest index that has
  - *resourceAllocation* = *resourceAllocationType0* and all bits of the corresponding block of the frequency domain resource assignment field equal to 0, or
  - *resourceAllocation* = *resourceAllocationType1* and all bits of the corresponding block of the frequency domain resource assignment field equal to 1, or
  - *resourceAllocation = dynamicSwitch* and all bits of the corresponding block of the frequency domain resource assignment field equal to 0 or 1

If the DCI format includes a priority indicator field having a value, a priority value of first HARQ-ACK information in the first HARQ-ACK codebook is same as the value of the priority indicator field; otherwise, the priority value of the first HARQ-ACK information is zero.

If a UE

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on active DL BWPs of serving cells, and
- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on active DL BWPs of the serving cells, and
- is provided *ackNackFeedbackMode* = *separate*

the first HARQ-ACK codebook is associated with the first CORESETs or with the second CORESETs, as described in clause 9, when the UE receives the PDCCH providing the DCI format in a CORESET from the first CORESETs or from the second CORESETs, respectively.

If the UE would also multiplex in the PUCCH transmission in slot $n+k$ a second HARQ-ACK codebook with second HARQ-ACK information of same priority value as for the first HARQ-ACK information in the first HARQ-ACK codebook, the UE appends the first HARQ-ACK codebook to the second HARQ-ACK codebook. The UE determines to multiplex the second HARQ-ACK information in the PUCCH transmission in slot $n+k$ as described in clause 9.2.3. O_{ACK} is the total number of the first HARQ-ACK information bits and the second HARQ-ACK information bits if any.

If the UE performs a procedure for deferring third HARQ-ACK information for SPS PDSCH receptions to slot $n+k$, as described in clause 9.2.5.4, and the third HARQ-ACK information has same priority value as a priority value indicated by the DCI format triggering the PUCCH transmission in slot $n+k$, the UE multiplexes in the PUCCH transmission in slot $n+k$ the first HARQ-ACK information with the priority value that results in slot $n+k$ according to the procedure in this clause, by appending the third HARQ-ACK information to the first HARQ-ACK information. If the UE would also multiplex in the PUCCH transmission in slot $n+k$ the second HARQ-ACK information with the priority value, the UE appends the first HARQ-ACK information followed by the third HARQ-ACK information to the second HARQ-ACK information. O_{ACK} is the total number of the first HARQ-ACK information bits, the second HARQ-ACK information bits if any and the third HARQ-ACK information bits if any.

If in slot m the UE would transmit a first PUCCH with first HARQ-ACK information over more than one slot and a second PUCCH with second HARQ-ACK information over one or more slots, where the first and second HARQ-ACK information have same priority value, the UE multiplexes in the PUCCH transmission in slot $n+k$ one of

- the first HARQ-ACK information if the first PUCCH starts at an earlier slot than the second PUCCH, or
- the second HARQ-ACK information if the second PUCCH starts at an earlier slot than the first PUCCH.

If $O_{\mathrm{ACK}}+O_{\mathrm{SR}}+O_{\mathrm{CSI}}\leq 11$, the UE determines a number of HARQ-ACK information bits for obtaining a transmission power for a PUCCH, as described in clause 7.2.1, as $n_{\mathrm{HARQ-ACK}}=\ n_{\mathrm{HARQ-ACK,0}}+n_{\mathrm{HARQ-ACK,1}}+n_{\mathrm{HARQ-ACK,2}}$ where

- $n_{\mathrm{HARQ-ACK,0}}$ is the number of HARQ-ACK information bits that the UE determines as described in clause 9.1.2.1 or 9.1.3.1 for the first HARQ-ACK information bits,
- $n_{\mathrm{HARQ-ACK,1}}$ is the number of HARQ-ACK information bits, if any, that the UE determines as described in clause 9.1.2.1 or 9.1.3.1 for the second HARQ-ACK information bits,
- $n_{\mathrm{HARQ-ACK,2}}$ is determined as described in clause 9.1.2.1 or 9.1.3.1 for the third HARQ-ACK information bits for SPS PDSCH receptions deferred to slot $n+k$, if any.

9.2 UCI reporting in physical uplink control channel

UCI types reported in a PUCCH include HARQ-ACK information, SR, LRR, and CSI. UCI bits include HARQ-ACK information bits, if any, SR information bits, if any, LRR information bit, if any, and CSI bits, if any. The HARQ-ACK information bits correspond to a HARQ-ACK codebook as described in clause 9.1. For the remaining of this clause, any reference to SR is applicable for SR and/or for LRR.

A UE may transmit one or two PUCCHs on a serving cell in different symbols within a slot. When the UE transmits two PUCCHs in a slot and the UE is not provided *ackNackFeedbackMode* = *separate*, at least one of the two PUCCHs uses PUCCH format 0 or PUCCH format 2.

If a UE is provided *ackNackFeedbackMode* = *separate*, the UE may transmit up to two PUCCHs with HARQ-ACK information in different symbols within a slot.

In clauses 9.2.3, 9.2.5.1, 9.2.5.2 and 9.2.5.3, a UE assumes 11 CRC bits if a number of respective UCI bits is larger than or equal to 360; otherwise, the UE determines a number of CRC bits based on the number of respective UCI bits as described in [5, TS 38.212].

9.2.1 PUCCH Resource Sets

If a UE does not have dedicated PUCCH resource configuration, provided by *PUCCH-ResourceSet* in *PUCCH-Config*, a PUCCH resource set is provided by *pucch-ResourceCommon* through an index to a row of Table 9.2.1-1 for transmission of HARQ-ACK information on PUCCH in an initial UL BWP of $N_{\mathrm{BWP}}^{\mathrm{size}}$ PRBs. For operation in FR2-2, *nrofPRBs* provided in *PUCCH-ConfigCommon* can also provide a number of N_{RB} RBs for the PUCCH resource set; otherwise $N_{RB}=1$.

The PUCCH resource set includes sixteen resources, each corresponding to a PUCCH format, a first symbol, a duration, a PRB offset $RB_{\mathrm{BWP}}^{\mathrm{offset}}$, and a cyclic shift index set for a PUCCH transmission.

The UE transmits a PUCCH using frequency hopping if not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*; otherwise, the UE transmits a PUCCH without frequency hopping.

An orthogonal cover code with index 0 is used for a PUCCH resource with PUCCH format 1 in Table 9.2.1-1 except when index 3, 7, or 11 is indicated by *pucch-ResourceCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* is provided.

The UE transmits the PUCCH using the same spatial domain transmission filter as for a PUSCH transmission scheduled by a RAR UL grant as described in clause 8.3.

If a UE is not provided any of *pdsch-HARQ-ACK-Codebook*, *pdsch-HARQ-ACK-Codebook-r16*, or *pdsch-HARQ-ACK-OneShotFeedback*, the UE generates at most one HARQ-ACK information bit.

If the UE provides HARQ-ACK information in a PUCCH transmission in response to detecting a DCI format scheduling a PDSCH reception or having associated HARQ-ACK information without scheduling a PDSCH reception, the UE determines a PUCCH resource with index r_{PUCCH}, $0 \le r_{\text{PUCCH}} \le 15$, as $r_{\text{PUCCH}} = \left\lfloor \frac{2 \cdot n_{\text{CCE},0}}{N_{\text{CCE}}} \right\rfloor + 2 \cdot \Delta_{\text{PRI}}$, where N_{CCE} is a number of CCEs in a CORESET of a PDCCH reception with the DCI format, as described in clause 10.1, $n_{\text{CCE},0}$ is the index of a first CCE for the PDCCH reception, and Δ_{PRI} is a value of the PUCCH resource indicator field in the DCI format.

When the PDCCH reception by a UE includes first and second PDCCH candidates from respective first and second search space sets, as described in clause 10.1, the CORESET and $n_{\text{CCE},0}$ are associated with the search space set having the smaller index. If

- the first search space set has larger index than the second search space set and includes the first PDCCH candidate and a third PDCCH candidate that have same first CCE index and CCE aggregation levels 8 and 16, or 16 and 8, respectively,
- the second search space set includes the second PDCCH candidate that has same index and same CCE aggregation level as the first PDCCH candidate, and a fourth PDCCH candidate that has same index and same CCE aggregation level as the third PDCCH candidate,
- the CORESET associated with the first search space set has *cce-REG-MappingType* = '*nonInterleaved*' and has duration of one symbol, and
- the second PDCCH candidate has different first CCE index than the fourth PDCCH candidate

the UE determines $n_{\text{CCE},0}$ from the PDCCH candidate with CCE aggregation level 16 among the second PDCCH candidate and the fourth PDCCH candidate.

If $\lfloor r_{\text{PUCCH}}/8 \rfloor = 0$ and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as $RB_{\text{BWP}}^{\text{offset}} \cdot N_{RB} + \lfloor r_{\text{PUCCH}}/N_{\text{CS}} \rfloor \cdot N_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $N_{\text{BWP}}^{\text{size}} - RB_{\text{BWP}}^{\text{offset}} \cdot N_{RB} - (1 + \lfloor r_{\text{PUCCH}}/N_{\text{CS}} \rfloor) \cdot N_{RB}$, where N_{CS} is the total number of initial cyclic shift indexes in the set of initial cyclic shift indexes
- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $r_{\text{PUCCH}} \bmod N_{\text{CS}}$

If $\lfloor r_{\text{PUCCH}}/8 \rfloor = 1$ and a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines the lowest PRB index of the PUCCH transmission in the first hop as $N_{\text{BWP}}^{\text{size}} - RB_{\text{BWP}}^{\text{offset}} \cdot N_{RB} - (1 + \lfloor (r_{\text{PUCCH}} - 8)/N_{\text{CS}} \rfloor) \cdot N_{RB}$ and the lowest PRB index of the PUCCH transmission in the second hop as $RB_{\text{BWP}}^{\text{offset}} \cdot N_{RB} + \lfloor (r_{\text{PUCCH}} - 8)/N_{\text{CS}} \rfloor \cdot N_{RB}$
- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $(r_{\text{PUCCH}} - 8) \bmod N_{\text{CS}}$

If a UE is provided a PUCCH resource by *pucch-ResourceCommon* and is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon*

- the UE determines for the PUCCH resource an interlace index m as $m = (m_0 + \lfloor r_{\text{PUCCH}}/N_{\text{CS}} \rfloor) \bmod M$ where M is a number of interlaces [4, TS 38.211] and $m_0 = RB_{\text{BWP}}^{\text{offset}}$ is an interlace index offset and $RB_{\text{BWP}}^{\text{offset}}$ is as given in Table 9.2.1-1

- the UE determines an initial cyclic shift index in a set of initial cyclic shift indexes as $r_{\mathrm{PUCCH}} \bmod N_{\mathrm{CS}}$, where N_{CS} is the total number of initial cyclic shifts indexes in the set of initial cyclic shift indexes in Table 9.2.1-1

- if *pucch-ResourceCommon* indicates

  - index 0: the first symbol is 9 for a PUCCH resource with PUCCH format 0 if $r_{\mathrm{PUCCH}} \geq 10$

  - index 1 or 2: the first symbol is 9 for a PUCCH resource with PUCCH format 0 if $r_{\mathrm{PUCCH}} = 15$

  - index 3, 7, or 11: an orthogonal cover code with index 1 is used for a PUCCH resource with PUCCH format 1 if $r_{\mathrm{PUCCH}} \geq 10$; otherwise, an orthogonal cover code with index 0 is used for a PUCCH resource with PUCCH format 1

- the UE does not expect *pucch-ResourceCommon* to indicate index 15

Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration

Index	PUCCH format	First symbol	Number of symbols	PRB offset $RB_{\mathrm{BWP}}^{\mathrm{offset}}$	Set of initial CS indexes
0	0	12	2	0	{0, 3}
1	0	12	2	0	{0, 4, 8}
2	0	12	2	3	{0, 4, 8}
3	1	10	4	0	{0, 6}
4	1	10	4	0	{0, 3, 6, 9}
5	1	10	4	2	{0, 3, 6, 9}
6	1	10	4	4	{0, 3, 6, 9}
7	1	4	10	0	{0, 6}
8	1	4	10	0	{0, 3, 6, 9}
9	1	4	10	2	{0, 3, 6, 9}
10	1	4	10	4	{0, 3, 6, 9}
11	1	0	14	0	{0, 6}
12	1	0	14	0	{0, 3, 6, 9}
13	1	0	14	2	{0, 3, 6, 9}
14	1	0	14	4	{0, 3, 6, 9}
15	1	0	14	$\lfloor N_{\mathrm{BWP}}^{\mathrm{size}}/4 \rfloor$	{0, 3, 6, 9}

If a UE has dedicated PUCCH resource configuration, the UE is provided by higher layers with one or more PUCCH resources.

A PUCCH resource includes the following parameters:

- a PUCCH resource index provided by *pucch-ResourceId*

- an index of the first PRB prior to frequency hopping or for no frequency hopping by *startingPRB*, if a UE is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- an index of the first PRB after frequency hopping by *secondHopPRB*, if a UE is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- an indication for intra-slot frequency hopping by *intraSlotFrequencyHopping*, if a UE is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- an index of a first interlace by *interlace0*, if a UE is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- if provided, an index of a second interlace by *interlace1*, if a UE is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- an index of an RB set by *rb-SetIndex*, if a UE is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- an indication for applying one or both of *TCI-State* or *TCI-UL-State* by *apply-IndicatedTCIState*, if provided

- a configuration for a PUCCH format provided by *format*

For operation with shared spectrum channel access, the UE does not expect that two hops of a PUCCH transmission are in different RB sets.

The UE expects that *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* are provided either in all UL BWPs or in none of the UL BWPs for a serving cell.

If a UE is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*, the UE determines available RBs for PUCCH transmissions within the active UL BWP as the intersection of RBs corresponding to an interlace index provided by *interlace0* and, if provided, *interlace1*, and RBs of an RB set provided by *rb-SetIndex*. The intersection results in $M_{\mathrm{interlace},0}^{\mathrm{PUCCH}}$ RBs in the first interlace and the UE expects that $M_{\mathrm{interlace},0}^{\mathrm{PUCCH}}$ is either 10 or 11. If *interlace1* is provided, the intersection results in $M_{\mathrm{interlace},1}^{\mathrm{PUCCH}}$ RBs in the second interlace and the UE expects that $M_{\mathrm{interlace},1}^{\mathrm{PUCCH}}$ is either 10 or 11.

If the *format* indicates *PUCCH-format0*, the PUCCH format configured for a PUCCH resource is PUCCH format 0, where the PUCCH resource also includes an index for an initial cyclic shift provided by *initialCyclicShift*, a number of symbols for a PUCCH transmission provided by *nrofSymbols*, a first symbol for the PUCCH transmission provided by *startingSymbolIndex*. For PUCCH transmission in FR2-2, the PUCCH resource can also include a number of PRBs $M_{\mathrm{RB}}^{\mathrm{PUCCH},0}$ provided by *nrofPRBs*; otherwise, $M_{\mathrm{RB}}^{\mathrm{PUCCH},0} = 1$.

If the *format* indicates *PUCCH-format1*, the PUCCH format configured for a PUCCH resource is PUCCH format 1, where the PUCCH resource also includes an index for an initial cyclic shift provided by *initialCyclicShift*, a number of symbols for a PUCCH transmission provided by *nrofSymbols*, a first symbol for the PUCCH transmission provided by *startingSymbolIndex*, and an index for an orthogonal cover code by *timeDomainOCC*. For PUCCH transmission in FR2-2, the PUCCH resource can also include a number of PRBs $M_{\mathrm{RB}}^{\mathrm{PUCCH},1}$ provided by *nrofPRBs*; otherwise, $M_{\mathrm{RB}}^{\mathrm{PUCCH},1} = 1$.

If the *format* indicates *PUCCH-format2* or *PUCCH-format3*, the PUCCH format configured for a PUCCH resource is PUCCH format 2 or PUCCH format 3, respectively, where the PUCCH resource also includes a number of PRBs provided by *nrofPRBs*, a number of symbols for a PUCCH transmission provided by *nrofSymbols*, and a first symbol for the PUCCH transmission provided by *startingSymbolIndex*. If a UE is provided by *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*, and the *format* indicates *PUCCH-format2* or *PUCCH-format3* and *PUCCH-ResourceExt* is provided, the PUCCH resource also includes an index of a second interlace by *interlace1*, if provided; otherwise, if *interlace1* is not provided, the PUCCH resource also includes, if provided, an orthogonal cover code length by *occ-Length* and an orthogonal cover code index by *occ-Index*. If the *format* indicates *PUCCH-format3* and *PUCCH-ResourceExt* is provided, the UE assumes that the $M_{\mathrm{RB}}^{\mathrm{PUCCH},3}$ [4, TS 38.211] PRBs with the lowest indexes within the first, and if configured, second interlace are used for PUCCH transmission.

If the *format* indicates *PUCCH-format4*, the PUCCH format configured for a PUCCH resource is PUCCH format 4, where the PUCCH resource also includes a number of symbols for a PUCCH transmission provided by *nrofSymbols*, an orthogonal cover code length by *occ-Length*, an orthogonal cover code index by *occ-Index*, and a first symbol for the PUCCH transmission provided by *startingSymbolIndex*. For PUCCH transmission in FR2-2, the PUCCH resource can also include a number of PRBs $M_{\mathrm{RB}}^{\mathrm{PUCCH},4}$ provided by *nrofPRBs*; otherwise, $M_{\mathrm{RB}}^{\mathrm{PUCCH},4} = 1$.

If a UE is provided *subslotLengthForPUCCH* in a *PUCCH-Config*, the first symbol of a PUCCH resource provided by *PUCCH-ResourceSet* or *SPS-PUCCH-AN-List* in *PUCCH-Config* or by *n1PUCCH-AN* in SPS-Config for multiplexing HARQ-ACK in a PUCCH transmission is relative to the first symbol of the *subslotLengthForPUCCH* symbols [12, TS 38.331]. For the remaining cases, the first symbol of a PUCCH resource is relative to the first symbol of a slot with $N_{\mathrm{symb}}^{\mathrm{slot}}$ symbols [4, TS 38.211].

A UE can be configured up to four sets of PUCCH resources in a *PUCCH-Config*. A PUCCH resource set is provided by *PUCCH-ResourceSet* and is associated with a PUCCH resource set index provided by *pucch-ResourceSetId*, with a set of PUCCH resource indexes provided by *resourceList* that provides a set of *pucch-ResourceId* used in the PUCCH resource set, and with a maximum number of UCI information bits the UE can transmit using a PUCCH resource in the PUCCH resource set provided by *maxPayloadSize*. For the first PUCCH resource set, the maximum number of UCI information bits is 2. A maximum number of PUCCH resource indexes for a set of PUCCH resources is provided by *maxNrofPUCCH-ResourcesPerSet*. The maximum number of PUCCH resources in the first PUCCH resource set is 32 and the maximum number of PUCCH resources in the other PUCCH resource sets is 8.

If the UE transmits O_{UCI} UCI information bits, that include HARQ-ACK information bits, the UE determines a PUCCH resource set to be

- a first set of PUCCH resources with *pucch-ResourceSetId* = 0 if $O_{\mathrm{UCI}} \leq 2$ including 1 or 2 HARQ-ACK information bits and a positive or negative SR on one SR transmission occasion if transmission of HARQ-ACK information and SR occurs simultaneously, or

- a second set of PUCCH resources with *pucch-ResourceSetId* = 1, if provided by higher layers, if $2 < O_{\mathrm{UCI}} \leq N_2$ where N_2 is equal to *maxPayloadSize* if *maxPayloadSize* is provided for the PUCCH resource set with *pucch-ResourceSetId* = 1; otherwise N_2 is equal to 1706, or

- a third set of PUCCH resources with *pucch-ResourceSetId* = 2, if provided by higher layers, if $N_2 < O_{\mathrm{UCI}} \leq N_3$ where N_3 is equal to *maxPayloadSize* if *maxPayloadSize* is provided for the PUCCH resource set with *pucch-ResourceSetId* = 2; otherwise N_3 is equal to 1706, or

- a fourth set of PUCCH resources with *pucch-ResourceSetId* = 3, if provided by higher layers, if $N_3 < O_{\mathrm{UCI}} \leq 1706$.

If the UE is provided *SPS-PUCCH-AN-List* and transmits O_{UCI} UCI information bits that include only HARQ-ACK information bits in response to one or more SPS PDSCH receptions and SR, if any, the UE determines a PUCCH resource to be

- a PUCCH resource provided by *sps-PUCCH-AN-ResourceID* obtained from the first entry in *sps-PUCCH-AN-List* if $O_{\mathrm{UCI}} \leq 2$ including 1 or 2 HARQ-ACK information bits and a positive or negative SR on one SR transmission occasion if transmission of HARQ-ACK information and SR occurs simultaneously, or

- a PUCCH resource provided by *sps-PUCCH-AN-ResourceID* obtained from the second entry in *sps-PUCCH-AN-List*, if provided, if $2 < O_{\mathrm{UCI}} \leq N_{1,SPS}$ where $N_{1,SPS}$ is either provided by *maxPayloadSize* obtained from the second entry in *sps-PUCCH-AN-List* or is otherwise equal to 1706, or

- a PUCCH resource provided by *sps-PUCCH-AN-ResourceID* obtained from the third entry in *sps-PUCCH-AN-List*, if provided, if $N_{1,SPS} < O_{\mathrm{UCI}} \leq N_{2,SPS}$ where $N_{2,SPS}$ is either provided by *maxPayloadSize* obtained from the third entry in *sps-PUCCH-AN-List* or is otherwise equal to 1706, or

- a PUCCH resource provided by *sps-PUCCH-AN-ResourceID* obtained from the fourth entry in *sps-PUCCH-AN-List*, if provided, if $N_{2,SPS} < O_{\mathrm{UCI}} \leq N_{3,SPS}$ where $N_{3,SPS}$ is equal to 1706.

9.2.2 PUCCH Formats for UCI transmission

If a UE is not transmitting PUSCH, and the UE is transmitting UCI, the UE transmits UCI in a PUCCH using

- PUCCH format 0 if
  - the transmission is over 1 symbol or 2 symbols,
  - the number of HARQ-ACK information bits with positive or negative SR (HARQ-ACK/SR bits) is 1 or 2
- PUCCH format 1 if
  - the transmission is over 4 or more symbols,
  - the number of HARQ-ACK/SR bits is 1 or 2
- PUCCH format 2 if
  - the transmission is over 1 symbol or 2 symbols,
  - the number of UCI bits is more than 2
- PUCCH format 3 if
  - the transmission is over 4 or more symbols,
  - the number of UCI bits is more than 2,
  - the PUCCH resource does not include an orthogonal cover code, or the UE is provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

- PUCCH format 4 if
  - the transmission is over 4 or more symbols,
  - the number of UCI bits is more than 2,
  - the PUCCH resource includes an orthogonal cover code and the UE is not provided *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*

A spatial setting for a PUCCH transmission by a UE is provided by

- an indicated *TCI-State* or *TCI-UL-State*, if provided, as described in [6, TS 38.214];
- *PUCCH-SpatialRelationInfo* if the UE is configured with a single value for *pucch-SpatialRelationInfoId*;
- as described in [11, TS 38.321], if the UE is provided multiple values for *PUCCH-SpatialRelationInfo*. The UE applies corresponding actions in [11, TS 38.321] and a corresponding setting for a spatial domain filter to transmit PUCCH in the first slot that is after slot $k + 3 \cdot N_{\text{slot}}^{\text{subframe},\mu}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information with ACK value corresponding to a PDSCH reception providing the *PUCCH-SpatialRelationInfo*, each slot consists of $N_{\text{symb}}^{\text{slot}}$ symbols as defined in [4, TS 38.211], and μ is the SCS configuration for the PUCCH
  - If *PUCCH-SpatialRelationInfo* or the indicated *TCI-UL-State* provides *ssb-Index*, the UE transmits the PUCCH using a same spatial domain filter as for a reception of a SS/PBCH block with index provided by *ssb-Index* for a same serving cell or, if *servingCellId* is provided, for a serving cell indicated by *servingCellId*
  - else if *PUCCH-SpatialRelationInfo* or the indicated *TCI-UL-State* provides *csi-RS-Index*, or the indicated *TCI-State* provides *csi-rs* configured with *qcl-Type* set to 'typeD', the UE transmits the PUCCH using a same spatial domain filter as for a reception of a CSI-RS with resource index provided by *csi-RS-Index* or csi-rs for a same serving cell or, if *servingCellId* or *cell* is provided, for a serving cell indicated by *servingCellId* or *cell*
  - else *PUCCH-SpatialRelationInfo* or the indicated *TCI-UL-State* provides *srs*, the UE transmits the PUCCH using a same spatial domain filter as for a transmission of an SRS with resource index provided by *resource* for a same serving cell and/or active UL BWP or, if *servingCellId* and/or *uplinkBWP* are provided, for a serving cell indicated by *servingCellId* and/or for an UL BWP indicated by *uplinkBWP*
- an indicated *apply-IndicatedTCIState*, if provided
  - if *apply-IndicatedTCIState* = 'first', the UE transmits a PUCCH using a spatial domain filter corresponding to a first *TCI-State* or *TCI-UL-State*
  - if *apply-IndicatedTCIState* = 'second', the UE transmits a PUCCH using a spatial domain filter corresponding to second *TCI-State* or *TCI-UL-State*
  - if *apply-IndicatedTCIState* = 'both', the UE transmits a PUCCH using respective first and second spatial domain filters corresponding to the first and the second *TCI-State* or *TCI-UL-State*

  If the UE

  - is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on an active DL BWP of a serving cell, and
  - is provided *coresetPoolIndex* with a value of 1 for second CORESETs on the active DL BWP of the serving cells,

  the first and second *TCI-State* or *TCI-UL-State* are specific to the first and second CORESETs, respectively.

If a UE

- is not provided *pathlossReferenceRSs* in *PUCCH-PowerControl*,
- is provided *enableDefaultBeamPL-ForPUCCH*, and
- is not provided *PUCCH-SpatialRelationInfo*, and

- is not provided *coresetPoolIndex* value of 1 for any CORESET, or is provided *coresetPoolIndex* value of 1 for all CORESETs, in *ControlResourceSet* and no codepoint of a TCI field, if any, in a DCI format of any search space set maps to two TCI states [5, TS 38.212]

a spatial setting for a PUCCH transmission from the UE is same as a spatial setting for PDCCH receptions by the UE in the CORESET with the lowest ID on the active DL BWP of the PCell and, if the CORESET has two activated TCI states as described in clause 10.1, the UE determines the spatial setting for the PUCCH transmission based on the first TCI state. For a PUCCH transmission over multiple slots, a same spatial setting applies to the PUCCH transmission in each of the multiple slots.

A number of DMRS symbols for a PUCCH transmission using PUCCH format 3 or 4 is provided by *additionalDMRS*.

Use of π/2-BPSK, instead of QPSK, for a PUCCH transmission using PUCCH format 3 or 4 is indicated by *pi2BPSK*.

A UE that has indicated a capability *beamCorrespondenceWithoutUL-BeamSweeping* set to 'supported', as described in [18, TS 38.306], can determine a spatial domain filter to be used while performing the applicable channel access procedures described in [15, TS 37.213] prior to a PUCCH transmission as follows:

- if UE is configured with a single value for *pucch-SpatialRelationInfoId* for the UL transmission, the UE may use a spatial domain filter that is same as the spatial domain filter associated with *referenceSignal* in the corresponding *pucch-SpatialRelationInfo*,

- if UE is configured with more than one value for *pucch-SpatialRelationInfoId* for the UL transmission, the UE may use a spatial domain filter that is same as the spatial domain filter associated with *referenceSignal* in the activated *pucch-SpatialRelationInfo*.

9.2.3 UE procedure for reporting HARQ-ACK

In this clause, for the purpose of determining a PUCCH resource for a PUCCH transmission in a slot using a PUCCH resource indicator field in a DCI format that schedules a PDSCH reception, and for the purpose of determining the slot for the PUCCH transmission

- a UE is assumed to generate HARQ-ACK information regardless of whether or not the PDSCH reception provides a transport block for a HARQ process with disabled HARQ-ACK information as indicated by *downlinkHARQ-FeedbackDisabled*, if provided

- a UE is assumed to not generate HARQ-ACK information associated with a G-RNTI for multicast or a G-CS-RNTI with disabled HARQ-ACK information as described in clause 18.

The UE determines a number of HARQ-ACK information bits O_{ACK} as described in clauses 9.1 through 9.1.5 and a corresponding set of PUCCH resources as described in clause 9.2.1. If $O_{\mathrm{ACK}} = 0$, the UE does not transmit a PUCCH that only includes HARQ-ACK information bits.

A UE does not expect to transmit more than one PUCCH with HARQ-ACK information in a slot per priority index, if the UE is not provided *ackNackFeedbackMode = separate*.

For DCI format 1_0, the PDSCH-to-HARQ_feedback timing indicator field values map to {1, 2, 3, 4, 5, 6, 7, 8} for SCS configuration of PUCCH transmission $\mu \le 3$, to {7, 8, 12, 16, 20, 24, 28, 32} for $\mu = 5$, and to {13, 16, 24, 32, 40, 48, 56, 64} for $\mu = 6$. For a unicast DCI format, other than DCI format 1_0, the PDSCH-to-HARQ_feedback timing indicator field values, if present, map to values for a set of number of slots provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-DCI-1-2-r17*, or *dl-DataToUL-ACK-v1700* as defined in Table 9.2.3-1. If the DCI format indicates a cell for the PUCCH transmission, as described in clause 9.A, the PDSCH-to-HARQ_feedback timing indicator field value maps to slots of the active UL BWP of the cell; otherwise, the PDSCH-to-HARQ_feedback timing indicator field value maps to slots of the active UL BWP of the PCell. For DCI format 4_1, the PDSCH-to-HARQ_feedback timing indicator field values are provided by *dl-DataToUL-ACK-MulticastDCI-Format4-1* or, if *dl-DataToUL-ACK-MulticastDCI-Format4-1* is not provided, by {1, 2, 3, 4, 5, 6, 7, 8}. For DCI format 4_2, the PDSCH-to-HARQ_feedback timing indicator field values are provided by *dl-DataToUL-ACK* from *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1* or *pucch-ConfigMulticast2/pucch-ConfigurationListMulticast2* if provided; otherwise, from *pucch-Config/pucch-ConfigurationList.*

The following apply to the PCell if the UE is provided *pucch-sSCellPattern*; otherwise, the following apply to the serving cell of the PUCCH transmission. If the UE is provided *subslotLengthForPUCCH*, n is the last UL slot for PUCCH transmission that overlaps with a PDSCH reception or with a PDCCH reception providing a DCI format having associated HARQ-ACK information without scheduling a PDSCH reception; otherwise, n is the last UL slot for PUCCH transmission that overlaps with the DL slot n_D for the PDSCH reception or with the DL slot n_D for the PDCCH reception in case of a DCI format that triggers a HARQ-ACK information report and does not schedule a PDSCH reception.

For a SPS PDSCH reception ending in DL slot n_D, the UE transmits the PUCCH in UL slot $n + k$ where k is provided by the PDSCH-to-HARQ_feedback timing indicator field, if present, in a DCI format activating the SPS PDSCH reception.

If the UE detects a DCI format that does not include a PDSCH-to-HARQ_feedback timing indicator field and schedules a PDSCH reception or activates a SPS PDSCH reception ending in DL slot n_D, the UE provides corresponding HARQ-ACK information in a PUCCH transmission within UL slot $n + k$ where k is provided by *dl-DataToUL-ACK*, or *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-DCI-1-2-r17*, or *dl-DataToUL-ACK-v1700*.

If the UE detects a DCI format scheduling a number of PDSCH receptions ending in DL slot n_D or if the UE detects a DCI format generating a HARQ-ACK information bit and does not schedule a PDSCH reception through a PDCCH reception ending in DL slot n_D, the UE provides corresponding HARQ-ACK information in a PUCCH transmission within UL slot $n + k$, where k is a number of slots and is indicated by the PDSCH-to-HARQ_feedback timing indicator field in the DCI format, if present, or provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-DCI-1-2-r17*, or *dl-DataToUL-ACK-v1700*.

A PUCCH transmission with HARQ-ACK information is subject to the limitations for UE transmissions described in clause 11.1, clause 11.1.1 and clause 17.2.

Table 9.2.3-1: Mapping of PDSCH-to-HARQ_feedback timing indicator field values to numbers of slots

PDSCH-to-HARQ_feedback timing indicator			Number of slots k
1 bit	2 bits	3 bits	
'0'	'00'	'000'	1st value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
'1'	'01'	'001'	2nd value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
	'10'	'010'	3rd value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
	'11'	'011'	4th value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
		'100'	5th value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
		'101'	6th value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
		'110'	7th value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*
		'111'	8th value provided by *dl-DataToUL-ACK*, *dl-DataToUL-ACK-r16*, *dl-DataToUL-ACK-DCI-1-2*, *dl-DataToUL-ACK-r17*, *dl-DataToUL-ACK-DCI-1-2-r17*, *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*

For a PUCCH transmission with HARQ-ACK information, a UE determines a PUCCH resource on the cell of the PUCCH transmission, as described in clause 9.A, after determining a set of PUCCH resources for O_{UCI} HARQ-ACK information bits, as described in clause 9.2.1. The PUCCH resource determination is based on a PUCCH resource indicator field [5, TS 38.212], if present, in a last DCI format, excluding the SPS activation DCI, among the DCI formats that have a value of a PDSCH-to-HARQ_feedback timing indicator field, if present, or a value of *dl-DataToUL-ACK*, or *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-DCI-1-2-r17*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*, or *dl-DataToUL-ACK-v1700*, indicating a same slot for the PUCCH transmission, that the UE detects and for which the UE transmits corresponding HARQ-ACK information in the PUCCH.

The PUCCH resource indicator field values map to values of a set of PUCCH resource indexes, as defined in Table 9.2.3-2 for a PUCCH resource indicator field of 3 bits, provided by *resourceList* for PUCCH resources from a set of PUCCH resources provided by *PUCCH-ResourceSet* with a maximum of eight PUCCH resources. If the PUCCH resource indicator field includes 1 bit or 2 bits, the values map to the first two values or the first four values, respectively, of Table 9.2.3-2. If the last DCI format does not include a PUCCH resource indicator field, the first value of Table 9.2.3-2 is used.

For the first set of PUCCH resources and when the size R_{PUCCH} of *resourceList* is larger than eight, when a UE provides HARQ-ACK information in a PUCCH transmission in response to detecting a last DCI format in a PDCCH reception, excluding the SPS activation DCI, among DCI formats with a value of the PDSCH-to-HARQ_feedback timing indicator field, if present, or a value of *dl-DataToUL-ACK*, or *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-DCI-1-2-r17*, or *dl-DataToUL-ACK-MulticastDCI-Format4-1*, or *dl-DataToUL-ACK-v1700*, indicating a same slot for the PUCCH transmission, the UE determines a PUCCH resource with index r_{PUCCH}, $0 \le r_{\mathrm{PUCCH}} \le R_{\mathrm{PUCCH}} - 1$, as

$$r_{\mathrm{PUCCH}} = \begin{cases} \left\lfloor \frac{n_{\mathrm{CCE},p} \cdot \lceil R_{\mathrm{PUCCH}}/8 \rceil}{N_{\mathrm{CCE},p}} \right\rfloor + \Delta_{\mathrm{PRI}} \cdot \left\lceil \frac{R_{\mathrm{PUCCH}}}{8} \right\rceil & \text{if} \quad \Delta_{\mathrm{PRI}} < R_{\mathrm{PUCCH}} \bmod 8 \\ \left\lfloor \frac{n_{\mathrm{CCE},p} \cdot \lfloor R_{\mathrm{PUCCH}}/8 \rfloor}{N_{\mathrm{CCE},p}} \right\rfloor + \Delta_{\mathrm{PRI}} \cdot \left\lfloor \frac{R_{\mathrm{PUCCH}}}{8} \right\rfloor + R_{\mathrm{PUCCH}} \bmod 8 & \text{if} \quad \Delta_{\mathrm{PRI}} \ge R_{\mathrm{PUCCH}} \bmod 8 \end{cases}$$

where $N_{\mathrm{CCE},p}$ is a number of CCEs in CORESET p of the PDCCH reception for the DCI format as described in clause 10.1, $n_{\mathrm{CCE},p}$ is the index of a first CCE for the PDCCH reception, and Δ_{PRI} is a value of the PUCCH resource indicator field in the DCI format. When the PDCCH reception includes first and second PDCCH candidates from respective first and second search space sets, as described in clause 10.1, the CORESET is associated with the search space set having the smaller index. If

- the first search space set has larger index than the second search space set and includes the first PDCCH candidate and a third PDCCH candidate that have same first CCE index and CCE aggregation levels 8 and 16, or 16 and 8, respectively,

- the second search space set includes the second PDCCH candidate that has same index and same CCE aggregation level as the first PDCCH candidate, and a fourth PDCCH candidate that has same index and same CCE aggregation level as the third PDCCH candidate,

- the CORESET associated with the first search space set has *cce-REG-MappingType* = '*nonInterleaved*' and has duration of one symbol, and

- the second PDCCH candidate has different first CCE index than the fourth PDCCH candidate

the UE determines $n_{\mathrm{CCE},0}$ from the PDCCH candidate with CCE aggregation level 16 among the second PDCCH candidate and the fourth PDCCH candidate.

If the DCI format does not include a PUCCH resource indicator field, $\Delta_{\mathrm{PRI}} = 0$.

Table 9.2.3-2: Mapping of PUCCH resource indication field values to a PUCCH resource in a PUCCH resource set with maximum 8 PUCCH resources

PUCCH resource indicator			PUCCH resource
1 bit	2 bits	3 bits	
'0'	'00'	'000'	1st PUCCH resource provided by *pucch-ResourceId* obtained from the 1st value of *resourceList*
'1'	'01'	'001'	2nd PUCCH resource provided by *pucch-ResourceId* obtained from the 2nd value of *resourceList*
	'10'	'010'	3rd PUCCH resource provided by *pucch-ResourceId* obtained from the 3rd value of *resourceList*
	'11'	'011'	4th PUCCH resource provided by *pucch-ResourceId* obtained from the 4th value of *resourceList*
		'100'	5th PUCCH resource provided by *pucch-ResourceId* obtained from the 5th value of *resourceList*
		'101'	6th PUCCH resource provided by *pucch-ResourceId* obtained from the 6th value of *resourceList*
		'110'	7th PUCCH resource provided by *pucch-ResourceId* obtained from the 7th value of *resourceList*
		'111'	8th PUCCH resource provided by *pucch-ResourceId* obtained from the 8th value of *resourceList*

If a UE determines a first resource for a PUCCH transmission with HARQ-ACK information corresponding only to a PDSCH reception without a corresponding PDCCH or detects a first DCI format indicating a first resource for a PUCCH transmission with corresponding HARQ-ACK information in a slot and also detects at a later time a second DCI format indicating a second resource for a PUCCH transmission with corresponding HARQ-ACK information in the slot, the UE does not expect to multiplex HARQ-ACK information corresponding to the second DCI format in a PUCCH resource in the slot if the PDCCH reception that includes the second DCI format is not earlier than $N_3 \cdot (2048 + 144) \cdot \kappa \cdot 2^{-\mu} \cdot T_c$ from the beginning of a first symbol of the first resource for PUCCH transmission in the slot where, κ and T_c are defined in clause 4.1 of [4, TS 38.211] and μ corresponds to the smallest SCS configuration among the SCS configurations of the PDCCHs providing the DCI formats and the SCS configuration of the PUCCH. If *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for the serving cell with the second DCI format and for all serving cells with corresponding HARQ-ACK information multiplexed in the PUCCH transmission in the slot, $N_3 = 3$ for $\mu = 0$, $N_3 = 4.5$ for $\mu = 1$, $N_3 = 9$ for $\mu = 2$; otherwise, $N_3 = 8$ for $\mu = 0$, $N_3 = 10$ for $\mu = 1$, $N_3 = 17$ for $\mu = 2$, $N_3 = 20$ for $\mu = 3$, $N_3 = 80$ for $\mu = 5$, and $N_3 = 160$ for $\mu = 6$.

If a UE is not provided *SPS-PUCCH-AN-List* and transmits HARQ-ACK information corresponding only to a PDSCH reception without a corresponding PDCCH, which includes the first SPS PDSCH reception associated with the corresponding activation DCI, a PUCCH resource for corresponding PUCCH transmission with HARQ-ACK information is provided by *n1PUCCH-AN*.

If a UE transmits a PUCCH with HARQ-ACK information using PUCCH format 0, the UE determines values m_0 and m_{CS} for computing a value of cyclic shift α [4, TS 38.211] where m_0 is provided by *initialCyclicShift* of *PUCCH-format0* or, if *initialCyclicShift* is not provided, by the initial cyclic shift index as described in clause 9.2.1 and m_{CS} is determined from the value of one HARQ-ACK information bit or from the values of two HARQ-ACK information bits as in Table 9.2.3-3 and Table 9.2.3-4, respectively.

Table 9.2.3-3: Mapping of values for one HARQ-ACK information bit to sequences for PUCCH format 0

HARQ-ACK Value	0	1
Sequence cyclic shift	$m_{\mathrm{CS}} = 0$	$m_{\mathrm{CS}} = 6$

Table 9.2.3-4: Mapping of values for two HARQ-ACK information bits to sequences for PUCCH format 0

HARQ-ACK Value	{0, 0}	{0, 1}	{1, 1}	{1, 0}
Sequence cyclic shift	$m_{\mathrm{CS}} = 0$	$m_{\mathrm{CS}} = 3$	$m_{\mathrm{CS}} = 6$	$m_{\mathrm{CS}} = 9$

If a UE transmits a PUCCH with HARQ-ACK information using PUCCH format 1, the UE is provided a value for m_0 by *initialCyclicShift* of *PUCCH-format1* or, if *initialCyclicShift* is not provided, by the initial cyclic shift index as described in clause 9.2.1.

If a UE transmits a PUCCH with O_{ACK} HARQ-ACK information bits and O_{CRC} bits using PUCCH format 2 or PUCCH format 3 in a PUCCH resource that includes $M_{\text{RB}}^{\text{PUCCH}}$ PRBs, the UE determines a number of PRBs $M_{\text{RB,min}}^{\text{PUCCH}}$ for the PUCCH transmission to be the minimum number of PRBs, that is smaller than or equal to a number of PRBs $M_{\text{RB}}^{\text{PUCCH}}$ provided respectively by *nrofPRBs* of *PUCCH-format2* or *nrofPRBs* of *PUCCH-format3* and start from the first PRB from the number of PRBs, that results to $(O_{\text{ACK}} + O_{\text{CRC}}) \leq M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and, if $M_{\text{RB}}^{\text{PUCCH}} > 1$, $(O_{\text{ACK}} + O_{\text{CRC}}) > \left(M_{\text{RB,min}}^{\text{PUCCH}} - 1\right) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $N_{\text{sc,ctrl}}^{\text{RB}}$, $N_{\text{symb-UCI}}^{\text{PUCCH}}$, Q_m, and r are defined in clause 9.2.5.2. For PUCCH format 3, if $M_{\text{RB,min}}^{\text{PUCCH}}$ is not equal $2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$ according to [4, TS 38.211], $M_{\text{RB,min}}^{\text{PUCCH}}$ is increased to the nearest allowed value of *nrofPRBs* [12, TS 38.331]. If $(O_{\text{ACK}} + O_{\text{CRC}}) > \left(M_{\text{RB}}^{\text{PUCCH}} - 1\right) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the PUCCH over $M_{\text{RB}}^{\text{PUCCH}}$ PRBs.

If a UE is provided a first interlace of $M_{\text{Interlace,0}}^{\text{PUCCH}}$ PRBs by *interlace0* in *InterlaceAllocation* and transmits a PUCCH with O_{ACK} HARQ-ACK information bits and O_{CRC} bits using PUCCH format 2 or PUCCH format 3, the UE transmits the PUCCH over the first interlace if $(O_{\text{ACK}} + O_{\text{CRC}}) \leq M_{\text{Interlace,0}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$; otherwise, if the UE is provided a second interlace by *interlace1* in *PUCCH-format2* or *PUCCH-format3*, the UE transmits the PUCCH over the first and second interlaces.

9.2.4 UE procedure for reporting SR

A UE can be provided by *SchedulingRequestResourceConfig* a set of configurations for SR in a PUCCH transmission using either PUCCH format 0 or PUCCH format 1.

A UE can be provided by *schedulingRequestID-BFR-SCell* a configuration for LRR in a PUCCH transmission using either PUCCH format 0 or PUCCH format 1.

A UE can be provided by *schedulingRequestID-BFR* a first configuration for LRR and, if the UE provides *twoLRRcapability*, the UE can be provided by *schedulingRequestID-BFR2* a second configuration for LRR in a PUCCH transmission using either PUCCH format 0 or PUCCH format 1.

A UE can be provided by *schedulingRequestID-LBT-SCell* a configuration for consistent LBT failure recovery, as described in [11, TS 38.321], in a PUCCH transmission using either PUCCH format 0 or PUCCH format 1. The UE can be provided, by *phy-PriorityIndex* in *SchedulingRequestResourceConfig*, a priority index 0 or a priority index 1 for the SR. If the UE is not provided a priority index for SR, the priority index is 0.

The UE is also provided a periodicity $SR_{\text{PERIODICITY}}$ in symbols or slots and an offset SR_{OFFSET} in slots by *periodicityAndOffset* for a PUCCH transmission conveying SR. If $SR_{\text{PERIODICITY}}$ is larger than one slot, the UE determines a SR transmission occasion in a PUCCH to be in a slot with number $n_{s,f}^{\mu}$ [4, TS 38.211] in a frame with number n_f if $\left(n_f \cdot N_{\text{slot}}^{\text{frame},\mu} + n_{s,f}^{\mu} - SR_{\text{OFFSET}}\right) \text{mod} SR_{\text{PERIODICITY}} = 0$.

If $SR_{\text{PERIODICITY}}$ is one slot, the UE expects that $SR_{\text{OFFSET}} = 0$ and every slot is a SR transmission occasion in a PUCCH.

If $SR_{\text{PERIODICITY}}$ is smaller than one slot, the UE determines a SR transmission occasion in a PUCCH to start in a symbol with index l [4, TS 38.211] if $(l - l_0 \text{mod} SR_{\text{PERIODICITY}}) \text{mod} SR_{\text{PERIODICITY}} = 0$ where l_0 is the value of *startingSymbolIndex*.

If the UE determines that, for a SR transmission occasion in a PUCCH, the number of symbols available for the PUCCH transmission in a slot is smaller than the value provided by *nrofSymbols*, the UE does not transmit the PUCCH in the slot.

SR transmission occasions in a PUCCH are subject to the limitations for UE transmissions described in clause 11.1, clause 11.1.1 and clause 17.2.

The UE transmits a PUCCH in the PUCCH resource for the corresponding SR configuration only when the UE transmits a positive SR. For a positive SR transmission using PUCCH format 0, the UE transmits the PUCCH as described in [4, TS 38.211] by obtaining m_0 as described for HARQ-ACK information in clause 9.2.3 and by setting $m_{\text{cs}} = 0$. For a positive SR transmission using PUCCH format 1, the UE transmits the PUCCH as described in [4, TS 38.211] by setting $b(0) = 0$.

9.2.5 UE procedure for reporting multiple UCI types

This clause is applicable to the case that a UE has resources for PUCCH transmissions or for PUCCH and PUSCH transmissions that overlap in time and each PUCCH transmission is over a single slot without repetitions. Any case that a PUCCH transmission is with repetitions over multiple slots is described in clause 9.2.6. If a UE is configured with multiple PUCCH resources in a slot to transmit CSI reports

- if the UE is not provided *multi-CSI-PUCCH-ResourceList* or if PUCCH resources for transmissions of CSI reports do not overlap in the slot, the UE determines a first resource corresponding to a CSI report with the highest priority [6, TS 38.214]
  - if the first resource includes PUCCH format 2, and if there are remaining resources in the slot that do not overlap with the first resource, the UE determines a CSI report with the highest priority, among the CSI reports with corresponding resources from the remaining resources, and a corresponding second resource as an additional resource for CSI reporting
  - if the first resource includes PUCCH format 3 or PUCCH format 4, and if there are remaining resources in the slot that include PUCCH format 2 and do not overlap with the first resource, the UE determines a CSI report with the highest priority, among the CSI reports with corresponding resources from the remaining resources, and a corresponding second resource as an additional resource for CSI reporting
- if the UE is provided *multi-CSI-PUCCH-ResourceList* and if any of the multiple PUCCH resources overlap, the UE multiplexes all CSI reports in a resource from the resources provided by *multi-CSI-PUCCH-ResourceList*, as described in clause 9.2.5.2.

A UE multiplexes DL HARQ-ACK information, with or without SR, and CSI report(s) in a same PUCCH if the UE is provided *simultaneousHARQ-ACK-CSI*; otherwise, the UE drops the CSI report(s) and includes only DL HARQ-ACK information, with or without SR, in the PUCCH. If the UE would transmit multiple PUCCHs in a slot that include DL HARQ-ACK information and CSI report(s), the UE expects to be provided a same configuration for *simultaneousHARQ-ACK-CSI* each of PUCCH formats 2, 3, and 4.

If a UE would multiplex CSI reports that include Part 2 CSI reports in a PUCCH resource, the UE determines the PUCCH resource and a number of PRBs for the PUCCH resource or a number of Part 2 CSI reports assuming that each of the CSI reports and, if any, each CSI sub-report included in a CSI report, indicates rank 1, or rank combination of {1, 1} if applicable. If the higher layer parameter *csi-ReportMode* of CSI reports is set to 'Mode2', the UE determines the PUCCH resource and a number of PRBs for the PUCCH resource or a number of Part 2 CSI reports assuming that each CRI in the CSI report is associated with a resource pair.

If a UE would transmit multiple overlapping PUCCHs in a slot or overlapping PUCCH(s) and PUSCH(s) in a slot and, when applicable as described in clauses 9.2.5.1, 9.2.5.2, 9.2.5.3 and 18, the UE is configured to multiplex different UCI types or UCI of different priority indexes in one PUCCH, and at least one of the multiple overlapping PUCCHs or PUSCHs is in response to a DCI format detection by the UE, the UE multiplexes all corresponding UCI types or UCI of different priority indexes if the following conditions are met. If one of the PUCCH transmissions or PUSCH transmissions is in response to a DCI format detection by the UE, the UE expects that the first symbol S_0 of the earliest PUCCH or PUSCH, among a group overlapping PUCCHs and PUSCHs in the slot, satisfies the following timeline conditions

- S_0 is not before a symbol with CP starting after $T_{proc,1}^{mux}$ after a last symbol of any corresponding PDSCH, $T_{proc,1}^{mux}$ is given by maximum of $\left\{T_{proc,1}^{mux,1}, \cdots, T_{proc,1}^{mux,i}, \cdots\right\}$ where for the i-th PDSCH with corresponding HARQ-ACK transmission on a PUCCH which is in the group of overlapping PUCCHs and PUSCHs, $T_{proc,1}^{mux,i} = \left(N_1 + d_{1,1} + 1\right) \cdot (2048 + 144) \cdot \kappa \cdot 2^{-\mu} \cdot T_C$, $d_{1,1}$ is selected for the i-th PDSCH following [6, TS 38.214], N_1 is selected based on the UE PDSCH processing capability of the i-th PDSCH and SCS configuration μ, where μ corresponds to the smallest SCS configuration among the SCS configurations used for the PDCCH scheduling the i-th PDSCH if any, the i-th PDSCH, the PUCCH with corresponding HARQ-ACK transmission for the i-th PDSCH, and all PUSCHs in the group of overlapping PUCCHs and PUSCHs.

- S_0 is not before a symbol with CP starting after $T_{proc,release}^{mux}$ after a last symbol of a PDCCH reception providing a DCI format having associated HARQ-ACK information without scheduling a PDSCH reception. $T_{proc,release}^{mux}$ is given by maximum of $\left\{T_{proc,release}^{mux,1}, \cdots, T_{proc,release}^{mux,i}, \cdots\right\}$ where for the i-th PDCCH providing the DCI format with corresponding HARQ-ACK transmission on a PUCCH which is in the group of overlapping PUCCHs and

PUSCHs, $T_{proc,release}^{mux,i} = (N+1) \cdot (2048+144) \cdot \kappa \cdot 2^{-\mu} \cdot T_C$, N as described in clause 10.2, where μ corresponds to the smallest SCS configuration among the SCS configurations used for the PDCCH, the PUCCH with corresponding HARQ-ACK information, and all PUSCHs in the group of overlapping PUCCHs and PUSCHs.

- if there is no aperiodic CSI report multiplexed in a PUSCH in the group of overlapping PUCCHs and PUSCHs, S_0 is not before a symbol with CP starting after $T_{proc,2}^{mux}$ after a last symbol of
  - any PDCCH with the DCI format scheduling an overlapping PUSCH, and
  - any PDCCH providing a DCI format with corresponding HARQ-ACK information in an overlapping PUCCH in the slot

  If there is at least one PUSCH in the group of overlapping PUCCHs and PUSCHs, $T_{proc,2}^{mux}$ is given by maximum of $\{T_{proc,2}^{mux,1}, \cdots, T_{proc,2}^{mux,i}, \cdots\}$ where for the i-th PUSCH which is in the group of overlapping PUCCHs and PUSCHs, $T_{proc,2}^{mux,i} = max\left((N_2 + d_{2,1} + 1) \cdot (2048+144) \cdot \kappa \cdot 2^{-\mu} \cdot T_C + T_{\text{switch}}, d_{2,2}\right)$, $d_{2,1}$, $d_{2,2}$ and T_{switch} are selected for the i-th PUSCH following [6, TS 38.214], N_2 is selected based on the UE PUSCH processing capability of the i-th PUSCH and SCS configuration μ, where μ corresponds to the smallest SCS configuration among the SCS configurations used for the PDCCH scheduling the i-th PUSCH, the PDCCHs scheduling the PDSCHs, or providing the DCI formats without scheduling PDSCHs, with corresponding HARQ-ACK information on a PUCCH which is in the group of overlapping PUCCHs/PUSCHs, and all PUSCHs in the group of overlapping PUCCHs and PUSCHs.

  If there is no PUSCH in the group of overlapping PUCCHs and PUSCHs, $T_{proc,2}^{mux}$ is given by maximum of $\{T_{proc,2}^{mux,1}, \cdots, T_{proc,2}^{mux,i}, \cdots\}$ where for the i-th PDSCH, or the i-th PDCCH providing a DCI format without scheduling PDSCH, with corresponding HARQ-ACK information on a PUCCH which is in the group of overlapping PUCCHs, $T_{proc,2}^{mux,i} = (N_2 + 1) \cdot (2048+144) \cdot \kappa \cdot 2^{-\mu} \cdot T_C$, N_2 is selected based on the UE PUSCH processing capability of the PUCCH serving cell if configured. N_2 is selected based on the UE PUSCH processing capability 1, if PUSCH processing capability is not configured for the PUCCH serving cell. μ is selected based on the smallest SCS configuration between the SCS configuration used for the PDCCH scheduling the i-th PDSCH, or providing the i-th DCI format without scheduling PDSCH, with corresponding HARQ-ACK information on a PUCCH which is in the group of overlapping PUCCHs, and the SCS configuration for the PUCCH serving cell.

- if there is an aperiodic CSI report multiplexed in a PUSCH in the group of overlapping PUCCHs and PUSCHs, S_0 is not before a symbol with CP starting after $T_{proc,CSI}^{mux} = max\left((Z+d) \cdot (2048+144) \cdot \kappa \cdot 2^{-\mu} \cdot T_C + T_{\text{switch}}, d_{2,2}\right)$ after a last symbol of
  - any PDCCH with the DCI format scheduling an overlapping PUSCH, and
  - any PDCCH scheduling a PDSCH, or providing a DCI format , with corresponding HARQ-ACK information in an overlapping PUCCH in the slot

  where μ corresponds to the smallest SCS configuration among the SCS configuration of the PDCCHs, the smallest SCS configuration for the group of the overlapping PUSCHs, and the smallest SCS configuration of CSI-RS associated with the DCI format scheduling the PUSCH with the multiplexed aperiodic CSI report, and $d = 2$ for $\mu = 0,1$, $d = 3$ for $\mu = 2$, and $d = 4$ for $\mu \geq 3$. T_{switch} is defined in [6, TS 38.214] and it is applied only if Z_1 of Table 5.4-1 in [6, TS 38.214] is applied to the determination of Z.

- N_1, N_2, $d_{1,1}$, $d_{2,1}$, $d_{2,2}$, and Z are defined in [6, TS 38.214] and κ and T_C are defined in [4, TS 38.211].

If a UE would transmit multiple overlapping PUCCHs in a slot or overlapping PUCCH(s) and PUSCH(s) in a slot, one of the PUCCHs includes HARQ-ACK information in response to an SPS PDSCH reception, and any PUSCH is not in response to a DCI format detection, the UE expects that the first symbol S_0 of the earliest PUCCH or PUSCH satisfies the first of the previous timeline conditions with the exception that components associated to a SCS configuration for a PDCCH scheduling a PDSCH or a PUSCH are absent from the timeline conditions.

A UE does not expect a PUCCH or a PUSCH that is in response to a DCI format detection to overlap with any other PUCCH or PUSCH that does not satisfy the above timing conditions.

A UE that

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on active DL BWPs of serving cells, and

- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on active DL BWPs of the serving cells, and

- is provided *ackNackFeedbackMode* = *separate*

does not expect a PUCCH or a PUSCH transmission triggered by a detection of a DCI format in a PDCCH received in a CORESET from the first CORESETs to overlap in time with a PUCCH or a PUSCH transmission triggered by a detection of a DCI format in a PDCCH received in a CORESET from the second CORESETs if the UE is not provided *enableSTx2PofmDCI*; else, if the UE is provided *enableSTx2PofmDCI*, the UE does not expect to transmit a PUCCH that includes HARQ-ACK information and is associated with either the first or the second CORESETs to overlap with a PUSCH transmission associated with either the second or the first CORESETs and not overlap with a PUSCH transmission associated with either the first or the second CORESETs, respectively.

If there is one or more aperiodic CSI reports multiplexed on a PUSCH in the group of overlapping PUCCHs and PUSCHs and if symbol S_0 is before symbol $Z'^{\text{mux}}_{\text{ref}}$ that is a next uplink symbol with CP starting after $Z'^{\text{mux}}_{\text{proc,CSI}} = (Z'+d)\cdot(2048+144)\cdot\kappa\cdot 2^{-\mu}\cdot T_C$ after the end of the last symbol of

- the last symbol of aperiodic CSI-RS resource for channel measurements, and

- the last symbol of aperiodic CSI-IM used for interference measurements, and

- the last symbol of aperiodic NZP CSI-RS for interference measurements for a *CSI-ReportConfig*, or for all triggered sub-configurations if *CSI-ReportConfig* contains multiple sub-configurations, when aperiodic CSI-RS is used for channel measurement for triggered CSI report n

the UE is not required to update the CSI report for the triggered CSI report n. Z' is defined in [6, TS 38.214] and μ corresponds to the smallest SCS configuration among the SCS configurations of the PDCCHs scheduling the PUSCHs, the smallest SCS configuration of aperiodic CSI-RSs associated with DCI formats provided by the PDCCHs triggering the aperiodic CSI reports, and the smallest SCS configuration of the overlapping PUCCHs and PUSCHs and $d = 2$ for $\mu = 0{,}1$, $d = 3$ for $\mu = 2$, and $d = 4$ for $\mu \geq 3$.

If a UE would transmit multiple PUCCHs in a slot that include HARQ-ACK information, and/or SR, and/or CSI reports and any PUCCH with HARQ-ACK information in the slot satisfies the above timing conditions and does not overlap with any other PUCCH or PUSCH in the slot that does not satisfy the above timing conditions, the UE multiplexes the HARQ-ACK information, and/or SR, and/or CSI reports and determines corresponding PUCCH(s) for transmission in the slot according to the following pseudo-code. If the multiple PUCCHs do not include HARQ-ACK information and do not overlap with any PUSCH transmission by the UE in response to a DCI format detection by the UE, the timing conditions do not apply.

If

- a UE is not provided *multi-CSI-PUCCH-ResourceList*, and

- a resource for a PUCCH transmission with HARQ-ACK information in response to SPS PDSCH reception and/or a resource for a PUCCH associated with a SR occasion overlap in time with two resources for respective PUCCH transmissions with two CSI reports, and

- there is no resource for a PUCCH transmission with HARQ-ACK information in response to a DCI format detection that overlaps in time with any of the previous resources, and

- the following pseudo code results to the UE attempting to determine a single PUCCH resource from the HARQ-ACK and/or the SR resource and the two PUCCH resources with CSI reports

the UE

- multiplexes the HARQ-ACK information and/or the SR in the resource for the PUCCH transmission with the CSI report having the higher priority, and

- does not transmit the PUCCH with the CSI report having the lower priority

Set Q to the set of resources for transmission of corresponding PUCCHs in a single slot without repetitions where

- a resource with earlier first symbol is placed before a resource with later first symbol
- for two resources with same first symbol, the resource with longer duration is placed before the resource with shorter duration
- for two resources with same first symbol and same duration, the placement is arbitrary
  - the above three steps for the set Q are according to a subsequent pseudo-code for a function $\mathrm{order}(Q)$
- a resource for negative SR transmission that does not overlap with a resource for HARQ-ACK or CSI transmission is excluded from set Q
- if the UE is not provided *simultaneousHARQ-ACK-CSI* and resources for transmission of HARQ-ACK information include PUCCH format 0 or PUCCH format 2, resources that include PUCCH format 2, or PUCCH format 3, or PUCCH format 4 for transmission of CSI reports are excluded from the set Q if they overlap with any resource from the resources for transmission of HARQ-ACK information
- if the UE is not provided *simultaneousHARQ-ACK-CSI* and at least one of the resources for transmission of HARQ-ACK information includes PUCCH format 1, PUCCH format 3, or PUCCH format 4
  - resources that include PUCCH format 3 or PUCCH format 4 for transmission of CSI reports are excluded from the set Q
  - resources that include PUCCH format 2 for transmission of CSI reports are excluded from the set Q if they overlap with any resource from the resources for transmission of HARQ-ACK information

Set $\mathcal{C}(Q)$ to the cardinality of Q

Set $Q(j,0)$to be the first symbol of resource $Q(j)$ in the slot

Set $L(Q(j))$ to be the number of symbols of resource $Q(j)$ in the slot

Set $j = 0$ - index of first resource in set Q

Set $o = 0$ - counter of overlapped resources

while $j \leq \mathcal{C}(Q) - 1$

if

$j < \mathcal{C}(Q) - 1$ and resource $Q(j-o)$ overlaps with resource $Q(j+1)$ and the resources in set Q are of same priority index, or

$j < \mathcal{C}(Q) - 1$ and resource $Q(j-o)$ overlaps with resource $Q(j+1)$, $o = 0$, the resources in set Q are of different priority indexes, and the UE is provided *uci-MuxWithDiffPrio*

then

$o = o + 1;$

$j = j + 1;$

else

if $o > 0$

determine a single resource for multiplexing UCI associated with resources $\{Q(j-o), Q(j-o+1), \ldots, Q(j)\}$ as described in clauses 9, 9.2.5.0, 9.2.5.1, 9.2.5.2, 9.2.5.3, and 18

set the index of the single resource to j

$$Q = Q \setminus \{Q(j-o), Q(j-o+1), \ldots, Q(j-1)\}$$

$j = 0$ % start from the beginning after reordering unmerged resources at next step

$o = 0;$

$\mathrm{order}(Q)$ % function that re-orders resources in current set Q

Set $\mathcal{C}(Q)$ to the cardinality of Q

else

$j = j + 1;$

end if

end if

end while

The function $\mathrm{order}(Q)$ performs the following pseudo-code

{

$k = 0;$

while $k < \mathcal{C}(Q) - 1$ % the next two while loops are to re-order the unmerged resources

$l = 0;$

while $k < \mathcal{C}(Q) - 1 - k$

if $Q(l,0) > Q(l+1,0)$ OR $(Q(l,0) = Q(l+1,0) \& L(Q(l)) < L(Q(l+1)))$

$\mathrm{temp} = Q(l);$

$Q(l) = Q(l+1);$

$Q(l+1) = \mathrm{temp};$

end if

$l = l + 1;$

end while

$k = k + 1;$

end while

}

For each PUCCH resource in the set Q that satisfies the aforementioned timing conditions, when applicable,

- the UE transmits a PUCCH using the PUCCH resource if the PUCCH resource does not overlap in time with a PUSCH transmission after multiplexing UCI following the procedures described in clauses 9, 9.2.5.1, 9.2.5.2, 9.2.5.3 and 18
- the UE multiplexes HARQ-ACK information and/or CSI reports in a PUSCH if the PUCCH resource overlaps in time with a PUSCH transmission, as described in clause 9.3, and does not transmit SR. In case the PUCCH resource overlaps in time with multiple PUSCH transmissions, the PUSCH for multiplexing HARQ-ACK information and/or CSI is selected as described in clause 9. If the PUSCH transmission by the UE is not in response to a DCI format detection and the UE multiplexes only CSI reports, the timing conditions are not applicable
- the UE does not expect the resource to overlap with a second resource of a PUCCH transmission over multiple slots if the resource is obtained from a group of resources that do not overlap with the second resource

clauses 9.2.5.0, 9.2.5.1, 9.2.5.2, 9.2.5.3 and 18 assume the following

- resources for transmissions of UCI types, prior to multiplexing or dropping, overlap in a slot

- multiplexing conditions of corresponding UCI types in a single PUCCH are satisfied, and
- the UE does not transmit any PUSCH time-overlapping with PUCCH in the slot.

9.2.5.0 UE procedure for prioritization between SL HARQ-ACK information in a PUCCH and DL HARQ-ACK or SR or CSI in a PUCCH

The priority value of a PUCCH transmission is as described in clause 16.2.4.3.1.

For prioritization between SL HARQ-ACK information in a first PUCCH and DL HARQ-ACK or SR or CSI in a second PUCCH

- if the second PUCCH has priority index 1,
  - if *sl-PriorityThreshold-UL-URLLC* is provided
    - the UE transmits the first PUCCH if a smallest priority value of the first PUCCH is smaller than *sl-PriorityThreshold-UL-URLLC*; otherwise, the UE transmits the second PUCCH
  - else
    - the UE transmits the second PUCCH
- else
  - the UE transmits the first PUCCH if the smallest priority value of the first PUCCH is smaller than *sl-PriorityThreshold*; otherwise, the UE transmits the second PUCCH

When the UE determines to transmit the second PUCCH, the UE determines a single resource for multiplexing UCI in the second PUCCH as described in clauses 9.2.5.1 and 9.2.5.2.

9.2.5.1 UE procedure for multiplexing HARQ-ACK or CSI and SR in a PUCCH

In the following, a UE is configured to transmit K PUCCHs for respective K SRs in a slot, as determined by a set of *schedulingRequestResourceId*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR-SCell*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR2* if the UE provides *twoLRRcapability*, and a *schedulingRequestResourceId* associated with *schedulingRequestID-LBT-SCell*, with SR transmission occasions that would overlap with a transmission of a PUCCH with HARQ-ACK information from the UE in the slot or with a transmission of a PUCCH with CSI report(s) from the UE in the slot.

If a UE would transmit a PUCCH with positive SR and at most two HARQ-ACK information bits in a resource using PUCCH format 0, the UE transmits the PUCCH in the resource using PUCCH format 0 in PRB(s) for HARQ-ACK information as described in clause 9.2.3. The UE determines a value of m_0 and m_{CS} for computing a value of cyclic shift α [4, TS 38.211] where m_0 is provided by *initialCyclicShift* of *PUCCH-format0*, and m_{CS} is determined from the value of one HARQ-ACK information bit or from the values of two HARQ-ACK information bits as in Table 9.2.5-1 and Table 9.2.5-2, respectively.

If the UE would transmit negative SR and a PUCCH with at most two HARQ-ACK information bits in a resource using PUCCH format 0, the UE transmits the PUCCH in the resource using PUCCH format 0 for HARQ-ACK information as described in clause 9.2.3.

Table 9.2.5-1: Mapping of values for one HARQ-ACK information bit and positive SR to sequences for PUCCH format 0

HARQ-ACK Value	0	1
Sequence cyclic shift	$m_{\mathrm{CS}} = 3$	$m_{\mathrm{CS}} = 9$

Table 9.2.5-2: Mapping of values for two HARQ-ACK information bits and positive SR to sequences for PUCCH format 0

HARQ-ACK Value	{0, 0}	{0, 1}	{1, 1}	{1, 0}
Sequence cyclic shift	$m_{\mathrm{CS}} = 1$	$m_{\mathrm{CS}} = 4$	$m_{\mathrm{CS}} = 7$	$m_{\mathrm{CS}} = 10$

If a UE would transmit SR in a resource using PUCCH format 0 and HARQ-ACK information bits in a resource using PUCCH format 1 in a slot, the UE transmits only a PUCCH with the HARQ-ACK information bits in the resource using PUCCH format 1.

If the UE would transmit positive SR in a first resource using PUCCH format 1 and at most two HARQ-ACK information bits in a second resource using PUCCH format 1 in a slot, the UE transmits a PUCCH with HARQ-ACK information bits in the first resource using PUCCH format 1 as described in clause 9.2.3. If a UE would not transmit a positive SR in a resource using PUCCH format 1 and would transmit at most two HARQ-ACK information bits in a resource using PUCCH format 1 in a slot, the UE transmits a PUCCH in the resource using PUCCH format 1 for HARQ-ACK information as described in clause 9.2.3.

If a UE would transmit a PUCCH with O_{ACK} HARQ-ACK information bits in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 in a slot, as described in clauses 9.2.1 and 9.2.3, $\lceil \log_2(K+1) \rceil$ bits representing a negative or positive SR, in ascending order of the values of *schedulingRequestResourceId*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR-SCell*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR2* if the UE provides *twoLRRcapability*, and a *schedulingRequestResourceId* associated with *schedulingRequestID-LBT-SCell*, are appended to the HARQ-ACK information bits and the UE transmits the combined $O_{\mathrm{UCI}} = O_{\mathrm{ACK}} + \lceil \log_2(K+1) \rceil$ UCI bits in a PUCCH using a resource with PUCCH format 2 or PUCCH format 3 or PUCCH format 4 that the UE determines as described in clauses 9.2.1 and 9.2.3. If one of the SRs is a positive LRR, the value of the $\lceil \log_2(K+1) \rceil$ bits indicates the positive LRR. An all-zero value for the $\lceil \log_2(K+1) \rceil$ bits represents a negative SR value across all K SRs.

If a UE would transmit a PUCCH with O_{CSI} CSI report bits in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 in a slot, $\lceil \log_2(K+1) \rceil$ bits representing corresponding negative or positive SR, in ascending order of the values of *schedulingRequestResourceId*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR-SCell*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR*, a *schedulingRequestResourceId* associated with *schedulingRequestID-BFR2* if the UE provides *twoLRRcapability*, and a *schedulingRequestResourceId* associated with *schedulingRequestID-LBT-SCell*, are prepended to the CSI information bits as described in clause 9.2.5.2 and the UE transmits a PUCCH with the combined $O_{\mathrm{UCI}} = \lceil \log_2(K+1) \rceil + O_{\mathrm{CSI}}$ UCI bits in a resource using the PUCCH format 2 or PUCCH format 3 or PUCCH format 4 for CSI reporting. If one of the SRs is a positive LRR, the value of the $\lceil \log_2(K+1) \rceil$ bits indicates the positive LRR. An all-zero value for the $\lceil \log_2(K+1) \rceil$ bits represents a negative SR value across all K SRs.

If a UE transmits a PUCCH with O_{ACK} HARQ-ACK information bits, $O_{\mathrm{SR}} = \lceil \log_2(K+1) \rceil$ SR bits, and O_{CRC} CRC bits using PUCCH format 2 or PUCCH format 3 in a PUCCH resource that includes $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs, the UE determines a number of PRBs $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}$ for the PUCCH transmission to be the minimum number of PRBs, that is smaller than or equal to a number of PRBs provided by *nrofPRBs* in *PUCCH-format2* or *nrofPRBs* in *PUCCH-format3* and starts from the first PRB from the number of PRBs, that results to $(O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CRC}}) \leq M_{\mathrm{RB,min}}^{\mathrm{PUCCH}} \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} \cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}} \cdot Q_m \cdot r$ and, if $M_{\mathrm{RB}}^{\mathrm{PUCCH}} > 1$, $(O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CRC}}) > \left(M_{\mathrm{RB,min}}^{\mathrm{PUCCH}} - 1\right) \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} \cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}} \cdot Q_m \cdot r$, where $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}$, $N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}}$, Q_m, and r are defined in clause 9.2.5.2. For PUCCH format 3, if $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}$ is not equal $2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5}$ according to [4, TS 38.211], $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}$ is increased to the nearest allowed value of *nrofPRBs* [12, TS 38.331]. If $(O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CRC}}) > \left(M_{\mathrm{RB}}^{\mathrm{PUCCH}} - 1\right) \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} \cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the PUCCH over the $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs.

If a UE is provided a first interlace of $M_{\mathrm{Interlace,0}}^{\mathrm{PUCCH}}$ PRBs by *interlace0* in *InterlaceAllocation* and transmits a PUCCH with O_{ACK} HARQ-ACK information bits, $O_{\mathrm{SR}} = \lceil log_2(K+1) \rceil$ SR bits, and O_{CRC} CRC bits using PUCCH format 2 or PUCCH format 3, the UE transmits the PUCCH over the first interlace if $(O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CRC}}) \leq M_{\mathrm{Interlace,0}}^{\mathrm{PUCCH}} \cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} \cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}} \cdot Q_m \cdot r$; otherwise, if the UE is provided a second interlace by *interlace1* in *PUCCH-format2* or *PUCCH-format3*, the UE transmits the PUCCH over the first and second interlaces.

9.2.5.2 UE procedure for multiplexing HARQ-ACK/SR/CSI in a PUCCH

For a transmission occasion of a single CSI report, a PUCCH resource is provided by *pucch-CSI-ResourceList*. For a transmission occasion of multiple CSI reports, corresponding PUCCH resources can be provided by *multi-CSI-PUCCH-ResourceList*. If a UE is provided first and second *PUCCH-Config*, *multi-CSI-PUCCH-ResourceList* is provided by the first *PUCCH-Config*, and *PUCCH-ResourceId* in *pucch-CSI-ResourceList* or *multi-CSI-PUCCH-ResourceList* indicates a corresponding PUCCH resource in *PUCCH-Resource* provided by the first *PUCCH-Config*.

If a UE is provided only one PUCCH resource set for transmission of HARQ-ACK information in response to PDSCH reception scheduled by a DCI format or in response to a DCI format having associated HARQ-ACK information without scheduling PDSCH reception, the UE does not expect to be provided *simultaneousHARQ-ACK-CSI*.

A UE is configured by *maxCodeRate* a code rate for multiplexing HARQ-ACK, SR, and CSI report(s) in a PUCCH transmission using PUCCH format 2, PUCCH format 3, or PUCCH format 4.

If a UE transmits CSI reports using PUCCH format 2, the UE transmits only wideband CSI for each CSI report [6, TS 38.214]. In the following, a Part 1 CSI report refers either to a CSI report with only wideband CSI or to a Part 1 CSI report with wideband CSI and sub-band CSI. In the following, a Part 2 CSI report refers to a Part 2 CSI sub-report if a CSI report configuration includes a list of sub-configurations provided by *csi-ReportSubConfigList* for the Part 2 CSI report [6, TS 38.214].

Denote as

- O_{ACK} a total number of HARQ-ACK information bits, if any
- O_{SR} a total number of SR bits. $O_{\mathrm{SR}} = 0$ if there is no scheduling request bit; otherwise, $O_{\mathrm{SR}} = \lceil \log_2(K+1) \rceil$ as described in clause 9.2.5.1
- $O_{\mathrm{CSI}} = \sum_{n=1}^{N_{\mathrm{CSI}}^{\mathrm{total}}} \left(O_{\mathrm{CSI\text{-}part1},n} + O_{\mathrm{CSI\text{-}part2},n}\right)$, where $O_{\mathrm{CSI\text{-}part1},n}$ is a number of Part 1 CSI report bits for CSI report with priority value n, $O_{\mathrm{CSI\text{-}part2},n}$ is a number of Part 2 CSI report bits, if any, for CSI report with priority value n [6, TS 38.214], and $N_{\mathrm{CSI}}^{\mathrm{total}}$ is a number of CSI reports that include overlapping CSI reports
- $O_{\mathrm{CRC}} = O_{\mathrm{CRC,CSI\text{-}part1}} + O_{\mathrm{CRC,CSI\text{-}part2}}$, where $O_{\mathrm{CRC,CSI\text{-}part1}}$ is a number of CRC bits, if any, for encoding HARQ-ACK, SR and Part 1 CSI report bits and $O_{\mathrm{CRC,CSI\text{-}part2}}$ is a number of CRC bits, if any, for encoding Part 2 CSI report bits

In the following

- r is a code rate given by *maxCodeRate* as in Table 9.2.5.2-1.
- $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ is a number of PRBs provided by *nrofPRBs*; otherwise, if *nrofPRBs* is not provided, $M_{\mathrm{RB}}^{\mathrm{PUCCH}} = 1$
- $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} = N_{\mathrm{sc}}^{\mathrm{RB}} - 4$ for PUCCH format 2 or, if the PUCCH resource with PUCCH format 2 includes an orthogonal cover code with length $N_{\mathrm{SF}}^{\mathrm{PUCCH,2}}$ provided by *occ-Length*, $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} = \left(N_{\mathrm{sc}}^{\mathrm{RB}} - 4\right) / N_{\mathrm{SF}}^{\mathrm{PUCCH,2}}$, $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} = N_{\mathrm{sc}}^{\mathrm{RB}}$ for PUCCH format 3 or, if the PUCCH resource with PUCCH format 3 includes an orthogonal cover code with length $N_{\mathrm{SF}}^{\mathrm{PUCCH,3}}$ provided by *occ-Length*, $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} = N_{\mathrm{sc}}^{\mathrm{RB}} / N_{\mathrm{SF}}^{\mathrm{PUCCH,3}}$, and $N_{\mathrm{sc,ctrl}}^{\mathrm{RB}} = N_{\mathrm{sc}}^{\mathrm{RB}} / N_{\mathrm{SF}}^{\mathrm{PUCCH,4}}$ for PUCCH format 4, where $N_{\mathrm{sc}}^{\mathrm{RB}}$ is a number of subcarriers per resource block [4, TS 38.211]
- $N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}}$ is equal to a number of PUCCH symbols $N_{\mathrm{symb}}^{\mathrm{PUCCH,2}}$ for PUCCH format 2 provided by *nrofSymbols* in *PUCCH-format2*. For PUCCH format 3 or for PUCCH format 4, $N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}}$ is equal to a number of PUCCH symbols $N_{\mathrm{symb}}^{\mathrm{PUCCH,3}}$ for PUCCH format 3 or equal to a number of PUCCH symbols $N_{\mathrm{symb}}^{\mathrm{PUCCH,4}}$ for PUCCH format 4 provided by *nrofSymbols* in *PUCCH-format3* or *nrofSymbols* in *PUCCH-format4*, respectively, after excluding a number of symbols used for DM-RS transmission for PUCCH format 3 or for PUCCH format 4, respectively [4, TS 38.211]

- $Q_m = 1$ if pi/2-BPSK is the modulation scheme and $Q_m = 2$ if QPSK is the modulation scheme as indicated by *pi2BPSK* for PUCCH format 3 or PUCCH format 4. For PUCCH format 2, $Q_m = 2$

If a UE has one or more CSI reports and zero or more HARQ-ACK/SR information bits to transmit in a PUCCH where the HARQ-ACK, if any, is in response to a PDSCH reception without a corresponding PDCCH

- if any of the CSI reports are overlapping and the UE is provided by *multi-CSI-PUCCH-ResourceList* with $J \le 2$ PUCCH resources in a slot, for PUCCH format 2 and/or PUCCH format 3 and/or PUCCH format 4, as described in clause 9.2.1, where the resources are indexed according to an ascending order for the product of a number of corresponding REs, modulation order Q_m, and configured code rate r ;
  - if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \le \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r\right)_0$, the UE uses PUCCH format 2 resource 0 , or the PUCCH format 3 resource 0 , or the PUCCH format 4 resource 0
  - else if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) > \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r\right)_j$ and $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \le \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r\right)_{j+1}$, $0 \le j < J-1$, the UE transmits a PUCCH conveying HARQ-ACK information, SR and CSI report(s) in a respective PUCCH where the UE uses the PUCCH format 2 resource $j+1$, or the PUCCH format 3 resource $j+1$, or the PUCCH format 4 resource $j+1$
  - else the UE uses the PUCCH format 2 resource $J-1$, or the PUCCH format 3 resource $J-1$, or the PUCCH format 4 resource $J-1$ and the UE selects $N_{\text{CSI}}^{\text{reported}}$ CSI report(s) for transmission together with HARQ-ACK information and SR, when any, in ascending priority value as described in [6, TS 38.214]
- else, the UE transmits the $O_{\text{ACK}}+O_{\text{SR}}+O_{\text{CSI}}+O_{\text{CRC}}$ bits in a PUCCH resource provided by *pucch-CSI-ResourceList* and determined as described in clause 9.2.5

If a UE has HARQ-ACK, SR and wideband or sub-band CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 2, or the UE has HARQ-ACK, SR and wideband CSI reports [6, TS 38.214] to transmit and the UE determines a PUCCH resource with PUCCH format 3 or PUCCH format 4, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field [5, TS 38.212] in a last of a number of DCI formats, excluding the SPS activation DCI, with a value of a PDSCH-to-HARQ_feedback timing indicator field, if present, or a value of *dl-DataToUL-ACK*, or *dl-DataToUL-ACK-r16*, or *dl-DataToUL-ACK-DCI-1-2*, or *dl-DataToUL-ACK-r17*, or *dl-DataToUL-ACK-v1700*, or *dl-DataToUL-ACK-DCI-1-2-r17*, indicating a same slot for the PUCCH transmission, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and
- the UE determines the PUCCH resource set as described in clause 9.2.1 and clause 9.2.3 for O_{UCI} UCI bits

and

- if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI-part1}} + O_{\text{CRC,CSI-part1}}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR, and CSI reports bits by selecting the minimum number $M_{\text{RB,min}}^{\text{PUCCH}}$ of the $M_{\text{RB}}^{\text{PUCCH}}$ PRBs satisfying $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI-part1}} + O_{\text{CRC,CSI-part1}}\right) \le M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in clauses 9.2.3 and 9.2.5.1;
- else, the UE selects $N_{\text{CSI}}^{\text{reported}}$ CSI report(s), from the $N_{\text{CSI}}^{\text{total}}$ CSI reports, for transmission together with HARQ-ACK and SR in ascending priority value [6, TS 38.214], where the value of $N_{\text{CSI}}^{\text{reported}}$ satisfies $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1},N}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}+1} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1},N+1}\right) > M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $O_{\text{CRC,CSI-part1},N}$ is a number of CRC bits corresponding to $O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}} O_{\text{CSI-part1},n}$ UCI bits, and $O_{\text{CRC,CSI-part1},N+1}$ is a number of CRC bits corresponding to $O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}+1} O_{\text{CSI-part1},n}$ UCI bits.

If a UE is provided a first interlace of $M_{\text{Interlace},0}^{\text{PUCCH}}$ PRBs by *interlace0* in *InterlaceAllocation*, the UE has HARQ-ACK, SR and wideband or sub-band CSI reports to transmit, and the UE determines a PUCCH resource with PUCCH format 2, or the UE has HARQ-ACK, SR and wideband CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 3, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field in a last of a number of DCI formats, excluding the SPS activation DCI, with a value of a PDSCH-to-HARQ_feedback timing indicator field, or a value provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in a DCI format, indicating a same slot for the PUCCH transmission, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and

- the UE determines the PUCCH resource set as described in clauses 9.2.1 and 9.2.3 for O_{UCI} UCI bits

and

- if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI-part1}} + O_{\text{CRC,CSI-part1}}\right) \leq M_{\text{Interlace},0}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR, and CSI reports bits in a PUCCH over the first interlace

- else, if the UE is provided a second interlace of $M_{\text{Interlace},1}^{\text{PUCCH}}$ PRBs by *interlace1* and if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI-part1}} + O_{\text{CRC,CSI-part1}}\right) \leq \left(M_{\text{Interlace},0}^{\text{PUCCH}} + M_{\text{Interlace},1}^{\text{PUCCH}}\right) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR, and CSI reports bits in a PUCCH over both the first and second interlaces

- else, the procedure is same as the corresponding one when the UE is provided *PUCCH-ResourceSet* by replacing $M_{\text{RB}}^{\text{PUCCH}}$ with $M_{\text{Interlace},0}^{\text{PUCCH}}$, or, if the UE is provided *interlace1*, by $M_{\text{Interlace},0}^{\text{PUCCH}} + M_{\text{Interlace},1}^{\text{PUCCH}}$.

If a UE has HARQ-ACK, SR and sub-band CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 3 or PUCCH format 4, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field [5, TS 38.212] in a last of a number of DCI formats, excluding the SPS activation DCI, with a value of a PDSCH-to-HARQ_feedback timing indicator field indicating a same slot for the PUCCH transmission, or by a value provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-v1700* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in the last DCI format, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and

- the UE determines the PUCCH resource set as described in clause 9.2.1 and clause 9.2.3 for O_{UCI} UCI bits

and

- if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \leq M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR and the $N_{\text{CSI}}^{\text{total}}$ CSI report bits by selecting the minimum number $M_{\text{RB,min}}^{\text{PUCCH}}$ of PRBs from the $M_{\text{RB}}^{\text{PUCCH}}$ PRBs satisfying $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \leq M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in clauses 9.2.3 and 9.2.5.1

- else,

  - if for $N_{\text{CSI-part2}}^{\text{reported}} > 0$ Part 2 CSI report priority value(s), it is

    $$\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}} O_{\text{CSI-part2},n} + O_{\text{CRC,CSI-part2},N} \leq \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} - \left\lceil \left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{total}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1}}\right) \Big/ \left(Q_m \cdot r\right) \right\rceil \right) \cdot Q_m \cdot r$$

    and

    $$\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}+1} O_{\text{CSI-part2},n} + O_{\text{CRC,CSI-part2,N+1}} > \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} - \left\lceil \left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{total}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1}}\right) \Big/ \left(Q_m \cdot r\right) \right\rceil \right) \cdot Q_m \cdot r$$

    ,

    the UE selects the first $N_{\text{CSI-part2}}^{\text{reported}}$ Part 2 CSI reports, according to respective priority value(s) [6, TS 38.214], for transmission together with the HARQ-ACK, SR and $N_{\text{CSI}}^{\text{total}}$ Part 1 CSI reports , where $O_{\text{CSI-part1},n}$ is the number of Part 1 CSI report bits for the n_{th} CSI report and $O_{\text{CSI-part2},n}$ is the number of Part 2 CSI report bits for the n_{th} CSI report priority value, $O_{\text{CRC,CSI-part2},N}$ is a number of CRC bits corresponding to $\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}} O_{\text{CSI-part2},n}$, and $O_{\text{CRC,CSI-part2},N+1}$ is a number of CRC bits corresponding to $\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}+1} O_{\text{CSI-part2},n}$

- else, the UE drops all Part 2 CSI reports and selects $N_{\text{CSI-part1}}^{\text{reported}}$ Part 1 CSI report(s), from the $N_{\text{CSI}}^{\text{total}}$ CSI reports in ascending priority value [6, TS 38.214], for transmission together with the HARQ-ACK and SR information bits where the value of $N_{\text{CSI-part1}}^{\text{reported}}$ satisfies

$$\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1},N}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r \text{ and}$$

$$\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}+1} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1},N+1}\right) > M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$$

, where $O_{\text{CRC,CSI-part1},N}$ is a number of CRC bits corresponding to $O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}} O_{\text{CSI-part1},n}$ UCI bits, and $O_{\text{CRC,CSI-part1},N+1}$ is a number of CRC bits corresponding to $O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}+1} O_{\text{CSI-part1},n}$ UCI bits.

If a UE is provided a first interlace of $M_{\text{Interlace},0}^{\text{PUCCH}}$ PRBs by *interlace0* in *InterlaceAllocation*, the UE has HARQ-ACK, SR and sub-band CSI reports to transmit, and the UE determines a PUCCH resource with PUCCH format 3, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field in a last of a number of DCI formats, excluding the SPS activation DCI, that have a value of a PDSCH-to-HARQ_feedback timing indicator field indicating a same slot for the PUCCH transmission, or a value provided by *dl-DataToUL-ACK* or *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-DCI-1-2* or *dl-DataToUL-ACK-r17* or *dl-DataToUL-ACK-DCI-1-2-r17* if the PDSCH-to-HARQ_feedback timing indicator field is not present in the last DCI format, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and

- the UE determines the PUCCH resource set as described in clauses 9.2.1 and 9.2.3 for O_{UCI} UCI bits

and

- if $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \le M_{\text{Interlace},0}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR and the $N_{\text{CSI}}^{\text{total}}$ CSI report bits in a PUCCH over the first interlace

- else if the UE is provided a second interlace of $M_{\text{Interlace},1}^{\text{PUCCH}}$ PRBs by *interlace1* and if $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \le \left(M_{\text{Interlace},0}^{\text{PUCCH}} + M_{\text{Interlace},1}^{\text{PUCCH}}\right) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE transmits the HARQ-ACK, SR, and CSI reports bits in a PUCCH over both the first and second interlaces

- else, the procedure is same as the corresponding one when the UE is provided *PUCCH-ResourceSet* by replacing $M_{\text{RB}}^{\text{PUCCH}}$ with $M_{\text{Interlace},0}^{\text{PUCCH}}$, or, if the UE is provided *interlace1*, with $M_{\text{Interlace},0}^{\text{PUCCH}} + M_{\text{Interlace},1}^{\text{PUCCH}}$.

Table 9.2.5.2-1: Code rate r corresponding to value of *maxCodeRate*

maxCodeRate	**Code rate r**

0	0.08
1	0.15
2	0.25
3	0.35
4	0.45
5	0.60
6	0.80
7	Reserved

9.2.5.3 UE procedure for reporting UCI of different priorities

If a UE

- is provided *PUCCH-ConfigurationList* for PUCCH transmissions with priority 0 and 1,
- is provided *uci-MuxWithDiffPrio*, and
- would transmit overlapping PUCCHs that include a first PUCCH with $O_{\mathrm{ACK},0}$ HARQ-ACK information bits of priority 0 and a second PUCCH with $O_{\mathrm{ACK},1}$ HARQ-ACK information bits of priority 1
    - if the PUCCH resource for the second PUCCH includes PUCCH format 2, 3, or 4 and additionally includes $O_{\mathrm{SR},1}$ SR bits of priority 1, $O_{\mathrm{ACK},1}$ is replaced by $O_{\mathrm{ACK},1}+O_{\mathrm{SR},1}$ where $O_{\mathrm{SR},1}$ is determined according to clause 9.2.5.1

the UE

- determines
    - a PUCCH resource set from the second *PUCCH-Config* using $O_{\mathrm{UCI}}=O_{\mathrm{ACK},0}+O_{\mathrm{ACK},1}$ as described in clause 9.2.1, and a PUCCH resource from the PUCCH resource set as described in clause 9.2.3 where a DCI format, if any, triggers PUCCH transmission of priority 1, or
    - a PUCCH resource from the second *sps-PUCCH-AN-List* using $O_{\mathrm{UCI}}=O_{\mathrm{ACK},0}+O_{\mathrm{ACK},1}$ as described in clause 9.2.1, and
- multiplexes the $O_{\mathrm{ACK},0}$ and $O_{\mathrm{ACK},1}$ HARQ-ACK information bits in a same PUCCH using the PUCCH resource.

If the PUCCH resource includes PUCCH format 2 or PUCCH format 3 and $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs, the UE determines a number of $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}\le M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs for the PUCCH transmission to be the minimum number of PRBs that starts from the first PRB from the $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs and results to

$$\left(O_{\mathrm{ACK},0}+O_{\mathrm{CRC},0}\right)\cdot r_1+\left(O_{\mathrm{ACK},1}+O_{\mathrm{CRC},1}\right)\cdot r_0\le M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}\cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}\cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}}\cdot Q_m\cdot r_0\cdot r_1$$

where $O_{\mathrm{CRC},0}$ or $O_{\mathrm{CRC},1}$ is a number of CRC bits, if any, for encoding the $O_{\mathrm{ACK},0}$ or the $O_{\mathrm{ACK},1}$ HARQ-ACK information bits, respectively, r_0 is provided by *maxCodeRateLP*, and the remaining parameters are as defined in clause 9.2.5.2 with $r_1=r$. For PUCCH format 3, if $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}$ is not equal to $2^{\alpha_2}\cdot 3^{\alpha_3}\cdot 5^{\alpha_5}$ [4, TS 38.211], $M_{\mathrm{RB,min}}^{\mathrm{PUCCH}}$ is increased to a nearest value that is equal to $2^{\alpha_2}\cdot 3^{\alpha_3}\cdot 5^{\alpha_5}$ and does not exceed *nrofPRBs*.

If $\left(O_{\mathrm{ACK},0}+O_{\mathrm{CRC},0}\right)\cdot r_1+\left(O_{\mathrm{ACK},1}+O_{\mathrm{CRC},1}\right)\cdot r_0> M_{\mathrm{RB}}^{\mathrm{PUCCH}}\cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}\cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}}\cdot Q_m\cdot r_0\cdot r_1$, the UE transmits the PUCCH over the $M_{\mathrm{RB}}^{\mathrm{PUCCH}}$ PRBs.

If a UE transmits a PUCCH that includes HARQ-ACK information bits of priority 0 and 1 using a PUCCH resource that includes PUCCH format 2, 3 or 4, the UE determines a power for the PUCCH transmission as described in clause 7.2.1 assuming that the PUCCH includes only UCI bits of priority 1, where $N_{\mathrm{RE}}(i)=\min\left(M_{\mathrm{RB}}^{\mathrm{PUCCH}}\cdot N_{\mathrm{sc,ctrl}}^{\mathrm{RB}}\cdot N_{\mathrm{symb\text{-}UCI}}^{\mathrm{PUCCH}},\left\lceil\left(O_{\mathrm{ACK},1}+O_{\mathrm{CRC},1}\right)/\left(Q_m\cdot r_1\right)\right\rceil\right)$. If $O_{ACK,1}\le 11$ bits, $n_{\mathrm{HARQ-ACK},1}+O_{\mathrm{SR},1}$ replaces $n_{\mathrm{HARQ-ACK}}(\mathrm{i})+O_{\mathrm{SR}}(i)+O_{\mathrm{CSI}}(i)$ in the $\Delta_{\mathrm{TF},b,f,c}(i)$ calculation in clause 7.2.1; otherwise, $O_{\mathrm{ACK},1}+O_{\mathrm{CRC},1}$ replaces $O_{\mathrm{ACK}}(i)+O_{\mathrm{SR}}(i)+O_{\mathrm{CSI}}(i)+O_{\mathrm{CRC}}(i)$ in the BPRE(i) calculation in clause 7.2.1.

If a UE transmits a PUCCH that includes one HARQ-ACK information bit of priority 0 and one HARQ-ACK information bit of priority 1

- if the PUCCH transmission uses a resource that includes PUCCH format 0, the HARQ-ACK information bits of priority 1 and priority 0 are set as the first and second bits in Table 9.2.3-4, respectively, to derive the m_{CS} of the PUCCH transmission
- if the PUCCH transmission uses a resource that includes PUCCH format 1, the HARQ-ACK information bits of priority 1 and priority 0 are the first and second bits, respectively, of the QPSK modulated symbol for the PUCCH transmission

If a UE transmits a PUCCH that includes HARQ-ACK information bits of priority 0 and 1 using PUCCH format 1, the UE determines a power for the PUCCH transmission as described in clause 7.2.1 assuming that all HARQ-ACK information bits have priority 1.

If a UE is provided a first interlace of $M_{\text{Interlace},0}^{\text{PUCCH}}$ PRBs by *interlace0* in *InterlaceAllocation*

- if the UE is provided a second interlace of $M_{\text{Interlace},1}^{\text{PUCCH}}$ PRBs by *interlace1* in *InterlaceAllocation*
  - if $\left(O_{\text{ACK},0} + O_{\text{CRC},0}\right) \cdot r_1 + \left(O_{\text{ACK},1} + O_{\text{CRC},1}\right) \cdot r_0 \leq M_{\mathtt{Interlace},0}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb-UCI}}^{\text{PUCCH}} \cdot Q_m \cdot r_0 \cdot r_1$, the UE transmits the PUCCH over the first interlace
  - else, the UE transmits the PUCCH over both the first and second interlaces
- else the UE transmits the PUCCH over the first interlace

If the UE transmits a PUCCH that includes HARQ-ACK information bits of priority 0 and 1 over interlaces, the UE determines a power for the PUCCH transmission as described in clause 7.2.1 assuming that the PUCCH includes only UCI bits of priority 1.

9.2.5.4 UE procedure for deferring HARQ-ACK for SPS PDSCH

If a UE is provided *sps-HARQ-Deferral* and, after performing the procedures in clauses 9 and 9.2.5 to resolve overlapping among PUCCHs and PUSCHs in a first slot, if any, the UE determines a PUCCH resource for a PUCCH transmission with first HARQ-ACK information bits for SPS PDSCH receptions that the UE would report for a first time, and the PUCCH resource

- is provided by *SPS-PUCCH-AN-List* as described in clause 9.2.1, or by *n1PUCCH-AN* if *SPS-PUCCH-AN-List* is not provided
- is not cancelled by an overlapping PUCCH or PUSCH transmission of larger priority index
- overlaps with a symbol indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigDedicated*, or indicated for a SS/PBCH block by *ssb-PositionsInBurst*, or belonging to a CORESET associated with a Type0-PDCCH CSS set

the UE

- determines an earliest second slot and, after performing the procedures in clauses 9.2.1 and 9.2.3 to determine a PUCCH with third HARQ-ACK information bits including second HARQ-ACK information bits and then performing the procedures in clauses 9 and 9.2.5 to resolve overlapping among PUCCHs and PUSCHs, if any, a PUSCH or a PUCCH in the earliest second slot to multiplex the third HARQ-ACK information bits that include second HARQ-ACK information bits from the first HARQ-ACK information bits , where the second HARQ-ACK information bits correspond to SPS PDSCH configurations with *sps-HARQ-Deferral* values that are larger than or equal to a time difference, with reference to slots for PUCCH transmissions on the primary cell, between the second slot and the slot of the SPS PDSCH reception, if any
  - if the UE detects a DCI format in a PDCCH reception that triggers a PUCCH transmission with a Type-3 HARQ-ACK codebook in a slot as described in clause 9.1.4, the UE stops the procedure to determine the earliest second slot in the slot
  - if the UE is provided a periodic cell switching pattern for PUCCH transmissions by *pucch-sSCellPattern*, the UE determines the earliest second slot and a corresponding cell based on the periodic cell switching pattern as described in clause 9.A

  - if the UE multiplexes the second HARQ-ACK information in a PUSCH, or in a PUCCH using a resource that is not from *SPS-PUCCH-AN-List*, or from *n1PUCCH-AN* if *SPS-PUCCH-AN-List* is not provided, the UE stops the procedure to determine the earliest second slot in the slot
  - if the UE multiplexes the second HARQ-ACK information in a first PUCCH using a resource provided by *SPS-PUCCH-AN-List*, or by *n1PUCCH-AN* if *SPS-PUCCH-AN-List* is not provided, of smaller priority index and the UE drops the first PUCCH transmission due to an overlapping with a second PUSCH or PUCCH transmission of larger priority index, the UE stops the procedure to determine the earliest second slot in the slot
  - if the UE multiplexes the second HARQ-ACK information in a first PUCCH using a resource provided by *SPS-PUCCH-AN-List*, or by *n1PUCCH-AN* if *SPS-PUCCH-AN-List* is not provided, and the PUCCH transmission is not dropped due to an overlapping with a PUSCH or PUCCH transmission of larger priority and does not have any symbol that overlaps with a symbol indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigDedicated*, or indicated for a SS/PBCH block by *ssb-PositionsInBurst*, or belonging to a CORESET associated with a Type0-PDCCH CSS set, the UE stops the procedure to determine the earliest second slot in the slot
  - the second HARQ-ACK information bits, generated as described in clause 9.1.2, are appended to fourth HARQ-ACK information bits the UE generates as described in clauses 9.1.2, 9.1.2.1, 9.1.3.1, or 9.1.5
  - if the UE would receive a PDSCH providing a TB for a same HARQ process as a HARQ-ACK information bit from the second HARQ-ACK information bits prior to transmitting the PUCCH or the PUSCH, the UE does not include the HARQ-ACK information bit in the second HARQ-ACK information bits.

The UE does not expect to be provided both *sps-HARQ-Deferral* and *nrofSlots* or *pucch-RepetitionNrofSlots* for any PUCCH resource of same priority.

O_{ACK} is the number of the third HARQ-ACK information bits.

If $O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CSI}} \leq 11$, the UE determines a number of HARQ-ACK information bits for obtaining a transmission power for a PUCCH transmission in the second slot, as described in clause 7.2.1, as $n_{\mathrm{HARQ-ACK}} = n_{\mathrm{HARQ-ACK,0}} + n_{\mathrm{HARQ-ACK,1}}$ where

- $n_{\mathrm{HARQ-ACK,0}}$ is the number of HARQ-ACK information bits, if any, that the UE determines as described in clause 9.1.2.1, 9.1.3.1 or 9.1.5 for the fourth HARQ-ACK information bits,
- $n_{\mathrm{HARQ-ACK,1}}$ is determined as described in clause 9.1.2.1 or 9.1.3.1 for the second HARQ-ACK information bits.

9.2.6 PUCCH repetition procedure

A UE that does not have dedicated PUCCH resource configuration and indicates a capability to transmit with repetitions a PUCCH with HARQ-ACK information [11, TS 38.321], determines a number of $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ slots for repetitions of a PUCCH transmission with HARQ-ACK information based on an indication by *numberOfPUCCHforMsg4HARQACK-RepetitionsList*. If *numberOfPUCCHforMsg4HARQACK-RepetitionsList* provides more than one values, the DAI field in a DCI format 1_0 with CRC scrambled by a TC-RNTI scheduling a PDSCH reception that includes a UE contention resolution identity indicates $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ from the more than one values. The UE transmits any PUCCH with repetitions over $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ slots before dedicated PUCCH resource configuration is provided. The UE transmits each repetition of the PUCCH using frequency hopping as described in Clause 9.2.1.

In the remaining of this clause, a UE without dedicated PUCCH resource configuration determines a value of a parameter, if applicable, according to Table 9.2.1-1 and/or as specified above in this clause for a PUCCH transmission with repetitions from the UE.

A UE can be indicated to transmit a PUCCH over $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ slots using a PUCCH resource, where

- if the PUCCH resource is indicated by a DCI format and includes *pucch-RepetitionNrofSlots*, $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ is provided by *pucch-RepetitionNrofSlots*
- otherwise, $N_{\mathrm{PUCCH}}^{\mathrm{repeat}}$ is provided by *nrofSlots*

If the UE is provided *subslotLengthForPUCCH*, a slot for a PUCCH transmission with repetitions over $N_{\text{PUCCH}}^{\text{repeat}} > 1$ slots includes a number of symbols indicated by *subslotLengthForPUCCH*.

For $N_{\text{PUCCH}}^{\text{repeat}} > 1$,

- the UE repeats the PUCCH transmission with the UCI over $N_{\text{PUCCH}}^{\text{repeat}}$ slots
  - if the UE is provided *multipanelSFN-Scheme* and *apply-IndicatedTCIState* = 'both', a repetition of the PUCCH transmission simultaneously uses first and second spatial domain filters corresponding to first and second *TCI-State* or *TCI-UL-State*
- a repetition of the PUCCH transmission in each of the $N_{\text{PUCCH}}^{\text{repeat}}$ slots has a same number of consecutive symbols, as provided by *nrofSymbols*
- a repetition of the PUCCH transmission in each of the $N_{\text{PUCCH}}^{\text{repeat}}$ slots has a same first symbol, as provided by *startingSymbolIndex* if *subslotLengthForPUCCH* is not provided; otherwise mod(*startingSymbolIndex*, *subslotLengthForPUCCH*)
- the UE is configured by *interslotFrequencyHopping* whether or not to perform frequency hopping for repetitions of the PUCCH transmission in different slots
  - if the UE is configured to perform frequency hopping for repetitions of a PUCCH transmission across slots and the UE is not provided *pucch-DMRS-Bundling* = 'enabled'
    - the UE performs frequency hopping per slot
    - the UE transmits the PUCCH starting from a first PRB, provided by *startingPRB*, in slots with even number and starting from a second PRB, provided by *secondHopPRB*, in slots with odd number. The slot indicated to the UE for the first repetition of the PUCCH transmission has number 0 and each subsequent slot until the UE transmits the PUCCH in $N_{\text{PUCCH}}^{\text{repeat}}$ slots is counted regardless of whether or not the UE transmits the PUCCH in the slot
    - the UE does not expect to be configured to perform frequency hopping for a repetition of the PUCCH transmission within a slot
  - if the UE is configured to perform frequency hopping for repetitions of a PUCCH transmission across slots and the UE is provided *pucch-DMRS-Bundling* = 'enabled'
    - the UE performs frequency hopping per interval of $N_{\text{PUCCH}}^{\text{interval}}$ consecutive slots, that start from a slot indicated to the UE and where the UE would transmit a first repetition of the PUCCH, where $N_{\text{PUCCH}}^{\text{interval}}$ is the value of *pucch-FrequencyHoppingInterval*, if provided; otherwise, $N_{\text{PUCCH}}^{\text{interval}}$ is the value of *pucch-TimeDomainWindowLength*
    - the UE transmits the PUCCH over intervals until the UE transmits the PUCCH in $N_{\text{PUCCH}}^{\text{repeat}}$ slots, where the first interval has number 0 and each subsequent interval is counted regardless of whether or not the UE transmits the PUCCH in a slot
    - the UE transmits the PUCCH starting from a first PRB, provided by *startingPRB*, in intervals with even number and starting from a second PRB, provided by *secondHopPRB*, in intervals of frequency hopping intervals with odd number
    - the UE does not expect to be configured to perform frequency hopping for a repetition of the PUCCH transmission within a slot
  - if the UE is not configured to perform frequency hopping for repetitions of a PUCCH transmission across slots and the UE is configured to perform frequency hopping for a repetition of the PUCCH transmission within a slot, the frequency hopping pattern between the first PRB and the second PRB is same within each slot

If the UE determines that, for a repetition of a PUCCH transmission in a slot, the number of symbols available for the PUCCH transmission is smaller than the value provided by *nrofSymbols* for the corresponding PUCCH format, the UE does not transmit the PUCCH repetition in the slot.

A SS/PBCH block symbol is a symbol of an SS/PBCH block with candidate SS/PBCH block index corresponding to the SS/PBCH block index indicated to a UE by *ssb-PositionsInBurst* in *SIB1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon* or, if the UE is not provided *dl-OrJointTCI-StateList*, by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* associated to physical cell ID with active TCI states for PDCCH or PDSCH, or for a set of symbols of a slot corresponding to SS/PBCH blocks configured for L1 beam measurement/reporting.

For unpaired spectrum, the UE determines the $N_{\text{PUCCH}}^{\text{repeat}}$ slots for a PUCCH transmission starting from a slot indicated to the UE as described in clause 9.2.3 for HARQ-ACK reporting, or a slot determined as described in clause 9.2.4 for SR reporting or in clause 5.2.1.4 of [6, TS 38.214] for CSI reporting and having

- an UL symbol, as described in clause 11.1, or flexible symbol that is not SS/PBCH block symbol provided by *startingSymbolIndex* as a first symbol, and

- consecutive UL symbols, as described in clause 11.1, or flexible symbols that are not SS/PBCH block symbols, starting from the first symbol, equal to or larger than a number of symbols provided by *nrofsymbols*

For paired spectrum or supplementary uplink band, the UE determines the $N_{\text{PUCCH}}^{\text{repeat}}$ slots for a PUCCH transmission as the $N_{\text{PUCCH}}^{\text{repeat}}$ consecutive slots starting from a slot indicated to the UE as described in clause 9.2.3 for HARQ-ACK reporting, or a slot determined as described in clause 9.2.4 for SR reporting or in clause 5.2.1.4 of [6, TS 38.214] for CSI reporting.

If a UE would transmit a PUCCH over a first number $N_{\text{PUCCH}}^{\text{repeat}} > 1$ of slots and the UE would transmit a PUSCH with repetition Type A or with TB processing over multiple slots over a second number of slots, and the PUCCH transmission would overlap with the PUSCH transmission in one or more slots, and the conditions in clause 9.2.5 for multiplexing the UCI in the PUSCH are satisfied in the overlapping slots, the UE transmits the PUCCH and does not transmit the PUSCH in the overlapping slots.

If a UE would transmit a PUCCH over a first number $N_{\text{PUCCH}}^{\text{repeat}} > 1$ of slots and the UE would transmit a PUSCH with repetition Type B over a second number of slots, and the PUCCH transmission would overlap with actual PUSCH repetitions in one or more slots, and the conditions in clause 9.2.5 for multiplexing the UCI in the PUSCH are satisfied for the overlapping actual PUSCH repetitions, the UE transmits the PUCCH and does not transmit the overlapping actual PUSCH repetitions.

A UE does not multiplex different UCI types in a PUCCH transmission with repetitions over $N_{\text{PUCCH}}^{\text{repeat}} > 1$ slots. If a UE would transmit a first PUCCH over more than one slot and at least a second PUCCH over one or more slots, and the transmissions of the first PUCCH and the second PUCCH would overlap in a number of slots then, for each slot of the number of slots and with UCI type priority of HARQ-ACK > SR > CSI with higher priority > CSI with lower priority, the UE determines an earliest first PUCCH in a slot with the order of earliest starting symbol followed by longest duration and the second PUCCHs overlapping with the earliest first PUCCH, and then performs the following

- the UE does not expect more than one PUCCH from the first PUCCH and the second PUCCHs to start at a same slot and include a UCI type with same priority

- if more than one PUCCH from the first PUCCH and the second PUCCHs include a UCI type with the same highest priority, the UE transmits the PUCCH with the highest priority starting at an earliest slot and does not transmit the other PUCCHs, otherwise,

- the UE transmits the PUCCH that includes the UCI type with the highest priority and does not transmit the PUCCHs that include the UCI type with lower priority

The UE repeats the above procedure until there is no PUCCH overlapping with any PUCCH with repetitions in the slot.

When a PUCCH resource used for repetitions of a PUCCH transmission by a UE includes

- first and second spatial settings, or first and second sets of power control parameters, as described in [11, TS 38.321] and in clauses 7 and 7.2.1, or

- first and second *TCI-State* or *TCI-UL-State* and *apply-IndicatedTCIState* = 'both', and the PUCCH resource does not include *multipanelSFN-Scheme*

the UE

- uses the first and second spatial settings or the first and second indicated *TCI-State* or *TCI-UL-State*, or the first and second sets of power control parameters, for first and second repetitions of the PUCCH transmission, respectively, when $N_{\text{PUCCH}}^{\text{repeat}} = 2$,

- alternates between the first and second spatial settings or between the first and second indicated *TCI-State* or *TCI-UL-State*, or between the first and second sets of power control parameters, respectively, per $N_{\text{PUCCH}}^{\text{switch}}$ repetitions of the PUCCH transmission, where $N_{\text{PUCCH}}^{\text{switch}} = 1$ if *mappingPattern* = 'cyclicMapping'; else, $N_{\text{PUCCH}}^{\text{switch}} = 2$.

A UE does not expect a PUCCH that is in response to a DCI format detection to overlap with any other PUCCH that does not satisfy the corresponding timing conditions in clause 9.2.5.

If a UE would transmit a PUCCH over $N_{\text{PUCCH}}^{\text{repeat}}$ slots and the UE does not transmit the PUCCH in a slot from the $N_{\text{PUCCH}}^{\text{repeat}}$ slots due to overlapping with another PUCCH transmission in the slot, the UE counts the slot in the number of $N_{\text{PUCCH}}^{\text{repeat}}$ slots.

For DAPS operation, if a UE would transmit a PUCCH over $N_{\text{PUCCH}}^{\text{repeat}}$ slots on the source MCG and the UE does not transmit the PUCCH in a slot from the $N_{\text{PUCCH}}^{\text{repeat}}$ slots due to overlapping in time with UE transmission on the target MCG in the slot, the UE counts the slot in the number of $N_{\text{PUCCH}}^{\text{repeat}}$ slots.

9.3 UCI reporting in physical uplink shared channel

Offset values are defined for a UE to determine a number of resources for multiplexing HARQ-ACK information and for multiplexing CSI reports in a PUSCH. Offset values are also defined for multiplexing CG-UCI or UTO-UCI [5, TS 38.212] in a CG-PUSCH. The offset values are signalled to a UE either by a DCI format scheduling the PUSCH transmission or by higher layers.

If a DCI format that does not include a beta_offset indicator field schedules the PUSCH transmission from the UE and the UE is provided *betaOffsets = 'semiStatic'* or *betaOffsetsDCI-0-2 = 'semiStaticDCI-0-2'*, the UE applies the $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{CSI-1}}$, and $\beta_{\text{offset}}^{\text{CSI-2}}$ values that are provided by *betaOffsets = 'semiStatic'* for DCI formats 0_0/0_1/0_3 or by *betaOffsetsDCI-0-2 = 'semiStaticDCI-0-2'* for DCI format 0_2 for the corresponding HARQ-ACK information, Part 1 CSI reports and Part 2 CSI reports. If the PUSCH transmission has priority 0 or priority 1 and the UE is configured by *uci-MuxWithDiffPrio* to multiplex HARQ-ACK information of priority 1 or priority 0, respectively, and if the UE multiplexes HARQ-ACK information of priority 1 or priority 0, the UE applies corresponding $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$ or $\beta_{\text{offset}}^{\text{HARQ-ACK,0}}$ provided by *betaOffsetsCrossPri1 = 'semiStatic'* for DCI formats 0_0/0_1/0_3 and by *betaOffsetsCrossPri1DCI-0-2= 'semiStatic'* for DCI format 0_2, or by *betaOffsetsCrossPri0 = 'semiStatic'* for DCI format 0_0/0_1/0_3 and by *betaOffsetsCrossPri0DCI-0-2= 'semiStatic'* for DCI format 0_2, respectively.

If the PUSCH transmission is with a configured grant and the UE is provided *CG-UCI-OnPUSCH= 'semiStatic'*, the UE applies the $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{CSI-1}}$, and $\beta_{\text{offset}}^{\text{CSI-2}}$ values that are provided by *CG-UCI-OnPUSCH = 'semiStatic'* for the corresponding HARQ-ACK information, Part 1 CSI reports and Part 2 CSI reports. If the PUSCH transmission has priority 0 or priority 1 and the UE is configured by *uci-MuxWithDiffPrio* to multiplex HARQ-ACK information of priority 1 or priority 0, respectively, and if the UE multiplexes HARQ-ACK information of priority 1 or priority 0, the UE applies corresponding $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$ or $\beta_{\text{offset}}^{\text{HARQ-ACK,0}}$ provided by *cg-betaOffsetsCrossPri1 = 'semiStatic'* or *cg-betaOffsetsCrossPri0 = 'semiStatic'*, respectively.

If the PUSCH transmission is scheduled by DCI format 0_0 and the UE is provided *betaOffsets = 'dynamic'*, the UE applies the $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{CSI-1}}$, and $\beta_{\text{offset}}^{\text{CSI-2}}$ values that are determined from the first value of *betaOffsets = 'dynamic'*. If the UE is configured by *uci-MuxWithDiffPrio* to multiplex HARQ-ACK information of priority 1, the UE applies corresponding $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$ provided by the first value of *betaOffsetsCrossPri1 = 'dynamic'*.

If the PUSCH transmission is a configured grant Type 2 PUSCH and the UE is provided *CG-UCI-OnPUSCH ='dynamic'*, the UE applies the $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{CSI-1}}$, and $\beta_{\text{offset}}^{\text{CSI-2}}$ values that are determined from the first value of *CG-UCI-OnPUSCH = 'dynamic'*. If the PUSCH transmission has priority 0 or priority 1 and the UE is configured by *uci-MuxWithDiffPrio* to multiplex HARQ-ACK information of priority 1 or priority 0, respectively, and if the UE multiplexes HARQ-ACK information of priority 1 or priority 0, the UE applies corresponding $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$ or $\beta_{\text{offset}}^{\text{HARQ-ACK,0}}$ provided by the first value of *cg-betaOffsetsCrossPri1 = 'dynamic'* or *cg-betaOffsetsCrossPri0 = 'dynamic'*, respectively.

HARQ-ACK information offsets $\beta_{\text{offset}}^{\text{HARQ-ACK}}$ are configured to values according to Table 9.3-1. The *betaOffsetACK-Index1*, *betaOffsetACK-Index2*, and *betaOffsetACK-Index3* respectively provide indexes $I_{\text{offset},0}^{\text{HARQ-ACK}}$, $I_{\text{offset},1}^{\text{HARQ-ACK}}$, and $I_{\text{offset},2}^{\text{HARQ-ACK}}$ for the UE to use if the UE multiplexes up to 2 HARQ-ACK information bits, more than 2 and up to 11 HARQ-ACK information bits, and more than 11 bits in the PUSCH, respectively.

Offsets $\beta_{\text{offset}}^{\text{HARQ-ACK,0}}$ for multiplexing HARQ-ACK information with priority 0 in a PUSCH transmission with priority 1 are configured to values according to Table 9.3-1. The first, second and third values provided by any of *betaOffsetsCrossPri0*, *betaOffsetsCrossPri0DCI-0-2*, or *cg-betaOffsetsCrossPri0* respectively provide indexes $I_{\text{offset},0}^{\text{HARQ-ACK,0}}$, $I_{\text{offset},1}^{\text{HARQ-ACK,0}}$, and $I_{\text{offset},2}^{\text{HARQ-ACK,0}}$ for the UE to use if the UE multiplexes up to 2 bits, more than 2 and up to 11 bits, and more than 11 bits of HARQ-ACK information with priority 0 in the PUSCH transmission with priority 1, respectively.

Offsets $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$ for multiplexing HARQ-ACK information with priority 1 in a PUSCH transmission with priority 0 are configured to values according to Table 9.3-1. The first, second and third values provided by any of *betaOffsetsCrossPri1*, *betaOffsetsCrossPri1DCI-0-2, or cg-betaOffsetsCrossPri1* respectively provide indexes $I_{\text{offset},0}^{\text{HARQ-ACK,1}}$, $I_{\text{offset},1}^{\text{HARQ-ACK,1}}$, and $I_{\text{offset},2}^{\text{HARQ-ACK,1}}$ for the UE to use if the UE multiplexes up to 2 bits, more than 2 and up to 11 bits, and more than 11 bits of HARQ-ACK information with priority 1 in the PUSCH transmission with priority 0, respectively.

Part 1 CSI report and Part 2 CSI report offsets $\beta_{\text{offset}}^{\text{CSI-1}}$ and $\beta_{\text{offset}}^{\text{CSI-2}}$, respectively, are configured to values according to Table 9.3-2. The *betaOffsetCSI-Part1-Index1* and *betaOffsetCSI-Part2-Index1* respectively provide indexes $I_{\text{offset},0}^{\text{CSI-1}}$ and $I_{\text{offset},0}^{\text{CSI-2}}$ for the UE to use if the UE multiplexes up to 11 bits for Part 1 CSI reports or Part 2 CSI reports in the PUSCH. The *betaOffsetCSI-Part1-Index2* and *betaOffsetCSI-Part2-Index2* respectively provide indexes $I_{\text{offset},1}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-2}}$ for the UE to use if the UE multiplexes more than 11 bits for Part 1 CSI reports or Part 2 CSI reports in the PUSCH.

If a DCI format that includes a beta_offset indicator field with one bit or two bits, as configured by *UCI-OnPUSCH* for DCI format 0_1 or *UCI-OnPUSCH-DCI-0-2* for DCI format 0_2 or *UCI-OnPUSCH-DCI-0-3,* schedules the PUSCH transmission from the UE, the UE is provided by each of {*betaOffsetACK-Index1*, *betaOffsetACK-Index2*, *betaOffsetACK-Index3*}, the {first, second, third} values provided by *betaOffsetsCrossPri0*, or *betaOffsetsCrossPri0DCI-0-2*, and the {first, second, third} values provided by *betaOffsetsCrossPri1*, or *betaOffsetsCrossPri1DCI-0-2*, a set of two or four $I_{\text{offset}}^{\text{HARQ-ACK}}$, $I_{\text{offset}}^{\text{HARQ-ACK,0}}$, and $I_{\text{offset}}^{\text{HARQ-ACK,1}}$ indexes from Table 9.3-1 for multiplexing HARQ-ACK information in the PUSCH transmission and by each of {*betaOffsetCSI-Part1-Index1*, *betaOffsetCSI-Part1-Index2*} a set of two or four $I_{\text{offset}}^{\text{CSI-1}}$ indexes, and by each of {*betaOffsetCSI-Part2-Index1*, *betaOffsetCSI-Part2-Index2*} a set of two or four $I_{\text{offset}}^{\text{CSI-2}}$ indexes from Table 9.3-2, respectively, for multiplexing Part 1 CSI reports and Part 2 CSI reports, respectively, in the PUSCH transmission. The beta_offset indicator field indicates a $I_{\text{offset}}^{\text{HARQ-ACK}}$ value and/or a $I_{\text{offset}}^{\text{HARQ-ACK,0}}$ value, and/or a $I_{\text{offset}}^{\text{HARQ-ACK,1}}$ value, a $I_{\text{offset}}^{\text{CSI-1}}$ value and a $I_{\text{offset}}^{\text{CSI-2}}$ value from the respective sets of values, with the mapping defined in Table 9.3-3 and in Table 9.3-3A. If the PUSCH transmission has priority 0 or priority 1, and the UE is provided *uci-MuxWithDiffPrio*, and the UE multiplexes HARQ-ACK information of priority 1 or priority 0 in the PUSCH, the UE applies the {first, second, third} values provided by *betaOffsetsCrossPri1 = 'dynamic'* for DCI format 0_1/0_3, *betaOffsetsCrossPri1DCI-0-2= 'dynamic'* for DCI format 0_2, or applies the {first, second, third} values provided by *betaOffsetsCrossPri0 = 'dynamic'* for DCI format 0_1/0_3, *betaOffsetsCrossPri0DCI-0-2= 'dynamic'* for DCI format 0_2.

For a PUSCH transmission that is configured by a *ConfiguredGrantConfig* and includes CG-UCI, the UE multiplexes the CG-UCI in the PUSCH transmission using a $I_{\text{offset}}^{\text{CG-UCI}}$ value provided by *betaOffsetCG-UCI* with the mapping defined in Table 9.3-1. The CG-UCI has same priority value as the PUSCH. If the UE is provided *cg-UCI-Multiplexing* and multiplexes HARQ-ACK information of same priority value as the CG-UCI in the PUSCH transmission, as described in clauses 9 and 9.2.5, the UE jointly encodes the HARQ-ACK information and the CG-UCI [5, TS 38.212] and determines a number of resources for multiplexing the combined information in a PUSCH using $\beta_{\text{offset}}^{\text{HARQ-ACK}}$ which provides indexes $I_{\text{offset},1}^{\text{HARQ-ACK}}$ and $I_{\text{offset},2}^{\text{HARQ-ACK}}$ for the UE to use if the UE multiplexes up to 11, and more than 11 combined information bits, respectively.

For a PUSCH transmission that is configured by a *ConfiguredGrantConfig* and includes UTO-UCI, the UE multiplexes the UTO-UCI in the PUSCH transmission using a $I_{\text{offset}}^{\text{UTO-UCI}}$ value provided by *betaOffsetUTO-UCI* with the mapping defined in Table 9.3-1. The UTO-UCI has same priority value as the PUSCH. If the UE multiplexes HARQ-ACK information of same priority value as the UTO-UCI in the PUSCH transmission, as described in clauses 9 and 9.2.5, the UE jointly encodes the HARQ-ACK information and the UTO-UCI and determines a number of resources for multiplexing the combined information in the PUSCH using $\beta_{\mathrm{offset}}^{\mathrm{HARQ-ACK}}$ which provides indexes $I_{\mathrm{offset},1}^{\mathrm{HARQ-ACK}}$ and $I_{\mathrm{offset},2}^{\mathrm{HARQ-ACK}}$ for the UE to use if the UE multiplexes up to 11, and more than 11 combined information bits, respectively.

Table 9.3-1: Mapping of beta_offset values for HARQ-ACK information, CG-UCI, or UTO-UCI and the index signalled by higher layers

$I_{\text{offset},0}^{\text{HARQ-ACK}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK}}$ or $I_{\text{offset}}^{\text{CG-UCI}}$ or $I_{\text{offset}}^{\text{UTO-UCI}}$ or $I_{\text{offset},0}^{\text{HARQ-ACK,0}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK,0}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK,0}}$ or $I_{\text{offset},0}^{\text{HARQ-ACK,1}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK,1}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK,1}}$	$\beta_{\text{offset}}^{\text{HARQ-ACK}}$ or $\beta_{\text{offset}}^{\text{CG-UCI}}$ or $\beta_{\text{offset}}^{\text{UTO-UCI}}$ or $\beta_{\text{offset}}^{\text{HARQ-ACK,0}}$ or $\beta_{\text{offset}}^{\text{HARQ-ACK,1}}$
0	1.000
1	2.000
2	2.500
3	3.125
4	4.000
5	5.000
6	6.250
7	8.000
8	10.000
9	12.625
10	15.875
11	20.000
12	31.000
13	50.000
14	80.000
15	126.000
16	0.6
17	0.4
18	0.2
19	0.1
20	0.05
21	Reserved
22	Reserved
23	Reserved
24	Reserved
25	Reserved
26	Reserved
27	Reserved
28	Reserved
29	Reserved
30	Reserved
31	Reserved

Table 9.3-2: Mapping of beta_offset values for CSI and the index signalled by higher layers

$I_{\text{offset},0}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-1}}$ $I_{\text{offset},0}^{\text{CSI-2}}$ or $I_{\text{offset},1}^{\text{CSI-2}}$	$\beta_{\text{offset}}^{\text{CSI}-1}$ $\beta_{\text{offset}}^{\text{CSI}-2}$
0	1.125
1	1.250
2	1.375
3	1.625
4	1.750
5	2.000
6	2.250
7	2.500
8	2.875
9	3.125
10	3.500
11	4.000
12	5.000
13	6.250
14	8.000
15	10.000
16	12.625
17	15.875
18	20.000
19	Reserved
20	Reserved
21	Reserved
22	Reserved
23	Reserved
24	Reserved
25	Reserved
26	Reserved
27	Reserved
28	Reserved
29	Reserved
30	Reserved
31	Reserved

Table 9.3-3: Mapping of four beta_offset indicator values to offset indexes

beta_offset indicator	$(I_{\text{offset},0}^{\text{HARQ-ACK}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK}})$, $(I_{\text{offset},0}^{\text{HARQ-ACK},0}$ or $I_{\text{offset},1}^{\text{HARQ-ACK},0}$ or $I_{\text{offset},2}^{\text{HARQ-ACK},0})$, $(I_{\text{offset},0}^{\text{HARQ-ACK},1}$ or $I_{\text{offset},1}^{\text{HARQ-ACK},1}$ or $I_{\text{offset},2}^{\text{HARQ-ACK},1})$, $(I_{\text{offset},0}^{\text{CSI-1}}$ or $I_{\text{offset},0}^{\text{CSI-2}})$, $(I_{\text{offset},1}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-2}})$
'00'	1st offset index provided by higher layers
'01'	2nd offset index provided by higher layers
'10'	3rd offset index provided by higher layers
'11'	4th offset index provided by higher layers

Table 9.3-3A: Mapping of two beta_offset indicator values to offset indexes

beta_offset indicator	$(I_{\text{offset},0}^{\text{HARQ-ACK}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK}})$, $(I_{\text{offset},0}^{\text{HARQ-ACK},0}$ or $I_{\text{offset},1}^{\text{HARQ-ACK},0}$ or $I_{\text{offset},2}^{\text{HARQ-ACK},0})$, $(I_{\text{offset},0}^{\text{HARQ-ACK},1}$ or $I_{\text{offset},1}^{\text{HARQ-ACK},1}$ or $I_{\text{offset},2}^{\text{HARQ-ACK},1})$, $(I_{\text{offset},0}^{\text{CSI-1}}$ or $I_{\text{offset},0}^{\text{CSI-2}})$, $(I_{\text{offset},1}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-2}})$
'0'	1st offset index provided by higher layers
'1'	2nd offset index provided by higher layers

9.3.1 UE procedure for reporting UTO-UCI

If the UE is provided *nrofBitsInUTO-UCI* with value equal to $O^{UTO-UCI}$ in *configuredGrantConfig* of a CG-PUSCH configuration, the UE multiplexes UTO-UCI represented by a bitmap of $O^{UTO-UCI}$ bits in each CG-PUSCH transmission for the CG-PUSCH configuration. The $O^{UTO-UCI}$ bits of UTO-UCI, $\tilde{o}_0^{UTO-UCI}, \tilde{o}_1^{UTO-UCI}, \ldots, \tilde{o}_{O^{UTO-UCI}-1}^{UTO-UCI}$, have a one-to-one mapping to $O^{UTO-UCI}$ subsequent CG-PUSCH TOs of the CG-PUSCH configuration in ascending order of start time. For unpaired spectrum operation, the $O^{UTO-UCI}$ subsequent CG-PUSCH TOs exclude invalid ones where a UE does not transmit a PUSCH due to collision of the PUSCH with DL symbol(s) indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if provided, or with symbol(s) of an SS/PBCH block with index provided by *ssb-PositionsInBurst*, based on the procedures in Clause 11.1. A bit value of '0' indicates that the UE may transmit CG-PUSCH, and a bit value of '1' indicates that the UE will not transmit CG-PUSCH, in a corresponding CG-PUSCH TO. When the UE indicates by UTO-UCI a value of '1' for a CG-PUSCH TO, the UE continues to indicate the value of '1' for the CG-PUSCH TO by UTO-UCI multiplexed in subsequent CG-PUSCH transmissions, and the UE does not transmit CG-PUSCH in the CG-PUSCH TO.

10 UE procedure for receiving control information

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG except for PDCCH monitoring in Type0/0A/0B/2/2A -PDCCH CSS sets where the UE is not required to apply the procedures in this clause for the SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.

- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

A UE monitors a set of PDCCH candidates in one or more CORESETs on the active DL BWP on each activated serving cell configured with PDCCH monitoring according to corresponding search space sets where monitoring implies receiving each PDCCH candidate and decoding according to the monitored DCI formats.

In the remaining of this clause, when a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1

- a PDCCH monitoring occasion is the union of the PDCCH monitoring occasions for the two PDCCH candidates
- the start of the PDCCH reception is the start of the earlier PDCCH candidate
- the end of the PDCCH reception is the end of the PDCCH candidate that ends later

The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

If a UE is provided *monitoringCapabilityConfig* for a serving cell, the UE obtains an indication to monitor PDCCH on the active DL BWP of the serving cell for a maximum number of PDCCH candidates and non-overlapping CCEs

- per slot, as in Tables 10.1-2 and 10.1-3, if *monitoringCapabilityConfig* = *r15monitoringcapability*, or
- per span, as in Tables 10.1-2A and 10.1-3A, if *monitoringCapabilityConfig* = *r16monitoringcapability*, or
- per group of X_s slots according to combination (X_s, Y_s), as in Tables 10.1-2B and 10.1-3B, if *monitoringCapabilityConfig* = *r17monitoringcapability*

The remaining of this clause, including clause 10.1, considers that a UE is provided *monitoringCapabilityConfig* for a serving cell. If the UE is not provided *monitoringCapabilityConfig* for the serving cell, corresponding statements that the UE is provided *monitoringCapabilityConfig* for the serving cell are substituted as follows

- for SCS configuration $\mu \in \{0, 1, 2, 3\}$, the UE monitors PDCCH on the active DL BWP of the serving cell for maximum numbers of PDCCH candidates and non-overlapping CCEs per slot as in Tables 10.1-2 and 10.1-3.
- for SCS configuration $\mu \in \{5, 6\}$, the UE monitors PDCCH on the active DL BWP of the serving cell for maximum numbers of PDCCH candidates and non-overlapping CCEs per group of X_s slots according to combination $(X_s, Y_s) = (4, 1)$ for $\mu = 5$ and $(X_s, Y_s) = (8, 1)$ for $\mu = 6$ as in Tables 10.1-2B and 10.1-3B.

The UE does not expect to monitor PDCCH with SCS configuration $\mu = 6$ before the UE is provided dedicated higher layer parameters.

A UE can indicate a capability to monitor PDCCH according to one or more of the combinations (X, Y) = (2, 2), (4, 3), and (7, 3) per SCS configuration of $\mu = 0$ and $\mu = 1$. A span is a number of consecutive symbols in a slot where the UE is configured to monitor PDCCH. Each PDCCH monitoring occasion is within one span. If a UE monitors PDCCH on a cell according to combination (X, Y), the UE supports PDCCH monitoring occasions in any symbol of a slot with minimum time separation of X symbols between the first symbol of two consecutive spans, including across slots. A span starts at a first symbol where a PDCCH monitoring occasion starts and ends at a last symbol where a PDCCH monitoring occasion ends, where the number of symbols of the span is up to Y.

If a UE indicates a capability to monitor PDCCH according to multiple (X, Y) combinations and a configuration of search space sets to the UE for PDCCH monitoring on a cell results to a separation of every two consecutive PDCCH monitoring spans that is equal to or larger than the value of X for more than one of the multiple combinations (X, Y), the UE monitors PDCCH on the cell according to the combination (X, Y), from the more than one combinations (X, Y), that is associated with the largest maximum number of $M_{\mathrm{PDCCH}}^{max,(X,Y),\mu}$ and $C_{\mathrm{PDCCH}}^{max,(X,Y),\mu}$ defined in Table 10.1-2A and Table 10.1-3A. The UE expects to monitor PDCCH according to the same combination (X, Y) in every slot on the active DL BWP of a cell.

For SCS configuration $\mu = 5$ or $\mu = 6$, a UE can indicate a capability to monitor PDCCH according to one or more combinations (X_s, Y_s), where X_s and Y_s are numbers of consecutive slots. Groups of X_s slots are consecutive and non-overlapping and the Y_s slots are within the X_s slots. The first group of X_s slots starts from the beginning of a subframe. The start of two consecutive groups of Y_s slots is separated by X_s slots.

If a UE monitors PDCCH on a cell according to combination (X_s, Y_s), the UE can monitor PDCCH for Type1-PDCCH CSS set provided by dedicated higher layer signalling, Type3-PDCCH CSS sets, and USS sets in any slot of the Y_s slots, and the UE can monitor PDCCH for Type0/0A/2-PDCCH CSS set and Type1-PDCCH CSS set provided in *SIB1* in any slot of the X_s slots. The UE determines the number of monitored PDCCH candidates and the number of non-overlapped CCEs for combination (X_s, Y_s) based on all search space sets within the X_s slots, as applicable according to the search space set configurations, and maximum corresponding values are provided in Table 10.1-2B and Table 10.1-3B, respectively.

For $\mu = 6$, if the UE indicates a capability to monitor PDCCH according to multiple combinations (X_s, Y_s) and a configuration of search space sets to the UE for PDCCH monitoring on a serving cell results to a separation of every two consecutive groups of Y_s slots that is not smaller than X_s for more than one combinations (X_s, Y_s), of the multiple combinations (X_s, Y_s), the UE monitors PDCCH on the cell according to the combination (X_s, Y_s), from the more than one combinations (X_s, Y_s), that is associated with the largest maximum number of $M_{\text{PDCCH}}^{\max,X_s,\mu}$ and $C_{\text{PDCCH}}^{\max,X_s,\mu}$ defined in Table 10.1-2B and Table 10.1-3B.

A UE capability for PDCCH monitoring per slot, or per group of X_s slots according to combination (X_s, Y_s), or per span on an active DL BWP of a serving cell is defined by a maximum number of PDCCH candidates and non-overlapped CCEs the UE can monitor per slot, or per group of X_s slots according to combination (X_s, Y_s), or per span, respectively, on the active DL BWP of the serving cell.

For monitoring of a PDCCH candidate by a UE, if the UE

- has received *ssb-PositionsInBurst* in *SIB1* and has not received *ssb-PositionsInBurst* in *ServingCellConfigCommon* for a serving cell, and
- does not monitor PDCCH candidates in a Type0-PDCCH CSS set, and
- at least one RE for a PDCCH candidate overlaps with at least one RE of a candidate SS/PBCH block, after puncturing if applicable, corresponding to a SS/PBCH block index provided by *ssb-PositionsInBurst* in *SIB1*,

the UE is not required to monitor the PDCCH candidate.

For monitoring of a PDCCH candidate by a UE, if the UE

- has received *ssb-PositionsInBurst* in *ServingCellConfigCommon* for a serving cell, and
- does not monitor PDCCH candidates in a Type0-PDCCH CSS set, and
- at least one RE for a PDCCH candidate overlaps with at least one RE of a candidate SS/PBCH block, after puncturing if applicable, corresponding to a SS/PBCH block index provided by *ssb-PositionsInBurst* in *ServingCellConfigCommon*,

the UE is not required to monitor the PDCCH candidate.

For monitoring of a PDCCH candidate by a UE, if the UE

- has received *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* for a serving cell, and
- at least one RE for a PDCCH candidate overlaps with at least one RE of a candidate SS/PBCH block, after puncturing if applicable, corresponding to a SS/PBCH block index provided by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* with same physical cell identity as the one associated with a RS having same quasi-collocation properties as a CORESET for the PDCCH candidate,

the UE is not required to monitor the PDCCH candidate.

A UE is not required to monitor PDCCH candidates for a Type0/0A/0B/1/1A /2/2A -PDCCH CSS set when the active TCI state for a corresponding CORESET is not associated with *physCellId* in *ServingCellConfigCommon*.

If a UE monitors the PDCCH candidate for a Type0-PDCCH CSS set on the serving cell according to the procedure described in clause 13, the UE may assume that no SS/PBCH block is transmitted in REs used for monitoring the PDCCH candidate on the serving cell.

If at least one RE of a PDCCH candidate for a UE on the serving cell overlaps with at least one RE of *lte-CRS-ToMatchAround* or of *LTE-CRS-PatternList*, the UE

- is not required to monitor the PDCCH candidate if the UE is not provided *pdcchCandidateReception-WithCRSOverlap*,
- monitors the PDCCH candidate if the UE is provided *pdcchCandidateReception-WithCRSOverlap* and the UE indicates an associated capability corresponding to the configuration of *lte-CRS-ToMatchAround* or of *LTE-CRS-PatternList* [18, TS 38.306].

If a UE is provided *availableRB-SetsPerCell*, the UE is not required to monitor PDCCH candidates that overlap with any RB from RB sets that are indicated as unavailable for receptions by an available RB set indicator field in DCI format 2_0 as described in clause 11.1.1. If the UE does not obtain the available RB set indicator for a symbol, the UE monitors PDCCH candidates on all RB sets in the symbol.

If a UE can support

- a first set of $N_{\text{cells},0}^{\text{DL}}$ serving cells where the UE is either not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a single value for all CORESETs on all DL BWPs of each scheduling cell from the first set of serving cells, and

- a second set of $N_{\text{cells},1}^{\text{DL}}$ serving cells where the UE is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value 0 for a first CORESET, and with a value 1 for a second CORESET on any DL BWP of each scheduling cell from the second set of serving cells

the UE determines, for the purpose of reporting *pdcch-BlindDetectionCA*, *pdcch-BlindDetectionCA1*, and *pdcch-BlindDetectionCA3*, a number of serving cells as $N_{\text{cells},0}^{\text{DL}} + R \cdot N_{\text{cells},1}^{\text{DL}}$ where R is a value reported by the UE.

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than 4 serving cells and the UE is not provided *monitoringCapabilityConfig* for any downlink cell or if the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and for a maximum number of non-overlapped CCEs the UE can monitor per slot when the UE is configured for carrier aggregation operation over more than 4 cells. When a UE is not configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot that corresponds to $N_{\text{cells}}^{\text{cap}}$ downlink cells, where

- $N_{\text{cells}}^{\text{cap}}$ is $N_{\text{cells},0}^{\text{DL}} + R \cdot N_{\text{cells},1}^{\text{DL}}$ if the UE does not provide *pdcch-BlindDetectionCA* where $N_{\text{cells},0}^{\text{DL}} + N_{\text{cells},1}^{\text{DL}}$ is the number of configured downlink serving cells

- otherwise, $N_{\text{cells}}^{\text{cap}}$ is the value of *pdcch-BlindDetectionCA*

When a UE is configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot that corresponds to $N_{\text{cells}}^{\text{cap}} = N_{\text{cells}}^{\text{MCG}}$ downlink cells for the MCG where $N_{\text{cells}}^{\text{MCG}}$ is provided by *pdcch-BlindDetection* for the MCG and determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot that corresponds to $N_{\text{cells}}^{\text{cap}} = N_{\text{cells}}^{\text{SCG}}$ downlink cells for the SCG where $N_{\text{cells}}^{\text{SCG}}$ is provided by *pdcch-BlindDetection* for the SCG. When the UE is configured for carrier aggregation operation over more than 4 cells, or for a cell group when the UE is configured for NR-DC operation, the UE does not expect to monitor per slot a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{\text{cells}}^{\text{cap}}$.

When a UE is configured for NR-DC operation with a total of $N_{\text{NR-DC}}^{\text{DL,cells}}$ downlink cells on both the MCG and the SCG, the UE expects to be provided *pdcch-BlindDetection* for the MCG and *pdcch-BlindDetection* for the SCG with values that satisfy

- *pdcch-BlindDetection* for the MCG + *pdcch-BlindDetection* for the SCG <= *pdcch-BlindDetectionCA*, if the UE reports *pdcch-BlindDetectionCA*, or

- *pdcch-BlindDetection* for the MCG + *pdcch-BlindDetection* for the SCG <= $N_{\text{NR-DC}}^{\text{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA*.

For NR-DC operation, the UE may indicate, through *pdcch-BlindDetectionMCG-UE* and *pdcch-BlindDetectionSCG-UE*, respective maximum values for *pdcch-BlindDetection* for the MCG and *pdcch-BlindDetection* for the SCG.

If the UE reports *pdcch-BlindDetectionCA*,

- the value range of *pdcch-BlindDetectionMCG-UE* or of *pdcch-BlindDetectionSCG-UE* is [1, …, *pdcch-BlindDetectionCA*-1], and

- *pdcch-BlindDetectionMCG-UE* + *pdcch-BlindDetectionSCG-UE* >= *pdcch-BlindDetectionCA*.

Otherwise, if $N_{\text{NR-DC,max}}^{\text{DL,cells}}$ is a maximum total number of downlink cells that the UE can be configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*,

- the value range of *pdcch-BlindDetectionMCG-UE* or of *pdcch-BlindDetectionSCG-UE* is [1, 2, 3], and

- *pdcch-BlindDetectionMCG-UE* + *pdcch-BlindDetectionSCG-UE* >= $N_{\text{NR-DC,max}}^{\text{DL,cells}}$.

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than two downlink cells, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs that the UE can monitor per span when the UE is configured for carrier aggregation operation over more than two downlink cells with *monitoringCapabilityConfig = r16monitoringcapability*. When a UE is not configured for NR-DC operation and the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per span that corresponds to $N_{cells}^{cap-r16}$ downlink cells, where

- $N_{cells}^{cap-r16}$ is the number of configured downlink cells if the UE does not provide *pdcch-MonitoringCA*

- otherwise, $N_{cells}^{cap-r16}$ is the value of *pdcch-MonitoringCA*

When a UE is configured for NR-DC operation and the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per span that corresponds to

- $N_{\text{cells}}^{\text{cap-r16}} = N_{\text{cells,r16}}^{\text{MCG}}$ downlink cells for the MCG where $N_{\text{cells,r16}}^{\text{MCG}}$ is provided by *pdcch-BlindDetection2* for the MCG, and

- $N_{\text{cells}}^{\text{cap-r16}} = N_{\text{cells,r16}}^{\text{SCG}}$ downlink cells for the SCG where $N_{\text{cells,r16}}^{\text{SCG}}$ is provided by *pdcch-BlindDetection2* for the SCG

When the UE is configured for carrier aggregation operation over more than 2 cells, or for a cell group when the UE is configured for NR-DC operation, the UE does not expect to monitor per span a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{\text{cells}}^{\text{cap-r16}}$.

When a UE is configured for NR-DC operation with a total of $N_{\text{NR-DC}}^{\text{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection2* for the MCG and *pdcch-BlindDetection2* for the SCG with values that satisfy

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= *pdcch-MonitoringCA*, if the UE reports *pdcch-MonitoringCA*, or

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= $N_{\text{NR-DC}}^{\text{DL,cells}}$, if the UE does not report *pdcch-MonitoringCA*

When a UE is configured for NR-DC operation and the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionMCG-UE-r16* and *pdcch-BlindDetectionSCG-UE-r16*, respective maximum values for *pdcch-BlindDetection* for the MCG and *pdcch-BlindDetection* for the SCG.

If the UE reports *pdcch-MonitoringCA*,

- the value range of *pdcch-BlindDetectionMCG-UE-r16* or of *pdcch-BlindDetectionSCG-UE-r16* is [1, …, *pdcch-MonitoringCA*-1], and

- *pdcch-BlindDetectionMCG-UE-r16* + *pdcch-BlindDetectionSCG-UE-r16* >= *pdcch-MonitoringCA.*

Otherwise, if $N_{\text{NR-DC,max,r16}}^{\text{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value of *pdcch-BlindDetectionMCG-UE-r16* or of *pdcch-BlindDetectionSCG-UE-r16* is 1,

- *pdcch-BlindDetectionMCG-UE-r16* + *pdcch-BlindDetectionSCG-UE-r16* >= $N_{\text{NR-DC,max,r16}}^{\text{DL,cells}}$.

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than four downlink cells, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs that the UE can monitor per group of X_s slots when the UE is configured for carrier aggregation operation over more than four downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability*. When a UE is not configured for NR-DC operation for all downlink cells where the UE monitors PDCCH, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per group of X_s slots that corresponds to $N_{\text{cells}}^{\text{cap-r17}}$ downlink cells, where

- $N_{\text{cells}}^{\text{cap-r17}}$ is $N_{\text{cells},0}^{\text{DL}} + R \cdot N_{\text{cells},1}^{\text{DL}}$ if the UE does not provide *pdcch-MonitoringCA-r17* where $N_{\text{cells},0}^{\text{DL}} + N_{\text{cells},1}^{\text{DL}}$ is the number of configured downlink serving cells
- otherwise, $N_{\text{cells}}^{\text{cap-r17}}$ is the value of *pdcch-MonitoringCA-r17*

When the UE is configured for carrier aggregation operation over more than 4 cells, the UE does not expect to monitor per group of X_s slots a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{\text{cells}}^{\text{cap-r17}}$.

When a UE is configured for NR-DC operation and the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per group of X_s slots that corresponds to

- $N_{\text{cells}}^{\text{cap-r17}} = N_{\text{cells,r17}}^{\text{MCG}}$ downlink cells for the MCG where $N_{\text{cells,r17}}^{\text{MCG}}$ is provided by *pdcch-BlindDetection4* for the MCG, and
- $N_{\text{cells}}^{\text{cap-r17}} = N_{\text{cells,r17}}^{\text{SCG}}$ downlink cells for the SCG where $N_{\text{cells,r17}}^{\text{SCG}}$ is provided by *pdcch-BlindDetection4* for the SCG

When a UE is configured for NR-DC operation with a total of $N_{\text{NR-DC}}^{\text{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection4* for the MCG and *pdcch-BlindDetection4* for the SCG with values that satisfy

- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= *pdcch-MonitoringCA-r17*, if the UE reports *pdcch-MonitoringCA-r17*, or
- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= $N_{\text{NR-DC}}^{\text{DL,cells}}$, if the UE does not report *pdcch-MonitoringCA-r17*

When a UE is configured for NR-DC operation and the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for all downlink cells where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionMCG-UE-r17* and *pdcch-BlindDetectionSCG-UE-r17*, respective maximum values for *pdcch-BlindDetection4* for the MCG and *pdcch-BlindDetection4* for the SCG.

If the UE reports *pdcch-MonitoringCA-r17*,

- the value range of *pdcch-BlindDetectionMCG-UE-r17* or of *pdcch-BlindDetectionSCG-UE-r17* is [1, …, *pdcch-MonitoringCA-r17*-1], and
- *pdcch-BlindDetectionMCG-UE-r17* + *pdcch-BlindDetectionSCG-UE-r17* >= *pdcch-MonitoringCA-r17*.

Otherwise, if $N_{\text{NR-DC,max,r17}}^{\text{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionMCG-UE-r17* or of *pdcch-BlindDetectionSCG-UE-r17* is [1, 2, 3], and
- *pdcch-BlindDetectionMCG-UE-r17* + *pdcch-BlindDetectionSCG-UE-r17* >= $N_{\text{NR-DC,max,r17}}^{\text{DL,cells}}$.

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than one downlink cell with *monitoringCapabilityConfig = r15monitoringcapability* or larger than one downlink cell with *monitoringCapabilityConfig = r16monitoringcapability*, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs the UE can monitor for downlink cells with *monitoringCapabilityConfig = r15monitoringcapability* or for downlink cells with *monitoringCapabilityConfig = r16monitoringcapability* when the UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig =*

r15monitoringcapability and at least one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability*. When a UE is not configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot or per span that corresponds to $N_{cells,r15}^{cap-r16}$ downlink cells or to $N_{cells,r16}^{cap-r16}$ downlink cells, respectively, where

- $N_{cells,r15}^{cap-r16}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA1*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*), $N_{cells,r15}^{cap-r16}$ is the value of *pdcch-BlindDetectionCA1*
  - else, $N_{\mathrm{cells,r15}}^{\mathrm{cap-r16}}$ is the value of *pdcch-BlindDetectionCA1* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) that is provided by *pdcch-BlindDetectionCA-CombIndicator*

and

- $N_{cells,r16}^{cap-r16}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA2*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*), $N_{cells,r16}^{cap-r16}$ is the value of *pdcch-BlindDetectionCA2*
  - else, $N_{\mathrm{cells,r16}}^{\mathrm{cap-r16}}$ is the value of *pdcch-BlindDetectionCA2* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) that is provided by *pdcch-BlindDetectionCA-CombIndicator*

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability* or larger than one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs the UE can monitor for downlink cells with *monitoringCapabilityConfig* = *r15monitoringcapability* or for downlink cells with *monitoringCapabilityConfig* = *r17monitoringcapability* when the UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability* and at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*. When a UE is not configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot or per group of X_s slots that corresponds to $N_{cells,r15/r17}^{cap-r17}$ downlink cells or to $N_{cells,r17/r15}^{cap-r17}$ downlink cells, respectively, where

- $N_{\mathrm{cells,r15/r17}}^{\mathrm{cap-r17}}$ is $N_{\mathrm{cells},0}^{\mathrm{DL}} + R \cdot N_{\mathrm{cells},1}^{\mathrm{DL}}$ if the UE does not provide *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList1*, where $N_{\mathrm{cells},0}^{\mathrm{DL}} + N_{\mathrm{cells},1}^{\mathrm{DL}}$ is the number of configured downlink serving cells
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) in *pdcch-BlindDetectionMixedList1*, $N_{cells,r15/r17}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA1*
  - else, $N_{cells,r15/r17}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA1* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

and

- $N_{\mathrm{cells,r17/r15}}^{\mathrm{cap-r17}}$ is $N_{\mathrm{cells},0}^{\mathrm{DL}} + R \cdot N_{\mathrm{cells},1}^{\mathrm{DL}}$ if the UE does not provide *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList1*, where $N_{\mathrm{cells},0}^{\mathrm{DL}} + N_{\mathrm{cells},1}^{\mathrm{DL}}$ is the number of configured downlink serving cells
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) in *pdcch-BlindDetectionMixedList1*, $N_{cells,r17/r15}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA2*

- else, $N_{cells,r17/r15}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA3* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability* or larger than one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs the UE can monitor for downlink cells with *monitoringCapabilityConfig* = *r16monitoringcapability* or for downlink cells with *monitoringCapabilityConfig* = *r17monitoringcapability* when the UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability* and with at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*. When a UE is not configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per span or per group of X_s slots that corresponds to $N_{cells,r16/r17}^{cap-r17}$ downlink cells or to $N_{cells,r17/r16}^{cap-r17}$ downlink cells, respectively, where

- $N_{cells,r16/r17}^{cap-r17}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList2*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) in *pdcch-BlindDetectionMixedList2*, $N_{cells,r16/r17}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA1*
  - else, $N_{cells,r16/r17}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA2* from a combination of (*pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

and

- $N_{cells,r17/r16}^{cap-r17}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList2*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*) in *pdcch-BlindDetectionMixedList2*, $N_{cells,r17/r16}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA2*
  - else, $N_{cells,r17/r16}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA3* from a combination of (*pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability*, or larger than one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability*, or larger than one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs the UE can monitor for downlink cells with *monitoringCapabilityConfig* = *r15monitoringcapability*, or for downlink cells with *monitoringCapabilityConfig* = *r16monitoringcapability*, or for downlink cells with *monitoringCapabilityConfig* = *r17monitoringcapability* when the UE is configured for carrier aggregation operation over more than three downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability*, at least one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability* and at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*. When a UE is not configured for NR-DC operation, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs per slot or per span or per group of X_s slots that corresponds to $N_{cells,r15/\{r16,r17\}}^{cap-r17}$ downlink cells or to $N_{cells,r16/\{r15,r17\}}^{cap-r17}$ downlink cells or to $N_{cells,r17/\{r15,r16\}}^{cap-r17}$ downlink cells, respectively, where

- $N_{cells,r15/\{r16,r17\}}^{cap-r17}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList3*
- otherwise,

  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) in *pdcch-BlindDetectionMixedList3*, $N_{cells,r15/\{r16,r17\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA1*
  - else, $N_{cells,r15/\{r16,r17\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA1* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*
- $N_{cells,r16/\{r15,r17\}}^{cap-r17}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList3*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) in *pdcch-BlindDetectionMixedList3*, $N_{cells,r16/\{r15,r17\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA2*
  - else, $N_{cells,r16/\{r15,r17\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA2* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

and

- $N_{cells,r17/\{r15,r16\}}^{cap-r17}$ is the number of configured downlink cells if the UE does not provide *pdcch-BlindDetectionCA3* in *pdcch-BlindDetectionMixedList3*
- otherwise,
  - if the UE reports only one combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, *pdcch-BlindDetectionCA3*) in *pdcch-BlindDetectionMixedList3*, $N_{cells,r17/\{r15,r16\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA3*
  - else, $N_{cells,r17/\{r15,r16\}}^{cap-r17}$ is the value of *pdcch-BlindDetectionCA3* from a combination of (*pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2, pdcch-BlindDetectionCA3*) that is provided by *pdcch-BlindDetectionCA-CombIndicator-r17*

When a UE is configured for NR-DC operation and is provided *monitoringCapabilityConfig = r15monitoringcapability* for at least one downlink cell and *monitoringCapabilityConfig = r16monitoringcapability* for at least one downlink cell where the UE monitors PDCCH, the UE determines a capability to monitor a maximum number of PDCCH candidates and a maximum number of non-overlapped CCEs that corresponds to

- $N_{\text{cells,r15}}^{\text{cap-r16}} = N_{\text{cells,r15}}^{\text{MCG}}$ downlink cells for the MCG where $N_{\text{cells,r15}}^{\text{MCG}}$ is provided by *pdcch-BlindDetection3* for the MCG,
- $N_{\text{cells,r15}}^{\text{cap-r16}} = N_{\text{cells,r15}}^{\text{SCG}}$ downlink cells for the SCG where $N_{\text{cells,r15}}^{\text{SCG}}$ is provided by *pdcch-BlindDetection3* for the SCG, and
- $N_{\text{cells,r16}}^{\text{cap-r16}} = N_{\text{cells,r16}}^{\text{MCG}}$ downlink cells for the MCG where $N_{\text{cells,r16}}^{\text{MCG}}$ is provided by *pdcch-BlindDetection2* for the MCG,
- $N_{\text{cells,r16}}^{\text{cap-r16}} = N_{\text{cells,r16}}^{\text{SCG}}$ downlink cells for the SCG where $N_{\text{cells,r16}}^{\text{SCG}}$ is provided by *pdcch-BlindDetection2* for the SCG

When a UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig = r15monitoringcapability*, at least one downlink cell with *monitoringCapabilityConfig = r16monitoringcapability*, and no downlink cell has SCS configuration $\mu \in \{5, 6\}$, or for a cell group when the UE is configured for NR-DC operation, the UE does not expect to

- monitor per slot a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{\text{cells,r15}}^{\text{cap-r16}}$, and

- monitor per span a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{\mathrm{cells,r16}}^{\mathrm{cap-r16}}$

When the UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability*, at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, and no downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability*, the UE does not expect to

- monitor per slot a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r15/r17}^{cap-r17}$, and

- monitor per group of X_s slots a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r17/r15}^{cap-r17}$

When the UE is configured for carrier aggregation operation over more than two downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability*, at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, and no downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability*, the UE does not expect to

- monitor per span a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r16/r17}^{cap-r17}$, and

- monitor per group of X_s slots a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r17/r16}^{cap-r17}$

When the UE is configured for carrier aggregation operation over more than three downlink cells with at least one downlink cell with *monitoringCapabilityConfig* = *r15monitoringcapability*, at least one downlink cell with *monitoringCapabilityConfig* = *r16monitoringcapability*, and at least one downlink cell with *monitoringCapabilityConfig* = *r17monitoringcapability*, the UE does not expect to

- monitor per slot a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r15/\{r16,r17\}}^{cap-r17}$, and

- monitor per span a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r16/\{r15,r17\}}^{cap-r17}$, and

- monitor per group of X_s slots a number of PDCCH candidates or a number of non-overlapped CCEs that is larger than the maximum number as derived from the corresponding value of $N_{cells,r17/\{r15,r16\}}^{cap-r17}$

When a UE is configured for NR-DC operation with a total of $N_{\mathrm{NR-DC}}^{\mathrm{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$ downlink cells and *monitoringCapabilityConfig* = *r16monitoringcapability* for $N_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$ downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection3* and *pdcch-BlindDetection2* for the MCG, and *pdcch-BlindDetection3* and *pdcch-BlindDetection2* for the SCG with values that satisfy

- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= *pdcch-BlindDetectionCA1*, if the UE reports *pdcch-BlindDetectionCA1*, or

- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA1*

and

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= *pdcch-BlindDetectionCA2*, if the UE reports *pdcch-BlindDetectionCA2*, or

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= $\mathrm{N}_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA2*

When a UE is configured for NR-DC operation and is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for at least one downlink cell and *monitoringCapabilityConfig* = *r16monitoringcapability* for at least one downlink cell where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionMCG-UE1* and *pdcch-BlindDetectionSCG-UE1*, respective maximum values for *pdcch-BlindDetection3* for the MCG and *pdcch-BlindDetection3* for the SCG, and through *pdcch-BlindDetectionMCG-UE2* and *pdcch-BlindDetectionSCG-UE2* respective maximum values for *pdcch-BlindDetection2* for the MCG and *pdcch-BlindDetection2* for the SCG.

If the UE reports *pdcch-BlindDetectionCA1*,

- the value range of *pdcch-BlindDetectionMCG-UE1* or of *pdcch-BlindDetectionSCG-UE1* is [0, 1, …, *pdcch-BlindDetectionCA1*], and
- *pdcch-BlindDetectionMCG-UE1* + *pdcch-BlindDetectionSCG-UE1* >= *pdcch-BlindDetectionCA1*.

Otherwise, if $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionMCG-UE1* or of *pdcch-BlindDetectionSCG-UE1* is [0, 1, 2],
- *pdcch-BlindDetectionMCG-UE1* + *pdcch-BlindDetectionSCG-UE1* >= $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$.

If the UE reports *pdcch-BlindDetectionCA2*

- the value range of *pdcch-BlindDetectionMCG-UE2* or of *pdcch-BlindDetectionSCG-UE2* is [0, 1, …, *pdcch-BlindDetectionCA2*], and
- *pdcch-BlindDetectionMCG-UE2* + *pdcch-BlindDetectionSCG-UE2* >= *pdcch-BlindDetectionCA2.*

Otherwise, if $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionMCG-UE2* or of *pdcch-BlindDetectionSCG-UE2* is [0, 1],
- *pdcch-BlindDetectionMCG-UE2* + *pdcch-BlindDetectionSCG-UE2* >= $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$.

When a UE is configured for NR-DC operation with a total of $N_{\mathrm{NR-DC}}^{\mathrm{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$ downlink cells and *monitoringCapabilityConfig* = *r17monitoringcapability* for $N_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$ downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection3* and *pdcch-BlindDetection4* for the MCG, and *pdcch-BlindDetection3* and *pdcch-BlindDetection4* for the SCG with values that satisfy

- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= *pdcch-BlindDetectionCA1*, if the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList1*, or
- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList1*

and

- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= *pdcch-BlindDetectionCA2*, if the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList1*, or
- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= $\mathrm{N}_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList1*

When a UE is configured for NR-DC operation and is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for at least one downlink cell and *monitoringCapabilityConfig* = *r17monitoringcapability* for at least one downlink cell where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionMCG-UE-Mixed* and *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionSCG-UE-Mixed*, respective maximum values for *pdcch-BlindDetection3* for the MCG and *pdcch-BlindDetection3* for the SCG, and through *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionMCG-UE-Mixed* and *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionSCG-UE-Mixed*, respective maximum values for *pdcch-BlindDetection4* for the MCG and *pdcch-BlindDetection4* for the SCG.

If the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList1*,

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA1*], and
- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionCG-UE1* for the SCG >= *pdcch-BlindDetectionCA1*.

Otherwise, if $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1, 2],
- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionSCG-UE1* for the SCG >= $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$.

If the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList1*

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA3*], and
- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= *pdcch-BlindDetectionCA2.*

Otherwise, if $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1, 2],
- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$.

When a UE is configured for NR-DC operation with a total of $N_{\mathrm{NR-DC}}^{\mathrm{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for $N_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$ downlink cells and *monitoringCapabilityConfig = r17monitoringcapability* for $N_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$ downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection2* and *pdcch-BlindDetection4* for the MCG, and *pdcch-BlindDetection2* and *pdcch-BlindDetection4* for the SCG with values that satisfy

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= *pdcch-BlindDetectionCA1*, if the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList2*, or
- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= $N_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList2*

and

- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= *pdcch-BlindDetectionCA2*, if the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList2*, or
- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= $\mathrm{N}_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList2*

When a UE is configured for NR-DC operation and is provided *monitoringCapabilityConfig = r16monitoringcapability* for at least one downlink cell and *monitoringCapabilityConfig = r17monitoringcapability* for at least one downlink cell where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionMCG-UE-Mixed* and *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionSCG-UE-Mixed*, respective maximum values for *pdcch-BlindDetection2* for the MCG and *pdcch-BlindDetection2* for the SCG, and through *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionMCG-UE-Mixed* and *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionSCG-UE-Mixed*, respective maximum values for *pdcch-BlindDetection4* for the MCG and *pdcch-BlindDetection4* for the SCG.

If the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList2*,

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA1*], and
- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionCG-UE1* for the SCG >= *pdcch-BlindDetectionCA1*.

Otherwise, if $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1],
- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionCG-UE1* for the SCG >= $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$.

If the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList2*

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA2*], and
- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= *pdcch-BlindDetectionCA2.*

Otherwise, if $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1, 2],
- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$.

When a UE is configured for NR-DC operation with a total of $N_{\mathrm{NR-DC}}^{\mathrm{DL,cells}}$ downlink cells on both the MCG and the SCG and the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* for $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$ downlink cells, *monitoringCapabilityConfig = r16monitoringcapability* for $N_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$ downlink cells, and *monitoringCapabilityConfig = r17monitoringcapability* for $N_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$ downlink cells where the UE monitors PDCCH, the UE expects to be provided *pdcch-BlindDetection3*, *pdcch-BlindDetection2*, and *pdcch-BlindDetection4* for the MCG, and *pdcch-BlindDetection3*, *pdcch-BlindDetection2*, and *pdcch-BlindDetection4* for the SCG with values that satisfy

- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= *pdcch-BlindDetectionCA1*, if the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList3*, or
- *pdcch-BlindDetection3* for the MCG + *pdcch-BlindDetection3* for the SCG <= $N_{\mathrm{NR-DC,r15}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList3*

and

- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= *pdcch-BlindDetectionCA2*, if the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList3*, or
- *pdcch-BlindDetection2* for the MCG + *pdcch-BlindDetection2* for the SCG <= $N_{\mathrm{NR-DC,r16}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList3*

and

- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= *pdcch-BlindDetectionCA3*, if the UE reports *pdcch-BlindDetectionCA3* in *pdcch-BlindDetectionMixedList3*, or
- *pdcch-BlindDetection4* for the MCG + *pdcch-BlindDetection4* for the SCG <= $\mathrm{N}_{\mathrm{NR-DC,r17}}^{\mathrm{DL,cells}}$, if the UE does not report *pdcch-BlindDetectionCA3* in *pdcch-BlindDetectionMixedList3*

When a UE is configured for NR-DC operation and is provided *monitoringCapabilityConfig = r15monitoringcapability* for at least one downlink cell, *monitoringCapabilityConfig = r16monitoringcapability* for at least one downlink cell, and *monitoringCapabilityConfig = r17monitoringcapability* for at least one downlink cell where the UE monitors PDCCH, the UE may indicate, through *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionMCG-UE-Mixed1* and *pdcch-BlindDetectionCG-UE1* in *pdcch-BlindDetectionSCG-UE-Mixed1* respective maximum values for *pdcch-BlindDetection3* for the MCG and *pdcch-BlindDetection3* for the SCG, through *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionMCG-UE-Mixed1* and *pdcch-BlindDetectionCG-UE2* in *pdcch-BlindDetectionSCG-UE-Mixed1* respective maximum values for *pdcch-BlindDetection2* for the MCG and *pdcch-BlindDetection2* for the SCG, and through *pdcch-BlindDetectionCG-UE3* in *pdcch-BlindDetectionMCG-UE-Mixed1* and *pdcch-BlindDetectionCG-UE3* in *pdcch-BlindDetectionSCG-UE-Mixed1* respective maximum values for *pdcch-BlindDetection4* for the MCG and *pdcch-BlindDetection4* for the SCG.

If the UE reports *pdcch-BlindDetectionCA1* in *pdcch-BlindDetectionMixedList3*,

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA1*], and

- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionCG-UE1* for the SCG >= *pdcch-BlindDetectionCA1*.

Otherwise, if $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE1* for the MCG or of *pdcch-BlindDetectionCG-UE1* for the SCG is [0, 1, 2],

- *pdcch-BlindDetectionCG-UE1* for the MCG + *pdcch-BlindDetectionCG-UE1* for the SCG >= $N_{\mathrm{NR-DC,max,r15}}^{\mathrm{DL,cells}}$.

If the UE reports *pdcch-BlindDetectionCA2* in *pdcch-BlindDetectionMixedList3*,

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA2*], and

- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= *pdcch-BlindDetectionCA2*.

Otherwise, if $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE2* for the MCG or of *pdcch-BlindDetectionCG-UE2* for the SCG is [0, 1],

- *pdcch-BlindDetectionCG-UE2* for the MCG + *pdcch-BlindDetectionCG-UE2* for the SCG >= $N_{\mathrm{NR-DC,max,r16}}^{\mathrm{DL,cells}}$.

If the UE reports *pdcch-BlindDetectionCA3* in *pdcch-BlindDetectionMixedList3*

- the value range of *pdcch-BlindDetectionCG-UE3* for the MCG or of *pdcch-BlindDetectionCG-UE3* for the SCG is [0, 1, …, *pdcch-BlindDetectionCA3*], and

- *pdcch-BlindDetectionCG-UE3* for the MCG + *pdcch-BlindDetectionCG-UE3* for the SCG >= *pdcch-BlindDetectionCA3*.

Otherwise, if $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$ is a maximum total number of downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and the UE is configured on both the MCG and the SCG for NR-DC as indicated in *UE-NR-Capability*

- the value range of *pdcch-BlindDetectionCG-UE3* for the MCG or of *pdcch-BlindDetectionCG-UE3* for the SCG is [0, 1, 2],

- *pdcch-BlindDetectionCG-UE3* for the MCG + *pdcch-BlindDetectionCG-UE3* for the SCG >= $N_{\mathrm{NR-DC,max,r17}}^{\mathrm{DL,cells}}$.

10.1 UE procedure for determining physical downlink control channel assignment

A set of PDCCH candidates for a UE to monitor is defined in terms of PDCCH search space sets. A search space set can be a CSS set or a USS set. A UE monitors PDCCH candidates in one or more of the following search spaces sets

- a Type0-PDCCH CSS set on the primary cell of the MCG configured by
  - *pdcch-ConfigSIB1* in MIB or by *searchSpaceSIB1* in *PDCCH-ConfigCommon* or by *searchSpaceZero* in *PDCCH-ConfigCommon* for a DCI format 1_0 with CRC scrambled by a SI-RNTI, or
  - *searchSpaceZero* by providing *searchSpaceID*=0 for *searchSpaceMCCH* or *searchSpaceMTCH* for a DCI format 4_0 with CRC scrambled by a MCCH-RNTI or a G-RNTI for broadcast, or
  - *searchSpaceZero* by providing *searchSpaceID*=0 for *searchspaceMulticastMCCH* for a DCI format 4_0 with CRC scrambled by a multicast-MCCH-RNTI, or by *searchSpaceMulticastMTCH* for a DCI format 4_1 with CRC scrambled by a G-RNTI for multicast in RRC_INACTIVE state
- a Type0A-PDCCH CSS set configured by *searchSpaceOtherSystemInformation* in *PDCCH-ConfigCommon* for a DCI format 1_0 with CRC scrambled by a SI-RNTI on the primary cell of the MCG
- a Type0B-PDCCH CSS set configured by
  - *searchSpaceMCCH* and *searchSpaceMTCH* for a DCI format 4_0 with CRC scrambled by a MCCH-RNTI or a G-RNTI for broadcast, on the primary cell of the MCG
  - *searchspaceMulticastMCC*H for a DCI format 4_0 with CRC scrambled by a multicast-MCCH-RNTI, or by *searchSpaceMulticastMTCH* for a DCI format 4_1 with CRC scrambled by a G-RNTI for PDCCH receptions in RRC_INACTIVE state
- a Type1-PDCCH CSS set configured by *ra-SearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a RA-RNTI, a MsgB-RNTI, or a TC-RNTI on the primary cell
- a Type1A-PDCCH CSS set configured by *sdt-SearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a C-RNTI or a CS-RNTI on the primary cell as described in clause 19.1
- a Type2-PDCCH CSS set configured by *pagingSearchSpace* in *PDCCH-ConfigCommon* for a DCI format 1_0 with CRC scrambled by a P-RNTI on the primary cell of the MCG
- a Type2A-PDCCH CSS set configured by *pei-SearchSpace* in *pei-ConfigBWP* for a DCI format 2_7 with CRC scrambled by a PEI-RNTI on the primary cell of the MCG
- a Type3-PDCCH CSS set configured by
  - *SearchSpace* in *PDCCH-Config* with *searchSpaceType* = *common* for DCI formats with CRC scrambled by INT-RNTI, SFI-RNTI, TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, TPC-SRS-RNTI, CI-RNTI, or cellDTRX-RNTI and, only for the primary cell, C-RNTI, MCS-C-RNTI, CS-RNTI(s), or PS-RNTI, or
  - *SearchSpace* in *pdcch-ConfigMulticast* for DCI formats with CRC scrambled by G-RNTI, or G-CS-RNTI, or
  - *searchSpaceMCCH* and *searchSpaceMTCH* on a secondary cell for a DCI format 4_0 with CRC scrambled by a MCCH-RNTI or a G-RNTI for broadcast, and
- a USS set configured by
  - *SearchSpace* in *PDCCH-Config* with *searchSpaceType* = *ue-Specific* for DCI formats with CRC scrambled by C-RNTI, MCS-C-RNTI, SP-CSI-RNTI, CS-RNTI(s), SL-RNTI, SL-CS-RNTI, SL Semi-Persistent Scheduling V-RNTI, or NCR-RNTI

In the following, DCI formats with CRC scrambled by C-RNTI or CS-RNTI or MCS-C-RNTI are also referred to as unicast DCI formats, DCI formats with CRC scrambled by G-RNTI for multicast or G-CS-RNTI are also referred to as multicast DCI formats, and DCI formats with CRC scrambled by MCCH-RNTI or G-RNTI for broadcast scheduling PDSCH receptions are also referred to as broadcast DCI formats, and DCI formats with CRC scrambled by multicast-MCCH-RNTI or G-RNTI for multicast scheduling PDSCH receptions in RRC_INACTIVE state are also referred as multicast DCI formats for RRC_INACTIVE state.

For a DL BWP, if a UE is not provided *searchSpaceSIB1* for Type0-PDCCH CSS set by *PDCCH-ConfigCommon*, the UE does not monitor PDCCH candidates for a Type0-PDCCH CSS set on the DL BWP. The Type0-PDCCH CSS set is defined by the CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level given in Table 10.1-1.

If the active DL BWP and the initial DL BWP for a UE have same SCS and same CP length and the active DL BWP includes all RBs of the CORESET with index 0, or the active DL BWP is the initial DL BWP, or the active DL BWP includes all RBs of an MBS frequency resource provided by *cfr-ConfigMCCH-MTCH* or *cfr-ConfigMCCH-MTCH-RedCap* as described in clause 18, the CORESET configured for Type0-PDCCH CSS set has CORESET index 0 and the Type0-PDCCH CSS set has search space set index 0.

If the active DL BWP and an MBS frequency resource provided by *cfr-ConfigMCCH-MTCH* or *cfr-ConfigMCCH-MTCH-RedCap* or determined by CORESET with index 0 when *cfr-ConfigMCCH-MTCH* or *cfr-ConfigMCCH-MTCH-RedCap* is not provided for a UE have same SCS and same CP length and the active DL BWP includes all RBs of the MBS frequency resource, and if the UE is provided *searchSpaceMCCH* or *searchSpaceMTCH* for Type0B-PDCCH CSS set on the primary cell or for Type3-PDCCH CSS set on a secondary cell, the UE monitors PDCCH for detection of broadcast DCI formats, as described in clause 18, on the active DL BWP.

For a DL BWP, if a UE is not provided *searchSpaceOtherSystemInformation* for Type0A-PDCCH CSS set, the UE does not monitor PDCCH for Type0A-PDCCH CSS set on the DL BWP. The CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level for Type0A-PDCCH CSS set are given in Table 10.1-1.

For a DL BWP, if a UE is not provided *ra-SearchSpace* for Type1-PDCCH CSS set, the UE does not monitor PDCCH for Type1-PDCCH CSS set on the DL BWP. If the UE has not been provided a Type3-PDCCH CSS set, or a Type1A-PDCCH CSS set, or a USS set and the UE has received a C-RNTI and has been provided a Type1-PDCCH CSS set, the UE monitors PDCCH candidates for DCI format 0_0 and DCI format 1_0 with CRC scrambled by the C-RNTI in the Type1-PDCCH CSS set.

If a UE is not provided *pagingSearchSpace* for Type2-PDCCH CSS set, the UE does not monitor PDCCH for Type2-PDCCH CSS set on the DL BWP. The CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level for Type2-PDCCH CSS set are given in Table 10.1-1.

If a UE is not provided *pei-SearchSpace* for Type2A-PDCCH CSS set, the UE does not monitor PDCCH for Type2A-PDCCH CSS set on the DL BWP. The CCE aggregation levels and the maximum number of PDCCH candidates per CCE aggregation level for Type2A-PDCCH CSS set are given in Table 10.1-1. If the UE is provided *pei-SearchSpace* with zero value for the Type2A-PDCCH CSS set index, and for the SS/PBCH block and CORESET multiplexing patterns 2 and 3, the UE determines PDCCH monitoring occasions as described in clause 13 and the CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level for Type2A-PDCCH CSS set are given in Table 10.1-1.

If a UE is provided a zero value for *searchSpaceID* in *PDCCH-ConfigCommon* for a Type0/0A/1A/2-PDCCH CSS set, the UE determines monitoring occasions for PDCCH candidates of the Type0/0A/1A/2-PDCCH CSS set as described in clause 13, and the UE is provided a C-RNTI, the UE monitors PDCCH candidates only at monitoring occasions associated with a SS/PBCH block, where the SS/PBCH block is determined by the most recent of

- a MAC CE activation command indicating a TCI state of the active BWP that includes a CORESET with index 0, as described in [6, TS 38.214], where the TCI-state includes a CSI-RS which is quasi-co-located with the SS/PBCH block, or
- a random access procedure that is not initiated by a PDCCH order that triggers a contention-free random access procedure, or
- configured-grant based PUSCH transmission in RRC_INACTIVE state as described in clause 19.1.

If a UE monitors PDCCH candidates for DCI formats with CRC scrambled by a C-RNTI and the UE is provided a non-zero value for *searchSpaceID* in *PDCCH-ConfigCommon* for a Type0/0A/1A/2-PDCCH CSS set, or monitors PDCCH candidates for DCI formats with CRC scrambled by a MCCH-RNTI or a G-RNTI for broadcast and the UE is provided a non-zero value for *searchSpaceMCCH* and *searchSpaceMTCH* in *PDCCH-ConfigCommon* for a Type0B-PDCCH CSS set, or monitors PDCCH candidates for DCI formats with CRC scrambled by a multicast-MCCH-RNTI or a G-RNTI for multicast in RRC_INACTIVE state and the UE is provided a non-zero value for *searchSpaceMulticastMCCH* and *searchSpaceMulticastMTCH* in *PDCCH-ConfigCommon* for a Type0B-PDCCH CSS set, the UE determines monitoring occasions for PDCCH candidates of the Type0/0A/1A/2-PDCCH CSS set, or of the Type0B-PDCCH CSS set, respectively, based on the search space set associated with the value of *searchSpaceID*.

The UE may assume that the DM-RS antenna port associated with PDCCH receptions in the CORESET configured by *pdcch-ConfigSIB1* in *MIB*, the DM-RS antenna port associated with corresponding PDSCH receptions, and the corresponding SS/PBCH block are quasi co-located with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable [6, TS 38.214], if the UE is not provided a TCI state indicating quasi co-location information of the DM-RS antenna port for PDCCH reception in the CORESET. The value for the DM-RS scrambling sequence initialization is the cell ID. For operation without shared spectrum channel access in FR1 and FR2-1, a SCS is provided by *subCarrierSpacingCommon* in *MIB*. For operation with shared spectrum channel access in FR1 and for operation in FR2-2, a SCS is same as the SCS of a corresponding SS/PBCH block.

For single cell operation or for operation with carrier aggregation in a same frequency band, a UE does not expect to monitor a PDCCH in a Type0/0A/0B/2/3-PDCCH CSS set or in a USS set if a DM-RS for monitoring a PDCCH in a Type1-PDCCH CSS set is not configured with same *qcl-Type* set to 'typeD' properties [6, TS 38.214] with a DM-RS for monitoring the PDCCH in the Type0/0A/0B/2/3-PDCCH CSS set or in the USS set, and if the PDCCH or an associated PDSCH overlaps in at least one symbol with a PDCCH the UE monitors in a Type1-PDCCH CSS set or with an associated PDSCH.

If a UE is provided

- one or more search space sets by corresponding one or more of *searchSpaceZero*, *searchSpaceSIB1*, *searchSpaceOtherSystemInformation*, *pagingSearchSpace*, *ra-SearchSpace*, and

- a C-RNTI, an MCS-C-RNTI, or a CS-RNTI

the UE monitors PDCCH candidates for DCI format 0_0 and DCI format 1_0 with CRC scrambled by the C-RNTI, the MCS-C-RNTI, or the CS-RNTI in the one or more search space sets in a slot where the UE monitors PDCCH candidates for at least a DCI format 0_0 or a DCI format 1_0 with CRC scrambled by SI-RNTI, RA-RNTI, MsgB-RNTI, or P-RNTI.

If a UE is provided

- one or more search space sets by corresponding one or more of *searchSpaceZero*, *searchSpaceSIB1*, *searchSpaceOtherSystemInformation*, *pagingSearchSpace*, *pei-SearchSpace*, *ra-SearchSpace*, or a CSS set by *PDCCH-Config*, and

- a SI-RNTI, a P-RNTI, a PEI-RNTI, a RA-RNTI, a MsgB-RNTI, a SFI-RNTI, an INT-RNTI, a TPC-PUSCH-RNTI, a TPC-PUCCH-RNTI, or a TPC-SRS-RNTI

then, for a RNTI from any of these RNTIs, the UE does not expect to process information from more than one DCI format with CRC scrambled with the RNTI per slot.

Table 10.1-1: CCE aggregation levels and maximum number of PDCCH candidates per CCE aggregation level for CSS sets configured by *searchSpaceSIB1*

CCE Aggregation Level	Number of Candidates
4	4
8	2
16	1

For each DL BWP configured to a UE in a serving cell, the UE can be provided by higher layer signalling with

- $P \leq 3$ CORESETs if *coresetPoolIndex* is not provided, or if a value of *coresetPoolIndex* is same for all CORESETs if *coresetPoolIndex* is provided

- $P \leq 5$ CORESETs if *coresetPoolIndex* is not provided for a first CORESET, or is provided and has a value 0 for a first CORESET, and is provided and has a value 1 for a second CORESET

For each CORESET, the UE is provided the following by *ControlResourceSet*:

- a CORESET index p, by *controlResourceSetId* or by *controlResourceSetId-v1610*, where

  - $0 < p < 12$ if *coresetPoolIndex* is not provided, or if a value of *coresetPoolIndex* is same for all CORESETs if *coresetPoolIndex* is provided;

  - $0 < p < 16$ if *coresetPoolIndex* is not provided for a first CORESET, or is provided and has a value 0 for a first CORESET, and is provided and has a value 1 for a second CORESET;
- a DM-RS scrambling sequence initialization value by *pdcch-DMRS-ScramblingID*;
- a precoder granularity for a number of REGs in the frequency domain where the UE can assume use of a same DM-RS precoder by *precoderGranularity*;
- a number of consecutive symbols provided by *duration*;
- a set of resource blocks provided by *frequencyDomainResources*;
- CCE-to-REG mapping parameters provided by *cce-REG-MappingType*;
- an antenna port quasi co-location, from a set of antenna port quasi co-locations provided by *TCI-State*, indicating quasi co-location information of the DM-RS antenna port for PDCCH reception;
- an indication for a presence or absence of a transmission configuration indication (TCI) field for a DCI format, other than DCI format 1_0, that schedules PDSCH receptions or has associated HARQ-ACK information without scheduling PDSCH and is provided by a PDCCH in CORESET p, by *tci-PresentInDCI* or *tci-PresentDCI-1-2*.

When *precoderGranularity* = *allContiguousRBs*, a UE does not expect

- to be configured a set of resource blocks of a CORESET that includes more than four sub-sets of resource blocks that are not contiguous in frequency
- any RE of a CORESET to overlap with any RE determined from
  - *lte-CRS-ToMatchAround* or *LTE-CRS-PatternList*, if the UE is not provided *pdcchCandidateReception-WithCRSOverlap*, or
  - a SS/PBCH block.

If a UE is provided two TCI states indicating quasi co-location information of the DM-RS antenna port for PDCCH reception in a CORESET associated with a Type3-PDCCH CSS set, the UE may assume the quasi co-location information indicated in both of the two TCI states for the PDCCH reception in the CORESET.

For each CORESET in a DL BWP of a serving cell, a respective *frequencyDomainResources* provides a bitmap

- if a CORESET is not associated with any search space set configured with *freqMonitorLocations*, the bits of the bitmap have a one-to-one mapping with non-overlapping groups of 6 consecutive PRBs, in ascending order of the PRB index in the DL BWP bandwidth of $N_{\mathrm{RB}}^{\mathrm{BWP}}$ PRBs with starting common RB position $N_{\mathrm{BWP}}^{\mathrm{start}}$, where the first common RB of the first group of 6 PRBs has common RB index $6 \cdot \lceil N_{\mathrm{BWP}}^{\mathrm{start}}/6 \rceil$ if *rb-Offset* is not provided, or the first common RB of the first group of 6 PRBs has common RB index $N_{\mathrm{BWP}}^{\mathrm{start}} + N_{\mathrm{RB}}^{\mathrm{offset}}$ where $N_{\mathrm{RB}}^{\mathrm{offset}}$ is provided by *rb-Offset.*
- if a CORESET is associated with at least one search space set configured with *freqMonitorLocations*, the first $N_{\mathrm{RBG,set0}}^{\mathrm{size}}$ bits of the bitmap have a one-to-one mapping with non-overlapping groups of 6 consecutive PRBs, in ascending order of the PRB index in each RB set k in the DL BWP bandwidth of $N_{\mathrm{RB}}^{\mathrm{BWP}}$ PRBs with starting common RB position $RB_{s0+k,\mathrm{DL}}^{\mathrm{start},\mu}$ [6, TS 38.214], where the first common RB of the first group of 6 PRBs has common RB index $RB_{s0+k,\mathrm{DL}}^{\mathrm{start},\mu} + N_{\mathrm{RB}}^{\mathrm{offset}}$ and k is indicated by *freqMonitorLocations* if provided for a search space set; otherwise, $k = 0$. $N_{\mathrm{RBG,set0}}^{\mathrm{size}} = \lfloor (N_{\mathrm{RB,set0}}^{\mathrm{size}} - N_{\mathrm{RB}}^{\mathrm{offset}})/6 \rfloor$, $N_{\mathrm{RB,set0}}^{\mathrm{size}}$ is a number of available PRBs in the RB set 0 for the DL BWP, and $N_{\mathrm{RB}}^{\mathrm{offset}}$ is provided by *rb-Offset* or $N_{\mathrm{RB}}^{\mathrm{offset}} = 0$ if *rb-Offset* is not provided. If a UE is provided RB sets in the DL BWP, the UE expects that the RBs of the CORESET are within the union of the PRBs in the RB sets of the DL BWP.

For each CORESET provided by *cfr-ConfigMCCH-MTCH* or *cfr-ConfigMCCH-MTCH-RedCap* or *cfr-ConfigMulticast* in a CFR of a serving cell, the quantities $N_{\mathrm{RB}}^{\mathrm{BWP}}$ and $N_{\mathrm{BWP}}^{\mathrm{start}}$ in this clause are replaced by the size of CFR $N_{\mathrm{RB}}^{\mathrm{CFR}}$ and starting common RB position of CFR $N_{\mathrm{CFR}}^{\mathrm{start}}$, respectively.

For a CORESET other than a CORESET with index 0,

- if a UE has not been provided a configuration of TCI state(s) by *tci-StatesPDCCH-ToAddList* and *tci-StatesPDCCH-ToReleaseList* for the CORESET, or has been provided initial configuration of more than one TCI states for the CORESET by *tci-StatesPDCCH-ToAddList* and *tci-StatesPDCCH-ToReleaseList* and has not received a MAC CE activation command for one of the TCI states as described in [11, TS 38.321], the UE assumes that the DM-RS antenna port associated with PDCCH receptions is quasi co-located with the SS/PBCH block the UE identified during the initial access procedure, or for a most recent configured grant PUSCH transmission as described in clause 19 for a same HARQ process;

- if a UE has been provided a configuration of more than one TCI states by *tci-StatesPDCCH-ToAddList* and *tci-StatesPDCCH-ToReleaseList* for the CORESET as part of Reconfiguration with sync procedure as described in [12, TS 38.331] and has not received a MAC CE activation command for one of the TCI states as described in [11, TS 38.321], the UE assumes that the DM-RS antenna port associated with PDCCH receptions is quasi co-located with the SS/PBCH block or the CSI-RS resource the UE identified during the random access procedure initiated by the Reconfiguration with sync procedure as described in [12, TS 38.331].

For a CORESET with index 0,

- if the UE is provided *TCI-State* and *followUnifiedTCI-State* for the CORESET, the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET and a DM-RS antenna port for PDSCH receptions scheduled by DCI formats provided by PDCCH receptions in the CORESET are quasi co-located with the reference signals provided by the indicated *TCI-State* [6, TS 38.214]

- else if the UE is provided *dl-OrJointTCI-StateList* and is indicated a first *TCI-State* and a second *TCI-State*, and *apply-IndicatedTCIState* for the CORESET

  - if the CORESET is associated with a Type 0/0A/2-PDCCH CSS set that has search space set index 0

    - if *apply-IndicatedTCIState* = 'first', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State*,

    - if *apply-IndicatedTCIState* = 'second', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the second *TCI-State*,

    - if *apply-IndicatedTCIState* = 'none', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the one or more DL RS configured by a TCI state, where the TCI state is indicated by a MAC CE activation command for the CORESET, if any

  - else

    - if *apply-IndicatedTCIState* = 'first', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State*,

    - if *apply-IndicatedTCIState* = 'second', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the second *TCI-State*,

    - if *apply-IndicatedTCIState* = 'both', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first and the second *TCI-State*,

    - if *apply-IndicatedTCIState* = 'none', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the one or more DL RS configured by a TCI state, where the TCI state is indicated by a MAC CE activation command for the CORESET.

- else, the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with

  - the one or more DL RS configured by a TCI state, where the TCI state is indicated by a MAC CE activation command for the CORESET, if any, or

  - a SS/PBCH block the UE identified during a most recent random access procedure not initiated by a PDCCH order that triggers a contention-free random access procedure, if no MAC CE activation command indicating a TCI state for the CORESET is received after the most recent random access procedure, or a SS/PBCH block the UE identified during a most recent configured grant PUSCH transmission as described in clause 19.

For a CORESET other than a CORESET with index 0, if a UE is provided a single TCI state for a CORESET, or if the UE receives a MAC CE activation command for one or two of the provided TCI states for a CORESET, the UE assumes that the DM-RS antenna port associated with PDCCH receptions in the CORESET is quasi co-located with the one or more DL RS configured by the TCI states. For a CORESET with index 0, the UE expects that a CSI-RS configured with *qcl-Type* set to 'typeD' in a TCI state indicated by a MAC CE activation command for the CORESET is provided by a SS/PBCH block

- if the UE receives a MAC CE activation command for one of the TCI states, the UE applies the activation command in the first slot that is after slot $k + 3N_{\text{slot}}^{\text{subframe},\mu} + 2^{\mu} \cdot k_{\text{mac}}$ where k is the slot where the UE would transmit a PUCCH with HARQ-ACK information for the PDSCH providing the activation command, μ is the SCS configuration for the PUCCH in the slot when the activation command is applied, and k_{mac} is a number of slots for SCS configuration $\mu = 0$ provided by *kmac* or $k_{\text{mac}} = 0$ if *kmac* is not provided.

If a UE is provided *TCI-State* in *dl-OrJointTCI-StateList*, a DM-RS antenna port for PDCCH receptions in a CORESET, other than a CORESET with index 0, associated only with USS sets and/or Type3-PDCCH CSS sets, and a DM-RS antenna port for PDSCH receptions scheduled by DCI formats provided by PDCCH receptions in the CORESET are quasi co-located with reference signals provided by the indicated *TCI-State* [6, TS 38.214].

If a UE is provided *followUnifiedTCI-State* for a CORESET, other than a CORESET with index 0, associated at least with CSS sets other than Type3-PDCCH CSS sets, a DM-RS antenna port for PDCCH receptions in the CORESET and a DM-RS antenna port for PDSCH receptions scheduled by DCI formats provided by PDCCH receptions in the CORESET are quasi co-located with reference signals provided by the indicated *TCI-State*.

If a UE is provided *dl-OrJointTCI-StateList* and is indicated a first *TCI-State* and a second *TCI-State*, and is provided *apply-IndicatedTCIState* for a CORESET, other than a CORESET with index 0,

- if the CORESET is associated only with USS sets and/or Type3-PDCCH CSS sets
  - if *apply-IndicatedTCIState* = 'first', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State*
  - if *apply-IndicatedTCIState* = 'second', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the second *TCI-State*
  - if *apply-IndicatedTCIState* = 'both', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State* and the second *TCI-State*
- if the CORESET is associated at least with CSS sets other than Type3-PDCCH CSS sets,
  - if *apply-IndicatedTCIState* = 'first', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State*
  - if *apply-IndicatedTCIState* = 'second', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the second *TCI-State*
  - if *apply-IndicatedTCIState* = 'both', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the reference signals provided by the first *TCI-State* and the second *TCI-State*
  - if *apply-IndicatedTCIState* = 'none', the UE assumes that a DM-RS antenna port for PDCCH receptions in the CORESET is quasi co-located with the one or more DL RS configured by a TCI state indicated by a MAC CE activation command for the CORESET

If the UE is provided *dl-OrJointTCI-StateList* and

- is not provided *coresetPoolIndex* or is provided *coresetPoolIndex* with a value of 0 for first CORESETs on an active DL BWP of a serving cell,
- is provided *coresetPoolIndex* with a value of 1 for second CORESETs on the active DL BWP of the serving cells, and
- is provided *followUnifiedTCI-State* for the first and second CORESETs, that do not include a CORESET with index 0 and are associated only with USS sets and/or Type3-PDCCH CSS sets, or with CSS sets other than Type3-PDCCH CSS sets,

the UE

- assumes that DM-RS antenna ports for PDCCH receptions in the first and second CORESETs, and DM-RS antenna ports for PDSCH receptions scheduled by DCI formats provided by PDCCH receptions in the first and second CORESETs, are quasi co-located with the reference signals provided by indicated *TCI-State* specific to the first and second CORESETs, respectively

- transmits PUSCH scheduled by DCI formats provided by PDCCH receptions in the first and second CORESETs using a spatial domain filter corresponding to *TCI-State* or *TCI-UL-State* specific to the first and second CORESETs, respectively.

If a UE is provided two *coresetPoolIndex* values 0 and 1 for first and second CORESETs, or is not provided *coresetPoolIndex* value for first CORESETs and is provided *coresetPoolIndex* value of 1 for second CORESETs, respectively, a MAC CE command activating TCI states for the first or second CORESETs [11, TS 38.321] can include *coresetPoolIndex* value 0 or 1

- if the UE is provided *SSB_MTC_AdditionalPCI*, the activated TCI states for the first and/or the second CORESETs are for *physCellId* from *ServingCellConfigCommon* and the activated TCI states for either the first or the second CORESETs can be for *physCellId* from *additionalPCI*.

If a UE is provided by *simultaneousTCI-UpdateList1* or *simultaneousTCI-UpdateList2* up to two lists of cells for simultaneous TCI state activation, the UE applies the antenna port quasi co-location provided by one or two *TCI-State* each with same activated *tci-StateID* value, to CORESETs with a same index in all configured DL BWPs of all configured cells in a list determined from a serving cell index, where one or two *tci-StateID*, the CORESET index, and the serving cell index are provided by a MAC CE command.

For each DL BWP configured to a UE in a serving cell, the UE is provided by higher layers with $S \leq 10$ search space sets where, for each search space set from the S search space sets, the UE is provided the following by *SearchSpace*:

- a search space set index s, $0 < s < 40$, by *searchSpaceId*

- an association between the search space set s and a CORESET p by *controlResourceSetId* or by *controlResourceSetId-v1610*

- a PDCCH monitoring periodicity of k_s slots and a PDCCH monitoring offset of o_s slots, by *monitoringSlotPeriodicityAndOffset* or by *monitoringSlotPeriodicityAndOffset-r17*

- a PDCCH monitoring pattern within a slot, indicating first symbol(s) of the CORESET for PDCCH monitoring within each slot where the UE monitors PDCCH, by *monitoringSymbolsWithinSlot*

- a duration of $T_s < k_s$ indicating a number of slots that the search space set s exists by *duration*, or a number of slots in consecutive groups of slots where the search space set s can exist by *duration-r17*

- a bitmap, by *monitoringSlotsWithinSlotGroup*, that applies per group of slots and provides a PDCCH monitoring pattern indicating slots in a group of slots for PDCCH monitoring

  - a size of the group of slots is same as a size of *monitoringSlotsWithinSlotGroup*

  - for a Type1-PDCCH CSS set provided by *ra-SearchSpace* in dedicated RRC signaling, or for a Type3-PDCCH CSS set, or for a USS set, the PDCCH monitoring pattern indicates only consecutive slots in the group of slots for PDCCH monitoring and, at least for one combination (X_s, Y_s) indicated by the UE as a capability, a number of the consecutive slots is not larger than Y_s

  - for a Type1-PDCCH CSS set provided by *ra-SearchSpace* in *SIB1*, the PDCCH monitoring pattern indicates only up to 1 slot in the group of slots for PDCCH monitoring

  - for a Type0-PDCCH CSS set or for a Type0A-PDCCH CSS set, or for a Type2-PDCCH CSS set, the PDCCH monitoring pattern indicates slots in the group of slots for PDCCH monitoring, and the slots are not restricted to be consecutive, and the number of those slots is not larger than the size of *monitoringSlotsWithinSlotGroup*

- a number of PDCCH candidates $M_s^{(L)}$ per CCE aggregation level L by *aggregationLevel1*, *aggregationLevel2*, *aggregationLevel4*, *aggregationLevel8*, and *aggregationLevel16*, for CCE aggregation level 1, CCE aggregation level 2, CCE aggregation level 4, CCE aggregation level 8, and CCE aggregation level 16, respectively

- an indication that search space set s is either a CSS set or a USS set by *searchSpaceType*
- if search space set s is a CSS set
  - an indication by *dci-Format0-0-AndFormat1-0* to monitor PDCCH candidates for DCI format 0_0 and DCI format 1_0
  - an indication by *dci-Format2-0* to monitor one or two PDCCH candidates, or to monitor one PDCCH candidate per RB set if the UE is provided *freqMonitorLocations* for the search space set, for DCI format 2_0 and a corresponding CCE aggregation level
  - an indication by *dci-Format2-1* to monitor PDCCH candidates for DCI format 2_1
  - an indication by *dci-Format2-2* to monitor PDCCH candidates for DCI format 2_2
  - an indication by *dci-Format2-3* to monitor PDCCH candidates for DCI format 2_3
  - an indication by *dci-Format2-4* to monitor PDCCH candidates for DCI format 2_4
  - an indication by *dci-Format2-6* to monitor PDCCH candidates for DCI format 2_6
  - an indication by *dci-Format2-9* to monitor PDCCH candidates for DCI format 2_9
  - an indication by *dci-Format4-0* to monitor PDCCH candidates for DCI format 4_0
  - an indication by *dci-Format4-1*, or *dci-Format4-2*, or *dci-Format4-1-AndFormat4-2* to monitor PDCCH candidates for DCI format 4_1, or DCI format 4_2, or for both DCI format 4_1 and DCI format 4_2, respectively
- an indication by *searchSpaceLinkingId* that search space set s is linked to another search space set for which is provided a same value for *searchSpaceLinkingId*
- if search space set s is a USS set,
  - an indication by *dci-Formats* to monitor PDCCH candidates either for DCI format 0_0 and DCI format 1_0, or for DCI format 0_1 and DCI format 1_1, or
  - an indication by *dci-FormatsExt* to monitor PDCCH candidates for DCI format 0_2 and DCI format 1_2, or for DCI format 0_1, DCI format 1_1, DCI format 0_2, and DCI format 1_2, or
  - an indication by *dci-FormatsMC* to monitor PDCCH candidates for one or both of DCI format 0_3 and DCI format 1_3, or
  - an indication by *dci-FormatsSL* to monitor PDCCH candidates for DCI format 0_0 and DCI format 1_0, or for DCI format 0_1 and DCI format 1_1, or for DCI format 3_0, or for DCI format 3_1, or for DCI format 3_0 and DCI format 3_1, on an indication by *dci-Format-NCR* to monitor PDCCH candidates for DCI format 2_8
- a bitmap by *freqMonitorLocations*, if provided, to indicate an index of one or more RB sets for the search space set s, where the MSB k in the bitmap corresponds to RB set $k-1$ in the DL BWP. For RB set k indicated in the bitmap, the first PRB of the frequency domain monitoring location confined within the RB set is given by $RB_{s0+k,\mathrm{DL}}^{\mathrm{start},\mu}+N_{\mathrm{RB}}^{\mathrm{offset}}$, where $RB_{s0+k,\mathrm{DL}}^{\mathrm{start},\mu}$ is the index of first common RB of the RB set k [6, TS 38.214], and $N_{\mathrm{RB}}^{\mathrm{offset}}$ is provided by *rb-Offset* or $N_{\mathrm{RB}}^{\mathrm{offset}}=0$ if *rb-Offset* is not provided. For each RB set with a corresponding value of 1 in the bitmap, the frequency domain resource allocation pattern for the monitoring location is determined based on the first $N_{\mathrm{RBG,set\ 0}}^{\mathrm{size}}$ bits in *frequencyDomainResources* provided by the associated CORESET configuration.

If the *monitoringSymbolsWithinSlot* indicates to a UE to monitor PDCCH in a subset of up to three consecutive symbols that are same in every slot where the UE monitors PDCCH for all search space sets, the UE does not expect to be configured with a PDCCH SCS other than 15 kHz if the subset includes at least one symbol after the third symbol.

A UE does not expect to be provided a first symbol and a number of consecutive symbols for a CORESET that results to a PDCCH candidate mapping to symbols of different slots.

A UE does not expect any two PDCCH monitoring occasions on an active DL BWP, for a same search space set or for different search space sets, in a same CORESET to be separated by a non-zero number of symbols that is smaller than the CORESET duration.

A UE determines a PDCCH monitoring occasion on an active DL BWP from the PDCCH monitoring periodicity, the PDCCH monitoring offset, and the PDCCH monitoring pattern within a slot. If *monitoringSlotsWithinSlotGroup* is not provided, the UE determines that PDCCH monitoring occasions exist in a slot with number $n_{s,f}^{\mu}$ [4, TS 38.211] in a frame with number n_f if $(n_f N_{slot}^{frame,\mu} + n_{s,f}^{\mu} - o_s) \bmod k_s = 0$. The UE monitors PDCCH candidates for search space set s for T_s consecutive slots, starting from slot $n_{s,f}^{\mu}$, and does not monitor PDCCH candidates for search space set s for the next $k_s - T_s$ consecutive slots. If *monitoringSlotsWithinSlotGroup* is provided, for search space set s, the UE determines that the slot with number $n_{s,f}^{\mu}$ [4, TS 38.211] in a frame with number n_f satisfying $(n_f N_{slot}^{frame,\mu} + n_{s,f}^{\mu} - o_s) \bmod k_s = 0$ is the first slot in a first group of L_s slots and that PDCCH monitoring occasions exist in T_s/L_s consecutive groups of slots starting from the first group, where L_s is the size of *monitoringSlotsWithinSlotGroup*. The UE monitors PDCCH candidates for search space set s within each of the T_s/L_s consecutive groups of slots according to *monitoringSlotsWithinSlotGroup*, starting from slot $n_{s,f}^{\mu}$, and does not monitor PDCCH candidates for search space set s for the next $k_s - T_s$ consecutive slots.

A USS at CCE aggregation level $L \in \{1, 2, 4, 8, 16\}$ is defined by a set of PDCCH candidates for CCE aggregation level L.

If a UE is configured with *CrossCarrierSchedulingConfig* for a serving cell, the carrier indicator field value corresponds to the value indicated by *cif-InSchedulingCell* in *CrossCarrierSchedulingConfig*. If a UE is configured with *MC-DCI-SetofCells* for a set of serving cells, the UE is provided *nCI-Value* for the set of serving cells.

For an active DL BWP of a serving cell on which a UE monitors PDCCH candidates in a USS, if the UE is not configured with a carrier indicator field, the UE monitors the PDCCH candidates without carrier indicator field. For an active DL BWP of a serving cell on which a UE monitors PDCCH candidates in a USS, if a UE is configured with a carrier indicator field, the UE monitors the PDCCH candidates with carrier indicator field.

A UE does not expect to monitor PDCCH candidates on an active DL BWP of a secondary cell if the UE is configured to monitor PDCCH candidates for detection of DCI formats scheduling on that secondary cell in another serving cell. For a serving cell included in *MC-DCI-SetofCells*, if provided, the UE does not expect to monitor PDCCH candidates on more than one scheduling cell for detection of DCI formats scheduling on the serving cell. For the active DL BWP of a serving cell on which the UE monitors PDCCH candidates, the UE monitors PDCCH candidates at least for the same serving cell.

For a search space set s associated with CORESET p, the CCE indexes for aggregation level L corresponding to PDCCH candidate $m_{s,n_{CI}}^{(L)}$ of the search space set in slot $n_{s,f}^{\mu}$ for an active DL BWP of a serving cell corresponding to carrier indicator field value n_{CI}, or corresponding to value n_{CI} of *nCI-Value* associated with a set of serving cells *MC-DCI-SetofCells*, are given by

$$L \cdot \left\{ \left(Y_{p,n_{s,f}^{\mu}} + \left\lfloor \frac{m_{s,n_{CI}}^{(L)} \cdot N_{\mathrm{CCE},p}}{L \cdot M_{s,\max}^{(L)}} \right\rfloor + n_{CI} \right) mod \left\lfloor N_{\mathrm{CCE},p}/L \right\rfloor \right\} + i$$

where

for any CSS, $Y_{p,n_{s,f}^{\mu}} = 0$;

for a USS, $Y_{p,n_{s,f}^{\mu}} = \left(A_p \cdot Y_{p,n_{s,f}^{\mu}-1} \right) mod D$, $Y_{p,-1} = n_{\mathrm{RNTI}} \neq 0$, $A_p = 39827$ for $p mod 3 = 0$, $A_p = 39829$ for $p mod 3 = 1$, $A_p = 39839$ for $p mod 3 = 2$, and $D = 65537$;

$i = 0, \cdots, L-1$;

$N_{\mathrm{CCE},p}$ is the number of CCEs, numbered from 0 to $N_{\mathrm{CCE},p} - 1$, in CORESET p and, if any, per RB set

- for CORESET 0, the CCEs are obtained prior to puncturing, if any, of corresponding RBs [4, TS 38.211];

n_{CI} is

- the carrier indicator field value, if provided by *cif-InSchedulingCell* in *CrossCarrierSchedulingConfig* for the serving cell on which PDCCH is monitored, except for scheduling of the serving cell from the same serving cell in which case $n_{CI} = 0$;

- the *nCI-Value* provided for the set of serving cells *MC-DCI-SetofCells*, if *MC-DCI-SetofCells* is provided;

- otherwise, including for any CSS, $n_{CI} = 0$

$m_{s,n_{CI}}^{(L)} = 0, \cdots, M_{s,n_{CI}}^{(L)} - 1$, where $M_{s,n_{CI}}^{(L)}$ is the number of PDCCH candidates the UE is configured to monitor for aggregation level L of a search space set s for a serving cell corresponding to n_{CI};

for any CSS, $M_{s,\max}^{(L)} = M_{s,0}^{(L)}$;

for a USS, $M_{s,\max}^{(L)}$ is the maximum of $M_{s,n_{CI}}^{(L)}$ over all configured n_{CI} values for a CCE aggregation level L of search space set s ;

the RNTI value used for n_{RNTI} is the C-RNTI.

For search space sets s_i and s_j that include *searchSpaceLinkingId* with same value, a UE monitors, in monitoring occasions with same index according to each of search space sets s_i and s_j in a slot, PDCCH candidates $m_{s_i,n_{CI}}^{(L)}$ and $m_{s_j,n_{CI}}^{(L)}$, with $m_{s_i,n_{CI}}^{(L)} = m_{s_j,n_{CI}}^{(L)}$, for detection of a DCI format with same information. The UE expects $k_{s_i} = k_{s_j}$, $o_{s_i} = o_{s_j}$, $T_{s_i} = T_{s_j}$, $M_{s_i}^{(L)} = M_{s_j}^{(L)}$, and a same number of non-overlapping PDCCH monitoring occasions per slot based on corresponding *monitoringSymbolsWithinSlot*, for search space sets s_i and s_j. For CORESET p_i associated with the search space set s_i and for CORESET p_j associated with the search space set s_j, the UE is provided *tci-PresentInDCI* or *tci-PresentDCI-1*-2 for either none or both of CORESETs p_i and p_j. For CORESET p_i associated with the search space set s_i and for CORESET p_j associated with the search space set s_j, the UE is either not provided *coresetPoolIndex* value of 1 for any of the two CORESETs, or is provided *coresetPoolIndex* value of 1 for both CORESETs.

A UE can indicate by *numBD-twoPDCCH-r17* a capability for counting PDCCH candidates $m_{s_i,n_{CI}}^{(L)}$ and $m_{s_j,n_{CI}}^{(L)}$ either as 2 PDCCH candidates or as 3 PDCCH candidates.

For search space sets s_i and s_j that include *searchSpaceLinkingId* with same value, and for search space sets s_k and s_l that include *searchSpaceLinkingId* with same value, a UE expects to simultaneously monitor PDCCH candidates $m_{s_i,n_{CI,1}}^{(8)} = m_{s_j,n_{CI,1}}^{(8)}$, and $m_{s_k,n_{CI,2}}^{(16)} = m_{s_l,n_{CI,2}}^{(16)}$ only if a first CCE of $m_{s_i,n_{CI,1}}^{(8)}$ or $m_{s_j,n_{CI,1}}^{(8)}$ has different index than a first CCE of $m_{s_k,n_{CI,2}}^{(16)}$ or $m_{s_l,n_{CI,2}}^{(16)}$ in a CORESET configured with *cce-REG-MappingType* = '*nonInterleaved*' and with duration of one symbol.

If a UE

- is provided *monitoringCapabilityConfig = r16monitoringcapability* for a downlink cell,

- is provided, by *searchSpaceLinkingId* a same value for search space sets s_i and s_j on the downlink cell, and

- indicates *numBD-twoPDCCH-r17* with value of 3

the UE counts each PDCCH candidate for the one of the search space sets s_i and s_j that the UE monitors PDCCH in the later span, as two PDCCH candidates. The UE does not expect a first PDCCH candidate from search space set s_i or s_j and a second PDCCH candidate from a search space set s_k that does not include *searchSpaceLinkingId* to use a same set of CCEs and same scrambling in a same CORESET, and provide respective first and second DCI formats with same size, in any span other than the first span in a slot.

A UE does not expect to be provided *freqMonitorLocations* for a search space set s in a serving cell if *intraCellGuardBandsDL-List* indicates that no intra-cell guard-bands are configured for the serving cell.

A UE that

- is configured for operation with carrier aggregation, and

- indicates support of search space sharing through *searchSpaceSharingCA-UL* or through *searchSpaceSharingCA-DL*, and
- has a PDCCH candidate with CCE aggregation level L in CORESET p associated with search space set s_i of a scheduling cell for detection of a first DCI format, other than DCI format 0_0 or DCI format 1_0, having a first size and scheduling
  - PUSCH transmission or configured grant Type 2 PUSCH release on serving cell $n_{CI,2}$, or
  - PDSCH reception or having associated HARQ-ACK information without scheduling PDSCH reception on serving cell $n_{CI,2}$

can receive a corresponding PDCCH through a PDCCH candidate with CCE aggregation level L in CORESET p associated with search space set s_j of the scheduling cell for detection of a second DCI format having a second size and associated with scheduling on serving cell $n_{CI,1}$ if the first size and the second size are same and if neither of search space sets s_i and s_j includes *searchSpaceLinkingId*.

A UE expects to monitor PDCCH candidates for up to 4 sizes of DCI formats that include up to 3 sizes of DCI formats with CRC scrambled by C-RNTI per serving cell. The UE counts a number of sizes for DCI formats per serving cell based on a number of configured PDCCH candidates in respective search space sets for the corresponding active DL BWP. If the UE monitors PDCCH candidates for detection of one or both of DCI format 0_3 and DCI format 1_3 for scheduling on serving cells from a set of serving cells, the serving cell for counting the size of one or both DCI format 0_3 and DCI format 1_3, respectively, is

- the scheduling cell, if the scheduling cell is included in the set of serving cells and the UE is provided search space sets for the PDCCH candidates only on the scheduling cell
- a serving cell from the set of serving cells, if search space sets with same *searchSpaceId* for one or both of DCI format 0_3 and DCI format 1_3, respectively, are provided on the serving cell and on the scheduling cell.

A UE does not expect to detect, in a same PDCCH monitoring occasion, a DCI format with CRC scrambled by a SI-RNTI, RA-RNTI, MsgB-RNTI, TC-RNTI, P-RNTI, C-RNTI, CS-RNTI, MCS-RNTI, MCCH-RNTI, G-RNTI, G-CS-RNTI, or multicast-MCCH-RNTI and a DCI format with CRC scrambled by a SL-RNTI or a SL-CS-RNTI for scheduling respective PDSCH reception and PSSCH transmission on a same serving cell.

A PDCCH candidate with index $m_{s_j,n_{CI}}^{(L)}$ for a search space set s_j using a set of L CCEs in a CORESET p on the active DL BWP for serving cell n_{CI}, or for set of serving cells associated with *nCI-Value* having value n_{CI}, is not counted for monitoring if there is a PDCCH candidate with index $m_{s_i,n_{CI}}^{(L)}$ for a search space set $s_i < s_j$, or if there is a PDCCH candidate with index $n_{s_j,n_{CI}}^{(L)}$ and $n_{s_j,n_{CI}}^{(L)} < m_{s_j,n_{CI}}^{(L)}$, in the CORESET p on the active DL BWP for serving cell n_{CI}, or for set of serving cells n_{CI}, respectively, using a same set of L CCEs, the PDCCH candidates have identical scrambling, and the corresponding DCI formats for the PDCCH candidates have a same size; otherwise, the PDCCH candidate with index $m_{s_j,n_{CI}}^{(L)}$ is counted for monitoring.

For search space sets s_i and s_j that include *searchSpaceLinkingId* with same value, and for search space set s_k that does not include *searchSpaceLinkingId*, when a UE

- monitors PDCCH candidates $m_{s_i,n_{CI,1}}^{(L)} = m_{s_j,n_{CI,1}}^{(L)}$ for detection of a first DCI format,
- monitors PDCCH candidate $m_{s_k,n_{CI,2}}^{(L)}$ for detection of a second DCI format having a same size as the first DCI format,
- the PDCCH candidate $m_{s_i,n_{CI,1}}^{(L)}$, or the PDCCH candidate $m_{s_j,n_{CI,1}}^{(L)}$, and the PDCCH candidate $m_{s_k,n_{CI,2}}^{(L)}$ have identical scrambling and use a same set of CCEs over same symbols in a slot in a CORESET p,

the PDCCH candidate $m_{s_k,n_{CI,2}}^{(L)}$ is not counted for monitoring and the UE assumes that a detected DCI format is the first DCI format. A UE may monitor PDCCH candidate $m_{s_k,n_{CI,2}}^{(L)}$ depending on a corresponding capability [18, TS 38.306].

For search space sets s_i and s_j that include *searchSpaceLinkingId* with same value, and for search space set s_k that does not include *searchSpaceLinkingId*, when a UE

- monitors PDCCH candidates $m_{s_i,n_{CI,1}}^{(8)} = m_{s_j,n_{CI,1}}^{(8)}$ for detection of a first DCI format and monitors PDCCH candidate $m_{s_k,n_{CI,2}}^{(16)}$ for detection of a second DCI format, or monitors PDCCH candidates $m_{s_i,n_{CI,1}}^{(16)} = m_{s_j,n_{CI,1}}^{(16)}$ for detection of the first DCI format and monitors PDCCH candidate $m_{s_k,n_{CI,2}}^{(8)}$ for detection of the second DCI format, and

- one of the PDCCH candidates $m_{s_i,n_{CI,1}}^{(8)}$ and $m_{s_j,n_{CI,1}}^{(8)}$, and the PDCCH candidate $m_{s_k,n_{CI,2}}^{(16)}$, or one of the PDCCH candidates $m_{s_i,n_{CI,1}}^{(16)}$ and $m_{s_j,n_{CI,1}}^{(16)}$, and the PDCCH candidate $m_{s_k,n_{CI,2}}^{(8)}$, have a first CCE with same index and are simultaneously monitored in a CORESET p with *cce-REG-MappingType* = '*nonInterleaved*' and duration of one symbol,

the UE assumes that a detected DCI format is the first DCI format.

For search space sets s_i and s_j, that include *searchSpaceLinkingId* with same value, and for search space sets s_k and s_l that include *searchSpaceLinkingId* with same value, and for detection of DCI formats with same size, a UE expects different CCEs or different scrambling in a CORESET p for any of first PDCCH candidates $m_{s_i,n_{CI,1}}^{(L)}$ and $m_{s_j,n_{CI,1}}^{(L)}$, with $m_{s_i,n_{CI,1}}^{(L)} = m_{s_j,n_{CI,1}}^{(L)}$, and any of second PDCCH candidates $m_{s_k,n_{CI,2}}^{(L)}$ and $m_{s_l,n_{CI,2}}^{(L)}$, with $m_{s_k,n_{CI,2}}^{(L)} = m_{s_l,n_{CI,2}}^{(L)}$ that the UE would simultaneously monitor.

Table 10.1-2 provides the maximum number of monitored PDCCH candidates, $M_{\mathrm{PDCCH}}^{max,slot,\mu}$, per slot for a UE in a DL BWP with SCS configuration μ for operation with a single serving cell.

Table 10.1-2: Maximum number $M_{\mathrm{PDCCH}}^{max,slot,\mu}$ of monitored PDCCH candidates per slot for a DL BWP with SCS configuration $\mu \in \{0, 1, 2, 3\}$ for a single serving cell

μ	Maximum number of monitored PDCCH candidates per slot and per serving cell $M_{\mathrm{PDCCH}}^{max,slot,\mu}$
0	44
1	36
2	22
3	20

Table 10.1-2A provides the maximum number of monitored PDCCH candidates, $M_{\mathrm{PDCCH}}^{max,(X,Y),\mu}$, per span for a UE in a DL BWP with SCS configuration μ for operation with a single serving cell.

Table 10.1-2A: Maximum number $M_{\mathrm{PDCCH}}^{max,(X,Y),\mu}$ of monitored PDCCH candidates in a span for combination (X, Y) for a DL BWP with SCS configuration $\mu \in \{0, 1\}$ for a single serving cell

	Maximum number $M_{\mathrm{PDCCH}}^{max,(X,Y),\mu}$ of monitored PDCCH candidates per span for combination (X, Y) and per serving cell		
μ	(2, 2)	(4, 3)	(7, 3)
0	14	28	44
1	12	24	36

Table 10.1-2B provides the maximum number of monitored PDCCH candidates, $M_{\mathrm{PDCCH}}^{max,X_s,\mu}$, per group of X_s slots for combination (X_s, Y_s) for a UE in a DL BWP with SCS configuration μ for operation with a single serving cell.

Table 10.1-2B: Maximum number $M_{\mathrm{PDCCH}}^{max,X_s,\mu}$ of monitored PDCCH candidates per group of X_s slots for combination (X_s, Y_s) for a DL BWP with SCS configuration $\mu \in \{5, 6\}$ for a single serving cell

	Maximum number $M_{\mathrm{PDCCH}}^{max,X_s,\mu}$ of monitored PDCCH candidates in a group of X_s slots per combination (X_s, Y_s) and per serving cell			
μ	(4, 1)	(4, 2)	(8, 1)	(8, 4)
5	20	20	-	-
6	10	10	20	20

Table 10.1-3 provides the maximum number of non-overlapped CCEs, $C_{\text{PDCCH}}^{max,slot,\mu}$, for a DL BWP with SCS configuration μ that a UE is expected to monitor corresponding PDCCH candidates per slot for operation with a single serving cell.

CCEs for PDCCH candidates are non-overlapped if they correspond to

- different CORESET indexes, or
- different first symbols for the reception of the respective PDCCH candidates.

Table 10.1-3: Maximum number $C_{\text{PDCCH}}^{max,slot,\mu}$ of non-overlapped CCEs per slot for a DL BWP with SCS configuration $\mu \in \{0,1,2,3\}$ for a single serving cell

μ	Maximum number of non-overlapped CCEs per slot and per serving cell $C_{\text{PDCCH}}^{max,slot,\mu}$
0	56
1	56
2	48
3	32

Table 10.1-3A provides the maximum number of non-overlapped CCEs, $C_{\text{PDCCH}}^{max,(X,Y),\mu}$, for a DL BWP with SCS configuration μ that a UE is expected to monitor corresponding PDCCH candidates per span for operation with a single serving cell.

Table 10.1-3A: Maximum number $C_{\text{PDCCH}}^{max,(X,Y),\mu}$ of non-overlapped CCEs in a span for combination (X,Y) for a DL BWP with SCS configuration $\mu \in \{0,1\}$ for a single serving cell

	Maximum number $C_{\text{PDCCH}}^{max,(X,Y),\mu}$ of non-overlapped CCEs per span for combination (X,Y) and per serving cell		
μ	(2, 2)	(4, 3)	(7, 3)
0	18	36	56
1	18	36	56

Table 10.1-3B provides the maximum number of non-overlapped CCEs, $C_{\text{PDCCH}}^{max,X_s,\mu}$, for a DL BWP with SCS configuration μ that a UE is expected to monitor corresponding PDCCH candidates per group of X_s slots for combination (X_s, Y_s) for operation with a single serving cell.

Table 10.1-3B: Maximum number $C_{\text{PDCCH}}^{max,X_s,\mu}$ of non-overlapped CCEs in a group of X_s slots for any combination (X_s, Y_s) for a DL BWP with SCS configuration $\mu \in \{5,6\}$ for a single serving cell

	Maximum number of non-overlapped CCEs in a group of X_s slots per combination (X_s, Y_s) and per serving cell $C_{\text{PDCCH}}^{max,X_s,\mu}$			
μ	(4, 1)	(4, 2)	(8, 1)	(8, 4)
5	32	32	-	-
6	16	16	32	32

In the following, if a UE monitors PDCCH candidates on a scheduling cell for detection of DCI format 0_3 or DCI format 1_3 for scheduling on serving cells from a set of serving cells, the serving cell for counting the PDCCH candidates and a corresponding number of non-overlapping CCEs is

- the scheduling cell, if the scheduling cell is included in the set of serving cells and the UE is provided search space sets for the PDCCH candidates only on the scheduling cell
- a serving cell from the set of serving cells, if search space sets with same *searchSpaceId* for one or both of DCI format 0_3 and DCI format 1_3, respectively, are provided on the serving cell and on the scheduling cell.

For the following procedures in this clause, downlink cells are scheduled cells on which a UE is provided search space sets.

If a UE

- does not report *pdcch-BlindDetectionCA*, *pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, or *pdcch-BlindDetectionCA3*, or is not provided *BDFactorR*, $\gamma = R$

- reports *pdcch-BlindDetectionCA*, *pdcch-BlindDetectionCA1*, *pdcch-BlindDetectionCA2*, or *pdcch-BlindDetectionCA3*, the UE can be indicated by *BDFactorR* either $\gamma = 1$ or $\gamma = R$

If a UE is configured with $N_{\text{cells},0}^{\text{DL},\mu} + N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells for which the UE is not provided *monitoringCapabilityConfig*, or is provided *monitoringCapabilityConfig = r15monitoringcapability* and is not provided *CORESETPoolIndex*, with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration μ where $\sum_{\mu=0}^{3}\left(N_{\text{cells},0}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells},1}^{\text{DL},\mu}\right) \leq N_{\text{cells}}^{\text{cap}}$, the UE is not required to monitor, on the active DL BWPs of the scheduling cells,

- more than $M_{\text{PDCCH}}^{\text{total,slot},\mu} = M_{\text{PDCCH}}^{\text{max,slot},\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total,slot},\mu} = C_{\text{PDCCH}}^{\text{max,slot},\mu}$ non-overlapped CCEs per slot for each scheduled cell when the scheduling cell is from the $N_{\text{cells},0}^{\text{DL},\mu}$ downlink cells, or

- more than $M_{\text{PDCCH}}^{\text{total,slot},\mu} = \gamma \cdot M_{\text{PDCCH}}^{\text{max,slot},\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total,slot},\mu} = \gamma \cdot C_{\text{PDCCH}}^{\text{max,slot},\mu}$ non-overlapped CCEs per slot for each scheduled cell when the scheduling cell is from the $N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells

- more than $M_{\text{PDCCH}}^{\text{max,slot},\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{max,slot},\mu}$ non-overlapped CCEs per slot for CORESETs with same *coresetPoolIndex* value for each scheduled cell when the scheduling cell is from the $N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells

$N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells,r15}}^{\text{cap-r16}}$, if a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability*. $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r15/r17}}^{\text{cap-r17}}$, if a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r17monitoringcapability*. $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r15/ \{r16, r17\}}}^{\text{cap-r17}}$, if a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability* and *monitoringCapabilityConfig = r17monitoringcapability*.

If a UE

- is configured with $N_{\text{cells},0}^{\text{DL},\mu} + N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells for which the UE is not provided *monitoringCapabilityConfig*, or is provided *monitoringCapabilityConfig = r15monitoringcapability* and is not provided *coresetPoolIndex*,

- with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cell(s) using SCS configuration μ, where $\sum_{\mu=0}^{3}\left(N_{\text{cells},0}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells},1}^{\text{DL},\mu}\right) > N_{\text{cells}}^{\text{cap}}$, and

- a DL BWP of an activated cell is the active DL BWP of the activated cell, and a DL BWP of a deactivated cell is the DL BWP with index provided by *firstActiveDownlinkBWP-Id* for the deactivated cell,

the UE is not required to monitor more than $M_{\text{PDCCH}}^{\text{total,slot},\mu} = \left\lfloor N_{\text{cells}}^{\text{cap}} \cdot M_{\text{PDCCH}}^{\text{max,slot},\mu} \cdot \left(N_{\text{cells},0}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells},1}^{\text{DL},\mu}\right) / \sum_{j=0}^{3}\left(N_{\text{cells},0}^{\text{DL},j} + \gamma \cdot N_{\text{cells},1}^{\text{DL},j}\right)\right\rfloor$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total,slot},\mu} = \left\lfloor N_{\text{cells}}^{\text{cap}} \cdot C_{\text{PDCCH}}^{\text{max,slot},\mu} \cdot \left(N_{\text{cells},0}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells},1}^{\text{DL},\mu}\right) / \sum_{j=0}^{3}\left(N_{\text{cells},0}^{\text{DL},j} + \gamma \cdot N_{\text{cells},1}^{\text{DL},j}\right)\right\rfloor$ non-overlapped CCEs per slot on the active DL BWP(s) of scheduling cell(s) from the $N_{\text{cells},0}^{\text{DL},\mu} + N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells. $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells,r15}}^{\text{cap-r16}}$ if a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability*. $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r15/r17}}^{\text{cap-r17}}$, if a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r17monitoringcapability*. $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r15/ \{r16, r17\}}}^{\text{cap-r17}}$. If a UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability* and *monitoringCapabilityConfig = r17monitoringcapability*.

For each scheduled cell from the $N_{\text{cells},0}^{\text{DL},\mu}$ downlink cells, the UE is not required to monitor on the active DL BWP with SCS configuration μ of the scheduling cell more than $min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ PDCCH candidates or more than $min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ non-overlapped CCEs per slot.

For each scheduled cell from the $N_{\text{cells},1}^{\text{DL},\mu}$ downlink cells, the UE is not required to monitor on the active DL BWP with SCS configuration μ of the scheduling cell

- more than $min\left(\gamma \cdot M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ PDCCH candidates or more than $min\left(\gamma \cdot C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ non-overlapped CCEs per slot

- more than $min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ PDCCH candidates or more than $min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ non-overlapped CCEs per slot for CORESETs with same *coresetPoolIndex* value

If a UE is configured with $N_{\text{cells,r16}}^{\text{DL},\mu}$ downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* and with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration μ, and with $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ of the $N_{\text{cells,r16}}^{\text{DL},\mu}$ downlink cells using combination (X, Y) for PDCCH monitoring, where $\sum_{\mu=0}^{1} N_{\text{cells,r16}}^{\text{DL},\mu} \leq N_{\text{cells}}^{\text{cap-r16}}$, the UE is not required to monitor, on the active DL BWP of the scheduling cell, more than $M_{\text{PDCCH}}^{\text{total},(X,Y),\mu} = M_{\text{PDCCH}}^{\text{max},(X,Y),\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total},(X,Y),\mu} = C_{\text{PDCCH}}^{\text{max},(X,Y),\mu}$ non-overlapped CCEs per span for each scheduled cell when the scheduling cell is from the $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ downlink cells. If a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig* = *r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability*, $N_{\text{cells}}^{\text{cap-r16}}$ is replaced by $N_{\text{cells,r16}}^{\text{cap-r16}}$. If a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig* = *r16monitoringcapability* and *monitoringCapabilityConfig = r17monitoringcapability*, $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r16/r17}}^{\text{cap-r17}}$. If a UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* and *monitoringCapabilityConfig = r16monitoringcapability* and *monitoringCapabilityConfig* = *r17monitoringcapability*, $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r16/ \{r15, r17\}}}^{\text{cap-r17}}$.

If a UE is configured only with $N_{\text{cells,r16}}^{\text{DL},\mu}$ downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* and with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration μ, and with $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ of the $N_{\text{cells,r16}}^{\text{DL},\mu}$ downlink cells using combination (X, Y) for PDCCH monitoring, where $\sum_{\mu=0}^{1} N_{\text{cells,r16}}^{\text{DL},\mu} > N_{\text{cells}}^{\text{cap-r16}}$, a DL BWP of an activated cell is the active DL BWP of the activated cell, and a DL BWP of a deactivated cell is the DL BWP with index provided by *firstActiveDownlinkBWP-Id* for the deactivated cell, the UE is not required to monitor more than $M_{\text{PDCCH}}^{\text{total},(X,Y),\mu} = \left\lfloor N_{\text{cells}}^{\text{cap-r16}} \cdot M_{\text{PDCCH}}^{\text{max},(X,Y),\mu} \cdot N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu} / \sum_{j=0}^{1} N_{\text{cells,r16}}^{\text{DL},j} \right\rfloor$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total},(X,Y),\mu} = \left\lfloor N_{\text{cells}}^{\text{cap-r16}} \cdot C_{\text{PDCCH}}^{\text{max},(X,Y),\mu} \cdot N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu} / \sum_{j=0}^{1} N_{\text{cells,r16}}^{\text{DL},j} \right\rfloor$ non-overlapped CCEs

- per set of spans on the active DL BWP(s) of all scheduling cell(s) from the $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ downlink cells within every X symbols, if the union of PDCCH monitoring occasions on all scheduling cells from the $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ downlink cells results to PDCCH monitoring according to the combination (X, Y) and any pair of spans in the set is within Y symbols, where first X symbols start at a first symbol with a PDCCH monitoring occasion and next X symbols start at a first symbol with a PDCCH monitoring occasion that is not included in the first X symbols

- per set of spans across the active DL BWP(s) of all scheduling cells from the $N_{\text{cells,r16}}^{\text{DL},(X,Y),\mu}$ downlink cells, with at most one span per scheduling cell for each set of spans, otherwise

where $N_{\text{cells,r16}}^{\text{DL},j}$ is a number of configured cells with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration j. If a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig* = *r15monitoringcapability* and *monitoringCapabilityConfig* = *r16monitoringcapability*, $N_{\text{cells}}^{\text{cap-r16}}$ is replaced by $N_{\text{cells,r16}}^{\text{cap-r16}}$. If a UE is configured with downlink cells for which the UE is provided both *monitoringCapabilityConfig* = *r16monitoringcapability* and *monitoringCapabilityConfig* = *r17monitoringcapability*, $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r16/r17}}^{\text{cap-r17}}$. If a UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* and *monitoringCapabilityConfig* = *r16monitoringcapability* and *monitoringCapabilityConfig* = *r17monitoringcapability*, $N_{\text{cells}}^{\text{cap}}$ is replaced by $N_{\text{cells, r16/ \{r15, r17\}}}^{\text{cap-r17}}$.

For each scheduled cell from the $N_{\text{cells,r16}}^{\text{DL},(\text{X},\text{Y}),\mu}$ downlink cells using combination (X,Y), the UE is not required to monitor on the active DL BWP with SCS configuration μ of the scheduling cell, more than $min\left(M_{\text{PDCCH}}^{\max,(\text{X},\text{Y}),\mu}, M_{\text{PDCCH}}^{\text{total},(\text{X},\text{Y}),\mu}\right)$ PDCCH candidates or more than $min\left(C_{\text{PDCCH}}^{\max,(\text{X},\text{Y}),\mu}, C_{\text{PDCCH}}^{\text{total},(\text{X},\text{Y}),\mu}\right)$ non-overlapped CCEs per span.

A UE does not expect to be configured CSS sets, except for CSS sets provided by *searchSpaceMCCH*, *searchSpaceMTCH*, *searchSpaceMulticastMCCH*, *searchSpaceMulticastMTCH* or by *SearchSpace* in *pdcch-ConfigMulticast* for DCI formats with CRC scrambled by G-RNTI or G-CS-RNTI, that result to corresponding total, or per scheduled cell, numbers of monitored PDCCH candidates and non-overlapped CCEs per slot, per group of X_s slots for a corresponding combination (X_s, Y_s), or per span that exceed the corresponding maximum numbers per slot, or per group of X_s slots for a corresponding combination (X_s, Y_s), or per span, respectively.

For same cell scheduling or for cross-carrier scheduling, a UE does not expect a number of PDCCH candidates, and a number of corresponding non-overlapped CCEs per slot, or per group of X_s slots for a corresponding combination (X_s, Y_s), or per span, on a secondary cell to be larger than the corresponding numbers that the UE is capable of monitoring on the secondary cell per slot, or per group of X_s slots for a corresponding combination (X_s, Y_s), or per span, respectively. If a UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for the primary cell, except the first span of each slot, the UE does not expect a number of PDCCH candidates and a number of corresponding non-overlapped CCEs per span on the primary cell to be larger than the corresponding numbers that the UE is capable of monitoring on the primary cell per span.

If a UE is configured with $N_{\text{cells,r17,0}}^{\text{DL},\mu} + N_{\text{cells,r17,1}}^{\text{DL},\mu}$ downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration μ, and with $N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu} + N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ of the $N_{\text{cells,r17,0}}^{\text{DL},\mu} + N_{\text{cells,r17,1}}^{\text{DL},\mu}$ downlink cells using any combination (X_s, Y_s) for a group of X_s slots for PDCCH monitoring, where $\sum_{\mu=5}^{6}\left(N_{\text{cells,r17,0}}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},\mu}\right) \leq N_{\text{cells}}^{\text{cap-r17}}$, the UE is not required to monitor, on the active DL BWP of the scheduling cell,

- more than $M_{\text{PDCCH}}^{\text{total},X_s,\mu} = M_{\text{PDCCH}}^{\max,X_s,\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total},X_s,\mu} = C_{\text{PDCCH}}^{\max,X_s,\mu}$ non-overlapped CCEs per group of X_s slots for each scheduled cell when the scheduling cell is from the $N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu}$ downlink cells, or
- more than $M_{\text{PDCCH}}^{\text{total},X_s,\mu} = \gamma \cdot M_{\text{PDCCH}}^{\max,X_s,\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\text{total},X_s,\mu} = \gamma \cdot C_{\text{PDCCH}}^{\max,X_s,\mu}$ non-overlapped CCEs per group of X_s slots for each scheduled cell when the scheduling cell is from the $N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ downlink cells, or
- more than $M_{\text{PDCCH}}^{\max,X_s,\mu}$ PDCCH candidates or more than $C_{\text{PDCCH}}^{\max,X_s,\mu}$ non-overlapped CCEs per group of X_s slots for CORESETs with same *coresetPoolIndex* for each scheduled cell when the scheduling cell is from the $N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ downlink cells

If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/r15}}^{\text{cap-r17}}$. If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/r16}}^{\text{cap-r17}}$. If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig = r15monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig = r16monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/\{r15,r16\}}}^{\text{cap-r17}}$. If, for one or more of the cells, the UE is provided with *monitoringCapabilityConfig = r16monitoringcapability*, $\gamma = 1$.

If a UE is configured $N_{\text{cells,r17,0}}^{\text{DL},\mu} + N_{\text{cells,r17,1}}^{\text{DL},\mu}$ downlink cells for which the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* and with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration μ, and with $N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu} + N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ of the $N_{\text{cells,r17,0}}^{\text{DL},\mu} + N_{\text{cells,r17,1}}^{\text{DL},\mu}$ downlink cells using any combination (X_s, Y_s) for a group of X_s slots for PDCCH monitoring, where $\sum_{\mu=5}^{6}\left(N_{\text{cells,r17,0}}^{\text{DL},\mu} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},\mu}\right) > N_{\text{cells}}^{\text{cap-r17}}$, a DL BWP of an activated cell is the active DL BWP of the activated cell, and a DL BWP of a deactivated cell is the

DL BWP with index provided by *firstActiveDownlinkBWP-Id* for the deactivated cell, the UE is not required to monitor more than $M_{\text{PDCCH}}^{\text{total},X_s,\mu} = \left\lfloor N_{\text{cells}}^{\text{cap-r17}} \cdot M_{\text{PDCCH}}^{\max,X_s,\mu} \cdot \left(N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}\right) / \sum_{j=5}^{6}\left(N_{\text{cells,r17,0}}^{\text{DL},j} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},j}\right)\right\rfloor$ PDCCH candidates, or more than $C_{\text{PDCCH}}^{\text{total},X_s,\mu} = \left\lfloor N_{\text{cells}}^{\text{cap-r17}} \cdot C_{\text{PDCCH}}^{\max,X_s,\mu} \cdot \left(N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}\right) / \sum_{j=5}^{6}\left(N_{\text{cells,r17,0}}^{\text{DL},j} + \gamma \cdot N_{\text{cells,r17,1}}^{\text{DL},j}\right)\right\rfloor$ non-overlapped CCEs, per group of X_s slots on the active DL BWP(s) of scheduling cell(s) from the $N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu} + N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ downlink cells where $N_{\text{cells,r17,0}}^{\text{DL},j} + N_{\text{cells,r17,1}}^{\text{DL},j}$ is a number of configured cells with associated PDCCH candidates monitored in the active DL BWPs of the scheduling cells using SCS configuration j.

If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/r15}}^{\text{cap-r17}}$. If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/r16}}^{\text{cap-r17}}$. If the UE is configured with downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* and downlink cells for which the UE is provided *monitoringCapabilityConfig* = *r17monitoringcapability* for the active DL BWPs, $N_{\text{cells}}^{\text{cap-r17}}$ is replaced by $N_{\text{cells,r17/\{r15,r16\}}}^{\text{cap-r17}}$. If, for one or more of the cells, the UE is provided with *monitoringCapabilityConfig* = *r16monitoringcapability*, $\gamma = 1$.

For each scheduled cell from the $N_{\text{cells,r17,0}}^{\text{DL},X_s,\mu}$ downlink cells using any combination (X_s, Y_s) for a group of X_s slots, the UE is not required to monitor on the active DL BWP with SCS configuration μ of the scheduling cell, more than $min\left(M_{\text{PDCCH}}^{\max,X_s,\mu}, M_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ PDCCH candidates or more than $min\left(C_{\text{PDCCH}}^{\max,X_s,\mu}, C_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ non-overlapped CCEs per group of X_s slots.

For each scheduled cell from the $N_{\text{cells,r17,1}}^{\text{DL},X_s,\mu}$ downlink cells using any combination (X_s, Y_s) for a group of X_s slots, the UE is not required to monitor on the active DL BWP with SCS configuration μ of the scheduling cell,

- more than $min\left(\gamma \cdot M_{\text{PDCCH}}^{\max,X_s,\mu}, M_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ PDCCH candidates or more than $min\left(\gamma \cdot C_{\text{PDCCH}}^{\max,X_s,\mu}, C_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ non-overlapped CCEs per group of X_s slots
- more than $min\left(M_{\text{PDCCH}}^{\max,X_s,\mu}, M_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ PDCCH candidates or more than $min\left(C_{\text{PDCCH}}^{\max,X_s,\mu}, C_{\text{PDCCH}}^{\text{total},X_s,\mu}\right)$ non-overlapped CCEs per group of X_s slots for CORESETs with the same *coresetPoolIndex* value.

For cross-carrier scheduling, the number of PDCCH candidates for monitoring and the number of non-overlapped CCEs per span or per slot or per group of X_s slots are separately counted for each scheduled cell.

The UE allocates PDCCH candidates for monitoring to USS sets for the primary cell having an active DL BWP with SCS configuration μ in a slot if the UE is not provided *monitoringCapabilityConfig* for the primary cell or if the UE is provided *monitoringCapabilityConfig* = *r15monitoringcapability* for the primary cell, or in the first span of each slot if the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* for the primary cell, or in a group of X_s slots for a corresponding combination (X_s, Y_s) if the UE is provided *monitoringCapabilityConfig* = *r17monitoringcapability* for the primary cell, according to the following pseudocode.

If for the USS sets for scheduling on the primary cell the UE is not provided *coresetPoolIndex* for first CORESETs, or is provided *coresetPoolIndex* with value 0 for first CORESETs, and is provided *coresetPoolIndex* with value 1 for second CORESETs, and if $min\left(\gamma \cdot M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right) > min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ or $min\left(\gamma \cdot C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right) > min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$, the following pseudocode applies only to USS sets associated with the first CORESETs. A UE does not expect to monitor PDCCH in a USS set without allocated PDCCH candidates for monitoring.

In the following pseudocode, if the UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* for the primary cell, $M_{\text{PDCCH}}^{\text{max,slot},\mu}$ and $C_{\text{PDCCH}}^{\text{max,slot},\mu}$ are replaced by $M_{\text{PDCCH}}^{\max,(X,Y),\mu}$ and $C_{\text{PDCCH}}^{\max,(X,Y),\mu}$ respectively, and $M_{\text{PDCCH}}^{\text{total,slot},\mu}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu}$ are replaced by $M_{\text{PDCCH}}^{\text{total},(X,Y),\mu}$ and $C_{\text{PDCCH}}^{\text{total},(X,Y),\mu}$ respectively.

In the following pseudocode, if the UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for the primary cell, $M_{\mathrm{PDCCH}}^{\mathrm{max,slot,\mu}}$ and $C_{\mathrm{PDCCH}}^{\mathrm{max,slot,\mu}}$ are replaced by $M_{\mathrm{PDCCH}}^{\mathrm{max,X_s,\mu}}$ and $C_{\mathrm{PDCCH}}^{\mathrm{max,X_s,\mu}}$ respectively, and $M_{\mathrm{PDCCH}}^{\mathrm{total,slot,\mu}}$ and $C_{\mathrm{PDCCH}}^{\mathrm{total,slot,\mu}}$ are replaced by $M_{\mathrm{PDCCH}}^{\mathrm{total,X_s,\mu}}$ and $C_{\mathrm{PDCCH}}^{\mathrm{total,X_s,\mu}}$ respectively.

For all search space sets that a UE monitors PDCCH on the primary cell within a slot n, or within a group of X_s slots for a corresponding combination (X_s, Y_s), or within a span in slot n, denote by S_{css} a set of CSS sets, except for CSS sets provided by *searchSpaceMCCH*, *searchSpaceMTCH*, *searchSpaceMulticastMCCH*, *searchSpaceMulticastMTCH* or by *SearchSpace* in *pdcch-ConfigMulticast* for DCI formats with CRC scrambled by G-RNTI or G-CS-RNTI, with cardinality of I_{css} and by S_{uss} a set of USS sets and CSS sets provided by *searchSpaceMCCH*, *searchSpaceMTCH* or by *SearchSpace* in *pdcch-ConfigMulticast* for DCI formats with CRC scrambled by G-RNTI or G-CS-RNTI with cardinality of J_{uss} for scheduling on the primary cell. The location of search space sets s_j, $0 \le j < J_{uss}$, in S_{uss} is according to an ascending order of the search space set index.

Denote by $M_{S_{\mathrm{css}}(i)}^{(L)}$, $0 \le i < I_{css}$, the number of counted PDCCH candidates for monitoring for CSS set $S_{\mathrm{css}}(i)$ and by $M_{S_{\mathrm{uss}}(j)}^{(L)}$, $0 \le j < J_{uss}$, the number of counted PDCCH candidates for monitoring for search space set $S_{\mathrm{uss}}(j)$. If a UE indicates *numBD-twoPDCCH-r17* with value of 3 and is provided *searchSpaceLinkingId* with same value for search space sets s_j and s_i, with $s_i < s_j$, set $M_{S_{\mathrm{css}}(j)}^{(L)} = 2 \cdot M_{S_{\mathrm{css}}(j)}^{(L)}$ if s_i and s_j are CSS sets or set $M_{S_{\mathrm{uss}}(j)}^{(L)} = 2 \cdot M_{S_{\mathrm{uss}}(j)}^{(L)}$ if s_i and s_j are USS sets.

For the CSS sets in S_{css}, a UE monitors $M_{\mathrm{PDCCH}}^{\mathrm{css}} = \sum_{i=0}^{I_{\mathrm{css}}-1} \sum_L M_{S_{\mathrm{css}}(i)}^{(L)}$ PDCCH candidates requiring a total of $C_{\mathrm{PDCCH}}^{\mathrm{css}}$ non-overlapping CCEs in a slot, of in group of X_s slots for a corresponding combination (X_s, Y_s), or in a span.

Denote by $V_{\mathrm{CCE}}(S_{\mathrm{uss}}(j))$ the set of non-overlapping CCEs for search space set $S_{\mathrm{uss}}(j)$ and by $\mathcal{C}\big(V_{\mathrm{CCE}}(S_{\mathrm{uss}}(j))\big)$; the cardinality of $V_{\mathrm{CCE}}(S_{\mathrm{uss}}(j))$ where a UE determines the non-overlapping CCEs for search space set $S_{\mathrm{uss}}(j)$ considering the allocated PDCCH candidates for monitoring for the CSS sets in S_{css} and the allocated PDCCH candidates for monitoring for all search space sets $S_{\mathrm{uss}}(k)$, $0 \le k \le j$.

Set $M_{\mathrm{PDCCH}}^{\mathrm{uss}} = min\big(M_{\mathrm{PDCCH}}^{\mathrm{max,slot,\mu}}, M_{\mathrm{PDCCH}}^{\mathrm{total,slot,\mu}}\big) - M_{\mathrm{PDCCH}}^{\mathrm{css}}$

Set $C_{\mathrm{PDCCH}}^{\mathrm{uss}} = min\big(C_{\mathrm{PDCCH}}^{\mathrm{max,slot,\mu}}, C_{\mathrm{PDCCH}}^{\mathrm{total,slot,\mu}}\big) - C_{\mathrm{PDCCH}}^{\mathrm{css}}$

Set $j = 0$

while $\sum_L M_{S_{\mathrm{uss}}(j)}^{(L)} \le M_{\mathrm{PDCCH}}^{\mathrm{uss}}$ AND $\mathcal{C}\big(V_{\mathrm{CCE}}(S_{\mathrm{uss}}(j))\big) \le C_{\mathrm{PDCCH}}^{\mathrm{uss}}$

allocate $\sum_L M_{S_{\mathrm{uss}}(j)}^{(L)}$ PDCCH candidates for monitoring to search space set $S_{\mathrm{uss}}(j)$

$M_{\mathrm{PDCCH}}^{\mathrm{uss}} = M_{\mathrm{PDCCH}}^{\mathrm{uss}} - \sum_L M_{S_{\mathrm{uss}}(j)}^{(L)}$;

$C_{\mathrm{PDCCH}}^{\mathrm{uss}} = C_{\mathrm{PDCCH}}^{\mathrm{uss}} - \mathcal{C}\big(V_{\mathrm{CCE}}(S_{\mathrm{uss}}(j))\big)$;

$j = j + 1$;

end while

If a UE

- is configured for single cell operation or for operation with carrier aggregation in a same frequency band, and

- monitors PDCCH candidates in overlapping PDCCH monitoring occasions in multiple CORESETs that have been configured with same or different *qcl-Type* set to 'typeD' properties on active DL BWP(s) of one or more cells

the UE monitors PDCCHs only in a CORESET, and in any other CORESET from the multiple CORESETs that have been configured with *qcl-Type* set to same 'typeD' properties as the CORESET, on the active DL BWP of a cell from the one or more cells

- the CORESET corresponds to the CSS set with the lowest index in the cell with the lowest index containing CSS, if any; otherwise, to the USS set with the lowest index in the cell with lowest index

- the lowest USS set index is determined over all USS sets with at least one PDCCH candidate in overlapping PDCCH monitoring occasions

If a UE

- is not provided *coresetPoolIndex* for first CORESETs, or is provided *coresetPoolIndex* with value 0 for first CORESETs, and
- is provided *coresetPoolIndex* with value 1 for second CORESETs, and
- is provided *twoQCLTypeDforMulti-DCI*

the UE applies the procedures in the above paragraph independently across the first CORESETs and the second CORESETs.

If a UE

- is configured for single cell operation or for operation with carrier aggregation in a same frequency band,
- monitors PDCCH candidates in overlapping PDCCH monitoring occasions in multiple CORESETs that have been configured with same or different *qcl-Type* set to 'typeD' properties on active DL BWP(s) of one or more cells, and
- is provided *twoQCLTypeDforPDCCHRepetition*

the UE monitors PDCCHs only in a first CORESET with *qcl-Type* set to first 'typeD' properties and, if any, in a second CORESET with *qcl-Type* set to second 'typeD' properties that are different than the first 'typeD' properties, and in any other CORESET from the multiple CORESETs with corresponding *qcl-Type* set to either the first 'typeD' properties or to the second 'typeD' properties

- the first CORESET corresponds to the CSS set with the lowest index in the cell with the lowest index containing CSS sets, if any; otherwise, to the USS set with the lowest index in the cell with lowest index
- excluding CSS sets and USS sets associated with CORESETs with *qcl-Type* set to first 'typeD' properties, the second CORESET corresponds to the CSS set with the lowest index in the cell with the lowest index containing CSS sets, if any; otherwise, to the USS set with the lowest index in the cell with lowest index, where the CSS set or the USS set includes *searchSpaceLinkingId* with same value as any CSS set or any USS set associated with CORESETs with *qcl-Type* set to first 'typeD' properties
- the lowest USS set index is determined over all USS sets with at least one PDCCH candidate in overlapping PDCCH monitoring occasions

If a UE

- is configured for single cell operation or for operation with carrier aggregation in a same frequency band,
- monitors PDCCH candidates in overlapping PDCCH monitoring occasions in multiple CORESETs that have been configured with same or different *qcl-Type* set to 'typeD' properties on active DL BWP(s) of one or more cells,
- one or more CORESETs have two activated TCI states, and
- reports *sfn-QCL-TypeD-Collision-twoTCI*

the UE monitors PDCCHs only in a CORESET with a first *qcl-Type* set to first 'typeD' properties and, if any, a second *qcl-Type* set to second 'typeD' properties that are different than the first 'typeD' properties, and in any other CORESET from the multiple CORESETs with corresponding *qcl-Type* set to the first 'typeD' properties and/or to the second 'typeD' properties

- the CORESET corresponds to the CSS set with the lowest index in the cell with the lowest index containing CSS, if any; otherwise, to the USS set with the lowest index in the cell with lowest index
- the lowest USS set index is determined over all USS sets with at least one PDCCH candidate in overlapping PDCCH monitoring occasions

For the purpose of determining the CORESET, a SS/PBCH block is considered to have different QCL 'typeD' properties than a CSI-RS.

For the purpose of determining the CORESET, a first CSI-RS associated with a SS/PBCH block in a first cell and a second CSI-RS in a second cell that is also associated with the SS/PBCH block are assumed to have same QCL 'typeD' properties.

The allocation of non-overlapping CCEs and of PDCCH candidates for PDCCH monitoring is according to all search space sets associated with the multiple CORESETs on the active DL BWP(s) of the one or more cells.

The number of active TCI states is determined from the multiple CORESETs.

If a UE

- is configured for single cell operation or for operation with carrier aggregation in a same frequency band, and
- monitors PDCCH candidates in overlapping PDCCH monitoring occasions in multiple CORESETs where none of the CORESETs has TCI-states configured with *qcl-Type* set to 'typeD',

the UE is required to monitor PDCCH candidates in overlapping PDCCH monitoring occasions for search space sets associated with different CORESETs.

For a scheduled cell and at any time, if a UE is provided a C-RNTI, the UE expects to have received at most 16 PDCCHs for DCI formats with CRC scrambled by C-RNTI, CS-RNTI, MCS-C-RNTI, G-RNTI for multicast, or G-CS-RNTI scheduling 16 PDSCH receptions for which the UE has not received any corresponding PDSCH symbol and at most 16 PDCCHs for DCI formats with CRC scrambled by C-RNTI, CS-RNTI, or MCS-C-RNTI scheduling 16 PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol.

If a UE is not provided *monitoringCapabilityConfig* = *r16monitoringcapability* for any serving cell, and

- is not configured for NR-DC operation and indicates through *pdcch-BlindDetectionCA* a capability to monitor PDCCH candidates for $N_{\text{cells}}^{\text{cap}} \geq 4$ downlink cells and the UE is configured with $N_{\text{cells}}^{\text{DL}} > 4$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 4$ uplink cells, or
- is configured with NR-DC operation and for a cell group with $N_{\text{cells}}^{\text{DL}}$ downlink cells or $N_{\text{cells}}^{\text{UL}}$ uplink cells

the UE expects to have respectively received at most $16 \cdot N_{\text{cells}}^{\text{cap}}$ PDCCHs for

- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{\text{cells}}^{\text{cap}}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all $N_{\text{cells}}^{\text{DL}}$ downlink cells
- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{\text{cells}}^{\text{cap}}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all $N_{\text{cells}}^{\text{UL}}$ uplink cells

If a UE is provided *monitoringCapabilityConfig* = *r16monitoringcapability* for all serving cells, and

- is not configured for NR-DC operation and indicates through *pdcch-MonitoringCA* a capability to monitor PDCCH candidates for $N_{cells}^{cap-r16} \geq 2$ downlink cells and the UE is configured with $N_{\text{cells}}^{\text{DL}} > 2$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 2$ uplink cells, or
- is configured with NR-DC operation and for a cell group with $N_{\text{cells}}^{\text{DL}}$ downlink cells or $N_{\text{cells}}^{\text{UL}}$ uplink cells

the UE expects to have respectively received at most $16 \cdot N_{cells}^{cap-r16}$ PDCCHs for

- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells}^{cap-r16}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all $N_{\text{cells}}^{\text{DL}}$ downlink cells
- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells}^{cap-r16}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all $N_{\text{cells}}^{\text{UL}}$ uplink cells.

If a UE is provided *monitoringCapabilityConfig = r16monitoringcapability* for at least one serving cell and is not provided *monitoringCapabilityConfig = r16monitoringcapability* for at least one serving cell, and

- is not configured for NR-DC operation, and indicates a capability to monitor PDCCH candidates for $N_{cells,r15}^{cap-r16} \geq 1$ downlink cells and $N_{cells,r16}^{cap-r16} \geq 1$ downlink cells, and the UE is configured with $N_{\text{cells}}^{\text{DL}} > 1$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 1$ uplink cells, or

- is configured with NR-DC operation and for a cell group with $N_{\text{cells}}^{\text{DL}}$ downlink cells or $N_{\text{cells}}^{\text{UL}}$ uplink cells

the UE expects to have respectively received

- at most $16 \cdot N_{cells,r15}^{cap-r16}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r15}^{cap-r16}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are not provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r15}^{cap-r16}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r15}^{cap-r16}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are not provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r16}^{cap-r16}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r16}^{cap-r16}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r16}^{cap-r16}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r16}^{cap-r16}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

If a UE is provided serving cells with SCS configuration $\mu \in \{5, 6\}$ for the active DL BWP, is not configured for NR-DC operation and indicates through *pdcch-MonitoringCA* a capability to monitor PDCCH candidates for $N_{\text{cells}}^{\text{cap-}r17} \geq 4$ downlink cells and the UE is configured with $N_{\text{cells}}^{\text{DL}} > 4$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 4$ uplink cells, the UE expects to have respectively received at most $16 \cdot N_{\text{cells}}^{\text{cap-}r17}$ PDCCHs for

- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{\text{cells}}^{\text{cap-}r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all $N_{\text{cells}}^{\text{DL}}$ downlink cells

- DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{\text{cells}}^{\text{cap-}r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all $N_{\text{cells}}^{\text{UL}}$ uplink cells.

If a UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for at least one serving cell, is provided *monitoringCapabilityConfig = r15monitoringcapability* for at least one serving cell, is not provided *monitoringCapabilityConfig = r16monitoringcapability* for any serving cell, is not configured for NR-DC operation, indicates a capability to monitor PDCCH candidates for $N_{\text{cells},r15/r17}^{\text{cap-}r17} \geq 1$ downlink cells and $N_{\text{cells},r17/r15}^{\text{cap-}r17} \geq 1$ downlink cells, and UE is configured with $N_{\text{cells}}^{\text{DL}} > 1$ downlink cell or $N_{\text{cells}}^{\text{UL}} > 1$ uplink cells, the UE expects to have respectively received

- at most $16 \cdot N_{cells,r15/r17}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r15/r17}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r15monitoringcapability*

- at most $16 \cdot N_{cells,r15/r17}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r15/r17}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r15monitoringcapability*

- at most $16 \cdot N_{cells,r17/r15}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r17/r15}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

- at most $16 \cdot N_{cells,r17/r15}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r17/r15}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

If a UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for at least one serving cell, is provided *monitoringCapabilityConfig = r16monitoringcapability* for at least one serving cell, is not provided *monitoringCapabilityConfig = r15monitoringcapability* for any serving cell, is not configured for NR-DC operation, indicates a capability to monitor PDCCH candidates for $N_{\text{cells},r16/r17}^{\text{cap}-r17} \geq 1$ downlink cells and $N_{\text{cells},r17/r16}^{\text{cap}-r17} \geq 1$ downlink cells, and the UE is configured with $N_{\text{cells}}^{\text{DL}} > 1$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 1$ uplink cells

the UE expects to have respectively received

- at most $16 \cdot N_{cells,r16/r17}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r16/r17}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r16/r17}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r16/r17}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r17/r16}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r17/r16}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

- at most $16 \cdot N_{cells,r17/r16}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r17/r16}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

If a UE is provided *monitoringCapabilityConfig = r17monitoringcapability* for at least one serving cell, is provided *monitoringCapabilityConfig = r16monitoringcapability* for at least one serving cell, and *monitoringCapabilityConfig = r15monitoringcapability* for at least one serving cell, is not configured for NR-DC operation, indicates a capability to monitor PDCCH candidates for $N_{\text{cells},r15/\{r16,r17\}}^{\text{cap}-r17} \geq 1$ downlink cells, $N_{\text{cells},r16/\{r15,r17\}}^{\text{cap}-r17} \geq 1$, and $N_{\text{cells},r17/\{r15,r16\}}^{\text{cap}-r17} \geq 1$ downlink cells, and is configured with $N_{\text{cells}}^{\text{DL}} > 1$ downlink cells or $N_{\text{cells}}^{\text{UL}} > 1$ uplink cells

the UE expects to have respectively received

- at most $16 \cdot N_{cells,r15/\{r16,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r15/\{r16,r17\}}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r15monitoringcapability*

- at most $16 \cdot N_{cells,r15/\{r16,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r15/\{r16,r17\}}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r15monitoringcapability*

- at most $16 \cdot N_{cells,r16/\{r15,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r16/\{r15,r17\}}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r16/\{r15,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r16/\{r15,r17\}}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells that are provided *monitoringCapabilityConfig = r16monitoringcapability*

- at most $16 \cdot N_{cells,r17/\{r16,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI, or a G-RNTI for multicast, or a G-CS-RNTI scheduling $16 \cdot N_{cells,r17/\{r16,r17\}}^{cap-r17}$ PDSCH receptions for which the UE has not received any corresponding PDSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

- at most $16 \cdot N_{cells,r17/\{r16,r17\}}^{cap-r17}$ PDCCHs for DCI formats with CRC scrambled by a C-RNTI, or a CS-RNTI, or a MCS-C-RNTI scheduling $16 \cdot N_{cells,r17/\{r16,r17\}}^{cap-r17}$ PUSCH transmissions for which the UE has not transmitted any corresponding PUSCH symbol over all serving cells with *monitoringCapabilityConfig = r17monitoringcapability*

If a UE

- is configured to monitor a first PDCCH candidate for a DCI format 0_0 and a DCI format 1_0 from a CSS set and a second PDCCH candidate for a DCI format 0_0 and a DCI format 1_0 from a USS set, where the CSS set and the USS set do not include *searchSpaceLinkingId,* in a CORESET with index zero on an active DL BWP, and

- the DCI formats 0_0/1_0 associated with the first PDCCH candidate and the DCI formats 0_0/1_0 associated with the second PDCCH candidate have same size, and

- the UE receives the first PDCCH candidate and the second PDCCH candidate over a same set of CCEs, and

- the first PDCCH candidate and the second PDCCH candidate have identical scrambling, and

- the DCI formats 0_0/1_0 for the first PDCCH candidate and the DCI formats 0_0/1_0 for the second PDCCH candidate have CRC scrambled by either C-RNTI, or MCS-C-RNTI, or CS-RNTI

the UE decodes only the DCI formats 0_0/1_0 associated with the first PDCCH candidate.

If a UE detects a DCI format with inconsistent information, the UE discards all the information in the DCI format.

A UE configured with a bandwidth part indicator in a DCI format determines, in case of an active DL BWP or of an active UL BWP change, that the information in the DCI format is applicable to the new active DL BWP or UL BWP, respectively, as described in clause 12.

For unpaired spectrum operation, if a UE is not configured for PUSCH/PUCCH transmission on serving cell c_2, the UE does not expect to monitor PDCCH on serving cell c_1 if the PDCCH overlaps in time with SRS transmission (including any interruption due to uplink or downlink RF retuning time [10, TS 38.133]) on serving cell c_2 and if the UE is not capable of simultaneous reception and transmission on serving cell c_1 and serving cell c_2.

If a UE is provided *resourceBlocks* and s*ymbolsInResourceBlock* in *RateMatchPattern*, or if the UE is additionally provided *periodicityAndPattern* in *RateMatchPattern*, the UE can determine a set of RBs in symbols of a slot that are not available for PDSCH reception scheduled by a DCI format as described in [6, TS 38.214]. If a PDCCH candidate that provides a DCI format is mapped to one or more REs that overlap with REs of any RB in the set of RBs in symbols of the slot, the UE does not expect to monitor the PDCCH candidate.

A UE does not expect to be configured with *dci-FormatsSL* and *dci-FormatsExt* in a same USS.

10.1.1 Self-carrier and cross-carrier scheduling on the primary cell

A UE can be configured for scheduling on the primary cell from the primary cell and from a secondary cell [12, TS 38.331]. The UE is either not provided *monitoringCapabilityConfig* for the primary cell or for the secondary cell, or the

UE is provided only *monitoringCapabilityConfig* = *r15monitoringcapability* for the primary cell and for the secondary cell. The UE is not provided *coresetPoolIndex* on the primary cell or on the secondary cell.

The SCS configuration μ_P for the active DL BWP on the primary cell is smaller than or equal to the SCS configuration μ_S for the active DL BWP on the secondary cell.

If a UE indicates capability *disablingScalingFactorDeactSCell* [18, TS 38.306] and the secondary cell is deactivated, or if the UE indicates capability *disablingScalingFactorDormantSCell* [18, TS 38.306] and the active DL BWP of the secondary cell is a dormant DL BWP for the UE, $\alpha = 1$ applies for the procedures described in the remaining of this clause. If $\mu_P < \mu_S$, the UE determines $M_{\text{PDCCH}}^{\text{total,slot},\mu_P}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu_P}$, and determines $M_{\text{PDCCH}}^{\text{total,slot},\mu_S}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu_S}$, by including the primary cell only in the $N_{\text{cells},0}^{\text{DL},\mu_P}$ downlink cells in $\sum_{j=0}^{3}\left(N_{\text{cells},0}^{\text{DL},j} + \gamma \cdot N_{\text{cells},1}^{\text{DL},j}\right)$, as described in clause 10.1. If $\mu_P = \mu_S = \mu$, the UE determines $M_{\text{PDCCH}}^{\text{total,slot},\mu}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu}$ by including the primary cell once in the $N_{\text{cells},0}^{\text{DL},\mu}$ downlink cells in $\sum_{j=0}^{3}\left(N_{\text{cells},0}^{\text{DL},j} + \gamma \cdot N_{\text{cells},1}^{\text{DL},j}\right)$, as described in clause 10.1.

For scheduling on the primary cell from the primary cell, the UE is not required to monitor more than $\left\lfloor \alpha \cdot \min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu_P}, M_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right)\right\rfloor$ PDCCH candidates per slot or more than $\left\lfloor \alpha \cdot \min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu_P}, C_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right)\right\rfloor$ non-overlapping CCEs per slot on the active DL BWP of the primary cell, where α is provided by *ccs-BlindDetectionSplit*.

For scheduling on the primary cell from the secondary cell, the UE is not required to monitor on the active DL BWP of the secondary cell more than

- $M_{\text{PDCCH}}^{\text{max,slot},\mu_S}$ PDCCH candidates per slot or more than $C_{\text{PDCCH}}^{\text{max,slot},\mu_S}$ non-overlapping CCEs per slot of the active DL BWP of the secondary cell

- $\min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu_P}, M_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right) - \left\lfloor \alpha \cdot \min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu_P}, M_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right)\right\rfloor$ PDCCH candidates per slot or more than $\min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu_P}, C_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right) - \left\lfloor \alpha \cdot \min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu_P}, C_{\text{PDCCH}}^{\text{total,slot},\mu_P}\right)\right\rfloor$ non-overlapping CCEs per slot of the active DL BWP of the primary cell

If $\mu_P < \mu_S$, the UE does not count PDCCH candidates and non-overlapping CCEs that the UE monitors for scheduling on the primary cell from the secondary cell towards $M_{\text{PDCCH}}^{\text{total,slot},\mu_S}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu_S}$, respectively.

If $\mu_P < \mu_S$, the UE counts PDCCH candidates and non-overlapping CCEs that the UE monitors for scheduling on the primary cell from the secondary cell towards $M_{\text{PDCCH}}^{\text{total,slot},\mu_P}$ and $C_{\text{PDCCH}}^{\text{total,slot},\mu_P}$, respectively.

For allocation of PDCCH candidates and non-overlapping CCEs to search space sets for scheduling on the primary cell from the primary cell, the UE applies the procedure in clause 10.1 using $\left\lfloor \alpha \cdot \min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)\right\rfloor$ instead of $\min\left(M_{\text{PDCCH}}^{\text{max,slot},\mu}, M_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$, and using $\left\lfloor \alpha \cdot \min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)\right\rfloor$ instead of $\min\left(C_{\text{PDCCH}}^{\text{max,slot},\mu}, C_{\text{PDCCH}}^{\text{total,slot},\mu}\right)$ for the primary cell.

10.2 PDCCH validation for DL SPS and UL grant Type 2

A UE validates, for scheduling activation or scheduling release, a DL SPS assignment PDCCH or a configured UL grant Type 2 PDCCH if

- the CRC of a corresponding DCI format is scrambled with a CS-RNTI provided by *cs-RNTI* or a G-CS-RNTI provided by g-cs-RNTI, and

- the new data indicator field in the DCI format for the enabled transport block is set to '0', and

- the DFI flag field, if present, in the DCI format is set to '0', and

- the time domain resource assignment field in the DCI format indicates a row with single SLIV, and

- if validation is for scheduling activation and if the PDSCH-to-HARQ_feedback timing indicator field in the DCI format is present, the PDSCH-to-HARQ_feedback timing indicator field does not provide an inapplicable value from *dl-DataToUL-ACK-r16* or *dl-DataToUL-ACK-r17*.

If a UE is provided a single configuration for UL grant Type 2 PUSCH or for SPS PDSCH, validation of the DCI format is achieved if all fields for the DCI format are set according to Table 10.2-1 or Table 10.2-2.

If a UE is provided more than one configuration for UL grant Type 2 PUSCH or for SPS PDSCH, a value of the HARQ process number field in a DCI format indicates an activation for a corresponding UL grant Type 2 PUSCH or for a SPS PDSCH configuration with a same value as provided by *ConfiguredGrantConfigIndex* or by *sps-ConfigIndex*, respectively. Validation of the DCI format is achieved if the RV field for the DCI format is set as in Table 10.2-3.

If a UE is provided more than one configuration for UL grant Type 2 PUSCH or for SPS PDSCH

- if the UE is provided *ConfiguredGrantConfigType2DeactivationStateList* or *sps-ConfigDeactivationStateList*, a value of the HARQ process number field in a DCI format indicates a corresponding entry for scheduling release of one or more UL grant Type 2 PUSCH or SPS PDSCH configurations

- if the UE is not provided *ConfiguredGrantConfigType2DeactivationStateList* or *sps-ConfigDeactivationStateList*, a value of the HARQ process number field in a DCI format indicates a release for a corresponding UL grant Type 2 PUSCH or for a SPS PDSCH configuration with a same value as provided by *ConfiguredGrantConfigIndex* or by *sps-ConfigIndex*, respectively

The UE does not expect to receive a multicast DCI format that releases either a unicast SPS PDSCH configuration or more than one SPS PDSCH configurations.

Validation of the DCI format is achieved if all fields for the DCI format are set according to Table 10.2-4.

If validation is achieved, the UE considers the information in the DCI format as a valid activation or valid release of DL SPS or configured UL grant Type 2. If validation is not achieved, the UE discards all the information in the DCI format.

Table 10.2-1: Special fields for single DL SPS or single UL grant Type 2 scheduling activation PDCCH validation when a UE is provided a single SPS PDSCH or UL grant Type 2 configuration in the active DL/UL BWP of the scheduled cell

	DCI format 0_0/0_2	**DCI format 0_1**	**DCI format 1_0/1_2/4_1**	**DCI format 1_1/4_2**
HARQ process number (if present)	set to all '0's	set to all '0's	set to all '0's	set to all '0's
Redundancy version (if present)	set to all '0's	For the enabled transport block: set to all '0's	set to all '0's	For the enabled transport block: set to all '0's

Table 10.2-2: Special fields for single DL SPS or single UL grant Type 2 scheduling release PDCCH validation when a UE is provided a single SPS PDSCH or UL grant Type 2 configuration in the active DL/UL BWP of the scheduled cell

	DCI format 0_0/0_1/0_2	**DCI format 1_0/1_1/1_2/4_1/4_2**
HARQ process number (if present)	set to all '0's	set to all '0's
Redundancy version (if present)	set to all '0's	set to all '0's
Modulation and coding scheme	set to all '1's	set to all '1's
Frequency domain resource assignment	set to all '0's for FDRA Type 2 with $\mu = 1$ set to all '1's, otherwise	set to all '0's for FDRA Type 0 or for *dynamicSwitch* set to all '1's for FDRA Type 1

Table 10.2-3: Special fields for a single DL SPS or single UL grant Type 2 scheduling activation PDCCH validation when a UE is provided multiple DL SPS or UL grant Type 2 configurations in the active DL/UL BWP of the scheduled cell

	DCI format 0_0/0_2	DCI format 0_1	DCI format 1_0/1_2/4_1	DCI format 1_1/4_2
Redundancy version (if present)	set to all '0's	For the enabled transport block: set to all '0's	set to all '0's	For the enabled transport block: set to all '0's

Table 10.2-4: Special fields for a single or multiple DL SPS and UL grant Type 2 scheduling release PDCCH validation when a UE is provided multiple DL SPS or UL grant Type 2 configurations in the active DL/UL BWP of the scheduled cell

	DCI format 0_0/0_1/0_2	DCI format 1_0/1_1/1_2/4_1/4_2
Redundancy version (if present)	set to all '0's	set to all '0's
Modulation and coding scheme	set to all '1's	set to all '1's
Frequency domain resource assignment	set to all '0's for FDRA Type 2 with $\mu = 1$ set to all '1's, otherwise	set to all '0's for FDRA Type 0 or for *dynamicSwitch* set to all '1's for FDRA Type 1

A UE is expected to provide HARQ-ACK information in response to a SPS PDSCH release after N symbols from the last symbol of a PDCCH providing the SPS PDSCH release. If *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for the serving cell with the PDCCH providing the SPS PDSCH release, $N = 5$ for $\mu = 0$, $N = 5.5$ for $\mu = 1$, and $N = 11$ for $\mu = 2$, otherwise, $N = 10$ for $\mu = 0$, $N = 12$ for $\mu = 1$, $N = 22$ for $\mu = 2$, $N = 25$ for $\mu = 3$, $N = 100$ for $\mu = 5$, and $N = 200$ for $\mu = 6$, wherein μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH providing the SPS PDSCH release and the SCS configuration of a PUCCH carrying the HARQ-ACK information in response to a SPS PDSCH release.

10.2A PDCCH validation for SL configured grant Type 2

A UE validates, for scheduling activation or scheduling release, a SL configured grant Type 2 PDCCH if

- the CRC of a corresponding DCI format 3_0 is scrambled with a SL-CS-RNTI provided by *sl-CS-RNTI*, and
- the new data indicator field in the DCI format 3_0 for the enabled transport block is set to '0'

Validation of the DCI format 3_0 is achieved if all fields for the DCI format 3_0 are set according to Table 10.2A-1 or Table 10.2A-2.

If validation is achieved, the UE considers the information in the DCI format 3_0 as a valid activation or valid release of SL configured grant Type 2. If validation is not achieved, the UE discards all the information in the DCI format 3_0.

Table 10.2A-1: Special fields for SL configured grant Type 2 scheduling activation PDCCH validation

	DCI format 3_0
HARQ process number	set to all '0's

Table 10.2A-2: Special fields for SL configured grant Type 2 scheduling release PDCCH validation

	DCI format 3_0
HARQ process number	set to all '1's
Frequency resource assignment (if present)	set to all '1's

A UE validates, for SL PRS activation or release, a SL configured grant Type 2 PDCCH if

- the CRC of a corresponding DCI format 3_2 is scrambled with a SL-PRS-CS-RNTI provided by *sl-PRS-CS-RNTI*, and

- the activation/release indication field in the DCI format 3_2 is set to '1' for activation and to '0' for release.

10.3 PDCCH monitoring indication and dormancy/non-dormancy behaviour for SCells

A UE configured with DRX mode operation [11, TS 38.321] can be provided the following for detection of a DCI format 2_6 in a PDCCH reception on the PCell or on the SpCell [12, TS 38.331]

- a PS-RNTI for DCI format 2_6 by *ps-RNTI*
- a number of search space sets, by *dci-Format2-6*, to monitor PDCCH for detection of DCI format 2_6 on the active DL BWP of the PCell or of the SpCell according to a common search space as described in clause 10.1
- a payload size for DCI format 2_6 by *sizeDCI-2-6*
- a location in DCI format 2_6 of a Wake-up indication bit by *ps-PositionDCI-2-6*
  - a '0' value for the Wake-up indication bit, when reported to higher layers, indicates to not start the *drx-onDurationTimer* for the next long DRX cycle [11, TS 38.321]
  - a '1' value for the Wake-up indication bit, when reported to higher layers, indicates to start the *drx-onDurationTimer* for the next long DRX cycle [11, TS 38.321]
- a bitmap, when the UE is provided a number of groups of configured SCells by *dormancyGroupOutsideActiveTime*, where
  - the bitmap location is immediately after the Wake-up indication bit location
  - the bitmap size is equal to the number of groups of configured SCells where each bit of the bitmap corresponds to a group of configured SCells from the number of groups of configured SCells
  - a '0' value for a bit of the bitmap indicates an active DL BWP, provided by *dormantBWP-Id*, for the UE [11, TS 38.321] for each activated SCell in the corresponding group of configured SCells
  - a '1' value for a bit of the bitmap indicates
    - an active DL BWP, provided by *firstOutsideActiveTimeBWP-Id*, for the UE for each activated SCell in the corresponding group of configured SCells, if a current active DL BWP is the dormant DL BWP
    - a current active DL BWP, for the UE for each activated SCell in the corresponding group of configured SCells, if the current active DL BWP is not the dormant DL BWP
  - the UE sets the active DL BWP to the indicated active DL BWP
- an offset by *ps-Offset* indicating a time, where the UE starts monitoring PDCCH for detection of DCI format 2_6 according to the number of search space sets, prior to a slot where the *drx-onDurationTimer* would start on the PCell or on the SpCell [11, TS 38.321]
  - for each search space set, the PDCCH monitoring occasions are the ones in the first T_s slots indicated by *duration*, or $T_s = 1$ slot if *duration* is not provided, starting from the first slot of the first T_s slots and ending prior to the start of *drx-onDurationTimer*.

On PDCCH monitoring occasions associated with a same long DRX Cycle, a UE does not expect to detect more than one DCI format 2_6 with different values of the Wake-up indication bit for the UE or with different values of the bitmap for the UE.

The UE does not monitor PDCCH for detecting DCI format 2_6 during Active Time [11, TS 38.321].

If a UE reports for an active DL BWP a *MinTimeGap* or *MinTimeGapFR2-2* value that is X slots prior to the beginning of a slot where the UE would start the *drx-onDurationTimer*, the UE is not required to monitor PDCCH for detection of

DCI format 2_6 during the X slots, where X corresponds to the *MinTimeGap* or *MinTimeGapFR2-2* value of the SCS of the active DL BWP in Table 10.3-1.

Table 10.3-1 Minimum time gap value X

SCS (kHz)	Minimum Time Gap X (slots)	
	Value 1	Value 2
15	1	3
30	1	6
60	1	12
120	2	24
480	8	96
960	16	192

If a UE is provided search space sets to monitor PDCCH for detection of DCI format 2_6 in the active DL BWP of the PCell or of the SpCell and the UE detects DCI format 2_6, the physical layer of a UE reports the value of the Wake-up indication bit for the UE to higher layers [11, TS 38.321] for the next long DRX cycle.

If a UE is provided search space sets to monitor PDCCH for detection of DCI format 2_6 in the active DL BWP of the PCell or of the SpCell and the UE does not detect DCI format 2_6, the physical layer of the UE does not report a value of the Wake-up indication bit to higher layers for the next long DRX cycle.

If a UE is provided search space sets to monitor PDCCH for detection of DCI format 2_6 in the active DL BWP of the PCell or of the SpCell and the UE

- is not required to monitor PDCCH for detection of DCI format 2_6, as described in clauses 10, 11.1, 12, and in clause 5.7 of [11, TS 38.321] for all corresponding PDCCH monitoring occasions outside Active Time prior to a next long DRX cycle, or
- does not have any PDCCH monitoring occasions for detection of DCI format 2_6 outside Active Time of a next long DRX cycle

the physical layer of the UE reports a value of 1 for the Wake-up indication bit to higher layers for the next long DRX cycle.

If a UE is provided search space sets to monitor PDCCH for detection of DCI format 0_1/0_3/1_1/1_3 and if any of DCI format 0_1/0_3/1_1/1_3 includes a SCell dormancy indication field,

- the SCell dormancy indication field is a bitmap with size equal to a number of groups of configured SCells, provided by *dormancyGroupWithinActiveTime*,
- each bit of the bitmap corresponds to a group of configured SCells from the number of groups of configured SCells
- if the UE detects a DCI format 0_1/1_1 that does not include a carrier indicator field, or a DCI format 0_1/1_1 that includes a carrier indicator field with value equal to 0, and if the DCI format 0_1 does not indicate UL grant Type 2 release nor deactivate semi-persistent CSI report(s) on PUSCH, or if the DCI format 1_1 does not indicate SPS PDSCH release, or if the DCI format 1_1 does not indicate a TCI state update without scheduling PDSCH reception, or if the UE detects a DCI format 0_3/1_3
  - a '0' value for a bit of the bitmap indicates an active DL BWP, provided by *dormantBWP-Id*, for the UE for each activated SCell in the corresponding group of configured SCells
  - a '1' value for a bit of the bitmap indicates
    - an active DL BWP, provided by *firstWithinActiveTimeBWP-Id*, for the UE for each activated SCell in the corresponding group of configured SCells, if a current active DL BWP is the dormant DL BWP
    - a current active DL BWP, for the UE for each activated SCell in the corresponding group of configured SCells, if the current active DL BWP is not the dormant DL BWP
  - the UE sets the active DL BWP to the indicated active DL BWP

If a UE is provided search space sets to monitor PDCCH for detection of DCI format 1_1, or of DCI format 1_3, and if

- the CRC of DCI format 1_1 or of DCI format 1_3 is scrambled by a C-RNTI or an MCS-C-RNTI, and if

- a one-shot HARQ-ACK request field is not present or has a '0' value, and if
- for DCI format 1_3, a HARQ-ACK retransmission indicator field is not present or has a '0' value, and if
- the UE detects a DCI format 1_1 on the primary cell that does not include a carrier indicator field, or detects a DCI format 1_1 on the primary cell that includes a carrier indicator field with value equal to 0, or detects a DCI format 1_3 on the primary cell,

and if

- *resourceAllocation* = *resourceAllocationType0* and all bits of the frequency domain resource assignment field in DCI format 1_1, or for one or more blocks of the frequency domain resource assignment field in DCI format 1_3, are equal to 0, or
- *resourceAllocation* = *resourceAllocationType1* and all bits of the frequency domain resource assignment field in DCI format 1_1, or for one or more blocks of the frequency domain resource assignment field in DCI format 1_3, are equal to 1, or
- *resourceAllocation* = *dynamicSwitch* and all bits of the frequency domain resource assignment field in DCI format 1_1, or for one or more blocks of the frequency domain resource assignment field in DCI format 1_3, are equal to 0 or 1

the UE considers the DCI format 1_1 or the DCI format 1_3 as indicating SCell dormancy, not scheduling a PDSCH reception on a serving cell, where for DCI format 1_3 the serving cell is the one with the smallest index that is associated with a block from the one or more blocks of the frequency domain resource assignment field, and for transport block 1 interprets the sequence of fields of

- modulation and coding scheme
- new data indicator
- redundancy version

and of

- HARQ process number
- antenna port(s) for DCI format 1_1, or for DCI format 1_3 if *AntennaPortsDCI1-3* is configured as '*type2*'
- DMRS sequence initialization for DCI format 1_1

as providing a bitmap to each configured SCell, in an ascending order of the SCell index, where

- a '0' value for a bit of the bitmap indicates an active DL BWP, provided by *dormantBWP-Id*, for the UE for a corresponding activated SCell
- a '1' value for a bit of the bitmap indicates
  - an active DL BWP, provided by *firstWithinActiveTimeBWP-Id*, for the UE for a corresponding activated SCell, if a current active DL BWP is the dormant DL BWP
  - a current active DL BWP, for the UE for a corresponding activated SCell, if the current active DL BWP is not the dormant DL BWP
- the UE sets the active DL BWP to the indicated active DL BWP

If an active DL BWP provided by *dormantBWP-Id* for a UE on an activated SCell is not a default DL BWP for the UE on the activated SCell, as described in clause 12, the BWP inactivity timer is not used for transitioning from the active DL BWP provided by *dormantBWP-Id* to the default DL BWP on the activated SCell.

A UE is expected to provide HARQ-ACK information in response to a detection of a DCI format 1_1/1_3 indicating SCell dormancy after N symbols from the last symbol of a PDCCH providing the DCI format 1_1/1_3. If *processingType2Enabled* of *PDSCH-ServingCellConfig* is set to *enable* for the serving cell with the PDCCH providing the DCI format 1_1/1_3, $N = 7$ for $\mu = 0$, $N = 7.5$ for $\mu = 1$, and $N = 15$ for $\mu = 2$; otherwise, $N = 14$ for $\mu = 0$, $N = 16$ for $\mu = 1$, $N = 27$ for $\mu = 2$, $N = 31$ for $\mu = 3$, $N = 124$ for $\mu = 5$, and $= 248$ for $\mu = 6$, where μ is the smallest SCS configuration between the SCS configuration of the PDCCH providing the DCI format 1_1/1_3 and the

SCS configuration of a PUCCH with the HARQ-ACK information in response to the detection of the DCI format 1_1/1_3.

10.4 Search space set group switching and skipping of PDCCH monitoring

A UE can be provided

- a group index for a respective Type3-PDCCH CSS set or USS set by *searchSpaceGroupIdList* for PDCCH monitoring on a serving cell,

- a group index for a respective Type3-PDCCH CSS set or USS set by *searchSpaceGroupIdList-r17* for PDCCH monitoring on an active DL BWP of a serving cell.

If the UE is not provided *searchSpaceGroupIdList* or *searchSpaceGroupIdList-r17* for a search space set, the following procedures that are based on search space set group switching are not applicable for PDCCH monitoring according to the search space set.

A UE can be provided a set of durations by *pdcch-SkippingDurationList* for Type3-PDCCH CSS set or USS set for PDCCH monitoring on an active DL BWP of a serving cell. If the UE is not provided *pdcch-SkippingDurationList*, the following procedures related to skipping of PDCCH monitoring are not applicable.

If a UE is provided *cellGroupsForSwitchList*, indicating one or more groups of serving cells, the following procedures apply to all serving cells within each group; otherwise, the following procedures apply only to a serving cell for which the UE is provided *searchSpaceGroupIdList*.

When a UE is provided *searchSpaceGroupIdList* or *searchSpaceGroupIdList-r17*, the UE resets PDCCH monitoring according to search space sets with group index 0, if provided by *searchSpaceGroupIdList* or *searchSpaceGroupIdList-r17*.

A UE can be provided by *searchSpaceSwitchDelay* or *searchSpaceSwitchDelay-r17* a number of symbols P_{switch} where a minimum value of P_{switch} is provided in Table 10.4-1 for UE processing capability 1 and UE processing capability 2 and SCS configuration μ. UE processing capability 1 for SCS configuration μ applies unless the UE indicates support for UE processing capability 2.

Table 10.4-1: Minimum value of P_{switch} [symbols]

μ	Minimum P_{switch} value for UE processing capability 1 [symbols]	Minimum P_{switch} value for UE processing capability 2 [symbols]
0	25	10
1	25	12
2	25	22
3	40	-
5	160	-
6	320	-

A UE can be provided, by *searchSpaceSwitchTimer*, a timer value for a serving cell that the UE is provided *searchSpaceGroupIdList* or, if provided, for a set of serving cells provided by *cellGroupsForSwitchList*. The UE decrements the timer value by one after each slot based on a reference SCS configuration that is the smallest SCS configuration μ among all configured DL BWPs in the serving cell, or in the set of serving cells. The UE maintains the reference SCS configuration during the timer decrement procedure.

If a UE is provided by *SearchSpaceSwitchTrigger* a location of a search space set group switching flag field in a DCI format 2_0, as described in clause 11.1.1, for a serving cell where the UE has active DL BWP with SCS configuration μ

- if the UE detects a DCI format 2_0 and a value of the search space set group switching flag field in the DCI format 2_0 is 0, the UE starts monitoring PDCCH according to search space sets with group index 0, and stops monitoring PDCCH according to search space sets with group index 1, for the serving cell

    - at the beginning of the first slot that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format 2_0 when $\mu \in \{0, 1, 2, 3\}$

  - at the beginning of the first slot, of a group of X_s slots, that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format 2_0 when $\mu \in \{5, 6\}$

- if the UE detects a DCI format 2_0 and a value of the search space set group switching flag field in the DCI format 2_0 is 1, the UE starts monitoring PDCCH according to search space sets with group index 1, and stops monitoring PDCCH according to search space sets with group index 0, for the serving cell

  - at the beginning of the first slot that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format 2_0, when $\mu \in \{0, 1, 2, 3\}$

  - at the beginning of the first slot, of a group of X_s slots, that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format 2_0 when $\mu \in \{5, 6\}$

  and the UE sets the timer value to the value provided by *searchSpaceSwitchTimer*

- if the UE monitors PDCCH for a serving cell according to search space sets with group index 1, the UE starts monitoring PDCCH for the serving cell according to search space sets with group index 0, and stops monitoring PDCCH according to search space sets with group index 1, for the serving cell

  - at the beginning of the first slot that is at least P_{switch} symbols after a slot where the timer expires or after a last symbol of a remaining channel occupancy duration for the serving cell if indicated by DCI format 2_0 when $\mu \in \{0, 1, 2, 3\}$

  - at the beginning of the first slot, of a group of X_s slots, that is at least P_{switch} symbols after a slot where the timer expires or after a last symbol of a remaining channel occupancy duration for the serving cell if indicated by DCI format 2_0 when $\mu \in \{5, 6\}$

If a UE is provided *searchSpaceGroupIdList* and is not provided *SearchSpaceSwitchTrigger* for a serving cell,

- if the UE detects a DCI format by monitoring PDCCH according to a search space set with group index 0, the UE starts monitoring PDCCH according to search space sets with group index 1, and stops monitoring PDCCH according to search space sets with group index 0, for the serving cell

  - at the beginning of the first slot that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format when $\mu \in \{0, 1, 2, 3\}$,

  - at the beginning of the first slot, of a group of X_s slots, that is at least P_{switch} symbols after the last symbol of the PDCCH with the DCI format when $\mu \in \{5, 6\}$

  the UE sets the timer value to the value provided by *searchSpaceSwitchTimer* if the UE detects a DCI format by monitoring PDCCH in any search space set

- if the UE monitors PDCCH for a serving cell according to search space sets with group index 1, the UE starts monitoring PDCCH for the serving cell according to search space sets with group index 0, and stops monitoring PDCCH according to search space sets with group index 1, for the serving cell

  - at the beginning of the first slot that is at least P_{switch} symbols after a slot where the timer expires or, if the UE is provided a search space set to monitor PDCCH for detecting a DCI format 2_0, after a last symbol of a remaining channel occupancy duration for the serving cell if indicated by DCI format 2_0 when $\mu \in \{0, 1, 2, 3\}$

  - at the beginning of the first slot, of a group of X_s slots, that is at least P_{switch} symbols after a slot where the timer expires or, if the UE is provided a search space set to monitor PDCCH for detecting a DCI format 2_0, after a last symbol of a remaining channel occupancy duration for the serving cell if indicated by DCI format 2_0 when $\mu \in \{5, 6\}$

A UE determines a slot and a symbol in the slot to start or stop PDCCH monitoring according to search space sets for a serving cell that the UE is provided *searchSpaceGroupIdList* or, if *cellGroupsForSwitchList* is provided, for a set of serving cells, based on the largest X_s if the SCS configuration μ among all configured DL BWPs in the set of serving cells equals to 6, otherwise, based on the smallest SCS configuration μ among all configured DL BWPs in the serving cell or in the set of serving cells and, if any, in the serving cell where the UE receives a PDCCH and detects a corresponding DCI format 2_0 triggering the start or stop of PDCCH monitoring according to search space sets.

A UE can be provided a set of durations by *pdcch-SkippingDurationList* for PDCCH monitoring on an active DL BWP of a serving cell and, if the UE is not provided *searchSpaceGroupIdList-r17* on the active DL BWP of the serving cell, a DCI format 0_1/0_2/0_3 that schedules PUSCH transmission, and a DCI format 1_1/1_2/1_3 that schedules PDSCH reception, can include a PDCCH monitoring adaptation field of 1 bit or of 2 bits.

If the field has 1 bit and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on the active DL BWP of the serving cell

- a '0' value for the bit indicates no skipping in PDCCH monitoring
- a '1' value for the bit indicates skipping PDCCH monitoring for a duration provided by the first value in the set of durations

If the field has 2 bits and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on the active DL BWP of the serving cell

- a '00' value for the bits indicates no skipping in PDCCH monitoring
- a '01' value for the bits indicates skipping PDCCH monitoring for a duration provided by the first value in the set of durations
- a '10' value for the bits indicates skipping PDCCH monitoring for a duration provided by the second value in the set of durations
- a '11' value for the bits indicates skipping PDCCH monitoring for a duration provided by the third value in the set of durations, if any; otherwise, if the set of durations includes two values, a use of the '11' value is reserved

A UE can be provided group indexes for a Type3-PDCCH CSS set or USS set by *searchSpaceGroupIdList-r17* for PDCCH monitoring on an active DL BWP of a serving cell and, if the UE is not provided *pdcch-SkippingDurationList* for the active DL BWP of the serving cell, a DCI format 0_1/0_2/0_3 that schedules PUSCH transmission, and a DCI format 1_1/1_2/1_3 that schedules PDSCH reception, can include a PDCCH monitoring adaptation field of 1 bit or of 2 bits for the serving cell.

If the field has 1 bit and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on the active DL BWP of the serving cell

- a '0' value for the bit indicates start of PDCCH monitoring according to search space sets with group index 0 and stop of PDCCH monitoring according to search space sets with other group indexes, if any
- a '1' value for the bit indicates start of PDCCH monitoring according to search space sets with group index 1 and stop of PDCCH monitoring according to search space sets with other group indexes, if any, and the UE sets the timer value to the one provided by *searchSpaceSwitchTimer-r17*, if provided

If the field has 2 bits and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on the active DL BWP of the serving cell

- a '00' value for the bit indicates start of PDCCH monitoring according to search space sets with group index 0 and stop of PDCCH monitoring according to search space sets with other group indexes, if any
- a '01' value for the bit indicates start of PDCCH monitoring according to search space sets with group index 1 and stop of PDCCH monitoring according to search space sets with other group indexes, if any, and the UE sets the timer value to the one provided by *searchSpaceSwitchTimer-r17*, if provided
- a '10' value for the bit indicates start of PDCCH monitoring according to search space sets with group index 2 and stop of PDCCH monitoring according to search space sets with other group indexes, if any, and the UE sets the timer value to the one provided by *searchSpaceSwitchTimer-r17*, if provided
- a '11' value is reserved

A UE can be provided a set of durations by *pdcch-SkippingDurationList* and group indexes for a Type3-PDCCH CSS set or USS set by *searchSpaceGroupIdList-r17* for PDCCH monitoring on an active DL BWP of a serving cell and, a DCI format 0_1/0_2/0_3 that schedules PUSCH transmission, and a DCI format 1_1/1_2/1_3 that schedules PDSCH reception, can include a PDCCH monitoring adaptation field of 2 bits.

If the set of durations includes one value and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on the active DL BWP of the serving cell

- a '00' value for the bits indicates start of PDCCH monitoring according to search space sets with group index 0 and stop of PDCCH monitoring according to search space sets with group index 1, if any
- a '01' value for the bits indicates start of PDCCH monitoring according to search space sets with group index 1 and stop of PDCCH monitoring according to search space sets with group index 0, if any, and the UE sets the timer value to the one provided by *searchSpaceSwitchTimer-r17*, if provided
- a '10' value for the bits indicates skipping PDCCH monitoring for a duration provided by the value in the set of durations
- a '11' value is reserved

If the set of durations includes two values and for PDCCH monitoring by the UE according to Type3-PDCCH CSS sets or USS sets on active DL BWP of the serving cell

- a '00' value for the bits indicates start of PDCCH monitoring according to search space sets with group index 0 and stop of PDCCH monitoring according to search space sets with group index 1, if any
- a '01' value for the bits indicates start of PDCCH monitoring according to search space sets with group index 1 and stop of PDCCH monitoring according to search space sets with group index 0, if any, and the UE sets the timer value to the one provided by *searchSpaceSwitchTimer-r17*, if provided
- a '10' value for the bits indicates skipping PDCCH monitoring for a duration provided by the first value in the set of durations
- a '11' value for the bits indicates skipping PDCCH monitoring for a duration provided by the second value in the set of durations

When the PDCCH monitoring adaptation field indicates to a UE to start PDCCH monitoring according to search space sets with a first group index and stop PDCCH monitoring according to search space sets with a second group index, the UE applies the indication

- at the beginning of a first slot that is at least P_{switch} symbols after the last symbol of the PDCCH reception providing the DCI format with the PDCCH monitoring adaptation field when $\mu \in \{0, 1, 2, 3\}$,
- at the beginning of a first slot, of a slot group of X_s slots, that is at least P_{switch} symbols after the last symbol of the PDCCH reception providing the DCI format with the PDCCH monitoring adaptation field when $\mu \in \{5, 6\}$

When the PDCCH monitoring adaptation field indicates to a UE to skip PDCCH monitoring for a duration on the active DL BWP of a serving cell, the UE starts skipping of PDCCH monitoring at the beginning of a first slot that is after the last symbol of the PDCCH reception providing the DCI format with the PDCCH monitoring adaptation field.

- If the UE transmits a PUCCH providing a positive SR before the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of the serving cell, the UE shall monitor PDCCH regardless of PDCCH skipping indication on all serving cells of the corresponding Cell Group when the SR is pending [11, TS 38.321].
- If the UE transmits a PUCCH providing a positive SR after the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of the serving cell, the UE resumes PDCCH monitoring starting at the beginning of a first slot that is after a last symbol of the PUCCH transmission in all serving cells of the corresponding Cell Group.
- When the UE is provided *pdcchMornitoringResumptionAfterNack*, after the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of the serving cell, if the UE transmits a PUCCH or a PUSCH providing a NACK value associated with a PDSCH reception that is scheduled by a DCI format in a PDCCH reception on the serving cell, the UE terminates PDCCH skipping, starting from the beginning of a first slot that is after a last symbol of the PUCCH or PUSCH transmission on the serving cell.
- During the time of *ra-ResponseWindow* or *msgB-ResponseWindow* or the duration where *ra-ContentionResolutionTimer* is running, the UE shall not skip PDCCH monitoring on SpCell.
- After the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of a SpCell, when contention resolution is successful [11, TS 38.321], the UE resumes PDCCH monitoring on the SpCell.

- After the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of a serving cell, when a pending SR is cancelled [11, TS 38.321], the UE resumes PDCCH monitoring in all serving cells of the corresponding Cell Group.

- If UE transmits a RACH due to positive SR, the UE shall not skip PDCCH monitoring on any serving cell of the corresponding Cell Group during the time of *ra-ResponseWindow* or *msgB-ResponseWindow* or the duration where *ra-ContentionResolutionTimer* is running. If DRX is configured and the DRX group of the serving cell enters outside Active Time, the UE terminates PDCCH skipping for the serving cell.

If the UE changes to a new active DL BWP of the serving cell by the expiration of *bwp-InactivityTimer* or by RRC configuration, the UE

- resumes PDCCH monitoring according to the search space sets on the new active BWP of the serving cell when UE is in a PDCCH skipping duration, if the UE is not provided *searchSpaceGroupIdList-r17* on the new active DL BWP

- monitors PDCCH according to search space sets with group index 0 on the new active BWP of the serving cell, if the UE is provided *searchSpaceGroupIdList-r17*.

If a UE is provided group indexes for a Type3-PDCCH CSS set or a USS set by *searchSpaceGroupIdList-r17* and a timer value by *searchSpaceSwitchTimer-r17* for PDCCH monitoring an active DL BWP of on a serving cell and the timer is running, the UE

- resets the timer after a slot of the active DL BWP of the serving cell if the UE detects a DCI format in a PDCCH reception in the slot for with CRC scrambled by C-RNTI/CS-RNTI/MCS-C-RNTI/G-RNTI for multicast/G-CS-RNTI

- otherwise, decrements the timer value by one after a slot of the active DL BWP of the serving cell

When the timer expires in a first slot, the UE monitors PDCCH on the serving cell according to search space sets with group index 0 starting in a second slot that

- is not earlier than P_{switch} symbols after the first slot when $\mu \in \{0, 1, 2, 3\}$,

- is a first slot in a slot group of X_s slots that is not earlier than P_{switch} symbols after the first slot when $\mu \in \{5, 6\}$,

- is not earlier than a slot where a PDCCH skipping duration expires, if applicable

When a UE receives

- a first PDCCH in a first slot that provides a DCI format with a PDCCH monitoring adaptation field having a first value indicating skipping PDCCH monitoring, or indicating start of PDCCH monitoring according to a search space sets with a first group index and stop of PDCCH monitoring according to search space sets with a second group index, for an active DL BWP and

- a second PDCCH that provides a DCI format with a PDCCH monitoring adaptation field having a second value indicating skipping PDCCH monitoring, or indicating start of PDCCH monitoring according to search space sets with a first group index and stop of PDCCH monitoring according to search space sets with a second group index different than the first group index, for the active DL BWP where the second PDCCH is received

  - in the first slot if the first value indicates skipping PDCCH monitoring

  - before a slot that is at least P_{switch} symbols after the first slot if the first value indicates start of PDCCH monitoring according to search space sets with a first group index

the UE does not expect the second value to be different than the first value.

A UE does not expect to receive in a second slot a PDCCH on an active DL BWP that provides a DCI format indicating skipping PDCCH monitoring, or start of PDCCH monitoring according to search space sets with group index 1 or 2 for the active DL BWP, if the second slot is not at least P_{switch} symbols after a first slot where the timer expires.

10.4A PDCCH monitoring for early indication of paging

A UE can be provided the following for detection of a DCI format 2_7 in RRC_IDLE state or in RRC_INACTIVE state [12, TS 38.331]

- a search space set, by *pei-SearchSpace*, to monitor PDCCH for detection of DCI format 2_7 according to a Type2A-PDCCH CSS set as described in clause 10.1
- a number of frames, by *pei-FrameOffset*, from the start of a frame to the start of a first paging frame of paging frames associated with a number of PDCCH monitoring occasions for DCI format 2_7 [17, TS 38.304]
- a number of symbols, by *firstPDCCH-MonitoringOccasionOfPEI-O*, from the start of the frame to the start of the first PDCCH monitoring occasion for DCI format 2_7
- a size, by *payloadSizeDCI-2-7*
- a number of subgroups per paging occasion, $N_{\mathrm{SG}}^{\mathrm{PO}}$, by *subgroupsNumPerPO*
- a number of paging occasions associated with the number of PDCCH monitoring occasions for DCI format 2_7, $N_{\mathrm{PO}}^{\mathrm{PEI}}$, by *po-NumPerPEI*

A paging indication field of DCI format 2_7 includes $N_{\mathrm{PO}}^{\mathrm{PEI}}$ segments of K bits, where $K = N_{\mathrm{SG}}^{\mathrm{PO}}$. For a subgroup index i_{SG}, $0 \le i_{SG} < K$, a UE determines a value for the $(i_{PO} \cdot K + i_{SG})$ bit in the paging indication field, where $i_{PO} = \left((\mathrm{UE\_ID} \bmod N) \cdot N_S + i\_s\right) mod N_{\mathrm{PO}}^{\mathrm{PEI}}$ is a paging occasion index, and UE_ID, N, N_S, i_{SG}, and i_s are defined in [17, TS 38.304]. When the value is '1', the UE monitors a paging occasion determined according to [17, TS 38.304]; otherwise, the UE is not required to monitor the paging occasion.

If $N_{\mathrm{PO}}^{\mathrm{PEI}} < N_S$, the number of symbols from the start of the frame to the start of the first PDCCH monitoring occasion for DCI format 2_7 that is associated with paging occasion index i_{PO} is the $\left(\left\lfloor i\_s / N_{\mathrm{PO}}^{\mathrm{PEI}} \right\rfloor + 1\right)$-th value from the $N_S / N_{\mathrm{PO}}^{\mathrm{PEI}}$ values provided by *firstPDCCH-MonitoringOccasionOfPEI-O*.

10.4B Indication of TRS resources

A UE in RRC_IDLE state or RRC_INACTIVE state can be provided by *trs-ResourceSetConfig* a set of TRS occasions [6, TS 38.214]. If *trs-ResourceSetConfig* is provided, a DCI format 2_7, if *pei-SearchSpace* is provided, and a DCI format 1_0 with CRC scrambled by P-RNTI includes a TRS availability indication field [4, TS 38.212] that provides a bitmap to groups of TRS resource sets where the configuration of each TRS resource set includes an association to a bit of the bitmap. The UE can be additionally provided a multiple, by *validityDuration*, for a number of frames provided by *defaultPagingCycle* for TRS resource sets with indicated presence; if *validityDuration* is not provided, the multiple is equal to 2.

A value of '1' for a bit of the bitmap indicates presence of associated TRS resource sets for the multiple of the number of frames, starting from a SFN determined from $(\mathrm{SFN} + \mathrm{PF\_offset}) \mathrm{mod} T = 0$ [17, TS 38.304] that corresponds to the frame within the DRX cycle that includes the PDCCH providing the DCI format 2_7, or the DCI format 1_0 with CRC scrambled by P-RNTI, with the TRS availability indication field indicating the TRS resource sets, where T is provided by *defaultPagingCycle*. A value of '0' for a bit of the bitmap indicates no change to a current assumption for the availability or unavailability of associated TRS resource sets.

A UE can receive first and second PDCCHs that provide DCI format 2_7 or DCI format 1_0 with CRC scrambled by P-RNTI that indicate presence of TRS resource sets for the multiple of the number of frames, where the second PDCCH reception after the first PDCCH reception by a time that is smaller than the multiple of the number of frames.

10.5 HARQ-ACK information for PUSCH transmissions

A UE can be configured a number of search space sets to monitor PDCCH for detecting a DCI format 0_1 with a DFI flag field and CRC scrambled with a CS-RNTI provided by *cs-RNTI*. The UE determines that the DCI format provides HARQ-ACK information for PUSCH transmissions based on when a DFI flag field value is set to '1', if a PUSCH transmission is configured by *ConfiguredGrantConfig*.

The HARQ-ACK information corresponds to transport blocks in PUSCH transmissions for all HARQ processes for a serving cell of a PDCCH reception that provides DCI format 0_1 or, if DCI format 0_1 includes a carrier indicator field, for a serving cell indicated by a value of the carrier indicator field.

For a PUSCH transmission configured by *ConfiguredGrantConfig*, HARQ-ACK information for a transport block of a corresponding HARQ process number is valid if a first symbol of the PDCCH reception is after a last symbol of the PUSCH transmission, or of any repetition of the PUSCH transmission, by a number of symbols provided by *cg-minDFI-Delay*.

For an initial transmission by a UE of a transport block in a PUSCH configured by *ConfiguredGrantConfig*, if the UE receives a CG-DFI that provides HARQ-ACK information for the transport block, the UE assumes that the transport block was correctly decoded if the HARQ-ACK information value is ACK; otherwise, the UE assumes that the transport block was not correctly decoded.

For a PUSCH transmission scheduled by a DCI format, if the UE receives a CG-DFI that provides HARQ-ACK information for the transport block, the UE assumes that the transport block was correctly decoded if the HARQ-ACK information value is ACK; otherwise, the UE assumes that the transport block was not correctly decoded.

For a PUSCH transmission scheduled by a DCI format, HARQ-ACK information for a transport block of a corresponding HARQ process number is valid if a first symbol of the PDCCH reception is after a last symbol of the PUSCH transmission by a number of symbols provided by *cg-minDFI-Delay* or, if the PUSCH transmission is over multiple slots,

- after a last symbol of the PUSCH transmission in a first slot from the multiple slots by a number of symbols provided by *cg-minDFI-Delay*, if a value of the HARQ-ACK information is ACK.

- after a last symbol of the PUSCH transmission in a last slot from the multiple slots by a number of symbols provided by *cg-minDFI-Delay*, if a value of the HARQ-ACK information is NACK.

UE does not expect to be configured with different *cg-minDFI-Delay* among multiple *ConfiguredGrantConfig* in one BWP.

11 UE-group common signalling

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.

- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

In the remaining of this clause, unless stated otherwise, when a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1

- a PDCCH monitoring occasion is the union of the PDCCH monitoring occasions for the two PDCCH candidates

- the start of the PDCCH reception is the start of the earlier PDCCH candidate

- the end of the PDCCH reception in the end of the PDCCH candidate that ends later

The PDCCH reception includes the two PDCCH candidates also when the UE is not required to monitor one of the two PDCCH candidates as described in clauses 10 (except clause 10.4), 11.1, 11.1.1 and 17.2.

11.1 Slot configuration

A slot format includes downlink symbols, uplink symbols, and flexible symbols.

The following are applicable for each serving cell.

If a UE is provided *tdd-UL-DL-ConfigurationCommon*, the UE sets the slot format per slot over a number of slots as indicated by *tdd-UL-DL-ConfigurationCommon*.

The *tdd-UL-DL-ConfigurationCommon* provides

- a reference SCS configuration μ_{ref} by *referenceSubcarrierSpacing*
- a *pattern1*.

The *pattern1* provides

- a slot configuration period of P msec by *dl-UL-TransmissionPeriodicity*
- a number of slots d_{slots} with only downlink symbols by *nrofDownlinkSlots*
- a number of downlink symbols d_{sym} by *nrofDownlinkSymbols*
- a number of slots u_{slots} with only uplink symbols by *nrofUplinkSlots*
- a number of uplink symbols u_{sym} by *nrofUplinkSymbols*

A value P =0.625 msec is valid only for $\mu_{\text{ref}} = 3,\ \mu_{\text{ref}} = 5\ or\ \mu_{\text{ref}} = 6$. A value P =1.25 msec is valid only for $\mu_{\text{ref}} = 2,\ \mu_{\text{ref}} = 3,\ \mu_{\text{ref}} = 5\ or\ \mu_{\text{ref}} = 6$. A value P =2.5 msec is valid only for $\mu_{\text{ref}} = 1,\ \mu_{\text{ref}} = 2,\ \mu_{\text{ref}} = 3, \mu_{\text{ref}} = 5\ or\ \mu_{\text{ref}} = 6$. A value P =10 msec is valid only for $\mu_{\text{ref}} = 0,\ \mu_{\text{ref}} = 1,\ \mu_{\text{ref}} = 2,\ \mu_{\text{ref}} = 3$ or $\mu_{\text{ref}} = 5$.

A slot configuration period of P msec includes $S = P \cdot 2^{\mu_{\text{ref}}}$ slots with SCS configuration μ_{ref} . From the S slots, a first d_{slots} slots include only downlink symbols and a last u_{slots} slots include only uplink symbols. The d_{sym} symbols after the first d_{slots} slots are downlink symbols. The u_{sym} symbols before the last u_{slots} slots are uplink symbols. The remaining $(S - d_{\text{slots}} - u_{\text{slots}}) \cdot N_{\text{symb}}^{\text{slot}} - d_{\text{sym}} - u_{\text{sym}}$ are flexible symbols.

The first symbol every $20/P$ periods is a first symbol in an even frame.

If *tdd-UL-DL-ConfigurationCommon* provides both *pattern1* and *pattern2*, the UE sets the slot format per slot over a first number of slots as indicated by *pattern1* and the UE sets the slot format per slot over a second number of slots as indicated by *pattern2*.

The *pattern2* provides

- a slot configuration period of P_2 msec by *dl-UL-TransmissionPeriodicity*
- a number of slots $d_{\text{slots,2}}$ with only downlink symbols by *nrofDownlinkSlots*
- a number of downlink symbols $d_{\text{sym,2}}$ by *nrofDownlinkSymbols*
- a number of slots $u_{\text{slots,2}}$ with only uplink symbols by *nrofUplinkSlots*
- a number of uplink symbols $u_{\text{sym,2}}$ by *nrofUplinkSymbols*

The applicable values of P_2 are same as the applicable values for P .

A slot configuration period of $P + P_2$ msec includes first $S = P \cdot 2^{\mu_{\text{ref}}}$ slots and second $S_2 = P_2 \cdot 2^{\mu_{\text{ref}}}$ slots.

From the S_2 slots, a first $d_{\text{slots,2}}$ slots include only downlink symbols and a last $u_{\text{slots,2}}$ include only uplink symbols. The $d_{\text{sym,2}}$ symbols after the first $d_{\text{slots,2}}$ slots are downlink symbols. The $u_{\text{sym,2}}$ symbols before the last $u_{\text{slots,2}}$ slots are uplink symbols. The remaining $(S_2 - d_{\text{slots,2}} - u_{\text{slots,2}}) \cdot N_{\text{symb}}^{\text{slot}} - d_{\text{sym,2}} - u_{\text{sym,2}}$ are flexible symbols.

A UE expects that $P+P_2$ divides 20 msec.

The first symbol every $20/(P+P_2)$ periods is a first symbol in an even frame.

A UE expects that the reference SCS configuration μ_{ref} is smaller than or equal to a SCS configuration μ for any configured DL BWP or UL BWP. Each slot provided by *pattern1* or *pattern2* is applicable to $2^{(\mu-\mu_{\text{ref}})}$ consecutive slots in the active DL BWP or the active UL BWP where the first slot starts at a same time as a first slot for the reference SCS configuration μ_{ref} and each downlink or flexible or uplink symbol for the reference SCS configuration μ_{ref} corresponds to $2^{(\mu-\mu_{\text{ref}})}$ consecutive downlink or flexible or uplink symbols for the SCS configuration μ .

If the UE is additionally provided *tdd-UL-DL-ConfigurationDedicated*, the parameter *tdd-UL-DL-ConfigurationDedicated* overrides only flexible symbols per slot over the number of slots as provided by *tdd-UL-DL-ConfigurationCommon*.

The *tdd-UL-DL-ConfigurationDedicated* provides

- a set of slot configurations by *slotSpecificConfigurationsToAddModList*
- for each slot configuration from the set of slot configurations
  - a slot index for a slot provided by *slotIndex*
  - a set of symbols for a slot by *symbols* where
    - if *symbols* = *allDownlink*, all symbols in the slot are downlink
    - if *symbols* = *allUplink*, all symbols in the slot are uplink
    - if *symbols* = *explicit*, *nrofDownlinkSymbols* provides a number of downlink first symbols in the slot and *nrofUplinkSymbols* provides a number of uplink last symbols in the slot. If *nrofDownlinkSymbols* is not provided, there are no downlink first symbols in the slot and if *nrofUplinkSymbols* is not provided, there are no uplink last symbols in the slot. The remaining symbols in the slot are flexible

For each slot having a corresponding index provided by *slotIndex*, the UE applies a format provided by a corresponding *symbols*. The UE does not expect *tdd-UL-DL-ConfigurationDedicated* to indicate as uplink or as downlink a symbol that *tdd-UL-DL-ConfigurationCommon* indicates as a downlink or as an uplink symbol, respectively.

For each slot configuration provided by *tdd-UL-DL-ConfigurationDedicated*, a reference SCS configuration is the reference SCS configuration μ_{ref} provided by *tdd-UL-DL-ConfigurationCommon*.

A slot configuration period and a number of downlink symbols, uplink symbols, and flexible symbols in each slot of the slot configuration period are determined from *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* and are common to each configured BWP.

A UE considers symbols in a slot indicated as downlink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* to be available for receptions and considers symbols in a slot indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated* to be available for transmissions.

If a UE is not configured to monitor PDCCH for DCI format 2_0, for a set of symbols of a slot that are indicated as flexible by *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* if provided, or when *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* are not provided to the UE

- the UE receives PDSCH or CSI-RS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format
- the UE transmits PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR

For operation on a single carrier in unpaired spectrum, if a UE is configured by higher layers to receive a PDCCH, or a PDSCH, or a CSI-RS, or a DL PRS in a set of symbols of a slot, the UE receives the PDCCH, the PDSCH, the CSI-RS, or the DL PRS if the UE does not detect a DCI format that indicates to the UE to transmit a PUSCH, a PUCCH, a PRACH, or a SRS in at least one symbol of the set of symbols of the slot; otherwise, the UE does not receive the PDCCH, or the PDSCH, or the CSI-RS, or the DL PRS in the set of symbols of the slot.

For a UE operation with shared spectrum channel access in FR1, or in FR2-2 when the UE is provided *ChannelAccessMode2* = '*enabled*', if the UE is provided *csi-RS-ValidationWithDCI*, is not provided *CO-DurationsPerCell*, and is not provided *SlotFormatCombinationsPerCell*, and if the UE is configured by higher layers to receive a CSI-RS in a set of symbols of a slot, the UE cancels the CSI-RS reception in the set of symbols of the slot if the UE does not detect a DCI format indicating an aperiodic CSI-RS reception or scheduling a PDSCH reception in the set of symbols of the slot.

If a UE is provided *channelAccessMode ='dynamic'* and is provided *availableRB-SetsToAddModList* and *availableRB-SetsToReleaseList*, the UE expects to be provided *co-DurationsPerCellToAddModList* and *co-DurationsPerCellToReleaseList* and/or *slotFormatCombToAddModList* and *slotFormatCombToReleaseList*.

For operation on a single carrier in unpaired spectrum, if a UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH, or PRACH in a set of symbols of a slot and the UE detects a DCI format indicating to the UE to receive CSI-RS or PDSCH in a subset of symbols from the set of symbols, then

- If the UE does not indicate the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH or PUSCH or PRACH in the set of symbols if the first symbol in the set occurs within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format; otherwise, the UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], determined from clauses 9, 9.2.5 and 9.2.6 or clause 6.1 of [6, TS 38.214], or the PRACH transmission in the set of symbols.

- If the UE indicates the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH or PUSCH or PRACH in symbols from the set of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format. The UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], determined from clauses 9, 9.2.5 and 9.2.6 or clause 6.1 of [6, TS 38.214], or the PRACH transmission in remaining symbols from the set of symbols.

- The UE does not expect to cancel the transmission of SRS in symbols from the subset of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format. The UE cancels the SRS transmission in remaining symbols from the subset of symbols.

  $T_{\mathrm{proc},2}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 1$ and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the SRS, PUCCH, PUSCH or μ_r, where μ_r corresponds to the SCS configuration of the PRACH if it is 15kHz or higher; otherwise $\mu_r = 0$.

For a set of symbols of a slot that are indicated to a UE as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, the UE does not receive PDCCH, PDSCH, or CSI-RS when the PDCCH, PDSCH, or CSI-RS overlaps, even partially, with the set of symbols of the slot.

For a set of symbols of a slot that are indicated to a UE as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, the UE does not receive DL PRS in the set of symbols of the slot, if the UE is not provided with a measurement gap.

For a set of symbols of a slot that are indicated to a UE as downlink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, the UE does not transmit PUSCH, PUCCH, PRACH, or SRS when the PUSCH, PUCCH, PRACH, or SRS overlaps, even partially, with the set of symbols of the slot.

For a set of symbols of a slot that are indicated to a UE as flexible by *tdd-UL-DL-ConfigurationCommon*, and *tdd-UL-DL-ConfigurationDedicated* if provided, the UE does not expect to receive both dedicated higher layer parameters configuring transmission from the UE in the set of symbols of the slot and dedicated higher layer parameters configuring reception by the UE in the set of symbols of the slot.

For operation on a single carrier in unpaired spectrum, for a set of symbols of a slot indicated to a UE for reception of SS/PBCH blocks by *ssb-PositionsInBurst* in *SIB1* or by *ssb-PositionsInBurst* in *ServingCellConfigCommon* or, if the UE is not provided *dl-OrJointTCI-StateList*, by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* associated to physical cell ID with active TCI states for PDCCH or PDSCH, or for a set of symbols of a slot corresponding to SS/PBCH blocks configured for L1 beam measurement/reporting, the UE does not transmit PUSCH, PUCCH, PRACH in the slot if a transmission would overlap with any symbol from the set of symbols and the UE does not transmit SRS in the set of symbols of the slot. The UE does not expect the set of symbols of the slot to be indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, when provided to the UE.

If a UE

- is configured with multiple serving cells and is provided with *directionalCollisionHandling-r16* = 'enabled' for a set of serving cell(s) among the multiple serving cells, and
- indicates support of *half-DuplexTDD-CA-SameSCS-r16* capability, and
- is not configured to monitor PDCCH for detection of DCI format 2_0 on any of the multiple serving cells,

for a set of symbols of a slot that are indicated to the UE for reception of SS/PBCH blocks in a first cell of the multiple serving cells by *ssb-PositionsInBurst* in *SystemInformationBlockType1* or by *ssb-PositionsInBurst* in *ServingCellConfigCommon* or, if the UE is not provided *dl-OrJointTCI-StateList*, by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* associated to physical cell ID with active TCI states for PDCCH or PDSCH, or for a set of symbols of a slot corresponding to SS/PBCH blocks configured for L1 beam measurement/reporting, the UE does not transmit PUSCH, PUCCH, or PRACH in the slot if a transmission would overlap with any symbol from the set of symbols, and the UE does not transmit SRS in the set of symbols of the slot in

- any of the multiple serving cells if the UE is not capable of simultaneous transmission and reception as indicated by *simultaneousRxTxInterBandCA* among the multiple serving cells, and
- any one of the cells corresponding to the same band as the first cell, irrespective of any capability indicated by *simultaneousRxTxInterBandCA*.

For a set of symbols of a slot corresponding to a valid PRACH occasion and N_{gap} symbols before the valid PRACH occasion, as described in clause 8.1, the UE does not receive PDCCH, PDSCH, or CSI-RS in the slot if a reception would overlap with any symbol from the set of symbols. The UE does not expect the set of symbols of the slot to be indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*.

For a set of symbols of a slot indicated to a UE by *pdcch-ConfigSIB1* in *MIB* for a CORESET for Type0-PDCCH CSS set, the UE does not expect the set of symbols to be indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*.

If a UE is scheduled by a DCI format to receive PDSCH over multiple slots, and if *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, indicate that, for a slot from the multiple slots, at least one symbol from a set of symbols where the UE is scheduled PDSCH reception in the slot is an uplink symbol, the UE does not receive the PDSCH in the slot.

If a UE is scheduled by a DCI format to transmit PUSCH over multiple slots, and if *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, indicates that, for a slot from the multiple slots, at least one symbol from a set of symbols where the UE is scheduled PUSCH transmission in the slot is a downlink symbol, the UE does not transmit the PUSCH in the slot.

If a UE

- is configured with multiple serving cells and is provided with *directionalCollisionHandling-r16* = 'enabled' for a set of serving cell(s) among the configured multiple serving cells, and
- indicates support of *half-DuplexTDD-CA-SameSCS-r16* capability, and
- is not configured to monitor PDCCH for detection of DCI format 2_0 on any of the multiple serving cells,

the UE determines a reference cell for a symbol as an active cell with the smallest cell index among

- the configured multiple serving cells if the UE is not capable of simultaneous transmission and reception as indicated by *simultaneousRxTxInterBandCA* among the multiple serving cells, and
- the cells of each band respectively if the UE is capable of simultaneous transmission and reception by *simultaneousRxTxInterBandCA* for the configured multiple serving cells,

where the symbol is configured as

- downlink, or uplink, as indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*
- uplink, if the symbol is flexible and the UE is configured to transmit SRS, PUCCH, PUSCH, or PRACH on the symbol
- downlink, if the symbol is flexible and the UE is configured to receive PDCCH, PDSCH or CSI-RS on the symbol.

And if another cell among the cells configured with *directionalCollisionHandling-r16* operates in the same frequency band as the reference cell, the UE does not expect

- a symbol to be indicated as downlink or uplink on the reference cell and as uplink or downlink on another cell, respectively, by *tdd-UL-DL-ConfigurationCommon* or by *tdd-UL-DL-ConfigurationDedicated*,
- *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* to indicate a symbol as downlink on the reference cell and to detect a DCI format scheduling a transmission on the symbol on another cell, and
- to be configured by higher layers to receive PDCCH, PDSCH, or CSI-RS on a flexible symbol on the reference cell and to detect a DCI format scheduling a transmission on the symbol on another cell,

if the reference cell and another cell among the cells configured with *directionalCollisionHandling-r16* operate in different frequency bands,

the UE

- assumes symbol as flexible, is not required to receive higher layer configured PDCCH, PDSCH, or CSI-RS and not expected to transmit higher layer configured SRS, PUCCH, PUSCH, or PRACH, when *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* indicates symbol as downlink or uplink on another cell and as uplink or downlink for the reference cell, respectively,
- transmits a signal/channel scheduled by a DCI format on a symbol of another cell when the symbol is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* for the reference cell,
- is not required to receive a higher layer configured PDCCH, PDSCH, or CSI-RS on flexible symbols on the reference cell in a set of symbols, if the UE detects a DCI format scheduling a transmission on one or more symbols in the set of symbols on another cell,

and regardless of whether the reference cell and another cell operate in same or different frequency bands,

the UE

- does not expect *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* for the reference cell to indicate a symbol as uplink and to detect a DCI format scheduling a reception on the symbol on another cell
- does not expect to be configured by higher layers to transmit SRS, PUCCH, PUSCH, or PRACH on a flexible symbol on the reference cell and to detect a DCI format scheduling a reception on the symbol on another cell
- does not transmit a PUCCH, PUSCH or PRACH that is configured by higher layers on a set of symbols on another cell if at least one symbol from the set of symbols is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* or is a symbol corresponding to a PDCCH, PDSCH, or CSI-RS reception that is configured by higher layers on the reference cell
- does not transmit a SRS that is configured by higher layers on a set of symbols on another cell if the set of symbols is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* or corresponds to a PDCCH, PDSCH or CSI-RS reception that is configured by higher layers on the reference cell
- does not receive a PDCCH, PDSCH or CSI-RS that is configured by higher layers on a set of symbols on another cell if at least one symbol from the set of symbols is indicated as uplink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* or is a symbol corresponding to a SRS, PUCCH, PUSCH, or PRACH transmission that is configured by higher layers on the reference cell
- assumes a symbol indicated as downlink or uplink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* on another cell to be flexible, if the UE is respectively configured by higher layers to transmit SRS, PUCCH, PUSCH, or PRACH or to receive PDCCH, PDSCH, or CSI-RS on the reference cell
- does not expect to detect a first DCI format scheduling a transmission or reception on a symbol on a first cell and a second DCI format scheduling a reception or transmission on the symbol on a second cell, respectively.

After the UE applies the procedures described above for directional collision handling within the set of cells that have been configured with *directionalCollisionHandling-r16*, the UE does not expect any directional collision among the serving cells that the UE is not capable of simultaneous transmission and reception.

11.1.1 UE procedure for determining slot format

This clause applies for a serving cell that is included in a set of serving cells configured to a UE by *slotFormatCombToAddModList* and *slotFormatCombToReleaseList*, *availableRB-SetsToAddModList* and *availableRB-SetsToReleaseList*, *switchTriggerToAddModList* and *switchTriggerToReleaseList*, or *co-DurationsPerCellToAddModList* and *co-DurationsPerCellToReleaseList*.

If a UE is configured by higher layers with parameter *SlotFormatIndicator*, the UE is provided an SFI-RNTI by *sfi-RNTI* and with a payload size of DCI format 2_0 by *dci-PayloadSize*.

The UE is also provided in one or more serving cells with a configuration for a search space set s and a corresponding CORESET p for monitoring $M_{p,s}^{(L_{\mathrm{SFI}})}$ PDCCH candidates for DCI format 2_0 with a CCE aggregation level of L_{SFI} CCEs as described in clause 10.1. The $M_{p,s}^{(L_{\mathrm{SFI}})}$ PDCCH candidates are the first $M_{p,s}^{(L_{\mathrm{SFI}})}$ PDCCH candidates for CCE aggregation level L_{SFI} for search space set s in CORESET p.

For each serving cell in the set of serving cells, the UE can be provided:

- an identity of the serving cell by *servingCellId*
- a location of a SFI-index field in DCI format 2_0 by *positionInDCI*
- a set of slot format combinations by *slotFormatCombinations*, where each slot format combination in the set of slot format combinations includes
  - one or more slot formats indicated by a respective *slotFormats* for the slot format combination, and
  - a mapping for the slot format combination provided by *slotFormats* to a corresponding SFI-index field value in DCI format 2_0 provided by *slotFormatCombinationId*
- for unpaired spectrum operation, a reference SCS configuration μ_{SFI} by *subcarrierSpacing* and, when a supplementary UL carrier is configured for the serving cell, a reference SCS configuration $\mu_{\mathrm{SFI,SUL}}$ by *subcarrierSpacing2* for the supplementary UL carrier
- for paired spectrum operation, a reference SCS configuration $\mu_{\mathrm{SFI,DL}}$ for a DL BWP by *subcarrierSpacing* and a reference SCS configuration $\mu_{\mathrm{SFI,UL}}$ for an UL BWP by *subcarrierSpacing2*
- a location of an available RB set indicator field in DCI format 2_0, by *availableRB-SetsPerCell*, where the field is
  - one bit, if *intraCellGuardBandsDL-List* for the serving cell indicates no intra-cell guard-bands are configured, where a value of '1' indicates that the serving cell is available for receptions, a value of '0' indicates that the serving cell is not available for receptions, and the serving cell remains available or unavailable for reception until the end of the remaining channel occupancy duration; or,
  - a bitmap having a one-to-one mapping with the RB sets [6, TS 38.214] of the serving cell, if *intraCellGuardBandsDL-List* for the serving cell indicates intra-cell guard-bands are configured or if *intraCellGuardBandsDL-List* is not provided for the serving cell, where the bitmap includes $N_{\mathrm{RB,set,DL}}$ bits and $N_{\mathrm{RB,set,DL}}$ is the number of RB sets in the serving cell, a value of '1' indicates that an RB set is available for receptions, a value of '0' indicates that an RB set is not available for receptions, and a RB set remains available or unavailable for receptions until the end of the remaining channel occupancy duration
- a location of a channel occupancy duration field in DCI format 2_0, by *CO-DurationsPerCell*, where the field indicates a remaining channel occupancy duration for the serving cell starting from a first symbol of a slot where the UE detects the DCI format 2_0 by providing a value from *co-DurationList*. The channel occupancy duration field includes $\max\{\lceil\log_2(\mathrm{COdurationListSize})\rceil, 1\}$ bits, where $\mathrm{COdurationListSize}$ is the number of values provided by *co-DurationList*. If *CO-DurationsPerCell* is not provided, the remaining channel occupancy duration for the serving cell is a number of slots, starting from the slot where the UE detects the DCI format 2_0, that the SFI-index field value provides corresponding slot formats
  - a reference SCS configuration for *co-DurationList*, by *subcarrierSpacing*
- a location of a search space set group switching flag field in DCI format 2_0, by *SearchSpaceSwitchTrigger*, where the field indicates a group from two groups of search space sets for PDCCH monitoring for scheduling for the serving cell or the set of serving cells, provided by *CellGroupsForSwitching*, as described in clause 10.4.

If neither *CO-DurationsPerCell* nor *SlotFormatCombinationsPerCell* are provided and if *channelAccessMode* = "*semiStatic*" is provided, the procedures in this clause apply with assuming a channel occupancy time defined in clause 4.3 of [15, TS 37.213] is the remaining channel occupancy duration if a DL transmission burst(s) is detected within the channel occupancy time.

A SFI-index field value in a DCI format 2_0 indicates to a UE a slot format for each slot in a number of slots for each DL BWP or each UL BWP starting from a slot where the UE detects the DCI format 2_0. The number of slots is equal to or larger than a PDCCH monitoring periodicity for DCI format 2_0. The SFI-index field includes $\max\{\lceil \log_2(\text{maxSFIindex}+1)\rceil, 1\}$ bits where maxSFIindex is the maximum value of the values provided by corresponding *slotFormatCombinationId*. A slot format is identified by a corresponding format index as provided in Table 11.1.1-1 where 'D' denotes a downlink symbol, 'U' denotes an uplink symbol, and 'F' denotes a flexible symbol.

If a PDCCH monitoring periodicity for DCI format 2_0, provided to a UE for the search space set s by *monitoringSlotPeriodicityAndOffset*, is smaller than a duration of a slot format combination the UE obtains at a PDCCH monitoring occasion for DCI format 2_0 by a corresponding SFI-index field value, and the UE detects more than one DCI formats 2_0 indicating a slot format for a slot, the UE expects each of the more than one DCI formats 2_0 to indicate a same format for the slot.

A UE does not expect to be configured to monitor PDCCH for DCI format 2_0 on a second serving cell that uses larger SCS than the serving cell.

Table 11.1.1-1: Slot formats for normal cyclic prefix

Format	Symbol number in a slot													
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
0	D	D	D	D	D	D	D	D	D	D	D	D	D	D
1	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2	F	F	F	F	F	F	F	F	F	F	F	F	F	F
3	D	D	D	D	D	D	D	D	D	D	D	D	D	F
4	D	D	D	D	D	D	D	D	D	D	D	D	F	F
5	D	D	D	D	D	D	D	D	D	D	D	F	F	F
6	D	D	D	D	D	D	D	D	D	D	F	F	F	F
7	D	D	D	D	D	D	D	D	D	F	F	F	F	F
8	F	F	F	F	F	F	F	F	F	F	F	F	F	U
9	F	F	F	F	F	F	F	F	F	F	F	F	U	U
10	F	U	U	U	U	U	U	U	U	U	U	U	U	U
11	F	F	U	U	U	U	U	U	U	U	U	U	U	U
12	F	F	F	U	U	U	U	U	U	U	U	U	U	U
13	F	F	F	F	U	U	U	U	U	U	U	U	U	U
14	F	F	F	F	F	U	U	U	U	U	U	U	U	U
15	F	F	F	F	F	F	U	U	U	U	U	U	U	U
16	D	F	F	F	F	F	F	F	F	F	F	F	F	F
17	D	D	F	F	F	F	F	F	F	F	F	F	F	F
18	D	D	D	F	F	F	F	F	F	F	F	F	F	F
19	D	F	F	F	F	F	F	F	F	F	F	F	F	U
20	D	D	F	F	F	F	F	F	F	F	F	F	F	U
21	D	D	D	F	F	F	F	F	F	F	F	F	F	U
22	D	F	F	F	F	F	F	F	F	F	F	F	U	U
23	D	D	F	F	F	F	F	F	F	F	F	F	U	U
24	D	D	D	F	F	F	F	F	F	F	F	F	U	U
25	D	F	F	F	F	F	F	F	F	F	F	U	U	U
26	D	D	F	F	F	F	F	F	F	F	F	U	U	U
27	D	D	D	F	F	F	F	F	F	F	F	U	U	U
28	D	D	D	D	D	D	D	D	D	D	D	D	F	U
29	D	D	D	D	D	D	D	D	D	D	D	F	F	U
30	D	D	D	D	D	D	D	D	D	D	F	F	F	U
31	D	D	D	D	D	D	D	D	D	D	D	F	U	U
32	D	D	D	D	D	D	D	D	D	D	F	F	U	U
33	D	D	D	D	D	D	D	D	D	F	F	F	U	U
34	D	F	U	U	U	U	U	U	U	U	U	U	U	U
35	D	D	F	U	U	U	U	U	U	U	U	U	U	U
36	D	D	D	F	U	U	U	U	U	U	U	U	U	U
37	D	F	F	U	U	U	U	U	U	U	U	U	U	U
38	D	D	F	F	U	U	U	U	U	U	U	U	U	U
39	D	D	D	F	F	U	U	U	U	U	U	U	U	U
40	D	F	F	F	U	U	U	U	U	U	U	U	U	U
41	D	D	F	F	F	U	U	U	U	U	U	U	U	U
42	D	D	D	F	F	F	U	U	U	U	U	U	U	U
43	D	D	D	D	D	D	D	D	D	F	F	F	F	U
44	D	D	D	D	D	D	F	F	F	F	F	F	U	U
45	D	D	D	D	D	D	F	F	U	U	U	U	U	U
46	D	D	D	D	D	F	U	D	D	D	D	D	F	U
47	D	D	F	U	U	U	U	D	D	F	U	U	U	U
48	D	F	U	U	U	U	U	D	F	U	U	U	U	U
49	D	D	D	D	F	F	U	D	D	D	D	F	F	U
50	D	D	F	F	U	U	U	D	D	F	F	U	U	U
51	D	F	F	U	U	U	U	D	F	F	U	U	U	U
52	D	F	F	F	F	F	U	D	F	F	F	F	F	U
53	D	D	F	F	F	F	U	D	D	F	F	F	F	U
54	F	F	F	F	F	F	F	D	D	D	D	D	D	D
55	D	D	F	F	F	U	U	U	D	D	D	D	D	D
56 – 254	Reserved													
255	UE determines the slot format for the slot based on *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated* and, if any, on detected DCI formats													

For unpaired spectrum operation for a UE on a serving cell, the UE is provided by *subcarrierSpacing* a reference SCS configuration μ_{SFI} for each slot format in a combination of slot formats indicated by an SFI-index field value in DCI format 2_0. The UE expects that for a reference SCS configuration μ_{SFI} and for an active DL BWP or an active UL BWP with SCS configuration μ, it is $\mu \geq \mu_{\mathrm{SFI}}$. Each slot format in the combination of slot formats indicated by the SFI-index field value in DCI format 2_0 is applicable to $2^{(\mu-\mu_{\mathrm{SFI}})}$ consecutive slots in the active DL BWP or the active UL BWP where the first slot starts at a same time as a first slot for the reference SCS configuration μ_{SFI} and each downlink or flexible or uplink symbol for the reference SCS configuration μ_{SFI} corresponds to $2^{(\mu-\mu_{\mathrm{SFI}})}$ consecutive downlink or flexible or uplink symbols for the SCS configuration μ.

For paired spectrum operation for a UE on a serving cell, the SFI-index field in DCI format 2_0 indicates a combination of slot formats that includes a combination of slot formats for a reference DL BWP and a combination of slot formats for a reference UL BWP of the serving cell. The UE is provided by *subcarrierSpacing* a reference SCS configuration $\mu_{\mathrm{SFI,DL}}$ for the combination of slot formats indicated by the SFI-index field value in DCI format 2_0 for the reference DL BWP of the serving cell. The UE is provided by *subcarrierSpacing2* a reference SCS configuration $\mu_{\mathrm{SFI,UL}}$ for the combination of slot formats indicated by the SFI-index field value in DCI format 2_0 for the reference UL BWP of the serving cell. If $\mu_{\mathrm{SFI,DL}} \geq \mu_{\mathrm{SFI,UL}}$ and for each $2^{(\mu_{\mathrm{SFI,DL}}-\mu_{\mathrm{SFI,UL}})}+1$ values provided by a value of *slotFormats*, where the value of *slotFormats* is determined by a value of *slotFormatCombinationId* in *slotFormatCombination* and the value of *slotFormatCombinationId* is set by the value of the SFI-index field value in DCI format 2_0, the first $2^{(\mu_{\mathrm{SFI,DL}}-\mu_{\mathrm{SFI,UL}})}$ values for the combination of slot formats are applicable to the reference DL BWP and the next value is applicable to the reference UL BWP. If $\mu_{\mathrm{SFI,DL}} < \mu_{\mathrm{SFI,UL}}$ and for each $2^{(\mu_{\mathrm{SFI,UL}}-\mu_{\mathrm{SFI,DL}})}+1$ values provided by *slotFormats*, the first value for the combination of slot formats is applicable to the reference DL BWP and the next $2^{(\mu_{\mathrm{SFI,UL}}-\mu_{\mathrm{SFI,DL}})}$ values are applicable to the reference UL BWP.

The UE is provided a reference SCS configuration $\mu_{\mathrm{SFI,DL}}$ so that for an active DL BWP with SCS configuration μ_{DL}, it is $\mu_{\mathrm{DL}} \geq \mu_{\mathrm{SFI,DL}}$. The UE is provided a reference SCS configuration $\mu_{\mathrm{SFI,UL}}$ so that for an active UL BWP with SCS configuration μ_{UL}, it is $\mu_{\mathrm{UL}} \geq \mu_{\mathrm{SFI,UL}}$. Each slot format for a combination of slot formats indicated by the SFI-index field value in DCI format 2_0 for the reference DL BWP, by indicating a value for *slotFormatCombinationId* that is mapped to a value of *slotFormats* in *slotFormatCombination*, is applicable to $2^{(\mu_{\mathrm{DL}}-\mu_{\mathrm{SFI,DL}})}$ consecutive slots for the active DL BWP where the first slot starts at a same time as a first slot in the reference DL BWP and each downlink or flexible symbol for the reference SCS configuration $\mu_{\mathrm{SFI,DL}}$ corresponds to $2^{(\mu_{\mathrm{DL}}-\mu_{\mathrm{SFI,DL}})}$ consecutive downlink or flexible symbols for the SCS configuration μ_{DL}. Each slot format for the combination of slot formats for the reference UL BWP is applicable to $2^{(\mu_{\mathrm{UL}}-\mu_{\mathrm{SFI,UL}})}$ consecutive slots for the active UL BWP where the first slot starts at a same time as a first slot in the reference UL BWP and each uplink or flexible symbol for the reference SCS configuration $\mu_{\mathrm{SFI,UL}}$ corresponds to $2^{(\mu_{\mathrm{UL}}-\mu_{\mathrm{SFI,UL}})}$ consecutive uplink or flexible symbols for the SCS configuration μ_{UL}.

For unpaired spectrum operation with a second UL carrier for a UE on a serving cell, the SFI-index field value in DCI format 2_0 indicates a combination of slot formats that includes a combination of slot formats for a reference first UL carrier of the serving cell and a combination of slot formats for a reference second UL carrier of the serving cell. The UE is provided by *subcarrierSpacing* a reference SCS configuration μ_{SFI} for the combination of slot formats indicated by the SFI-index field in DCI format 2_0 for the reference first UL carrier of the serving cell. The UE is provided by *subcarrierSpacing2* a reference SCS configuration $\mu_{\mathrm{SFI,SUL}}$ for the combination of slot formats indicated by the SFI-index field value in DCI format 2_0 for the reference second UL carrier of the serving cell. For each $2^{(\mu_{\mathrm{SFI}}-\mu_{\mathrm{SFI,SUL}})}+1$ values of *slotFormats*, the first $2^{(\mu_{\mathrm{SFI}}-\mu_{\mathrm{SFI,SUL}})}$ values for the combination of slot formats are applicable to the reference first UL carrier and the next value is applicable to the reference second UL carrier.

The UE expects to be provided a reference SCS configuration $\mu_{\mathrm{SFI,SUL}}$ so that for an active UL BWP in the second UL carrier with SCS configuration μ_{SUL}, it is $\mu_{\mathrm{SUL}} \geq \mu_{\mathrm{SFI,SUL}}$. Each slot format for a combination of slot formats indicated by the SFI-index field in DCI format 2_0 for the reference first UL carrier is applicable to $2^{(\mu-\mu_{\mathrm{SFI}})}$ consecutive slots for the active DL BWP and the active UL BWP in the first UL carrier where the first slot starts at a same time as a first slot in the reference first UL carrier. Each slot format for the combination of slot formats for the reference second UL carrier is applicable to $2^{(\mu_{\mathrm{SUL}}-\mu_{\mathrm{SFI,SUL}})}$ consecutive slots for the active UL BWP in the second UL carrier where the first slot starts at a same time as a first slot in the reference second UL carrier.

If a BWP in the serving cell is configured with $\mu = 2$ and with extended CP, the UE expects $\mu_{\mathrm{SFI}} = 0$, $\mu_{\mathrm{SFI}} = 1$, or $\mu_{\mathrm{SFI}} = 2$. A format for a slot with extended CP is determined from a format for a slot with normal CP. A UE determines an extended CP symbol to be a downlink/uplink/flexible symbol if the overlapping normal CP symbols that are downlink/uplink/flexible symbols, respectively. A UE determines an extended CP symbol to be a flexible symbol if one of the overlapping normal CP symbols is flexible. A UE determines an extended CP symbol to be a flexible symbol if the pair of the overlapping normal CP symbols includes a downlink and an uplink symbol.

A reference SCS configuration μ_{SFI}, or $\mu_{\mathrm{SFI,DL}}$, or $\mu_{\mathrm{SFI,UL}}$, or $\mu_{\mathrm{SFI,SUL}}$ is either 0, or 1, or 2 for FR1 and is either 2 or 3 for FR2.

For a set of symbols of a slot, a UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols of the slot as uplink and to detect a DCI format indicating to the UE to receive PDSCH or CSI-RS in the set of symbols of the slot.

For a set of symbols of a slot, a UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols in the slot as downlink and to detect a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot.

For a set of symbols of a slot that are indicated by a DCI format 2_0 as being within a remaining channel occupancy duration either by a channel occupancy duration field or by an SFI-index field, a UE does not expect to detect at a later time a DCI format 2_0 indicating, either by a channel occupancy duration field or by an SFI-index field, that any symbol from the set of symbols is not within a remaining channel occupancy duration.

For a set of symbols of a slot that are indicated as downlink/uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, the UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols of the slot as uplink/downlink, respectively, or as flexible.

For a set of symbols of a slot corresponding to SS/PBCH blocks with candidate SS/PBCH block indices corresponding to the SS/PBCH block indexes indicated to a UE by *ssb-PositionsInBurst* in *SIB1*, or by *ssb-PositionsInBurst* in *ServingCellConfigCommon*, as described in clause 4.1, or by *NonCellDefiningSSB* or, if the UE is not provided *dl-OrJointTCI-StateList*, by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* associated to physical cell ID with active TCI states for PDCCH or PDSCH, or for a set of symbols of a slot corresponding to SS/PBCH blocks configured for L1 beam measurement/reporting, the UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols of the slot as uplink.

For a set of symbols of a slot corresponding to a valid PRACH occasion and N_{gap} symbols before the valid PRACH occasion, as described in clause 8.1, the UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols of the slot as downlink.

For a set of symbols of a slot indicated to a UE by *pdcch-ConfigSIB1* in *MIB* for a CORESET for Type0-PDCCH CSS set, the UE does not expect to detect a DCI format 2_0 with an SFI-index field value indicating the set of symbols of the slot as uplink.

For a set of symbols of a slot indicated to a UE as flexible by *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* if provided, or when *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* are not provided to the UE, and if the UE detects a DCI format 2_0 providing a format for the slot using a slot format value other than 255

- if one or more symbols from the set of symbols are symbols in a CORESET configured to the UE for PDCCH monitoring, the UE receives PDCCH in the CORESET only if an SFI-index field value in DCI format 2_0 indicates that the one or more symbols are downlink symbols

- if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as flexible and the UE detects a DCI format indicating to the UE to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE receives PDSCH or CSI-RS in the set of symbols of the slot

- if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as flexible and the UE detects a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot the UE transmits the PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot

- if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as flexible, and the UE does not detect a DCI format indicating to the UE to receive PDSCH or CSI-RS, or the UE does not detect a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot, the UE does not transmit or receive in the set of symbols of the slot

- if the UE is configured by higher layers to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE receives the PDSCH or the CSI-RS in the set of symbols of the slot only if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as downlink and, if applicable, the set of symbols is within remaining channel occupancy duration

- if the UE is configured by higher layers to receive DL PRS in the set of symbols of the slot, the UE receives the DL PRS in the set of symbols of the slot only if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as downlink or flexible.

- if the UE is configured by higher layers to transmit PUCCH, or PUSCH, or PRACH in the set of symbols of the slot, the UE transmits the PUCCH, or the PUSCH, or the PRACH in the slot only if an SFI-index field value in DCI format 2_0 indicates the set of symbols of the slot as uplink

- if the UE is configured by higher layers to transmit SRS in the set of symbols of the slot, the UE transmits the SRS only in a subset of symbols from the set of symbols of the slot indicated as uplink symbols by an SFI-index field value in DCI format 2_0

- a UE does not expect to detect an SFI-index field value in DCI format 2_0 indicating the set of symbols of the slot as downlink and also detect a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR indicating to the UE to transmit SRS, PUSCH, PUCCH, or PRACH, in one or more symbols from the set of symbols of the slot

- a UE does not expect to detect an SFI-index field value in DCI format 2_0 indicating the set of symbols of the slot as downlink or flexible if the set of symbols of the slot includes symbols corresponding to any repetition of a PUSCH transmission activated by an UL Type 2 grant PDCCH as described in clause 10.2

- a UE does not expect to detect an SFI-index field value in DCI format 2_0 indicating the set of symbols of the slot as uplink and also detect a DCI format indicating to the UE to receive PDSCH or CSI-RS in one or more symbols from the set of symbols of the slot

If a UE is configured by higher layers to receive a CSI-RS or a PDSCH in a set of symbols of a slot and the UE detects a DCI format 2_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as uplink or flexible, or the UE detects a DCI format indicating to the UE to transmit PUSCH, PUCCH, SRS, or PRACH in at least one symbol in the set of the symbols, the UE cancels the CSI-RS reception in the set of symbols of the slot or cancels the PDSCH reception in the slot.

For a UE operation with shared spectrum channel access in FR1, or in FR2-2 when the UE is provided *ChannelAccessMode2* = '*enabled*', if a UE is configured by higher layers to receive a CSI-RS and the UE is provided *CO-DurationsPerCell*, for a set of symbols of a slot that are indicated as downlink or flexible by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated*, or when *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationDedicated* are not provided, the UE cancels the CSI-RS reception in the set of symbols of the slot that are not within the remaining channel occupancy duration.

If a UE is configured by higher layers to receive a DL PRS in a set of symbols of a slot and the UE detects a DCI format 2_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as uplink, or the UE detects a DCI format indicating to the UE to transmit PUSCH, PUCCH, SRS, or PRACH in at least one symbol in the set of the symbols, the UE cancels the DL PRS reception in the set of symbols of the slot.

If a UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH, or PRACH in a set of symbols of a slot and the UE detects a DCI format 2_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as downlink or flexible, or the UE detects a DCI format indicating to the UE to receive CSI-RS or PDSCH in a subset of symbols from the set of symbols, then

- If the UE does not indicate the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH or PUSCH or PRACH in the set of symbols if the first symbol in the set occurs within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format; otherwise, the UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], determined from clauses 9, 9.2.5 and 9.2.6 or clause 6.1 of [6, TS 38.214], or the PRACH transmission in the set of symbols.

- If the UE indicates the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH or PUSCH or PRACH in symbols from the set of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format. The UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], determined from clauses 9, 9.2.5 and 9.2.6 or clause 6.1 of [6, TS 38.214], or the PRACH transmission in remaining symbols from the set of symbols.

- The UE does not expect to cancel the transmission of SRS in symbols from the subset of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE detects the DCI format. The UE cancels the SRS transmission in remaining symbols from the subset of symbols.

$T_{\text{proc},2}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 1$ and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the SRS, PUCCH, PUSCH or μ_r, where μ_r corresponds to the SCS configuration of the PRACH if it is 15kHz or higher; otherwise $\mu_r = 0$.

If a UE is configured by higher layers to receive a CSI-RS or detects a DCI format 0_1 indicating to the UE to receive a CSI-RS in one or more RB sets and a set of symbols of a slot, and the UE detects a DCI format 2_0 with bitmap indicating that any RB set from the one or more RB sets is not available for reception, the UE cancels the CSI-RS reception in the set of symbols of the slot.

A UE assumes that flexible symbols in a CORESET configured to the UE for PDCCH monitoring are downlink symbols if the UE does not detect an SFI-index field value in DCI format 2_0 indicating the set of symbols of the slot as flexible or uplink and the UE does not detect a DCI format indicating to the UE to transmit SRS, PUSCH, PUCCH, or PRACH in the set of symbols.

For a set of symbols of a slot that are indicated as flexible by *tdd-UL-DL-ConfigurationCommon*, and *tdd-UL-DL-ConfigurationDedicated* if provided, or when *tdd-UL-DL-ConfigurationCommon*, and *tdd-UL-DL-ConfigurationDedicated* are not provided to the UE, and if the UE does not detect a DCI format 2_0 providing a slot format for the slot

- the UE receives PDSCH or CSI-RS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format
- the UE transmits PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format, a RAR UL grant, fallbackRAR UL grant, or successRAR
- the UE receives PDCCH as described in clause 10.1
- if the UE is configured by higher layers to receive PDSCH in the set of symbols of the slot, the UE does not receive the PDSCH in the set of symbols of the slot
- if the UE is configured by higher layers to receive CSI-RS in the set of symbols of the slot, the UE does not receive the CSI-RS in the set of symbols of the slot, except when UE is provided *CO-DurationsPerCell* and the set of symbols of the slot are within the remaining channel occupancy duration.
- if the UE is configured by higher layers to receive DL PRS in the set of symbols of the slot, the UE receives the DL PRS
- if the UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH, or PRACH in the set of symbols of the slot and the UE is not provided *enableConfiguredUL*, then
    - if the UE does not indicate the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], as determined in clauses 9, 9.2.5 and 9.2.6 or in clause 6.1 of [6. TS 38.214], or the PRACH in the slot if the first symbol of the PUCCH or the PUSCH or actual repetition of the PUSCH or the PRACH in the slot occurs within $T_{\text{proc},2}$ relative to a last symbol of a PDCCH reception where the UE is configured to monitor PDCCH for DCI format 2_0; otherwise, the UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], as determined in clauses 9, 9.2.5 and 9.2.6 or in clause 6.1 of [6. TS 38.214], or the PRACH in the slot;
    - if the UE indicates the capability of [partialCancellation], the UE does not expect to cancel the transmission of the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], as determined in clauses 9, 9.2.5 and 9.2.6 or in clause 6.1 of [6. TS 38.214], or the PRACH in symbols from the set of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE is configured to monitor PDCCH for DCI format 2_0. The UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], as determined in clauses 9, 9.2.5 and 9.2.6 or in clause 6.1 of [6. TS 38.214], or the PRACH transmission in remaining symbols from the set of symbols;
    - the UE does not expect to cancel the transmission of SRS in symbols from the set of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the UE is configured to monitor PDCCH for DCI format 2_0. The UE cancels the SRS transmission in remaining symbols from the set of symbols;
    - $T_{\text{proc},2}$ is the PUSCH preparation time for the corresponding UE processing capability [6, TS 38.214] assuming $d_{2,1} = 1$ and μ corresponds to the smallest SCS configuration between the SCS configuration of

the PDCCH carrying the DCI format 2_0 and the SCS configuration of the SRS, PUCCH, PUSCH or μ_r, where μ_r corresponds to the SCS configuration of the PRACH if it is 15kHz or higher; otherwise $\mu_r = 0$;

- if the UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH, or PRACH in the set of symbols of the slot and the UE is provided *enableConfiguredUL*, the UE can transmit the SRS, or PUCCH, or PUSCH, or PRACH, respectively.

For unpaired spectrum operation for a UE on a cell in a frequency band of FR1, and when the scheduling restrictions due to RRM measurements [10, TS 38.133] are not applicable, if the UE detects a DCI format indicating to the UE to transmit in a set of symbols, the UE is not required to perform RRM measurements [10, TS 38.133] based on a SS/PBCH block or CSI-RS reception on a different cell in the frequency band if the SS/PBCH block or CSI-RS reception includes at least one symbol from the set of symbols.

11.2 Interrupted transmission indication

If a UE is provided *DownlinkPreemption*, the UE is configured with an INT-RNTI provided by *int-RNTI* for monitoring PDCCH conveying DCI format 2_1 [5, TS 38.212]. The UE is additionally configured with

- a set of serving cells by *int-ConfigurationPerServingCell* that includes a set of serving cell indexes provided by corresponding *servingCellId* and a corresponding set of locations for fields in DCI format 2_1 by *positionInDCI*
- an information payload size for DCI format 2_1 by *dci-PayloadSize*
- an indication granularity for time-frequency resources by *timeFrequencySet*

If a UE detects a DCI format 2_1 for a serving cell from the configured set of serving cells, the UE may assume that no transmission to the UE is present in PRBs and in symbols that are indicated by the DCI format 2_1, from a set of PRBs and a set of symbols of the last monitoring period. The indication by the DCI format 2_1 is not applicable to receptions of SS/PBCH blocks.

The set of PRBs is equal to the active DL BWP as defined in clause 12 and includes B_{INT} PRBs.

If a UE detects a DCI format 2_1 in a PDCCH reception in a slot, the set of symbols is the last $N_{\text{symb}}^{\text{slot}} \cdot T_{\text{INT}} \cdot 2^{\mu - \mu_{\text{INT}}}$ symbols prior to the first symbol of the PDCCH reception in the slot where T_{INT} is the PDCCH monitoring periodicity provided by the value of *monitoringSlotPeriodicityAndOffset*, as described in clause 10.1, $N_{\text{symb}}^{\text{slot}}$ is the number of symbols per slot, μ is the SCS configuration for a serving cell with mapping to a respective field in the DCI format 2_1, μ_{INT} is the SCS configuration of the DL BWP where the UE receives the PDCCH with the DCI format 2_1. If the UE is provided *tdd-UL-DL-ConfigurationCommon*, symbols indicated as uplink by *tdd-UL-DL-ConfigurationCommon* are excluded from the last $N_{\text{symb}}^{\text{slot}} \cdot T_{\text{INT}} \cdot 2^{\mu - \mu_{\text{INT}}}$ symbols prior to the first symbol of the PDCCH reception in the slot. The resulting set of symbols includes a number of symbols that is denoted as N_{INT}.

The UE does not expect to be provided values of μ, μ_{INT}, and T_{INT} resulting to a value of $N_{\text{symb}}^{\text{slot}} \cdot T_{\text{INT}} \cdot 2^{\mu - \mu_{\text{INT}}}$ that is not an integer. The UE does not expect to be configured by *monitoringSymbolsWithinSlot* with more than one PDCCH monitoring occasion for DCI format 2_1 in a slot.

A UE is provided the indication granularity for the set of PRBs and for the set of symbols by *timeFrequencySet*.

If the value of *timeFrequencySet* is 'set0', 14 bits from MSB of a field in DCI format 2_1 have a one-to-one mapping with 14 groups of consecutive symbols from the set of symbols where each of the first $N_{\text{INT}} - \lfloor N_{\text{INT}}/14 \rfloor \cdot 14$ symbol groups includes $\lceil N_{\text{INT}}/14 \rceil$ symbols, each of the last $14 - N_{\text{INT}} + \lfloor N_{\text{INT}}/14 \rfloor \cdot 14$ symbol groups includes $\lfloor N_{\text{INT}}/14 \rfloor$ symbols, a bit value of 0 indicates transmission to the UE in the corresponding symbol group and a bit value of 1 indicates no transmission to the UE in the corresponding symbol group.

If the value of *timeFrequencySet* is 'set1', 7 pairs of bits from MSB of a field in the DCI format 2_1 have a one-to-one mapping with 7 groups of consecutive symbols where each of the first $N_{\text{INT}} - \lfloor N_{\text{INT}}/7 \rfloor \cdot 7$ symbol groups includes $\lceil N_{\text{INT}}/7 \rceil$ symbols, each of the last $7 - N_{\text{INT}} + \lfloor N_{\text{INT}}/7 \rfloor \cdot 7$ symbol groups includes $\lfloor N_{\text{INT}}/7 \rfloor$ symbols, a first bit in a pair of bits for a symbol group is applicable to the subset of first $\lceil B_{\text{INT}}/2 \rceil$ PRBs from the set of B_{INT} PRBs, a second bit in the pair of bits for the symbol group is applicable to the subset of last $\lfloor B_{\text{INT}}/2 \rfloor$ PRBs from the set of B_{INT} PRBs, a bit value of 0 indicates transmission to the UE in the corresponding symbol group and subset of PRBs, and a bit value of 1 indicates no transmission to the UE in the corresponding symbol group and subset of PRBs.

11.2A Cancellation indication

If a UE is provided *UplinkCancellation*, the UE is provided, in one or more serving cells, search space sets for monitoring the first PDCCH candidate with a CCE aggregation level of L_{CI} CCEs of each search space set for detection of a DCI format 2_4 [5, TS 38.212] with a CI-RNTI provided by *ci-RNTI* as described in clause 10.1. *UplinkCancellation* additionally provides to the UE

- a set of serving cells, by *ci-ConfigurationPerServingCell*, that includes a set of serving cell indexes and a corresponding set of locations for fields in DCI format 2_4 by *positionInDCI*
- a number of fields in DCI format 2_4, by *positionInDCI-forSUL*, for each serving cell for a SUL carrier, if the serving cell is configured with a SUL carrier
- an information payload size for DCI format 2_4 by *dci-PayloadSize-ForCI*
- an indication for time-frequency resources by *timeFrequencyRegion*

For a serving cell having an associated field in a DCI format 2_4, for the field denote by

- N_{CI} a number of bits provided by *ci-PayloadSize*
- B_{CI} a number of PRBs provided by *frequencyRegionforCI* in *timeFrequencyRegion*
- T_{CI} a number of symbols, excluding symbols for reception of SS/PBCH blocks and DL symbols indicated by *tdd-UL-DL-ConfigurationCommon*, from a number of symbols that
  - is provided by *timeDurationforCI* in *timeFrequencyRegion*, if the PDCCH monitoring periodicity for the search space set with the DCI format 2_4 is one slot and there are more than one PDCCH monitoring occasions in a slot, or
  - is equal to the PDCCH monitoring periodicity, otherwise.
- G_{CI} a number of partitions for the T_{CI} symbols provided by *timeGranularityforCI* in *timeFrequencyRegion*

G_{CI} sets of bits from the MSB of the N_{CI} bits have a one-to-one mapping with G_{CI} groups of symbols where each of the first $G_{\mathrm{CI}} - T_{\mathrm{CI}} + \lfloor T_{\mathrm{CI}}/G_{\mathrm{CI}} \rfloor \cdot G_{\mathrm{CI}}$ groups includes $\lfloor T_{\mathrm{CI}}/G_{\mathrm{CI}} \rfloor$ symbols and each of the remaining $T_{\mathrm{CI}} - \lfloor T_{\mathrm{CI}}/G_{\mathrm{CI}} \rfloor \cdot G_{\mathrm{CI}}$ groups includes $\lceil T_{\mathrm{CI}}/G_{\mathrm{CI}} \rceil$ symbols. A UE determines a symbol duration with respect to a SCS configuration of an active DL BWP where the UE monitors PDCCH for DCI format 2_4 detection.

For a group of symbols, $N_{\mathrm{BI}} = N_{\mathrm{CI}}/G_{CI}$ bits from MSB of each set of bits have a one-to-one mapping with N_{BI} groups of PRBs where each of the first $N_{\mathrm{BI}} - B_{\mathrm{CI}} + \lfloor B_{\mathrm{CI}}/N_{\mathrm{BI}} \rfloor \cdot N_{\mathrm{BI}}$ groups includes $\lfloor B_{\mathrm{CI}}/N_{\mathrm{BI}} \rfloor$ PRBs and each of the remaining $B_{\mathrm{CI}} - \lfloor B_{\mathrm{CI}}/N_{\mathrm{BI}} \rfloor \cdot N_{\mathrm{BI}}$ groups includes $\lceil B_{\mathrm{CI}}/N_{\mathrm{BI}} \rceil$ PRBs. A UE determines a first PRB index as $N_{RFR}^{start} = O_{\mathrm{carrier}} + RB_{start}$ and a number of contiguous RBs as $B_{\mathrm{CI}} = L_{\mathrm{RB}}$ from *frequencyRegionforCI* that indicates an offset RB_{start} and a length L_{RB} as RIV according to [6, TS 38.214], and from *offsetToCarrier* in *FrequencyInfoUL-SIB* or *FrequencyInfoUL* that indicates O_{carrier} for a SCS configuration of an active DL BWP where the UE monitors PDCCH for DCI format 2_4 detection.

An indication by a DCI format 2_4 for a serving cell is applicable to a PUSCH transmission or an SRS transmission on the serving cell. If the PUSCH transmission or the SRS transmission is scheduled by a DCI format, the indication by the DCI format 2_4 is applicable to the PUSCH transmission or SRS transmission only if the last symbol of the PDCCH reception providing the DCI format is earlier than the first symbol of the PDCCH reception providing the DCI format 2_4.

For the serving cell, the UE determines the first symbol of the T_{CI} symbols to be the first symbol that is after $T'_{\mathrm{proc,2}}$ from the end of a PDCCH reception where the UE detects the DCI format 2_4, where $T'_{\mathrm{proc,2}}$ is obtained from $T_{\mathrm{proc,2}}$ for PUSCH processing capability 2 [6, TS 38.214] assuming $d_{2,1} = d_{\mathrm{offset}} \cdot 2^{-\mu_{UL}}/2^{-\mu}$ where d_{offset} is provided by *delta_Offset*, μ being the smallest SCS configuration between the SCS configuration of the PDCCH and the smallest SCS configuration μ_{UL} provided in *scs-SpecificCarrierList* of *FrequencyInfoUL* or *FrequencyInfoUL-SIB*. The UE does not expect to cancel the PUSCH transmission or the SRS transmission before a corresponding symbol that is $T_{\mathrm{proc},2}$ assuming that $d_{2,1} = 0$ after a last symbol of the PDCCH reception where the UE detects the DCI format 2_4.

A UE that detects a DCI format 2_4 for a serving cell cancels a PUSCH transmission or an actual repetition of a PUSCH transmission [6, TS 38.214] if the PUSCH transmission is with repetition Type B, as determined in clauses 9 and 9.2.5 or in clause 6.1 of [6, TS 38.214], or an SRS transmission on the serving cell if, respectively,

- the transmission is PUSCH with priority 0, if the UE is provided *uplinkCancellationPriority*,
- a group of symbols, from the T_{CI} symbols, has at least one bit value of '1' in the corresponding set of N_{BI} bits in the DCI format 2_4 and includes a symbol of the (repetition of the) PUSCH transmission or of the SRS transmission, and
- a group of PRBs, from the B_{CI} PRBs, has a corresponding bit value of '1' in the set of bits corresponding to the group of symbols in the DCI format 2_4 and includes a PRB of the (repetition of the) PUSCH transmission or of the SRS transmission,

where

- the cancellation of the (repetition of the) PUSCH transmission includes all symbols from the earliest symbol of the (repetition of the) PUSCH transmission that is in a group of symbols having corresponding bit values of '1' in the DCI format 2_4;
- the cancellation of the SRS transmission includes only symbols that are in one or more groups of symbols having corresponding bit values of '1' in the DCI format 2_4.

If, based on an indication by a DCI format 2_4, a UE cancels a PUSCH transmission or an SRS transmission, the UE does not expect to be scheduled by a second DCI format to transmit a PUSCH or an SRS over symbols that include symbols of the cancelled PUSCH transmission or SRS transmission, where the last symbol of the PDCCH reception providing the second DCI format is no earlier than the first symbol of the PDCCH reception providing the DCI format 2_4.

11.3 Group TPC commands for PUCCH/PUSCH

For PUCCH transmission on a serving cell, a UE can be provided

- a TPC-PUCCH-RNTI for a DCI format 2_2 by *tpc-PUCCH-RNTI*
  - a field in DCI format 2_2 is a TPC command of 2 bits mapping to $\delta_{\mathrm{PUCCH},b,f,c}$ values as described in clause 7.2.1
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for the PCell, or for a carrier of the PCell by *tpc-IndexPCell*
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for a PUCCH-sSCell in the primary PUCCH cell group, by *tpc-IndexPUCCH-sScell*
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for the PUCCH-SCell or for a carrier for the PUCCH-SCell by *tpc-IndexPUCCH-Scell*
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for a PUCCH-sSCell in the secondary PUCCH cell group, by *tpc-IndexPUCCH-sScellSecondaryPUCCHgroup*
- a mapping for the PUCCH power control adjustment state $l \in \{0,1\}$, by a corresponding {0, 1} value of a closed loop index field that is appended to the TPC command field in DCI format 2_2 if the UE indicates a capability to support two PUCCH power control adjustment states by *twoDifferentTPC-Loop-PUCCH*, and if the UE is configured for two PUCCH power control adjustment states by *twoPUCCH-PC-AdjustmentStates*

The UE is also provided on a serving cell with a configuration for a search space set s and a corresponding CORESET p for monitoring PDCCH candidates for DCI format 2_2 with CRC scrambled by a TPC-PUCCH-RNTI as described in clause 10.1.

For PUSCH transmission on a serving cell, a UE can be provided

- a TPC-PUSCH-RNTI for a DCI format 2_2 by *tpc-PUSCH-RNTI*
  - a field in DCI format 2_2 is a TPC command of 2 bits mapping to $\delta_{\mathrm{PUSCH},b,f,c}$ values as described in clause 7.1.1
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for an uplink carrier of the serving cell by *tpc-Index*
- an index for a location in DCI format 2_2 of a first bit for a TPC command field for a supplementary uplink carrier of the serving cell by *tpc-IndexSUL*
- an index of the serving cell by *targetCell*. If *targetCell* is not provided, the serving cell is the cell of the PDCCH reception for DCI format 2_2
- a mapping for the PUSCH power control adjustment state $l \in \{0,1\}$, by a corresponding {0, 1} value of a closed loop index field that is appended to the TPC command field for the uplink carrier or for the supplementary uplink carrier of the serving cell in DCI format 2_2 if the UE indicates a capability to support two PUSCH power control adjustment states, by *twoDifferentTPC-Loop-PUSCH*, and if the UE is configured for two PUSCH power control adjustment states by *twoPUSCH-PC-AdjustmentStates*

The UE is also provided for the serving cell of the PDCCH reception for DCI format 2_2 with a configuration for a search space set s and a corresponding CORESET p for monitoring PDCCH candidates for DCI format 2_2 with CRC scrambled by a TPC-PUSCH-RNTI as described in clause 10.1.

11.4 SRS switching

DCI format 2_3 is applicable for uplink carrier(s) of serving cells where a UE is not configured for PUSCH/PUCCH transmission or for uplink carrier(s) of a serving cell where *srs-PowerControlAdjustmentStates* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions.

A UE configured by higher layers with parameter *carrierSwitching* can be provided

- a TPC-SRS-RNTI for a DCI format 2_3 by *tpc-SRS-RNTI*
- an index of a serving cell where the UE interrupts transmission in order to transmit SRS on one or more other serving cells by *srs-SwitchFromServCellIndex*
- an indication of an uplink carrier where the UE interrupts transmission in order to transmit SRS on one or more other serving cells by *srs-SwitchFromCarrier*
- a DCI format 2_3 field configuration type by *typeA* or *typeB*
  - for *typeA*, an index for a set of serving cells is provided by *cc-SetIndex*, indexes of serving cells in the set of serving cells are provided by *cc-IndexInOneCC-Set*, and a DCI format 2_3 field includes a TPC command for each serving cell from the set of serving cells and can also include a SRS request for SRS transmission on the set of serving cells
  - for *typeB*, DCI format 2_3 field includes a TPC command for a serving cell index and can also include a SRS request for SRS transmission on the serving cell
- an indication for a serving cell for whether or not a field in DCI format 2_3 includes a SRS request by *fieldTypeFormat2-3* where a value of 0/1 indicates absence/presence of the SRS request – a mapping for a 2 bit SRS request to SRS resource sets is as provided in [6, TS 38.214]
- an index for a location in DCI format 2_3 of a first bit for a field for a non-supplementary uplink carrier of the serving cell by *startingBitOfFormat2-3*
- an index for a location in DCI format 2_3 of a first bit for a field for a supplementary uplink carrier of the serving cell by *startingBitOfFormat2-3SUL-v1530*

11.5 Adaptation of cell operation

A UE configured for operation on a serving cell according to one or both of a cell DTX operation and a cell DRX operation by c*ellDTXDRX-Config* for the serving cell [11, TS 38.321], can be additionally provided by *dci-Format2-9* a Type3-PDCCH CSS set to monitor PDCCH for detection of DCI format 2_9 as described in clause 10.1 during Active Time [11, TS 38.321], and a location in DCI format 2_9 by *positionInDCI-cellDTRX* of a cell DTX/DRX indication field for the serving cell and/or a NES-mode indication field for the PCell

- if the UE is configured with both cell DTX operation and cell DRX operation for the serving cell and if *cellDTXDRX-L1activation* is provided, the cell DTX/DRX indication field includes two bits where the first bit indicates the cell DTX operation and the second bit indicates the cell DRX operation
- if the UE is configured with only one of the cell DTX operation and cell DRX operation for the serving cell and if *cellDTXDRX-L1activation* is provided, the cell DTX/DRX indication field includes one bit indicating one of the cell DTX operation and cell DRX operation, respectively, for the serving cell
- a '0' value for a bit of the cell DTX/DRX indication field indicates deactivation of cell DTX or of cell DRX
- a '1' value for a bit of the cell DTX/DRX indication field indicates activation of cell DTX or of cell DRX
- if the serving cell is configured with a SUL carrier, the cell DTX/DRX indication field indication for activation or deactivation of cell DRX applies to both the UL carrier and the SUL carrier
- if *nesEvent* is configured, the NES-mode indication field includes one bit indicating NES-specific CHO execution condition, as described in [12, TS 38.331]
  - a '0' value for the NES-mode indication field indicates NES-specific CHO execution condition is disabled
  - a '1' value for the NES-mode indication field, indicates NES-specific CHO execution condition is enabled

A UE does not expect to monitor PDCCH for detection of DCI format 2_9 on more than one serving cells of one cell group.

When a UE receives in slot m on the active DL BWP of a first serving cell a PDCCH providing DCI format 2_9 that indicates a change in activation or deactivation of a current cell DTX operation or cell DRX operation for a second serving cell, the UE operates on the second serving cell according to the indicated cell DTX operation or cell DRX operation starting from a slot on the active DL BWP or on the active UL BWP of the second serving cell, respectively, that is not before the beginning of the slot $m + d$ on the active DL BWP of the first serving cell where d is a number of slots for the SCS of the active DL BWP of the first serving cell in Table 11.5-1.

Table 11.5-1: Minimum time gap value d

SCS (kHz)	Number of slots
15	3
30	6
60	12
120	24
480	96
960	192

12 Bandwidth part operation

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.

- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

A UE configured for operation in bandwidth parts (BWPs) of a serving cell, is configured by higher layers for the serving cell a set of at most four bandwidth parts (BWPs) for receptions by the UE (DL BWP set) in a DL bandwidth by parameter *BWP-Downlink* or by parameter *initialDownlinkBWP* with a set of parameters configured by *BWP-DownlinkCommon* and *BWP-DownlinkDedicated*, and a set of at most four BWPs for transmissions by the UE (UL BWP set) in an UL bandwidth by parameter *BWP-Uplink* or by parameter *initialUplinkBWP* with a set of parameters configured by *BWP-UplinkCommon* and *BWP-UplinkDedicated*.

For operation with shared spectrum channel access, a UE expects that the BWP configured by the parameter *initialUplinkBWP* provided in *UplinkConfigCommonSIB* is mapped to only a single RB set.

If a UE is not provided *initialDownlinkBWP*, an initial DL BWP is defined by a location and number of contiguous PRBs, starting from a PRB with the lowest index and ending at a PRB with the highest index among PRBs of a CORESET for Type0-PDCCH CSS set, after puncturing if any [4, TS 38.211], and a SCS and a cyclic prefix for PDCCH reception in the CORESET for Type0-PDCCH CSS set; otherwise, the initial DL BWP is provided by *initialDownlinkBWP*. For operation on the primary cell or on a secondary cell, a UE is provided an initial UL BWP by *initialUplinkBWP*. If the UE is configured with a supplementary UL carrier, the UE can be provided an initial UL BWP on the supplementary UL carrier by *initialUplinkBWP*.

If a UE has dedicated BWP configuration, the UE can be provided by *firstActiveDownlinkBWP-Id* a first active DL BWP for receptions and by *firstActiveUplinkBWP-Id* a first active UL BWP for transmissions on a carrier of the primary cell.

For each DL BWP or UL BWP in a set of DL BWPs or UL BWPs, respectively, the UE is provided the following parameters for the serving cell as defined in [4, TS 38.211] or [6, TS 38.214]:

- a SCS by *subcarrierSpacing*
- a cyclic prefix by *cyclicPrefix*
- a common RB $N_{\mathrm{BWP}}^{\mathrm{start}} = O_{\mathrm{carrier}} + RB_{\mathrm{start}}$ and a number of contiguous RBs $N_{\mathrm{BWP}}^{\mathrm{size}} = L_{\mathrm{RB}}$ provided by *locationAndBandwidth* that indicates an offset RB_{start} and a length L_{RB} as RIV according to [6, TS 38.214], setting $N_{\mathrm{BWP}}^{\mathrm{size}} = 275$, and a value O_{carrier} provided by *offsetToCarrier* for the *subcarrierSpacing*
- an index in the set of DL BWPs or UL BWPs by respective *BWP-Id*
- a set of BWP-common and a set of BWP-dedicated parameters by *BWP-DownlinkCommon* and *BWP-DownlinkDedicated* for the DL BWP, or *BWP-UplinkCommon* and *BWP-UplinkDedicated* for the UL BWP [12, TS 38.331]

For unpaired spectrum operation, a DL BWP from the set of configured DL BWPs with index provided by *BWP-Id* is linked with an UL BWP from the set of configured UL BWPs with index provided by *BWP-Id* when the DL BWP index and the UL BWP index are same. For unpaired spectrum operation, a UE does not expect to receive a configuration where the center frequency for a DL BWP is different than the center frequency for an UL BWP when the *BWP-Id* of the DL BWP is same as the *BWP-Id* of the UL BWP.

For each DL BWP in a set of DL BWPs of the PCell, a UE can be configured CORESETs for every type of CSS sets and for USS as described in clause 10.1. The UE does not expect to be configured without a CSS set on the PCell in the active DL BWP.

If a UE is provided *controlResourceSetZero* and *searchSpaceZero* in *PDCCH-ConfigSIB1* or *PDCCH-ConfigCommon*, the UE determines a CORESET for a search space set from *controlResourcesetZero* as described in clause 13 and for Tables 13-0 through 13-10, and determines corresponding PDCCH monitoring occasions as described in clause 13 and for Tables 13-11 through 13-15. If the active DL BWP is not the initial DL BWP, the UE determines PDCCH monitoring occasions for the search space set only if the CORESET bandwidth is within the active DL BWP and the active DL BWP has same SCS configuration and same cyclic prefix as the initial DL BWP.

For each UL BWP in a set of UL BWPs of the PCell, or of the PUCCH-SCell, or of the PUCCH-sSCell the UE is configured resource sets for PUCCH transmissions as described in clause 9.2.1.

A UE receives PDCCH and PDSCH in a DL BWP according to a configured SCS and CP length for the DL BWP. A UE transmits PUCCH and PUSCH in an UL BWP according to a configured SCS and CP length for the UL BWP.

If a bandwidth part indicator field is configured in a DCI format, the bandwidth part indicator field value indicates the active DL BWP, from the configured DL BWP set, for DL receptions as described in [5, TS 38.212]. If a bandwidth part indicator field is configured in a DCI format, the bandwidth part indicator field value indicates the active UL BWP, from the configured UL BWP set, for UL transmissions as described in [5, TS 38.212].

If a bandwidth part indicator field is provided by a DCI format 0_3/1_3,

- the UE applies for a serving cell the value of the bandwidth part indicator field, if
  - the UE is scheduled by the DCI format 0_3/1_3 to transmit PUSCH/receive PDSCH, respectively, on the serving cell, and
  - the serving cell includes a configured UL/DL BWP with index corresponding to the value of the bandwidth part indicator field, and
  - *resourceAllocation* = *resourceAllocationType0* and not all bits of a block of the frequency domain resource assignment field associated with the serving cell in the DCI format 0_3/1_3 are equal to 0, or
  - *resourceAllocation* = *resourceAllocationType1* and not all bits of a block of the frequency domain resource assignment field associated with the serving cell in the DCI format 0_3/1_3 are equal to 1, or
  - *resourceAllocation = dynamicSwitch* and not all bits of a block of the frequency domain resource assignment field associated with the serving cell in the DCI format 0_3/1_3 are equal to either 0 or 1, or
  - *useInterlacePUCCH-PUSCH* is provided and not all bits of a block of the frequency domain resource assignment field associated with the serving cell in the DCI format 0_3 are equal to 1 for $\mu = 0$ or are not equal to 0 for $\mu = 1$
- otherwise, the UE does not apply for the serving cell the value of the bandwidth part indicator field.

The UE does not expect to be scheduled by a DCI format 1_3 to receive a PDSCH on an activated SCell, if:

- the DCI format 1_3 indicates an active DL BWP provided by *dormantBWP-Id* for the activated SCell, and
- *resourceAllocation* = *resourceAllocationType0* and not all bits of a block of the frequency domain resource assignment field associated with the activated SCell in the DCI format 1_3 are equal to 0, or
- *resourceAllocation* = *resourceAllocationType1* and not all bits of a block of the frequency domain resource assignment field associated with the activated SCell in the DCI format 1_3 are equal to 1, or
- *resourceAllocation = dynamicSwitch* and not all bits of a block of the frequency domain resource assignment field associated with the activated SCell in the DCI format 1_3 are equal to either 0 or 1.

If a bandwidth part indicator field is configured in a DCI format and indicates an UL BWP or a DL BWP different from the active UL BWP or DL BWP, respectively, the UE shall

- for each information field in the DCI format
  - if the size of the information field is smaller than the one required for the DCI format interpretation for the UL BWP or DL BWP that is indicated by the bandwidth part indicator, the UE prepends zeros to the information field until its size is the one required for the interpretation of the information field for the UL BWP or DL BWP prior to interpreting the DCI format information fields, respectively
  - if the size of the information field is larger than the one required for the DCI format interpretation for the UL BWP or DL BWP that is indicated by the bandwidth part indicator, the UE uses a number of least significant bits of the DCI format equal to the one required for the UL BWP or DL BWP indicated by bandwidth part indicator prior to interpreting the DCI format information fields, respectively
  - for a DCI format 0_3, or for a DCI format 1_3, and for an information field that includes a number of blocks [5, TS 38.212], the above procedures apply separately for each block of the information field
- set the active UL BWP or DL BWP to the UL BWP or DL BWP indicated by the bandwidth part indicator in the DCI format

If a bandwidth part indicator field is configured in a DCI format 0_1/0_3 and indicates an active UL BWP with different SCS configuration μ, or with different number $N_{\mathrm{RB-set,UL}}^{\mathrm{BWP}}$ of RB sets for a serving cell, than a current active

UL BWP for the serving cell, the UE determines an uplink frequency domain resource allocation Type 2 for the serving cell based on X' bits and Y' bits that are generated by independently truncating or padding the X MSBs and the Y LSBs [6, TS 38.214] of the frequency domain resource assignment field of DCI format 0_1, or the block of the frequency domain resource assignment field in DCI format 0_3 corresponding to the serving cell, where truncation starts from the MSBs of the X bits or the Y bits, zero-padding prepends zeros to the X bits or the Y bits, and

- if the indicated active UL BWP for the serving cell has SCS configuration $\mu = 1$ and the current active BWP for the serving cell has SCS configuration $\mu = 0$, the X MSBs are truncated to $X^{'} = X - 1$ bits, or
- if the indicated active UL BWP for the serving cell has SCS configuration $\mu = 0$ and the current active BWP for the serving cell has SCS configuration $\mu = 1$, the X MSBs are zero-padded to $X^{'} = X + 1$ bits
- otherwise, the X MSBs are unchanged

and

- the Y LSBs are truncated or zero-padded to $Y' = \left\lceil \log_2 \left(\frac{N_{\text{RB-set,UL}}^{\text{BWP}} (N_{\text{RB-set,UL}}^{\text{BWP}} + 1)}{2} \right) \right\rceil$ bits where $N_{\text{RB-set,UL}}^{\text{BWP}}$ is a number of RB sets configured for the indicated active UL BWP for the serving cell.

A UE does not expect to detect a DCI format with a BWP indicator field that indicates an active DL BWP or an active UL BWP change with the corresponding time domain resource assignment field providing a slot offset value for a PDSCH reception or PUSCH transmission that is smaller than a delay required by the UE for an active DL BWP change or UL BWP change, respectively [10, TS 38.133].

If a UE detects a DCI format with a BWP indicator field that indicates an active DL BWP change for a cell, the UE is not required to receive or transmit in the cell during a time duration from the end of the third symbol of a slot where the UE receives the PDCCH that includes the DCI format in a scheduling cell until the beginning of a slot indicated by the slot offset value of the time domain resource assignment field in the DCI format.

If a UE detects a DCI format with SCell dormancy indication that indicates an active DL BWP change for an Scell in slot *n* of primary cell, the UE is not required to receive or transmit in the SCell during a time duration specified in [10, TS 38.133].

If a UE detects a DCI format indicating an active UL BWP change for a cell, the UE is not required to receive or transmit in the cell during a time duration from the end of the third symbol of a slot where the UE receives the PDCCH that includes the DCI format in the scheduling cell until the beginning of a slot indicated by the slot offset value of the time domain resource assignment field in the DCI format.

A UE does not expect to detect a DCI format indicating an active DL BWP change or an active UL BWP change for a scheduled cell within FR1 (or FR2) in a slot other than the first slot of a set of slots for the DL SCS of the scheduling cell that overlaps with a time duration where the UE is not required to receive or transmit, respectively, for an active BWP change in a different cell from the scheduled cell within FR1 (or FR2).

A UE expects to detect a DCI format with a BWP indicator field that indicates an active UL BWP change or an active DL BWP change only if a corresponding PDCCH is received within the first 3 symbols of a slot. If the UE detects the DCI format from two PDCCH receptions in search space sets s_i and s_j that include *searchSpaceLinkingId* with same value, as described in clause 10.1, the UE considers the PDCCH reception where the UE detects the DCI format to be the one from the two PDCCH receptions that ends later.

For a serving cell, a UE can be provided by *defaultDownlinkBWP-Id* a default DL BWP among the configured DL BWPs. If a UE is not provided a default DL BWP by *defaultDownlinkBWP-Id*, the default DL BWP is the initial DL BWP.

If a UE is provided by *bwp-InactivityTimer* a timer value for the serving cell [11, TS 38.321] and the timer is running, the UE decrements the timer at the end of a subframe for FR1 or at the end of a half subframe for FR2 if the restarting conditions in [11, TS 38.321] are not met during the interval of the subframe for FR1 or of the half subframe for FR2.

For a cell where a UE changes an active DL BWP due to a BWP inactivity timer expiration and for accommodating a delay in the active DL BWP change or the active UL BWP change required by the UE [10, TS 38.133], the UE is not required to receive or transmit in the cell during a time duration from the beginning of a subframe for FR1, or of half of a subframe for FR2, that is immediately after the BWP inactivity timer expires until the beginning of a slot where the UE can receive or transmit.

When a UE's BWP inactivity timer for a cell within FR1 (or FR2) expires within a time duration where the UE is not required to receive or transmit for an active UL/DL BWP change in the cell or in a different cell within FR1 (or FR2), the UE delays the active UL/DL BWP change triggered by the BWP inactivity timer expiration until a subframe for FR1 or half a subframe for FR2 that is immediately after the UE completes the active UL/DL BWP change in the cell or in the different cell within FR1 (or FR2).

If a UE is provided by *firstActiveDownlinkBWP-Id* a first active DL BWP and by *firstActiveUplinkBWP-Id* a first active UL BWP on a carrier of a secondary cell, the UE uses the indicated DL BWP and the indicated UL BWP as the respective first active DL BWP on the secondary cell and first active UL BWP on the carrier of the secondary cell.

If a UE is provided *NonCellDefiningSSB* in *BWP-DownlinkDedicated* for an active DL BWP, the UE assumes that the active DL BWP includes the SS/PBCH blocks provided by *NonCellDefiningSSB*. The SS/PBCH blocks provided by *NonCellDefiningSSB* and the SS/PBCH blocks that the UE used to obtain SIB1 have same QCL properties if they have a same index. Unless otherwise stated, handling of overlapping between downlink receptions or uplink transmissions and the SS/PBCH blocks provided by *NonCellDefiningSSB* is same as handling of overlapping between downlink receptions or uplink transmissions and the SS/PBCH blocks provided by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon*. The SS/PBCH blocks in Clause 11.1 for resolving directional collisions for a set of serving cells among multiple serving cells, when the UE is provided *directionalCollisionHandling* and indicates support of *half-DuplexTDD-CA-SameSCS*, correspond to the SS/PBCH blocks the UE used to obtain SIB1.

A UE does not expect to monitor PDCCH when the UE performs RRM measurements [10, TS 38.133] over a bandwidth that is not within the active DL BWP for the UE.

13 UE procedure for monitoring Type0-PDCCH CSS sets

If during cell search a UE determines from *MIB* that a CORESET for Type0-PDCCH CSS set is present, as described in clause 4.1, the UE determines a number of consecutive resource blocks and a number of consecutive symbols for the CORESET of the Type0-PDCCH CSS set from *controlResourceSetZero* in *pdcch-ConfigSIB1*, as described in Tables 13-0 through 13-10, for operation without shared spectrum channel access in FR1 and FR2-1, or as described in Tables 13-1A and 13-4A for operation with shared spectrum channel access in FR1, or as described in Table 13-10A for FR2-2, and determines PDCCH monitoring occasions from *searchSpaceZero* in *pdcch-ConfigSIB1*, included in *MIB*, as described in Tables 13-11 through 13-15A. $\mathrm{SFN_c}$ and n_c are the SFN and slot index within a frame of the CORESET based on SCS of the CORESET and $\mathrm{SFN}_{\mathrm{SSB},i}$ and $n_{\mathrm{SSB},i}$ are the SFN and slot index based on SCS of the CORESET, respectively, where the SS/PBCH block with index i overlaps in time with system frame $\mathrm{SFN}_{\mathrm{SSB},i}$ and slot $n_{\mathrm{SSB},i}$. The symbols of the CORESET associated with *pdcch-ConfigSIB1* in *MIB* or with *searchSpaceSIB1* in *PDCCH-ConfigCommon* have normal cyclic prefix. In Table 13-0, configurations with index 0 to 9 are applicable when an associated SS/PBCH block is located according to Table 5.4.3.3-2 in [8-1, TS 38.101-1], configurations with index 10 to 11 are applicable when an associated SS/PBCH block is located according to NOTE 12 of Table 5.4.3.3-1 in [8-1, TS 38.101-1], and non-interleaved CCE-to-REG mapping applies for configurations with index 6 to 9. In Table 13-1, the associated SS/PBCH block is not located according to NOTE 12 of Table 5.4.3.3-1 in [8-1, TS 38.101-1].

For operation with shared spectrum channel access in FR2-2 and for operation without shared spectrum channel access, a UE assumes that the offset in Tables 13-0 through 13-10A is defined with respect to the SCS of the CORESET for Type0-PDCCH CSS set from the smallest RB index of the CORESET for Type0-PDCCH CSS set to the smallest RB index of the common RB overlapping with the first RB of the corresponding SS/PBCH block, after puncturing if any [4, TS 38.211]. The SCS of the CORESET for Type0-PDCCH CSS set is provided by *subCarrierSpacingCommon* for FR1 and FR2-1 and same as the SCS of the corresponding SS/PBCH block for FR2-2. In Tables 13-7, 13-8, and 13-10, k_{SSB} is defined in [4, TS 38.211].

For operation with shared spectrum channel access in FR1, a UE determines an offset from a smallest RB index of the CORESET for Type0-PDCCH CSS set to a smallest RB index of the common RB overlapping with a first RB of the corresponding SS/PBCH block

- according to the offset in Table 13-1A or Table 13-4A, if the frequency position of the SS/PBCH block corresponds to the GSCN of a synchronization raster entry as defined in [8-1, TS 38.101-1], and
- according to a sum of a first offset and a second offset if the frequency position of the SS/PBCH block is provided by *ssbFrequency* in a measurement configuration associated with a reporting configuration providing *reportCGI* and does not correspond to the GSCN of a synchronization raster entry as defined in [8-1, TS 38.101-1], where

- the first offset is provided in Table 13-1A or Table 13-4A, and
- the second offset is determined as the offset from a smallest RB index of the common RB overlapping with the first RB of the SS/PBCH block indicated in the measurement configuration to a smallest RB index of the common RB overlapping with the first RB of a SS/PBCH block hypothetically located at the GSCN of a synchronization raster entry, where the single synchronization raster entry is located in the same channel as the SS/PBCH block used for the shared spectrum channel access procedure, as described in [15, TS 37.213]

where the offsets are defined with respect to the SCS of the CORESET for Type0-PDCCH CSS set that is same as the SCS of the corresponding SS/PBCH block.

For operation without shared spectrum channel access and for the SS/PBCH block and CORESET multiplexing pattern 1, a UE monitors PDCCH in the Type0-PDCCH CSS set over two slots. For SS/PBCH block with index i, the UE determines an index of slot n_0 as $n_0 = (O \cdot 2^\mu + \lfloor i \cdot M \rfloor) \mathrm{mod} N_{\mathrm{slot}}^{\mathrm{frame},\mu}$ that is in a frame with system frame number (SFN) $\mathrm{SFN_C}$ satisfying $\mathrm{SFN_c} \mathrm{mod} 2 = 0$ if $\lfloor (O \cdot 2^\mu + \lfloor i \cdot M \rfloor)/N_{\mathrm{slot}}^{\mathrm{frame},\mu} \rfloor \mathrm{mod} 2 = 0$, or in a frame with SFN satisfying $\mathrm{SFN_c} \mathrm{mod} 2 = 1$ if $\lfloor (O \cdot 2^\mu + \lfloor i \cdot M \rfloor)/N_{\mathrm{slot}}^{\mathrm{frame},\mu} \rfloor \mathrm{mod} 2 = 1$ where $\mu \in \{0,1,2,3,5,6\}$ based on the SCS for PDCCH receptions in the CORESET [4, TS 38.211].

- For $\mu \in \{0, 1, 2, 3\}$ and for a SS/PBCH block index i, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 1$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 1$ are provided by Table 13-11 and Table 13-12.
- For $\mu = 5$ and for a SS/PBCH block index i, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 4$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 4$ are provided by Table 13-12A, where $X = 1.25$.
- For $\mu = 6$ and for a SS/PBCH block index i, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 8$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 8$ are provided by Table 13-12A, where $X = 0.625$.

For operation with shared spectrum channel access and for the SS/PBCH block and CORESET multiplexing pattern 1, a UE monitors PDCCH in the Type0-PDCCH CSS set over slots that include Type0-PDCCH monitoring occasions associated with SS/PBCH blocks that are quasi co-located with the SS/PBCH block that provides a CORESET for Type0-PDCCH CSS set with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable [6, TS 38.214]. For a candidate SS/PBCH block index $\bar{i}$, where $0 \leq \bar{i} \leq \bar{L}_{max} - 1$, two slots include the associated Type0-PDCCH monitoring occasions. The UE determines an index of slot n_0 as $n_0 = (O \cdot 2^\mu + \lfloor \bar{i} \cdot M \rfloor) \bmod N_{\mathrm{slot}}^{\mathrm{frame},\mu}$ that is in a frame with system frame number (SFN) SFN_C satisfying $\mathrm{SFN}_C \; mod \; 2 = 0$ if $\lfloor (O \cdot 2^\mu + \lfloor \bar{i} \cdot M \rfloor)/N_{\mathrm{slot}}^{\mathrm{frame},\mu} \rfloor \; mod \; 2 = 0$, or in a frame with SFN satisfying $\mathrm{SFN}_C \; mod \; 2 = 1$ if $\lfloor (O \cdot 2^\mu + \lfloor \bar{i} \cdot M \rfloor)/N_{\mathrm{slot}}^{\mathrm{frame},\mu} \rfloor \; mod \; 2 = 1$ where $\mu \in \{0, 1,3,5,6\}$ based on the SCS for PDCCH receptions in the CORESET [4, TS 38.211].

- For $\mu \in \{0, 1\}$ and for a candidate SS/PBCH block index $\bar{i}$, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 1$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 1$ are provided by Table 13-11. The UE does not expect to be configured with $M = 1/2$, or with $M = 2$, when $N_{SSB}^{QCL} = 1$.
- For $\mu = 3$ and for a candidate SS/PBCH block index $\bar{i}$, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 1$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 1$ are provided by Table 13-12.
- For $\mu = 5$ and for a candidate SS/PBCH block index $\bar{i}$, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 4$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 4$ are provided by Table 13-12A, where $X = 1.25$.
- For $\mu = 6$ and for a candidate SS/PBCH block index $\bar{i}$, the two slots including the associated Type0-PDCCH monitoring occasions are slots n_0 and $n_0 + 8$. M, O, and the index of the first symbol of the CORESET in slots n_0 and $n_0 + 8$ are provided by Table 13-12A, where $X = 0.625$.

For operation without shared spectrum channel access and for the SS/PBCH block and CORESET multiplexing patterns 2 and 3, a UE monitors PDCCH in the Type0-PDCCH CSS set over one slot with Type0-PDCCH CSS set periodicity equal to the periodicity of SS/PBCH block. For a SS/PBCH block with index i, the UE determines the slot index n_{c} and $\mathrm{SFN_c}$ based on parameters provided by Tables 13-13 through 13-15A.

For operation with shared spectrum channel access and for SS/PBCH block and CORESET multiplexing pattern 3, a UE monitors PDCCH in the Type0-PDCCH CSS set over slots that include Type0-PDCCH monitoring occasions associated with SS/PBCH blocks that are quasi co-located with the SS/PBCH block that provides a CORESET for Type0-PDCCH CSS set with respect to average gain, quasi co-location 'typeA' and 'typeD' properties, when applicable. For a candidate SS/PBCH block index $\bar{\iota}$, where $0 \leq \bar{\iota} \leq \bar{L}_{\max} - 1$, the periodicity of the slot including the associated Type0-PDCCH monitoring occasion is same as the periodicity of the candidate SS/PBCH block, and the UE determines the slot index n_{c} and $\mathrm{SFN}_{\mathrm{c}}$ based on parameters provided by Tables 13-15 and 13-15A, where i is replaced by $\bar{\iota}$ for operation with shared spectrum channel access in FR2-2.

For the SS/PBCH block and CORESET multiplexing patterns 2 and 3, if the active DL BWP is the initial DL BWP, the UE is expected to be able to perform radio link monitoring, as described in clause 5, and measurements for radio resource management [10, TS 38.133] using a SS/PBCH block that provides a CORESET for Type0-PDCCH CSS set.

Table 13-0: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands with minimum channel bandwidth 3 MHz and channel bandwidth 3 MHz or 5 MHz.

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	12	2	0
1	1	12	3	0
2	1	24	2	0
3	1	24	2	2
4	1	24	3	0
5	1	24	3	2
6	1	24	2	0
7	1	24	2	2
8	1	24	3	0
9	1	24	3	2
10	1	24	2	0
11	1	24	3	0
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-1: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz or with minimum channel bandwidth 3 MHz and channel bandwidth larger than 3 MHz

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	2
2	1	24	2	4
3	1	24	3	0
4	1	24	3	2
5	1	24	3	4
6	1	48	1	12
7	1	48	1	16
8	1	48	2	12
9	1	48	2	16
10	1	48	3	12
11	1	48	3	16
12	1	96	1	38
13	1	96	2	38
14	1	96	3	38
15	Reserved			

Table 13-1A: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands operated with shared spectrum channel access

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	96	1	10
1	1	96	1	12
2	1	96	1	14
3	1	96	1	16
4	1	96	2	10
5	1	96	2	12
6	1	96	2	14
7	1	96	2	16
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-2: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 30} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	5
1	1	24	2	6
2	1	24	2	7
3	1	24	2	8
4	1	24	3	5
5	1	24	3	6
6	1	24	3	7
7	1	24	3	8
8	1	48	1	18
9	1	48	1	20
10	1	48	2	18
11	1	48	2	20
12	1	48	3	18
13	1	48	3	20
14	Reserved			
15	Reserved			

Table 13-3: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 15} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz except for the frequency bands defined by note 17 of Table 5.2-1 in [8-1, TS 38.101-1]

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{RB}^{CORESET}$	Number of Symbols $N_{symb}^{CORESET}$	Offset (RBs)
0	1	48	1	2
1	1	48	1	6
2	1	48	2	2
3	1	48	2	6
4	1	48	3	2
5	1	48	3	6
6	1	96	1	28
7	1	96	2	28
8	1	96	3	28
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-4: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz except for the frequency bands defined by note 17 of Table 5.2-1 in [8-1, TS 38.101-1]

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{RB}^{CORESET}$	Number of Symbols $N_{symb}^{CORESET}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	1
2	1	24	2	2
3	1	24	2	3
4	1	24	2	4
5	1	24	3	0
6	1	24	3	1
7	1	24	3	2
8	1	24	3	3
9	1	24	3	4
10	1	48	1	12
11	1	48	1	14
12	1	48	1	16
13	1	48	2	12
14	1	48	2	14
15	1	48	2	16

Table 13-4A: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands operated with shared spectrum channel access

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	0
1	1	48	1	1
2	1	48	1	2
3	1	48	1	3
4	1	48	2	0
5	1	48	2	1
6	1	48	2	2
7	1	48	2	3
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-5: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 15} kHz for frequency bands with minimum channel bandwidth 40MHz or for the frequency bands defined by note 17 of Table 5.2-1 in [8-1, TS 38.101-1]

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	4
1	1	48	2	4
2	1	48	3	4
3	1	96	1	0
4	1	96	1	56
5	1	96	2	0
6	1	96	2	56
7	1	96	3	0
8	1	96	3	56
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-6: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands with minimum channel bandwidth 40MHz or for the frequency bands defined by note 17 of Table 5.2-1 in [8-1, TS 38.101-1]

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	4
2	1	24	3	0
3	1	24	3	4
4	1	48	1	0
5	1	48	1	28
6	1	48	2	0
7	1	48	2	28
8	1	48	3	0
9	1	48	3	28
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-7: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {120, 60} kHz

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	0
1	1	48	1	8
2	1	48	2	0
3	1	48	2	8
4	1	48	3	0
5	1	48	3	8
6	1	96	1	28
7	1	96	2	28
8	2	48	1	-41 if $k_{\mathrm{SSB}} = 0$ -42 if $k_{\mathrm{SSB}} > 0$
9	2	48	1	49
10	2	96	1	-41 if $k_{\mathrm{SSB}} = 0$ -42 if $k_{\mathrm{SSB}} > 0$
11	2	96	1	97
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-8: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {120, 120} kHz for FR2-1

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	4
2	1	48	1	14
3	1	48	2	14
4	3	24	2	-20 if $k_{\mathrm{SSB}} = 0$ -21 if $k_{\mathrm{SSB}} > 0$
5	3	24	2	24
6	3	48	2	-20 if $k_{\mathrm{SSB}} = 0$ -21 if $k_{\mathrm{SSB}} > 0$
7	3	48	2	48
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-9: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {240, 60} kHz

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	96	1	0
1	1	96	1	16
2	1	96	2	0
3	1	96	2	16
4	Reserved			
5	Reserved			
6	Reserved			
7	Reserved			
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-10: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {240, 120} kHz

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	0
1	1	48	1	8
2	1	48	2	0
3	1	48	2	8
4	2	24	1	-41 if $k_{\mathrm{SSB}} = 0$ -42 if $k_{\mathrm{SSB}} > 0$
5	2	24	1	25
6	2	48	1	-41 if $k_{\mathrm{SSB}} = 0$ -42 if $k_{\mathrm{SSB}} > 0$
7	2	48	1	49
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-10A: Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {120, 120} kHz, {480, 480} kHz, or {960, 960} kHz for FR2-2

Index	SS/PBCH block and CORESET multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	4
2	1	48	1	0
3	1	48	1	14
4	1	48	1	28
5	1	48	2	0
6	1	48	2	14
7	1	48	2	28
8	1	96	1	0
9	1	96	1	76
10	1	96	2	0
11	1	96	2	76
12	3	24	2	-20 if $k_{\mathrm{SSB}} = 0$ -21 if $k_{\mathrm{SSB}} > 0$
13	3	24	2	24
14	3	48	2	-20 if $k_{\mathrm{SSB}} = 0$ -21 if $k_{\mathrm{SSB}} > 0$
15	3	48	2	48

Table 13-11: Parameters for PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 1 and FR1

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
1	0	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
2	2	1	1	0
3	2	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
4	5	1	1	0
5	5	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
6	7	1	1	0
7	7	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
8	0	1	2	0
9	5	1	2	0
10	0	1	1	1
11	0	1	1	2
12	2	1	1	1
13	2	1	1	2
14	5	1	1	1
15	5	1	1	2

Table 13-12: Parameters for PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 1 and FR2-1, or SS/PBCH block and CORESET multiplexing pattern 1 and {SS/PBCH block, PDCCH} SCS {120, 120} kHz in FR2-2

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
1	0	2	1/2	{0, if i is even}, {7, if i is odd}
2	2.5	1	1	0
3	2.5	2	1/2	{0, if i is even}, {7, if i is odd}
4	5	1	1	0
5	5	2	1/2	{0, if i is even}, {7, if i is odd}
6	0	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
7	2.5	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
8	5	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
9	7.5	1	1	0
10	7.5	2	1/2	{0, if i is even}, {7, if i is odd}
11	7.5	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
12	0	1	2	0
13	5	1	2	0
14	Reserved			
15	Reserved			

Table 13-12A: Parameters for PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 1 and {SS/PBCH block, PDCCH} SCS {480, 480} kHz or {960, 960} kHz in FR2-2

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
1	0	2	1/2	{0, if i is even}, {7, if i is odd}
2	X	1	1	0
3	X	2	1/2	{0, if i is even}, {7, if i is odd}
4	5	1	1	0
5	5	2	1/2	{0, if i is even}, {7, if i is odd}
6	0	2	1/2	{0, if i is even}, {$N_{\mathrm{symb}}^{\mathrm{CORESET}}$, if i is odd}
7	X	2	1/2	{0, if i is even}, {$N_{\mathrm{symb}}^{\mathrm{CORESET}}$, if i is odd}
8	5	2	1/2	{0, if i is even}, {$N_{\mathrm{symb}}^{\mathrm{CORESET}}$, if i is odd}
9	5+X	1	1	0
10	5+X	2	1/2	{0, if i is even}, {7, if i is odd}
11	5+X	2	1/2	{0, if i is even}, {$N_{\mathrm{symb}}^{\mathrm{CORESET}}$, if i is odd}
12	0	1	2	0
13	5	1	2	0
14	Reserved			
15	Reserved			

Table 13-13: PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 2 and {SS/PBCH block, PDCCH} SCS {120, 60} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (k = 0, 1, … 15)
0	$\mathrm{SFN_c} = \mathrm{SFN}_{\mathrm{SSB},i}$ $n_{\mathrm{c}} = n_{\mathrm{SSB},i}$	0, 1, 6, 7 for $i = 4k$, $i = 4k + 1$, $i = 4k + 2$, $i = 4k + 3$
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Table 13-14: PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 2 and {SS/PBCH block, PDCCH} SCS {240, 120} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (*k* = 0, 1, …, 7)
0	$\mathrm{SFN_c} = \mathrm{SFN}_{\mathrm{SSB},i}$ $n_\mathrm{c} = n_{\mathrm{SSB},i}$ or $n_\mathrm{c} = n_{\mathrm{SSB},i} - 1$	0, 1, 2, 3, 0, 1 in $i = 8k$, $i = 8k + 1$, $i = 8k + 2$, $i = 8k + 3$, $i = 8k + 6$, $i = 8k + 7$ ($n_\mathrm{c} = n_{\mathrm{SSB},i}$) 12, 13 in $i = 8k + 4$, $i = 8k + 5$ ($n_\mathrm{c} = n_{\mathrm{SSB},i} - 1$)
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Table 13-15: PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 3 and {SS/PBCH block, PDCCH} SCS {120, 120} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (*k* = 0, 1, … 15)
0	$\mathrm{SFN_c} = \mathrm{SFN}_{\mathrm{SSB},i}$ $n_\mathrm{c} = n_{\mathrm{SSB},i}$	4, 8, 2, 6 in $i = 4k$, $i = 4k + 1$, $i = 4k + 2$, $i = 4k + 3$
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Table 13-15A: PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET multiplexing pattern 3 and {SS/PBCH block, PDCCH} SCS {480, 480} kHz or {960, 960} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (***k*** **= 0, 1, … 31)**
0	$\mathrm{SFN_c} = \mathrm{SFN}_{\mathrm{SSB},i}$ $n_\mathrm{c} = n_{\mathrm{SSB},i}$	2, 9 in $i = 2k$, $i = 2k + 1$
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

If a UE detects a first SS/PBCH block and determines that a CORESET for Type0-PDCCH CSS set is not present, and for $24 \le k_{\mathrm{SSB}} \le 29$ for FR1 or for $12 \le k_{\mathrm{SSB}} \le 13$ for FR2, the UE may determine the nearest (in the corresponding frequency direction) global synchronization channel number (GSCN) of a second SS/PBCH block having a CORESET for an associated Type0-PDCCH CSS set as $N_{\mathrm{GSCN}}^{\mathrm{Reference}} + N_{\mathrm{GSCN}}^{\mathrm{Size}} \cdot N_{\mathrm{GSCN}}^{\mathrm{Offset}}$. $N_{\mathrm{GSCN}}^{\mathrm{Reference}}$ is the GSCN of the first SS/PBCH block, $N_{\mathrm{GSCN}}^{\mathrm{Size}} = 1$ in FR1 and FR2-1, $N_{\mathrm{GSCN}}^{\mathrm{Size}} = 3$ in FR2-2, and $N_{\mathrm{GSCN}}^{\mathrm{Offset}}$ is a GSCN offset provided by Table 13-16 for FR1 and Table 13-17 for FR2. If the UE detects the second SS/PBCH block and the second SS/PBCH block does not provide a CORESET for Type0-PDCCH CSS set, as described in clause 4.1, the UE may ignore the information related to GSCN of SS/PBCH block locations for performing cell search.

If a UE detects a SS/PBCH block and determines that a CORESET for Type0-PDCCH CSS set is not present, and for $k_{\mathrm{SSB}} = 31$ for FR1 or for $k_{\mathrm{SSB}} = 15$ for FR2, the UE determines that there is no SS/PBCH block having an associated Type0-PDCCH CSS set within a GSCN range $\left[N_{\mathrm{GSCN}}^{\mathrm{Reference}} - N_{\mathrm{GSCN}}^{\mathrm{Start}}, N_{\mathrm{GSCN}}^{\mathrm{Reference}} + N_{\mathrm{GSCN}}^{\mathrm{End}}\right]$. $N_{\mathrm{GSCN}}^{\mathrm{Start}}$ and $N_{\mathrm{GSCN}}^{\mathrm{End}}$ are respectively determined by *controlResourceSetZero* and *searchSpaceZero* in *pdcch-ConfigSIB1*. If the GSCN range is $\left[N_{\mathrm{GSCN}}^{\mathrm{Reference}}, N_{\mathrm{GSCN}}^{\mathrm{Reference}}\right]$, the UE determines that there is no information for a second SS/PBCH block with a CORESET for an associated Type0-PDCCH CSS set on the detected SS/PBCH block.

If a UE does not detect any SS/PBCH block providing a CORESET for Type0-PDCCH CSS set, as described in clause 4.1, within a time period determined by the UE, the UE may ignore the information related to GSCN of SS/PBCH locations in performing cell search.

Table 13-16: Mapping between the combination of k_{SSB} and *controlResourceSetZero* and *searchSpaceZero* in *pdcch-ConfigSIB1* to $N_{\mathrm{GSCN}}^{\mathrm{Offset}}$ for FR1

k_{SSB}	*16×controlResourceSetZero +searchSpaceZero*	$N_{\mathrm{GSCN}}^{\mathrm{Offset}}$
24	0, 1, …, 255	1, 2, …, 256
25	0, 1, …, 255	257, 258, …, 512
26	0, 1, …, 255	513, 514, …., 768
27	0, 1, …, 255	-1, -2, …, -256
28	0, 1, …, 255	-257, -258, …, -512
29	0, 1, …, 255	-513, -514, …., -768
30	0, 1, …, 255	Reserved, Reserved, …, Reserved

Table 13-17: Mapping between the combination of k_{SSB} and *controlResourceSetZero* and *searchSpaceZero* in *pdcch-ConfigSIB1* to $N_{\mathrm{GSCN}}^{\mathrm{Offset}}$ for FR2

k_{SSB}	*16×controlResourceSetZero +searchSpaceZero*	$N_{\mathrm{GSCN}}^{\mathrm{Offset}}$
12	0, 1, …, 255	1, 2, …, 256
13	0, 1, …, 255	-1, -2, …, -256
14	0, 1, …, 255	Reserved, Reserved, …, Reserved

14 Integrated access-backhaul operation

Throughout this specification, unless otherwise noted, statements using the term "UE" in clauses 4 through 13 are equally applicable to the IAB-MT of an IAB node.

A procedure for an IAB-MT to perform cell search, system information acquisition, or random access procedure is same as a corresponding one for a UE except for the following.

For initial cell selection, an IAB-MT may assume that half frames with SS/PBCH blocks occur with a periodicity of 16 frames.

For PRACH transmission, an IAB-MT determines frames and subframes/slots within the frames containing PRACH occasions as described in [4, TS 38.211].

The IAB-MT determines an association period for mapping SS/PBCH blocks to PRACH occasions based on a PRACH configuration period as described in clause 8.1 and according to Table 14-1 instead of Table 8.1-1. An association pattern period includes one or more association periods and is determined so that a pattern between PRACH occasions and SS/PBCH blocks repeats at most every 640 msec. A PRACH occasion in a PRACH slot is valid according to the conditions in clause 8.1.

Table 14-1: Mapping between PRACH configuration period and SS/PBCH block to PRACH occasion association period for an IAB-MT

PRACH configuration period (msec)	Association period (number of PRACH configuration periods)
10	{1, 2, 4, 8, 16, 32, 64}
20	{1, 2, 4, 8, 16, 32}
40	{1, 2, 4, 8, 16}
80	{1, 2, 4, 8}
160	{1, 2, 4}
320	{1, 2}
640	{1}

If an IAB-node is provided an index T_{delta} in a Timing Delta MAC CE [11, TS 38.321] from a serving cell, the IAB-node may assume that $T_{\text{TA}}/2 + \left(N_{\text{delta}} + T_{\text{delta}} \cdot \text{G}_{\text{step}} - N_{\text{TA,Offset}}/2\right) \cdot \text{T}_{\text{c}}$ is a time difference between a DU transmission of a signal from the serving cell and a reception of the signal by the IAB-MT when $T_{\text{TA}}/2 + \left(N_{\text{delta}} + T_{\text{delta}} \cdot \text{G}_{\text{step}} - N_{\text{TA,Offset}}/2\right) \cdot \text{T}_{\text{c}} > 0$, where

- T_{TA} is the difference between the IAB-MT reception time and the IAB-MT transmission time for IAB-MT transmission timing mode 'Case-6', and is defined in clause 4.3.1 of [4, TS 38.211] for IAB-MT transmission timing mode 'Case-1' and parent node reception mode 'Case-7'
- N_{delta} and G_{step} are determined as
  - $N_{delta} = -70528$ and $G_{step} = 64$, if the serving cell providing the Timing Delta MAC CE operates in FR1
  - $N_{delta} = -17664$ and $G_{step} = 32$, if the serving cell providing the Timing Delta MAC CE operates in FR2

The IAB node may assume that a same value of index T_{delta} is provided from a serving cell for the IAB-MT transmission timing modes 'Case-7' and 'Case-1'

The IAB-node may use the time difference to determine a DU transmission time.

For a serving cell of an IAB-MT, the IAB-MT can be provided by Timing Case Indication MAC CE [11, TS 38.321] an indication of the IAB-MT transmission timing mode in a slot. Upon reception of the Timing Case Indication for a serving cell in a TAG, the IAB-MT applies a same IAB-MT transmission timing mode in a slot on all serving cells in the TAG.

If the indicated IAB-MT transmission timing mode in a slot is set to 'Case-1' or the IAB-MT transmission timing mode indication in a slot is not provided, the IAB-MT transmission time is determined as for a "UE" in clause 4.2.

If the indicated IAB-MT transmission timing mode in a slot is set to 'Case-6', the IAB-node sets the IAB-MT transmission time to the transmission time of the IAB-DU.

If the indicated IAB-MT transmission timing mode in a slot is set to 'Case-7', the IAB-MT is provided a timing advance offset value $N_{\text{TA,offset,2}}$ for a serving cell by Case-7 Timing advance offset MAC CE [11, TS 38.321]. The IAB-MT determines its uplink transmission timing as $\text{T}_{\text{TA}} + \text{N}_{\text{TA,offset,2}} \cdot \text{T}_{\text{c}}$ where T_{TA} is defined in clause 4.3.1 of [4, TS 38.211] and $N_{\text{TA,offset,2}} = T_{\text{offset,2}} \cdot 16 \cdot 64/2^{\mu}$ where $T_{\text{offset,2}}$ is provided by the Case-7 Timing advance offset MAC CE [11, TS 38.321].

A slot format for an IAB-DU or an IAB-MT includes downlink symbols, uplink symbols, and flexible symbols.

For each cell of an IAB-DU, the IAB-DU can be provided an indication for a slot format over a number of slots by *gNB-DU Cell Resource Configuration* [16, TS 38.473].

For each serving cell, an IAB-MT can be provided an indication for a slot format over a number of slots by *tdd-UL-DL-ConfigurationDedicated-IAB-MT*. If the IAB-MT is provided *tdd-UL-DL-ConfigurationDedicated-IAB-MT*, the statements in clause 11.1 that include "*tdd-UL-DL-ConfigurationDedicated*" apply to the IAB-MT of an IAB node by replacing "*tdd-UL-DL-ConfigurationDedicated*" with "*tdd-UL-DL-ConfigurationDedicated-IAB-MT*" for the IAB-MT, except that the *tdd-UL-DL-ConfigurationDedicated-IAB-MT* provides

- a set of slot configurations by *slotSpecificConfigurationsToAddModList-IAB-MT*
- for each slot configuration from the set of slot configurations

- a slot index for a slot provided by *slotIndex*
- a set of symbols for a slot by *symbols-IAB-MT* where
    - if *symbols-IAB-MT* = *allDownlink*, all symbols in the slot are downlink
    - if *symbols-IAB-MT* = *allUplink*, all symbols in the slot are uplink
    - if *symbols-IAB-MT* = *explicit*, *nrofDownlinkSymbols* provides a number of downlink first symbols in the slot and *nrofUplinkSymbols* provides a number of uplink last symbols in the slot. If *nrofDownlinkSymbols* is not provided, there are no downlink first symbols in the slot and if *nrofUplinkSymbols* is not provided, there are no uplink last symbols in the slot. The remaining symbols in the slot are flexible.
    - if *symbols-IAB-MT* = *explicit-IAB-MT*, *nrofUplinkSymbols* provides a number of uplink first symbols in the slot and *nrofDownlinkSymbols* provides a number of downlink last symbols in the slot. If *nrofUplinkSymbols* is not provided, there are no uplink first symbols in the slot and if *nrofDownlinkSymbols* is not provided, there are no downlink last symbols in the slot. The remaining symbols in the slot are flexible.

If an IAB-MT is configured with an MCG and an SCG, is not capable of simultaneous transmission and reception, and would simultaneously transmit and receive on the MCG and the SCG,

- if flexible symbols are configured by both parent nodes for operation with inter-donor NR-DC, the IAB-MT operates according to the scheduling from the MCG
- otherwise, if the IAB-MT is configured with multiple serving cells, is provided *directionalCollisionHandling*-r17 = 'enabled' for a set of serving cell(s) from the multiple serving cells, and indicates *half-DuplexTDD-CA-SameSCS* capability across MCG and SCG for NR-DC operation, the IAB-MT applies the procedures for resolving directional collisions as described in clause 11.1 for resolving directional collisions across serving cells.

An IAB-MT can be provided, by *SlotFormatCombinationsPerCell*, a list of slot format combinations applicable for one serving cell and, by *SlotFormatIndicator*, a configuration for monitor a DCI format 2_0 indicating a slot format combination, from the list of slot format combinations, over a number of slots as described in clause 11.1.1. In addition to the slot formats in Table 11.1.1-1, an SFI field for an IAB-MT in DCI format 2_0 can indicate to the IAB-MT a slot format from the slot formats in Table 14-2.

Table 14-2: Slot formats for normal cyclic prefix

Slot Format	Symbol number in a slot													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
56	U	U	U	U	U	U	U	U	U	U	U	U	U	F
57	U	U	U	U	U	U	U	U	U	U	U	U	F	F
58	U	U	U	U	U	U	U	U	U	U	U	F	F	F
59	U	U	U	U	U	U	U	U	U	U	F	F	F	F
60	U	U	U	U	U	U	U	U	U	F	F	F	F	F
61	U	U	U	U	U	U	U	U	F	F	F	F	F	F
62	U	U	U	U	U	U	U	F	F	F	F	F	F	F
63	U	U	U	U	U	U	F	F	F	F	F	F	F	F
64	U	U	U	U	U	F	F	F	F	F	F	F	F	F
65	U	U	U	U	F	F	F	F	F	F	F	F	F	F
66	U	U	U	F	F	F	F	F	F	F	F	F	F	F
67	U	U	F	F	F	F	F	F	F	F	F	F	F	F
68	U	F	F	F	F	F	F	F	F	F	F	F	F	F
69	U	F	F	F	F	F	F	F	F	F	F	F	F	D
70	U	U	F	F	F	F	F	F	F	F	F	F	F	D
71	U	U	U	F	F	F	F	F	F	F	F	F	F	D
72	U	F	F	F	F	F	F	F	F	F	F	F	D	D
73	U	U	F	F	F	F	F	F	F	F	F	F	D	D
74	U	U	U	F	F	F	F	F	F	F	F	F	D	D
75	U	F	F	F	F	F	F	F	F	F	F	D	D	D
76	U	U	F	F	F	F	F	F	F	F	F	D	D	D
77	U	U	U	F	F	F	F	F	F	F	F	D	D	D
78	U	U	U	U	U	U	U	U	U	U	U	U	F	D
79	U	U	U	U	U	U	U	U	U	U	U	F	F	D
80	U	U	U	U	U	U	U	U	U	U	F	F	F	D
81	U	U	U	U	U	U	U	U	U	U	U	F	D	D
82	U	U	U	U	U	U	U	U	U	U	F	F	D	D
83	U	U	U	U	U	U	U	U	U	F	F	F	D	D
84	U	F	D	D	D	D	D	D	D	D	D	D	D	D
85	U	U	F	D	D	D	D	D	D	D	D	D	D	D
86	U	U	U	F	D	D	D	D	D	D	D	D	D	D
87	U	F	F	D	D	D	D	D	D	D	D	D	D	D
88	U	U	F	F	D	D	D	D	D	D	D	D	D	D
89	U	U	U	F	F	D	D	D	D	D	D	D	D	D
90	U	F	F	F	D	D	D	D	D	D	D	D	D	D
91	U	U	F	F	F	D	D	D	D	D	D	D	D	D
92	U	U	U	F	F	F	D	D	D	D	D	D	D	D
93	U	U	U	U	U	U	U	U	U	F	F	F	F	D
94	U	U	U	U	U	U	F	F	F	F	F	F	D	D
95	U	U	U	U	U	U	F	F	D	D	D	D	D	D
96	U	U	U	U	U	U	U	D	D	D	D	D	D	D

For a serving cell of an IAB-MT, the IAB-MT can be provided by Provided Guard Symbols MAC CE, for Case-1, Case-6 and Case-7 timing modes, respectively, a number of symbols that will not be used for the IAB-MT in slots where the IAB-node transitions between IAB-MT and IAB-node DU and a SCS configuration for the number of symbols [11, TS 38.321].

With reference to slots of an IAB-DU cell, a symbol in a slot of an IAB-DU cell can be configured to be of hard, soft, or unavailable type by *HSNA Slot Configuration List* in *gNB-DU Cell Resource Configuration* [16, TS 38.473].

When a downlink, uplink, or flexible symbol is configured as hard, the IAB-DU cell can respectively transmit, receive, or either transmit or receive in the symbol. A symbol of a slot is equivalent to being configured as hard if an IAB-DU would transmit a SS/PBCH block, PDCCH for Type0-PDCCH CSS sets configured by *pdcchConfigSIB1*, or a periodic CSI-RS in the symbol of the slot, or would receive a PRACH or a SR in the symbol of the slot.

When a downlink, uplink, or flexible symbol is configured as soft, the IAB-DU cell can respectively transmit, receive or either transmit or receive in the symbol only if

- the IAB-MT does not transmit or receive during the symbol of the IAB-DU cell, or
- with respect to all serving cells, the IAB-MT would transmit or receive during the symbol of the IAB-DU cell, and the transmission or reception during the symbol of the IAB-DU cell is not changed due to a use of the symbol by the IAB-DU, or
- the IAB-MT detects a DCI format 2_5 with an AI index field value indicating the soft symbol as available if the IAB-MT is not configured with an SCG, or
- the IAB-MT detects two DCI formats 2_5 with an AI index field indicating the soft symbol as available from the MCG and SCG, respectively, or
- the IAB-MT detects a DCI format 2_5 with an AI index field value indicating the soft symbol as available from one cell group and with respect to all serving cells of the other cell group
  - the IAB-MT does not transmit or receive during the symbol of the IAB-DU cell, or
  - the IAB-MT would transmit or receive during the symbol of the IAB-DU cell, and the transmission or reception during the symbol of the IAB-DU cell does not change due to a use of the symbol by the IAB-DU.

When the IAB-MT receives a DCI format 2_5 from a serving cell in a cell group, the IAB-MT applies the information of the DCI format 2_5 to all serving cells of the cell group.

When a symbol is configured as unavailable, the IAB-DU neither transmits nor receives in the symbol.

With reference to slots of an IAB-DU cell, the IAB-DU can be provided an indication of hard, soft or unavailable type per RB set for symbols configured as downlink, uplink or flexible in a slot by *Frequency-Domain HSNA Configuration List* [16, TS 38.473]. The RB set size and the number of RB sets are configured by *RB Set Configuration* [16, TS 38.473]. The IAB-node can assume the RB set size for the IAB-DU cell is larger than or equal to the IAB-MT's smallest RBG size of the configured BWPs of the FDM required IAB-MT's serving cell(s) as indicated in Multiplexing Info [16, TS 38.473] of the DU cell. If an indication of hard, soft or unavailable type is not provided for an RB set of a symbol in a slot, the IAB-DU applies the configuration of hard, soft or unavailable type provided by *HSNA Slot Configuration List* in *gNB-DU Cell Resource Configuration* [16, TS 38.473] for the RB set of the symbol in the slot. If an indication of hard, soft, or unavailable type is provided for an RB set in a symbol of a slot, the IAB-DU applies the configuration of hard, soft, or unavailable type provided by *Frequency-Domain HSNA Configuration List* [16, TS 38.473] unless the symbol is configured as soft type in *HSNA Slot Configuration List* in *gNB-DU Cell Resource Configuration* [16, TS 38.473] and the IAB-DU cell can transmit or receive in the symbol.

When an RB set of a downlink, uplink, or flexible symbol is configured as hard, the IAB-DU cell can respectively transmit, receive, or either transmit or receive on the RB set in the symbol. An RB set of a symbol is equivalent to being configured as hard if an IAB-DU would transmit a SS/PBCH block, PDCCH for Type0-PDCCH CSS sets configured by *pdcchConfigSIB1*, or a periodic CSI-RS in the RB set of the symbol, or would receive a PRACH or a SR in the RB set of the symbol.

When an RB set of a downlink, uplink, or flexible symbol is configured as soft, the IAB-DU cell can respectively transmit, receive or either transmit or receive on the RB set in the symbol only if

- the IAB-MT does not transmit or receive on the RB set during the symbol of the IAB-DU cell, or
- with respect to all serving cells, the IAB-MT would transmit or receive on the RB set during the symbol of the IAB-DU cell, and the transmission or reception on the RB set or any RB set that is configured as unavailable or configured as soft and not indicated as available during the symbol of the IAB-DU cell is not changed due to a use of the RB set in the symbol by the IAB-DU, or
- the IAB-MT detects a DCI format 2_5 with an AI index field value indicating the soft RB set as available if the IAB-MT is not configured with an SCG, or
- the IAB-MT detects two DCI formats 2_5 with an AI index field value indicating the soft RB set as available from the MCG and SCG, respectively, or
- the IAB-MT detects a DCI format 2_5 with an AI index field value indicating the soft RB set as available from one cell group and with respect to all serving cells of the other cell group, the IAB-MT would transmit or receive on the RB set during the symbol of the IAB-DU cell, and the transmission or reception on the RB set during the symbol of the IAB-DU cell does not change due to a use of the RB set in the symbol by the IAB-DU.

When an RB set of a downlink, uplink, or flexible symbol is configured as unavailable, the IAB-DU neither transmits nor receives in the RB set in the symbol.

If an IAB-node is provided an *AvailabilityIndicator*, the IAB-node is provided an AI-RNTI by *ai-RNTI* and a payload size of a DCI format 2_5 by *dci-PayloadSizeAI*. The IAB-node is also provided a search space set configuration, by *SearchSpace*, for monitoring PDCCH.

For each cell of an IAB-DU in a set of cells of the IAB-DU, the IAB-DU can be provided:

- an identity of the IAB-DU cell by *iab-DU-CellIdentity*
- a location of an availability indicator (AI) index field in DCI format 2_5 by *positionInDCI-AI-r16* and/or by *positionInDCI-AI-RBGroups-v1720*
- a set of availability combinations by *availabilityCombinations-r16* or by *availabilityCombinationsRB-Groups-r17*, where each availability combination in the set of availability combinations includes
  - *resourceAvailability-r16* indicating availability of soft symbols in one or more slots for the IAB-DU cell, or one *resourceAvailability-r17* indicating availability of soft resources in all RB sets in one or more slots for the IAB-DU cell, or one or multiple RB set groups by *rb-SetGroups-r17* with each RB set groups by *RB-SetGroup-r17* indicating *resourceAvailability-r17* for soft resources in one or more slots for the associated *rb-Sets-r17*, and
  - a mapping for the soft symbol, and/or for soft resources, availability combinations provided by *resourceAvailability-r16 or resourceAvailability-r17* to a corresponding AI index field value in DCI format 2_5 provided by *availabilityCombinationId-r16 or availabilityCombinationId-r17, respectively*

With reference to a slot of an IAB-DU cell, if the IAB-DU is not provided an indication of hard, soft or unavailable type per RB set by *Frequency-Domain HSNA Configuration List* [16, TS 38.473], the indication of availability for the slot is based solely on *availabilityCombinations-r16*.

The IAB-DU can assume a same SCS configuration for *availabilityCombinations-r16* or *availabilityCombinationsRB-Groups-r17* for slots of a cell as an SCS configuration provided by *gNB-DU Cell Resource Configuration* for the cell.

The IAB-DU can assume a same SCS configuration for *availabilityCombinationsRB-Groups-r17* for RB sets of a cell as a SCS configuration provided by *RB Set Configuration* for the cell.

An AI index field value in a DCI format 2_5 indicates to an IAB-DU a soft symbol and/or a soft RB set in an RB set group availability in each slot for a number of slots starting from the earliest slot of the IAB-DU which overlaps in time with the slot of the IAB-MT where the IAB-MT detects the DCI format 2_5. The number of slots is equal to or larger than a PDCCH monitoring periodicity for DCI format 2_5 as provided by *SearchSpace*. The AI index field includes $\max\{\lceil \log_2(\text{maxAIindex}+1) \rceil, 1\}$ bits where maxAIindex is the maximum of the values provided by corresponding *availabilityCombinationId*. An availability for a soft symbol or a soft RB set in an RB set group in a slot is identified by a corresponding value *resourceAvailability* as provided in Table 14-3.

Table 14-3: Mapping between values of *resourceAvailability* elements and types of soft symbol or soft RB set availability in a slot

Value	Indication
0	No indication of availability for soft symbols or soft RB sets in an RB set group
1	DL soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for UL and Flexible soft symbols or soft RB sets in an RB set group
2	UL soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for DL and Flexible soft symbols or soft RB sets in an RB set group
3	DL and UL soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for Flexible soft symbols or soft RB sets in an RB set group
4	Flexible soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for DL and UL soft symbols or soft RB sets in an RB set group
5	DL and Flexible soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for UL soft symbols or soft RB sets in an RB set group
6	UL and Flexible soft symbols or soft RB sets in an RB set group are indicated available No indication of availability for DL soft symbols or soft RB sets in an RB set group
7	DL, UL, and Flexible soft symbols or soft RB sets in an RB set group are indicated available

If a PDCCH monitoring periodicity for DCI format 2_5 is smaller than a duration of an availability combination of soft symbols over a number of slots that the IAB-MT obtains at a PDCCH monitoring occasion for DCI format 2_5 by a corresponding AI index field value, and the IAB-MT detects more than one DCI formats 2_5 indicating an availability combination of soft symbols or of soft RB sets in RB set groups in a slot, the IAB-MT expects that each of the more than one DCI formats 2_5 indicates a same value for the availability combination of the soft symbols or of soft RB sets in an RB set group in the slot. An IAB-MT monitors PDCCH candidates for a DCI format 2_5 with CRC scrambled by AI-RNTI in one or both of the following search space sets:

- a Type3-PDCCH CSS set configured by *SearchSpace* in *PDCCH-Config* with *searchSpaceType* = *common*;
- a USS set configured by SearchSpace in PDCCH-Config with searchSpaceType = ue-Specific.

The IAB-node can be provided by the parent node a set of RS resource indexes that indicate quasi co-location properties of an IAB-DU cell where simultaneous transmission/reception from the IAB-MT and transmission from the IAB-DU cells is restricted by Child IAB-DU Restricted Beam Indication MAC CE as described in [11, TS 38.321]. The IAB-DU does not transmit on a cell if the IAB node is operating in a non-TDM multiplexing mode using an indicated RS resource index on a symbol or RB set configured as soft in an IAB-DU cell

- when it is not indicated as available by *resourceAvailability*
- when the IAB-MT is operating on an associated carrier, if that indication is provided
- when the current IAB-DU transmission mode corresponds to an associated multiplexing mode, if that indication is provided
- when one of the associated TCI states, RS resource indexes, or SRI of the IAB-MT, if provided, is simultaneously used for reception or transmission of the IAB-MT
- when simultaneous transmission/reception by the IAB-MT and transmission from the IAB-DU cell occur in non-overlapping frequency resources, if such indication is provided, or when simultaneous transmission/reception by the IAB-MT and transmission from the IAB-DU cell occur in overlapping frequency resources
- in a given slot, if that indication is provided

For a serving cell of an IAB-MT, the IAB-MT can be provided a set of TCI states or a set of RS resource indexes corresponding to a SS/PBCH block or to a CSI-RS resource index for a slot where a PDSCH EPRE adjustment is indicated by DL Tx Power Adjustment MAC CE as described in [11, TS 38.321]. The PDSCH EPRE can be derived from a downlink CSI-RS EPRE as described in [6, TS 38.214] and a power offset provided by the *DL Tx Power adjustment* field in *DL TX Power Adjustment* MAC CE as described in [11, TS 38.321]. The downlink CSI-RS EPRE refers to the CSI-RS indicated by Reference CSI-RS ID in *DL Tx Power Adjustment* MAC CE as described in [11, TS 38.321]. The *DL TX Power Adjustment* provides the offset between PDSCH EPRE and CSI-RS EPRE. For a downlink DM-RS and/or PT-RS associated with a PDSCH, the IAB-MT may assume that the ratio of PDSCH EPRE to DM-RS EPRE, and/or PT-RS EPRE to PDSCH EPRE, is obtained as for a "UE" in [6, TS 38.214]. If no TCI state or RS resource index is provided to the IAB-MT, the IAB-MT may assume that a same PDSCH EPRE adjustment applies to all TCI states or RS resource indexes configured for the IAB-MT. A PDSCH EPRE adjustment provided by DL Tx Power Adjustment MAC CE may be associated with

- multiplexing mode of the IAB-node, if provided, and/or
- when simultaneous reception by the IAB-MT and transmission/reception by an IAB-DU cell occur in non-overlapping frequency resources, if provided, or when simultaneous reception by the IAB-MT and transmission/reception by an IAB-DU cell occur in overlapping frequency resources, if provided, and/or
- slots indicated by slot indexes, if provided.

15 Dual active protocol stack based handover

If a UE indicates a capability for dual active protocol stack based handover (DAPS HO), the UE can be provided with a source MCG and a target MCG.

If a UE is configured with a target MCG using NR radio access in FR1 or in FR2 and with a source MCG using NR radio access in FR2 or in FR1, respectively, the UE performs transmission power control independently per cell group as described in clauses 7.1 through 7.5.

When a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1, the end of the PDCCH reception is the end of the PDCCH candidate that ends later.

If a UE is configured with a target MCG using NR radio access in FR1 and a source MCG using NR radio access in FR1, the UE is configured a maximum power P_{MCG} for transmissions on the target MCG by *p-DAPS-Target* and a maximum power P_{SCG} for transmissions on the source MCG by *p-DAPS-Source* and with an inter-CG power sharing mode by *uplinkPowerSharingDAPS-Mode*. The UE determines a transmission power on the target MCG and a transmission power on the source MCG per frequency range.

If the UE indicates support for semi-static power sharing mode1 and is provided *uplinkPowerSharingDAPS-Mode = Semi-static-mode1*, the UE determines a transmission power for the target MCG or for the source MCG as described in clause 7.6.2 for *nrdc-PCmode-FR1 = Semi-static-mode1* by considering the target MCG as the MCG and the source MCG as the SCG.

If the UE indicates support for semi-static power sharing mode2 and is provided *uplinkPowerSharingDAPS-Mode = Semi-static-mode2*, the UE determines a transmission power for the target MCG or for the source SCG as described in clause 7.6.2 for *nrdc-PCmode-FR1 = Semi-static-mode2* by considering the target MCG as the MCG and the source MCG as the SCG. The UE expects to be provided *uplinkPowerSharingDAPS-Mode = Semi-static-mode2* only for synchronous DAPS HO operation [10, TS 38.133].

If the UE indicates support for dynamic power sharing and is provided *uplinkPowerSharingDAPS-Mode = Dynamic*, the UE determines a transmission power for the target MCG or for the source MCG as described in clause 7.6.2 for *nrdc-PCmode-FR1 = Dynamic* by considering the target MCG as the MCG and the source MCG as the SCG.

Intra-frequency DAPS handover is described in clause 6.1.3.2 of [10, TS 38.133].

For DAPS handover that is not intra-frequency, if

- the UE does not indicate support of *interFreqUL-TransCancellationDAPS-r16*, and
- UE does not indicate a capability for power sharing between source and target MCG in DAPS handover or the UE is not provided with *uplinkPowerSharingDAPS-Mode*,

the UE does not expect transmissions on the target and source cell in overlapping time resources.

For DAPS handover that is not intra-frequency, if

- the UE indicates support of *interFreqUL-TransCancellationDAPS-r16*, and
- UE does not indicate a capability for power sharing between source and target MCG in DAPS handover or the UE is not provided with *uplinkPowerSharingDAPS-Mode*, and
- UE transmissions on the target cell and the source cell are in overlapping time resources,

the UE transmits only on the target cell, and cancels the transmission to source cell.

For intra-frequency DAPS handover, if

- UE transmissions on the target cell and the source cell are in overlapping time resources,

the UE transmits only on the target cell and cancels the transmission on the source cell.

The UE does not expect to cancel a transmission on the source cell if a first symbol of the transmission on the source cell is less than $T_{\text{proc},2} + d$ after a last symbol of a PDCCH reception where the UE receives a PDCCH providing a DCI format scheduling a transmission on the target cell. $T_{\text{proc},2}$ is the PUSCH preparation time for the corresponding PUSCH processing capability [6, TS 38.214] assuming $d_{2,1} = 1$, d is a time duration corresponding to 2 symbols for SCS configuration μ, and μ is the smallest SCS configuration between the SCS configuration of the PDCCH providing the DCI format and the SCS configuration for the transmission on the source cell. If the UE transmits PRACH using 1.25 kHz or 5 kHz SCS on the source cell, the UE determines $T_{\text{proc},2}$ assuming SCS configuration $\mu = 0$.

A UE does not expect to cancel a transmission on the source cell if the first symbol of the source cell transmission occurs, relative to a last symbol of a PDSCH reception conveying a RAR message with a RAR UL grant on the target cell, after a number of symbols that is smaller than $N_{\text{T},1} + N_{\text{T},2} + 0.5$ msec, where $N_{\text{T},1}$ is a time duration of N_1 symbols corresponding to a PDSCH processing time for UE processing capability 1 when additional PDSCH DM-RS is configured, $N_{\text{T},2}$ is a time duration of N_2 symbols corresponding to a PUSCH preparation time for UE processing capability 1 [6, TS 38.214] and the UE considers that N_1 and N_2 correspond to the smaller of the SCS configurations for the PDSCH on the target cell and the transmission on the source cell. For $\mu = 0$, the UE assumes $N_{1,0} = 14$ [6, TS 38.214].

For intra-frequency DAPS handover operation, the UE expects that an active DL BWP and an active UL BWP on the target cell are within an active DL BWP and an active UL BWP on the source cell, respectively.

If a UE is provided search space sets on both the target MCG and the source MCG, in any slot the UE does not expect to have USS sets on both the target MCG and the source MCG that result in the number of monitored PDCCH candidates and the total number of non-overlapped CCEs in both cells that each exceed the corresponding maximum numbers per slot defined in Table 10.1-2 and Table 10.1-3.

For DAPS operation in a same frequency band, a UE does not transmit PUSCH/PUCCH/SRS to the source MCG in a slot overlapping in time with a PRACH transmission to the target MCG or when a gap between a first or last symbol of a PRACH transmission to the target MCG in a first slot would be separated by less than N symbols from a last or first symbol, respectively, of the PUSCH/PUCCH/SRS transmission to the source MCG in a second slot. For DAPS operation in a same frequency band, a UE does not transmit PRACH on the source MCG in a slot overlapping in time with a PUSCH/PUCCH/SRS transmission on the target MCG or when a gap between the first or last symbol of a PUSCH/PUCCH/SRS transmission on the target MCG is separated by less than N symbols from a last or a first symbol, respectively, of a PRACH transmission on the source MCG. $N = 2$ for $\mu = 0$ or $\mu = 1$, $N = 4$ for $\mu = 2$ or $\mu = 3$, and μ is the SCS configuration of the active UL BWP for the PUSCH/PUCCH/SRS transmission. The PUSCH processing capability is the processing capability of source cell.

16 UE procedures for sidelink

A UE is provided by *SL-BWP-Config* or *SL-BWP-ConfigCommon* a BWP for SL transmissions (SL BWP) with numerology and resource grid determined as described in [4, TS 38.211].

For a resource pool within the SL BWP,

- for operation without shared spectrum channel access, or for operation with shared spectrum channel access and when *sl-TransmissionStructureForPSCCHandPSSCH* = 'contiguousRB', the UE is provided by *sl-NumSubchannel* a number of sub-channels where each sub-channel includes a number of contiguous RBs provided by *sl-SubchannelSize*. The first RB of the first sub-channel in the SL BWP is indicated by *sl-StartRB-Subchannel*

- for operation with shared spectrum channel access and when *sl-TransmissionStructureForPSCCHandPSSCH* = 'interlaceRB', the UE is provided by *sl-NumSubchannel* a number of sub-channels where each sub-channel includes a number of interlaces, provided by *sl-NumInterlacePerSubchannel*, and the interlaces have contiguous interlace indexes

Available slots for a resource pool are provided by *sl-TimeResource* and occur with a periodicity of 10240 ms. For operation without shared spectrum channel access and for an available slot without S-SS/PSBCH blocks, SL transmissions can start from a first symbol indicated by *sl-StartSymbol* and be within a number of consecutive symbols indicated by *sl-LengthSymbols*. For operation with shared spectrum channel access and for an available slot without S-SS/PSBCH blocks, SL transmissions can start from a first symbol indicated by *sl-StartingSymbolFirst* and be within a number of consecutive symbols indicated by *sl-LengthSymbols*, or from a second symbol indicated by *sl-StartingSymbolSecond* [6, TS 38.214], where the ending symbol of SL transmissions starting from the first symbol is same as the ending symbol of SL transmissions starting from the second symbol. For an available slot with S-SS/PSBCH blocks, the first symbol and the number of consecutive symbols are predetermined.

The UE expects to use a same numerology in the SL BWP and in an active UL BWP in a same carrier of a same cell. If the active UL BWP numerology is different than the SL BWP numerology, the SL BWP is deactivated.

A priority of a PSSCH according to NR radio access or according to E-UTRA radio access is indicated by a priority field in a respective scheduling SCI format. A priority of a PSSS/SSSS/PSBCH according to E-UTRA radio access is provided by *sl-SSB-PriorityEUTRA* [13, TS 36.213]. A priority of an S-SS/PSBCH block is provided by *sl-SSB-PriorityNR*. A priority of a PSFCH is determined as described in clause 16.2.4.2.

A UE does not expect to be provided search space sets associated with CORESETs on more than one cell to monitor PDCCH for detection of DCI format 3_0 or DCI format 3_1 or DCI format 3_2.

16.1 Synchronization procedures

A UE receives the following SL synchronization signals in order to perform synchronization procedures based on S-SS/PSBCH blocks: SL primary synchronization signals (S-PSS) and SL secondary synchronization signals (S-SSS) [4, TS 38.211].

A UE assumes that reception occasions of a physical sidelink broadcast channel (PSBCH), S-PSS, and S-SSS are in consecutive symbols [4, TS 38.211] and form a S-SS/PSBCH block.

For reception of a S-SS/PSBCH block,

- for operation without shared spectrum channel access, or for operation with shared spectrum channel access and when *sl-NumOfSSS-Brepetition* is not provided and for RB-set j, a UE assumes a frequency location corresponding to the subcarrier with index 66 in the S-SS/PSBCH block [4, TS 38.211], is provided by
  - *sl-AbsoluteFrequencySSB*, for operation without shared spectrum channel access or when RB-set j is the anchor RB-set that is the RB set that includes the S-SS/PSBCH block
  - a corresponding value in *sl-AbsoluteFrequencySSB-NonAnchorList* when RB-set j is a non-anchor RB-set
- for operation with shared spectrum channel access when *sl-NumOfSSS-Brepetition* is provided and in RB-set j, a UE assumes a frequency location corresponding to the subcarrier with index 66 in the S-SS/PSBCH block [4, TS 38.211] is provided by $f_{\mathrm{start},j}^{\mathrm{S-SSB}} + k_{\mathrm{S-SSB},j} \cdot \left(N_{\mathrm{gap},j}^{\mathrm{S-SSB}} + M_{\mathrm{RB}}^{\mathrm{S-SSB}}\right) \cdot 12 \cdot 2^{\mu} \cdot 15$ kHz, where
  - $f_{\mathrm{start},j}^{\mathrm{S-SSB}}$ is a frequency location of a lowest S-SS/PSBCH block in RB-set j, where $f_{\mathrm{start},j}^{\mathrm{S-SSB}}$ is provided by
    - *sl-AbsoluteFrequencySSB* when RB-set j is the anchor RB-set,
    - a corresponding value in *sl-AbsoluteFrequencySSB-NonAnchorList* when RB-set j is a non-anchor RB-set
  - $k_{\mathrm{S-SSB},j}$ is an index of an S-SS/PSBCH block from repeated S-SS/PSBCH blocks in the frequency domain and within the RB-set j, where $0 \le k_{\mathrm{S-SSB},j} \le N_{\mathrm{repetition},j}^{\mathrm{S-SSB}} - 1$, and $N_{\mathrm{repetition},j}^{\mathrm{S-SSB}}$ is provided by a value in *sl-NumOfSSS-Brepetition* corresponding to RB-set j;
  - $N_{\mathrm{gap},j}^{\mathrm{S-SSB}}$ is a number of resource blocks, provided by *sl-GapRepeatedSSB*, for a gap between two adjacent repeated S-SS/PSBCH blocks;
  - $M_{\mathrm{RB}}^{\mathrm{S-SSB}} = 11$ is a number of resource blocks for a S-SS/PSBCH block transmission with SCS configuration μ.

For operation with shared spectrum channel access, a UE attempts to transmit at least S-SS/PSBCH blocks in the slots including S-SS/PSBCH blocks in the anchor RB set. The UE applies CP extension to the first symbol of an S-

SS/PSBCH block and within the first one or two symbols before the first symbol of the S-SS/PSBCH block according to an index [4, TS 38.211] provided by *sl-CPE-StartingPositionS-SSB*. The UE assumes PRB(s) in an intra-cell guard band [6, TS 38.214] are not used for transmission of S-SS/PSBCH blocks.

The UE assumes that a S-PSS symbol, a S-SSS symbol, and a PSBCH symbol have a same transmission power. The UE assumes a same numerology of the S-SS/PSBCH as for a SL BWP of the S-SS/PSBCH block reception, and that a bandwidth of the S-SS/PSBCH is within a bandwidth of the SL BWP. The UE assumes the subcarrier with index 0 in the S-SS/PSBCH block is aligned with a subcarrier with index 0 in an RB of the SL BWP.

A UE is provided, by *sl-NumSSB-WithinPeriod*, a number $N_{\text{period}}^{\text{S-SSB}}$ of S-SS/PSBCH blocks in a period of 16 frames. The UE assumes that a transmission of the S-SS/PSBCH blocks in the period is with a periodicity of 16 frames. The UE determines indexes of slots that include S-SS/PSBCH block as $N_{\text{offset}}^{\text{S-SSB}}+\left(N_{\text{interval}}^{\text{S-SSB}}+1\right)\cdot i_{\text{S-SSB}}$, where

- index 0 corresponds to a first slot in a frame with SFN of the serving cell satisfying $(SFN \bmod 16) = 0$ or DFN satisfying (DFN mod 16) = 0

- $i_{\text{S-SSB}}$ is a S-SS/PSBCH block index within the number of S-SS/PSBCH blocks in the period, with $0 \le i_{\text{S-SSB}} \le N_{\text{period}}^{\text{S-SSB}}-1$

- $N_{\text{offset}}^{\text{S-SSB}}$ is a slot offset from a start of the period to the first slot including S-SS/PSBCH block, provided by *sl-TimeOffsetSSB*

- $N_{\text{interval}}^{\text{S-SSB}}$ is a slot interval between S-SS/PSBCH blocks, provided by *sl-TimeInterval*

For operation with shared spectrum channel access and for each slot that includes S-SS/PSBCH blocks, a UE is provided, by *sl-NumOfAdditionalSSSBOccasion*, a number $N_{\text{additional}}^{\text{S-SSB}}$ of additional candidate S-SS/PSBCH block transmission occasions. When the UE determines to transmit S-SS/PSBCH blocks on additional candidate S-SS/PSBCH block transmission occasions, the UE attempts to transmit S-SS/PSBCH blocks at least in the anchor RB set. When $N_{\text{additional}}^{\text{S-SSB}} > 0$, for S-SS/PSBCH block with index $i_{\text{S-SSB}}$, the UE determines indexes of slots that include the additional candidate S-SS/PSBCH block transmission occasions as $N_{\text{offset}}^{\text{S-SSB}}+\left(N_{\text{interval}}^{\text{S-SSB}}+1\right)\cdot i_{\text{S-SSB}}+\left(N_{\text{gap}}^{\text{S-SSB}}+1\right)\cdot\left(\bar{i}_{\text{S-SSB}}+1\right)$, where

- $N_{\text{gap}}^{\text{S-SSB}}$ is a slot gap, provided by *sl-GapOfAdditionalSSSB-Occasion*, for determining the additional candidate S-SS/PSBCH block transmission occasions, and

- $\bar{i}_{\text{S-SSB}}$ is an index of the additional candidate S-SS/PSBCH block transmission occasions, with $0 \le \bar{i}_{\text{S-SSB}} \le N_{\text{additional}}^{\text{S-SSB}}-1$.

For paired spectrum, an S-SS/PSBCH block can be transmitted/received only in a slot of an UL carrier. For unpaired spectrum, an S-SS/PSBCH block can be transmitted/received only in a slot of which all OFDM symbols are configured as UL by *tdd-UL-DL-ConfigurationCommon* of the serving cell if provided or *sl-TDD-Configuration* if provided or *sl-TDD-Config* of the received PSBCH if provided. If *tdd-UL-DL-ConfigurationCommon* and *sl-TDD-Configuration* are not provided for a spectrum indicated with only PC5 interface in Table 5.2E.1-1 in [TS 38.101-1], an S-SS/PSBCH block can be transmitted/received in any slot of the spectrum.

For transmission of an S-SS/PSBCH block, a UE includes a bit sequence $a_0, a_1, a_2, a_3, \ldots, a_{11}$ in the PSBCH payload to indicate *sl-TDD-Config* and provide a slot format over a number of slots.

For paired spectrum, or if *tdd-UL-DL-ConfigurationCommon* and *sl-TDD-Configuration* are not provided for a spectrum indicated with only PC5 interface in Table 5.2E.1-1 in [TS 38.101-1],

- $a_0, a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}$ are set to '1';

else

- $a_0 = 0$ if *pattern1* is provided by *sl-TDD-Configuration* or *tdd-UL-DL-ConfigurationCommon*; $a_0 = 1$ if both *pattern1* and *pattern2* are provided by *sl-TDD-Configuration* or *tdd-UL-DL-ConfigurationCommon* as described in clause 11.1

- a_1, a_2, a_3, a_4 are determined based on

  - P in *pattern1* as described in Table 16.1-1 for $a_0 = 0$

  - P in *pattern1* and P_2 *in pattern2* as described in Table 16.1-2 for $a_0 = 1$

where P and P_2 are as described in clause 11.1

- $a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}$ are the 7th to 1st LSBs of $u_{\text{slots}}^{\text{SL}}$, respectively
  - for $a_0 = 0$, $u_{\text{slots}}^{\text{SL}} = u_{\text{slots}} * 2^{\mu-\mu_{\text{ref}}} + \left\lfloor \frac{u_{\text{sym}} * 2^{\mu-\mu_{\text{ref}}}}{L} \right\rfloor + I_1$
  - for $a_0 = 1$, $u_{\text{slots}}^{\text{SL}} = \left\lfloor \frac{u_{\text{slots},2} * 2^{\mu-\mu_{\text{ref}}} + \left\lfloor \frac{u_{\text{sym},2} * 2^{\mu-\mu_{\text{ref}}}}{L} \right\rfloor + I_2}{w} \right\rfloor * \left\lceil \frac{P * 2^{\mu} + 1}{w} \right\rceil + \left\lfloor \frac{u_{\text{slots}} * 2^{\mu-\mu_{\text{ref}}} + \left\lfloor \frac{u_{\text{sym}} * 2^{\mu-\mu_{\text{ref}}}}{L} \right\rfloor + I_1}{w} \right\rfloor$

  where

  - L is the number of symbols in a slot: $L = 12$ if *cyclicPrefix* = "ECP"; else, $L = 14$
  - I_1 is 1 if $u_{\text{sym}} * 2^{\mu-\mu_{\text{ref}}} \, mod \, L \geq L - Y$, else I_1 is 0
  - I_2 is 1 if $u_{\text{sym},2} * 2^{\mu-\mu_{\text{ref}}} \, mod \, L \geq L - Y$, else I_2 is 0
  - Y is the sidelink starting symbol index provided by *sl-StartSymbol*
  - w is the granularity of slots indication as described in Table 16.1-2
  - μ_{ref}, u_{slots}, u_{sym}, $u_{\text{slots},2}$, $u_{\text{sym},2}$ are the parameters of *tdd-UL-DL-ConfigurationCommon* as described in clause 11.1, or the parameters of *sl-TDD-Configuration* as defined in [12, TS 38.331]
  - $\mu = 0, 1, 2, 3$ corresponds to SL SCS as defined in [4, TS 38.211]

Table 16.1-1: Slot configuration period when one pattern is indicated

a_1, a_2, a_3, a_4	Slot configuration period of *pattern1* P (msec)
0, 0, 0, 0	0.5
0, 0, 0, 1	0.625
0, 0, 1, 0	1
0, 0, 1, 1	1.25
0, 1, 0, 0	2
0, 1, 0, 1	2.5
0, 1, 1, 0	4
0, 1, 1, 1	5
1, 0, 0, 0	10
Reserved	Reserved

Table 16.1-2: Slot configuration period and granularity when two patterns are indicated

a_1, a_2, a_3, a_4	Slot configuration period of *pattern1* P (msec)	Slot configuration period of *pattern2* P_2 (msec)	Granularity w in slots with different SCS			
			15kHz	30 kHz	60 kHz	120 kHz

<table>
<tr><td>0, 0, 0, 0</td><td>0.5</td><td>0.5</td><td colspan="4" rowspan="6">1</td></tr>
<tr><td>0, 0, 0, 1</td><td>0.625</td><td>0.625</td></tr>
<tr><td>0, 0, 1, 0</td><td>1</td><td>1</td></tr>
<tr><td>0, 0, 1, 1</td><td>0.5</td><td>2</td></tr>
<tr><td>0, 1, 0, 0</td><td>1.25</td><td>1.25</td></tr>
<tr><td>0, 1, 0, 1</td><td>2</td><td>0.5</td></tr>
<tr><td>0, 1, 1, 0</td><td>1</td><td>3</td><td colspan="3" rowspan="8">1</td><td rowspan="8">2</td></tr>
<tr><td>0, 1, 1, 1</td><td>2</td><td>2</td></tr>
<tr><td>1, 0, 0, 0</td><td>3</td><td>1</td></tr>
<tr><td>1, 0, 0, 1</td><td>1</td><td>4</td></tr>
<tr><td>1, 0, 1, 0</td><td>2</td><td>3</td></tr>
<tr><td>1, 0, 1, 1</td><td>2.5</td><td>2.5</td></tr>
<tr><td>1, 1, 0, 0</td><td>3</td><td>2</td></tr>
<tr><td>1, 1, 0, 1</td><td>4</td><td>1</td></tr>
<tr><td>1, 1, 1, 0</td><td>5</td><td>5</td><td colspan="2">1</td><td>2</td><td>4</td></tr>
<tr><td>1, 1, 1, 1</td><td>10</td><td>10</td><td>1</td><td>2</td><td>4</td><td>8</td></tr>
</table>

If a UE would transmit or receive an S-SS/PSBCH block, and the transmission or reception would overlap in time with transmissions or receptions on the sidelink using E-UTRA radio access, the UE transmits or receives the signal/channel with the higher priority.

If a UE would transmit or receive sidelink synchronization signals for E-UTRA radio access, and the transmission or reception would overlap in time with sidelink transmissions or receptions using NR radio access, the UE transmits or receives the signal/channel with the higher priority.

16.2 Power control

16.2.0 S-SS/PSBCH blocks

A UE determines a power $P_{\text{S-SSB}}(i)$ for an S-SS/PSBCH block transmission occasion in slot i, in the anchor RB-set if applicable, on active SL BWP b of carrier f as

$$P_{\text{S-SSB}}(i) = min\left(P_{\text{CMAX}} - P_{\text{offset}}, P_{\text{O,S-SSB}} + 10\,log_{10}\left(2^{\mu} \cdot M_{\text{RB}}^{\text{S-SSB}}\right) + \alpha_{\text{S-SSB}} \cdot PL\right) \text{ [dBm]}$$

where

- P_{CMAX} is defined in [8-1, TS 38.101-1]
- $P_{\text{O,S-SSB}}$ is a value of *dl-P0-PSBCH-r17* if using the parameter is supported by the UE and the parameter is provided; else *dl-P0-PSBCH-r16* if provided; otherwise, $P_{\text{S-SSB}}(i) = P_{\text{CMAX}} - P_{\text{offset}}$
- $\alpha_{\text{S-SSB}}$ is a value of *dl-Alpha-PSBCH*, if provided; else, $\alpha_{\text{S-SSB}} = 1$
- $PL = PL_{b,f,c}(q_d)$ when the active SL BWP is on a serving cell c, as described in clause 7.1.1 except that
    - the RS resource is the one the UE uses for determining a power of a PUSCH transmission scheduled by a DCI format 0_0 in serving cell c when the UE is configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
    - the RS resource is the one corresponding to the SS/PBCH block the UE uses to obtain MIB when the UE is not configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
- $M_{\text{RB}}^{\text{S-SSB}} = 11$ is a number of resource blocks for a S-SS/PSBCH block transmission with SCS configuration μ
- P_{offset} is a value of *sl-SSSBPowerOffsetOfAnchorRBSet*, if provided; otherwise, $P_{\text{offset}} = 0$.

For operation with shared spectrum channel access, after allocating power $P_{\text{S-SSB}}(i)$ for transmission of each S-SS/PSBCH block in the anchor RB-set, the UE equally allocates power $P'_{\text{S-SSB}}(i)$ remaining from P_{CMAX}, if any, for transmission of each S-SS/PSBCH block in all non-anchor RB-sets within the SL BWP

- if *dl-P0-PSBCH* is not provided, a power $P''_{\text{S-SSB}}(i)$ for transmission of each S-SS/PSBCH block in a non-anchor RB-set is $P''_{\text{S-SSB}}(i) = P'_{\text{S-SSB}}(i)$

- otherwise, a power $P''_{\text{S-SSB}}(i)$ for transmission of each S-SS/PSBCH block in a non-anchor RB-set is $P''_{\text{S-SSB}}(i) = \min\left(P'_{\text{S-SSB}}(i), P_{0,S-SSB} + 10\log_{10}(2^{\mu} \cdot M_{RB}^{S-SSB}) + \alpha_{S-SSB} \cdot PL\right)$.

16.2.1 PSSCH

A UE determines a power $P_{\text{PSSCH}}(i)$ for a PSSCH transmission on a resource pool in symbols where a corresponding PSCCH is not transmitted in PSCCH-PSSCH transmission occasion i on active SL BWP b of carrier f as:

$$P_{\text{PSSCH}}(i) = min\left(P_{\text{CMAX}}, P_{\text{MAX,CBR}}, min\left(P_{\text{PSSCH},D}(i), P_{\text{PSSCH},SL}(i)\right)\right) \text{ [dBm]}$$

where

- P_{CMAX} is defined in [8-1, TS 38.101-1]
- $P_{\text{MAX,CBR}}$ is determined by a value of *sl-MaxTxPower* based on a priority level of the PSSCH transmission and a CBR range that includes a CBR measured in slot $i - N$ [6, TS 38.214]; if *sl-MaxTxPower* is not provided, then $P_{\text{MAX,CBR}} = P_{\text{CMAX}}$;
- if *dl-P0-PSSCH-PSCCH* is provided
  - $P_{\text{PSSCH},D}(i) = P_{\text{O},D} + 10\, log_{10}\left(2^{\mu} \cdot M_{\text{RB}}^{\text{PSSCH}}(i)\right) + \alpha_D \cdot PL_D$ [dBm]
- else
  - $P_{\text{PSSCH},D}(i) = min\left(P_{\text{CMAX}}, P_{\text{MAX,CBR}}\right)$ [dBm]

  where

  - $P_{0,D}$ is a value of *dl-P0-PSSCH-PSCCH-r17* if using the parameter is supported by the UE and the parameter is provided; else *dl-P0-PSSCH-PSCCH-r16* if provided
  - α_D is a value of *dl-Alpha-PSSCH-PSCCH*, if provided; else, $\alpha_D = 1$
  - $PL_D = PL_{b,f,c}(q_d)$ when the active SL BWP is on a serving cell c, as described in clause 7.1.1 except that
    - the RS resource is the one the UE uses for determining a power of a PUSCH transmission scheduled by a DCI format 0_0 in serving cell c when the UE is configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
    - the RS resource is the one corresponding to the SS/PBCH block the UE uses to obtain MIB when the UE is not configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
  - $M_{\text{RB}}^{\text{PSSCH}}(i)$ is a number of resource blocks for the PSSCH transmission occasion i and μ is a SCS configuration
- if *sl-P0-PSSCH-PSCCH* is provided, if a SCI format scheduling the PSSCH transmission includes a cast type indicator field indicating unicast or is SCI format 2-C, and if a $higher\ layer\ filtered\ RSRP$ is reported to the UE transmitting the PSSCH from the UE intended to receive the PSCCH-PSSCH transmission
  - $P_{\text{PSSCH},SL}(i) = P_{\text{O},SL} + 10\, log_{10}\left(2^{\mu} \cdot M_{\text{RB}}^{\text{PSSCH}}(i)\right) + \alpha_{SL} \cdot PL_{SL}$ [dBm]
- else
  - $P_{\text{PSSCH,SL}}(i) = min\left(P_{\text{CMAX}}, P_{\text{PSSCH},D}(i)\right)$ [dBm]

  where

  - $P_{0,SL}$ is a value of *sl-P0-PSSCH-PSCCH-r17*, if using the parameter is supported by the UE and the parameter is provided; else *sl-P0-PSSCH-PSCCH-r16* if provided
  - α_{SL} is a value of *sl-Alpha-PSSCH-PSCCH*, if provided; else, $\alpha_{SL} = 1$
  - $PL_{SL} = referenceSignalPower - higher\ layer\ filtered\ RSRP$, where

   - $referenceSignalPower$ is obtained from a PSSCH transmit power per RE summed over the antenna ports of the UE, higher layer filtered across PSSCH transmission occasions using a filter configuration provided by *sl-FilterCoefficient*, and

   - $higher\ layer\ filtered\ RSRP$ is a RSRP, as defined in [7, TS 38.215], that is reported to the UE from a UE receiving the PSCCH-PSSCH transmission and is obtained from a PSSCH DM-RS using a filter configuration provided by *sl-FilterCoefficient*

- $M_{\mathrm{RB}}^{\mathrm{PSSCH}}(i)$ is a number of resource blocks for PSCCH-PSSCH transmission occasion i and μ is a SCS configuration

The UE splits the power $P_{\mathrm{PSSCH}}(i)$ equally across the antenna ports on which the UE transmits the PSSCH with non-zero power.

A UE determines a power $P_{\mathrm{PSSCH2}}(i)$ for a PSSCH transmission on a resource pool in the symbols where a corresponding PSCCH is transmitted in PSCCH-PSSCH transmission occasion i on active SL BWP b of carrier f as

$$P_{\mathrm{PSSCH2}}(i) = 10\,log_{10}\left(\frac{M_{\mathrm{RB}}^{\mathrm{PSSCH}}(i) - M_{\mathrm{RB}}^{\mathrm{PSCCH}}(i)}{M_{\mathrm{RB}}^{\mathrm{PSSCH}}(i)}\right) + P_{\mathrm{PSSCH}}(i)\ [\mathrm{dBm}]$$

where $M_{\mathrm{RB}}^{\mathrm{PSCCH}}(i)$ is a number of resource blocks for the corresponding PSCCH transmission in PSCCH-PSSCH transmission occasion i.

The UE splits the power $P_{\mathrm{PSSCH2}}(i)$ equally across the antenna ports on which the UE transmits the PSSCH with non-zero power.

16.2.2 PSCCH

A UE determines a power $P_{\mathrm{PSCCH}}(i)$ for a PSCCH transmission on a resource pool in PSCCH-PSSCH transmission occasion i as

$$P_{\mathrm{PSCCH}}(i) = 10\,log_{10}\left(\frac{M_{\mathrm{RB}}^{\mathrm{PSCCH}}(i)}{M_{\mathrm{RB}}^{\mathrm{PSSCH}}(i)}\right) + P_{\mathrm{PSSCH}}(i)\ [\mathrm{dBm}]$$

where

- $P_{\mathrm{PSSCH}}(i)$ is specified in clause 16.2.1

- $M_{\mathrm{RB}}^{\mathrm{PSCCH}}(i)$ is a number of resource blocks for the PSCCH transmission in PSCCH-PSSCH transmission occasion i

- $M_{\mathrm{RB}}^{\mathrm{PSSCH}}(i)$ is a number of resource blocks for PSCCH-PSSCH transmission occasion i

For a PSCCH transmission by a UE on a dedicated SL PRS resource pool, a power of the PSCCH transmission in a slot is same as a power of SL PRS transmission by the UE in the slot. The UE determines the power as described in Clause 16.2.3A.

For sidelink co-channel coexistence between E-UTRA and NR, and for NR PSCCH/PSSCH transmissions with SCS configuration $\mu = 1$ in slots that overlap with an E-UTRA subframe on the sidelink, the UE transmits NR PSCCH/PSSCH in the earlier overlapping slot with a power that is larger than or equal to the power in the later overlapping slot.

16.2.3 PSFCH

A UE with $N_{\mathrm{sch,Tx,PSFCH}}$ scheduled PSFCH transmissions for HARQ-ACK information and conflict information, and capable of transmitting a maximum of $N_{\mathrm{max,PSFCH}}$ PSFCHs, determines a number $N_{\mathrm{Tx,PSFCH}}$ of simultaneous PSFCH transmissions and a power $P_{\mathrm{PSFCH,k}}(i)$ for a PSFCH transmission k, $1 \le k \le N_{\mathrm{Tx,PSFCH}}$, on all the resource pools in PSFCH transmission occasion i on active SL BWP b of carrier f as

- if *dl-P0-PSFCH* is provided,

$$P_{\mathrm{PSFCH,one}} = P_{\mathrm{O},PSFCH} + 10\,log_{10}(2^{\mu}) + \alpha_{PSFCH} \cdot PL\ [\mathrm{dBm}]$$

  where

- $P_{\mathrm{PSFCH,one}}$ is applicable for
  - the PRB of the PSFCH transmission for operation without shared spectrum channel access,
  - each PRB in the interlace of the PSFCH transmission for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = "dedicatedInterlace",
  - each PRB in the subset of PRBs in the second interlace of the PSFCH transmission for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace'
- $P_{\mathrm{O},PSFCH}$ is a value of *dl-P0-PSFCH-r17*, if using the parameter is supported by the UE and the parameter is provided; else *dl-P0-PSFCH-r16* if provided
- α_{PSFCH} is a value of *dl-Alpha-PSFCH*, if provided; else, $\alpha_{PFSCH} = 1$
  - $PL = PL_{b,f,c}(q_d)$ when the active SL BWP is on a serving cell c, as described in clause 7.1.1 except that
    - the RS resource is the one the UE uses for determining a power of a PUSCH transmission scheduled by a DCI format 0_0 in serving cell c when the UE is configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
    - the RS resource is the one corresponding to the SS/PBCH block the UE uses to obtain MIB when the UE is not configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
- for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', $P_{\mathrm{PSFCH,k}}(i)$ includes the power on PRBs in both the first and second interlaces and, for more than one PSFCH transmissions from the UE, the power on any PRB in the first interlace is not accumulated among the more than one PSFCH transmissions within a same RB set and is same as the power $P_{\mathrm{PSFCH,PRB,first},k}(i)$ on the PRB in the first interlace for PSFCH transmission k.
- if $N_{\mathrm{sch,Tx,PSFCH}} \leq N_{\mathrm{max,PSFCH}}$
  - if $P_{\mathrm{PSFCH,one}} + 10log_{10}(N_{\mathrm{PSFCH,one}}) \leq P_{\mathrm{CMAX}}$, where P_{CMAX} is determined for $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmissions according to [8-1, TS 38.101-1] and
    - $N_{\mathrm{PSFCH,one}} = N_{\mathrm{sch,Tx,PSFCH}}$ for operation without shared spectrum channel access
      - $N_{\mathrm{Tx,PSFCH}} = N_{\mathrm{sch,Tx,PSFCH}}$ and $P_{\mathrm{PSFCH,k}}(i) = P_{\mathrm{PSFCH,one}}$ [dBm]
    - $N_{\mathrm{PSFCH,one}} = \sum_{k=1}^{N_{\mathrm{sch,Tx,PSFCH}}} N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace', where $N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}$ is the number of PRBs in the interlace for PSFCH transmission k
      - $N_{\mathrm{Tx,PSFCH}} = N_{\mathrm{sch,Tx,PSFCH}}$ and $P_{\mathrm{PSFCH,k}}(i) = P_{\mathrm{PSFCH,one}} + 10log_{10}(N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}})$ [dBm], where the power on one PRB in the interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB},k}(i) = P_{\mathrm{PSFCH,one}}$
    - $N_{\mathrm{PSFCH,one}} = N_{\mathrm{sch,Tx,PSFCH}} \cdot N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}} \cdot 10^{(-P_{\mathrm{PSFCH,offset}}/10)}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where $N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}}$ is provided by *sl-NumDedicatedPRBs-ForPSFCH*, $P_{\mathrm{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*, and $N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}}$ is the number of PRBs in the first interlace for all $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmissions after excluding PRBs for PSFCH transmissions as described in Clause 16.3.0
      - $N_{\mathrm{Tx,PSFCH}} = N_{\mathrm{sch,Tx,PSFCH}}$ and $P_{\mathrm{PSFCH,k}}(i) = P_{\mathrm{PSFCH,one}} + 10log_{10}(N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}} \cdot 10^{(-P_{\mathrm{PSFCH,offset}}/10)})$ [dBm], where the power on one PRB in the first interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB,first},k}(i) = P_{\mathrm{PSFCH,PRB,second},k}(i) - P_{\mathrm{PSFCH,offset}}$ and the power on one PRB in the subset of PRBs in the second interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB,second},k}(i) = P_{\mathrm{PSFCH,one}}$, where $P_{\mathrm{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*
  - else
    - UE autonomously determines $N_{\mathrm{Tx,PSFCH}}$ PSFCH transmissions first with ascending order of corresponding priority field values as described in clause 16.2.4.2 over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH

transmissions with conflict information, if any, such that $N_{\mathrm{Tx,PSFCH}} \geq \max(1, \sum_{i=1}^{K} M_i)$ where M_i, for $1 \leq i \leq 8$, is a number of PSFCHs with priority value i for PSFCH with HARQ-ACK information and M_i, for $i > 8$, is a number of PSFCHs with priority value $i - 8$ for PSFCH with conflict information and K is defined as

- the largest value satisfying $P_{\mathrm{PSFCH,one}} + 10log_{10}\left(N_{\mathrm{PSFCH,one}}^{K}\right) \leq P_{\mathrm{CMAX}}$ where P_{CMAX} is determined according to [8-1, TS 38.101-1] for transmission of all PSFCHs in $\sum_{i=1}^{K} M_i$, if any
  - $N_{\mathrm{PSFCH,one}}^{K} = \max(1, \sum_{i=1}^{K} M_i)$ for operation without shared spectrum channel access
  - $N_{\mathrm{PSFCH,one}}^{K} = \sum_{k=1}^{\max(1,\sum_{i=1}^{K} M_i)} N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace'
  - $N_{\mathrm{PSFCH,one}}^{K} = \max(1, \sum_{i=1}^{K} M_i) \cdot N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1},K} \cdot 10^{(-P_{\mathrm{PSFCH,offset}}/10)}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where $N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1},K}$ is the number of PRBs in the first interlace for the $\max(1, \sum_{i=1}^{K} M_i)$ PSFCH transmissions after excluding PRBs for PSFCH transmissions as described in Clause 16.3.0
- zero, otherwise

and

- $P_{\mathrm{PSFCH,k}}(i) = min\left(P_{\mathrm{CMAX}} - 10log_{10}(N_{\mathrm{Tx,PSFCH}}), P_{\mathrm{PSFCH,one}}\right)$ [dBm] for operation without shared spectrum channel access
- $P_{\mathrm{PSFCH,k}}(i) = min\left(P_{\mathrm{CMAX}} - 10log_{10}\left(\sum_{k=1}^{N_{\mathrm{Tx,PSFCH}}} N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}\right), P_{\mathrm{PSFCH,one}} + \right) + 10log_{10}\left(N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace', where the power on one PRB in the interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB},k}(i) = min\left(P_{\mathrm{CMAX}} - 10log_{10}\left(\sum_{k=1}^{N_{\mathrm{Tx,PSFCH}}} N_{\mathrm{PSFCH,one},k}^{\mathrm{interlace}}\right), P_{\mathrm{PSFCH,one}}\right)$
- $P_{\mathrm{PSFCH,k}}(i) = min\left(P_{\mathrm{CMAX}} - 10log_{10}\left(N_{\mathrm{Tx,PSFCH}} \cdot N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}} \cdot 10^{\left(-\frac{P_{\mathrm{PSFCH,offset}}}{10}\right)}\right), P_{\mathrm{PSFCH,one}}\right) + 10log_{10}\left(N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}} \cdot 10^{(-P_{\mathrm{PSFCH,offset}}/10)}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where the power on one PRB in the first interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB,first},k}(i) = P_{\mathrm{PSFCH,PRB,second},k}(i) - P_{\mathrm{PSFCH,offset}}$ and the power on one PRB in the subset of PRBs in the second interlace for PSFCH transmission is $P_{\mathrm{PSFCH,PRB,second},k}(i) = min\left(P_{\mathrm{CMAX}} - 10log_{10}\left(N_{\mathrm{Tx,PSFCH}} \cdot N_{\mathrm{PSFCH,one}}^{\mathrm{interlace2}} + N_{\mathrm{PSFCH,one}}^{\mathrm{interlace1}} \cdot 10^{(-P_{\mathrm{PSFCH,offset}}/10)}\right), P_{\mathrm{PSFCH,one}}\right)$, where $P_{\mathrm{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*

where P_{CMAX} is defined in [8-1, TS 38.101-1] and is determined for the $N_{\mathrm{Tx,PSFCH}}$ PSFCH transmissions

- else
  - the UE autonomously selects $N_{\mathrm{max,PSFCH}}$ PSFCH transmissions with ascending order of corresponding priority field values as described in clause 16.2.4.2
    - if $P_{\mathrm{PSFCH,one}} + 10log_{10}\left(N_{\mathrm{PSFCH,one,max}}\right) \leq P_{\mathrm{CMAX}}$, where P_{CMAX} is determined for the $N_{\mathrm{max,PSFCH}}$ PSFCH transmissions according to [8-1, TS 38.101-1]
      - $N_{\mathrm{PSFCH,one,max}} = N_{\mathrm{max,PSFCH}}$ [dBm] for operation without shared spectrum channel access
        - $N_{\mathrm{Tx,PSFCH}} = N_{\mathrm{max,PSFCH}}$ and $P_{\mathrm{PSFCH,k}}(i) = P_{\mathrm{PSFCH,one}}$ [dBm]

- $N_{\text{PSFCH,one,max}} = \sum_{k=1}^{N_{\text{max,PSFCH}}} N_{\text{PSFCH,one},k}^{\text{interlace}}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace', where $N_{\text{PSFCH,one},k}^{\text{interlace}}$ is the number of PRBs in the interlace for the PSFCH transmission k

  - $N_{\text{Tx,PSFCH}} = N_{\text{max,PSFCH}}$ and $P_{\text{PSFCH,k}}(i) = P_{\text{PSFCH,one}} + 10log_{10}\left(N_{\text{PSFCH,one},k}^{\text{interlace}}\right)$ [dBm], where the power on one PRB in the interlace for PSFCH transmission is $P_{\text{PSFCH,PRB},k}(i) = P_{\text{PSFCH,one}}$

- $N_{\text{PSFCH,one,max}} = N_{\text{max,PSFCH}} \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where $N_{\text{PSFCH,one}}^{\text{interlace2}}$ is provided by *sl-NumDedicatedPRBs-ForPSFCH*, $P_{\text{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*, and $N_{\text{PSFCH,one}}^{\text{interlace1}}$ is the number of PRBs in the first interlace for all $N_{\text{max,PSFCH}}$ PSFCH transmissions after excluding PRBs for PSFCH transmissions as described in Clause 16.3.0

  - $N_{\text{Tx,PSFCH}} = N_{\text{max,PSFCH}}$ and $P_{\text{PSFCH,k}}(i) = P_{\text{PSFCH,one}} + 10log_{10}\left(N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}\right)$ [dBm], where the power on one PRB in the first interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,first},k}(i) = P_{\text{PSFCH,PRB,second},k}(i) - P_{\text{PSFCH,offset}}$ and the power on one PRB in the subset of PRBs in the second interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,second},k}(i) = P_{\text{PSFCH,one}}$, where $P_{\text{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*

- else

  - the UE autonomously selects $N_{\text{Tx,PSFCH}}$ PSFCH transmissions in ascending order of corresponding priority field values as described in clause 16.2.4.2 over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH transmissions with conflict information, if any, such that $N_{\text{Tx,PSFCH}} \geq \max(1, \sum_{i=1}^{K} M_i)$ where M_i, $1 \leq i \leq 8$, is a number of PSFCHs with priority value i for PSFCH with HARQ-ACK information and M_i, $i > 8$, is a number of PSFCHs with priority value $i - 8$ for PSFCH with conflict information and K is defined as

    - the largest value satisfying $P_{\text{PSFCH,one}} + 10log_{10}\left(N_{\text{PSFCH,one}}^{K}\right) \leq P_{\text{CMAX}}$ where P_{CMAX} is determined according to [8-1, TS 38.101-1] for transmission of all PSFCHs in $\sum_{i=1}^{K} M_i$, if any

      - $N_{\text{PSFCH,one}}^{K} = \max(1, \sum_{i=1}^{K} M_i)$ for operation without shared spectrum channel access

      - $N_{\text{PSFCH,one}}^{K} = \sum_{k=1}^{\max(1,\sum_{i=1}^{K} M_i)} N_{\text{PSFCH,one},k}^{\text{interlace}}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace'

      - $N_{\text{PSFCH,one}}^{K} = \max(1, \sum_{i=1}^{K} M_i) \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1},K} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}$ for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where $N_{\text{PSFCH,one}}^{\text{interlace1},K}$ is the number of PRBs in the first interlace for the $\max(1, \sum_{i=1}^{K} M_i)$ PSFCH transmissions after excluding PRBs for PSFCH transmissions as described in Clause 16.3.0

    - zero, otherwise

    and

    - $P_{\text{PSFCH,k}}(i) = min\left(P_{\text{CMAX}} - 10log_{10}(N_{\text{Tx,PSFCH}}), P_{\text{PSFCH,one}}\right)$ [dBm] for operation without shared spectrum channel access

    - $P_{\text{PSFCH,k}}(i) = min\left(P_{\text{CMAX}} - 10log_{10}(\sum_{k=1}^{N_{\text{Tx,PSFCH}}} N_{\text{PSFCH,one},k}^{\text{interlace}}), P_{\text{PSFCH,one}}\right) + 10log_{10}\left(N_{\text{PSFCH,one},k}^{\text{interlace}}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH*= 'dedicatedInterlace', where the power on one PRB in the interlace for PSFCH transmission is $P_{\text{PSFCH,PRB},k}(i) = min\left(P_{\text{CMAX}} - 10log_{10}\left(\sum_{k=1}^{N_{\text{Tx,PSFCH}}} N_{\text{PSFCH,one},k}^{\text{interlace}}\right), P_{\text{PSFCH,one}}\right)$

- $P_{\text{PSFCH,k}}(i) = min\left(P_{\text{CMAX}} - 10log_{10}(N_{\text{Tx,PSFCH}} \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}), P_{\text{PSFCH,one}}\right) + 10log_{10}\left(N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where the power on one PRB in the first interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,first},k}(i) = P_{\text{PSFCH,PRB,second},k}(i) - P_{\text{PSFCH,offset}}$ and the power on one PRB in the subset of PRBs in the second interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,second},k}(i) = min\left(P_{\text{CMAX}} - 10log_{10}\left(N_{\text{Tx,PSFCH}} \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}\right), P_{\text{PSFCH,one}}\right)$, where $P_{\text{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*

  where P_{CMAX} is determined for the $N_{\text{Tx,PSFCH}}$ simultaneous PSFCH transmissions according to [8-1, TS 38.101-1]

- else

  - $P_{\text{PSFCH,k}}(i) = P_{\text{CMAX}} - 10log_{10}(N_{\text{Tx,PSFCH}})$ [dBm] for operation without shared spectrum channel access

  - $P_{\text{PSFCH,k}}(i) = P_{\text{CMAX}} - 10log_{10}(\sum_{k=1}^{N_{\text{Tx,PSFCH}}} N_{\text{PSFCH,one},k}^{\text{interlace}}) + 10log_{10}\left(N_{\text{PSFCH,one},k}^{\text{interlace}}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'dedicatedInterlace', where the power on one PRB in the interlace for PSFCH transmission is $P_{\text{PSFCH,PRB},k}(i) = P_{\text{CMAX}} - 10log_{10}\left(\sum_{k=1}^{N_{\text{Tx,PSFCH}}} N_{\text{PSFCH,one},k}^{\text{interlace}}\right)$

  - $P_{\text{PSFCH,k}}(i) = P_{\text{CMAX}} - 10log_{10}(N_{\text{Tx,PSFCH}} \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}) + 10log_{10}\left(N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}\right)$ [dBm] for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', where the power on one PRB in the first interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,first},k}(i) = P_{\text{PSFCH,PRB,second},k}(i) - P_{\text{PSFCH,offset}}$ and the power on one PRB in the subset of PRBs in the second interlace for PSFCH transmission is $P_{\text{PSFCH,PRB,second},k}(i) = P_{\text{CMAX}} - 10log_{10}\left(N_{\text{Tx,PSFCH}} \cdot N_{\text{PSFCH,one}}^{\text{interlace2}} + N_{\text{PSFCH,one}}^{\text{interlace1}} \cdot 10^{(-P_{\text{PSFCH,offset}}/10)}\right)$, where $P_{\text{PSFCH,offset}}$ is provided by *sl-PSFCH-PowerOffset*

- for operation with shared spectrum channel access and *sl-TransmissionStructureForPSFCH* = 'commonInterlace', $P_{\text{PSFCH,k}}(i)$ includes the power on PRBs in both the first and second interlaces and, for more than one PSFCH transmissions from the UE, the power on any PRB in the first interlace is not accumulated among the more than one PSFCH transmissions within a same RB set and is same as the power $P_{\text{PSFCH,PRB,first},k}(i)$ on the PRB in the first interlace for PSFCH transmission k. where the UE autonomously determines $N_{\text{Tx,PSFCH}}$ PSFCH transmissions with ascending order of corresponding priority field values as described in clause 16.2.4.2 over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH transmissions with conflict information, if any, such that $N_{\text{Tx,PSFCH}} \geq 1$ and where P_{CMAX} is determined for the $N_{\text{Tx,PSFCH}}$ PSFCH transmissions according to [8-1, TS 38.101-1].

For resource pools configured with PSFCH resources overlapping in time, the UE either expects not to be provided with *dl-P0-PSFCH* or *dl-Alpha-PSFCH* in any of the resource pools, or expects to be provided with the same values of *dl-P0-PSFCH* and the same values of *dl-Alpha-PSFCH* for all the resource pools.

16.2.3A SL PRS

A UE determines a power $P_{\text{SL-PRS}}(i)$ for a SL PRS transmission on a resource pool in SL PRS transmission occasion i on active SL BWP b of carrier f as:

$$P_{\text{SL-PRS}}(i) = \min\left(P_{\text{CMAX}}, P_{\text{MAX,CBR}}, \min\left(P_{\text{SL-PRS,D}}(i), P_{\text{SL-PRS,SL}}(i)\right)\right)$$

where,

- P_{CMAX} is defined in [8-1, TS 38.101-1]

- $P_{\text{MAX,CBR}}$ is determined by

  - if the resource pool is a shared SL PRS resource pool, a value of *sl-MaxTxPower* based on a priority level and a CBR range for a CBR measured in slot $i - N$, where N is the congestion control processing time [6, TS

38.214]; if *sl-MaxTxPower* is not provided, $P_{\mathrm{MAX,CBR}} = P_{\mathrm{CMAX}}$. The priority level is same for PSSCH and SL PRS

- if the resource pool is a dedicated SL PRS resource pool, a value of *sl-PRS-MaxTx-Power* based on a priority level and a CBR range for a CBR measured in slot $i - N$, where N is the congestion control processing time [6, TS 38.214]; if *sl-PRS-MaxTx-Power* is not provided, $P_{\mathrm{MAX,CBR}} = P_{\mathrm{CMAX}}$. The priority level is for SL PRS

- if a value for $P_{\mathrm{O,D}}$ is provided
  - $P_{\mathrm{SL-PRS,D}}(i) = P_{\mathrm{O,D}} + 10\log_{10}\left(2^{\mu} \cdot M_{\mathrm{RB}}^{\mathrm{SL-PRS}}(i)\right) + \alpha_D \cdot PL_D$ [dBm]
- else
  - $P_{\mathrm{SL-PRS,D}}(i) = \min\left(P_{\mathrm{CMAX}}, P_{\mathrm{MAX,CBR}}\right)$ [dBm]

  where
  - if the resource pool is a shared SL PRS resource pool, $P_{\mathrm{O,D}}$ is a value of *dl-P0-PSSCH-PSCCH* or *dl-P0-PSSCH-PSCCH-r17*; else, if the resource pool is a dedicated SL PRS resource pool, $P_{\mathrm{O,D}}$ is a value of *dl-P0-SL-PRS*
  - if the resource pool is a shared SL PRS resource pool, α_D is a value of *dl-Alpha-PSSCH-PSCCH*, if provided, and $\alpha_D = 1$ if *dl-Alpha-PSSCH-PSCCH* is not provided; else, if the resource pool is a dedicated SL PRS resource pool, α_D is provided by *dl-Alpha-SLPRS*, if provided, and $\alpha_D = 1$ if *dl-Alpha-SL-PRS* is not provided
  - $PL_D = PL_{b,f,c}(q_d)$ when the active SL BWP is on a serving cell c, as described in clause 7.1.1 except that
    - the RS resource q_d is the one the UE uses for determining a power of a PUSCH transmission scheduled by a DCI format 0_0 in serving cell c when the UE is configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
    - the RS resource q_d is the one corresponding to the SS/PBCH block the UE uses to obtain MIB when the UE is not configured to monitor PDCCH for detection of DCI format 0_0 in serving cell c
  - $M_{\mathrm{RB}}^{\mathrm{SL-PRS}}(i)$ is a number of resource blocks for the SL PRS transmission occasion i and μ is a SCS configuration for the SL PRS transmission

- if a value for $P_{\mathrm{O,SL}}$ is provided
  - $P_{\mathrm{SL-PRS,SL}}(i) = P_{\mathrm{O,SL}} + 10\log_{10}\left(2^{\mu} \cdot M_{\mathrm{RB}}^{\mathrm{SL-PRS}}(i)\right) + \alpha_{SL} \cdot PL_{SL}$ [dBm]
- else
  - $P_{\mathrm{SL-PRS,SL}}(i) = \min\left(P_{\mathrm{CMAX}}, P_{\mathrm{SL-PRS,D}}(i)\right)$ [dBm]

  where
  - if the resource pool is a shared SL PRS resource pool, $P_{\mathrm{O,SL}}$ is a value of *sl-P0-PSSCH-PSCCH* or *sl-P0-PSSCH-PSCCH-r17*; else, if the resource pool is dedicated for SL PRS transmissions, $P_{\mathrm{O,SL}}$ is a value of *sl-P0-SL-PRS*
  - if the resource pool is a shared SL PRS resource pool, α_{SL} is a value of *sl-Alpha-PSSCH-PSCCH*, if provided and $\alpha_{SL} = 1$ if *sl-Alpha-PSSCH-PSCCH* is not provided; else, if the resource pool is a dedicated SL PRS resource pool, α_{SL} is provided by *sl-Alpha-SL-PRS* if provided, and $\alpha_{SL} = 1$ if *sl-Alpha-SL-PRS* is not provided
  - $PL_{SL} = referenceSignalPower - higher\ layer\ filtered\ RSRP$, where
    - $referenceSignalPower$ is obtained

    - if the resource pool is a shared SL PRS resource pool, from a PSSCH transmit power per RE summed over the antenna ports of the UE and higher layer filtered across PSSCH transmission occasions using a filter configuration provided by *sl-FilterCoefficient*,
    - else, if the resource pool is a dedicated SL PRS resource pool, from a SL PRS transmit power per RE and higher layer filtered across SL PRS transmission occasions using a filter configuration provided by *sl-FilterCoefficient*
- $higher\ layer\ filtered\ RSRP$ is a RSRP, as defined in [7, TS 38.215], that is reported to the UE from a UE receiving the SL PRS transmission and is obtained
    - if the resource pool is a shared SL PRS resource pool, from a PSSCH DM-RS using a filter configuration provided by *sl-FilterCoefficient*
    - else, if the resource pool is a dedicated SL PRS resource pool, from a SL PRS using a filter configuration provided by *sl-FilterCoefficient*
- $M_{\mathrm{RB}}^{\mathrm{SL-PRS}}(i)$ is a number of resource blocks for the SL PRS transmission occasion i and μ is a SCS configuration for the SL PRS transmission

16.2.4 Prioritization of transmissions/receptions

16.2.4.1 Simultaneous NR and E-UTRA transmission/reception

If a UE

- would transmit a first channel/signal using E-UTRA radio access and second channels/signals using NR radio access, and
- a transmission of the first channel/signal would overlap in time with a transmission of the second channels/signals, and
- the priorities of the channels/signals are known to both E-UTRA radio access and NR radio access at the UE T msec prior to the start of the earliest of the two transmissions, where $T \leq 4$ and is based on UE implementation,

the UE transmits only the channels/signals of the radio access technology with the highest priority

- as determined by the SCI formats scheduling the transmissions, or
- as indicated by higher layers in case of a S-SS/PSBCH block or a sidelink synchronization signal using E-UTRA radio access, or
- as determined in clause 16.2.4.2 in case of PSFCH transmissions.

If a UE

- would respectively transmit or receive a first channel/signal using E-UTRA radio access and receive a second channel/signal or transmit second channels/signals using NR radio access, and
- a transmission or reception of the first channel/signal would respectively overlap in time with a reception of the second channel/signal or transmission of the second channels/signals, and
- the priorities of the channels/signals are known to both E-UTRA radio access and NR radio access at the UE T msec prior to the start of the earliest transmission or reception, where $T \leq 4$ and is based on UE implementation,

the UE transmits or receives the channels/signals of the radio access technology with the highest priority

- as determined by the SCI formats scheduling the transmissions, or
- as indicated by higher layers in case of a S-SS/PSBCH block or a sidelink synchronization signal using E-UTRA radio access, or
- as determined in clause 16.2.4.2 among PSFCH transmissions/receptions.

16.2.4.2 Simultaneous PSFCH transmission/reception

For a PSFCH transmission or reception with HARQ-ACK information, a priority value for the PSFCH is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH.

For PSFCH transmission with conflict information, a priority value for the PSFCH is equal to the smallest priority value determined by the corresponding SCI format(s) 1-A for the conflicting resource(s).

For PSFCH reception with conflict information, a priority value for the PSFCH is equal to the priority value determined by the corresponding SCI format 1-A for the conflicting resource.

If a UE

- would transmit $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and receive $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs, and
- transmissions of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs would overlap in time with receptions of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs

the UE transmits or receives only a set of PSFCHs corresponding to the smallest priority field value, as determined by a first set of SCI format 1-A and/or a second set of SCI format 1-A [5, TS 38.212] that are respectively associated with PSFCHs with HARQ-ACK information from the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and PSFCHs with HARQ-ACK information from the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs when one or more of the PSFCHs provide HARQ-ACK information. If none of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and none of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs provide HARQ-ACK information, the UE transmits or receives only a set of PSFCHs corresponding to the smallest priority value of the first set of PSFCHs and the second set of PSFCHs that are respectively associated with the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs when the PSFCHs provide conflict information.

If a UE would transmit $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs in a PSFCH transmission occasion, the UE first transmits PSFCHs with HARQ-ACK information from $N_{\mathrm{Tx,PSFCH}}$ PSFCHs corresponding to the smallest priority field values from the $N_{\mathrm{Tx,PSFCH}}$ priority field values, if any. Subsequently, the UE transmits remaining PSFCHs with conflict information corresponding to the smallest remaining priority field values from the $N_{\mathrm{Tx,PSFCH}}$ priority field values, if any.

For operation with shared spectrum channel access, if a UE does not support PSFCH transmission in non-contiguous RB sets, the UE selects for PSFCH transmission any contiguous RB set(s) that include PSFCH with the smallest priority value among the PSFCHs with HARQ-ACK information. If none of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and none of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs provide HARQ-ACK information, the UE selects for PSFCH transmission any contiguous RB sets that include PSFCH with the smallest priority value.

If a UE indicates a capability to receive $N_{\mathrm{Rx,PSFCH}}$ PSFCHs in a PSFCH reception occasion [18, TS 38.306], the UE first receives PSFCHs with HARQ-ACK information, if any, and subsequently receives PSFCHs with conflict information, if any.

16.2.4.3 Simultaneous SL and UL transmissions/receptions

If a UE

- would simultaneously transmit on the UL and on the SL in a carrier or in two respective carriers, and
- the UE is not capable of simultaneous transmissions on the UL and on the SL in the carrier or in the two respective carriers

the UE transmits only on the link, UL or SL, with the higher priority.

If a UE

- would simultaneously transmit on the UL and receive on the SL in a carrier, or
- would simultaneously transmit on the UL and receive on the SL in two respective carriers and the UE is not capable of simultaneous transmission on the UL and reception on the SL in the two respective carriers

the UE transmits on UL or receives on SL, with the higher priority.

If a UE

- is capable of simultaneous transmissions on the UL and on the SL in two respective carriers,

- would transmit on the UL and on the SL in the two respective carriers,
- the transmission on the UL would overlap with the transmission on the SL over a time period, and
- the total UE transmission power over the time period would exceed P_{CMAX}

the UE

- reduces the power for the UL transmission prior to the start of the UL transmission, if the SL transmission has higher priority than the UL transmission as determined in clause 16.2.4.3.1, so that the total UE transmission power would not exceed P_{CMAX}
- reduces the power for the SL transmission prior to the start of the SL transmission, if the UL transmission has higher priority than the SL transmission as determined in clause 16.2.4.3.1, so that the total UE transmission power would not exceed P_{CMAX}

16.2.4.3.1 Prioritizations for sidelink and uplink transmissions/receptions

A UE performs prioritization between SL transmissions/receptions and UL transmissions after performing the procedures described in clause 9, clause 9.2.5, and clause 9.2.6, and in clause 6.1 of [6, TS 38.214].

PSFCH transmissions in a slot, as determined in clause 16.2.4.2, have a same priority value as the smallest priority value among PSSCH receptions with corresponding HARQ-ACK information provided by the PSFCH transmissions in the slot, if any, and among PSFCH transmissions with conflict information in the slot, if any, where each priority value is equal to the smallest priority value determined by corresponding SCI formats 1-A as described in clause 16.3.

PSFCH receptions in a slot, as determined in clause 16.2.4.2, have a same priority value as the smallest priority value among PSSCH transmissions with corresponding HARQ-ACK information provided by the PSFCH receptions in the slot, if any, and among PSFCH receptions with conflict information in the slot, if any, where each priority value is equal to the priority value determined by corresponding SCI format 1-A as described in clause 16.3.

A priority of S-SS/PSBCH block transmission or reception is provided by *sl-SSB-PriorityNR*.

For prioritization between SL transmission or PSFCH/S-SS/PSBCH block reception and UL transmission other than a PRACH, or a PUSCH scheduled by an UL grant in a RAR and its retransmission, or a PUSCH corresponding to Type-2 random access procedure and its retransmission, or a PUCCH with sidelink HARQ-ACK information report

- if the UL transmission is for a PUSCH or for a PUCCH with priority index 1,
  - if *sl-PriorityThreshold-UL-URLLC* is provided
    - the SL transmission or reception has higher priority than the UL transmission if the priority value of the SL transmission or reception is smaller than *sl-PriorityThreshold-UL-URLLC*; otherwise, the UL transmission has higher priority than the SL transmission or reception
  - else
    - the UL transmission has higher priority than the SL transmission or reception
- else
  - the SL transmission or reception has higher priority than the UL transmission if the priority value of the SL transmission(s) or reception is smaller than *sl-PriorityThreshold*; otherwise, the UL transmission has higher priority than the SL transmission or reception

A PRACH transmission, or a PUSCH scheduled by an UL grant in a RAR and its retransmission, or a PUSCH for Type-2 random access procedure and its retransmission, or a PUCCH with HARQ-ACK information in response to successRAR, or a PUCCH indicated by a DCI format 1_0 with CRC scrambled by a corresponding TC-RNTI has higher priority than a SL transmission or reception.

A PUCCH transmission with a sidelink HARQ-ACK information report has higher priority than a SL transmission if a priority value of the PUCCH is smaller than a priority value of the SL transmission. The priority value of the PUCCH transmission is as described in clause 16.5. If the priority value of the PUCCH transmission is larger than the priority value of the SL transmission, the SL transmission has higher priority.

A PUCCH transmission with a sidelink HARQ-ACK information report has higher priority than a PSFCH/S-SS/PSBCH block reception if a priority value of the PUCCH is smaller than a priority value of the SL reception. If the priority value of the PUCCH transmission is larger than the priority value of the PSFCH/S-SS/PSBCH block reception, the SL reception has higher priority.

When one or more SL transmissions from a UE overlap in time with multiple non-overlapping UL transmissions from the UE, the UE performs the SL transmissions if at least one SL transmission is prioritized over all UL transmissions subject to the UE processing timeline with respect to the first SL transmission and the first UL transmission.

When one or more UL transmissions from a UE overlap in time with multiple non-overlapping SL transmissions, the UE performs the UL transmissions if at least one UL transmission is prioritized over all SL transmissions subject to the UE processing timeline with respect to the first SL transmission and the first UL transmission.

When one SL transmission overlaps in time with one or more overlapping UL transmissions, the UE performs the SL transmission if the SL transmission is prioritized over all UL transmissions subject to both the UE multiplexing and processing timelines with respect to the first SL transmission and the first UL transmission, where the UE processing timeline with respect to the first SL transmission and the first UL transmission is same as when one or more SL transmissions overlap in time with multiple non-overlapping UL transmissions.

When one SL transmission overlaps in time with one or more overlapping UL transmissions, the UE performs the UL transmission if at least one UL transmission is prioritized over the SL transmission subject to both the UE multiplexing and processing timelines with respect to the first SL transmission and the first UL transmission, where the UE processing timeline with respect to the first SL transmission and the first UL transmission is same as when one or more SL transmissions overlap in time with multiple non-overlapping UL transmissions.

16.2.5 SL Carrier Aggregation

If a UE is configured for sidelink operation on multiple carriers, the UE applies the synchronization procedures in Clause 16.1 on each of the multiple carriers [12, TS 38.331].

If a UE would transmit S-SS/PSBCH blocks on multiple carriers, the UE determines a power for each S-SS/PSBCH block transmission as described in Clause 16.2.0. If the UE would transmit S-SS/PSBCH blocks that would overlap in time on respective carriers and a total power for the transmissions of the S-SS/PSBCH blocks would exceed P_{CMAX} [8-1, TS 38.101-1], the UE autonomously reduces a power for one or more of the S-SS/PSBCH blocks transmissions so that a resulting total power would not exceed P_{CMAX}.

If a UE would transmit PSCCHs/PSSCHs on multiple carriers, the UE determines a power for each PSCCH/PSSCH transmission as described in Clauses 16.2.1 and 16.2.2, respectively. If the UE would transmit PSCCHs/PSSCHs that would overlap in time on respective carriers and a total power for the PSCCH/PSSCH transmissions would exceed P_{CMAX}, the UE reduces a power for a PSCCH/PSSCH transmission that has the largest priority value as determined by SCI formats provided by the PSCCHs scheduling the respective PSSCHs. If more than one PSCCH/PSSCH transmission have the largest priority value, the UE autonomously selects one of the more than one PSCCH/PSSCH transmissions to reduce a respective power. If, after the reduction of the power of the PSCCH/PSSCH transmission with the largest priority value, a total power exceeds P_{CMAX}, the UE drops the PSCCH/PSSCH transmission with the largest priority value, respectively, and repeats the procedure over the remaining PSCCH/PSSCH transmission(s).

If a UE would simultaneously transmit PSFCHs and receive PSFCHs on multiple carriers, the UE performs the procedures in Clause 16.2.4.2 by considering all the PSFCHs for transmission and all the PSFCHs for reception in order to determine either PSFCHs to transmit or PSFCHs to receive. If a UE would simultaneously transmit PSFCHs on multiple carriers, the UE performs the procedures for single carrier in Clause 16.2.3 by considering all the PSFCHs for transmission using a corresponding $N_{\mathrm{max,PSFCH}}$ and P_{CMAX} in order to determine PSFCHs to transmit and a corresponding power per PSFCH transmission, where P_{CMAX} is defined in Clause 6.2E.4A of [8-1, TS 38.101-1]. The UE expects to be provided a (pre)configuration such that the PSFCH transmissions on the multiple carriers are with time resource alignment and a same power.

A UE expects that *sl-StartSymbol*, *sl-LengthSymbols*, *cyclicPrefix*, and *subcarrierSpacing* are (pre)configured to have same respective values on multiple carriers.

16.3 UE procedure for reporting and obtaining control information in PSFCH

Control information provided by a PSFCH transmission includes HARQ-ACK information or conflict information.

16.3.0 UE procedure for transmitting PSFCH with control information

A UE can be indicated by an SCI format scheduling a PSSCH reception to transmit a PSFCH with HARQ-ACK information in response to the PSSCH reception. The UE provides HARQ-ACK information that includes ACK or NACK, or only NACK.

A UE can be provided, by *sl-PSFCH-Period*, a number of slots in a resource pool for a period of PSFCH transmission occasion resources. If the number is zero, PSFCH transmissions from the UE in the resource pool are disabled.

A UE can be enabled, by *sl-InterUE-CoordinationScheme2*, to transmit a PSFCH with conflict information in a resource pool. The UE can determine, based on an indication by a SCI format 1-A, a set of resources that includes one or more slots and resource blocks that are reserved for PSSCH transmission. If the UE determines a conflict for a reserved resource for PSSCH transmission, the UE provides conflict information in a PSFCH.

A UE expects that a slot t'^{SL}_k $(0 \le k < T'_{max})$ has a PSFCH transmission occasion resource if $k \bmod N_{\text{PSSCH}}^{\text{PSFCH}} = 0$, where t'^{SL}_k is defined in [6, TS 38.214], T'_{max} is a number of slots that belong to the resource pool within 10240 msec according to [6, TS 38.214], and $N_{\text{PSSCH}}^{\text{PSFCH}}$ is provided by *sl-PSFCH-Period*.

A UE may be indicated by higher layers to not transmit a PSFCH that includes HARQ-ACK information in response to a PSSCH reception [11, TS 38.321].

If a UE receives a PSSCH in a resource pool and the HARQ feedback enabled/disabled indicator field in an associated SCI format 2-A/2-B/2-C has value 1 [5, TS 38.212], the UE provides the HARQ-ACK information in a PSFCH transmission in the resource pool. For operation without shared spectrum channel access, the UE transmits the PSFCH in a first slot that includes PSFCH resources and is at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of the PSSCH reception. For operation with shared spectrum channel access, the UE can attempt to transmit the PSFCH over a number of first $N_{\text{occasion}}^{\text{PSFCH}}$ slots, provided by *sl-NumPSFCH-Occasions* and indexed from 1 to $N_{\text{occasion}}^{\text{PSFCH}}$ in ascending order in time, that include PSFCH resources and are at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of the PSSCH reception. The UE attempts to transmit PSFCH in a slot only when the UE fails to transmit PSFCH associated with the PSSCH in all previous slots for PSFCH within the $N_{\text{occasion}}^{\text{PSFCH}}$ slots.

For operation without shared spectrum channel access, a UE is provided by *sl-PSFCH-RB-Set* a set of $M_{\text{PRB, set}}^{\text{PSFCH}}$ PRBs in a resource pool for PSFCH transmission with HARQ-ACK information in a PRB of the resource pool. A UE can be provided by *sl-RB-SetPSFCH* a set of $M_{\text{PRB, set}}^{\text{PSFCH}}$ PRBs in a resource pool for PSFCH transmission with conflict information in a PRB of the resource pool. A UE expects that different PRBs are (pre)configured for conflict information and HARQ-ACK information. For a number of N_{subch} sub-channels for the resource pool, provided by *sl-NumSubchannel*, and a number of PSSCH slots associated with a PSFCH slot that is less than or equal to $N_{\text{PSSCH}}^{\text{PSFCH}}$, the UE allocates the $\left[\left(i + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot}}^{\text{PSFCH}}, \left(i + 1 + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot}}^{\text{PSFCH}} - 1\right]$ PRBs from the $M_{\text{PRB, set}}^{\text{PSFCH}}$ PRBs to slot i among the PSSCH slots associated with the PSFCH slot and sub-channel j, where $M_{\text{subch, slot}}^{\text{PSFCH}} = M_{\text{PRB, set}}^{\text{PSFCH}} / \left(N_{\text{subch}} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right)$, $0 \le i < N_{\text{PSSCH}}^{\text{PSFCH}}$, $0 \le j < N_{\text{subch}}$, and the allocation starts in an ascending order of i and continues in an ascending order of j. The UE expects that $M_{\text{PRB, set}}^{\text{PSFCH}}$ is a multiple of $N_{\text{subch}} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}$.

For operation with shared spectrum channel access, when *sl-TransmissionStructureForPSFCH* is not provided and within RB-set k, for the n-th candidate PSFCH transmission occasion, $1 \le n \le N_{\text{occasion}}^{\text{PSFCH}}$, a UE determines a set of $M_{\text{PRB, set},k}^{\text{PSFCH},n}$ PRBs in a resource pool based on the n-th indication provided by *sl-PSFCH-RB-SetList* or *sl-IUC-RB-SetList* for PSFCH transmission with HARQ-ACK information or conflict information, respectively. The UE expects that different PRBs are (pre)configured for conflict information and HARQ-ACK information. For a number of N_{subch}^{k} sub-channels in RB-set k and a number of PSSCH slots associated with a PSFCH slot that is less than or equal to $N_{\text{PSSCH}}^{\text{PSFCH}}$, the UE allocates the $\left[\left(i + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n}, \left(i + 1 + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n} - 1\right]$ PRBs from the $M_{\text{PRB, set},k}^{\text{PSFCH},n}$ PRBs to slot i among the PSSCH slots associated with the PSFCH slot and sub-channel j, where $M_{\text{subch, slot},k}^{\text{PSFCH},n} = M_{\text{PRB, set},k}^{\text{PSFCH},n} / \left(N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right)$, $0 \le i < N_{\text{PSSCH}}^{\text{PSFCH}}$, $0 \le j < N_{\text{subch}}^{k}$, and the allocation starts in an ascending order of i and continues in an ascending order of j. The UE expects that $M_{\text{PRB, set},k}^{\text{PSFCH},n}$ is a multiple of $N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}$.

For operation with shared spectrum channel access, when *sl-TransmissionStructureForPSFCH* = ' dedicatedInterlace ' and within RB-set k, a UE determines, based on *sl-PSFCH-RB-SetList*, all PRBs of an interlace for one PSFCH transmission with HARQ-ACK information in the resource pool. Within RB-set k, the UE determines, based on *sl-IUC-RB-SetList*, all PRBs of an interlace for one PSFCH transmission with conflict information in the resource pool. For the n-th candidate PSFCH transmission occasion, $1 \le n \le N_{\text{occasion}}^{\text{PSFCH}}$, the UE determines a set of interlaces that includes a number $M_{\text{interlace},k}^{\text{PSFCH},n}$ of interlaces based on the n-th indication provided by *sl-PSFCH-RB-SetList* or *sl-IUC-RB-SetList* for HARQ-ACK information or conflict information, respectively. The UE expects that different interlaces are determined for conflict information and HARQ-ACK information. The set of interlaces are indexed in an ascending order of interlace indexes. For each interlace of the set of interlaces, all PRBs in the interlace are available for PSFCH transmission. For a number of N_{subch}^{k} sub-channels in RB-set k and a number of PSSCH slots that is not larger than $N_{\text{PSSCH}}^{\text{PSFCH}}$ and is associated with a slot for PSFCH transmission, the UE allocates the $\left[\left(i + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n}, \left(i + 1 + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n} - 1\right]$ interlaces from the $M_{\text{interlace},k}^{\text{PSFCH},n}$ interlaces to slot i and sub-channel j, where $M_{\text{subch, slot},k}^{\text{PSFCH},n} = M_{\text{interlace},k}^{\text{PSFCH},n} / \left(N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right)$, $0 \le i < N_{\text{PSSCH}}^{\text{PSFCH}}$, $0 \le j < N_{\text{subch}}^{k}$. The allocation starts in an ascending order of i and continues in an ascending order of j. The UE expects that $M_{\text{interlace},k}^{\text{PSFCH},n}$ is a multiple of $N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}$.

For operation with shared spectrum channel access, when *sl-TransmissionStructureForPSFCH* = ' commonInterlace' and within RB-set k, a UE determines a subset of PRBs in a first interlace and, based on *sl-PSFCH-RB-SetList*, a subset of $N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$ PRBs in a second interlace for a PSFCH transmission with HARQ-ACK information in a resource pool, or based on *sl-IUC-RB-SetList*, a subset of $N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$ PRBs in a second interlace for a PSFCH transmission with conflict information in a resource pool. An index of the first interlace is provided by *sl-PSFCH-CommonInterlaceIndex*. The $N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$ PRBs in the second interlace are provided by *sl-NumDedicatedPRBs-ForPSFCH* where, for the n-th candidate PSFCH transmission occasion, $1 \le n \le N_{\text{occasion}}^{\text{PSFCH}}$, and for each interlace l, the UE determines $M_{\text{PRB},k,l}^{\text{PSFCH},n}$ PRBs based on the n-th indication provided by *sl-PSFCH-RB-SetList* or *sl-IUC-RB-SetList* for HARQ-ACK information or conflict information, respectively. The UE expects that different subsets of $N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$ PRBs are determined for conflict information and HARQ-ACK information. The UE expects that $M_{\text{PRB},k,l}^{\text{PSFCH},n}$ is a multiple of $N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$. For interlace l, the UE determines a PRB subset with index s to include PRBs $\left\{N_{\mathbf{PRB}}^{\mathbf{PSFCH}} \cdot s, N_{\mathbf{PRB}}^{\mathbf{PSFCH}} \cdot s + 1, \ldots, N_{\mathbf{PRB}}^{\mathbf{PSFCH}} \cdot (s+1) - 1\right\}$, $0 \le s \le M_{\text{PRB},k,l}^{\text{PSFCH},n} / N_{\mathbf{PRB}}^{\mathbf{PSFCH}} - 1$. The UE determines the $M_{\text{subset},k}^{\text{PSFCH},n}$ PRB subsets by ordering the PRB subsets first in an ascending order of PRB subset index within an interlace and second in ascending order of interlace index, where $M_{\text{subset},k}^{\text{PSFCH},n} = \sum_{l} M_{\text{PRB},k,l}^{\text{PSFCH},n} / N_{\mathbf{PRB}}^{\mathbf{PSFCH}}$. For a number of N_{subch}^{k} sub-channels in RB-set k and a number of slots for PSSCH transmissions that is not larger than $N_{\text{PSSCH}}^{\text{PSFCH}}$ and is associated with a slot for PSFCH transmission, the UE allocates the $\left\{\left(i + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n}, \left(i + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n} + 1, \ldots, \left(i + 1 + j \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right) \cdot M_{\text{subch, slot},k}^{\text{PSFCH},n} - 1\right\}$ PRB subsets from the $M_{\text{subset},k}^{\text{PSFCH},n}$ PRB subsets to slot i among the slots for PSSCH transmissions that are associated with the slot and sub-channel j for PSFCH transmissions, where $M_{\text{subch, slot},k}^{\text{PSFCH},n} = M_{\text{subset},k}^{\text{PSFCH},n} / \left(N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}\right)$ and $0 \le i < N_{\text{PSSCH}}^{\text{PSFCH}}$, $0 \le j < N_{\text{subch}}^{k}$. The allocation starts in an ascending order of i and continues in an ascending order of j. The UE expects that $M_{\text{subset},k}^{\text{PSFCH},n}$ is a multiple of $N_{\text{subch}}^{k} \cdot N_{\text{PSSCH}}^{\text{PSFCH}}$.

The second OFDM symbol l' of PSFCH transmission in a slot is defined as $l' = \mathit{sl\text{-}StartSymbol} + \mathit{sl\text{-}LengthSymbols} - 2$.

For operation without shared spectrum channel access, a UE determines a number of PSFCH resources available for multiplexing HARQ-ACK or conflict information in a PSFCH transmission as $R_{\text{PRB, CS}}^{\text{PSFCH}} = N_{\text{type}}^{\text{PSFCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}} \cdot N_{\text{CS}}^{\text{PSFCH}}$ where $N_{\text{CS}}^{\text{PSFCH}}$ is a number of cyclic shift pairs for the resource pool provided by *sl-NumMuxCS-Pair* and, based on an indication by *sl-PSFCH-CandidateResourceType*,

- if *sl-PSFCH-CandidateResourceType* is configured as *startSubCH*, $N_{\text{type}}^{\text{PSFCH}} = 1$ and the $M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs are associated with the starting sub-channel of the corresponding PSSCH
- if *sl-PSFCH-CandidateResourceType* is configured as *allocSubCH*, $N_{\text{type}}^{\text{PSFCH}} = N_{\text{subch}}^{\text{PSSCH}}$ and the $N_{\text{subch}}^{\text{PSSCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs are associated with the $N_{\text{subch}}^{\text{PSSCH}}$ sub-channels of the corresponding PSSCH
- for conflict information, the corresponding PSSCH is determined based on *sl-PSFCH-Occasion*

The PSFCH resources are first indexed according to an ascending order of the PRB index, from the $N_{\text{type}}^{\text{PSFCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs, and then according to an ascending order of the cyclic shift pair index from the $N_{\text{CS}}^{\text{PSFCH}}$ cyclic shift pairs.

For operation with shared spectrum channel access and for the n-th candidate PSFCH transmission occasion, a UE determines a number of PSFCH resources available for multiplexing HARQ-ACK or conflict information in a PSFCH transmission as $R_{\text{PRB, CS}}^{\text{PSFCH}} = N_{\text{type}}^{\text{PSFCH}} \cdot M \cdot N_{\text{CS}}^{\text{PSFCH}}$ where $N_{\text{CS}}^{\text{PSFCH}}$ is a number of cyclic shift pairs for the resource pool provided by *sl-NumMuxCS-Pair* and, based on an indication by *sl-PSFCH-CandidateResourceType*

- if *sl-PSFCH-CandidateResourceType* is indicated as *startSubCH*, $N_{\text{type}}^{\text{PSFCH}} = 1$, $M = M_{\text{subch, slot},k}^{\text{PSFCH},n}$, and the $N_{\text{type}}^{\text{PSFCH}} \cdot M$ interlaces or PRB subsets are associated with the lowest sub-channel index within the RB-set with smallest index of the corresponding PSSCH
- if *sl-PSFCH-CandidateResourceType* is indicated as *allocSubCH*, $N_{\text{type}}^{\text{PSFCH}} = N_{\text{subch}}^{\text{PSSCH}}$ and $M = \sum_k M_{\text{subch, slot},k}^{\text{PSFCH},n}$ where the sum is over all RB-sets including resources for the corresponding PSSCH, and the $N_{\text{type}}^{\text{PSFCH}} \cdot M$ combinations of interlaces and RB-sets or PRB subsets are associated with the $N_{\text{subch}}^{\text{PSSCH}}$ sub-channels of the corresponding PSSCH
- for conflict information, the corresponding PSSCH is determined based on *sl-PSFCH-Occasion*

The PSFCH resources are first indexed according to an ascending order of the interlace or PRB subset index, second according to an ascending order of the RB-set index, and then according to an ascending order of the cyclic shift pair index from the $N_{\text{CS}}^{\text{PSFCH}}$ cyclic shift pairs. The UE applies CP extension to the first symbol of a PSFCH and within the first one or two symbols before the first symbol of the PSFCH according to an index [4, TS 38.211] provided by *sl-CPE-StartingPositionPSFCH*.

A UE determines an index of a PSFCH resource for a PSFCH transmission with HARQ-ACK information in response to a PSSCH reception or with conflict information corresponding to a reserved resource as $(P_{\text{ID}} + M_{\text{ID}}) mod R_{\text{PRB, CS}}^{\text{PSFCH}}$ where P_{ID} is a physical layer source ID provided by SCI format 2-A/2-B/2-C [5, TS 38.212] scheduling the PSSCH reception, or by SCI format 2-A/2-B/2-C with corresponding SCI format 1-A reserving the resource from another UE to be provided with the conflict information. For HARQ-ACK information, M_{ID} is the identity of the UE receiving the PSSCH as indicated by higher layers if the UE detects a SCI format 2-A with Cast type indicator field value of "01"; otherwise, M_{ID} is zero. For conflict information, M_{ID} is zero.

For operation with shared spectrum channel access, when *sl-TransmissionStructureForPSFCH* = 'commonInterlace', a PRB s_1 in the first interlace is excluded from the resources for a PSFCH transmission, if $|s_1 - s_2| \leq 5$ for $\mu = 0$ or $|s_1 - s_2| \leq 2$ for $\mu = 1$ for any PRB s_2 in the PRB subset when the PRB subset is selected for PSFCH transmission, and $(s_{\text{high}} - s_{\text{low}}) \geq 88$ for $\mu = 0$ or $(s_{\text{high}} - s_{\text{low}}) \geq 44$ for $\mu = 1$, where PRB s_{high} and PRB s_{low} are the largest and smallest PRB indexes, respectively, in the resources for the PSFCH transmission assuming PRB s_1 is excluded.

For a PSFCH transmission with HARQ-ACK information or conflict information, a UE determines a m_0 value, for computing a value of cyclic shift α [4, TS 38.211], from a cyclic shift pair index corresponding to a PSFCH resource index and from $N_{\text{CS}}^{\text{PSFCH}}$ using Table 16.3-1.

Table 16.3-1: Set of cyclic shift pairs

$N_{\text{CS}}^{\text{PSFCH}}$	m_0					
	Cyclic Shift Pair Index 0	**Cyclic Shift Pair Index 1**	**Cyclic Shift Pair Index 2**	**Cyclic Shift Pair Index 3**	**Cyclic Shift Pair Index 4**	**Cyclic Shift Pair Index 5**
1	0	-	-	-	-	-
2	0	3	-	-	-	-
3	0	2	4	-	-	-
6	0	1	2	3	4	5

For a PSFCH transmission with HARQ-ACK information, a UE determines a m_{cs} value, for computing a value of cyclic shift α [4, TS 38.211], as in Table 16.3-2 if the UE detects a SCI format 2-A with Cast type indicator field value of "01" or "10" or a SCI format 2-C, or as in Table 16.3-3 if the UE detects a SCI format 2-B or a SCI format 2-A with Cast type indicator field value of "11". For a PSFCH transmission with conflict information, a UE determines a m_{cs} value for computing a value of cyclic shift α [4, TS 38.211] as in Table 16.3-4. The UE applies one cyclic shift from a cyclic shift pair to a sequence used for the PSFCH transmission [4, TS 38.211].

Table 16.3-2: Mapping of HARQ-ACK information bit values to a cyclic shift, from a cyclic shift pair, of a sequence for a PSFCH transmission when HARQ-ACK information includes ACK or NACK

HARQ-ACK Value	0 (NACK)	1 (ACK)
Sequence cyclic shift	0	6

Table 16.3-3: Mapping of HARQ-ACK information bit values to a cyclic shift, from a cyclic shift pair, of a sequence for a PSFCH transmission when HARQ-ACK information includes only NACK

HARQ-ACK Value	0 (NACK)	1 (ACK)
Sequence cyclic shift	0	N/A

Table 16.3-4: Mapping of conflict information bit values to a cyclic shift, from a cyclic shift pair, of a sequence for a PSFCH transmission

Conflict information	Conflict information for a next in time reserved resource indicated in SCI
Sequence cyclic shift	0

A first UE determines a second UE for providing the conflict information to in a PSFCH as follows

- if the first UE is an intended receiver of the second UE for a reserved resource of a PSSCH transmission in a slot,
- does not expect to perform reception on the sidelink due to half-duplex operation in the slot,
- the PSFCH occasion for resource conflict information of the second UE is not passed,
- the conflict information receiver flag in SCI format 1-A from the second UE is set to 1, if *sl-IndicationUE-B* = 'enabled', and
- determines to transmit to the second UE the PSFCH with the conflict information.

A first UE determines a UE for providing the conflict information to in a PSFCH as follows

- if, for a resource pool, *sl-TypeUE-A* is not provided, the first UE has been indicated a first reserved resource and a second reserved resource as resources for PSSCH reception or, if for a resource pool *sl-TypeUE-A* is provided, has been indicated at least the first reserved resource or the second reserved resource for PSSCH reception,
- detects a first SCI format 1-A that includes a first priority value, p_1, and the first reserved resource for PSSCH transmission from a second UE,
- detects a second SCI format 1-A that includes a second priority value, $p_2 < p_1$, and the second reserved resource for PSSCH transmission from a third UE, and
- determines that the first and second resources overlap in time and frequency
- the PSFCH occasions for resource conflict information of the second UE and the third UE are not passed
- the conflict information receiver flag in SCI Format 1-A from the second UE and the third UE is set to 1, if *sl-IndicationUE-B* = 'enabled'
- determines the first SCI format 1-A and the second SCI format 1-A are not received later than *sl-MinTimeGapPSFCH* before the PSFCH occasion for conflict information
- determines to transmit to the second UE the PSFCH with the conflict information
- determines to transmit to either the second UE or the third UE the PSFCH with the conflict information, if $p_2 = p_1$

The first UE can be provided conditions by *sl-OptionForCondition2-A-1* to determine conflict of reserved resources in a resource pool

- if *sl-OptionForCondition2-A-1* = '0', the first UE can be provided by, *sl-Thres-RSRP-List* $Th\left(p_i, p_j\right)$, a list of RSRP thresholds for each priority combination $\left(p_i, p_j\right)$ [6, TS 38.214]
  - if the first UE is an intended receiver for PSSCH in a reserved resource of the second UE, the first UE determines a resource conflict if the RSRP [6, TS 38.214] of the third UE is above a threshold $Th(p_2, p_1)$
  - if the first UE is an intended receiver for PSSCH in a reserved resource of the third UE, the first UE determines a resource conflict if the RSRP of the second UE is above a threshold $Th(p_1, p_2)$
- if *sl-OptionForCondition2-A-1* = '1', the first UE can be provided a value $deltaRSRPThresh$ by *sl-DeltaRSRP-Thresh*
  - if the first UE is an intended receiver for PSSCH in a reserved resource of the second UE, the first UE determines a resource conflict if $RSRP_2 > RSRP_1 + deltaRSRPThresh$, where $RSRP_1$ and $RSRP_2$ are the RSRP measurements from the first UE for the second UE and the third UE, respectively
  - if the first UE is an intended receiver for PSSCH in a reserved resource of the third UE, the first UE determines a resource conflict if $RSRP_1 > RSRP_2 + deltaRSRPThresh$

If a UE transmits a PSFCH with conflict information corresponding to a reserved resource indicated in an SCI format 1-A, the UE transmits the PSFCH in the resource pool in a slot determined based on *sl-PSFCH-Occasion*

- If *sl-PSFCH-Occasion* = '0',
  - for operation without shared spectrum channel access, the UE transmits the PSFCH in a first slot that includes PSFCH resources and is at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a slot of a PSCCH reception that provides the SCI format 1-A. The PSFCH resource is in a slot that is at least T_3 slots [6, TS 38.214] before the resource associated with the conflict information; otherwise, the UE does not transmit the PSFCH with conflict information.
  - for operation with shared spectrum channel access, the UE can attempt to transmit the PSFCH over a number of first $N_{\text{occasion}}^{\text{PSFCH}}$ slots, provided by *sl-NumPSFCH-Occasions* and indexed from 1 to $N_{\text{occasion}}^{\text{PSFCH}}$ in ascending order in time, that include PSFCH resources and are at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of a PSCCH reception that provides the SCI format 1-A. If the PSFCH resource is in a slot within the $N_{\text{occasion}}^{\text{PSFCH}}$ slots that is at least T_3 slots before the resource associated with conflict information, the UE can attempt to transmit the PSFCH with conflict information in the slot; otherwise, the UE does not transmit the PSFCH with conflict information in the slot.
- If *sl-PSFCH-Occasion* = '1',
  - for operation without shared spectrum channel access, the UE transmits the PSFCH in a latest slot that includes PSFCH resources and is at least T_3 slots of the resource pool before a slot of the resource associated with conflict information. The PSFCH resource is in a slot that is at least *sl-MinTimeGapPSFCH* slots after a slot of a PSCCH reception that provides the SCI format 1-A; otherwise, the UE does not transmit the PSFCH with conflict information.
  - for operation with shared spectrum channel access, the UE can attempt to transmit the PSFCH over a latest number of $N_{\text{occasion}}^{\text{PSFCH}}$ slots, provided by *sl-NumPSFCH-Occasions* and indexed from 1 to $N_{\text{occasion}}^{\text{PSFCH}}$ in ascending order in time, that include PSFCH resources and are at least T_3 slots of the resource pool before a slot of the resource associated with conflict information. If the PSFCH resource is in a slot that is at least *sl-MinTimeGapPSFCH* slots after a slot of a PSCCH reception that provides the SCI format 1-A, the UE can attempt to transmit the PSFCH with conflict information in the slot; otherwise, the UE does not transmit the PSFCH with conflict information in the slot.

16.3.1 UE procedure for receiving PSFCH with control information

A UE that transmitted a PSSCH scheduled by a SCI format 2-A/2-B/2-C that indicates HARQ feedback enabled, attempts to receive associated PSFCHs with HARQ-ACK information according to PSFCH resources determined as described in clause 16.3.0. The UE determines an ACK or a NACK value for HARQ-ACK information provided in each PSFCH resource as described in [8-4, TS 38.101-4]. The UE does not determine both an ACK value and a NACK value at a same time for a PSFCH resource.

For each PSFCH reception occasion, from a number of PSFCH reception occasions, the UE generates HARQ-ACK information to report to higher layers. For operation with shared spectrum channel access, the UE attempts to receive PSFCH on $N_{\text{occasion}}^{\text{PSFCH}}$ PSFCH occasion(s), as described in clause 16.3.0, until the UE detects one PSFCH from each UE expected to transmit a PSFCH, or the UE attempts to receive PSFCH on all the $N_{\text{occasion}}^{\text{PSFCH}}$ PSFCH occasion(s). For generating the HARQ-ACK information, the UE can be indicated by a SCI format to perform one of the following

- if the UE receives a PSFCH associated with a SCI format 2-A with Cast type indicator field value of "10" or a SCI format 2-C
  - report to higher layers HARQ-ACK information with same value as a value of HARQ-ACK information that the UE determines from the PSFCH reception for operation without shared spectrum channel access, or from the PSFCH reception(s) on $N_{\text{occasion}}^{\text{PSFCH}}$ PSFCH reception occasion(s), as described in clause 16.3.0, for operation with shared spectrum channel access
- if the UE receives a PSFCH associated with a SCI format 2-A with Cast type indicator field value of "01"
  - report an ACK value to higher layers if the UE determines an ACK value from at least one PSFCH reception occasion from the number of PSFCH reception occasions in PSFCH resources corresponding to every identity M_{ID} of UEs that the UE expects to receive corresponding PSSCHs as described in clause 16.3; otherwise, report a NACK value to higher layers
- if the PSFCH reception occasion is associated with a SCI format 2-B or a SCI format 2-A with Cast type indicator field value of "11"
  - report to higher layers an ACK value if the UE determines absence of PSFCH reception for the PSFCH reception occasion; otherwise, report a NACK value to higher layers

A UE that transmitted SCI format 1-A, indicating one or more reserved resources in a resource pool enabled by *sl-InterUE-CoordinationScheme2*, attempts to receive associated PSFCH with conflict information in the resource pool with PSFCH resources that the UE determines as described in clause 16.3.0. If the UE determines presence of a resource conflict based on conflict information in a PSFCH reception, the UE reports the resource conflict to higher layers

- if *sl-SlotLevelResourceExclusion* is not provided, the UE reports resources overlapping with a next in time reserved resource indicated by the SCI format 1-A
- if *sl-SlotLevelResourceExclusion* is provided, the UE reports resources in a slot of a next in time reserved resource indicated by the SCI format 1-A

If a UE receives a PSFCH with conflict information corresponding to a reserved resource indicated in an SCI format 1-A, the UE receives the PSFCH in the resource pool in a slot determined based on *sl-PSFCH-Occasion*

- if sl-PSFCH-Occasion = '0',
  - for operation without shared spectrum channel access, the UE receives the PSFCH in a first slot that includes PSFCH resources and is at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a slot of a PSCCH transmission that provides the SCI format 1-A. The PSFCH resource is in a slot that is at least T_3 slots [6, TS 38.214] before the resource associated with the conflict information; otherwise, the UE does not receive the PSFCH with conflict information
  - for operation with shared spectrum channel access, the UE attempts to receive the PSFCH on a number of first $N_{\text{occasion}}^{\text{PSFCH}}$ slots, provided by *sl-NumPSFCH-Occasions* and indexed from 1 to $N_{\text{occasion}}^{\text{PSFCH}}$ in ascending order in time, that include PSFCH resources and are at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of a PSCCH reception that provides the SCI format 1-A, until the UE detects one PSFCH with conflict information, or the UE attempts to receive PSFCH on all $N_{\text{occasion}}^{\text{PSFCH}}$ PSFCH occasions. If the PSFCH resource is in a slot that is at least T_3 slots before the resource associated with the conflict information, the UE can attempt to receive the PSFCH with conflict information in the slot; otherwise, the UE does not receive the PSFCH with conflict information in the slot
- if sl-PSFCH-Occasion = '1',
  - for operation without shared spectrum channel access, the UE receives the PSFCH in a latest slot that includes PSFCH resources and is at least T_3 slots of the resource pool before a slot of the resource associated with conflict information. The PSFCH resource is in a slot that is at least *sl-MinTimeGapPSFCH* slots after a

slot of a PSCCH transmission that provides the SCI format 1-A; otherwise, the UE does not receive the PSFCH with conflict information

- for operation with shared spectrum channel access, the UE attempts to receive the PSFCH on a number of latest $N_{\text{occasion}}^{\text{PSFCH}}$ slots, provided by *sl-NumPSFCH-Occasions* and indexed from 1 to $N_{\text{occasion}}^{\text{PSFCH}}$ in ascending order in time, that include PSFCH resources and are at least T_3 slots of the resource pool before a slot of the resource associated with conflict information, until the UE detects one PSFCH with conflict information, or the UE attempts to receive PSFCH on all $N_{\text{occasion}}^{\text{PSFCH}}$ PSFCH occasions. If the PSFCH resource is in a slot that is at least *sl-MinTimeGapPSFCH* slots after a slot of a PSCCH transmission that provides the SCI format 1-A, the UE can attempt to receive the PSFCH with conflict information in the slot; otherwise, the UE does not receive the PSFCH with conflict information in the slot.

16.4 UE procedure for transmitting PSCCH

A UE can be provided a number of symbols in a resource pool, by *sl-TimeResourcePSCCH*, starting from

- *startingSymbolFirst*+1 or *startingSymbolSecond*+1 in a slot without PSFCH symbols, or *startingSymbolFirst*+1 in a slot with PSFCH symbols, if *startingSymbolFirst* and *startingSymbolSecond* are provided for the SL-BWP
- *sl-StartSymbol*+1, otherwise

and a number of PRBs in the resource pool, by *sl-FreqResourcePSCCH*, starting from the lowest PRB index of the lowest sub-channel index, in an RB-set with a lowest index if applicable, of the associated PSSCH for a PSCCH transmission with a SCI format 1-A. For operation with shared spectrum channel access,

- if *sl-TransmissionStructureForPSCCHandPSSCH* = *'interlaceRB'*, the PRBs for PSCCH are within the sub-channel with the lowest index and within the RB-set with the lowest index among the RB-set(s) for the associated PSSCH transmission,
- if *sl-TransmissionStructureForPSCCHandPSSCH* = *'contiguousRB'*, the PRBs for PSCCH are within the sub-channel with the lowest index in the RB-set with the lowest index among the RB-set(s) for the associated PSSCH transmission, and all PRBs in the sub-channel overlapping with intra-cell guard band [6, TS 38.214] are not used for PSCCH.

A UE that transmits a PSCCH with SCI format 1-A using sidelink resource allocation mode 2 [6, TS 38.214] sets

- "Resource reservation period" as an index in *sl-ResourceReservePeriodList* corresponding to a reservation period provided by higher layers [11, TS 38.321], if the UE is provided *sl-MultiReserveResource*
- the values of the frequency resource assignment field and the time resource assignment field as described in [6, TS 38.214] to indicate N resources from a set $\{R_{\text{y}}\}$ of resources selected by higher layers as described in [11, TS 38.321] with N smallest slot indices y_i for $0 \le i \le N-1$ such that $y_0 < y_1 < \cdots < y_{N-1} \le y_0 + 31$, where:
  - $N = \min(N_{\text{selected}}, N_{\text{max\_reserve}})$, where N_{selected} is a number of resources in the set $\{R_{\text{y}}\}$ with slot indices y_j, $0 \le j \le N_{\text{selected}} - 1$, such that $y_0 < y_1 < \cdots < y_{N_{\text{selected}}-1} \le y_0 + 31$, and $N_{\text{max\_reserve}}$ is provided by *sl-MaxNumPerReserve*
  - each resource, from the set of $\{R_{\text{y}}\}$ resources, corresponds to L_{subCH} contiguous sub-channels and a slot in a set of slots $\{t'^{SL}_y\}$, where L_{subCH} is the number of sub-channels available for PSSCH/PSCCH transmission in a slot
  - $\left(t'^{SL}_0, t'^{SL}_1, t'^{SL}_2, \ldots\right)$ is a set of slots in a sidelink resource pool [6, TS 38.214]
  - y_0 is an index of a slot where the PSCCH with SCI format 1-A is transmitted.

A UE that transmits a PSCCH with SCI format 1-A using sidelink resource allocation mode 1 [6, TS 38.214] sets

- the values of the frequency resource assignment field and the time resource assignment field for the SCI format 1-A transmitted in the m-th resource for PSCCH/PSSCH transmission provided by a dynamic grant or by a SL configured grant, where $m = \{1, \ldots, M\}$ and M is the total number of resources for PSCCH/PSSCH transmission provided by a dynamic grant or the number of resources for PSCCH/PSSCH transmission in a period provided by a SL configured grant type 1 or SL configured grant type 2, as follows:

- the frequency resource assignment field and time resource assignment field indicate the m-th to M-th resources as described in [6, TS 38.214].

For decoding of a SCI format 1-A, a UE may assume that a number of bits provided by *sl-NumReservedBits* can have any value as described in [4, TS 38.212].

16.4A UE procedure for transmitting PSCCH in dedicated SL PRS resource pool

For a dedicated SL PRS resource pool, a UE can be provided a number of symbols in the resource pool, by *timeResourcePSCCH-DedicatedSL-PRS-RP*, starting from a second symbol that is available for SL transmissions in a slot, and a number of PRBs in the resource pool, by *freqResourcePSCCH-DedicatedSL-PRS-RP*, starting from a PRB with lowest index for a sub-channel determined according to an index of an associated SL PRS resource, for a PSCCH transmission with a SCI format 1-B.

A UE that transmits a PSCCH with SCI format 1-B using SL PRS resource allocation mode 2 [6, TS 38.214] sets

- "Source ID" as indicated by higher layers
- "Destination ID" as indicated by high layers
- "Cast type indicator" as indicated by higher layers
- "Resource reservation period" as an index in *sl-PRS-ResourceReservePeriodList* corresponding to a reservation period provided by higher layers [11, TS 38.321], if the UE is provided *sl-MultiReserveResource*
- the values of the time resource assignment field and of the resource ID indication field as described in [6, TS 38.214] to indicate N resources from a set $\{R_{\mathrm{y}}\}$ of resources selected by higher layers as described in [11, TS 38.321] with N smallest slot indices y_i for $0 \le i \le N-1$ such that $y_0 < y_1 < \cdots < y_{N-1} \le y_0 + 31$, where:
  - $N = \min(N_{\mathrm{selected}}, N_{\mathrm{max\_reserve}})$, where N_{selected} is a number of resources in the set $\{R_{\mathrm{y}}\}$ with slot indices y_j, $0 \le j \le N_{\mathrm{selected}} - 1$, such that $y_0 < y_1 < \cdots < y_{N_{\mathrm{selected}}-1} \le y_0 + 31$, and $N_{\mathrm{max\_reserve}}$ is provided by *sl-MaxNumPerReserveDedicatedSL-PRS-RP*
  - each resource, from the set of $\{R_{\mathrm{y}}\}$ resources, corresponds to a SL PRS resource and the corresponding PSCCH, and a slot in a set of slots $\{t'^{SL}_{y}\}$
  - $(t'^{SL}_0, t'^{SL}_1, t'^{SL}_2, \ldots)$ is a set of slots in a sidelink resource pool [6, TS 38.214]
  - y_0 is an index of a slot where the PSCCH with SCI format 1-B is transmitted.
- "SL PRS request" as indicated by higher layers

A UE that transmits a PSCCH with SCI format 1-B using SL PRS resource allocation mode 1 [6, TS 38.214] sets

- "Source ID" as indicated by higher layers
- "Destination ID" as indicated by high layers
- "Cast type indicator" as indicated by higher layers
- the values of the resource ID indication field and the time resource assignment field for the SCI format 1-B transmitted in the m-th resource for SL PRS and the corresponding PSCCH transmission provided by a dynamic grant or by a SL configured grant, where $m = \{1, \ldots, M\}$ and M is the total number of resources for SL PRS and the corresponding PSCCH transmission provided by a dynamic grant or the number of resources for SL PRS transmission in a period provided by a SL configured grant type 1 or SL configured grant type 2, as follows:
  - the resource ID indication field and time resource assignment field indicate the m-th to M-th resources as described in [6, TS 38.214].

- "SL PRS request" as indicated by higher layers

For decoding of a SCI format 1-B, a UE may assume that a number of bits provided by *sl-NumReservedBitsSCI1B-DedicatedSL-PRS-RP* can have any value as described in [4, TS 38.212].

16.5 UE procedure for reporting HARQ-ACK on uplink

A UE can be provided PUCCH resources or PUSCH resources [12, TS 38.331] to report HARQ-ACK information that the UE generates based on HARQ-ACK information that the UE obtains from PSFCH receptions, or from absence of PSFCH receptions. The UE reports HARQ-ACK information on the primary cell of the PUCCH group, as described in clause 9, of the cell where the UE monitors PDCCH for detection of DCI format 3_0.

For SL configured grant Type 1 or Type 2 PSSCH transmissions by a UE within a time period provided by *sl-PeriodCG*, the UE generates one HARQ-ACK information bit in response to the PSFCH receptions to multiplex in a PUCCH transmission occasion that is after a last time resource, in a set of time resources.

For PSSCH transmissions scheduled by a DCI format 3_0, a UE generates HARQ-ACK information in response to PSFCH receptions to multiplex in a PUCCH transmission occasion that is after a last time resource in a set of time resources provided by the DCI format 3_0.

From a number of PSFCH reception occasions, the UE generates HARQ-ACK information to report in a PUCCH or PUSCH transmission. The UE can be indicated by a SCI format to perform one of the following and the UE constructs a HARQ-ACK codeword with HARQ-ACK information, when applicable

- for one or more PSFCH reception occasions associated with SCI format 2-A with Cast type indicator field value of "10"
  - generate HARQ-ACK information with same value as a value of HARQ-ACK information the UE determines from the last PSFCH reception from the number of PSFCH reception occasions corresponding to PSSCH transmissions or, if the UE determines that a PSFCH is not received at the last PSFCH reception occasion and ACK is not received in any of previous PSFCH reception occasions, generate NACK
- for one or more PSFCH reception occasions associated with SCI format 2-A with Cast type indicator field value of "01"
  - generate ACK if the UE determines ACK from at least one PSFCH reception occasion, from the number of PSFCH reception occasions corresponding to PSSCH transmissions, in PSFCH resources corresponding to every identity M_{ID} of the UEs that the UE expects to receive the PSSCH, as described in clause 16.3; otherwise, generate NACK
- for one or more PSFCH reception occasions associated with SCI format 2-B or SCI format 2-A with Cast type indicator field value of "11"
  - generate ACK when the UE determines absence of PSFCH reception for the last PSFCH reception occasion from the number of PSFCH reception occasions corresponding to PSSCH transmissions; otherwise, generate NACK

After a UE transmits PSSCHs and receives PSFCHs in corresponding PSFCH resource occasions, the priority value of HARQ-ACK information is same as the priority value of the PSSCH transmissions that is associated with the PSFCH reception occasions providing the HARQ-ACK information.

The UE generates a NACK when, due to prioritization, as described in clause 16.2.4, the UE does not receive PSFCH in any PSFCH reception occasion associated with a PSSCH transmission in a resource provided by a DCI format 3_0 and the UE transmitted PSSCH in the resource or, for a configured grant, in a resource provided in a single period and for which the UE is provided a PUCCH resource to report HARQ-ACK information and the UE transmitted PSSCH in the resource. The priority value of the NACK is same as the priority value of the PSSCH transmission.

The UE generates a NACK when, due to prioritization as described in clause 16.2.4, or due to a failed channel access procedure [15, TS 37.213] for operation with shared spectrum channel access, the UE does not transmit a PSSCH in any of the resources provided by a DCI format 3_0 or, for a configured grant, in any of the resources provided in a single period and for which the UE is provided a PUCCH resource to report HARQ-ACK information. The priority value of the NACK is same as the priority value of the PSSCH that was not transmitted due to prioritization or due to the failed channel access procedure.

The UE generates an ACK if the UE does not transmit a PSCCH with a SCI format 1-A scheduling a PSSCH in any of the resources provided by a configured grant in a single period and for which the UE is provided a PUCCH resource to report HARQ-ACK information. The priority value of the ACK is same as the largest priority value among the possible priority values for the configured grant.

The UE generates an ACK if the UE does not transmit a PSCCH with a SCI format 1-A scheduling a PSSCH in any of the resources provided by a DCI format 3_0 and for which the UE is provided a PUCCH resource to report HARQ-ACK information. The priority value of the ACK is same as the largest priority value among the possible priority values for the dynamic grant.

For reporting HARQ-ACK information on uplink corresponding to one or multiple PSSCH transmissions with a corresponding SCI format with the field 'HARQ feedback enabled/disabled indicator' set to disabled, the UE generates HARQ-ACK information with the contents instructed by higher layer. The priority value of the HARQ-ACK information is same as the priority value of the PSSCH transmission.

A UE does not expect to be provided PUCCH resources or PUSCH resources to report HARQ-ACK information that start earlier than $T_{prep} = (N+1) \cdot (2048+144) \cdot \kappa \cdot 2^{-\mu} \cdot T_c$ after the end of a last symbol of a last PSFCH reception occasion if *numPSFCHOccasions* is not (pre-)configured, or of a last candidate PSFCH reception occasion if *numPSFCHOccasions* is (pre-)configured, from a number of PSFCH reception occasions if *numPSFCHOccasions* is not (pre-)configured, or from a number of candidate PSFCH reception occasions if *numPSFCHOccasions* is (pre-)configured, that the UE generates HARQ-ACK information to report in a PUCCH or PUSCH transmission, where

- κ and T_c are defined in [4, TS 38.211]
- $\mu = \min(\mu_{SL}, \mu_{UL})$, where μ_{SL} is the SCS configuration of the SL BWP and μ_{UL} is the SCS configuration of the active UL BWP on the primary cell
- N is determined from μ according to Table 16.5-1

Table 16.5-1: Values of N

μ	N
0	14
1	18
2	28
3	32

For DCI format 3_0, if present, the PSFCH-to-HARQ feedback timing indicator field values map to values for a set of number of slots provided by *sl-PSFCH-ToPUCCH* as defined in Table 16.5-2.

Table 16.5-2: Mapping of PSFCH-to-HARQ feedback timing indicator field values to numbers of slots

PSFCH-to-HARQ feedback timing indicator			Number of slots k
1 bit	2 bits	3 bits	
'0'	'00'	'000'	1st value provided by *sl-PSFCH-ToPUCCH*
'1'	'01'	'001'	2nd value provided by *sl-PSFCH-ToPUCCH*
	'10'	'010'	3rd value provided by *sl-PSFCH-ToPUCCH*
	'11'	'011'	4th value provided by *sl-PSFCH-ToPUCCH*
		'100'	5th value provided by *sl-PSFCH-ToPUCCH*
		'101'	6th value provided by *sl-PSFCH-ToPUCCH*
		'110'	7th value provided by *sl-PSFCH-ToPUCCH*
		'111'	8th value provided by *sl-PSFCH-ToPUCCH*

With reference to slots for PUCCH transmissions and for a number of PSFCH reception occasions if *numPSFCHOccasions* is not (pre-)configured, or candidate PSFCH reception occasions if *numPSFCHOccasions* is (pre-)configured, ending in slot n, the UE provides the generated HARQ-ACK information in a PUCCH transmission within slot $n + k$, subject to the overlapping conditions in clause 9.2.5, where k is a number of slots indicated by a PSFCH-to-HARQ feedback timing indicator field, if present, in a DCI format indicating a slot for PUCCH transmission to report the HARQ-ACK information, or k is provided by *sl-PSFCH-ToPUCCH* for a transmission scheduled by a DCI format or for a SL configured grant type 2, or by *sl-PSFCH-ToPUCCH-CG-Type1* for a SL configured grant type 1. $k = 0$ corresponds to a last slot for a PUCCH transmission that would overlap with the last PSFCH reception occasion if *numPSFCHOccasions* is not (pre-)configured, or the last candidate PSFCH reception occasion if *numPSFCHOccasions* is (pre-)configured, assuming that the start of the sidelink frame is same as the start of the downlink frame [4, TS 38.211].

For a PSSCH transmission by a UE that is scheduled by a DCI format, or for a SL configured grant Type 2 PSSCH transmission activated by a DCI format, the DCI format indicates to the UE that a PUCCH resource is not provided when a value of the PUCCH resource indicator field is zero and a value of PSFCH-to-HARQ feedback timing indicator field, if present, is zero. For a SL configured grant Type 2 PSSCH transmission without a corresponding PDCCH, the DCI format activating the SL configured grant Type 2 indicates to the UE that a PUCCH resource is not provided when a value of the PUCCH resource indicator field is zero and a value of PSFCH-to-HARQ feedback timing indicator field, if present, is zero. For a SL configured grant Type 1 PSSCH transmission, a PUCCH resource can be provided by *sl-N1PUCCH-AN* and *sl-PSFCH-ToPUCCH-CG-Type1*. For transmission of HARQ-ACK information corresponding only to a SL configured grant Type 2 PSSCH transmission, including the PSSCH transmission(s) associated with the corresponding activation DCI format 3_0, a UE can be provided a PUCCH resource by *sl-N1PUCCH-AN-Type2*. If a PUCCH resource is not provided, the UE does not transmit a PUCCH with generated HARQ-ACK information from PSFCH reception occasions.

For a PUCCH transmission with HARQ-ACK information, a UE determines a PUCCH resource after determining a set of PUCCH resources from up to four PUCCH resource sets provided by *sl-PUCCH-Config*, for O_{UCI} HARQ-ACK information bits, as described in clause 9.2.1. The PUCCH resource determination is based on a PUCCH resource indicator field [5, TS 38.212] in a last DCI format 3_0, excluding DCI format 3_0 for the SL configured grant Type 2 activation, among the DCI formats 3_0 that have a value of a PSFCH-to-HARQ feedback timing indicator field indicating a same slot for the PUCCH transmission, that the UE detects and for which the UE transmits corresponding HARQ-ACK information in the PUCCH where, for PUCCH resource determination, detected DCI formats are indexed in an ascending order across PDCCH monitoring occasion indexes.

The PUCCH resource indicator field values map to values of a set of PUCCH resource indexes, as described in clause 9.2.3.

A UE transmits a PUCCH with HARQ-ACK information using PUCCH format 0 or PUCCH format 1 or PUCCH format 2 or PUCCH format 3 or PUCCH format 4 as described in clause 9.2.3.

A UE does not expect to multiplex HARQ-ACK information for more than one SL configured grants in a same PUCCH.

A priority value of a PUCCH transmission with one or more sidelink HARQ-ACK information bits is the smallest priority value for the one or more HARQ-ACK information bits.

In the following, the CRC for DCI format 3_0 is scrambled with a SL-RNTI or a SL-CS-RNTI.

16.5.1 Type-1 HARQ-ACK codebook determination

This clause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*.

If a UE is configured a SL configured grant Type 1, and the UE is configured a SL configured grant Type 2 or to monitor PDCCH for detection of DCI format 3_0 with CRC scrambled by SL-RNTI or SL-CS-RNTI, and the UE is provided a set of slot timing values K_1 associated with a SL BWP by *sl-PSFCH-ToPUCCH* and *sl-PSFCH-ToPUCCH-CG-Type1*, the *sl-PSFCH-ToPUCCH-CG-Type1* is one of *sl-PSFCH-ToPUCCH*.

A UE reports HARQ-ACK information for PSSCH transmissions with corresponding PSFCH reception occasions in slot n only in a HARQ-ACK codebook that the UE includes in a PUCCH or PUSCH transmission in slot $n + k$, where k is a number of slots indicated by the PSFCH-to-HARQ feedback timing indicator field in a DCI format 3_0 scheduling the PSSCH transmissions, or by a value of PSFCH-to-HARQ feedback timing indicator field in a DCI format 3_0 activating a SL configured grant Type-2 transmission, or by a value of *sl-PSFCH-ToPUCCH-CG-Type1* for a SL configured grant Type-1. If the UE reports HARQ-ACK information for the PSSCH transmissions with corresponding PSFCH reception occasions in a slot other than slot $n + k$, the UE sets a value for each corresponding HARQ-ACK information bit to NACK.

If a UE reports HARQ-ACK information in a PUCCH only for

- PSFCH reception occasions associated with PSSCH transmissions scheduled by a DCI format 3_0 with counter SAI field value of 1, or

- PSFCH reception occasions associated with PSSCH transmissions corresponding to a SL configured grant

within a set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions as determined in clause 16.5.1.1, the UE determines a HARQ-ACK codebook only for the PSFCH reception occasion associated with PSSCH transmissions scheduled by DCI format 3_0 or only for the PSFCH reception occasion associated with PSSCH transmissions corresponding to a SL configured grant according to corresponding set M_A of occasions, where a value of a counter SAI in DCI format 3_0 is according to Table 16.5.2.1-1. Otherwise, the procedures in clause 16.5.1.1 and in clause 16.5.1.2 for a HARQ-ACK codebook determination apply.

16.5.1.1 Type-1 HARQ-ACK codebook in physical uplink control channel

For a SL BWP on a carrier, and an active UL BWP on the primary cell, as described in clause 12, a UE determines a set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions for which the UE can multiplex corresponding HARQ-ACK information in a PUCCH transmission in slot n_U. The determination is based on:

a) a set of slot timing values K_1 associated with the SL BWP where K_1 is provided by *sl-PSFCH-ToPUCCH* for DCI format 3_0 or by *sl-PSFCH-ToPUCCH-CG-Type1*

b) the ratio $2^{\mu_{\mathrm{SL}}-\mu_{\mathrm{UL}}}$ between the sidelink SCS configuration μ_{SL} and the uplink SCS configuration μ_{UL} provided by *subcarrierSpacing* in *SL-BWP-Config* or *SL-BWP-ConfigCommon* and *BWP-Uplink* for the SL BWP and the active UL BWP, respectively

c) a configured sidelink resource pool bitmap

d) a value of a period of PSFCH transmission occasion resources for a sidelink resource pool provided by a respective *sl-PSFCH-Period*

For the set of slot timing values K_1, the UE determines a set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions according to the following pseudo-code.

Set $j = 0$ - index of occasion for candidate PSSCH transmissions with corresponding PSFCH reception occasions

Set $M_A = \emptyset$

Set $\mathcal{C}(K_1)$ to the cardinality of set K_1

Set $k = 0$ – index of slot timing values $K_{1,k}$, in descending order of the slot timing values, in set K_1

Set N_{PSFCH} to the value of the period of PSFCH transmission occasion resources for the sidelink resource pool

while $k < \mathcal{C}(K_1)$

 if $mod\ \left(n_U - K_{1,k} + 1, max(2^{\mu_{\mathrm{UL}}-\mu_{\mathrm{SL}}}, 1)\right) = 0$

  Set $n_S = 0$ – index of a SL slot within an UL slot

  while $n_S < max(2^{\mu_{\mathrm{SL}}-\mu_{\mathrm{UL}}}, 1)$

   if slot n_U starts at a same time as or after a slot for an active UL BWP change on the serving cell of PUCCH transmission and slot $\lfloor (n_U - K_{1,k}) \cdot 2^{\mu_{\mathrm{SL}}-\mu_{\mathrm{UL}}} \rfloor + n_S$ is before the slot for the active UL BWP change on the serving cell of PUCCH transmission

    $n_S = n_S + 1;$

   else

    if slot $\lfloor (n_U - K_{1,k}) \cdot 2^{\mu_{\mathrm{SL}}-\mu_{\mathrm{UL}}} \rfloor + n_S$ belongs to the sidelink resource pool and includes PSFCH resources as indicated by a sidelink resource pool bitmap and *sl-PSFCH-Period*, where $K_{1,k}$ is the *k*-th slot timing value in set K_1

     Set $n_F = 0$ – index of a SL slot within an PSFCH period

     while $n_F < N_{PSFCH}$

$M_A = M_A \cup j$;

$j = j + 1$;

$n_F = n_F + 1$;

end while

end if

$n_S = n_S + 1$;

end if

end while

end if

$k = k + 1$;

end while

The cardinality of the set M_A defines a total number M of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions corresponding to the HARQ-ACK information bits. For operation with shared spectrum channel access, when there are more than one candidate PSFCH occasions associated with one PSCCH/PSSCH transmission, each of the M candidate PSSCH transmissions is derived by the last associated PSFCH occasion. A UE determines $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O_{\mathrm{ACK}}-1}^{ACK}$ HARQ-ACK information bits, for a total number of O_{ACK} HARQ-ACK information bits as $\tilde{o}_j^{ACK}$ = HARQ-ACK information bit for candidate PSSCH transmission with index j with corresponding PSFCH reception, for $0 \leq j < M$, as described in clause 16.5. If the UE does not transmit a PSSCH in an occasion for candidate PSSCH transmission with corresponding PSFCH reception occasion, due to the UE not detecting a corresponding DCI format 3_0, the UE generates a NACK value for the occasion for candidate PSSCH transmission with corresponding PSFCH reception occasion.

If $O_{\mathrm{ACK}} \leq 11$, the UE determines a number of HARQ-ACK information bits $n_{\mathrm{HARQ-ACK}}$ for obtaining a transmission power for a PUCCH, as described in clause 7.2.1, as $n_{\text{HARQ-ACK}} = \sum_{\mathrm{m}=0}^{\mathrm{M}-1} N_{\mathrm{m}}^{\mathrm{received}}$ where N_m^{received} is a number of HARQ-ACK information bits determined for corresponding PSSCH transmissions with corresponding PSFCH reception occasions in PSFCH reception occasion m.

16.5.1.2 Type-1 HARQ-ACK codebook in physical uplink shared channel

If a UE would multiplex HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by a DCI format without an SAI field, then

- if the UE
    - has not received any PDCCH with a DCI format 3_0 scheduling PSSCH transmissions with corresponding PSFCH reception occasions that the UE transmits corresponding HARQ-ACK information in the PUSCH, based on a value of a respective PSFCH-to-HARQ feedback timing indicator field in a DCI format scheduling the PSSCH transmissions or on the value of PSFCH-to-HARQ feedback timing indicator field in a DCI format 3_0 activating a SL configured grant Type 2 transmission, or
    - has not been provided PSSCH resources with corresponding PSFCH reception occasions that the UE transmits corresponding HARQ-ACK information based on the value of *sl-PSFCH-ToPUCCH-CG-Type1* for a SL configured grant Type 1,

  then in any of the set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions, as described in clause 16.5.1.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission;

- else the UE generates the HARQ-ACK codebook as described in clause 16.5.1.1, unless the UE generates HARQ-ACK information only for
    - PSFCH reception occasions associated with PSSCH transmissions corresponding to a SL configured grant, or

- PSFCH reception occasions associated with PSSCH transmissions that are scheduled by DCI format 3_0 with a counter SAI field value of 1

in the set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions, in which case the UE generates HARQ-ACK information only for the PSFCH reception occasions as described in clause 16.5.1.

A UE sets to NACK value in the HARQ-ACK codebook any HARQ-ACK information corresponding to PSFCH reception occasions associated with PSSCH transmissions scheduled by a DCI format 3_0 that the UE detects in a PDCCH monitoring occasion that starts after a PDCCH monitoring occasion where the UE detects a DCI format scheduling the PUSCH transmission.

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by a DCI format that includes a SAI field, the UE generates the HARQ-ACK codebook as described in clause 16.5.1.1 when a value of the SAI field in the DCI format is $V_{T-\mathrm{SAI}}^{\mathrm{UL}} = 1$. The UE does not generate a HARQ-ACK codebook for multiplexing in the PUSCH transmission when $V_{T-\mathrm{SAI}}^{\mathrm{UL}} = 0$ unless the UE generates HARQ-ACK information only for

- PSFCH reception occasions associated with PSSCH transmissions corresponding to a SL configured grant, or
- PSFCH reception occasions associated with PSSCH transmissions that are scheduled by a DCI format 3_0 with a counter SAI field value of 1,

in the set M_A of occasions for candidate PSSCH transmissions with corresponding PSFCH reception occasions as described in clause 16.5.1.

$V_{T-\mathrm{SAI}}^{\mathrm{UL}} = 0$ if the SAI field in the DCI format is set to '0'; otherwise, $V_{T-\mathrm{SAI}}^{\mathrm{UL}} = 1$.

16.5.2 Type-2 HARQ-ACK codebook determination

This clause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic*.

16.5.2.1 Type-2 HARQ-ACK codebook in physical uplink control channel

A UE determines monitoring occasions for PDCCH with DCI format 3_0 for scheduling PSSCH transmissions with associated PSFCH reception occasions on an active DL BWP of a serving cell c, as described in clause 10.1, and for which the UE transmits HARQ-ACK information in a same PUCCH in slot n based on

- PSFCH-to-HARQ feedback timing indicator field values, or a value provided by *sl-PSFCH-ToPUCCH-CG-Type1*, for PUCCH transmission with HARQ-ACK information in slot n in response to PSFCH receptions;
- time gap field in DCI format 3_0 for scheduling PSSCH transmissions with associated PSFCH receptions;
- time resource assignment in DCI format 3_0 for scheduling PSSCH transmissions with associated PSFCH receptions;
- a configured sidelink resource pool bitmap;
- a value of a period of PSFCH resources provided in *sl-PSFCH-Period*;
- a value of a minimum time gap provided in *sl-MinTimeGapPSFCH*.

The set of PDCCH monitoring occasions for DCI format 3_0 for scheduling PSSCH transmissions with associated PSFCH reception occasions is defined as the PDCCH monitoring occasions in the active DL BWP of the configured serving cell, indexed in ascending order of start time of the associated search space sets. The cardinality of the set of PDCCH monitoring occasions defines a total number M of PDCCH monitoring occasions. A UE is not expected to receive a DCI format 3_0 with CRC scrambled by SL-RNTI and a DCI format 3_0 with CRC scrambled by SL-CS-RNTI for scheduling retransmission corresponding to a SL configured grant Type 1 or a sidelink configured grant Type 2 simultaneously in a same monitoring occasion.

A value of a counter sidelink assignment indicator (SAI) field in DCI format 3_0, excluding DCI format 3_0 for the SL configured grant Type 2 activation, denotes an accumulative number of PDCCH monitoring occasions where PSSCH transmissions with associated PSFCH receptions are scheduled, up to a current PDCCH monitoring occasion, in ascending order of PDCCH monitoring occasion index m, where $0 \leq m < M$.

Denote by $V_{C-\mathrm{SAI},m}^{\mathrm{SL}}$ the value of the counter SAI in DCI format 3_0 in PDCCH monitoring occasion m according to Table 16.5.2.1-1.

If the UE transmits HARQ-ACK information in a PUCCH in slot n, the UE determines the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O_{\mathrm{ACK}}-1}^{ACK}$, for a total number of O_{ACK} HARQ-ACK information bits, according to the following pseudo-code:

Set $m = 0$ – PDCCH with DCI format 3_0 monitoring occasion index: lower index corresponds to earlier PDCCH with DCI format 3_0 monitoring occasion

Set $j = 0$

Set $V_{temp} = 0$

Set $V_s = \emptyset$

Set M to the number of PDCCH monitoring occasions

while $m < M$

if PDCCH monitoring occasion m is before an active UL BWP change on the serving cell of PUCCH transmission

$m = M$;

else

if there is a PSFCH reception occasion associated with a PSSCH transmission scheduled by a DCI format in PDCCH monitoring occasion m

if $V_{C-\mathrm{SAI},m}^{\mathrm{SL}} \leq V_{temp}$

$j = j + 1$;

end if

$V_{temp} = V_{C-\mathrm{SAI},m}^{\mathrm{SL}}$

$\tilde{o}_{4j+V_{C-SAI,m}^{SL}-1}^{ACK}$ = HARQ-ACK information bit

$V_s = V_s \cup \left\{4j + V_{C-\mathrm{SAI},m}^{\mathrm{SL}} - 1\right\}$

end if

end if

$m = m + 1$;

end while

$O_{ACK} = 4 \cdot j + V_{temp}$

$\tilde{o}_i^{ACK} = NACK$ for any $i \in \{0,1, \ldots, O_{ACK} - 1\} \backslash V_s$

if a SL configured grant Type 1 is configured for a UE, or a SL configured grant Type 2 is configured and activated for a UE, and the SL configured grant provides a grant for PSSCH transmissions, including the PSSCH transmission(s) associated with the corresponding activation DCI format 3_0, with PSFCH reception occasions in a slot $n - K_1$, where K_1 is the k value for the SL configured grant as described in clause 16.5

$O_{ACK} = O_{ACK} + 1$;

$\tilde{o}_{O_{ACK}-1}^{ACK}$= HARQ-ACK information bit associated with the PSFCH reception occasions associated with the PSSCH transmissions scheduled by the SL configured grant

end if

If $O_{\mathrm{ACK}} \leq 11$, the UE determines a number of HARQ-ACK information bits $n_{\mathrm{HARQ-ACK}}$ for obtaining a transmission power for a PUCCH, as described in clause 7.2.1, as

$$\mathrm{n}_{\text{HARQ-ACK}} = \left(V_{\mathrm{SAI,m_{last}}}^{\mathrm{SL}} - U_{\mathrm{SAI}}\right) \bmod 4 + \sum_{\mathrm{m}=0}^{\mathrm{M}-1} N_{\mathrm{m}}^{\mathrm{received}} + N_{\mathrm{CG}}$$

where

- $V_{\mathrm{SAI},m_{\mathrm{last}}}^{\mathrm{SL}}$ is a value of a counter SAI field in a last DCI format 3_0, excluding the DCI format 3_0 activating a SL configured grant, scheduling PSSCH transmissions associated with PSFCH reception occasions that the UE detects within the M PDCCH monitoring occasions

- $V_{\mathrm{SAI},m_{\mathrm{last}}}^{\mathrm{SL}} = 0$ if the UE does not detect any DCI format 3_0, excluding the DCI format 3_0 activating a SL configured grant, scheduling PSSCH transmissions associated with PSFCH reception occasions in any of the M PDCCH monitoring occasions

- U_{SAI} is a total number of DCI format 3_0, excluding the DCI format 3_0 activating a SL configured grant, scheduling PSSCH transmissions associated with PSFCH reception occasions, that the UE detects within the M PDCCH monitoring occasions. $U_{\mathrm{SAI}} = 0$ if the UE does not detect any DCI format 3_0, excluding the DCI format 3_0 activating a SL configured grant, scheduling PSSCH transmissions with associated PSFCH reception occasions in any of the M PDCCH monitoring occasions

- N_m^{received} is a number of DCI format 3_0, excluding the DCI format 3_0 activating a SL configured grant, scheduling PSSCH transmissions with associated PSFCH reception occasions that the UE detects in PDCCH monitoring occasion m

- N_{CG} is a number of SL configured grants for which the UE transmits corresponding HARQ-ACK information in a same PUCCH as for HARQ-ACK information corresponding to PSFCH reception occasions associated with PSSCH transmissions scheduled by a dynamic grant within the M PDCCH monitoring occasions

Table 16.5.2.1-1: Value of counter SAI in DCI format 3_0

SAI MSB, LSB	$V_{C-\mathrm{SAI}}^{\mathrm{SL}}$	Number of PDCCH monitoring occasions in which DCI format 3_0 scheduling PSSCH transmissions with corresponding PSFCH reception occasions is present, denoted as Y and $Y \geq 1$
0,0	1	$(Y-1)mod4+1=1$
0,1	2	$(Y-1)mod4+1=2$
1,0	3	$(Y-1)mod4+1=3$
1,1	4	$(Y-1)mod4+1=4$

16.5.2.2 Type-2 HARQ-ACK codebook in physical uplink shared channel

If a UE would multiplex HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by a DCI format without an SAI field, then

- if the UE
  - has not received any PDCCH within the monitoring occasions for DCI format 3_0 for scheduling PSSCH with corresponding PSFCH reception occasions on any serving cell, and
  - does not have HARQ-ACK information in response to a PSSCH transmission with corresponding PSFCH reception occasions associated with a SL configured grant to multiplex in the PUSCH, as described in clause 16.5.2.1,

  the UE does not multiplex HARQ-ACK information in the PUSCH transmission;

- else, the UE generates and multiplexes in the PUSCH transmission the HARQ-ACK codebook as described in clause 16.5.2.1.

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by a DCI format that includes a SAI field, the UE generates the HARQ-ACK codebook as described in clause 16.5.2.1, with the following modifications:

- For the pseudo-code for the HARQ-ACK codebook generation in clause 16.5.2.1, after the completion of the m loop, the UE sets $V_{temp} = V_{\text{T-SAI}}^{\text{UL}}$ where $V_{\text{T-SAI}}^{\text{UL}}$ is the value of the SAI field in the DCI format according to Table 16.5.2.2-1.

If a UE

- is scheduled for a PUSCH transmission by a DCI format that includes a SAI field with value $V_{\text{T-SAI}}^{\text{UL}} = 4$, and
- has not received any PDCCH within the monitoring occasions for PDCCH with DCI format 3_0 for scheduling PSSCH with corresponding PSFCH reception occasions on a serving cell, and
- does not have HARQ-ACK information in response to PSFCH reception occasions associated with a SL configured grant to multiplex in the PUSCH, as described in clause 16.5.2.1,

the UE does not multiplex HARQ-ACK information in the PUSCH transmission.

Table 16.5.2.2-1: Value of SAI

SAI MSB, LSB	$V_{\text{T-SAI}}^{\text{UL}}$	Number of PDCCH monitoring occasions in which DCI format 3_0 scheduling PSSCH transmissions with corresponding PSFCH reception occasions is present, denoted as X and $X \geq 1$
0,0	1	$(X-1)mod4+1=1$
0,1	2	$(X-1)mod4+1=2$
1,0	3	$(X-1)mod4+1=3$
1,1	4	$(X-1)mod4+1=4$

16.6 UE procedure for LTE sidelink transmission

If the UE detects a DCI format 3_1 with CRC scrambled by SL Semi-Persistent Scheduling V-RNTI in slot n, the DCI format 3_1 activates or releases an LTE sidelink SPS configuration that is indicated by a SL SPS configuration index field [5, TS 38.212]. If the DCI format 3_1 activates an SL SPS configuration, the UE procedure for transmitting a PSCCH and a PSSCH is as described in [13, TS 36.213] except that a transmission starts no earlier than $T_{DCI} - \frac{N_{\text{TA}}}{2} \times T_{\text{C}} \times 10^3 + X + (4+m)$ ms, where T_{DCI} is a start time of slot n, N_{TA} and T_C are defined in [4, TS 38.211], X is a value indicated by a Timing offset field in DCI format 3_1, and m is a value indicated by SL index field in DCI format 3_1 if the SL index field is present; otherwise, $m = 0$.

16.7 Operation for in-device coexistence and for co-channel coexistence

If a UE would transmit or receive a first channel/signal using E-UTRA radio access and a second channel/signal using NR radio access, when

- the first channel/signal and the second channel/signal are time-division multiplexed, and
- the UE knows the frame indexes of the first channel/signal and the frame indexes of the second channel/signal,

the UE transmits or receives each channel/signal so that the subframe boundary of the second channel/signal is aligned with the subframe boundary of the first channel/signal where the subframe boundary alignment is achieved by UE implementation means.

17 UE with reduced capabilities

A UE with reduced capabilities (RedCap UE) supports all Layer-1 UE features that are mandatory without capability signalling, unless stated otherwise. Procedures for a RedCap UE are same as described for a UE in all other clauses of this document unless stated otherwise.

17.1 First procedures for RedCap UE

In this clause, the term 'UE' refers to a RedCap UE that indicates *supportOfRedCap* or *supportOfERedCap*.

A UE expects the initial DL BWP and the active DL BWP after the UE (re)establishes dedicated RRC connection to be smaller than or equal to the maximum DL bandwidth that the UE supports. A UE can be provided a DL BWP by *initialDownlinkBWP-RedCap* in *DownlinkConfigCommonSIB*, and an UL BWP by *initialUplinkBWP-RedCap* in *UplinkConfigCommonSIB*. If *initialUplinkBWP* in *UplinkConfigCommonSIB* indicates an UL BWP that is larger than a maximum UL BWP that a UE supports, the UE expects to be provided an UL BWP by *initialUplinkBWP-RedCap* in *UplinkConfigCommonSIB* that is smaller than or equal to the maximum UL bandwidth that the UE supports.

For unpaired spectrum operation, a RedCap UE does not expect to receive a configuration where the center frequency for an initial DL BWP in which the UE is configured to monitor Type1-PDCCH CSS set, or a CSS set provided by *sdt-SearchSpace* for random-access based PUSCH transmission as described in clause 19.2, is different than the center frequency for an initial UL BWP in which the RedCap UE may transmit Msg1/Msg3 or MsgA.

A UE can be provided by *BWP-DownlinkDedicated* a DL BWP, other than the initial DL BWP. A UE can be provided by *BWP-UplinkDedicated* an UL BWP, other than the initial UL BWP, that is smaller than or equal to the maximum UL bandwidth that the UE supports.

If a UE is provided an UL BWP by *initialUplinkBWP-RedCap* in *UplinkConfigCommonSIB* and is provided *rach-ConfigCommon* or *msgA-ConfigCommon* in *BWP-UplinkCommon* for the UL BWP, the UE uses corresponding parameters to perform the procedures in clauses 8.1, 8.1A, and 8.3; otherwise, the UE uses corresponding parameters from *rach-ConfigCommon* or *msgA-ConfigCommon* in *BWP-UplinkCommon* for the UL BWP provided by *initialUplinkBWP*.

If a UE is provided *initialUplinkBWP-RedCap* in *UplinkConfigCommonSIB* and does not have dedicated PUCCH resource configuration, the UE transmits PUCCH with HARQ-ACK information as described in clause 9.2.1 using a PUCCH resource set provided by *pucch-ResourceCommonRedCap*, except that frequency hopping for the PUCCH transmission is disabled if *intra-SlotFH* is present in *PUCCH-ConfigCommon*. If frequency hopping of the PUCCH transmission is disabled then, for the PUCCH transmission, the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as $r_{\text{PUCCH}} \bmod N_{\text{CS}}$ and determines the PRB index as

- $RB_{\text{BWP}}^{\text{offset}} + RB_{\text{BWP}}^{\text{offset-add}} + \lfloor r_{\text{PUCCH}} / N_{\text{CS}} \rfloor$, if *intra-SlotFH* = '*fromLowerEdge*'
- $N_{\text{BWP}}^{\text{size}} - RB_{\text{BWP}}^{\text{offset}} - RB_{\text{BWP}}^{\text{offset-add}} - 1 - \lfloor r_{\text{PUCCH}} / N_{\text{CS}} \rfloor$, otherwise

where $RB_{\text{BWP}}^{\text{offset-add}}$ is provided by *additionalPRBOffset*, if provided; otherwise, $RB_{\text{BWP}}^{\text{offset-add}} = 0$.

If a UE is not provided *initialUplinkBWP-RedCap* in *UplinkConfigCommonSIB* and does not have dedicated PUCCH resource configuration, the UE transmits PUCCH with HARQ-ACK information as described in clause 9.2.1 using a PUCCH resource set provided by *pucch-ResourceCommonRedCap* if *pucch-ResourceCommonRedCap* is present or by *pucch-ResourceCommon* if *pucch-ResourceCommonRedCap* is absent. For an initial DL BWP provided by *initialDownlinkBWP-RedCap* in *DownlinkConfigCommonSIB*, if a UE in RRC_IDLE state or in RRC_INACTIVE state monitors PDCCH according to Type1-PDCCH CSS set and does not monitor PDCCH according to Type2-PDCCH CSS set, the UE does not expect the initial DL BWP to include SS/PBCH blocks and the CORESET with index 0.

For an active DL BWP not provided by *BWP-DownlinkDedicated*, if a UE does not indicate a capability to operate in the active DL BWP without receiving an SS/PBCH block, the UE in RRC_CONNECTED state assumes that the active DL BWP includes the SS/PBCH blocks that the UE used to obtain SIB1 and, for SS/PBCH block and CORESET multiplexing pattern 1, the CORESET with index 0.

For an active DL BWP provided by *BWP-DownlinkDedicated*, unless a UE indicates a capability to operate in the active DL BWP without receiving an SS/PBCH block, the UE in RRC_CONNECTED state assumes that the active DL BWP includes the SS/PBCH blocks that the UE used to obtain SIB1 or the SS/PBCH blocks provided by *NonCellDefiningSSB*. If the active DL BWP includes the SS/PBCH blocks that the UE used to obtain SIB1, for SS/PBCH block and CORESET multiplexing pattern 1, the UE expects the active DL BWP to include the CORESET with index 0.

For a RedCap UE indicating a capability to use an initial DL BWP that includes the SS/PBCH blocks provided by *NonCellDefiningSSB* for PUSCH transmission in RRC_INACTIVE state, if the UE is provided *NonCellDefiningSSB* in *ncd-SSB-RedCapInitialBWP-SDT*, then during procedure of PUSCH transmission in RRC_INACTIVE state (as described in clause 19) the UE uses the SS/PBCH blocks provided by *NonCellDefiningSSB* for the purposes for which the UE would otherwise have used the SS/PBCH blocks that the UE used to obtain SIB1.

If the active DL BWP provided by *BWP-DownlinkDedicated*, or the initial DL BWP during procedure of PUSCH transmission in RRC_INACTIVE state (as described in clause 19), includes the SS/PBCH blocks provided by *NonCellDefiningSSB*, these SS/PBCH blocks and the SS/PBCH blocks that the UE used to obtain SIB1 have the same QCL properties, if they have the same index.

For a RedCap UE indicated presence of SS/PBCH blocks within an active DL BWP by *NonCellDefiningSSB*, collision handling between downlink receptions or uplink transmissions and the SS/PBCH blocks are same as described for a UE indicated presence of SS/PBCH blocks by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* described in all other clauses, unless otherwise stated.

For monitoring of a PDCCH candidate by a UE configured with *NonCellDefiningSSB*, if the UE

- does not monitor PDCCH candidates in a Type0-PDCCH CSS set, and
- at least one RE for a PDCCH candidate overlaps with at least one RE of a candidate SS/PBCH block corresponding to a SS/PBCH block index provided by *NonCellDefiningSSB*,

the UE is not required to monitor the PDCCH candidate.

The SS/PBCH blocks in clause 8.1 for determining valid PRACH occasions in unpaired spectrum correspond to the SS/PBCH blocks that the UE used to obtain SIB1.

The SS/PBCH blocks in clause 8.1A for determining valid PUSCH occasions in unpaired spectrum correspond to the SS/PBCH blocks that the UE used to obtain SIB1.

The SS/PBCH blocks in clause 6.1.2.1 in [6, TS 38.214] and clause 8.3 for determining the $N_{\text{PUSCH}}^{\text{repeat}}$ slots for a PUSCH transmission in unpaired spectrum correspond to the SS/PBCH blocks that the UE used to obtain SIB1.

The SS/PBCH blocks in clause 19.1 for determining valid PUSCH occasions in unpaired spectrum correspond to the SS/PBCH blocks that the UE used to obtain SIB1.

17.1A Second procedures for RedCap UE

In this clause, the term 'UE' refers to a RedCap UE that indicates *supportOfERedCap*.

A UE that has not indicated *eRedCapNotReducedBB-BW* does not expect to transmit a PUSCH over a bandwidth that is larger than 25 PRBs for 15 kHz SCS, or larger than 12 PRBs for 30 kHz SCS, per hop in a slot.

A UE that has not indicated *eRedCapNotReducedBB-BW* does not expect to process a PDSCH reception that is scheduled by a DCI format with CRC scrambled by a C-RNTI, CS-RNTI, MCS-C-RNTI, G-RNTI for multicast, or G-CS-RNTI, or is associated with a SPS PDSCH configuration activated by a DCI format with CRC scrambled by CS-RNTI or G-CS-RNTI, over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS, or larger than 12 PRBs for 30 kHz SCS, in a slot.

A UE that has not indicated *eRedCapNotReducedBB-BW* is not required to process a PDSCH reception in slot n that is scheduled by a DCI format with CRC scrambled by a G-RNTI for broadcast or a MCCH-RNTI over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS, or larger than 12 PRBs for 30 kHz SCS, when the PDSCH reception is with repetitions or when the UE receives another PDSCH in slot $n+1$.

A UE is not required to process a PDSCH reception that is scheduled by a DCI format with CRC scrambled by a TC-RNTI over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS, or larger than 12 PRBs for 30 kHz SCS, in a slot.

A UE does not expect to transmit a PUSCH over a bandwidth that is larger than 25 PRBs for 15 kHz SCS, or larger than 12 PRBs for 30 kHz SCS, per hop in a slot, where the PUSCH is scheduled by RAR UL grant or by a DCI scrambled by a TC-RNTI, or is configured for a Type-2 random access procedure.

When

- a UE receives a PDSCH scheduled by a DCI format with CRC scrambled by a RA-RNTI or a MsgB-RNTI over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS or larger than 12 PRBs for 30 kHz SCS, and
- the PDSCH includes a RAR message with an RAR UL grant scheduling a Msg3 PUSCH transmission from the UE, as described in Clauses 8.2 and 8.2A

the UE transmits the Msg3 PUSCH if a time between the last symbol of a PDSCH reception conveying the RAR message and the first symbol of the Msg3 PUSCH transmission is not smaller than $N_{T,1} + N_{T,2} + 1.5$ msec for 15 kHz SCS or $N_{T,1} + N_{T,2} + 1.0$ msec for 30 kHz SCS where $N_{T,1}$ and $N_{T,2}$ are defined in clause 8.3; otherwise, the UE behaviour is based on UE implementation.

When

- a UE receives a PDSCH scheduled by a DCI format with CRC scrambled by a RA-RNTI or a MsgB-RNTI over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS or larger than 12 PRBs for 30 kHz SCS, and
- the UE does not correctly receive the transport block provided by the PDSCH, or if the higher layers at the UE do not identify a RAPID associated with a corresponding PRACH transmission from the UE

if requested by higher layers, the UE shall be ready to transmit a PRACH no later than $N_{T,1} + 1.75$ msec for 15 kHz SCS, or no later than $N_{T,1} + 1.25$ msec for 30 kHz SCS, after the last symbol of the PDSCH reception, or after the last symbol of the window as described in Clauses 8.2 and 8.2A.

When

- a UE receives a PDSCH scheduled by a DCI format with CRC scrambled by MsgB-RNTI over a number of PRBs that is larger than 25 PRBs for 15 kHz SCS or larger than 12 PRBs for 30 kHz SCS, and
- the PDSCH includes a RAR message that is for successRAR for the UE as described in Clause 8.2A

the UE transmits a PUCCH with HARQ-ACK information if a time between the last symbol of the PDSCH reception conveying the RAR message and the first symbol of the PUCCH transmission is not smaller than $N_{T,1} + 1.5$ msec for 15 kHz SCS or $N_{T,1} + 1.0$ msec for 30 kHz SCS; otherwise, the UE behaviour is based on UE implementation.

17.2 Half-Duplex UE in paired spectrum

A half-duplex UE (HD-UE) in paired spectrum is not capable of simultaneous transmissions and receptions on a serving cell with paired spectrum. This clause is applicable for communication of a HD-UE on a serving cell with paired spectrum. Procedures for a HD-UE are same as described for a UE in all other clauses of this document unless stated otherwise.

A HD-UE does not expect to detect a DCI format scheduling a reception in a set of symbols and detect a DCI format scheduling a transmission in any symbol from the set of symbols.

When a PDCCH reception by a UE includes two PDCCH candidates from corresponding search space sets, as described in clause 10.1, the end of the PDCCH reception is the end of the PDCCH candidate that ends later.

If a HD-UE is configured by higher layers to receive a PDCCH, or PDSCH, or CSI-RS, or DL PRS in a set of symbols, the HD-UE receives the PDCCH, or PDSCH, or CSI-RS, or DL PRS if the HD-UE does not detect a DCI format that indicates to the HD-UE to transmit a PUSCH, or PUCCH, or PRACH, or SRS in at least one symbol of the set of symbols; otherwise, the HD-UE does not receive the PDCCH, or PDSCH, or CSI-RS, or DL PRS in the set of symbols.

If a HD-UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH in a set of symbols and the UE detects a DCI format indicating to the HD-UE to receive CSI-RS or PDSCH in a subset of symbols from the set of symbols, then

- the HD-UE does not expect to cancel the transmission of the PUCCH or PUSCH in the set of symbols if the first symbol in the set occurs within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the HD-UE detects the DCI format; otherwise, the HD-UE cancels the PUCCH, or the PUSCH, or an actual repetition of the PUSCH [6, TS 38.214], determined from clauses 9 and 9.2.5 or clause 6.1 of [6, TS 38.214].
- the HD-UE does not expect to cancel the transmission of SRS in symbols from the subset of symbols that occur within $T_{proc,2}$ relative to a last symbol of a PDCCH reception where the HD-UE detects the DCI format. The HD-UE cancels the SRS transmission in remaining symbols from the subset of symbols.

  $T_{\mathrm{proc},2}$ is the PUSCH preparation time for UE processing capability 1 [6, TS 38.214] assuming $d_{2,1} = 1$ and μ corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format and the SCS configuration of the SRS, PUCCH, PUSCH.

A HD-UE does not expect to receive both dedicated higher layer parameters configuring transmission in a set of symbols and dedicated higher layer parameters configuring reception in the set of symbols. A HD-UE does not expect to receive both a Type-0/0A/0B/1/2-PDCCH CSS set configuration for PDCCH reception in a set of symbols and dedicated higher layer parameters configuring transmission in the set of symbols, except a Type-2-PDCCH CSS set configuration for PDCCH reception in a set of symbols and dedicated higher layer parameters configuring configured-grant based PUSCH transmission as described in clause 19.1 in the set of symbols for which case the UE follows the procedure as in clause 5.1B.2.6 in [10, TS 38.133]. The UE expects to be configured with a Type-2-PDCCH CSS set configuration for PDCCH reception such that there is at least one paging occasion that does not overlap with configured-grant based PUSCH transmission as described in clause 19.1 per SI modification period.

If a HD-UE would transmit a PUSCH, or PUCCH, or SRS based on a configuration by higher layers and the HD-UE is indicated presence of SS/PBCH blocks within the active DL BWP by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* or by *NonCellDefiningSSB*, the HD-UE does not transmit

- PUSCH or PUCCH if a last symbol of the PUSCH or PUCCH transmission would not be at least $N_{\text{Tx-Rx}} \cdot T_{\text{c}}$ [4, TS 38.211] prior to a first symbol of the next earliest SS/PBCH block

- PUSCH or PUCCH if a first symbol of the PUSCH or PUCCH transmission would not be at least $N_{\text{Rx-Tx}} \cdot T_{\text{c}}$ [4, TS 38.211] after a last symbol of the previous latest SS/PBCH block

- SRS in symbols that would not be at least $N_{\text{Tx-Rx}} \cdot T_{\text{c}}$ prior to a first symbol of the next earliest SS/PBCH block

- SRS in symbols that would not be at least $N_{\text{Rx-Tx}} \cdot T_{\text{c}}$ after a last symbol of the previous latest SS/PBCH block

If a HD-UE would transmit a PRACH based on a detected DCI format, or PUSCH, or PUCCH, or SRS and the HD-UE is indicated presence of SS/PBCH blocks within the active DL BWP by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* or by *NonCellDefiningSSB* in a set of symbols, the HD-UE does not transmit PUSCH or PUCCH or PRACH if a transmission would overlap with any symbol from the set of symbols and the HD-UE does not transmit SRS in the set of symbols.

If a HD-UE would transmit a PRACH or MsgA PUSCH triggered by higher layers in a set of symbols and would receive a PDCCH, or a PDSCH, or a CSI-RS, or a DL PRS, or is indicated presence of SS/PBCH blocks within the active DL BWP by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* or by *NonCellDefiningSSB* in symbols that include any symbol from the set of symbols, the HD-UE can select based on its implementation whether to either transmit the PRACH or the MsgA PUSCH or receive the PDSCH, or the CSI-RS, or the PL RS, or the PDCCH, or the SS/PBCH blocks.

If a HD-UE would receive a PDCCH, or a PDSCH, or a CSI-RS, or a DL PRS based on a configuration by higher layers or is indicated presence of SS/PBCH blocks within the active DL BWP by *ssb-PositionsInBurst* in *SIB1* or in *ServingCellConfigCommon* or by *NonCellDefiningSSB* in a set of symbols, and the HD-UE would transmit PRACH or MsgA PUSCH triggered by higher layers starting or ending at a symbol that is earlier or later than $N_{\text{Rx-Tx}} \cdot T_{\text{c}}$ or $N_{\text{Tx-Rx}} \cdot T_{\text{c}}$, respectively, from the last or first symbol in the set of symbols, the HD-UE can select based on its implementation whether to either transmit the PRACH or the MsgA PUSCH or receive the PDSCH, or the CSI-RS, or the DL PRS, or the PDCCH, or the SS/PBCH blocks.

18 Multicast Broadcast Services

This clause is applicable only for PDCCH receptions, PDSCH receptions, and PUCCH transmissions for MBS on a serving cell. DCI formats with CRC scrambled by multicast-MCCH-RNTI for multicast PDSCH receptions in RRC_INACTIVE state, G-RNTI for multicast, or G-CS-RNTI scheduling PDSCH receptions are referred to as multicast DCI formats and the PDSCH receptions are referred to as multicast PDSCH receptions. DCI formats with CRC scrambled by MCCH-RNTI or G-RNTI for broadcast scheduling PDSCH receptions are referred to as broadcast DCI formats and the PDSCH receptions are referred to as broadcast PDSCH receptions. HARQ-ACK information associated with multicast DCI formats or multicast PDSCH receptions in RRC_CONNECTED state is referred to as multicast HARQ-ACK information.

A UE can be provided one or more G-RNTIs for multicast per serving cell for scrambling the CRC of multicast DCI formats for scheduling PDSCH receptions. The UE can be provided one or more G-CS-RNTI per serving cell for scrambling the CRC of multicast DCI formats providing activation/release/scheduling retransmission for SPS PDSCH receptions in RRC_CONNECTED state.

A UE can be configured by *cfr-ConfigMCCH-MTCH* or *cfr-ConfigMCCH-MTCH-RedCap* an MBS frequency resource for PDCCH and PDSCH receptions providing broadcast MCCH and broadcast MTCH [12, TS 38.331]; otherwise, the MBS frequency resource is same as for the CORESET with index 0 that is associated with the Type0-PDCCH CSS set for PDCCH and PDSCH receptions providing broadcast MCCH and broadcast MTCH. The SCS and CP of MBS frequency resource for broadcast are same as the initial DL BWP. A UE monitors PDCCH for scheduling PDSCH receptions for broadcast MCCH or broadcast MTCH as described in clause 10.1.

In clauses referring to a higher layer parameter value provided by *PDCCH-ConfigCommon* or *PDSCH-ConfigMCCH*/*PDSCH-ConfigMTCH* for broadcast, when applicable a corresponding higher layer parameter value for broadcast MCCH/broadcast MTCH PDCCH receptions or PDSCH receptions, respectively, is provided as described in [12, TS 38.331].

A UE can be configured by *cfr-ConfigMCCH-MTCH-r18* an MBS frequency resource for PDCCH and PDSCH receptions providing multicast MCCH and multicast MTCH in RRC_INACTIVE state [12, TS 38.331]; otherwise, the MBS frequency resource is same as for the CORESET with index 0 that is associated with the Type0-PDCCH CSS set for PDCCH and PDSCH receptions providing multicast MCCH and multicast MTCH in RRC_INACTIVE state. A UE monitors PDCCH for scheduling PDSCH receptions for multicast MCCH or multicast MTCH in RRC_INACTIVE state as described in clause 10.1.

In clauses referring to a higher layer parameter value provided by *PDCCH-ConfigCommon* or *PDSCH-ConfigMCCH/PDSCH-ConfigMTCH* for multicast in RRC_INACTIVE state, when applicable a corresponding higher layer parameter value for multicast MCCH/multicast MTCH PDCCH receptions or PDSCH receptions in RRC_INACTIVE state, respectively, is provided as described in [12, TS 38.331].

A UE can be configured, per DL BWP by *cfr-ConfigMulticast*, an MBS frequency resource within the DL BWP for PDCCH and PDSCH receptions [4, TS 38.211]. If *cfr-ConfigMulticast* does not include *locationAndBandwidthMulticast*, the MBS frequency resource is the DL BWP. The SCS and CP of MBS frequency resource provided by *CFR-ConfigMulticast* are same as the associated DL BWP. In clauses referring to a higher layer parameter value provided by *PDCCH-Config* or *PDSCH-Config* or *SPS-Config* for a DL BWP, when applicable a corresponding higher layer parameter value for multicast PDCCH, PDSCH, or SPS PDSCH receptions is provided as described in [12, TS 38.331].

In clauses referring to a higher layer parameter value provided by a first or second *PUCCH-Config*, when applicable a corresponding higher layer parameter value for PUCCH transmissions associated with multicast PDCCH or PDSCH receptions is provided as described in [12, TS 38.331]. In clauses referring to a higher layer parameter value provided by *n1-PUCCH-AN* or *SPS-PUCCH-AN-List*, when applicable a corresponding higher layer parameter value for PUCCH transmissions associated with multicast SPS PDSCH receptions is provided as described in [12, TS 38.331]. In clauses referring to a higher layer parameter value provided by *pdsch-HARQ-ACK-Codebook* or *pdsch-HARQ-ACK-CodebookList*, when applicable a corresponding higher layer parameter value for HARQ-ACK codebooks associated with multicast HARQ-ACK information is provided as described in [12, TS 38.331].

A UE monitors PDCCH for scheduling PDSCH receptions or for activation/release of SPS PDSCH receptions for a corresponding SPS PDSCH configuration as described in clause 10.1.

A UE can be configured by *harq-FeedbackOptionMulticast*, for a G-RNTI for multicast or for a G-CS-RNTI, to provide HARQ-ACK information for a transport block reception associated with the G-RNTI for multicast or with the G-CS-RNTI, according to the first HARQ-ACK reporting mode if *harq-FeedbackOptionMulticast* is set to '*ack-nack*' or according to the second HARQ-ACK reporting mode if *harq-FeedbackOptionMulticast* is set to '*nack-only*'. The UE determines a priority for a PUCCH transmission with multicast HARQ-ACK information according to any HARQ-ACK reporting mode as described in clause 9 for a PUCCH transmission with unicast HARQ-ACK information.

For the first HARQ-ACK reporting mode, the UE generates HARQ-ACK information with ACK value when a UE correctly decodes a transport block; otherwise, the UE generates HARQ-ACK information with NACK value, as described in clauses 9 and 9.1 through 9.3. The UE determines a PUCCH or a PUSCH to provide the HARQ-ACK information as described in clause 9.2.

For the second HARQ-ACK reporting mode, the UE does not transmit a PUCCH that would include only HARQ-ACK information with ACK values. The second HARQ-ACK reporting mode is not applicable for the first SPS PDSCH reception after activation of SPS PDSCH receptions for a SPS configuration.

For the second HARQ-ACK reporting mode, when a number of HARQ-ACK information bits is one, a UE transmits a PUCCH only when the HARQ-ACK information bit has NACK value. The UE determines a PUCCH to provide the HARQ-ACK information as described in clause 9.2.1 or 9.2.3 when UE is not provided *moreThanOneNackOnlyMode*, or as the first PUCCH in Table 18-1 when UE is provided *moreThanOneNackOnlyMode.* For a PUCCH resource associated with PUCCH format 0, the UE transmits the PUCCH as described in [4, TS 38.211] by obtaining m_0 as described for HARQ-ACK information in clause 9.2.3 and by setting $m_{\mathrm{cs}} = 0$. For a PUCCH resource associated with PUCCH format 1, the UE transmits the PUCCH as described in [4, TS 38.211] by setting $b(0) = 0$.

A UE that is indicated '*nack-only*' by *harq-FeedbackOptionMulticast*, and for the case when the UE reports more than one HARQ-ACK information bits, the UE can be indicated to provide the HARQ-ACK information bits in a PUCCH either according to the first HARQ-ACK reporting mode when the UE is not provided *moreThanOneNackOnlyMode* or, for only one G-RNTI or only one G-CS-RNTI, according to the second HARQ-ACK reporting mode by selecting a PUCCH resource from a set of PUCCH resources for the PUCCH transmission based on the values of the HARQ-ACK information bits as described in Table 18-1 when the UE is provided *moreThanOneNackOnlyMode*. The UE generates HARQ-ACK information bits for the second HARQ-ACK reporting mode according to a Type-2 HARQ-ACK codebook as described in clause 9.1.3.1. For a PUCCH resource associated with PUCCH format 0, the UE transmits the PUCCH as described in [4, TS 38.211] by obtaining m_0 as described for HARQ-ACK information in clause 9.2.3 and by setting $m_{\mathrm{cs}} = 0$. For a PUCCH resource associated with PUCCH format 1, the UE transmits the PUCCH as described in [4, TS 38.211] by setting $b(0) = 0$.

For a UE that is indicated the second HARQ-ACK reporting mode, the UE does not expect to be provided *pdsch-HARQ-ACK-Codebook = semi-static* for multicast HARQ-ACK information.

For a UE that is indicated the second HARQ-ACK reporting mode and *moreThanOneNackOnlyMode*, all PUCCH resources associated with the second HARQ-ACK reporting mode have same starting symbol and same number of symbols and, when PUCCH resources in Table 18-1 are located in more than one PRBs, the more than one PRBs are adjacent and are associated with a same MPR value [8-1, TS 38.101-1].

Table 18-1: Mapping of values of HARQ-ACK information bits to PUCCH resources for the second HARQ-ACK reporting mode

Value of HARQ-ACK information bits				PUCCH resource
{0}	{0,0}	{0,0,0}	{0,0,0,0}	1st PUCCH resource from *resourceList/n1PUCCH-AN/sps-PUCCH-AN-ListMulticast*
	{1,0}	{1,0,0}	{1,0,0,0}	2nd PUCCH resource from *resourceList/sps-PUCCH-AN-ListMulticast*
	{0,1}	{0,1,0}	{0,1,0,0}	3rd PUCCH resource from *resourceList/sps-PUCCH-AN-ListMulticast*
		{1,1,0}	{1,1,0,0}	4th PUCCH resource from *resourceList*
		{0,0,1}	{0,0,1,0}	5th PUCCH resource from *resourceList*
		{1,0,1}	{1,0,1,0}	6th PUCCH resource from *resourceList*
		{0,1,1}	{0,1,1,0}	7th PUCCH resource from *resourceList*
			{1,1,1,0}	8th PUCCH resource from *resourceList*
			{0,0,0,1}	9th PUCCH resource from *resourceList*
			{1,0,0,1}	10th PUCCH resource from *resourceList*
			{0,1,0,1}	11th PUCCH resource from *resourceList*
			{1,1,0,1}	12th PUCCH resource from *resourceList*
			{0,0,1,1}	13th PUCCH resource from *resourceList*
			{1,0,1,1}	14th PUCCH resource from *resourceList*
			{0,1,1,1}	15th PUCCH resource from *resourceList*

If a UE is provided *pucch-ConfigurationListMulticast1* or *pucch-ConfigurationListMulticast2* for PUCCH transmissions with a priority value, the UE transmits a PUCCH with the priority value according to *pucch-ConfigurationListMulticast1* or *pucch-ConfigurationListMulticast2* for each G-RNTI for multicast or G-CS-RNTI that the UE provides associated HARQ-ACK information according to the first HARQ-ACK reporting mode or the second HARQ-ACK reporting mode, respectively. For HARQ-ACK information associated only with the second HARQ-ACK reporting mode and for more than one HARQ-ACK information bit, when the UE is not provided *moreThanOneNackOnlyMode* and the UE provides the HARQ-ACK information according to the first HARQ-ACK reporting mode, the UE determines a PUCCH resource from *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1*, if provided; otherwise, the UE determines a PUCCH resource from *pucch-Config/pucch-ConfigurationList* as described in clause 9.2.3.

A PDSCH reception providing an initial transmission of a transport block is scheduled only by a multicast DCI format. For the first HARQ-ACK reporting mode, a PDSCH reception providing a retransmission of the transport block can be scheduled either by a multicast DCI format using a same G-RNTI for multicast as the G-RNTI for multicast of the initial transmission of the transport block, or by a unicast DCI format using a C-RNTI [6, TS 38.214].

An activation for SPS PDSCH receptions using a G-CS-RNTI for a corresponding SPS PDSCH configuration is provided only by a multicast DCI format as described in clause 10.2 by replacing CS-RNTI with the G-CS-RNTI. A release for SPS PDSCH receptions using a G-CS-RNTI for a corresponding SPS PDSCH configuration is provided by a multicast DCI format as described in clause 10.2 by replacing CS-RNTI with the G-CS-RNTI, or by a DCI format with CRC scrambled by CS-RNTI. For the first HARQ-ACK reporting mode and for a transport block that a UE received in a SPS PDSCH, a PDSCH reception providing a retransmission of the transport block can be scheduled either by a unicast DCI format using a CS-RNTI or by a multicast DCI format using a same G-CS-RNTI as the G-CS-RNTI of the initial transmission of the transport block [6, TS 38.214].

For a DCI format indicating SPS PDSCH release, the UE provides the associated HARQ-ACK information as described in clause 9.1.

A UE can be configured per G-RNTI for multicast or per G-CS-RNTI, by *harq-FeedbackEnablerMulticast* with value set to 'enabled', to provide HARQ-ACK information for PDSCH receptions. When the UE is not provided *harq-FeedbackEnablerMulticast* for a G-RNTI for multicast or G-CS-RNTI and *pdsch-HARQ-ACK-Codebook = dynamic* for multicast HARQ-ACK information, the UE does not provide HARQ-ACK information for respective PDSCH receptions. If a UE is provided *harq-FeedbackEnablerMulticast* with value set to 'dci-enabler' for a G-RNTI for multicast or a G-CS-RNTI, the UE provides HARQ-ACK information for PDSCH receptions scheduled by multicast DCI format 4_1 associated with the G-RNTI or the G-CS-RNTI, and determines whether or not to provide the HARQ-ACK information for PDSCH receptions scheduled or activated by multicast DCI format 4_2 based on an indication by the multicast DCI format 4_2 associated with the G-RNTI for multicast or the G-CS-RNTI [4, TS 38.212]. If a UE is provided *pdsch-HARQ-ACK-Codebook = semi-static* for multicast HARQ-ACK information, the UE does not expect to be provided *harq-FeedbackEnablerMulticast* with value set to 'dci-enabler' for a G-RNTI for multicast or a G-CS-RNTI.

If a UE would multiplex second multicast HARQ-ACK information according to the second HARQ-ACK reporting mode with first multicast HARQ-ACK information according to the first HARQ-ACK reporting mode, or unicast HARQ-ACK information, or CSI reports in a first PUCCH or in a PUSCH, as described in clauses 9 and 9.2.5, the UE provides the second HARQ-ACK information according to the first HARQ-ACK reporting mode. If the UE would multiplex the second multicast HARQ-ACK information, for resolving an overlapping among a second PUCCH with the second HARQ-ACK information and other PUCCHs or PUSCHs prior to multiplexing the second HARQ-ACK information in a PUCCH or PUSCH, the UE considers that the UE would transmit the second PUCCH when all values of the HARQ-ACK information are 'ACK'. If the UE would multiplex the second multicast HARQ-ACK information, for resolving an overlapping among a second PUCCH with the second HARQ-ACK information and other PUCCHs or PUSCHs prior to multiplexing the second HARQ-ACK information in a PUCCH or PUSCH when the UE is provided *moreThanOneNackOnlyMode*, the UE considers that the UE would transmit the second PUCCH using any PUCCH resource from the PUCCH resources associated with the second HARQ-ACK reporting mode when all values of the second HARQ-ACK information are 'ACK'.

If a UE would only transmit a first PUCCH with only positive SR and a second PUCCH with HARQ-ACK information according to the second HARQ-ACK reporting mode, where the first and second PUCCHs would overlap in time in a slot and have same priority index, it is up to UE implementation for the UE to transmit either the first PUCCH or the second PUCCH.

If a UE is provided multiple G-RNTIs for multicast or G-CS-RNTIs, a configuration for a HARQ-ACK codebook type applies to all G-RNTIs for multicast or G-CS-RNTIs.

If a UE is provided *pdsch-HARQ-ACK-Codebook = semi-static* for multicast HARQ-ACK information, the UE generates a Type-1 HARQ-ACK codebook as described in clauses 9.1.2, 9.1.2.1, and 9.1.2.2.

If a UE is provided *pdsch-HARQ-ACK-Codebook = dynamic* for multicast HARQ-ACK information, the UE generates a Type-2 HARQ-ACK codebook as described in clauses 9.1.3.1 and 9.1.3.2.

If a UE would report unicast HARQ-ACK information and multicast HARQ-ACK information with same priority index in a slot, the UE multiplexes the unicast HARQ-ACK information and the multicast HARQ-ACK information following the procedures in this clause and in clauses 9.1.2, 9.1.3, and 9.1.4.

If, for unicast and multicast HARQ-ACK information of same priority value, a UE

- is provided
  - either *pdsch-HARQ-ACK-Codebook* = *dynamic* or *pdsch-HARQ-ACK-Codebook-r16* for unicast HARQ-ACK information and *pdsch-HARQ-ACK-Codebook* = *semi-static* for multicast HARQ-ACK information,
  - or *pdsch-HARQ-ACK-Codebook* = *semi-static* or *pdsch-HARQ-ACK-Codebook-r16* for unicast HARQ-ACK information and *pdsch-HARQ-ACK-Codebook* = *dynamic* for multicast HARQ-ACK information, and
- would multiplex the unicast and multicast HARQ-ACK information in a same PUCCH or PUSCH

the UE

- appends the HARQ-ACK codebooks for the multicast HARQ-ACK information to the HARQ-ACK codebooks for the unicast HARQ-ACK information
- if $O_{\mathrm{ACK}} + O_{\mathrm{SR}} + O_{\mathrm{CSI}} \leq 11$, the UE determines $n_{\mathrm{HARQ-ACK}}$ for obtaining a power of a PUCCH transmission with the HARQ-ACK information, as described in clause 7.2.1, as a sum of the $n_{\mathrm{HARQ-ACK}}$ value from clause 9.1.3.1 or clause 9.1.3.3 and the $n_{\mathrm{HARQ-ACK}}$ value from clause 9.1.2.1 or as a sum of the $n_{\mathrm{HARQ-ACK}}$ value from clause 9.1.2.1 or clause 9.1.3.3 and the $n_{\mathrm{HARQ-ACK}}$ value from clause 9.1.3.1.

A UE determines a PUCCH resource for a PUCCH transmission with HARQ-ACK information as described in clauses 9.2 and 9.2.1 through 9.2.5.

If a UE multiplexes in a PUCCH HARQ-ACK information of same priority associated with unicast DCI formats and with multicast DCI formats in a same PUCCH, the last DCI format that the UE uses to determine the PUCCH resource from *pucch-Config/pucch-ConfigurationList*, as described in clause 9.2.3, is a last unicast DCI format.

If the UE multiplexes in a PUCCH only multicast HARQ-ACK information of same priority that is according to both the first and second HARQ-ACK reporting modes, the last DCI format that the UE uses to determine the PUCCH resource from *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1*, if provided; otherwise, from *pucch-Config/pucch-ConfigurationList*, as described in clause 9.2.3, is a last DCI format associated with multicast HARQ-ACK information that is according to the first HARQ-ACK reporting mode.

If a UE multiplexes in a PUCCH only first HARQ-ACK information associated with multicast SPS PDSCH receptions and second HARQ-ACK information associated with multicast DCI formats and having same priority value as the first HARQ-ACK information, and both the first and second HARQ-ACK information are according to the first HARQ-ACK reporting mode, the UE determines the PUCCH resource based on the last multicast DCI format from *pucch-ConfigMulticast1/pucch-ConfigurationListMulticast1*, if provided; otherwise, from *pucch-Config/pucch-ConfigurationList*, as described in clause 9.2.3.

If a UE multiplexes in a PUCCH only first HARQ-ACK information associated with multicast SPS PDSCH receptions and second HARQ-ACK information associated with multicast DCI formats and having same priority value as the first HARQ-ACK information, and the first and second HARQ-ACK information are indicated by *harq-FeedbackOptionMulticast* different HARQ-ACK reporting modes, the UE determines the PUCCH resource based on:

- *sps-PUCCH-AN-ListMulticast*, or *sps-PUCCH-AN-List* if *sps-PUCCH-AN-ListMulticast* is not provided, if the first HARQ-ACK information is according to the first HARQ-ACK reporting mode or
- the last multicast DCI format, as described in clause 9.2.3, if the second HARQ-ACK information is according to the first HARQ-ACK reporting mode.

If a UE multiplexes in a PUCCH first HARQ-ACK information associated with unicast SPS PDSCH receptions and second HARQ-ACK information associated with multicast DCI formats and having same priority value as the first HARQ-ACK information in a same PUCCH, the UE determines the PUCCH resource from

- if provided, *SPS-PUCCH-AN-List* for unicast SPS PDSCH receptions as described in clause 9.2.1;
- else, if provided, *PUCCH-Config/PUCCH-ConfigurationList* for multicast PDSCH receptions;
- else, *PUCCH-Config/PUCCH-ConfigurationList* for unicast PDSCH receptions.

If a UE multiplexes in a PUCCH first HARQ-ACK information associated with unicast SPS PDSCH receptions and second HARQ-ACK information associated with multicast SPS PDSCH receptions and having same priority value as the first HARQ-ACK information in a same PUCCH, the UE determines the PUCCH resource from *SPS-PUCCH-AN-List* for unicast SPS PDSCH receptions as described in clause 9.2.1.

If a UE multiplexes in a PUCCH only HARQ-ACK information associated with multicast SPS PDSCHs receptions of same priority that is according to the first HARQ-ACK reporting mode and is not provided *sps-PUCCH-AN-ListMulticast*, the UE determines the PUCCH resource from the *sps-PUCCH-AN-List* provided for unicast SPS PDSCH reception as described in clause 9.2.1.

If a UE multiplexes in a PUCCH multicast HARQ-ACK information only according to second HARQ-ACK reporting modes and CSI reports and, if any, SR, the UE determines a PUCCH resource as described in clause 9.2.5.2 for multiplexing CSI reports with HARQ-ACK information that is in response to PDSCH receptions without corresponding PDCCHs.

A UE is not required to multiplex in a PUCCH multicast HARQ-ACK information of a priority and unicast UCI of the priority if the UE is provided *subslotLengthForPUCCH* for PUCCH transmissions with unicast UCI of the priority.

19 PUSCH transmission in RRC_INACTIVE state

19.1 Configured-grant based PUSCH transmission

A UE indicated to release a dedicated RRC connection can be provided one or more configurations by respective one or more *ConfiguredGrantConfig*, for configured grant Type 1 PUSCH transmissions on the initial UL BWP [12, TS 38.331]. For the remaining of this clause, PUSCH transmissions refer to configured grant Type-1 PUSCH transmissions for a configuration provided by *ConfiguredGrantConfig*.

A UE can be provided by *sdt-SSB-Subset* a number of SS/PBCH block indexes $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ to map to a number of valid PUSCH occasions for PUSCH transmissions over an association period. If the UE is not provided *sdt-SSB-Subset*, the UE determines $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ from the value of *ssb-PositionsInBurst* in *SIB1*. A PUSCH occasion for a PUSCH transmission is defined by a time resource and a frequency resource and is associated with a DM-RS provided by *cg-DMRS-Configuration* for the configuration of PUSCH transmissions. A UE can be provided a number of repetitions for a PUSCH transmission by *repK* or *numberOfRepetitions*. If the number of repetitions is provided and larger than 1, all the PUSCH occasions of the repetitions for the PUSCH transmission are mapped to the same SS/PBCH block index(es). All the PUSCH occasions of the repetitions are not valid if any PUSCH occasion of the repetitions is not valid.

An association period, starting from frame with SFN 0 and hyper frame with hyper SFN 0, for mapping $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes, from the number of SS/PBCH block indexes, to valid PUSCH occasions and associated DM-RS resources is the smallest value in the set determined by the PUSCH configuration period provided by *periodicity* in *ConfiguredGrantConfig* according to Table 19.1-1 such that $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes are mapped at least once to valid PUSCH occasions and associated DM-RS resources within the association period. A UE is provided a number of SS/PBCH block indexes associated with a PUSCH occasion and a DM-RS resource by *sdt-SSB-PerCG-PUSCH*. If after an integer number of SS/PBCH block indexes to PUSCH occasions and associated DMRS resources mapping cycles within the association period there is a set of PUSCH occasions and associated DMRS resources that are not mapped to $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes, no SS/PBCH block indexes are mapped to the set of PUSCH occasions and associated DMRS resources. An association pattern period, when PUSCH configuration period is no longer than 640 msec, includes one or more association periods and is determined so that a pattern between PUSCH occasions with associated DMRS resources and SS/PBCH block indexes repeats at most every 640 msec. PUSCH occasions and associated DMRS resources not associated with SS/PBCH block indexes after an integer number of association periods, if any, are not used for PUSCH transmissions.

Table 19.1-1: Mapping between PUSCH configuration period and SS/PBCH block to configured PUSCH resource association period

PUSCH configuration period T_{cg} (msec)	**Association period (number of PUSCH configuration periods)**
5	{1, 2, 4, 8,16, 32, 64, 128}
8	{1, 2, 4, 5, 8, 10, 16, 20, 40, 80}
10	{1, 2, 4, 8,16, 32, 64}
16	{1, 2, 4, 5, 8,10,20,40}
20	{1, 2, 4, 8,16, 32}
32	{1, 2, 4, 5, 10, 20}
40	{1, 2, 4, 8, 16}
64	{1, 2, 5, 10}
80	{1, 2, 4, 8}
128	{1, 5}
160	{1, 2, 4}
320	{1, 2}
640	{1}
1280	{1}
2560	{1}
5120	{1}
10240	{1}
61440	{1}
122880	{1}
307200	{1}
604160	{1}
1208320	{1}
1802240	{1}
3604480	{1}

$N_{\text{PUSCH}}^{\text{SS/PBCH}}$ SS/PBCH block indexes are mapped to valid PUSCH occasions and associated DMRS resources in the following order

- first, in increasing order of DMRS resource indexes within a PUSCH occasion, where a DMRS resource index $DMRS_{id}$ is determined first in an ascending order of a DMRS port index and second in an ascending order of a DMRS sequence index [4, TS 38.211]
- second, in increasing order of PUSCH configuration period indexes

A PUSCH occasion is valid if it does not overlap with a valid PRACH occasion as described in clause 8.1.

For unpaired spectrum and for SS/PBCH blocks with indexes provided by *ssb-PositionsInBurst* in *SIB1*

- if a UE is not provided *tdd-UL-DL-ConfigurationCommon*, a PUSCH occasion is valid if the PUSCH occasion
  - does not precede a SS/PBCH block in the PUSCH slot, and
  - starts at least N_{gap} symbols after a last SS/PBCH block symbol, where N_{gap} is provided in Table 8.1-2
- if a UE is provided *tdd-UL-DL-ConfigurationCommon*, a PUSCH occasion is valid if the PUSCH occasion
  - is within UL symbols
  - starts at least N_{gap} symbols after a last downlink symbol, and at least N_{gap} symbols after a last SS/PBCH block symbol, where N_{gap} is provided in Table 8.1-2

A UE determines a power of a PUSCH transmission as described in clause 7.1.1, where the UE obtains $PL_{b,f,c}(q_d)$ using a RS resource from an SS/PBCH block with index associated with the PUSCH transmission.

A UE can be provided a USS set by *SearchSpace*, or a CSS set by *sdt-SearchSpace*, to monitor PDCCH for detection of DCI format 0_0 with CRC scrambled by C-RNTI or CS-RNTI for scheduling PUSCH transmission or of DCI format 1_0 with CRC scrambled by C-RNTI for scheduling PDSCH receptions [12, TS 38.331]. The UE may assume that the DM-RS antenna port associated with the PDCCH receptions, the DM-RS antenna port associated with the PDSCH receptions, and the SS/PBCH block associated with the PUSCH transmission are quasi co-located with respect to average gain and quasi co-location 'typeA' or 'typeD' properties. The UE transmits a PUCCH with HARQ-ACK information associated with the PDSCH receptions as described in clause 9.2.1 using a same spatial domain transmission filter as for the last PUSCH transmission.

For initial transmission or autonomous retransmission of an initial transport block provided for the PUSCH transmission as described in clause 18.0 in [19, TS 38.300], the UE encodes the transport block using redundancy version number 0 if the UE is not provided *repK-RV*.

19.2 Random-access based PUSCH transmission

A UE indicated to release a dedicated RRC connection can be provided a configuration for a Type-1 and/or a Type-2 random access procedure on the initial UL BWP [12, TS 38.331]. PRACH occasions can have either a common configuration as, or a separate configuration from, PRACH occasions for Type-1 or Type-2 random access procedure as described in clause 8.1. The UE procedure is as described in clause 8, including clauses 8.1 through 8.4. The UE transmits a PRACH preamble with a power determined as described in clause 7.4.

For a common configuration of PRACH occasions and a Type-1 or a Type-2 random access procedure, a UE can be provided a number of contention based preambles per SS/PBCH block index per valid PRACH occasion by *startPreambleForThisPartition* and *numberOfPreamblesPerSSB-ForThisPartition* when *smallData* is present in corresponding *FeatureCombination*. A PRACH transmission can be on a subset of PRACH occasions associated with a same SS/PBCH block index within an SSB-RO mapping cycle as determined by a PRACH mask index provided by *ssb-SharedRO-MaskIndex* according to [11, TS 38.321].

A UE can be provided by *sdt-SearchSpace* a CSS set to monitor, after contention resolution as described in clause 8.4, PDCCH for detection of a DCI format 0_0 or DCI format 1_0 with CRC scrambled by C-RNTI for scheduling respective PUSCH transmissions or PDSCH receptions; otherwise, if the UE is not provided *sdt-SearchSpace*, the UE monitors PDCCH according to a Type1-PDCCH CSS set as described in clause 10.1. The UE may assume that the DM-RS antenna port associated with the PDCCH receptions, the DM-RS antenna port associated with the PDSCH receptions, and the SS/PBCH block associated with the PRACH transmission are quasi co-located with respect to average gain and quasi co-location 'typeA' or 'typeD' properties.

20 Network controlled repeater

An NCR includes an NCR-MT entity and an NCR-Fwd entity [19, TS 38.300].

Throughout this specification, unless otherwise noted, statements using the term "UE" in Clauses 4 through 13 are equally applicable to the NCR-MT.

A procedure for the NCR-MT to perform cell search, system information acquisition, random access procedure, UCI reporting, or PDCCH monitoring is same as a corresponding one for a UE. A procedure for the NCR-MT to perform PDSCH reception, CSI-RS measurements and CSI determination, PUSCH transmission, or SRS transmission is same as a corresponding one for a UE as described in [6, TS 38.214].

The NCR-Fwd transmits or receives only after the NCR-MT receives on the control link an indication for one or more beams [20, TS 38.106] for the NCR-Fwd to use for transmissions or receptions over corresponding one or more time resources on the access link.

The timing for transmission and reception by the NCR-Fwd on the backhaul link follows the frame timing for transmission and reception, respectively, by the NCR-MT.

When the NCR-MT performs a link recovery procedure as described in Clause 6, the NCR-Fwd does not transmit or receive until the link recovery procedure is complete [11, TS 38.321].

The NCR can be provided, through the NCR-MT, *tdd-UL-DL-ConfigurationCommon* and can be additionally provided *tdd-UL-DL-ConfigurationDedicated*. The NCR-Fwd receives on the backhaul link or transmits on the access link only in symbols indicated as downlink by *tdd-UL-DL-ConfigurationCommon* and, if provided, *tdd-UL-DL-*

ConfigurationDedicated. The NCR-Fwd receives on the access link or transmits on the backhaul link only in symbols indicated as uplink by *tdd-UL-DL-ConfigurationCommon* and, if provided, *tdd-UL-DL-ConfigurationDedicated*.

If the NCR does not support simultaneous transmissions on control link and the backhaul link, the NCR-Fwd does not transmit over a time resource if the NCR-MT transmits over the time resource.

When the NCR simultaneously receives via both the control link and the backhaul link in a set of symbols, a TCI state for receptions on the backhaul link is same as a TCI state for receptions on the control link in the set of symbols. When the NCR simultaneously transmits via both the control link and the backhaul link in a set of symbols, a spatial filter for transmissions on the backhaul link is same as a spatial filter for transmissions on the control link in the set of symbols.

When the NCR does not simultaneously receive on the control link and the backhaul link

- if the NCR does not support determination of a TCI state for receptions on the backhaul link based on an indication of a TCI state by the serving cell, or if the NCR does not receive an indication of a TCI state, for receptions on the backhaul link [11, TS 38.321]
    - if the NCR does not receive an indication of a unified TCI state for receptions by the NCR-MT, receptions on the backhaul link use same QCL parameters as the ones for PDCCH receptions in a CORESET with the lowest *controlResourceSetId* in the active DL BWP
    - else, receptions on the backhaul link use the QCL parameters provided by an indicated unified TCI state for receptions by the NCR-MT
- else receptions on the backhaul link use QCL parameters provided by a TCI state in NCR Downlink Backhaul Link Beam Indication MAC CE [11, TS 38.321].

When the NCR does not simultaneously transmit on the control link and the backhaul link

- if the NCR does not support determination of a spatial filter for transmissions on the backhaul link based on an indication of a unified TCI state or of an SRI by the serving cell, or if the NCR-MT does not receive an indication of a unified TCI state or of an SRI for determining a spatial filter, for transmissions on the backhaul link
    - if the NCR does not receive an indication of a unified TCI state for transmissions by the NCR-MT, transmissions on the backhaul link use a same spatial filter as the one associated with the PUCCH resource with the smallest *pucch-ResourceId* in *PUCCH-ResourceSet* in the active UL BWP
    - else, transmissions on the backhaul link use a spatial filter corresponding to the indicated unified TCI state for transmissions by the NCR-MT.
- else transmissions on the backhaul link use a spatial filter corresponding to a unified TCI state or an SRI provided in NCR Uplink Backhaul Link Beam Indication MAC CE [11, TS 38.321].

If the NCR receives an indication of a TCI state for receptions on the backhaul link in a MAC CE command, or an indication of a unified TCI state or of an SRI for determining a spatial filter for transmissions on the backhaul link in a MAC CE command, the NCR applies the MAC CE command from the first slot that is after slot $k + 3 \cdot N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ where k is the slot where the NCR-MT would transmit a PUCCH with HARQ-ACK information associated with the PDSCH providing the MAC CE command, $N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$ is a number of slots per subframe for the SCS configuration μ of the PUCCH transmission.

The NCR-Fwd uses a same beam for transmissions and receptions on the access link during respective time resources associated with a same beam index.

The NCR can be provided by *periodicFwdRsrcSetToAddModList* a list of sets of resources for transmissions or receptions on the access link. A set of resources, from the list of sets of resources, is provided by *NCR-PeriodicFwdResourceSet* and occurs with a periodicity provided by *periodicityAndOffset-r18*. A resource from the set of resources is provided by *NCR-PeriodicFwdResource* and includes a pair of a time resource provided by *periodicTimeRsrc* and a beam [20, TS 38.106] with an index provided by *beamIndex*. The time resource starts at a slot that is offset by a number of slots provided by *periodicityAndOffset-r18* from the start of the period for the set of resources and at a symbol that is offset by *symbolOffset* from the start of the slot, and has a duration provided by *durationInSymbols* for a SCS provided by *referenceSCS* and the *cyclicPrefix* of the active DL BWP.

The NCR can be provided by *semiPersistentFwdRsrcSetToAddModList* a list of sets of resources for transmissions or receptions on the access link and the NCR Access Link Beam Indication MAC CE command can indicate a set of resources for the NCR to use or to stop using based on a corresponding identity provided by *semiPersistentFwdRsrcSetId* [11, TS 38.321]. The NCR uses or stops using the set of resources starting from the first slot that is after slot $k + 3N_{\text{slot}}^{\text{subframe},\mu}$ where k is the slot where the NCR-MT would transmit a PUCCH with HARQ-ACK information associated with the PDSCH providing the MAC CE command and μ is the SCS configuration for the PUCCH transmission. The set of resources is provided by *NCR-SemiPersistentFwdResourceSet* and occurs with a periodicity provided by *periodicityAndOffset-r18*. A resource from the set of resources is provided by *NCR-SemiPersistentFwdResource* and includes a pair of a time resource provided by *semiPersistentTimeRsrc* and a beam with an index provided by *beamIndex*, where *beamIndex* can be updated by the NCR Access Link Beam Indication MAC CE command. The time resource starts at a slot that is offset by a number of slots provided by *periodicityAndOffset-r18* from the start of the period for the set of resources and at a symbol that is offset by *symbolOffset* from the start of the slot, and has a duration provided by *durationInSymbols* for a SCS provided by *referenceSCS* and the *cyclicPrefix* of the active DL BWP.

The NCR-MT can be configured to monitor PDCCH according to USS sets for detection of a DCI format 2_8 with CRC scrambled by an NCR-RNTI. A time resource and a corresponding beam index for transmissions or receptions on the access link are indicated by corresponding fields in DCI format 2_8 [4, TS 38.212]. When the NCR detects more than one DCI formats 2_8 that indicate beam indexes for time resources overlapping in a set of symbols, the NCR uses for the set of symbols a beam index that is indicated by a DCI format 2_8 that the NCR-MT detects in a most recent PDCCH monitoring occasion. If the NCR detects a DCI format 2_8 indicating more than one time resources that overlap in a set of symbols, the NCR expects that beam indexes associated with the more than one time resources have a same value. The time resource starts at a slot that is offset by *slotOffsetAperiodic* slots from a reference slot and at a symbol that is offset by *symbolOffset* from the start of the slot, and has a duration provided by *durationInSymbols* for a SCS provided by *referenceSCS* and the *cyclicPrefix* of the active DL BWP. The reference slot is the first slot with the SCS provided by *referenceSCS* that starts no earlier than the start of a slot that is after a slot of a PDCCH reception that provides the DCI format 2_8 by a number of slots indicated by *ncr-AperiodicBeamInd-AccessLink* [18, TS 38.306] with the SCS of PDCCH reception.

If

- a first time resource provided by *NCR-SemiPersistentFwdResourceSet* is indicated by the NCR Access Link Beam Indication MAC CE command and is associated with a first beam index, and

- a second time resource is provided by *NCR-PeriodicFwdResourceSet* and is associated with a second beam index, and

- the first time resource overlaps with the second time resource in a set of symbols,

the NCR applies, for transmissions or receptions on the access link in the set of symbols, the second beam index if only *NCR-PeriodicFwdResourceSet* includes *priorityFlag*, and the first beam index otherwise.

If

- a first time resource is provided by *NCR-PeriodicFwdResourceSet*, or provided by *NCR-SemiPersistentFwdResourceSet* and indicated by the NCR Access Link Beam Indication MAC CE command, and is associated with a first beam index, and

- a second time resource is indicated by DCI format 2_8 and is associated with a second beam index provided by the DCI format 2_8, and

- the first time resource overlaps with the second time resource in a set of symbols,

the NCR applies, for transmissions or receptions on the access link in the set of symbols,

- the first beam index if *NCR-PeriodicFwdResourceSet* or *NCR-SemiPersistentFwdResourceSet* includes *priorityFlag*, and

- the second beam index if *NCR-PeriodicFwdResourceSet* or *NCR-SemiPersistentFwdResourceSet* does not include *priorityFlag*.

The NCR does not expect overlapping time resources provided by either *NCR-PeriodicFwdResourceSet* or *NCR-SemiPersistentFwdResourceSet* to be associated with different beam indexes.

21 L1/L2-triggered mobility procedures

A UE can be indicated, by *LTM-Config*, candidate cells and SS/PBCH blocks per candidate cell for the UE to obtain synchronization and measure corresponding L1-RSRPs [10, TS 38.133]. A Candidate Cell TCI States Activation/Deactivation MAC CE can activate TCI states, provided by *CandidateTCI-State* or/and *CandidateTCI-UL-State*, associated with SS/PBCH blocks or TRS of corresponding candidate cells [11, TS 38.321]. If the Candidate Cell TCI States Activation/Deactivation MAC CE activates TCI states, an LTM Cell Switch Command MAC CE can indicate a TCI state from the activated TCI states; otherwise, the LTM Cell Switch Command MAC CE can activate and indicate a TCI state, provided by *CandidateTCI-State* or/and *CandidateTCI-UL-State*. After reception of the LTM Cell Switch Command MAC CE, activated TCI states that are not indicated by the MAC CE are deactivated. The UE is provided configurations by *LTM-CSI-ReportConfigToAddModList* for reporting L1-RSRP measurements [6, TS 38.214] that include a number of candidate cells and a number of SS/PBCH blocks per candidate cell from the number of candidate cells.

If *ltm-UE-MeasuredTA-ID* of a candidate cell and *ltm-UE-MeasuredTA-ID* of the serving cell are provided to a UE and have same value, the UE estimates based on the UE implementation a timing advance to apply from a first transmission on the candidate cell that is after the reception of a cell switch command for the candidate cell [11, TS 38.321].

A UE can be provided configurations, by *EarlyUlSyncConfig*, for PRACH transmission parameters for each of the candidate cells. The UE can be triggered a PRACH transmission on a candidate cell by a PDCCH order that the UE receives on a serving cell and includes an indication of the candidate cell for the PRACH transmission [4, TS 38.212]. If the serving cell and the candidate cell operate in a same frequency range and the UE would have transmissions that overlap in time, or when a gap between a first or last symbol of a PRACH transmission to the candidate cell is less than N symbols from a last or first symbol, respectively, of an UL transmission to the serving cell, where N is defined in Clause 8.1, the UE

- drops the transmissions on the serving cell when the UE does not support transmissions that overlap in time or are separated by less than the gap on the serving cell and the candidate cell
- prioritizes power allocation to the PRACH transmission on the candidate cell in clause 7.5 when the UE supports transmissions that overlap in time or are separated by less than the gap, and a total UE transmit power in the frequency range would exceed $\hat{P}_{\text{CMAX}}$

The UE transmits the PRACH on the candidate cell as described in Clause 8.1 with a power determined as described in Clause 7.4.

A UE can be provided by a LTM Cell Switch Command MAC CE in a PDSCH reception on the serving cell [11, TS 38.321] a *CandidateTCI-State* and/or *CandidateTCI-UL-State* in *ltm-DL-OrJointTCI-StateToAddModList* and/or *ltm-UL-TCI-ToAddModList* indicating a unified TCI state [6, TS 38.214] for applicable receptions or transmissions on a candidate cell from the number of candidate cells. The UE may assume that DM-RS antenna ports for PDCCH receptions and for PDSCH receptions are quasi co-located with the SS/PBCH block or the TRS in the TCI state with respect to quasi co-location 'typeA' and 'typeD' properties, when applicable. The UE does not expect to be indicated quasi co-location 'typeA' properties when a SS/PBCH block is configured as a source RS of the TCI state. The UE applies the *CandidateTCI-State* and/or *CandidateTCI-UL-State,* if indicated by the MAC CE, no later than $T_{\text{LTM-RRC-processing}} + T_{\text{LTM-processing}} + T_{\text{first-RS}} + T_{\text{RS-proc}} + 3$ msec after the last symbol of a PUCCH or PUSCH with HARQ-ACK information for the PDSCH providing the MAC CE, where $T_{\text{LTM-RRC-processing}}$, $T_{\text{LTM-processing}}$, $T_{\text{first-RS}}$ and $T_{\text{RS-proc}}$ are defined in [10, TS 38.133]. For RACH-based LTM cell switch [19, TS 38.300], the UE applies the *CandidateTCI-State* for receptions on the candidate cell, and applies a spatial domain filter corresponding to the *CandidateTCI-State* or the *CandidateTCI-UL-State* for transmissions on the candidate cell, that are after the completion of the random access procedure associated with the PRACH transmission on the candidate cell and before a new TCI state is indicated for the candidate cell. For RACH-less LTM cell switch [19, TS 38.300], the UE applies the *CandidateTCI-State* for receptions on the candidate cell and applies a spatial domain filter corresponding to the *CandidateTCI-State* or the *CandidateTCI-UL-State* for transmissions on the candidate cell before a new TCI state is indicated for the candidate cell.

22 PUSCH transmission in NTN RACH-less handover

22.1 Configured-grant PUSCH transmission

A UE indicated to perform PUSCH transmission in RACH-less handover can be provided one or more configurations by respective one or more *ConfiguredGrantConfig*, for configured grant Type 1 PUSCH transmissions on the initial UL BWP [12, TS 38.331]. For the remaining of this clause, PUSCH transmissions refer to configured grant Type-1 PUSCH transmissions for a configuration provided by *ConfiguredGrantConfig*.

A UE can be provided by *ntn-SSB-Subset* a number of SS/PBCH block indexes $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ to map to a number of valid PUSCH occasions for PUSCH transmissions over an association period. If the UE is not provided *ntn-SSB-Subset*, the UE determines $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ from the value of *ssb-PositionsInBurst* in *ServingCellConfigCommon*. A PUSCH occasion for a PUSCH transmission is defined by a time resource and a frequency resource and is associated with a DM-RS provided by *cg-DMRS-Configuration* for the configuration of PUSCH transmissions. A UE can be provided a number of repetitions for a PUSCH transmission by *repK* or *numberOfRepetitions*. If the number of repetitions is provided and larger than 1, all the PUSCH occasions of the repetitions for the PUSCH transmission are mapped to the same SS/PBCH block index(es) and the UE encodes the transport block using redundancy version number 0 if the UE is not provided *repK-RV*.

An association period, starting from frame with SFN 0, for mapping $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes, from the number of SS/PBCH block indexes, to valid PUSCH occasions and associated DM-RS resources is the smallest value in the set determined by the PUSCH configuration period provided by *periodicity* in *ConfiguredGrantConfig* according to Table 19.1-1 such that $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes are mapped at least once to valid PUSCH occasions and associated DM-RS resources within the association period. A UE is provided a number of SS/PBCH block indexes associated with a PUSCH occasion and a DM-RS resource by *ntn-SSB-PerCG-PUSCH*. If after an integer number of SS/PBCH block indexes to PUSCH occasions and associated DMRS resources mapping cycles within the association period there is a set of PUSCH occasions and associated DMRS resources that are not mapped to $N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes, no SS/PBCH block indexes are mapped to the set of PUSCH occasions and associated DMRS resources. An association pattern period includes one or more association periods and is determined so that a pattern between PUSCH occasions with associated DMRS resources and SS/PBCH block indexes repeats at most every 640 msec. PUSCH occasions and associated DMRS resources not associated with SS/PBCH block indexes after an integer number of association periods, if any, are not used for PUSCH transmissions.

$N_{\mathrm{PUSCH}}^{\mathrm{SS/PBCH}}$ SS/PBCH block indexes are mapped to valid PUSCH occasions and associated DMRS resources in the following order

- first, in increasing order of DMRS resource indexes within a PUSCH occasion, where a DMRS resource index $DMRS_{id}$ is determined first in an ascending order of a DMRS port index and second in an ascending order of a DMRS sequence index [4, TS 38.211]
- second, in increasing order of PUSCH configuration period indexes

A PUSCH occasion is valid if it does not overlap with a valid PRACH occasion as described in clause 8.1.

A UE determines a power of a PUSCH transmission as described in clause 7.1.1, where the UE obtains $PL_{b,f,c}(q_d)$ using a RS resource from an SS/PBCH block with index associated with the PUSCH transmission.

22.2 Dynamic-grant PUSCH transmission

If *dg-beam* is provided in *RACH-LessHO*, the UE may assume that the DM-RS antenna port associated with the PDCCH receptions for scheduling initial PUSCH transmission and the SS/PBCH block indicated by *dg-beam* are quasi co-located with respect to average gain and quasi co-location 'typeA' or 'typeD' properties.

Annex A: Change history

Date	TSG #	TSG Doc.	CR	Rev	Cat	Subject/Comment	New version
2017-04	RAN1#89	R1-1707925				Draft skeleton	0.0.0
2017-07	AH_NR2	R1-1712015				Inclusion of agreements until RAN1-adhoc#2	0.0.1
2017-08	RAN1#90	R1-1714553				Inclusion of agreements on CA and first revisions	0.0.2
2017-08	RAN1#90	R1-1714565				Second revisions	0.0.3
2017-08	RAN1#90	R1-1714658				Endorsed by RAN1#90	0.1.0
2017-08	RAN1#90	R1-1715323				Inclusion of agreements from RAN1#90	0.1.1
2017-08	RAN1#90	R1-1715330				Updated editor's version	0.1.2
2017-09	RAN#77	RP-171995				For information to plenary	1.0.0
2017-09	RAN1#90bis	R1-1716929				Inclusion of agreements until RAN1-adhoc#3	1.0.1
2017-10	RAN1#90bis	R1-1719107				Endorsed by RAN1#90bis	1.1.0
2017-11	RAN1#90bis	R1-1719226				Inclusion of agreements from RAN1#90bis	1.1.1
2017-11	RAN1#90bis	R1-1719243				Updated editor's version	1.1.2
2017-11	RAN1#90bis	R1-1721050				Endorsed by RAN1#90bis	1.2.0
2017-12	RAN1#91	R1-1721343				Inclusion of agreements from RAN1#91	1.3.0
2017-12	RAN#78	RP-172703				Endorsed version for approval by plenary	2.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-03	RAN#79	RP-180200	0001	-	F	CR capturing the NR ad-hoc 1801 and RAN1#92 meeting agreements	15.1.0
2018-06	RAN#80	RP-181172	0002	1	F	CR to TS 38.213 capturing the RAN1#92bis and RAN1#93 meeting agreements and aligning higher layer parameters with TS 38.331	15.2.0
2018-09	RAN#81	RP-181789	0005	-	F	CR to 38.213 capturing the RAN1#94 meeting agreements	15.3.0
2018-09	RAN#81	RP-182071	0006	-	C	Support maximum 8 SS/PBCH blocks for unpaired spectrum beyond 2.4GHz	15.3.0
2018-12	RAN#82	RP-182523	0007	2	F	Combined CR of all essential corrections to 38.213 from RAN1#94bis and RAN1#95.	15.4.0
2019-03	RAN#83	RP-190449	0009	-	F	Correction on search space sharing	15.5.0
2019-03	RAN#83	RP-190449	0010	-	F	CR on timing adjustment indicator	15.5.0
2019-03	RAN#83	RP-190449	0011	-	F	CR on SSB-RO association	15.5.0
2019-03	RAN#83	RP-190449	0012	-	F	Removal of CSI request in RAR grant	15.5.0
2019-03	RAN#83	RP-190449	0014	-	F	Correction to dynamic HARQ codebook in NR	15.5.0
2019-03	RAN#83	RP-190449	0015	1	F	Corrections to TS 38.213	15.5.0
2019-03	RAN#83	RP-190449	0016	-	F	CR on simultaneous active BWP switching across carriers	15.5.0
2019-03	RAN#83	RP-190449	0017	-	F	CR on using CORESET#0 in dedicated DL BWP	15.5.0
2019-03	RAN#83	RP-190449	0018	-	F	PDCCH monitoring for overlapped CORESETs	15.5.0
2019-03	RAN#83	RP-190449	0019	-	F	Correction to last PUCCH resource set configuration	15.5.0
2019-03	RAN#83	RP-190449	0020	-	F	Correction on physical downlink control channel	15.5.0
2019-03	RAN#83	RP-190449	0021	-	F	Correction to align RAN1 and RAN4 specifications for EN-DC power control	15.5.0
2019-03	RAN#83	RP-190449	0022	-	F	(Late Drop) CR on PRACH Power Ramping Counter Suspension	15.5.0
2019-03	RAN#83	RP-190449	0023	-	F	QCL properties of Msg4 in CONNECTED Mode	15.5.0
2019-03	RAN#83	RP-190449	0024	-	F	CR on latency after gNB response for recovery	15.5.0
2019-03	RAN#83	RP-190449	0025	-	F	Clarifying DL reception and UL transmission related restrictions	15.5.0
2019-03	RAN#83	RP-190449	0026	-	F	CR on QCL assumption for receiving PDCCH for RAR	15.5.0
2019-03	RAN#83	RP-190449	0027	-	F	CR on identifying transmission occasion after resetting a PC closed loop	15.5.0
2019-03	RAN#83	RP-190449	0028	-	F	CR on overlapping of CSI and PUSCH with slot aggregation	15.5.0
2019-03	RAN#83	RP-190449	0029	-	F	Correction on PHR timing for configured grant	15.5.0
2019-03	RAN#83	RP-190449	0030	-	F	CR on QCL assumption for a CORESET other than 0	15.5.0
2019-03	RAN#83	RP-190449	0031	-	F	Correction on DCI format 2_3 for SUL cell in TS 38.213	15.5.0
2019-03	RAN#83	RP-190449	0032	-	F	Correction to support FR1 extension to 7.125 GHz	15.5.0
2019-03	RAN#83	RP-190449	0033	-	F	CR on UE procedure for reporting multiple UCI types	15.5.0
2019-03	RAN#83	RP-190449	0034	-	F	Correction to transmission timing adjustments in TS 38.213	15.5.0
2019-06	RAN#84	RP-191283	0035	-	F	CR on missing case for DCI format 1_1 with CS-RNTI	15.6.0
2019-06	RAN#84	RP-191283	0036	1	F	CR on the determination of the minimum number of PRBs for PUCCH transmission	15.6.0

2019-06	RAN#84	RP-191283	0037	-	F	CR on PHR determination and transmission	15.6.0
2019-06	RAN#84	RP-191283	0038	4	F	Corrections to 38.213 including alignment of terminology across specifications	15.6.0
2019-06	RAN#84	RP-191283	0039	1	F	Correction on PUSCH power scaling	15.6.0
2019-06	RAN#84	RP-191283	0040	-	F	Correction on PDCCH monitoring	15.6.0
2019-06	RAN#84	RP-191283	0041	-	F	Correction on CRC assumption for multi-CSI resource selection and CSI report(s) selection	15.6.0
2019-06	RAN#84	RP-191283	0042	-	F	Clarification of reference to PDSCH processing capability 1 in TS 38.213	15.6.0
2019-06	RAN#84	RP-191283	0043	-	F	Correction on the timeline condition of multiplexing two HARQ-ACK information in one slot	15.6.0
2019-06	RAN#84	RP-191283	0044	-	F	CR on Type-1 HARQ-ACK codebook determination	15.6.0
2019-06	RAN#84	RP-191283	0045	-	F	Correction on PHR in EN-DC	15.6.0
2019-06	RAN#84	RP-191283	0046	-	F	CR to 38.213 on deactivation timing for ScellDeactivationTimer	15.6.0
2019-06	RAN#84	RP-191283	0047	-	F	CR on single transmission timing for synchronous intra-band EN-DC	15.6.0
2019-06	RAN#84	RP-191283	0048	-	F	CR on PDCCH Monitoring for NR-DC	15.6.0
2019-06	RAN#84	RP-191283	0049	-	F	CR on Timing for MAC CE Applicability	15.6.0
2019-09	RAN#85	RP-191942	0051	-	F	Correction on RA procedure triggered by higher layers	15.7.0
2019-09	RAN#85	RP-191942	0052	1	F	CR on UE procedure for reporting multiple UCI types	15.7.0
2019-09	RAN#85	RP-191942	0053	-	F	CR to 38.213 fix to HARQ-ACK Type-1 codebook pseudo-code	15.7.0
2019-09	RAN#85	RP-191942	0054	-	F	CR to 38.213 on clarification of the RNTI used for scrambling a PUSCH transmission scheduled by RAR UL grant	15.7.0
2019-09	RAN#85	RP-191942	0055	2	F	Corrections to 38.213 including alignment of terminology across specifications in RAN1#98	15.7.0
2019-09	RAN#85	RP-191942	0056	-	F	Correction on intra-band EN-DC with single TAG	15.7.0
2019-09	RAN#85	RP-191942	0057	-	F	Correction on PHR in EN-DC/NE-DC/NR-CA	15.7.0
2019-09	RAN#85	RP-191942	0058	-	F	Correction on the time gap definition	15.7.0
2019-09	RAN#85	RP-191942	0059	-	F	Correction on slot configuration	15.7.0
2019-09	RAN#85	RP-191942	0060	-	F	CR to 38.213 on PUCCH configuration for NR-DC	15.7.0
2019-09	RAN#85	RP-191942	0061	-	F	Correction on PUCCH power control	15.7.0
2019-12	RAN#86	RP-192626	0062	1	F	CR on beta_offset values for UCI reporting in PUSCH	15.8.0
2019-12	RAN#86	RP-192626	0063	-	F	Correction on RACH occasion	15.8.0
2019-12	RAN#86	RP-192626	0064	-	F	Correction on HARQ-ACK transmission with BWP change	15.8.0
2019-12	RAN#86	RP-192626	0065	-	F	CR on slot configuration regarding PUSCH scheduled by RAR	15.8.0
2019-12	RAN#86	RP-192626	0066	-	F	Correction on power control for NE-DC	15.8.0
2019-12	RAN#86	RP-192626	0067	-	F	Correction on time gap definition for HARQ-ACK transmission	15.8.0
2019-12	RAN#86	RP-192626	0068	-	F	Correction on time gap definition for random access procedure	15.8.0
2019-12	RAN#86	RP-192626	0069	3	F	Corrections to 38.213 including alignment of terminology across specifications in RAN1#98bis and RAN1#99	15.8.0
2019-12	RAN#86	RP-193121	0070	1	B	Introduction of two-step RACH in NR	16.0.0
2019-12	RAN#86	RP-193221	0071	2	B	Introduction of shared spectrum channel access	16.0.0
2019-12	RAN#86	RP-193123	0072	1	B	Introduction of integrated access and backhaul in NR	16.0.0
2019-12	RAN#86	RP-193222	0073	2	B	Introduction of Industrial IoT	16.0.0
2019-12	RAN#86	RP-193125	0074	1	B	Introduction of Ultra Reliable Low Latency Communications Enhancements	16.0.0
2019-12	RAN#86	RP-193127	0075	1	B	Introduction of MIMO enhancements in NR	16.0.0
2019-12	RAN#86	RP-193128	0076	1	B	Introduction of UE power savings	16.0.0
2019-12	RAN#86	RP-193131	0077	1	B	Introduction of NR-DC in same Frequency Range and of Cross-carrier Scheduling with Different Numerologies	16.0.0
2019-12	RAN#86	RP-193132	0078	1	B	Introduction of multiple LTE CRS rate matching patterns	16.0.0
2019-12	RAN#86	RP-193124	0079	1	B	Introduction of V2X in NR	16.0.0
2019-12	RAN#86	RP-193129	0080	1	B	Introduction of positioning support in NR	16.0.0
2019-12	RAN#86	RP-193223	0081	2	B	Introduction of mobility enhancements in NR	16.0.0
2020-03	RAN#87-e	RP-200184	0085	-	F	Corrections on two-step RACH	16.1.0
2020-03	RAN#87-e	RP-200194	0086	-	F	Corrections on NR-DC and on Cross-carrier Scheduling with Different Numerologies	16.1.0
2020-03	RAN#87-e	RP-200186	0087	-	F	Corrections on integrated access and backhaul	16.1.0
2020-03	RAN#87-e	RP-200189	0088	-	F	Corrections on Industrial IoT	16.1.0
2020-03	RAN#87-e	RP-200190	0089	-	F	Corrections on MIMO enhancements	16.1.0
2020-03	RAN#87-e	RP-200193	0090	-	F	Corrections on Mobility Enhancements	16.1.0
2020-03	RAN#87-e	RP-200185	0091	-	F	Corrections on shared spectrum channel access	16.1.0
2020-03	RAN#87-e	RP-200192	0092	-	F	Corrections on Positioning	16.1.0
2020-03	RAN#87-e	RP-200187	0093	-	F	Corrections on Sidelink	16.1.0
2020-03	RAN#87-e	RP-200191	0094	-	F	Corrections on UE power savings	16.1.0
2020-03	RAN#87-e	RP-200188	0095	-	F	Corrections on Ultra Reliable Low Latency Communications Enhancements	16.1.0
2020-03	RAN#87-e	RP-200195	0097	-	F	Introduction of half-duplex operation in CA with unpaired spectrum	16.1.0
2020-03	RAN#87-e	RP-200447	0098	-	A	Corrections to 38.213 including alignment of terminology across specifications in RAN1#100-e	16.1.0

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2020-06	RAN#88-e	RP-200688	0103	1	F	Corrections on integrated access and backhaul	16.2.0
2020-06	RAN#88-e	RP-200690	0104	1	F	Corrections on Ultra Reliable Low Latency Communications Enhancements	16.2.0
2020-06	RAN#88-e	RP-200693	0105	1	F	Corrections on UE power savings	16.2.0
2020-06	RAN#88-e	RP-200689	0106	1	F	Corrections on Sidelink	16.2.0
2020-06	RAN#88-e	RP-200694	0107	1	F	Corrections on Positioning	16.2.0
2020-06	RAN#88-e	RP-200687	0108	1	F	Corrections on shared spectrum channel access	16.2.0
2020-06	RAN#88-e	RP-200692	0109	1	F	Corrections on MIMO enhancements	16.2.0
2020-06	RAN#88-e	RP-200691	0110	1	F	Corrections on Industrial IoT	16.2.0
2020-06	RAN#88-e	RP-200696	0111	1	F	Corrections on NR-DC and on Cross-carrier Scheduling with Different Numerologies	16.2.0
2020-06	RAN#88-e	RP-200686	0112	1	F	Corrections on two-step RACH	16.2.0
2020-06	RAN#88-e	RP-200697	0113	1	F	Corrections on half-duplex operation in CA with unpaired spectrum	16.2.0
2020-06	RAN#88-e	RP-200705	0114	-	B	Introduction of UL transmission switching	16.2.0
2020-06	RAN#88-e	RP-200695	0115	-	F	Corrections on Mobility Enhancements	16.2.0
2020-06	RAN#88-e	RP-201349	0117	1	A	Extending 8 SSB support to the newly introduced 30 kHz Case C SSB pattern on band n40	16.2.0
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2020-09	RAN#89-e	RP-201813	0133	-	F	CR to 38.213 on RRC parameter alignment for SCell dormancy	16.3.0
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2020-12	RAN#90-e	RP-202380	0147	-	F	CR on 2-step RACH for 38.213	16.4.0
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2020-12	RAN#90-e	RP-202383	0171	-	F	Correction on periodicity of resource pool bitmap	16.4.0
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2021-03	RAN#91-e	RP-210055	0180	-	F	Type-1 HARQ-ACK for PDSCH repetition with different SCSs in DL and UL	16.5.0
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2021-03	RAN#91-e	RP-210049	0189	-	D	Correction on PUCCH power control for enhanced Type-2 HARQ-ACK codebook and for Type-3 HARQ-ACK codebook	16.5.0
2021-03	RAN#91-e	RP-210052	0190	-	F	CR on HARQ-ACK	16.5.0
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2021-03	RAN#91-e	RP-210058	0193	-	F	Correction on uplink Tx switching	16.5.0
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2021-03	RAN#91-e	RP-210054	0201	-	F	CR to 38.213 on PRACH handling for NR-DC power control	16.5.0
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2021-03	RAN#91-e	RP-210055	0203	-	F	38.213 CR on DCI ordering in a search space set	16.5.0
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2021-03	RAN#91-e	RP-210059	0207	-	F	Editorial corrections for 38.213	16.5.0
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2021-06	RAN#92-e	RP-211234	0209	-	F	Correction on multiplexing timeline definition for Type-3 HARQ-ACK codebook	16.6.0
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2021-06	RAN#92-e	RP-211236	0224	-	F	CR on not supporting Type 1 HARQ-ACK codebook for sub-slot HARQ-ACK in R16	16.6.0
2021-06	RAN#92-e	RP-211236	0225	-	F	CR on Number of PUCCH resource sets per PUCCH-config	16.6.0
2021-06	RAN#92-e	RP-211236	0226	-	F	Correction on UL cancellation due to dynamic SFI	16.6.0
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2021-06	RAN#92-e	RP-211236	0230	-	F	Correction on UE procedure for determining physical downlink control channel assignment for Rel-16 PDCCH monitoring capability	16.6.0
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2021-09	RAN#93-e	RP-211846	0250	1	F	Corrections on SCell dormancy indication	16.7.0
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2021-09	RAN#93-e	RP-211842	0253	-	F	Clarification on PUCCH Power control	16.7.0
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2021-12	RAN#94-e	RP-212959	0261	-	F	CR on SL HARQ-ACK feedback reporting to gNB	16.8.0
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History

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