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*Technical Specification*

**LTE;  
Evolved Universal Terrestrial Radio Access (E-UTRA);  
Medium Access Control (MAC) protocol specification  
(3GPP TS 36.321 version 8.4.0 Release 8)**

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## Foreword

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# 1 Scope

The present document specifies the E-UTRA MAC protocol.

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## 2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
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- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
  - [2] 3GPP TR 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer Procedures".
  - [3] 3GPP TS 36.322: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification'.
  - [4] 3GPP TS 36.323: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) Specification'.
  - [5] 3GPP TS 36.212: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding'.
  - [6] 3GPP TS 36.214: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements'.
  - [7] 3GPP TS 36.211: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation'.
  - [8] 3GPP TS 36.331: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification'.
  - [9] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".
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## 3 Definitions and abbreviations

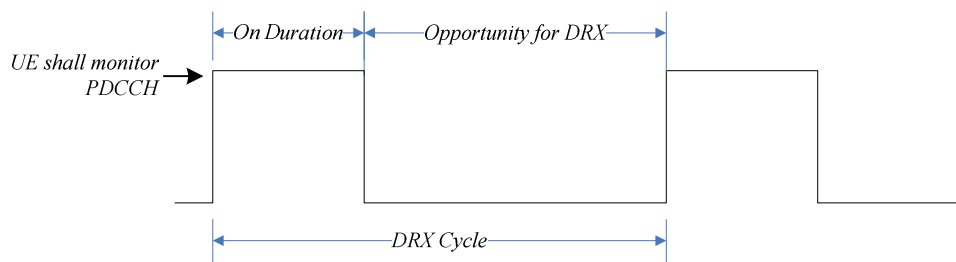
### 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**Active Time:** Time related to DRX operation, as defined in subclause 5.7, during which the UE monitors the PDCCH in PDCCH-subframes.

**Contention Resolution Timer:** Specifies the number of consecutive PDCCH-subframe(s) during which the UE shall monitor the PDCCH after the uplink message containing the C-RNTI MAC control element or the uplink message associated with UE Contention Resolution Identity submitted from upper layer is transmitted.

**DRX Cycle:** Specifies the periodic repetition of the On Duration followed by a possible period of inactivity (see figure 3.1-1 below).



**Figure 3.1-1: DRX Cycle**

**DRX Inactivity Timer:** Specifies the number of consecutive PDCCH-subframe(s) after successfully decoding a PDCCH indicating an initial UL or DL user data transmission for this UE.

**DRX Retransmission Timer:** Specifies the maximum number of consecutive PDCCH-subframe(s) for as soon as a DL retransmission is expected by the UE.

**DRX Short Cycle Timer:** This parameter specifies the number of consecutive subframe(s) the UE shall follow the short DRX cycle after the DRX Inactivity Timer has expired.

**HARQ information:** HARQ information consists of New Data Indicator (NDI), Redundancy Version (RV), Transport Block (TB) size. For DL-SCH transmissions the HARQ information also includes HARQ process ID. In case of spatial multiplexing on DL-SCH the HARQ information comprises a set of NDI, RV and TB size for each transport block.

**HARQ RTT Timer:** This parameter specifies the minimum amount of subframe(s) before a DL HARQ retransmission is expected by the UE.

**Msg3:** Uplink transmission on UL-SCH containing a C-RNTI MAC CE or CCCH SDU as part of a random access procedure.

**On Duration Timer:** Specifies the number of consecutive PDCCH-subframe(s) at the beginning of a DRX Cycle.

**PDCCH-subframe:** For FDD UE operation, this represents any subframe; for TDD, only downlink subframes and subframes including DwPTS.

**PRACH Resource Index:** The index of a PRACH within a system frame [7]

**PRACH Mask Index:** The PRACH Mask Index defines in which PRACHs within a system frame the UE can transmit a Random Access Preamble (see subclause 7.3).

**RA-RNTI:** The Random Access RNTI is used on the PDCCH when Random Access Response messages are transmitted. It unambiguously identifies which time-frequency resource was utilized by the UE to transmit the Random Access preamble.

NOTE: A timer is running once it is started, until it is stopped or until it expires.

## 3.2 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 TR 21.905 [1].

|         |   |
|---------|---|
| BSR     | Buffer Status Report                          |
| C-RNTI  | Cell RNTI                                     |
| CQI     | Channel Quality Indicator                     |
| E-UTRA  | Evolved UMTS Terrestrial Radio Access         |
| E-UTRAN | Evolved UMTS Terrestrial Radio Access Network |
| MAC     | Medium Access Control                         |
| LCG     | Logical Channel Group                         |



|                |   |
|----------------|---|
| PHR            | Power Headroom Report                                       |
| PMI            | Precoding Matrix Index                                      |
| P-RNTI         | Paging RNTI   |
| RA-RNTI        | Random Access RNTI  |
| RI             | Rank Indicator  |
| RNTI           | Radio Network Temporary Identifier                          |
| SI-RNTI        | System Information RNTI                                     |
| SR             | Scheduling Request  |
| SRS            | Sounding Reference Symbols                                  |
| TB             | Transport Block   |
| TPC-PUCCH-RNTI | Transmit Power Control-Physical Uplink Control Channel-RNTI |
| TPC-PUSCH-RNTI | Transmit Power Control-Physical Uplink Shared Channel-RNTI  |

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## 4 General

### 4.1 Introduction

The objective is to describe the MAC architecture and the MAC entity from a functional point of view.

### 4.2 MAC architecture

The description in this sub clause is a model and does not specify or restrict implementations.

RRC is in control of configuration of MAC.

#### 4.2.1 MAC Entities

E-UTRA defines two MAC entities; one in the UE and one in the E-UTRAN. These MAC entities handle the following transport channels:

- Broadcast Channel (BCH);
- Downlink Shared Channel (DL-SCH);
- Paging Channel (PCH);
- Uplink Shared Channel (UL-SCH);
- Random Access Channel(s) (RACH).

The exact functions performed by the MAC entities are different in the UE from those performed in the E-UTRAN.

### 4.3 Services

#### 4.3.1 Services provided to upper layers

This clause describes the different services provided by MAC sublayer to upper layers.

- data transfer
- radio resource allocation

#### 4.3.2 Services expected from physical layer

The physical layer provides the following services to MAC:

- data transfer services;
- signalling of HARQ feedback;
- signalling of Scheduling Request;
- measurements (e.g. Channel Quality Indication (CQI)).

The access to the data transfer services is through the use of transport channels. The characteristics of a transport channel are defined by its transport format (or format set), specifying the physical layer processing to be applied to the transport channel in question, such as channel coding and interleaving, and any service-specific rate matching as needed.

## 4.4 Functions

The following functions are supported by MAC sublayer:

- mapping between logical channels and transport channels;
- multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels;
- demultiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels;
- scheduling information reporting;
- error correction through HARQ;
- priority handling between UEs by means of dynamic scheduling;
- priority handling between logical channels of one UE;
- Logical Channel prioritisation;
- transport format selection.

NOTE: How the multiplexing relates to the QoS of the multiplexed logical channels is FFS.

The location of the different functions and their relevance for uplink and downlink respectively is illustrated in Table 4.4-1.

**Table 4.4-1: MAC function location and link direction association.**

| MAC function  | UE | eNB | Downlink | Uplink |
|---|----|-----|----------|--------|
| Mapping between logical channels and transport channels | X  |     | X        | X      |
|   |    | X   | X        | X      |
| Multiplexing  | X  |     | X        | X      |
|   |    | X   | X        |        |
| Demultiplexing  | X  |     | X        |        |
|   |    | X   |          | X      |
| Error correction through HARQ                           | X  |     | X        | X      |
|   |    | X   | X        | X      |
| Transport Format Selection                              |    | X   | X        | X      |
| Priority handling between UEs                           |    | X   | X        | X      |
| Priority handling between logical channels of one UE    |    | X   | X        | X      |
| Logical Channel prioritisation                          | X  |     |          | X      |
| Scheduling information reporting                        | X  |     |          | X      |

## 4.5 Channel structure

The MAC sublayer operates on the channels defined below; transport channels are SAPs between MAC and Layer 1, logical channels are SAPs between MAC and RLC.

## 4.5.1 Transport Channels

The transport channels used by MAC are described in Table 4.5.1-1 below.

**Table 4.5.1-1: Transport channels used by MAC**

| Transport channel name  | Acronym | Downlink | Uplink |
|-------------------------|---------|----------|--------|
| Broadcast Channel       | BCH     | X        |        |
| Downlink Shared Channel | DL-SCH  | X        |        |
| Paging Channel          | PCH     | X        |        |
| Uplink Shared Channel   | UL-SCH  |          | X      |
| Random Access Channel   | RACH    |          | X      |

## 4.5.2 Logical Channels

The MAC layer provides data transfer services on logical channels. A set of logical channel types is defined for different kinds of data transfer services as offered by MAC.

Each logical channel type is defined by what type of information is transferred.

MAC provides the control and traffic channels listed in Table 4.5.2-1 below. When MAC uses the PDCCH to indicate radio resource allocation, the RNTI that is mapped on the PDCCH depends on the logical channel type:

- C-RNTI, Temporary C-RNTI and Semi-Persistent Scheduling C-RNTI for DCCH and DTCH;
- P-RNTI for PCCH;
- RA-RNTI for Random Access Response on DL-SCH;
- Temporary C-RNTI for CCCH during the random access procedure;
- SI-RNTI for BCCH.

**Table 4.5.2-1: Logical channels provided by MAC.**

| Logical channel name      | Acronym | Control channel | Traffic channel |
|---------------------------|---------|-----------------|-----------------|
| Broadcast Control Channel | BCCH    | X               |                 |
| Paging Control Channel    | PCCH    | X               |                 |
| Common Control Channel    | CCCH    | X               |                 |
| Dedicated Control Channel | DCCH    | X               |                 |
| Dedicated Traffic Channel | DTCH    |                 | X               |

## 4.5.3 Mapping of Transport Channels to Logical Channels

The mapping of logical channels on transport channels depends on the multiplexing that is configured by RRC.

### 4.5.3.1 Uplink mapping

The MAC entity is responsible for mapping logical channels for the uplink onto uplink transport channels. The uplink logical channels can be mapped as described in Figure 4.5.3.1-1 and Table 4.5.3.1-1.

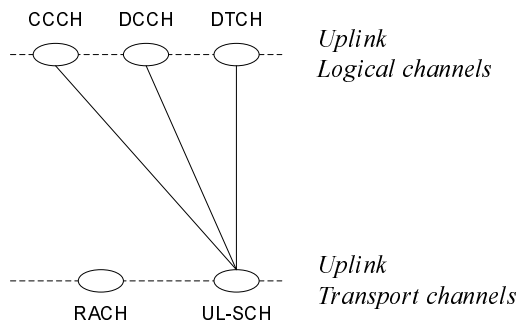


Figure 4.5.3.1-1

Table 4.5.3.1-1: Uplink channel mapping.

| Logical channel | Transport channel | UL-SCH | RACH |
|-----------------|-------------------|--------|------|
| CCCH            |                   | X      |      |
| DCCH            |                   | X      |      |
| DTCH            |                   | X      |      |

4.5.3.2 Downlink mapping

The MAC entity is responsible for mapping the downlink logical channels to downlink transport channels. The downlink logical channels can be mapped as described in Figure 4.5.3.2-1 and Table 4.5.3.2-1.

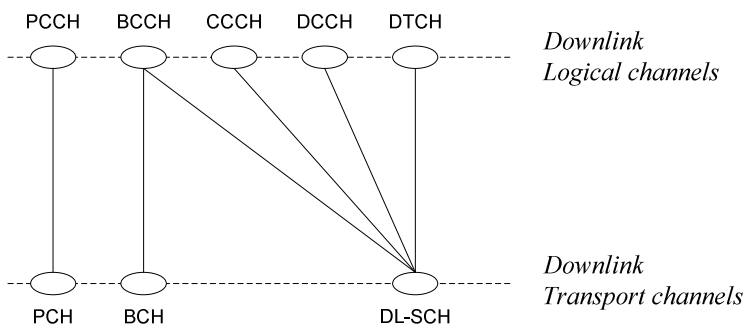


Figure 4.5.3.2-1

Table 4.5.3.2-1: Downlink channel mapping.

| Logical channel | Transport channel | BCH | PCH | DL-SCH |
|-----------------|-------------------|-----|-----|--------|
| BCCH            |                   | X   |     | X      |
| PCCH            |                   |     | X   |        |
| CCCH            |                   |     |     | X      |
| DCCH            |                   |     |     | X      |
| DTCH            |                   |     |     | X      |

## 5 MAC procedures

### 5.1 Random Access procedure

#### 5.1.1 Random Access Procedure initialization

The Random Access procedure described in this subclause is initiated by a PDCCH order or by the MAC sublayer itself. The PDCCH order or RRC optionally indicate a Random Access Preamble and PRACH resource.

Before the procedure can be initiated, the following information is assumed to be available:

- the available set of PRACH resources for the transmission of the Random Access Preamble and their corresponding RA-RNTIs.
- the groups of Random Access Preambles and the set of available Random Access Preambles in each group:

The preambles that are contained in Random Access Preambles group A and Random Access Preambles group B are calculated from the parameters *numberOfRA-Preambles* and *sizeOfRA-PreamblesGroupA* [8]:

If *sizeOfRA-PreamblesGroupA* is equal to *numberOfRA-Preambles* then there is no Random Access Preambles group B. The preambles in Random Access Preamble group A are the preambles 0 to *sizeOfRA-PreamblesGroupA* - 1 and, if it exists, the preambles in Random Access Preamble group B are the preambles *sizeOfRA-PreamblesGroupA* to *numberOfRA-Preambles* - 1 from the set of 64 preambles as defined in [7].

- the thresholds, *messagePowerOffsetGroupB* and MESSAGE\_SIZE\_GROUP\_A, that are required for selecting one of the two groups of Random Access Preambles.
- the RA response window size *ra-ResponseWindowSize* [8].
- the power-ramping factor POWER\_RAMP\_STEP.
- the parameter PREAMBLE\_TRANS\_MAX [integer > 0].
- the initial preamble power PREAMBLE\_INITIAL\_RECEIVED\_TARGET\_POWER.
- the preamble format based offset DELTA\_PREAMBLE (see subclause 7.6).
- the maximum allowed transmission power P<sub>max</sub>.
- the offset between preamble and the Msg3, DELTA\_PREAMBLE\_MSG3.
- the parameter Maximum number of Msg3 HARQ transmissions.

[Note that the above parameters may be updated from upper layers before each Random Access procedure is initiated.]

The Random Access procedure shall be performed as follows:

- Flush the Msg3 buffer;
- set the PREAMBLE\_TRANSMISSION\_COUNTER to 1;
- set the backoff parameter value in the UE to 0 ms;
- proceed to the selection of the Random Access Resource (see subclause 5.1.2).

NOTE: There is only one Random Access procedure ongoing at any point in time. If the UE receives a request for a new Random Access procedure while another is already ongoing, it is up to UE implementation whether to continue with the ongoing procedure or start with the new procedure.

#### 5.1.2 Random Access Resource selection

The Random Access Resource selection procedure shall be performed as follows:

- If the Random Access Preamble and the PRACH Mask Index have been explicitly signalled and the signalled random access preamble ID is not 000000:
  - the Random Access Preamble and the PRACH Mask Index are those explicitly signalled.
- else the Random Access Preamble shall be selected by the UE as follows:
  - If the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU has not yet been transmitted, the UE shall:
    - if Random Access Preambles group B exists and if the potential message size (data available for transmission plus MAC header and, where required, MAC control elements) is greater than MESSAGE\_SIZE\_GROUP\_A and if the pathloss is less than  $P_{max} - \text{PREAMBLE\_INITIAL\_RECEIVED\_TARGET\_POWER} - \text{DELTA\_PREAMBLE\_MSG3} - \text{messagePowerOffsetGroupB}$ , then:
      - select the Random Access Preambles group B;
    - else:
      - select the Random Access Preambles group A.
  - else, if the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU is being retransmitted, the UE shall:
    - select the same group of Random Access Preambles as was used for the preamble transmission attempt corresponding to the first transmission of the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU.
  - randomly select a Random Access Preamble within the selected group. The random function shall be such that each of the allowed selections can be chosen with equal probability;
  - set PRACH Mask Index to 0.
- determine the next available subframe containing PRACH permitted by the restrictions given by the PRACH Mask Index (see subclause 7.3) (a UE may take into account the possible occurrence of measurement gaps when determining the next available PRACH subframe);
- if the transmission mode is TDD and the PRACH Mask Index is equal to zero:
  - if the Random Access Preamble was explicitly signalled and the signalled random access preamble ID was not 000000 (i.e., not selected by MAC):
    - randomly select, with equal probability, one PRACH from the PRACHs available in the determined subframe.
  - else:
    - randomly select, with equal probability, one PRACH from the PRACHs available in the determined subframe and the next two consecutive subframes.
- else:
  - determine a PRACH within the determined subframe in accordance with the requirements of the PRACH Mask Index.
- proceed to the transmission of the Random Access Preamble (see subclause 5.1.3).

### 5.1.3 Random Access Preamble transmission

The random-access procedure shall be performed as follows:

- set the parameter PREAMBLE\_RECEIVED\_TARGET\_POWER to  $\text{PREAMBLE\_INITIAL\_RECEIVED\_TARGET\_POWER} + \text{DELTA\_PREAMBLE} + (\text{PREAMBLE\_TRANSMISSION\_COUNTER} - 1) * \text{POWER\_RAMP\_STEP}$ ;

- instruct the physical layer to transmit a preamble using the selected PRACH, corresponding RA-RNTI, preamble index and PREAMBLE\_RECEIVED\_TARGET\_POWER.

#### 5.1.4 Random Access Response reception

Once the Random Access Preamble is transmitted and regardless of the possible occurrence of a measurement gap, the UE shall monitor the PDCCH for Random Access Response(s) identified by the RA-RNTI defined below, in the TTI window [RA\_WINDOW\_BEGIN—RA\_WINDOW\_END] which starts at the subframe that contains the end of the preamble transmission [7] plus three subframes and has length *ra-ResponseWindowSize* subframes. The RA-RNTI associated with the PRACH in which the Random Access Preamble is transmitted, is computed as:

$$\text{RA-RNTI} = t\_id + 10 * f\_id$$

Where *t\_id* is the index of the first subframe of the specified PRACH ( $0 \leq t\_id < 10$ ), and *f\_id* is the index of the specified PRACH within that subframe, in ascending order of frequency domain ( $0 \leq f\_id < 6$ ). The UE may stop monitoring for Random Access Response(s) after successful reception of a Random Access Response containing Random Access Preamble identifiers that matches the transmitted Random Access Preamble.

- If a downlink assignment for this TTI has been received on the PDCCH for the RA-RNTI and the received TB is successfully decoded, the UE shall regardless of the possible occurrence of a measurement gap:
  - if the Random Access Response contains a Backoff Indicator subheader:
    - set the backoff parameter value in the UE as indicated by the BI field of the Backoff Indicator subheader and Table 7.2-1.
    - else, set the backoff parameter value in the UE to 0 ms.
  - if the Random Access Response contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble (see subclause 5.1.3), the UE shall:
    - consider this Random Access Response reception successful;
    - process the received Timing Advance Command (see subclause 5.2);
    - indicate the amount of power ramping applied to the latest preamble transmission to lower layers (i.e.,  $(\text{PREAMBLE\_TRANSMISSION\_COUNTER} - 1) * \text{POWER\_RAMP\_STEP}$ );
    - process the received UL grant value and indicate it to the lower layers;
    - if the Random Access Preamble was explicitly signalled and the signalled random access preamble ID was not 000000 (i.e., not selected by MAC):
      - consider the Random Access procedure successfully completed.
    - else, if the Random Access Preamble was selected by UE MAC:
      - set the Temporary C-RNTI to the value received in the Random Access Response message no later than at the time of the first transmission corresponding to the UL grant provided in the Random Access Response message;
      - if this is the first successfully received Random Access Response within this Random Access procedure:
        - if the transmission is not being made for the CCCH logical channel, indicate to the Multiplexing and assembly entity to include a C-RNTI MAC control element in the subsequent uplink transmission;
        - obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity and store it in the Msg3 buffer.

NOTE: When an uplink transmission is required, e.g., for contention resolution, the eNB should not provide a grant smaller than 80 bits in the Random Access Response.

NOTE: If within a Random Access procedure, an uplink grant provided in the Random Access Response for the same group of Random Access Preambles has a different size than the first uplink grant allocated during that Random Access procedure, the UE behavior is not defined.

If no Random Access Response is received within the TTI window [RA\_WINDOW\_BEGIN—RA\_WINDOW\_END], or if all received Random Access Responses contain Random Access Preamble identifiers that do not match the transmitted Random Access Preamble, the Random Access Response reception is considered not successful and the UE shall:

- increment PREAMBLE\_TRANSMISSION\_COUNTER by 1;
- If PREAMBLE\_TRANSMISSION\_COUNTER = PREAMBLE\_TRANS\_MAX + 1:
  - indicate a Random Access problem to upper layers.
- if in this Random Access procedure, the Random Access Preamble was selected by MAC:
  - based on the backoff parameter in the UE, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value;
  - delay the subsequent Random Access transmission by the backoff time;
- proceed to the selection of a Random Access Resource (see subclause 5.1.2).

### 5.1.5 Contention Resolution

Contention Resolution is based on either C-RNTI on PDCCH or UE Contention Resolution Identity on DL-SCH.

Once the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU is transmitted, the UE shall:

- start the Contention Resolution Timer and restart the Contention Resolution Timer at each HARQ retransmission;
- regardless of the possible occurrence of a measurement gap, monitor the PDCCH until the Contention Resolution Timer expires or is stopped;
- if notification of a reception of a PDCCH transmission is received from lower layers, the UE shall:
  - if the C-RNTI MAC control element was included in uplink message:
    - if the Random Access procedure was initiated by the MAC sublayer itself and the PDCCH transmission is addressed to the C-RNTI and contains an UL grant for a new transmission; or
    - if the Random Access procedure was initiated by a PDCCH order and the PDCCH transmission is addressed to the C-RNTI:
      - consider this Contention Resolution successful;
      - stop the Contention Resolution Timer;
      - discard the Temporary C-RNTI;
      - consider this Random Access procedure successfully completed.
  - else if the uplink message included the CCCH SDU and the PDCCH transmission is addressed to its Temporary C-RNTI:
    - if the MAC PDU is successfully decoded:
      - stop the Contention Resolution Timer;
      - if the MAC PDU contains a UE Contention Resolution Identity MAC control element; and
      - if the UE Contention Resolution Identity included in the MAC control element matches the CCCH SDU transmitted in the uplink message;



- consider this Contention Resolution successful and finish the disassembly and demultiplexing of the MAC PDU;
- set the C-RNTI to the value of the Temporary C-RNTI;
- discard the Temporary C-RNTI;
- consider this Random Access procedure successfully completed.
- else
  - discard the Temporary C-RNTI;
  - consider this Contention Resolution not successful and discard the successfully decoded MAC PDU.
- if the Contention Resolution Timer expires:
  - discard the Temporary C-RNTI;
  - consider the Contention Resolution not successful.
- if the Contention Resolution is considered not successful the UE shall:
  - if the Random Access procedure was initiated by the MAC sublayer itself; or
  - if the Random Access procedure was initiated by a PDCCH order and the PREAMBLE\_TRANSMISSION\_COUNTER is less than PREAMBLE\_TRANS\_MAX:
    - increment PREAMBLE\_TRANSMISSION\_COUNTER by 1;
    - If  $\text{PREAMBLE\_TRANSMISSION\_COUNTER} = \text{PREAMBLE\_TRANS\_MAX} + 1$ :
      - indicate a Random Access problem to upper layers.
    - based on the backoff parameter in the UE, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value;
    - delay the subsequent Random Access transmission by the backoff time;
    - proceed to the selection of a Random Access Resource (see subclause 5.1.2).

### 5.1.6 Completion of the Random Access procedure

At successful completion of the Random Access procedure, the UE shall:

- discard explicitly signalled Random Access Preamble and PRACH Mask Index, if any;
- flush the HARQ buffer used for transmission of the MAC PDU in the Msg3 buffer and consider the next transmission for this process as the very first transmission;
- if the PREAMBLE\_TRANSMISSION\_COUNTER is greater than PREAMBLE\_TRANS\_MAX:
  - indicate recovery from a Random Access problem to upper layers.

## 5.2 Maintenance of Uplink Time Alignment

The UE has a configurable Time Alignment Timer. The Time Alignment Timer is valid only in the cell for which it was configured and started.

The UE shall:

- when a Timing Advance Command MAC control element is received:
  - apply the Timing Advance Command;

- start the Time Alignment Timer (if not running) or restart the Time Alignment Timer (if already running).
- when a Timing Advance Command is received in a Random Access Response message:
  - if the Random Access Preamble and PRACH resource were explicitly signalled:
    - apply the Timing Advance Command;
    - start the Time Alignment Timer (if not running) or restart the Time Alignment Timer (if already running).
  - else, if the Time Alignment Timer is not running or has expired:
    - apply the Timing Advance Command;
    - start the Time Alignment Timer;
  - when the contention resolution is considered not successful as described in subclause 5.1.5, stop the Time Alignment Timer.
- else:
  - ignore the received Timing Advance Command.
- when the Time Alignment Timer has expired or is not running:
  - prior to any UL-SCH transmission, use the Random Access procedure (see subclause 5.1) in order to obtain uplink Time Alignment.
- when the Time Alignment Timer expires:
  - flush all HARQ buffers and consider the next transmission for each process as the very first transmission;
  - notify RRC of PUCCH/SRS release;
  - clear any configured downlink assignments and uplink grants.

## 5.3 DL-SCH data transfer

### 5.3.1 DL Assignment reception

Downlink assignments transmitted on the PDCCH indicate if there is a transmission on the DL-SCH for a particular UE and provide the relevant HARQ information.

When the UE has a C-RNTI, Semi-Persistent Scheduling C-RNTI, or Temporary C-RNTI, the UE shall for each TTI during which it monitors PDCCH:

- if a downlink assignment for this TTI has been received on the PDCCH for the UE's C-RNTI, or Temporary C-RNTI:
  - if this is the first downlink assignment for this Temporary C-RNTI:
    - consider the NDI to have been toggled.
  - if either a downlink assignment has been received for the UE's Semi-Persistent Scheduling C-RNTI or a configured downlink assignment has occurred since the previous received downlink assignment for the UE's C-RNTI for the same HARQ process:
    - consider the NDI to have been toggled regardless of the value of the NDI.
  - indicate the presence of a downlink assignment and deliver the associated HARQ information to the HARQ entity for this TTI.
- else, if a downlink assignment for this TTI has been received on the PDCCH for the UE's Semi-Persistent Scheduling C-RNTI:

- if the NDI in the received HARQ information is 1:
  - consider the NDI not to have been toggled;
  - indicate the presence of a downlink assignment and deliver the associated HARQ information to the HARQ entity for this TTI.
- else, if the NDI in the received HARQ information is 0:
  - if PDCCH contents indicate SPS release:
    - clear the configured downlink assignment (if any);
    - instruct the physical layer to transmit a positive acknowledgement.
  - else:
    - store the downlink assignment and the associated HARQ information as configured downlink assignment;
    - initialise (if not active) or re-initialise (if already active) the configured downlink assignment to start in this TTI and to recur according to rules in subclause 5.10.1;
    - set the HARQ Process ID to the HARQ Process ID associated with this TTI;
    - consider the NDI bit to have been toggled;
    - indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.
- else, if a downlink assignment for this TTI has been configured and there is no measurement gap in this TTI:
  - instruct the physical layer to receive, in this TTI, transport(s) block on the DL-SCH according to the configured downlink assignment and to deliver it to the HARQ entity;
  - set the HARQ Process ID to the HARQ Process ID associated with this TTI;
  - consider the NDI bit to have been toggled;
  - indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.

The HARQ Process ID associated with this TTI is derived from the following equation:

$$\text{HARQ Process ID} = [\text{floor}(\text{CURRENT\_TTI}/(\text{Downlink Semi-Persistent Scheduling Interval}))] \text{ modulo Number of Configured SPS Processes}$$

where  $\text{CURRENT\_TTI} = [(\text{SFN} * 10) + \text{subframe number}]$ , Downlink Semi-Persistent Scheduling Interval is the periodicity of semi-persistent scheduling signalled via RRC and Number of Configured SPS Processes is the number of HARQ processes allocated for semi-persistent scheduling signalled via RRC.

When the UE needs to read BCCH, the UE may, based on the scheduling information from RRC:

- if a downlink assignment for this TTI has been received on the PDCCH for the SI-RNTI;
  - the redundancy version of the received downlink assignment for this TTI is determined by  $RV_k = \text{ceiling}(3/2*k) \text{ modulo } 4$ , where  $k$  depends on the type of system information message: for *SystemInformationBlockType1* message,  $k = (\text{SFN}/2) \text{ modulo } 4$ , where SFN is the system frame number; for *SystemInformation* messages,  $k = i \text{ modulo } 4$ ,  $i = 0, 1, \dots, n_s^w - 1$ , where  $i$  denotes the subframe number within the SI window  $n_s^w$ ;
  - indicate a downlink assignment and redundancy version for the dedicated broadcast HARQ process to the HARQ entity for this TTI.

NOTE: Downlink assignments for both C-RNTI and SI-RNTI or both Semi persistent scheduling C-RNTI and SI-RNTI can be received in the same TTI.

## 5.3.2 HARQ operation

### 5.3.2.1 HARQ Entity

There is one HARQ entity at the UE which maintains a number of parallel HARQ processes. Each HARQ process is associated with a HARQ process identifier. The HARQ entity directs HARQ information and associated TBs received on the DL-SCH to the corresponding HARQ processes (see subclause 5.3.2.2).

The number of DL HARQ processes is specified in [2], clause 7.

When the physical layer is configured for spatial multiplexing [2], one or two TBs are expected per subframe and they are associated with the same HARQ process. Otherwise, one TB is expected per subframe.

The UE shall:

- If a downlink assignment has been indicated for this TTI:
  - allocate the TBs received from the physical layer and the associated HARQ information to the HARQ process indicated by the associated HARQ information.
- If a downlink assignment has been indicated for the broadcast HARQ process:
  - allocate the received TB to the broadcast HARQ process.

NOTE: In case of BCCH a dedicated broadcast HARQ process is used.

### 5.3.2.2 HARQ process

For each subframe where a transmission takes place for the HARQ process, one or two (in case of spatial multiplexing) TBs and the associated HARQ information are received from the HARQ entity.

For each received TB and associated HARQ information, the HARQ process shall:

- if the NDI, when provided, has been toggled compared to the value of the previous received transmission corresponding to this TB; or
- if the HARQ process is equal to the broadcast process and the physical layer indicates a new transmission; or
- if this is the very first received transmission for this TB:
  - consider this transmission to be a new transmission.
- else:
  - consider this transmission to be a retransmission.

The UE then shall:

- if this is a new transmission:
  - replace the data currently in the soft buffer for this TB with the received data.
- else if this is a retransmission:
  - if the data has not yet been successfully decoded:
    - combine the received data with the data currently in the soft buffer for this TB.
  - if the TB size is different from the last valid TB size signalled for this TB:
    - the UE may replace the data currently in the soft buffer for this TB with the received data.
- attempt to decode the data in the soft buffer for this TB;
- if the data in the soft buffer was successfully decoded for this TB:

- if the HARQ process is equal to the broadcast process:
  - deliver the decoded MAC PDU to upper layers.
- else:
  - deliver the decoded MAC PDU to the disassembly and demultiplexing entity.
- generate a positive acknowledgement (ACK) of the data in this TB.
- else:
  - generate a negative acknowledgement (NACK) of the data in this TB.
- if the HARQ process is associated with a transmission indicated with a Temporary C-RNTI and the Contention Resolution is not successful (see subclause 5.1.5); or
- if the HARQ process is equal to the broadcast process; or
- if there is a measurement gap at the time of the transmission of the HARQ feedback:
  - do not indicate the generated positive or negative acknowledgement to the physical layer.
- else:
  - indicate the generated positive or negative acknowledgement for this TB to the physical layer.

The UE shall ignore NDI received in all downlink assignments on PDCCH for its Temporary C-RNTI when determining if NDI on PDCCH for its C-RNTI has been incremented compared to the value in the previous transmission.

### 5.3.3 Disassembly and demultiplexing

## 5.4 UL-SCH data transfer

### 5.4.1 UL Grant reception

In order to transmit on the UL-SCH the UE must have a valid uplink grant (except for non-adaptive HARQ retransmissions) which it may receive dynamically on the PDCCH or in a Random Access Response or which may be configured semi-persistently. To perform requested transmissions, the MAC layer receives HARQ information from lower layers.

When the UE has a C-RNTI, Semi-Persistent Scheduling C-RNTI, or Temporary C-RNTI, the UE shall for each TTI during which it monitors PDCCH:

- if an uplink grant for this TTI has been received on the PDCCH for the UE's C-RNTI or Temporary C-RNTI; or
- if an uplink grant for this TTI has been received in a Random Access Response:
  - if either an uplink grant has been received for the UE's Semi-Persistent Scheduling C-RNTI or a configured uplink grant has occurred since the previous received uplink grant for the UE's C-RNTI for the same HARQ process:
    - consider the NDI to have been toggled regardless of the value of the NDI.
  - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if an uplink grant for this TTI has been received on the PDCCH for the UE's Semi-Persistent C-RNTI:
  - if the NDI in the received HARQ information is 1:
    - consider the NDI not to have been toggled;
    - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.

- else if the NDI in the received HARQ information is 0:
  - if PDCCH contents indicate SPS release:
    - clear the configured uplink grant (if any).
  - else:
    - store the uplink grant and the associated HARQ information as configured uplink grant;
    - initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI and to recur according to rules in subclause 5.10.2;
    - consider the NDI bit to have been toggled;
    - deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if an uplink grant for this TTI has been configured:
  - consider the NDI bit to have been toggled;
  - deliver the configured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

NOTE: The period of configured uplink grants is expressed in TTIs.

NOTE: If the UE receives both a grant for its RA-RNTI and a grant for its C-RNTI or Semi persistent scheduling C-RNTI, the UE may choose to continue with either the grant for its RA-RNTI or the grant for its C-RNTI or Semi persistent scheduling C-RNTI.

NOTE: When a configured uplink grant is indicated during a measurement gap and indicates an UL-SCH transmission during a measurement gap, the UE processes the grant but does not transmit on UL-SCH.

## 5.4.2 HARQ operation

### 5.4.2.1 HARQ entity

There is one HARQ entity at the UE, which maintains a number of parallel HARQ processes allowing transmissions to take place continuously while waiting for the feedback on the successful or unsuccessful reception of previous transmissions.

The number of parallel HARQ processes is specified in [2], clause 8.

At a given TTI, if an uplink grant is indicated for the TTI, the HARQ entity identifies the HARQ process for which a transmission should take place. It also routes the received feedback (ACK/NACK information), MCS and resource, relayed by the physical layer, to the appropriate HARQ process.

If TTI bundling is configured, the parameter TTI\_BUNDLE\_SIZE provides the number of TTIs of a TTI bundle. Within a bundle HARQ retransmissions are non-adaptive and shall be performed without waiting for feedback from previous transmissions according to TTI\_BUNDLE\_SIZE. The feedback for a bundle is only received for the TTI corresponding to TTI\_BUNDLE\_SIZE. A retransmission of a TTI bundle is also a TTI bundle.

For transmission of an uplink message containing the C-RNTI MAC control element or an uplink message including a CCCH SDU during Random Access (see section 5.1.5) TTI bundling does not apply.

For each TTI, the HARQ entity shall:

- identify the HARQ process associated with this TTI;
- if an uplink grant has been indicated for this TTI:
  - if the received grant was not addressed to a Temporary C-RNTI on PDCCH and if the NDI provided in the associated HARQ information has been toggled compared to the value in the previous transmission of this HARQ process; or

- if this is the very first transmission for this HARQ process (i.e. , no previous NDI is available); or
- if the uplink grant was received in a Random Access Response:
  - if there is a MAC PDU in the Msg3 buffer and the uplink grant was received in a Random Access Response:
    - obtain the MAC PDU to transmit from the Msg3 buffer.
  - else:
    - obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity;
  - deliver the MAC PDU and the uplink grant and the HARQ information to the identified HARQ process;
  - instruct the identified HARQ process to trigger a new transmission.
- else:
  - deliver the uplink grant and the HARQ information (redundancy version) to the identified HARQ process;
  - instruct the identified HARQ process to generate an adaptive retransmission.
- else, if the HARQ buffer of the HARQ process corresponding to this TTI is not empty:
  - instruct the identified HARQ process to generate a non-adaptive retransmission.

When determining if NDI has been incremented compared to the value in the previous transmission UE shall ignore NDI received in all uplink grants on PDCCH for its Temporary C-RNTI.

NOTE: A retransmission triggered by the HARQ entity should be cancelled by the corresponding HARQ process if it collides with a measurement gap or if a non-adaptive retransmission is not allowed.

#### 5.4.2.2 HARQ process

Each HARQ process is associated with a HARQ buffer.

Each HARQ process shall maintain a state variable CURRENT\_TX\_NB, which indicates the number of transmissions that have taken place for the MAC PDU currently in the buffer, and a state variable HARQ\_FEEDBACK, which indicates the HARQ feedback for the MAC PDU currently in the buffer. When the HARQ process is established, CURRENT\_TX\_NB shall be initialized to 0.

The sequence of redundancy versions is 0, 2, 3, 1. The variable CURRENT\_IRV is an index into the sequence of redundancy versions. This variable is up-dated modulo 4.

New transmissions and adaptive retransmissions are performed on the resource and with the MCS indicated on PDCCH, except for new transmissions of Msg3 which are performed according to UL grant in Random Access Response. Non-adaptive retransmission is performed on the same resource and with the same MCS as was used for the last made transmission attempt,

The UE is configured with a Maximum number of HARQ transmissions and a Maximum number of Msg3 HARQ transmissions by RRC. For transmissions on all HARQ processes and all logical channels except for transmission of a MAC PDU stored in the Msg3 buffer, maximum number of transmissions shall be set to Maximum number of HARQ transmissions. For transmission of a MAC PDU stored in the Msg3 buffer, maximum number of transmissions shall be set to Maximum number of Msg3 HARQ transmissions.

When the HARQ feedback is received for this HARQ process:

- set HARQ\_FEEDBACK to the received value.

If the HARQ entity requests a new transmission, the HARQ process shall:

- set CURRENT\_TX\_NB to 0;
- set CURRENT\_IRV to 0;
- store the MAC PDU in the associated HARQ buffer;
- store the uplink grant received from the HARQ entity;
- set HARQ\_FEEDBACK to NACK;
- generate a transmission as described below.

If the HARQ entity requests a retransmission, the HARQ process shall:

- increment CURRENT\_TX\_NB by 1;
- if the HARQ entity requests an adaptive retransmission:
  - store the uplink grant received from the HARQ entity;
  - set CURRENT\_IRV to the index corresponding to the redundancy version value provided in the HARQ information;
  - set HARQ\_FEEDBACK to NACK;
  - generate a transmission as described below.
- else if the HARQ entity requests a non-adaptive retransmission:
  - if HARQ\_FEEDBACK = NACK; or
  - if TTI bundling is configured and CURRENT\_TX\_NB is less than TTI\_BUNDLE\_SIZE:
    - generate a transmission as described below.

NOTE: When receiving a HARQ ACK alone, the UE keeps the data in the HARQ buffer.

NOTE: When no UL-SCH transmission can be made due to the occurrence of a measurement gap, no HARQ feedback can be received and a non-adaptive retransmission follows.

To generate a transmission, the HARQ process shall:

- if there is no measurement gap at the time of the transmission or if the MAC PDU was obtained from the Msg3 buffer:
  - instruct the physical layer to generate a transmission according to the stored uplink grant with the redundancy version corresponding to the CURRENT\_IRV value;
  - increment CURRENT\_IRV by 1;
- if there is a measurement gap at the time of the feedback reception for this transmission and if the MAC PDU was not obtained from the Msg3 buffer:
  - set HARQ\_FEEDBACK to ACK.

The HARQ process shall:

- if CURRENT\_TX\_NB = maximum number of transmissions - 1:
  - flush the HARQ buffer;



The HARQ process may:

- if CURRENT\_TX\_NB = maximum number of transmissions - 1; and
- if the last feedback received (i.e., the feedback received for the last transmission of this process) is a HARQ NACK except for the transmission of a MAC PDU stored in the Msg3 buffer:
  - notify the relevant ARQ entities in the upper layer that the transmission of the corresponding RLC PDUs failed.

## 5.4.3 Multiplexing and assembly

### 5.4.3.1 Logical channel prioritization

The Logical Channel Prioritization procedure is applied when a new transmission is performed.

RRC can control the scheduling of uplink data by giving each logical channel a priority where increasing priority values indicate lower priority levels. In addition, each logical channel is given a Prioritized Bit Rate (PBR) and a Bucket Size Duration (BSD).

The UE shall maintain a variable  $B_j$  for each logical channel  $j$ .  $B_j$  shall be initialized to zero, and incremented by PBR of the logical channel  $j$  for each TTI. However, the value of  $B_j$  can never exceed the bucket size and if the value of  $B_j$  is larger than the bucket size of logical channel  $j$ , it shall be set to the bucket size. The bucket size of a logical channel is equal to  $PBR \times BSD$ , where PBR and BSD are configured by upper layers.

The UE shall perform the following Logical Channel Prioritization procedure when a new transmission is performed:

- The UE shall allocate resources to the logical channels in the following steps:
  - Step 1: All the logical channels with  $B_j > 0$  are allocated resources in a decreasing priority order. If the PBR of a radio bearer is set to 'infinity', the UE shall allocate resources for all the data that is available for transmission on the radio bearer before meeting the PBR of the lower priority radio bearer(s);
  - Step 2: the UE shall decrement  $B_j$  by the total size of MAC SDUs served to logical channel  $j$  in Step 1

NOTE: The value of  $B_j$  can be negative.

- Step 3: if any resources remain, all the logical channels are served in a strict decreasing priority order (regardless of the value of  $B_j$ ) until either the data for that logical channel or the UL grant is exhausted, whichever comes first. Logical channels configured with equal priority should be served equally.
- The UE shall also follow the rules below during the scheduling procedures above:
  - the UE should not segment an RLC SDU (or partially transmitted SDU or retransmitted RLC PDU) if the whole SDU (or partially transmitted SDU or retransmitted RLC PDU) fits into the remaining resources;
  - if the UE segments an RLC SDU from the logical channel, it shall maximize the size of the segment to fill the grant as much as possible;
  - UE should maximise the transmission of data.

The UE shall not transmit data for a logical channel corresponding to a radio bearer that is suspended (the conditions for when a radio bearer is considered suspended are defined in [8]).

For the Logical Channel Prioritization procedure, the UE shall take into account the following relative priority in decreasing order:

- MAC control element for C-RNTI or data from UL-CCCH;
- MAC control element for BSR, with exception of BSR included for padding;
- MAC control element for PHR;
- data from any Logical Channel, except data from UL-CCCH;

- MAC control element for BSR included for padding.

#### 5.4.3.2 Multiplexing of MAC SDUs

### 5.4.4 Scheduling Request

The Scheduling Request (SR) is used for requesting UL-SCH resources for new transmission.

When an SR is triggered, it shall be considered as pending until it is cancelled.

If an SR is triggered and there is no other SR pending, the UE shall set the SR\_COUNTER to 0.

As long as one SR is pending, the UE shall for each TTI:

- if no UL-SCH resources are available for a transmission in this TTI:
  - if the UE has no valid PUCCH resource for SR configured in any TTI: initiate a Random Access procedure (see subclause 5.1) and cancel all pending SRs;
  - else if the UE has a valid PUCCH resource for SR configured for this TTI and if this TTI is not part of a measurement gap:
    - if SR\_COUNTER < SR\_TRANS\_MAX:
      - increment SR\_COUNTER by 1;
      - instruct the physical layer to signal the SR on PUCCH;
    - else:
      - notify RRC of PUCCH/SRS release, initiate a Random Access procedure (see subclause 5.1) and cancel all pending SRs.
- else if UL-SCH resources for new transmission are granted in this TTI, cancel all pending SR(s).

### 5.4.5 Buffer Status Reporting

The Buffer Status reporting procedure is used to provide the serving eNB with information about the amount of data available for transmission in the UL buffers of the UE.

For the Buffer Status reporting procedure, the UE shall consider all radio bearers which are not suspended and may consider radio bearers which are suspended.

A Buffer Status Report (BSR) shall be triggered if any of the following events occur:

- UL data, for a logical channel which belongs to a LCG, becomes available for transmission in the RLC entity or in the PDCP entity (the definition of what data shall be considered as available for transmission is specified in [3] and [4] respectively) and either the data belongs to a logical channel with higher priority than the priorities of the logical channels which belong to any LCG and for which data is already available for transmission, or there is no data available for transmission for any of the logical channels which belong to a LCG, in which case the BSR is referred below to as "Regular BSR";
- UL resources are allocated and number of padding bits is equal to or larger than the size of the Buffer Status Report MAC control element, in which case the BSR is referred below to as "Padding BSR";
- a serving cell change occurs, in which case the BSR is referred below to as "Regular BSR";
- the RETX\_BSR\_TIMER expires and the UE has data available for transmission, in which case the BSR is referred below to as "Regular BSR";
- the PERIODIC\_BSR\_TIMER expires, in which case the BSR is referred below to as "Periodic BSR".

For Regular and Periodic BSR:

- if more than one LCG has data available for transmission in the TTI where the BSR is transmitted: report Long BSR;
- else report Short BSR.

For Padding BSR:

- if the number of padding bits is equal to or larger than the size of the Short BSR plus its subheader but smaller than the size of the Long BSR plus its subheader:
  - if more than one LCG has buffered data in the TTI where the BSR is transmitted: report Truncated BSR of the LCG with the highest priority logical channel with data available for transmission;
  - else report Short BSR.
- else if the number of padding bits is equal to or larger than the size of the Long BSR plus its subheader, report Long BSR.

If the Buffer Status reporting procedure determines that at least one BSR has been triggered since the last transmission of a BSR or if this is the first time that at least one BSR is triggered:

- if the UE has UL resources allocated for new transmission for this TTI:
  - instruct the Multiplexing and Assembly procedure to generate a BSR MAC control element;
  - start or restart the PERIODIC\_BSR\_TIMER except when the BSR is a Truncated BSR;
  - start (if not running) or restart (if running) the RETX\_BSR\_TIMER.
- else if a Regular BSR has been triggered:
  - a Scheduling Request shall be triggered.

A MAC PDU shall contain at most one MAC BSR control element, even when multiple events trigger a BSR by the time a BSR can be transmitted in which case the Regular BSR and the Periodic BSR shall have precedence over the padding BSR.

The UE shall restart (if running) the RETX\_BSR\_TIMER upon reception of a grant for transmission of new data on UL-SCH.

All triggered BSRs shall be cancelled in case the UL grant can accommodate all pending data available for transmission but is not sufficient to additionally accommodate the BSR MAC control element. All triggered BSRs shall be cancelled when a BSR is included in a MAC PDU for transmission.

## 5.4.6 Power Headroom Reporting

The Power Headroom reporting procedure is used to provide the serving eNB with information about the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission. The reporting period, delay and mapping of Power Headroom are defined in subclause 9.1.8 of 3GPP TS 36.133 [9].

A Power Headroom Report (PHR) shall be triggered if any of the following events occur:

- the PROHIBIT\_PHR\_TIMER expires or has expired and the path loss has changed more than *DL\_PathlossChange* dB since the last power headroom report when UE has UL resources for new transmission;
- the PERIODIC PHR TIMER expires, in which case the PHR is referred below to as 'Periodic PHR';
- upon configuration and reconfiguration of a Periodic PHR.

If the UE has UL resources allocated for new transmission for this TTI:

- if the Power Headroom reporting procedure determines that a PHR has been triggered since the last transmission of a PHR:
  - obtain the value of the power headroom from the physical layer;

- instruct the Multiplexing and Assembly procedure to generate a PHR MAC control element based on the value reported by the physical layer;
- if a "Periodic PHR" has been triggered since the last transmission of a PHR, start or restart the PERIODIC PHR TIMER;
- restart the PROHIBIT\_PHR\_TIMER.

NOTE: Even if multiple events occur by the time a PHR can be transmitted, only one PHR is included in the MAC PDU.

## 5.5 PCH reception

When the UE needs to receive PCH, the UE shall:

- if a PCH assignment has been received on the PDCCH for the P-RNTI:
  - attempt to decode the TB on the PCH as indicated by the PDCCH information.
- if a TB on the PCH has been successfully decoded:
  - deliver the decoded MAC PDU to upper layers.

## 5.6 BCH reception

When the UE needs to receive BCH, the UE shall:

- receive and attempt to decode the BCH;
- if a TB on the BCH has been successfully decoded:
  - deliver the decoded MAC PDU to upper layers.

## 5.7 Discontinuous Reception (DRX)

The UE may be configured by RRC with a DRX functionality that controls the UE's PDCCH monitoring activity for the UE's C-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI and Semi-Persistent Scheduling C-RNTI (if configured). When in RRC\_CONNECTED, if DRX is configured, the UE is allowed to monitor the PDCCH discontinuously using the DRX operation specified in this subclause; otherwise the UE monitors the PDCCH continuously. When using DRX operation, the UE shall also monitor PDCCH according to requirements found in other subclauses of this specification. The DRX operation is based on a Long DRX cycle, a DRX Inactivity Timer, a HARQ RTT Timer per DL HARQ process (except for the broadcast process), a DRX Retransmission Timer per DL HARQ process (except for the broadcast process) and optionally a Short DRX Cycle and a DRX Short Cycle Timer, all defined in subclause 3.1.

When a DRX cycle is configured, the Active Time includes the time while:

- the On Duration Timer or the DRX Inactivity Timer or a DRX Retransmission Timer or the Contention Resolution Timer (as described in subclause 5.1.5) is running; or
- a Scheduling Request sent on PUCCH is pending (as described in subclause 5.4.4); or
- an uplink grant for a pending HARQ retransmission can occur; or
- a PDCCH indicating a new transmission addressed to the C-RNTI of the UE has not been received after successful reception of a Random Access Response for the explicitly signaled preamble (as described in subclause 5.1.4).

When DRX is configured, the UE shall for each subframe:

- If the Short DRX Cycle is used and  $[(SFN * 10) + \text{subframe number}] \bmod (\text{Short DRX Cycle}) = (\text{DRX Start Offset}) \bmod (\text{Short DRX Cycle})$ ; or

- if the Long DRX Cycle is used and  $[(SFN * 10) + \text{subframe number}] \bmod (\text{Long DRX Cycle}) = \text{DRX Start Offset}$ :
  - start the On Duration Timer.
- if a HARQ RTT Timer expires in this subframe and the data in the soft buffer of the corresponding HARQ process was not successfully decoded:
  - start the DRX Retransmission Timer for the corresponding HARQ process.
- if a DRX Command MAC control element is received:
  - stop the On Duration Timer;
  - stop the DRX Inactivity Timer.
- if the DRX Inactivity Timer expires or a DRX Command MAC control element is received in this subframe:
  - if the short DRX cycle is configured:
    - start or restart the DRX Short Cycle Timer;
    - use the Short DRX Cycle.
  - else:
    - use the Long DRX cycle.
- if the DRX Short Cycle Timer expires in this subframe:
  - use the long DRX cycle.
- during the Active Time, for a PDCCH-subframe except if the subframe is required for uplink transmission for half-duplex FDD UE operation and except if the subframe is part of a configured measurement gap:
  - monitor the PDCCH;
  - if the PDCCH indicates a DL transmission or if a DL assignment has been configured for this subframe:
    - start the HARQ RTT Timer for the corresponding HARQ process;
    - stop the DRX Retransmission Timer for the corresponding HARQ process.
  - if the PDCCH indicates a new transmission (DL or UL):
    - start or restart the DRX Inactivity Timer.
- when not in Active Time, CQI/PMI/RI on PUCCH and SRS shall not be reported.

Regardless of whether the UE is monitoring PDCCH or not the UE receives and transmits HARQ feedback when such is expected.

NOTE: A UE may optionally choose to not send CQI/PMI/RI reports on PUCCH and/or SRS transmissions for up to 4 subframes following a PDCCH indicating a new transmission (UL or DL) received in the last subframe of active time. This is not applicable for subframes where On Duration timer is running.

## 5.8 MAC reconfiguration

*Editor's note: This subclause describes the procedure for handling reconfiguration of MAC parameters during normal operation.*

If a reconfiguration of the MAC entity is requested by upper layers, the UE shall:

- apply immediately the configurations received from upper layers.

## 5.9 MAC Reset

*Editor's note: This subclause describes the procedure for resetting MAC [FFS]; e.g. at handover.*

If a reset of the MAC entity is requested by upper layers, the UE shall:

- initialize  $B_j$  for each logical channel to zero;
- stop and reset all timers, if running;
- consider the Time Alignment Timer as expired and perform the corresponding actions in 5.2;
- stop, if any, ongoing RACH procedure;
- flush Msg3 buffer;
- cancel, if any, triggered Scheduling Request procedure;
- cancel, if any, triggered Buffer Status Reporting procedure;
- cancel, if any, triggered Power Headroom Reporting procedure;
- flush all UL HARQ buffers;
- flush all DL HARQ buffers;
- for UL, consider the next transmission for each process as very first;
- for DL, consider the next received TB for each process as very first;
- release, if any, configured downlink assignment;
- release, if any, configured uplink grant;
- release, if any, Temporary C-RNTI.

## 5.10 Semi-Persistent Scheduling

When Semi-Persistent Scheduling is enabled by upper layer, the following information is provided:

- Semi-Persistent Scheduling C-RNTI;
- Uplink Semi-Persistent Scheduling Interval, if Semi-Persistent Scheduling is enabled for the uplink;
- Whether [two-intervals-Semi-Persistent Scheduling] is enabled or disabled for uplink, only for TDD;
- Downlink Semi-Persistent Scheduling Interval, if Semi-Persistent Scheduling is enabled for the downlink;

When Semi-Persistent Scheduling for uplink or downlink is disabled by RRC, the corresponding configured grant or configured assignment shall be discarded.

### 5.10.1 Downlink

After a Semi-Persistent downlink assignment is configured, the UE shall consider that the assignment recurs in each subframe for which:

- $(10 * SFN + \text{subframe}) = [(10 * SFN_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * (\text{Downlink Semi-Persistent Scheduling Interval})] \text{ modulo } 10240$ , for all  $N > 0$ .

Where  $SFN_{\text{start time}}$  and  $\text{subframe}_{\text{start time}}$  are the SFN and subframe, respectively, at the time the configured downlink assignment were (re-)initialised.

## 5.10.2 Uplink

After a Semi-Persistent Scheduling uplink grant is configured, the UE shall:

- if [two-intervals-Semi-Persistent Scheduling] is enabled by upper layer;
  - set the Subframe\_Offset according to Table 7.4-1.
- else:
  - set Subframe\_Offset to 0.
- consider that the grant recurs in each subframe for which:
  - $(10 * SFN + \text{subframe}) = [(10 * SFN_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * (\text{Uplink Semi-Persistent Scheduling Interval}) + \text{Subframe\_Offset} * (N \bmod 2)] \bmod 10240$ , for all  $N > 0$ .

Where  $SFN_{\text{start time}}$  and  $\text{subframe}_{\text{start time}}$  are the SFN and subframe, respectively, at the time the configured uplink grant were (re-)initialised.

The UE shall clear the configured uplink grant immediately after transmitting the number of consecutive new uplink transmissions on the Semi-Persistent Scheduling resource, configured by RRC, each containing zero MAC SDU.

## 5.X Handling of unknown, unforeseen and erroneous protocol data

*Editor's note: This subclause describes how MAC treats and acts on unexpected data.*

*Editor's note: The subclause on 'Handling of unknown, unforeseen and erroneous protocol data' should be the last subsection of Section 'MAC procedures'.*

# 6 Protocol Data Units, formats and parameters

## 6.1 Protocol Data Units

### 6.1.1 General

A MAC PDU is a bit string that is byte aligned (i.e. multiple of 8 bits) in length. In the figures in subclause 6.1, bit strings are represented by tables in which the most significant bit is the leftmost bit of the first line of the table, the least significant bit is the rightmost bit on the last line of the table, and more generally the bit string is to be read from left to right and then in the reading order of the lines. The bit order of each parameter field within a MAC PDU is represented with the first and most significant bit in the leftmost bit and the last and least significant bit in the rightmost bit.

MAC SDUs are bit strings that are byte aligned (i.e. multiple of 8 bits) in length. An SDU is included into a MAC PDU from the first bit onward.

The UE ignores the value of Reserved bits in downlink MAC PDUs.

### 6.1.2 MAC PDU (DL-SCH and UL-SCH except transparent MAC and Random Access Response)

A MAC PDU consists of a MAC header, zero or more MAC Service Data Units (MAC SDU), zero, or more MAC control elements, and optionally padding; as described in Figure 6.1.2-3.

Both the MAC header and the MAC SDUs are of variable sizes.

A MAC PDU header consists of one or more MAC PDU sub-headers; each subheader corresponding to either a MAC SDU, a MAC control element or padding.

A MAC PDU subheader consists of the six header fields R/R/E/LCID/F/L but for the last subheader in the MAC PDU and for fixed sized MAC control elements. The last subheader in the MAC PDU and sub-headers for fixed sized MAC control elements consist solely of the four header fields R/R/E/LCID. It follows that a MAC PDU subheader corresponding to padding consists of the four header fields R/R/E/LCID.

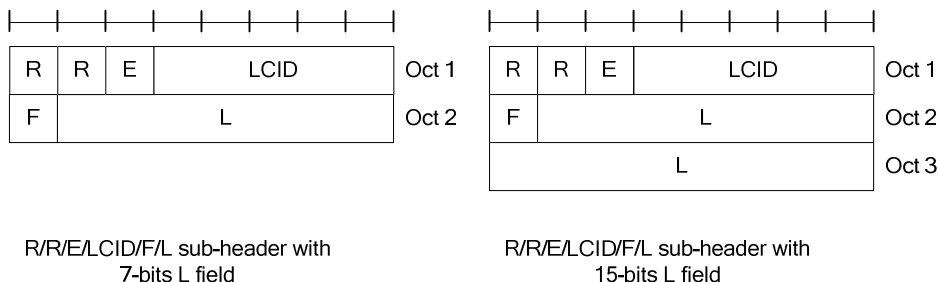


Figure 6.1.2-1: R/R/E/LCID/F/L MAC subheader

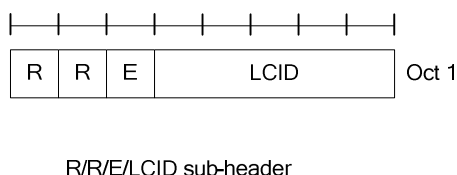


Figure 6.1.2-2: R/R/E/LCID MAC subheader

MAC PDU sub-headers have the same order as the corresponding MAC SDUs, MAC control elements and padding.

MAC control elements, are always placed before any MAC SDU.

Padding occurs at the end of the MAC PDU, except when single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU. Padding may have any value and the UE shall ignore it.

When single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU, one or two MAC PDU sub-headers corresponding to padding are inserted before the first MAC PDU subheader corresponding to a MAC SDU; or if such subheader is not present, before the last MAC PDU subheader corresponding to a MAC control element.

A maximum of one MAC PDU can be transmitted per TB per UE.

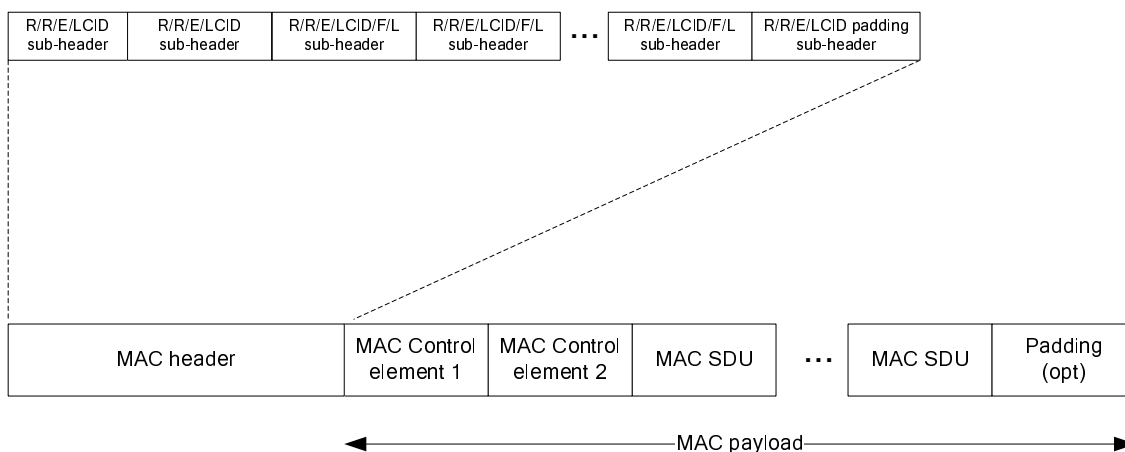


Figure 6.1.2-3: Example of MAC PDU consisting of MAC header, MAC control elements, MAC SDUs and padding



### 6.1.3 MAC Control Elements

#### 6.1.3.1 Buffer Status Report MAC Control Elements

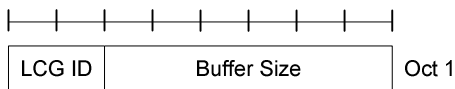
Buffer Status Report (BSR) MAC control elements consist of either:

- Short BSR and Truncated BSR format: one LCG ID field and one corresponding Buffer Size field (figure 6.1.3.1-1); or
- Long BSR format: four Buffer Size fields, corresponding to LCG IDs #0 through #3 (figure 6.1.3.1-2).

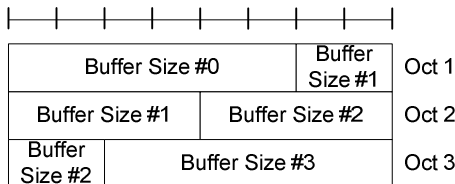
The BSR formats are identified by MAC PDU subheaders with LCIDs as specified in table 6.2.1.-1.

The fields LCG ID and Buffer Size are defined as follow:

- LCG ID: The Logical Channel Group ID field identifies the group of logical channel(s) which buffer status is being reported. The length of the field is 2 bits;
- Buffer Size: The Buffer Size field identifies the total amount of data available across all logical channels of a logical channel group after the MAC PDU has been built. The amount of data is indicated in number of bytes. It shall include all data that is available for transmission in the RLC layer and in the PDCP layer; the definition of what data shall be considered as available for transmission is specified in [3] and [4] respectively. The size of the RLC and MAC headers are not considered in the buffer size computation. The length of this field is 6 bits. The values taken by the Buffer Size field are shown in Table 6.1.3.1-1.



**Figure 6.1.3.1-1: Short BSR and Truncated BSR MAC control element**



**Figure 6.1.3.1-2: Long BSR MAC control element**

Table 6.1.3.1-1: Buffer size levels for BSR

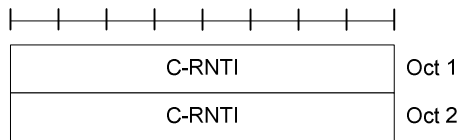
| Index | Buffer Size (BS) value [bytes] | Index | Buffer Size (BS) value [bytes] |
|-------|--------------------------------|-------|--------------------------------|
| 0     | BS = 0                         | 32    | 1132 < BS <= 1326              |
| 1     | 0 < BS <= 10                   | 33    | 1326 < BS <= 1552              |
| 2     | 10 < BS <= 12                  | 34    | 1552 < BS <= 1817              |
| 3     | 12 < BS <= 14                  | 35    | 1817 < BS <= 2127              |
| 4     | 14 < BS <= 17                  | 36    | 2127 < BS <= 2490              |
| 5     | 17 < BS <= 19                  | 37    | 2490 < BS <= 2915              |
| 6     | 19 < BS <= 22                  | 38    | 2915 < BS <= 3413              |
| 7     | 22 < BS <= 26                  | 39    | 3413 < BS <= 3995              |
| 8     | 26 < BS <= 31                  | 40    | 3995 < BS <= 4677              |
| 9     | 31 < BS <= 36                  | 41    | 4677 < BS <= 5476              |
| 10    | 36 < BS <= 42                  | 42    | 5476 < BS <= 6411              |
| 11    | 42 < BS <= 49                  | 43    | 6411 < BS <= 7505              |
| 12    | 49 < BS <= 57                  | 44    | 7505 < BS <= 8787              |
| 13    | 57 < BS <= 67                  | 45    | 8787 < BS <= 10287             |
| 14    | 67 < BS <= 78                  | 46    | 10287 < BS <= 12043            |
| 15    | 78 < BS <= 91                  | 47    | 12043 < BS <= 14099            |
| 16    | 91 < BS <= 107                 | 48    | 14099 < BS <= 16507            |
| 17    | 107 < BS <= 125                | 49    | 16507 < BS <= 19325            |
| 18    | 125 < BS <= 146                | 50    | 19325 < BS <= 22624            |
| 19    | 146 < BS <= 171                | 51    | 22624 < BS <= 26487            |
| 20    | 171 < BS <= 200                | 52    | 26487 < BS <= 31009            |
| 21    | 200 < BS <= 234                | 53    | 31009 < BS <= 36304            |
| 22    | 234 < BS <= 274                | 54    | 36304 < BS <= 42502            |
| 23    | 274 < BS <= 321                | 55    | 42502 < BS <= 49759            |
| 24    | 321 < BS <= 376                | 56    | 49759 < BS <= 58255            |
| 25    | 376 < BS <= 440                | 57    | 58255 < BS <= 68201            |
| 26    | 440 < BS <= 515                | 58    | 68201 < BS <= 79846            |
| 27    | 515 < BS <= 603                | 59    | 79846 < BS <= 93479            |
| 28    | 603 < BS <= 706                | 60    | 93479 < BS <= 109439           |
| 29    | 706 < BS <= 826                | 61    | 109439 < BS <= 128125          |
| 30    | 826 < BS <= 967                | 62    | 128125 < BS <= 150000          |
| 31    | 967 < BS <= 1132               | 63    | BS > 150000                    |

### 6.1.3.2 C-RNTI MAC Control Element

The C-RNTI MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-2.

It has a fixed size and consists of a single field defined as follows (figure 6.1.3.2-1):

- C-RNTI: This field contains the C-RNTI of the UE. The length of the field is 16 bits.



**Figure 6.1.3.2-1: C-RNTI MAC control element**

### 6.1.3.3 DRX Command MAC Control Element

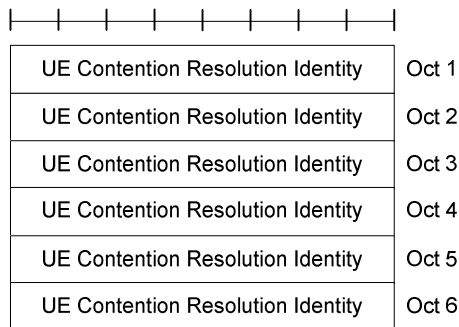
The DRX Command MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1.

It has a fixed size of zero bits.

### 6.1.3.4 UE Contention Resolution Identity MAC Control Element

The UE Contention Resolution Identity MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1. This control element has a fixed 48-bit size and consists of a single field defined as follows (figure 6.1.3.4-1)

- UE Contention Resolution Identity: This field contains the uplink CCCH SDU.



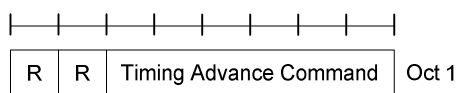
**Figure 6.1.3.4-1: UE Contention Resolution Identity MAC control element**

### 6.1.3.5 Timing Advance Command MAC Control Element

The Timing Advance Command MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1.

It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.5-1):

- R: reserved bit;
- Timing Advance Command: This field indicates the index value  $T_A$  (0, 1, 2... 63) used to control the amount of timing adjustment that UE has to apply (see subclause 4.2.3 of [2]). The length of the field is 6 bits.



**Figure 6.1.3.5-1: Timing Advance Command MAC control element**

### 6.1.3.6 Power Headroom MAC Control Element

The Power Headroom MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.6-1):

- R: reserved bit, set to "0";

- Power Headroom (PH): this field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.6.1-1 below (the corresponding measured values in dB can be found in subclause 9.1.8.4 of [17]).

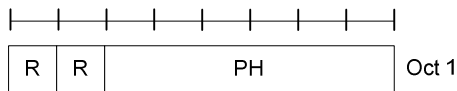


Figure 6.1.3.6-1: Power Headroom MAC control element

Table 6.1.3.6-1: Power Headroom levels for PHR

| PH  | Power Headroom Level |
|-----|----------------------|
| 0   | POWER_HEADROOM_0     |
| 1   | POWER_HEADROOM_1     |
| 2   | POWER_HEADROOM_2     |
| 3   | POWER_HEADROOM_3     |
| ... | ...                  |
| 60  | POWER_HEADROOM_60    |
| 61  | POWER_HEADROOM_61    |
| 62  | POWER_HEADROOM_62    |
| 63  | POWER_HEADROOM_63    |

### 6.1.4 MAC PDU (transparent MAC)

A MAC PDU consists solely of a MAC Service Data Unit (MAC SDU) whose size is aligned to a TB; as described in figure 6.1.4-1.

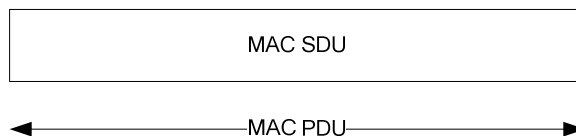


Figure 6.1.4-1: Example of MAC PDU (transparent MAC)

### 6.1.5 MAC PDU (Random Access Response)

A MAC PDU consists of a MAC header and one or more MAC Random Access Responses (MAC RAR) and optionally padding as described in figure 6.1.5-4.

The MAC header is of variable size.

A MAC PDU header consists of one or more MAC PDU sub-headers; each subheader corresponding to a MAC RAR except for the Backoff Indicator sub-header.

A MAC PDU subheader consists of the three header fields E/T/RAPID (as described in figure 6.1.5-1) but for the Backoff Indicator subheader which consists of the five header field E/T/R/R/BI (as described in figure 6.1.5-2).

A MAC RAR consists of the four fields R/Timing Advance Command/UL Grant/Temporary C-RNTI (as described in figure 6.1.5-3).

Padding may occur after the last MAC RAR. Presence and length of padding is implicit based on TB size, size of MAC header and number of RARs.

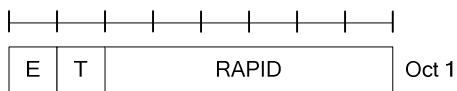


Figure 6.1.5-1: E/T/RAPID MAC sub-header

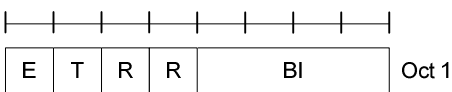


Figure 6.1.5-2: E/T/R/R/BI MAC sub-header

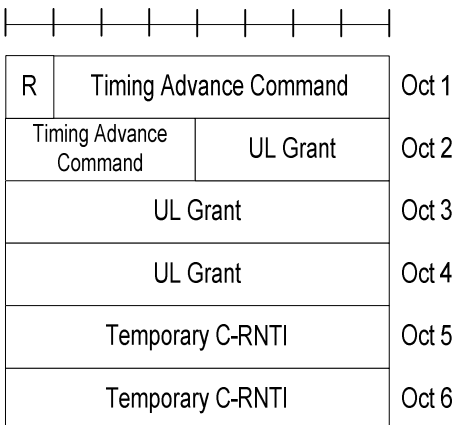


Figure 6.1.5-3: MAC RAR

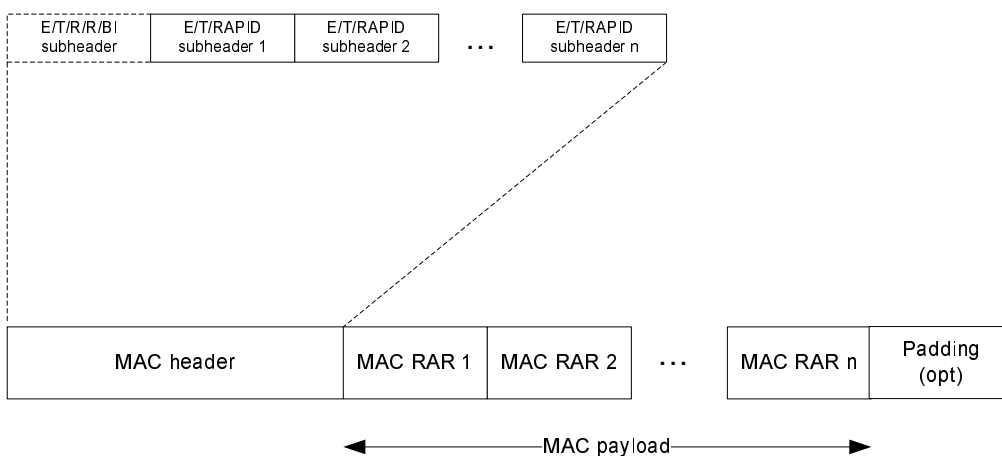


Figure 6.1.5-4: Example of MAC PDU consisting of a MAC header and MAC RARs

## 6.2 Formats and parameters

### 6.2.1 MAC header for DL-SCH and UL-SCH

The MAC header is of variable size and consists of the following fields:

- LCID: The Logical Channel ID field identifies the logical channel instance of the corresponding MAC SDU or the type of the corresponding MAC control element or padding as described in tables 6.2.1-1 and 6.2.1-2 for the DL and UL-SCH respectively. There is one LCID field for each MAC SDU, MAC control element or padding included in the MAC PDU. In addition to that, one or two additional LCID fields are included in the MAC PDU, when single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU. The LCID field size is 5 bits;

- L: The Length field indicates the length of the corresponding MAC SDU or MAC control element in bytes. There is one L field per MAC PDU subheader except for the last subheader and sub-headers corresponding to fixed-sized MAC control elements. The size of the L field is indicated by the F field;
- F: The Format field indicates the size of the Length field as indicated in table 6.2.1-3. There is one F field per MAC PDU subheader except for the last subheader and sub-headers corresponding to fixed-sized MAC control elements. The size of the F field is 1 bit. If the size of the MAC SDU or MAC control element is less than 128 bytes, the UE shall set the value of the F field to 0, otherwise the UE shall set it to 1;
- E: The Extension field is a flag indicating if more fields are present in the MAC header or not. The E field is set to "1" to indicate another set of at least R/R/E/LCID fields. The E field is set to "0" to indicate that either a MAC SDU, a MAC control element or padding starts at the next byte;
- R: Reserved bit, set to "0".

The MAC header and sub-headers are octet aligned.

**Table 6.2.1-1 Values of LCID for DL-SCH**

| Index       | LCID values                       |
|-------------|-----------------------------------|
| 00000       | CCCH                              |
| 00001-01010 | Identity of the logical channel   |
| 01011-11011 | Reserved                          |
| 11100       | UE Contention Resolution Identity |
| 11101       | Timing Advance Command            |
| 11110       | DRX Command                       |
| 11111       | Padding                           |

**Table 6.2.1-2 Values of LCID for UL-SCH**

| Index       | LCID values                     |
|-------------|---------------------------------|
| 00000       | CCCH                            |
| 00001-01010 | Identity of the logical channel |
| 01011-11001 | Reserved                        |
| 11010       | Power Headroom Report           |
| 11011       | C-RNTI                          |
| 11100       | Truncated BSR                   |
| 11101       | Short BSR                       |
| 11110       | Long BSR                        |
| 11111       | Padding                         |

**Table 6.2.1-3 Values of F field:**

| Index | Size of Length field (in bits) |
|-------|--------------------------------|
| 0     | 7                              |
| 1     | 15                             |

## 6.2.2 MAC header for Random Access Response

The MAC header is of variable size and consists of the following fields:

- E: The Extension field is a flag indicating if more fields are present in the MAC header or not. The E field is set to "1" to indicate another set of at least E/T/RAPID or E/T/R/R/BI fields. The E field is set to "0" to indicate that a MAC RAR starts at the next byte;
- T: The Type field is a flag indicating whether the MAC subheader contains a Random Access ID or a Backoff Indicator. The T field is set to '0' to indicate the presence of a Backoff Indicator field in the subheader (BI). The T field is set to '1' to indicate the presence of a Random Access Preamble ID field in the subheader (RAPID);
- R: Reserved bit, set to "0";

- BI: The Backoff Indicator field identifies the overload condition in the cell. The size of the BI field is 4 bits;
- RAPID: The Random Access Preamble IDentifier field identifies the transmitted Random Access Preamble (see subclause 5.1.3). The size of the RAPID field is 6 bits.

The MAC header and sub-headers are octet aligned.

### 6.2.3 MAC payload for Random Access Response

The MAC RAR is of fixed size and consists of the following fields:

- R: Reserved bit, set to "0";
- Timing Advance Command: The Timing Advance Command field indicates the index value  $T_A$  (0, 1, 2... 1282) used to control the amount of timing adjustment that UE has to apply (see subclause 4.2.3 of [2]). The size of the Timing Advance Command field is 11 bits;
- UL Grant: The UpLink Grant field indicates the resources to be used on the uplink (see subclause 6.2 of [2]). The size of the UL Grant field is 20 bits;
- Temporary C-RNTI: The Temporary C-RNTI field indicates the temporary identity that is used by the UE during Random Access. The size of the Temporary C-RNTI field is 16 bits.

The MAC RAR is octet aligned.

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## 7 Variables and constants

### 7.1 RNTI values

RNTI values are presented in Table 7.1-1.

**Table 7.1-1: RNTI values.**

| Value (hexa-decimal) |           | RNTI   |
|----------------------|-----------|--|
| FDD                  | TDD       |  |
| 0000-0009            | 0000-003B | RA-RNTI  |
| 000A-FFF2            | 003C-FFF2 | C-RNTI, Semi-Persistent Scheduling C-RNTI, Temporary C-RNTI, TPC-PUCCH-RNTI and TPC-PUSCH-RNTI |
| FFF3-FFFC            |           | Reserved for future use  |
| FFFE                 |           | P-RNTI   |
| FFFF                 |           | SI-RNTI  |

### 7.2 Backoff Parameter values

Backoff Parameter values are presented in Table 7.2-1.

Table 7.2-1: Backoff Parameter values.

| Index | Backoff Parameter value (ms) |
|-------|------------------------------|
| 0     | 0                            |
| 1     | 10                           |
| 2     | 20                           |
| 3     | 30                           |
| 4     | 40                           |
| 5     | 60                           |
| 6     | 80                           |
| 7     | 120                          |
| 8     | 160                          |
| 9     | 240                          |
| 10    | 320                          |
| 11    | 480                          |
| 12    | 960                          |

### 7.3 PRACH Mask Index values

Table 7.3-1: PRACH Mask Index values

| PRACH Mask Index | Allowed PRACH (FDD)   | Allowed PRACH (TDD)   |
|------------------|---|---|
| 0                | All   | All   |
| 1                | PRACH Resource Index 0  | PRACH Resource Index 0  |
| 2                | PRACH Resource Index 1  | PRACH Resource Index 1  |
| 3                | PRACH Resource Index 2  | PRACH Resource Index 2  |
| 4                | PRACH Resource Index 3  | PRACH Resource Index 3  |
| 5                | PRACH Resource Index 4  | PRACH Resource Index 4  |
| 6                | PRACH Resource Index 5  | PRACH Resource Index 5  |
| 7                | PRACH Resource Index 6  | Reserved  |
| 8                | PRACH Resource Index 7  | Reserved  |
| 9                | PRACH Resource Index 8  | Reserved  |
| 10               | PRACH Resource Index 9  | Reserved  |
| 11               | Every, in the time domain, even PRACH opportunity<br>1 <sup>st</sup> PRACH Resource Index in subframe | Every, in the time domain, even PRACH opportunity<br>1 <sup>st</sup> PRACH Resource Index in subframe |
| 12               | Every, in the time domain, odd PRACH opportunity<br>1 <sup>st</sup> PRACH Resource Index in subframe  | Every, in the time domain, odd PRACH opportunity<br>1 <sup>st</sup> PRACH Resource Index in subframe  |
| 13               | Reserved  | 1 <sup>st</sup> PRACH Resource Index in subframe  |
| 14               | Reserved  | 2 <sup>nd</sup> PRACH Resource Index in subframe  |
| 15               | Reserved  | 3 <sup>rd</sup> PRACH Resource Index in subframe  |

### 7.4 Subframe\_Offset values

Subframe\_Offset values are presented in Table 7.4-1.

Table 7.4-1: Subframe\_Offset values

| TDD UL/DL configuration | Position of initial Semi-Persistent grant | Subframe_Offset value (ms) |
|-------------------------|---|----------------------------|
| 0                       | N/A                                       | 0                          |
| 1                       | Subframes 2 and 7                         | 1                          |
|                         | Subframes 3 and 8                         | -1                         |
| 2                       | Subframe 2                                | 5                          |
|                         | Subframe 7                                | -5                         |
| 3                       | Subframes 2 and 3                         | 1                          |
|                         | Subframe 4                                | -2                         |
| 4                       | Subframe 2                                | 1                          |
|                         | Subframe 3                                | -1                         |
| 5                       | N/A                                       | 0                          |
| 6                       | N/A                                       | 0                          |



## 7.5 TTI\_BUNDLE\_SIZE value

The parameter TTI\_BUNDLE\_SIZE is 4.

## 7.6 DELTA\_PREAMBLE values

The DELTA\_PREAMBLE preamble format based power offset values are presented in Table 7.6-1.

**Table 7.6-1: DELTA\_PREAMBLE values.**

| Preamble Format | DELTA_PREAMBLE value |
|-----------------|----------------------|
| 0               | 0 dB                 |
| 1               | 0 dB                 |
| 2               | -3 dB                |
| 3               | -3 dB                |
| 4               | 8 dB                 |

Where the Preamble Format is given by the PRACH Configuration Index in [7].

## 7.7 HARQ RTT Timer

For FDD the HARQ RTT Timer is set to 8 subframes. For TDD the HARQ RTT Timer is set to  $k + 4$  subframes, where  $k$  is the interval between the downlink transmission and the transmission of associated HARQ feedback, as indicated in Table 10.1-1 of [2].

## Annex A (informative): Change history

| Change history |             |           |      |     |  |       |       |
|----------------|-------------|-----------|------|-----|--|-------|-------|
| Date           | TSG #       | TSG Doc.  | CR   | Rev | Subject/Comment  | Old   | New   |
| 2007-06        | RAN2#58 bis | R2-072710 |      |     | MAC Protocol Specification Baseline  | -     |       |
| 2007-06        | RAN2#58 bis | R2-072912 |      |     | Text Proposal for UL HARQ (Tdoc R2-072708)<br>Text Proposal for DL HARQ (Tdoc R2-072707)<br>Text Proposal for RACH procedure (Tdoc R2-072640)<br>Text Proposal for Logical Channel prioritization (Tdoc R2-072643)   |       | 0.1.0 |
| 2007-06        | RAN2#58 bis | R2-072994 |      |     | Basic MAC PDU structure (Tdoc R2-072983) with updates<br>Agreements on time-frequency resource configuration (Tdoc R2-072993)<br>Agreement on RA-RNTI association (Tdoc R2-072993)<br>Clarification on RA Response reception (Tdoc R2-072993)  | 0.1.0 | 0.1.1 |
| 2007-08        | RAN2#59     | R2-073715 |      |     | Removed reference to non-existing table (Tdoc R2-073473)<br>Incorrect mapping of logical to transport channel (Tdoc R2-073473)<br>Un-necessary error checking in HARQ process procedure (Tdoc R2-073473)<br>Removal of reference to timing relation for HARQ feedback (Tdoc R2-073473)<br>Correction of Internal variable name (Tdoc R2-073473)<br>Correction of procedure in case of successful HARQ reception (Tdoc R2-073473)   | 0.1.1 | 0.2.0 |
| 2007-09        | RAN2#59     | R2-073885 |      |     | Text proposal for Random Access procedure<br>Text proposal on HARQ clarification for TDD<br>Text proposal on HARQ for grants   | 0.2.0 | 0.2.1 |
| 2007-09        | RAN#37      | RP-070688 |      |     | Clean version for information  | 0.2.1 | 1.0.0 |
| 2007-10        | RAN2#59 bis | R2-074530 |      |     | Editorial update with Editor's notes (Tdoc R2-074211).   | 1.0.0 | 1.1.0 |
| 2007-11        | RAN2#60     | R2-075093 |      |     | Agreements on MAC PDU format (R2-074536)<br>Corrections on Random Access Procedure (R2-074536)   | 1.1.0 | 1.1.1 |
| 2007-11        | RAN2#60     | R2-075243 |      |     | Endorsement of v1.1.1<br>Removal of FFS on DL CCCH existence   | 1.1.1 | 1.2.0 |
| 2007-11        | RAN2#60     | R2-075488 |      |     | Agreement on identity used Random Access Response (R2-075038)<br>Agreement on Local Nack1 (R2-074949)<br>PUCCH Resource handling (R2-075432)<br>UL HARQ agreements (R2-075432)<br>Agreements on semi-persistent scheduling (R2-075432, 36.300)<br>Agreements on BSR/SR triggers (R2-075432)<br>Agreements on BSR contents (R2-075432)<br>Agreements on Timing Advance principles (36.300)<br>Agreements on DRX control (36.300)<br>Handling of P-BCH, D-BCH, PCH (R2-075246) | 1.2.0 | 1.3.0 |
| 2007-11        | RP-38       | RP-070917 |      |     | Clean version, presented at TSG RAN-38 for approval  | 1.3.0 | 2.0.0 |
| 2007-12        | RP-38       | -         |      |     | Approved at TSG RAN-38 and placed under change control   | 2.0.0 | 8.0.0 |
| 2008-03        | RP-39       | RP-080162 | 0001 | 2   | CR to 36.321 with E-UTRA MAC protocol specification update   | 8.0.0 | 8.1.0 |
| 2008-05        | RP-40       | RP-080410 | 0002 | 1   | 36.321 CR covering agreements of RAN2 #61bis and RAN2#62   | 8.1.0 | 8.2.0 |
| 2008-09        | RP-41       | RP-080690 | 0003 | -   | Clarification on data available for transmission for BSR triggering  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0004 | -   | CR to 36.321 on failure indication after maximum number of HARQ transmissions  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0005 | 4   | Clarifications and Corrections of DL and UL Data Transfer (SCH, RACH and SR)   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0006 | -   | CR to 36.321 on Buffer size levels for BSR   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0007 | -   | Clarifications on DRX  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0008 | -   | Clarification on UE behavior for DRX and configured measurement gaps   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0009 | 3   | Correction to MAC Padding BSR  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0010 | -   | Correction to UE transmission power headroom report for LTE  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0011 | -   | Corrections on BSR   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0012 | -   | CR to 36.321 REL-8 on Format of UL grant in Message 2  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0015 | -   | CR to 36.321 REL-8 on PUSCH PUCCH Power Control RNTIs  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0016 | -   | CR to 36.321 REL-8 on RACH uniform random backoff  | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0017 | 1   | E-UTRA MAC protocol specification update   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0020 | -   | TP for number of HARQ processes and MIMO   | 8.2.0 | 8.3.0 |
|                | RP-41       | RP-080690 | 0022 | -   | Update of MAC dedicated preamble expiry  | 8.2.0 | 8.3.0 |

|         |       |           |      |   |  |       |       |
|---------|-------|-----------|------|---|--|-------|-------|
|         | RP-41 | RP-080690 | 0027 | - | Handling of Semi-Persistent grants and assignments   | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0051 | 1 | Corrections relating to RACH   | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0058 | 1 | UL Channel Prioritisation  | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0071 | 2 | Corrections relating to RACH partitioning  | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0091 | - | Correction on Random Access Response reception behaviour                                       | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0103 | - | Upper limit of logical channel id  | 8.2.0 | 8.3.0 |
|         | RP-41 | RP-080690 | 0104 | - | Clarifications and Corrections for HARQ operation at TAT expiry and RACH contention resolution | 8.2.0 | 8.3.0 |
| 2008-12 | RP-42 | RP-081018 | 0105 | - | CR0105 to 36.321 [Rel-8] on PHR Periodic Timer Start   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0106 | 1 | Proposed R1 of CR0106 to 36.321 [Rel-8] on PHR Reference                                       | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0107 | 1 | CR 0107 to 36.321 Interactions between measurement gap and Msg3 transmission                   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0108 | 2 | Proposed R1 of CR0108 to 36.321 [Rel-8] on PHR Reporting Values                                | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0109 | - | Correction relating to equal priorities  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0110 | - | CR 0110 to 36.321 on Correction to PHR   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0112 | 1 | CR0112r1 to 36.321 [Rel-8] Correction to BCCH Reception procedure                              | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0113 | - | Contention Resolution Timer  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0114 | - | PCH reception  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0115 | - | Correction to reception of assignments and grants  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0116 | - | Correction on Contention Resolution  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0117 | 2 | Proposed R1 of CR0117 to 36.321 [Rel-8] on on SR Clarifications and Repetitions                | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081078 | 0118 | 2 | Clarification on Padding value   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0119 | - | CR 0119 to 36.321 Correction and Clarification on TTI Bundling                                 | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0120 | 1 | Clarification of DRX Active Time   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0121 | 4 | Text Proposal for Dedicated Preamble Assignment  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0122 | - | CR0122 to 36.321 [Rel-8] on Message 3 Definition   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0123 | 1 | Correction to prevent wrong contention resolution by adaptive retransmission command           | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0124 | - | Bucket Size Parameter  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0125 | 2 | CR0125r2 to 36.321 [Rel-8] Correction to Multiple BSR  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0127 | - | CR0127 to 36.321 [Rel-8] RACH preambles labelling  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0128 | 1 | CR0128r1 to 36.321 [Rel-8] merging CR0126r0 and CR0128r0                                       | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0129 | 1 | CR0129r1 to 36.321 [Rel-8] Correction to PDU Format  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0130 | - | CQI/ SRS/PMI/RI transmission during active time  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0131 | 1 | NDI and Msg4 Carrying Contention Resolution ID   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0132 | 1 | CR0132 to 36.321 [Rel-8] on MAC BSR trigger  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0133 | - | Clarification about Restarting the Periodic BSR Timer  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0134 | - | Correction to RA procedure initiated by eNB PDCCH order  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0135 | 1 | Correction on PHR triggering condition   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0136 | - | CR 0136 to 36.321 on Correction to UL HARQ Process for the transmission of Msg3                | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0137 | 2 | SPS occasions  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0138 | - | Robustness of Buffer Status Reporting  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0139 | - | Proposed CR to 36.321 [Rel-8] on UL HARQ and Measurement Gaps                                  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0142 | 1 | TAT and RACH procedure   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0143 | 1 | SRS and CQI Resources Release upon TAT Expiry  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0157 | 1 | Proposed CR to 36.321 Correction to RACH procedure   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0162 | 1 | BSR format for reporting empty buffers   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0165 | - | TTI Bundling Configuration   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0166 | 1 | Corrections to semi-persistent scheduling  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0167 | 2 | Priotitization of MAC control elements   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0168 | - | Correction to starting of TA timer   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0173 | 1 | Proposed CR to 36.321 SPS implicit release on UL   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0174 | - | Proposed CR to 36.321 Measurement gaps and SPS   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0175 | - | Proposed CR to 36.321 Setting reserved bits to zero  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0185 | - | Proposed CR to 36.321 [Rel-8] MAC ResetReconfig Option 2                                       | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0188 | 2 | RV setting   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0189 | - | Corrections to Random Access Procedure   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0198 | - | Number of HARQ processes for MIMO  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0201 | - | Corrections to power control and random access   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0206 | - | Correction on the definition of the PDCCH-subframe   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0211 | 1 | Correction to the coexist of SPS-RNTI and SI-RNTI or RA-RNTI                                   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0220 | - | Explicit release of SPS  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0225 | 2 | Linking HARQ process ID with the SPS resource  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0231 | - | Bucket Parameter Update  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0232 | 1 | Clarification on 'PDCCH indicates a new transmission' for DRX                                  | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0233 | 1 | Editorial corrections to MAC   | 8.3.0 | 8.4.0 |
|         | RP-42 | RP-081018 | 0236 | - | RB suspension and BSR contents   | 8.3.0 | 8.4.0 |

|  |       |           |      |   |  |       |       |
|--|-------|-----------|------|---|--|-------|-------|
|  | RP-42 | RP-081018 | 0239 | - | RV setting                                   | 8.3.0 | 8.4.0 |
|  | RP-42 | RP-081018 | 0240 | 2 | Preamble group selection                     | 8.3.0 | 8.4.0 |
|  | RP-42 | RP-081018 | 0241 | - | Use of dedicated preambles after HO complete | 8.3.0 | 8.4.0 |
|  | RP-42 | RP-081018 | 0242 | - | Introduction of HARQ RTT Timer               | 8.3.0 | 8.4.0 |
|  | RP-42 | RP-081018 | 0243 | - | Correction to DRX configuration              | 8.3.0 | 8.4.0 |
|  |       |           |      |   |  |       |       |

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## History

| <b>Document history</b> |               |             |
|-------------------------|---------------|-------------|
| V8.2.0                  | November 2008 | Publication |
| V8.3.0                  | November 2008 | Publication |
| V8.4.0                  | January 2009  | Publication |
|                         |               |             |
|                         |               |             |