ETSI TS 102 178 V1.1.1 (2003-11)

Technical Specification

Broadband Radio Access Networks (BRAN);
HIPERMAN;
Data Link Control (DLC) layer

Reference

DTS/BRAN-0040002

Keywords

access, broadband, HIPERMAN, FWA, layer 2, MAN, radio

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Sous-Préfecture de Grasse (06) N° 7803/88

Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Project Broadband Radio Access Networks (BRAN).

The present document supplements IEEE Standard P802.16-2001 [1] as amended by IEEE Standard P802.16c [2], which shall be considered normative in its entirety, with exclusion of the Physical Layer (PHY) and profiles defined therein.

The present document describes the supplemental data transport and radio control functions of the Data Link Control (DLC) of HIgh PErformance Radio Metropolitan Area Network (HIPERMAN) systems, which operate on frequencies between 2 GHz and 11 GHz. A separate ETSI document, TS 102 177 [3], specifies the PHY.

With permission of IEEE® (on file as BRAN32_5d009), portions of the present document are excerpted from IEEE Standard 802.16-2002 and IEEE Standard 802.16a-2003.

1 Scope

The present document supplements IEEE Standard P802.16-2001 [1] as amended by IEEE Standard P802.16c [2], which defines the DLC and PHY of metropolitan area network systems operating on licensed frequencies between 10 GHz and 66 GHz. The present document provides the supplemental DLC functions required for systems operating on licensed frequencies between 2 GHz and 11 GHz to support PMP and optionally Mesh network topologies. These supplemental DLC functions are defined to support the different physical environment that exists on frequencies between 2 GHz and 11 GHz compared to frequencies between 10 GHz and 66 GHz.

The physical characteristics of frequencies between 2 GHz and 11 GHz, as well as the characteristics of the Broadband Wireless Access (BWA) market segments for which the present document is designed, result in an environment, where Line Of Sight (LOS) is not necessary, multipath may be severe and the physical medium may be lossy.

The present document does not address the requirements and technical characteristics for conformance testing, nor the requirements for the applicable 2 GHz to 11 GHz PHY Layer. Those are covered in separate documents.

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 and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

[1] IEEE P802.16-2001: "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems".

[2] IEEE P802.16c: "Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems - Detailed System Profiles for 10-66 GHz ".

[3] ETSI TS 102 177: "Broadband Radio Access Networks (BRAN); HIPERMAN; Physical layer".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Adaptive Antenna System (AAS): system adaptively exploiting more than one antenna to improve the coverage and the system capacity

NOTE: AAS-enabled in the context of a PMP BS denotes the implementation of AAS as defined. AAS-enabled in the context of a PMP SS denotes the ability to communicate with an AAS-enabled BS using the AAS specific mechanisms. Though a PMP SS may itself implement AAS as defined, this has no impact on the air interface and hence no specific differentiation is made.

adaptive modulation: system's ability to communicate with another system using multiple burst profiles and a system's ability to subsequently communicate with multiple systems using different burst profiles

ARQ Block: distinct unit of data that is carried on an ARQ-enabled connection

NOTE: Such a unit is assigned a sequence number, and is managed as a distinct entity by the ARQ state machines.

bandwidth stealing: use, by a subscriber station operating on a grant per subscriber station basis, of a portion of the bandwidth allocated in response to a bandwidth request for a connection to send another bandwidth request rather than sending data

NOTE: See also: grant per subscriber station.

DC carrier: in an OFDM or OFDMA signal, the carrier whose frequency would be equal to the RF centre frequency of the station

MeSH (MSH): network architecture, wherein systems are capable of forwarding traffic from and to multiple other systems

RF centre frequency: centre of the frequency band in which a BS or SS is intended to transmit

Rx/Tx Transition Gap (RTG): gap, used by TDD and H-FDD systems, between the uplink burst and the subsequent downlink burst

NOTE: This gap allows time for the BS to switch from receive to transmit mode and SSs to switch from transmit to receive mode. During this gap, the BS and SS are not transmitting modulated data but simply allowing the BS transmitter carrier to ramp up, the Tx/Rx antenna switch to actuate, and the SS receiver sections to activate.

SS Rx/Tx Gap (SSRTG): the minimum receive to transmit turnaround gap

NOTE: SSRTG is measured from the time of the last sample of the received burst to the first sample of the transmitted burst, at the antenna port of the SS.

SS Tx/Rx Gap (SSTTG): the minimum transmit to receive turnaround gap

NOTE: SSTTG is measured from the time of the last sample of the transmitted burst to the first sample of the transmitted burst, at the antenna port of the SS.

Tx/Rx Transition Gap (TTG): gap, used by TDD and H-FDD systems, between the downlink burst and the subsequent uplink burst

NOTE: This gap allows time for the BS to switch from transmit to receive mode and SSs to switch from receive to transmit mode. During this gap, the BS and SS are not transmitting modulated data but simply allowing the BS transmitter carrier to ramp down, the Tx/Rx antenna switch to actuate, and the BS receiver section to activate.

Turbo decoding: iterative decoding, using soft inputs and soft outputs

3.2 Symbols

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

α_{avg}	Averaging parameter for CINR and RSSI computations
$RSS_{\mathrm{IR,max}}$	Initial Ranging Max. Received Signal Strength at BS

3.3 Abbreviations

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

AAS	Adaptive Antenna System
ARQ	Automatic Repeat reQuest
BW	BandWidth
CID	Connection IDentifier
CINR	Carrier to noise and INterference Ratio

CSCF	Centralized Scheduling ConFiguration
CSCH	Centralized SCHedule
DCD	DL Channel Descriptor
DCE	Downlink Channel Emission
DIUC	Downlink Interval Usage Code
DSA-RSP	Dynamic Service Addition-ReSPonse
DSCH	Distributed SCHedule
DSC-REQ	Dynamic Service Change-REQuest
DSC-RSP	Dynamic Service Change-ReSPonse
FPC	Fast Power Control
FWA	Fixed Wireless Access
HCS	Header Check Sequence
H-FDD	Half-duplex FDD
IE	Information Element
LOS	Line Of Sight
MIMO	Multiple In Multiple Out
MS	Mini-Slot
MSH	MeSH
NCFG	Network ConFiGuration
NENT	Network ENTry
NLOS	Non Line Of Sight
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PKM	Privacy Key Management
PMP	Point-to-MultiPoint
REQ	REQuest
RNG	RaNGing
RSP	ReSPonse
RTG	Receive/Transmit Transition Gap
SNR	Signal-to-Noise Ratio
TTG	Transmit/receive Transition Gap
UCD	UL Channel Descriptor
UIUC	Uplink Interval Usage Code

4 PDU formats

4.1 MAC header type encodings

4.1.1 Type encodings

The Type field in the Generic MAC Header shall indicate the presence of subheaders and payload as shown in table 1.

Table 1: Type encodings

Type bit	Value
#0 (lsb)	Grant Management Subheader 1 = present, 0 = absent Shall be 0 on DL
#1	Packing Subheader 1 = present, 0 = absent
#2	Fragmentation Subheader 1 = present, 0 = absent
#3	ARQ Extended Packing/Fragmentation Subheader 1 = extended, 0 = not extended
#4	ARQ Feedback Payload 1 = present, 0 = absent
#5 (msb)	Mesh Subheader 1 = present, 0 = absent

Four types of Subheaders may be present. The per-PDU subheaders (the Mesh subheader, the Fragmentation subheader and the Grant Management subheader) may be inserted in MAC PDUs immediately following the Generic MAC. If both the Fragmentation Subheader and Grant Management Subheader are indicated, the Grant Management Subheader shall come first. If the Mesh Subheader is indicated, it shall precede all other subheaders.

4.1.2 Header Check Sequence encoding

The transmitter shall calculate the HCS value for the first five octets of the cell header, and insert the result into the HCS field (the last octet of the MAC header). It shall be the remainder of the division (Modulo 2) by the generator polynomial $g(D) = D^8+D^2+D+1$ of the polynomial D^8 multiplied by the content of the header excluding the HCS field.

EXAMPLE: [HT EC Type] = 0x80, BR = 0xAAAA, CID = 0x0F0F; HCS should then be set to 0xD5.

4.2 MAC subheaders

4.2.1 Mesh subheader

The Mesh Subheader as shown in table 2 shall always immediately follow the generic MAC header when operating in Mesh mode, but shall not be used when operating in PMP mode.

Table 2: Mesh subheader format

Syntax	Size	Notes
Mesh Subheader() {		
Xmt Node Id	16 bits	Node Id of the originating mesh node.
}		

4.2.2 ARQ feedback payload

If the ARQ Feedback Payload bit in the MAC Header Type field (see table 1) is set, the ARQ Feedback Payload shall be transported. If packing is used, it shall be transported as the first packed payload. See clause 5.1.2.

4.2.3 Fragmentation subheader

The Fragmentation Subheader is shown in table 3.

Table 3: Fragmentation subheader format

Syntax	Size	Notes
Fragmentation Subheader() {		
Fragmentation Control (FC)	2 bits	Indicates the fragmentation state of the payload: 00 = no fragmentation 01 = last fragment 10 = first fragment 11 = continuing (middle) fragment
If (Type bit#3 (Extended Type) == 0)		See table 1.
Fragmentation Sequence Number (FSN)	3 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 8) for each fragment, including unfragmented SDUs. Applicable to connections where ARQ is not enabled.
Else		
Block Sequence Number (SN)	11 bits	Sequence number of the first block in the current SDU or SDU fragment. This field increments by one (modulo 2 048) for each block. Applicable to connections where ARQ is enabled.
Reserved	3 bits	
}		

4.2.4 Packing subheader

When Packing is used, multiple SDUs may be packed into a single MAC PDU. When packing variable-length MAC SDUs, the MAC precedes each one with a Packing subheader as shown in table 4.

Table 4: Packing subheader format

Syntax	Size	Notes
Packing Subheader() {		
Fragmentation Control	2 bits	Indicates the fragmentation state of the payload: 00 = no fragmentation 01 = last fragment 10 = first fragment 11 = continuing (middle) fragment
If (Type bit#3 == 0)		See table 1
Fragmentation Sequence Number	3 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 8) for each fragment, including unfragmented SDUs. Applicable to connections where ARQ is not enabled.
Else		
Block Sequence Number	11 bits	Sequence number of the first block in the current SDU fragment. This field increments by one (modulo 2 048) for each block. Applicable to connections where ARQ is enabled.
Length	11 bits	The length in bytes of the MAC SDU or SDU fragment, including the length of the Packing Subheader.
}		

4.3 MAC management messages

TLVs within MAC Management messages shall be ordered as follows. Parameters for optional features shall occur after those listed for support of mandatory features. Features that are defined optional, but are mandated by the implemented System Profile, if any, shall be ordered as optional. Both mandatory and optional TLVs shall subsequently be sequenced in order of increasing Type value. Parameters with defined default values should be omitted if the desired value coincides with the default one.

When reporting parameters in MAC Management messages, Service Class Names should not be used.

4.3.1 Supplemental MAC management messages

As shown in table 5, supplemental MAC management messages are defined to facilitate ARQ, channel measurements and mesh functionality.

Table 5: MAC management messages

Type	Message	Connection	Description
33	ARQ-Feedback	Basic	
34	ARQ-Discard	Basic	
35	ARQ-Reset	Basic	
36	REP-REQ	Basic	
37	REP-RSP	Basic	
38	FPC	Broadcast	
39	MSH-NCFG	Broadcast	
40	MSH-NENT	Basic	
41	MSH-DSCH	Broadcast	
42	MSH-CSCH	Broadcast	
43	MSH-CSCF	Broadcast	
44	AAS-FBCK-REQ	Basic	
45	AAS-FBCK-RSP	Basic	
46-255	Reserved		

4.3.2 Type 1/3: DL/UL Channel Descriptor (DCD/UCD) message

TLVs which may be included in the DCD message shall be limited to those listed in table 6.

Table 6: DL Channel Descriptor TLVs

Name	Type	Length	Value
Burst Profile	1	variable	May appear more than once. The length is the number of bytes in the overall object, including embedded TLV items. See table 10.
BS EIRP	2	2	Signed in units of 1 dBm.
TTG	11	1	TTG (in PSs). See TS 102 177 [3], clause 14.
RTG	12	1	RTG (in PSs). See TS 102 177 [3], clause 14.
$EIRxP_{\mathrm{IR,max}}$	13	1	Maximum equivalent isotropic received power (see clause 8.1) in dB. Signed integer.

Burst Profile encodings which may be included in the DCD message shall be limited those shown in table 7.

Table 7: DL burst profile TLVs

Name	Type	Length	Value
FEC Code Type	2	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2 = 16QAM (RS+CC) 1/2 3 = 16QAM (RS+CC) 3/4 4 = 64QAM (RS+CC) 2/3 5 = 64QAM (RS+CC) 3/4 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16QAM (CTC) 1/2 16 = 16QAM (CTC) 3/4 17 = 64QAM (CTC) 2/3 18 = 64QAM (CTC) 5/6 or 4/5 6-11, 19-256 Reserved
DIUC Mandatory Exit Threshold	13	1	0 - 63. 75 dB. C/(N+I) at or below which this DIUC can no longer be used and at which a change to a more robust DIUC is required, in 0,25 dB units.
DIUC Mandatory Entry Threshold	14	1	0 - 63. 75 dB. The minimum C/(N+I) required to start using this DIUC when changing from a more robust DIUC is required, in 0,25 dB units.

TLVs which may be included in the UCD message shall be limited to those listed in table 8.

Table 8: UL Channel Descriptor TLVs

Name	Type	Length	Value
Burst Profile	1	variable	May appear more than once. The length is the number of bytes in the overall object, including embedded TLV items. See table 10.
Frequency	3	4	Uplink centre frequency (kHz).
Contention-based Reservation Timeout	10	1	Number of UL-MAPs to receive before contention- based reservation is attempted again for the same connection.
Channel Width	11	2	Uplink channel width, increments of 10 KHz.
Sub-channelized initial ranging	18	1	Indicates whether sub-channelized initial ranging is supported 0 = Not supported 1 = Supported.
Sub-channelization focused contention code	19	1	Number of contention codes (C_{SE}) that shall only be used to request a sub-channelized allocation. Default value 0. Allowed values 0-48.
Sub-channelized REQ-Region-Full Parameters	20	1	Bits 0…2: Number of sub-channels used by each transmit opportunity when REQ Region-Full is allocated in sub-channelization region, per the following enumeration: 0b000: 1 Sub-channel. 0b001: 2 Sub-channels. 0b010: 4 Sub-channels. 0b011: 8 Sub-channels. Bits 3…7: Number of OFDM symbols used by each transmit opportunity when REQ Region-Full is allocated in sub-channelization region.

Burst Profile encodings which may be included in the UCD message shall be limited those shown in table 9.

Table 9: UL burst profile TLVs

Name	Type	Length	Value
FEC Code Type	5	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2 = 16QAM (RS+CC) 1/2 3 = 16QAM (RS+CC) 3/4 4 = 64QAM (RS+CC) 2/3 5 = 64QAM (RS+CC) 3/4 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16QAM (CTC) 1/2 16 = 16QAM (CTC) 3/4 17 = 64QAM (CTC) 2/3 18 = 64QAM (CTC) 5/6 or 4/5 6-11, 19-256 Reserved
Focused Contention Power Boost	17	1	The power boost in dB of focused contention carriers. See TS 102 177 [3] for details.

Table 10 defines the format of the Burst_Profile, which is used in both DCD and UCD messages.

The Burst Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC/UIUC which is associated with the Burst Profile and Thresholds. The DIUC/UIUC value is used in the DL-MAP respectively UL-MAP message to specify the Burst Profile to be used for a specific burst.

Table 10: Burst profile format

Syntax	Size	Notes
DL/UL_Burst_Profile_format {		
Type = 1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to 0.
DIUC / UIUC	4 bits	
TLV encoded information	variable	
}		

4.3.3 Type 2/3: DL-MAP / UL-MAP message

The following formats shall be used in the DL-MAP and UL-MAP messages.

4.3.3.1 DL-MAP PHY Synchronization Field

The PHY Synchronization Field of the DL-MAP message shall have the format shown in table 11.

Table 11: PHY synchronization field

Syntax	Size	Notes
Synchronization_field {		
Frame Number	24 bits	
}		

Frame Number

The modulo 2^{24} frame number is increased by one every frame.

4.3.3.2 DL-MAP IE format

DL-MAP Information Elements shall have the format shown in table 12.

Table 12: DL-MAP information element

Syntax	Size	Notes
DL-MAP_information_element() {		
CID	16 bits	
DIUC	4 bits	
Preamble present	1 bit	0 = not present, 1 = present if DIUC == 15, shall be 0
Start Time	11 bits	
if (DIUC == 15)		
Extended DIUC dependent IE	variable	Report_IE() or AAS_DL_IE() or STC_IE()
Padding nibble, if needed	4 bits	Completing to nearest byte
}		

Connection Identifier (CID)

Represents the assignment of the IE to a broadcast, multicast, or unicast address.

Downlink Interval Usage Code (DIUC)

A four-bit Downlink Interval Usage Code (DIUC) shall be used to define the burst type associated with that time interval. Burst Descriptor shall be included into DCD Message for each DIUC used in the DL-MAP except those associated with Gap, End of Map and Extended. The DIUC shall be one of the values defined in table 13.

Preamble present

If set, the indicated burst shall start with the short preamble.

Start Time

Indicates the start time, in units of symbol duration, relative to the beginning of the frame. The end of the last allocated burst is indicated by allocating a NULL burst (DIUC = 14) with zero duration. The time instants indicated by the Start Time values are the transmission times of the first symbol of the burst including preamble.

4.3.3.2.1 DIUC allocations

Table 13 contains the DIUC values used in DL-MAP_IE().

Table 13: OFDM DIUC values

DIUC	Usage
0	Reserved
1-12	Burst Profiles
13	Gap
14	End of Map
15	Extended DIUC

4.3.3.2.2 DL-MAP Report IE format

The BS may use the DL-MAP Report IE to create a gap during which all SSs shall measure the background noise using the RSSI method. The IE shall be followed by the End of Map IE (DIUC = 14).

Table 14: Channel measurement Information Element format

Syntax	Size	Notes
Report_Information_Element() {		
extended DIUC code	4 bits	Channel measurement = 0x0
Length	4 bits	Length = 0x1
Reserved	8 bits	Shall be set to 0x00
}		

4.3.3.2.3 DL-MAP AAS IE format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_IE() shown in table 15 to indicate that the subsequent allocations, until the start of the first UL-MAP allocation using TDD, and until the end of the frame using FDD, shall be for AAS traffic. When used, the CID in the DL-MAP_IE() shall be set to the broadcast CID. Subsequent AAS PHY bursts shall all start with the short preamble.

Table 15: AAS DL Information Element format

Syntax	Size	Notes
AAS_DL_Information_element() {		
extended DIUC	4 bits	AAS = 0x2
Length	4 bits	Length = 0x0
}		

4.3.3.2.4 DL-MAP STC IE format

In the DL-MAP, an STC enabled BS may transmit DIUC = 15 with the STC_IE() shown in table 16 to indicate that the subsequent allocations shall be STC encoded. No preceding DL allocations shall be STC encoded and all subsequent DL allocations until the end of the frame shall be STC encoded. After this allocation, the BS shall transmit from both its antennas until the end of the frame. The first DL allocation following the STC_IE shall contain a preamble. The number of OFDM data symbols between two preambles and the number of OFDM data symbols between the last preamble and the end of the DL subframe must be even.

Table 16: STC Information Element format

Syntax	Size	Notes
STC_Information_element() {		
extended DIUC code	4 bits	STC = 0x1
Length	4 bits	Length = 0x0
}		

4.3.3.2.5 DL-MAP DUMMY IE format

A SS shall be able to decode the DL-MAP DUMMY IE for forward compatibility. A BS shall not transmit this IE (unless under test). A SS may skip decoding DL bursts scheduled after the Start Time of this IE within the current frame.

Table 17: DL-MAP DUMMY Information Element format

Syntax	Size	Notes
DUMMY_Information_element() {		
extended DIUC	4 bits	0x2...0xF
Length	4 bits	0..15
Unspecified data	Length×8 bits	
}		

4.3.3.3 UL-MAP IE format

The UL-MAP Information Element defines the physical parameters and the start time for UL PHY bursts. The format of UL-MAP elements is shown in table 18.

When sub-channelization is active (see clause 4.3.3.3.4), UIUC 3 shall not be used.

Table 18: OFDM UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_information_element() {		
CID	16 bits	
UIUC	4bits	
Reserved	1 bit	
Start Time	11 bits	
if (UIUC == 4)		
Focused_contention_IE()	16 bits	
if (UIUC == 15)		
Extended UIUC dependent IE	Variable	AAS_UL_IE() or sub-channelization_IE()
else if (sub-channelization) {		See clause 4.3.3.3.4.
Duration	11 bits	
Sub-channel Index	5 bits	
Reserved	2 bits	Set to 0b00
Midamble Present	2 bits	0b00 = Preamble only 0b01 = Midambles after every 8 data symbols 0b10 = Midambles after every 16 data symbols 0b11 = Midambles after every 32 data symbols
}		
Padding nibble	0/4 bits	Shall be set to 0x0
}		

Connection Identifier (CID)

Represents the assignment of the IE to a unicast, multicast, or broadcast address. When specifically addressed to allocate a bandwidth grant, the CID may be either the Basic CID of the SS or a Traffic CID for one of the connections of the SS.

Uplink Interval Usage Code (UIUC)

Shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included into an UCD message for each Uplink Interval Usage Code that is to be used in the UL-MAP. The UIUC shall be one of the values defined in table 19.

Start Time

Indicates the start time, in units of symbol duration, relative to the Allocation Start Time given in the UL-MAP message. For non-sub-channelized allocations, the duration of the burst is indicated as the difference between the start times of current and next map elements. The end of the last allocated burst is indicated by allocating a NULL burst (CID = 0 and UIUC = 14). The time instant indicated by the Start Time value is the start of the transmission of the preamble.

Duration

Indicates the duration, in units of OFDM symbols, of the sub-channelized allocation. The duration is inclusive of the preamble and the midambles contained in the allocation.

Sub-channel Index

See table 1.

Midamble Present

Indicates the preamble repetition interval in OFDM symbols.

4.3.3.3.1 UIUC allocations

Table 19 contains the UIUC values used in the UL-MAP_IE().

Table 19: UIUC values

UIUC	Usage
0	Reserved
1	initial ranging
2	REQ Region Full
3	REQ Region Focused
4	Focused Contention IE
5-12	Burst Profiles
13	Gap
14	End of Map
15	Extended UIUC

4.3.3.3.2 UL-MAP focused contention IE format

Table 20 defines the UL-MAP IE for allocation Bandwidth (BW) for a SS that requested bandwidth using Focused Contention Reservation Requests. This UL-MAP IE is identified by UIUC = 4 (see table 19). A SS responding to a bandwidth allocation using the Focused Contention IE shall start its burst with a short preamble (see clause 5.6) and use only the most robust mandatory burst profile in that burst.

Table 20: Focused contention Information Element format

Syntax	Size	Notes
Focused_Contention_IE() {		
Transmit Opportunity Index	6 bits	
Contention Channel Index	6 bits	
Contention Code Index	3 bits	
Reserved	1 bit	Shall be set to 0b0
}		

Transmit Opportunity Index

Index number of the Transmit Opportunity that was used in the Bandwidth Request, which this message is responding to. Focused Contention Reservation Requests Transmit Opportunities are numbered from 63 to 0, starting from the beginning of the frame where the UL-MAP is transmitted.

Contention Channel Index

Index number of the Contention Channel that was used in the Bandwidth Request, which this message is responding to.

Contention Code Index

Index number of the Contention Code that was used in the Bandwidth Request, which this message is responding to.

4.3.3.3.3 UL-MAP AAS IE format

Within a frame, indication of AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_IE() shown in table 21 to indicate that the subsequent allocations be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID. Subsequent AAS PHY bursts shall all start with the short preamble. Stations not supporting the AAS functionality may treat the AAS_IE as a start of gap. The AAS_IE() shall not be used in AAS private map messages.

Table 21: AAS UL IE format

Syntax	Size	Notes
AAS_Information_element() {		
extended UIUC code	4 bits	AAS = 0x02
Length	4 bits	Length = 0x0
}		

4.3.3.3.4 UL-MAP sub-channelization IE format

Within a frame, the BS may allocate a portion of the UL allocations to sub-channelized traffic.

Table 22: Sub-channelization IE format

Syntax	Size	Notes
Sub-channelization_Information_element() {		
extended UIUC code	4 bits	Sub-channelization = 0x03
Length	4 bits	Length = 0x2
Length of Allocations	16 bits	
}		

Length of allocations

The number of bytes, following the sub-channelization_IE, that are used to define sub-channelized allocations. A SS not capable of using sub-channelization may skip interpreting this number of bytes in the UL-MAP.

4.3.3.3.5 UL-MAP DUMMY IE format

An SS shall be able to decode the UL-MAP DUMMY IE for forward compatibility. A BS shall not transmit this IE (unless under test).

Table 23: UL-MAP DUMMY Information Element format

Syntax	Size	Notes
DUMMY_Information_element() {		
extended UIUC	4 bits	0x4...0xF
Length	4 bits	0…15
Unspecified data	Length×8 bits	
}		

4.3.4 Type 4/5: RaNGing REQuest/ReSPonse (RNG-REQ/RSP) message

In addition to the TLVs listed in IEEE P802.16-2001 [1], the following TLVs are defined.

4.3.4.1 AAS Support

To indicate whether it can receive broadcast transmissions, an AAS-enabled SS may include the following TLV in RNG-REQ messages:

AAS Broadcast Capability

Table 24: Supplemental RNG-REQ TLVs

Name	Type	Length	Value
AAS broadcast capability	4	1	0 = SS can receive broadcast messages. 1 = SS cannot receive broadcast messages.

To indicate whether an SS, which set the AAS Broadcast Capability, may issue contention-based BW requests, an AAS-enabled BS may use the following TLV in RNG-RSP messages:

AAS Broadcast Permission

The following RNG-RSP TLVs may be sent by the BS to indicate the reception of an undecodable initial ranging (RNG-REQ) attempt or to indicate the reception of a sub-channelized initial ranging attempt.

Frame Number:

Initial Ranging Opportunity Number

Table 25: Supplemental RNG-RSP TLVs

Name	Type	Length	Value
Timing Adjust	1	4	Tx timing offset adjustment (signed 32-bit). The time by which to advance SS transmission so that frames arrive at the expected time instance at the BS. Units are PHY specific. See TS 102 177 [3], clause 14 for unit definition.
AAS broadcast permission	16	1	0 = SS may issue in contention-based BW requests.
AAS broadcast capability	17	1	0 = SS can receive broadcast messages. 1 = SS cannot receive broadcast messages.
Frame Number	18	3	Frame number in which the undecodable initial ranging or sub-channelized initial ranging attempt was detected by the BS. Usage is mutually exclusive with SS MAC Address. The opportunity within the frame is assumed to be 1 (the first) if the Initial Ranging Opportunity Number field is not supplied.
Initial Ranging Opportunity Number	19	1	Initial Ranging opportunity (1-255) in which the undecodable initial ranging or sub-channelized initial ranging attempt was detected by the BS. Usage is mutually exclusive with SS MAC Address.

4.3.4.2 Power management support

Table 26: TLVs for power management

Name	Type (1 byte)	Length	Value (Variable Length)
Power level Adjust	2	1	Tx Power offset adjustment (signed 8-bit, 0,25 dB units). Specifies the relative change in transmission power level that the SS is to make in order that transmissions arrive at the BS at the desired power. When sub-channelization is employed, The subscriber shall interpret the power offset adjustment as a required change to the transmitted power density.

4.3.5 Type 6: REGistration-REQuest (REG-REQ) message

In PMP mode during Registration, the SS shall generate REG-REQ messages including the following parameter in addition to those specified in IEEE P802.16-2001 [1]:

MAC Version
Maximum transmit power
Amplifier backoffs
Current transmitted power.

The transmitted power parameters are defined in table 27.

Table 27: Transmitted power parameters

Name	Type (1 byte)	Length	Value (Variable Length)	Scope
Maximum Tx Power	5.23	1	Achievable transmit power (peak) signed, 0,5 dB increments.	
Amplifier Backoffs	5.24	3	Byte 0: QPSK Byte 1: 16QAM Byte 2: 64QAM (report as 0x0 if not supported). Backoff values in 0,25 dB increments.	
Current Tx power	5.25	1	Current transmit power (peak) signed. 0,5 dB increments.	

In Mesh mode during Registration, the Candidate Node shall generate REG-REQ messages including the following parameters:

SS MAC Address
MAC Version

The MAC version implemented in the Candidate Node

HMAC Tuple

Message digest calculated using HMAC_KEY_U

Both in PMP and Mesh mode, the REG-REQ may in addition contain the following parameters:

IP Version
SS Capabilities Encodings
Vendor ID Encoding

4.3.6 Type 7: REGistration-ReSPonse (REG-RSP) message

In Mesh mode during Registration, the Registration Node shall generate REG-RSP messages including the following parameters:

Node ID
MAC Version

MAC Version used in the network

HMAC Tuple

Message digest calculated using HMAC_KEY_D

In Mesh mode, the REG-RSP may in addition contain the following parameters:

IP Version
SS Capabilities Encodings

Capabilities returned in the REG-RSP shall not be set to require greater capability of the Node than is reported in the REG-REQ.

Vendor Specific Extensions

4.3.7 Type 9/10: Privacy Key Management (PKM-REQ/RSP) messages

In Mesh mode, the Authorization reply attributes and the Key request attributes listed in tables 28 and 29 shall be used. The HMAC-Digest's authentication key is derived from the Authorization key or the Operator Shared Secret.

Table 28: Authorization Reply attributes

Attribute	Contents
Operator Shared Secret	Key known to all nodes
Key-Sequence-Number	Operator Shared Secret 's sequence number
Key-Lifetime	Operator Shared Secret 's active lifetime

Table 29: Key Request attributes

Attribute	Contents
SS Certificate	X.509 Certificate of the node
SAID	SA Identifier
HMAC-Digest	HMAC using HMAC_KEY_S

4.3.8 Type 12: Dynamic Service Addition-ReSPonse (DSA-RSP)

No TLVs besides Error Encodings and HMAC Tuples shall be reported back in DSA-RSP.

4.3.9 Type 13: Dynamic Service Addition-ACKnowledgement (DSA-ACK)

No TLVs besides HMAC Tuples shall be reported back in DSA-ACK messages.

4.3.10 Type 14: Dynamic Service Change-REQuest (DSC-REQ)

DSC-REQ messages shall not contain Request/Transmission Policy, Fixed vs. Variable Length SDU Indicator, SDU Size, ATM Switching, or Convergence Sublayer Specification TLVs.

4.3.11 Type 15: Dynamic Service Change-ReSPonse (DSC-RSP)

No TLVs besides Error Encodings and HMAC Tuples shall be reported back in DSC-RSP.

4.3.12 Type 26/27: SS Basic Capability-REQuest/ReSPonse (SBC-REQ/RSP)

The following Physical Parameter encodings shall be available for use with SBC-REQ and SBC-RSP. The Physical Parameters listed in IEEE P802.16-2001 [1] shall not be used.

4.3.12.1 OFDM demodulator

This field indicates the different demodulator options supported by a SS for DL reception. A bit value of 0 indicates 'not supported' while 1 indicates 'supported.'

Type	Length	Value	Scope
5.12.28	1	bit#0 64-QAM bit#1 Reserved. Set to 0 bit#2 CTC bit#3 STC bit#4 AAS bit#5-7 Reserved. Set to 0	SBC-REQ SBC-RSP

4.3.12.2 OFDM modulator

This field indicates the different modulator options supported by a SS for UL transmission. A bit value of 0 indicates 'not supported' while 1 indicates 'supported.'

Type	Length	Value	Scope
5.12.29	1	bit#0 64-QAM bit#1 Reserved. Set to 0 bit#2 CTC bit#3 Sub-channelization bit#4 Focused contention BW request bit#5-7 Reserved. Set to 0	SBC-REQ SBC-RSP

4.3.12.3 Subscriber transition gaps

This field indicates the transition speed SSTTG and SSRTG for TDD and H-FDD SSs.

Type	Length	Value	Scope
5.12.30	2	Bit #0-7: SSTTG (μs) Bit #8-15: SSRTG (μs) Allowed values: TDD: 0…50 μs; H-FDD: 0…100 μs	SBC-REQ SBC-RSP

4.3.12.4 Bandwidth allocation support

This field indicates the different BW allocation options supported by a SS. A bit value of 0 indicates 'not supported' while 1 indicates 'supported.'

Type	Length	Value	Scope
5.15	1	bit #0: Reserved. Set to 0 bit #1 = 0: Half-Duplex bit #1 = 1: Full-Duplex bit #2-7: *reserve*d; shall be set to zero	SBC-REQ SBC-RSP

4.3.13 Type 33: ARQ Feedback message

A system supporting ARQ shall be able to receive and process the ARQ Feedback message.

The ARQ Feedback message, as shown in table 30, can be used to signal any combination of different ARQ ACKs (cumulative, selective, selective with cumulative). The message shall be sent on the appropriate basic management connection.

Table 30: ARQ Feedback message format

Syntax	Size	Notes
ARQ_Feedback_Message_Format() {		
Management Message Type = 33	8 bits	
ARQ_Feedback_Payload	variable	See table 60.
}		

ARQ Feedback information shall be either sent using this ARQ Feedback message or by packing the ARQ_Feedback_Payload as described in clause 5.1.2.

4.3.14 Type 34: ARQ_Discard message

This message is applicable to ARQ-enabled connections only.

The transmitter sends this message when it wants to skip a certain number of ARQ blocks. The ARQ Discard message shown in table 31 shall be sent as a MAC management message on the basic management connection of the appropriate direction.

Table 31: ARQ Discard message format

Syntax	Size	Notes
ARQ_Discard_Message_Format() {		
Management Message Type = 34	8 bits	
Connection ID	16 bits	Applicable CID.
Reserved	5 bits	
Block Sequence Number	11 bits	Sequence number of the last block in the transmission window to be discarded.
}		

4.3.15 Type 35: ARQ_Reset message

This message is applicable to ARQ-enabled connections only.

The transmitter or the receiver may send this message. The message is used in a three-part dialog to reset the parent connection's ARQ transmitter and receiver state machines. The ARQ Reset message, as shown in table 32, shall be sent as a MAC management message on the basic management connection of the appropriate direction.

Table 32: ARQ_Reset message format

Syntax	Size	Notes
ARQ_Reset_Message_Format() {		
Management Message Type = 36	8 bits	
Connection ID	16 bits	Applicable CID
Type	2 bits	00 = Original Message from Initiator 01 = Acknowledgement from Responder 10 = Confirmation from Initiator 11 = Reserved
Reserved	6 bits	
}		

4.3.16 Type 36/37: Report-Request (REP-REQ/RSP) message

The Report Request message, shown in table 33, shall be used by the BS to request RSSI and CINR channel measurement reports.

Table 33: REP-REQ message format

Syntax	Size	Notes
Report_Request_Message_Format() {		
Management Message Type = 36	8 bits	
Report Request TLV	variable	
}		

The Report Request TLV shall have the format shown in table 34.

Table 34: Report Request TLV

Name	Type	Length	Value
Report Request	1	Variable	

The Report Request shall consist of the parameters in table 35.

Table 35: Report Request parameters

Name	Type	Length	Value
Report Type	1.1	1	Bit #0 Reserved, shall be set to 0 bit #1 1 = Include CINR report bit #2 1 = Include RSSI report bit #3-6 α_{avg} in multiples of 1/32 (range [1/32, 16/32]) See TS 102 177 [3], clause 10.2 bit #7 1 = Report background noise

When bit#7 is set, bit#1 shall be 0 and bit#2 shall be 1. The response shall contain the RSSI as measured during the period indicated by the last DL-MAP Report IE.

The Report Response message, shown in table 36 shall be used by the SS to respond with the channel measurements requested in the last received Report Request.

Table 36: REP-RSP message format

Syntax	Size	Notes
Report_Response_Message_Format() {		
Management Message Type = 37	8 bits	
Current Tx Power	8 bits	Current transmit power (peak) in 0,5 dB increments
Report Response TLV	variable	Compound TLV that shall contain the measurement Report in accordance with the Report Request
}		

The Report Response TLV shall have the format shown in table 37.

Table 37: Report Response TLV

Name	Type	Length	Value
Report Response	1	Variable	

The Report Response shall consist of the parameters in table 38.

Table 38: Report Response parameters

Name	Type	Length	Value
CINR Report	1.3	2	Insert if REP-REQ bit#1 = 1. 1 byte CINR mean 1 byte CINR standard deviation
RSSI Report	1.4	2	Insert if REP-REQ bit#2 = 1. 1 byte RSSI mean 1 byte RSSI standard deviation

4.3.17 Type 38: Fast Power Control (FPC) message

Power control shall be provisioned by the use of periodic ranging. In addition, the BS may adjust the power levels of multiple subscribers simultaneously with the Fast Power Control (FPC) message. SSs shall apply the indicated change within the "SS DL management message processing time". PFC shall be sent on the broadcast CID.

Table 39: Fast Power Control message format

Syntax	Size	Notes
Fast_Power_Control message format () {		
Management message type = 38	8 bits	
Number of stations	8 bits	
for (i = 0;i<Number of stations;i++) {		
Basic CID	16 bits	
Power Adjust	8 bits	
}		
}		

Number of stations

Number of CID and Power Adjust tuples contained in this message.

Basic CID

Basic connection identifier associated with the SS.

Power Adjust

Signed integer, which expresses the change in power level (in multiples of 0,25 dB) that the SS shall apply to its current transmission power.

4.3.18 Type 39: MeSH Network ConFiGuration (MSH-NCFG) message

MeSH Network ConFiGuration (MSH-NCFG) messages provide a basic level of communication between nodes in different nearby networks whether from the same or different equipment vendors or wireless operators. All the nodes (BS and SS) in the mesh network shall transmit MSH-NCFGs as described in clause 6.5.2.

The MSH-NCFG packets shall be used to convey information about network status and configuration such as:

Synchronization across multiple mesh networks;
Communication of channels in use across multiple networks; and
Support of network entry for new or mobile nodes.

All the nodes shall generate MSH-NCFGs in the format shown in table 40.

Table 40: MSH-NCFG message format

Syntax	Size	Notes
Report_Response_Message_Format() {		
Management Message Type = 39	8 bits	
NumNbrEntries	5 bits	
NumBSEntries	2 bits	Number of mesh BS neighbours to be reported on
Embedded_Packet_Flag	1 bit	1 = present, 0 = not present
Xmt Power	4 bits	In 2 dBm steps, starting from 0x0 = 8 dBm
Xmt Antenna	3 bits	Antenna used for transmission of this message
NetEntry_MAC_Address_Flag	1 bit	1 = present, 0 = not present
Network Base Channel Logical Number	4 bits	
Reserved	4 bits	
NetConfig Counter	4 bits	Incremented by 1 for every transmitted MSH-NCFG
TimeStamp Frame_Number Network Ctrl Slot Number in frame Number of hops to master sync. node	 12 bits 4 bits 8 bits	
NetConfig Schedule Info Next Xmt Mx Xmt Holdoff Exponent	 3 bits 5 bits	
If (NetEntry_MAC_Address_Flag) NetEntry MAC Address	 48 bits	
for (i = 0; i<NumBSEntries;++i) {		
BS Node ID	16 bits	Node ID of the mesh BS reported on
Number of hops to BS	3 bits	Number of hops to this mesh BS
Xmt energy/bit to BS	5 bits	
}		
for (i = 0; i<NumNbrEntries;++i) {		
Nbr Node ID	16 bits	Node ID of the neighbour node reported on
MSH-NCFG_Nbr_Physical_IE()	16 bits	See table 41
if (Logical_Link_Info_Present) MSH-NCFG_Nbr_Logical_IE()	 16 bits	Indicated in preceding MSH-Nbr_Physical_IE() See table 42
}		
If (Embedded_Packet_Flag) MSH-NCFG_embedded_data()	variable	
}		

NumNbrEntries

Number of neighbours reported on in the message. The number of neighbours reported on may be a fraction of the whole set of neighbours known to this node. A node can report on subsequent subsets of neighbours in its subsequent MSH-NCFG transmissions.

The following procedure is used to select the list neighbours of which only the Physical IE is reported:

i) All neighbour entries with the 'Reported Flag' set to TRUE are excluded as defined below

ii) The remaining neighbour entries are ordered by the Next Xmt Time and those with the Next Xmt Time the furthest in the future are reported in this MSH-NCFG packet. (In general, learning of nodes with Next Xmt Times furthest into the future is more valuable than learning of nodes with Next Xmt Times approaching soon, since the neighbours will have more time to use this ineligibility information before it is stale.)

The 'Reported Flag' for all neighbours in either of the above neighbour lists is set to TRUE upon transmission of this MSH-NCFG packet. It is set to FALSE as described in clause 6.5.1.

Network Base Channel Logical Number

The logical number of the base channel being used in this node's network, which is the logical number of the physical channel which shall be used to broadcast schedule control information. The possible physical channel numbers is mapped to logical channels in the Network Descriptor (see clause 4.3.18.3.1).

Netconfig counter

Counter of MSH-NCFG packets transmitted by this node. Used by neighbours to detect missed transmissions. Incremented by 1 for every MSH-NCFG transmission by this node.

Frame number

A modulo 2^{12} number, which shall be increased by one for every frame.

Network Control Slot Number in frame

See TS 102 177 [3] for details.

Number of hops to master sync. node

This counter is used to determine superiority between nodes when synchronizing the network. Nodes can be assigned as master time keepers, which are synchronized externally (for example using GPS). Nodes shall synchronize to the node with the lowest number of hops to master sync. node, or if counts are the same, to the node with the lower Node ID.

Netconfig Schedule Info

Xmt Holdoff Exponent

The Xmt Holdoff Time is the number of MSH-NCFG transmit opportunities after Next Xmt Time (there are *MSH-CTRL-LEN -1* opportunities per network control subframe, that this node is not eligible not transmit MSH-NCFG packets.

$$\text{Xmt Holdoff Time} = 2^{(\text{Xmt Holdoff Exponent}+4)} \quad (1)$$

Next Xmt Mx

Next Xmt Time is the next MSH-NCFG eligibility interval for this neighbour and computed as the range:

$$2^{\text{Xmt Holdoff Exponent}} \times \text{Next Xmt Mx} < \text{Next Xmt Time} \leq 2^{\text{Xmt Holdoff Exponent}} \times (\text{Next Xmt Mx} + 1). \quad (2)$$

For example, if Next Xmt Mx = 3 and Xmt Holdoff Exponent = 4, then the node shall be considered eligible for its next MSH-NCFG transmission between 49 and 64 (due to the granularity) transmission opportunities away and ineligible before that time.

If the Next Xmt Mx field is set to 0x1F (all ones), then the neighbour should be considered to be eligible to transmit from the time indicated by this value and every MSH-NCFG opportunity thereafter (i.e. treat Xmt Holdoff Time = 0).

NetEntry MAC Address

Indicates presence or sponsorship of new node. See MSH-NENT message in clause 4.3.19 and network entry in clause 6.6.

Xmt energy/bit factor

Indication of energy/bit needed to reach mesh BS through this node. Xmt energy/bit is computed as:

$$E_i = \min_{j \in N_i} \left\lfloor P_{Tx} / R_{i \to j} + E_j \right\rfloor \text{ mW}\mu\text{s} \quad (3)$$

where: N is the set of neighbours reporting this mesh BS:

P_{Tx} is the transmission power in mW from node i to node j

$R_{i \to j}$ is the datarate in Mbps from node i to node j.

E_j is the Xmt energy/bit reported by neighbour j.

The reported Xmt energy/bit factor is computed as:

$$\text{Xmt energy/bit factor} = \text{Xmt energy/bit} \Big/ 2^{(\text{XmtEnergyUnitExponent-4})} \quad (4)$$

where XmtEnergyUnitExponent is a 4-bit field reported in the most recent Network Descriptor.

4.3.18.1 Nbr Physical Information Element

Table 41: MSH-NCFG_Nbr_Physical_Information_Element

Syntax	Size	Notes
MSH-NCFG_Nbr_Physical_IE() {		
Logical Link Info Present	1 bit	Indicates whether MSH-NCFG_Nbr_Logical_IE follows
Logical Link requested	1 bit	1 = Yes, 0 = No
Logical Link Accepted	1 bit	1 = Yes, 0 = No
Hops to Nbr	1 bit	0 = 1 hop (direct neighbour), 1 = 2 hops
Propagation delay	4 bits	Estimated propagation delay in μs
Nbr NetConfig Schedule Info Nbr Next Xmt Mx Nbr Xmt Holdoff Exponent	 5 bits 3 bits	
}		

4.3.18.2 Nbr Logical Information Element

Table 42: MSH-NCFG_Nbr_Logical_Information_Element

Syntax	Size	Notes
MSH-NCFG_Nbr_Logical_IE() {		
Rcv Link Quality	3 bits	
Nbr Burst Profile	4 bits	
Excess Traffic Demand	1 bit	1 = Yes, 0 = No
Nbr Xmt Power	4 bits	(see table 40)
Nbr Xmt Antenna	3 bits	(see table 40)
Short Preamble Flag	1 bit	0 = don't use, 1 = use requested/confirmed
}		

Rcv Link Quality

Measure of the receive link reliability, indicating the reliability of MSH-NCFG size packets using the indicated burst profile. The estimated reliability is indicated as:

$$\text{reliability} = 100 \times \left(1 - 10^{-(\text{Rcv Link Quality}+1)/4}\right)\% \qquad (5)$$

Nbr burst profile

Indicated the burst profile the indicated node should use when sending data bursts to the reporting node.

Excess traffic demand

May be used to indicate to the neighbour that the current schedule is insufficient to transfer pending traffic.

Short Preamble flag

A node may optionally set this bit to notify the neighbour to use the short preamble for transmissions in the data portion of the frame. Capability to transmit the short preamble is mandatory. Capability to receive it is optional.

4.3.18.3 Embedded data

The Embedded_Data shall consist of the form shown in table 43.

Table 43: MSH-NCFG_Embedded_Data

Syntax	Size	Notes
MSH-NCFG_Embedded_Data() {		
Extended embedded_data	1 bit	Indicates whether this embedded IE is followed by another one. 0 = No, 1 = Yes
Reserved	3 bits	
Embedded_Data_IE_Type	4 bits	0x0 = Reserved 0x1 = Network Descriptor 0x2 = Network Entry Open 0x3 = Network Entry Reject 0x4 = Network Entry Ack (Length shall be set to 0) 0x5 = Neighbour Link Establishment Protocol
Length	8 bits	Length of the MSH-NCFG_Embedded_Data_IE in bytes, exclusive this header
MSH-NCFG_Embedded_data_IE()	variable	Embedded_Data_IE_Type dependent
}		

4.3.18.3.1 Network Descriptor Embedded Data Information Element

The Network Descriptor Embedded_data_IE shall contain the shown in table 44.

Table 44: Network Descriptor Information Element

Syntax	Size	Notes
MSH-NCFG_Embedded_Data_IE() {		
Frame Length Code	4 bits	4 lsb of Frame Duration Code. See TS 102 177 [3]
MSH-CTRL-LEN	4 bits	Control subframe length
MSH-DSCH-NUM	4 bits	Number of DSCH opportunities in schedule control subframe
MSH-CSCH-DATA-FRACTION	4 bits	
Scheduling Frames	4 bits	Defines how many frames have a schedule control subframe between two frames with network control subframes in multiples of 4 frames 0 = 0 frames; 1 = 4 frames etc.
Num_Burst_Profiles	4 bits	
Operator ID	16 bits	
XmtEnergyUnitsExponent	4 bits	
Num_Channels	4 bits	Number of logical channels
MinCSForwardingDelay	7 bits	Number of OFDM symbols delay inserted between receiving and forwarding control packets
ExtendedNeighborhoodType	1 bit	0 = 2-hop neighbourhood 1 = 3-hop neighbourhood
If (Num_Channels) MSH-NCFG_NetDesc_Channel_IE()	variable	
for (i = 0;i < BurstProfileCount;i++) {		
FEC Code Type	8 bits	See table 8
Mandatory Exit Threshold	8 bits	
Mandatory Entry Threshold	8 bits	
}		
}		

MSH-CSCH-DATA-FRACTION

Maximum percentage (value × 6.67) of minislots in the data-subframe allocated to centralized scheduling. The number of minislots is rounded to the nearest whole number of minislots and allocated starting from the beginning of the data subframe. The remainder of the data subframe, as well as any minislots not occupied by the current centralized schedule, may be used for distributed scheduling.

ExtendedNeighborhoodType

If value 0, then only nodes with Hops to Neighbour = 0 are reported, if value 1, then also nodes with Hops to Neighbour = 1 are reported.

MinCSForwardingDelay

The minimum delay in OFDM symbols that shall be inserted between the end of reception and the start of transmission of a Centralized Scheduling message (i.e. MSH-CSCH and MSH-CSCF) by any node.

Table 45: MSH-NCFG_NetDesc_Channel Information Element

Syntax	Size	Notes
MSH-NCFG_NetDesc_Channel_IE() {		
for (i = 0;i< Channels; ++i) {		PHY dependent. Index 'i' corresponds to logical channel
Physical channel centre frequency	24 bits	Positive integer in kHz
Physical channel width	8 bits	Positive integer in 100 kHz
}		
Channel Re-use	3 bits	Minimum number of hops of separation between links, before a channel can be re-used by the centralized scheduling algorithm. Range is 1 hop to 7 hops, 0 for no re-use
Reserved	5 bits	
}		

4.3.18.3.2 Network Entry Open Embedded Data Information Element

The Network Entry Open, which is used to respond to MSH-NENT request messages, shall contain the form as shown in table 46.

Table 46: Network Entry Open Information Element

Syntax	Size	Notes
MSH-NCFG_Embedded_Data_IE() {		
Minislot Start	8 bits	Schedule start for upper layer network entry
Minislot Range	8 bits	Schedule range for upper layer network entry
Frame number	12 bits	Frame number this schedule becomes valid
Channel	4 bits	Logical channel for new node to Xmt in above Minislot Range
Schedule validity	12 bits	Validity of Schedule in frames
Channel	4 bits	Logical Rcv channel for new node
Estimated Propagation Delay	4 bits	In µs
Reserved	4 bits	
}		

4.3.18.3.3 Network Entry Reject Embedded Data Information Element

The Network Entry Reject, which is used to reject MSH-NENT request messages, shall contain the form as shown in table 47.

Table 47: Network Entry Reject Information Element

Syntax	Size	Notes
MSH-NCFG_Embedded_Data_IE() {		
Rejection Code	8 bits	0x0: Operator Authentication Value Invalid 0x1: Excess Propagation delay 0x2: Select new sponsor
Rejection Reason	160 bits	ASCII string
}		

4.3.18.3.4 Neighbour Link Establishment Embedded Data Information Element

The Neighbour Link Establishment, which is used to establish links between nodes as described in clause 6.2, shall contain the form as shown in table 48.

Table 48: Link Establishment Information Element

Syntax	Size	Notes
MSH-NCFG_Embedded_Data_IE() {		
Action Code	2 bits	0x0 = Challenge 0x1 = Challenge Response 0x2 = Accept 0x3 = Reject
Reserved	6 bits	
if (Action Code == 0x0 or 0x1) Nbr Authentication Value	 32 bits	
if (Action Code == 0x1 or 0x2) Link ID	 8 bits	 Transmitting node's Link ID for this link
}		

Nbr Authentication Value

$$\text{Nbr Authentication Value} = \text{HMAC}\{\text{Authorization Key} \mid \text{Frame Number} \mid \text{Node ID self} \mid \text{Node ID other}\} \quad (6)$$

where the Authorization Key is a secret key (obtained from Operator)

4.3.19 Type 40: MeSH-Network ENTry (MSH-NENT) message

MeSH Network ENTry (MSH-NENT) messages provide the means for a new node to gain synchronization and initial network entry into a mesh network. When a MSH-NENT message, shown in table 49, is sent, the mesh Subheader is set to 0x0000 until the node has been assigned a node ID. In the Mesh CID, The Network ID is set the sponsor's network code or to 0x0000 if not known and the Link ID is set to 0xFF (Broadcast).

Table 49: MSH-NENT message format

Syntax	Size	Notes
MSH-NENT_Message_Format() {		
MAC Management Message Type = 40	8 bits	
MSH-NENT_Type	3 bits	0x0 = Reserved 0x1 = NetEntryAck 0x2 = NetEntryRequest 0x3 = NetEntryClose

if (MSH-NENT_Type == 0x1)
MSH-NENT_Type being Ack-ed
else
Xmt counter for this MSH-NENT_Type
	
	3 bits
	
	3 bits	

Reserved	2 bits	
Sponsor Node ID	16 bits	ID of the node sought to assist the requesting node in entering the network
Xmt Power	4 bits	See table 40
Xmt Antenna	3 bits	See table 40
Reserved	1 bit	
if (MSH-NENT_Type == 0x2)		
MAC Address	48 bits	MAC Address of the new node sending the request.
OpConfInfo	64 bits	Operator Configuration Information (obtained from Operator)
Operator Authentication Value	32 bits	
Node Serial Number	32 bits	
}		
}		

Operator Authentication Value

$$\text{Operator Authentication Value} = \text{HMAC}\{\text{MAC Address} \mid \text{Node Serial Number} \mid \text{Authorization Key}\} \quad (7)$$

where the Authorization Key is a secret key (obtained from Operator)

4.3.20 Type 41: MeSH-Distributed SCHeduling (MSH-DSCH) message

MeSH Distributed SCHeduling (MSH-DSCH) messages shall be transmitted in mesh mode when using distributed scheduling. In coordinated distributed scheduling, all the nodes shall transmit a MSH-DSCH, shown in table 50 at a regular interval to inform all the neighbours of the schedule of the transmitting station. This transmission time is determined by the same algorithm used for MSH-NCFG messages. In both coordinated and uncoordinated scheduling, MSH-DSCH messages shall be used to convey resource requests and grants to the neighbours. Further the MSH-DSCH messages shall be used to convey information about free resources that the neighbours can issue grants in. This message shall not be fragmented.

Table 50: MSH-DSCH message format

Syntax	Size	Notes
MSH-DSCH_Message_Format() {		
MAC Management Message Type = 41	8 bits	
Coordination Flag	1 bit	0 = Coordinated 1 = Uncoordinated
Grant/Request Flag	1 bit	0 = Request message 1 = Grant message (also used as Grant confirmation)
MSH-DSCH Sequence Counter	6 bits	
Num_Requests	4 bits	Number of Request IEs in the message
Num_Availabilities	4 bits	Number of Availability IEs in the message. The Availability IEs are used to indicate free minislot ranges that neighbours could issue Grants in
Num_Grants	6 bits	Number of Grant IEs in this message
Reserved	2 bits	
if (Coordination Flag == 0x0) MSH-DSCH_Scheduling_IE()	variable	
for (i = 0;i< Num_Requests; ++i) MSH-DSCH_Request_IE()	16 bits	
for (i = 0;i< Num_Availabilities; ++i) MSH-DSCH_Availability_IE()	32 bits	
for (i = 0;i< Num_Grants; ++i) MSH-DSCH_Grant_IE()	40 bits	
}		

Co-ordination Flag

Coordinated MSH-DSCH transmissions take place in the control subframe. Uncoordinated MSH-DSCH transmissions take place in the data subframe. Both the cases require a threeway handshake (Request, Grant and Grant confirmation) to establish a valid schedule. Uncoordinated scheduling may only take place in minislots which cause no interference with the coordinated schedule.

Grant/Request Flag

The Request Type indicates that a new Request is made of one or more other nodes. The No. Requests shall be non-zero in this case. The message may also contain Availabilities and Grants.
The Grant Type indicates that one or more Grants are given or confirmed. The Num_Grants shall be non-zero in this case. The message may also contain Availabilities and Requests. Requests in this type of message indicate pending demand to the indicated node(s), but do not solicit a Grant from this node.
This flag is always set to 0 for coordinated distributed scheduling

MSH-DSCH Sequence Counter

Sequentially increased counter for solicit messages in uncoordinated scheduling (used as multiple solicits might be outstanding). In coordinated scheduling, it allows nodes to detect missed scheduling messages. Independent counters are used for the coordinated and uncoordinated messages.

4.3.20.1 MSH-DSCH Scheduling Information Element

The Coordinated distributed scheduling information carried in the MSH-DSCH message, shown in table 51, shall be used to distribute information needed to determine transmission timing of the MSH-DSCH messages with coordinated distributed scheduling. Each node shall report the two related parameters both of its own and all its neighbours.

Table 51: MSH-DSCH Scheduling Information Element

Syntax	Size	Notes
MSH-DSCH_Scheduling_IE() {		
DSCH Schedule Info Next Xmt Mx Xmt Holdoff Exponent	 3 bits 5 bits	
Num_SchedEntries	8 bits	Number of Neighbour MSH-DSCH Scheduling Entries in the message.
for (i = 0; i< Num_SchedEntries; ++i) {		
Nbr Node ID	16 bits	The Node ID of the neighbour being reported on.
Nbr DSCH Schedule Info Nbr Next Xmt Mx Nbr Xmt Holdoff Exponent	 3 bits 5 bits	Advertise as reported by neighbour.
}		

DSCH Schedule Info

Xmt Holdoff Exponent

The Xmt Holdoff Time is the number of MSH-DSCH transmit opportunities after Next Xmt Time (there are *MSH-CTRL-LEN -1* opportunities per network control subframe, that this node is not eligible not transmit MSH-DSCH packets.

$$\text{Xmt Holdoff Time} = 2^{(\text{Xmt Holdoff Exponent}+4)} \quad (8)$$

Next Xmt Mx

Next Xmt Time is the next MSH-DSCH eligibility interval for this neighbour and computed as the range

$$2^{\text{Xmt Holdoff Exponent}} \times \text{Next Xmt Mx} < \text{Next Xmt Time} \le 2^{\text{Xmt Holdoff Exponent}} \times (\text{Next Xmt Mx} + 1) \quad (9)$$

EXAMPLE: If Next Xmt Mx = 3 and Xmt Holdoff Exponent = 4, then the node shall be considered eligible for its next MSH-DSCH transmission between 49 and 64 (due to the granularity) transmission opportunities away and ineligible before that time.

If the Next Xmt Mx field is set to 0x1F (all ones), then the neighbour should be considered to be eligible to transmit from the time indicated by this value and every MSH-DSCH opportunity thereafter (i.e. treat Xmt Holdoff Time = 0).

4.3.20.2 MSH-DSCH Scheduling Information Element

The Requests carried in the MSH-DSCH message shall convey resource requests on per link basis, as shown in table 52.

Table 52: MSH-DSCH Request Information Element

Syntax	Size	Notes
MSH-DSCH_Request_IE() {		
Link ID	8 bits	The ID assigned by the transmitting node to the link to this neighbour that this request involves.
Demand Level	8 bits	Demand in minislots (assuming the current burst profile).
Persistence	3 bits	Persistency field for demands. Number of frames over which the demand exists. 0 = cancel reservation, 1 = single frame, 2 = 2 frames, 3 = 4 frames, 4 = 8 frames , 5 = 32 frames, 6 = 128 frames, 7 = Good until cancelled or reduced.
Reserved	1 bits	
}		

4.3.20.3 MSH-DSCH Availability Information Element

The Availabilities carried in the MSH-DSCH message shall be used to indicate free minislot ranges that neighbours could issue Grants in. Each Availability shall be indicated using the IE shown in table 53.

Table 53: MSH-DSCH Availability Information Element

Syntax	Size	Notes
MSH-DSCH_Availability_IE() {		
Start Frame Number	8 bits	Indicates lowest 8 bits of frame number in which the availability starts.
Minislot start	8 bits	The start position of the availability within the frame.
Minislot Range	7 bits	The number of consecutive available minislots.
Direction	2 bits	0 = Minislot range is unavailable. 1 = Available for transmission in this minislot range. 2 = Available for reception in this minislot range. 3 = Available for either transmission or reception.
Persistence	3 bits	Persistency field for Availabilities. Number of frames over which the Availability is valid. 0 = cancel availability, 1 = single frame, 2 = 2 frames , 3 = 4 frames, 4 = 8 frames, 5 = 32 frames 6 = 128 frames, 7 = Good until cancelled or reduced.
Channel	4 bits	Logical channel number on which the availability exists.
}		

4.3.20.4 MSH-DSCH Grant Information Element

The Grants carried in the MSH-DSCH message shall convey information, as shown in table 54, about a granted minislot range selected from the range reported as available. Grants shall be used both to grant and confirm a grant.

Table 54: MSH-DSCH Grant Information Element

Syntax	Size	Notes
MSH-DSCH_Grant_IE() {		
Link ID		The ID assigned by the transmitting node to the neighbour that this Grant involves.
Start Frame Number	8 bits	Indicates lowest 8 bits of frame number in which the Grant starts.
Minislot start	8 bits	The start position of the Grant within the frame.
Minislot Range	7 bits	The number of consecutive minislots granted.
Direction	2 bits	0 = From requester to granter. 1 = To requester from granter.
Persistence	3 bits	Persistency field for Grants. Number of frames over which the Availability is valid. 0 = cancel reservation, 1 = single frame, 2 = 2 frames , 3 = 4 frames, 4 = 8 frames, 5 = 32 frames, 6 = 128 frames, 7 = Good until cancelled or reduced.
Channel	4 bits	Logical channel number on which the availability exists.
}		

4.3.21 Type 42: MeSH-Centralized SCHeduling (MSH-CSCH) message

A MeSH Centralized SCHeduling (MSH-CSCH) message shall be created by a mesh BS when using centralized scheduling. The BS shall broadcast the MSH-CSCH message, as shown in table 55, to all its neighbours, and all the nodes with hop count lower than HOPRANGE_THRESHOLD shall forward the MSH-CSCH message to their neighbours that have a higher hop count. In all these cases, the Grant/Request Flag = 0. HOPRANGE_THRESHOLD is a configuration value that need only be known to the mesh BS, as it can be derived by the other nodes from the MSH-CSCF message.

Nodes can use MSH-CSCH messages to request bandwidth from the mesh BS setting the Grant/Request Flag = 1. Each node reports the individual traffic demand requests of each 'child' node in its subtree from the BS. The nodes in the subtree are those in the current scheduling tree to and from them mesh BS, known to all nodes in the network, and ordered by node ID.

Table 55: MSH-CSCH message format

Syntax	Size	Notes
MSH-CSCH_Message_Format() {		
MAC Management Message Type = 42	8 bits	
MSH-CSCF Sequence Number	3 bits	Indicates the configuration, which shall be used to interpret this packet.
Grant/Request Flag	1 bit	0 = Grant message (transmitted up the tree). 1 = Request message (transmitted down the tree).
Frame Schedule Flag	1 bit	If this flag is set, the allocation of flows shall occur over two frames, rather than one.
Configuration Flag	1 bit	
Reserved	2 bits	
Num_FlowEntries	8 bits	
for (i = 0;i< Num_FlowEntries; ++i) {		
UL_Flow	4 bits	
If (Grant/Request Flag == 0)		
DL_Flow	4 bits	
}		
FlowScale Exponent	4 bits	
Padding Nibble	4 bits	Pad till byte boundary.
If (Grant/Request Flag == 1) {		
Num_LinkUpdates	4 bits	
for (i = 0;i< Num_LinkUpdates; ++i) {		
Node Index self	8 bits	Index self in MSH-CSCF list.
Node Index parent	8 bits	Index parent in MSH-CSCF list.
UL Burst Profile	4 bits	Burst Profile for transmitting up the tree.
DL Burst Profile	4 bits	Burst Profile for transmitting down the tree.
}		
} else {		Sponsor Node Request.
Sponsor Node	8 bits	index in MSH-CSCF list.
DL Burst Profile	4 bits	
UL Burst Profile	4 bits	
}		
}		

Sponsor Node Request

Three parameters (Sponsor Node, and Burst Profiles) shall be set to 0, except by nodes which wish to reserve an allocation for the "upper MAC initialization" as specified in clause 6.6.4. A node may only set these values if all its children report these values as 0. The Mesh BS shall in response provide a grant to Node Index 0x00, which shall be reserved for this purpose.

Configuration Flag

Indicates which centralized scheduling control message type (CSCH or CSCF) will be transmitted next by the Mesh BS. This bit may be set to aid the nodes in computing the validity of the schedule indicated in the current message (see clause 6.8.2).

FlowScale Exponent

Determines scale of the granted bandwidth. Its value typically depends on the number of nodes in the network, the achievable PHY bitrate, the traffic demand and the provided service.

For the DL, this gives the absolute values of flow granted, so the total minislot range allowed for centralized scheduling need not be used if not needed, with the remainder set aside for distributed scheduling.

For the UL, the lowest exponent possible is used at each hop, with quantization of forwarded requests rounded up (e.g. avoids reducing any requests to zero).

NumFlowEntries

Number of 8-bit assignment fields followed, ordered according to appearance in MSH-CSCF. This number shall match the number of entries in the most recent MSH-CSCF message.

UL_Flow
DL_Flow

Base of the granted/requested bandwidth as bits/s for DL respectively UL traffic of the node in the BS's scheduling tree. The flow only indicates traffic that initiates or terminates in the node itself (i.e. forwarded traffic is not included), except for traffic forwarded from/to nodes not part of the MSH-CSCF tree. The actual granted/requested bandwidth shall be calculated as:

$$BW_{\mathrm{UL}} = \mathrm{UL\_Flow} \times \left(2^{\mathrm{FlowScale\ Exponent} + 14}\right) \text{ bits/s}$$
$$BW_{\mathrm{DL}} = \mathrm{DL\_Flow} \times \left(2^{\mathrm{FlowScale\ Exponent} + 14}\right) \text{ bits/s} \quad (10)$$

The assignments in the list are ordered according to the order in the MSH-CSCF message.

Num_LinkUpdates

Link updates are inserted by the mesh BS if the number of link tree changes does not warrant a MSH-CSCF broadcast. The mesh BS shall repeat the link update in every MSH-CSCH either until the update becomes invalid, or until the change is reflected in a MSH-CSCF message.

4.3.22 Type 43: MeSH-Centralized Scheduling ConFiguration (MSH-CSCF) message

A MeSH Centralized Scheduling ConFiguration (MSH-CSCF) message shall be broadcast in mesh mode when using centralized scheduling. The mesh BS shall broadcast the MSH-CSCF message, as shown in table 56, to all its neighbours, and all nodes shall forward (rebroadcast) the message according to its index number specified in the message.

Table 56: MSH-CSCF message format

Syntax	Size	Notes
MSH-CSCF_Message_Format() {		
MAC Management Message Type = 43	8 bits	
MSH-CSCF Sequence Number	4 bits	The BS shall increment this number by one for every MSH-CSCF message it transmits.
Num_Channels	4 bits	Number of channels available for centralized scheduling.
for (i = 0;i< Num_Channels; ++i) { Logical Channel Number	4 bits	The logical index of the Physical channel, as reported in MSH-NCFG Network Descriptor.
Padding nibble	0/4 bits	Pad till byte boundary.
Num_Nodes	8 bits	
for (i = 0;i< Num_Nodes; ++i) {		
Node ID	16 bits	Unique node identifier assigned to node.
Num_Children	8 bits	
for (j = 0;j< Num_Children; ++j) {		
Child Index	8 bits	Index child in Node list.
UL Burst Profile	4 bits	Burst Profile for transmitting up the tree from this child.
DL Burst Profile	4 bits	Burst Profile for transmitting down the tree to this child.
}		
}		
}		

4.3.23 Type 44/45: AAS-FeedBaCK REQuest/ReSPonse (AAS-FBCK REQ/RSP) message

AAS Feedback messages as shown in table 57 and table 58 are used to obtain channel state information as described in clause 7.4.

Table 57: AAS-FeedBaCK REQuest (AAS-FBCK-REQ) message format

Syntax	Size	Notes
AAS_Feedback_Request_Message_Format() {		
Management Message Type = 44	8 bits	
Frame Number	24 bits	
Number of Frames	7 bits	
Measurement Data Type	1 bits	0 = measure on DL preamble only 1 = measure on DL data (for this SS) only
Feedback Request Counter	6 bits	
Frequency Measurement Subcarrier Resolution	2 bits	0b00 = 4 0b01 = 8 0b10 = 16 0b11 = 32
}		

Frame Number

The Frame Number in which the measurement shall be started.

Number of Frames

The number of frames over which the measurement shall be averaged.

Frequency Measurement Subcarrier Resolution

Indicates the frequency measurement points to report on. Measurement points shall be on the frequencies corresponding to the negative subcarrier offset indices $-N_{used}/2$ plus n times the indicated subcarrier resolution and corresponding to the positive subcarrier offset indices $N_{used}/2$ minus n times the indicated subcarrier resolution where n a positive integer. See TS 102 177 [3], clause 4.2.

Feedback Request Counter

Increased by one every time an AAS-FBCK-REQ is sent to the SS. Individual counters shall be maintained for each SS.

Table 58: AAS-FeedBaCK-ReSPonse (AAS-FBCK-RSP) message format

Syntax	Size	Notes
AAS_Feedback_Response_Message_Format() {		
Management Message Type = 45	8 bits	
Reserved	2 bits	Set to 0b00
Feedback Request Counter	6 bits	
for (i = 0; i<Number of Frequencies; i++) {		According to Frequency Measurement Subcarrier Resolution
Re(Frequency[i])	8 bits	
Im(Frequency[i])	8 bits	
}		
}		

Feedback Request Counter

Counter from the AAS-FBCK-REQ messages to which this is the response.

Frequency

The real (Re) and imaginary (Im) part of the measured amplitude on the frequency measurement point (low to high frequency) in signed integer fixed point format ([±][4 bits].[4 bits].

4.3.24 Type 46-255: DUMMY message

A SS shall be capable of decoding the DUMMY message shown in table 59. A BS shall not transmit this message unless in test mode. A SS shall not transmit this message.

Table 59: DUMMY message format

Syntax	Size	Notes
DUMMY_Message_Format() {		
Management Message Type = 46...255	8 bits	
Length	8 bits	
Unspecified data	Length×8 bits	
}		

Length

The Length in bytes of the following 'Unspecified data'.

5 Automatic Repeat reQuest (ARQ)

The ARQ mechanism is an optional part of the MAC layer and can be enabled on a per-connection basis. The per-connection ARQ and associated parameters shall be specified and negotiated during connection creation or change. A connection cannot have a mixture of ARQ and non-ARQ traffic. Similar to other properties of the MAC protocol the scope of a specific instance of ARQ is limited to one unidirectional connection.

Connections are set and defined dynamically through the DSA/DSC class of messages. CRC-32 shall be used for error detection of PDUs for all ARQ-enabled connections. All ARQ parameters (see clause 5.2) shall be set and all ARQ variables (see clause 5.3) shall be reset (set to 0) on connection setup.

ARQ feedback information can be sent as a standalone MAC management message (see table 30) on the appropriate basic management connection, or can be piggybacked on an existing connection using the ARQ Feedback Payload (see table 60). ARQ Feedback shall not be fragmented.

5.1 Packing for ARQ-enabled connections

The use of packing subheaders for ARQ-enabled connections is similar to that for non-ARQ connections, except that ARQ-enabled connections set bit#3 in the general MAC header's Type field (see table 1). MAC PDUs transmitted at ARQ-enabled connections must have either Fragmentation Subheader or Packing Subheaders to provide each payload with block sequence numbers information. If packing is turned on for a connection, the MAC may pack multiple MAC SDUs into a single MAC PDU. The transmitting side has full discretion whether or not to pack a group of MAC SDUs and/or fragments in a single MAC PDU. Depending on the ARQ policies, the transmitter may choose to pack multiple fragments of the same SDU into a single MAC PDU, even if there is sufficient bandwidth to send the whole MAC PDU un-fragmented.

The packing of variable-length MAC SDUs for the ARQ-enabled connections is similar to that of non-ARQ connections, when fragmentation is enabled. The BSN of the Packing Subheader shall be used by the ARQ protocol to identify and retransmit lost fragments. The primary difference between ARQ and non-ARQ packing is in the interaction with fragmentation.

5.1.1 Interaction of packing with fragmentation

For ARQ-enabled connections, when the general MAC header's Type (see table 1) indicates packing is used (i.e. when bit#5 is set) , fragmentation information for each individual MAC SDU or MAC SDU fragment is contained in the associated Packing Subheader.

When the Type field indicates that packing is not used, fragmentation information for the MAC PDU's single payload (MAC SDU or MAC SDU fragment) is contained in the Fragmentation Subheader. Each of the packed MAC SDU or MAC SDU fragments or ARQ feedback payload shall have its own packing subheader and some of them may be transmissions while others are re-transmissions.

5.1.2 Packing ARQ Feedback Information Elements

An ARQ Feedback Payload (see table 60) consists of one or more ARQ Feedback Information Elements (see table 61). The ARQ Feedback Payload may be sent on an ARQ or non-ARQ connection. However, policies based on implementation and/or QoS constraints may restrict the use of certain connections for transporting the ARQ Feedback Payload. The ARQ Feedback Payload is treated like any other payload (SDU or fragments) from the packing perspective, except that only one ARQ Feedback Payload shall be present within a single MAC PDU.

Table 60: ARQ Feedback Payload

Syntax	Size	Notes
ARQ Feedback Payload {		
do		
ARQ_Feedback_IE(last)	variable	Insert as many as desired, until last == TRUE
until (last)		
}		

The presence of an ACK Feedback Payload in a MAC PDU is indicated by the value of bit #4 of the Type field in the generic MAC header. When present, the first packed payload shall be the ARQ Feedback Payload. The Packing Subheader preceding the ARQ Feedback Payload indicates the total length of the payload including the Packing Subheader and all ARQ Feedback Information Elements within the payload. The FSN/BSN field of the Packing Subheader shall be ignored for the ARQ Feedback Payload and the FC bits shall be set to 0b00.

Table 61: ARQ Feedback Information Element

Syntax	Size	Notes
ARQ_feedback_IE (last) {	variable	
CID	16 bits	The ID of the connection being referenced.
Last	1 bit	0 = More ARQ feedback IE in the list. 1 = Last ARQ feedback IE in the list.
ACK Type	2 bit	0x0 = Selective ACK entry, 0x1 = Cumulative ACK entry, 0x2 = Cumulative with Selective ACK entry, 0x3 = Reserved.

BSN	11 bits	If (ACK Type == 0x0): BSN value corresponds to the most significant bit of the first 16-bit ARQ ACK map.
		If (ACK Type == 0x1): BSN value indicates that its corresponding block and all blocks with lesser values within the transmission window have been successfully received.
		If (ACK Type == 0x2): Combines the functionality of ACK Types 0x0 and 0x1.

Num_ACK_Maps	2 bits	If ACK Type == 01, the field is reserved and set to 00. Otherwise the field indicates the number of ACK maps: 0x0 = 1, 0x1 = 2, 0x2 = 3, 0x3 = 4.
if (ACK Type! = 01) {		
for (i = 0; i< NUM_ACK_Maps + 1; ++i)		
ACK Map	16 bits	Each bit set to one indicates the corresponding ARQ block has been received without errors. The bit corresponding to the BSN value in the IE, is the most significant bit of the first map entry. The bits for succeeding block numbers are assigned left-to-right (msb to lsb) within the map entry. If the ACK Type is 10, then the most significant bit of the first map entry shall be set to one and the IE shall be interpreted as a cumulative ACK for the BSN value in the IE. The rest of the bitmap shall be interpreted similar to ACK Type 00.
}		

5.2 ARQ parameters

ARQ_BLOCK_SIZE
: ARQ_BLOCK_SIZE is the basic retransmission unit and it should be negotiated during connection setup. The concept of blocks is described in clause 5.4.

ARQ_BSN_MODULUS
: ARQ_BSN_MODULUS is equal to the number of unique BSN values, i.e. 2 048.

ARQ_WINDOW_SIZE
: ARQ_WINDOW_SIZE is the maximum number of the unacknowledged ARQ blocks at any given time, which shall be less than or equal to half of ARQ_BSN_MODULUS. An ARQ block is unacknowledged if it has been transmitted but no acknowledgement has been received.

ARQ_BLOCK_LIFETIME
: ARQ_BLOCK_LIFETIME is the maximum time interval beyond which a transmitter shall discard unacknowledged ARQ blocks.

ARQ_RETRY_TIMEOUT
: ARQ_RETRY_TIMEOUT is the minimum time interval a transmitter shall wait before retransmitting an unacknowledged ARQ block.

ARQ_SYNC_LOSS_TIMEOUT
: ARQ_SYNC_LOSS_TIMEOUT is the length of a time interval from last transmitted/received SDU, in which at least one MAC PDU was transmitted/received with no change in the position of ARQ Tx/Rx window, after this time interval passed, ARQ synchronization shall be considered lost.

5.3 ARQ variables

ARQ_TX_WINDOW_START
: All BSN up to (ARQ_TX_WINDOW_START - 1) have been acknowledged.

ARQ_TX_NEXT_BSN
: BSN of the next block to send. This value shall be between ARQ_TX_WINDOW_START and (ARQ_TX_WINDOW_START + ARQ_WINDOW_SIZE).

ARQ_RX_WINDOW_START
: All BSN up to (ARQ_RX_WINDOW_START - 1) have been correctly received.

ARQ_RX_HIGHEST_BSN
: BSN of the highest block received, plus one. This value shall be between ARQ_RX_WINDOW_START and (ARQ_RX_WINDOW_START + ARQ_WINDOW_SIZE).

5.4 ARQ operation

5.4.1 ARQ block usage

The clause describes the use of blocks for ARQ. A MAC SDU is logically divided into blocks of given.

ARQ_BLOCK_SIZE. The last block of a MAC SDU may be smaller than ARQ_BLOCK_SIZE. Once defined, the block never changes.

This value of the ARQ_BLOCK_SIZE TLV specifies the ARQ block size. This parameter is negotiated upon connection setup. The DSA-REQ shall contain the suggested value of this parameter. The DSA-RSP message shall contain the confirmation value or an alternate value for this parameter.

A set of blocks selected for transmission or retransmission is encapsulated into a PDU. A PDU may contain blocks that are transmitted for the first time as well as retransmitted blocks. If fragmentation is enabled for this connection, the fragmentation shall occur only on ARQ block boundaries. If a PDU is not packed, all the blocks in that PDU must have contiguous block numbers. When a PDU is packed, any sequence of blocks between MAC subheaders and the sequence of blocks after the last packing subheader must have contiguous block numbers.

If ARQ is enabled at the connection, Fragmentation and Packing subheaders contain a BSN, which is the sequence number of the first ARQ block in the sequence of blocks following this subheader. It is a matter of transmitter's policy whether a set of blocks once transmitted as a single PDU should be retransmitted also as a single PDU or not. Figure NNN illustrates the use of blocks for ARQ transmissions and retransmissions; two options for retransmission presented: with and without rearrangements of blocks.

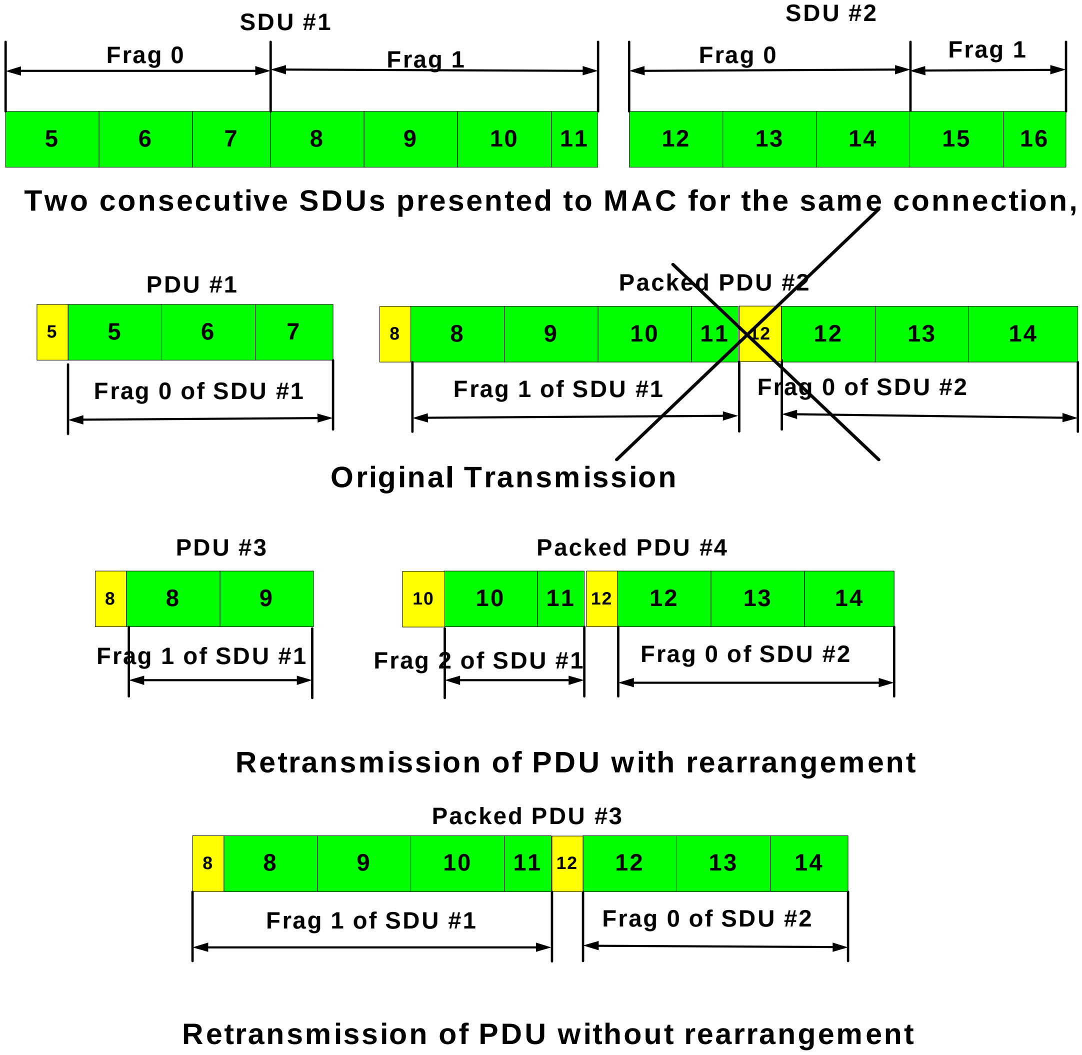


Figure 1: Block usage examples for ARQ transmissions and retransmissions

5.4.2 Comparison of BSNs

As numbers assigned to blocks occasionally wrap around zero, BSNs cannot be compared by directly comparing their values. Instead, both BSNs need to be normalized before a comparison can be made. Normalization of a BSN on the transmit side is accomplished using the expression:

$$\begin{cases} \text{Tx side:} \quad bsn_n = (bsn - ARQ\_TX\_WINDOW\_START)_{\text{mod ARQ\_BSN\_MODULUS}} \\ \text{Rx side:} \quad bsn_n = (bsn - ARQ\_RX\_WINDOW\_START)_{\text{mod ARQ\_BSN\_MODULUS}} \end{cases} \qquad (11)$$

5.4.3 Transmitter state machine

An ARQ block may be in one of the following four states: *Not-sent*, *Outstanding*, *Discarded*, *Waiting-for-retransmit* or *Done*. Any ARQ block begins as *Not-sent,* and transfers to other states as shown in figure 2.

For a given connection, the transmitter shall first handle (transmit or discard) blocks in *Waiting-for- retransmit* state and only then blocks in *Not-sent* state. Blocks in *Outstanding*, *Discarded,* or *Done* state shall not be transmitted. When blocks are retransmitted, the block with the lowest FSN shall be retransmitted first.

When a block in *not-sent* state is included in a MAC PDU, it is assigned the current value of ARQ_TX_NEXT_BSN, which is then incremented.

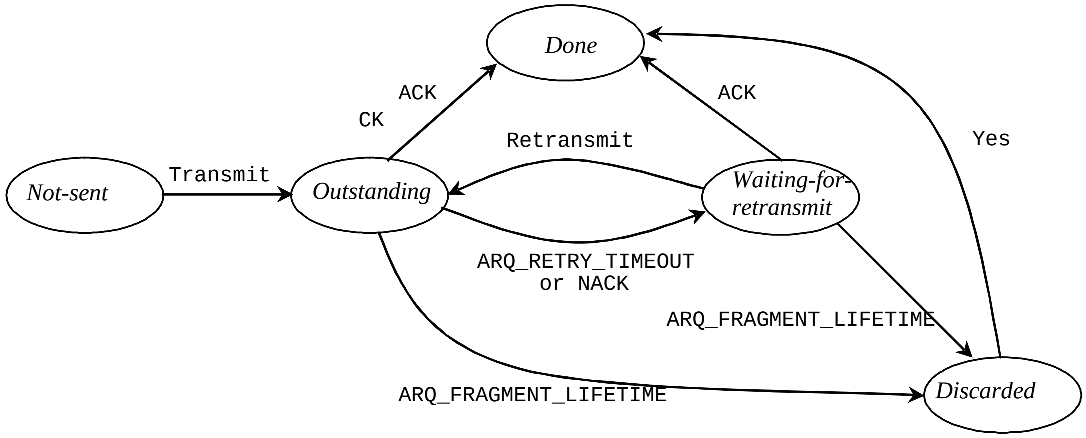


Figure 2: Transmitter ARQ state machine

When any acknowledgement is received, the transmitter shall check the validity of the BSN(s). A BSN is valid if:

0 ≤ BSN- ARQ_TX_WINDOW_START < ARQ_TX_NEXT_BSN-ARQ_TX_WINDOWN_START

If the BSN is invalid, the transmitter shall ignore the acknowledgement. All timers associated with acknowledged blocks shall be cancelled.

When a cumulative acknowledgement (ACK Type == 0x0)with a valid BSN is received, the transmitter shall consider all blocks in the interval ARQ_TX_WINDOW_START to BSN (inclusive) as ACK-ed and set ARQ_TX_WINDOW_START to BSN+1.

When a selective acknowledgement (ACK TYPE == 0x1) is received, the transmitter shall validate all BSNs indicated by the acknowledgement entries in the bitmap, and consider all such valid BSNs as ACK-ed. As the bitmap entries are processed in increasing BSN order, ARQ_TX_WINDOW_START shall be incremented each time the BSN of an acknowledged fragment equals ARQ_TX_WINDOW_START.

When ARQ_TX_WINDOW_START has been advanced by either of the above methods and acknowledgement of reception has already been received for the fragment with the BSN value now assigned to ARQ_TX_WINDOW_START, the value of ARQ_TX_WINDOW_START shall be incremented until a BSN value is reached for which no acknowledgement has been received.

A bitmap entry not indicating acknowledged that has a BSN lower than a bitmap entry which does indicate acknowledged shall be considered a NACK for the corresponding block. A not acknowledged bit map entry may also be considered a NACK if sufficient time elapsed before the feedback IE was transmitted to allow the receiver to receive and process the corresponding block.

When a cumulative with selective acknowledgement (ACK TYPE == 0x2) with a valid BSN is received, the transmitter performs the actions described above for cumulative acknowledgement, followed by those for a selective acknowledgement.

An ARQ Discard message shall be sent when a block reaches *Discard* state. The message may be sent immediately or may be delayed up to ARQ_RX_PURGE_TIMEOUT + ARQ_RETRY_TIMEOUT. Following the first transmission, subsequent discard orders shall be sent to the receiver at intervals of ARQ_RETRY_TIMEOUT until an acknowledgement to the discarded BSN has been received. Discard orders for adjacent BSN values may be accumulated in a single Discard message.

5.4.4 Receiver state machine

When a PDU is received, its integrity shall be determined based on the CRC-32 checksum. If a PDU passes the checksum, it is unpacked and de-fragmented, if necessary. The receiver maintains a sliding-window defined by ARQ_RX_WINDOW_START state variable and the ARQ_WINDOW_SIZE parameter. When an ARQ block with a number that falls in the range defined by the sliding window is received, the receiver shall accept it. ARQ block numbers outside the sliding window shall be rejected. The receiver should discard duplicate ARQ blocks (i.e. ARQ blocks that where already received correctly) within the window.

As each block is received, a timer is started for that block. When the value of the timer for a block exceeds ARQ_RX_PURGE_TIMEOUT, the timeout condition is marked. When this occurs, ARQ_RX_WINDOW_START is advanced to the BSN of the next block not yet received after the marked block. Timers for delivered blocks remain active and are monitored for timeout until the BSN values are outside the receive window.

When ARQ_RX_WINDOW_START is advanced, any BSN values corresponding to blocks that have not yet been received residing in the interval between the previous and current ARQ_RX_WINDOW_START value shall be marked as received and the receiver shall send an ARQ Feedback IE to the transmitter with the updated information. Any blocks belonging to complete SDUs shall be delivered. Blocks from partial SDUs shall be discarded.

When a discard message is received from the transmitter, the receiver shall discard the specified blocks, advance ARQ_RX_WINDOW_START to the BSN of the first block not yet received after the BSN provided in the Discard message, and mark all not received blocks in the interval from the previous to new ARQ_RX_WINDOW_START values as received for ARQ feedback IE reporting.

For each ARQ block received, an acknowledgment shall be sent to the transmitter. Acknowledgment for blocks outside the sliding window shall be cumulative. Acknowledgments for blocks within the sliding window may be either for specific ARQ blocks (i.e. contain information on the acknowledged ARQ block numbers), or cumulative (i.e. contain the highest ARQ block number below which all ARQ blocks have been received correctly) or a combination of both (i.e. cumulative with selective). Acknowledgments shall be sent in the order of the ARQ block numbers they acknowledge. The frequency of acknowledgement generation is not specified here and is implementation dependent.

A MAC SDU is ready to be handed to the upper layers when all of the ARQ blocks of the MAC SDU have been correctly received within the time-out values defined.

When ARQ_DELIVER_IN_ORDER is enabled, a MAC SDU is handed to the upper layers as soon as all the ARQ blocks of the MAC SDU have been correctly received within the defined time-out values and all blocks with sequence numbers smaller than those of the completed message have either been discarded due to time-out violation or delivered to the upper layers.

When ARQ_DELIVER_IN_ORDER is not enabled, MAC SDUs are handed to the upper layers as soon as all blocks of the MAC SDU have been successfully received within the defined time-out values.

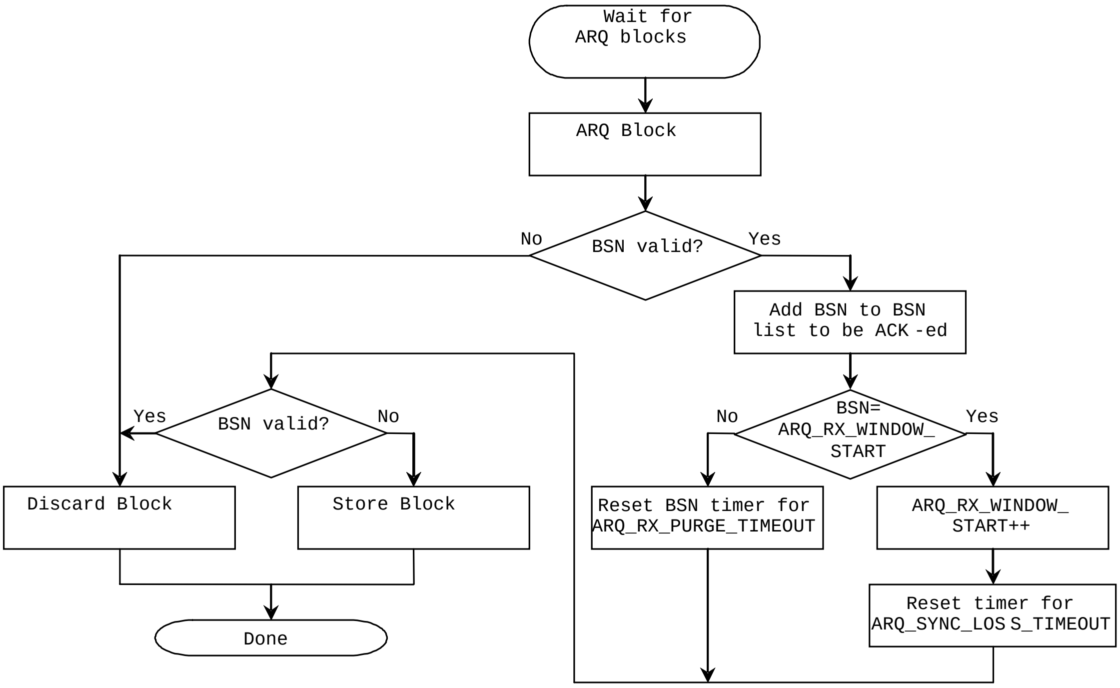


Figure 3: ARQ block reception

5.4.5 Resetting the ARQ state machine

Synchronization of the ARQ state machines is governed by timers managed by the transmitter and receiver state machine. Each time ARQ_TX_WINDOW_START is updated, the transmitter timer is reset (set to zero). Each time ARQ_RX_WINDOW_START is updated, the transmitter timer is reset.

When the timer exceeds the value of ARQ_SYNC_LOSS_TIMEOUT the state machine shall initiate the ARQ Reset process for that connection. The process of executing an ARQ Reset on a connection is shown in figures 4 and 5.

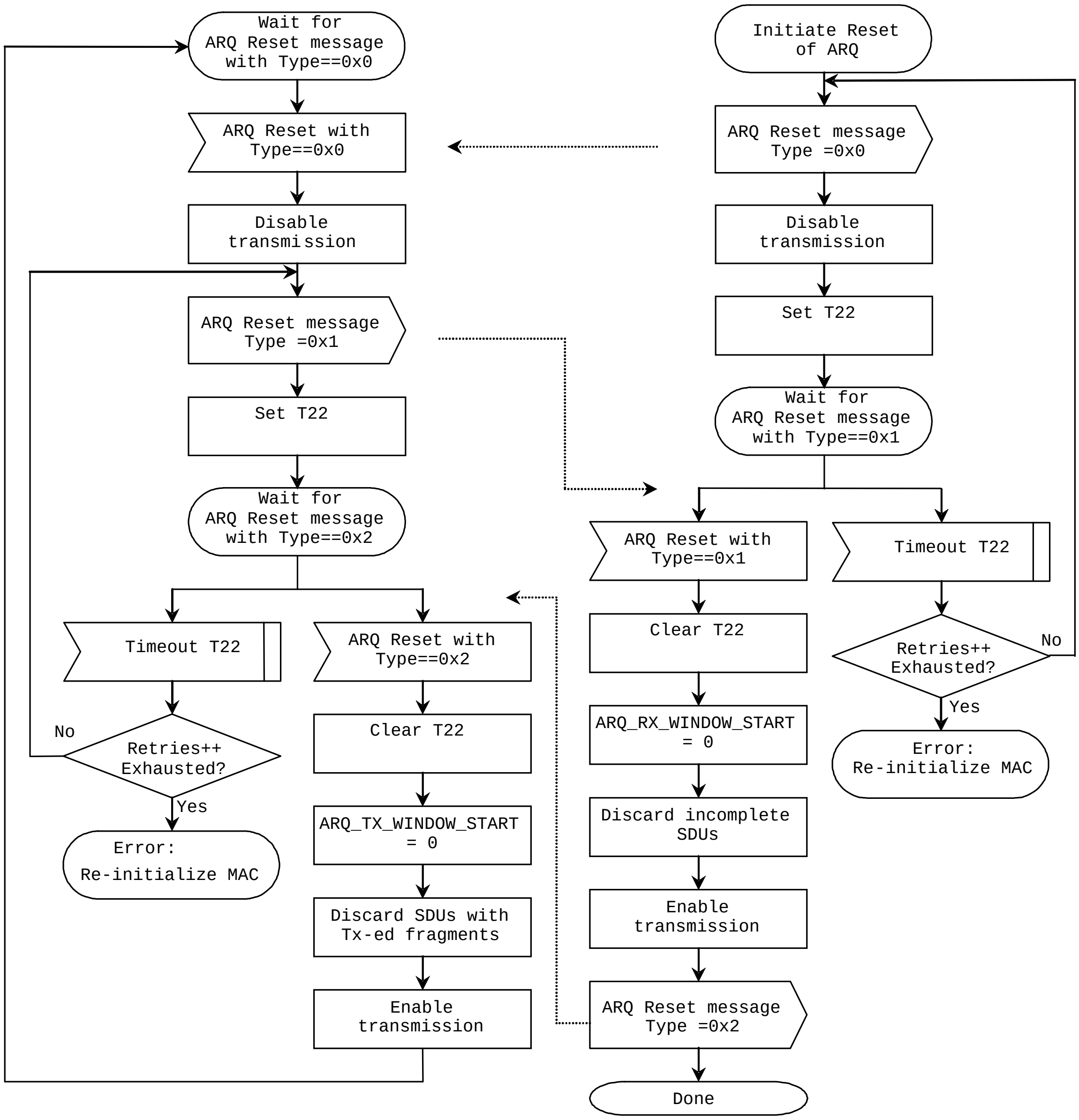


Figure 4: Receiver initiated ARQ Reset

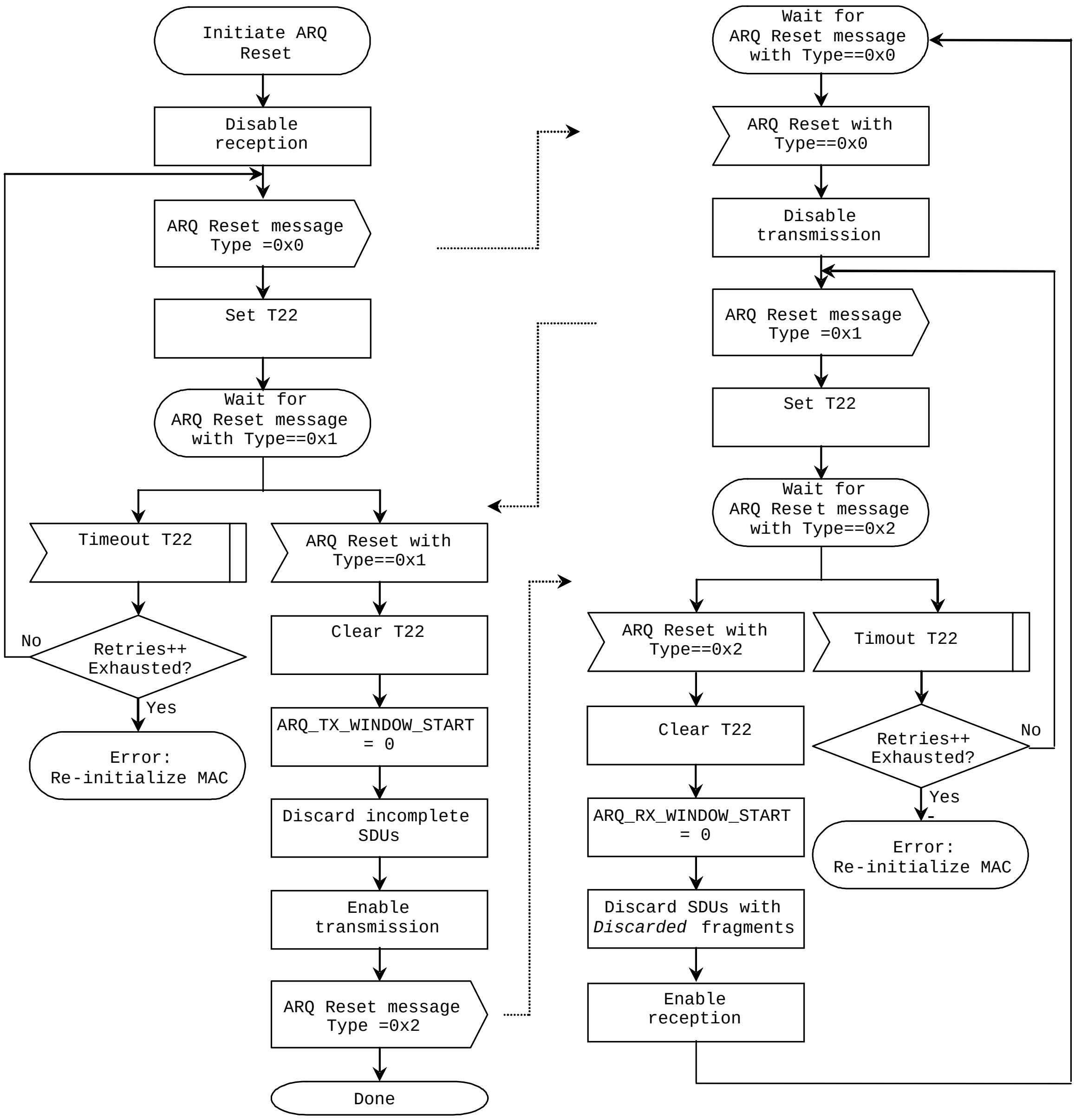


Figure 5: Transmitter initiated ARQ Reset

5.5 ARQ service flow TLVs

The following TLV encodings shall be available.

ARQ SUPPORT

The ARQ SUPPORT indicates whether or not ARQ is supported by the system. When the system supports ARQ, this TLV shall be included in the REG-REQ by the SS whereas the BS shall indicate acceptance or rejection of the ability. ARQ shall be available for connections only if both sides support it.

ARQ ENABLE

The ARQ ENABLE TLV indicates whether or not ARQ is available for the connection that is being setup. The DSA-REQ shall contain the request to use ARQ or not. The DSA-RSP message shall contain the acceptance or rejection of the request. ARQ shall be enabled for this connection only if both sides support it. When a DSA-REQ is issued by the BS, the use of ARQ may be mandated for the requested connection (if ARQ availability was confirmed during registration). In that case, the SS shall either reject the connection or accept the connection with ARQ.

ARQ WINDOW SIZE

This parameter is negotiated upon connection setup. The DSA-REQ/DSC-REQ message shall contain the suggested value for this parameter. The DSA-RSP/DSC-RSP message shall contain the confirmation value or an alternate value for this parameter. The smaller of the two shall be used as the actual ARQ_WINDOW_SIZE.

ARQ RETRY TIMEOUT

The ARQ retry timeout should account for the transmitter and receiver processing delays and any other delays relevant to the system. This is achieved through the use of the following two TLVs:

- ARQ_TX_DELAY: This is the total estimated transmitter delay, including sending (e.g. MAC PDUs) and receiving (e.g. ARQ feedback) delays and other implementation dependent processing delays. If the transmitter is the BS, it may include other delays such as scheduling and propagation delay.
- ARQ_RX_DELAY: This is the total estimated receiver delay, including receiving (e.g. MAC PDUs) and sending (e.g. ARQ feedback) delays and other implementation dependent processing delays. If the receiver is the BS, it may include other delays such as scheduling and propagation delay.

The DSA-REQ and DSA-RSP messages shall contain the values for these parameters, where the receiver and transmitter each declare their capabilities. When the DSA handshake is completed, each party shall calculate:

ARQ_RETRY_TIMEOUT = ARQ_TX_DELAY + ARQ_RX_DELAY

ARQ BLOCK LIFETIME

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the ARQ_BLOCK_LIFETIME value shall be considered infinite.

ARQ_SYNC_LOSS_TIMEOUT

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the ARQ_SYNC_LOSS_TIMEOUT value shall be considered infinite.

ARQ_DELIVER_IN_ORDER

The transmitter shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter. This TLV indicates whether or not data is to be delivered by the receiving MAC to its client application in the order in which the data was handed off to the originating MAC.

ARQ_RX_PURGE_TIMEOUT

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the ARQ_RX_PURGE_TIMEOUT value shall be considered infinite.

Table 62: ARQ TLVs

Name	Type	Length	Value	Scope
ARQ_SUPPORT	5.21	1	0: No ARQ support capability 1-254: Max. simultaneous connections for which ARQ can be supported 255: 255 or more simultaneously supportable ARQ connections	REG-REQ REG-RSP
ARQ_ENABLE	[24/25].11	1	0 = ARQ not support 1 = ARQ supported 2 = ARQ mandated (BS in DSA-REQ only)	DSA-REQ DSA-RSP
ARQ_WINDOW_SIZE	[24/25].12	2	1-(ARQ_BSN_MODULUS/2)	DSx-REQ DSx-RSP
ARQ_TX_DELAY	[24/25].13	2	Estimated transmitter delay 0 - 655 350 (10 μs granularity)	DSA-REQ DSA-RSP
ARQ_RX_DELAY	[24/25].22	2	Estimated receiver delay 0 - 655 350 (10 μs granularity)	DSA-REQ DSA-RSP
ARQ_BLOCK_LIFETIME	[24/25].17	2	0 = Infinite 1 - 655 350 (10 μs granularity)	DSA-REQ DSA-RSP
ARQ_SYNC_LOSS_TIMEOUT	[24/25].19	2	0 = Infinite 1 - 655 350 (10 μs granularity)	DSA-REQ DSA-RSP
ARQ_DELIVER_IN_ORDER	[24/25].20	1	0 = Order of delivery is not preserved 1 = Order of delivery is preserved	DSA-REQ DSA-RSP
ARQ_RX_PURGE_TIMEOUT	[24/25].21	2	0 = Infinite 1 - 655 350 (10 μs granularity)	DSA-REQ DSA-RSP
ARQ_BLOCK_SIZE	[24/25].22	1	Length of ARQ block, bytes	DSA-REQ DSA-RSP

6 Mesh topology support

6.1 Introduction

The main difference between the PMP and optional Mesh modes is that in the PMP mode, traffic only occurs between the BS and SSs, while in the Mesh mode traffic can be routed through other SSs and can occur directly between SSs. Depending on the transmission protocol algorithm used, sharing of channel resources can be done on the basis of equality using distributed scheduling, or on the basis of superiority of the mesh BS, which effectively results in centralized scheduling, or on a combination of both.

Where optional mesh systems are addressed, a system consists of an MAC and PHY implementation with at least two mesh nodes communicating via a multipoint-to-multipoint radio air interface, along with the interfaces to external networks and services transported by the MAC and PHY.

Within a mesh network, a system that has a direct connection to backhaul services outside the mesh network, is termed a mesh BS. All the other systems of a mesh network are termed mesh SS. In general, the systems of a mesh network are termed nodes. Within mesh context, uplink and downlink are defined as traffic in the direction of the mesh BS and traffic away from the mesh BS respectively.

The other three important terms of mesh systems are neighbour, neighbourhood and extended neighbourhood. The stations with which a node has direct links are called neighbours. Neighbours of a node shall form a neighbourhood. A node's neighbours are considered to be 'one hop' away from the node. An extended neighbourhood contains, additionally, all the neighbours of the neighbourhood.

Using distributed scheduling, all the nodes including the mesh BS shall coordinate their transmissions in their two-hop neighbourhood and shall broadcast their schedules (available resources, requests and grants) to all their neighbours. Optionally the schedule may also be established by directed un-coordinated requests and grants between two nodes. Nodes shall ensure that the resulting transmissions do not cause collisions with the data and control traffic scheduled by any other node in the two-hop neighbourhood. There is no difference in the mechanism used in determining the schedule for downlink and uplink.

In the mode of operation with centralized scheduling, resources are granted in a more centralized manner. The mesh BS shall gather resource requests from all the mesh SSs within a certain hop range. It shall determine amount of granted resources for each link in the network both in downlink and uplink, and communicates these grants to all the mesh SSs within the hop range. The grant messages do not contain the actual schedule but each node shall compute it by using the predetermined algorithm with given parameters.

All the communications are in the context of a link, which is established between two nodes. One link shall be used for all the data transmissions between the two nodes. QoS is provisioned over links on a message by message basis. No service or QoS parameters are associated with a link but each unicast message has service parameters in the header. Traffic classification and flow regulation are performed at ingress node by upper-layer classification/regulation protocol. The service parameters associated with each message shall be communicated together with the message content via the MAC SAP.

Mesh systems typically use omni directional or 360° steerable antennas, but can also be co-located using sector antennas. At the edge of the coverage area of the mesh network, where only a connection to a single point is needed, even highly directional antennas can be used.

6.2 Addressing and connections

Each node shall have a 48-bit universal MAC address. The address uniquely defines the node from within the set of all possible vendors and equipment types. This address is used during the network entry process and as part of the authorization process by which the candidate node and the network verify the identity of each other.

When authorized to the network the candidate node shall receive a 16-bit Node Identifier (Node ID) upon a request to the mesh BS. Node ID is the basis for identifying nodes during normal operation. The Node ID is transferred in the Mesh subheader, which follows the Generic MAC header, in both unicast and broadcast messages.

For addressing nodes in the local neighbourhood, 8-bit link identifiers (Link IDs) shall be used. Each node shall assign an ID for each link it has established to its neighbours. The Link IDs are communicated during the Link Establishment process as neighbouring nodes establish new links. The Link ID is transmitted as part of the CID in the Generic MAC header in unicast messages. The Link IDs shall be used in distributed scheduling to identify resource requests and grants. Since these messages are broadcast, the receiver nodes shall be able to identify the schedule of their own using both the transmitter's Node ID in the Mesh subheader, and the Link ID in the MSH-DSCH payload.

After entering the network, a node can establish links with nodes other than its sponsor by following the secure process as defined in table 63. This process uses the MSH-NCFG Neighbour Link Establishment IE (see table 48).

1) Node A sends a challenge (action code = 0x0) containing:

   HMAC{Operator Shared Secret, frame number, Node ID of node A, Node ID of node B} (12)

   in which the Operator Shared Secret is a private key obtained from the provider (which is also used to enter the network) and the frame number is the last known frame number in which Node B send a MSH-NCFG message.

2) Node B, upon reception, computes the same value (it may also attempt some earlier frame numbers in which it sent MSH-NCFG messages, in case node A missed the last of its MSH-NCFGs) as above and compares. If the values do not match, a rejection (action code = 0x3) is returned. If a match is achieved, Node B sends, implicitly accepting the link, a challenge response (action code = 0x1) containing:

   HMAC{Operator Shared Secret, frame number, Node ID of node B, Node ID of node A} (13)

   in which the frame number is the frame number in which Node A sent the MSH-NCFG message with challenge. It also randomly selects and includes an unused link ID, which shall from this point forward indicate the link from node B to node A.

3) Node A, upon reception, computes the same value as above and compares. If the values do not match a rejection (action code = 0x3) is returned. If a match is achieved, Node A sends an Accept. It also randomly selects and includes an unused link ID, which shall from this point forward indicate the link from node A to node B.

Table 63: Link establishment

Node A		Node B
Send MSH-NCFG Neighbour Link Establishment IE Action Code = Challenge	Challenge →	
	← Challenge Response	If (HMAC match (see eq. 12)) send MSH-NCFG Neighbour Link Establishment IE Action Code = Challenge Response new Link ID B → A
If (HMAC match (see eq. 13)) send MSH-NCFG Neighbour Link Establishment IE Action Code = Accept new Link ID A → B	Accept →	

The Connection ID in mesh mode is specified as shown in table 64 to convey broadcast/unicast, service parameters and the link identification.

Table 64: Connection ID

Syntax	Size	Notes
CID() {		
if (Xmt Link ID == 0xFF) {		
Logical Network ID	8 bits	0x00 All-net Broadcast
} else {		
Type	2 bits	0x0 MAC Management 0x1 IP 0x2-0x3 Reserved
Reliability	1 bit	0x0 No retransmissions 0x1 Up to 4 retransmissions
Priority/Class	3 bits	Indicates message class.
Drop Precedence	2 bits	Messages with larger Drop Precedence shall have higher dropping likelihood during congestion.
}		
Xmt Link ID	8 bits	0xFF MAC management broadcast
}		

6.3 MAC service definition

6.3.1 Primitives

The following primitives are supported at the MAC Service Access Point in mesh mode:

MAC_CREATE_CONNECTION.indication

MAC_CHANGE_CONNECTION.indication

MAC_TERMINATE_CONNECTION.request

MAC_TERMINATE_CONNECTION.indication

MAC_DATA.request

MAC_DATA.indication

MAC_FORWARDING_UPDATE.request

MAC_FORWARDING_UPDATE.indication

In mesh mode none of the actions cause the initiating CS to send a REQUEST primitive to its MAC sublayer. They are either indications of the results from the processes handled by the MAC CPS management entity, or data delivery actions needed to convey information to the peer CS.

6.3.2 MAC_CREATE_CONNECTION.indication

Function:

This primitive is issued by a MAC entity to the CS, to report a new link established to a neighbour node.

Generation:

This primitive is generated whenever a new link has been established to a neighbour node.

Effect of receipt:

The receipt of the primitive is an indication to the CS that a link to the given neighbour node is up and can be used for data delivery.

Semantics:

MAC_CREATE_CONNECTION.indication
{

CID,
max length,
service flow parameters,
encryption flag

}

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.
The max length parameter specifies the maximum length of SDUs that are allowed over the link.
The service flow parameters include information on:

Data rate (Mbps)

Data rate associated with the burst profile for the physical link over which the connection is created.

Transmit power (dB)

Transmit power at the antenna port for the physical link over which the connection is created.

Estimate of packet error rate for 256-byte packets

The encryption flag specifies that the data carried over this link is encrypted, if ON, If OFF, then no encryption is used.

6.3.3 MAC_CHANGE_CONNECTION.indication

Function:

This primitive is issued by a MAC entity to the CS, to report new parameters of an existing link to a neighbour node.

Generation:

This primitive is generated whenever parameters of an existing link has changed.

Effect of receipt:

The CS shall take into account new link parameters in the use of the link.

Semantics:

MAC_CHANGE_CONNECTION.indication
{

CID,
max length,
service parameters,
encryption flag

}

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.
The max length parameter specifies the maximum length of SDUs that are allowed over the link.
The service parameters include information on:

Target data rate for the link in Mbps.
Transmit energy for the link.
Estimate of packet error rate for 256-byte packets.
The encryption flag specifies that over this link encryption is possible, if ON, If OFF, then no encryption is possible.

6.3.4 MAC_TERMINATE_CONNECTION.request

Function:
This primitive is issued by a CS, to terminate an existing link to a neighbour node.

Generation:
This primitive is generated to bring down an existing link to a neighbour node.

Effect of receipt:
The receipt of the primitive causes the MAC to terminate the connection and report that to the MAC entity in the neighbour the link was to.

Semantics:
MAC_TERMINATE_CONNECTION.request
{

CID

}

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.

6.3.5 MAC_TERMINATE_CONNECTION.indication

Function:
This primitive is issued by the MAC entity of the non-initiating side to indicate termination of the link to a neighbour node.

Generation:
This primitive is generated by the MAC sublayer when it receives an indication in a MSH-NCFG message.

Effect of receipt:
The receipt of the primitive is an indication to the CS that the link to the given neighbour node is down and cannot be used for data delivery.

Semantics:
MAC_TERMINATE_CONNECTION.indication
{

CID,

}

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.

6.3.6 MAC_DATA.request

Function:

This primitive defines the transfer of data to the MAC entity from a convergence sublayer service access point.

Generation:

This primitive is generated by a convergence sublayer whenever an MAC SDU is to be transferred to a peer entity.

Effect of receipt:

The receipt of the primitive causes the MAC entity to process the MAC SDU through the MAC sublayer and pass the appropriately formatted PDUs to the PHY layer for transfer to the peer MAC sublayer entity, using the Node ID specified.

Semantics:

```
MAC_DATA.request
{

    CID,
    length,
    data,
    encryption flag

}
```

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.
The length parameter specifies the length of the MAC SDU in bytes.
The data parameter specifies the MAC SDU as received by the local MAC entity.
The priority/class parameter embedded in the CID specifies priority class of the MAC SDU.
The reliability parameter embedded in the CID specifies maximum number of transmission attempts at each link.
The drop precedence parameter embedded in the CID indicates relative MSDU dropping likelihood.
The encryption flag specifies that the data sent over this link is to be encrypted, if ON. If OFF, then no encryption is used.

6.3.7 MAC_DATA.indication

Function:

This primitive defines the transfer of data from the MAC to the convergence sublayer.

Generation:

This primitive is generated whenever an MAC SDU is to be transferred to a peer convergence entity.

Effect of receipt:

The effect of receipt of this primitive by a convergence entity is dependent on the validity and content of the MAC SDU.

Semantics:

```
MAC_DATA.request
{

    CID
    length,
    data,
    reception status,
    encryption flag

}
```

The CID is the Connection ID in Mesh as conveyed in the Generic MAC header.
The length parameter specifies the length of the MAC SDU in bytes.
The data parameter specifies the MAC SDU as received by the local MAC entity.
The reception status parameter indicates transmission success or failure for those PDUs received via the MAC_DATA.indication.

6.3.8 MAC_FORWARDING_UPDATE.request

Function:

This primitive defines the transfer of the centralized scheduling configuration to the MAC entity from a convergence sublayer service access point in the mesh BS.

Generation:

This primitive is generated in the mesh BS whenever it has changed the schedule tree.

Effect of receipt:

The receipt of this primitive causes the MAC to generate a MSH-CSCF message with the given information. The message shall be distributed to all the nodes listed in the tree.

Semantics:

The parameters of the primitive are as follows:

MAC_FORWARDING_UPDATE.request
{

number of nodes,
node parameters[number of nodes]

}

The number of nodes parameter indicates number of nodes in the scheduling tree of this mesh BS.
The node parameters entry shall contain the following information:

Node ID: The Node ID parameter indicates the node.
number of children: The number of nodes parameter indicates number of children the given node.
child parameters[number of children]
Each child parameters entry shall containing the following information:

child index: The child index indicates index into the list of Node IDs
uplink burst profile: The uplink burst profile indicates burst profile of link to child node
downlink burst profile: The downlink burst profile indicates burst profile of link from child node.

6.3.9 MAC_FORWARDING_UPDATE.indication

Function:

This primitive defines the transfer of the centralized scheduling configuration from the MAC to the convergence sublayer.

Generation:

This primitive is generated by the MAC sublayer at all the nodes, which have received the MSH-CSCF message, when new centralized schedule with revised schedule tree takes effect.

Effect of receipt:

The receipt of this primitive synchronizes the forwarder and MAC scheduler to routing changes.

Semantics:

MAC_FORWARDING_UPDATE.indication
{

Node ID self
number of nodes,
node parameters[number of nodes]

}

The Node ID self indicates the Node ID of the node itself.
The number of nodes parameter indicates number of nodes in the scheduling tree of this mesh BS.
The node parameters entry shall contain the following information:

Node ID: The Node ID parameter indicates the node.
number of children: The number of nodes parameter indicates number of children the given node.
child parameters[number of children]
Each child parameters entry shall contain the following information:

child index: The child index indicates index into the list of Node IDs
uplink burst profile: The uplink burst profile indicates burst profile of link to child node
downlink burst profile: The downlink burst profile indicates burst profile of link from child node.

6.4 MAC management message applicability

When implementing the mesh mode, all clauses referring to the mesh mode in the standard shall apply as mandatory. Basic functionalities are mandatory for a mesh node as they are for a PMP node, except those that are stated as optional below.

For a mesh-enabled system, the messages below and the corresponding functionality are always mandatory to implement:

MSH-NCFG
MSH-NENT
MSH-DSCH
MSH-CSCH
MSH-CSCF
REG-REQ
REG-RSP
PKM-REQ
PKM-RSP
SBC-REQ
SBC-RSP
TFTP-CPLT
TFTP-RSP
RES-CMD

For a mesh enabled system, the following messages and the corresponding functionality are mandatory/optional whenever they are correspondingly optional/mandatory for a PMP system:

ARQ-Feedback
AAS-FBCK-REQ
AAS-FBCK-RSP

When operating in the mesh mode, the messages below and the corresponding functionality are not used.

DL-MAP
DCD
DSC-ACK
DSC-REQ
DSC-RSP
DSD-RSP
DSX-RVD
UCD
UL-MAP
CLK-CMP
DBPC-REQ
DBPC-RSP
DREG-CMD
MCA-REQ
MCA-RSP
RNG-REQ

RNG-RSP
DSA-ACK
DSA-REQ
DSA-RSP

6.5 Network synchronization

Network configuration (MSH-NCFG) and network entry (MSH-NENT) packets provide a basic level of communication between nodes in different nearby networks whether from the same or different equipment vendors or wireless operators. These packets are used to synchronize both centralized and distributed control mesh networks.

This communication is used to support basic configuration activities such as: synchronization between nearby networks used (for instance, for multiple, co-located BSs to synchronize their uplink and downlink transmission periods), communication and coordination of channel usage by nearby networks, and discovery and basic network entry of new nodes.

MSH-NCFG, MSH-NENT and MSH-DSCH can all assist a node in synchronizing to the start of frames. For these messages, the control subframe, which initiates each frame, is divided into transmit opportunities (see TS 102 177 [3]). The first transmit opportunity in a network control subframe may only contain MSH-NENT messages, while the remainder MSH_CTRL_LEN-1 may only contain MSH-NCFG messages. In scheduling control subframes, the MSH-DSCH_NUM transmit opportunities assigned for MSH-DSCH messages come last in the control subframe. The MSH-NCFG messages also contain the number of its transmit opportunity, which allows nodes to easily calculate the start time of the frame.

6.5.1 Physical neighbour list

All the basic functions like scheduling and network synchronization are based on the neighbour information all the nodes in the mesh network shall maintain. Each node (BS and SS) maintains a physical neighbourhood list with each entry containing the following fields:

MAC Address
: 48-bit MAC address of the neighbour.

Hop Count
: Indicates distance in hops of this neighbour from the present node. If a packet has been success-fully received from this neighbour recently (defined further below), it is considered to be 1 hop away.

Node Identifier
: 16-bit Number used to identify this node in a more efficient way in MSH-NCFG messages.

Xmt Holdoff Time
: The minimum number of MSH-NCFG transmit opportunities that no MSH-NCFG message transmission is expected from this node after Next Xmt Time (see for detailed definition).

Next Xmt Time
: The MSH-NCFG transmit opportunity(ies) in which the next MSH-NCFG from this node is expected (see for detailed definition).

Reported Flag
: Set to TRUE if this Next Xmt Time has been reported by this node in a MSH-NCFG packet. Else set to FALSE.

Synchronization hop count
: This counter is used to determine superiority between nodes when synchronizing the network. Nodes can be assigned as master time keepers, which are synchronized externally (for example using GPS). These nodes transmit Synchronization hop count of 0. Nodes shall synchronize to nodes with lower synchronization hop count, or if counts are the same, to the node with the lower Node ID.

The Physical Neighbourhood List is updated as follows when a MSH-NCFG packet is received from a neighbour:

> The hop count field in the Physical Neighbourhood List for the neighbour itself is set to 1. The hop count field for other nodes listed in the MSH-NCFG message is set to Hops to Neighbour +2 (see table) unless they are already listed with a lower hop count.

The Next Xmt Time and Xmt Holdoff Time of the neighbour and all nodes listed in the MSH-NCFG are updated.
The 'Reported Flag' for each entry in the Physical Neighbour table which was modified is set to FALSE.

6.5.2 MSH-NCFG / MSH-NENT transmission channel and timing

MSH-NCFG and MSH-NENT packets are scheduled for transmission during control subframes. So that all nearby nodes receive these transmissions, the channel used is cycled through the available channels in the band, with the channel selection being based on the Frame number. So, for Frame Number *i*, the channel is determined by the array lookup:

$$\text{NetConfigChannel} = \text{Logical channel list}\left[\left(\frac{\text{Frame Number}}{\text{Scheduling Frames} \times 4 + 1}\right)_{\text{mod Num\_Channels}}\right] \qquad (14)$$

where the Logical channel List and Scheduling Frames are derived from the MSH-NCFG:Network Descriptor (see table 44).

6.5.2.1 MSH-NCFG next transmission scheduling

During the current Xmt Time of a node (i.e. the time slot when a node transmits its MSH-NCFG packet), the node uses the following pseudo-code procedure to determine its Next Xmt Time:

```
Order its physical neighbour list by Next Xmt Time.
For each entry in the neighbour list:
     Entry's Earliest Subsequent Xmt Time = Entry's Next Xmt Time + Entry's Xmt Holdoff Time
Success = FALSE;
TempXmtTime = Xmt Time + Xmt Holdoff Time
While (Success == FALSE) do {
    Determine the eligible competing nodes, which is the set of all nodes in the physical-
    neighbour list for which:
```

TempXmtTime $\subset$ Entry's Next Xmt Time eligibility interval (see Eq. 2) OR

Entry's Earliest Subsequent Xmt Time $\leq$ TempXmtTime.

```
     if ( MeshElection (TempXmtTime,MyNodeID,CompetingNodeIDsList [ ] == FALSE)
         Set TempXmtTime equal to the next MSH-NCFG Xmt opportunity.
     else:
         Success = TRUE
         Next Xmt Time =TempXmtTime.
 }
```

The Mesh Election procedure determines whether the local node is the winner for a specific TempXmtTime among all the competing nodes. It returns TRUE if the local node wins or FALSE otherwise .The algorithm works as follows:

```
boolean MeshElection (uint32 XmtTime,uint16 MyNodeID,uint16 NodeIDList [ ] )) {
 uint32 nbr_smear_val,smear_val1,smear_val2;
 smear_val1 =inline_smear(MyNodeID ^ XmtTime ));
 smear_val2 =inline_smear(MyNodeID +XmtTime );
 For each Node ID nbrsNodeID in NodeIDList Do {
     nbr_smear_val =inline_smear(nbrsNodeID ^ XmtTime ));
     if(nbr_smear_val >smear_val1 ) {
         return FALSE;//This node loses.
     }
     else if(nbr_smear_val ==smear_val1 ) {
         //1st tie-breaker.
         nbr_smear_val =inline_smear(nbrsNodeID +XmtTime );
         if(nbr_smear_val >smear_val2 ) {
             return FALSE;//This node loses.
         }
         else if(nbr_smear_val ==smear_val2 ) {
             //If we still collide at this point Break the tie based on MacAdr
             if ((XmtTime is even &&(nbrsNodeID >MyNodeID))||
                 (XmtTime is odd &&(nbrsNodeID <MyNodeID ))) {
                 return FALSE;//This node looses.
             }
         }
```

```
     }
     //This node won over this competing node
 }//End for all competing nodes
//This node is winner,it won over all competing nodes.
return TRUE;
}

// Convert a uniform 16-bit value to an uncorrelated uniform 16-bit hash value, uses mixing.

uint32 inline_smear(uint16 val) {
 val +=(val <<12);
 val ^=(val >>22);
 val +=(val <<4);
 val ^=(val >>9);
 val +=(val <<10);
 val ^=(val >>2);
 val +=(val <<7);
 val ^=(val >>12);
 return(val);
}
```

6.5.2.2 MSH-NENT next transmission scheduling

The NetEntry scheduling protocol provides the upper layer protocol an unreliable mechanism to access the NetEntry slot(s), so that new nodes, which are not yet fully-functional members of the network, can communicate with the fully-functional members of the network.

In the NetEntry slots new nodes shall transmit MSH-NENT messages using the following two step procedure:

1) The initial MSH-NENT packet with request IE is sent in a random, contention-based fashion in a free network entry transmission slot in the immediately following MSH-NENT transmission opportunity after the targeted sponsor sends a MSH-NCFG. with sponsored MAC address 0x000000000000.

2) After the sponsor advertises the new nodes MAC Address in a MSH-NCFG message, the new node may send a MSH-NENT in the immediately following MSH-NENT transmission opportunity.

A new node uses the algorithm specified by the following pseudocode to access NetEntry transmission slots:

```
/*Variable Definitions */
Pkt *MSH-NENT_MsgQ =NULL;            //MSH-NENT Message queue
uint SponsorsState =UNAVAILABLE;     //SponsorsState and OthersState record the NetEntry
uint OthersState =BUSY;
// Address in the MSH-NCFG packet form the sponsor or other nodes,
// which can be used to determine the availability of the next NetEntry transmission opportunity
//SponsorsState can be UNAVAILABLE,AVAILABLE and POLLING.
//OthersState can be AVAILABLE and BUSY.
uint OthersMaxMacAdr =0xFFFFFFFF;
uint OthersMinMacAdr =0x00000000;

void RecvOutgoingMSH-NENT_Msg (Pkt *MSH-NENT_Msg) {
 MSH-NENT_MsgQ->enqueue (MSH-NENT_Msg);
}

void RecvIncomingMSH-NCFG_Msg (Pkt *MSH-NCFG_Msg) {
 if (MSH-NCFG_Msg->sourceMacAdr ==sponsorsMacAdr) {
     switch (MSH-NCFG_Msg->NetEntryAddress)
     {
         case 0x000000000000:    SponsorsState =AVAILABLE; break;
         case myMacAdr:          SponsorsState =POLLING; break;
         default:                break;
     }
 } else {
     switch (MSH-NCFG_Msg->NetEntryAddress)
     {
         case 0x000000000000:break;
         default:OthersState =BUSY;
                 if (OthersMaxMacAdr <MSH-NCFG_Msg->NetEntryAddress)
                     OtherMaxMacAdr=MSH-NCFG_Msg->NetEntryAddress;
                 if (OthersMinMacAdr >MSH-NCFG_Msg->NetEntryAddress)
                     OtherMinMacAdr =MSH-NCFG_Msg->NetEntryAddress;
     }
 }
}
```

```
void NetworkControlSubframeStart() {
 boolean xmt =FALSE;
 if (MSH-NENT_MsgQ->qLength())   {
     if (SponsorsState ==AVAILABLE) {
         if (OthersState !=BUSY)
             xmt =TRUE;
         }
     else if (SponsorsState ==POLLING) {
         if (OthersState !=BUSY)
             xmt =TRUE;
         else if (((mayMacAdr >OthersMaxMacAdr)&&(even supperframe))||
                 ((mayMacAdr <OthersMinMacAdr)&&(odd supperframe)))
             xmt =TRUE;
     }
 }
 if (xmt) {
     Pkt*MSH-NENT_Msg =MSH-NENT_MsgQ->getHead();
     MSH-NENT_MsgQ->dequeue(MSH-NENT_Msg);
     SendOutPkt (MSH-NENT_Msg,nextNetEntryslot);
 }
 SponsorsState =UNAVAILABLE;
 OthersState =AVAILABLE;
 OthersMaxMacAdr =0x000000000000;
 OthersMinMacAdr =0xFFFFFFFFFFFF;
}
```

The individual subroutines are triggered by the transmission of a MSH-NENT packet, the reception of a MSH-NCFG packet and the start of a NetworkControl Subframe respectively.

6.6 Network entry and synchronization

Node initialization and network entry procedures in mesh mode are in some aspects different from those in PMP mode. A new node entering the mesh network obeys the following procedures. The whole entry pro-cess to the stage when the node can start scheduled transmissions can be divided into the following phases:

1) Scan for active network and establish coarse synchronization with the network.

2) Obtain network parameters (from MSH-NCFG messages).

3) Open Sponsor Channel.

4) Node authorization.

5) Perform registration.

6) Establish IP connectivity.

7) Establish time of day.

8) Transfer operational parameters.

Each node shall contain a 48-bit universal MAC address assigned during the manufacturing process. This is used to identify the node to the various provisioning servers during initialization and whenever performing authentication with a neighbour node.

6.6.1 MAC management message tunnelling

In Mesh networks during network entry certain MAC Message protocols take place between entities separated by multiple hops. In these cases the Sponsor Node shall relay the MAC Messages from the new node acting as the SS to the peer performing the duties of the PMP BS. The sponsor shall also relay the messages from the BS entity to the new node.

The Sponsor shall tunnel the MAC Messages received from the New Node (SS) listed in table 65 over UDP as shown in figure 6. to the entity performing the BS part of the protocol. The UDP source and destination port used for tunnelled messages shall be equal to 80216_UDP_PORT. The sponsor shall also extract the MAC messages from the UDP packets arriving from the BS entity and transmit them over the air to the New Node.

Table 65: MAC management message tunnelling over UDP

Message	Sponsor action	Direction of message
PKM-REQ: Auth Request	Tunnel	SS to BS
PKM-REQ: Auth Info	Tunnel	SS to BS
PKM-REQ: Auth Reply	Extract	BS to SS
PKM-REQ: Auth Reject	Extract	BS to SS
REG-REQ	Tunnel	SS to BS
REG-RSP	Extract	BS to SS
DSA-REQ	Tunnel	SS to BS
DSA-RSP	Extract	BS to SS
DSA-ACK	Tunnel	SS to BS

IP header(s)	UDP header	Tunnel Subheader	Message including headers

Figure 6: MAC management message tunnelling message format

The format of the Tunnel Subheader is defined in table 66.

Table 66: Tunnel Subheader format

Syntax	Size	Notes
Tunnel Subheader() {		
Type	8 bits	0 = Reserved 1 = HIPERMAN MAC header 2-255 = Reserved
}		

Also, MAC messages may need to be tunnelled end to end in cases when the protocol takes place between peers separated by several hops. The packet format in figure 6 shall be used in these cases with the Tunnel Subheader format defined in table 66.

6.6.2 Scanning and coarse synchronization to network

On initialization or after signal loss, the node shall search for MSH-NCFG messages to acquire coarse synchronization with the network. Upon receiving a MSH-NCFG message the node acquires the network time from the Timestamp field. The node may have non-volatile storage in which all the last operational parameters are stored and shall first try to re-acquire coarse synchronization with the network. If this fails, it shall begin to continuously scan the possible channels of the frequency band of operation until a valid network is found.

Once the PHY has achieved synchronization, the MAC Sublayer shall attempt to acquire network parameters. At the same time the node shall build a Physical Neighbour List (see clause 6.5.1).

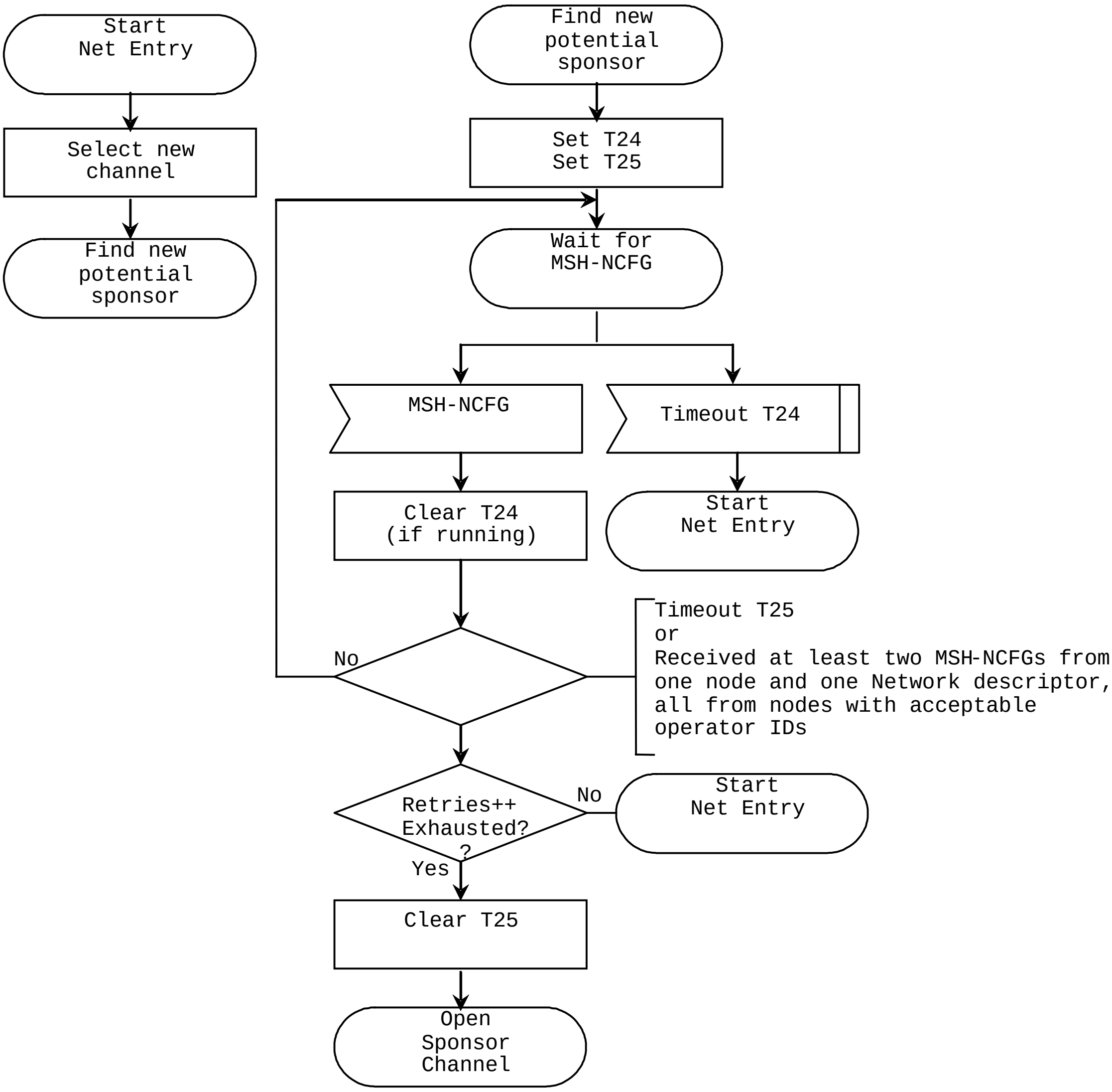


Figure 7: Synchronization and network entry - new node I

6.6.3 Obtaining network parameters

A node shall remain in synchronization as long as it receives MSH-NCFG messages. A node shall accumulate MSH-NCFG messages at least until it receives a MSH-NCFG message from the same node twice and until it has received a MSH-NCFG Network Descriptor with an operator ID matching (one of) its own if it has any. In parallel the new node shall update its Physical Neighbour List (see clause 6.5.1) from the acquired information.

From the established physical neighbour list, the new node shall select a potential Sponsoring Node out of all nodes having the Logical Network ID of the node for which it found a suitable Operator ID. The new node then shall then synchronize its time to the potential sponsor assuming 0 propagation delay after which it shall send a MSH-NENT NetEntryRequest including the Node ID of the potential sponsor. To determine a suitable transmission time, the node shall adhere to clause 6.5.2.2.

Until the node has obtained a unique Node ID, it shall use temporary Node ID (0x0000) as Transmitter's Node ID in all transmissions.

Once the Candidate Node has selected a Sponsoring Node, it shall use the Sponsoring Node to negotiate basic capabilities and to perform authorization. For that purpose the Candidate Node shall first request the Sponsoring Node to open Sponsor Channel for a more effective message exchange.

6.6.4 Opening sponsor channel

Once the new node has selected one of its neighbours as the candidate Sponsoring Node it becomes a Candidate Node. To get further in the initialization procedure the Candidate Node shall request the candidate Sponsoring Node to establish a temporary schedule which could be used for further message delivery during the Candidate Node initialization. The temporary schedule requested is termed Sponsor Channel.

The process is initiated by the Candidate Node which transmits a MSH-NENT NetEntryRequest message (a MSH-NENT message with Type set to 0x2) to the Sponsoring Node.

Upon reception of the MSH-NENT NetEntryRequest message with the Sponsor Node ID equal to Node ID of its own, the candidate Sponsoring Node shall assess the request and either opens the Sponsor Channel or rejects the request. The response is given in a MSH-NCFG message with an Embedded Data as defined in clause 4.3.18.3. If the candidate Sponsoring Node does not advertise the Candidate Node's MAC address in the sponsor's next MSH-NCFG transmission, then the procedure is repeated MSH_SPONSOR_ATTEMPTS times using a random backoff between attempts. If these attempts all fail, then a different Candidate Sponsoring Node is selected and the procedure repeated (including re-initializing coarse network synchronization). If the selected candidate Sponsoring Node does advertise the Candidate Node's MAC address, it shall continue to advertise this MAC address in all its MSH-NCFG messages until the sponsorship is terminated.

Once the Candidate Node has received a positive response (a NetEntryOpen message) in from the candidate Sponsoring Node in the MSH-NCFG message, it shall acknowledge the response by transmitting a MSH- NENT NetEntryAck message (a MSH-NENT message with Type set to 0x1) to the Sponsoring Node at the first following network entry transmission opportunity. Before that the Candidate Node shall perform fine time synchronization. It makes a correction to its transmission timing by the Estimated propagation delay indicated in the embedded MSH-NCFG NetEntryOpen message.

If the Sponsoring Node accepted the request and opened a Sponsor Channel, the channel is ready for use immediately after the transmission of the acknowledgement message. At the same the candidate Sponsoring Node becomes the Sponsoring Node.

If the candidate Sponsoring Node embedded a MSH-NCFG NetEntryReject, the new node shall perform the following action based on the rejection code:

0x0: Operator Authentication Value Invalid
The Candidate Node shall select a new candidate Sponsoring Node with a different operator ID.

0x1: Excess Propagation delay
The Candidate Node shall repeat its MSH-NENT:NetEntryRequest in the following network entry transmission opportunity to the same candidate Sponsoring Node.

0x2: Select new sponsor
The Candidate Node shall select a new candidate Sponsoring Node.

If the candidate Sponsoring Node embedded neither MSH-NCFG NetEntryOpen nor MSH-NCFG NetEntryReject, the Candidate Node shall wait (with timeout time T2), for the next MSH-NCFG with NetEntryOpen from the candidate Sponsoring Node and resend the MSH-NENT NetEntryRequest on timeout.

The Candidate Node and the Sponsoring Node use the schedule indicated in the NetEntryOpen message to perform message exchanges described in clauses 6.6.5 through 6.6.10. After this is completed, the Candidate Node shall terminate the entry process by sending a MSH-NENT NetEntryClose message to the Sponsoring Node in the network entry transmission immediately following a MSH-NCFG transmission from the Sponsoring Node, which shall Ack termination with MSH-NCFG NetEntryAck.

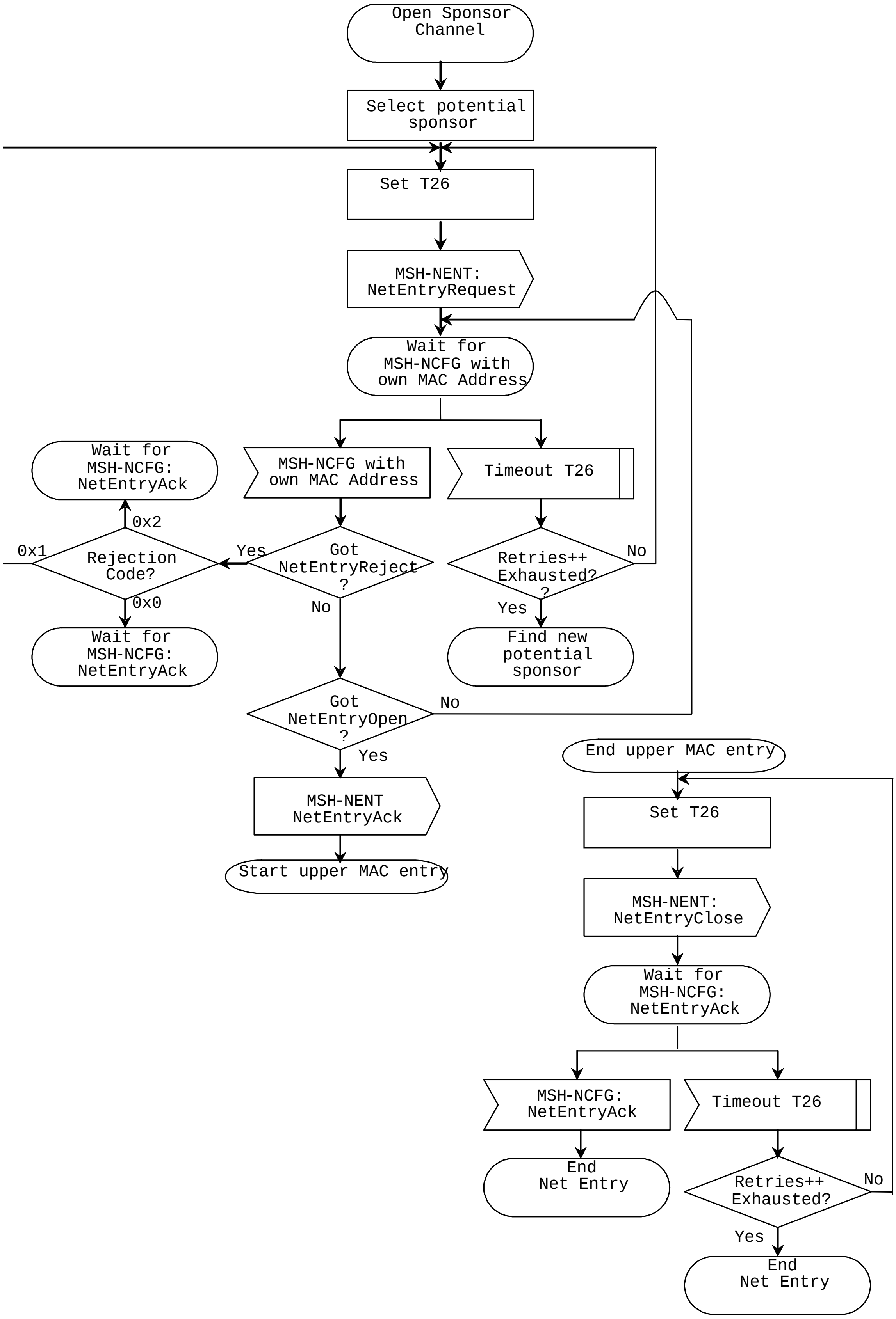


Figure 8: Synchronization and network entry - new node II

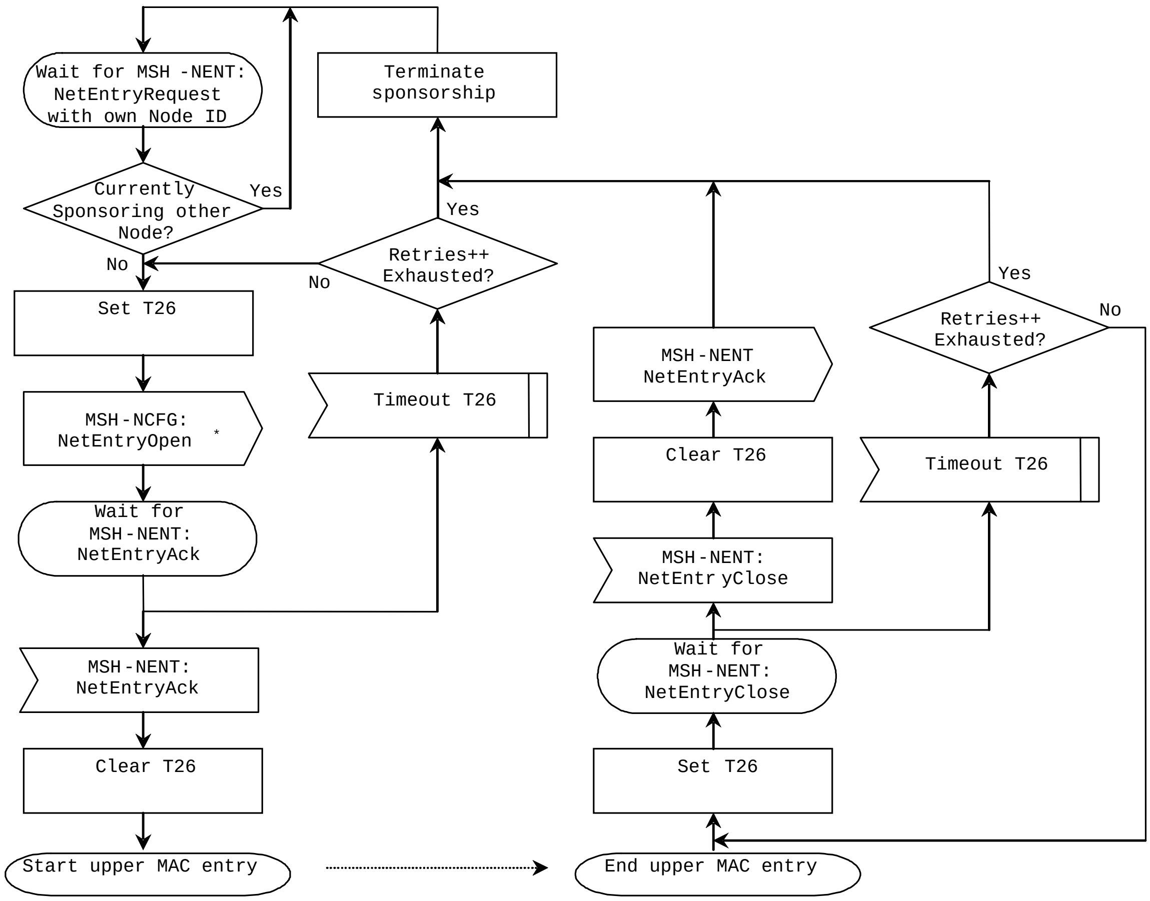


Figure 9: Synchronization and network entry - sponsor node

Table 67 displays the message transfer sequence during a successful network entry without repetitions or time-outs.

Table 67: Network entry successful message exchange

Sponsor node		New node
Nodes in network routinely advertise network with MSH-NCFG:Network Descriptor	MSH-NCFG: Network Descriptor →	
		[detecting MSH-NCFG messages with Network Descriptor] Attempt to enter the network
	← MSH-NENT: NetEntryRequest	
[MSH-NENT NetEntryRequest with own Node ID] Send NetEntryReject or NetEntryOpen with new node's MAC address and schedule allocation for higher layer authentication and configuration exchange	MSH-NCFG: NetEntryOpen →	
	← MSH-NENT: NetEntryAck	Send ACK to confirm schedule
	Security sublayer and basic capability exchange operations	
		After authentication and configuration, close entry procedure
	← MSH-NENT: NetEntryClose	
Acknowledge closure of sponsorship And drop new node's MAC address from subsequent MSH-NCFG messages	MSH-NENT NetEntryAck →	
		New node is now regular node in network

6.6.5 Negotiating basic capabilities

In Mesh Mode, basic capability negotiation is the same as for PMP systems and shall be performed after a logical link has been established. The node which requested the logical link shall act as the SS and initiate the SBC-REQ.

6.6.6 Node Authorization

The new node shall perform authorization in an identical fashion as PMP systems. The new node shall act as the SS. The sponsor node upon reception of the Authent Info and Auth Request shall tunnel the messages as described in to the Authorization Node. The Authorization Node, acting as the BS, shall verify the SS Certificate of the new node and determine whether the new node is authorized to join the Network. Upon receiving tunnelled PKM-RSP MAC Messages from the Authorization Node the Sponsor shall forward the messages to the new node.

6.6.7 Node Registration

Registration is the process by which a node is assigned its Node ID. The sponsoring node upon reception of the REG-REQ shall tunnel the message as described in clause 6.6.1 to the Registration Node. Upon receiving tunnelled REG-RSP MAC Messages from the Registration Node the Sponsor shall forward the messages to the new node. The new node shall follow the procedure in figure 10. The Registration Node shall follow the procedure in figure 11.

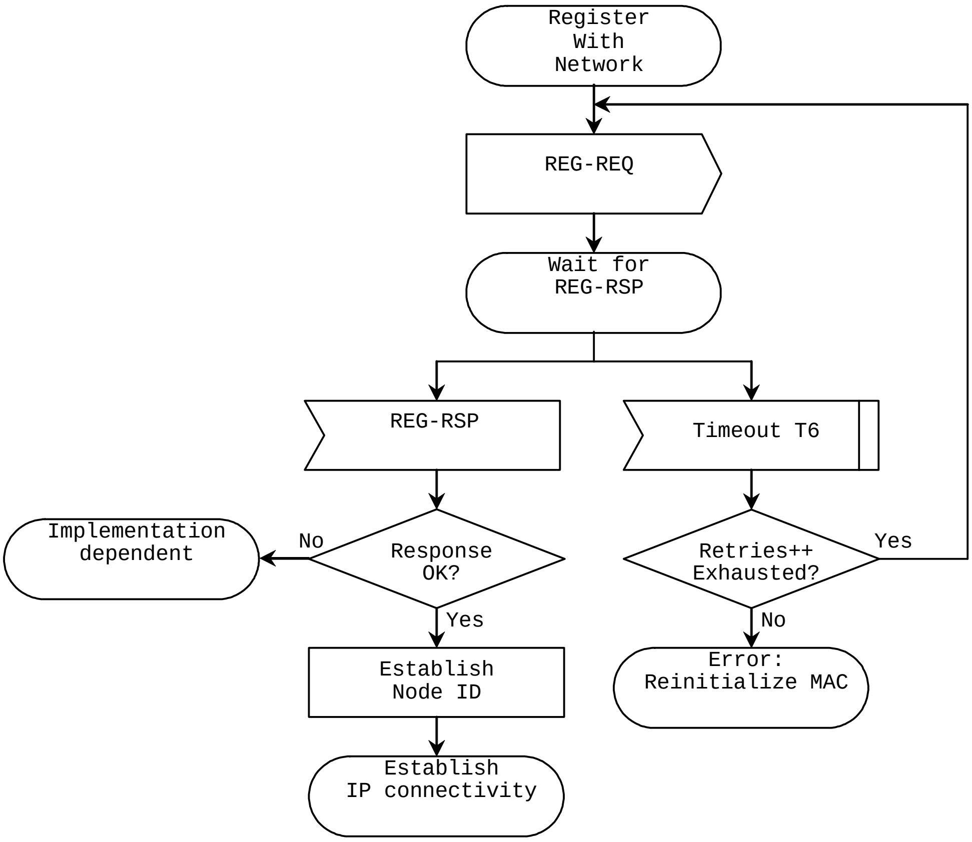


Figure 10: Registration - candidate node

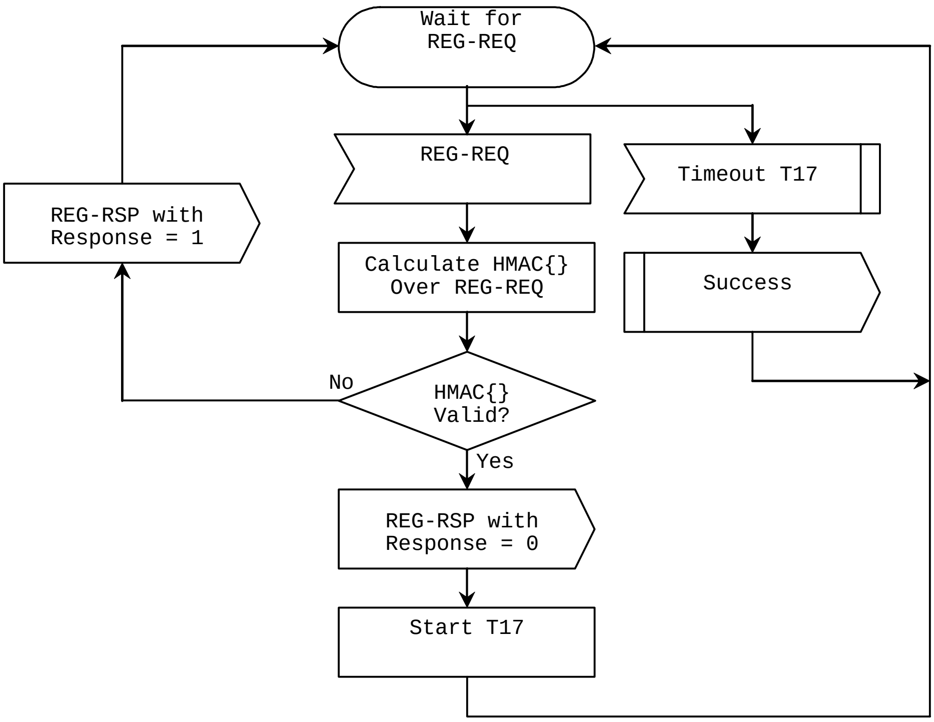


Figure 11: Registration - registration node

6.6.8 Establishing IP connectivity

The node shall acquire an IP address using DHCP in a fashion identical to PMP systems. However, the procedure shall take place over the Sponsor Channel.

6.6.9 Establishing time of day

The node shall retrieve the time of day in a fashion identical to PMP. However, the messages shall be carried over UDP in the Sponsor Channel.

6.6.10 Transfer of operational parameters

After successfully acquiring an IP address via DHCP the node shall download a parameter file using TFTP in a fashion identical to PMP systems. However, the node shall use the Sponsor Channel instead of the Secondary Management connection.

Upon receiving tunnelled REG-RSP MAC Messages from the Provisioning Node the Sponsor shall forward the messages to the Candidate Node.

The following additional configuration file encodings are available:

Name	Type	Length	Value
Authorization Node	22	4 or 16	IP Address of the Authorization Node
Registration Node	23	4 or 16	IP Address of the Registration Node
Provisioning Node	18	4 or 16	IP Address of the Provisioning Node

Using mesh, QoS is provisioned on a packet-by-packet basis using the Mesh CID. The connection-based QoS provisioning using the DSx messages are hence not used. A node obtains its AuthorizedQoSParamSet during the transfer of operational parameters.

6.7 Privacy sublayer

The privacy sublayer for Mesh mode is identical to that of PMP mode with the following exceptions.

6.7.1 TEK exchange overview

Upon achieving authorization, a Node starts for each Neighbour a separate TEK state machine for each of the SAIDs identified in the Authorization Reply message. Each TEK state machine operating within the Node is responsible for managing the keying material associated with its respective SAID. The Node is responsible for maintaining the TEKs between itself and all nodes it initiates TEK exchange with. Its TEK state machines periodically send Key Request messages to the Neighbours of the node, requesting a refresh of keying material for their respective SAIDs.

The Neighbour replies to a Key Request with a Key Reply message, containing the BS's active keying material for a specific SAID.

The Traffic Encryption Key (TEK) in the Key Reply is encrypted, using the node's public key found in the SS-Certificate attribute.

Note that at all times the node maintains two active sets of keying material per SAID per neighbour. The life-times of the two generations overlap such that each generation becomes active halfway through the life of its predecessor and expires halfway through the life of its successor. A neighbour includes in its Key Replies both of an SAID's active generations of keying material.

The Key Reply provides the requesting Node, in addition to the TEK, the remaining lifetime of each of the two sets of keying material. The receiving Node uses these remaining lifetimes to estimate when the Neighbour invalidates a particular TEK, and therefore when to schedule future Key Requests. The transmit regime between the initiating Node and the Neighbour provides for seamless key transition.

6.7.2 Node Re-Authorization

When re-authorizing with the network, the re-authorizing node shall tunnel the authorization messages as shown in figure 6 over UDP.

6.7.3 TEK usage

For each of its SAIDs, the neighbour shall transition between active TEKs according to the following rules:

- At expiration of the older TEK, the neighbour shall immediately transition to using the newer TEK for encryption.
- The neighbour that generated the TEK shall use the older of the two active TEKs for encrypting traffic towards the Node that initiated the TEK.
- The neighbour that generated the TEK shall be able to decrypt traffic from each node using either the older or newer TEK.

For each of its authorized SAIDs, the initiator node shall use the newer of its two TEKs to encrypt traffic towards its neighbours with which it initiated a TEK exchange, and shall be able to decrypt traffic from the neighbour's traffic encrypted with either of the TEKs.

6.7.4 Usage of operator shared key

Each node shall be capable of maintaining two active Operator Shared Secrets. A node shall use the Operator Shared Secret to calculate a HMAC digest for the Key Request and Key Reply messages when exchanging TEKs with its neighbouring nodes.

6.7.5 HMAC authentication keys and calculation of HMAC digests

The HMAC_KEY_S shall be derived as follows:

$$\text{HMAC\_KEY\_S} = \text{SHA}(\text{H\_PAD\_D} \mid \text{Operator Shared Secret}) \tag{15}$$

where H_PAD_D = 0x3A repeated 64 times.

HMAC digests calculated with the key HMAC_KEY_S shall be supported. When calculating the digest with this key the HMAC sequence Number in the HMAC tuple shall be equal to the Operator Shared Secret Sequence Number.

6.8 Data scheduling

Unlike the PMP mode, there are no clearly separate downlink and uplink subframes in the mesh mode. Each station is able to create direct communication links to a number of other stations in the network instead of communicating only with a BS. However, in typical installations, there will still be certain nodes which provide the BS function of connecting the mesh network to the backhaul links. In fact, when using mesh centralized scheduling (described below), these BS nodes perform much of the same basic functions as does the BS in PMP mode. Thus, the key difference is that in mesh mode all the SSs may have a direct links with other SSs. Further, there is no need to have direct link from a SS to the BS of the mesh network. This connection can be provided via other SSs. Communication in all these links shall be controlled by a centralized algorithm (either by the BS or 'decentralized' by all nodes periodically), scheduled in a distributed manner within each node's extended neighbourhood, or scheduled using a combination of these.

6.8.1 Distributed scheduling

The stations with which a station has direct links are called neighbours and shall form a neighbourhood. A node's neighbours are considered to be 'one hop' away from the node. A two-hop extended neighbourhood contains, additionally, all the neighbours of the neighbourhood. In the coordinated distributed scheduling mode, all the stations (BS and SSs) shall coordinate their transmissions in their extended two-hop neighbour-hood.

The coordinated distributed scheduling mode uses some or the entire control portion of each frame to regularly transmit its own schedule and proposed schedule changes on a PMP basis to all its neighbours. Within a given channel all neighbour stations receive the same schedule transmissions. All the stations in a network shall use this same channel to transmit schedule information in a format of specific resource requests and grants.

Coordinated distributed scheduling ensures that transmissions are scheduled in a manner that does not rely on the operation of a BS, and that are not necessarily directed to or from the BS.

Within the constraints of the coordinated schedules (distributed or centralized), uncoordinated distributed scheduling can be used for fast, ad-hoc setup of schedules on a link-by-link basis. Uncoordinated distributed schedules are established by directed requests and grants between two nodes, and shall be scheduled to ensure that the resulting data transmissions (and the request and grant packets themselves) do not cause collisions with the data and control traffic scheduled by the coordinated distributed nor the centralized scheduling methods.

Both the coordinated and uncoordinated distributed scheduling employ a three-way handshake.

1) A MSH-DSCH:Request is made along with MSH-DSCH:Availabilities, which indicate potential slots for replies and actual schedule.

2) A MSH-DSCH:Grant is sent in response indicating a subset of the suggested availabilities which fits, if possible, the request. The neighbours of this node not involved in this schedule shall assume the transmission takes place as granted.

3) A MSH-DSCH:Grant is sent by the original requester containing a copy of the grant from the other party, to confirm the schedule to the other party. The neighbours of this node not involved in this schedule shall assume the transmission takes place as granted.

The differences between coordinated and uncoordinated distributed scheduling is, that in the coordinated case, the MSH-DSCH messages are scheduled themselves in the control subframe in a collision free manner, whereas in the uncoordinated case, MSH-DSCH messages may collide. Nodes responding to a Request should, in the uncoordinated case, wait a sufficient number of minislots of the indicated Availabilities before responding with a grant, such that nodes listed earlier in the Request have an opportunity to respond. The Grant confirmation is sent in the minislots immediately following the first successful reception of an associated Grant packet.

The relevance of the MSH-DSCH is solely defined by the message itself and entirely up to the station transmitting it.

6.8.2 Centralized scheduling

The schedule using centralized scheduling is determined in a more centralized manner than in the distributed scheduling mode.

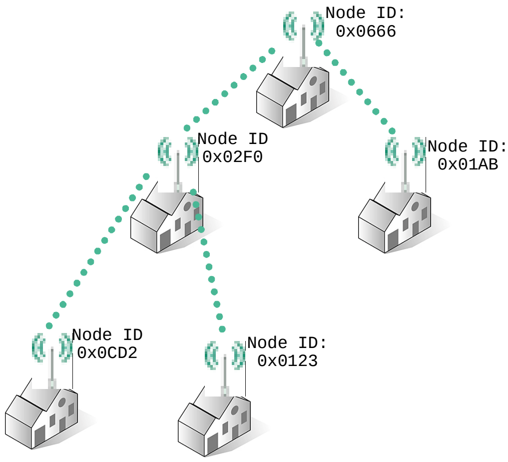
The network connections and topology are the same as in the distributed scheduling mode described in , but some portion of the scheduled transmissions for the SSs less than or equal to HOPRANGE_THRESHOLD hops from the BS shall be either defined by the BS or computed by the SSs themselves. HOPRANGE_THRESHOLD, may be determined at the system start up phase or may be dynamic according to considerations such as network density, the proximity of other BSs, and/or the dynamic characteristics of the traffic streams.

In the basic form, the BS shall provide the schedule for all the SSs less than or equal to HOPRANGE_THRESHOLD hops from the BS. The BS determines the flow assignments from the resource requests from the SSs within the HOPRANGE_THRESHOLD hop range. Subsequently, the SSs themselves determine the actual schedule from these flow assignments by using a common algorithm that divides the frame proportionally to the assignments. Thus the BS acts just like the BS in a PMP network except that not all the SSs have to be directly connected to the BS and the assignments determined by the BS extends also to those SSs not directly connected to the BS but less than HOPRANGE_THRESHOLD hops from it. The SS resource requests and the BS assignments are both transmitted during the control portion of the frame.

Centralized scheduling ensures that transmissions are coordinated to ensure collision-free scheduling over the links in the routing tree to and from the BS, typically in a more optimal manner than the distributed scheduling method for traffic streams (or collections of traffic streams which share links) which persist over a duration that is greater than the cycle time to relay the new resource requests and distribute the updated schedule.

A simple example of the use of the centralized scheduling flow-mechanism in MSH-CSCH is provided. For the network in figure 12, the requested flows are shown. For simplicity of notation, the data rate is assumed to be the burst profile number.

The link fractions shown in figure 13 are multiplied with $2^{\text{FlowScale Exponent}+14}$ (see table 55) and with the Frame Duration, then rounded up to the nearest duration of a whole number of minislots required to transmit this fraction (including preamble).



i	Node ID	Child Indexes
0	0x0666	{1:[r_{u1},r_{d1}], 2:[r_{u2},r_{d2}]}
1	0x02F0	{3:[r_{u3},r_{d3}], 4:[r_{u4},r_{d4}]}
2	0x01AB	{}
3	0x0CD2	{}
4	0X0123	{}

[r_u,r_d] is the burst profile, up and down

Figure 12: MSH-CSCF schedule example

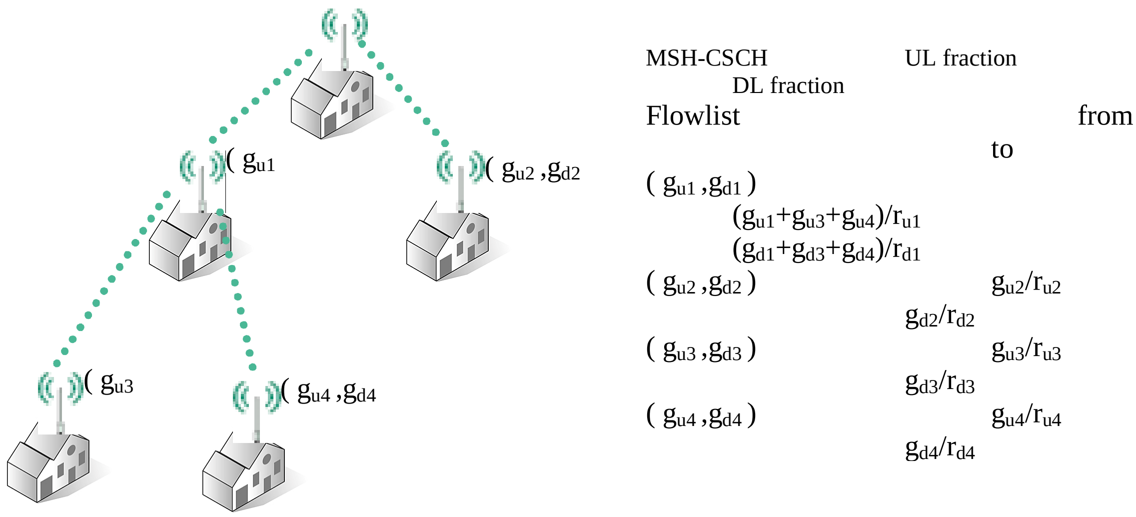


Figure 13: MSH-CSCH flow usage example

The number of frames over which the CSCH schedule is valid is limited by the number of frames it takes to aggregate and distribute the next schedule.

Each node uses the newly received schedule to compute its retransmission time (if eligible) and the last frame when a node will be receiving this schedule, as well as the time when the mesh BS sent it. To compute this, the node uses the routing tree from the last MSH-CSCF messages as modified by the link updates of the last MSH-CSCH message (which dictates the size of MSH-CSCH messages) and the following rules:

- The mesh BS transmits first in a new frame.
- Then, the eligible children of the mesh BS (i.e. nodes with hop count equal 1), ordered by their appearance in the routing tree, transmit.
- Then, the eligible children of the nodes from step 2 (i.e. nodes with hop count equal 2), also ordered by their appearance in the routing tree, transmit.
- …continue until all eligible nodes in the routing tree have transmitted.
- Nodes shall fragment their message if it does not fit entirely before the end of the control subframe and at least the preamble and one data symbol fit.
- All nodes are eligible to transmit the grant schedule, except those that have no children.

- If a node's order requires it to transmit immediately after receiving, a delay of MinCSForwardingDelay µs is inserted.

Each node shall also compute the timing of the uplink requests. Uplink requests start in the last frame in which a node received the previous schedule. All nodes are eligible to transmit requests, except the mesh BS. The request transmission order is reverse in hopcount (i.e. largest hopcount first), but retains the transmission order as listed in the routing tree for nodes with the same hopcount.

The number of frames over which the CSCH schedule is valid is limited by the number of frames it takes to aggregate and distribute the next schedule. The time between the first frame in which a node sends the request schedule and the last frame in which a node receives the new grant schedule marks the validity of the previous grant schedule (see figure 14). This validity time overrides the Frame schedule flag two frame usage at the end of the validity time. Note that MSH-CSCF messages may be sent after the last request is received and before the grant schedule is transmitted by the mesh BS.

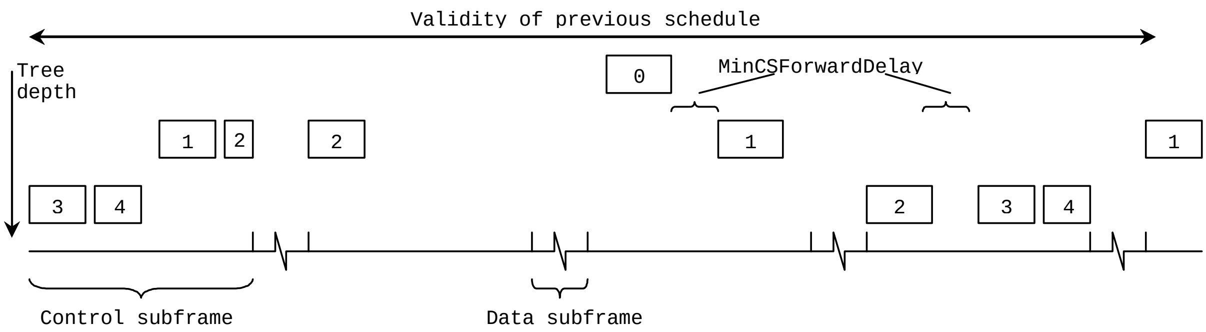


Figure 14: MSH-CSCH schedule validity

7 Adaptive antenna system support

The use of adaptive antenna arrays can improve range and system capacity, by adapting the joint antenna pattern and concentrating its radiation to each individual subscriber. The spectral efficiency can be increased linearly with the number of antenna elements. This is achieved by steering beams to multiple users simultaneously so as to realize an inter-cell frequency reuse of one and an in-cell reuse factor proportional to the number of antenna elements. An additional benefit is the SNR gain realized by coherently combining multiple signals, and the ability to direct this gain to particular users. Another possible benefit is the reduction in interference achieved by steering nulls in the direction of co-channel interferers.

Support mechanisms for AAS are specified, which allow a system to deliver the benefits of adaptive arrays while maintaining compatibility for non-AAS SSs.

The design of the AAS option provides a mechanism to migrate from a non-AAS system to an AAS enabled system, in which the initial replacement of the non-AAS capable BS by an AAS capable BS should cause the only service interruption to (non-AAS) SSs.

This is achieved by dedicating part of the frame to non-AAS traffic and part to AAS traffic. The allocation is performed dynamically by the BS. Non-AAS SSs shall ignore AAS traffic, which they can identify based on the DL-MAP/UL-MAP messages. AAS enabled SSs use dedicated private DL-MAP/ UL-MAP messages and are therefore prevented from colliding with non-AAS traffic.

Special considerations apply to those parts of the frame that are not scheduled, e.g. initial-ranging and BW-request, as discussed in clauses 7.3 and 7.5.

7.1 DLC control functions

The control of AAS part of the frame shall be done by unicasting private management messages to individual SSs. These messages (DL-MAP, UL-MAP, DCD, UCD and CLK-CMP) shall be the same as the broadcast MAC Management messages, except that the basic CID assigned to the SS is used instead of the Broadcast CID.

7.2 DL synchronization

When the SS first attempts to synchronize to the DL transmission, the BS is unaware of its presence, and therefore is not aiming the adaptive array at its direction. Nevertheless, the frame preamble defined in TS 102 177 [3] is a repetitive well-known pattern, and SS may utilize the inherent processing gain associated with it in order to synchronize timing and frequency parameters with the BS.

7.3 Initial ranging

In an AAS system, a SS may be able to obtain the DL parameters if it receives the broadcast channel with enough energy so it can decode the DL-MAP and DCD messages. If this is the case, the SS can continue with the network entry process just like the non-AAS case, and the BS will get the chance to tune the adaptive array to it during the ranging process. Alternatively, an AAS SS may use the following procedure to alert the BS to its presence, so the BS can adapt its antenna array to the SS position.

For AAS SS that are not able to initially decode the broadcast messages, a procedure is defined for them to alert the BS to their presence, so the BS can adapt the adaptive array to their position.

An AAS-enabled BS may reserve initial-ranging contention slots for this alert procedure. The number of contention slots and their location in the frame is defined in clause 8.2 of TS 102 177 [3]. These contention slots shall be called AAS-alert-slots.

AAS-enabled SSs not capable of decoding the DL broadcast messages shall use all available contention slots for initial ranging, in order to allow the BS adaptive array enough time and processing gain to shape the beam for it. After such an attempt the SS shall wait for a private DL-MAP and private DCD messages from the BS, and shall continue the network entry process like a non-AAS SS. If the private DL-MAP and DCD messages fail to arrive, the SS shall use an exponential backoff algorithm for selecting the next frame in which to attempt alerting the BS to its presence.

7.4 Channel state information

Adaptive array systems require channel state information. This information can be derived by relying on reciprocity of the channel or by using feedback messages. An AAS BS may use either method with TDD duplexing, and shall use the feedback messages with FDD duplexing. A SS shall be capable of provisioning feedback responses.

The feedback method shall use two MAC control messages: AAS-FBCK-REQ and AAS-FBCK-RSP. The request instructs the SS to measure, the results of which shall be returned in the response after the measurement period has ended. The BS shall provide an UL allocation to enable the SS to transmit this response.

7.5 Bandwidth requests

AAS subscribers might not be able to request bandwidth using the usual contention mechanism. This happens because the BS's adaptive array may not have a beam directed at the SS when it is requesting BW, and the BW request will be lost. In order to avoid this situation, an AAS SS is directed by the BS as to whether or not it may use broadcast allocations for requesting bandwidth. The BS may change its direction dynamically using a TLV called ALLOW_BCAST_REQ, which is carried by the RNG-RSP message. The SS shall signify by using the CAN_RCV_BCAST TLV in the RNG_REQ message whether or not it can receive the broadcast messages.

When a SS is directed not to use the broadcast CID to request bandwidth, it is the responsibility of the BS to provide a polling mechanism to learn about the SS bandwidth requirements.

Note that AAS-enabled BSs are capable of receiving polled bandwidth requests from multiple AAS-enabled SS simultaneous, because multiple beams can be simultaneously formed.

8 Ranging

The following specification shall apply instead of clause 6.2.10 in IEEE P802.16-2001 [1]. However, the DL burst profile management clause 6.2.10.1 remains applicable. Clauses 8.1 and 8.2 also supplement clause 6.2.95 in IEEE P802.16-2001 [1].

8.1 Initial ranging

The SS shall calculate the maximum transmit signal strength for initial ranging from:

$$P_{TX\_IR\_MAX} = EIRxP_{IR,max} + BS_{EIRP} - RSS \qquad (16)$$

where the $EIRxP_{IR,max}$ and BS_EIRP are obtained from the DCD and RSS is the measured RSSI, by the SS.

Note that $EIRxP_{IR,max}$ is the maximum equivalent isotropic received power, which is computed for a simple single-antenna receiver as $RSS_{IR,max}$ - $G_{ANT\_BS\_Rx}$, where the $RSS_{IR,max}$ is the received signal strength at the antenna input and $G_{ANT\_BS\_Rx}$ is the receive antenna gain. The BS_{EIRP} is the equivalent isotropic radiated power of the base station, which is computed for a simple single-antenna transmitter as $P_{Tx} + G_{ANT\_BS\_Tx}$, where P_{Tx} is the transmit power and $G_{ANT\_BS\_Tx}$ is the transmit antenna gain.

The SS shall send the RNG-REQ at a power level below $P_{TX\_IR\_MAX}$, measured at the antenna connector.

If the SS does not receive a response, it shall resend it at the next Initial Maintenance transmission opportunity at one step higher power level. If the SS receives a response that contains the frame number in which the RNG-REQ was transmitted, but does not contain its Mac Address, it shall consider the transmission attempt unsuccessful but implement the corrections specified in the RNG-RSP and issue another RNG-REQ message after the appropriate back-off delay. If the SS receives a response containing its MAC Address, is shall consider the RNG-RSP reception successful.

SSs which compute their $P_{TX\_IR\_max}$ to exceed their maximum power level and SSs which have attempted initial ranging with the maximum power level using RNG-REQ may, if the BS supports sub-channelization, attempt sub-channelized initial ranging (see TS 102 177 [3]).

When the BS detects a transmission in the ranging slot that it is unable to decode (including sub-channelized transmissions, it may respond by transmitting a RNG-RSP that includes transmission parameters but identifies the Frame Number and Initial Ranging Opportunity Number when the transmission was received instead of the MAC Address of the transmitting SS.

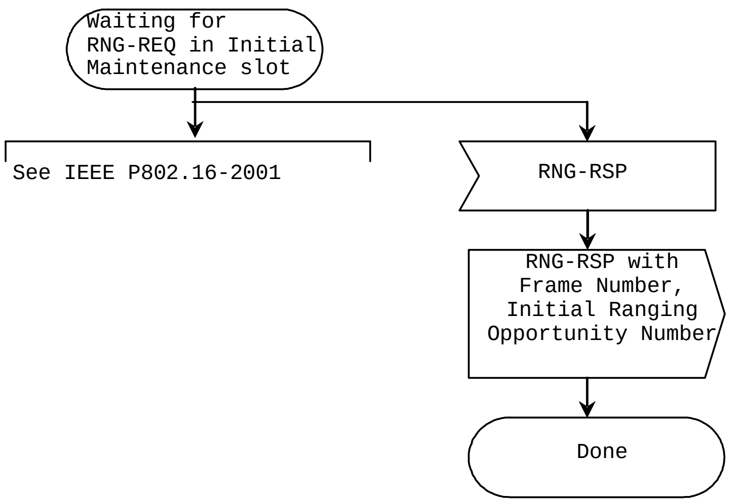


Figure 15: Initial ranging - BS

Table 68: Ranging and automatic adjustment procedure

Sponsor node		New node
[Time to send the Initial Maintenance interval] Send map containing Initial Maintenance IE with a broadcast CID.	UL-MAP →	
	← RNG-REQ	Transmit ranging packet in contention mode with CID = 0.
[Detect un-decodable RNG-REQ] Send response including Frame Number, Initial Ranging Opportunity Number, CID = 0.	RNG-RSP →	
		[Recognize Frame Number/ Opportunity when RNG-REQ was send] Adjust parameters according to RNG-RSP.
[Time to send the Initial Maintenance interval] Send map containing Initial Maintenance IE with a broadcast CID.	UL-MAP →	
	← RNG-REQ	Transmit ranging packet in contention mode with CID = 0.
[Detect decodable RNG-REQ] Allocate Basic and Primary Management CID and add Basic CID to poll list. Send response including SS MAC Address, Basic CID		
	RNG-RSP →	
		[Recognize own MAC Address] Store Basic CID and adjust parameters according to RNG-RSP.
[time to send next map] send map with Station Management IE to SS using Basic CID	UL-MAP →	
	← RNG-REQ	[Recognize own Basic CID] reply to Station Management opportunity poll.
Send ranging response	RNG-RSP →	Adjust local parameters.
Send periodic transmit opportunity to broadcast address	UL-MAP →	

8.2 Periodic ranging

Two different ranging procedures shall be supported: initial ranging and periodic ranging. Initial ranging, which is described as part of the network entry and initialization process, serves to allow a new SS to acquire correct transmission parameters, such as time offset and Tx power level, so that the new SS can communicate with the BS properly. Periodic ranging serves to allow SSs to adjust transmission parameters during normal operations so that the SSs can communicate with the BS properly. Diagrams for periodic ranging are shown in figures 16, 17 and 18.

The following summarizes the periodic ranging:

1) Both the BS and the SSs shall use a timer T4 for periodic ranging and set the Initial Ranging timer T3 after a RNG-REQ message has been sent.

2) The periodic ranging shall be conducted periodically at an interval sufficiently shorter than T4 that a map could be missed without the SS timing out. Any allocation to an SS constitutes a periodic ranging opportunity.

3) A periodic ranging procedure can be originated by either the BS or the SSs.

   - The BS can originate a periodic ranging procedure by sending an unsolicited RNG-RSP with adjustments based on any UL transmission it received from the SS.

- A SS can originate a periodic ranging procedure by sending a RNG-REQ message in an allocation of UL bandwidth or a contention-based initial ranging slot. Upon receiving this RNG-REQ message, the BS shall send a RNG-RSP to the SS.

4) Upon receiving a RNG-RSP message, the SS shall adjust the indicated transmission parameters accordingly and clear timer T3.

5) The SS shall re-initialize its MAC sublayer (and re-register) when T3 expires and the number of RNG-REQ retries has been exceeded and when the Ranging Status indicates Abort.

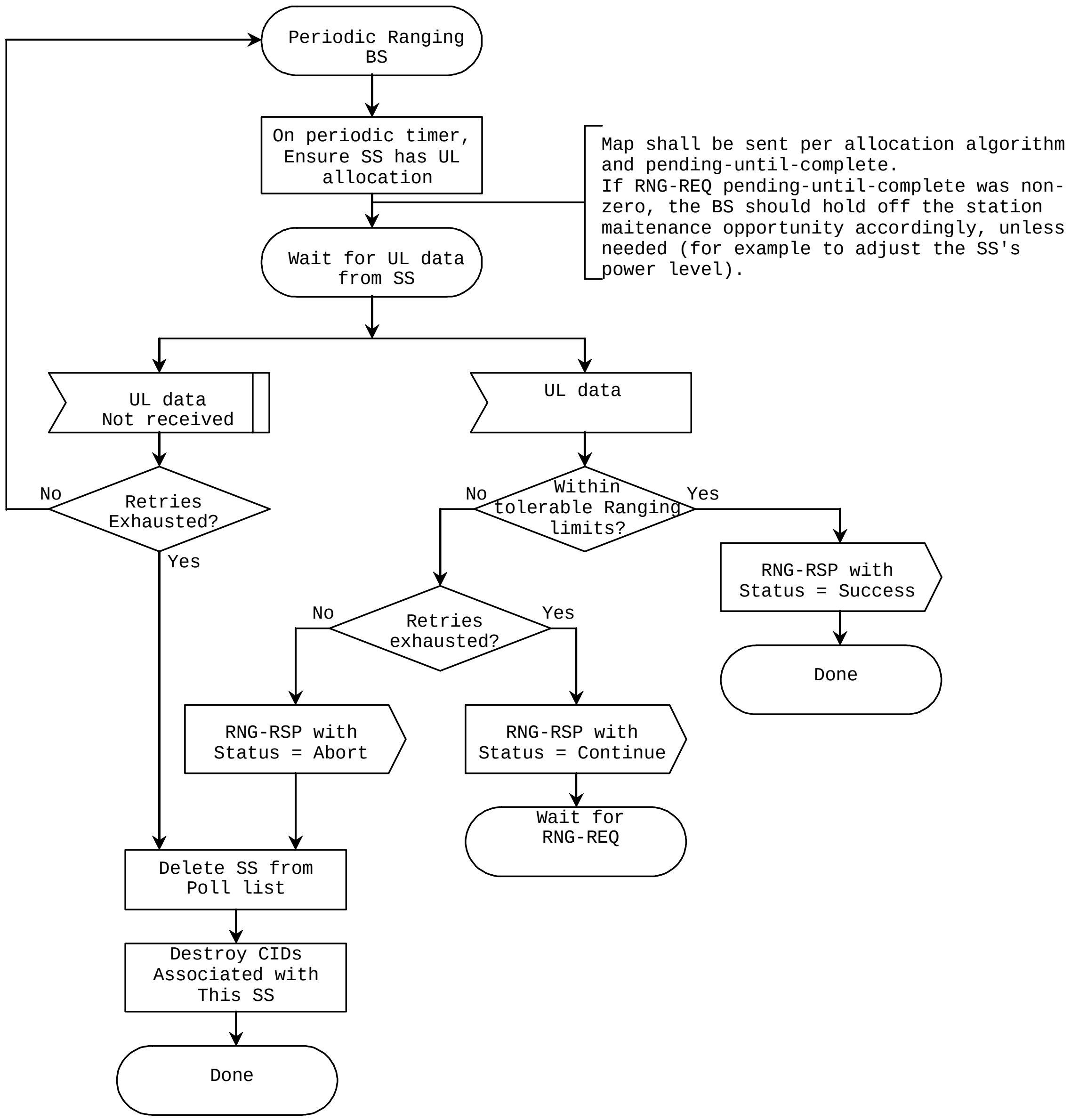


Figure 16: Periodic ranging - BS

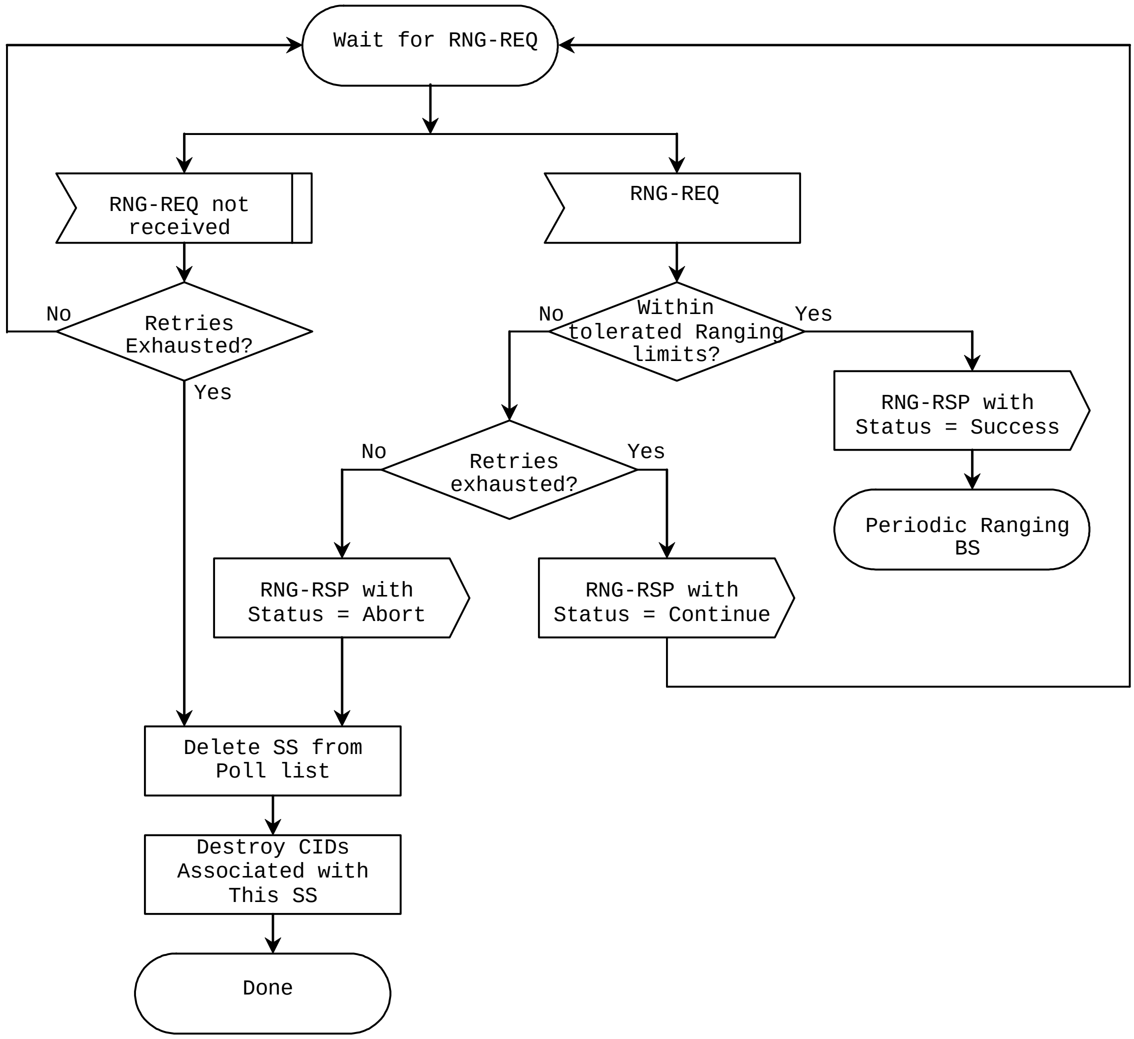


Figure 17: Periodic ranging - BS: Waiting for RNG-REQ

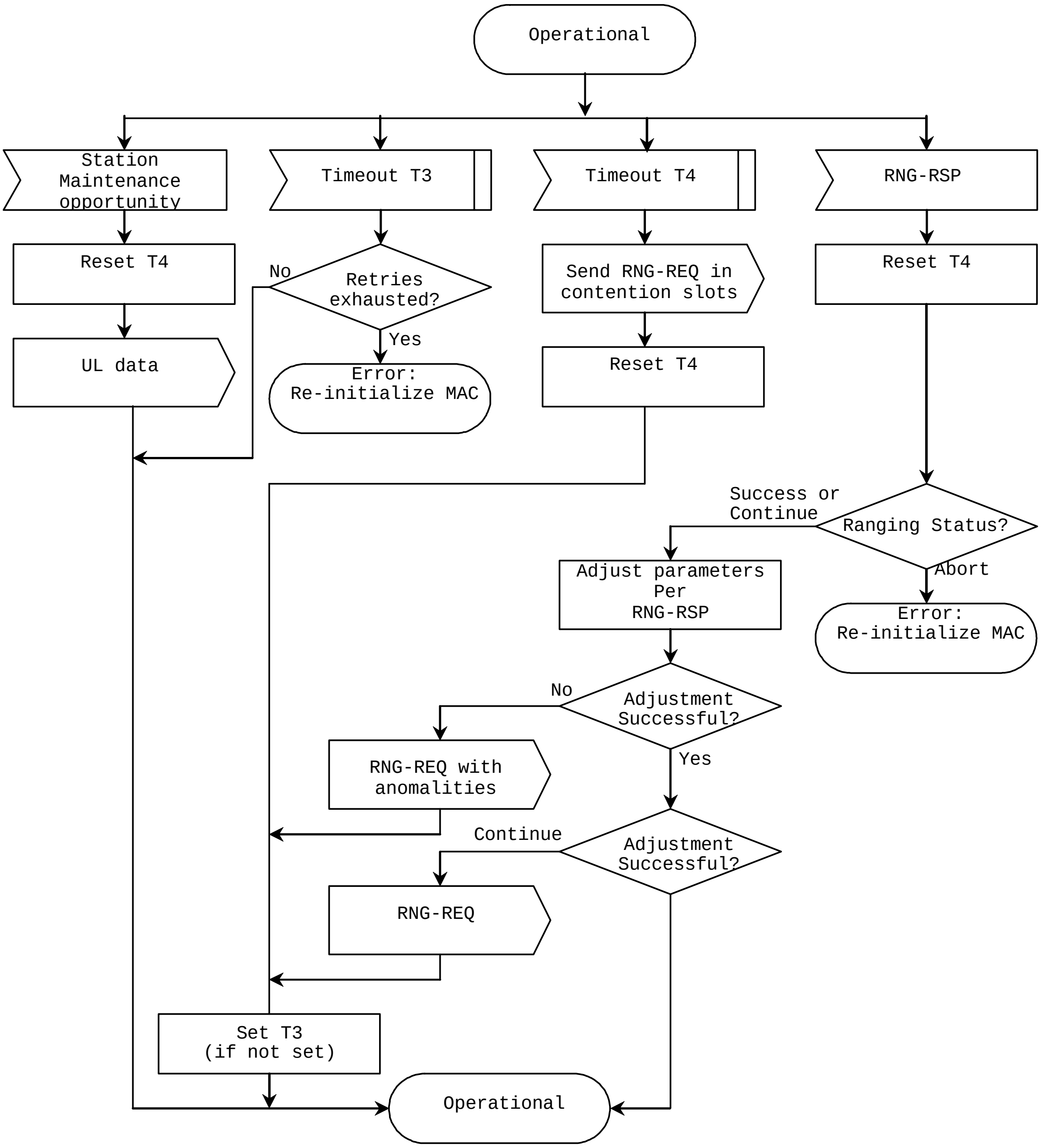


Figure 18: Periodic ranging - SS

9 Bandwidth allocation and request mechanism

A compliant device shall not support the GPC mode as defined in IEEE P802.16-2001 [1].

9.1 Contention-based BW requests for OFDM PHY

The OFDM PHY supports two contention-based BW request mechanisms. The mandatory mechanism allows the SS to send the Bandwidth Request Header as specified in IEEE P802.16-2001 [1] during a REQ Region-Full.

Alternatively, the SS may send a Focused Contention Transmission during a REQ Region-Focused. This transmission uses the Focused Contention transmission, described in clause 7.3.3. One of the codes in table 12 will be randomly selected. The signal will be transmitted on a randomly selected TO, within time-frequency defined focused contention transmission window.

Upon detection, the BS shall provide a UL allocation for the SS to transmit a BW request MAC PDU, but instead of indicating a Basic CID, the broadcast CID shall be sent in combination with an OFDM Focused_Contention_IE, which specifies the Contention Channel, Contention Code and Transmit Opportunity which were used by the SS. This allows a SS to determine whether it has been given an allocation by matching these parameters with the parameters it used. In addition to the BW request header, the SS may send data as well.

If the BS does not issue the UL allocation described above, or the BW request MAC PDU does not result in a subsequent allocation of any bandwidth, the SS shall assume that the Focused Contention Transmission resulted in a collision and follow the contention resolution as specified in clause 6.2.8 of IEEE P802.16-2001 [1].

10 Other

10.1 Service definition: Usage of MAC_create_connection.request for multicast

This clause supplements clause 6.1.1.1 of IEEE P802.16-2001 [1].

For a downlink multicast service, a MAC_CREATE_CONNECTION.request is issued by the CS at the BS for each SS that is associated with the service. An individual request contains the MAC Address of the SS to which the connection establishment is directed. It is stimulated by either the entry of the SS into the system or the provisioning of the service flow if this happens after the SS enters the system.

After the BS MAC receives such a request, it establishes a DL MAC connection with the SS via a DSA-REQ message, using the CID associated with the multicast connection. All SSs involved in a multicast connection shall process the data transmitted on the connection with the given CID. Since a multicast connection is associated with a Service Flow, it is associated with the QoS and traffic parameters for that service flow. ARQ shall not be used on multicast connections.

If a DL multicast connection is to be encrypted, each SS participating in the connection shall have an additional SA, allowing that connection to be encrypted using keys that are independent of those used for other encrypted transmissions between the SSs and the BS.

10.2 Fragmentation

This clause supplements clause 6.1.1.1 of IEEE P802.16-2001 [1].

The maximum size of a fragment may be negotiated during or after connection establishment. When a maximum value has been established, the transmitter shall only form fragments whose length is less than or equal to this value even if the pending bandwidth allocation would accept a larger fragment.

This value of the MAX_FRAGMENT_LENGTH TLV specifies the maximum size fragment a transmitter shall ever form or a receiver shall ever expect to receive. Valid values are 32 bytes to 2 041 bytes. A value of zero indicates no restriction. It is established by negotiation during the connection creation and connection change dialogs. The requester includes its desired setting in the REQ message. The receiver of the REQ message shall take the smaller of the value it prefers and value in the REQ message. This minimum value is included in the RSP message and becomes the agreed upon length value. Absence of the parameter during a DSA dialog shall indicate the originator of the message desires the maximum value. Absence of the parameter during a DSC dialog indicates the current setting shall remain in force.

Table 69: Maximum fragment length TLV

Name	Type	Length	Value	Scope
MAX_FRAGMENT_LENGTH	[24/25].23	2	0 - 31 Reserved 32-2 040 Maximum length in bytes	DSA-REQ DSA-RSP DSC-REQ DSC-RSP

10.3 Map relevance and synchronization

This clause supplements clause 6.2.7.6.1 of IEEE P802.16-2001 [1].

All the timing information in the DL-MAP and UL-MAP is relative. The following time instants are used as a reference for the timing information

- DL-MAP: the start of the first symbol (including the pre-amble if present) of the burst where the message is transmitted.
- UL-MAP: the start of the first symbol (including the pre-amble if present) of the burst where the message is transmitted + Allocation Start Time value.

The Maximum Map Pending shall be the end of the subsequent frame.

10.4 CID allocations

There are several CIDs defined in table 70 that have specific meaning. These identifiers shall not be used for any other purposes.

Table 70: CID allocations

CID	Value	Description
Initial Ranging	0x0000	Used by an SS during initial ranging as part of initial ranging process.
Basic	0x0001-*m*	
Primary Management	*m*+1-2*m*	
Transport and Secondary Management	2*m*+*1*-0xFEFE	
AAS Initial Ranging	0xFEFF	
Multicast Polling	0xFF00-0xFFFD	An SS may be included in one or more multicast groups for the purposes of obtaining bandwidth via polling. These connections have no associated Service Flow.
Padding	0xFFFE	Used for transmission of padding information.
Broadcast	0xFFFF	Used for broadcast information that is transmitted on a DL to all SS.

10.5 Configuration file encodings - TEK encryption identifiers

The following TEK encryption algorithm identifiers are defined.

Table 71: TEK encryption algorithm identifiers

Value	Description
0	Reserved
1	3-DES EDE with 128-bit key
2	RSA with 1 024 bit key
3-255	Reserved

10.6 Global values

This clause supplements clause 10.1 of IEEE P802.16-2001 [1]. Systems shall meet the additional timing requirements contained in table 72.

Table 72: Global values

System	Name	Time reference	min	Default	Max
BS	Max. Map Pending	Maximum validity of map.			End next frame
BS,SS	SS DL management message processing time	Max. time between transmission of management message by BS and compliance to its instructions by SS.			200 µs
BS	SBC Request retries		3	3	16
BS	TFTP-CPLT retries		3	3	16
SS, BS	T22	Wait for ARQ-Reset.			0,5 s
SS	T23	Wait for TFTP-RSP.			0,5 s
Mesh node	T24	Network Entry: Detect network.	1 s		
Mesh node	T25	Network Entry: Accumulate MSH-NCFG messages.		120 s	
Mesh node	T26	Network Entry: Wait for MSH-NENT / MSH-NCFG.		1 s	

10.7 Additional encodings

10.7.1 DLC version encodings

The value of this field specifies a list of matching values for the IPv6 Flow label field. As the flow label field has a length of 20 bits, the first 4 bits of the most significant byte shall be set to 0x0 and disregarded.

Table 73: DLC version encoding TLV

Name	Type	Length	Value	Scope
DLC version	16	1	Version of the DLC supported on this channel. The current version is 1.	REG-REQ REG-RSP DCD

10.7.2 Additional packet classification rules

Table 74: IPv6 flow label

Name	Type	Length	Value
IPv6 Flow Label	[24/25].100.9.14	n×3	Flow Label 1 … Flow label n

History

Document history		
V1.1.1	November 2003	Publication