

802.16a™

IEEE Standard for
Local and metropolitan area networks

Part 16: Air Interface for Fixed Broadband Wireless Access Systems— Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2–11 GHz

IEEE Computer Society
and the
IEEE Microwave Theory and Techniques Society

Sponsored by the
LAN/MAN Standards Committee



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Approved 29 January 2003
IEEE-SA Standards Board

Abstract: This document amends IEEE Std 802.16-2001 by enhancing the medium access control layer and providing additional physical layer specifications in support of broadband wireless access at frequencies from 2–11 GHz. The resulting standard specifies the air interface of fixed (stationary) broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layer specifications optimized for the frequency bands of application. The standard includes particular physical layer specifications applicable to systems operating between 2 and 66 GHz. It supports point-to-multipoint and optional mesh topologies.

Keywords: broadband wireless access network, metropolitan area network, microwave, WirelessMAN™ standards

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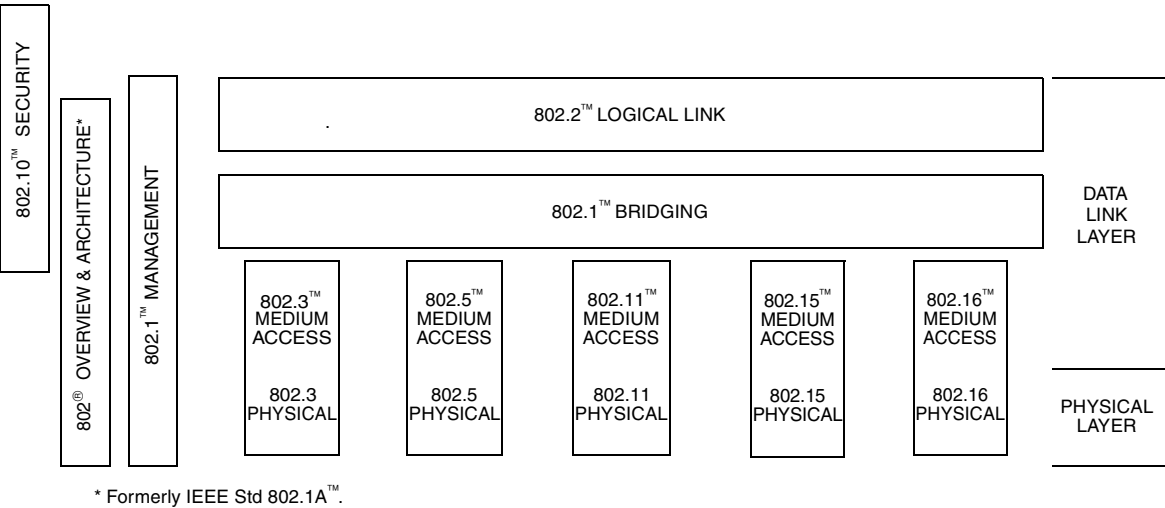
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Introduction

(This introduction is not part of IEEE Std 802.16a-2003, IEEE Standard for Local and metropolitan area networks—Part 16: Air Interface for Fixed Broadband Wireless Access Systems—Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2–11 GHz.)

This amendment expands the scope of IEEE Std 802.16-2001 by extending the WirelessMAN_U air interface to address operational frequencies from 2–11 GHz. It provides new physical-layer specifications and also includes appropriate enhancements to the base standard’s point-to-multipoint medium access control layer (MAC). In addition, it specifies an optional Mesh topology enhancement to the MAC.

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard designations.¹)



This family of standards deals with the Physical and Data Link Layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection Basic Reference Model (ISO/IEC 7498-1:1994). The access standards define several types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining the technologies noted above are as follows:

- IEEE Std 802:²
Overview and Architecture. This standard provides an overview to the family of IEEE 802 Standards. This document forms part of the IEEE Std 802.1 scope of work.
- IEEE Std 802.1B™ and 802.1k™ [ISO/IEC 15802-2]:
LAN/MAN Management. Defines an Open Systems Interconnection (OSI) management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.

¹The IEEE standard designations referred to in the above figure and list are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

²The IEEE 802 Overview and Architecture Specification, originally known as IEEE Std 802.1A, has been renumbered as IEEE Std 802. This has been done to accommodate recognition of the base standard in a family of standards. References to IEEE Std 802.1A should be considered as references to IEEE Std 802.

- IEEE Std 802.1D™ *Media Access Control (MAC) Bridges.* Specifies an architecture and protocol for the [ISO/IEC 15802-3]: interconnection of IEEE 802 LANs below the MAC service boundary.

- IEEE Std 802.1E™ [ISO/IEC 15802-4]: *System Load Protocol.* Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.

- IEEE Std 802.1F™ *Common Definitions and Procedures for IEEE 802 Management Information.*

- IEEE Std 802.1G™ [ISO/IEC 15802-5]: *Remote Media Access Control (MAC) Bridging.* Specifies extensions for the interconnection, using non-LAN systems communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.

- IEEE Std 802.1H™ [ISO/IEC TR 11802-5]
• IEEE Std 802.1Q™ *Recommended Practice for Media Access Control (MAC) Bridging of Ethernet V2.0 in IEEE 802 Local Area Networks. Virtual Bridged Local Area Networks.* Defines an architecture for Virtual Bridged LANs, the services provided in Virtual Bridged LANs, and the protocols and algorithms involved in the provision of those services.

- IEEE Std 802.2 [ISO/IEC 8802-2]: *Logical Link Control.*

- IEEE Std 802.3 [ISO/IEC 8802-3]: *CSMA/CD Access Method and Physical Layer Specifications.*

- IEEE Std 802.5 [ISO/IEC 8802-5]: *Token Ring Access Method and Physical Layer Specifications.*

- IEEE Std 802.10: *Standard for Interoperable LAN Security (SILS).* Currently approved: Secure Data Exchange (SDE).

- IEEE Std 802.11: [ISO/IEC 8802-11] *Wireless LAN Medium Access Control (MAC) Sublayer and Physical Layer Specifications.*

- IEEE Std 802.15: *Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for: Wireless Personal Area Networks.*

- IEEE Std 802.16: *Air Interface for Fixed Broadband Wireless Access Systems.*

The reader of this standard is urged to become familiar with the complete family of standards.

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An additional standards series, identified by the number 1802™, has been established to identify the conformance test methodology documents for the IEEE 802 family of standards. For example, the conformance test documents for IEEE 802.3 are numbered 1802.3™. Traditionally, ISO will use 18802 to number conformance test standards for 8802 standards.

Interpretations and errata

Interpretations and errata associated with this amendment may be found at one of the following Internet locations:

- <http://standards.ieee.org/reading/ieee/interp/>
- <http://standards.ieee.org/reading/ieee/updates/errata/>

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IEEE Standard for
Local and metropolitan area networks

Part 16: Air Interface for Fixed Broadband
Wireless Access Systems—

Amendment 2: Medium Access Control
Modifications and Additional Physical Layer
Specifications for 2–11 GHz

EDITORIAL NOTE—The editing instructions contained in this amendment define how to merge the material contained herein into the existing base standard (IEEE Std 802.16™-2001) to form the comprehensive standard.

The editing instructions are shown ***bold italic***. Four editing instructions are used: ***change***, ***delete***, ***insert***, and ***replace***. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~striketrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

1.1 Scope

Replace first paragraph with the following:

This standard specifies the physical layer (PHY) and medium access control layer (MAC) of the air interface of interoperable point-to-multipoint and optional Mesh topology broadband wireless access systems. The specification enables access to data, video, and voice services with a specified quality of service. The medium access control layer is structured to support multiple PHY specifications, each suited to a particular operational environment, both in licensed bands designated for public network access and in license-exempt bands. It applies to systems operating between 2 and 66 GHz, where such services are permitted.

Insert at end of 1.1:

Where optional Mesh systems are addressed, a system consists of an IEEE 802.16 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.

Replace 1.2.2 with the following:

1.2.2 2–11 GHz licensed bands

The 2–11 GHz bands provide a physical environment where, due to the longer wavelength, LOS is not necessary and multipath may be significant. The ability to support near- and non-line-of-sight scenarios requires additional PHY functionality, such as the support of advanced power management techniques, interference mitigation/coexistence and multiple antennas.

Additional MAC features are also introduced, such as ARQ on a per-connection basis to deal with the inherent lossy behavior of the wireless medium, and the support of Mesh topology.

Insert 1.2.3 and 1.2.4:

1.2.3 2–11 GHz license-exempt bands (primarily 5–6 GHz)

The physical environment for the 2–11 GHz license-exempt bands is similar to that of 2–11 GHz licensed bands as described in 1.2.2. However, the license-exempt nature introduces additional interference and coexistence issues, whereas regulatory constraints limit the allowed radiated power. In addition to the features described in 1.2.2, the PHY and MAC introduce mechanisms such as DFS to detect and avoid interference.

1.2.4 Air interface nomenclature and PHY compliance

Table 0a summarizes the nomenclature for the various air interface specifications in this standard.

Table 0a—Air interface nomenclature

Designation	Applicability	PHY specification	Additional MAC requirements	Options	Duplexing alternative
WirelessMAN-SC	10–66 GHz	8.2			TDD FDD
WirelessMAN-SCa	2–11 GHz licensed bands	8.3		AAS (6.2.7.7) ARQ (6.2.4) STC (8.3.3)	TDD FDD
WirelessMAN-OFDM	2–11 GHz licensed bands	8.4		AAS (6.2.7.7) ARQ (6.2.4) Mesh (6.2.6.7) STC (8.4.7)	TDD FDD
WirelessMAN-OFDMA	2–11 GHz licensed bands	8.5		AAS (6.2.7.7) ARQ (6.2.4) STC (8.5.8)	TDD FDD
WirelessHUMAN	2–11 GHz license-exempt bands	[8.3, 8.4 or 8.5] and 8.6	DFS (6.2.14)	AAS (6.2.7.7) ARQ (6.2.4) Mesh (6.2.6.7) (with 8.4 only) STC (8.3.3/8.4.7/8.5.8)	TDD

All implementations of this standard shall comply with the requirements of Clause 6 and Clause 7.

Implementations of this standard for any applicable frequencies between 10 and 66 GHz shall comply with the WirelessMAN-SC PHY as described in 8.2.

Implementations of this standard for licensed frequencies between 2 and 11 GHz (such as those listed in B.1) shall comply with the WirelessMAN-SCa PHY as described in 8.3, the WirelessMAN-OFDM PHY as described in 8.4, or the WirelessMAN-OFDMA PHY as described in 8.5.

Implementations of this standard for license-exempt frequencies between 2 and 11 GHz (such as those listed in B.1) shall comply with the WirelessMAN-SCa PHY as described in 8.3, the WirelessMAN-OFDM PHY as described in 8.4, or the WirelessMAN-OFDMA PHY as described in 8.5. They shall further comply with the DFS protocols (6.2.14) and with 8.6.

3. Definitions

Change 3.1, delete 3.20 and 3.21, and insert the following definitions. Subsequently re-sort and re-number alphabetically.

3.1 bandwidth stealing: The 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. ~~See also: grant per subscriber station.~~

3.20 ~~grant per connection (GPC):~~ A bandwidth allocation method in which grants are allocated to a specific connection within a subscriber station. ~~Note that bandwidth requests are always made for a connection.~~

3.21 ~~grant per subscriber station (GPSS):~~ A bandwidth allocation method in which grants are aggregated for all connections within a subscriber station and are allocated to the subscriber station as that aggregate. ~~Note that bandwidth requests are always made for a connection.~~

3.57 adaptive modulation: A 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.

3.58 adaptive antenna system (AAS): A system adaptively exploiting more than one antenna to improve the coverage and the system capacity.

3.59 ARQ Fragment: A distinct unit of data that is carried on an ARQ-enabled connection. Such a unit is assigned a sequence number, and is managed as a distinct entity by the ARQ state machines. An ARQ fragment may be a complete SDU or may be a portion of an SDU that has been partitioned in accordance with the MAC rules for SDU fragmentation.

3.60 carrier index: An index number identifying a particular used carrier in an OFDM or OFDMA signal. Carrier indices are greater than or equal to zero.

3.61 DC carrier: In an OFDM or OFDMA signal, the carrier whose frequency would be equal to the RF center frequency of the station.

3.62 dynamic frequency selection (DFS): The ability of a system to switch to different physical RF channels between transmit and receive activity based on channel measurement criteria.

3.63 frequency offset index: An index number identifying a particular carrier in an OFDM or OFDMA signal, which is related to its carrier index. Frequency offset indices may be positive or negative.

3.64 Mesh (MSH): Network architecture, wherein systems are capable of forwarding traffic from and to multiple other systems.

3.65 RF center frequency: The center of the frequency band in which a BS or SS is intended to transmit.

3.66 Rx/Tx Transition Gap (RTG): The RTG is a gap between the uplink burst and the subsequent downlink burst in a TDD or H-FDD transceiver. 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.

3.67 Tx/Rx Transition Gap (TTG): The TTG is a gap between the downlink burst and the subsequent uplink burst in a TDD or H-FDD transceiver. 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.

3.68 Turbo decoding: Iterative decoding, using soft inputs and soft outputs.

4. Abbreviations and acronyms

Delete the following:

GPC	~~grant per connection~~
GPSS	~~grant per subscriber station~~

Insert, maintaining alphabetical order:

AAS	adaptive antenna system
AGC	automatic gain control
BER	bit error ratio
BSN	Block Sequence Number
BW	bandwidth
CCI	co-channel interference
CINR	carrier to noise and interference ratio
CDMA	code division multiple access
CSCF	centralized scheduling configuration
CSCH	centralized schedule
CEPT	European Conference of Postal and Telecommunications Administrations
CIR	channel impulse response
CP	Cyclic Prefix
DARS	digital audio radio satellite
DFS	dynamic frequency selection
DSCH	distributed schedule
EESS	earth exploratory satellite systems
EVM	error vector magnitude
FCH	Frame Control Header
FFT	fast Fourier transform
FSS	fixed satellite service
FWA	fixed wireless access
GPS	global positioning satellite
GS	guard symbol
H-FDD	half-duplex FDD
HUMAN	High-Speed Unlicensed Metropolitan Area Network
I	inphase
IE	Information Element
IIP3	input intercept point of third order
IFFT	inverse fast Fourier transform
LOS	line of sight
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
PMP	point-to-multipoint
PRBS	pseudo random binary sequence
Q	quadrature
REQ	request
RLAN	Radio Local Access Network
RNG	ranging
RSP	response

RTG	Receive/Transmit Transition Gap
RxDS	Receiver Delay Spread Clearing Interval
SAR	synthetic aperture radar
SC	single carrier
SNR	signal-to-noise ratio
SSTG	subscriber station transition gap
STC	space time coding
TCM	trellis coded modulation
TTG	Transmit/Receive Transition Gap
UW	Unique Word
U-NII	Unlicensed National Information Infrastructure

6. MAC sublayer—common part

Change the first paragraph of Clause 6 to read:

A network that utilizes a shared medium shall provide an efficient sharing mechanism. Two-way point-to-multipoint and Mesh topology wireless networks are examples for sharing wireless media. Here the medium is the space through which the radio waves propagate.

Though the MAC specification invokes IP protocols, they are required only as a standard basis for element management rather than MAC operation, since, in all practicality, element management is necessary in this type of network.

Insert heading after the first paragraph of Clause 6:

6.A Point-to-multipoint

Insert before heading 6.1:

6.B Mesh

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, this 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.

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 neighbor, neighborhood and extended neighborhood. The stations with which a node has direct links are called neighbors. Neighbors of a node shall form a neighborhood. A node's neighbors are considered to be "one hop" away from the node. An extended neighborhood contains, additionally, all the neighbors of the neighborhood.

In a Mesh system not even the Mesh BS can transmit without having to coordinate with other nodes. Using distributed scheduling, all the nodes including the Mesh BS shall coordinate their transmissions in their two-hop neighborhood and shall broadcast their schedules (available resources, requests and grants) to all their

neighbors. 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 neighborhood. There is no difference in the mechanism used in determining the schedule for downlink and uplink.

Using 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 omnidirectional 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.

6.1 MAC service definition

Insert before heading “6.1.1 Primitives”:

6.1.1 MAC service definition for PMP

Renumber all remaining 6.1.x headers to 6.1.1.x.

Change the first sentence of the renumbered 6.1.1.1 to read:

The IEEE Std 802.16-2001 MAC supports the following primitives at the MAC SAP to support services between the MAC and the Convergence Sublayers in PMP mode.

6.1.1.1 MAC_CREATE_CONNECTION.request

Insert 6.1.1.1.5:

6.1.1.1.5 Establishment of multicast connections

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. Any available CID value can be used for the service (i.e., there are no dedicated CIDs for multicast transport connections), but to ensure proper multicast operation, the same CID is used for the service for all SSs on the same channel that participate in the connection. The SSs need not be aware that the connection is a multicast connection. The data transmitted on the connection with the given CID shall be received and processed by the MAC layers of all involved SSs. Thus each

multicast SDU is transmitted only once per BS channel. Since a multicast connection is associated with a Service Flow it is associated with the QoS and traffic parameters for that service flow.

ARQ is not applicable to 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.

Insert new 6.1.2 before 6.2:

6.1.2 MAC service definition for Mesh

6.1.2.1 Primitives

The IEEE 802.16 MAC supports the following primitives 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 sub-layer. 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.

6.1.2.1.1 MAC_CREATE_CONNECTION.indication

6.1.2.1.1.1 Function

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

6.1.2.1.1.2 Semantics of the service primitive

The parameters of the primitive are as follows:

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 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
Estimate of PER for the physical link over which the connection is created.

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

6.1.2.1.1.3 When generated

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

6.1.2.1.1.4 Effect of receipt

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

6.1.2.1.2 MAC_CHANGE_CONNECTION.indication

6.1.2.1.2.1 Function

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

6.1.2.1.2.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
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.

6.1.2.1.2.3 When generated

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

6.1.2.1.2.4 Effect of receipt

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

6.1.2.1.3 MAC_TERMINATE_CONNECTION.request

6.1.2.1.3.1 Function

This primitive is issued by a CS, to terminate an existing link to a neighbor node.

6.1.2.1.3.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MAC_TERMINATE_CONNECTION.request
{
  CID
}
```

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

6.1.2.1.3.3 When generated

This primitive is generated to bring down an existing link to a neighbor node.

6.1.2.1.3.4 Effect of receipt

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

6.1.2.1.4 MAC_TERMINATE_CONNECTION.indication

6.1.2.1.4.1 Function

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

6.1.2.1.4.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MAC_TERMINATE_CONNECTION.indication
{
  CID,
}
```

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

6.1.2.1.4.3 When generated

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

6.1.2.1.4.4 Effect of receipt

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

6.1.2.1.5 MAC_DATA.request

6.1.2.1.5.1 Function

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

6.1.2.1.5.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
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 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.

6.1.2.1.5.3 When generated

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

6.1.2.1.5.4 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.

6.1.2.1.6 MAC_DATA.indication

6.1.2.1.6.1 Function

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

6.1.2.1.6.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
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.

6.1.2.1.6.3 When generated

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

6.1.2.1.6.4 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.

6.1.2.1.7 MAC_FORWARDING_UPDATE.request

6.1.2.1.7.1 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.

6.1.2.1.7.2 Semantics of the service primitive

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

6.1.2.1.7.3 When generated

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

6.1.2.1.7.4 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.

6.1.2.1.8 MAC_FORWARDING_UPDATE.indication

6.1.2.1.8.1 Function

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

6.1.2.1.8.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
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 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

6.1.2.1.8.3 When generated

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.

6.1.2.1.8.4 Effect of receipt

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

6.2 Data/control plane

6.2.1 Addressing and connections

Insert new heading directly underneath heading 6.2.1:

6.2.1.1 Point-to-multipoint

Insert at end of 6.2.1.1:

6.2.1.2 Mesh

Each node shall have a 48-bit universal MAC address, as defined in IEEE Std 802[®]. 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 neighborhood, 8-bit link identifiers (Link IDs) shall be used. Each node shall assign an ID for each link it has established to its neighbors. The Link IDs are communicated during the Link Establishment process as neighboring 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.

The Connection ID in Mesh mode is specified as shown in Table 1b to convey broadcast/unicast, service parameters and the link identification.

Table 1b—Mesh CID construction

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	
Drop Precedence	2 bits	
}		
Xmt Link ID	8 bits	0xFF: MAC management broadcast
}		

Priority/Class

Priority field indicates message class.

Drop Precedence

Messages with larger Drop Precedence shall have higher dropping likelihood during congestion.

Xmt Link ID

The Link ID is assigned by the transmitter node to the link to the receiver node.

6.2.2 MAC PDU formats

6.2.2.1 MAC header formats

Replace sentence above Table 4 and replace Table 4 and Table 5 with Table 4 as follows:

~~The allowed values for the Type field are listed in Table 4 and Table 5.~~

The definition of the Type field is indicated in Table 4.

Table 4—Type encodings

Type bit	Value
#5 (msb)	Mesh Subheader 1= present, 0= absent
#4	ARQ Feedback Payload 1= present, 0= absent
#3	Extended Type 1 = Extended, 0 = not Extended Indicates whether the present Packing or Fragmentation Subheaders, is Extended.
#2	Fragmentation Subheader 1= present, 0= absent
#1	Packing Subheader 1= present, 0= absent
#0 (lsb)	Grant Management Subheader 1= present, 0= absent Shall be set to 0 in DL.

6.2.2.2 MAC subheaders

Change first paragraph to read:

~~Three~~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.

6.2.2.2.1 Fragmentation subheader

Replace Table 7 through Table 8 with the following:

Table 7—Fragmentation subheader format

Syntax	Size	Notes
Fragmentation Subheader() {		
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 Extended Type)		See Table 4.
FSN	11 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 2048) for each fragment, including unfragmented SDUs.

Table 7—Fragmentation subheader format (continued)

Syntax	Size	Notes
else		
FSN	3 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 2048) for each fragment, including unfragmented SDUs.
Reserved	3 bits	
}		

6.2.2.2.3 Packing subheaders

Replace Table 11 through Table 12 with the following:

Table 11—Packing subheader format

Syntax	Size	Notes
Packing Subheader() {		
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 Extended Type)		See Table 4.
FSN	11 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 2048) for each fragment, including unfragmented SDUs.
else		
FSN	3 bits	Sequence number of the current SDU fragment. This field increments by one (modulo 2048) for each fragment, including unfragmented SDUs.
Length	11 bits	
}		

Insert 6.2.2.2.4 and 6.2.2.2.5:

6.2.2.2.4 ARQ Feedback

If the ARQ Feedback Payload bit in the MAC Header Type field (see Table 4) is set, the ARQ Feedback Payload shall be transported. If packing is used, it shall be transported as the first packed payload. See 6.2.3.4.3.

6.2.2.2.5 Mesh subheader

The Mesh subheader, which, when using the Mesh mode, always follows the generic MAC header as specified in 6.2.2.1.1 is specified as shown in Table 12b.

Table 12b—Mesh subheader format

Syntax	Size	Notes
Mesh Subheader {		
Xmt Node Id	16 bits	
}		

6.2.2.3 MAC Management messages

Replace last line of Table 13 with the contents of Table 13a as follows:

Table 13a—MAC Management messages

Type	Message Name	Message Description	Connection
33	ARQ-Feedback	Standalone ARQ Feedback	Basic
34	ARQ-Discard	ARQ Discard message	Basic
35	ARQ-Reset	ARQ Reset message	Basic
36	REP-REQ	Channel measurement Report Request	Basic
37	REP-RSP	Channel measurement Report Response	Basic
39	MSH-NCFG	Mesh Network Configuration	Broadcast
40	MSH-NENT	Mesh Network Entry	Basic
41	MSH-DSCH	Mesh Distributed Schedule	Broadcast
42	MSH-CSCH	Mesh Centralized Schedule	Broadcast
43	MSH-CSCF	Mesh Centralized Schedule Configuration	Broadcast
44	AAS-FBCK-REQ	AAS Feedback Request	Basic
45	AAS-FBCK-RSP	AAS Feedback Response	Basic
38, 46–255	Reserved		

During the AAS portion of the frame, DL-MAP, UL-MAP, DCD, UCD and CLK-CMP messages shall be sent using the basic CID.

6.2.2.3.4 Uplink MAP (UL-MAP) message

Change Map Information Elements to read:

~~Each Information Element (IE) consists of at least three fields:~~

- ~~1) Connection Identifier~~
- ~~2) Uplink Interval Usage Code~~
- ~~3) Offset~~

The contents of a DL-MAP IE is PHY-specification dependent.

6.2.2.3.5 Ranging Response (RNG-REQ) message

Insert at end of 6.2.2.3.5:

The following parameter may be included in the RNG-REQ message:

AAS broadcast capability

6.2.2.3.6 Ranging Response (RNG-RSP) message

Insert at end of 6.2.2.3.6:

AAS broadcast permission

The following WirelessMAN-OFDM and WirelessMAN-SCa PHY specific parameters may also be included in the RNG-RSP message:

Frame Number

Frame number in which the corresponding RNG-REQ message was received. When Frame Number is included, SS MAC Address shall not appear in the same message.

Initial Ranging Opportunity Number

Initial Ranging opportunity within the frame in which the corresponding RNG-REQ message was received. If not provided, and Frame Number is included in the message, Initial Ranging Opportunity is assumed to be one.

The following WirelessMAN-OFDMA PHY specific parameters shall be included in the RNG-RSP message when a CDMA-based initial ranging message is received, in which case the RNG-RSP shall use the initial ranging CID.

Ranging Code

The received ranging CDMA code.

Ranging Symbol

The OFDM symbol in which the ranging CDMA code was received.

Ranging subchannel

The Ranging subchannel in which the ranging CDMA code was received.

Ranging frame number

The frame number in which the ranging CDMA code was received.

6.2.2.3.7 Registration Request (REG-REQ) message

Insert under “HMAC Tuple”:

MAC Version (see 11.4.4)

Insert at end of 6.2.2.3.7:

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

The REG-REQ may in addition contain the following parameters:

IP Version

SS Capabilities Encodings

Vendor ID Encoding

6.2.2.3.8 Registration Response (REG-RSP) message

Insert at end of 6.2.2.3.8:

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

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

6.2.2.3.9 Privacy key management (PKM-REQ/PKM-RSP)

6.2.2.3.9.3 Authorization Reply (Auth Reply) message

Insert attributes listed in Table 28a at the end of Table 28:

Table 28a—Auth reply attributes

Attributes	Contents
Operator Shared Secret	Mesh Mode Only. Key known to all
Key-Sequence-Number	Mesh Mode Only. Sequence number of the Operator Shared Secret
Key-Lifetime	Mesh Mode Only. Lifetime of the Operator Shared Secret

6.2.2.3.9.5 Key Request message

Insert the following sentence and Table 30a after Table 30:

When operating in Mesh Mode, the attributes of the Key Request message shall be those of Table 30a.

Table 30a—Key Request Attributes for Mesh Mode

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

Change last paragraph of 6.2.2.3.9.5 to read:

Inclusion of the keyed digest allows the BS to authenticate the Key Request message. ~~The HMAC-Digest's authentication key is derived from Authorization key.~~ The HMAC-Digest's authentication key is derived from the Authorization key or the Operator Shared Secret.

Insert 6.2.2.3.30 through 6.2.2.3.38:

6.2.2.3.30 ARQ Feedback message

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

The ARQ Feedback message, as shown in Table 56a, 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 56a—ARQ Feedback message format

Syntax	Size	Notes
ARQ_Feedback_Message_Format() {		
Management message Type =33	8 bits	
ARQ_Feedback_Payload	variable	See 6.2.3.4.3.
}		

ARQ Feedback information shall be either sent using this ARQ Feedback message or by packing (“piggy-backing”) the ARQ_Feedback_Payload as described in 6.2.3.4.3.

6.2.2.3.31 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 fragments. The ARQ Discard message shall be sent as a MAC management message on the basic management connection of the appropriate direction. Table 56b shows the format of the Discard message.

Table 56b—ARQ Discard message format

Syntax	Size	Notes
ARQ_Discard_Message_Format() {		
Management Message Type = 34	8 bits	
Connection ID	16 bits	CID to which this message refers.
Reserved	5 bits	
FSN	11 bits	Fragment Sequence Number of the last fragment in the transmission window that the transmitter wants to discard.
}		

6.2.2.3.32 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 messages shall be sent as a MAC management message on the basic management connection of the appropriate direction. Table 56c shows the format of the Reset message.

Table 56c—ARQ Reset message format

Syntax	Size	Notes
ARQ_Reset_Message_Format() {		
Management Message Type = 35	8 bits	
Connection ID	16 bits	CID for which this message refers to.
Type	2 bit	00 = Original Message from Initiator 01 = Acknowledgement from Responder 10 = Confirmation from Initiator 11 = Reserved
Reserved	6 bits	
}		

6.2.2.3.33 Channel measurement Report Request/Response (REP-REQ/RSP)

The channel measurements Report Request message shall be used by a BS, operating in bands below 11 GHz, to request RSSI and CINR channel measurement reports. In license-exempt bands, it shall additionally be used to request the results of the DFS measurements the BS has previously scheduled.

Table 56d—Channel measurements Report Request (REP-REQ) message format

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

The REP-REQ message shall contain the following TLV encoded parameters:

Report Request

The channel measurement Report Response message shall be used by the SS to respond to the channel measurements listed in the received Report Requests. In license-exempt bands, the SS shall also send a REP-RSP in an unsolicited fashion upon detecting a Primary User on the channel it is operating in.

Table 56e—Channel measurement Report Response (REP-RSP) message format

Syntax	Size	Notes
Report_Response_Message_Format {		
Management Message Type = 37	8 bits	
Report Response TLVs	variable	
}		

The REP-RSP shall contain the following TLV encoded parameters:

Report

Compound TLV that shall contain the measurement Report in accordance with the Report Request (see 11.1.6).

6.2.2.3.34 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 6.2.7.6.4.

All the nodes shall generate MSH-NCFGs in the format shown in Table 56f, including all of the following parameters:

Table 56f—MSH-NCFG message format

Syntax	Size	Notes
MSH-NCFG_Message_Format() {		
Management Message Type = 39	8 bits	
NumNbrEntries	5 bits	
NumBSEntries	2 bits	
Embedded Packet Flag	1 bits	0 = Not present, 1 = present
Xmt Power	4 bits	
Xmt Antenna	3 bits	
NetEntry MAC Address Flag	1 bits	0 = Not present, 1 = present
Network base channel	4 bits	
Reserved	4 bits	
NetConfig Count	4 bits	
Timestamp Frame Number Network Control Slot Number in frame Synchronization Hop Count	12 bits 4 bits 8 bits	See 8.4.4.2
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	
Number of hops	3 bits	
Xmt energy/bit	5 bits	
}		
for (i=0; i< NumNbrEntries; ++i) {		
Nbr Node ID	16 bits	
MSH-Nbr_Physical_IE()	16 bits	See Table 56g.
if (Logical Link Info Present Flag) MSH-Nbr_Logical_IE()	16 bits	See Table 56g. See Table 56h.
}		
if (Embedded Packet Flag) MSH-NCFG_embedded_data()	variable	See Table 56i.
}		