IEEE Standards

IEEE Std 802.16a™-2003
(Amendment to
IEEE Std 802.16™-2001)

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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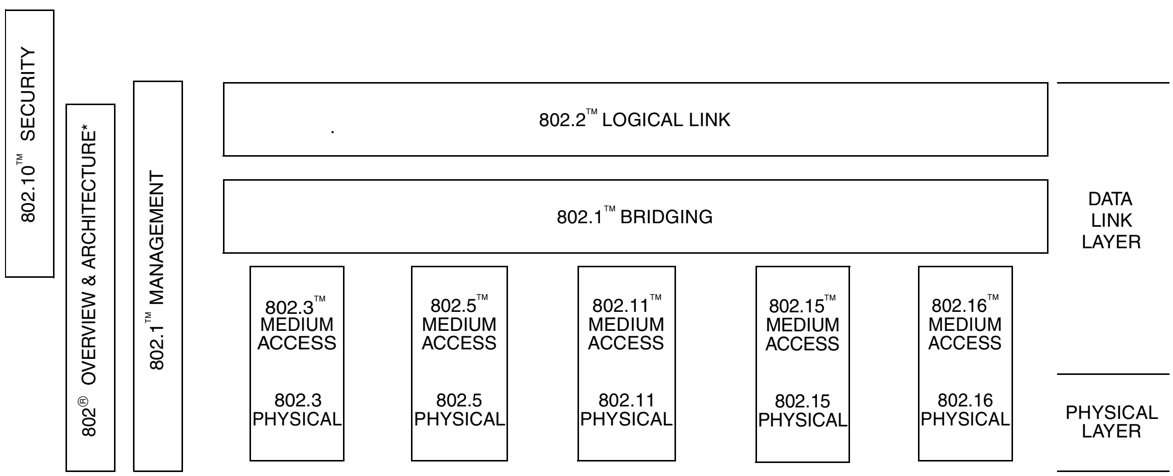
Introduction

(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_ 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])



* Formerly IEEE Std 802.1A™.

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.

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

[2]The 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™	*Recommended Practice for Media Access Control (MAC)*
[ISO/IEC TR 11802-5]	*Bridging of Ethernet V2.0 in IEEE 802 Local Area Networks.*
• IEEE Std 802.1Q™	*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.

Patents

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Conformance test methodology

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/

Participants

This document was developed by the IEEE 802.16 Working Group on Broadband Wireless Access, which develops the WirelessMAN™ Standard for Wireless Metropolitan Area Networks.

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Roger B. Marks, *Chair*
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Dean Chang, *Secretary*

Brian G. Kiernan served as Working Group Vice Chair during much of the document's development (November 2000–March 2002). Paul F. Struhsaker served as Vice Chair from March–September 2002. Carl J. Bushue served as Secretary from May through November 2001.

Technical contributions to the document came from many individuals. The Working Group especially acknowledges the contributions of its member Walt Roehr, who passed away shortly before the Working Group's May 2002 meeting.This document is dedicated to him.

Primary development was carried out by the Working Group's Task Group a:

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Before November 2001, the draft was developed by separate Task Groups 3 and 4. Task Group 3, which considered licensed bands, had the following officers: Brian G. Kiernan, Chair; Carl J. Bushue, Vice Chair; Subir Varma, MAC Chair; Dean Chang, Secretary. Task Group 4, which considered license-exempt bands, had the following officers: Durga P. Satapathy, Chair; Sanjay Moghe, Vice Chair; Kenneth Peirce, MAC Chair; John M. Liebetreu, PHY Chair. Up to March 2002, Kenneth Peirce also performed the function of Lead MAC Editor and TGa MAC Chair and Jerome Krinock performed the function of lead OFDMA PHY editor.

Brian Petry served as editor of the Functional Requirements Document from which this standard was developed; George Fishel chaired the development of that document.

The following members of the IEEE 802.16 Working Group on Broadband Wireless Access participated in the Working Group Letter Ballot in which the draft of this standard was prepared and finalized for IEEE Ballot:

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When the IEEE-SA Standards Board approved this standard on 29 January 2003, it had the following membership:

Also included is the following nonvoting IEEE-SA Standards Board liaison:

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Donald R. Volzka, *TAB Representative*

Don Messina
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Local and metropolitan area networks

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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 ~~strikethrough~~ (to remove old material) and <u>underscore</u> (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 co-existence 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 summaries 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 basi*~~s, 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^{o} 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<u>, to support services between the MAC and the Convergence Sublayers in PMP mode</u>.

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~~
<u>The contents of a DL-MAP IE is PHY-specification dependent.</u>

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.~~ <u>The HMAC-Digest's authentication key is derived from the Authorization key or the Operator Shared Secret.</u>

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.
}		

NumNbrEntries

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

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

i) All neighbor entries with the “Reported Flag” set to TRUE are excluded as defined below in this subclause.

ii) The remaining neighbor 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 neighbors will have more time to use this ineligibility information before it’s stale.)

The “Reported Flag” for all neighbors in either of the above neighbor lists is set to TRUE upon transmission of this MSH-NCFG packet. It is set to FALSE as described in 6.2.7.6.4.8.

NumBSEntries

Number of Mesh BS neighbors reported on in this message.

Xmt Power

In 2 dBm steps, starting from 8 dBm. (i.e., 1111 indicates 38 dBm).

Xmt Antenna

The logical antenna used for transmission of this message. This allows for support for up to eight antenna directions.

Network base channel

The base channel being used in this node’s network, which is the logical number of the physical channel (see 8.6.1), shall be used to broadcast schedule control information. A subset of the possible physical channel numbers is mapped to logical channels in the Network Descriptor.

Netconfig count

Counter of MSH-NCFG packets transmitted by this node. Used by neighbors 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 8.4.4.2.

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 a 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.

Netconfig schedule info

See **Xmt Holdoff Exponent** and **Next Xmt Mx**.

Xmt Holdoff Exponent

The **Xmt Holdoff Time** is the number of MSH-NCFG transmit opportunities after **Next Xmt Time** (there are $\text{MSH-CTRL-LEN} - 1$ opportunities per network control subframe, see 8.4.4.2), that this node is not eligible not transmit MSH-NCFG packets (see 6.2.7.6.4.6).

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

Next Xmt Mx

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

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

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 neighbor 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 6.2.2.3.35 and Mesh network entry in 6.2.7.6.4.4.

BS node ID

Node ID of the Mesh BS node reported on.

Number of hops

Number of hops between the reporting node and the reported Mesh BS node.

Xmt energy/bit factor

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

$$E_i = \min_{j \in N_i} [E_{j \to i} + E_j] \quad mW \cdot \mu s \tag{3}$$

where N is the set of neighbors reporting the Mesh BS and $E_{i \to j} = P_{Tx} / R_{i \to j}$, P_{Tx} is the transmission power in mW from node i to node j, and $R_{i \to j}$ is the datarate in Mbps from node i to node j. E_j is the **Xmt energy/bit** reported by neighbor j.

The reported **Xmt energy/bit factor** is the computed **Xmt energy/bit** divided by $2^{(\mathrm{XmtEnergyUnitExponent} - 4)}$.

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

Nbr node ID

Node ID of the neighbor node reported on.

6.2.2.3.34.1 Nbr Physical Information Element

Table 56g—Nbr Physical Information Element

Syntax	Size	Notes
MSH-Nbr_Physical_IE() {		
Logical Link Info Present	1 bit	0= Not present, 1=present
Logical Link Requested	1 bit	0= No, 1= Yes
Logical Link Accepted	1 bit	0= No, 1= Yes
Hops to Neighbor	1 bit	0 = 1 hop (direct neighbor), 1 = 2 hops
Estimated propagation delay	4 bits	in μs
Nbr Next Xmt Mx	5 bits	
Nbr Xmt Holdoff Exponent	3 bits	
}		

6.2.2.3.34.2 Nbr Logical Information Element

Table 56h—Nbr Logical Information Element

Syntax	Size	Notes
MSH-Nbr_Logical_IE() {		
Rcv Link Quality	3 bit	
Nbr burst Profile	4 bit	Burst profile Nbr shall use in next transmission to this node
Excess Traffic Demand	1 bit	0= No, 1= Yes
Nbr Xmt Power	4 bits	
Nbr Xmt Antenna	3 bits	
Short Preamble flag	1 bit	0= Don't use, 1= Use Requested/Use Confirmed
}		

Rcv Link Quality

Measure of the receive link reliability, indicating the reliability of MSH-NCFG size packets using the indicated burst profile.This is an estimated measure.

The reliability is indicated as:

$$\text{Reliability} = 100 \cdot (1 - 10^{-(\text{Rcv Link Quality}+1)/4})\ \%. \tag{4}$$

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 neighbor that the current schedule is insufficient to transfer pending traffic.

Nbr Xmt Power

The suggested transmit power for this neighbor to use for this link in 2 dBm steps, starting from 8 dBm. (i.e., 1111 indicates 38 dBm).

Short Preamble flag

A node may optionally set this bit to notify the neighbor to use the short preamble (see 8.4.3.6) for transmissions in the data portion of the frame. Capability to transmit the short preamble is mandatory. Capability to receive it is optional.

6.2.2.3.34.3 MSH-NCFG embedded data

Table 56i—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	
Type	4 bits	
Length	8 bits	Length of embedded_IE in bytes, exclusive this header
Embedded_data_IE()	variable	Type dependent
}		

Type
The following types are defined:
0x0: Reserved
0x1: Network Descriptor
0x2: Network Entry Open
0x3: Network Entry Reject
0x4: Network Entry Ack (Embedded_data_IE() == NULL)
0x5: Neighbor Link Establishment Protocol

The Network Descriptor shall contain the following parameters:

Table 56j—Network Descriptor Information Element

Syntax	Size	Notes
MSH-NCFG_embedded_data_IE() {		
Frame Length Code	4 bits	4 lsb of Frame Duration Code. See Table 116aq.
MSH-CTRL-LEN	4 bits	Control subframe length (see 8.4.4.2)
MSH-DSCH-NUM	4 bits	Number of DSCH opportunities in schedule control subframe (see 8.4.4.2)
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 (see 8.4.4.2) in multiples of 4 frames. 0= 0 frames, 1= 4 frames etc.
Num_Burst_Profiles	4 bits	Number of burst profile definitions. If not set to zero, shall total all defined burst profiles.
Operator ID	16 bits	

Table 56j—Network Descriptor Information Element *(continued)*

Syntax	Size	Notes
XmtEnergyUnitsExponent	4 bits	
Channels	4 bits	Number of logical channels. A value of 0 indicates the channel information is not carried in this message.
MinCSForwardingDelay	7 bits	Number of OFDM symbols delay inserted between receiving and forwarding control packets.
ExtendedNeighborhoodType	1 bit	0 = 2-hop neighborhood 1 = 3-hop neighborhood
if (**Channels**) **MSH-NCFG_Channel_IE()**		variable
for (i=0;i < Num_Burst_Profiles;i++) {		
FEC Code Type	8 bits	See Table 125b.
Mandatory Exit Threshold	8 bits	See Table 125b.
Mandatory Entry Threshold	8 bits	See Table 125b.
}		
}		

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 Neighbor** = 0 (see 6.2.2.3.34.1) are reported, if value 1, then also nodes with **Hops to Neighbor** = 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 56k—MSH-NCFG Channel Information Element (license-exempt)

Syntax	Size	Notes
MSH-NCFG_Channel_IE() {		For license-exempt channels.
for (i=0; i< Channels; ++i)		
Physical Channel code	8 bits	Physical channel (see 8.6.1) the logical channel *i* is mapped to. Ordered with channels with same regulatory rules successive.
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.
Peak/Average flag	1 bits	Regulatory limits are peak or average.
Reserved	2 bits	
NumChannelMaps	2 bits	
for (i=0; i< NumChannelMaps; ++i) {		
Number of Channels	8 bits	Nodes in channel map to which rules apply.
Max. xmt power at antenna port	6 bits	Regulatory limit in dBm.
Max. EIRP	6 bits	Regulatory limit in dBm.
}		
}		

Table 56l—MSH-NCFG Channel Information Element (licensed)

Syntax	Size	Notes
MSH-NCFG_Channel_IE() {		For licensed channels
for (i=0; i< Channels; ++i) {		
Physical Channel center 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	
}		

The Network Entry Open, which is used to respond to MSH-NENT request messages, shall contain the following parameters:

Table 56m—Network Entry Open Information Element

Syntax	Size	Notes
MSH-CNFG_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	μs
Reserved	4 bits	
}		

The Network Entry Reject, which is used to reject MSH-NENT requests, shall contain the following parameters:

Table 56n—Network Entry Reject Information Element

Syntax	Size	Notes
MSH-NCFG_embedded_data_IE() {		
Rejection Code	8 bits	
Rejection Reason	160 bits	ASCII string
}		

Rejection Code

0x0: Operator Authentication Value Invalid
0x1: Excess Propagation delay
0x2: Select new sponsor

Table 56o—Neighbor 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
HMAC{Authorization Key | frame number | own Node ID, Node ID of other node} where the Authorization Key is a secret key (obtained from Operator).

6.2.2.3.35 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 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 56p—MSH-NENT message format

Syntax	Size	Notes
MSH-NENT_Message_Format() {		
Management Message Type = 40	8 bits	
Type	3 bits	0x0 Reserved 0x1 NetEntryAck 0x2 NetEntryRequest 0x3 NetEntryClose
Xmt counter for this Type	3 bits	For NetEntryAck, this is the Type being acknowledged.
Reserved	2 bits	
Sponsor Node ID	16 bits	
Xmt Power	4 bits	
Xmt Antenna	3 bits	

Table 56p—MSH-NENT message format *(continued)*

Syntax	Size	Notes
Reserved	1 bits	
if (Type == 0x2)		
MSH-NENT_Request_IE()	variable	
}		

Sponsor Node ID
ID of the node sought to assist the requesting node in entering the network.
Xmt Power
In 2 dBm steps, starting from 8 dBm. (i.e., 0xF indicates 38 dBm).
Xmt Antenna
The logical antenna used for transmission of this message. This allows for support for up to eight antenna directions.

The MSH-NENT_request_IE is given in Table 56q:

Table 56q—MSH-NENT Request Information Element

Syntax	Size	Notes
MSH-NENT_Request_IE() {		
MAC Address	48 bits	
OpConfInfo	64 bits	
Operator Authentication Value	32 bits	
Node serial Number	32 bits	
}		

MAC Address
MAC Address of the new node sending the request.
OpConfInfo
Operator Configuration Information (obtained from Operator).
Operator Authentication Value
HMAC{MAC Address | Node Serial Number | Authorization Key}
where the Authorization Key is a secret key (obtained from Operator).

6.2.2.3.36 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 at a regular interval to inform all the neighbors of the schedule of the transmitting station. This transmission time is determined by the same algorithm used for MSH-NCFG messages (see 6.2.7.6.4.6). In both coordinated and uncoordinated scheduling, MSH-DSCH messages shall be used to convey resource requests and grants to the neighbors. Further the MSH-DSCH messages shall be used to convey information about free resources that the neighbors can issue grants in. This message shall not be fragmented. The MSH-DSCH message format is given in Table 56r.

Table 56r—MSH-DSCH message format

Syntax	Size	Notes
MSH-DSCH_Message_Format() {		
Management Message Type =41	8 bits	
Coordination Flag	1 bits	
Grant/Request Flag	1 bits	
Sequence counter	6 bits	
No. Requests	4 bits	
No. Availabilities	4 bits	
No. Grants	6 bits	
Reserved	2 bits	
if (Coordination Flag == 0)		
MSH-DSCH_Scheduling_IE()	variable	
for (i=0; i< No_Requests; ++i)		
MSH-DSCH_Request_IE()	16 bits	
for (i=0; i< No_Availabities; ++i)		
MSH-DSCH_Availability_IE()	32 bits	
for (i=0; i< No_Grants; ++i)		
MSH-DSCH_Grant_IE()	40 bits	
}		

Co-ordination Flag

0 = Coordinated

1 = Uncoordinated

Coordinated MSH-DSCH transmissions take place in the control subframe (see 8.4.4.2). Uncoordinated MSH-DSCH transmissions take place in the data subframe (see 8.4.4.2). 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 that cause no interference with the coordinated schedule.

Grant/Request Flag

0 = Request message

1 = Grant message (also used as Grant confirmation)

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 **No. 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.

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.

No. Requests

Number of Request IEs in the message.

No. Availabilities

Number of Availability IEs in the message. The Availability IEs are used to indicate free minislot ranges that neighbors could issue Grants in.

No. Grants

Number of Grant IEs in the message.

6.2.2.3.36.1 MSH-DSCH Scheduling Information Element

The Coordinated distributed scheduling information carried in the MSH-DSCH message 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 neighbors. The scheduling information shall include all of the following parameters:

Next Xmt Mx

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

$$2^{\text{Xmt Holdoff Exponent}} \cdot \text{Next Xmt Mx} < \text{Next Xmt Time} \le 2^{\text{Xmt Holdoff Exponent}} \cdot (\text{Next Xmt Mx}+1)\,. \tag{5}$$

For 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 neighbor 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).

Neighbor Next Xmt Mx

Advertises the **Next Xmt Mx** as reported by this neighbor.

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, see 8.4.4.2), that this node is not eligible not transmit MSH-DSCH packets (see 6.2.7.6.4.6).

$$\textbf{Xmt Holdoff Time} = 2^{(\text{Xmt Holdoff Exponent}+4)} \tag{6}$$

Neighbor Xmt Holdoff Exponent
Advertises the **Xmt Holdoff Exponent** as reported by this neighbor.
No. SchedEntries
Number of Neighbor MSH-DSCH Scheduling Entries in the message.
Neighbor Node ID
The Node ID of the neighbor being reported on.

Table 56s—MSH-DSCH Scheduling Information Element

Syntax	Size	Notes
MSH-DSCH_Scheduling_IE() {		
Next Xmt Mx	5 bits	
Xmt holdoff exponent	3 bits	
No. SchedEntries	8 bits	
for (i=0; i< No_SchedEntries; ++i) {		
Neighbor Node ID	16 bits	
Neighbor Next Xmt Mx	5 bits	
Neighbor Xmt holdoff exponent	3 bits	
}		
}		

6.2.2.3.36.2 MSH-DSCH Request Information Element

The Requests carried in the MSH-DSCH message shall convey resource requests on per link basis. The Requests shall include all of the following parameters:

Table 56t—MSH-DSCH Request Information Element

Syntax	Size	Notes
MSH-DSCH_Request_IE() {		
Link ID	8 bits	
Demand Level	8 bits	
Persistence	3 bits	
Reserved	1 bit	
}		

Link ID
The ID assigned by the transmitting node to the link to this neighbor that this request involves.
Demand level
Demand in minislots (assuming the current burst profile):

Demand Persistence

Persistency field for demands. Number of frames wherein 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 canceled or reduced

6.2.2.3.36.3 MSH-DSCH Availabilities Information Element

The Availabilities carried in the MSH-DSCH message shall be used to indicate free minislot ranges that neighbors could issue Grants in. The Availabilities shall include all of the following parameters:

Table 56u—MSH-DSCH Availability Information Element

Syntax	Size	Notes
MSH-DSCH_Availability_IE() {		
Start Frame number	8 bits	8 lsb of Frame number
Minislot start	8 bits	
Minislot range	7 bits	
Direction	2 bits	
Persistence	3 bits	
Channel	4 bits	
}		

Start Frame number

Availability start:

Indicates lowest 8 bits of frame number in which the availability starts.

Minislot start

The start position of the availability within a frame (minislots as time unit, see 8.4.4.2 for definition).

Minislot range

The number of minislots free for grants

Direction

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

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 canceled or reduced

Channel
Logical channel number, which is the logical number of the physical channel. A subset of the possible physical channel numbers is mapped to logical channels in the Network Descriptor.

6.2.2.3.36.4 MSH-DSCH Grants Information Element

The Grants carried in the MSH-DSCH message shall convey information about a granted minislot range selected from the range reported as available. Grants shall be used both to grant and confirm a grant. The Grants shall include all of the following parameters:

Table 56v—MSH-DSCH Grants Information Element

Syntax	Size	Notes
MSH-DSCH_Grants_IE() {		
Link ID	8 bits	
Start Frame number	8 bits	8 lsb of Start Frame number
Minislot start	8 bits	
Minislot range	8 bits	
Direction	1 bit	
Persistence	3 bits	
Channel	4 bits	
}		

Link ID
The ID assigned by the transmitting node to the neighbor that this grant involves.
Start Frame number
Schedule start:
Indicates lowest 8 bits of frame number in which the schedule is granted.
Minislot start
The start position of the reservation within a frame (minislots as time unit, see 8.4.4.2 for definition).
Minislot range
The number of minislots reserved.
Direction
0= From requester (i.e., to granter)
1= To requester (i.e., from granter)
Persistence
Persistency field for grants. Number of frames over which the grant is allocated.
0 = cancel reservation
1 = single frame
2 = 2 frames
3 = 4 frames
4 = 8 frames
5 = 32 frames
6 = 128 frames
7 = Good until canceled or reduced

Channel

Logical channel number, which is the logical number of the physical channel. A subset of the possible physical channel numbers is mapped to logical channels in the Network Descriptor.

6.2.2.3.37 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 to all its neighbors, and all the nodes with hop count lower than $HR_{threshold}$ shall forward the MSH-CSCH message to their neighbors that have a higher hop count. In all these cases, the **Grant/Request Flag** =0. $HR_{threshold}$ 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 the Mesh BS, known to all nodes in the network, and ordered by node ID.

The BS shall generate MSH-CSCHs in the format shown in Table 56w, including all of the following parameters:

Configuration sequence number

Indicates the configuration, which shall be used to interpret this packet. It refers to the configuration number in the MSH-CSCF packet.

Grant/Request Flag

0=Grant (transmitted in downlink)

1=Request (transmitted in uplink)

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 6.2.6.7.2).

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

Num_Link_updates

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 a link update in every MSH-CSCH either until the update becomes invalid, or until the change is reflected in a MSH-CSCF message.

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.

UplinkFlow

Base of the granted/requested bandwidth as bits/s for the uplink traffic of the node in the BS's scheduling tree. The allocation is the same as for **DownlinkFlow**.

DownlinkFlow

Parameter used, as shown in Equation (7), to compute the granted/requested bandwidth as bits/s for the downlink respectively uplink traffic of the node in the BS's scheduling tree. The flow indicates only 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

$$\begin{aligned} BW_{\text{traffic to BS}} &= \text{UplinkFlow} \cdot 2^{\text{Flowscale Exponent+14}} \quad \text{bits/s} \\ BW_{\text{traffic from BS}} &= \text{DownlinkFlow} \cdot 2^{\text{Flowscale Exponent+14}} \quad \text{bits/s} \end{aligned} \tag{7}$$

The assignments in the list are ordered according to the order in the MSH-CSCF message (see 6.2.2.3.38).

Frame schedule flag

If this flag is set, the allocation of flows shall occur over two frames, rather than one.

Sponsor Node Request

Three parameters (Sponsor Node, and Burst Profiles) shall be set to 0, except by nodes that wish to reserve an allocation for the 'upper MAC initialization' as specified in 6.2.9.14.3. 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.

Table 56w—MSH-CSCH message format

Syntax	Size	Notes
MSH-CSCH_Message_Format() {		
Management Message Type = 42	8 bits	
Configuration sequence number	3 bits	Last MSH-CSCF sequence number
Grant / Request Flag	1 bits	0 = Grant,1 = Request
Frame schedule Flag	1 bits	
Configuration Flag	1 bits	0 = Next schedule control message is MSH-CSCH. 1 = Next schedule control message is MSH-CSCF.
Reserved	2 bits	
NumFlowEntries	8 bits	
for (i=0; i< NumFlowEntries; ++i) {		
UplinkFlow	4 bits	
if (Grant / Request Flag == 0) **DownlinkFlow**	4 bits	
}		
Flow Scale Exponent	4 bits	

Table 56w—MSH-CSCH message format *(continued)*

Syntax	Size	Notes
Padding Nibble	4 bits	
if (Grant/Request Flag = =0) {		
No_link_updates	4 bits	
for (i=0; i< No_link_updates; ++i) {		
Node Index self	8 bits	index in MSH-CSCF list
Node Index parent	8 bit	index in MSH-CSCF list
Uplink Burst Profile	4 bit	
Downlink Burst Profile	4 bit	
}		
} else {		Sponsor Node Request
Sponsor Node	8 bits	index in node tree
DL Burst Profile	4 bits	
UL Burst Profile	4 bits	
}		
}		

6.2.2.3.38 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 to all its neighbors, and all nodes shall forward (rebroadcast) the message according to its index number specified in the message. The BS shall generate MSH-CSCFs in the format shown in Table 56x.

Table 56x—MSH-CSCF message format

Syntax	Size	Nodes
MSH-CSCF_Message_Format() {		
Management Message Type = 43	8 bits	
Configuration sequence number	4 bits	
NumberOfChannels	4 bits	
for (i=0; i< NumberOfChannels; ++i) {		
Channel index	4 bits	
}		
Padding Nibble	0 or 4 bits	Pad till byte boundary
NumberOfNodes	8 bits	
for (i=0; i< NumberOfNodes; ++i) {		

Table 56x—MSH-CSCF message format *(continued)*

Syntax	Size	Nodes
NodeID	16 bits	Node index for this node is *i*.
NumOfChildren	8 bits	
for (j=0; j< NumberOfChildren; ++j) {		
Child Index	8 bits	index of j^{th} child node
Uplink Burst Profile	4 bits	burst profile from j^{th} child node
Downlink Burst Profile	4 bits	burst profile to j^{th} child node
}		
}		
}		

Configuration sequence number
Number of the configuration. With each new configuration message, the number is incremented by 1.

NumberOfChannels
Number of channels available for centralized scheduling.

Channel Index
The logical index of the Physical channel, as reported in MSH-NCFG:NetworkDescriptor.

NumberOfNodes
Number of nodes in scheduling tree.

Each entry of the scheduling tree shall include all of the following parameters:

Node ID
Unique node identifier assigned to node.

NumberOfChildren
Number of child nodes for this node. A child node is a neighbor with a hop count, which is one higher than this nodes hop count.

ChildIndex
NumberOfChildren index in this table of child node.

Uplink/Downlink Burst Profile
Burst profile of link from/to child node.

6.2.2.3.39 AAS Channel Feedback Request/Response (AAS-FBCK-REQ/RSP)

The AAS Channel Feedback Request message shall be used by a system supporting AAS and operating in FDD mode. It may also be used by a system supporting AAS and operating in TDD mode. This message serves to request channel measurement that will help in adjusting the direction of the adaptive array.

Table 56y—AAS Feedback Request (AAS-FBCK-REQ) message format

Syntax	Size	Nodes
AAS-FBCK-REQ_Message_Format() {		
Management Message Type = 44	8 bits	
Frame Number	24 bits	
NumberOfFrames	7 bits	
DataType	1 bit	0 = measure on DL preamble only 1 = measure on DL data (for this SS) only.
NumberOfFrequencies	16 bits	
Feedback Request Counter	8 bits	
}		

Frame Number
The Frame Number in which to start the measurement.

NumberOfFrames
The number of frames over which to measure.

NumberOfFrequencies
The frequency measurement points shall be evenly distributed across the channel BW such the the first points coincides with the low channel edge, and the last point coincides with the higher channel edge.

Feedback Request Counter
Modulo 256 counter of the number of AAS-FBCK-REQs sent to the SS.

The AAS Channel Feedback Response message shall be sent as a response to the AAS-FBCK-REQ message after the indicated measurement period has expired.

Table 56z—AAS Feedback Response (AAS-FBCK-RSP) message format

Syntax	Size	Nodes
AAS-FBCK-RSP_Message_Format() {		
Management Message Type = 45	8 bits	
for (i=0; i<**NumberOfFrequencies**; i++) {		
Re(F**requency_value[i]**)	16 bits	
Im(**Frequency_value[i]**)	16 bit	
}		
Feedback Request Number	8 bits	
}		

Re(**Frequency_value[i]**) and Im(**Frequency_value[i]**)
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].[11 bits].

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

6.2.3 Construction and transmission of MAC PDUs

6.2.3.3 Fragmentation

Insert at the end of 6.2.3.3:

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.

6.2.3.4 Packing

Insert at the end of 6.2.3.4:

The construction of PDUs varies for ARQ and non-ARQ connections with respect to packing and fragmentation syntax. The packing and fragmentation mechanisms for both the ARQ and non-ARQ connections are specified in 6.2.3.4.1 through 6.2.3.4.3.

Insert new heading:

6.2.3.4.1 Packing for non-ARQ connections

Change 6.2.3.4.1 heading to 6.2.3.4.1.1. Change the first paragraph to read:

6.2.3.4.1.1 Packing fixed-length MAC SDUs

For connections that do not use ARQ and are indicated by the fixed-length versus variable-length SDU indicator (11.4.8.15) to carry fixed-length MAC SDUs, the packing procedure described in this subclause may be used. For all other connections, the variable length packing algorithm described in section 6.2.3.4.2 shall be used.

Change 6.2.3.4.2 and following sentence to read:

6.2.3.4.1.2 Packing variable-length MAC SDUs

When a sequence number must be associated with each SDU payload, or when packing variable length SDU connections such as Ethernet, the $n*k+j$ relationship between the MAC header's length field and the higher-layer MAC SDUs no longer holds.

Delete 6.2.3.4.2.1 heading.

Insert 6.2.3.4.2 and 6.2.3.4.3:

6.2.3.4.2 Packing for ARQ-enabled connections

The use of packing subheaders for ARQ-enabled connections is similar to that for non-ARQ connections as described in 6.2.3.4.1, except that ARQ-enabled connections shall set the Extended Type bit (see Table 4) in the Generic MAC Header to 1, whereas non-ARQ connections shall set the Extended Type bit to 0. In addition, the fixed-length packing option (6.2.3.4.1.1) is not supported by ARQ-enabled connections. 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. While this does not change the semantics of the packing, the ARQ protocol may utilize this feature to allow flexibility in retransmission.

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 FSN 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.

For ARQ-enabled connections, when the type field indicates packing subheaders are in use, 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 in use, fragmentation information for the MAC PDU's single payload (MAC SDU or MAC SDU fragment) is contained in the fragmentation header appearing in the message. Figure 30a illustrates the use of Fragmentation subheader without packing.

Generic MAC Header	Other subheaders	Fragmentation subheader	Payload (One SDU or fragment of an SDU)	CRC-32

Figure 30a—Example MAC PDU with extended fragmentation subheaders

Figure 30b illustrates the structure of a MAC PDU with ARQ packing subheaders. Each of the packed MAC SDU or MAC SDU fragments or ARQ feedback payload requires its own packing subheader and some of them may be transmissions while others are re-transmissions.

Generic MAC Header	Grant Management subheader (UL only)	Packing subheader	Payload (One SDU or SDU fragment or a set of ARQ Feedback IEs)	. .	Packing subheader	Payload (One SDU or SDU fragment)	CRC-32

Figure 30b—Example MAC PDU with ARQ packing subheader

Unlike the non-ARQ case, it is possible to have continuation fragments packed with other fragments in the same MAC PDU for various reasons. For example, in order to support flexible re-transmission, the ARQ mechanism may choose to fragment a MAC SDU into multiple fragments and pack them into the same MAC PDU during the first transmission. Similarly MAC PDU may have fragments from different SDUs, including a mix of first transmissions and retransmissions. The 11-bit FSN and 2-bit FC fields uniquely identify each fragment or non-fragmented SDU.

6.2.3.4.3 Packing ARQ Feedback Information Elements

An ARQ Feedback Payload (see Table 57a) consists of one or more ARQ Feedback Information Elements (see 6.2.4.1). 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 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 57a—ARQ Feedback Payload format

Syntax	Size	Notes
ARQ_Feedback_Payload_Format() {		
do	8 bits	
ARQ_Feedback_IE(last)	variable	Insert as many as desired, until last==TRUE. See 6.2.4.2.
until (**last**)		
}		

The presence of an ACK Feedback Payload in a MAC PDU is indicated by the value of the ARQ Feedback Payload bit in the Type field (see Table 4) 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 field of the Packing Subheader shall be ignored for the ARQ Feedback Payload and the FC bits shall be set to 00.

Replace 6.2.4 with the following:

6.2.4 ARQ mechanism

NOTE—ARQ shall not be used with the PHY specification defined in 8.2.

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.

The ARQ feedback information can be sent as a standalone MAC management message on the appropriate basic management connection, or piggybacked on an existing connection. ARQ feedback cannot be fragmented. The implementation of ARQ is optional.

6.2.4.1 ARQ Feedback Information Element format

Table 57b defines the ARQ Feedback IE used by the receiver to signal positive or negative acknowledgments. A set of IEs of this format may be transported either as a packed payload ('piggybacked') within a packed MAC PDU or as a payload of a standalone MAC PDU.

Table 57b—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
FSN	11 bits	
Number of 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< Number of ACK Maps + 1; ++i) {		
ACK Map	16 bits	
}		
}		
}		

FSN

If (ACK Type == 0x0): FSN value corresponds to the most significant bit of the first 16-bit ARQ ACK map.

If (ACK Type == 0x1): FSN value indicates that its corresponding fragment and all fragments with lesser (see 6.2.4.5.1) values within the transmission window have been successfully received.

If (ACK Type == 0x2): Combines the functionality of types 0x0 and 0x1.

ACK Map

Each bit set to one indicates the corresponding ARQ fragment has been received without errors. The bit corresponding to the FSN value in the IE, is the most significant bit of the first map entry. The bits for succeeding fragment numbers are assigned left-to-right (msb to lsb) within the map entry. If the ACK Type is 0x2, 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 FSN value in the IE. The rest of the bitmap shall be interpreted similar to ACK Type 0x0.

6.2.4.2 ARQ parameters

6.2.4.2.1 ARQ_FSN_MODULUS

ARQ_FSN_MODULUS is equal to the number of unique FSN values, i.e., 2^11.

6.2.4.2.2 ARQ_WINDOW_SIZE

ARQ_WINDOW_SIZE is the maximum number of unacknowledged ARQ fragments at any given time. An ARQ fragment is unacknowledged if it has been transmitted but no acknowledgement has been received.

ARQ_WINDOW_SIZE shall be less than or equal to half of the *ARQ_FSN_MODULUS*.

6.2.4.2.3 ARQ_FRAGMENT_LIFETIME

ARQ_FRAGMENT_LIFETIME is the maximum time interval an ARQ fragment shall be managed by the transmitter ARQ state machine, once initial transmission of the fragment has occurred. If transmission (or subsequent retransmission) of the fragment is not acknowledged by the receiver before the time limit is reached, the fragment is discarded.

6.2.4.2.4 ARQ_RETRY_TIMEOUT

ARQ_RETRY_TIMEOUT is the time interval a transmitter shall wait before retransmission of an unacknowledged fragment for retransmission. The interval begins when the ARQ fragment was last transmitted.

6.2.4.2.5 ARQ_SYNC_LOSS_TIMEOUT

ARQ_SYNC_LOSS_TIMEOUT is the maximum time interval *ARQ_TX_WINDOW_START* or *ARQ_RX_WINDOW_START* shall be allowed to remain at the same value before declaring a loss of synchronization of the sender and receiver state machines when data transfer is known to be active. The ARQ receiver and transmitter state machines manage independent timers. Each has its own criteria for determining when data transfer is 'active' (see 6.2.4.5.2 and 6.2.4.5.3).

6.2.4.2.6 ARQ_RX_PURGE_TIMEOUT

ARQ_RX_PURGE_TIMEOUT is the time interval the receiver shall wait after successful reception of a fragment that does not result in advancement of *ARQ_RX_WINDOW_START*, before advancing *ARQ_RX_WINDOW_START* (see 6.2.4.5.3).

6.2.4.3 ARQ procedures

6.2.4.3.1 ARQ state machine variables

All ARQ state machine variables are set to 0 at connection creation or by an ARQ reset operation.

6.2.4.3.1.1 Transmitter variables

ARQ_TX_WINDOW_START: All FSN up to (*ARQ_TX_WINDOW_START* - 1) have been acknowledged.
ARQ_TX_NEXT_FSN: FSN of the next fragment to send. This value shall reside in the interval *ARQ_TX_WINDOW_START* to (*ARQ_TX_WINDOW_START* + *ARQ_WINDOW_SIZE*), inclusive.

6.2.4.3.1.2 Receiver variables

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

ARQ_RX_HIGHEST_FSN: FSN of the highest fragment received, plus one. This value shall reside in the interval *ARQ_RX_WINDOW_START* to (*ARQ_RX_WINDOW_START* + *ARQ_WINDOW_SIZE*), inclusive.

6.2.4.4 ARQ-enabled connection setup and negotiation

Connections are set up 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 the ARQ parameters (see 6.2.4.2) shall be set when an ARQ-enabled connection is set up. The transmitter and receiver variables (defined in 6.2.4.3.1) shall be reset on connection setup.

6.2.4.5 ARQ operation

6.2.4.5.1 Sequence number comparison

Transmitter and receiver state machine operations include comparing fragment sequence numbers and actions taken based on whether it is larger or smaller. In this context, it is not possible to compare the numeric sequence number values directly to make this determination. Instead, the comparison shall be made by normalizing the values relative to the appropriate state machine base value and the maximum value of sequence numbers, *ARQ_FSN_MODULUS*, and then comparing the normalized values. Normalization is accomplished by using the expression:

$$\text{fsn}' = (\text{fsn} - \text{FSN\_base}) \bmod \mathit{ARQ\_FSN\_MODULUS} \quad (8)$$

The base values for the receiver and transmitter state machines are *ARQ_TX_WINDOW_START* and *ARQ_RX_WINDOW_START*, respectively.

6.2.4.5.2 Transmitter state machine

The transmitter is responsible for choosing the appropriate fragment size on a per-fragment basis. Determining fragment size is outside the scope of this standard. Unlike non-ARQ connections, where a single MAC PDU would not normally have two consecutive fragments from the same MAC SDU, this is likely for ARQ-enabled connections, since such fragmentation can facilitate retransmission. The MAC SDU fragment structure shall be maintained for retransmissions. An ARQ fragment may be in one of the following four states: not-sent; outstanding; discarded; and waiting-for-retransmission. Any ARQ fragment begins as not-sent. After it is sent it becomes outstanding for a period of time termed *ACK_RETRY_TIMEOUT*. While a fragment is in outstanding state, it either is acknowledged and discarded, or transitions to waiting-for-retransmission after *ACK_RETRY_TIMEOUT* or NACK. An ARQ fragment can become waiting-for-retransmission before the *ACK_RETRY_TIMEOUT* period expires if it is negatively acknowledged. An ARQ fragment may also change from waiting-for-retransmission to discarded when an ACK message for it is received or after a timeout *ARQ_FRAGMENT_LIFETIME*.

For a given connection the transmitter shall first handle (transmit or discard) fragments in '*waiting-for-retransmission*' state and only then fragments in '*non-sent*' state. Fragments in '*outstanding*' or '*discarded*' state shall not be transmitted. When fragments are retransmitted, the fragment with the lowest FSN shall be retransmitted first.

The ARQ transmit fragment state sequence is shown in Figure 31a.

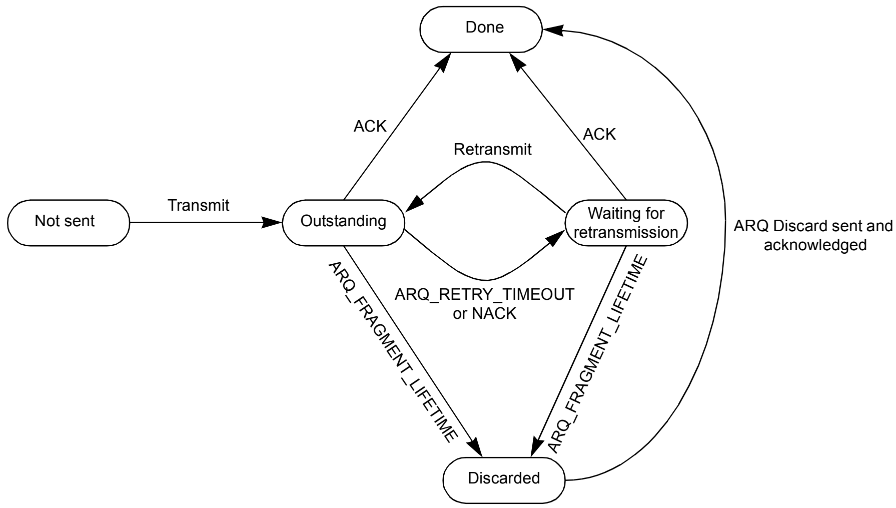


Figure 31a—ARQ transmit fragment states

MAC PDU formation continues with a connection's 'not-sent' MAC SDUs. The transmitter builds each MAC PDU using the rules for fragmentation and packing as long as the number of fragments to be sent plus the number of fragments already transmitted and awaiting retransmission does not exceed the limit imposed by *ARQ_WINDOW_SIZE*. As each 'not-sent' fragment is formed and included in a MAC PDU, it is assigned the current value of *ARQ_TX_NEXT_FSN*, which is then incremented.

When an acknowledgement is received, the transmitter shall check the validity of the FSN. A valid FSN is one in the interval *ARQ_TX_WINDOW_START* to *ARQ_TX_NEXT_FSN*-1 (inclusive). If FSN is not valid, the transmitter shall ignore the acknowledgement.

When a cumulative acknowledgement with a valid FSN is received, the transmitter shall consider all fragments in the interval *ARQ_TX_WINDOW_START* to FSN (inclusive) as acknowledged and set *ARQ_TX_WINDOW_START* to FSN+1.

When a selective acknowledgement is received, the transmitter shall consider as acknowledged all fragments so indicated by the entries in the bitmap for valid FSN values. As the bitmap entries are processed in increasing FSN order, *ARQ_TX_WINDOW_START* shall be incremented each time the FSN of an acknowledged fragment is equal to the value of *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 FSN value now assigned to *ARQ_TX_WINDOW_START*, the value of *ARQ_TX_WINDOW_START* shall be incremented until an FSN value is reached for which no acknowledgement has been received.

A bitmap entry not indicating acknowledged that has an FSN lower than a bitmap entry that does indicate acknowledged shall be considered a NACK for the corresponding fragment. 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 fragment.

When a cumulative with selective acknowledgement and a valid FSN is received, the transmitter performs the actions described above for cumulative acknowledgement, followed by those for a selective acknowledgement.

All timers associated with acknowledged fragments shall be cancelled.

A Discard message shall be sent following violation of *ARQ_FRAGMENT_LIFETIME*. 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 FSN has been received. Discard orders for adjacent FSN values may be accumulated in a single Discard message.

The actions to be taken by the transmitter state machine when an ARQ Reset Message is received are provided in Figure 31b. The actions to be taken by the transmitter state machine when it wants to initiate a reset of the receiver ARQ state machine are provided in Figure 31c.

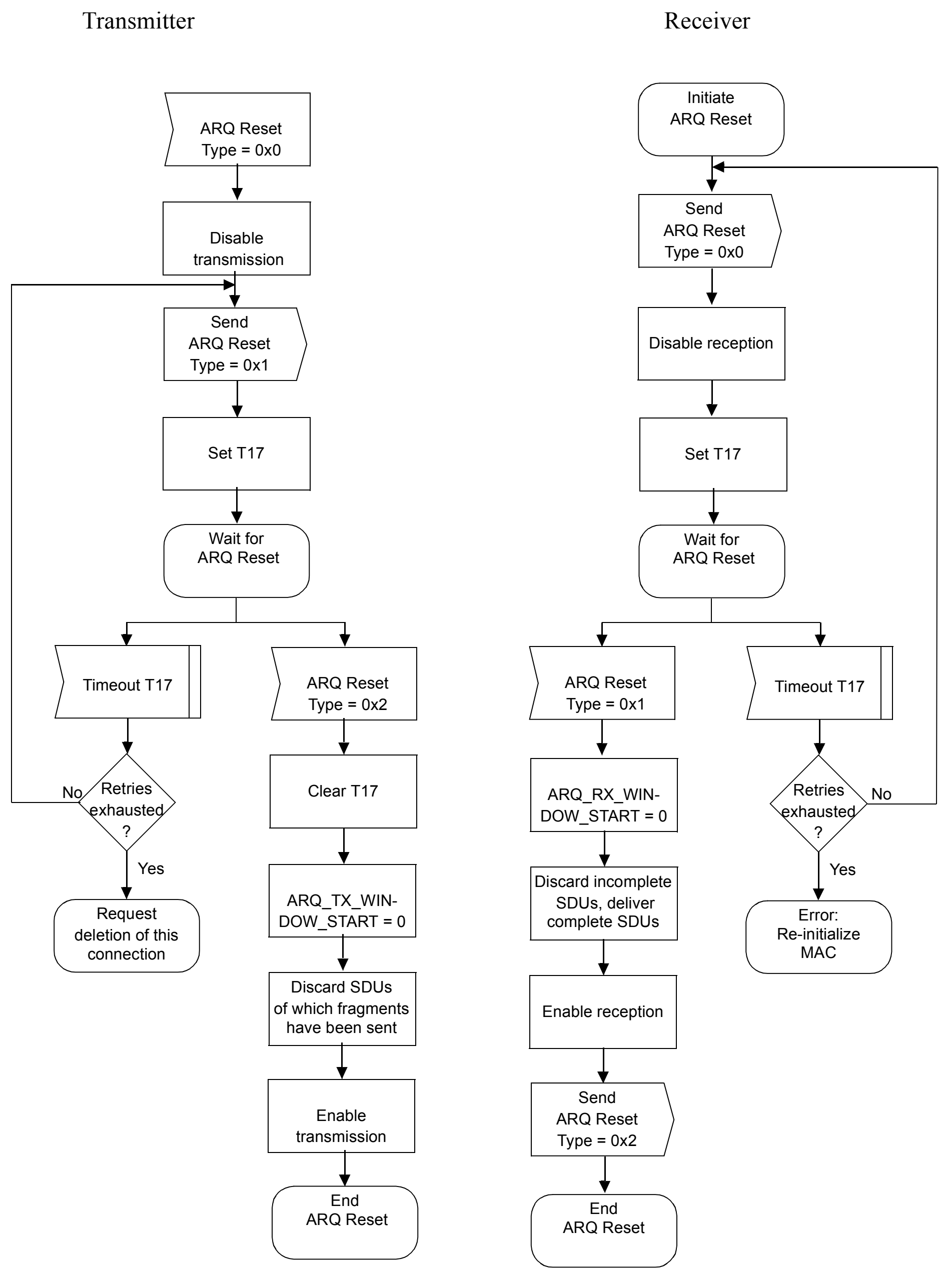


Figure 31b—ARQ Reset message dialog—receiver initiated

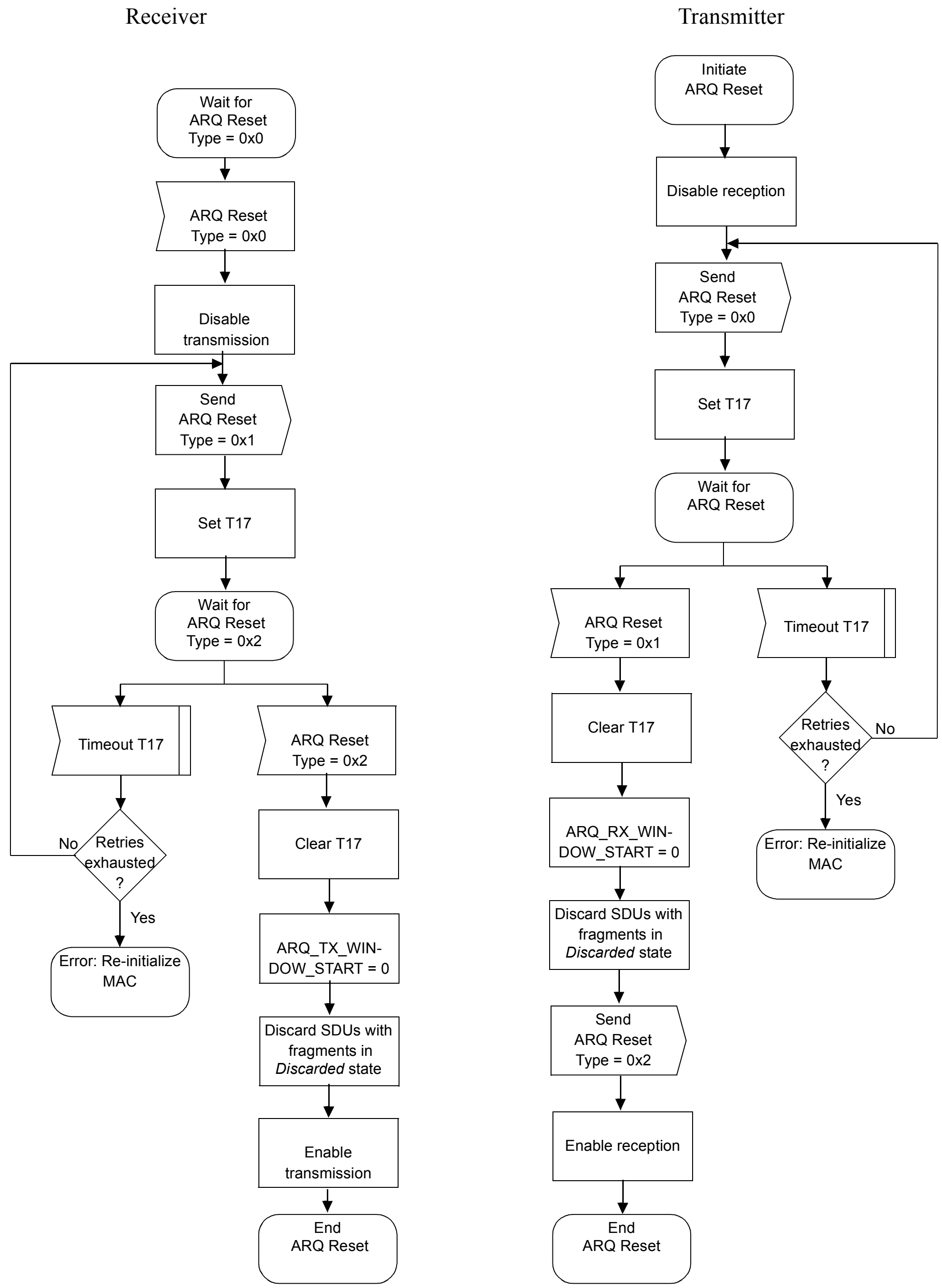


Figure 31c—ARQ Reset message dialog—transmitter initiated

Synchronization of the ARQ state machines is governed by a timer managed by the transmitter state machine. Each time *ARQ_TX_WINDOW_START* is updated, the timer is set to zero. When the timer exceeds the value of *ARQ_SYNC_LOSS_TIMEOUT* the transmitter state machine shall initiate a reset of the connection's state machines as described in Figure 140.

A Discard message may be sent to the receiver when the transmitter wants to skip ARQ fragments up to the FSN value specified in the Discard message. Upon receipt of the message, the receiver updates its state information to indicate the specified fragments were received and forwards the information to the transmitter through an ARQ Feedback IE at the appropriate time.

6.2.4.5.3 Receiver state machine

When a PDU is received, its integrity is 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 fragment with a number that falls in the range defined by the sliding window is received, the receiver shall accept it. ARQ fragment numbers outside the sliding window shall be rejected as out of order. The receiver should discard duplicate ARQ fragments (i.e., ARQ fragments that where already received correctly) within the window.

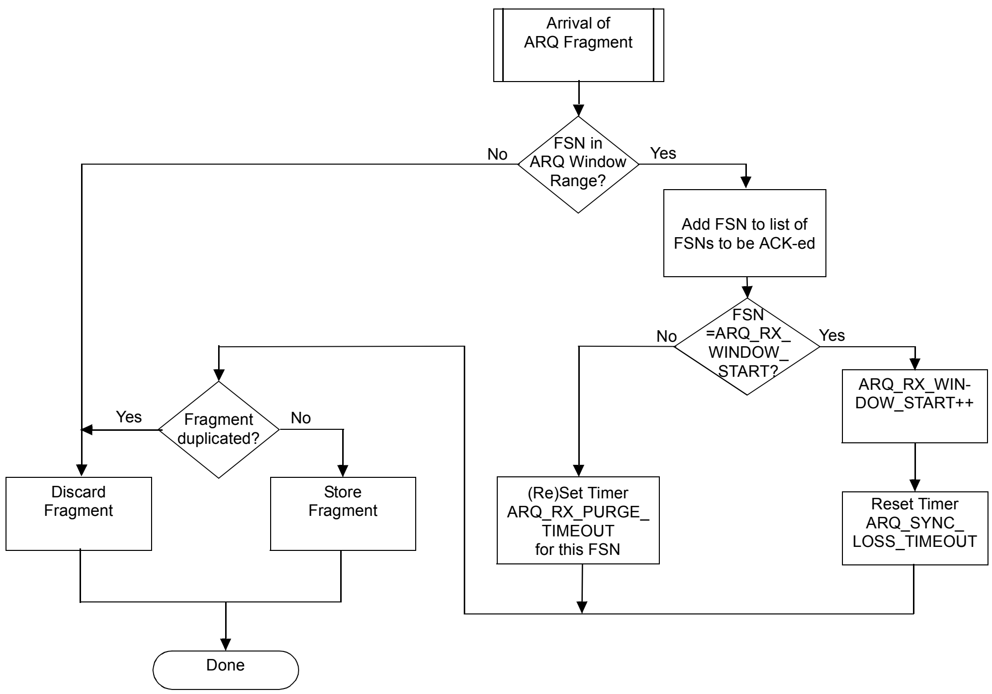


Figure 31d—ARQ fragment reception

The sliding window is maintained such that the *ARQ_RX_WINDOW_START* variable always points to the lowest numbered ARQ fragment that has not been received or has been received with errors. When an ARQ fragment with a number corresponding to the *ARQ_RX_WINDOW_START* is received, the window is advanced (i.e., *ARQ_RX_WINDOW_START* is incremented modulo *ARQ_FSN_MODULUS*) such that the *ARQ_RX_WINDOW_START* variable points to the next lowest numbered ARQ fragment that has not been received or has been received with errors. The timer associated with *ARQ_SYNC_LOSS_TIMEOUT* shall be reset.

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

When *ARQ_RX_WINDOW_START* is advanced, any FSN values corresponding to fragments 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 fragments belonging to complete SDUs shall be delivered. Fragments from partial SDUs shall be discarded.

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

For each ARQ fragment received, an acknowledgment shall be sent to the transmitter. Acknowledgment for fragments outside the sliding window shall be cumulative. Acknowledgments for fragments within the sliding window may be either for specific ARQ fragments (i.e., contain information on the acknowledged ARQ fragment numbers), or cumulative (i.e., contain the highest ARQ fragment number below which all ARQ fragments have been received correctly) or a combination of both (i.e., cumulative with selective). Acknowledgments shall be sent in the order of the ARQ fragment 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 fragments 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 fragments of the MAC SDU have been correctly received within the defined time-out values and all fragments 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 fragments of the MAC SDU have been successfully received within the defined time-out values.

The actions to be taken by the receiver state machine when an ARQ Reset Message is received are provided in Figure 31c. The actions to be taken by the receiver state machine when it wants to initiate a reset of the transmitter ARQ state machine are provided in Figure 31b.

Synchronization of the ARQ state machines is governed by a timer managed by the receiver state machine. Each time *ARQ_RX_WINDOW_START* is updated, the timer is set to zero. When the timer exceeds the value of *ARQ_SYNC_LOSS_TIMEOUT* the receiver state machine shall initiate a reset of the connection's state machines as described in Figure 31c.

6.2.5 Uplink scheduling service

Change Table 58 to read:

Table 58—Scheduling services and usage rules

Scheduling type	PiggyBack request	Bandwidth stealing	Polling
UGS	Not Allowed	Not allowed	PM bit is used to request a unicast poll for bandwidth needs of non-UGS connections.
rtPS	Allowed	Allowed ~~for GPSS~~	Scheduling only allows unicast polling.
nrtPS	Allowed	Allowed ~~for GPSS~~	Scheduling may restrict a service flow to unicast polling via the transmission/request policy; otherwise all forms of polling are allowed.
BE	Allowed	Allowed ~~for GPSS~~	All forms of polling allowed.

6.2.6 Bandwidth allocation and request mechanisms

6.2.6.1 Requests

Delete last two paragraphs of 6.2.6.1.

6.2.6.2 Grants per connection (GPC) mode

Delete 6.2.6.2 entirely (including header and Figure 32).

Change 6.2.6.3 to read:

6.2.6.3 Grants ~~per connection (GPC) mode~~

For an SS ~~operating in GPSS mode~~, the bandwidth requests are addressed to the individual connections while the bandwidth grant is addressed to the SS's Basic CIDs and not explicitly to individual CIDs. Since it is nondeterministic which request is being honored, when the SS receives a shorter transmission opportunity than expected (i.e., scheduler decision, request message lost, etc.), no explicit reason is given. In all cases, based on the latest information received from the BS and the status of the request, the SS may decide to perform backoff and request again or to discard the SDU.

A ~~GPSS~~ SS may use Request IEs that are broadcast, directed at a multicast polling group it is a member of, or directed at its Basic CID. In all cases, the Request IE burst profile is used, even if the BS is capable of receiving the SS with a more efficient burst profile. To take advantage of a more efficient burst profile, the SS should transmit in an interval defined by a Data Grant IE directed at its Basic CID. Because of this, unicast polling of a ~~GPSS~~ SS would normally be done by allocating a Data Grant IE directed at its Basic CID. Also note that, in a Data Grant IE directed at its Basic CID, the SS may make bandwidth requests for any of its connections.

The procedure followed by SSs ~~operating in GPSS mode~~ is shown in Figure 33.

Change Title of Figure 33 to read:

SS <u>Request/Grant</u> ~~GPSS mode~~ flow chart

Insert 6.2.6.5 through 6.2.6.7 as follows:

6.2.6.5 Contention-based focused bandwidth requests for WirelessMAN-OFDM

The WirelessMAN-OFDM PHY supports two contention based BW request mechanisms. The mandatory mechanism allows the SS to send the Bandwidth Request Header as specified in 6.2.6.1 during a REQ Region-Full. Alternatively, the SS may send a Focused Contention Transmission during a REQ Region-Focused. This transmission consists of a (with equal probability selected) Contention Code modulated on a, (with equal probability selected) Contention Channel consisting of 4 carriers. Upon detection, the BS shall provide a UL allocation for the SS to transmit a BW request MAC PDU and optionally additional data, 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 that 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. See also 8.4.6.3.3.

6.2.6.6 Contention-based CDMA bandwidth requests for WirelessMAN-OFDMA

The OFDMA based PHY supports two mandatory contention based BW request mechanisms: the SS shall either send the Bandwidth Request Header as specified in 6.2.6.1, or use the CDMA based mechanism as specified in the following paragraphs of this subclause.

As specified in 6.2.10.2, the OFDMA based PHY specifies a Ranging Subchannel and a subset of Ranging codes that shall be used for contention-based BW requests. The SS, upon a need to request for transmission slots, shall select, with equal probability, a Ranging Code from the code subset allocated to BW requests. This Ranging Code shall be modulated onto the Ranging Subchannel and transmitted during the appropriate UL allocation.

Upon detection, the BS shall provide (an implementation dependent) UL allocation for the SS, but instead of indicating a Basic CID, the broadcast CID shall be sent in combination with a CDMA_Allocation_IE, which specifies the transmit region and Ranging Code that 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. The SS shall use the allocation to transmit a BW request MAC PDU and/or data. The SS may only omit the BW request PDU when the BS indicated so in the CDMA_Allocation_IE (see Table 116bv).

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 Ranging Code transmission resulted in a collision and follow the contention resolution as specified in 6.2.8.

6.2.6.7 Optional Mesh topology support

The WirelessHUMAN system provides optional support for Mesh topology. 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 that 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 do 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 neighborhood, or scheduled using a combination of these.

6.2.6.7.1 Distributed scheduling

The stations that has direct links are called neighbors and shall form a neighborhood. A node’s neighbors are considered to be “one hop” away from the node. A two-hop extended neighborhood contains, additionally, all the neighbors of the neighborhood. In the coordinated distributed scheduling mode, all the stations (BS and SSs) shall coordinate their transmissions in their extended two-hop neighborhood.

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 neighbors. Within a given channel all neighbor 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.

— A MSH-DSCH:Request is made along with MSH-DSCH:Avalabilities, which indicate potential slots for replies and actual schedule.
— A MSH-DSCH:Grant is sent in response indicating a subset of the suggested availabilities that fits, if possible, the request. The neighbors of this node not involved in this schedule shall assume the transmission takes place as granted.
— 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 neighbors of this node not involved in this schedule shall assume the transmission takes place as granted.

The differences between coordinated and uncoordinated distributed scheduling are as follows: In the coordinated case, the MSH-DSCH messages are scheduled 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.

6.2.6.7.2 Centralized scheduling

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

The network connections and topology are the same as in the distributed scheduling mode described in 6.2.6.7.1, but the scheduled transmissions for the SSs shall be defined by the BS. The BS determines the flow assignments from the resource requests from the SSs. Subsequently, the SSs 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 of the SSs have to be directly connected to the BS, and the assignments determined by the BS extends to those SSs not directly connected to the BS. 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 that 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. The requested flows for the network are shown in Figure 36a. For simplicity of notation, the data rate is assumed to be the burst profile number.

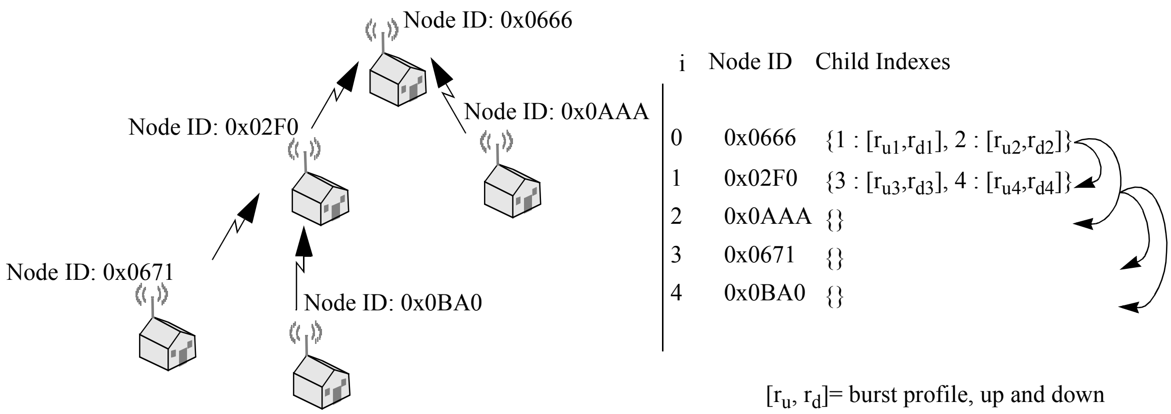


Figure 36a—MSH-CSCF schedule example

The link fractions shown in Figure 36b are multiplied with ($2^{\textbf{FlowScale Exponent+14}}$) 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).

Each node shall ensure that the duration of all resulting minislot allocations per channel does not exceed the available minislot space (in one or two frames depending on the **Frame schedule flag**) by reducing all allocations proportionally. Each node shall then recursively round down the number of minislots of the allocation with the smallest decimal fraction and add another minislot to the allocation with the largest decimal fraction. Before transmitting the schedule, the Mesh BS shall ensure that this computation does not result in non-zero allocations smaller than required to transmit a preamble and one data symbol.

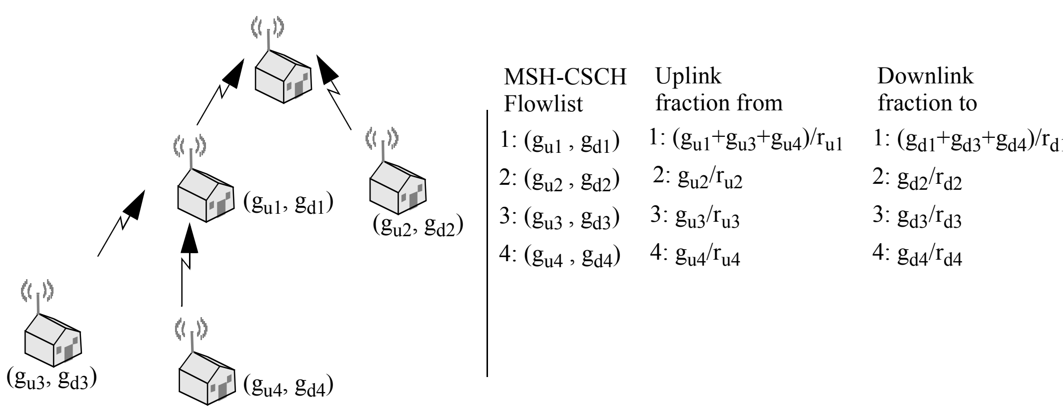


Figure 36b—MSH-CSCH flow usage example

The number of frames during 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 the following:

— The time the node shall transmit this schedule (if eligible) for nodes further down the transmission tree.
— The frame where the last node in the transmission tree will be receiving this schedule.
— The original transmission time by the Mesh BS of this schedule.

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:

Step 1) The Mesh BS transmits first in a new frame.

Step 2) Then, the eligible children of the Mesh BS (i.e., nodes with a hop count equals 1), ordered by their appearance in the routing tree, transmit.

Step 3) Then, the eligible children of the nodes from Step 2) (i.e., nodes with a hop count that equals 2), also ordered by their appearance in the routing tree, transmit.

Step 4) … 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 where 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 time between the first frame in which a node sends the request schedule and the last frame where a node receives the new grant schedule marks the validity of the previous grant schedule. 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.

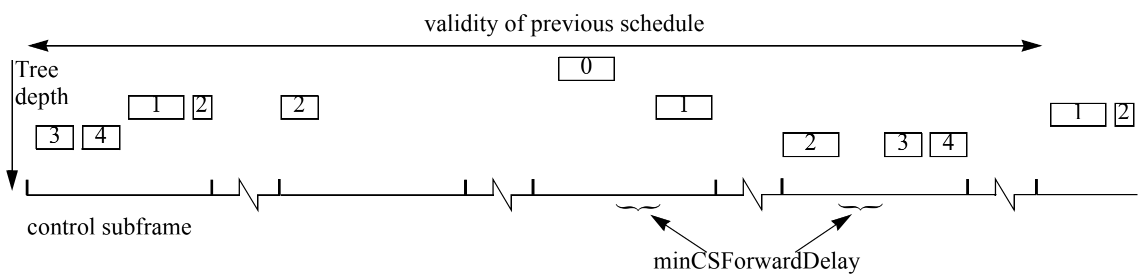


Figure 36c—MSH-CSCH schedule validity

6.2.7 MAC support of PHY layer

6.2.7.6 Map relevance and synchronization

Insert new header 6.2.7.6.1 WirelessMAN-SC PHY and change 6.2.7.6.1 and 6.2.7.6.2 headers to 6.2.7.6.1.1 and 6.2.7.6.1.2, respectively. Insert at end of 6.2.7.6 as follows:

6.2.7.6.2 WirelessMAN-SCa PHY

The first portion of a downlink (MAC) frame shall bear frame control information destined for all SSs. This control information shall not be encrypted. This control section shall contain a DL-MAP message for the downlink channel followed by one UL-MAP message for each associated uplink channel. In addition the control section may contain DCD and UCD messages following the last UL-MAP message. No other messages may be sent in the PHY/MAC Control portion of the frame.

The DL-MAP does not describe the beginning locations of the payload groups that immediately follow on the downlink channel; it describes the payload distributions starting at the time derived from the Allocation_Start_Time. The minimum Allocation_Start_Time for the DL shall be one frame duration (from the start of the DL-MAP). This delay is necessary so the FEC decoding of MAC information may be completed, the adaptive data interpreted, and the demodulator scheduling set up for the proper sequencing.

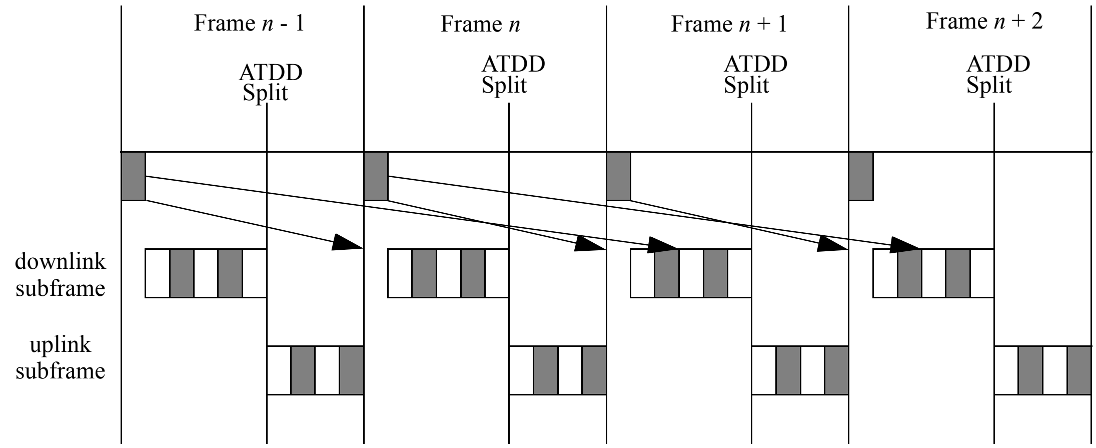


Figure 43a—Time relevance of PHY and MAC control information (TDD)

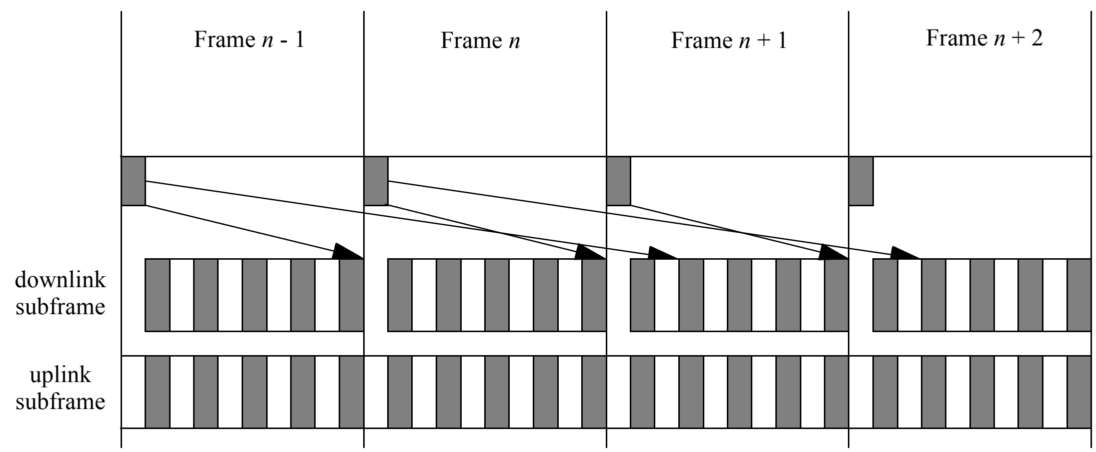


Figure 43b—Time relevance of PHY and MAC control information (FDD)

As shown in Figure 43a and Figure 43b, the portion of the time axis described by the map is a contiguous area whose duration is equal to the duration of a frame. In the example shown in Figure 43a, these contiguous time areas consist of a portion of the frame following the frame where the map was transmitted for the DL and a portion of the subsequent frame for the UL. The fraction of the downlink time in the current frame (or alternatively, the Allocation Start Time), is a quantity that is under the control of the scheduler.

6.2.7.6.3 WirelessMAN-OFDM and WirelessMAN-OFDMA PHY

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

6.2.7.6.4 Optional Mesh mode

Only TDD is supported in Mesh mode. Contrary to the basic PMP mode, there are no clearly separate downlink and uplink subframes in the Mesh mode. Stations shall transmit to each other either in scheduled channels or in random access channels as in PMP mode. The frame structure is described in 8.4.4.2.

6.2.7.6.4.1 Physical neighborhood list

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

MAC Address
48-bit MAC address of the neighbor.

Hop Count
Indicates distance in hops of this neighbor from the present node. If a packet has been successfully received from this neighbor 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 6.2.2.3.34 for detailed definition).

Next Xmt Time
The MSH-NCFG transmit opportunity(ies) when the next MSH-NCFG from this node is expected (see 6.2.2.3.34 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.

6.2.7.6.4.2 Schedule relevance with distributed scheduling

When using coordinated distributed scheduling all the stations in a network shall use the same channel to transmit schedule information in a format of specific resource requests and grants in Mesh Mode Schedule Messages with Distributed Scheduling (MSH-DSCH). A station shall indicate its own schedule by transmitting a MSH-DSCH regularly. The MSH-DSCH messages shall be transmitted during the control portion of the frame. Relevance of the MSH-DSCH is variable and entirely up to the station. An example case is given in Figure 43c, in which **Schedule Frames** = 0x2 (8 frames) has been assumed.

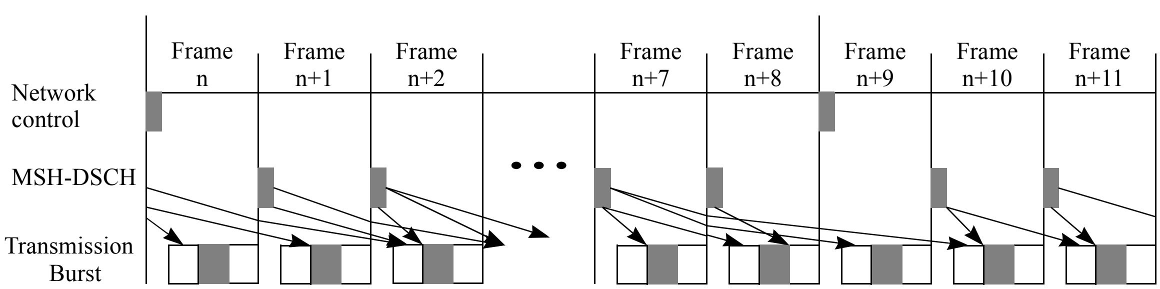


Figure 43c—Time relevance example of MSH-DSCH in distributed scheduling

MSH-DSCH messages are transmitted regularly throughout the whole Mesh network to distribute nodes' schedules and (together with network configuration packets) provide network synchronization information. A SS that has a direct link to the BS shall synchronize to the BS while a SS that is at least two hops from the BS shall synchronize to its neighbor SSs that are closer to the BS.

The control portion of every [**Schedule Frames** + 1] frames (see MSH-NCFG:Network descriptor, 6.2.2.3.34.3) is reserved for communication of MSH-NCFG and MSH-NENT packets.

6.2.7.6.4.3 Schedule relevance with centralized scheduling

When using centralized scheduling the BS shall act as a centralized scheduler for the SSs. Using centralized scheduling, the BS shall provide schedule configuration (MSH-CSCF) and assignments (MSH-CSCH) to all SSs.

The validity of a MSH-CSCH schedule is computed by each node as specified in 6.2.6.7.2. The BS determines the assignments from the resource requests received from the SSs. Intermediate SSs are responsible for forwarding these requests for SSs (listed in the current routing tree as specified by the last MSH-CSCF modified by the last MSH-CSCH update) that are further from the BS (i.e., more hops from the BS) as needed. All the SSs shall listen and compute the schedule. Further, they shall forward the MSH-CSCH message to their neighbors that are further away from the BS.

Additionally, as with distributed scheduling, the control portion of every [**Schedule Frames** + 1] frames (see MSH-NCFG:Network descriptor, 6.2.2.3.34.3) is reserved for communication of MSH-NCFG and MSH-NENT packets.

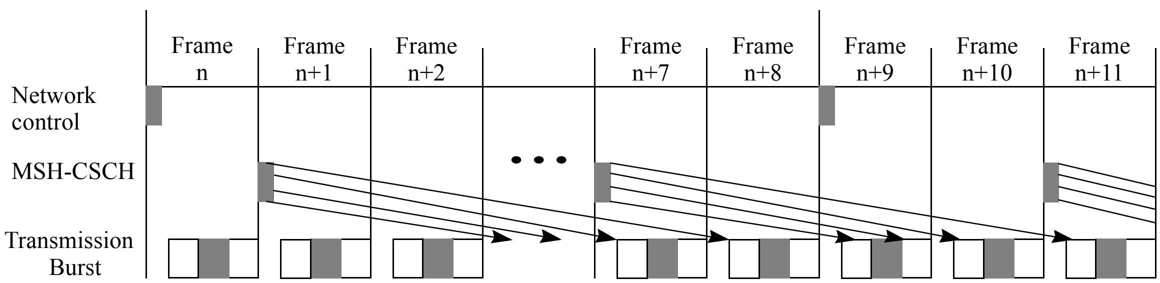


Figure 43d—Time relevance example of MSH-CSCH in centralized scheduling

6.2.7.6.4.4 Mesh 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 (i.e., 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 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 8.4.4.2). 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.

6.2.7.6.4.5 MSH-NCFG/MSH-NENT transmission timing

MSH-NCFG and MSH-NENT packets are scheduled for transmission during control subframes. To ensure 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:

$$\text{NetConfigChannel}=\text{Logical channel list}[(\text{Frame Number} / (\text{Scheduling Frames} \cdot 4 + 1))\%\text{Channels}] \quad (9)$$

where the Logical channel List, **Channels** and **Scheduling Frames** are derived from the MSH-NCFG:Network Descriptor (see 6.2.2.3.34.3). The location within frames, burst profile etc. of MSH-NCFG and MSH-NENT packets are described in 8.4.4.2.

6.2.7.6.4.6 Scheduling next MSH-NCFG transmission

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 procedure to determine its **Next Xmt Time**:

> Order its physical neighbor table by the **Next Xmt Time**.
> For each entry of the neighbor table, add the node's **Next Xmt Time** to the node's **Xmt Holdoff Time** to arrive at the node's **Earliest Subsequent Xmt Time**.
> Set **TempXmtTime** equal to this node's advertised **Xmt Holdoff Time** added to the current **Xmt Time**.
> Set *success* equal to false
> **While** *success* equals false **do**:
>> Determine the eligible competing nodes, which is the set of all nodes in the physical-neighbor list with a **Next Xmt Time** eligibility interval that includes **TempXmtTime** or with an **Earliest Subsequent Xmt Time** equal to or smaller than **TempXmtTime**.
>>
>> Hold a *Mesh Election* among this set of eligible competing nodes and the local node using **TempXmtTime** and the list of the Node IDs of all eligible competing nodes as the input: *MeshElection (TempXmtTime,MyNodeID,CompetingNodeIDsList [ ])*
>>
>> **If** (this node does not win *Mesh election)*
>>> Set **TempXmtTime** equal to next MSH-NCFG opportunity.
>>
>> **Else**:
>>> Set *success* equal to true
>>> Set the node's **Next Xmt Time** equal to **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 otherwise FALSE. 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);
}
```

6.2.7.6.4.7 Scheduling MSH-NENT messages

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 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 immediately following MSH-NENT transmission opportunity.

A new node uses the algorithm specified by the following C-like 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;
        }
```

6.2.7.6.4.8 MSH-NCFG Reception Procedure

When a MSH-NCFG packet is received from a neighbor, the following is performed:

The hop count field in the Physical Neighborhood List (see 6.2.7.6.4.1) for the neighbor itself is set to 1. The hop count field for other nodes listed in the MSH-NCFG message is set to **Hops to Neighbor +2** (see Table 56g) unless they are already listed with a lower hop count.

The **Next Xmt Time** and **Xmt Holdoff Time** of the transmitting node and all reported nodes are updated.

The “Reported Flag” for each entry in the Physical Neighbor Table that was modified is set to FALSE.

Insert 6.2.7.7 as follows:

6.2.7.7 Optional MAC Support of 2–11 GHz Adaptive Antenna Systems

6.2.7.7.1 AAS MAC services

AAS (see [B25], [B39], [B40], and [B42] for generic literature), through the use of more than one antenna element, can improve range and system capacity, by adapting the 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 6.2.7.7.3 and 6.2.7.7.6.

6.2.7.7.2 MAC control functions

The control of AAS part of the frame shall be done by unicasting private management messages to individual SSs. These messages shall be the same as the broadcast management messages, except that the basic CID assigned to the SS is used instead of the Broadcast CID.

6.2.7.7.3 AAS DL synchronization

The process of initial synchronization to the downlink in AAS systems is different from the non-AAS process. This is because the adaptive array operating in the PHY cannot be effective until the MAC and PHY of the BS identify the new SS. The adaptation of BS antenna array can be accomplished only after the BS has identified the SS.

When the SS first attempts to synchronize to the downlink transmission, the BS is unaware of its presence, and therefore is not aiming the adaptive array at its direction. Nevertheless, the frame start preamble 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.

6.2.7.7.4 Alerting the BS about presence of a new SS in an AAS system

In a non-AAS system, after synchronizing to the downlink, a SS attempts to obtain the downlink parameters by decoding the DL-MAP and DCD messages. In an AAS system, a SS may be able to obtain the downlink 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.

An AAS BS shall reserve a fixed, pre-defined part of the frame as initial-ranging contention slots for this alert procedure. These contention slots shall be located at a well-known location relative to the downlink preamble, so even an SS that can only identify the DL preamble shall be able to locate it. The number of contention slots and their location in the frame is PHY specific (see 8.3.1.4.5.3, 8.4.6.2, 8.5.4.2 respectively). These contention slots shall be called AAS-alert-slots.

When an AAS SS has synchronized to the downlink, yet is unable to obtain the downlink parameters because it cannot decode the DL-MAP and DCD messages, it shall attempt initial ranging on the AAS-alert-slots. Unlike usual initial ranging, the SS shall use all available contention slots, 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.

6.2.7.7.5 FDD/TDD support

Adaptive Arrays use channel state information in the PHY at both downlink and uplink. When channel state of the downlink is required at the BS, there are two ways to obtain it:

- By relying on reciprocity, thus using the uplink channel state estimation as the downlink channel state.
- By using feedback, thus transmitting the estimated channel state from the SS to BS.

The first method is simpler and is well suited for TDD systems. The second method is more suitable for FDD systems, where reciprocity does not apply (due to the large frequency separation between uplink and downlink channels). The second method may also be used for TDD systems.

Channel state information is obtained by using two MAC control messages: AAS-FBCK-REQ and AAS-FBCK-RSP (see 6.2.2.3.39). 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. Using FDD, the BS shall issue AAS-FBCK-REQ messages. Using TDD, the BS may issue AAS-FBCK messages.

6.2.7.7.6 Requesting bandwidth

AAS subscribers might not be able to request bandwidth using the usual contention mechanism. This happens because the 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.

6.2.9 Network entry and initialization

Insert at start of 6.2.9:

Systems shall support the applicable procedures for entering and registering a new SS or a new node to the network. All network entry procedures described hereunder till and including 6.2.9.12 apply only to PMP operation. The network entry procedure for Mesh operation is described in 6.2.9.14.

6.2.9.5 Initial ranging and automatic adjustment

Replace the sixth paragraph with the following:

~~The SS shall first send the RNG-REQ at minimum power level, and if it is not successful, the SS shall resend it at the next Initial Maintenance transmission opportunity at one step higher power level until successful.~~

The SS shall send the RNG-REQ at minimum power level. 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 containing the frame number in which the RNG-REQ was transmitted, 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, it shall consider the RNG_RSP reception successful.

When a WirelessMAN-SCa or WirelessMAN-OFDM BS detects a transmission in the ranging slot that it is unable to decode, it may respond by transmitting a RNG-RSP that includes transmission parameters but identifies the frame number and frame opportunity when the transmission was received instead of the MAC Address of the transmitting SS.

Change Table 61 to read as follows:

Table 61—Ranging and automatic adjustments procedure

BS		SS
[time to send the Initial Maintenance opportunity]		
send map containing Initial Maintenance information element with a broadcast Connection ID	-----------UL-MAP------------>	
	<---------RNG-REQ-------	transmit ranging packet in contention mode with Connection ID parameter = 0
[a][detect un-decodable ranging packet]		
[a]send ranging response, including Frame Number, Frame Opportunity, CID=0	----------RNG-RSP[a]------->	
		[a][recognize frame number/opportunity when packet was sent] Adjust parameters, prepare to transmit another RNG-REQ at next opportunity
[a][time to send next map] Send map containing Initial Maintenance IE with a broadcast CID	-----------UL-MAP[a]------------>	
	<---------RNG-REQ[a]-------	[a]transmit ranging packet in contention mode with CID parameter = 0
[receive recognizable ranging packet]		
allocate Basic and Primary Management Connection ID		
send ranging response	----------RNG-RSP------->	
add Basic Connection ID to poll list		[recognize own MAC Address] store Basic Connection ID and adjust other parameters
[time to send the next map]		
send map with Station Maintenance information element to SS using Basic CID	-----------UL-MAP------------>	[recognize own Basic Connection ID in map]
	<---------RNG-REQ-------	reply to Station Maintenance opportunity poll
send ranging response	----------RNG-RSP------->	
		adjust local parameters
send periodic transmit opportunity to broadcast address	------------UL-MAP----------->	

[a]WirelessMAN-SCa and WirelessMAN-OFDM PHY only.

Insert above 6.2.9.7 header:

For systems operating between 2 and 11 GHz, the BS may in addition respond to undecodable messages in an Initial Maintenance slot as shown in Figure 51a.

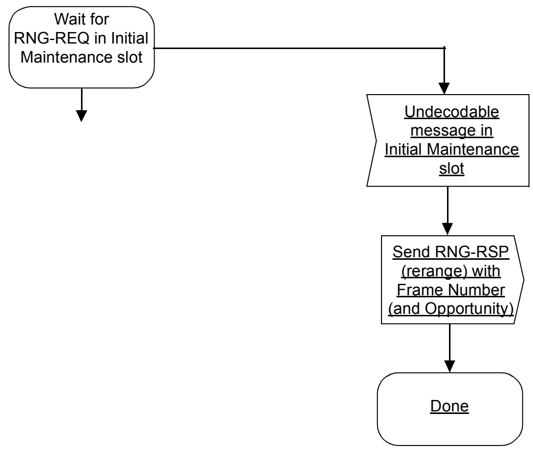


Figure 51a—Initial ranging—BS response to undecodable message

6.2.9.10 Establish IP connectivity

Change Table 62 to read:

Table 62—Establishing IP connectivity

SS/Node		**DHCP**
Send DHCP request to broadcast address		
	----------------DHCP discover------------>	
		Check SS MAC address and respond
	<--------------DHCP offer -----------------	
Choose server		
	----------------DHCP request-------------->	
		Process request
	<--------------DHCP response--------------	
Set up IP parameters from DHCP response		

Insert 6.2.9.14:

6.2.9.14 Network Entry and synchronization in Mesh mode

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 process to the stage when the node can start scheduled transmissions can be divided into the following phases:

a) Scan for active network and establish coarse synchronization with the network
b) Obtain network parameters (from MSH-NCFG messages)
c) Open Sponsor Channel
d) Node authorization
e) Perform registration
f) Establish IP connectivity
g) Establish time of day
h) Transfer operational parameters

The entry process is depicted in Figure 54a, Figure 54b, and Figure 54c.

Each node contains the following information when shipped from the manufacturer:

a) A 48-bit universal MAC address (per IEEE Std 802) 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 neighbor node.

6.2.9.14.1 Scanning and coarse synchronization to the 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 of the message. 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 neighbor list.

6.2.9.14.2 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 build a physical neighbor list (see 6.2.7.6.4.1) from the acquired information.

From the established physical neighbor 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 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 6.2.7.6.4.7.

Until the node has obtained an unique Node ID (see 6.2.9.14.5), 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 more effective message exchange.

6.2.9.14.3 Open Sponsor Channel

Once the new node has selected one of its neighbors 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 6.2.2.3.34.3. 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 (see 8.4.4.2). 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 time, 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 T18), 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 6.2.9.14.4 through 6.2.9.14.9. 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.

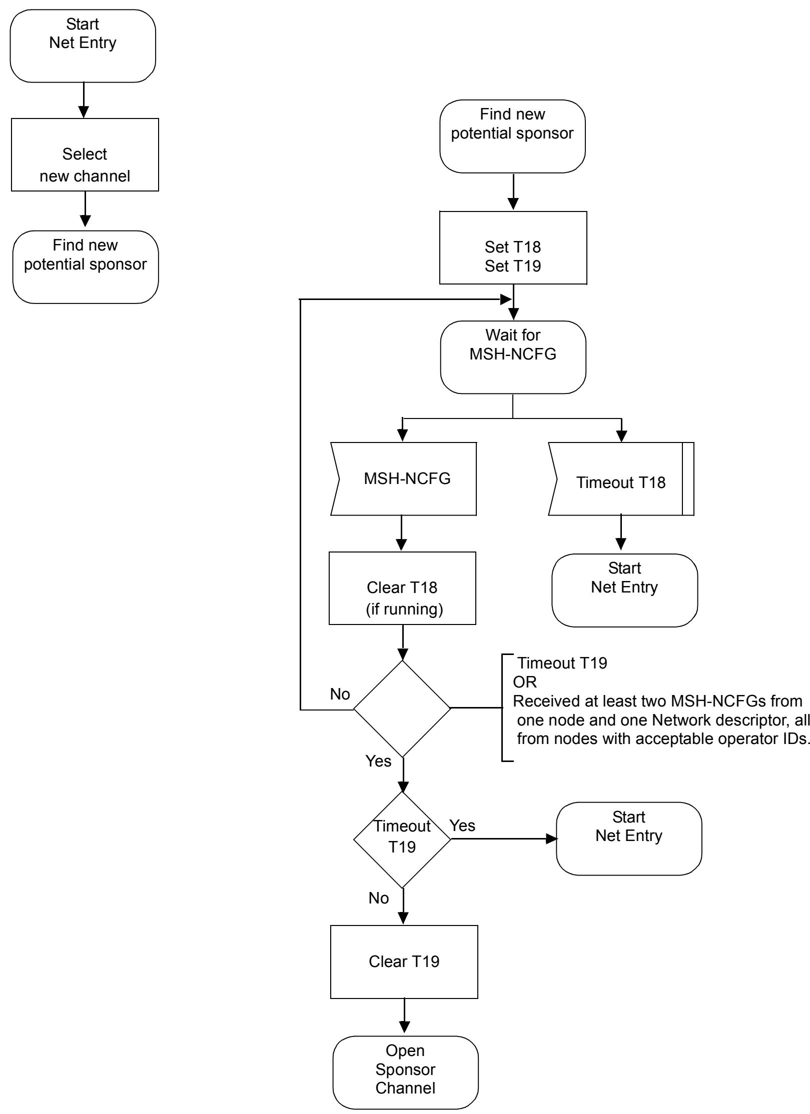


Figure 54a—Mesh network synchronization and entry—New node—I

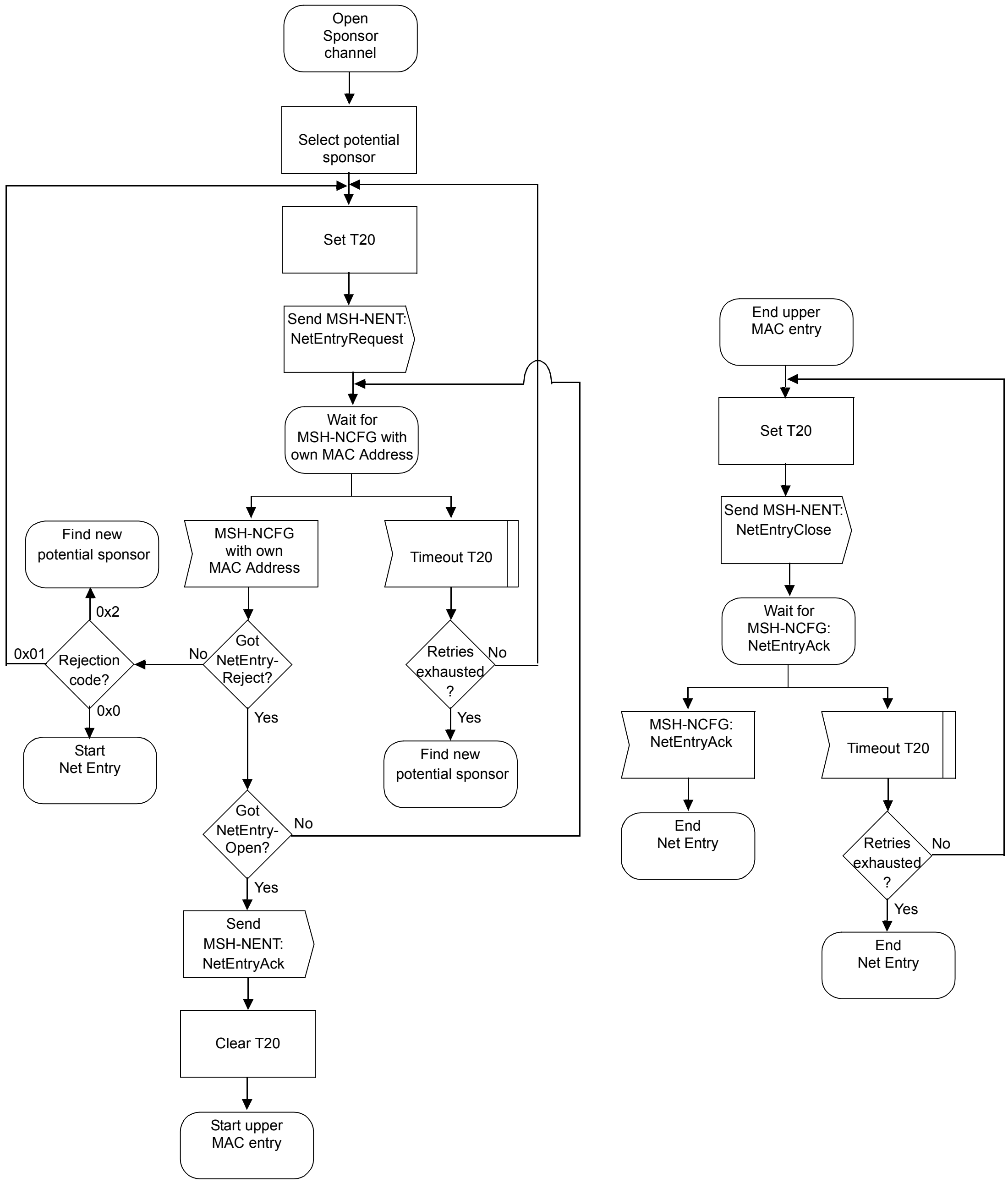


Figure 54b—Mesh network synchronization and entry—New node—II

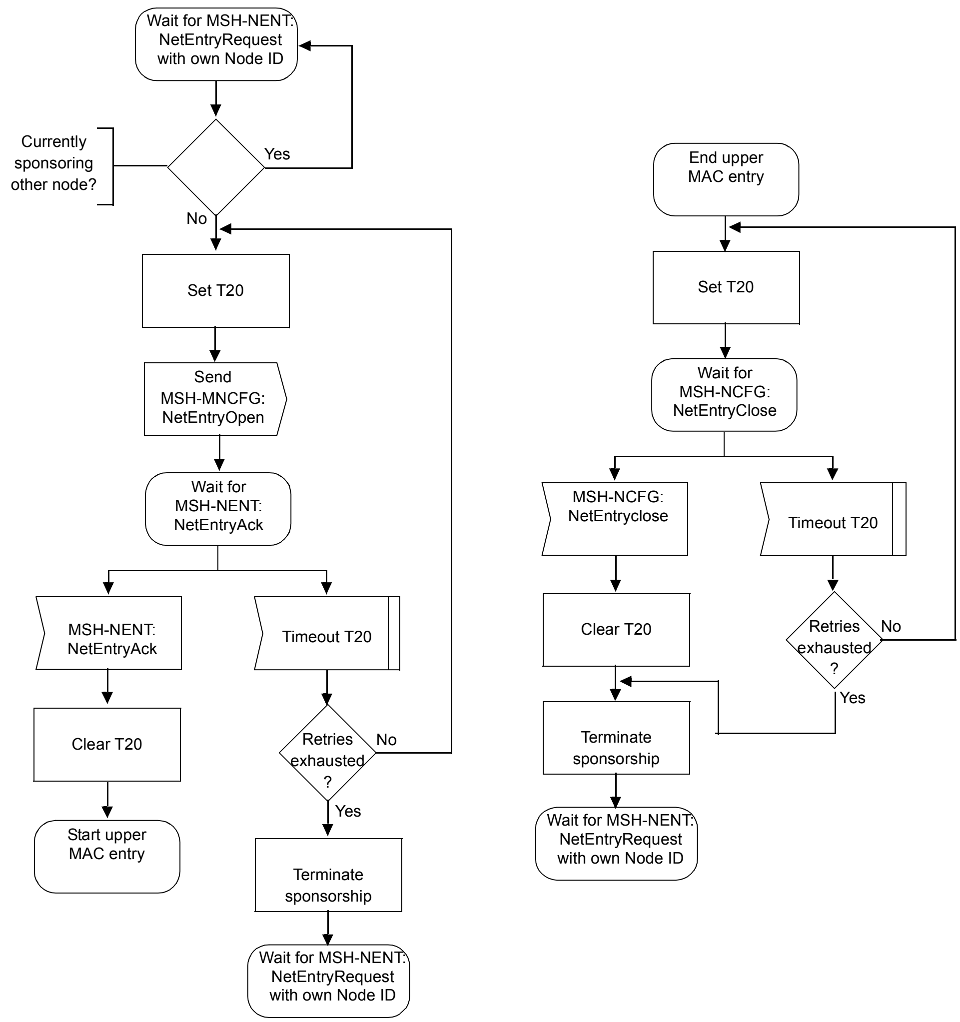


Figure 54c—Mesh network synchronization and entry—sponsor node

Table 63a displays the message transfer sequence during a successful network entry without repetitions or time-outs.

Table 63a—Successful network entry message exchange

Sponsor node		New node
Nodes in network routinely advertise network with Network Descriptor (see 6.2.7.6.4.4).	**MSH-NCFG: Network Descriptor** →	New node at startup searches for MSH-NCFG messages with Network Descriptor (see also Figure 54a).
	← **MSH-NENT: NetEntryRequest**	
Node can decide to respond negatively with NetEntryReject or can respond positively with NetEntryOpen reporting new node's MAC address and schedule allocation for higher layer authentication and configuration exchange.	**MSH-NCFG: NetEntryOpen** →	
	← **MSH-NENT: NetEntryAck**	New node sends ACK to confirm schedule.
	Security sublayer and basic capability exchange operations	
	← **MSH-NENT: NetEntryClose**	After authentication and configuration have been completed, node closes the entry procedure.
Sponsor ACK's closure of sponsorship. In following MSH-NCFG packets, node sends all-zero NetEntry MAC address (indicating ready to sponsor new node) or sets NetEntry MAC address flag to 0.	**MSH-NENT: NetEntryAck** →	Node is now regular node in the network.

6.2.9.14.4 Negotiate basic capabilities

In Mesh mode, the basic capabilities shall be negotiated as described in 6.2.9.7 after a logical link has been established between two nodes. The node that requested the logical link (see 6.2) shall act as the SS and initiate the SBC-REQ.

6.2.9.14.5 Node authorization

The new node shall perform authorization as described in 7.2. 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 6.2.15 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 tunneled PKM-RSP MAC Messages from the Authorization Node the Sponsor shall forward the messages to the new node.

6.2.9.14.6 Node registration

Registration is the process where a node is assigned its Node ID. The sponsoring node upon reception of the REG-REQ shall tunnel the message as described in 6.2.15 to the Registration Node. Upon receiving tunneled 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 54d and Figure 54e. The Registration Node shall follow the procedure in Figure 54f.

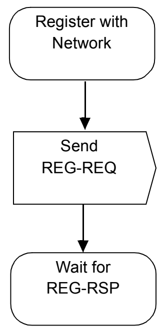


Figure 54d—Registration—candidate node

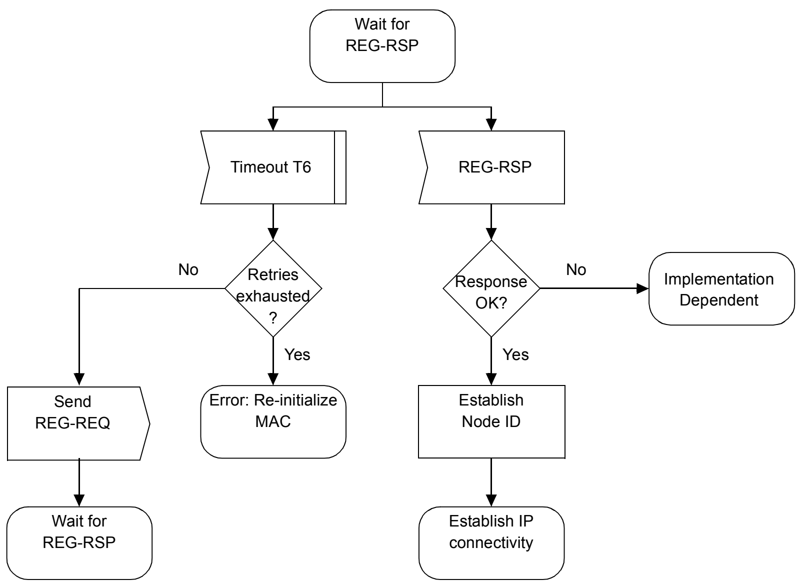


Figure 54e—Wait for registration response—candidate node

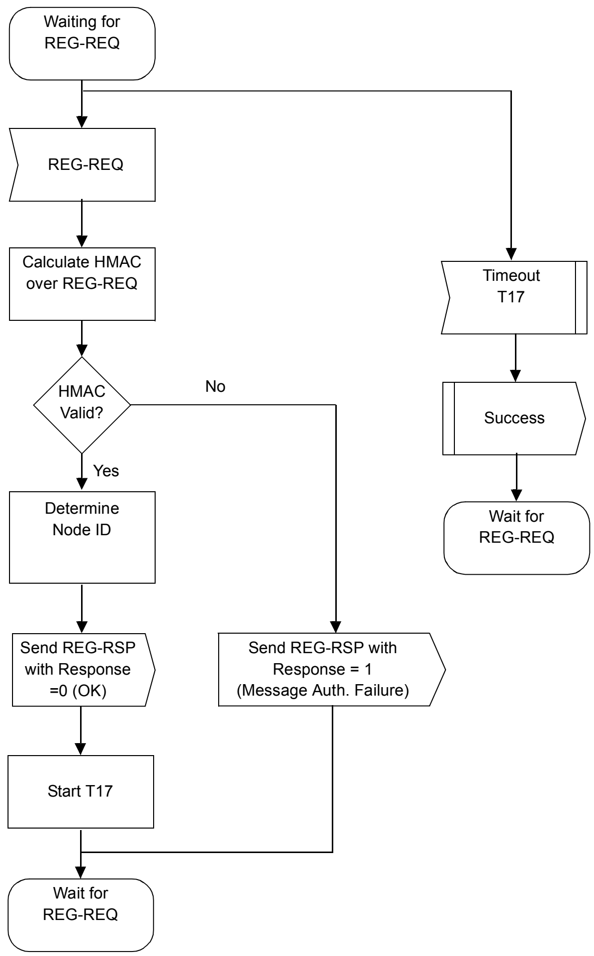


Figure 54f—Registration—registration node

6.2.9.14.7 Establish IP connectivity

The Node shall acquire an IP address using DHCP. The procedure is shown in Table 62 and takes place over the Sponsor Channel.

6.2.9.14.8 Establish time of day

The Nodes in a Mesh network shall retrieve the time of day using the protocol defined in [IETF RFC 868]. The messages shall be carried over UDP in the Sponsor Channel.

6.2.9.14.9 Transfer operational parameters

After successfully acquiring an IP address via DHCP the Node shall download a parameter file using TFTP. The procedure is described in 6.2.9.12. The Node shall instead of the Secondary Management connection use the Sponsor Channel for this purpose.

6.2.9.14.10 Setup provisioned traffic parameters

Using Mesh, QoS is provisioned on a packet-by-packet basis using the Mesh CID. The connection-based QoS provisioning using the DSx messages defined in 6.2.13 are hence not used. A Mesh node obtains its AuthorizedQoSParamSet during the transfer of operational parameters.

6.2.9.14.11 Establishing links to neighbors

After entering the network, a node can establish links with nodes other than its sponsor by following the secure process as defined in Table 54e. This process uses the MSH-NCFG:Neighbor Link Establishment IE.

a) 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}
   where 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 sent a MSH-NCFG message.

b) Node B, upon reception, computes the same value (it may also attempt some earlier frame numbers where it sent MSH-NCFG messages, in case node A missed the last of its MSH-NCFGs) in item a) and compares. If the values don't 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}
   where 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.

c) Node A, upon reception, computes the same value in item b) 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 54e—Establishing link connectivity

Node A		**Node B**
send challenge (action code=0x0)		
	---------------------Challenge--------------------->	
		if HMAC{} match, send challenge response (action code=0x1)
	<--------------Challenge response-----------------	
if HMAC{} match, send Accept (action code=0x2)		
	------------------------Accept--------------------->	

6.2.10 Ranging

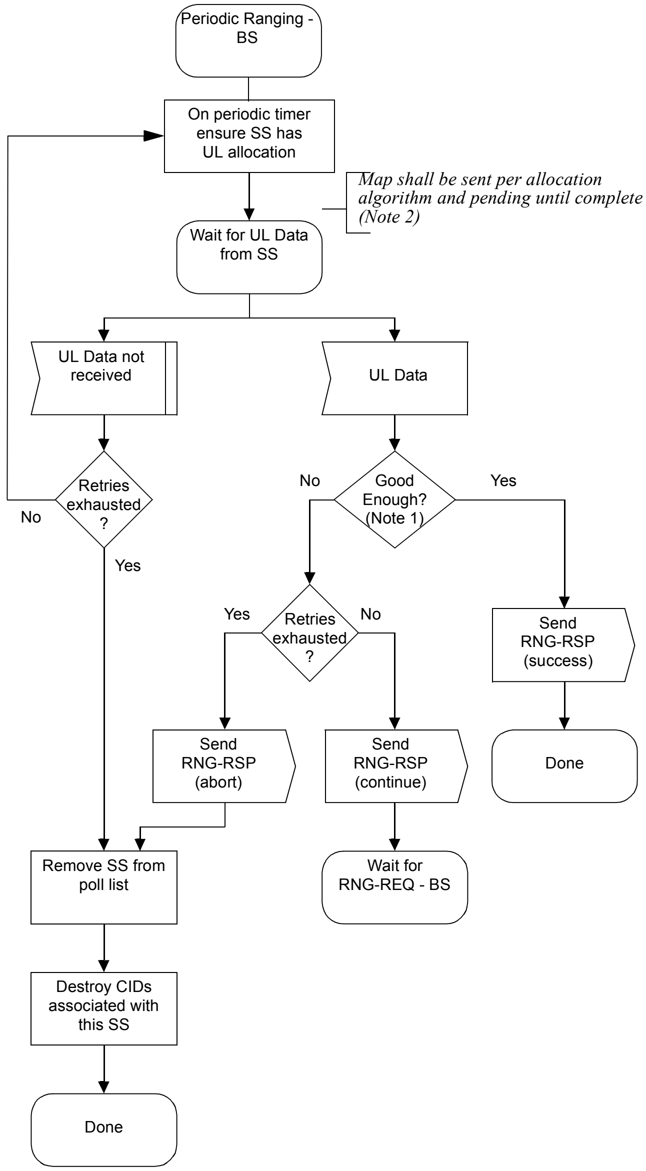
Replace first and second paragraph with the following:

There are two different ranging procedures: initial ranging and periodic ranging. Initial ranging, detailed in 6.2.9.5 is for 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 is for the SSs during normal operations to adjust transmission parameters so the SSs can communicate with the BS properly.

The following summarizes the periodic ranging (with exception of CDMA based ranging, which is covered in 6.2.10.2):

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

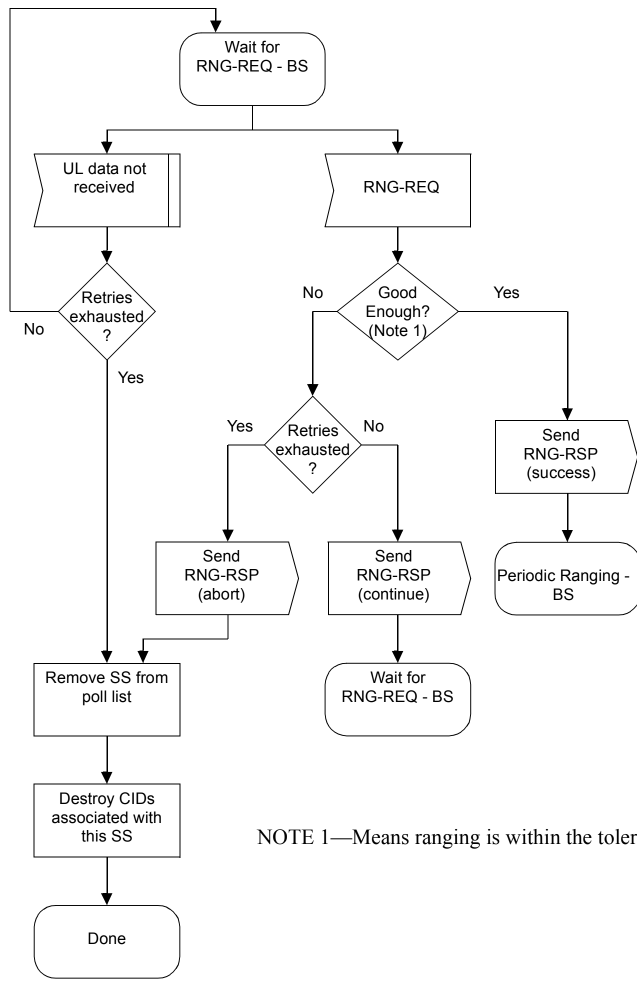
Replace Figure 55 with Figure 55a and Figure 55b as follows:



NOTE 1—Means ranging is within the tolerable limits of the BS.

NOTE 2—RNG-REQ pending-until-complete was nonzero, the BS should hold off the station maintenance opportunity accordingly unless needed, for example, to adjust the SS's power level.

Figure 55a—Periodic ranging—BS



NOTE 1—Means ranging is within the tolerable limits of the BS.

Figure 55b—Periodic ranging: Wait for RNG-REQ—BS

Replace Figure 56 as follows:

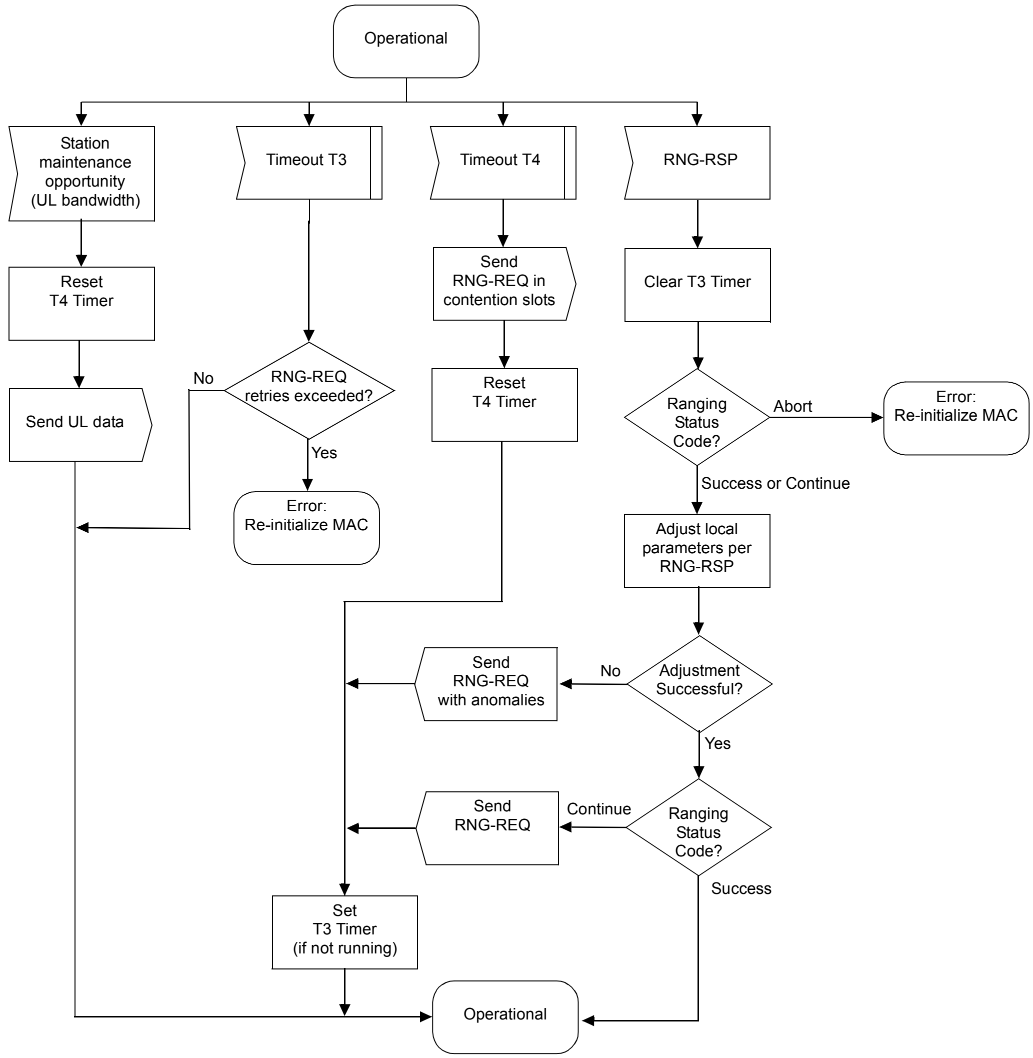


Figure 56—Periodic ranging—SS

6.2.10.1 Downlink burst profile management in framed operation

Change first paragraph to read:

The downlink burst profile is determined by the BS according to the quality of the signal that is received by each SS. To reduce the volume of uplink traffic, the SS monitors the carrier to noise and interference ratio [C/(N+I)] and compares the average value against the allowed range of operation. This region is bounded by threshold levels. If the received C/(N+I) goes outside of the allowed operating region, the SS requests a change to a new burst profile using one of three methods. If the SS has a station maintenance interval available, it shall send a RNG-REQ message to which the BS responds with a RNG-RSP message. Otherwise, the SS shall send a DBPC-REQ message in an uplink allocation addressed to that SS's basic connection ~~(regardless of whether the SS is GPC or GPT)~~. The BS responds with a DBPC-RSP message. If neither of these options is available and the SS requires a more robust burst profile on the downlink, the SS shall send a RNG-REQ message in an Initial Maintenance interval. In all three methods, the message is sent using the Basic CID of the SS. The coordination of message transmit and receipt relative to actual change of modulation is different depending upon whether an SS is transitioning to a more or less robust burst profile. Figure 57 shows the case where an SS is transitioning to a more robust type. Figure 58 shows transition to a less robust burst profile.

Insert 6.2.10.2 as follows:

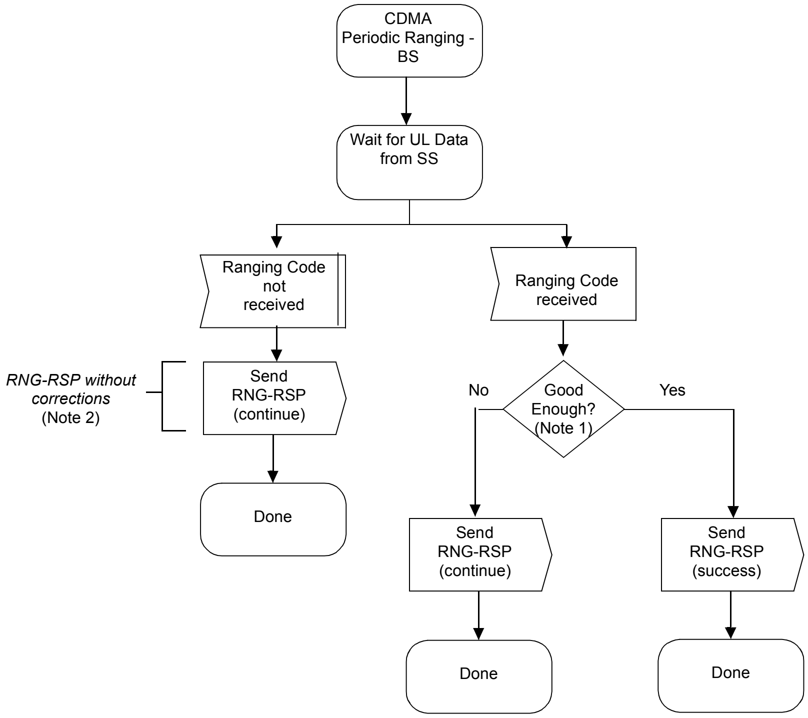
6.2.10.2 OFDMA Based Ranging

The WirelessMAN-OFDMA PHY specifies a Ranging Subchannel and a set of special pseudo-noise Ranging Codes. Subsets of codes shall be allocated in the UCD Channel Encoding for Initial Ranging, Periodic Ranging and BW Requests, such that the BS can determine the purpose of the received code by the subset to which the code belongs. An example of Ranging channel in OFDMA frame structure is specified in Figure 128av.

SSs that wish to perform one of the aforementioned operations shall select, with equal probability, one of the codes of the appropriate subset, modulate it onto the Ranging Subchannel and subsequently transmit in a with equal probability selected (pair of) OFDM symbol(s) within the appropriate UL allocation. Details on the modulation and Ranging Codes are specified in 8.5.7.

- The SS, after acquiring downlink synchronization and uplink transmission parameters, shall choose randomly a Ranging Slot (with the use of a binary truncated exponent algorithm to avoid possible re-collisions) as the time to perform the ranging, then it chooses randomly a Ranging Code (from the Initial Ranging domain) and sends it to the BS (as a CDMA code).
- The BS cannot tell which SS sent the CDMA ranging request, therefore upon successfully receiving a CDMA Ranging Code, the BS broadcasts a Ranging Response message that advertises the received Ranging Code as well as the ranging slot (i.e., OFDM symbol number, subchannel, etc.) where the CDMA Ranging code has been identified. This information is used by the SS that sent the CDMA ranging code to identify the Ranging Response message that corresponds to its ranging request. The Ranging Response message contains all the needed adjustment (e.g., time, power and possibly frequency corrections) and a status notification.
- Upon receiving Ranging Response message with continue status, the SS shall continue the ranging process as done on the first entry with ranging codes randomly chosen from the Periodic Ranging domain.
- Using the OFDMA ranging mechanism, the periodic ranging timer is controlled by the SS, not the BS.

Add Figure 59a, Figure 59b, and Figure 59c.



NOTE 1—Means ranging is within the tolerable limits of the BS.
NOTE 2—In this case, the RNG-RSP message is sent in order to initiate the SS to send ranging code.

Figure 59a—Periodic CDMA ranging—BS

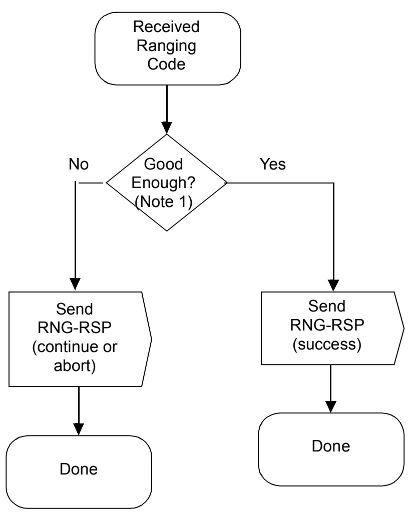


Figure 59b—Periodic ranging—Received ranging code—BS

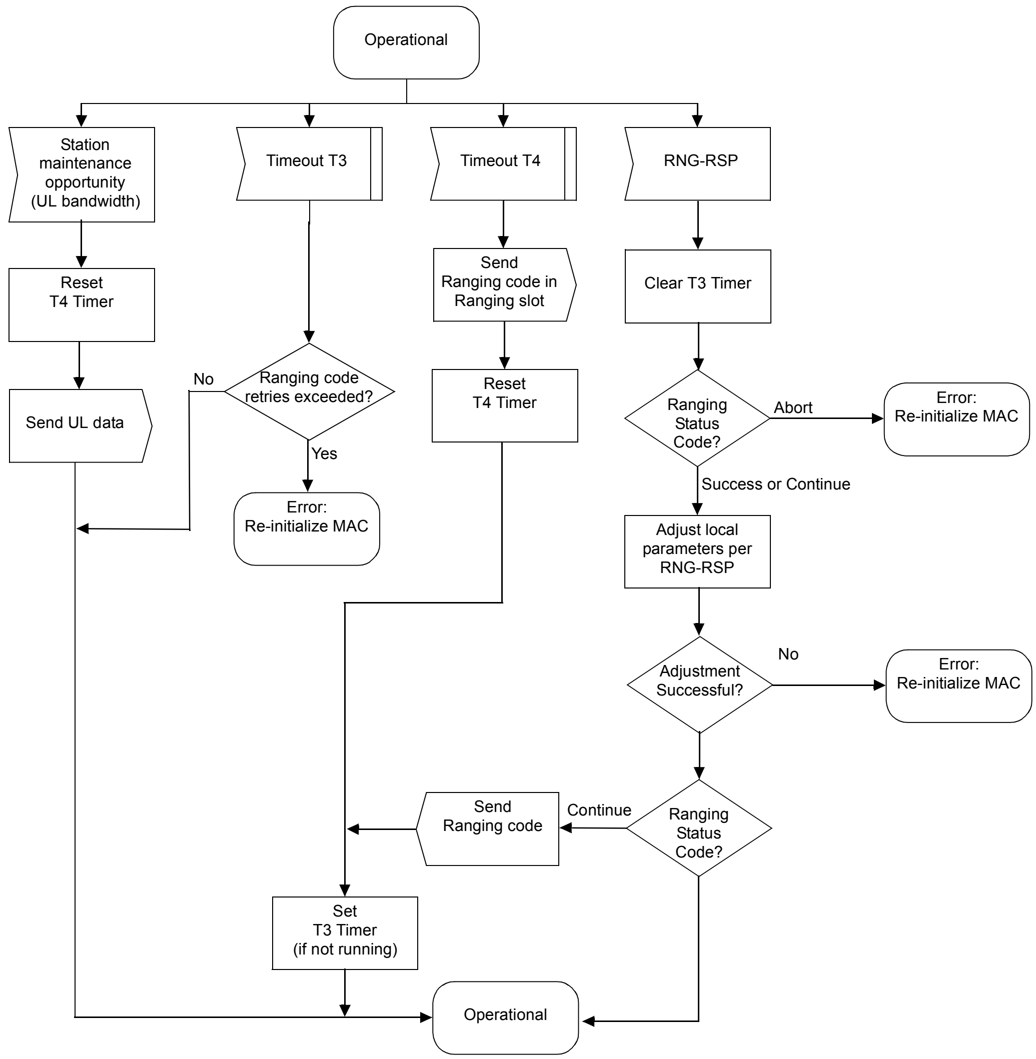


Figure 59c—Periodic CDMA ranging—SS

Table 63b describes the ranging adjustment process.

Table 63b—Ranging and automatic adjustments procedure

BS		SS
[time to send next map] Send map containing Ranging Region Information	**UL-MAP** →	
[Receive Ranging Code]	← **Ranging Code**	Transmit randomly selected Ranging code in a randomly selected Ranging Slot from available Ranging Region
Send Ranging Response with Time & Power Corrections and original Ranging Code and Ranging Slot Status = Continue	**RNG-RSP** →	Receive RNG-RSP message with Ranging Code and Ranging Slot matching sent values Adjust Time & Power parameters State = Continue
[time to send next map] Send map containing Ranging Region Information	**UL-MAP** →	
[Receive Ranging Code]	← **Ranging Code**	Transmit randomly selected Ranging code in a randomly selected Ranging Slot from available Ranging Region
Send Ranging Response with Time & Power Corrections and original Ranging Code and Ranging Slot Status = Success	**RNG-RSP** →	Receive RNG-RSP message with Ranging Code and Ranging Slot matching sent values Adjust Time & Power parameters State = Success

6.2.14 DFS for license-exempt operation

6.2.14.1 Introduction

DFS is mandatory for license-exempt operation. Systems should detect and avoid primary users. Further, the use of channel selection algorithms is required, which result in uniform channel spreading across a minimum number of channels. This specification is intended to be compliant with the regulatory requirements set forth in [B37]. The timing parameters used for DFS are specified by each regulatory administration.

The DFS procedures provide for:

- Testing channels for primary users (6.2.14.2).
- Discontinuing operations after detecting primary users (6.2.14.3).
- Detecting primary users (6.2.14.4).
- Scheduling for channel testing (6.2.14.5).
- Requesting and reporting of measurements (6.2.14.5).
- Selecting and advertising a new channel (6.2.14.7).

6.2.14.2 Testing channels for primary users

A BS or SS shall not use a channel that it knows contains primary users or has not been tested recently for the presence of primary users. A BS shall test for the presence of primary users for at least the following:

- **Startup Test Period** before operating in a new channel if the channel has not been tested for primary users for at least **Startup Test Period** during the last **Startup Test Valid**.
- **Startup Test Period** before operating in a new channel if a channel was previously determined to contain primary users during the last **Startup Test Valid**.
- **Operating Test Period** (where the period is only accumulated during testing) of each **Operating Test Cycle** period while operating in a channel. Testing may occur in quiet periods or during normal operation.

An SS may start operating in a new channel without following the above start-up testing procedures if:

- The SS moves to the channel as a result of the receipt of a Channel Switch Announcement from the BS.
- The SS is initializing with a BS that is not currently advertising, using the Channel Switch Announcement that it is about to move to a new channel.

A BS may start operating in a new channel without following the above start-up testing procedures if it has learned from another BS by means outside the scope of this standard that it is usable.

6.2.14.3 Discontinuing operations after detecting primary users

If a BS or an SS is operating in a channel and detects primary users, which interference might be caused in the channel, it shall discontinue any transmission of the following:

- MAC PDUs carrying data within **Max Data Operations Period**.
- MAC PDUs carrying MAC Management Messages within **Management Operations Period**.

6.2.14.4 Detecting primary users

Each BS and SS shall use a method to detect primary users operating in a channel that satisfies the regulatory requirements. The particular method used to perform the primary user detection is outside the scope of this specification.

6.2.14.5 Scheduling for channel testing

A BS may measure one or more channels itself and request any SS to measure one or more channels on its behalf, either in a quiet period or during normal operation.

To request the SSs to measure one channel the BS shall include in the DL-MAP a Report Measurement IE as specified in 8.4.5.2.2. The BS that requests the SSs to perform a measurement shall not transmit MAC PDUs to any SS during the measurement interval. If the channel measured is the operational channel, the BS shall not schedule any UL transmissions from SSs to take place during the measurement period.

An SS upon receiving a DL-MAP with the DFS Measurement IE shall start to measure the indicated channel no later than **Max. Channel Switch Time** after the start of the measurement period. An SS may stop the measurement no sooner than **Max. Channel Switch Time** before the expected start of the next frame or the next scheduled UL transmission (of any SS). If the channel to be measured is the operating channel, **Max. Channel Switch Time** shall be equal to the value of RTG, as specified in Table 124. **Max. Channel Switch Time** shall not exceed 2 ms.

6.2.14.6 Requesting and reporting of measurements

The SS shall for each measured channel keep track of the following information:

— Frame Number of the frame during which the first measurement was made
— Accumulated time measured
— Existence of a Primary User on the channel
— Whether a WirelessHUMAN using the same PHY system was detected on the measures channel
— Whether unknown transmissions (such as RLAN transmissions) were detected on the channel.

The BS may request a measurement report by sending a REP-REQ message. This is typically done after the aggregated measurement time for one or more channels exceeds the regulatory required measurement time. Upon receiving a REP-REQ the SS shall reply with a REP-RSP message and reset its measurement counters for each channel on which it reported.

If the SS detects a primary user on the channel it is operating during a measurement interval or during normal operation it shall immediately cease to send any user data and send at the earliest possible opportunity an unsolicited REP-RSP. The BS shall provide transmission opportunities for sending an unsolicited REP-RSP frequently enough to meet regulatory requirements.

6.2.14.7 Selecting and advertising a new channel

A BS may decide to stop operating in a channel at any time. The algorithm used to decide to stop operating in a channel is outside the scope of this standard but shall satisfy any regulatory requirements.

A BS may use a variety of information, including information learned during SS initialization and information gathered from measurements undertaken by the BS and the SSs, to assist in the selection of the new channel. The algorithm to choose a new channel is not standardized but shall satisfy any regulatory requirements, including uniform spreading rules and channel testing rules. If a BS would like to move to a new channel, a channel supported by all SSs in the sector should be selected.

A BS shall inform its associated SSs of the new channel using the Channel Nr in the DCD message. The new channel shall be used starting from the frame with the number given by the Channel Switch Frame Number in the DCD message. The BS shall not schedule any transmissions during the last **Max. Channel Switch Time** before the channel change is to take place.

The uplink burst profiles used on the old channel defined shall be considered valid also for the new channel, i.e., the BS need not define new UL Burst Profiles when changing channels. When operating in license-exempt bands the BS shall not send the Frequency (Type=3) parameter as a part of UCD message.

6.2.15 MAC Management Message tunneling in Mesh Mode

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 71a over UDP as shown in Figure 96a. to the entity performing the BS part of the protocol. The UDP source and destination port used for tunneled 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 71a—MAC Management Messages tunneled over UDP during network entry

Message	Action of sponsor	Direction of message
PKM-REQ:Auth Request	Tunnel	SS to BS
PKM-REQ:Auth Info	Tunnel	SS to BS
PKM-RSP:Auth Reply	Extract	BS to SS
PKM-RSP:Auth Reject	Extract	BS to SS
REG-REQ	Tunnel	SS to BS
REG-RSP	Extract	BS to SS

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

Figure 96a—MAC over UDP/IP tunneling

The format of the Tunnel Subheader is defined in Table 71b.

Table 71b—Tunnel Subheader Format

Syntax	Size	Notes
Tunnel_Subheader(){		
Type	1 byte	0 = Reserved 1 = WirelessMAN MAC header 2–255Reserved
}		

Also MAC messages may need to be tunneled end to end in cases when the protocol takes place between peers separated by several hops. The packet format in Figure 96a shall be used in these cases with the Tunnel Subheader format defined in Table 71b.

Replace heading numbers 6.A and 6.B with 6.1 and 6.2, respectively, and renumber all remaining headings within Clause 6 subsequently.

7. Privacy sublayer

7.2 Privacy Key Management (PKM) protocol

7.2.2 TEK exchange overview

Insert immediately after header:

7.2.2.1 TEK exchange overview for PMP topology

Insert at end of 7.2.2.1:

7.2.2.2 TEK exchange overview for Mesh Mode

Upon achieving authorization, a Node starts for each Neighbor 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 Neighbors of the node, requesting a refresh of keying material for their respective SAIDs.

The Neighbor 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 neighbor. The lifetimes 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 neighbor 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 Neighbor invalidates a particular TEK, and therefore when to schedule future Key Requests. The transmit regime between the initiating Node and the Neighbor provides for seamless key transition.

Insert 7.4.1.6, 7.4.2.4 and 7.4.2.5 as follows:

7.4.1.6 Node re-authorization in Mesh Mode during normal operation

When re-authorizing with the network, the re-authorizing node shall tunnel the authorization messages as shown in Figure 96a over UDP.

7.4.2.4 TEK usage in Mesh Mode

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

a) At expiration of the older TEK, the Neighbor shall immediately transition to using the newer TEK for encryption.

b) The Neighbor that generated the TEK shall use the older of the two active TEKs for encrypting traffic towards the Node that initiated the TEK exchange.

c) The Neighbor 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:

a) shall use the newer of its two TEKs to encrypt traffic towards its Neighbors with which it initiated a TEK exchange, and

b) shall be able to decrypt traffic from the Neighbor encrypted with either of the TEKs.

7.4.2.5 Node usage of the Operator Shared Secret in Mesh Nodes

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 neighboring nodes.

7.5.3 Calculation of HMAC digests

Insert after first paragraph:

In Mesh Mode 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.

7.5.4 Derivation of TEKs, KEKs and message authentication keys

7.5.4.3 HMAC Authentication Keys

Insert under HMAC_KEY_U = ...:

HMAC_KEY_S = SHA(H_PAD_D|Operator Shared Secret)

8. Physical layer

Insert 8.3 through 8.6 as follows:

8.3 WirelessMAN-SCa PHY layer

The WirelessMAN-SCa PHY is based on single carrier technology and designed for NLOS operation in the 2–11 GHz frequency bands (per 1.2.4). For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

Elements within this PHY include:

- TDD and FDD support.
- TDMA UL.
- TDM DL.
- Block adaptive modulation and FEC coding for both UL and DL.
- Framing elements that enable improved equalization and channel estimation performance over NLOS and extended delay spread environments.
- Symbol-unit granularity in packet sizes.
- Concatenated FEC using Reed Solomon and Pragmatic TCM with optional interleaving.
- FEC option using BTC and CTC.
- No-FEC option using ARQ for error control.
- STC transmit diversity option.
- Parameter settings and MAC/PHY messages that facilitate optional AAS implementations.

8.3.1 Transmit processing

Figure 128a illustrates the steps involved in transmit processing. Source data shall first be randomized, and then FEC encoded and mapped to QAM symbols. The QAM symbols shall next be framed within a message burst, which typically introduces additional framing symbols. The burst symbols shall then be multiplexed into a duplex frame, which may contain multiple bursts. The I and Q symbols components shall be injected into pulse shaping filters, quadrature modulated up to a carrier frequency, and amplified with power control so that the proper output power is transmitted.

Except where indicated otherwise, transmit processing is the same for both the UL and DL.

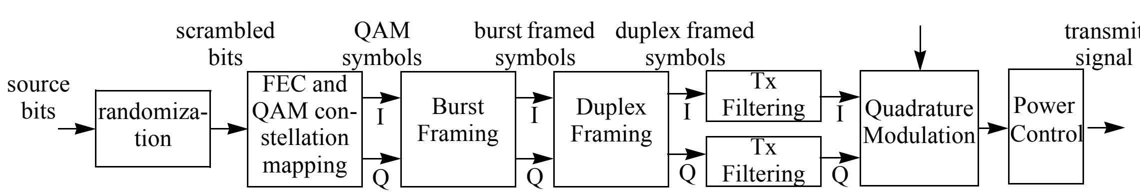


Figure 128a—Transmit processing

8.3.1.1 Source Bit Randomization

Source bits, i.e., the original information bits prior to FEC encoding, shall be randomized during transmissions.

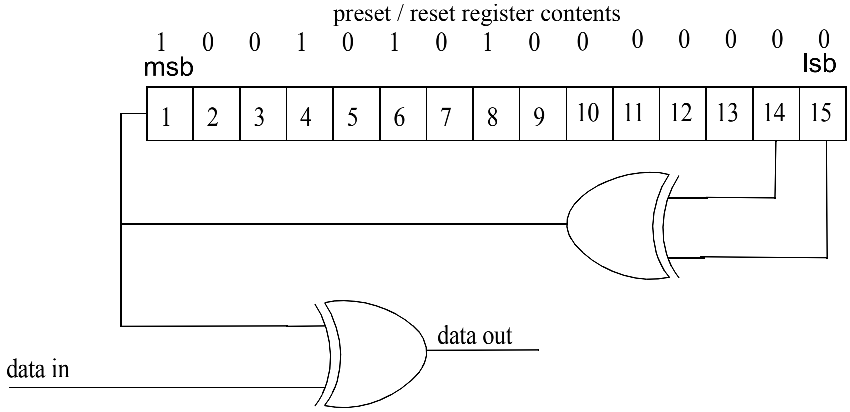


Figure 128b—Randomizer for energy dispersal

As Figure 128b illustrates, source bit randomization shall be performed by modulo-2 addition (XOR-ing) source (information) data with the output of Linear-Feedback Shift Register (LFSR) possessing characteristic polynomial $1 + X^{14} + X^{15}$. The LFSR shall be preset at the beginning of each burst (i.e., directly following the preamble) to the value 100101010000000, and shall be clocked once per processed bit. This implies that the LFSR is not preset between time division multiplexed allocations that may reside within a single burst.

Note that only source bits are randomized. This includes source payloads, plus uncoded null (zero) bits that may be used to fill empty payload segments. Only the source bits are randomized. Elements that are not a part of the source data, such as framing elements and pilot symbols shall not be randomized. Null (zero) bits used to complete a QAM symbol (when an allocation does not fill an entire QAM symbol) shall not be scrambled.

8.3.1.2 FEC

Broadcast messages shall use QPSK and the concatenated FEC of 8.3.1.2.1 with a rate 1/2 convolutional inner code. Adaptive modulation and the concatenated FEC of 8.3.1.2.1 shall be supported for non-broadcast messages. The support of 8.3.1.2.3 as FEC as well as omitting the FEC and relying solely on ARQ for error control (see 8.3.1.2.2) is optional for non-broadcast messages.

8.3.1.2.1 Concatenated FEC

The concatenated FEC is based on the serial concatenation of a Reed-Solomon outer code and a rate-compatible TCM inner code. Byte interleaving between the outer and inner encoders is optional. Figure 128c illustrates the flow between blocks used by a concatenated FEC encoder.

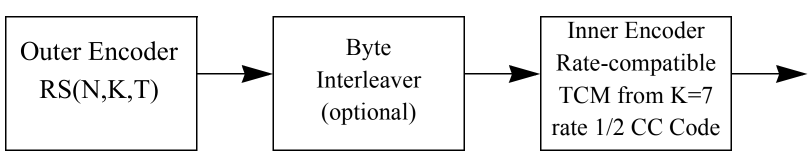


Figure 128c—Concatenated FEC encoder blocks

8.3.1.2.1.1 Outer code

The outer code consists of a Reed Solomon code.

This Reed-Solomon code shall be derived from a systematic RS (*N=255, K=239*) code using GF(2^8). The following polynomials are used for the systematic code:

Code Generator Polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX}$

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

The bit/byte conversion shall be msb first.

This RS code may be shortened and punctured to enable variable block sizes and variable error-correction capability,

where

N	is the number of overall bytes after encoding
K	is the number of data bytes before encoding
R=N–K	is the number of parity bytes.

When a block is shortened to K' data bytes, the first 239-K' data bytes of the block to be encoded shall be set to zero, but shall not be transmitted. When a codeword is punctured to R' parity bytes, only the first R' of the total R=16 parity bytes shall be transmitted.

Support of shortening K of the base code to values smaller than 239 bytes while maintaining R=16 is mandatory, and is governed by the burst profile specification for K (see 11.1.1.2 or 11.1.2.2). The capability to also puncture, such that $R \le 16$, is optional, and is governed by the burst profile specification for R.

When a source allocation does not divide into an integer number of K-byte Reed-Solomon code words, the last (fractional) RS code word shall be shortened to a smaller value $1 <= K' < K$ that accommodates the remainder bytes. All code words, including the shortened last codeword, shall use the R specified by the burst profile (see Table 123a and Table 125a) for the RS code words within that allocation.

8.3.1.2.1.2 Block Interleaver (optional)

Support of interleaving between the inner and outer code is optional. Interleaving shall not be used in broadcast burst profiles. When interleaving is used, its usage and parameters shall be specified within a burst profile.

The interleaver changes the order of bytes from the Reed Solomon (RS) encoder output. A de-interleaver in the receiver restores the order of the bytes prior to RS decoding. The interleaver is a block interleaver, where a table is 'written', i.e., filled, a byte at a time row-wise (one row per RS code word) and 'read' a byte at a time column-wise. The number of rows, N_R, used by the interleaver is a burst parameter. So that bursts are not generated that exceed an intended receiver's capabilities, the largest N_R supported by a terminal is communicated during SS basic capability negotiation.

Operating parameters for the interleaver are summarized in Table 116c.

Table 116c—Operating parameters for block interleaver

Parameter	Description
C	Interleaver Width (number of columns), in bytes. Equivalent to the nominal Reed Solomon codeword length, N.
N_R	Maximum Interleaver Depth (number of rows), in bytes. Equals the maximum number of RS codewords that the block interleaver may store at any given time.
B	Nominal Interleaver Block Size, in bytes. $B = C\,N_R$.
P	RS-encoded Size of Packet, in bytes, to be interleaved.

When $P \leq B$ and/or a RS codeword is shortened (so that not all of the columns within its row are filled), the interleaver shall be read column by column (taking a byte from each column), skipping empty elements within the table.

When $P > B$, data shall be parcelled into sub-blocks, and interleaving performed within each of the sub-blocks. The depth of these sub-blocks shall be chosen such that all sub-blocks have approximately the same depth (number of rows) using the following calculations:

Total RS codewords in packet: $T = \left\lceil \frac{P}{C} \right\rceil$

Number of sub-blocks: $S = \left\lceil \frac{P}{B} \right\rceil$

Interleaver depth of longest sub-blocks: $C_{max} = \left\lceil \frac{T}{S} \right\rceil$

Number of blocks with depth C_{max}: $Q_{C_{max}} = T - S(C_{max} - 1)$

Number of blocks with depth $C_{min} = C_{max} - 1$: $Q_{C_{min}} = S - Q_{C_{max}}$.

The first $Q_{C_{max}}$ sub-blocks within a packet shall use a (dynamic) interleaver depth C_{max}, and the remainder of the sub-blocks shall use an interleaver depth $C_{min} = C_{max} - 1$.

8.3.1.2.1.3 Inner code

The inner code is a rate-compatible pragmatic TCM code [B27], [B28] derived from a rate 1/2 constraint length K=7, binary convolutional code.

The encoder for the rate 1/2 binary code shall use the following polynomials to generate its two code bit outputs, denoted X and Y:

$$\begin{aligned} G_1 &= 171_{OCT} \qquad For\ X \\ G_2 &= 133_{OCT} \qquad For\ Y \end{aligned} \tag{10}$$

A binary encoder that implements this rate 1/2 code is depicted in Figure 128d.

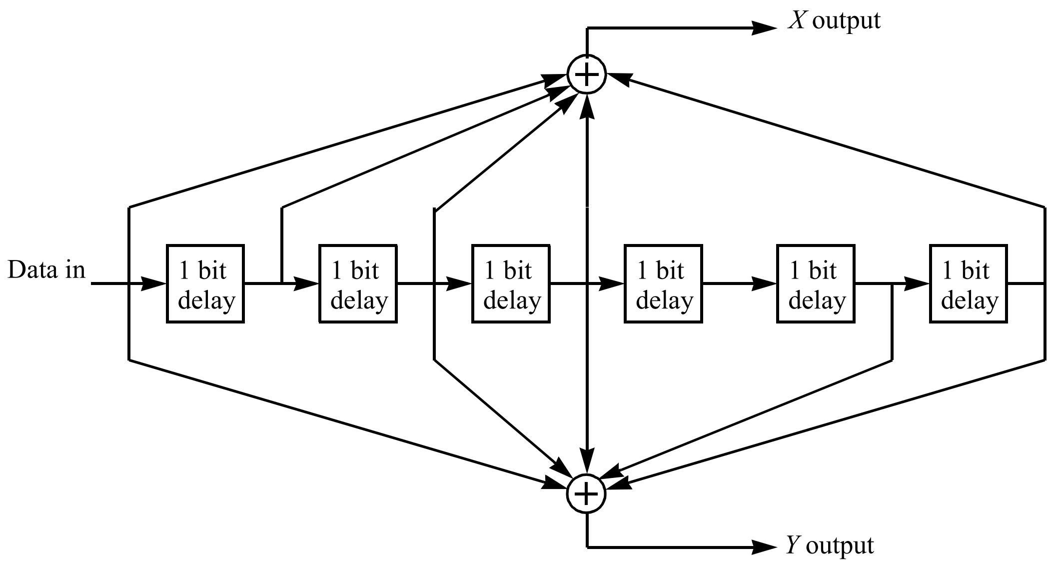


Figure 128d—Binary rate 1/2 convolutional encoder

To generate binary code rates of 2/3, 3/4, 5/6, and 7/8, the rate 1/2 encoder outputs shall be punctured. The puncturing patterns and serialization order for the *X* and *Y* outputs are defined in Table 116d. In the puncture patterns, a '1' denotes a transmitted output bit and a '0' denotes a non-transmitted (punctured) bit.

Table 116d—Puncture patterns and serialization for convolution code

	Code Rates				
Rate	1/2	2/3	3/4	5/6	7/8
X Output Puncture pattern	1	10	101	10101	1000101
Y Output Puncture pattern	1	11	110	11010	1111010
Punctured *XY* serialization	X_1Y_1	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$	$X_1Y_1Y_2Y_3Y_4X_5Y_6X_7$

The pragmatic TCM code is constructed from both non-systematic coded bits (that are taken from the outputs of the rate 1/2 binary convolutional encoder) and systematic uncoded bits (that are taken directly from the encoder input). The resulting coded bits are then mapped to symbol constellations. Supported modulations and code rates for UL and DL transmissions are listed in Table 116e. The choice of a particular code rate and modulation is made via burst profile parameters.

Since the RS outer code generates byte-denominated records but the inner code generates symbol-denominated outputs, some RS record sizes could require a fractional QAM symbol at the end of the data record. When this occurs, sufficient (non-randomized) zero-valued (null) bits shall be appended to the end of the inner encoder's input record to complete the final symbol. A receiver shall discard these null bits after inner decoding.

.

Table 116e—Supported modulations and code rates

Modulation	Support (M=Mandatory, O=Optional)		Code rates	Bits/symbol
	UL	DL		
BPSK	M	O	1/2, 3/4	1/2, 3/4
QPSK	M	M	1/2, 2/3, 3/4, 5/6, 7/8	1, 4/3, 3/2, 5/3, 7/4
16-QAM	M	M	1/2, 3/4	2, 3
64-QAM	O	M	2/3, 5/6	4, 5
256-QAM	O	O	3/4, 7/8	6, 7

Inner code blocks are to be zero-state terminated in transitions between adaptive modulation (and FEC) types, at the ends of bursts, or as instructed by the MAC and frame control.

When using zero state termination, the baseline rate 1/2 convolutional encoder shall be initialized with its registers in the all-zeros state. Inner encoding shall begin from this state, by accepting bit inputs. To terminate the inner code (and return the encoder to the all-zeros state) at the end of a code block, at least 6 zero inputs shall be fed into the baseline rate 1/2 binary convolutional encoder to ensure its register memory is flushed, i.e., its state memory is driven to zero. Once the first flushing zero bit is introduced into the convolutional encoder memory, all input bits, including the systematic input bits that are parallel to the binary convolutional encoder inputs, shall have zero value.

Table 116f specifies the exact number of systematic and non-systematic bits that shall be used to flush a pragmatic TCM encoder. It also tabulates the number of symbols consumed in the code termination process.

Table 116f—Flushing bit requirements for inner code termination

Modulation	Code rate	Number of flushing bits			Number of consumed symbols
		Non-systematic	Systematic	Total	
BPSK	1/2	6	0	6	12
	3/4	6	0	6	8
QPSK	1/2	6	0	6	6
	2/3	7	0	7	5
	3/4	6	0	6	4
	5/6	6	0	6	4
	7/8	7	0	7	4
16-QAM	1/2	6	0	6	3
	3/4	6	12	18	6

Table 116f—Flushing bit requirements for inner code termination *(continued)*

Modulation	Code rate	Number of flushing bits			Number of consumed symbols
		Non-systematic	Systematic	Total	
64-QAM	2/3	6	6	12	3
	5/6	6	4	10	2
256-QAM	3/4	6	12	18	3
	7/8	6	8	14	2

— **Encoding for BPSK and QPSK Modulations, All Rates**

For BPSK, the binary outputs of the punctured binary encoder shall be directly sent to the BPSK symbol mapper, using the multiplexed output sequence shown in the 'XY'-headed row of Table 116d. For QPSK, the multiplexed output sequence in Table 116d is alternately assigned to the I and Q coordinate QPSK mappers, with the I coordinate receiving the first assignment. Figure 128l depicts bits-to-symbol-constellation maps that shall be used for BPSK and QPSK.

— **Encoding for Rate 1/2 16-QAM**

Figure 128e illustrates the rate 1/2 pragmatic TCM encoder for 16-QAM. The baseline rate 1/2 binary convolutional encoder first generates a two-bit constellation index, b_3b_2, associated with the I symbol coordinate. Provided the next encoder input, it generates a two bit constellation index, b_1b_0, for the Q symbol coordinate. The I index generation shall precede the Q index generation. Note that this encoder should be interpreted as a rate 2/4 encoder, because it generates one four-bit code symbol per two input bits. For this reason, input records of lengths divisible by two shall be fed to this encoder.

Figure 128l depicts the bits-to-constellation map that shall be applied to the rate 1/2 16-QAM encoder output. This is a Gray code map.

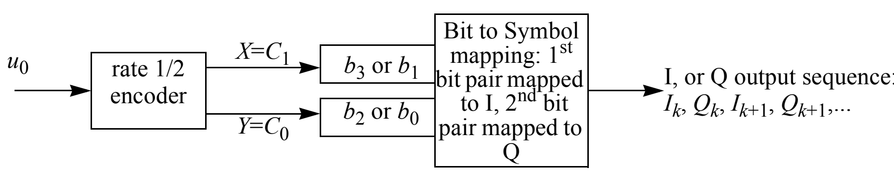


Figure 128e—Pragmatic TCM encoder for rate 1/2 16-QAM

— **Encoding for Rate 3/4 16-QAM**

Figure 128f illustrates the rate 3/4 pragmatic TCM encoder for 16-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. With this structure, the encoder is capable of simultaneously generating 4 output bits per three input bits. The sequence of arrival for the $u_2u_1u_0$ input into the encoder is u_2 arrives first, u_1 second, u_0 last. During the encoding process, the encoder generates a two bit constellation index, b_3b_2, for the I symbol coordinate, and simultaneously generates another two bit constellation index, designated b_1b_0, for the Q symbol coordinate. Note that whole symbols shall be transmitted, so input records of lengths divisible by three shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 3/4 16-QAM encoder output. This is pragmatic TCM map.

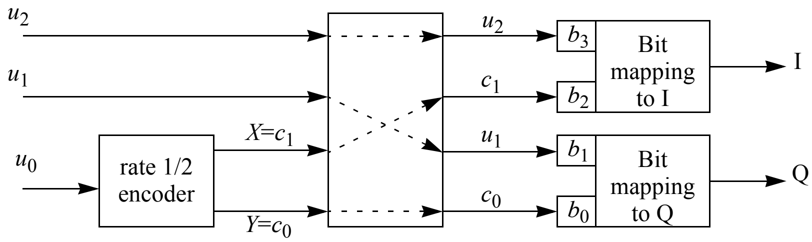


Figure 128f—Pragmatic TCM encoder for rate 3/4 16-QAM

— **Encoding for Rate 2/3 64-QAM**

Figure 128g illustrates the rate 2/3 pragmatic TCM encoder for 64-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with one systematic bit that is passed directly from the encoder input to the encoder output. The sequence of arrival for the u_1u_0 input into the encoder is u_1 arrives first, u_0 last. The encoder (as a whole) then generates a three-bit constellation index, $b_5b_4b_3$, which is associated with the I symbol coordinate. Provided another two-bit encoder input, the encoder generates another three-bit constellation index, $b_2b_1b_0$, which is associated with the Q symbol coordinate. The I index generation should precede the Q index generation. Note that this encoder should be interpreted as a rate 4/6 encoder, because it generates one six-bit code symbol per four input bits. For this reason, input records of lengths divisible by four shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 2/3 64-QAM encoder output. This is a pragmatic TCM map.

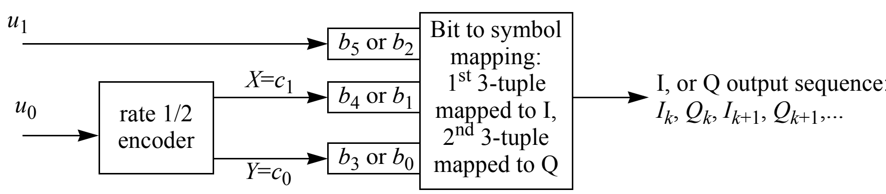


Figure 128g—Pragmatic TCM encoder for rate 2/3 64-QAM

— **Encoding for Rate 5/6 64-QAM**

Figure 128h illustrates the rate 5/6 pragmatic TCM encoder for 64-QAM. This encoder uses a rate 3/4 punctured version of the rate baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The rate 3/4 punctured code is generated from the baseline rate 1/2 code using the rate 3/4 puncture mask definition in Table 116d. Puncture samples are sequenced c_3 first, c_2 second, c_1 third, and c_0 last. The sequence of arrival for the $u_4u_3u_2u_1u_0$ input into the encoder is u_4 arrives first, u_3 arrives second, u_2 arrives third, u_1 arrives next to last, and u_0 arrives last. During the encoding process, the pragmatic encoder generates a three-bit constellation index, $b_5b_4b_3$, for the I symbol coordinate, and simultaneously generates another three-bit constellation index, $b_2b_1b_0$, for the Q symbol coordinate. Note that whole symbols shall be transmitted, so input records of lengths divisible by five shall be fed to this encoder.

Figure 128m depicts the bits-to-symbol-constellation map that shall be applied to the rate 5/6 64-QAM encoder output. This is a pragmatic TCM map.

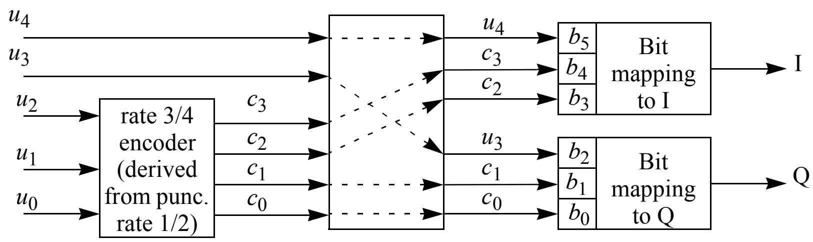


Figure 128h—Pragmatic TCM encoder for rate 5/6 64-QAM

— **Encoding for Rate 3/4 256-QAM**

Figure 128i illustrates the rate 3/4 pragmatic TCM encoder for 256-QAM. This encoder uses the baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The sequence of arrival for the $u_2u_1u_0$ input into the encoder is u_2 arrives first, u_1 next, u_0 last. Note that the encoder (as a whole) first generates a four-bit constellation index, $b_7b_6b_5b_4$, which is associated with the I symbol coordinate. Provided another four-bit encoder input, it generates a four-bit constellation index, $b_3b_2b_1b_0$, which is associated with the Q symbol coordinate. The I index generation should precede the Q index generation. Note that this encoder should be interpreted as a rate 6/8 encoder, because it generates one eight-bit code symbol per six input bits. For this reason, input records of lengths divisible by six shall be fed to this encoder.

Figure 128k depicts the bits-to-symbol-constellation map that shall be applied to the rate 3/4 256-QAM encoder output. This is a pragmatic TCM map.

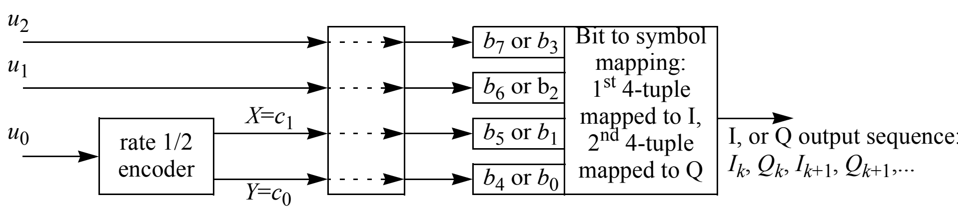


Figure 128i—Optional pragmatic TCM encoder for rate 3/4 256-QAM

— **Encoding for Rate 7/8 256-QAM**

Figure 128j illustrates the rate 7/8 pragmatic TCM encoder for 256-QAM. This encoder uses a rate 3/4 punctured version of the rate baseline rate 1/2 binary convolutional encoder, along with two systematic bits that are passed directly from the encoder input to the encoder output. The rate 3/4 punctured code is generated from the baseline rate 1/2 code using the rate 3/4 puncture mask definition in Table 116d. Puncture samples are sequenced c_3 first, c_2 second, c_1 third, and c_0 last. The sequence of arrival for the $u_6u_5u_4u_3u_2u_1u_0$ input into the encoder (as a whole) is u_6 arrives first, u_5 arrives second, u_4 arrives third, u_3 arrives fourth, u_2 arrives fifth, u_1 arrives next to last, and u_0 arrives last. During the encoding process, the encoder generates a four-bit constellation index, $b_7b_6b_5b_4$, for the I symbol coordinate, and simultaneously generates another four-bit constellation index, $b_3b_2b_1b_0$, for the Q symbol coordinate. Note that whole 256-QAM symbols should be transmitted, so input records of lengths divisible by seven shall be fed to this encoder.

Figure 128k depicts the bits-to-symbol-constellation map that shall be applied to the rate 7/8 256-QAM encoder output. This is a pragmatic TCM map.

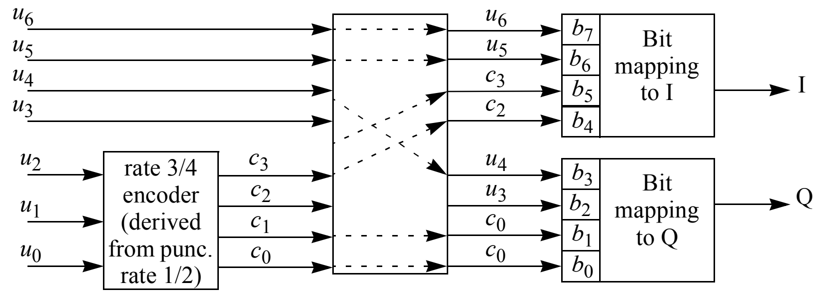


Figure 128j—Optional pragmatic TCM encoder for rate 7/8 256-QAM

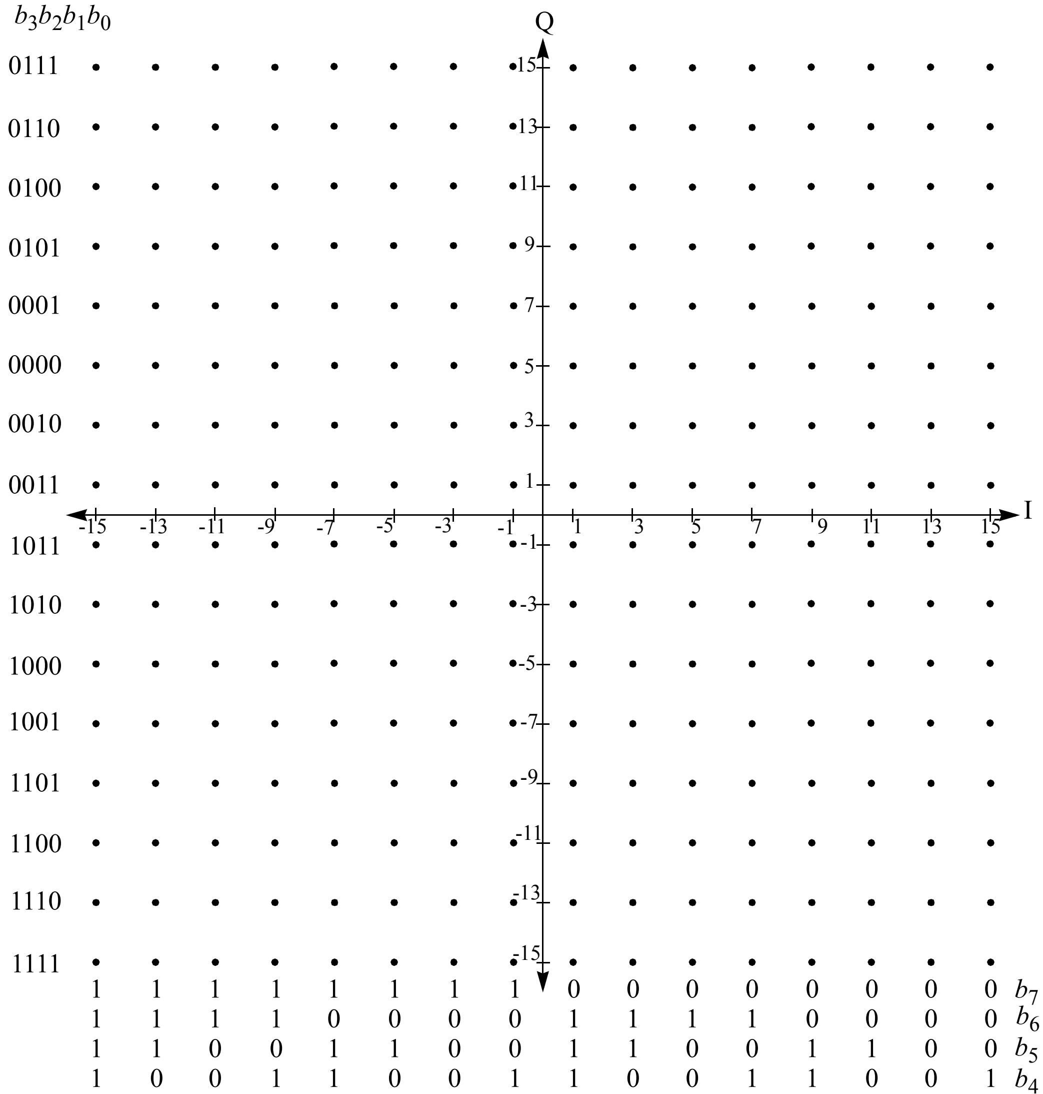


Figure 128k—Pragmatic map for 256-QAM constellation

8.3.1.2.1.4 Constellation mapping

For the concatenated FEC, code bits shall be mapped to I and Q symbol coordinates using either a pragmatic TCM or Gray code symbol map, depending on the code rate and modulation scheme. All BPSK and QPSK code rates and rate 1/2 16-QAM shall use the Gray coded constellation maps depicted in Figure 128l. Rate 3/4 16-QAM and all code rates for 64-QAM shall use the pragmatic TCM constellation map depicted in Figure 128m. All code rates for 256-QAM shall use the pragmatic TCM constellation map depicted in Figure 128k.

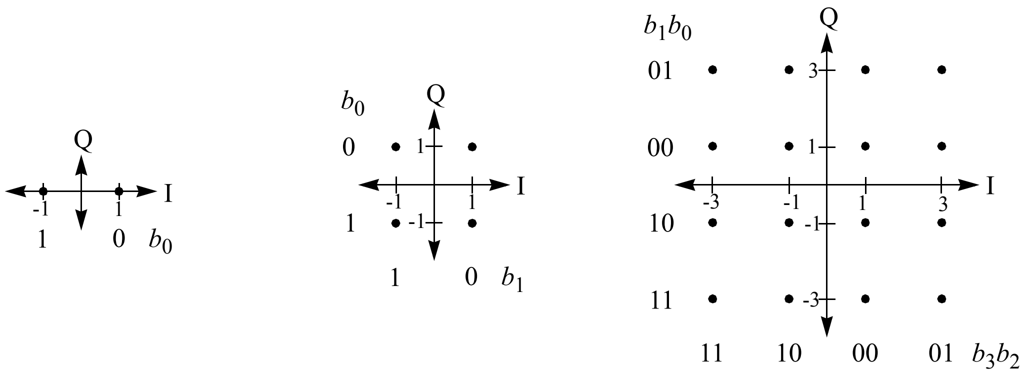


Figure 128l—Gray maps for BPSK, QPSK and 16-QAM constellations

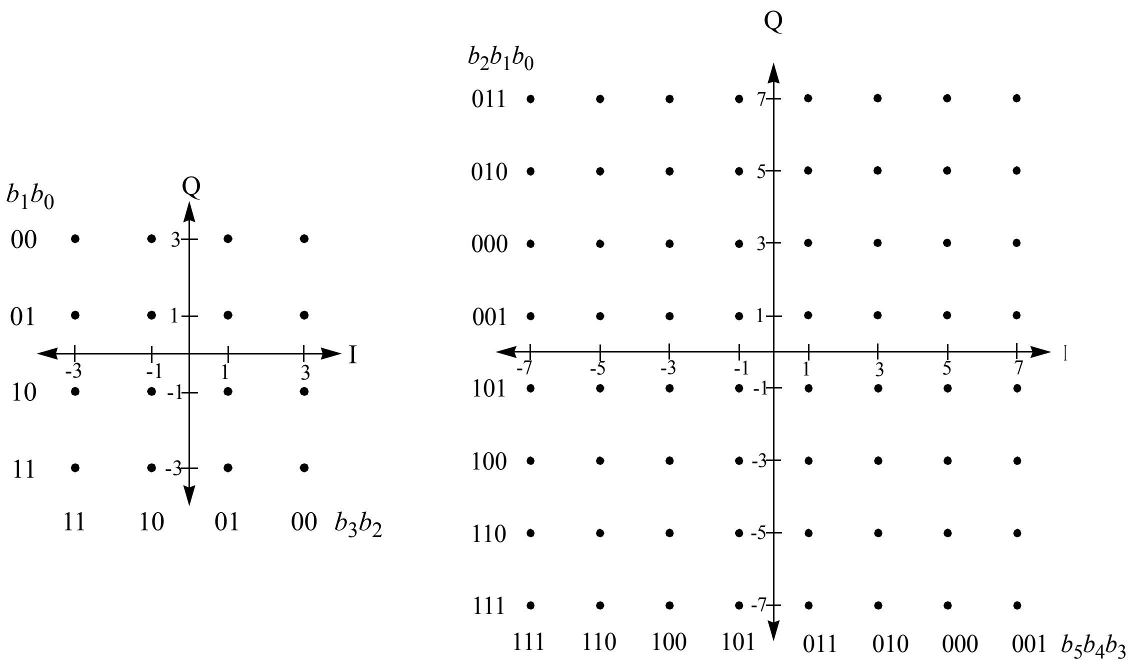


Figure 128m—Pragmatic maps for 16-QAM and 64-QAM constellations

To obtain unity average power of transmitted sequences, I and Q coordinates of constellation points are multiplied by the appropriate factor for c listed in Table 116g.

Table 116g—Unity average power normalization factors

Modulation scheme	Normalization constant for unity average power
QPSK	$c = 1/\sqrt{2}$
16-QAM	$c = 1/\sqrt{10}$
64-QAM	$c = 1/\sqrt{42}$
256-QAM	$c = 1/\sqrt{170}$

8.3.1.2.2 No FEC

In the No FEC option, scrambled source data shall be mapped directly to a QAM symbol constellation, using the appropriate Gray coding map. These maps are found in Figure 128l (for BPSK, QPSK, 16-QAM), Figure 128n (for 64-QAM), and Figure 128o (for 256-QAM). No-FEC operation is mandatory for QPSK but optional for other modulation methods.

In the event that the source record size in bytes does not divide into an integral number of QAM symbols, sufficient unscrambled zero-valued (null) bits shall be appended to the end of the data record to complete the last symbol. These null bits shall be discarded at the receiver.

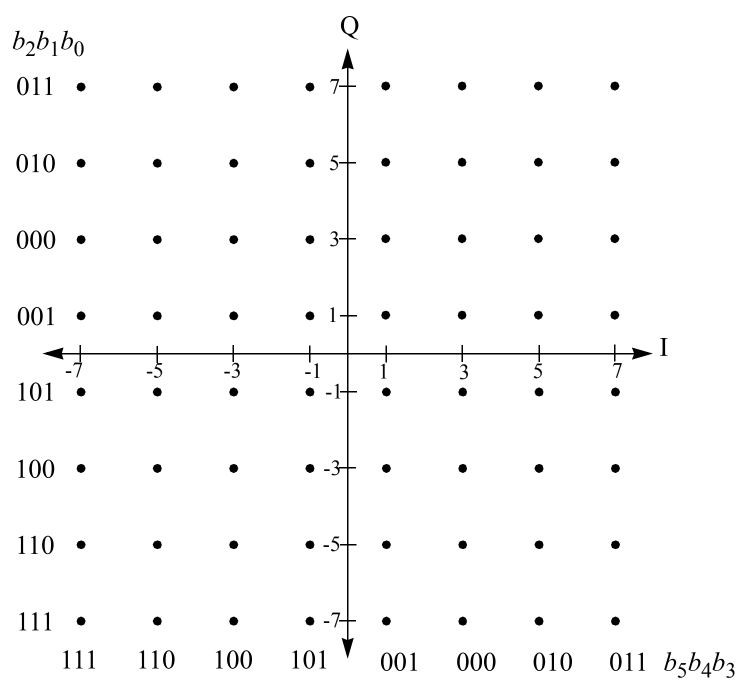


Figure 128n—Gray map for 64-QAM constellation

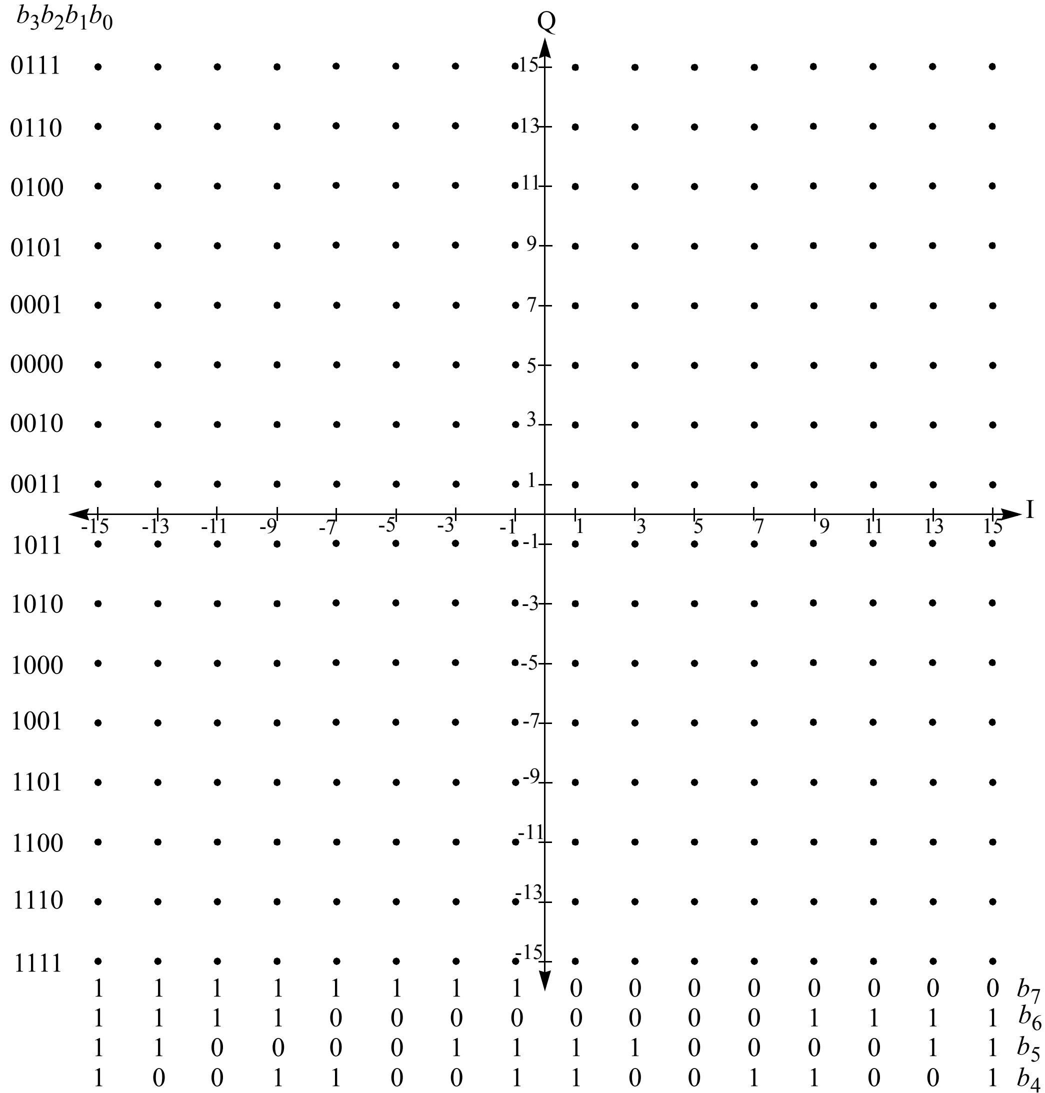


Figure 128o—Gray map for 256-QAM constellation

8.3.1.2.3 Block Turbo Codes

Support of the Block Turbo Code FEC is optional.

A BTC code is formed from block row codes, each with rate parameters (n_x, k_x) and block column codes, each with rate parameters (n_y, k_y). The BTC is encoded by writing data bits row by row into a two-dimensional matrix as illustrated in Figure 128p. The k_x information bits in each row are encoded into n_x bits by using a constituent block (n_x, k_x) row code. The k_y information bits in each column are encoded into n_y bits by using a constituent block (n_y, k_y) column code, where the checkbits of the rows are also encoded. The resulting BTC shall have block length $n = n_x \times n_y$ bits and information length $k = k_x \times k_y$.

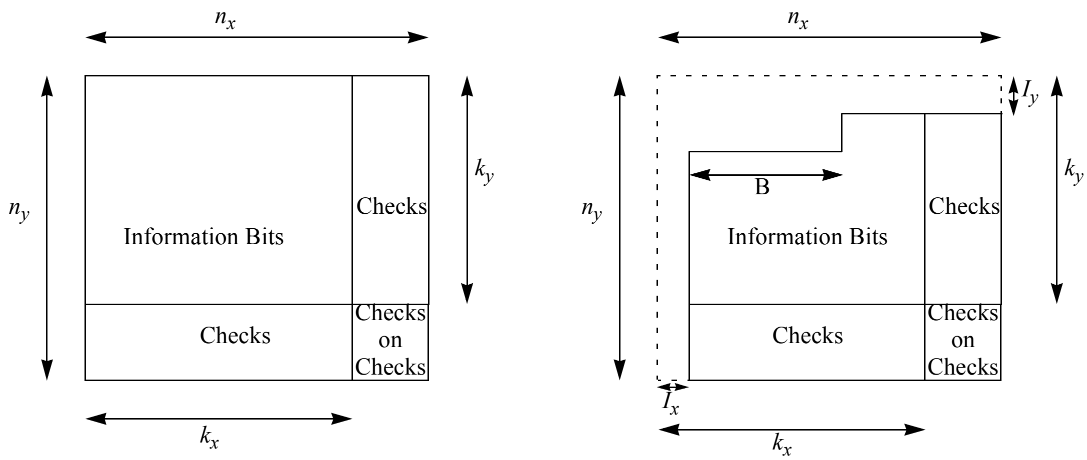


Figure 128p—BTC and shortened BTC structures

The constituent row code and constituent column code used to form the rows and columns of a BTC shall be specified by BTC-specific burst profile parameters. The constituent codes available for specification are listed in Table 116h. All codes in Table 116h shall be formed by appending a check bit or check bits to the end of the information bits. A parity check code shall use one check bit, derived by exclusive-OR-ing the information bits.

An extended Hamming component code shall use n-k check bits. The first $n–k–1$ check bits are the check bits of a ($n–1$, k) Hamming code derived from one of the generator polynomials listed in Table 116i, while the last check bit is a parity check bit, derived by exclusive-OR-ing the $n–1$ information and parity bits of the ($n–1$, k) Hamming code.

Table 116h—BTC component codes

Component codes (n, k)	Code type
(64,57), (32,26), (16,11), (8,4)	Extended Hamming Code
(64,63), (32,31), (16,15), (8,7)	Parity Check Code

Table 116i—(n-1,k) Hamming code generator polynomials

$n–1$	k	Generator polynomial
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

To match an arbitrary required packet size, BTCs may be shortened by removing symbols from the BTC array. Rows, columns or parts thereof can be removed until the appropriate size is reached. Two steps, illustrated in Figure 128p, are involved in the shortening of product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

The resulted block length of the code is $(n_x–I_x)(n_y–I_y)–B$. The corresponding information length is given as $(k_x–I_x)(k_y–I_y)–B$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B}{(n_x - I_x)(n_y - I_y) - B} \tag{11}$$

Data bit ordering for the composite BTC matrix is defined such that the left most bit in the first row is the lsb. The next bit in the first row is the next-to-lsb. The last data bit in the last data row is msb. An encoded BTC block shall be read out of the encoded matrix (for transmission) as a serial bit stream, starting with the lsb and ending with the msb. This bit stream shall be sent to a symbol mapper which uses a Gray map depicted in Figure 128l for BPSK, QPSK, and 16-QAM, and the Gray maps depicted in Figure 128n and Figure 128o for 64-QAM, and 256-QAM. If not enough encoded bits are available to fill the last symbol of an allocation, sufficient zero-valued bits (unscrambled) shall be appended to the end of the serial stream to complete the symbol.

Two independent variables, C_{bank} and K, collectively specify the BTC encoding and shortening process. C_{bank} is a burst profile parameter specified by the MAC. Its values range from 1 to 3, where each integer refers to a unique set of constituent codes, chosen to set the code rate of the BTC. K is the desired information block length, in bits, to be transmitted within an allocation. Table 116j specifies three code selection banks, each containing 4 different base BTCs, covering a range of information and encoded data block lengths. Each base BTC is composed from the specified row and column codes. The code selection bank that most closely matches the desired performance should be chosen as the active code bank.

Table 116j—BTC code banks

	Component row code (n_x,k_x) bits	**Component column code (n_y,k_y) bits**	**Base BTC block (n_yn_x,k_yk_x) bits**
C_{bank}=1 $R \cong 0.94$	(64,63)	(64,63)	(4096,3969)
	(32,31)	(32,31)	(1024,961)
	(16,15)	(16,15)	(256,225)
	(8,7)	(8,7)	(64,49)
C_{bank}=2 $R \cong 0.80$	(64,63)	(64,57)	(4096,3591)
	(32,31)	(32,26)	(1024,806)
	(16,15)	(16,11)	(256,165)
	(8,7)	(8,4)	(64,28)

Table 116j—BTC code banks *(continued)*

	Component row code (n_x,k_x) bits	Component column code (n_y,k_y) bits	Base BTC block $(n_y n_x, k_y k_x)$ bits
C_{bank}=3 $R \cong 0.69$	(64,57)	(64,57)	(4096,3249)
	(32,26)	(32,26)	(1024,676)
	(16,11)	(16,11)	(256,121)
	(8,4)	(8,4)	(64,16)

From the selected C_{bank}, a corresponding row and column constituent code shall be chosen that best matches the total number of information bits, *K,* to be encoded. Then the result shall be shortened to the exact information block size. The procedure for doing so shall be as follows:

Step 1: Determine the row and column component codes.

Select the base BTC with the smallest $k_x \times k_y$, such that $K \le k_x \times k_y$. Should K exceed the largest information block length available in the code selection bank, the *K* information bits shall be split across N_{blocks} = ceil(K/(8 * maxInfoBlock)), where maxInfoBlock is the number of information bytes in the largest BTC in the code selection bank. The first $N_{blocks} - 1$ blocks shall encode ceil(K/8/N_{blocks}) bytes. The final block shall encode the remaining (K/8)–(N_{blocks} – 1)*ceil(K/8/N_{blocks}) bytes. Each of the N_{blocks} blocks is encoded according to Step 2, substituting for *K* the number of information bits assigned to that block. Shortening of the BTC may be required for all N_{blocks} blocks. The code selection bank shall remain unchanged for the duration of the N_{blocks} blocks.

Step 2: Determine the row and column component codes for remnant bits

Select the base BTC with the smallest $k_x \times k_y$, such that $K \le k_x \times k_y$.

Should *K* be equal to $k_x \times k_y$, then *K* fits exactly into the base BTC and the information bits are encoded without shortening. If this is not the case, then the $(n_y \times n_x, k_y \times k_x)$ BTC shall be shortened according to Step 3 after which the *K* bits are encoded.

Step 3: Determine shortening parameters

Select *i* such that:

$$\arg_i \left[\min\left(\left(k_x - \left\lfloor \frac{i+1}{2} \right\rfloor \right) \cdot \left(k_y - \left\lfloor \frac{i}{2} \right\rfloor \right) - K \right) > 0 \right] \qquad 0 \le i < 2k_y - 1 . \tag{12}$$

The obtained *i* specifies the shortening parameters: $I_x = \lfloor (i+1)/2 \rfloor$, $I_y = \lfloor i/2 \rfloor$ and $B = (k_x - I_x) \times (k_y - I_y) - K$.

8.3.1.2.4 Convolutional Turbo Codes

Support of the Convolutional Turbo Code FEC is optional.

8.3.1.2.4.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128q. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to *A* and *B*, starting with the msb of the first byte being fed to *A*. The encoder is fed by blocks of *k* bits or *N* couples ($k = 2{*}N$ bits). For all the frame sizes *k* is a multiple of 8 and *N* is a multiple of 4. Further *N* shall be limited to: $8 \le N/4 \le 256$. Zero padding should be used for block sizes less than 32 bytes. For allocations longer than 256 bytes (i.e., 512 nibbles), the allocation (in units of nibbles), A_n determines the number of interleaver code blocks, n_B, that shall be transmitted. The first n_F of these blocks shall each use an interleaver of length N_F nibbles, whereas the remainder shall each use an interleaver of length $N_F + 1$ nibbles.

$$n_B = \left\lceil \frac{A_n}{512} \right\rceil$$
$$N_F = \left\lfloor \frac{A_n}{n_B} \right\rfloor \qquad (13)$$
$$n_F = n_B(N_F + 1) - A_n$$

The polynomials defining the connections are described in octal and symbol notations as follows:

— for the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— for the Y parity bit: 0xD, equivalently $1+D^2+D^3$

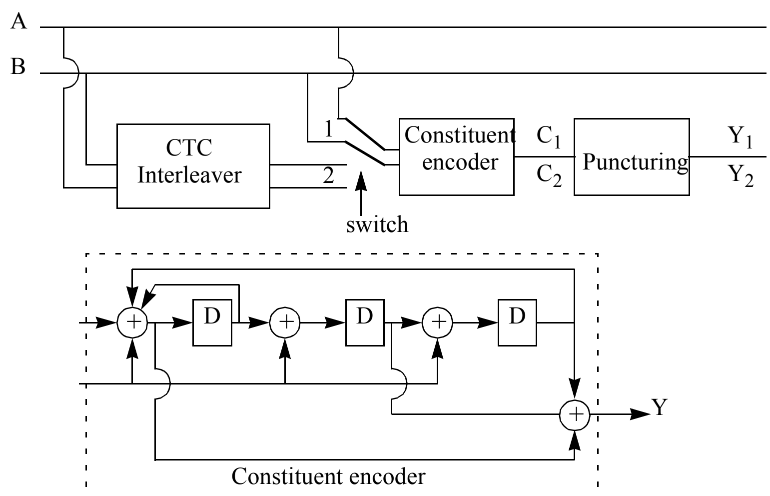


Figure 128q—CTC encoder

First, the encoder (after initialization by the circulation state Sc_1, see subclause 8.3.1.2.4.2) is fed the sequence in the natural order (position 1) with the incremental address $i = 0,...,N-1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see in subclause 8.3.1.2.4.2) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0,\ldots,N-1$. This second encoding is called C_2 encoding.

8.3.1.2.4.2 CTC interleaver

The interleaver requires the parameters P_0, which shall be the nearest prime number greater than $\sqrt{N/2}$, with $P_0 \geq 3$, which is dependent on the block size N. The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if (j_{mod_2} ==0) let $(B,A) = (A,B)$ (i.e. switch the couple)

Step 2: $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4} :

case 0 or 1: $i = (P_0 \cdot j + 1)_{\mathrm{mod}_N}$

case 2 or 3: $i = (P_0 \cdot j + 1 + N/4)_{\mathrm{mod}_N}$

8.3.1.2.4.3 Determination of CTC circulation states

The state of the encoder is denoted S ($0 <= S == 7$) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128q). The circulation states Sc_1 and Sc_2 are determined by the following operations:

Step 1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;
Step 2) According to the length N of the sequence, use Figure 116k to find Sc_1 or Sc_2.

Table 116k—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.3.1.2.4.4 CTC puncturing

The various code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116l—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	**Y**															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1/2	1	1														
2/3	1	0	1	0												
3/4	1	0	0	1	0	0										
5/6	1	0	0	0	0	1	0	0	0	0						
7/8	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

8.3.1.2.4.5 CTC modulation mapping

The encoded bit is fed into the mapper for BPSK and QPSK in the following order:

$$A_0, B_0 .. A_{N-1}, B_{N-1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,M},$$

where M is the number of parity bits and the I channel is fed first. The order in which the encoded bit are fed into the mapper for 16-QAM, 64-QAM and 265-QAM is:

$$A_0, B_0 .. A_{Rn} B_{Rn}, Y_{1,0}, A_{Rn+1}, B_{Rn+2} .. A_{2Rn}, B_{2Rn}, Y_{2,0} ..$$

Let S be half the number of bits in the modulation symbol. Then if (R_n+1) equals S, the parity bits are mapped to the two least protected locations in the constellation (16-QAM = $\{b_0, b_2\}$, 64-QAM = $\{b_0, b_3\}$, 256-QAM = $\{b_0, b_4\}$). If (R_n+1) equals $2S$, the parity bits are mapped to the least protected bit in the modulation scheme in the Q channel, using the mapping specified in the mandatory mode (b_0 for 16-QAM, 64-QAM and 256-QAM).

8.3.1.3 Burst framing

Both DL and UL data shall be formatted into bursts that use the Framed Burst format. The DL shall support the most general case of TDM bursts, while the UL shall support TDMA bursts.

TDMA burst and continuous DL operational modes are subclasses of the TDM burst DL mode of operation, and should be realizable using equipment designed for general TDM operation. The coordination of UL and DL bursts used to implement a TDD or FDD system is specified in 8.3.1.4.

8.3.1.3.1 Fundamental burst framing elements

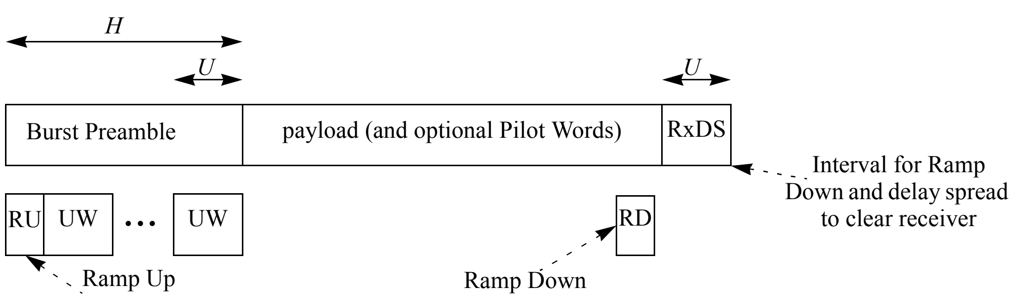


Figure 128r—Fundamental burst framing elements

As Figure 128r illustrates, a burst consists of three fundamental framing elements: a Burst Preamble that includes ramp up; a Payload; and an RxDS interval that includes ramp-down.

8.3.1.3.1.1 Burst preamble

A Burst Preamble shall consist of a ramp up region followed by a preamble body. Burst profile parameters shall specify R_r, the length of the ramp up region in symbols, and m, the number of Unique Words composing the preamble body. The burst profile shall also specify U, the number of symbols in a Unique Word.

A Burst Preamble shall be constructed from the last R symbols of a Unique Word (see Table 116m) followed by an integer multiple $m \geq 0$ of Unique Words, each Unique Word being U symbols in length. Figure 128s illustrates this requirement.

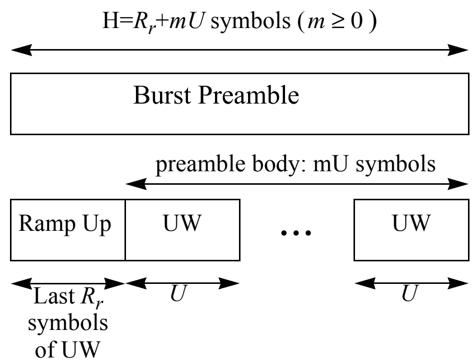


Figure 128s—Burst Preamble composition

For $R_r = 0$, a ramp up element within the Burst Preamble shall not be created.

For $R_r > 0$, a ramp up element shall be created. When creating a ramp up element, the transmit filter memory shall be initialized with zero-valued (null) symbols. R_r ramp up symbols shall then be sequentially fed into the transmit filter input stream. The transient preceding the first ramp up symbol shall be suppressed at the transmit filter output until the symbol period of the first ramp up symbol. A ramped power buildup shall then be achieved by superimposing a multiplicative raised cosine half-window of duration R_r symbols upon the samples leaving the transmit filter.

8.3.1.3.1.2 Burst Payload

The Burst Payload block depicted in Figure 128r contains payload data. The Burst Payload block may also contain periodically inserted Pilot Words (see 8.3.1.3.1.4), if the burst profile specifies their inclusion. The capability to demodulate payloads of arbitrary length and symbol-unit granularity is mandatory. The capability to insert Pilot Words at the transmitter and remove them at the receiver is also mandatory.

A DL burst may contain time division multiplexed messages that are adaptively modulated for the intended message recipients. When a MAC frame control message is to be transmitted within a DL burst, it shall always appear first, and shall use QPSK. Subsequent messages within the burst shall be sequenced in decreasing order of modulation robustness, beginning with the most robust modulation that is supported at the transmitter. The capability to transition between modulation types on any symbol boundary within a burst shall be supported. FEC blocks shall be terminated at every such transition.

One exception to the modulation sequencing rule is null payload fill, which shall always appear as the final message in a burst, and shall be transmitted using QPSK.

An UL burst contains a single message, and uses a single modulation format within a burst. However, different bursts may have different modulation formats. Additional description of MAC / PHY support for adaptive modulation and coding is provided in 6.2.7.

8.3.1.3.1.3 Null payload fill

When additional payload data is necessary to fill the end of a burst frame, e.g., when a continuous DL does not have enough data to fill a MAC frame, null payload fill may be inserted. The capability to insert null payload fill at a transmitter and discard it at a receiver is mandatory.

Null payload fill shall use the null fill data type. A MAC Frame control (map) message treats the null fill data type as an adaptive modulation type, and therefore shall indicate when and for how long this data type shall be transmitted within a burst. Null payload fill data shall also be subject to pilot word patterning within a burst.

The null fill data type is defined as zero-valued source bits that are randomized (see 8.3.1.1) and mapped directly to QPSK symbols using the Gray code map in Figure 128l. The randomizer shall run (without reset) through both the preceding burst payload and the null payload fill, but null payload fill shall not be covered (in the MAC) by a CRC code. During null payload fill transmission, a transmitter's output power may be reduced.

8.3.1.3.1.4 Pilot Words

A Pilot Word is a contiguous sequence of symbols composed of an integer $n \geq 0$ multiple of Unique Words, which may periodically pattern a burst. As Figure 128t illustrates, the period of a Pilot Word, *F* (in symbols), is defined to include the length, *P*, of the Pilot Word. Both *F* and *n* are parameters specified within a burst profile. The setting $n = 0$ indicates that no Pilot words shall be patterned within a burst.

When Pilot Words are patterned within a burst, *F* for that burst shall be constant, and the first symbol of the first Pilot Word shall commence *F–P+1* symbols into the burst. As Figure 128t illustrates, Pilot Word patterning shall cease when *F-P* or less payload data symbols remain in the burst.

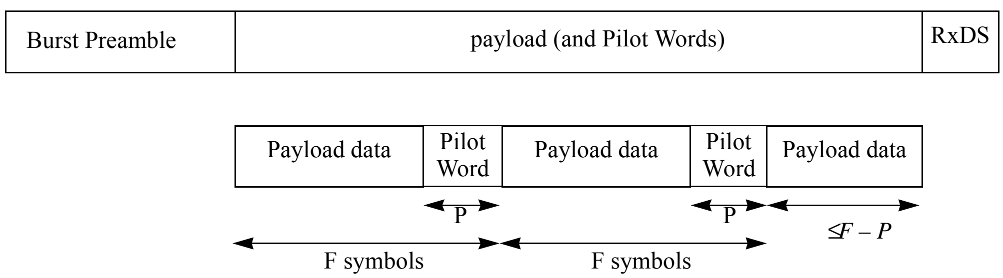


Figure 128t—Pilot Word patterning within a burst

8.3.1.3.1.5 Receiver delay spread clearing region (RxDS)

The receiver delay spread clearing interval (RxDS) illustrated in Figure 128r is a quiet period during which the transmitter ramps down, and the receiver collects delay-spread versions of symbols at the end of the burst. The capability to insert the RxDS at the transmitter is mandatory. The length of the RxDS shall always be the length of a Unique Word, unless it is suppressed (i.e., set to length zero). One instance where the RxDS is automatically suppressed is when bursts are concatenated.

If the RxDS is nonzero in length, a transmitter shall ramp down during this RxDS by inserting zero inputs into the transmit filter memory following the last intended data symbol, and allowing the natural response of the filter to drive the filter output to zero.

8.3.1.3.2 Unique Word

8.3.1.3.2.1 Selection

The length, *U*, in symbols of a Unique Word (UW) is a burst profile parameter. For best performance, *U* should be at least as long as the intended channel's span of significant delay spread.

8.3.1.3.2.2 Definition

Unique Words are derived from Frank-Zadoff [B22] or Chu [B23] sequences, and possess CAZAC (Constant Amplitude Zero [periodic] Auto-Correlation) properties. A burst profile specifies a Unique Word from the options listed in Table 116m. The sequence length U = 64 shall be supported and considered a default setting. U = 16 shall also be supported for symbol rates below 1.25 Msymb/s, and U = 256 shall also be supported for symbol rates above 20 Msymb/s. The other optional sequence lengths listed in Table 116m may be useful for longer or shorter delay spread channels.

Table 116m—UW lengths, types, and support

Length, U (symbols)	Sequence type	Support status
0	–	Optional
8	Chu	Optional
16	Frank-Zadoff	Optional (Mandatory below 1.25 Msymb/s)
32	Chu	Optional
64	Frank-Zadoff	Mandatory (default)
128	Chu	Optional
256	Frank-Zadoff	Optional (Mandatory above 20 Msymb/s)
512	Chu	Optional

The integer n-indexed I and Q components of a length U, $0 \le n < U$, Unique Word sequence shall be generated from

$$\begin{aligned} I[n] &= \cos(\theta[n]) \\ Q[n] &= \sin(\theta[n]) \end{aligned} \tag{14}$$

where $\theta[n] = \theta_{chu}[n]$ when generating a Chu sequence, and $\theta[n] = \theta_{frank}[n]$ when generating a Frank-Zadoff sequence. For a Chu sequence,

$$\theta_{chu}[n] = \frac{\pi n^2}{U} \tag{15}$$

for a Frank-Zadoff sequence,

$$\begin{aligned} \theta_{frank}[n = p + q\sqrt{U}] &= \frac{2\pi pq}{\sqrt{U}} \\ p &= 0,\ 1,\ \ldots,\ \sqrt{U} - 1 \\ q &= 0,\ 1,\ \ldots,\ \sqrt{U} - 1 \end{aligned} \tag{16}$$

The length U = 16, 64, and 256 Unique Word sequences are composed of symbols from QPSK, 8-PSK, and 16-PSK alphabets, respectively. However, the length U = 8, 32, 128, and 512 sequences are derived from polyphase symbol alphabets that may require additional care in a hardware implementation. The error vector magnitude (EVM) for Unique Word symbols in a transmitter implementation should conform with the general requirements stated in 8.3.4.4.

8.3.1.4 Duplex framing

Subclause 8.3.1.4.1 specifies FDD operation, while 8.3.1.4.2 specifies TDD operation. Support of at least one of these two duplexing modes is mandatory. FDD SSs may be Half Duplex FDD (H-FDD).

8.3.1.4.1 FDD

Frequency Division Duplexing (FDD) segregates the UL and DL on different-frequency carriers: BSs transmit at the DL carrier frequency, while SSs transmit at the UL carrier frequency.

A SS in a FDD system shall be capable of operation over a burst DL and UL. Moreover, given appropriate parameterization of a burst DL, a SS shall also be capable of continuous DL operation.

8.3.1.4.1.1 FDD with Burst DL

An example FDD system with burst-TDM DL is illustrated in Figure 128u. As Figure 128u illustrates, DL and UL sub-frames shall coincide in length, and shall repeat at regular (MAC-defined) constant intervals.

A DL burst shall not exceed the length of a DL sub-frame, but it need not fill the entire DL sub-frame. Also, although not illustrated in Figure 128u, the capability to support several DL bursts within a DL sub-frame is mandatory.

The first burst in each DL sub-frame shall commence with a Burst Preamble (BP), and shall be directly followed by a Frame Control Header (FCH), a broadcast payload that may contain DCD, UCD and MAPs. Only the first burst in a DL sub-frame shall contain the FCH.

Data within the FCH payload shall use the mandatory FEC with rate 1/2 QPSK inner convolutional code and Reed Solomon outer code. The inner convolutional code shall be zero-state terminated at the end of the FCH. During the FCH, no byte interleaving between the inner and outer code shall be used.

The first X_{FCH} source bytes of the FCH shall be outer encoded using a shortened RS code word specified by RS($N = X_{FCH} + 16$, $K = X_{FCH}$). This shortened code block shall then be inner encoded, and the inner code terminated at the end of the code block. The remainder of the FCH payload shall be encoded within one or more RS(N=255,K=239) code words, with the last code word shortened to RS(K_{last}+16,K_{last}) if K_{last}<239.

X_{FCH} is constant. Its value shall include the content of the DL-MAP message (including MAC header) up to and including the second DL information element. The decoded content of these X_{FCH} bytes is sufficient to determine of the length and location of a future DL sub-frame's entire FCH.

The first X_{FCH} symbols of the FCH shall contain MAC data that can be used to determine the allocation extent of data containing a future DL sub-frame's entire FCH. These X_{FCH} symbols shall be encapsulated within a 8-byte correcting RS codeword and a convolutional code that terminates at the X_{FCH} symbol point. X_{FCH} is a software system configuration parameter that is downloaded from the SS MAC during SS initialization. It shall not change within a system installation, unless a software update is provided to all current and future users of the system.

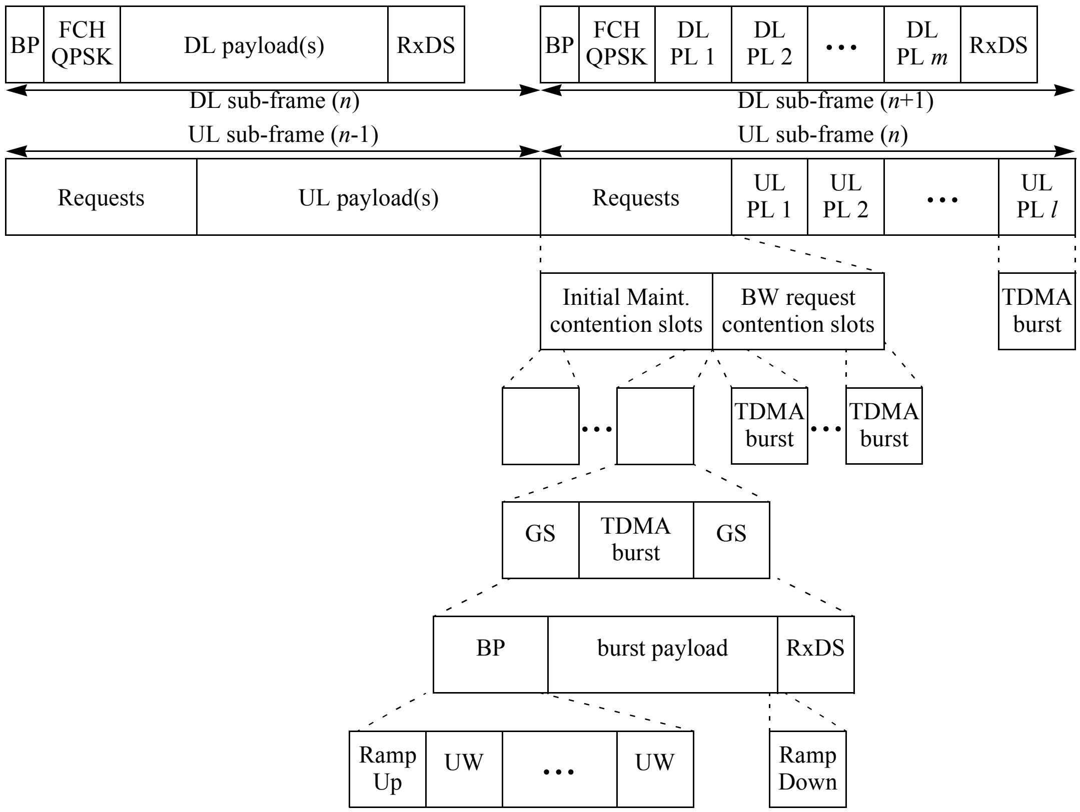


Figure 128u—Example of FDD with burst TDM DL

Time division multiplexed DL payload data may follow the FCH. A DL burst concludes with an RxDS to allow delay spread to clear the receiver. In the event that a DL-MAC frame is entirely filled with data, bursts may be concatenated and the RxDS suppressed. In other words, an RxDS of zero length shall be used, so that no ramp down occurs, and the Preamble of the next MAC frame may immediately commence. The preamble of that next MAC frame shall then use a ramp up parameter R_r of zero, so that no ramp up occurs.

When more than one burst is to be transmitted within a single DL MAC sub-frame, the DL-MAP of the first payload in the follow-up burst shall have a burst profile with its DL Burst Transition Gap (DL-BTG) entry enabled. The DL-BTG is a burst profile parameter. When enabled, the DL-BTG also indicates the length of the gap between bursts. The DL-BTG includes the RxDS terminating such a burst, and thus, when enabled, shall be specified to be at least as long as the RxDS.

An UL sub-frame contains three categories of bursts:

- Initial Maintenance Contention Slots that are transmitted in contention slots reserved for station initial maintenance;
- BW Request Contention Slots that are transmitted in contention slots reserved for response to multicast and broadcast polls for bandwidth needs;
- Grants of BW that are specifically allocated to individual SSs.

As Figure 128u illustrates, UL bursts are TDMA, and shall be constructed from a Burst Preamble (BP), including ramp up; a Burst Payload; and a receiver delay spread clear interval (RxDS), including ramp down. SS Transition Gaps (SSTGs) separate the burst transmissions of the various SSs using the UL. A SSTG specification includes the length of the RxDS, along with any additional guard symbols that may be inserted between UL bursts to reflect reference time uncertainties.

As shown in the UL sub-frame of Figure 128u, the Initial Maintenance and BW Request Contention Slots shall always be grouped contiguously as Request Slots. To insure interoperability, these request slots shall use UL burst profiles that all BSs and SSs can support. All UL bursts excluding Initial Maintenance slots shall use a SSTG (between bursts) that is specified as a UCD channel descriptor parameter. Since larger time uncertainties may be experienced on the Initial Maintenance slots, a special Initial Maintenance SSTG channel descriptor parameter shall be associated with the Initial Maintenance slots. The Initial Maintenance SSTG specification includes both the length of the RxDS and additional guard symbols. The additional guard symbols used by the Initial Maintenance SSTG are designated by 'GS' in Figure 128u.

The UL-MAP in the DL FCH governs the location, burst size, and burst profiles for exclusive BW grants to SSs. Burst profile selection may be based on the effects of distance, interference and environmental factors on transmission from the SS.

8.3.1.4.1.2 Generating a continuous DL from a burst DL

A continuous DL may be derived from a burst DL by null payload filling the end of a burst, to insure that it spans an entire DL frame. By so doing, a burst DL is forced to suppress both the RxDS and ramp up burst elements, because burst DLs are mandated to suppress these elements when a DL MAC frame is full. To insert null payload fill, the last entry in the DL-MAP of an FCH shall specify the burst profile for the null fill data type. Details on the null payload fill data type can be found in 8.3.1.3.1.3.

8.3.1.4.1.3 FDD Channel and Burst Descriptor field definitions

DL Channel Descriptor Parameters

Each DCD message channel descriptor shall include the following TLV encodings:

- Downlink_Burst_Profile
- BS EIRP
- Frame Duration Code
- DCD Channel ID

DL Burst Descriptor Parameters

Each DCD message burst descriptor shall include the following TLV encodings:

- Modulation Type
- Reed Solomon Information Bytes (K)
- Reed Solomon Parity Bytes (R)
- DIUC Mandatory Exit Threshold
- DIUC Minimum Entry Threshold
- Preamble Length
- CC-specific Parameters
- Unique Word Length
- Pilot Word Parameters
- Transmit Diversity Type
- DL Burst Transition Gap

Each DCD message burst descriptor may include the following additional TLV encodings:

- BTC Code Selector
- CTC Parameters
- Block Interleaver Depth
- STC Parameters

UL Channel Descriptor Parameters

Each UCD message channel descriptor shall include the following TLV encodings:

Uplink_Burst_Profile
Symbol Rate
Frequency
SS Transition Gap
Roll-Off Factor
Contention-Based Reservation Timeout
Channel Width
Initial Maintenance SSTG

UL Burst Descriptor Parameters

Each UCD message burst descriptor shall include the following TLV encodings:

Modulation Type
Preamble Length
RS Information Bytes (K)
RS Parity Bytes *(*R)
CC-specific Parameters
Preamble Parameters
Unique Word Length
Pilot Word Parameters
Transmit Diversity Type

Each UCD message burst descriptor may include the following additional TLV encodings:

BTC Code Selector
CTC Parameters
Block Interleaver Depth
STC Parameters

8.3.1.4.2 TDD

TDD multiplexes the UL and DL on the same carrier, over different time intervals within the same MAC frame.

Figure 128v illustrates TDD operation with a single-burst TDM downlink. In TDD, the DL and UL alternate between occupying a shared frame, with the DL sub-frame preceding the UL sub-frame. The size of shared frame shall be constant; however, the DL and UL sub-frame sizes within the shared frame shall vary according to allocations directed by the FCH. Although Figure 128v illustrates a single TDM burst per DL sub-frame, the capability to accommodate several TDM bursts is mandatory, with the first burst in the DL duplex sub-frame containing the FCH.

When more than one burst is to be transmitted within a single DL sub-frame, the DL-MAP of the first payload in the follow-up burst shall have a burst profile with its DL Burst Transition Gap (DL-BTG) entry enabled. The DL-BTG is a burst profile parameter. When enabled, the DL-BTG also indicates the length of the gap between bursts. The DL-BTG includes the RxDS terminating such a burst, and thus, when enabled, shall be specified to be at least as long as the RxDS.

Most framing elements within TDD are found in FDD and perform the same functions; therefore, for descriptions of these elements, consult 8.3.1.4.1.1. The only frame elements in TDD not found in FDD are TTG and RTG.

After the TTG, the BS receiver shall look for the first symbols of uplink burst. This gap is an integer number of PS durations and starts on a PS boundary.

After the RTG, SS receivers shall look for the first symbols of QPSK modulated data in the downlink burst. This gap is an integer number of physical slot (PS) durations and starts on a PS boundary.

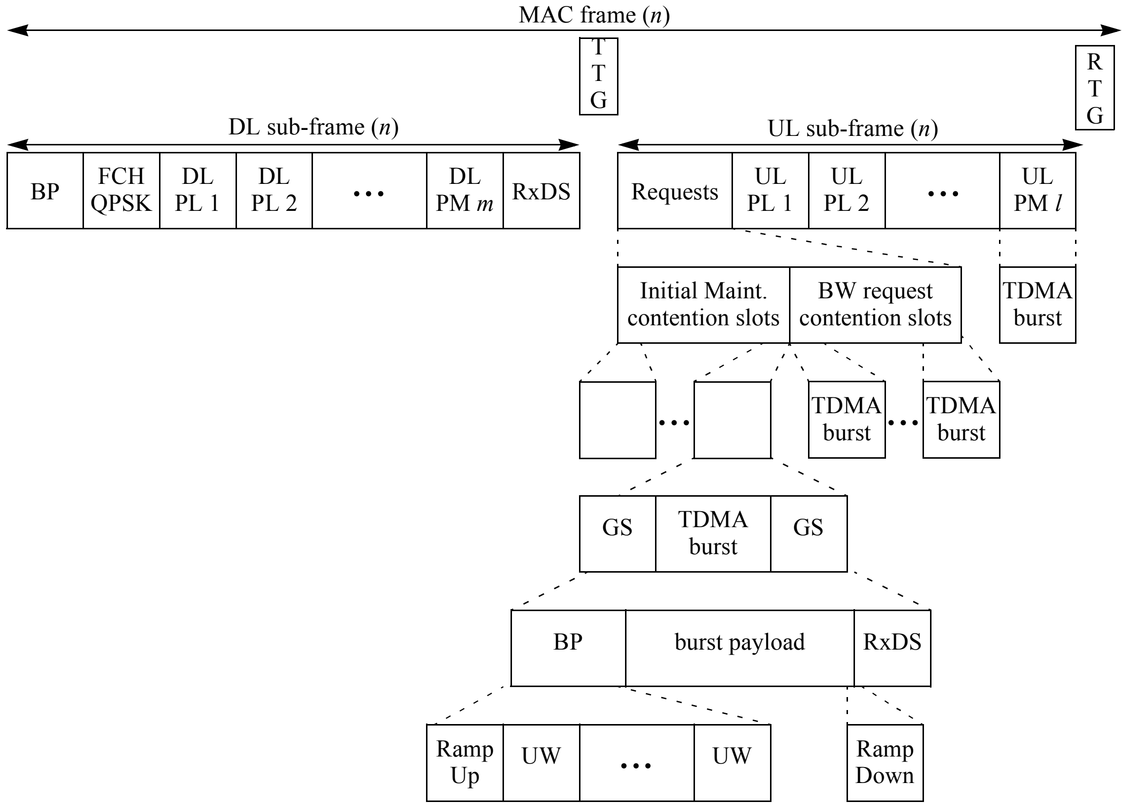


Figure 128v—Example of TDD with single-burst TDM DL sub-frame

8.3.1.4.2.1 TDD Channel Descriptor field definitions

DL Channel Descriptor Parameters

Each DCD message channel descriptor shall include the following TLV encodings:

Downlink_Burst_Profile
BS EIRP
Frame Duration Code
DCD Channel ID
TTG

DL Burst Descriptor Parameters

Each DCD message burst descriptor shall include the following TLV encodings:

Modulation Type
Reed Solomon Information Bytes (K)
Reed Solomon Parity Bytes (R)
DIUC Mandatory Exit Threshold
DIUC Minimum Entry Threshold
Preamble Length
CC-specific Parameters
Unique Word Length
Pilot Word Parameters
Transmit Diversity Type

Each DCD message burst descriptor may include the following additional TLV encodings:
BTC Code Selector
Block Interleaver Depth
STC Parameters

UL Channel Descriptor Parameters
Each UCD message channel descriptor shall include the following TLV encodings:
Uplink_Burst_Profile
Symbol Rate
Frequency
SS Transition Gap
Roll-Off Factor
Contention-Based Reservation Timeout
Channel Width
Initial Maintenance SSTG
Each UCD message channel descriptor may include the following additional TLV encodings:
CEI
UL Burst Descriptor Parameters
Each UCD message burst descriptor shall include the following TLV encodings:
Modulation Type
Preamble Length
RS Information Bytes (K)
RS Parity Bytes *(*R)
CC-specific Parameters
Preamble Parameters
Unique Word Length
Pilot Word Parameters
Transmit Diversity Type
Each UCD message burst descriptor may include the following additional TLV encodings:
BTC Code Selector
CTC Parameters
Block Interleaver Depth
STC Parameters

8.3.1.4.3 Burst Profiles for standard bursts

In order to inter-operate with any base station, a SS shall be capable of decoding DL bursts containing a FCH and sending Request messages over a contention channel in a format that the BS is seeking.

8.3.1.4.3.1 DL Bursts containing a Frame Control Header

A compliant SS shall be capable of demodulating a Frame Control Header with the parameters listed in Table 116n and Table 116o; a compliant BS shall be capable of transmitting FCHs using one of these sets.

Table 116n—DCD channel profile setting for Broadcast FCH message

DCD channel profile parameter	Default setting	Alternatives that shall supported by auto-detection or SW initialization
Roll-off factor	0.25	–

Table 116o—DCD burst profile settings for DL burst containing for Broadcast FCH

DCD burst profile parameter	Default setting	Alternatives that shall supported by auto-detection or SW download parameterization
Modulation type (FCH payload only)	QPSK, Concatenated FEC without block interleaving	–
Inner (CC) code rate (FCH payload only)	1/2	–
RS Parameters	base $K = 239$ bytes; K variable via shortening with fixed $R = N - K = 16$ bytes	–
Preamble length	length = $m\ U + R_r$ symbs; $m = 3$ repeated UWs; $R_r = 4$ ramp symbs	$2 \leq m < 11$; $0 \leq R \leq \frac{U}{2} \leq 60$ in increments of 4 symbs
Unique Word length	$U = 64$ symbs	$U = 16, 256$ (optional for some symb rates)
Pilot Word parameters	$n = 0$ repeated UWs; $F = 256$ symb interval	n=1,2; F= 256 (when $U \neq 256$), $F = 1024$
Transmit diversity type	None	–

8.3.1.4.3.2 Bursts on Request Slots

A compliant SS shall be capable of formatting a Request over a Initial Maintenance Slot or BW Request using all combinations of the channel and burst settings listed in Table 116p and Table 116q. A compliant BS shall designate at least one of these combinations as the expected format in its UL MAPs for these slots.

Table 116p—UCD channel profile settings for UL Request Contention Slots

UCD channel profile parameter	Default setting	Alternatives that shall be supported by a SS transmitter
Roll-off factor	0.25	–
SS Transition gap length	0 symbs + RxDS (UW) length	0–50 symbs + RxDS (UW) length
Initial maintenance SSTG	30 symbs + RxDS (UW) length	0–500 symbs + RxDS length

Table 116q—UCD burst profile settings for UL Contention Slots

UCD burst profile parameter	Default setting	Alternatives that shall be supported by a SS transmitter
Modulation type	QPSK, Concatenated FEC without block interleaving	–
Inner code rate	1/2	–
RS Parameters	base $K = 239$ bytes; K variable via shortening with fixed $R = N - K = 16$ bytes	–
Preamble length	length = $mU + R_r$ symbs; $m = 3$ repeated UWs; $R_r = 4$ ramp symbs	$2 \le m < 11$; $0 \le R \le \frac{U}{2} \le 60$ in increments of *4* symbs
Unique Word length	$U = 64$ symbs	$U = 16, 256$ (optional for some symb rates)
Pilot Word larameters	$n = 0$ repeated UWs $F = 256$ symb interval	$n = 1,2$; $F = 256$ (when $U \neq 256$), $F = 1024$
Transmit diversity type	None	–

8.3.1.4.4 Burst Profiles for non-broadcast and non-contention messages

Burst profiles for non-broadcast and non-contention messages are adaptive (and potentially negotiable). Such burst profiles are specified by the MAC management encodings of 11.1.

8.3.1.4.5 MAP message fields and IEs

8.3.1.4.5.1 DL-MAP PHY synchronization field

Table 116r provides the format of the PHY synchronization field of the frame control message described in 6.2.2.3.2.

Table 116r—SCa PHY synchronization field

Syntax	Size	Notes
PHY_synchronization_field() {		
Frame duration code()	8 bits	
Frame number	24 bits	
Allocation_Start_Time	32 bits	
}		

Frame duration code:

Table 116s indicates the various frame durations that are allowed. The actual frame time used by the DL can be determined by the periodicity of the frame start preambles.

Table 116s—SCa frame duration codes

Code (N)	Nominal frame duration (T_F ms)
0–6	$N/2+2$
7–11	$N–1$
12–255	Reserved

A frame is an integer multiple of PSs long, with the multiple being chosen such that the resulting actual duration is as close as possible to a nominal frame duration listed in Table 116s. For TTD systems, the TTG shall be no less than 5 μs in duration. When using STC encoding, the frame shall contain (in addition to all other requirements) an even number of dual blocks. This requirement shall also be taken into account when choosing an actual frame duration.

Frame number:

The Frame number is incremented by 1 for each frame and eventually wraps around to zero.

Allocation_Start_Time:

Effective start time of the downlink allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to one frame duration

8.3.1.4.5.2 DL-MAP Information Element formats

The Information Elements of Table 116u are used in DL-MAP messages. The format for these DL-MAP messages is specified in Table 116t.

Table 116t—SCa DL-MAP Information Element format

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (UIUC == 15) {		
Extended UIUC dependent IE	variable	AAS_DL_IE()
} else {		
Offset	12 bits	
}		
}		

Offset: Offset (in units of minislots) to the start of the data burst from the mini-slot boundary specified by the downlink Allocation_Start_Time.

Table 116u—SCa Downlink interval usage codes

IE name	DIUC	Minislot offset
Fill	0	Start of allocation for uncoded QPSK zero-fill.
Data Grant 1	1	Starting offset of data grant 1 burst type
Data Grant 2	2	Starting offset of data grant 2 burst type.
Data Grant 3	3	Starting offset of data grant 3 burst type
Data Grant 4	4	Starting offset of data grant 4 burst type
Data Grant 5	5	Starting offset of data grant 5 burst type
Data Grant 6	6	Starting offset of data grant 6 burst type
Data Grant 7	7	Starting offset of data grant 7 burst type
Data Grant 8	8	Starting offset of data grant 8 burst type
Data Grant 9	9	Starting offset of data grant 9 burst type
Data Grant 10	10	Starting offset of data grant 10 burst type
Data Grant 11	11	Starting offset of data grant 11 burst type
Data Grant 12	12	Starting offset of data grant 12 burst type
Gap	13	Start offset of an unallocated frame interval
Null	14	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Extended DIUC	15	

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_DL_IE() 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 UL-MAP_IE() shall be set to the broadcast CID.

Table 116v—SCa AAS Information Element format

Syntax	Size	Notes
AAS_Information_Element() {		
extended DIUC	4 bits	AAS = 0x02
Offset	12 bits	
Reserved	4 bits	
}		

When a channel measurement report is needed (see 6.2.14), the extended DIUC = 15 is used with the sub-code 0x00 and with 8-bit Channel Nr value as shown in Table 116w. The Report_IE shall be followed by the Null IE (DIUC=14). When used, the CID of the DL-MAP_IE() shall be set to the broadcast CID.

Table 116w—SCa channel measurement Information Element format

Syntax	Size	Notes
Report_Information_Element() {		
extended DIUC	4 bits	DFS = 0x00
Channel Nr	8 bits	Channel number (see 8.6.1) Set to 0x00 for licensed bands
Offset	12 bits	
Reserved	4 bits	
}		

8.3.1.4.5.3 UL Information Element formats

The Information Elements of Table 116y are used in UL-MAP messages. The format for these UL-MAP messages is specified in Table 116x.

Table 116x—SCa UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 15) {		
Extended UIUC dependent IE	variable	AAS_UL_IE()
} else {		
Offset	12 bits	
}		
}		

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):
A four-bit code used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included in 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 108 of 8.2.6.1.2.

Offset:

Indicates the start time, in units of minislots, of the burst relative to the Allocation Start Time given in the UL-MAP message. Consequently, the first IE shall have an offset of 0. The end of the last allocated burst is indicated by allocating a NULL burst (CID = 0 and UIUC = 14) with zero duration. The time instants indicated by offsets are the transmission times of the first symbol of the burst including preamble. .

Table 116y—SCa UL-MAP information elements

IE name	UIUC	CID	Mini-slot offset
Reserved	0	NA	Reserved for future use
Request	1	any	Starting offset of REQ region
Initial maintenance	2	broadcast	Starting offset of MAINT region (used in Initial Ranging)
Data grant burst type 0	3	unicast	Starting offset of Data Grant Burst Type 0 assignment
Data grant burst type 1	4	unicast	Starting offset of Data Grant Burst Type 1 assignment
Data grant burst Type 2	5	unicast	Starting offset of Data Grant Burst Type 2 assignment
Data grant burst type 3	6	unicast	Starting offset of Data Grant Burst Type 3 assignment
Data grant burst type 4	7	unicast	Starting offset of Data Grant Burst Type 4 assignment
Data grant burst type 5	8	unicast	Starting offset of Data Grant Burst Type 5 assignment
Data grant burst type 6	9	unicast	Starting offset of Data Grant Burst Type 6 assignment
Null IE	10	zero	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Empty	11	zero	Used to schedule gaps in transmission
Reserved	12–14	any	Reserved
Extended UIUC	15	extended UIUC	

A BS supporting the AAS option shall allocate at the end of the UL frame an initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance.

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_UL_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116z—SCa AAS UL information element format

Syntax	Size	Notes
AAS_UL_Information_element() {		
extended UIUC	4 bits	AAS = 0x02
Offset	12 bits	
Reserved	4 bits	
}		

8.3.1.4.5.4 Burst Profile format

Table 116aa defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

Table 116aa—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116ab defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

Table 116ab—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.3.1.5 Baseband Pulse Shaping

Prior to modulation, I and Q signals shall be filtered by square-root raised cosine. A roll-off factor of $\alpha = 0.25$ shall be supported; 0.15 and 0.18 are optional, but defined settings. The ideal square-root cosine is defined in the frequency domain by the transfer function

$$H(f) = \begin{cases} 1 & |f| < f_N(1-\alpha) \\ \sqrt{\frac{1}{2} + \frac{1}{2}\sin\left(\frac{\pi}{2f_N}\left[\frac{f_N - |f|}{\alpha}\right]\right)} & f_N(1-\alpha) \le |f| \le f_N(1+\alpha) \\ 0 & |f| \ge f_N(1+\alpha) \end{cases} \tag{17}$$

where

$$f_N = \frac{1}{2T_S} = \frac{R_S}{2}, \tag{18}$$

f_N is the Nyquist frequency, T_s is the modulation symbol duration, and R_s is the symbol rate.

8.3.1.6 Quadrature modulation

Define the quadrature modulated transmit waveform $s(t)$ as

$$s(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t) \tag{19}$$

where $I(t)$ and $Q(t)$ are the filtered baseband signals of the I and Q symbols and f_c is the carrier frequency.

8.3.1.7 Power control

Power control shall be supported on the UL, using both initial calibration and periodic adjustment procedures, and without loss of data. To support this, a BS shall be capable of making accurate power measurements of a received signal burst, nominally using the specifications for measurements found in 8.3.2.2. This measurement can then be compared against a reference level, and the resulting error fed back to a SS in a calibration message from the MAC.

Although its exact implementation is not specified, the power control algorithm shall be designed to respond power fluctuations at rates of no more than 30 dB/second and depths of at least 10 dB. Subclause 8.3.4.5

provides recommendations on overall power control range, stepsize, and absolute accuracy in an implementation.

A power control algorithm shall also account for the interaction of the RF power amplifier with different burst profiles. For example, when changing from the QAM modulation of one burst profile to another, amplifier back-off margins shall be maintained to prevent peak clipping and violation of emissions masks and/or excessive transmitter EVM.

8.3.2 Channel quality measurements

8.3.2.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.3.2.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the DL burst preambles. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{RSSI}[k-1] + \alpha_{avg}R[k] & k > 0 \end{cases} \quad \text{mW} \tag{20}$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\hat{\mu}_{RSSI\ dBm}[k] = 10\log(\hat{\mu}_{RSSI}[k]) \quad \text{dBm}. \tag{21}$$

To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{RSSI}[k-1] + \alpha_{avg}|R[k]|^2 & k > 0 \end{cases} \quad (22)$$

and the result applied to

$$\hat{\sigma}_{RSSI\ dB} = 5\log\left(\left|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2\right|\right) \quad \text{dB}\ . \quad (23)$$

8.3.2.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the DL burst preambles. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is by normalizing the mean-squared residual error of detected data symbols (and/or pilot symbols) by the average signal power using

$$CINR[k] = \frac{A[k]}{E[k]}\ , \quad (24)$$

where $CINR[k]$ is the (linear) CINR for message k, $r[k,\ n]$ is received symbol n within message k; $s[k,\ n]$ the corresponding detected or pilot symbol corresponding to received symbol n;

$$A[k] = \sum_{n=0}^{N-1} |s[k,\ n]|^2 \quad (25)$$

is the average signal power, which is normally kept constant within a message by action of AGC; and

$$E[k] = \sum_{n=0}^{N-1} |r[k,\ n] - s[k,\ n]|^2\ . \quad (26)$$

The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k]), \tag{27}$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{avg})\hat{\mu}_{CINR}[k-1] + \alpha_{avg}CINR[k] & k > 0 \end{cases} \tag{28}$$

k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism that delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{CINR}[k-1] + \alpha_{avg}|CINR[k]|^2 & k > 0 \end{cases} \tag{29}$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \tag{30}$$

8.3.3 Antenna diversity systems

Diversity techniques are likely to find application in some broadband wireless installations. Receive diversity does not require special considerations on the part of the air interface or framing. With two-way delay transmit diversity, where two transmit antennas are used and the output of the second antenna is delayed with respect to the first, the considerations are minor. Namely, both receiver equalization and framing shall be adequate to accommodate the extra delay spread introduced in the system due to the delayed output of the second transmitter.

However, framing considerations arise when the STC transmit diversity scheme [B26] is to be used. 8.3.3.1 describes the STC transmit diversity scheme for the SCa PHY and specifies framing that shall be used in its implementation.

8.3.3.1 STC transmit diversity

Implementation of STC transmit diversity is optional.

The STC transmit diversity scheme logically pairs blocks of data separated by delay spread guard intervals. These paired blocks are jointly processed at both the transmitter and receiver. The technique to be described is particularly amenable to a frequency domain equalizer implementation.

8.3.3.1.1 Paired block transmit processing

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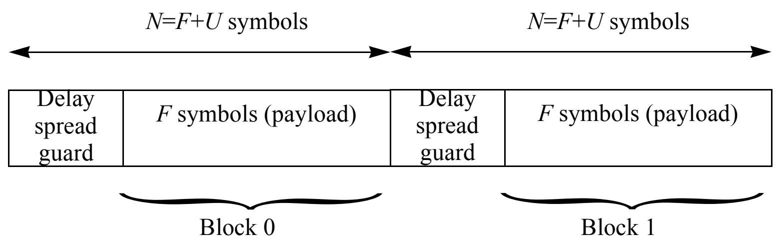

Figure 128w—Paired blocks used in STC transmit diversity combining

Figure 128w illustrates block pairing that shall be used by the STC transmit diversity scheme. Let $\{s_0[n]\}$ and $\{s_1[n]\}$ represent two sequences, each of length F symbols ($0 \le n < F$), which are desired to be delivered to a receiver using the STC transmit diversity scheme. Table 116ac indicates the block multiplexing structure that a two antenna transmitter shall use to transmit the two sequences over the paired blocks illustrated in Figure 128w. As Table 116ac indicates, Transmit Antenna 0 shall transmit its data sequences in order, with no modifications; however, Transmit Antenna 1 shall not only reverse the order in which its blocks are transmitted, but shall also conjugate the transmitted complex symbols and shall also time-reverse—cyclically about zero, modulo-*F*—the sequence of data symbols within each block. Subclause 8.3.3.1.4 provides details on the composition of the delay spread guard intervals between the blocks illustrated in Figure 128w.

Table 116ac—Multiplexing arrangement for block STC processing

Tx Antenna	Block 0	Block 1
0	$\{s_0[n]\}$	$\{s_1[n]\}$
1	$\{-s_1^*[(F-n)mod(F)]\}$	$\{s_0^*[(F-n)mod(F)]\}$

8.3.3.1.2 Paired block receive processing

If $S_0(e^{j\omega})$, $S_1(e^{j\omega})$, $H_0(e^{j\omega})$, $H_1(e^{j\omega})$, $N_0(e^{j\omega})$, and $N_1(e^{j\omega})$ represent the Discrete-time Fourier transforms, respectively, of the symbol sequences $\{s_0[n]\}$ and $\{s_1[n]\}$, channel impulse responses (for the channels associated with each transmitter antenna) $\{h_0[n]\}$ and $\{h_1[n]\}$, and additive noise sequences (associated with each block) $\{n_0[n]\}$ and $\{n_1[n]\}$, the received signals associated with each block, interpreted in the frequency domain, are as follows:

$$R_0(e^{j\omega}) = H_0(e^{j\omega})S_0(e^{j\omega}) - H_1(e^{j\omega})S_1^*(e^{j\omega}) + N_0(e^{j\omega}) \tag{31}$$

$$R_1(e^{j\omega}) = H_0(e^{j\omega})S_1(e^{j\omega}) + H_1(e^{j\omega})S_0^*(e^{j\omega}) + N_1(e^{j\omega}) \tag{32}$$

Assuming that the channel responses $H_0(e^{j\omega})$ and $H_1(e^{j\omega})$ are known, one shall use the frequency domain combining scheme

$$C_0(e^{j\omega}) = H_0^*(e^{j\omega})R_0(e^{j\omega}) + H_1(e^{j\omega})R_1^*(e^{j\omega}) \tag{33}$$

$$C_1(e^{j\omega}) = -H_1(e^{j\omega})R_0^*(e^{j\omega}) + H_0^*(e^{j\omega})R_1(e^{j\omega}) \tag{34}$$

to obtain the combiner outputs

$$C_0(e^{j\omega}) = (|H_0(e^{j\omega})|^2 + |H_1(e^{j\omega})|^2)S_0(e^{j\omega}) + H_0^*(e^{j\omega})N_0(e^{j\omega}) + H_1(e^{j\omega})N_1^*(e^{j\omega}) \tag{35}$$

$$C_1(e^{j\omega}) = (|H_0(e^{j\omega})|^2 + |H_1(e^{j\omega})|^2)S_1(e^{j\omega}) - H_1(e^{j\omega})N_0^*(e^{j\omega}) + H_0^*(e^{j\omega})N_1(e^{j\omega}) \tag{36}$$

The combiner outputs of Equation (35) and Equation (36) can then be independently equalized using frequency domain equalizer techniques (for an example see [B21]) to obtain estimates for $\{s_0[n]\}$ and $\{s_1[n]\}$.

8.3.3.1.3 Channel estimation using pilot symbols

The channel responses used by the equalizer(s) can be estimated using data received during pilot symbol intervals. Under the assumption that pilot symbols are the same in the 0 and 1 blocks, i.e., $S_0^{pilot}(e^{j\omega}) = S_1^{pilot}(e^{j\omega}) = S_{pilot}(e^{j\omega})$, the sum and differences of Equation 6 and Equation 5 can be multiplied by $S_{pilot}^*(e^{j\omega})$ to yield (ignoring noise terms) the following:

$$S_{pilot}^*(e^{j\omega})(R_0^{pilot}(e^{j\omega}) + R_1^{pilot}(e^{j\omega})) = 2|S_{pilot}e^{j\omega}|^2 H_0(e^{j\omega}) \tag{37}$$

$$S_{pilot}(e^{j\omega})(R_1^{pilot}(e^{j\omega}) - R_0^{pilot}(e^{j\omega})) = 2|S_{pilot}e^{j\omega}|^2 H_1(e^{j\omega}) \tag{38}$$

The channel estimation task simply involves dividing the left hand sides of Equation (11) and Equation (12) by a constant independent of frequency, since pilot symbols are derived from the Unique Words of 8.3.1.3.2, and these Unique Words have a constant frequency domain magnitude, i.e., $|S_{pilot}(e^{j\omega})|^2 = |S_{UW}(e^{j\omega})|^2 = C$.

8.3.3.1.4 Paired block profiles

Figure 128x and Figure 128y illustrate two defined frame (burst) profiles for STC transmit diversity signaling.

Figure 128x illustrates the baseline framing structure for STC transmit multiplexing. This is cyclic-prefix-based frame structure, with U-symbol cyclic prefixes, and F-symbol repetitions chosen to facilitate efficient FFT-based processing at the receiver. Note that although the cyclic prefix is not composed of Unique Words, the length, U, shall be the same as the Unique Word length being used by the burst profile. Observe that the payload portions of Figure 128x reflect the STC antenna multiplexing format described in Table 116ac for Transmit Antennas 0 and 1. Note that a UW may be inserted within Payloads 0 and 1 to facilitate the use of frequency domain equalizers with time-domain decision feedback taps.

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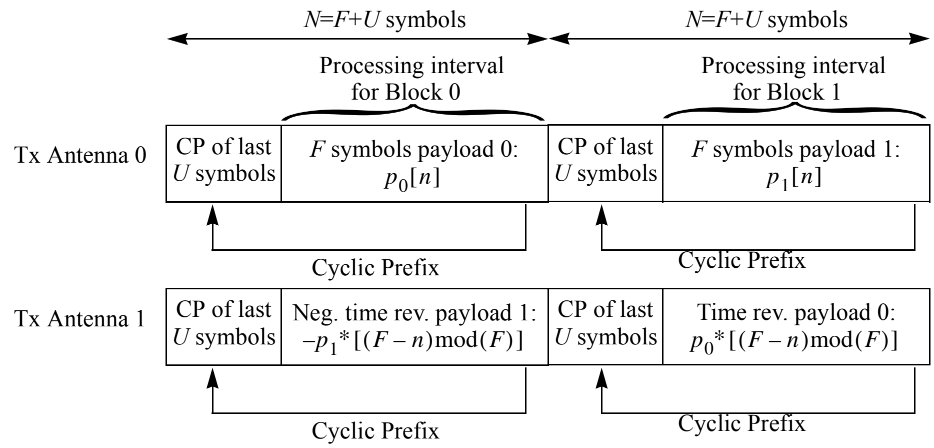

Figure 128x—Cyclic prefix-based STC framing

Figure 128y illustrates another burst profile which explicitly uses Unique Words, rather than a repetition of the payload data, to generate cyclic prefixes.

F, the length of an STC block, is a burst profile parameter. The choice of the burst profile for the paired blocks, i.e., the scheme illustrated in Figure 128x or the scheme illustrated in Figure 128y, is also a burst profile parameter.

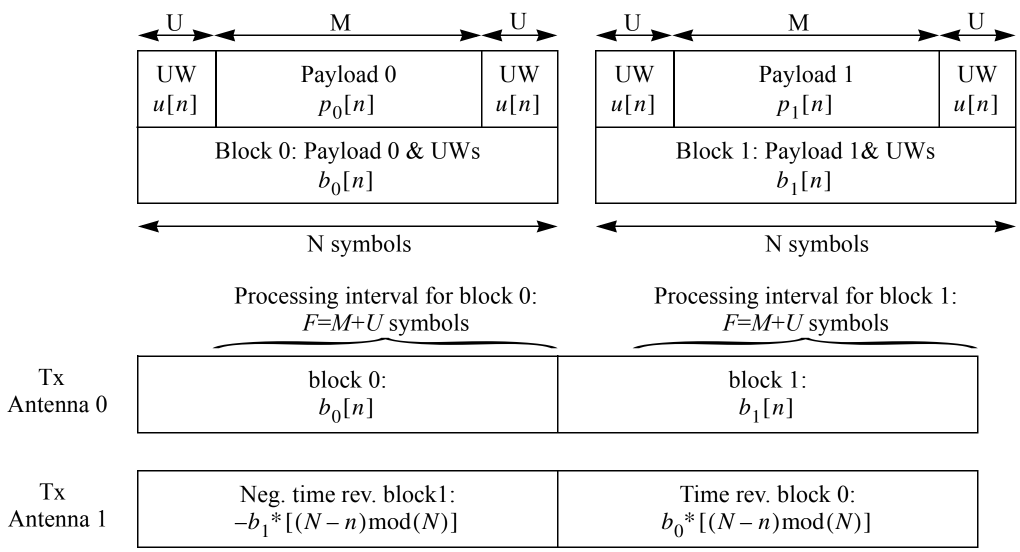

Figure 128y—STC framing using UWs as cyclic prefixes

8.3.3.1.5 STC burst elements

A STC burst shall consist of a preamble, followed by a payload, which may consist of multiple pairs of STC blocks.

Unlike conventional bursts, a RxDS element shall not appear at the conclusion of a STC burst.

8.3.3.1.5.1 Burst preamble

Figure 128z illustrates that the burst frame preamble shall be used for bursts utilizing STC transmit diversity encoding. The number of UW blocks composing a STC burst preamble is a burst profile paramater, through reuse of the general burst profile encoding for the number of UWs in a preamble. However, since two channels shall be estimated, the total number of UWs used to construct an STC burst preamble shall be twice the number specified in the burst profile encoding.

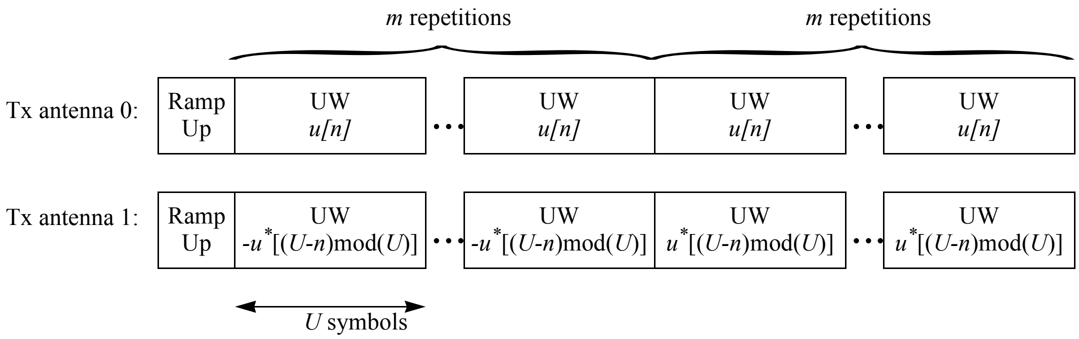

Figure 128z—STC frame preamble

Note that this preamble structure may also be inserted within a transmission as a group of contiguous Pilot Words, to assist in channel estimation and updating within a burst. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 128x, although the pilots may appear after every L^{th} paired payload block, where L is an integer greater than or equal to 1.

Ramp up shall use the same procedure described in 8.3.1.3.1.1, with the exception that the ramp up symbols for each transmit antenna are duplicates of the last R_r symbols of the first length-U data element in the preamble. Note that this implies that the first transmit antenna derives its ramp up symbols from a standard Unique Word sequence $\{u[n]\}$, while the second transmit antenna derives its ramp up symbols from the sequence $\{-u[(U-n)mod(U)]\}$.

8.3.3.1.5.2 Payload data

Payload data within an STC-encoded burst shall be formatted into block pairs, with each block pair possessing one of the block pair profiles described in 8.3.3.1.4. If insufficient data is available to fill the last block pair, then the payload shall be filled with null payload fill, as specified in 8.3.1.3.1.1. Except for the payload fill, modulations are sequenced in terms of decreasing modulation robustness on the Tx Ant 0 channel.

The preamble structure of Figure 128z, minus the ramp up symbols, may also be inserted within a transmission, as a group of contiguous Pilot Words to assist in channel estimation and updates within in a burst. In such an instance, this contiguous pilot symbol structure is considered external to the paired STC payload data blocks illustrated in Figure 128x, although the pilots may appear after every V^{th} paired payload block, where K is an integer greater than or equal to 1. The pilot word repetition interval, and the number of UWs composing a pilot word is a burst profile parameter.

8.3.3.1.5.3 Ramp down

Ramp down follows the end of a burst. A transmitter shall ramp down by inserting zero symbol inputs into the transmit filter memory following the last intended data symbol, and windowing the resulting, transmit-filtered output waveform with a multiplicative raised cosine window that diminishes to zero in R_r symbols. The (STC burst) ramp-down interval, R_r, shall be the same as the ramp up interval.

8.3.3.2 Interoperability with non-STC-encoded bursts

For interoperability reasons, STC-encoded data and conventionally-encoded data, shall not be time division multiplexed within the same burst. Instead, the STC data shall be encapsulated within its own burst and preamble.

All bursts with different STC pair block sizes, *F*, shall also be segregated, although they may share the same preamble.

8.3.4 System requirements

8.3.4.1 Channel frequency accuracy

RF channel frequency accuracy for a SS shall be within +/– 15 parts per million (ppm) of the selected RF carrier over a temperature range of –40 to +65 degrees C operational and up to 5 years from the date of manufacture of the equipment manufacture. The frequency accuracy for a BS shall be within +/– 4 ppm of the selected RF carrier over an operational temperature range of –40 to +65 degrees C, up to 10 years from the date of equipment manufacture.

8.3.4.2 Symbol rate

Utilizing a roll-off factor of $\alpha = 0.25$, the nominal symbol rate for the implemented channel bandwidth(s) BW shall be $(BW)/(1+\alpha) - 0.16$.

8.3.4.3 Symbol timing jitter

The minimum-to-maximum difference of symbol timing over a 2 second period shall be less than 2% of the nominal symbol period. This jitter specification shall be maintained over an operational temperature range of –40 to +65 degrees C.

8.3.4.4 Transmitter minimum SNR and EVM

A transmitted signal shall have an SNR of no less than 40 dB at the transmit antenna feed point. The transmitter EVM should be no greater than 3.1%, assuming 64-QAM.

8.3.4.5 Transmitter power level control

A SS transmitter shall provide 50 dB of monotonic power level control with an absolute tolerance of ± 3 and a stepsize of 1 dB ± 0.5 dB. A BS transmitter shall provide 20 dB of monotonic power level control with an absolute tolerance of ± 3 and a stepsize of 1 dB ± 0.5 dB.

8.3.4.6 Ramp up/down requirements

Transmit output power shall settle to within the tolerances specified in 8.3.4.5 within 5 µs. Transients due to the transmit filter impulse response shall be factored into settling time calculations.

8.3.4.7 Spurious emissions during burst on/off transients

A transmitter shall control spurious emissions to conform with applicable regulatory requirements. This includes prior to and during ramp up, during and following ramp down, and before and after a burst in a TDM/TDMA scheme.

8.3.4.8 Out of band spurious emissions

Out of band spurious emissions shall conform with applicable local regulatory spectral masks.

8.3.4.9 Receiver sensitivity

The Receiver sensitivity values shall be better than the values listed below (computed at 10^{-6} uncoded BER, and a total of 7 dB in receiver noise figure plus implementation loss). BW is specified in MHz.

QPSK: –93.4 + 10*log(BW)
16-QAM: –86.6 + 10*log(BW)
64-QAM: 80.4 + 10*log(BW)

Assumed SNR_{req} assumptions (for uncoded signals at 10^{-6} BER) are the following:

QPSK: 13.6 dB
16-QAM: 20.4 dB
64-QAM: 26.6 dB.

8.3.4.10 Receiver maximum input signal

A BS shall be capable of receiving a maximum on-channel operational signal of –40 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry. A SS shall be capable of receiving a maximum on-channel operational signal of –20 dBm and should tolerate a maximum input signal of 0 dBm without damage to circuitry.

8.3.4.11 Receiver adjacent channel interference

A system shall achieve the minimum adjacent and alternate adjacent channel interference performance as shown in Table 116ad. All measurements shall be performed uncoded.

Table 116ad—Minimum adjacent and alt. adjacent channel interference performance

	At BER 10–3, for 3 dB degradation	At BER 10–3, for 1 dB degradation	At BER 10–6, for 3 dB degradation	At BER 10–6, for 1 dB degradation
1st adjacent channel interference C/I	BPSK: –12 QPSK: –9 16-QAM: –2 64-QAM: +5 256-QAM: +12	BPSK: –8 QPSK: –5 16-QAM: +2 64-QAM: +9 256-QAM: +16	BPSK: –8 QPSK: –5 16-QAM: +2 64-QAM: +9 256-QAM: +16	BPSK: –4 QPSK: –1 16-QAM: +6 64-QAM: +13 256-QAM: +20
2nd adjacent channel interference C/I	BPSK: –37 QPSK: –34 16-QAM: –27 64-QAM: –20 256-QAM: –13	BPSK: –33 QPSK: –30 16-QAM: –22 64-QAM: –16 256-QAM: –9	BPSK: -33 QPSK: –30 16-QAM: –23 64-QAM: –16 256-QAM: –9	BPSK: –29 QPSK: –26 16-QAM: –20 64-QAM: –12 256-QAM: –5

8.4 WirelessMAN-OFDM-PHY layer

8.4.1 Introduction

The WirelessMAN-OFDM PHY is based on OFDM modulation and designed for NLOS operation in the 2–11 GHz frequency bands per 1.2.4. For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

8.4.1.1 OFDM symbol description

8.4.1.1.1 Time domain

Inverse-Fourier-transforming creates the OFDM waveform; this time duration is referred to as the useful symbol time T_b. A copy of the last T_g µs of the useful symbol period, termed Cyclic Prefix (CP), is used to collect multipath, while maintaining the orthogonality of the tones. The two together are referred to as the symbol time T_s. Figure 128aa illustrates this structure.

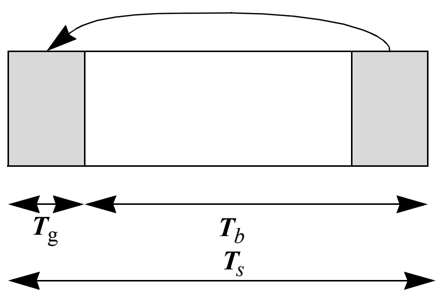

Figure 128aa—OFDM symbol time structure

The transmitter energy increases with the length of the guard time while the receiver energy remains the same (the cyclic extension is discarded), so there is a $10\log(1 - T_g / (T_b + T_g)) / \log(10)$ dB loss in SNR. The CP overhead fraction and resultant SNR loss could be reduced by increasing the FFT size, which would however, among other things, adversely affect the sensitivity of the system to phase noise of the oscillators. Using a cyclic extension, the samples required for performing the FFT at the receiver can be taken anywhere over the length of the extended symbol. This provides multipath immunity as well as a tolerance for symbol time synchronization errors.

On initialization, a SS should search all possible values of CP until it finds the CP being used by the BS. The SS shall use the same CP on the UL. Once a specific CP duration has been selected by the BS for operation on the DL, it should not be changed. Changing the CP would force all the SSs to resynchronize to the BS.

8.4.1.1.2 Frequency domain

The frequency domain description includes the basic structure of an OFDM symbol.

An OFDM symbol (see Figure 128ab) is made up from carriers, the number of which determines the FFT size used. There are several carrier types:

— Data carriers: for data transmission
— Pilot carriers: for various estimation purposes
— Null carriers: no transmission at all, for guard bands and DC carrier

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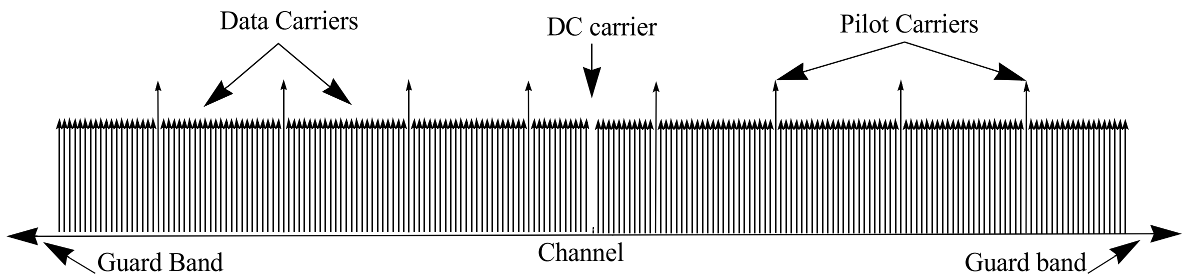

Figure 128ab—OFDM frequency description

The purpose of the guard bands is to enable the signal to naturally decay and create the FFT ‘brick Wall’ shaping.

8.4.2 OFDM symbol parameters and transmitted signal

8.4.2.1 Primitive parameter definitions

Three primitive parameters characterize the OFDM symbol:

— BW. This is the nominal channel bandwidth.
— (F_s / BW). This is the ratio of “sampling frequency” to the nominal channel bandwidth. Required values of this parameter are specified in 8.4.2.4.
— (T_g / T_b). This is the ratio of CP time to “useful” time. Required values of this parameter are specified in 8.4.2.4.
— N_{FFT}. This is the number of points in the FFT, if an FFT is used in the implementation.

8.4.2.2 Derived parameter definitions

The following parameters are defined in terms of the primitive parameters of 8.4.2.1.

— Sampling Frequency: $F_s = (F_s / BW) \cdot BW$
— Carrier Spacing: $\Delta f = f_s / N_{FFT}$
— Useful Time: $T_b = 1 / \Delta f$
— CP Time: $T_g = (T_g / T_b) \cdot T_b$
— OFDM Symbol Time: $T_s = T_b + T_g$
— Sample Time: $1 / F_s$

8.4.2.3 Transmitted signal

Equation (39) specifies the transmitted signal voltage to the antenna, as a function of time, during any OFDM symbol.

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k = -N_{used}/2 \\ k \neq 0}}^{N_{used}/2} c_k \cdot e^{j2\pi k \Delta f (t - T_g)} \right\} \tag{39}$$

where

t is the time, elapsed since the beginning of the subject OFDM symbol, with $0 < t < T_s$.

c_k is a complex number; the data to be transmitted on the carrier whose frequency offset index is *k,* during the subject OFDM symbol. It specifies a point in a QAM constellation.

8.4.2.4 Parameters of transmitted signal

The parameters of the transmitted OFDM signal, transmitted as in 8.4.2.3, are given in Table 116ae.

Table 116ae—OFDM symbol parameters

Parameter	Value
N_{FFT}	256
N_{used}	200
F_s/BW	licensed channel bandwidths which are multiples of 1.75 MHz and license-exempt: 8/7 any other bandwidth: 7/6
(T_g/T_b)	1/4, 1/8, 1/16, 1/32
Number of lower frequency guard carriers	28
Number of higher frequency guard carriers	27
Frequency offset indices of guard carriers	–128,–127...,–101 +101,+102,...,127
Frequency offset indices of BasicFixedLocationPilots	–84,–60,–36,–12,12,36,60,84
Subchannel number: Allocated frequency offset indices of carriers	1:{–88,...,–76},{–50,...,–39},{1,...,13},{64,...,75} 2:{–63,…,–51},{–25,...–14},{26,...,38},{89,...,100} 3:{–100,…,–89},{–38,...,–26},{14,...,25},{51,...,63} 4:{–75,…,–64},{–13,...,–1},{39,...,50},{76,...,88}

8.4.3 Channel coding

Channel coding is composed of three steps: randomizer, forward error correction (FEC) and interleaving. They shall be applied in this order at transmission. The complementary operations shall be applied in reverse order at reception.

8.4.3.1 Randomization

Data randomization is performed on data transmitted on the DL and UL. The randomization is performed on each allocation (DL or UL), which means that for each allocation of a data block (subchannels on the frequency domain and OFDM symbols on the time domain) the randomizer shall be used independently. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF ('1' only) shall be added to the end of the transmission block, up to the amount of data allocated minus one byte, which shall be reserved for the introduction of a 0x00 tail byte by the FEC.

The shift-register of the randomizer shall be initialized for each new allocation.

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 128ac. Each data byte to be transmitted shall enter sequentially into the randomizer, msb first. Preambles are not randomized. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The randomizer sequence is applied only to information bits.

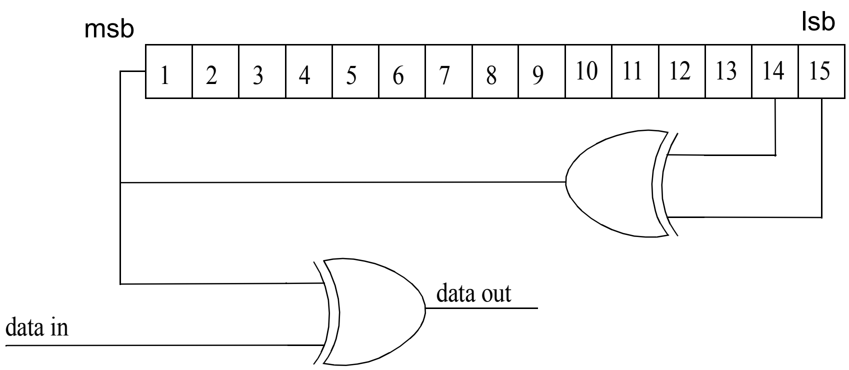

Figure 128ac—PRBS for data randomization

The bits issued from the randomizer shall be applied to the encoder.

In the DL, the scrambler shall be re-initialized at the start of each frame with the sequence: 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0.

On the UL, the scrambler is initialized with the vector shown in Figure 128ad.

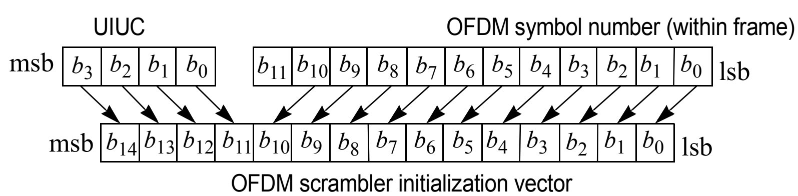

Figure 128ad—OFDM scrambler UL initialization vector

8.4.3.2 FEC

A FEC, consisting of the concatenation of a Reed-Solomon outer code and a rate-compatible convolutional inner code, shall be supported on both UL and DL. Support of BTC and CTC is optional. The Reed-Solomon-Convolutional coding rate 1/2 shall always be used as the coding mode when requesting access to the network and in the FCH burst.

The encoding is performed by first passing the data in block format through the RS encoder and then passing it through a zero-terminating convolutional encoder.

8.4.3.2.1 Concatenated Reed-Solomon / convolutional code (RS-CC)

The Reed-Solomon encoding shall be derived from a systematic RS (N=255, K=239, T=8) code using GF(28),

where:

N is the number of overall bytes after encoding

K is the number of data bytes before encoding

T is the number of data bytes which can be corrected.

The following polynomials are used for the systematic code:

Code Generator Polynomial: $$g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX} \tag{40}$$

Field Generator Polynomial: $$p(x) = x^8+x^4+x^3+x^2+1 \tag{41}$$

This code is shortened and punctured to enable variable block sizes and variable error-correction capability. When a block is shortened to K' data bytes, the first 239-K' bytes of the encoder block shall be zero. When a codeword is punctured to permit T' bytes to be corrected, only the first 2T' of the total 16 codeword bytes shall be employed. The bit/byte conversion shall be msb first.

Each RS block is encoded by the binary convolutional encoder, which shall have native rate of 1/2, a constraint length equal to **7**, and shall use the following generator polynomials codes to derive its two code bits:

$$\begin{array}{ll} G_1 = 171_{OCT} & FOR\ X \\ G_2 = 133_{OCT} & FOR\ Y \end{array} \tag{42}$$

The generator is depicted in Figure 128ae.

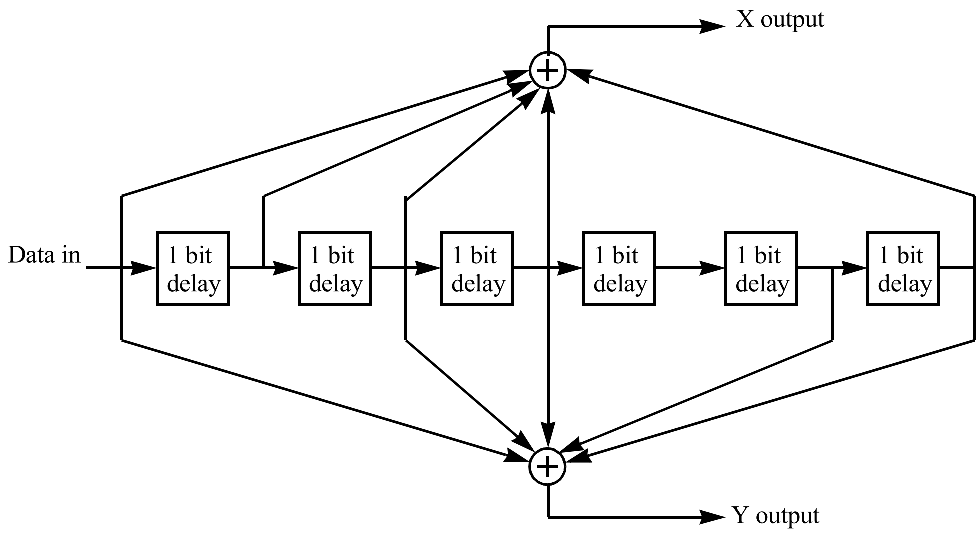

Figure 128ae—Convolutional encoder of rate 1/2

Puncturing patterns and serialization order that shall be used to realize different code rates are defined in Table 116af. In the table, “1” means a transmitted bit and “0” denotes a removed bit, whereas X and Y are in reference to Figure 128ae.

Table 116af—The inner convolutional code with puncturing configuration

	Code rates			
Rate	1/2	2/3	3/4	5/6
d_{free}	10	6	5	4
X	1	10	101	10101
Y	1	11	110	11010
XY	X_1Y_1	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$

RS-CC rate 1/2 shall always be used as the coding mode when requesting access to the network.

The encoding is performed by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder. A single 0x00 tail byte is appended to the end of each allocation. This tail byte shall be appended after scrambling. In the RS encoder, the redundant bits are sent before the input bits, keeping the 0x00 tail byte at the end of the allocation.

Table 116ag gives the block sizes and the code rates used for the different modulations and code rates. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ag—Mandatory channel coding per modulation

Modulation	Uncoded block size (bytes)	Coded block size (bytes)	Overall coding rate	RS code	CC code rate
QPSK	24	48	1/2	(32,24,4)	2/3
QPSK	36	48	3/4	(40,36,2)	5/6
16-QAM	48	96	1/2	(64,48,8)	2/3
16-QAM	72	96	3/4	(80,72,4)	5/6
64-QAM	96	144	2/3	(108,96,6)	3/4
64-QAM	108	144	3/4	(120,108,6)	5/6

When subchannelization is active (see 8.4.5.3.5), the FEC shall bypass the RS encoder and use the Overall Coding Rate as indicated in Table 116ag as CC Code Rate. The Uncoded Block Size and Coded Block size may be computed by dividing the values listed in Table 116ag by 4 and 2 for 1 and 2 subchannel allocations respectively.

8.4.3.2.2 Block Turbo Coding (optional)

The BTC is based on the product of two simple component codes, which are binary extended Hamming codes or parity check codes from the set depicted in Table 116ah.

Table 116ah—BTC component codes

Component code (*n*,*k*)	Code type
(64,57)	Extended Hamming code
(32,26)	Extended Hamming code
(16,11)	Extended Hamming code
(32,31)	Parity check code
(16,15)	Parity check code
(8,7)	Parity check code

Table 116ai specifies the generator polynomials for the Hamming codes. To create extended Hamming codes, an overall even parity check bit is added at the end of each code word.

Table 116ai—Hamming code generator polynomials

n'	*k'*	**Generator polynomial**
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

The component codes are used in a two-dimensional matrix form, which is depicted in Figure 128ag. The k_x information bits in the rows are encoded into n_x bits, by using the component block (n_x, k_x) code specified for the respective composite code. After encoding the rows, the columns are encoded using a block code (n_y, k_y), where the check bits of the first code are also encoded. The overall block size of such a product code is $n = n_x \times n_y$, the total number of information bits $k = k_x \times k_y$ and the code rate is $R = R_x \times R_y$, where $R_i = k_i / n_i$, i=x, y. The Hamming distance of the product code is $d = d_x \times d_y$. Data bit ordering for the composite BTC matrix is defined such that the first bit in the first row is the lsb, and the last data bit in the last data row is the msb.

Figure 128af illustrates an example of a BTC encoded with $(8, 4) \times (8, 4)$ extended Hamming component codes.

D_{11}	D_{21}	D_{31}	D_{41}	E_{51}	E_{61}	E_{71}	E_{81}
D_{12}	D_{22}	D_{32}	D_{42}	E_{52}	E_{62}	E_{72}	E_{82}
D_{13}	D_{23}	D_{33}	D_{43}	E_{53}	E_{63}	E_{73}	E_{83}
D_{14}	D_{24}	D_{34}	D_{44}	E_{54}	E_{64}	E_{74}	E_{84}
E_{15}	E_{25}	E_{35}	E_{45}	E_{55}	E_{65}	E_{75}	E_{85}
E_{16}	E_{26}	E_{36}	E_{46}	E_{56}	E_{66}	E_{76}	E_{86}
E_{17}	E_{27}	E_{37}	E_{47}	E_{57}	E_{67}	E_{77}	E_{87}
E_{18}	E_{28}	E_{38}	E_{48}	E_{58}	E_{68}	E_{78}	E_{88}

Figure 128af—Example of an encoded BTC block

Transmission of the block over the channel shall occur in a linear fashion, with all bits of the first row transmitted left to right followed by the second row, and so on. For the $(8, 4) \times (8, 4)$ example in Figure 128af, the output order for the 64 encoded bits would be: D_{11}, D_{21}, D_{31}, D_{41}, E_{51}, E_{61}, E_{71}, E_{81}, D_{12}, D_{22},..., E_{88}.

To match a required packet size, BTCs may be shortened by removing symbols from the BTC array. In the two-dimensional case, rows, columns or parts thereof can be removed until the appropriate size is reached. There are three steps in the process of shortening product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

Step 3) Use if the product code specified from Step 1) and Step 2) has a non-integral number of data bytes. In this case, the Q left over lsb bits are zero filled by the encoder. After decoding at the receive end, the decoder shall strip off these unused bits and only the specified data payload is passed to the next higher level in the physical layer.

The same process is used for shortening the last code word in a message where the available data bytes do not fill the available data bytes in a code block.

These three processes of code shortening are depicted in Figure 128ag. In the first two-dimensional BTC, a non-shortened product code is shown. By comparison, a shortened BTC is shown in the adjacent two-dimensional array. The new coded block length of the code is $(n_x–I_x)(n_y–I_y)–B$. The corresponding information length is given as $(k_x–I_x)(k_y–I_y)–B–Q$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B - Q}{(n_x - I_x)(n_y - I_y) - B} \tag{43}$$

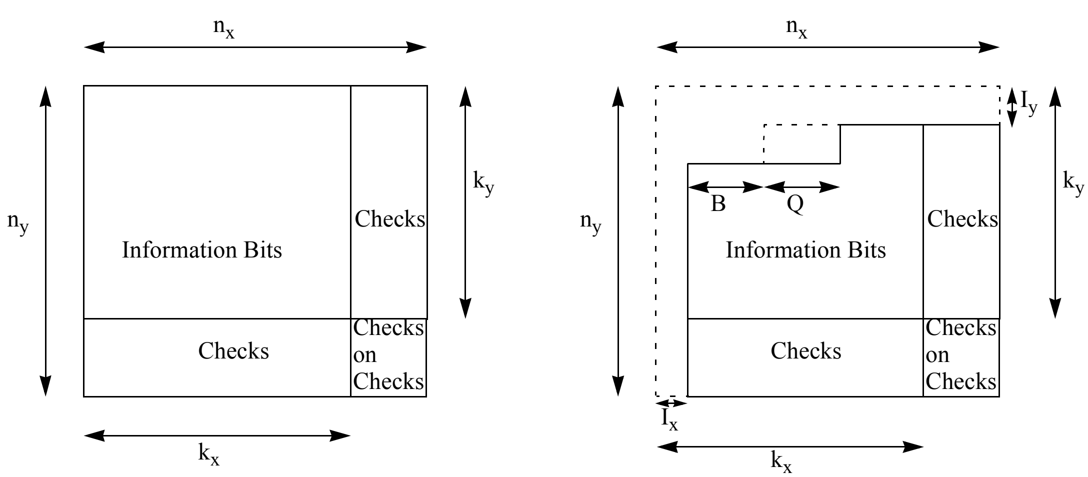

Figure 128ag—BTC and shortened BTC structure

Table 116aj gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116aj—Optional BTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	Efficiency (bit/s/Hz)	Constituent codes	Code parameter
QPSK	23	48	~1/2	1.0	(32,26)(16,11)	I_x=4, I_y=2, B=8, Q=6
QPSK	35	48	~3/4	1.5	(32,26)(16,15)	I_x=0, I_y=4, B=0, Q=6
16-QAM	58	96	~3/5	2.4	(32,26)(32,26)	I_x=0, I_y=8, B=0, Q=4
16-QAM	77	96	~4/5	3.3	(64,57)(16,15)	I_x=7, I_y=2, B=30, Q=4
64-QAM	96	144	~2/3	3.8	(64,63)(32,26)	I_x=3, I_y=13, B=7, Q=5
64-QAM	120	144	~5/6	5.0	(32,31)(64,57)	I_x=13, I_y=3, B=7, Q=5

8.4.3.2.3 Convolutional Turbo Codes (optional)

8.4.3.2.3.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128ah. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to *A* and *B,* starting with the msb of the first byte being fed to *A*. The encoder is fed by blocks of *k* bits or *N* couples (k = 2*N bits). For all the frame sizes *k* is a multiple of 8 and *N* is a multiple of 4. *N* shall be limited to: $8 \le N/4 \le 1024$.

The polynomials defining the connections are described in octal and symbol notations as follows:

— for the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— for the Y parity bit: 0xD, equivalently $1+D^2+D^3$

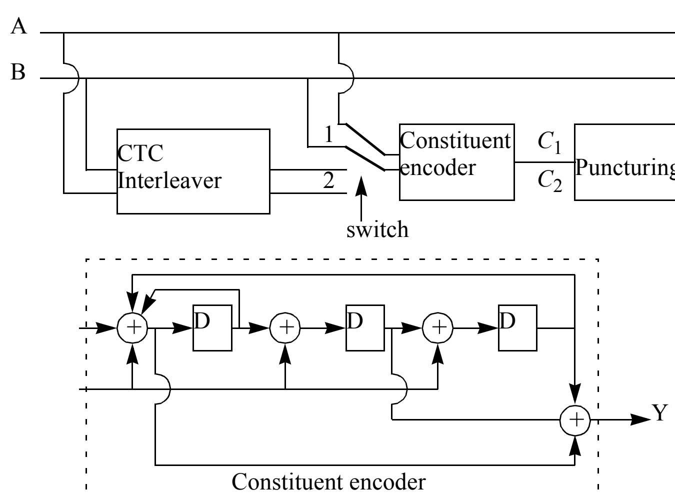

Figure 128ah—CTC encoder

First, the encoder (after initialization by the circulation state Sc_1, see 8.4.3.2.3.3) is fed the sequence in the natural order (position 1) with the incremental address $i = 0 .. N–1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see 8.4.3.2.3.3) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0, … N–1$. This second encoding is called C_2 encoding.

The order that the encoded bit shall be fed into the interleaver (8.4.3.3) is as follows:

$$A_0, B_0 .. A_{N\text{-}1}, B_{N\text{-}1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,M},$$

where M is the number of parity bits.

Table 116ak gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ak—Optional CTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	N	P_0	P_1
QPSK	24	48	1/2	96	7	3N/4
QPSK	32	48	2/3	128	11	3N/4
QPSK	36	48	3/4	144	17	3N/4
16-QAM	48	96	1/2	192	11	3N/4
16-QAM	72	96	3/4	288	13	3N/4
64-QAM	96	144	2/3	384	17	3N/4
64-QAM	108	144	3/4	432	17	3N/4

8.4.3.2.3.2 CTC Interleaver

The interleaver requires the parameters P_0 and P_1, shown in Table 116ak.

The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if (j_{mod_2} ==0) let (B,A) = (A,B) (i.e., switch the couple)

Step 2: $P_i(j)$

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4} :

case 0 or 1: $i = (P_0 \cdot j + 1)_{\text{mod}_N}$

case 2: $i = (P_0 \cdot j + 1 + N/4)_{\text{mod}_N}$

case 3: $i = (P_0 \cdot j + 1 + N/2 + P_1)_{\text{mod}_N}$

8.4.3.2.3.3 Determination of CTC circulation states

The state of the encoder is denoted S ($0 <= S == 7$) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128ah). The circulation states Sc_1 and Sc_2 are determined by the following operations:

Step 1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;

Step 2) According to the length N of the sequence, use Figure 116al to find Sc_1 or Sc_2.

Table 116al—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.4.3.2.3.4 CTC puncturing

The three code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116am—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	Y					
	0	**1**	**2**	**3**	**4**	**5**
1/2	1	1				
2/3	1	0	1	0		
3/4	1	0	0	1	0	0

8.4.3.3 Interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the specified allocation, N_{cbps}. The interleaver is defined by a two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent carriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Let N_{cpc} be the number of coded bits per carrier, i.e., 2, 4 or 6 for QPSK, 16-QAM or 64-QAM, respectively. Let $s = N_{cpc}/2$. Let k be the index of the coded bit before the first permutation at transmission; m be the index after the first and before the second permutation; and j be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule:

$$m = (N_{\text{cbps}} / 16) \cdot k_{mod(16)} + floor(k / 16) \qquad k = 0, 1, .., N_{\text{cbps}} - 1 \tag{44}$$

The second permutation is defined by the rule:

$$j = s \cdot floor(m / s) + (m + N_{\text{cbps}} - floor(16 \cdot m / N_{\text{cbps}}))_{mod\ s} \qquad m = 0, 1, .., N_{\text{cbps}} - 1 \tag{45}$$

The de-interleaver, which performs the inverse operation, is also defined by two permutations. Let j be the index of the received bit before the first permutation; m be the index after the first and before the second permutation; and k be the index after the second permutation, just prior to delivering the coded bits to the convolutional decoder.

The first permutation is defined by the rule:

$$m = s \cdot floor(j / s) + (j + floor(16 \cdot j / N_{\text{cbps}}))_{mod\ s} \qquad j = 0, 1, .., N_{\text{cbps}} - 1 \tag{46}$$

The second permutation is defined by the rule:

$$k = 16 \cdot m - (N_{\text{cbps}} - 1) \cdot floor(16 \cdot m / N_{\text{cbps}}) \qquad m = 0, 1, .., N_{\text{cbps}} - 1 \tag{47}$$

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely.

Table 116an shows the bit interleaver sizes as a function of modulation and coding.

Table 116an—Bit interleaved block sizes

Modulation	Coded bits per bit interleaved block (N_{cbps})		
	Default (4 subchannels)	2 subchannels	1 subchannel
QPSK	384	192	96
16-QAM	768	384	192
64-QAM	1152	576	288

The first bit out of the interleaver shall map to b_0 in the constellation.

8.4.3.4 Modulation

8.4.3.4.1 Data modulation

After bit interleaving, the data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM as shown in Figure 128ai shall be supported, whereas the support of 64-QAM is optional. The constellations as shown in Figure 128ai shall be normalized by multiplying the constellation point with the indicated factor c to achieve equal average power.

Per-allocation adaptive modulation and coding shall be supported in the DL. The UL shall support different modulation schemes for each SS based on the MAC burst configuration messages coming from the Base Station. Complete description of the MAC / PHY support of adaptive modulation and coding is provided in 6.2.7.

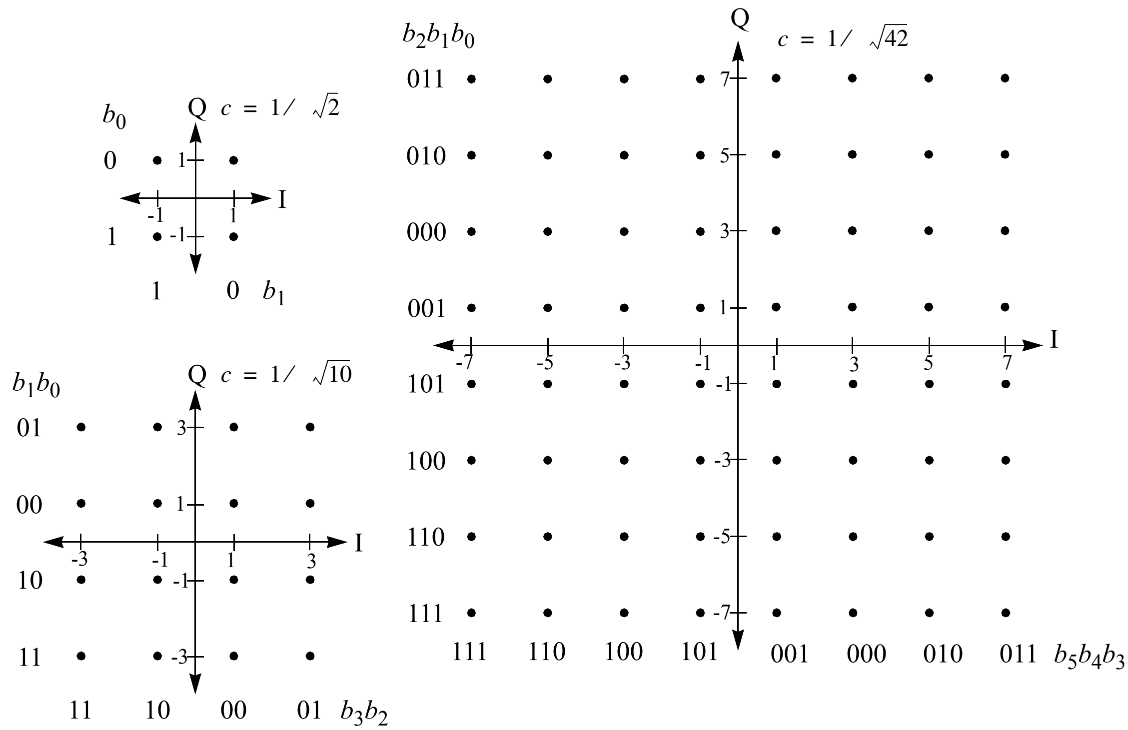

Figure 128ai—QPSK, 16-QAM and 64-QAM constellations

The constellation-mapped data shall be subsequently modulated onto the allocated data carriers. The first symbol out of the data constellation mapping shall be modulated onto frequency offset index $–N_{used}/2$.

8.4.3.4.2 Pilot modulation

Pilot carriers shall be inserted into each data burst in order to constitute the Symbol and they shall be modulated according to their carrier location within the OFDM symbol. The PRBS generator depicted hereafter shall be used to produce a sequence, w_k. The polynomial for the PRBS generator shall be $X^{11} + X^9 + 1$.

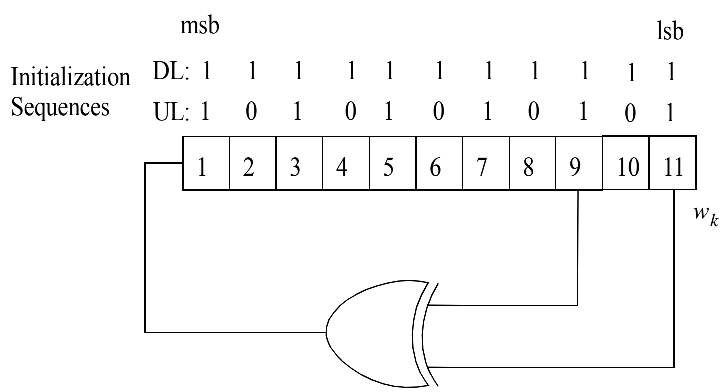

Figure 128aj—PRBS for pilot modulation

The value of the pilot modulation for OFDM symbol k, relative to the beginning of the frame, shall be derived from w_k. The initialization sequences that shall be used on the DL and UL are shown in Figure 128aj. On the DL, this shall result in the sequence 11111111111000000000110... where the 3rd 1, i.e.,

w_3=1, shall be used in the first OFDM DL symbol following the frame preamble. For each pilot (indicated by frequency offset index), the BPSK modulation shall be derived as follows:

$$\text{DL: } c_{-84} = c_{-36} = c_{60} = c_{84} = 1 - 2w_k \text{ and } c_{-60} = c_{-12} = c_{12} = c_{36} = 1 - 2\overline{w_k} \quad (48)$$

$$\text{UL: } c_{-84} = c_{-36} = c_{12} = c_{36} = c_{60} = c_{84} = 1 - 2w_k \text{ and } c_{-60} = c_{-12} = 1 - 2\overline{w_k} \quad (49)$$

8.4.3.4.3 Rate ID encodings

Rate_IDs, which indicate modulation and coding to be used in the first DL burst immediately following the FCH, are shown in Table 116ao. The Rate_ID encoding is static and cannot be changed during system operation.

Table 116ao—OFDM Rate ID encodings

Rate_ID	Modulation RS-CC rate
0	QPSK 1/2
1	QPSK 3/4
2	16-QAM 1/2
3	16-QAM 3/4
4	64-QAM 2/3
5	64-QAM 3/4
6–15	Reserved

8.4.3.5 Example OFDM UL RS-CC encoding

To illustrate the use of the RS-CC encoding, an example of one frame of OFDM UL data is provided, illustrating each process from randomization through carrier modulation.

Modulation Mode: QPSK, rate 3/4, Slot Offset: 14, UIUC: 7 (decimal values)

Input Data (Hex)

45 29 C4 79 AD 0F 55 28 AD 87 B5 76 1A 9C 80 50 45 1B 9F D9 2A 88 95 EB AE B5 2E 03 4F 09 14 69 58 0A 5D

Randomized Data (Hex)

D5 0E A4 AA EF E4 DB 51 88 91 6B 00 DF AA 1E E7 02 A8 0E 70 4F 7F C9 D8 66 1D 9D F0 E7 20 E4 9D 7A 32 91

Reed-Solomon encoded Data (Hex)

95 CE 22 76 D5 0E A4 AA EF E4 DB 51 88 91 6B 00 DF AA 1E E7 02 A8 0E 70 4F 7F C9 D8 66 1D 9D F0 E7 20 E4 9D 7A 32 91 00

Convolutionally Encoded Data (Hex)

D5 2E 96 38 FE 93 1E 6A AF 17 D3 44 E4 8B 45 8F 13 D6 AF 27 E3 B2 D5 0A 57 C1 2A F1 A9 73 86 71 3F F1 03 95 F8 ED 2D 30 A2 E0 DB D2 F8 8E B3 4C

Interleaved Data (Hex)

8F 7B 88 DA 4B 5C F1 DE 66 0B BE A1 37 A3 96 D2 59 CF 71 AA E2 6D 55 23 E8 48 C3 08 FE 17 1F F9 E6 16 1E 47 22 EE C4 72 21 AB BC 39 E7 E0 6A 78

Carrier Mapping (carrier index: I value Q value)

-100: -11 1, -99: 1 1, -98: -1 -1, -97: -1 -1, -96: 1 -1, -95: -1 -1, -94: -1 1, -93: -1 -1, -92: -1 1, -91: 1 1,
-90: -1 1, -89: 1 1, -88: -1 -1, -87: 1 -1, -86: -1 1, -85: -1 1, -84: pilot=1 0, -83: 1 -1, -82: 1 1, -81: -1 1,
-80: -1 -1, -79: 1 -1, -78: 1 -1, -77: -1 -1, -76: 1 1, -75: -1 -1, -74: -1 -1, -73: 1 1, -72: 1 -1, -71: -1 -1,
-70: 1 -1, -69: -1 -1, -68: -1 1, -67: 1 -1, -66: 1 -1, -65: 1 -1, -64: -1 1, -63: 1 1, -62: 1 1, -61: -1 1,
-60: pilot=-1 0, -59: -1 -1, -58: -1 1, -57: -1 -1, -56: -1 -1, -55: -1 1, -54: -1 1, -53: -1 1, -52: 1 1, -51: 1 -1,
-50: 1 1, -49: -1 -1, -48: 1 -1, -47: -1 -1, -46: -1 1, -45: -1 1, -44: 1 1, -43: -1 -1, -42: -1 1, -41: 1 -1,
-40: 1 -1, -39: -1 1, -38: -1 -1, -37: 1 -1, -36: pilot=1 0, -35: 1 1, -34: -1 1, -33: 1 -1, -32: 1 -1, -31: -1 1,
-30: 1 -1, -29: -1 -1, -28: 1 1, -27: -1 -1, -26: -1 -1, -25: 1 -1, -24: -1 -1, -23: 1 1, -22: 1 -1, -21: -1 1,
-20: -1 1, -19: -1 1, -18: -1 1, -17: -1 -1, -16: -1 1, -15: 1 1,-14: -1 1, -13: 1 -1, -12: pilot=-1 0, -11: -1 1,
-10: -1 -1, -9: 1 -1, -8: 1 -1, -7: 1 -1, -6: 1 -1, -5: 1 -1, -4: 1 1, -3: -1 1, -2: 1 1, -1: -1 -1,
0:DC, 1: -1 -1, 2: -1 1, 3: -1 1, 4: 1 1, 5: 1 -1, 6: 1 1, 7: -1 1, 8: 1 1, 9: -1 -1,
10: 1 1, 11: 1 1, 12: pilot=1 0, 13: -1 -1, 14: 1 1, 15: 1 1, 16: -1 1, 17: 1 1, 18: -1 -1, 19: -1 -1,
20: -1 -1, 21: -1 1, 22: 1 1, 23: 1 -1, 24: 1 -1, 25: -1 -1, 26: 1 1, 27: 1 -1, 28: -1 -1, 29: -1 -1,
30: -1 -1, 31: -1 -1, 32: -1 1, 33: 1 -1, 34: -1 -1, 35: -1 1, 36: pilot=1 0, 37: 1 -1, 38: -1 1, 39: 1 1,
40: 1 -1, 41: 1 -1, 42: -1 1, 43: 1 1, 44: 1 -1, 45: -1 -1, 46: -1 1, 47: 1 -1, 48: 1 1, 49: 1 -1,
50: -1 -1, 51: 1 1, 52: -1 1, 53: 1 1, 54: -1 1, 55: -1 -1, 56: -1 1, 57: -1 -1, 58: -1 1, 59: -1 -1,
60: pilot=1 0, 61: 1 1, 62: 1 -1, 63: 1 1, 64: 1 -1, 65: -1 -1, 66: 1 1, 67: -1 1, 68: 1 1, 69: -1 1,
70: 1 1, 71: 1 -1, 72: -1 1, 73: -1 1, 74: -1 1, 75: -1 -1, 76: -1 1, 77: -1 -1, 78: -1 -1, 79: 1 1,
80: 1 1, 81: -1 -1, 82: -1 1, 83: 1 -1, 84: pilot=1 0, 85: -1 -1, 86: -1 1, 87: 1 -1, 88: -1 -1, 89: -1 -1,
90: -1 1, 91: 1 1, 92: 1 1, 93: 1 -1, 94: -1 1, 95: -1 1, 96: -1 1, 97: 1 -1, 98: -1 -1, 99: -1 1, 100: 1 1.

Note that the above QPSK values (all values with exception of the BPSK pilots) are to be normalized with a factor as $1/\sqrt{2}$ indicated in Figure 128ai.

8.4.3.6 Preamble structure and modulation

In the uplink, the data preamble consists of 2 times 128 samples preceded by a cyclic prefix whose length is the same as the cyclic prefix in the traffic mode. This preamble is referred to as the short preamble. This preamble shall also precede all allocations during the AAS portion of a frame.

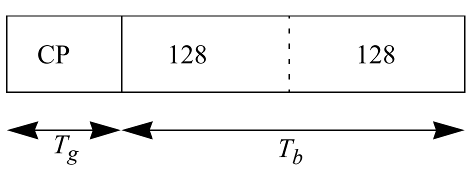

Figure 128ak—UL data and DL AAS preamble structure

The first preamble in the downlink PHY PDU, as well the initial ranging preamble, consists of a CP followed by 4 times 64 samples followed by a CP and 2 times 128 samples. This preamble is referred to as the long preamble.

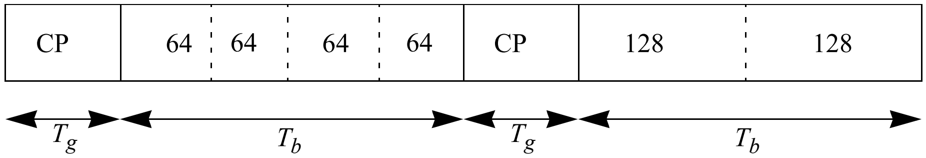

Figure 128al—DL and initial ranging preamble structure

The frequency domain sequence for the 4 times 64 sequence is defined by:

S(-100:100) = {+1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 ,
+1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 ,
+1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 ,
-1-j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 ,
-1-j , 0 , 0 , 0 , 0 , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , -1+j , (50)
0 , 0 , 0 , +1-j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , +1+j ,
0 , 0 , 0 , -1+j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , +1+j , 0 , 0 , 0 , +1-j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , +1-j ,
0 , 0 , 0 , +1+j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , -1+j , 0 , 0 , 0 , -1-j , 0 , 0 , 0 , +1-j ,
0 , 0 , 0 , -1+j , 0 , 0 , 0 , +1+j}*sqrt(2)*sqrt(2)

The frequency domain sequence for the 2 times 128 sequence is defined by:

P_1(-100:100) = sqrt(2)*sqrt(2)*{
1, 0, -1, 0, -1, 0, -1, 0, 1, 0, 1, 0, [-100:-89]
1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, [-88:-76]
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, [-75:-64]
0,-1, 0, 1, 0, 1, 0, 1, 0, -1, 0, 1, 0, [-63:-51]
-1, 0, 1, 0, 1, 0, -1, 0, -1, 0, 1, 0, [-50:-39]
-1, 0, 1, 0, -1, 0, 1, 0, 1, 0, -1, 0, 1, [-38:-26]
0, 1, 0, -1, 0, -1, 0, -1, 0, 1, 0, -1, [-25:-14]
0, -1, 0, -1, 0, -1, 0, -1, 0, 1, 0, 1, 0, [-13:-1]
0, [0] DC (51)
0, 1, 0, -1, 0, -1, 0, 1, 0, -1, 0, 1, 0, [1:13]
1, 0, 1, 0, 1, 0, -1, 0, 1, 0, 1, 0, [14:25]
1, 0, 1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1, [26:38]
0, -1, 0, 1, 0, 1, 0, -1, 0, 1, 0, -1, [39:50]
0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, [51:63]
-1, 0, 1, 0, 1, 0, 1, 0, -1, 0, -1, 0, [64:75]
-1, 0, 1, 0, 1, 0, -1, 0, -1, 0, -1, 0, 1, [76:88]
0, -1, 0, -1, 0, 1, 0, -1, 0, -1, 0, -1} [89:100]

The factor of sqrt(2) equates the RMS power with that of the data section. The additional factor of sqrt(2) is related to the 3 dB boost.

Using Mesh, bursts sent in the control subframe shall start with the long preamble. In the data subframe, the bursts shall by default start with the long preamble, but neighbors may negotiate to use the short preamble by setting the preamble flag in the Neighbor Link Info field (see 6.2.2.3.34).

If in the UL the allocation spans only one subchannel, the following preamble vector, P_1, is used in conjunction with subchannelization transmissions, and the preamble carriers that do not fall within the allocated subchannel shall not be transmitted.

P_1(-100:100) = sqrt(2)*sqrt(2)*{

-1, 0,-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,	[-100:-89]	subchannel 3	
-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1, 0,-1,	[-88:-76]	subchannel 1	
0,-1, 0,-1, 0,-1, 0,-1, 0, 1, 0, 1,	[-75:-64]	subchannel 4	
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,	[-63:-51]	subchannel 2	
1, 0,-1, 0,-1, 0, 1, 0,-1, 0,-1, 0,	[-50:-39]	subchannel 1	
1, 0, 1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1,	[-38:-26]	subchannel 3	
0,-1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1,	[-25:-14]	subchannel 2	
0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0,	[-13:-1]	subchannel 4	
0,	[0]	DC	(52)
0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0,	[1:13]	subchannel 1	
-1, 0,-1, 0,-1, 0,-1, 0, 1, 0, 1, 0,	[14:25]	subchannel 3	
-1, 0, 1, 0,-1, 0,-1, 0, 1, 0,-1, 0,-1,	[26:38]	subchannel 2	
0, 1, 0, 1, 0,-1, 0, 1, 0, 1, 0,-1,	[39:50]	subchannel 4	
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1, 0,	[51:63]	subchannel 3	
-1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[64:75]	subchannel 1	
1, 0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0, 1,	[76:88]	subchannel 4	
0, 1, 0, 1, 0,-1, 0,-1, 0, 1, 0, 1}	[89:100]	subchannel 2	

If in the UL the allocation spans two subchannels, the following preamble vector, P_2, is used in conjunction with subchannelization transmissions, and the preamble carriers that do not fall within the allocated subchannels shall not be transmitted.

P_2(-100:100) = sqrt(2)*sqrt(2)*{

1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1, 0,	[-100:-89]	subchannels 3+4	
1, 0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1,	[-88:-76]	subchannels 1+2	
0, 1, 0, 1, 0, 1, 0,-1, 0, 1, 0, 1,	[-75:-64]	subchannels 3+4	
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[-63:-51]	subchannels 1+2	
1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1, 0,	[-50:-39]	subchannels 1+2	
-1, 0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1,	[-38:-26]	subchannels 3+4	
0,-1, 0, 1, 0,-1, 0, 1, 0,-1, 0, 1,	[-25:-14]	subchannels 1+2	
0,-1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1, 0,	[-13:-1]	subchannels 3+4	
0,	[0]	DC	(53)
0, 1, 0,-1, 0,-1, 0, 1, 0, 1, 0, 1, 0,	[1:13]	subchannels 1+2	
-1, 0, 1, 0,-1, 0,-1, 0,-1, 0, 1, 0,	[14:25]	subchannels 3+4	
-1, 0, 1, 0, 1, 0,-1, 0,-1, 0, 1, 0,-1,	[26:38]	subchannels 1+2	
0, 1, 0, 1, 0, 1, 0,-1, 0,-1, 0,-1,	[39:50]	subchannels 3+4	
0, 1, 0,-1, 0, 1, 0, 1, 0, 1, 0, 1, 0,	[51:63]	subchannels 3+4	
-1, 0, 1, 0,-1, 0,-1, 0,-1, 0, 1, 0,	[64:75]	subchannels 1+2	
-1, 0,-1, 0,-1, 0, 1, 0, 1, 0,-1, 0, 1,	[76:88]	subchannels 3+4	
0, 1, 0,-1, 0,-1, 0, 1, 0, 1, 0, 1}	[89:100]	subchannels 1+2	

8.4.4 Frame structure

8.4.4.1 PMP

In licensed bands, the duplexing method shall be either FDD or TDD. FDD SSs may be Half Duplex FDD (H-FDD). In license-exempt bands, the duplexing method shall be TDD.

The frame interval contains transmissions (PHY PDUs) of BS and SSs, gaps and guard intervals.

The OFDM PHY supports a frame-based transmission. A frame consists of a DL sub-frame and an UL sub-frame. A DL sub-frame consists of only one DL PHY PDU. A UL sub-frame consists of contention intervals scheduled for initial ranging and bandwidth request purposes and one or multiple UL PHY PDUs, each transmitted from a different SS.

A UL PHY PDU consists of only one burst, which is made up of a short preamble and an integer number of OFDM symbols. The burst PHY parameters of an UL PHY PDU are specified by a 4-bit UIUC in the UL-MAP. The UIUC encoding is defined in the UCD messages. Note the difference between a PHY PDU and a Burst.

A DL PHY PDU starts from a long preamble, which is used for PHY synchronization. The preamble is followed by a FCH burst. The FCH burst is one OFDM symbol long and is transmitted using QPSK rate 1/2 with the mandatory coding scheme. The FCH contains DL_Frame_Prefix to specify the burst profile and length of the DL burst #1. The Rate_ID encoding is defined in Table 116ao. The FCH burst may also contain short MAC control messages, such as, DCD and/or UCD. It may also contain (partial) map messages. Although the DL burst #1 contains broadcast MAC control messages, it is not necessary to use the most robust well-know modulation/coding. A more efficient modulation/coding may be used if it is supported and applicable to all the SSs of a BS.

The FCH is followed by one or multiple DL bursts, each transmitted with different burst profiles. Each DL burst consists of an integer number of OFDM symbols, and its burst profiles are specified by a 4-bit DIUC in the DL-MAP. The DIUC encoding is defined in the DCD messages.

With the OFDM PHY, a PHY burst, either a DL PHY burst or an UL PHY burst, consists of an integer number of OFDM symbols, carrying MAC messages, i.e., MAC PDUs. To form an integer number of OFDM symbols, a burst payload may be padded by the bytes 0xFF. Then the payload should be scrambled, encoded, and modulated using the burst PHY parameters specified by this standard.

In each TDD frame (see Figure 128am), the Tx/Rx transition gap (TTG) and Rx/Tx transition gap (RTG) shall be inserted between the DL and UL sub-frame and at the end of each frame respectively to allow the BS to turn around. TTG and RTG shall be at least 5 µs and an integer multiple of the PS in duration, and start on a PS boundary. After the TTG, the BS receiver shall look for the first symbols of a UL burst. After the RTG, the SS receivers shall look for the first symbols of QPSK modulated data in the DL burst.

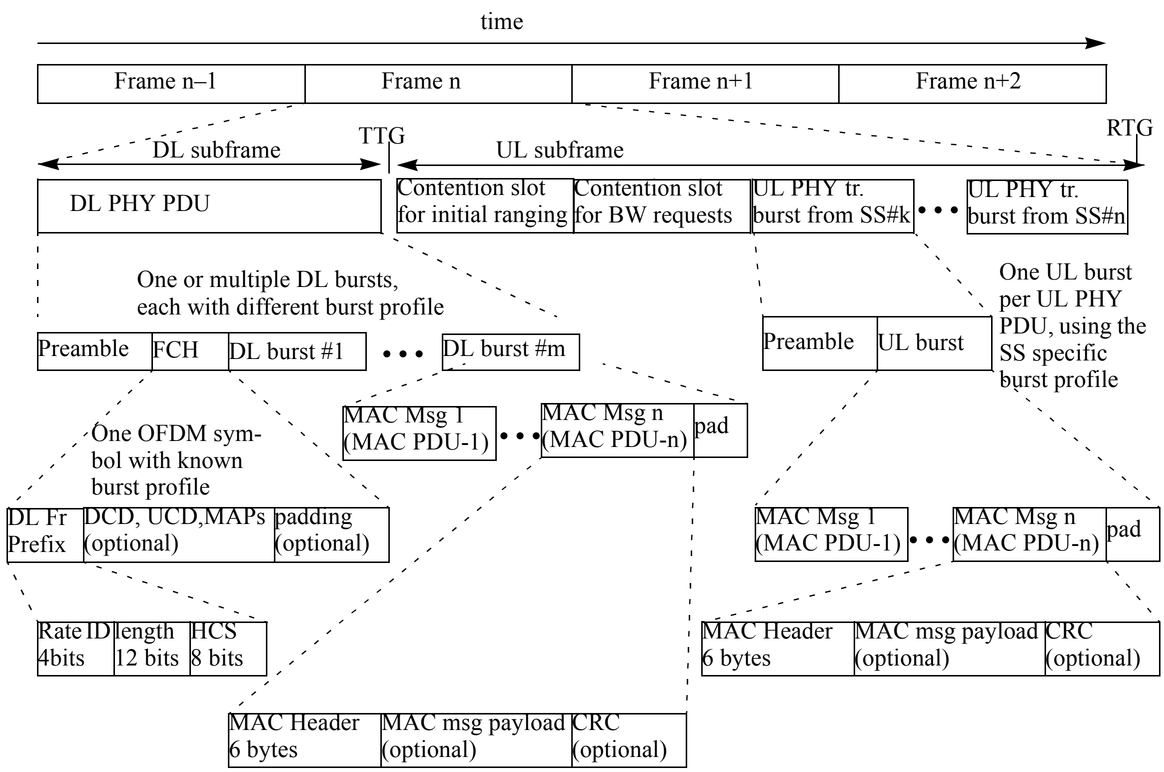

Figure 128am—Example of OFDM frame structure with TDD

In FDD systems (see Figure 128an) TTG and RTG are not needed as the downlink and uplink transmit on independent frequencies. Using FDD, the BS shall, within a frame, not schedule a DL allocation during or after a UL allocation to the same H-FDD terminal.

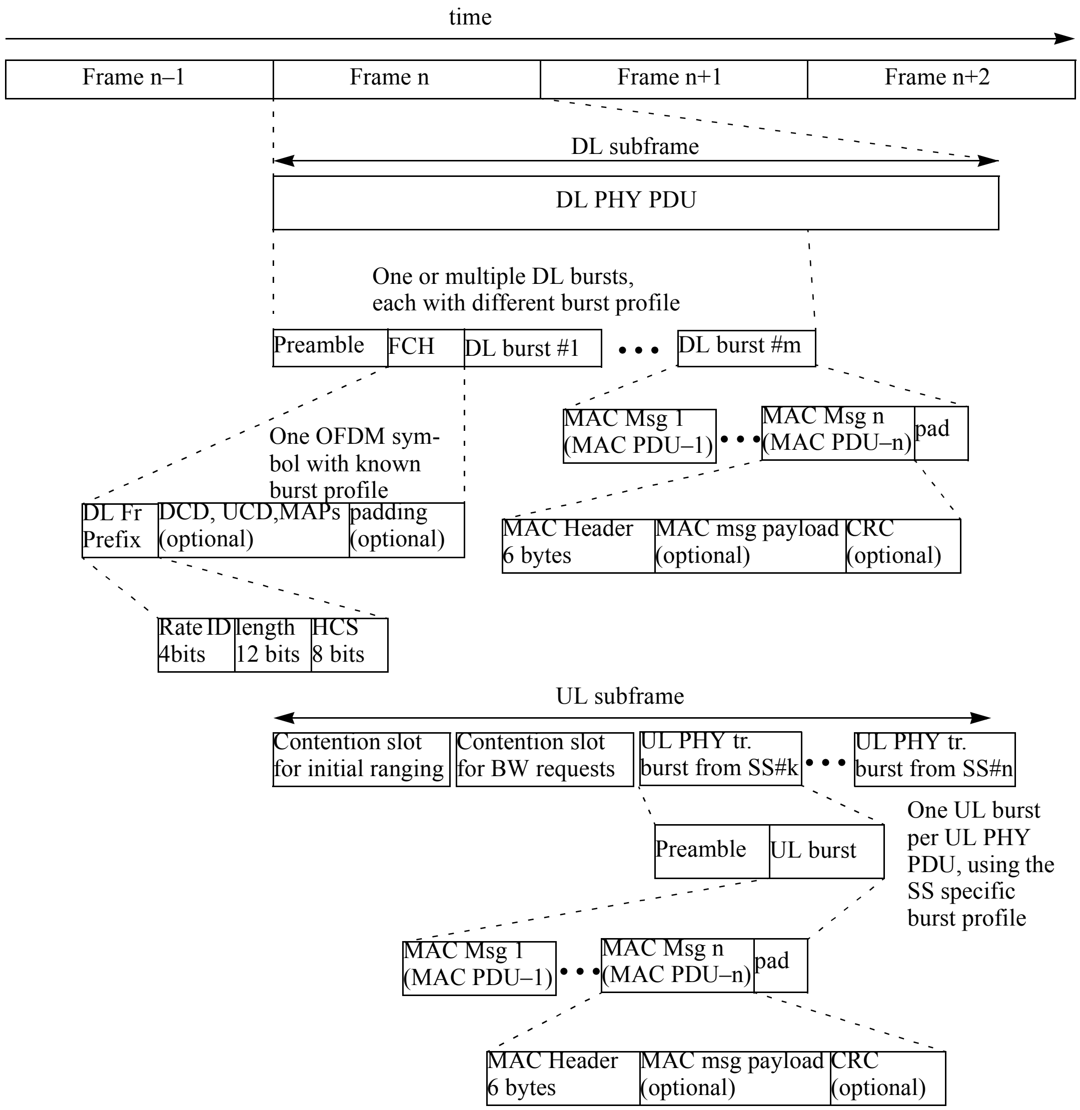

Figure 128an—Example of OFDM frame structure with FDD

Table 116ap—OFDM DL frame prefix format

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Rate_ID	4 bits	
Length	12 bits	
HCS	8 bits	
}		

The following are the fields of DL Frame Prefix:

Rate_ID
Field that defines the burst profile of the following burst. Encoding is specified in Table 116ao.

Length
Number of OFDM symbols (PHY payload) in the burst immediately following the FCH burst. The minimum value shall be 6.

HCS
An 8-bit Header Check Sequence used to detect errors in the DL Frame Prefix. The generator polynomial is $g(D)= D^8 + D^2 + D + 1$.

8.4.4.2 Mesh

In addition to the PMP frame structure in 8.4.4.1, an optional frame structure (see Figure 128ao) is defined to facilitate Mesh networks.

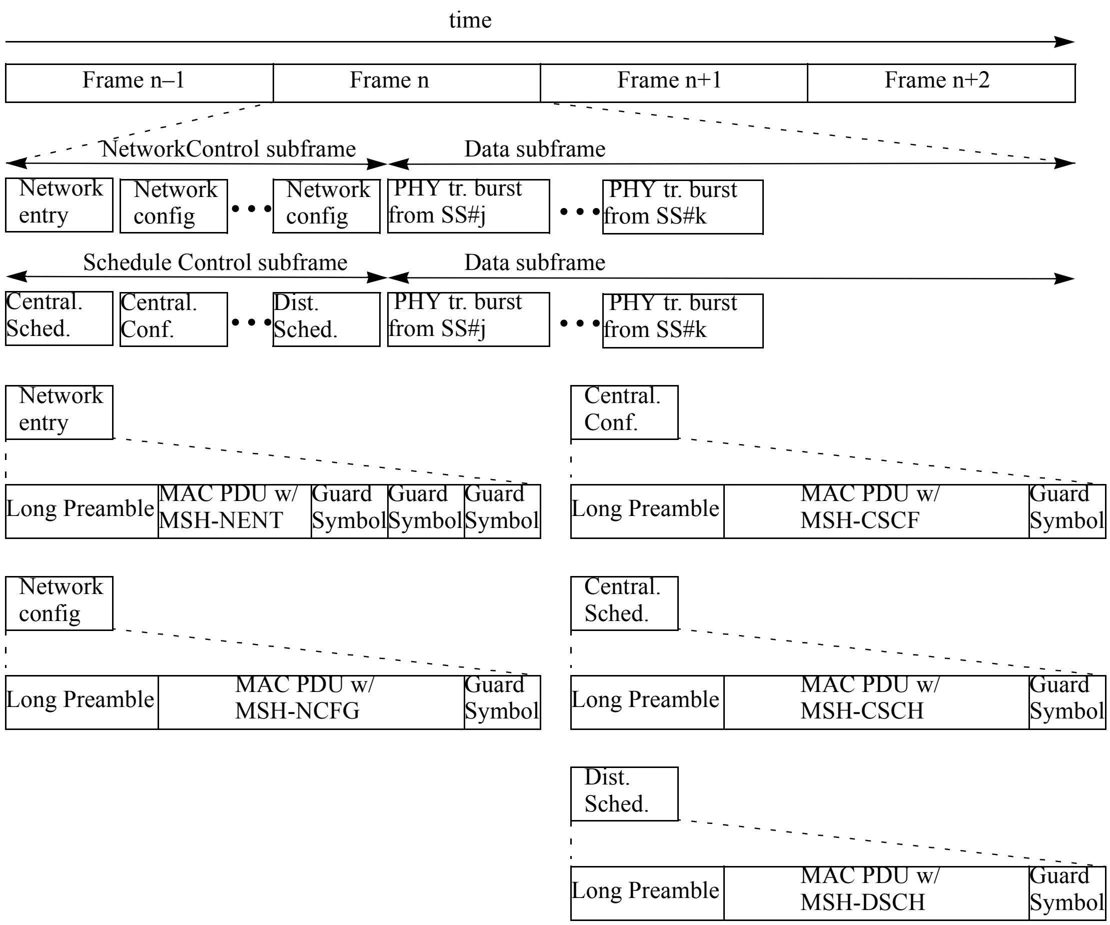

Figure 128ao—Mesh frame structure

A Mesh frame consists of a control and data subframe. The control subframe serves two basic functions. One is the creation and maintenance of cohesion between the different systems, termed “network control” in Figure 128ao. The other is the coordinated scheduling of data-transfers between systems, termed “schedule control” in Figure 128ao. Frames with a network control subframe occur periodically, as indicated in the network descriptor. All other frames have a schedule control subframe. The length of the control subframe is fixed and of length $\mathrm{MSH\text{-}CTRL\text{-}LEN} \times 7$ OFDM symbols, with MSH-CTRL-LEN indicated in the network descriptor.

During a network control subframe, the first 7 symbols are allocated for network entry, followed by $\mathrm{MSH\text{-}CTRL\text{-}LEN} - 1$ sets of 7 symbols for network configuration. During a schedule control subframe, the network descriptor indicates how many (MSH-DSCH-NUM) distributed scheduling messages may occur in the control subframe. The first $(\mathrm{MSH\text{-}CTRL\text{-}LEN} - \mathrm{MSH\text{-}DSCH\text{-}NUM}) \times 7$ symbols are allocated to transmission bursts containing MSH-CSCH and MSH-CSCF PDUs, whereas the remainder is allocated to transmission bursts containing MSH-DSCH PDUs.

Distributed scheduling messages (using the long preamble) may further occur in the data subframe if not in conflict with the scheduling dictated in the control subframe.

All transmissions in the control subframe are sent using QPSK-1/2 with the mandatory coding scheme. The data subframe is divided into minislots, which are, with possible exception of the last minislot in the frame, of size ceiling [(OFDM symbols per frame-$\mathrm{MSH\text{-}CTRL\text{-}LEN} \times 7$)/256]. A scheduled allocation consists of one or more minislots.

8.4.4.3 Frame duration codes

The frame length is encoded in the Frame duration code in the PHY synchronization field (see 8.4.5.1) of the DL-MAP and in the Mesh Network. Descriptor (see Table 56j). Table 116aq indicates the various frame durations that are allowed. The actual frame is an integer multiple of OFDM symbol durations as listed in Table 116aq, which can also be determined by the periodicity of the frame start preambles.

Table 116aq—OFDM frame duration (T_F ms) codes

Code (N)	PMP	Code (N)	Mesh
0–4	round((N/2+3)/T_S)*T_S	0–8	round((N+4)/T_S)*T_S
5–6	round((N+2)/T_S)*T_S		
7–12	round((2N-4)/T_S)*T_S		
13–255	Reserved	9–255	Reserved

8.4.4.4 Burst Profile format

Table 116ar defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

Table 116ar—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116as defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

Table 116as—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.4.5 Map message fields and IEs

8.4.5.1 DL-MAP PHY synchronization field

The PHY synchronization field of the DL-MAP message is structured as follows.

Table 116at—OFDM PHY synchronization field

Syntax	Size	Notes
Synchronization_field {		
Frame Duration Code	8 bits	
Frame Number	24 bits	
Allocation_Start_Time	32 bits	
}		

Frame Duration Code

The frame duration Code values are specified in Table 116aq.

Frame Number

The frame number is incremented by 1 MOD 2^{24} each frame.

Allocation_Start_Time

Effective start time of the DL allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to the length of the DL-MAP.

8.4.5.2 DL-MAP Information Element format

DL-MAP Information Elements have the following format:

Table 116au—OFDM DL-MAP Information Element

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (DIUC == 15)		
Extended DIUC dependent IE	variable	Report_IE() or AAS_DL_IE() or STC_IE()
else		
Start Time	12 bits	
}		

Downlink Interval Usage Code

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 116av.

Start Time

Indicates the start time, in units of symbol duration, relative to the start of the first symbol of the PHY PDU (including preamble) where the DL-MAP message is transmitted. 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.

8.4.5.2.1 DIUC allocations

Table 116av contains the DIUC values used in DL-MAP_IE().

Table 116av—OFDM DIUC values

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

8.4.5.2.2 DL-MAP Report IE format

When a channel measurement report is needed (see 6.2.14 and 8.4.8), the extended DIUC = 15 is used with the sub-code 0x00 and with 8-bit Channel Nr value as shown in Table 116aw. The OFDM Report_IE shall be followed by the End of Map IE (DIUC=14). When used, the CID of the DL-MAP_IE() shall be set to the broadcast CID.

Table 116aw—OFDM Channel measurement Information Element format

Syntax	Size	Notes
Report_Information_Element() {		
extended DIUC	4 bits	DFS = 0x00
Channel Nr	8 bits	Channel number (see 8.6.1) Set to 0x00 for licensed bands
Start Time	12 bits	
Reserved	4 bits	
}		

8.4.5.2.3 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() 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.

Table 116ax—OFDM AAS DL Information Element format

Syntax	Size	Notes
AAS_DL_Information_Element() {		
extended DIUC	4 bits	AAS = 0x02
}		

8.4.5.2.4 DL-MAP STC IE format

In the DL-MAP, an STC enabled BS (see 8.4.7) may transmit DIUC=15 with the STC_IE() 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.

Table 116ay—OFDM STC Information Element format

Syntax	Size	Notes
STC_Information_Element() {		
extended DIUC	4 bits	STC = 0x01
}		

The duration of the DIUC=15 STC_IE() allocation is always one OFDM symbol. From the start of the frame up to this allocation, only one antenna shall be used. During this allocation, the short preamble (see 8.4.3.6) shall be transmitted from the other antenna. After this allocation, the BS shall transmit from both antennas until the end of the frame.

8.4.5.3 UL-MAP Information Element 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 116az.

Appearance of the Extended UIUC, means that the UL-MAP information element contains an additional byte with UIUC sub-code immediately following the UIUC plus the value of the corresponding parameter.

Table 116az—OFDM UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 4)		
Focused_contention_IE()	28 bits	
else if (UIUC == 15)		
Extended UIUC dependent IE	variable	Power_Control_IE() or AAS_UL_IE() subchannelization_IE()
else {		
if (subchannelization[a]) {		
Subchannel Index	3 bits	0x1 = subchannel 1 0x5 = subchannel 1 and 2 0x2 = subchannel 2 0x6 = subchannel 3 and 4 0x3 = subchannel 3 0x0 = reserved 0x4 = subchannel 4 0x7 = reserved

Table 116az—OFDM UL-MAP Information Element format *(continued)*

Syntax	Size	Notes
Duration	5 bits	in OFDM symbols
Reserved	4 bits	Reserved
} else		
Duration	12 bits	
}		
}		

[a]When subchannelization is active (see 8.4.5.3.5), only UIUCs 5 through 13 shall be used.

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)
A four-bit 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 116ba.

Duration
The Duration indicates the length, in units of OFDM symbols, of the allocation. The start time of the first allocation shall be the Allocation Start Time given in the UL-MAP message. The last allocated burst shall be indicated by allocating a NULL burst (CID = 0 and UIUC = 14) with zero duration.

8.4.5.3.1 UIUC allocations

Table 116ba contains the UIUC values used in the UL-MAP_IE()

Table 116ba—OFDM 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

8.4.5.3.2 UL-MAP Focused Contention IE format

Table 116bb defines the UL-MAP IE for allocation BW for a SS that requested bandwidth using Focused Contention Reservation Requests (see 6.2.2.3.6). This UL-MAP IE is identified by UIUC = 4 (see Table 116ba).

Table 116bb—OFDM Focused Contention Information Element format

Syntax	Size	Notes
Focused_Contention_IE() {		
Duration	12 bits	
Transmit Opportunity Index	6 bits	
Contention Channel Index	6 bits	
Contention Code Index	4 bits	
}		

Duration

Length of the allocation in OFDM symbols.

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 0 to 63 backward, starting from the beginning of the frame where the UL-MAP is transmitted.

Contention Channel Index

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

Contention Code Index

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

8.4.5.3.3 UL-MAP Power Control IE format

When a power change for the SS is needed, the extended UIUC = 15 is used with the sub-code 0x00 and with 8-bit Power control value as shown in Table 116bc. The power control value is an 8-bit signed integer expressing the change in power level (in 0.25 dB units) that the SS should apply to correct it's current transmission power.

The CID used in the Information Element should be the Basic CID of the SS.

Table 116bc—OFDM Power Control Information Element format

Syntax	Size	Notes
Power_Control_Information_element() {		
extended UIUC	4 bits	Fast power control = 0x00
Power control	8 bits	Signed integer, which expresses the change in power level (in 0.25 dB units) that the SS should apply to correct its current transmission power.
}		

8.4.5.3.4 UL-MAP AAS IE format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116bd—OFDM AAS UL Information Element format

Syntax	Size	Notes
AAS_Information_Element() {		
extended UIUC	4 bits	AAS = 0x02
}		

8.4.5.3.5 UL-MAP subchannelization IE format

Within a frame, the BS may allocate a portion of the UL allocations to subchannelized traffic.

The UL Subchannelization_IE implicitly indicates the start of the allocation and explicitly indicates the Duration and the Number of Allocations. A SS not capable of subchannelization shall skip the next Number of Allocations UL-MAP_IEs in the UL-MAP and resume interpreting the UL-MAP afterwards with the start of the next allocation Duration OFDM symbols after the last allocation ended.

Table 116be—OFDM subchannelization Information Element format

Syntax	Size	Notes
subchannelization_Information_Element() {		
extended UIUC	4 bits	subchannelization = 0x3x
Duration	12 bits	
Number of allocations	12 bits	
}		

A SS capable of subchannelization shall decode the subchannelized allocations, whereby the 12 bit Duration field in non-subchannelized UL-MAP messages is replaced by a 3 bit Subchannel Index field, a 5 bit Duration field and 4 reserved bits as shown in Table 116be. A subchannelized allocation shall start when all preceding allocations to the allocated subchannels have terminated.

8.4.6 Control mechanisms

8.4.6.1 Synchronization

8.4.6.1.1 Network synchronization

For TDD and FDD realizations, it is recommended (but not required) that all BSs be time synchronized to a common timing signal. In the event of the loss of the network timing signal, BSs may continue to operate and shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing reference shall be a 1 pps timing pulse and a 10 MHz frequency reference. These signals are typically provided by a GPS receiver.

For both FDD and TDD realizations, frequency references derived from the timing reference may be used to control the frequency accuracy of Base-Stations provided that they meet the frequency accuracy requirements of 8.4.11. This applies during normal operation and during loss of timing reference.

8.4.6.2 Ranging

There are two types of ranging processes: initial ranging (see 6.2.9.5) and periodic ranging (see 6.2.10). Initial ranging (coarse synchronization) and power are performed during two phases of operation; during (re)registration and when synchronization is lost; and secondly, during transmission on a periodic basis. Initial ranging uses the initial ranging contention-based interval, which requires a long preamble. The periodic ranging uses the regular UL burst.

During registration, a new subscriber registers during the random access channel, and if successful it is entered into a ranging process under control of the base station. The ranging process is cyclic in nature where default time and power parameters are used to initiate the process followed by cycles where (re)calculated parameters are used in succession until parameters meet acceptance criteria for the new subscriber. These parameters are monitored, measured and stored at the base station, and transmitted to the subscriber unit for use during normal exchange of data. During normal exchange of data, the stored parameters are updated in a periodic manner based on configurable update intervals to ensure that changes in the channel can be accommodated. The update intervals shall vary in a controlled manner on a subscriber unit by subscriber unit basis. Initial ranging transmissions shall consist of a long preamble and one OFDM symbol using the most robust mandatory burst profile.

Ranging on re-registration follows the same process as new registration.

Regardless of duplexing type, the appropriate duration of the Initial Maintenance slot used for initial system access depends on the intended cell radius.

A BS supporting the AAS option shall allocate at the end of the UL frame a 5 OFDM symbol initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance. See 8.4.5.3 for details.

8.4.6.3 Bandwidth requesting

There may be two types of REQ Regions in a frame. These two types are REQ Region-Full and REQ Region-Focused.

In a REQ Region-Full, each Transmit Opportunity shall consist of a short preamble and one OFDM symbol using the most robust mandatory burst profile.

In a REQ Region-Focused, each Transmit Opportunity shall consist of two OFDM symbols. Each Transmit Opportunity shall be indexed by consecutive Transmit Opportunity Indices. The first occurring Transmit Opportunity shall be indexed 0.

All SS shall be capable of the Full Contention Transmission. Capability of the Focused Contention Transmission is optional. The SS shall follow the backoff procedure as described in 6.2.8.

8.4.6.3.1 Parameter selection

The SS shall examine the UL_MAP message for a future frame and select (in accordance with 6.2.8) a future REQ Region during which to make its request. If Focused Contention Supported = 1 was returned by the BS in SBC-RSP message during SS initialization and if the SS is capable of focused contention, it may choose either a REQ Region-Full or REQ Region-Focused. Otherwise, it shall choose a REQ Region-Full.

If the chosen REQ Region is a REQ Region-Focused, the SS shall also select, at random with equal probability, a *contention code* from Table 116bf and similarly a *contention channel* from Table 116bg. The indices {–100 to +100} in the body of Table 116bg refer to the carrier indices as defined in 8.4.2.4.

If the BS supports subchannelization, the last C_{SE} contention codes shall only be used by subchannelization-enabled SSs that wish to receive a subchannelized allocation. In response, the BS may provide the requested allocation as a subchannelized allocation; and may provide the requested allocation as a full (default) allocation, or may provide no allocation at all. The value of C_{SE} is transmitted in the UCD channel encoding TLV messages. The default value of C_{SE} is 0.

Table 116bf—OFDM Contention codes

Contention code index	bit 0	bit 1	bit 2	bit 3
0	1	1	1	1
1	1	–1	1	–1
2	1	1	–1	–1
3	1	–1	–1	1
4	–1	–1	–1	–1
5	–1	1	–1	1
6	–1	–1	1	1
7	–1	1	1	–1

Table 116bg—OFDM Contention channels

Contention channel index	Carrier offset index 0	Carrier offset index 1	Carrier offset index 2	Carrier offset index 3
0	–100	–50	+1	+51
1	–99	–49	+2	+52
2	-98	–48	+3	+53
...	...	...	...	...
k	k-100	k-50	k+1	k+51
...	...	...	...	...
48	–52	–2	+49	+99
49	–51	–1	+50	+100

8.4.6.3.2 Full Contention transmission

If the chosen REQ Region is a REQ Region-Full, the SS shall transmit the short preamble as defined in 8.4.3.6, followed by a Bandwidth Request MAC Header as defined in 6.2.2.1.2.

8.4.6.3.3 Focused Contention transmission

The REQ Region-Focused bandwidth requesting mechanism consists of two phases. The Phase-1 is that an SS requesting bandwidth sends a signal to the BS in the UL interval of REQ Region Focused identified by UIUC=3. One REQ Region Focused UL interval with UIUC=3 shall be two OFDM symbols. The Phase-1 bandwidth requesting signal transmission is described in this section. Following the Phase-1, the BS may include in its UL-MAP an allocation for the SS using UIUC=4 and the Focused_contention_IE as defined in Table 116bb. The SS is identified in this Focused_contention_IE by the Transmit Opportunity index, Contention Channel index, and Contention Code index which the SS used to send the Phase-1 bandwidth requesting signal. The Phase-2 is that the SS requesting bandwidth responds to this UL-MAP allocation with a bandwidth request MAC header as defined in 6.2.2.1.2. The Phase-2 UL interval with UIUC=4 shall consists of a short preamble and shall have the Duration indicated in the Focused_Contention_IE, and shall use the most robust mandatory burst profile.

If the chosen REQ Region is a REQ Region-Focused, after choosing its four parameters, the SS shall transmit, during the chosen Transmit Opportunity in the chosen frame, four carriers {carrier index 0, carrier index 1, carrier index 2, carrier index 3}that comprise the chosen contention channel. The amplitude of all other carriers shall be zero.

During both OFDM symbols, the amplitude of each of the four carriers shall be boosted somewhat above its *normal* amplitude, i.e., the amplitude used during a non-contention OFDM symbol, including the current power-control correction. The boost in dB shall equal the value of the Focused Contention Power Boost parameter in the current Uplink Channel Descriptor (UCD).

During the first OFDM symbol of the Transmit Opportunity, the phase of the four carriers is not specified.

During the second OFDM symbol of the Transmit Opportunity, the phases shall depend on the corresponding bit in the chosen contention code, and the phase transmitted during the first OFDM symbol on the same carrier. If the code bit is +1, the phase shall be the same as that transmitted during the first OFDM symbol. If the code bit is –1, the phase shall be inverted, 180 degrees with respect to the phase transmitted during the first OFDM symbol.

8.4.6.4 Power control

As with frequency control, a power control algorithm shall be supported for the uplink channel with both an initial calibration and periodic adjustment procedure without loss of data. The base station should be capable of providing accurate power measurements of the received burst signal. This value can then be compared against a reference level, and the resulting error can be fed back to the subscriber station in a calibration message coming from the MAC sublayer. The power control algorithm shall be designed to support power attenuation due to distance loss or power fluctuations at rates to 30 dB/second with depths of at least 10 dB. The exact algorithm implementation is vendor-specific. The total power control range consists of both a fixed portion and a portion that is automatically controlled by feedback. The power control algorithm shall take into account the interaction of the RF power amplifier with different burst profiles. For example, when changing from one burst profile to another, margins should be maintained to prevent saturation of the amplifier and to prevent violation of emissions masks.

8.4.7 Transmit diversity: Space-Time Coding (optional)

STC (see [B26]) may be used on the DL to provide 2nd order (Space) transmit diversity.

There are two transmit antennas on the BS side and one reception antenna on the SS side. This scheme requires Multiple Input Single Output channel estimation. Decoding is very similar to maximum ratio combining.

Figure 128ap shows STC insertion into the OFDM chain. Each Tx antenna has its own OFDM chain, but they have the same Local Oscillator for synchronization purposes.

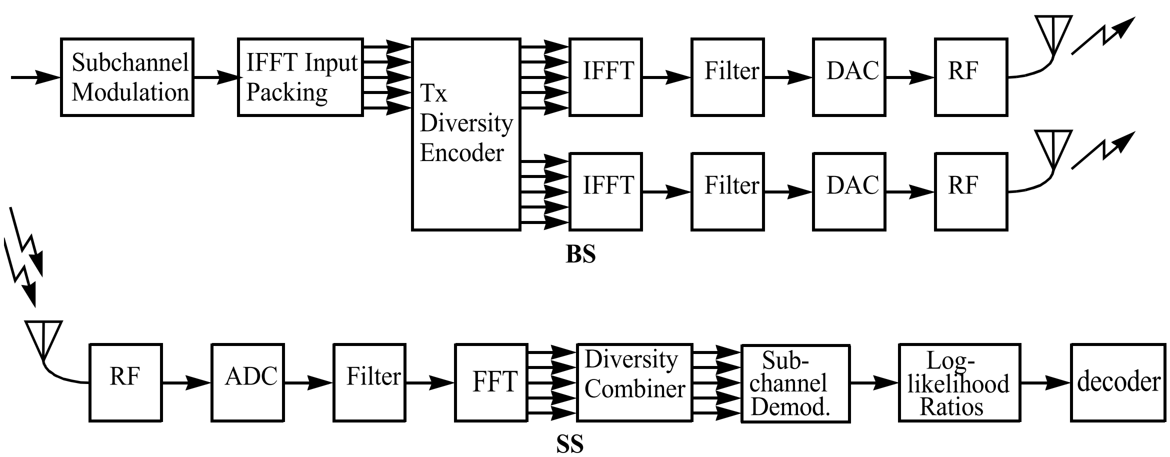

Figure 128ap—Illustration of STC

Both antennas transmit in the same time 2 different OFDM data symbols. Transmission is performed twice to decode and to get 2nd order diversity. Time domain (Space-Time) repetition is used.

8.4.7.1 Multiple input single output channel estimation and synchronization

Both antennas transmit in the same time, and they share the same Local Oscillator. Thus, the received signal has exactly the same auto-correlation properties as for a single antenna. So, time and frequency coarse and fine estimation can be performed in the same way as for a single antenna. The scheme requires MISO channel estimation, which is provisioned by inserting a short preamble using the STC_IE (see 8.4.5.2.4) to estimate the second antenna's channel.

8.4.7.2 STC encoding

The basic scheme [B26] transmits 2 complex symbols s_0 and s_1, using the multiple input single output channel (two Tx, one Rx) twice with channel vector values h_0 (for antenna 0) and h_1 (for antenna 1).

First channel use: Antenna 0 transmits s_0, antenna 1 transmits s_1.

Second channel use: Antenna 0 transmits $-s_1{}^*$, antenna 1 transmits $s_0{}^*$.

Receiver gets r_0 (first channel use) and r_1 (second channel use) and computes s_0 and s_1 estimates:

$$\hat{s}_0 = h_0{}^* \cdot r_0 + h_1 \cdot r_1{}^* \tag{54}$$

$$\hat{s}_1 = h_1{}^* \cdot r_0 - h_0 \cdot r_1{}^* \tag{55}$$

These estimates benefit from 2nd order diversity as in the 1Tx-2Rx Maximum Ratio Combining scheme. OFDM symbols are taken by pairs. (Equivalently, 2 Tx symbol duration is twice 1 Tx symbol duration, with twice more data in a symbol.) STC is applied independently on each carrier, in respect to pilot tones positions.

Figure 128aq shows the STC scheme (note that only pilot carrier –84 is depicted).

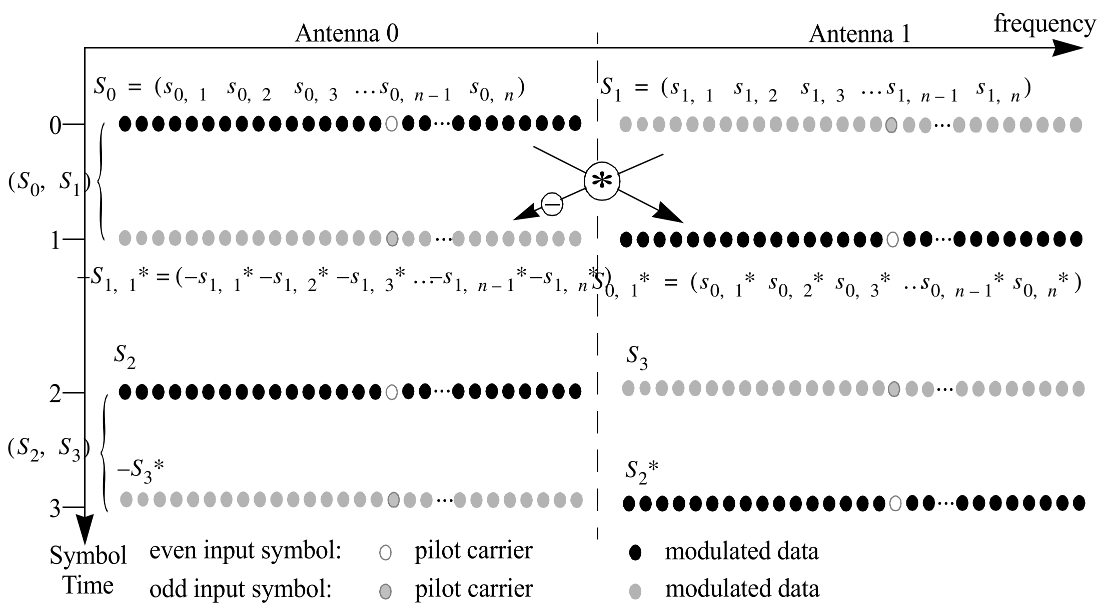

Figure 128aq—STC usage with OFDM

8.4.7.3 STC decoding

The receiver waits for 2 symbols, and combines them on a carrier basis according to Equation (54) and Equation (55) in 8.4.7.2.

8.4.8 Channel quality measurements

8.4.8.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.4.8.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the OFDM DL preambles. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{\text{avg}})\hat{\mu}_{RSSI}[k-1] + \alpha_{\text{avg}}R[k] & k > 0 \end{cases} \quad \text{mW} \tag{56}$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\hat{\mu}_{RSSI\ dBm}[k] = 10\log(\hat{\mu}_{RSSI}[k]) \quad \text{dBm}. \tag{57}$$

To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{\text{avg}})\hat{x}^2_{RSSI}[k-1] + \alpha_{\text{avg}}|R[k]|^2 & k > 0 \end{cases} \quad (58)$$

and the result applied to

$$\hat{\sigma}_{RSSI\ dB} = 5\log(|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2|) \qquad \text{dB}\,. \quad (59)$$

8.4.8.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the OFDM DL preamble. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is to compute the ratio of signal power to residual error for each data sample, and then average the results from each data sample, using

$$CINR[k] = \sum_{n=0}^{N-1} \frac{|s[k,\ n]|^2}{|r[k,\ n] - s[k,\ n]|^2} \quad (60)$$

where $r[k,\ n]$ received sample n within message k; $s[k,\ n]$ the corresponding detected or pilot sample (with channel state weighting) corresponding to received symbol n.

The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k])\,, \quad (61)$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{\text{avg}})\hat{\mu}_{CINR}[k-1] + \alpha_{\text{avg}}CINR[k] & k > 0 \end{cases} \quad (62)$$

k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism that delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{avg})\hat{x}^2_{CINR}[k-1] + \alpha_{avg}|CINR[k]|^2 & k > 0 \end{cases} \quad (63)$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \quad (64)$$

8.4.9 Transmitter requirements

8.4.9.1 Transmit power level control

The transmitter shall support monotonic power level control of 45 dB (30 dB for license-exempt bands) minimum with a minimum step size of 1 dB and a relative accuracy of +/– 0.5 dB.

8.4.9.1.1 Transmitter spectral flatness

The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in Table 116bh. The absolute difference between adjacent carriers shall not exceed 0.06 dB.

Table 116bh—OFDM Spectral flatness

Spectral lines	Spectral flatness
Spectral lines from –50 to –1 and +1 to +50	+/– 2dB from the measured energy averaged over all 200 active tones
Spectral lines from –100 to –50 and +50 to +100	+2/– 4dB from the measured energy averaged over all 200 active tones

This data shall be taken from the channel estimation step.

8.4.9.1.2 Transmitter constellation error and test method

To ensure that the receiver SNR does not degrade more than 0.5 dB due to the transmitter SNR, the relative constellation RMS error, averaged over carriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Table 116bi.

Table 116bi—Allowed relative constellation error versus data rate

Burst type	Relative constellation error (dB)
QPSK-1/2	–19.4
QPSK-3/4	–21.2
16-QAM-1/2	–26.4
16-QAM-3/4	–28.2
64-QAM-2/3	–32.7
64-QAM-3/4	–34.4

All measurement errors taken together shall be 10dB less than the required noise level, i.e., if a specification is TX S/N = 10dB, the measurement S/N should be at least 20dB. For all PHY modes, measurements shall be taken with all non-guard carriers active.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure [B30]:

a) Start of frame shall be detected.
b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) The packet shall be de-rotated according to estimated frequency offset.
e) The complex channel response coefficients shall be estimated for each of the carriers.
f) For each of the data OFDM symbols: transform the symbol into carrier received values, estimate the phase from the pilot carriers, de-rotate the carrier values according to estimated phase, and divide each carrier value with a complex estimated channel response coefficient.
g) For each data-carrying carrier, find the closest constellation point and compute the Euclidean distance from it.
h) Compute the RMS average of all errors in a packet. It is given by:

$$\mathrm{Error}_{RMS} = \frac{\displaystyle\sum_{i=1}^{N_f} \sqrt{\frac{\displaystyle\sum_{j=1}^{L_P}\left[\sum_{k=1}^{N_{FFT}}\left\{(I(i,j,k)-I_0(i,j,k))^2+(Q(i,j,k)-Q_0(i,j,k))^2\right\}\right]}{P_0 \cdot L_P \cdot N_{FFT}}}}{N_f} \tag{65}$$

where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} carrier of the OFDM symbol in the complex plane;

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} carrier of the OFDM symbol in the complex plane;

P_0 is the average power of the constellation.

8.4.10 Receiver requirements

8.4.10.1 Receiver sensitivity

The bit error rate (BER) shall be less than 10^{-6} at the power levels shown in Table 116bj for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— At the antenna connector or· through a calibrated radiated test environment,
— Using the defined standardized message packet formats, and
— Using an AWGN channel.

Table 116bj—Receiver minimum input level sensitivity (dBm)

Bandwidth (MHz)	QPSK		16-QAM		64-QAM	
	1/2	3/4	1/2	3/4	2/3	3/4
1.5	–91	–89	–84	–82	–78	–76
1.75	–90	–87	–83	–81	–77	–75
3	–88	–86	–81	–79	–75	–73
3.5	–87	–85	–80	–78	–74	–72
5	–86	–84	–79	–77	–72	–71
6	–85	–83	–78	–76	–72	–70
7	–84	–82	–77	–75	–71	–69
10	–83	–81	–76	–74	–69	–68
12	–82	–80	–75	–73	–69	–67
14	–81	–79	–74	–72	–68	–66
20	–80	–78	–73	–71	–66	–65

Table 116bj (as well as Table 116bi) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and E_b/N_0 values as listed in Table 116bk.

Table 116bk—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

Test messages for measuring Receiver Sensitivity shall be based on a continuous stream of MAC PDUs, each with a payload consisting of a $\boldsymbol{R}$ times repeated sequence $\boldsymbol{S_{modulation}}$. For each modulation, a different sequence applies:

$$
\begin{aligned}
\boldsymbol{S_{QPSK}} &= [0xE4, 0xB1, 0xE1, 0xB4]\\
\boldsymbol{S_{16QAM}} &= [0xA8, 0x20, 0xB9, 0x31, 0xEC, 0x64, 0xFD, 0x75]\\
\boldsymbol{S_{64QAM}} &= [0xB6, 0x93, 0x49, 0xB2, 0x83, 0x08, 0x96, 0x11, 0x41, 0x92, 0x01, 0x00,\\
&\quad 0xBA, 0xA3, 0x8A, 0x9A, 0x21, 0x82, 0xD7, 0x15, 0x51, 0xD3, 0x05,\\
&\quad 0x10, 0xDB, 0x25, 0x92, 0xF7, 0x97, 0x59, 0xF3, 0x87, 0x18, 0xBE,\\
&\quad 0xB3, 0xCB, 0x9E, 0x31, 0xC3, 0xDF, 0x35, 0xD3, 0xFB, 0xA7,\\
&\quad 0x9A, 0xFF, 0xB7, 0xDB]
\end{aligned}
\tag{66}
$$

For each mandatory test message, the ($\boldsymbol{R}$,$\boldsymbol{S_{modulation}}$) tuples that shall apply are:

Short length test message payload (288 data bytes): (72,$\boldsymbol{S_{QPSK}}$), (36,$\boldsymbol{S_{16QAM}}$), (6,$\boldsymbol{S_{64QAM}}$)
Mid length test message payload (864 data bytes): (216,$\boldsymbol{S_{QPSK}}$), (108,$\boldsymbol{S_{16QAM}}$), (18,$\boldsymbol{S_{64QAM}}$)
Long length test message payload (1536 data bytes): (384,$\boldsymbol{S_{QPSK}}$), (192,$\boldsymbol{S_{16QAM}}$), (32,$\boldsymbol{S_{64QAM}}$)

The test condition requirements are: ambient room temperature, shielded room, conducted measurement at the RF port if available, radiated measurement in a calibrated test environment if the antenna is integrated, and RS FEC is enabled. The test shall be repeated for each test message length and for each ($\boldsymbol{R}$,$\boldsymbol{S_{modulation}}$) tuple as identified above, using the mandatory FEC scheme. The results shall meet or exceed the sensitivity requirements set out in Table 116bj.

8.4.10.2 Receiver adjacent and alternate channel rejection

The adjacent channel rejection and alternate channel rejection shall be measured by setting the desired signal's strength 3dB above the rate dependent receiver sensitivity (see Table 116bj) and raising the power level of the interfering signal until the specified error rate is obtained. The power difference between the interfering signal and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conforming OFDM signal, unsynchronized with the signal in the channel under test. For non-adjacent channel testing the test method is identical except the interfering channel shall be any channel other than the adjacent channel or the co-channel. For the PHY to be compliant, the minimum rejection shall exceed the following:

Table 116bl—Adjacent and non-adjacent channel rejection

Modulation/coding	Adjacent channel rejection dB)	Non-adjacent channel rejection (dB)
16-QAM-3/4	11	30
64-QAM-2/3	4	23

8.4.10.3 Receiver maximum input signal

The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.

8.4.10.4 Receiver linearity

The receiver shall have a minimum Input Intercept Point (IIP3) of –10 dBm.

8.4.11 Frequency and timing requirements

At the BS, the transmitted center frequency, receive center frequency and the symbol clock frequency shall be derived from the same reference oscillator. At the BS the reference frequency tolerance shall be +/– 4 ppm in licensed bands.

At the SS, both the transmitted center frequency and the symbol clock frequency shall be synchronized to the BS with a tolerance of maximum 2% of the carrier spacing.

For Mesh capable devices, all devices shall have a +/– 20 ppm maximum frequency tolerance and achieve synchronization to its neighboring nodes with a tolerance of maximum 3% of the carrier spacing.

During the synchronization period, the SS shall acquire frequency synchronization within the specified tolerance before attempting any uplink transmission. During normal operation, the SS shall track the frequency changes and shall defer any transmission if synchronization is lost.

All SSs shall acquire and adjust their timing such that all uplink OFDM symbols arrive time coincident at the Base-Station to a accuracy of +/– 50% of the minimum guard-interval or better.

8.5 WirelessMAN-OFDMA PHY layer

8.5.1 Introduction

The WirelessMAN-OFDMA ([B24]) PHY, based on OFDM modulation, is designed for NLOS operation in the 2–11 GHz frequency bands per 1.2.4. For licensed bands, channel bandwidths allowed shall be limited to the regulatory provisioned bandwidth divided by any power of 2 no less than 1.25 MHz.

8.5.1.1 Generic OFDMA symbol description

8.5.2 OFDMA symbol description, symbol parameters and transmitted signal

8.5.2.1 Time domain description

Inverse-Fourier-transforming creates the OFDMA waveform; this time duration is referred to as the useful symbol time T_b. A copy of the last T_g µs of the useful symbol period, termed Cyclic Prefix (CP), is used to collect multipath, while maintaining the orthogonality of the tones. The two together are referred to as the symbol time T_s. Figure 128ar illustrates this structure.

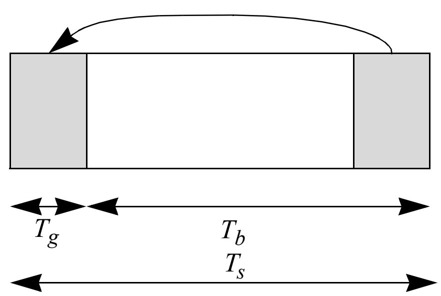

Figure 128ar—OFDM symbol time structure

The transmitter energy increases with the length of the guard time while the receiver energy remains the same (the cyclic extension is discarded), so there is a $0\log(1 - T_g / (T_b + T_g)) / \log(10$ dB loss in SNR. Using a cyclic extension, the samples required for performing the FFT at the receiver can be taken anywhere over the length of the extended symbol. This provides multipath immunity as well as a tolerance for symbol time synchronization errors.

On initialization, a SS should search all possible values of CP until it finds the CP being used by the BS. The SS shall use the same CP on the UL. Once a specific CP duration has been selected by the BS for operation on the DL, it should not be changed. Changing the CP would force all the SSs to resynchronize to the BS.

8.5.2.2 Frequency domain description

The frequency domain description includes the basic structure of an OFDMA symbol.

An OFDMA symbol is made up of carriers, the number of which determines the FFT size used. There are several carrier types:

- Data carriers: for data transmission
- Pilot carriers: for various estimation purposes
- Null carrier: no transmission at all, for guard bands and DC carrier.

The purpose of the guard bands is to enable the signal to naturally decay and create the FFT 'brick Wall' shaping.

In the OFDMA mode, the active carriers are divided into subsets of carriers, each subset is termed a subchannel. In the DL, a subchannel may be intended for different (groups of) receivers; in the UL, a transmitter may be assigned one or more subchannels, several transmitters may transmit in parallel. The carriers forming one subchannel may, but need not be adjacent. The concept is shown in Figure 128as.

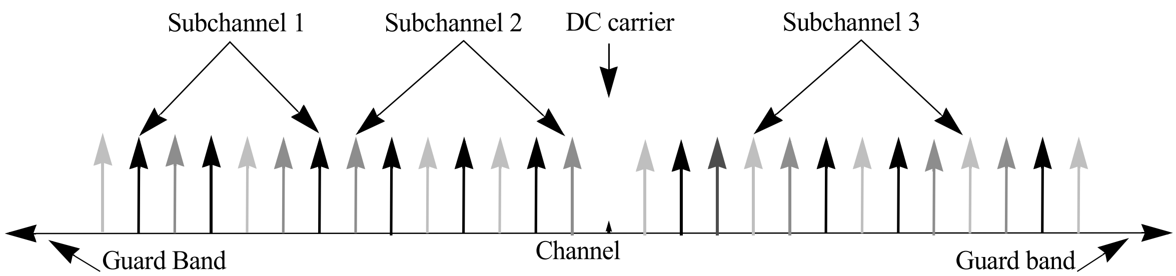

Figure 128as—OFDMA frequency description (3 channel schematic example)

The symbol is divided into logical subchannels to support scalability, multiple access, and advanced antenna array processing capabilities.

8.5.2.3 Primitive parameters

Four primitive parameters characterize the OFDMA symbol:

- BW. This is the nominal channel bandwidth.
- (F_s / BW). This is the ratio of "sampling frequency" to the nominal channel bandwidth. This value is set to 8/7.
- (T_g / T_b). This is the ratio of CP time to "useful" time. The following values shall be supported: 1/32, 1/16, 1/8, and 1/4.
- N_{FFT}. If an FFT is used in the implementation, this is the number of points in the FFT. The OFDMA PHY defines this value to be equal to 2048.

8.5.2.4 Derived parameters

The following parameters are defined in terms of the primitive parameters of 8.5.2.3.

$F_s = (F_s / BW) \cdot BW$ is Sampling Frequency

$\Delta f = F_s / N_{FFT}$ is the Carrier Spacing

$T_b = 1 / \Delta f$ is the Useful Time

$T_g = (T_g / T_b) \cdot T_b$ is the CP Time

$T_s = T_b + T_g$ is the OFDM Symbol Time

$1 / F_s$ is the Sample Time

8.5.2.5 Transmitted signal

Equation (67) specifies the transmitted signal voltage to the antenna, as a function of time, during any OFDMA symbol.

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k = -N_{used}/2 \\ k \neq 0}}^{N_{used}/2} c_k \cdot e^{j2\pi k \Delta f (t - T_g)} \right\} \tag{67}$$

where

t is the time, elapsed since the beginning of the subject OFDM symbol, with $0 < t < T_S$.

c_k is a complex number; the data to be transmitted on the carrier whose frequency offset index is *k,* during the subject OFDM symbol. It specifies a point in a QAM constellation.

T_g is the guard time.

T_S is the OFDM symbol duration, including guard time.

Δf is the carrier frequency spacing.

8.5.3 OFDMA slot definition

8.5.3.1 Data region and PHY burst

In addition to the time dimension that defines slots in other PHYs, a slot in the OFDMA PHY requires a subchannel dimension for complete definition. (Subchannels are defined in 8.5.6.)

A PHY burst in OFDMA is allocated a group of contiguous subchannels, in a group of contiguous OFDMA symbols. This allocation may be visualized as a rectangle, such as the 4x3 rectangle shown in Figure 128at. This type of two-dimensional allocation is called a data region.

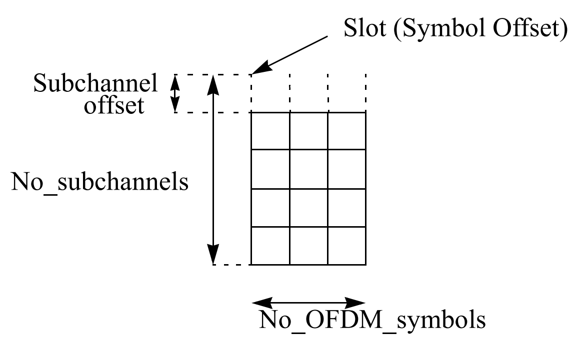

Figure 128at—Example of the data region which defines the OFDMA allocation

Such a data region can be assigned in the UL to a specific SS (or a group of subscribers) or can be transmitted in the DL by the BS as a transmission to a (group of) SS(s).

8.5.3.2 OFDMA data mapping

MAC data shall be processed as described in 8.5.9 and shall be mapped to an OFDMA Data Region (see 8.5.3.1) using the following algorithm:

1) Segment the data into blocks sized to fit into one FEC block.

2) Each FEC block spans one OFDMA subchannel in the subchannel axis and three OFDM symbols in the time axis (see Figure 128au). Map the FEC blocks such that the lowest numbered FEC block occupies the lowest numbered subchannel in the lowest numbered OFDM symbol.
3) Continue the mapping such that the OFDMA subchannel index is increased for each FEC block mapped. When the edge of the Data Region is reached, continue the mapping from the lowest numbered OFDMA subchannel in the next OFDM symbol.

Figure 128au illustrates the order in which FEC blocks are mapped to OFDMA subchannels and OFDM symbols.

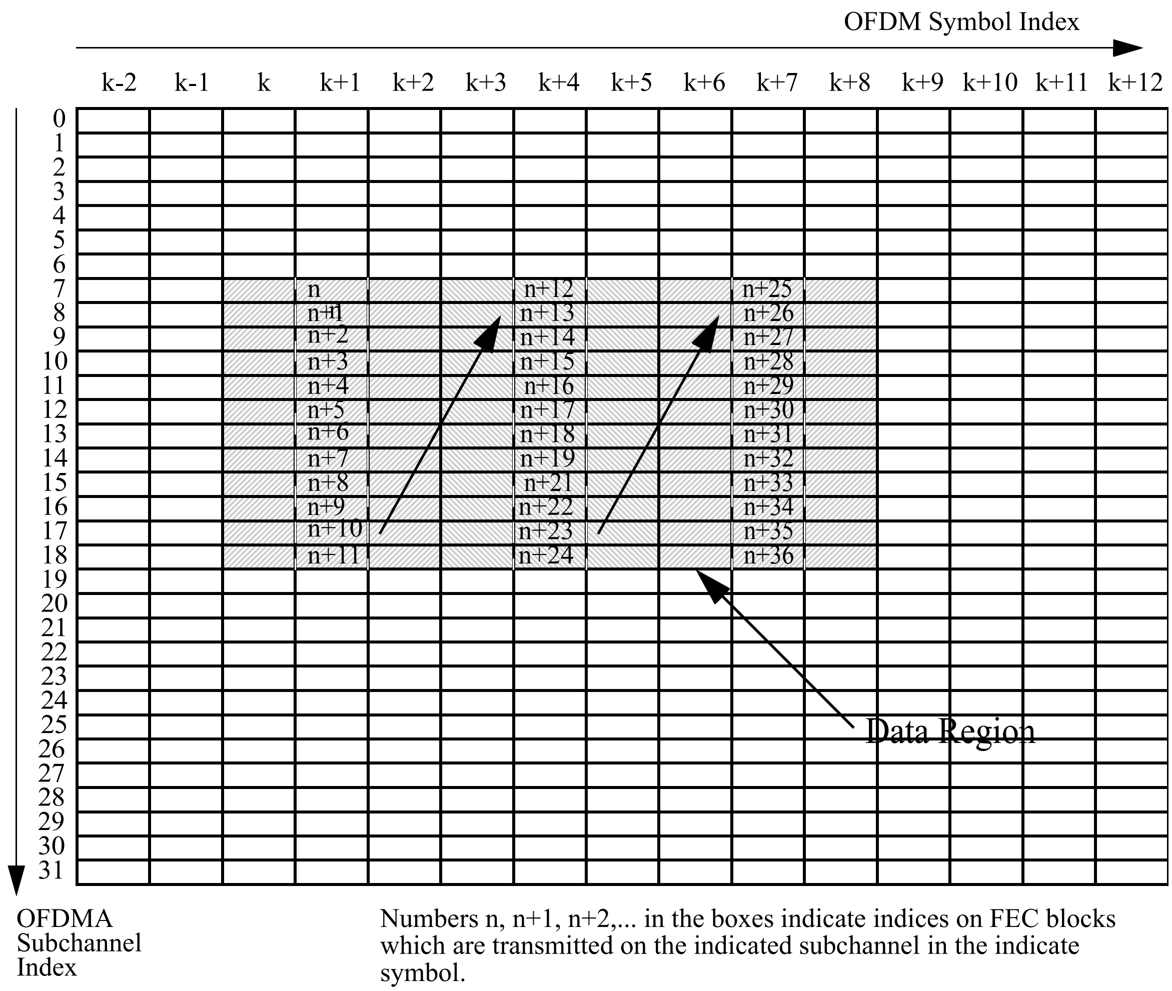

Figure 128au—Mapping of FEC blocks to OFDMA subchannels and symbols

8.5.4 Frame structure

8.5.4.1 Duplexing modes

In licensed bands, the duplexing method shall be either FDD or TDD. FDD SSs may be Half Duplex FDD (H-FDD). In license-exempt bands, the duplexing method shall be TDD.

8.5.4.2 PMP frame structure

When implementing a TDD system, the frame structure is built from BS and SS transmissions. Each burst transmission consists of multiples of three (or six, if STC used, see 8.5.8) OFDMA symbols. In each frame, the Tx/Rx transition gap (TTG) and Rx/Tx transition gap (RTG) shall be inserted between the downlink and uplink and at the end of each frame respectively to allow the BS to turn around. TTG and RTG shall be at least 5 μs and an integer multiple of the PS in duration, and start on a PS boundary. After the TTG, the BS receiver shall look for the first symbols of a UL burst. After the RTG, the SS receivers shall look for the first symbols of QPSK modulated data in the DL burst.

There is no need for TTG and RTG as the downlink and uplink transmit on independent frequencies in FDD systems.

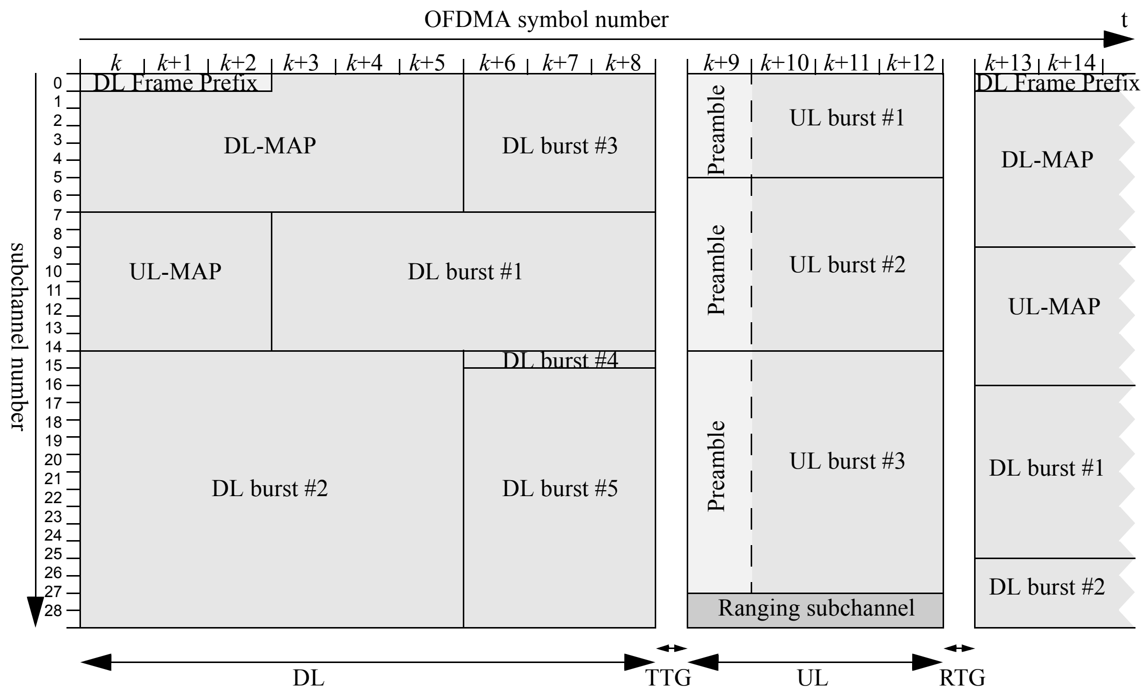

Figure 128av—Time plan - one TDD time frame

Regardless of duplexing type, the appropriate duration of the Initial Maintenance slot used for initial system access depends on the intended cell radius.

The framing structure used for the DL includes the transmission of a FCH, which is transmitted in the most robust burst profile of the system followed by transmission using burst profiles as defined in the FCH. The MAC layer also defines the DL transmission frame length and the length of the different transmission parts.

The transitions between modulations and coding take place on OFDMA symbol boundaries in time domain and on subchannels within an OFDM symbol in frequency domain.

A BS supporting the AAS option shall allocate at the end of the UL frame an initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but shall be marked by a non-used CID to ensure that no non-AAS subscriber (or AAS subscriber can decode the UL-MAP message) uses this interval for initial maintenance.

8.5.4.3 DL Frame Prefix

The FCH is transmitted at the beginning of each frame. It is a data structure that contains the DL-MAP message and may additionally include the UL-MAP, DCD or UCD messages. The first FEC block of the DL frame shall contain information about the FCH and beginning of the DL-MAP, as shown in Figure 128aw. The DL Frame prefix is always transmitted using the burst profile QPSK-1/2 with the mandatory coding scheme.

DL Frame Prefix	Beginning of DL-MAP Message

Figure 128aw—Structure of the first FEC block in OFDMA

The DL Frame Prefix is defined in Table 116bm and is used to provide information about where to demodulate the FCH (structure of the transmitted matrix) and how to demodulate it (PHY parameters).

Table 116bm—OFDMA DL Frame Prefix

Syntax	Size	Notes
DL_Frame_Prefix_Format() {		
Rate_ID	4 bits	
Reserved	4 bits	
DL_Information_Message_Rectangle() {		
No_OFDM_Symbols	10 bits	
No_subchannels	6 bits	
}		
Prefix_CS	8 bits	
}		

The fields in Table 116bm are defined as:

Rate_ID:
Enumerated field that describes the modulation/coding of the DL-MAP message. Encoding values of the Rate_ID field are defined in Table 116ao.

No_OFDM_Symbols
Indicates the number of OFDM symbols for the DL_MAP message starting from the first symbol of the frame.

No_subchannels
Indicates the number of subchannels for the DL_MAP message starting from subchannel 0.

Prefix_CS
An 8-bit checksum for the DL-Frame prefix fields, with the generator polynomial:
$g(D) = D^8+D^2+D+1$.

The remaining bytes of the first FEC block may contain the beginning of the frame control information (DL-MAP).

Two specific examples of the usage of the DL_Frame_Prefix are provided below:

1) The frame control information is transmitted at the beginning of the frame, using all or part of the subchannels (see Figure 128ax).

2) Taking advantage of the option of forward power control, the transmission of the frame control information is done by using 1-2 subchannels for the duration of the whole frame while power boosting the used carriers (see Figure 128ay).

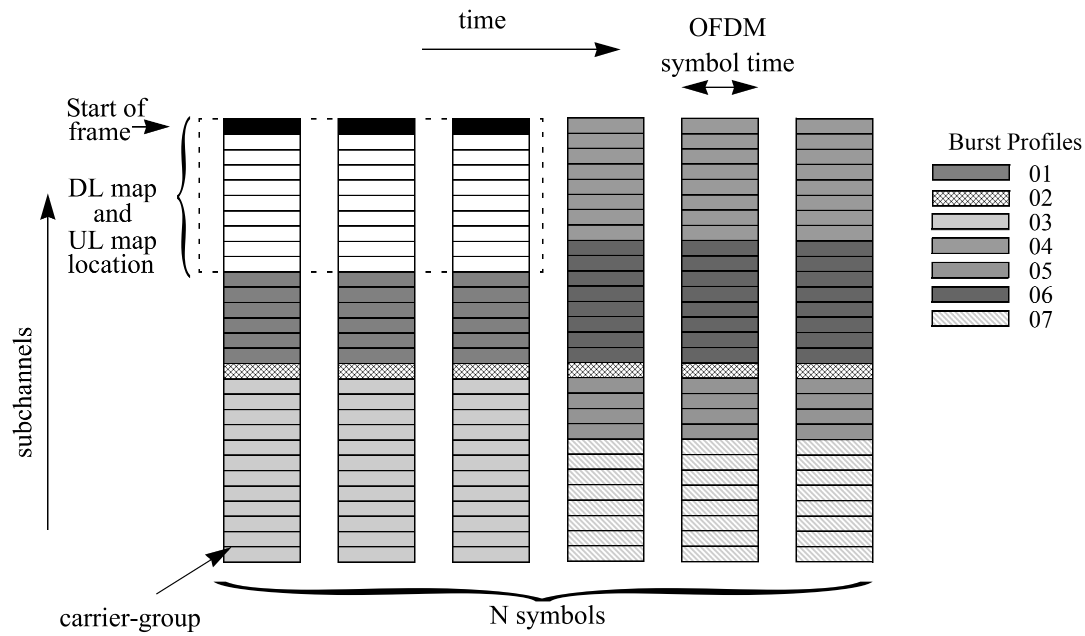

Figure 128ax—Example of OFDMA DL and UL map location

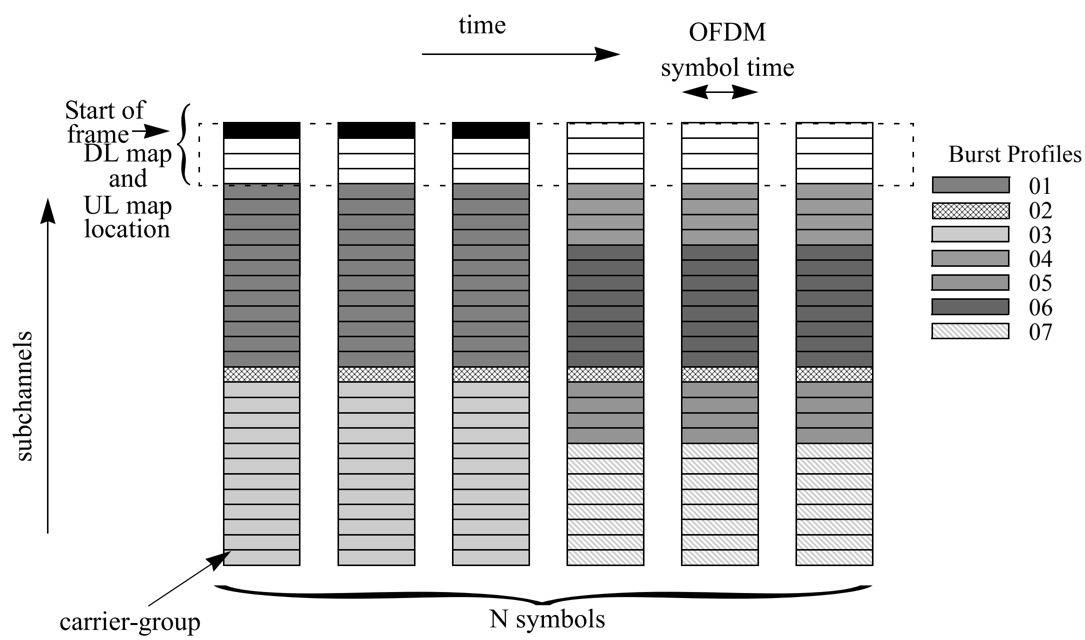

Figure 128ay—Another example of OFDMA DL and UL map location

8.5.4.4 Frame duration codes

Table 116bn indicates the various frame durations that are allowed. The actual frame duration can be determined by the periodicity of the DL frame start preamble.

Table 116bn—OFDMA frame duration (T_F ms) codes

<table>
<tr><th>Code
(N)</th><th>Nominal
(D)</th><th>Actual</th></tr>
<tr><td>0</td><td>N/A</td><td>AAS-only gap up to 200 ms following (see 8.5.6.3)</td></tr>
<tr><td>1</td><td>2</td><td rowspan="8">FDD: round(D/3T_s)*3T_s
TDD: max(round(D/T_s),7)*T_s</td></tr>
<tr><td>2</td><td>3.5</td></tr>
<tr><td>3</td><td>5</td></tr>
<tr><td>4</td><td>7</td></tr>
<tr><td>5</td><td>10</td></tr>
<tr><td>6</td><td>14</td></tr>
<tr><td>7</td><td>15</td></tr>
<tr><td>8</td><td>20</td></tr>
<tr><td>9–255</td><td colspan="2">Reserved</td></tr>
</table>

In an FDD case, the frame duration shall be an integer multiple of three OFDM symbols duration, such that the actual frame duration is as listed in Table 116bn. In a TDD case, the frame duration shall be an integer multiple of one OFDM symbol duration, such that the actual frame duration is as listed in Table 116bn, plus a RTG and TTG guard interval. Both RTG and TTG shall be no less than 5 µs in duration.

8.5.4.5 DL transmission allocations

The transmission of the DL is performed on the subchannels of the OFDMA symbol. The number of subchannels needed for the different transmissions (modulation and coding) and their mapping is defined in the DL-MAP message. The mapping of the subchannels is performed in a two-dimensional grid, involving the subchannels in the frequency domain and OFDMA symbols in the time domain, as explained in 8.5.3.2.

8.5.4.6 UL transmission allocations

The allocation for a user UL transmission is a number of subchannels over a number of OFDMA symbols. The number of symbols shall be equal to 1+3N, where N is a positive integer. During the first OFDMA symbol of an allocation, the SS shall send a preamble on all its allocated subchannels. The remaining 3N symbols shall contain data.

The smallest allocation, a basic allocation, is one subchannel for a duration of 4 times the OFDMA symbol duration T_s (N=1). Larger allocations are called extended allocations. These allocations are illustrated in Figure 128az.

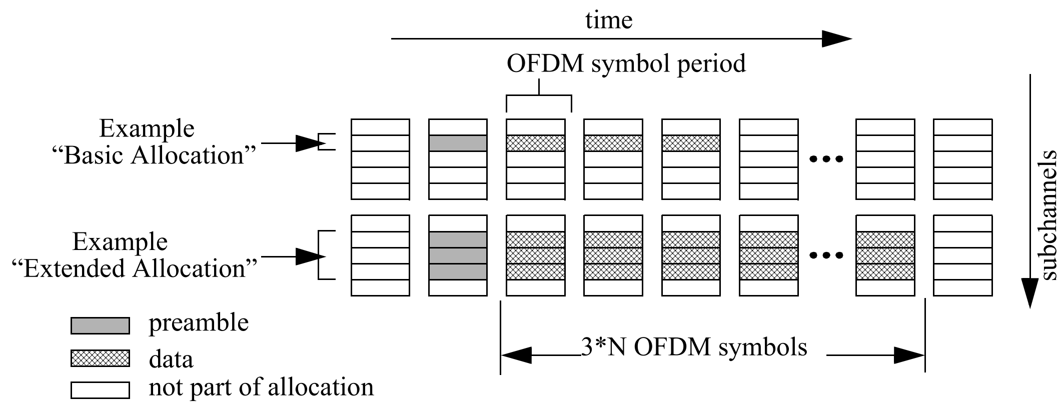

Figure 128az—OFDMA UL bandwidth allocations

The framing structure used for the UL includes the transmission of a possible symbol for Jamming monitoring, an allocation for Ranging and an allocation for data transmission. The MAC sets the length of the UL framing, and the UL mapping.

The framing for these modes involve the allocation of ranging subchannels within the OFDMA symbols, while the rest of the subchannels are used for users transmission, as shown in Figure 128az. An optional Null symbol may be inserted to facilitate Jamming monitoring.

8.5.5 Map message fields and IEs

8.5.5.1 DL-MAP PHY Synchronization Field

The format of the PHY Synchronization Field of the DL-MAP message, as described in 6.2.2.3.2, is given in Table 116bo. The Frame Duration Codes are given in Table 116bn. The Frame number is incremented by 1 each frame and eventually wraps around to zero.

Table 116bo—OFDMA PHY Synchronization Field

Syntax	Size	Notes
PHY_synchronization_field() {		
Frame duration code()	8 bits	
Frame number	24 bits	
Allocation_Start_Time	32 bits	
}		

A BS shall generate DL-MAP messages in the format shown in Table 116bo, including all of the following parameters:

Frame number
The frame number is incremented by 1 MOD 2^{24} each frame.

Frame Duration Code
The frame duration Code values are specified in Table 116bn.

Allocation_Start_Time
Effective start time of the downlink allocation defined by the DL-MAP in units of PSs. This start time is relative to the start of the frame in which the DL-MAP message is transmitted. The minimum value specified for this parameter shall correspond to one FEC block.

8.5.5.2 DL-MAP Information Element format

The OFDMA DL-MAP Information Element defines a two-dimensional allocation pattern as defined in Table 116bp:

Table 116bp—OFDMA DL-MAP_Information_Element format

Syntax	Size	Notes
DL-MAP_Information_Element() {		
DIUC	4 bits	
if (UIUC == 15) {		
Extended DIUC dependent IE	variable	AAS_DL_IE()
} else {		
OFDM Symbol offset	10 bits	
Subchannel offset	6 bits	
No. OFDM Symbols	10 bits	
No. Subchannels	6 bits	
}		
}		

DIUC
Downlink interval usage code used for the burst.
OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, measured in OFDM symbols from the allocation start time specified by the Allocation_Start_time field in the DL-MAP.
Subchannel offset
The lowest index OFDM subchannel used for carrying the burst, starting from subchannel 0.
No. OFDM Symbols
The number of OFDM symbols that are used (fully or partially) to carry the DL PHY Burst.
No. of subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.

8.5.5.2.1 DIUC allocation

Table 116bq defines the DIUC encoding that should be used in the DL-MAP Information Elements.

Table 116bq—OFDMA DIUC values

DIUC	Usage
0–12	Different burst profiles
13	Gap
14	End of map
15	Extended DIUC

8.5.5.2.2 AAS Information Element format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended DIUC = 15 with the AAS_DL_IE() 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.

Table 116br—OFDMA DL AAS information element

Syntax	Size	Notes
AAS_DL_IE() {		
extended DIUC	4 bits	AAS = 0x02
Permutation	2 bits	0 = distributed-carrier permutation 1 = adjacent-carrier permutation
OFDMA symbol offset	10 bits	
}		

8.5.5.2.3 STC Information Element format

In the DL-MAP, an STC enabled BS (see 8.5.8) may transmit DIUC=15 with the STC_IE() 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. The subsequent DL allocations shall span a multiple of 6 OFDM symbols in time.

Table 116bs—OFDMA DL STC Information Element

Syntax	Size	Notes
STC_IE() {		
extended DIUC	4 bits	AAS = 0x01
OFDMA symbol offset	10 bits	
}		

The duration of the DIUC=15 STC_IE() allocation shall be zero. From the start of the frame up to this allocation, only one antenna shall be used. The transmission in this allocation will be as specified in 8.5.8.2. After this allocation, the BS shall transmit from both its antennas until the end of the frame.

8.5.5.3 UL-MAP Information Element format

The OFDMA UL-MAP Information Element defines a two-dimensional allocation pattern for the UL bursts. Information Elements define uplink bandwidth allocations. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements shall be in strict chronological order within the UL-MAP. The Connection Identifier represents the assignment of the IE to either a unicast, multicast, or broadcast address. A UIUC shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be specified in the UCD for each UIUC to be used in the UL-MAP. The format of the UL-MAP IE is defined in Table 116bt.

Table 116bt—OFDMA UL-MAP Information Element format

Syntax	Size	Notes
UL-MAP_Information_Element() {		
CID	16 bits	
UIUC	4 bits	
if (UIUC == 4) {		
CDMA_Allocation_IE()	52 bits	
else if (UIUC == 15) {		
Extended UIUC dependent IE	variable	Power_Control_IE() or AAS_UL_IE()
} else {		
OFDM Symbol offset	9 bits	
Subchannel offset	5 bits	
Boosting	2 bits	00: normal (not boosted); 01: +6dB; 10: –6dB; 11: not used.
No. OFDM Symbols	9 bits	
No. Subchannels	5 bits	
Reserved	2 bits	
}		
}		

CID (Connection Identifier)
Represents the assignment of the IE.

UIUC
Uplink interval usage code used for the burst.

OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.

Subchannel offset
The lowest index OFDMA subchannel used for carrying the burst, starting from subchannel 0.

No. OFDM Symbols
The number of OFDM symbols that are used to carry the UL Burst.

No. subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.

Boosting
Indication whether the carriers for this allocation are power boosted.

The end of the last allocated burst is indicated by allocating a NULL burst (CID =0 and UIUC =10) with zero duration. The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

A BS supporting the AAS option shall allocate subchannels 30 and 31, during the last 4 symbols of the UL frame as initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial-Maintenance (UIUC=12), but shall be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance.

8.5.5.3.1 UIUC Allocation

Table 116bu defines the UIUC encoding that should be used in the UL-MAP_IE().

Table 116bu—OFDMA UIUC values

UIUC	Usage
0	Reserved
1–9	Different burst profiles
10	Null Information Element
11	BW request, periodic ranging
12	Initial ranging
13	Reserved
14	CDMA Allocation Information Element
15	Extended UIUC

8.5.5.3.2 CDMA allocation UL-MAP Information Element format

Table 116bv defines the UL-MAP_IE for allocation BW for a user that requested bandwidth using Request Code. This IE is identified by UIUC =14.

Table 116bv—CDMA Allocation Information Element format

Syntax	Size	Notes
CDMA_Allocation_IE() {		
Ranging Code	6 bits	
Ranging Symbol	10 bits	
OFDM Symbol offset	8 bits	
Subchannel offset	6 bits	
No. OFDM Symbols	6 bits	
No. Subchannels	6 bits	
Ranging subchannel	6 bits	
BW request mandatory	1 bit	1= yes, 0= no
Reserved	3 bits	
}		

Ranging Code
Indicating the CDMA Code sent by the SS.
Ranging Symbol
Indicating the OFDM symbol used by the SS.
OFDM Symbol offset
The offset of the OFDM symbol in which the burst starts, the offset value is defined in units of OFDM symbols and is relevant to the Allocation Start Time field given in the UL-MAP message.
Subchannel offset
The lowest index OFDMA subchannel used for carrying the burst, starting from subchannel 0.
No. OFDM Symbols.
The number of OFDM symbols that are used to carry the UL Burst.
Number of subchannels
The number OFDMA subchannels with subsequent indexes, used to carry the burst.
Ranging subchannel
Identifies the Ranging subchannel used by the SS to send the CDMA code.
BW request mandatory
Indicates whether the SS shall include a BW request in the allocation.

The end of the last allocated burst is indicated by allocating a NULL burst (CID=0 and UIUC=10) with zero duration.The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

8.5.5.3.3 Power Control Information Element format

When a power change for the SS is needed, the extended UIUC = 15 may be used with the sub-code 0x00 and with 8-bit Power control value as shown in Table 116bw. The power control value is an 8-bit signed integer expressing the change in power level (in 0.25 dB units) that the SS should apply to correct it's current transmission power.

The CID used in the Information Element should be the Basic CID of the SS.

Table 116bw—OFDMA Power Control Information Element

Syntax	Size	Notes
Power_Control_IE() {		
extended UIUC	4 bits	Fast power control = 0x00
Power control	8 bits	Signed integer, which expresses the change in power level (in 0.25 dB units) that the SS should apply to correct its current transmission power.
}		

8.5.5.3.4 AAS Information Element format

Within a frame, the switch from non-AAS to AAS-enabled traffic is marked by using the extended UIUC = 15 with the AAS_UL_IE() to indicate that the subsequent allocation until the end of the frame shall be for AAS traffic. When used, the CID in the UL-MAP_IE() shall be set to the broadcast CID.

Table 116bx—OFDMA UL AAS Information Element

Syntax	Size	Notes
AAS_UL_IE() {		
extended UIUC	4 bits	AAS = 0x02
Permutation	2 bits	0 = distributed-carrier permutation 1 = adjacent-carrier permutation
OFDMA symbol offset	10 bits	
Reserved	4 bits	
}		

8.5.5.4 Burst Profile format

Table 116by defines the format of the Downlink_Burst_Profile, which is used in the DCD message (6.2.2.3.1). The Downlink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit DIUC. The DIUC field is associated with the Downlink Burst Profile and Thresholds. The DIUC value is used in the DL-MAP message to specify the Burst Profile to be used for a specific downlink burst.

Table 116by—Downlink_burst_profile format

Syntax	Size	Notes
Downlink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
DIUC	4 bits	
TLV encoded information	variable	
}		

Table 116bz defines the format of the Uplink_Burst_Profile, which is used in the UCD message (6.2.2.3.1). The Uplink_Burst_Profile is encoded with a Type of 1, an 8-bit length, and a 4-bit UIUC. The UIUC field is associated with the Uplink Burst Profile and Thresholds. The UIUC value is used in the UL-MAP message to specify the Burst Profile to be used for a specific uplink burst.

Table 116bz—Uplink_burst_profile format

Syntax	Size	Notes
Uplink_burst_profile {		
Type=1	8 bits	
Length	8 bits	
Reserved	4 bits	Shall be set to zero
UIUC	4 bits	
TLV encoded information	variable	
}		

8.5.6 OFDMA carrier allocations

For OFDMA, $F_s = BW \cdot 8/7$. Subtracting the DC carrier and the guard tones from N_{FFT}, one obtains the set of "used" carriers N_{used}. For both uplink and downlink these used carriers are allocated to pilot carriers and data carriers. However, there is a subtle difference between uplink and downlink. This difference is that, in the downlink, the pilot tones are allocated first; what remains are subchannels that are used exclusively for data. In the uplink, however, the set of used carriers is first partitioned into subchannels, and then the pilot carriers are allocated from within each subchannel. Thus, in the downlink, there is one set of common pilot carriers, but in the uplink, each subchannel contains its own set of pilot carriers. This is necessary since, in OFDMA, the BS downlink is broadcast to all SS, but in the uplink, each subchannel may be transmitted from a different SS.

In the sequel, carriers are identified by a carrier index; however, in order to construct the OFDMA signal as specified in 8.5.2.5 the frequency offset index is required. The frequency offset index of a particular carrier is specified terms of its carrier index by Equation (68).

$$k_{foi} = \begin{cases} k_{ci} - N_{used}/2, & k_{ci} < N_{used}/2 \\ k_{ci} - N_{used}/2 + 1, & k_{ci} \geq N_{used}/2 \end{cases} \tag{68}$$

where

k_{foi} is the frequency offset index

k_{ci} is the carrier index

N_{used} is the number of used carriers.

8.5.6.1 Downlink

8.5.6.1.1 Assignment of pilots

The N_{used} used carriers are partitioned into fixed-location pilots, variable location pilots, and data subchannels. The carrier indices of the fixed-location pilots never change. These indices are the members of the set BasicFixedLocationPilots. The variable-location pilots shift their location every symbol repeating every 4 symbols, according to the formula:

$$varLocPilot_k = 3L + 12P_k$$

where

$varLocPilot_k$ is the carrier index of a of variable-location pilot

$L \in 0..3$ is a function of the symbol index, modulo 4

$P_k \in \{0, 1, 2, \ldots, N_{varLocPilots} - 1\}$

and $N_{varLocPilots}$ is given in Table 116ca.

L does not simply increment from one symbol to the next, but instead follows the sequence L = 0, 2, 1, 3, 0...

In some cases a variable-location pilot will coincide with a fixed-location pilot. The sets of BasicFixedLocationPilots are designed so that the number of coinciding pilots is the same for every L.

There is no all-pilot preamble in the DL.

The allocation of pilot carriers is illustrated in Figure 128ba.

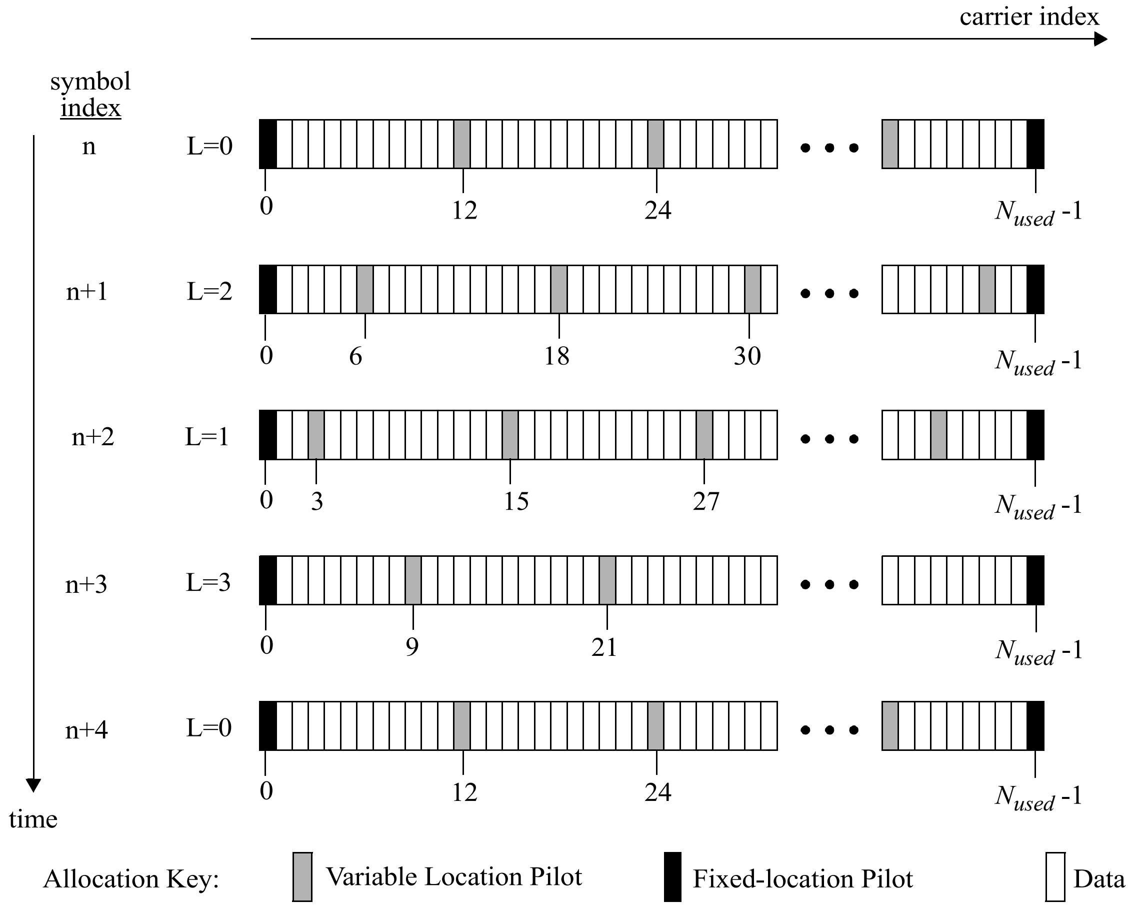

Figure 128ba—Carrier Allocations in the OFDMA DL

8.5.6.1.2 Partitioning of data carriers into subchannels

After mapping the pilots, the remainder of the used carriers are the data subchannels. Note that since the variable location pilots change location in each symbol, repeating every fourth symbol, the locations of the carriers in the data subchannels shall change also.

To allocate the data subchannels, the remaining carriers are partitioned into groups of contiguous carriers. Each subchannel consists of one carrier from each of these groups. The number of groups is therefore equal to the number of carriers per subchannel, and it is denoted $N_{subcarriers}$. The number of the carriers in a group is equal to the number of subchannels, and it is denoted $N_{subchannels}$. The number of data carriers is thus equal to $N_{subcarriers} \cdot N_{subchannels}$.

The exact partitioning into subchannels is according to Equation (69), called a permutation formula. (To clarify the operation of this formula, an example application is given subsequently in 8.5.6.2.1).

$$carrier(n,\ s) = N_{subchannels} \cdot n + \{p_s[n_{mod(N_{subchannels})}] + ID_{cell} \cdot ceil[(n+1)/ N_{subchannels}]\}_{mod(N_{subchannels})} \quad (69)$$

where

$carrier(n, s)$ is the carrier index of carrier n in subchannel s

s is the index number of a subchannel, from the set $[0..N_{(subchannel)s}$ -1]

n is the carrier-in-subchannel index from the set $[0..N_{subcarriers}$ -1]

$N_{(subchannel)s}$ is the number of subchannels

$p_s[j]$ is the series obtained by rotating $\{PermutationBase_0\}$ cyclically to the left s times

ceil[ ] is the function that rounds its argument up to the next integer

ID_{cell} is a positive integer assigned by the MAC to identify this particular BS sector

$X_{mod(k)}$ is the remainder of the quotient X/k (which is at most k–1)

and the numerical parameters are given in Table 116ca.

On initialization, a SS must search for the DL preamble for each possible value of the permutation index to determine the actual index being used for the cell. An AAS-enabled SS may additionally search for preambles based on the permutations (distributed, adjacent or both) it is capable of using for AAS traffic. However, an SS shall perform this search if it intends to initiate AAS-based initial ranging (see 6.2.7.7.4). Note that an AAS-enabled SS, which does not provision the same permutation (distributed or adjacent) for AAS traffic selected by the BS for this purpose, is not capable of using its AAS capabilities with this BS.

Table 116ca—OFDMA DL carrier allocations

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	173
Number of guard carriers, right	172
N_{used}, Number of used carriers	1702
Total number of carriers	2048
$N_{varLocPilots}$	142
Number of fixed-location pilots	32
Number of variable-location pilots which coincide with fixed-location pilots	8
Total number of pilots[a]	166
Number of data carriers	1536
$N_{subchannels}$	32
$N_{subcarriers}$	48
Number of data carriers per subchannel	48
BasicFixedLocationPilots	{0,39, 261, 330, 342, 351, 522, 636, 645, 651, 708, 726, 756, 792, 849, 855, 918, 1017, 1143, 1155, 1158, 1185, 1206, 1260, 1407, 1419,1428, 1461, 1530,1545, 1572, 1701}
$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

[a]Variable Location Pilots which coincide with Fixed-location Pilots are counted only once in this value.

8.5.6.2 Uplink

The N_{used} used carriers are first partitioned into subchannels, using the same procedure as in 8.5.6.1.2, including Equation (69), except that, for the uplink, the parameters are as given in Table 116cb. Note that since we have not first assigned pilots, $N_{subcarriers}$ in the uplink is 53, instead of 48 as in the downlink.

Table 116cb—OFDMA UL Carrier Allocations

Parameter	Value	
Number of dc carriers	1	
N_{used}	1696	
Guard carriers: left, right	176	175
$N_{subchannels}$	32	
$N_{subcarriers}$	53	
Number of data carriers per subchannel	48	
$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}	

Within each subchannel, there are 48 data carriers, 1 fixed-location pilot carrier, and 4 variable-location pilot carriers.

The fixed-location pilot is always at carrier-in-subchannel 26.

The variable-location pilots location changes in each symbol, repeating every 13 symbols, according to L_k where k = 0 to 12. The sequence L_k is given by $L_k = \{0,2,4,6,8,10,12,1,3,5,7,9,11\}$. The first symbol (in k=0) is produced after the all-pilot symbols (preamble), which consist of permuted carriers modulated according to 8.5.6.1. For k=0 the variable location pilots are positioned at indices: 0,13,27,40. For other k values these locations change by adding L_k to each index. For example, for k=9, L_k=5, and the variable pilots location are: 5,18, 32, 45.

The variable-location pilot locations just described will never coincide with the fixed-location pilot at carrier-in-subchannel 26.

The remaining 48 carriers are data carriers. Thus, due to the motion of the variable-location pilots, the locations of these data carriers also change with each symbol.

The partitioning of each UL subchannel just described in this subclause is illustrated in Figure 128bb.

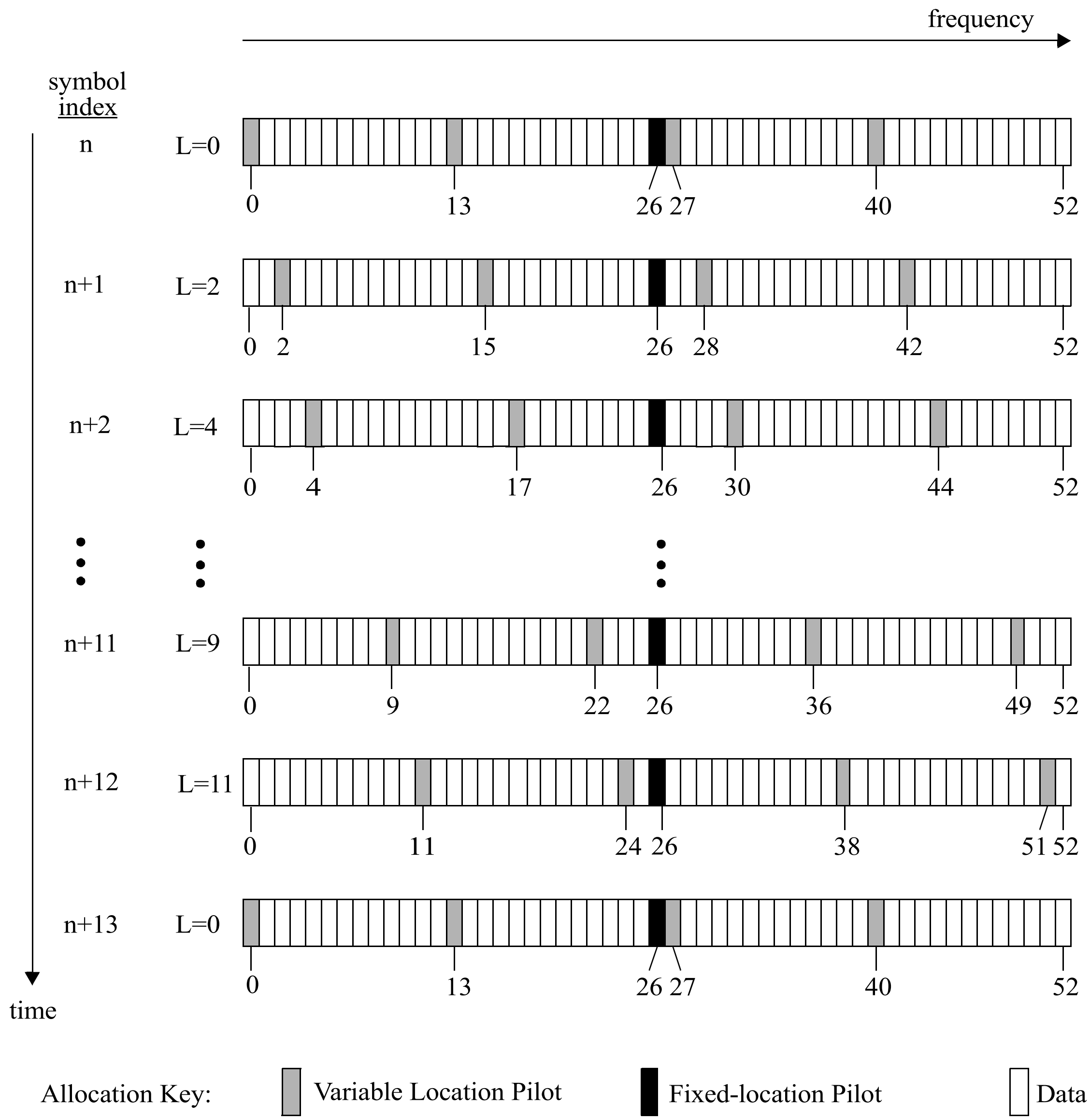

Figure 128bb—Carrier allocations within each OFDMA UL subchannel

8.5.6.2.1 UL permutation example

To illustrate the use of the permutations, an example is provided to clarify the operation of the permutation formula, Equation (69).

The carriers for subchannel s=1 in cell $ID_{cell} = 2$ are computed.

The relevant parameters characterizing the UL are therefore taken from Table 116cb.

— Number of subchannels: $N_{subchannels} = 32$

— Number of carriers in each subchannel: $N_{subcarriers} = 53$

— Number of data carriers in each subchannel = 48.

— $\{PermutationBase_0\}$ = {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

Using Equation (69),

1) The basic series of 32 numbers is {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}
2) In order to get 32 different permutation the series is rotated to the left (from no rotation at all up to 31 rotations). Since it is assumed s=1, ($permutationbase_{s=1}$) is: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}
3) Repeat the permuted series 2 times and take the first 53 numbers only: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}.
4) The concatenation depends on the ID_{cell} (which characterizes the working cell and can range from 0 to 31). It is assumed s=1 and $ID_{cell} = 2$, the last term in the equation becomes

   $\{p_s[n_{mod(32)}] + 2 \cdot ceil[(n+1)/32]\}_{mod(32)}$ with $n = 0, 1, .., 52$

   = {20, 4, 10, 18, 12, 13, 17, 28, 24, 8, 11, 29, 22, 27, 3, 31, 9, 23, 7, 30, 1, 25, 19, 6, 26, 2, 15, 14, 21, 16, 0, 5, 22, 6, 12, 20, 14, 15, 19, 30, 26, 10, 13, 31, 24, 29, 5, 1, 11, 25, 9, 0, 3}
5) Finally adding in the first term, the set of carriers is found: *carrier(n,1)* = {20, 36, 74, 114, 140, 173, 209, 252, 280, 296, 331, 381, 406, 443, 451, 511, 521, 567, 583, 638, 641, 697, 723, 742, 794, 802, 847, 878, 917, 944, 960, 997, 1046, 1062, 1100, 1140, 1166, 1199, 1235, 1278, 1306, 1322, 1357, 1407, 1432, 1469, 1477, 1505, 1547, 1593, 1609, 1632, 1667}.

8.5.6.3 Optional permutations for AAS

A BS using the AAS option may change from the “distributed carrier permutation” described in 8.5.6.1 and 8.5.6.2 to the “adjacent carrier permutation” when changing from non-AAS to AAS-enabled traffic to support AAS adjacent carrier user traffic in the cell. After this change, the BS shall only transmit / receive AAS-enabled traffic using the adjacent carrier permutation until the end of the frame. The BS shall always return to the distributed carrier permutation for the broadcast (non-AAS) traffic.

While the BS does not have any SSs registered that are not capable of using the AAS permutation selected by the BS, the BS may employ the AAS superframe structure. Otherwise, it shall always return to the distributed carrier permutation at the end of each frame and provision broadcast traffic at the start of each frame.

The AAS superframe shall have the following structure:

1) The BS shall start each superframe with no less than 20 consecutive frames, which contain both DL and UL broadcast OFDM symbols. Each of these frames shall provision DCD, UCD, DL-MAP and UL-MAP messages, and at least one initial ranging opportunity. The frame duration code in each frame except the last one shall be set to the actual frame duration used. The frame duration code in the last frame shall be set to 0x00.
2) Subsequently, the BS shall transmit up to 200 ms of AAS only frames, followed by a minimum of one frame containing at least one DL broadcast OFDM symbol, which shall provision DCD, UCD and DL-MAP messages. The frame duration code shall be set to 0x00.
3) The BS shall repeat Step 2) of this subclause, up to the AAS superframe duration, which shall be no more than 1s.

With the adjacent carrier permutation, symbol data within a subchannel is assigned to adjacent carriers and the pilot and data carriers are assigned fixed positions in the frequency domain within an OFDM symbol. This permutation is the same for both UL and DL. Within each frame, the BS shall indicate the switch to the optional permutation in the AAS_DL_IE() and AAS_UL_IE() when switching to AAS traffic. (see 8.5.5.2 and 8.5.5.3).

Table 116cc—OFDMA AAS carrier allocations

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	176
Number of guard carriers, right	175
N_{used} , Number of used carriers	1696
Total number of carriers	2048
$N_{varLocPilots}$	0
Number of fixed-location pilots	160
Number of variable-location pilots which coincide with fixed-location pilots	0
Total number of pilots (*)	160
Number of data carriers	1536
$N_{subchannels}$	32
$N_{subcarriers}$	48
Number of data carriers per subchannel	48
BasicFixedLocationPilots	{5,16,27,38,49}within each subchannel

8.5.7 OFDMA ranging

When used with the WirelessMAN-OFDMA PHY, the MAC shall define a single ranging channel. This ranging channel is composed of one or more pairs of adjacent subchannels, where the index of the lowest numbered subchannel is even. The indices of the subchannels that compose the ranging channel are specified in the UL-MAP message. Users are allowed to collide on this ranging channel. To effect a ranging transmission, each user randomly chooses one ranging code from a bank of specified binary codes. These codes are then BPSK modulated onto the carriers in the ranging channel, one bit per carrier.

8.5.7.1 Initial-ranging transmissions

The initial ranging transmission shall be used by any SS that wants to synchronize to the system channel for the first time. An initial-ranging transmission shall be performed during two consecutive symbols. The same ranging code is transmitted on the ranging channel during each symbol, with no phase discontinuity between the two symbols. A time-domain illustration of the initial-ranging transmission is shown in Figure 128bc.

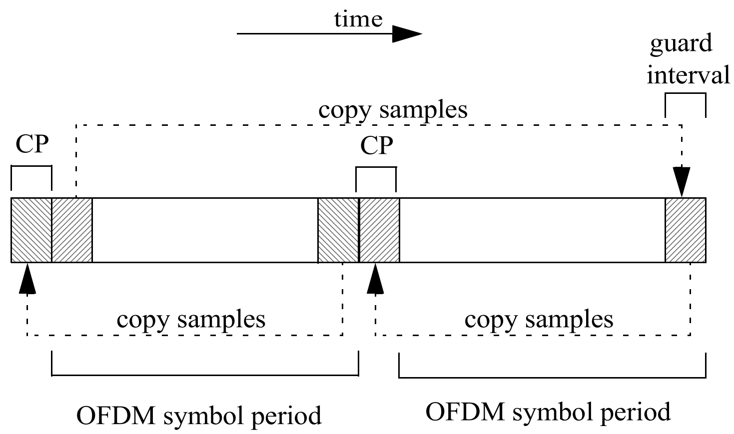

Figure 128bc—Initial-ranging transmission for OFDMA

8.5.7.2 Periodic-ranging and bandwidth-request transmissions

Periodic-ranging transmissions are sent periodically for system periodic ranging. Bandwidth-requests transmissions are for requesting UL allocations from the BS.

These transmissions shall be sent only by SS that have already synchronized to the system.

To perform either a periodic-ranging or bandwidth-request transmission, the SS shall modulate one ranging code on the ranging subchannel for a period of one OFDM symbol. Ranging subchannels are dynamically allocated by the MAC and indicated in the UL-MAP. A time-domain illustration of the periodic-ranging or bandwidth-request transmission is shown in Figure 128bd.

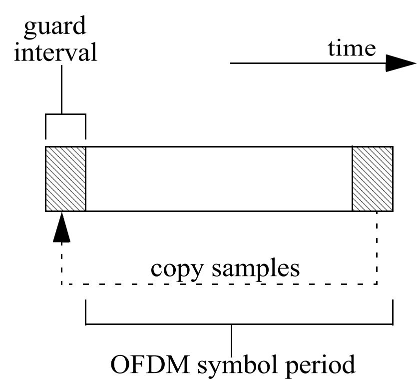

Figure 128bd—Periodic-ranging or bandwidth-request transmission for OFDMA

8.5.7.3 Ranging codes

The binary codes are the pseudo-noise (PN) codes produced by the PRBS described in Figure 128be, which implements the polynomial generator $1 + X^1 + X^4 + X^7 + X^{15}$.

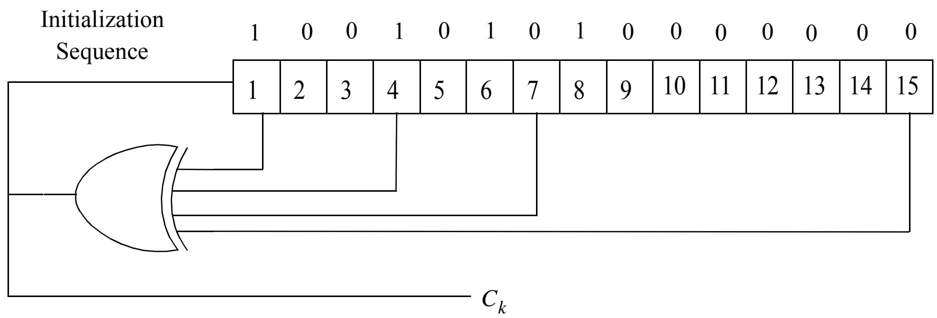

Figure 128be—PRBS for ranging code generation

The binary ranging codes are subsequences of the pseudo-noise sequence appearing at its output C_k. The length of each ranging code is 106 bits. These bits are used to modulate the sub-carriers in a pair of adjacent subchannels. The index of the lowest numbered subchannel in the pair is even. The pair is called a ranging subchannel. The ranging subchannel is referenced in the ranging and BW request messages by the index of lower numbered subchannel. The default allocation for the ranging channel is one ranging subchannel.

For example, if the BS has defined the ranging channel to be the default two subchannels, the first 106-bit code obtained by clocking the PN generator as specified, the first code shall be 011110000011111... The next ranging code is produced by taking the output of the 107th to 212th clock of the PRBS, etc.

The number of available codes is 48, numbered 0..47. These codes are divided in three usage groups (initial-ranging, periodic-ranging and bandwidth-requests). The codes are allocated dynamically to the groups by the BS. The default number of codes for each group is two.

— The first *N* codes produced are for initial-ranging. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *0* times to 106 *x N-1* times.
— The next *M* codes produced are for periodic-ranging. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *106 x N* times to *106 x (N + M)-1* times.
— The next *L* codes produced are for bandwidth-requests. For example, for the default case of two subchannels in the ranging channel, clock the PRBS *106 x (N + M)* times to *106 x (N + M + L)-1* times.

The BS can separate colliding codes and extract timing (ranging) information and power. In the process of user code detection, the BS gets the Channel Impulse Response (CIR) of the code, thus acquiring for the BS vast information about the user channel and condition. The time (ranging) and power measurements allow the system to compensate for the near/far user problems and the propagation delay caused by large cells.

8.5.8 Transmit diversity: Space-Time Coding (optional)

Space-Time Coding (STC) (see [B26]) may be used on the downlink to provide 2nd order (Space) transmit diversity.

There are two transmit antennas on the BS side and one reception antenna on the SS side. This scheme requires multiple input single output channel estimation. Decoding is very similar to maximum ratio combining.

Figure 128bf shows STC insertion into the OFDM chain. Each Tx antenna has its own OFDM chain, but they have the same Local Oscillator for synchronization purposes.

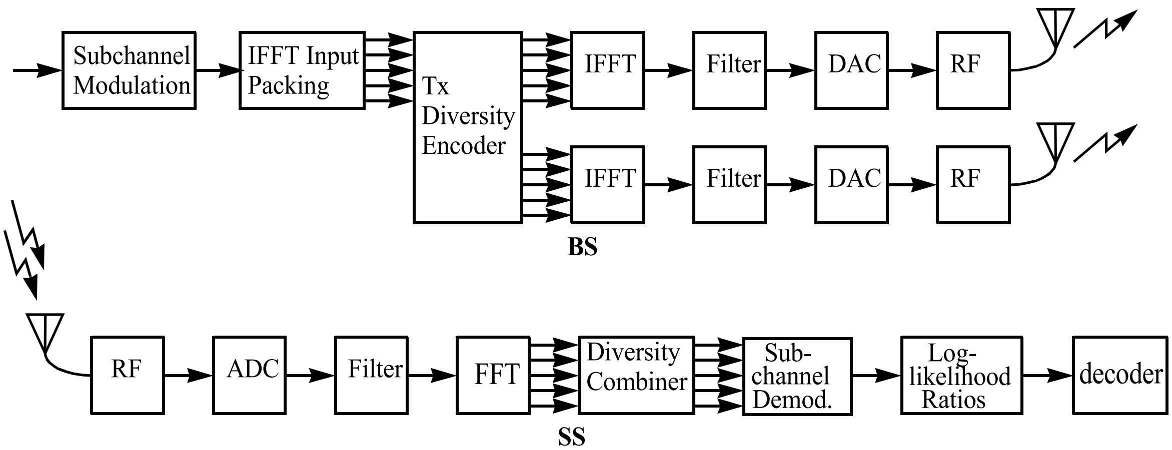

Figure 128bf—Illustration of STC

Both antennas transmit in the same time 2 different OFDM data symbols. Transmission is performed twice to decode and to get 2nd order diversity. Time domain (Space-Time) repetition is used.

8.5.8.1 Multiple in single out channel estimation and synchronization

Both antennas transmit in the same time, and they share the same Local Oscillator. Thus, the received signal has exactly the same auto-correlation properties as for a single antenna. So, time and frequency coarse and fine estimation can be performed in the same way as for a single antenna. The scheme requires multiple input single output channel estimation, which is allowed by splitting some preambles and pilots between the 2 Tx antennas, as described in 8.5.8.2.

8.5.8.2 STC encoding

The basic scheme [B26] transmits 2 complex symbols s_0 and s_1, using the multiple input single output channel (two Tx, one Rx) twice with channel vector values h_0 (for antenna 0) and h_1 (for antenna 1).

First channel use: Antenna0 transmits s_0, antenna1 transmits s_1.

Second channel use: Antenna0 transmits $-s_1*$, antenna1 transmits s_0*.

Receiver gets r_0 (first channel use) and r_1 (second channel use) and computes s_0 and s_1 estimates:

$$\hat{s}_0 = h_0* \cdot r_0 + h_1 \cdot r_1* \tag{70}$$

$$\hat{s}_1 = h_1* \cdot r_0 - h_0 \cdot r_1* \tag{71}$$

These estimates benefit from 2nd order diversity as in the 1Tx-2Rx Maximum Ratio Combining scheme. OFDM symbols are taken by pairs. (Equivalently, 2 Tx symbol duration is twice 1 Tx symbol duration, with twice more data in a symbol.) In the transmission frame, variable location pilots are kept identical for two symbols and L is constant for the duration of two symbols (see 8.5.6.1 for definition of L). STC is applied independently on each carrier, in respect to pilot tones positions.

Figure 128bg shows STC for OFDMA. Note that since pilot positions do not change from even to odd symbols, and pilot modulation is real, conjugation (and inversion) can be applied to a whole symbol (possibly in the time domain).

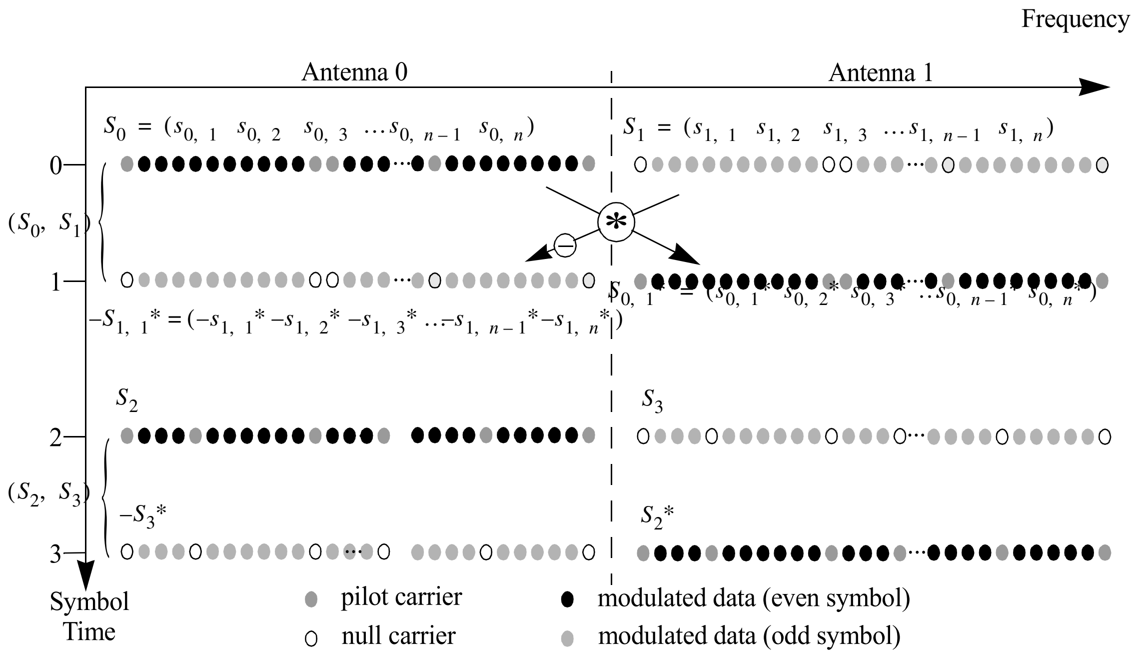

Figure 128bg— STC usage with OFDMA

8.5.8.3 STC decoding

The receiver waits for 2 symbols, and combines them on a carrier basis according to Equation (70) and Equation (71) in 8.5.8.2.

8.5.9 Channel coding

Channel coding procedures include randomization (see 8.5.9.1), FEC encoding (see 8.5.9.2), interleaving (see 8.5.9.3) and modulation (see 8.5.9.4).

8.5.9.1 Randomization

Data randomization is performed on data transmitted on the DL and UL. The randomization is performed on each allocation (DL or UL), which means that for each allocation of a data block (subchannels on the frequency domain and OFDM symbols on the time domain) the randomizer shall be used independently. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF ('1' only) shall be added to the end of the transmission block, up to the amount of data allocated.

The shift-register of the randomizer shall be initialized for each new allocation or for every 1250 bytes passed through (if the allocation is larger then 1250 bytes).

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + X^{14} + X^{15}$ as shown in Figure 128bh. Each data byte to be transmitted shall enter sequentially into the randomizer, msb first. Preambles are not randomized. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The randomizer sequence is applied only to information bits.

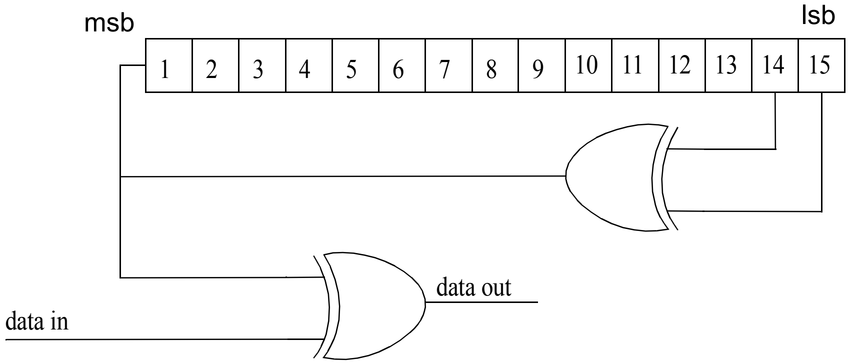

Figure 128bh—PRBS for data randomization

The bit issued from the randomizer shall be applied to the encoder.

In the downlink, the scrambler shall be re-initialized at the start of each frame with the sequence:

(msb) 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0 (lsb)

The produced sequence from the PRBS shall start with: 0 0 0 0 0 0 1 1 1 1 1 1 0 1 1 0 ....

In the uplink, the scrambler is initialized with the vector created as shown in Figure 128bi.

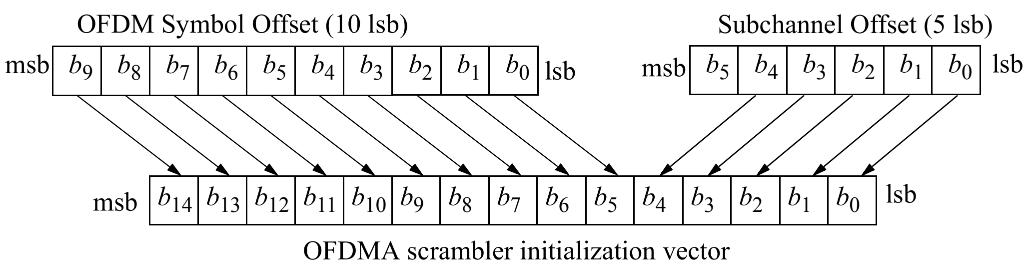

Figure 128bi—Creation of OFDMA scrambler initialization vector

8.5.9.2 FEC

A FEC, consisting of the concatenation of a Reed-Solomon outer code and a rate-compatible convolutional inner code, shall be supported on both UL and DL. Support of BTC and CTC is optional. The Reed-Solomon-Convolutional coding rate 1/2 with QPSK modulation, shall always be used as the default mode when requesting access to the network (except when using CDMA ranging) and in the DL Frame Prefix.

8.5.9.2.1 Concatenated Reed-Solomon / convolutional code (RS-CC)

The Reed-Solomon encoding shall be derived from a systematic RS (N=255, K=239, T=8) code using GF(2^8), where:

N is the number of overall bytes after encoding

K is the number of data bytes before encoding

T is the number of data bytes which can be corrected.

The following polynomials are used for the systematic code:

Code Generator Polynomial: $$g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)..(x+\lambda^{2T-1}),\ \lambda = 02_{HEX} \quad (72)$$

Field Generator Polynomial: $$p(x) = x^8+x^4+x^3+x^2+1 \quad (73)$$

This code is shortened and punctured to enable variable block sizes and variable error-correction capability. When a block is shortened to K' data bytes, the first 239-K' bytes of the encoder block shall be zero. When a codeword is punctured to permit T' bytes to be corrected, only the first 2T' of the total 16 codeword bytes shall be employed. The bit/byte conversion shall be msb first.

Each RS block is encoded by the binary convolutional encoder, which shall have native rate of 1/2, a constraint length equal to K=7, and shall use the following generator polynomials codes to derive its two code bits:

$$\begin{array}{ll} G_1 = 171_{OCT} & FOR\ X \\ G_2 = 133_{OCT} & FOR\ Y \end{array} \quad (74)$$

The generator is depicted in Figure 128bj.

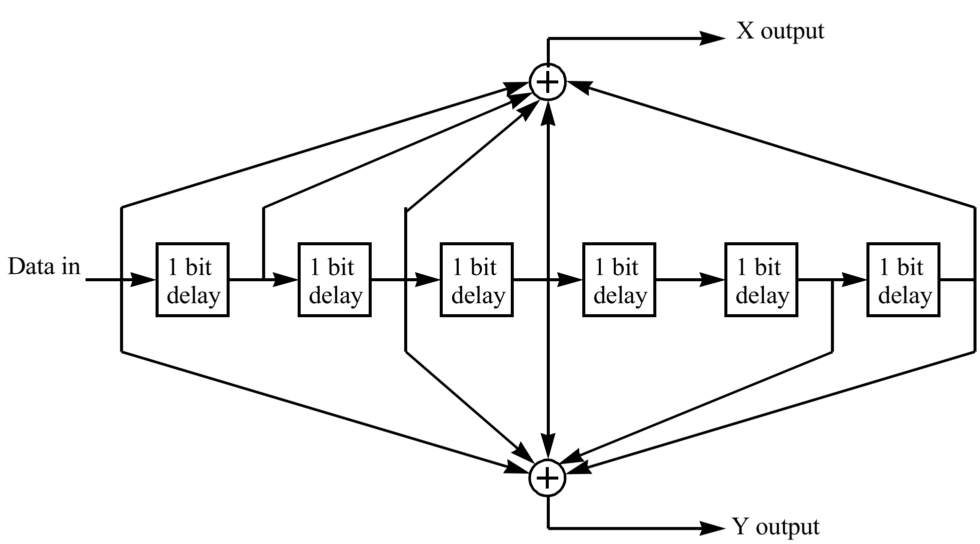

Figure 128bj—Convolutional encoder of rate 1/2

Puncturing patterns and serialization order which shall be used to realize different code rates are defined in Table 116cd. In the table, “1” means a transmitted bit and “0” denotes a removed bit, whereas X and Y are in reference to Figure 128bj.

Table 116cd—The inner convolutional code with puncturing configuration

	Code Rates		
Rate	2/3	3/4	5/6
d_{free}	6	5	4
X	10	101	10101
Y	11	110	11010
XY	$X_1Y_1Y_2$	$X_1Y_1Y_2X_3$	$X_1Y_1Y_2X_3Y_4X_5$

In order to allow sharing of the error correction decoder, each of the multiple data streams subdivides its data into RS blocks. Each RS block is encoded by a tail-biting convolutional encoder, which is achieved by initializing the encoders memory with the last data bits of the RS block being encoded (the packet data bits are numbered $b_b..b_n$).

Six schemes are defined, as shown in Table 116ce. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ce—Mandatory channel coding per modulation

Modulation	Uncoded block size (bytes)	Overall coding rate	Coded block size (bytes)	RS code	CC code rate
QPSK	18	1/2	36	(24,18,3)	2/3
QPSK	26	~3/4	36	(30,26,2)	5/6
16-QAM	36	1/2	72	(48,36,6)	2/3
16-QAM	54	3/4	72	(60,54,3)	5/6
64-QAM	72	2/3	108	(81,72,4)	3/4
64-QAM	82	~3/4	108	(90,82,4)	5/6

8.5.9.2.2 Block Turbo Coding (optional)

The BTC is based on the product of two simple component codes, which are binary extended Hamming codes or parity check codes from the set depicted in Table 116cf.

Table 116cf—BTC component codes

Component code (n,k)	Code type
(64,57)	Extended Hamming code
(32,26)	Extended Hamming code
(16,11)	Extended Hamming code
(32,31)	Parity check code
(16,15)	Parity check code
(8,7)	Parity check code

Table 116cg specifies the generator polynomials for the Hamming codes. To create extended Hamming codes, an overall even parity check bit is added at the end of each code word.

Table 116cg—Hamming code generator polynomials

n’	k’	Generator polynomial
7	4	X^3+X^1+1
15	11	X^4+X^1+1
31	26	X^5+X^2+1
63	57	X^6+X+1

The component codes are used in a two-dimensional matrix form, which is depicted in Figure 128bl. The k_x information bits in the rows are encoded into n_x bits, by using the component block (n_x, k_x) code specified for the respective composite code. After encoding the rows, the columns are encoded using a block code (n_y, k_y), where the check bits of the first code are also encoded. The overall block size of such a product code is $n = n_x \times n_y$, the total number of information bits $k = k_x \times k_y$ and the code rate is $R = R_x \times R_y$, where $R_i = k_i / n_i$, $i=x, y$. The Hamming distance of the product code is $d = d_x \times d_y$. Data bit ordering for the composite BTC matrix is the first bit in the first row is the lsb and the last data bit in the last data row is the msb.

Figure 128bk illustrates an example of a BTC encoded with $(8, 4) \times (8, 4)$ extended Hamming component codes.

D_{11}	D_{21}	D_{31}	D_{41}	E_{51}	E_{61}	E_{71}	E_{81}
D_{12}	D_{22}	D_{32}	D_{42}	E_{52}	E_{62}	E_{72}	E_{82}
D_{13}	D_{23}	D_{33}	D_{43}	E_{53}	E_{63}	E_{73}	E_{83}
D_{14}	D_{24}	D_{34}	D_{44}	E_{54}	E_{64}	E_{74}	E_{84}
E_{15}	E_{25}	E_{35}	E_{45}	E_{55}	E_{65}	E_{75}	E_{85}
E_{16}	E_{26}	E_{36}	E_{46}	E_{56}	E_{66}	E_{76}	E_{86}
E_{17}	E_{27}	E_{37}	E_{47}	E_{57}	E_{67}	E_{77}	E_{87}
E_{18}	E_{28}	E_{38}	E_{48}	E_{58}	E_{68}	E_{78}	E_{88}

Figure 128bk—Example of an encoded BTC block

Transmission of the block over the channel shall occur in a linear fashion, with all bits of the first row transmitted left to right followed by the second row, etc. For the $(8, 4) \times (8, 4)$ example in Figure 128bk, the output order for the 64 encoded bits would be: D_{11}, D_{21}, D_{31}, D_{41}, E_{51}, E_{61}, E_{71}, E_{81}, D_{12}, D_{22},..., E_{88}.

To match a required packet size, BTCs may be shortened by removing symbols from the BTC array. In the two-dimensional case, rows, columns or parts thereof can be removed until the appropriate size is reached. There are three steps in the process of shortening product codes:

Step 1) Remove I_x rows and I_y columns from the two-dimensional code. This is equivalent to shortening the constituent codes that make up the product code.

Step 2) Remove B individual bits from the first row of the two-dimensional code starting with the lsb.

Step 3) Use if the product code specified from Step 1) and Step 2) of this subclause has a non-integral number of data bytes. In this case, the Q left over lsb bits are zero filled by the encoder. After decoding at the receive end, the decoder shall strip off these unused bits and only the specified data payload is passed to the next higher level in the physical layer. The same general method is used for shortening the last code word in a message where the available data bytes do not fill the available data bytes in a code block.

These three processes of code shortening are depicted in Figure 128bl. In the first two-dimensional BTC, a non-shortened product code is shown. By comparison, a shortened BTC is shown in the adjacent two-dimensional array. The new coded block length of the code is $(n_x-I_x)(n_y-I_y)-B$. The corresponding information length is given as $(k_x-I_x)(k_y-I_y)-B-Q$. Consequently, the code rate is given by:

$$R = \frac{(k_x - I_x)(k_y - I_y) - B - Q}{(n_x - I_x)(n_y - I_y) - B} \tag{75}$$

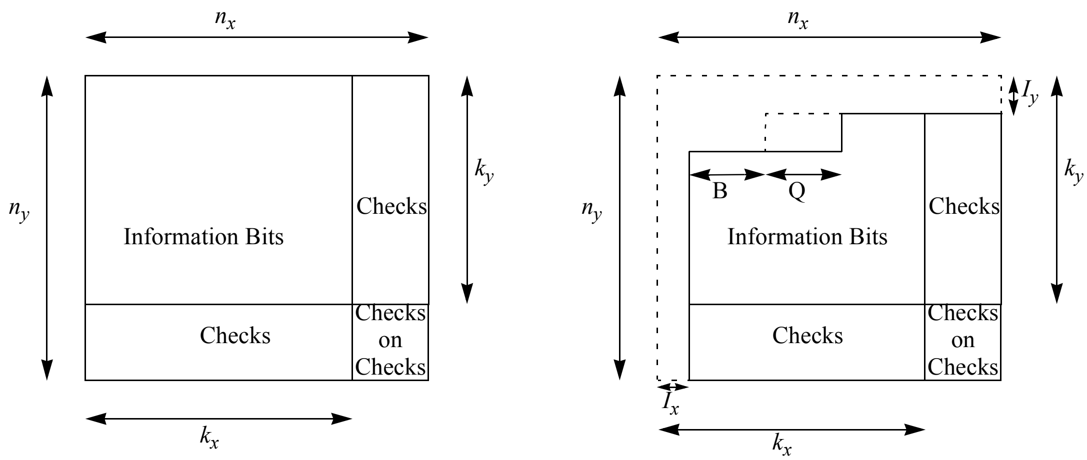

Figure 128bl—BTC and shortened BTC structure

Table 116ch gives the block sizes, code rates, channel efficiency, and code parameters for the optional modulation and coding schemes using BTC.

Table 116ch—Optional channel coding per codulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall coding rate	Efficiency bit/s/Hz	Constituent codes	Code parameters
QPSK	16	36	~1/2	0.9	(32,26)(16,11)	I_x=11,I_y=2,B=6,Q=7
QPSK	25	36	~2/3	1.4	(8,7)(64,57)	I_x=2,I_y=16,B=0,Q=5
16-QAM	40	72	~3/5	2.2	(32,26)(32,26)	I_x=8,I_y=8,B=0,Q=4
16-QAM	56	72	~4/5	3.1	(16,15)(64,57)	I_x=4,I_y=16,B=0,Q=3
64-QAM	68	108	~5/8	3.8	(32,26)(32,26)	I_x=0,I_y=5,B=0,Q=2
64-QAM	88	108	~4/5	4.9	(16,15)(64,57)	I_x=0,I_y=10,B=0,Q=1

8.5.9.2.3 Convolutional turbo codes (optional)

8.5.9.2.3.1 CTC encoder

The Convolutional Turbo Code encoder, including its constituent encoder, is depicted in Figure 128bm. It uses a double binary Circular Recursive Systematic Convolutional code. The bits of the data to be encoded are alternately fed to *A* and *B*, starting with the msb of the first byte being fed to *A*. The encoder is fed by blocks of k bits or N couples (k = 2*N bits). For all the frame sizes k is a multiple of 8 and N is a multiple of 4. Further N shall be limited to: $8 \leq N/4 \leq 1024$.

The polynomials defining the connections are described in octal and symbol notations as follows:

— For the feedback branch: 0xB, equivalently $1+D+D^3$ (in symbolic notation)
— For the Y parity bit: 0xD, equivalently $1+D^2+D^3$

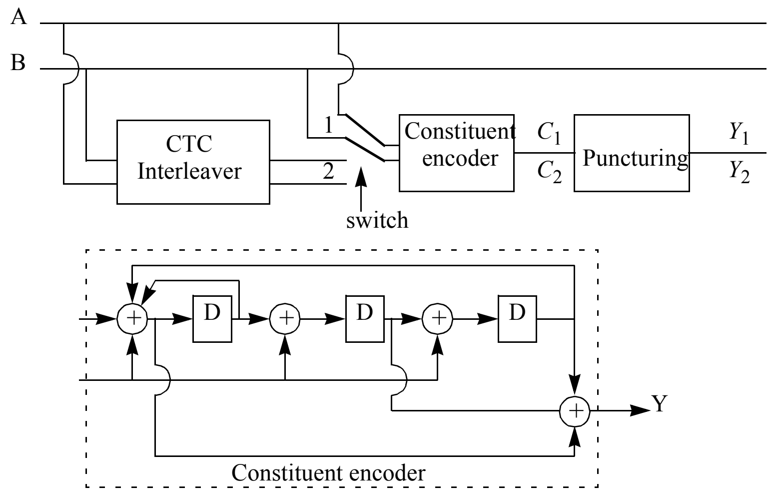

Figure 128bm—CTC encoder

First, the encoder (after initialization by the circulation state Sc_1, see 8.5.9.2.3.3) is fed the sequence in the natural order (position 1) with the incremental address $i = 0 .. N–1$. This first encoding is called C_1 encoding. Then the encoder (after initialization by the circulation state Sc_2, see 8.5.9.2.3.3) is fed by the interleaved sequence (switch in position 2) with incremental address $j = 0, \ldots N–1$. This second encoding is called C_2 encoding.

The order in which the encoded bit shall be fed into the interleaver (8.5.9.3) is:

$$A_0, B_0 .. A_{N-1}, B_{N\text{-}1}, Y_{10}, Y_{1,1} .. Y_{1,M}, Y_{20}, Y_{2,1} .. Y_{2,\mathrm{M}},$$

where M is the number of parity bits.

Table 116ci gives the block sizes, code rates, channel efficiency, and code parameters for the different modulation and coding schemes. As 64-QAM is optional, the codes for this modulation shall only be implemented if the modulation is implemented.

Table 116ci—Optional CTC channel coding per modulation

Modulation	Data block size (bytes)	Coded block size (bytes)	Overall code rate	N	P_0	P_1	P_2	P_3
QPSK	18	36	1/2	72	11	6	0	6
QPSK	24	36	2/3	96	7	48	24	72
QPSK	27	36	3/4	108	11	54	56	2
16-QAM	36	72	1/2	144	17	74	72	2
16-QAM	54	72	3/4	216	31	2	4	10
64-QAM	72	108	2/3	288	13	144	72	216
64-QAM	81	108	3/4	324	11	172	164	16

8.5.9.2.3.2 CTC interleaver

The interleaver requires the parameters P_0 and P_1, shown in Table 116ci.

The two-step interleaver shall be performed by:

Step 1: Switch alternate couples

for $j = 1..N$

if (j_{mod_2}==0) let (B,A) = (A,B) (i.e. switch the couple)

Step 2: *$P_i(j)$*

The function $P_i(j)$ provides the interleaved address i of the consider couple j.

for $j = 1..N$

switch j_{mod_4}:

case 0: $i = (P_0 \cdot j + 1)_{\mathrm{mod}_N}$

case 1: $i = (P_0 \cdot j + 1 + N/2 + P_1)_{\mathrm{mod}_N}$

case 2: $i = (P_0 \cdot j + 1 + P_2)_{\mathrm{mod}_N}$

case 3: $i = (P_0 \cdot j + 1 + N/2 + P_3)_{\mathrm{mod}_N}$

8.5.9.2.3.3 Determination of CTC circulation states

The state of the encoder is denoted S (0 <= S == 7) with S the value read binary (left to right) out of the constituent encoder memory (see Figure 128bm). The circulation states Sc_1 and Sc_2 are determined by the following operations:

1) Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is $S0_{N-1}$;
2) according to the length N of the sequence, use Figure 116cj to find Sc_1 or Sc_2.

Table 116cj—Circulation state lookup table (*Sc*)

N_{mod_7}	$S0_{N-1}$							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	4	2	7	1	3	5
2	0	3	7	4	5	6	2	1
3	0	5	3	6	2	7	1	4
4	0	4	1	5	6	2	7	3
5	0	2	5	7	1	3	4	6
6	0	7	6	1	3	4	5	2

8.5.9.2.3.4 CTC puncturing

The three code-rates are achieved through selectively deleting the parity bits (puncturing). The puncturing patterns are identical for both codes C_1 and C_2.

Table 116ck—Circulation state lookup table (*Sc*)

Rate $R_n/(R_n+1)$	Y					
	0	**1**	**2**	**3**	**4**	**5**
1/2	1	1				
2/3	1	0	1	0		
3/4	1	0	0	1	0	0

8.5.9.3 Interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the specified allocation, N_{cbps} (see Table 116cl). The interleaver is defined by a two-step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent carriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Table 116cl—Bit Interleaved Block Sizes and Modulo

Modulation	Coded bits per bit interleaved block (N_{cbps})	Modulo used (d)
QPSK	288	16
16-QAM	576	18
64-QAM	864	16

Let N_{cpc} be the number of coded bits per carrier, i.e., 2, 4 or 6 for QPSK, 16Q-AM or 64-QAM, respectively. Let $s = N_{\text{cpc}}/2$. Let k be the index of the coded bit before the first permutation at transmission, m be the index after the first and before the second permutation and j be the index after the second permutation, just prior to modulation mapping, and d be the modulo used for the permutation.

The first permutation is defined by the rule:

$$m = (N_{\text{cbps}}/d) \cdot k_{mod(d)} + floor(k/d) \qquad k = 0, 1, \ldots, N_{\text{cbps}} - 1 \tag{76}$$

The second permutation is defined by the rule:

$$j = s \cdot floor(m/s) + (m + N_{\text{cbps}} - floor(d \cdot m/N_{\text{cbps}}))_{mod\ s} \qquad m = 0, 1, \ldots, N_{\text{cbps}} - 1 \tag{77}$$

The de-interleaver, which performs the inverse operation, is also defined by two permutations. Let j be the index of the received bit before the first permutation, m be the index after the first and before the second permutation and k be the index after the second permutation, just prior to delivering the coded bits to the convolutional decoder.

The first permutation is defined by the rule:

$$m = s \cdot floor(j/s) + (j + floor(d \cdot j/N_{\text{cbps}}))_{mod\ s} \qquad j = 0, 1, \ldots, N_{\text{cbps}} - 1 \qquad (78)$$

The second permutation is defined by the rule:

$$k = d \cdot m - (N_{\text{cbps}} - 1) \cdot floor(d \cdot m/N_{\text{cbps}}) \qquad m = 0, 1, \ldots, N_{\text{cbps}} - 1 \qquad (79)$$

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely.

8.5.9.4 Modulation

8.5.9.4.1 Data modulation

After bit interleaving, the data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM as shown in Figure 128bn shall be supported, whereas the support of 64-QAM is optional. The constellations as shown in Figure 128bn shall be normalized by multiplying the constellation point with the indicated factor *c* to achieve equal average power.

Per-allocation adaptive modulation and coding shall be supported in the DL. The UL shall support different modulation schemes for each SS based on the MAC burst configuration messages coming from the Base Station. Complete description of the MAC / PHY support of adaptive modulation and coding is provided in 6.2.7.

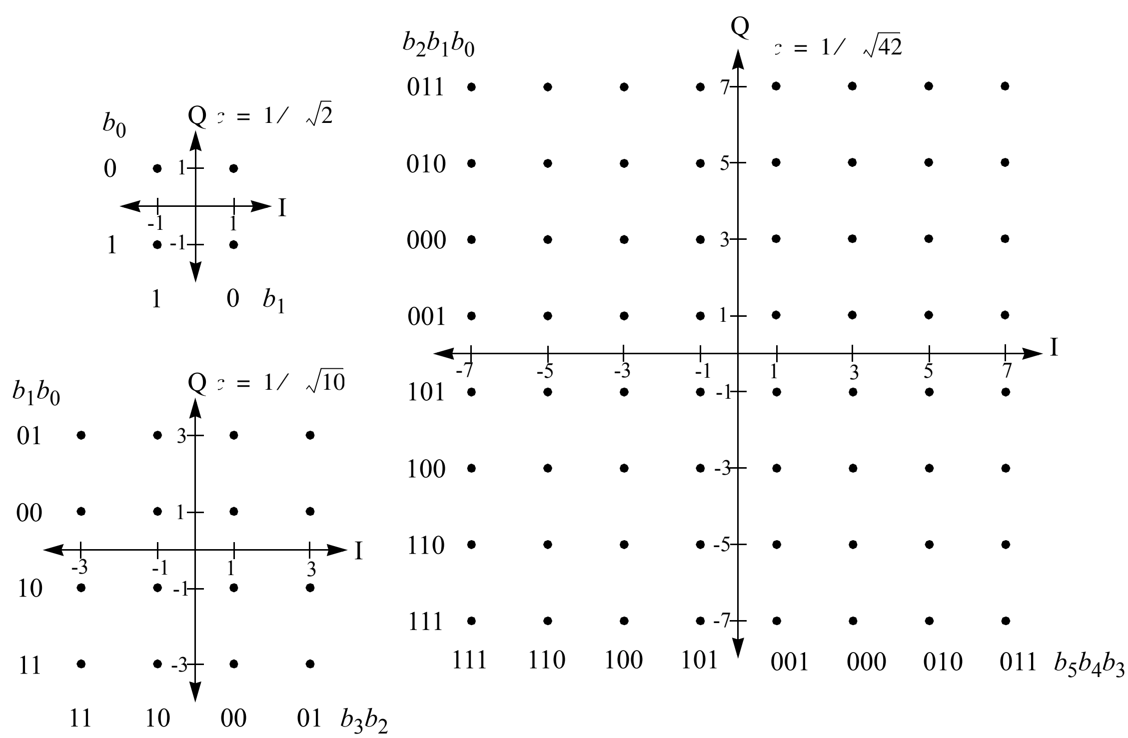

Figure 128bn—QPSK, 16-QAM and 64-QAM constellations

The constellation-mapped data shall be subsequently modulated onto the allocated data carriers.

8.5.9.4.2 Modulation and coding in the DL frame prefix

Rate_ID's, which indicate modulation and coding to be used in the first DL burst immediately following the FCH, are shown in Table 116cm. The Rate_ID encoding is static and cannot be changed during system operation.

Table 116cm—Rate ID encodings

Rate_ID	Modulation RS-CC rate
0	QPSK 1/2
1	QPSK 3/4
2	16-QAM 1/2
3	16-QAM 3/4
4	64-QAM 2/3
5	64-QAM 3/4
6–15	Reserved

8.5.9.4.3 Pilot modulation

Pilot carriers shall be inserted into each data burst in order to constitute the Symbol and they shall be modulated according to their carrier location within the OFDMA symbol. The PRBS generator depicted hereafter shall be used to produce a sequence, w_k. The polynomial for the PRBS generator shall be $X^{11} + X^9 + 1$.

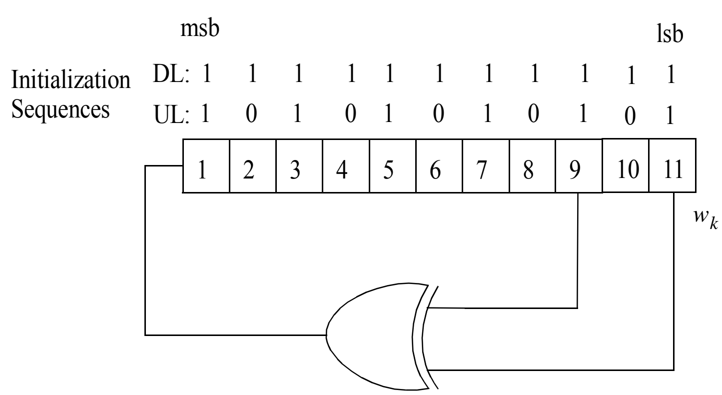

Figure 128bo—PRBS for pilot modulation

The value of the pilot modulation, on carrier *k*, shall be derived from w_k.

When using data transmission on the DL, the initialization vector of the PRBS is: [11111111111] except for the OFDMA DL PHY preamble (see 8.5.9.4.3.1). When using data transmission on the UL the initialization vector of the PRBS shall be: [10101010101]. These initializations result in the sequence w_k=11111111111000000001..... in the DL, and the sequence w_k=10101010101000000000.... in the UL. The PRBS shall be initialized so that its first output bit coincides with the first usable carrier (as defined in Table 116cb). A new value shall be generated by the PRBS on every usable carrier. For the PRBS allocation, the

DC carrier and the side-band carriers are not considered as usable carriers. Each pilot shall be transmitted with a boosting of 2.5 dB over the average power of each data tone, (including the UL preamble). The Pilot carriers shall be modulated according to the following formula:

$$\begin{aligned}\operatorname{Re}\{c_k\} &= \frac{8}{3}\left(\frac{1}{2} - w_k\right)\\ \operatorname{Im}\{c_k\} &= 0\end{aligned} \tag{80}$$

A ranging pilot modulation exception is defined in 8.5.9.4.3.2.

8.5.9.4.3.1 Preambles pilot modulation

The initialization vector of the pilot modulation PRBS (defined in 8.5.9.4.3) for the symbol in which the DL-MAP message starts, and two consecutive symbols thereafter is [01010101010]. These three symbols serve as the OFDMA DL preamble, in the sense that they indicate where the OFDMA frame starts. The pilots shall be boosted and shall be modulated according to the following formula:

$$\begin{aligned}\operatorname{Re}\{c_k\} &= \frac{8}{3}\left(\frac{1}{2} - w_k\right)\\ \operatorname{Im}\{c_k\} &= 0\end{aligned} \tag{81}$$

For the UL preamble, the pilots shall not be boosted and shall be modulated according to the following formula

$$\begin{aligned}\operatorname{Re}\{c_k\} &= 2\left(\frac{1}{2} - w_k\right)\\ \operatorname{Im}\{c_k\} &= 0\end{aligned} \tag{82}$$

8.5.9.4.3.2 Ranging pilot modulation

The BPSK modulation on the ranging transmissions, real and imaginary parts, is defined by the formula:

$$\begin{aligned}\operatorname{Re}\{c_k\} &= 2\cdot(1/2 - C_k)\\ \operatorname{Im}\{c_k\} &= 0\end{aligned} \tag{83}$$

where c_k is the k^{th} carrier of the Ranging Channel, and C_k is the k^{th} bit of the code generated according to 8.5.7.3

8.5.9.4.4 Example OFDMA UL RS-CC encoding

An example of one frame of OFDMA UL data is provided, illustrating each process from randomization through carrier modulation.

Modulation mode: 16-QAM-1/2, Slot Offset: 50, Subchannel Offset: 3, ID_{cell}: 5, UIUC: 4 (decimal values).

Input Data (Hex)

45 29 C4 79 AD 0F 55 28 AD 87 B5 76 1A 9C 80 50 45 1B 9F D9 2A 88 95 EB AE B5 2E 03 4F 09 14 69 58 0A 5D F5

Randomized Data (Hex)

5B 23 80 44 35 82 06 07 47 67 CB 37 1F 1A 9D 44 0B 62 3A CC F4 F4 50 E1 30 8A 6A 80 D4 00 4E 5E 84 BA 96 57

Reed-Solomon encoded Data (Hex)

5B 23 80 44 35 82 06 07 47 67 CB 37 1F 1A 9D 44 0B 62 3A CC F4 F4 50 E1 30 8A 6A 80 D4 00 4E 5E 84 BA 96 57 3A CE 4E 81 36 AB DA 26 13 3E D1 3B

Convolutional encoded Data (Hex)

F4 51 D6 42 63 7E D1 B0 90 E7 B2 BA A5 1B E8 BA 57 B5 37 BC F7 66 B1 A6 CF 04 A4 39 69 77 02 79 A7 5D D9 05 64 F7 FF F0 BC 3E ED EA C0 34 F2 11 AF 30 E8 A5 B7 A7 EC E9 71 27 FC FF A4 44 F7 48 AA 42 ED 92 03 5E 2C 7F

Interleaved Data (Hex)

72 4C 64 A4 06 5F 16 57 99 F2 3B F2 AC 15 D2 B7 46 62 0E A0 C2 05 FD FA 8B B3 10 F5 6C 7A 9E 43 77 E5 BB 1F F2 4F 1B 9F 93 5A E3 5C ED F6 12 7E 3C 45 3B 94 CB 63 24 A1 BC F7 E3 9B BE 8F BD 2F CD 23 2E F5 42 B2 C9 8F

Carrier Mapping (subchannel carrier number - usable carrier number: I value Q value,) preamble not shown.

0-13: 4/3 0, 1-53: 3 -3, 2-79: 1 -1, 3-112: 3 1, 4-148: -3 1, 5-191: 3 -1, 6-219: 3 1, 7-235: -1 -1, 8-270: 3 1, 9-288: 1 1, 10-345: 3 -1, 11-382: 3 3, 12-390: -3 -3, 13-418: -4/3 0, 14-460: 1 3, 15-506: 3 -1, 16-522: 3 3, 17-545: 3 -3, 18-580: -1 3, 19-636: -1 3, 20-662: -3 -3, 21-681: 1 -1, 22-733: 1 -3, 23-741: -1 -3, 24-786: -3 -3, 25-817: 1 -1, 26-856: -4/3 0, 27-883: 4/3 0, 28-899: -1 -1, 29-936: -3 1, 30-983: 1 3, 31-999: 3 3, 32-1042: -3 3, 33-1082: 1 -1, 34-1108: -1 -3, 35-1141: 3 -3, 36-1177: 3 1, 37-1188: 3 -1, 38-1216: 3 -1, 39-1264: 1 -1, 40-1299: -4/3 0, 41-1317: 1 1, 42-1374: -3 -1, 43-1379: -1 -1, 44-1419: 1 1, 45-1447: -3 1, 46-1489: 1 -1, 47-1535: 1 1, 48-1551: 3 3, 49-1574: -3 -3, 50-1609: -3 3, 51-1633: -3 -3, 52-1691: -1 -1,
0-13: -1 1, 1-53: -1 -3, 2-79: 4/3 0, 3-112: -1 -3, 4-148: 1 -3, 5-191: 1 3, 6-219: 1 1, 7-235: -3 -3, 8-270: 3 3, 9-288: 3 -1, 10-345: -3 1, 11-382: 3 -3, 12-390: -1 -1, 13-418: -1 3, 14-460: -3 -1, 15-506: -4/3 0, 16-522: 3 1, 17-545: 1 -3, 18-580: 3 -3, 19-636: 3 -3, 20-662: -3 -1, 21-681: 3 3, 22-733: -1 -3, 23-741: -1 -3, 24-786: 1 3, 25-817: -3 -3, 26-856: -4/3 0, 27-883: -3 -3, 28-899: 1 -1, 29-936: -4/3 0, 30-983: 3 1, 31-999: -3 -3, 32-1042: 1 3, 33-1082: -1 -3, 34-1108: -1 3, 35-1141: -3 -3, 36-1177: -1 3, 37-1188: 1 -3, 38-1216: 3 3, 39-1264: -1 -1, 40-1299: -3 -1, 41-1317: 1 -3, 42-1374: 4/3 0, 43-1379: 3 3, 44-1419: -3 1, 45-1447: -3 -1, 46-1489: -3 3, 47-1535: -3 -3, 48-1551: 3 -1, 49-1574: 1 3, 50-1609: 1 -1, 51-1633: 3 -3, 52-1691: -3 -1,
0-13: 1 -3, 1-53: -3 1, 2-79: 3 1, 3-112: 3 3, 4-148: 4/3 0, 5-191: 1 -3, 6-219: -1 -3, 7-235: -1 3, 8-270: 3 1, 9-288: -3 1, 10-345: -1 -3, 11-382: 3 -1, 12-390: 1 -3, 13-418: 1 -1, 14-460: 3 1, 15-506: -1 -1, 16-522: 1 3, 17-545: -4/3 0, 18-580: -1 -3, 19-636: -3 1, 20-662: -3 -3, 21-681: 3 -3, 22-733: -3 -1, 23-741: 1 -3, 24-786: -1 3, 25-817: -1 -3, 26-856: 4/3 0, 27-883: -1 -3, 28-899: -3 -1, 29-936: -1 1, 30-983: -3 -3, 31-999: -4/3 0, 32-1042: -1 -3, 33-1082: -3 3, 34-1108: 1 -1, 35-1141: -3 -3, 36-1177: -3 1, 37-1188: -3 3, 38-1216: 1 -1, 39-1264: 1 -3, 40-1299: 1 -1, 41-1317: -3 -1, 42-1374: -3 -3, 43-1379: 3 3, 44-1419: -4/3 0, 45-1447: 3 1, 46-1489: 1 -1, 47-1535: -1 -3, 48-1551: 1 -1, 49-1574: -3 1, 50-1609: -1 3, 51-1633: -1 1, 52-1691: -3 -3.

8.5.10 Control mechanisms

8.5.10.1 Synchronization

8.5.10.1.1 Network synchronization

For TDD and FDD realizations, it is recommended (but not required) that all BSs be time synchronized to a common timing signal. In the event of the loss of the network timing signal, BSs shall continue to operate and shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing reference shall be a 1pps timing pulse and a 10 MHz frequency reference. These signals are typically provided by a GPS receiver.

For both FDD and TDD realizations, frequency references derived from the timing reference may be used to control the frequency accuracy of Base-Stations provided that they meet the frequency accuracy requirements of 8.5.14. This applies during normal operation and during loss of timing reference.

8.5.10.1.2 SS synchronization

For any duplexing, all SSs shall acquire and adjust their timing such that all uplink OFDM symbols arrive time coincident at the Base-Station to a accuracy of +/– 25% of the minimum guard-interval or better.

8.5.10.2 Ranging

Ranging for time (coarse synchronization) and power is performed during two phases of operation: during (re)registration and when synchronization is lost; and second, during FDD or TDD transmission on a periodic basis.

During registration, a new subscriber registers using the random access channel, and if successful, is entered into a ranging process under control of the base station. The ranging process is cyclic in nature where default time and power parameters are used to initiate the process followed by cycles where (re)calculated parameters are used in succession until parameters meet acceptance criteria for the new subscriber. These parameters are monitored, measured, and stored at the base station, and transmitted to the subscriber unit for use during normal exchange of data. During normal exchange of data, the stored parameters are updated in a periodic manner based on configurable update intervals to ensure changes in the channel can be accommodated. The update intervals shall vary in a controlled manner on a subscriber unit by subscriber unit basis.

Ranging on re-registration follows the same process as new registration.

8.5.10.3 Power control

A power control algorithm shall be supported for the uplink channel with both an initial calibration and periodic adjustment procedure without loss of data. The base station should be capable of providing accurate power measurements of the received burst signal. This value can then be compared against a reference level, and the resulting error can be fed back to the subscriber station in a calibration message coming from the MAC sublayer. The power control algorithm shall be designed to support power attenuation due to distance loss or power fluctuations at rates of at most 30 dB/second with depths of at least 10 dB. The exact algorithm implementation is vendor-specific. The total power control range consists of both a fixed portion and a portion that is automatically controlled by feedback. The power control algorithm shall take into account the interaction of the RF power amplifier with different burst profiles. For example, when changing from one burst profile to another, margins should be maintained to prevent saturation of the amplifier and to prevent violation of emissions masks.

8.5.11 Channel quality measurements

8.5.11.1 Introduction

RSSI and CINR signal quality measurements and associated statistics can aid in such processes as BS selection/assignment and burst adaptive profile selection. As channel behavior is time-variant, both mean and standard deviation are defined. Implementation of the RSSI and CINR statistics and their reports is mandatory.

The process by which RSSI measurements are taken does not necessarily require receiver demodulation lock; for this reason, RSSI measurements offer reasonably reliable channel strength assessments even at low signal levels. On the other hand, although CINR measurements require receiver lock, they provide information on the actual operating condition of the receiver, including interference and noise levels, and signal strength.

8.5.11.2 RSSI mean and standard deviation

When collection of RSSI measurements is mandated by the BS, a SS shall obtain an RSSI measurement from the data associated with MAC map messages. From a succession of RSSI measurements, the SS shall derive and update estimates of the mean and the standard deviation of the RSSI, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics shall be reported in units of dBm. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the RSSI of a single message is left to individual implementation, but the relative accuracy of a single signal strength measurement, taken from a single message, shall be +/– 2 dB, with an absolute accuracy of +/– 4 dB. This shall be the case over the entire range of input RSSIs. In addition, the range over which these single-message measurements are measured should extend 3 dB on each side beyond the –40 dBm to –123 dBm limits for the final averaged statistics that are reported.

The (linear) mean RSSI statistics (in mW), derived from a multiplicity of single messages, shall be updated using

$$\hat{\mu}_{RSSI}[k] = \begin{cases} R[0] & k = 0 \\ (1-\alpha_{\mathrm{avg}})\hat{\mu}_{RSSI}[k-1] + \alpha_{\mathrm{avg}} R[k] & k > 0 \end{cases} \quad \mathrm{mW} \tag{84}$$

where k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.), $R[k]$ is the RSSI in mW measured during message k, and α_{avg} is an averaging parameter specified by the BS. The mean estimate in dBm shall then be derived from

$$\mu_{RSSI\ dBm}[k] = 10\log(\mu_{RSSI}[k]) \quad \mathrm{dBm}. \tag{85}$$

To solve for the standard deviation in dB, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{RSSI}[k] = \begin{cases} |R[0]|^2 & k = 0 \\ (1-\alpha_{\mathrm{avg}})\hat{x}^2_{RSSI}[k-1] + \alpha_{\mathrm{avg}} |R[k]|^2 & k > 0 \end{cases} \tag{86}$$

and the result applied to

$$\hat{\sigma}_{RSSI\ dB} = 5\log\left(\left|\hat{x}^2_{RSSI}[k] - (\hat{\mu}_{RSSI}[k])^2\right|\right) \quad \mathrm{dB}. \tag{87}$$

8.5.11.3 CINR mean and standard deviation

When Carrier-to-Interference-and-Noise-Ratio (CINR) measurements are mandated by the BS, a SS shall obtain a CINR measurement from the data associated with MAC map messages. From a succession of these measurements, the SS shall derive and update estimates of the mean and the standard deviation of the CINR, and report them when solicited via REP-RSP messages.

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be +/– 1 dB and +/– 2 dB, respectively, for all input CINRs above 0 dB. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

One possible method to estimate the CINR of a single message is to compute the ratio of signal power to residual error for each data sample, and then average the results from each data sample, using

$$CINR[k] = \sum_{n=0}^{N-1} \frac{|s[k,\ n]|^2}{|r[k,\ n] - s[k,\ n]|^2} \tag{88}$$

where $r[k,\ n]$ received sample n within message k; $s[k,\ n]$ the corresponding detected or pilot sample (with channel state weighting) corresponding to received symbol n.

The mean CINR statistic (in dB) shall be derived from a multiplicity of single messages using

$$\hat{\mu}_{CINR\ dB}[k] = 10\log(\hat{\mu}_{CINR}[k]), \tag{89}$$

where

$$\hat{\mu}_{CINR}[k] = \begin{cases} CINR[0] & k = 0 \\ (1-\alpha_{\text{avg}})\hat{\mu}_{CINR}[k-1] + \alpha_{\text{avg}} CINR[k] & k > 0 \end{cases} \tag{90}$$

k is the time index for the message (with the initial message being indexed by $k = 0$, the next message by $k = 1$, etc.); $CINR[k]$ is a linear measurement of CINR (derived by any mechanism which delivers the prescribed accuracy) for message k; and α_{avg} is an averaging parameter specified by the BS.

To solve for the standard deviation, the expectation-squared statistic shall be updated using

$$\hat{x}^2_{CINR}[k] = \begin{cases} |CINR[0]|^2 & k = 0 \\ (1-\alpha_{\text{avg}})\hat{x}^2_{CINR}[k-1] + \alpha_{\text{avg}} |CINR[k]|^2 & k > 0 \end{cases} \tag{91}$$

and the result applied to

$$\hat{\sigma}_{CINR\ dB} = 5\log\left(\left|\hat{x}^2_{CINR}[k] - (\hat{\mu}_{CINR}[k])^2\right|\right) \quad \text{dB}. \tag{92}$$

8.5.12 Transmitter requirements

8.5.12.1 Transmit power level control

The transmitter shall support monotonic power level control of 45 dB (30 dB for license-exempt bands) minimum with a minimum step size of 1 dB and a relative accuracy of +/– 0.5 dB.

8.5.12.2 Transmitter spectral flatness

The average energy of the constellations in each of the n spectral lines shall deviate no more than indicated in Table 116cn. The absolute difference between adjacent carriers shall not exceed 0.06 dB excluding intentional boosting or suppression of carriers.

Table 116cn—Spectral flatness

Spectral lines	Spectral flatness
Spectral lines from $-N_{used}/4$ to –1 and +1 to $N_{used}/4$	+/–2 dB from the measured energy averaged over all N_{used} active tones
Spectral lines from $-N_{used}/2$ to $-N_{used}/4$ and $+N_{used}/4$ to $N_{used}/2$	+2/–4 dB from the measured energy averaged over all N_{used} active tones

This data shall be taken from the channel estimation step.

8.5.12.3 Transmitter constellation error and test method

To ensure that the receiver SNR does not degrade more than 0.5 dB due to the transmitter SNR, the relative constellation RMS error, averaged over carriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to Table 116co.

Table 116co—Allowed relative constellation error versus data rate

Burst type	Relative constellation error (dB)
QPSK-1/2	–19.4
QPSK-3/4	–21.2
16-QAM-1/2	–26.4
16-QAM-3/4	–28.2
64-QAM-2/3	–32.7
64-QAM-3/4	–34.4

All measurement errors taken together shall be 10 dB less than the required noise level, i.e., if a specification is TX S/N = 10 dB, the measurement S/N should be at least 20 dB. For all PHY modes, measurements shall be taken with all non-guard carriers active.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure [B30]:

a) Start of frame shall be detected.
b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.
c) Coarse and fine frequency offsets shall be estimated.
d) The packet shall be de-rotated according to estimated frequency offset.
e) The complex channel response coefficients shall be estimated for each of the carriers.
f) For each of the data OFDM symbols: transform the symbol into carrier received values, estimate the phase from the pilot carriers, de-rotate the carrier values according to estimated phase, and divide each carrier value with a complex estimated channel response coefficient.
g) For each data-carrying carrier, find the closest constellation point and compute the Euclidean distance from it.
h) Compute the RMS average of all errors in a packet. It is given by:

$$\mathrm{Error}_{RMS} = \frac{\displaystyle\sum_{i=1}^{N_f} \frac{\displaystyle\sum_{j=1}^{L_P}\left[\sum_{k=1}^{N_{FFT}}\left\{(I(i,j,k)-I_0(i,j,k))^2+(Q(i,j,k)-Q_0(i,j,k))^2\right\}\right]}{P_0 \cdot L_P \cdot N_{FFT}}}{N_f} \tag{93}$$

where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the i[th] frame, j[th] OFDM symbol of the frame, k[th] carrier of the OFDM symbol in the complex plane;

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the i[th] frame, j[th] OFDM symbol of the frame,

k[th] is the carrier of the OFDM symbol in the complex plane;

P_0 is the average power of the constellation.

8.5.13 Receiver requirements

8.5.13.1 Receiver sensitivity

The bit error rate (BER) shall be less than 10^{-6} at the power levels shown in Table 116cp for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— At the antenna connector or· through a calibrated radiated test environment,
— Using the defined standardized message packet formats, and
— Using an AWGN channel.

Table 116cp—Receiver minimum input level sensitivity (dBm)

Bandwidth (MHz)	QPSK		16-QAM		64-QAM	
	1/2	3/4	1/2	3/4	2/3	3/4
1.5	–91	–89	–84	–82	–78	–76
1.75	–90	–87	–83	–81	–77	–75
3	–88	–86	–81	–79	–75	–73
3.5	–87	–85	–80	–78	–74	–72
5	–86	–84	–79	–77	–72	–71
6	–85	–83	–78	–76	–72	–70
7	–84	–82	–77	–75	–71	–69
10	–83	–81	–76	–74	–69	–68
12	–82	–80	–75	–73	–69	–67
14	–81	–79	–74	–72	–68	–66
20	–80	–78	–73	–71	–66	–65

Table 116cp (as well as Table 116co) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and E_b/N_0 values as listed in Table 116cq.

Table 116cq—Receiver SNR and E_b/N_0 assumptions

Modulation	E_b/N_0 (dB)	Coding rate	Receiver SNR (dB)
QPSK	10.5	1/2	9.4
		3/4	11.2
16-QAM	14.5	1/2	16.4
		3/4	18.2
64-QAM	19.0	2/3	22.7
		3/4	24.4

Test messages for measuring Receiver Sensitivity shall be based on a continuous stream of MAC PDUs, each with a payload consisting of a ***R*** times repeated sequence $\boldsymbol{S_{modulation}}$. For each modulation, a different sequence applies:

$$\boldsymbol{S_{QPSK}} = [0xE4, 0xB1, 0xE1, 0xB4]$$
$$\boldsymbol{S_{16QAM}} = [0xA8, 0x20, 0xB9, 0x31, 0xEC, 0x64, 0xFD, 0x75] \quad (94)$$
$$\boldsymbol{S_{64QAM}} = [0xB6, 0x93, 0x49, 0xB2, 0x83, 0x08, 0x96, 0x11, 0x41, 0x92, 0x01, 0x00, 0xBA, 0xA3, 0x8A, 0x9A, 0x21, 0x82, 0xD7, 0x15, 0x51, 0xD3, 0x05, 0x10, 0xDB, 0x25, 0x92, 0xF7, 0x97, 0x59, 0xF3, 0x87, 0x18, 0xBE, 0xB3, 0xCB, 0x9E, 0x31, 0xC3, 0xDF, 0x35, 0xD3, 0xFB, 0xA7, 0x9A, 0xFF, 0xB7, 0xDB]$$

For each mandatory test message, the ($\boldsymbol{R}$,$\boldsymbol{S_{modulation}}$) tuples that shall apply are:

Short length test message payload (288 data bytes): (72,$\boldsymbol{S_{QPSK}}$), (36,$\boldsymbol{S_{16QAM}}$), (6,$\boldsymbol{S_{64QAM}}$)
Mid length test message payload (864 data bytes): (216,$\boldsymbol{S_{QPSK}}$), (108,$\boldsymbol{S_{16QAM}}$), (18,$\boldsymbol{S_{64QAM}}$)
Long length test message payload (1536 data bytes): (384,$\boldsymbol{S_{QPSK}}$), (192,$\boldsymbol{S_{16QAM}}$), (32,$\boldsymbol{S_{64QAM}}$)

The test condition requirements are the following:

— ambient room temperature
— shielded room
— conducted measurement at the RF port if available
— radiated measurement in a calibrated test environment if the antenna is integrated
— RS FEC is enabled.

The test shall be repeated for each test message length and for each ($\boldsymbol{R}$,$\boldsymbol{S_{modulation}}$) tuple as identified above, using the mandatory FEC scheme. The results shall meet or exceed the sensitivity requirements set out in Table 116cp.

8.5.13.2 Receiver adjacent and alternate channel rejection

The adjacent channel rejection and alternate channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate dependent receiver sensitivity (see Table 116cp) and raising the power level of the interfering signal until the specified error rate is obtained. The power difference between the interfering signal and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conforming OFDM signal, not synchronized with the signal in the channel under test. For non-adjacent channel testing the test method is identical except the interfering channel shall be any channel other than the adjacent channel or the co-channel.

For the PHY to be compliant, the minimum rejection shall exceed the following:

Table 116cr—Adjacent and non-adjacent channel rejection

Modulation/coding	Adjacent channel rejection (dB)	Non-adjacent channel rejection (dB)
16-QAM-3/4	11	30
64-QAM-2/3	4	23

8.5.13.3 Receiver maximum input signal

The receiver shall be capable of receiving a maximum on-channel signal of –30 dBm, and shall tolerate a maximum signal of 0 dBm without damage.

8.5.13.4 Receiver linearity

The receiver shall have a minimum Input Intercept Point (IIP3) of –10 dBm.

8.5.14 Frequency control requirements

8.5.14.1 Center frequency and symbol clock frequency tolerance

At the BS, the transmitted center frequency, receive center frequency and the symbol clock frequency shall be derived from the same reference oscillator. At the BS the reference frequency tolerance shall be +/– 2 ppm.

At the SS, both the transmitted center frequency and the symbol clock frequency shall be synchronized to the BS with a tolerance of maximum 2% of the carrier spacing.

For Mesh capable devices, all devices shall have a +/– 20 ppm maximum frequency tolerance and achieve synchronization to its neighboring nodes with a tolerance of maximum 3% of the carrier spacing.

During the synchronization period, the SS shall acquire frequency synchronization within the specified tolerance before attempting any uplink transmission. During normal operation, the SS shall track the frequency changes and shall defer any transmission if synchronization is lost.

8.6 WirelessHUMAN specific components

8.6.1 Channelization

The channel center frequency shall follow the formula:

$$\text{Channel center frequency (MHz)} = 5000 + 5\, n_{ch} \tag{95}$$

where n_{ch} = 0,1,...199. This definition provides an 8-bit unique numbering system for all channels, with 5 MHz spacing, from 5 GHz to 6 GHz. This provides flexibility to define channelization sets for current and future regulatory domains. The set of allowed channel numbers is shown in Table 116cs for two regulatory domains. The support of any individual band in the table is not mandatory, but all channels within a band shall be supported.

Figure 128bp depicts the 20 MHz channelization scheme listed in Table 116cs. Channelization has been defined to be compatible with IEEE 802.11a for interference mitigation purposes, even though this results in less efficient spectrum usage in the middle U-NII band.

Table 116cs—Channelizations

Regulatory domain	Band (GHz)	Channelization (MHz)	
		20	10
USA	U-NII middle 5.25–5.35	56, 60, 64	55, 57, 59, 61, 63, 65, 67
	U-NII upper 5.725–5.825	149, 153, 157, 161, 165[a]	148, 150, 152, 154, 156, 158, 160, 162, 164[a],166[a]
Europe	CEPT band B[b] 5.47–5.725	100, 104, 108, 112, 116, 120, 124, 128, 132, 136	99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 131, 133, 135, 137
	CEPT band C[b] 5.725–5.875	148, 152, 156, 160, 164, 168	147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169

[a]See CFR 47 Part 15.247.
[b]Current applicable regulations do not allow this standard to be operated in the indicated band.

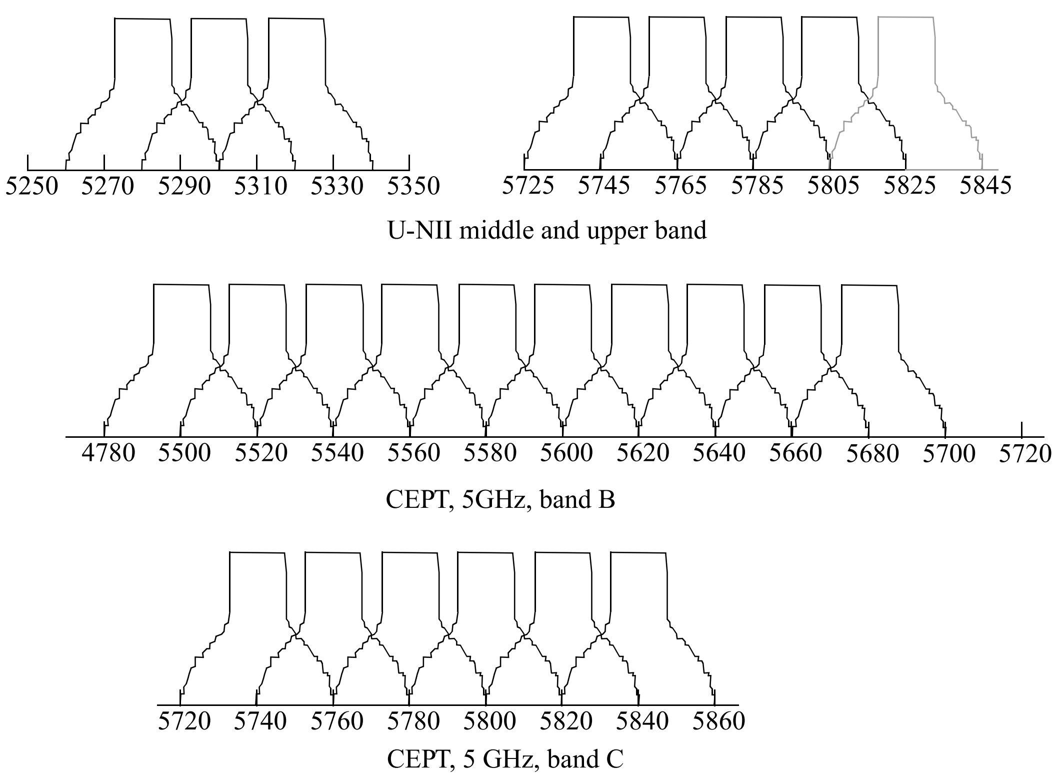

Figure 128bp—Channelization, 20 MHz

8.6.2 Transmit spectral mask

The transmitted spectral density of the transmitted signal shall fall within the spectral mask as shown Figure 128bq and Table 116ct. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth. The 0 dBr level is the maximum power allowed by the relevant regulatory body.

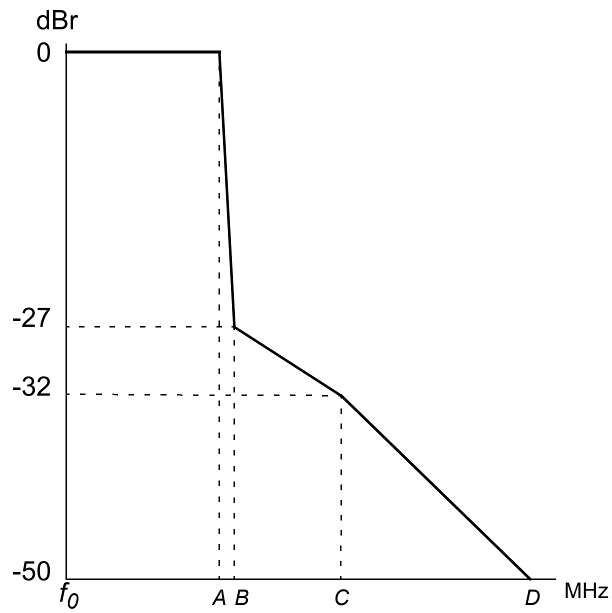

Figure 128bq—Transmit spectral mask (see Table 116ct)

Table 116ct—Transmit spectral mask parameters

Channelization (MHz)	A	B	C	D
20	9.5	10.5	19.5	29.5
10	4.75	5.25	9.75	14.75

10. Parameters and constants

10.1 Global values

In Table 118 change "SS UL-MAP processing time" as shown in Table 118a. Insert additional rows to Table 118 as shown in Table 118a:

Table 118a—Parameters and constants

System	Name	Time reference	Minimum value	Default value	Maximum value
BS	SS UL-MAP processing time (WirelessMAN-SC only)	Time provided between arrival of the last bit of a UL-MAP at an SS and effectiveness of that map.			200 µs
SS, BS	T17	Wait for ARQ-Reset			0.5 s
Mesh node	T18	Network Entry: Detect network	1 s		
Mesh node	T19	Network Entry: Accumulate MSH-NCFG messages		120 s	
Mesh node	T20	Network Entry: Wait for MSH-NENT / MSH-NCFG		1 s	

10.3 PHY-specific values

Change 10.3.1 header to read:

10.3.1 ~~10–66 GHz~~ WirelessMAN-SC parameter and constant definitions

Insert 10.3.1.6 and 10.3.1.7 as follows:

10.3.1.6 Allocation Start Time

Unit of Allocation Start Time shall be minislots from the start of the downlink frame in which UL-MAP message occurred.

10.3.1.7 Timing Adjust Units

The timing adjust units shall be 1/4 modulation symbols.

Insert 10.3.2 through 10.3.4 as follows:

10.3.2 WirelessMAN-SCa parameters and constant definitions

10.3.2.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to one frame duration.

10.3.2.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Symbol duration} . \tag{96}$$

10.3.2.3 Timing adjust units

The timing adjust units shall be 1/32 modulation symbols.

10.3.3 WirelessMAN-OFDM parameters and constant definitions

10.3.3.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to a point in the frame 200 μs after the last symbol of the UL-MAP.

10.3.3.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Sample Time} . \tag{97}$$

10.3.3.3 Timing adjust units

The timing adjust units shall be a single Sample Time.

10.3.4 WirelessMAN-OFDMA parameters and constant definitions

10.3.4.1 UL Allocation Start Time

Unit of Allocation Start Time shall be PSs from the start of the DL frame in which the UL-MAP message occurred. The minimum value specified for this parameter shall correspond to 1 FEC block.

10.3.4.2 Physical Slot

Physical Slots are defined as:

$$\text{Physical Slot} = 4 \cdot \text{Sample Time} . \tag{98}$$

10.3.4.3 Timing adjust units

The timing adjust units shall be a single Sample Time.

10.4 Well-known addresses and identifiers

Change Table 121 to read:

Table 121—Connection identifiers

Connection identifier	Value	Description
Initial ranging	0x0000	Used by an SS during initial ranging as part of initial ranging process.
Basic CID	0x0001—*m*	
Primary management	*m*+1—2*m*	
Transport CIDs and secondary Mgt CIDs	2*m*+1—0xFEFF	
Multicast polling CIDs	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 CID	0xFFFE	Used for transmission of padding information.
Broadcast CID	0xFFFF	Used for broadcast information that is transmitted on a downlink to all SS.

11. TLV-encodings

11.1 MAC management message encodings

11.1.1 UCD message encodings

11.1.1.1 UCD channel encodings

Replace Table 122 as follows:

Table 122—UCD channel encoding

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Uplink_Burst_Profile	1		May appear more than once (see 6.2.2.3.3). The length is the number of bytes in the overall object, including embedded TLV items.	All
Symbol rate	2	2	Symbol rate, in increments of 10 kBaud.	SC, SCa
Frequency	3	4	Uplink center frequency (kHz).	SCa, OFDM, OFDMA

Table 122—UCD channel encoding *(continued)*

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
SS Transition gap	7	1	The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of the subsequent SS burst. The SS shall take this into account when determining the length of the burst. The SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries include the time for a burst's ramp down.	SC
			The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of the subsequent SS burst. The SS shall take this into account when determining the length of the burst. The SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries accommodate the RxDS burst element, which includes time for both ramp down and delay spread to clear the receiver.	SCa
Roll-off factor	8	1	0=0.15, 1=0.25 2=0.35 (SC only), 3=0.18 (SCa only) 4–255 Reserved	SC, SCa
Power adjustment rule	9	1	0=Preserve Peak Power 1=Preserve Mean Power Describes the power adjustment rule when performing a transition from one burst profile to another.	SC
Contention-based reservation timeout	10	1	Number of UL-MAPs to receive before contention-based reservation is attempted again for the same connection.	All
Channel width	11	2	Channel width, increments of 10 KHz Shall not be used in license-exempt bands	SCa OFDM, OFDMA
Initial ranging codes	12	1	Number of initial ranging CDMA codes. Possible values are 0–47.[a]	OFDMA
Periodic ranging codes	13	1	Number of periodic ranging CDMA codes. Possible values are 0–47.[a]	OFDMA
Bandwidth request codes	14	1	Number of bandwidth request codes. Possible values are 0–47.[a]	OFDMA
Periodic ranging backoff start	15	1	Initial backoff window size for periodic ranging contention, expressed as a power of 2. Range: 0–15 (the highest order bits shall be unused and set to 0).	OFDMA
Periodic ranging backoff end	16	1	Final backoff window size for periodic ranging contention, expressed as a power of 2. Range: 0–15 (the highest order bits shall be unused and set to 0).	OFDMA

Table 122—UCD channel encoding *(continued)*

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Initial maintenance SSTG	17	1	The time, as measured at the BS and expressed in PSs, between the end of a SS burst and the beginning of a subsequent burst residing in an Initial Maintenance slot. Or, the time, as measured at the BS and expressed in PSs, between the end of burst in an Initial Maintenance slot and beginning of a subsequent SS burst. A SS shall take this into account when determining the length of a burst in an Initial Maintenance slot. The Initial Maintenance SSTG consumes the last n PS of the intervals allocated in the UL-MAP. That is, UL-MAP entries accommodate the RxDS burst element, which includes time for both ramp down and delay spread to clear the receiver.	SCa
Subchannelization focused contention codes	18	1	Number of contention codes (C_{SE}) that shall only be used to request a subchannelized allocation. Default value 0. Allowed values 0–48.	OFDM

[a]The total number of codes shall be equal or less than 48.

11.1.1.2 UCD burst profile encodings

Change the first sentence to read:

The uplink burst profile encodings ~~for 10-66 GHz systems~~ are provided in Table 123 <u>through Table 123c</u>.

Replace title of Table 123 with the following: UCD burst profile encodings—<u>WirelessMAN-SC</u>

Insert Table 123a, Table 123b and Table 123c after Table 123 as follows:

Table 123a—UCD burst profile encodings—WirelessMAN—SCa

Name	Type (1 byte)	Length	Value (variable length)
Modulation type	1	1	4 msb bits: 1 =QPSK, 2 = 16-QAM, 3 = 64-QAM, 4 = 256-QAM, 5 = BPSK, 5–15 Reserved 4 lsb bits: 1 = CC+RS without block interleaving 2 = CC+RS with block interleaving 3 = no FEC, 4 = BTC, 5 = CTC, 6–15=reserved
Preamble length	4	1	4 msb: Number of Unique Words in Preamble (m= 0–15) 4 lsb: Number of PSs (4x number of symbols) in ramp up
RS Information bytes (K)	6	1	K=6–255
RS Parity bytes *(*R)	7	1	2 msb: R=0-16 bytes (error correction capability = 0–8 bytes) R = 17–63 reserved 6 lsb: Last RS codeword length 0=fixed, 1=shortened, 2–3=Reserved
Block interleaver depth	18	1	Number of rows (Reed Solomon code words) used in block interleaver between Reed Solomon and CC: rows = 2–66; Reserved = 0, 1, 67–255

Table 123a—UCD burst profile encodings—WirelessMAN—SCa *(continued)*

Name	Type (1 byte)	Length	Value (variable length)
CC/CTC-Specific parameters	19	1	0 = rate 1/2 (for BPSK, QPSK, 16-QAM) 1 = rate 2/3 (for QPSK, 64-QAM) 2 = rate 3/4 (for BPSK, QPSK, 16-QAM, 256-QAM) 3 = rate 5/6 (for QPSK, 64-QAM) 4 = rate 7/8 (for QPSK, 256-QAM) 5–255 = reserved
Unique word length	20	1	Number of symbols (U) in a Unique Word: 1= None, 2–8: $2^{<value+1>}$, 9–255 = reserved
Pilot word parameters	21	1	msb 4 bits: Pilot Word Interval [regular bursts] (Pilot word's length in symbols included in interval). 1 = no pilot words, 2–10: $2^{<value+2>}$, 11–15 reserved [STC-encoded bursts] 0=no pilot words, 1–15 = number of paired blocks between pilot words lsb 4 bits: Number of contiguous Unique Words composing a Pilot Word (1–15)
Transmit-diversity type	22	1	0 = No Tx diversity, 1 = STC Tx diversity, 2–255 = reserved
STC Parameters	23	2	4 msb: Block length (segments are paired), in symbols: 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 reserved 4 lsb: Block burst profile type: 0 = CP derived from data and no UWs embedded within block 1 = CP derived from data an additional UW as first payload data element in block 2 = CP derived from UWs at beginning and end of segment 3–15 = reserved
BTC Code selector	24	1	Value used to choose set of BTC row/column codes. C_{bank}=1–3; 0,4–255 reserve

Table 123b—UCD burst profile encodings—WirelessMAN—OFDM

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	5	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
Focused contention power boost	17	1	The power boost in dB of focused contention carriers, as described in 8.4.6.3.3

Table 123c—UCD burst profile encodings—WirelessMAN—OFDMA

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	5	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
Ranging data ratio	16	1	Reducing factor in units of 1 dB, between the power used for this burst and power should be used for CDMA Ranging.

11.1.2 DCD message encodings

11.1.2.1 DCD channel encodings

Replace Table 124 as follows:

Table 124—DCD channel encoding

Name	Type (1 byte)	Length	Value (variable length)	PHY scope
Downlink_Burst_Profile	1		May appear more than once (see 6.2.2.3.1). The length is the number of bytes in the overall object, including embedded TLV items	All
BS EIRP	2	2	Signed in units of 1 dBM.	All
Frame duration	4	4	The number of PSs contained in a Burst FDD or TDD frame. Required only for framed downlinks	SC
PHY Type	5	1	The PHY Type to be used.	SC
Power adjustment rule	9	1	0=Preserve Peak Power 1=Preserve Mean Power Describes the power adjustment rule when performing a transition from one burst profile to another.	SC
Channel Nr	10	1	DL channel number as defined in 8.6. Used for license-exempt operation only.	SCa OFDM, OFDMA
TTG	11	1	TTG (in PSs)	SCa, OFDM, OFDMA
RTG	12	1	RTG (in PSs)	SCa, OFDM, OFDMA
MAC version	16	1	See 11.4.4.	All

11.1.2.2 DCD burst profile encodings

Change the first sentence to read:

The uplink burst profile encodings ~~for 10-66 GHz systems~~ are provided in Table 125 through Table 125c.

Replace title of Table 125 with the following: DCD burst profile encodings—WirelessMAN-SC

Insert Table 125a, Table 125b and Table 125c after Table 125 as follows:

Table 125a—DCD burst profile encodings—WirelessMAN—SCa

Name	Type (1 byte)	Length	Value (variable length)
Modulation type	1	1	4 msb bits: 1 =QPSK, 2 = 16-QAM, 3 = 64-QAM, 4 = 256-QAM, 5 = BPSK, 5–15 Reserved 4 lsb bits: 1 = CC+RS without block interleaving, 2 = CC+RS with block interleaving 3 = no FEC, 4 = BTC, 5 = CTC, 6–15=reserved
RS Parity bytes (R)	4	1	6 msb: R=0–16 bytes (error correction capability = 0–8 bytes) R = 17–63 reserved 2 lsb: Last RS codeword length 0=fixed, 1=shortened, 2-3=Reserved
DIUC Mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and at which a change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC Minimum 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. See Figure 59.
CC/CTC-Specific parameters	18	1	0 = rate 1/2 (for BPSK, QPSK, 16-QAM) 1 = rate 2/3 (for QPSK, 64-QAM) 2 = rate 3/4 (for BPSK, QPSK, 16-QAM, 256-QAM) 3 = rate 5/6 (for QPSK, 64-QAM) 4 = rate 7/8 (for QPSK, 256-QAM) 5–255 = reserved
Preamble length	19	1	4 msb: Number of Unique Words in Preamble (m= 0-15) 4 lsb: Number of PSs (4 x number of symbols) in ramp up
Rolloff	20	1	1 = 0.25, 2 = 0.18, 3 =.15, 4-255 = reserved
Unique word parameters	21	1	Number of symbols (U) in a Unique Word: 1= None, 2-8: $2^{\langle value+1 \rangle}$, 9-255 = reserved

Table 125a—DCD burst profile encodings—WirelessMAN—SCa *(continued)*

Name	Type (1 byte)	Length	Value (variable length)
Pilot word parameters	22	1	4 msb: Pilot Word Interval (Pilot word's length included in interval). 1 = no pilot words, 2 = 16 symbols, 3 = 32 symbols, 4 = 64 symbols, 5 = 128 symbols,..., 10 = 4096 symbols, 11–15 reserved 4 lsb: Number of contiguous Unique Words composing a Pilot Word (1–15)
Transmit-diversity type	23	1	0 = no Tx diversity, 1 = STC Tx diversity, 2–255 = reserved
Byte interleaver depth	24	1	Number of rows (Reed Solomon code words) used in block interleaver between Reed Solomon and CC: rows = 2–66 0,1,67–255 = reserved
DL Burst Transition Gap (DL-BTG)	25	1	1 msb: 0 = no DL-BTG; 1 = use DL-BTG. 7 lsb: The time, expressed in PSs, between the end of an BS burst and the beginning of a another burst with the same MAC frame. The DL Transition Gap consumes the last n PS of the intervals allocated in the DL-MAP. The minimum length of the DL Burst Transition Gap shall be at least one RxDS interval, so that ramp down can occur and delay spread can clear receivers.
STC Parameters	26	1	4 msb: block length (segments are paired), in symbols 1= 64, 2 = 128, 3 = 256, 4 = 512,..., 7 = 4096, 8–15 reserved 4 lsb: Block burst profile type 0 = Cyclic prefix derived from data and no UWs embedded within block 1 = Cyclic prefix derived from data an additional UW as first payload data element in block 2 = Cyclic prefix derived from UWs at beginning and end of segment 3–15 = reserved
BTC Code selector	27	1	Value used to choose set of BTC row/column codes. C_{bank}=1–3; 0,4–255 reserved

Table 125b—DCD burst profile encodings—WirelessMAN—OFDM

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	2	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
DIUC mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and where this change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC minimum 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. See Figure 59.

Table 125c—DCD burst profile encodings—WirelessMAN—OFDMA

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type	2	1	0 = QPSK (RS+CC) 1/2 1 = QPSK (RS+CC) 3/4 2= 16-QAM (RS+CC) 1/2 3= 16-QAM (RS+CC) 3/4 4= 64-QAM (RS+CC) 2/3 5= 64-QAM (RS+CC) 3/4 6= QPSK (BTC) 1/2 7= QPSK (BTC) 3/4 or 2/3 8= 16-QAM (BTC) 3/5 9= 16-QAM (BTC) 4/5 10 = 64-QAM (BTC) 2/3 or 5/8 11 = 64-QAM (BTC) 5/6 or 4/5 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19–256 Reserved
DIUC Mandatory exit threshold	13	1	0–63.75 dB C/(N+I) at or below where this DIUC can no longer be used and where this change to a more robust DIUC is required, in 0.25 dB units. See Figure 59.
DIUC Minimum entry theshold	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. See Figure 59.

11.1.4 RNG-RSP message encodings

Change the indicated parameters in Table 127 (do not change or remove the other parameters) to read:

Table 127—RNG-RSP message encodings

Name	Type	Length	Value
Timing adjust	1	4	Tx timing offset adjustment (signed 32-bit). The time required to advance SS transmission so frames arrive at the expected time instance at the BS. Units are PHY specific (see 10.3).
Downlink frequency override	5	4	Center frequency of new downlink channel in kHz where the SS should redo initial ranging. If this TLV is used, the Ranging Status value shall be set to 2. Shall be used for licensed bands only.
Uplink channel ID override	6	1	Licensed bands: The identifier of the uplink channel with where the SS should redo initial ranging (not used with PHYs without channelized uplinks). license-exempt bands: The Channel Nr (see 8.6.1) where the SS should redo initial ranging.

Insert under Table 127 as follows:

In addition to the RNG-RSP TLVs listed in Table 127, which are applicable to all PHYs, a set of PHY specific RNG-RSP TLVs is provided in Table 127a.

Table 127a—PHY specific RNG-RSP message encodings

Name	Type	Length	Value	PHY
Ranging symbol	12	2	Used to indicate the OFDM time symbol reference that was used to transmit the ranging code (unsigned 12-bit).	OFDMA
Ranging subchannel	13	1	Used to indicate the OFDM subchannel reference that was used to transmit the ranging code (unsigned 6-bit).	OFDMA
Ranging code	14	1	Used to indicate the ranging code that was sent by the SS (unsigned 6-bit).	OFDMA
Ranging frame number	15	1	The 8 least significant bits of the frame number of the OFDMA frame where the SS sent the ranging code.	OFDMA
AAS broadcast permission	16	1	0= SS may issue contention-based BW requests permission 1= SS shall not issue contention-based BW request	SCa OFDM OFDMA

Table 127a—PHY specific RNG-RSP message encodings *(continued)*

Name	Type	Length	Value	PHY
AAS broadcast capability	17	1	0 = SS can receive broadcast messages 1 = SS cannot receive broadcast messages	SCa OFDM OFDMA
Frame number	18	3	Frame number where the associated RNG_REQ message was detected by the BS. Usage is mutually exclusive with SS MAC Address (Type 8). The opportunity within the frame is assumed to be 1 (the first) if the Initial Ranging Opportunity field is not supplied.	SCa OFDM
Initial ranging opportunity number	19	1	Initial Ranging opportunity (1–255) in which the associated RNG_REQ message was detected by the Base Station. Usage is mutually exclusive with SS MAC Address (Type 8).	SCa OFDM

Insert 11.1.5 and 11.1.6 as follows:

11.1.5 REP-REQ parameters

Name	Type	Length	value
Report request	1	Compound	

The Report Command consists of the following parameters:

Name	Type	Length	value
Report type	1.1	1	Bit# 0 =1 Include DFS Basic report 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]) Bit# 7 Reserved
Channel number	1.2	1	Physical channel number (see 8.6.1) to be reported on. (license-exempt bands only)

11.1.6 REP-RSP parameters

Name	Type	Length	value
Report	1	Compound	

The report consists of the following parameters (see also 8.3.2, 8.4.8 or 8.5.11 for details).

REP-REQ Report type	Name	Type	Length	value
bit #0=1	Channel number	1.1	1	Physical channel number (see 8.6.1) to be reported on.
bit #0=1	Start frame	1.2	2	Frame number in which measurement for this channel started.
bit #0=1	Duration	1.3	3	Cumulative measurement duration on the channel in multiples of T_S. For any value exceeding 0xFFFFFF, report 0xFFFFFF.
bit #0=1	Basic report	1.4	1	Bit# 0: Wireless Human detected on the channel Bit# 1: Unknown transmissions detected on the channel Bit# 2: Primary User detected on the channel Bit# 3: Unmeasured. Channel not measured
bit #1=1	CINR report	1.5	2	1 byte: mean (see also 8.3.2, 8.4.8, 8.5.11) for details) 1 byte: standard deviation
bit #2=1	RSSI report	1.6	2	1 byte: mean (see also 8.3.2, 8.4.8, 8.5.11) for details) 1 byte: standard deviation

11.2 PKM message encodings

11.2.14 Cryptographic-Suite

Change Table 136 as shown:

Table 136—Version attribute values

Value	Description
0	*reserved*
1	3-DES EDE with 128-bit key
2	RSA with 1024 bit key
~~2~~3–255	*reserved*

11.3 Configuration file encodings

Insert 11.3.7 through 11.3.9 with the following:

11.3.7 Authorization Node

The Authorization Node parameter contains the IP address of the Authorization Node.

Type	Length	Value
22	4 or 16	IP Address

11.3.8 Registration Node

The Registration Node parameter contains the IP address of the Registration Node.

Type	Length	Value
23	4 or 16	IP Address

11.3.9 Provisioning Node

The Provisioning Node parameter contains the IP address of the Provisioning Node.

Type	Length	Value
18	4 or 16	IP Address

11.4 Common encodings

Insert 11.4.1.2.5 through 11.4.1.2.7 with the following:

11.4.1.2.5 WirelessMAN SCa SS Demodulator

11.4.1.2.5.1 SS Demodulation Types

This field indicates the optional modulation (and FEC) types supported by a SS for DL reception. Note that QPSK, 16-QAM, and 64-QAM shall be supported, as is the Concatenated FEC without byte interleaving and no-FEC QPSK. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.7	1	Bit# 0: 256-QAM Bit# 1: BPSK Bit# 2: Concatenated RS+CC FEC with byte interleaver Bit# 3: BTC Bit# 4: CTC Bit# 5: no FEC and QAM Bits# 6–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.2 Roll-off Factor

This field indicates the optional roll-off factors supported by a SS for DL reception. Note that support of a roll-factor of 0.25 is mandatory. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.8	1	Bit# 0: 0.18 Bit# 1: 0.25 Bits# 2–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.3 UW Length

This field indicates the optional UW lengths, in symbols, supported by a SS for DL reception. Note that support of the 64 symbol UW is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.9	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.4 Pilot Word Interval

This field indicates the optional pilot word intervals supported, in symbols, by a SS for DL reception. A Pilot Word interval of 256 symbols shall be supported. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.10	1	Bit# 0: 128 Bit# 1: 512 Bit# 2: 1024 Bit# 4: 2048 Bit# 5: 4096 Bits# 6–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.5 Byte interleaver depth

This field indicates the interleaver depth (number of rows) supported by a SS for DL reception. The value of 0 (no interleaver) shall be supported.

Type	Length	Value	Scope
5.12.11	1	0: no interleaver support 1–64: 2–66 rows 65–255: reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.6 Transmit diversity

This field indicates the types of transmit diversity supported by a SS for DL reception. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.12	1	Bit# 0: STC Transmit Diversity with CP Burst Profile Bit# 1: STC Transmit Diversity with CP and UW at beginning of block Burst Profile Bit# 2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile Bits# 3–7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.7 STC block size

This field indicates the STC block size (block = 1/2 length of a ‘STC pair’) supported by a SS for DL reception. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.13	1	Bit# 0: 64 Bit# 1: 128 Bit# 2: 256 Bit# 3: 512 Bit# 4: 1024 Bit# 5: 2048 Bit# 6: 4096 Bit# 7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.8 Maximum DL channel width

This field indicates the maximum DL channel width that the SS can demodulate.

Type	Length	Value	Scope
5.12.14	2	Bits# 0–15: Channel Width, in 10 kHz increments	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.5.9 Minimum DL channel width

This field indicates the minimum DL channel width over a SS can demodulate.

Type	Length	Value	Scope
5.12.15	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6 WirelessMAN SCa SS modulator

11.4.1.2.6.1 SS modulation types

This field indicates the optional modulation (and FEC) types supported by a SS for UL transmission. Note that QPSK, 16-QAM, and 64-QAM shall be supported, as is the Concatenated FEC without byte interleaving and no-FEC QPSK. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.16	1	Bit# 0: 256-QAM Bit# 1: Concatenated RS+CC FEC with byte interleaver Bit# 2: BTC Bit# 3: CTC Bit# 4: no FEC and QAM Bits# 5–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.2 Roll-off factor

This field indicates the optional roll-off factors supported by a SS for UL transmission. Note that support of a roll-factor of 0.25 is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.17	1	Bit# 0: 0.18 Bit# 1: 0.25 Bits# 2–7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.3 UW length

This field indicates the optional UW lengths, in symbols, supported by a SS for UL transmission. Note that support of the 64 symbol UW is mandatory. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.18	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.4 Pilot word interval

This field indicates the optional pilot word intervals supported, in symbols, by a SS for UL transmission. A Pilot Word interval of 256 symbols shall be supported. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.19	1	Bit# 0: 8 Bit# 1: 16 Bit# 2: 32 Bit# 4: 128 Bit# 5: 256 Bit# 6: 512 Bit# 7: reserved; shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.5 Byte interleaver depth

This field indicates the interleaver depth (number of rows) supported by a SS for UL transmission. The value of 0 (no interleaver) shall be supported.

Type	Length	Value	Scope
5.12.20	1	0: no interleaver support 1–64: 2–66 rows 65–255: reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.6 Transmit diversity

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
5.12.21	1	Bit# 0: STC Transmit Diversity with Cyclic Prefix Burst Profile Bit# 1: STC Transmit Diversity with Cyclic Prefix and UW at beginning of block Burst Profile Bit# 2: STC Transmit Diversity with UWs placed at beginning and end of block Burst Profile Bits# 3–7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.7 STC block size

This field indicates the STC block size (block = 1/2 length of a ‘STC pair’) supported by a SS for UL transmission. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.22	1	Bit# 0: 64 Bit# 1: 128 Bit# 2: 256 Bit# 3: 512 Bit# 4: 1024 Bit# 5: 2048 Bit# 6: 4096 Bit# 7: reserved, shall be set to 0.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.8 Maximum UL channel width

This field indicates the maximum UL channel width over a SS can transmit.

Type	Length	Value	Scope
5.12.23	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.9 Minimum UL channel width

This field indicates the minimum UL channel width over a SS can transmit.

Type	Length	Value	Scope
5.12.24	2	Bits# 0–15: Channel Width, in 10 kHz increments.	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.6.10 Power control limits

This field indicates the maximum transmit power, power control range, and power control granularity that a SS can deliver to the transmit antenna over the given UL channel.

Type	Length	Value	Scope
5.12.25	3	Bits# 0–5: Max output power in dBm, from 0 to 63 dBm Bits# 6–12: Power control range, in dB, from 0 to 127 dB Bits# 13–17: Power control granularity in 0.25 dB increments, from 0.25 to 8 dB. Bits# 18–23: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.7 WirelessMAN-OFDM/OFDMA FFT sizes

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.26	1	Bit# 0: FFT-256 Bit# 1: FFT-2048 Bits# 2–7: Reserved, shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.8 WirelessMAN-OFDM focused contention support

This field indicates the types of transmit diversity supported by a SS for UL transmission. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	Length	Value	Scope
5.12.27	1	Bit #0: Focused Contention Support Bits #1–7: Reserved, shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.9 WirelessMAN-OFDM/OFDMA demodulator

This field indicates the different demodulator options supported by a WirelessMAN-OFDM/OFDMA PHY SS for DL reception. This field is not used for other PHY specifications. 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: BTC Bit# 2: CTC Bit# 3: STC Bit# 4: AAS Bits# 5–7: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.1.2.10 WirelessMAN-OFDM/OFDMA modulator

This field indicates the different modulator options supported by a WirelessMAN-OFDM/OFDMA PHY SS for UL transmission This field is not used for other PHY specifications. 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: BTC Bit# 2: CTC Bits# 3–7: Reserved	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

Replace Table in 11.4.1.6 as follows:

11.4.1.6 Bandwidth allocation support

Type	Length	Value	Scope
5.15	1	~~bit #0=0: Grant per Connection~~ ~~bit #0=1: Grant per Subscriber Station (SS)~~ <u>bit #0: Reserved</u> Bit# 1=0: Half-Duplex Bit# 1=1: Full-Duplex <u>Bit# 2=0: Not capable of focused contention</u> <u>Bit# 2=1: Capable of focused contention</u> <u>Bit# 3=0: No OFDM subchannelization support</u> <u>Bit# 3=1: OFDM subchannelization support</u> Bits# ~~2~~<u>4</u>–7: *reserve*d; shall be set to zero	SBC-REQ (see 6.2.2.3.23) SBC-RSP (see 6.2.2.3.24)

11.4.4 MAC version encodings

Chance the following sentence to read:

Encodings are as defined for the Registration Request, <u>Registration Response and DCD,</u> including MAC version.

11.4.8 Service flow encodings

Insert 11.4.8.18 and 11.4.8.19 with the following:

11.4.8.18 ARQ TLVs for ARQ-enabled connections

11.4.8.18.1 ARQ support

This TLV indicates whether or not ARQ is available for the connection that is being setup. A value of 0 indicates the non-availability of ARQ support and a value 1 indicates otherwise. The DSA-REQ shall contain the request to use or not to use ARQ. 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.

Type	Length	Value	Scope
[24/25].11	1	0 = ARQ Not Supported 1 = ARQ Supported	DSx-REQ DSx-RSP

11.4.8.18.2 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 **ARQ_WINDOW_SIZE**.

Type	Length	Value	Scope
[24/25].12	1	1 - (ARQ_FSN_MODULUS/2)	DSx-REQ DSx-RSP

11.4.8.18.3 ARQ_RETRY_TIMEOUT

The ARQ retry timeout should account for the transmitter and receiver processing delays and any other delays relevant to the system.

TRANSMITTER_DELAY: This is the total 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.

RECEIVER_DELAY: This is the total 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** to be the sum of TRANSMITTER_DELAY and RECEIVER_DELAY.

Type	Length	Value	Scope
[24/25].13	2	TRANSMITTER_DELAY 0–655350 (10 μs granularity)	DSA-REQ DSA-RSP
[24/25].22	2	RECEIVER_DELAY 0–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.18.4 ARQ_FRAGMENT_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_FRAGMENT_LIFETIME* value shall be considered infinite.

Type	Length	Value	Scope
[24/25].17	2	0 = Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.18.5 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.

Type	Length	Value	Scope
[24/25].19	2	0 = Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.18.6 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.

Type	Length	Value	Scope
[24/25].20	1	0 – Order of delivery is not preserved 1 – Order of delivery is preserved	DSA-REQ DSA-RSP

If this flag is not set, then the order of delivery is not preserved. If this flag is set (to 1), then the order of delivery is preserved. This parameter does not apply to fixed length SDU services (i.e., ATM).

11.4.8.18.7 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.

Type	Length	Value	Scope
[24/25].23	2	0= Infinite 1–655350 (10 μs granularity)	DSA-REQ DSA-RSP

11.4.8.19 Maximum fragment length

The value of this parameter specifies the maximum size fragment a transmitter shall form or a receiver shall expect to receive.

This parameter 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.

Type	Length	Value	Scope
[24/25].22	2	0–31 Reserved 32–2040 Desired/Agreed max. length in bytes 2041–65535 Reserved	DSA-REQ DSA-RSP DSC-REQ DSC-RSP

12. System profiles

12.2 Basic Mesh system profile

The Mesh system profile addresses the requirements of a system that is intended to operate in the optional Mesh configuration. Basic functionalities are mandatory for a Mesh node as they are for a PMP node, except those that are stated below as optional in this subclause. All specifications referring to optional Mesh mode in the standard shall apply to a Mesh-enabled system as mandatory.

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 functionalities are mandatory/optional whenever they are optional/mandatory for a PMP system:

ARQ-Feedback

When operating in the Mesh mode, the messages below and the corresponding functionalities are not used; however, they are implemented to support the mandatory PMP mode.

DL-MAP
DCD
DSA-ACK
DSA-REQ
DSA-RSP
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

Generally, the following procedures are different for a Mesh node and a PMP node:

Synchronization
Network entry
Scheduling

Annex A

(informative)

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Insert the following references:

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[B31] ETSI TS 101 475 v1.1.1 (2000-4) *BRAN HIPERLAN Type 2; Physical Layer.*

[B32] ITU, *ITU Radio Regulations*, Appendix S8, 1998 Edition.

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[B37] ERC/DEC/(99)23 *ERC Decision on the harmonised frequency bands to be designated for the introduction of HIPERLANS, 29-11-1999,* http://www.ero.dk/doc98/official/pdf/DEC9923E.PDF

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Insert Annex B as follows:

[1]Contact WCAI at +1(202)452 7823 or sahar@wcai.com to obtain copy.

Annex B

(informative)

Applicable to systems between 2 and 11 GHz

B.1 Targeted frequency bands

Table B.1 indicates frequency bands, and their allowed channel spacings, where the 2–11 GHz PHY layer may be applicable.

Table B.1—Frequency bands and channel allocation

<table>
<tr><th colspan="2">Frequency bands (GHz)
(licensed unless noted)</th><th>Allowed channel spacing</th><th>Reference</th></tr>
<tr><td colspan="2">2.305–2.320
2.345–2.360</td><td>1 or 2 x (5 + 5 MHz) or 1 x5 MHz (Can be aggregated in any combinations) Interference Protection to DARS</td><td>USA CFR 47 part 27 (WCS) See FCC Docket IB95-91 for potential (increased) interference from DARS repeaters.</td></tr>
<tr><td colspan="2">2.150–2.162
2.500–2.690</td><td>125 kHZ to (n x 6) MHz
Single or multiple, contiguous or non-contiguous and combinations.
Interference Protection to video and ITFS users</td><td>USA CFR 47 part 21.901 (MDS)
USA CFR 47 part 74.902 (ITFS, MMDS)</td></tr>
<tr><td colspan="2">2.150–2.160
2.500–2.596
2.686–2.688</td><td>1 MHz – (nx6) MHz (1 or 2-way)
25 kHz-(n x 25 kHz) “return”
Contiguous channels preferred</td><td>Canada SRSP-302.5 (MCS)
MDS service allocated to adjacent sub-bands (incl. separate “return” channels)</td></tr>
<tr><td colspan="2">2.400–2.483.5
(license-exempt)</td><td>Frequency Hopping or Direct Sequence Spread Spectrum etc.</td><td>CEPT/ERC/REC 70-03
USA CFR 47 Part 15, subpart E [B19]</td></tr>
<tr><td rowspan="4">3.400–4.990</td><td>3.410–4.200</td><td>1.75–30 MHz paired with
1.75 MHz to 30 MHz
Symmetric only.
(50 MHz or 100 MHz separation)</td><td>Rec. ITU-R F.1488 Annex II
ETSI EN 301 021[B18],
CEPT/ERC Rec. 14-03 E, CEPT/ERC Rec. 12-08 E</td></tr>
<tr><td>3.400–3.700</td><td>n x 25 MHz (single or paired)
(50 MHz or 100 MHz separation if paired)</td><td>Rec. ITU-R F.1488 Annex I
CITEL PCC.III/REC.47 (XII-99)
Canada SRSP-303.4 (BWA)</td></tr>
<tr><td>3.650–3.700</td><td>Rulemaking in progress</td><td>USA FCC Docket WT00-32</td></tr>
<tr><td>4.940–4.990</td><td>Rulemaking in progress</td><td>USA FCC Dockets WT00-32 and ET-98-237</td></tr>
</table>

Table B.1—Frequency bands and channel allocation *(continued)*

<table>
<tr><th colspan="2">Frequency bands (GHz)
(licensed unless noted)</th><th>Allowed channel spacing</th><th>Reference</th></tr>
<tr><td rowspan="5">5.150–5.850
(license-
exempt)</td><td>5.150–5.350</td><td>n x 20 MHz (HIPERLAN)
Restricted to Indoor Use</td><td rowspan="2">CEPT/ERC/REC 70-03</td></tr>
<tr><td>5.470–5.725</td><td>n x 20 MHz (HIPERLAN)</td></tr>
<tr><td>5.250–5.350</td><td>100 MHz Max.
Restricted to Indoor Use</td><td rowspan="3">USA CFR 47 Part 15, subpart E [B19]
USA CFR 47 Part 15, subpart C [B19]</td></tr>
<tr><td>5.250–5.350</td><td>100 MHz Max</td></tr>
<tr><td>5.725 –5.850</td><td>125 MHz Max</td></tr>
<tr><td colspan="2">10.000–10.680</td><td>3.5 to 28 MHz paired with
3.5 to 28 MHz. Symmetric only
350 MHz separation</td><td>CEPT/ERC/REC. 12-05
ETSI EN 301 021 [B18]</td></tr>
</table>

B.2 License-exempt co-existence and interference analyses

B.2.1 Interference mitigation and sharing mechanisms

A number of license-exempt interference mitigation and sharing mechanisms are identified. Two categories are considered: mechanisms that fall within the scope of the WirelessHUMAN standard and methods that fall outside that scope.

Within the scope of the WirelessHUMAN standard, two methods are identified: DFS and transmit power control, both are mandated by the WirelessMAN standard (see 6.2.14 and 8.4.6.4 respectively) and by some regulatory regions such as ECC [B36].

Two methods outside the scope of the WirelessMAN standard are identified: antenna directivity and antenna polarization.

B.2.1.1 Dynamic frequency selection

As frequency planning is not practical in licensed-exempt bands, DFS can be used to avoid assigning a channel to a channel occupied by another system. DFS is generally based on comparison of a C/I threshold against idle time RSSI measurements. DFS is predominantly effective to combat interference from and to ground based systems, such as RLANS, RTTT, radar and other WirelessHUMAN compliant systems. It is generally ineffective to combat interference from and to airborne systems, such as airborne radars and satellites.

B.2.1.2 Transmit power control

With power control, the transmitter EIRP is reduced according to the link margin. Shorter link ranges result in lower transmitted power levels. For PMP systems, the average EIRP will typically be several dB’s below the legal limit assuming that SSs are spread throughout the coverage area. For Mesh systems, this means that EIRP values decrease rapidly as customer deployment density increases. As power control is also influenced by C/I levels, the use of adaptive power control with DFS, where possible, tends to result in the most effective interference mitigation.

B.2.1.3 Antenna directivity

Antenna directivity, in horizontal but especially in vertical direction can significantly reduce a BWA's interference potential and resilience. Vertical directivity especially reduces the interference caused to satellite systems, which are designated primary users of part of the addressed bands. It also can significantly help reduce interference to and from indoor RLAN systems. Horizontal directivity significantly reduces the probability of interference to other systems (assuming interference is mainly caused in the main lobe), but tends to increase the severity of the interference, as the energy in the main lobe is generally higher.

B.2.1.4 Antenna polarization

Antenna cross-polarization in the 5-GHz band can achieve an isolation of up to 15 dB in LOS, but reduces significantly in near-LOS and NLOS environments. Most deployments use both horizontal and vertical polarization (circular polarization is not as common in currently known systems) to maximize spectral re-use. Polarization hence has the potential to provide some isolation between differently polarized systems, especially in LOS, but given the operational needs and implementation of most systems in the targeted spectrum, the effectiveness will be mostly marginal.

B.2.2 Services in the 5 GHz band

To enable co-existence studies, a short description of the systems and services in the 5-GHz bands is provided together with the necessary parameters for the subsequent interference analysis. This includes assumptions on parameters of WirelessHUMAN compliant systems that are beyond the scope of this standard.

B.2.2.1 WirelessHUMAN PMP system

PMP are based upon the use of a central BS with distributed SSs.

Parameters shown in Table B.2 for sample systems BWA1 and BWA2 are assumed.

Table B.2—Single U-NII BWA to SAR-4 Interference

Parameter	BWA_1	BWA_2	units
Transmitted power (antenna port)	0		dBW
Antenna high elevation gain	0	–4	dB
Building loss (dB)	0		dB
Polarization	H/V	H/V	

B.2.2.2 WirelessHUMAN Mesh system

The Mesh deployment scenario is abstracted into a regular hexagonal shape as shown in Figure B.1. On each corner of each hexagon, one Mesh node is located. By parameterizing the distance between a set of neighboring nodes, different Mesh deployment density scenario's can relatively easily be analyzed.

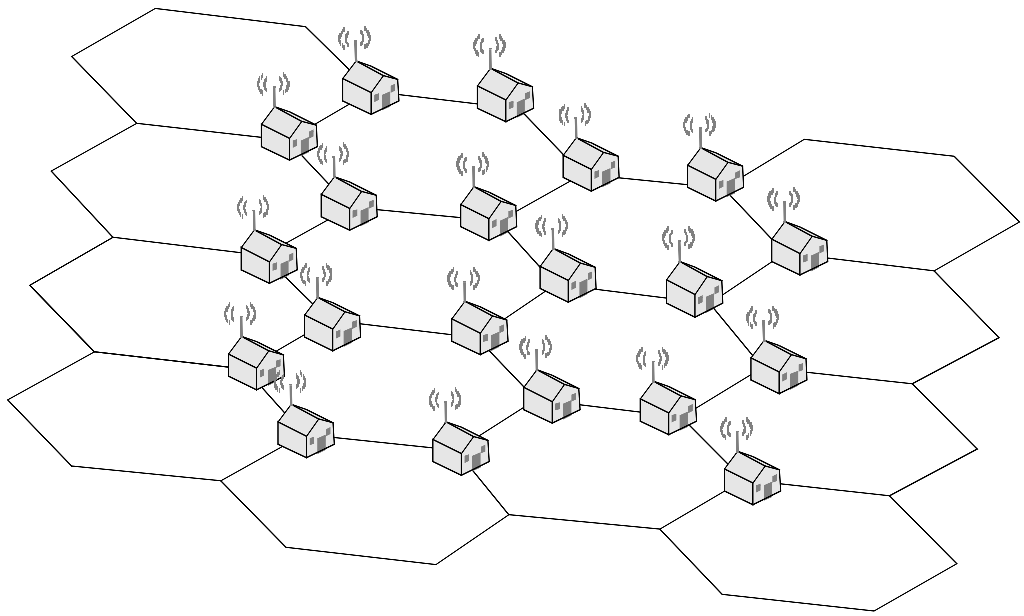


Figure B.1—WirelessHUMAN Mesh deployment model

If the distance between two nodes is denoted *r*, then from each node, there are 3 neighbors at distance *r*, 6 nodes at distance $2r\sqrt{3}/2$, 3 nodes at distance $2r$, 6 nodes at distance $3r\sqrt{3}/2$, 6 nodes at distance $3r$, 12 nodes at distance $\sim 4r\sqrt{3}/2$, 3 nodes at distance $4r$, 12 nodes at distance $\sim 5r\sqrt{3}/2$ etc.

Mesh devices that are close to each other cannot transmit at the same time on the same channel. This is normally defined in terms of extended neighborhoods, which comprises all nodes within two hops from the transmitting node. For modeling purposes, it is assumed that if a node is transmitting, all other nodes on the three hexagons that intersect on that node are silent. This translates into all nodes within a distance of $2r$ being silent.

In Table B.3, the topology and traffic assumptions are shown. The Tx activity of a node depends heavily on its position in the network, i.e., the amount of traffic that has to be forwarded from or to other nodes; and the activity of neighboring nodes. To keep the analysis simple, an average of 5% is assumed (This is based on the current average household internet usage of 30 minutes per day, as well as the activity probability during this on-time).

Table B.3—Tx activity parameters

Parameter	Value
Typical hops/packet	2
Total Tx activity	5%

Based on this model, the background interference at any node can be computed, which can be added to the interference from the node in question, resulting in the overall system interference.

B.2.2.2.1 Antenna parameters

The Mesh device is assumed to be using omni-directional antennas at all times, which is a worst-case assumption, as non-broadcast communications between nodes could be performed with multiple antennas to reduce overall interference.

It is extremely important to notice that the Mesh device is by necessity a roof-mounted device, as it has to extend coverage in all directions. In contrast to PMP Subscriber System (SSs), which are typically installed under the eaves, the amount of vertical scattering, which is harmful to both ground-based RLAN devices and satellites, is significantly less despite the lack of horizontal directivity. This is due to the relatively good probability of clear line-of-sight of the nodes to each other due to their individual mounting location as well as the significantly shorter distances to each other than a PMP SS typically enjoys to its BS.

For these reasons, no extra scattering in the vertical direction is assumed for this evaluation besides the antenna pattern.

Table B.4—Antenna parameters

Parameter	Value
Mounting	Outdoors/rooftop
Gain (Horizontal omni-directional)	8 dBi @ 90° –22 dBi @ 0–30° –15 dBi @ 30–50°
Polarization	vertical

As shown in Table B.4, the antenna is an 8dBi gain omni-directional antenna with a –22 dBi vertical gain and worst-case –15 dBi between 30 and 50° from vertical.

B.2.2.2.2 Radio parameters

Although 10 MHz channelization is also defined, the focus here is on the mandatory 20 MHz channelization, which gives the worst case scenarios.

It is important to note that, throughout this study, the use of 6 dBW max. EIRP is assumed for all parts of the spectrum with a backoff of only 3 dB for RLAN type devices. It should be understood that this study errs on the side of caution when considering the amount of interference that can be tolerated; as an example, in a practical OFDM system, the backoff is in the order of at least 6 dB minimum, whereas the rules commonly specify at most 0 dBW maximum mean EIRP [B37] or 6dBW maximum peak EIRP [B19] for fractions of the band.

Table B.5—Relevant Radio parameters

Parameter	Value
Transmit power	28 dBm (i.e., 36 dBm max EIRP) with dynamic power control
20 dB bandwidth	21 MHz
Peak-to-Average power ratio	3 dB

The Rx sensitivity and C/I parameters are obtained from Table 116bj (NF=7 dB, margin = 5 dB).

For the purpose of analytical full network interference analysis, the receiver sensitivity of the Mesh system is chosen to be –75 dBm, an average of the modulation and coding mode sensitivities up to rate 1/2, 16-QAM, which will be the most likely used in practical deployments.

B.2.2.3 EESS and FSS

Two types of satellite services are deployed in the 5 GHz: fixed satellite service (FSS) and earth exploratory satellite systems (EESS) services. EESS services are provided by two distinct types of satellite: Altimeter satellites and SAR satellites.

B.2.2.3.1 Altimeter satellites

The characteristics of altimeter satellites have been derived from [B29].

Table B.6—Altimeter satellite characteristics

Parameter	Value
Bandwidth	320 MHz
Rx sensitivity	–88 dBm
On-axis antenna gain	32.5 dBi
Off-axis antenna gain	$10^{3.25}(\mathrm{Sin}(\varphi)/\varphi)^2$ [a]
Antenna size	1.2 m
Height	1344 km
Input loss = Output loss	1 dB
Coverage	$\varphi \in [-60°, 60°]$
Bandwidth	320 MHz

[a] φ is the angle between the vertical and the direction of the ground-based device.

B.2.2.3.2 SAR satellites

The characteristics of SAR-1 through SAR-4 satellites have been derived from [B29].

Table B.7—Typical space borne imaging radar characteristics

Parameter	Value			
	SAR1	SAR2	SAR3	SAR4
Orbital altitude	426 km (circular)	600 km (circular)	400 km (circular)	400 km (circular)
Orbital inclination	57°	57°	57°	57°
RF Centre frequency	5305 MHz	5305 MHz	5305 MHz	5300 MHz
Peak radiated power	4.8 Watts	4800 Watts	1700 Watts	1700 Watts

Table B.7—Typical space borne imaging radar characteristics *(continued)*

Parameter	Value			
	SAR1	**SAR2**	**SAR3**	**SAR4**
Polarization	Horizontal (HH)	Horizontal and Vertical (HH,HV,VH,VV)	Horizontal and Vertical (HH,HV,VH,VV)	Horizontal and Vertical (HH,HV,VH,VV)
Pulse modulation	Linear FM chirp	Linear FM chirp	Linear FM chirp	Linear FM chirp
Pulse bandwidth	8.5 MHz	310 MHz	310 MHz	40 MHz
Pulse duration	100 µs	31 µs	33 µs	33 µs
Pulse repetition rate	650 pps	4492 pps	1395 pps	1395 pps
Duty cycle	6.5%	13.9%	5.9%	5.9%
Range compression ratio	850	9610	10230	1320
Antenna type	Planar phased array 0.5m x 16.0m	Planar phased array 1.8m x 3.8m	Planar phased array 0.7m x 12.0m	Planar phased array 0.7m x 12.0m
Antenna peak gain	42.2 dBi	42.9 dBi	42.7/38 dBi (full focus/beam-spoiling)	42.7/38 dBi (full focus/beam-spoiling)
Antenna median sidelobe gain	–5 dBi	–5 dBi	–5 dBi	–5 dBi
Antenna orientation	30° from nadir	20–38° from nadir	20–55° from nadir	20–55° from nadir
Antenna half-power beamwidth	8.5° (El), 0.25° (Az)	1.7° (El), 0.78° (Az)	4.9/18.0° (El), 0.25° (Az)	4.9/18.0° (El), 0.25° (Az)
Antenna polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System noise temperature	550 K	550 K	550 K	550 K
Image swath width	50 km	20 km	16 km/ 320 km	16 km/ 320 km

For both the SAR imaging missions and the topographic missions, a minimum signal-to-noise ratio (SNR) is defined, below which the radar image pixels, and/or differential phase measurements are unacceptably degraded. Studies suggest that:

— the degradation of the normalized standard deviation of power received from a pixel should be less than 10% in the presence of interference;
— the aggregate interference power-to-noise power ratio (corresponding to a pixel SNR of 0 dB) should be less than –6 dB;
— These levels may be exceeded upon consideration of the interference mitigation effect of SAR processing discrimination and the modulation characteristics of the radiolocation/ radio-navigation systems operating in the band;
— The maximum allowable interference level should not be exceeded for more than 1% of the images in the sensor service area for systematic occurrences of interference and should not be exceeded for more than 5% of the images in the sensor service area for random occurrences of interference.

The data loss criteria have been fully utilized to achieve sharing with the radio determination service. This study therefore uses the degradation interference criteria to derive the sharing constraints on BWA devices. Assuming that the interfering signal distribution is white Gaussian noise the maximum acceptable interference signal is indicated in Table B.8.

Table B.8—Typical space borne imaging radar characteristics

Parameter	Value			
Noise (dBW)	–129.5	–113.8	–113.8	–122.7
Min. desired signal (dBW)	–189.7	–198.6	–187.1	–187.0
Max. acceptable interfering signal (dBW)	–135.5	–119.8	–119.8	–128.7
Receiver bandwidth (MHz)	9.8	356.5	356.5	46
Max. acceptable interfering spectral power density (dBW/Hz)	–205.4	–205.4	–205.4	–205.4
Antenna polarization	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical	Linear horizontal/ vertical
System noise temperature	550 K	550 K	550 K	550 K
Receiver front end 1 dB compression point ref to receiver input	–62 dBW input	–62 dBW input	–62 dBW input	–62 dBW input
Ground illumination area	93 km (elevation), 2.2 km (azimuth)	At 20° from nadir: 20 km (elevation), 8.7 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)	At 20° from nadir: 40 km (elevation) 2 km (azimuth)

B.2.2.3.3 FSS satellites

The characteristics of Fixed Satellite Service satellites have been derived from [B29].

The maximum allowable interference power spectral density tolerated by FSS satellites is given by

$$p = -42 + (G/\ T) - \gamma \qquad dBW/\ Hz \tag{99}$$

where G is the gain of the satellite antenna, T the noise temperature (G/T is termed the merit factor), and γ the link gain. FSS satellites are geo-stationary and located at 36000 km, resulting in 199 dB pathloss. In the case of the Telecom 3 network [B29], which is used as an example, γ is 0 dB, the total link equivalent noise temperature is 870 K, the gain for the 'Metropole' spot is 34 dBi and the coverage area of this spot is all of Europe. G/T then becomes 4.6 dB.

B.2.2.4 RLANs

The RLAN deployments considered here are the ETSI BRAN HIPERLAN/2 [B31] and IEEE 802.11a devices. Only indoor deployments are considered in detail. It is clear that outdoor RLAN devices cannot generally co-exist in the same channel with BWA devices in the same geographical area. However, the use of DFS, as well as the fact that the hotspot locations envisioned for outdoor RLAN deployments (such as air-ports and school campuses) do not generally coincide with the residential areas Mesh devices are targeted towards, easily resolve this type of RLAN deployments.

Table B.9—RLAN Parameters I

Parameter	Value
Antenna type	Isotropical
Tx probability RLAN device	5%
Tx power	30 dBm max EIRP with dynamic power control
Radio access	TDD/TDMA

Table B.10—RLAN parameters II[a]

Modulation	Coding rate	Rx sensitivity (dBm @ 10% PER)	C/I (dB @ 10% PER)
BPSK	1/2	–82	6
	3/4	–81	11
QPSK	1/2	–79	9
	3/4	–77	14
16-QAM	1/2	–74	16
	3/4	–70	20
64-QAM	1/2	–66	25
	3/4	–65	30

[a]Copied from [B30], Table 91.

B.2.2.5 RTTT

Road transport & traffic telematics (RTTT) devices[B34] are allocated in the band 5795-5805 MHz (2×5 or 1×10), with an extension band 5805-5815 MHz (2×5 or 1×10), which may be used on a national basis at multi-lane road junctions. These devices are split into the Road Side Unit (RSU) and the onboard unit (OBU), the parameters for which are shown in Table B.11 and Table B.12.

Table B.11—RTTT RSU Parameters

Parameter	Value
Tx power (max EIRP)	3 dBW
Rx sensitivity	–105 to –130 dBW[a]
Antenna gain	20 dB
C/I: 2 / 4 / 8 - PSK	6 / 9 /12 dB
Polarization	circular

[a] This range is merely informative. The device shall merely meet the manufacturer's claim.

Table B.12—RTTT OBU Parameters (–35° to +35°)

Parameter	Value	
Class	A,B,C,D	E
Re-radiated carrier power (max EIRP)	–54 dBW	–44 dBW
Antenna gain	1 dB	
Rx sensitivity	–73 dBW	–70 dBW
C/I: 2 / 4 / 8 – PSK	6 / 9 /12 dB	C/I: 2 / 4 / 8 – PSK
Polarization	circular	polarization

In analyzing the compatibility between WirelessHUMAN systems and RTTT the basic approach taken is to use the Minimum Coupling Loss (MCL) technique to determine the necessary separation distances between the two systems.

Minimum coupling loss:
$$L = P_t - max\left\{10\log\left(\frac{B_i}{B_{Rx}}\right),\ 0\right\} - I_{Rx} \tag{100}$$

where

P_t is the transmitter power

B_{Rx} is the receiver bandwidth (MHz)

B_i is the interferer bandwidth (MHz)

I_{Rx} is the tolerable interference at receiver (dBW)

Required separation distance: $d = \frac{\lambda}{4\pi}10^{pathloss/\ 23}$ where *pathloss = L + Antenna and feeder gains and losses.*

B.2.2.6 Radar

The radar parameters used in the radar analysis are taken from [B29], [B36]. In the analysis, the MCL technique described in B.2.2.5 will be used, with the exception that for the airborne radar (radar type B), a propagation exponent 2.0 instead of 2.3 is used.

Table B.13—Relevant radar parameters

Parameter	Value				
Radar type	A	B	C	D	E
Peak EIRP (dBW)	98.6	26	60	93	97
BW_{radar} (MHz)	3	15	30	14	3
Antenna gain (dBi)	40	0	46	43	43
Tuning range (GHz)	5.30–5.60	5.70–5.80	5.40–5.82	5.25–5.85	5.60–5.65
Use	Transportable long range	Airborne	Fixed long range	Transportable multi-function	Fixed long range

B.2.3 WirelessHUMAN PMP interference analyses

B.2.3.1 Coexistence with SAR satellites in middle UNII

SAR-4 is used because the SAR-4 system is more interference sensitive than SAR-3, and the SAR-4 center frequency is 5.3 GHz. The SAR-4 Synthetic Aperture Radar scans a path from 20^{o} to 55^{o} from Nadir. This corresponds to Earth incident angles of 21^{o} and 60^{o}, which can be translated to angles of 69^{o} and 30^{o} with respect to the horizon. That is, any radiation from U-NII devices within that angular range could cause/ contribute to satellite interference.

An approach that can be used in analyzing the interference potential from Middle U-NII BWA systems into space-borne SAR-4 receiver is to determine the worst case signal power received from a single BWA transmitter at the space borne SAR. Then, the single interferer margin can be calculated by comparing the single BWA interferer level with the SAR-4 interference threshold. Knowing the SAR-4 footprint, the allowable density of active BWA transmitters can then be calculated, if a positive margin results from a single BWA interferer.

Table B.14—Single U-NII BWA to SAR-4 Interference

Parameter	BWA_1	BWA_2	units
Tx Power	0		dBW
Building loss	0		dB
Interference gain due to SS antenna directivity [B44]	–6		dB
Antenna high elevation gain	0	–4	dB
Pathloss (425.67 km)	–160.3		dB
Polarization gain (V/H –> H/V)	–3		dB
Noise figure	–4.62		dB
Noise power (46 MHz Rx bandwidth)	–122.73		dB
SAR-4 Interference threshold (I/N=–6dB)	128.71		dB
Margin (dB)	–4.71	–0.71	dB

Note that real-world antennas do not exhibit unity gain at high elevation look angles, and this feature can be used to mitigate interference.

A conclusion that can be drawn is that antenna directivity, if properly utilized, will provide interference margin for multiple transmitters. However, it should be noted that the satellite footprint is large (53 sq. km at 20^{o} from Nadir and 208 sq. km at 55^{o} from Nadir). Therefore, given the potential variables associated with the design, installation and maintenance of the various unlicensed transmitters, antenna directivity alone may not be sufficient to assure non-interference.

The margin calculation in Table B.14 includes 3 dB polarization loss. The fact that most PMP systems rely on polarization for maximizing channelization, as many as half of the U-NII transmitters in a given area could be transmitting on each polarization. If so, the 3 dB polarization loss may not be fully realizable.

If the satellite were restricted to one linear polarization and the U-NII transmitters were restricted to the other linear polarization, greater polarization isolation could be achieved. Given the operational needs of both services, this is unlikely to happen.

B.2.4 WirelessHUMAN Mesh interference analyses

B.2.4.1 Interference to EESS and FSS

B.2.4.1.1 Altimeter satellites

The interference from one Mesh node into the boresight of the SAR can be described by (see [B29])

$$P_r = \frac{P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L \qquad (101)$$

where $P_m G_m = 6dBm$ (28 dBm Output power –22 dBi top lobe) is the EIRP of the Mesh antenna in the vertical direction, $G_a = 32.5dBi$ the gain of the altimeter antenna, $\lambda = 5.66cm$ the wavelength, $L = -1dB$ the input loss of the altimeter, and $R = 1344km$ the lowest orbit.

From this a value for $P_r = -132dBm$ can be obtained.

The altimeter interference threshold is –88 dBm; we can thus deduce that the altimeter can withstand the operation of huge numbers of Mesh devices simultaneously, since there is a 44 dB margin. Furthermore, the altimeter is built to provide measurements mainly over oceans and is not able to provide accurate data when a significant amount of land is in view of its antenna beam. From this analysis, it is clear that the altimeter will not suffer from the operation of Mesh networks; however, for completeness, the number of Mesh devices per square kilometer tolerable by the altimeter can be calculated.

The distance between the satellite and a Mesh node under angle φ is R tan(φ) km. Only freespace attenuation, which ignores atmospheric properties (which further attenuate the signal, especially when φ>>0) has been considered.

For simplicity, the 3 Mesh nodes that on average exist in one hexagon, are assumed to be in the centre point of the hexagon. The hexagon grid then reduces to a square grid with 3 nodes every 2 times the distance of a single set of nodes.

The value for P_r is then obtained as follows:

$$P_r = \sum_{r_1}\sum_{r_2} \frac{3 P_m G_m G_a \lambda^2}{(4\pi)^2 R^2} L \left(1 + 4A \sum_{r_1}\sum_{r_2} \mathrm{sinc}^2[2\varphi(r_1, r_2)]\right) \quad \forall \sqrt{r_1^2 + r_2^2} < \frac{R\sqrt{3}}{2} \quad \varphi = arc\tan\left[\frac{2\sqrt{r_1^2 + r_2^2}}{R}\right] \qquad (102)$$

where r_1 and r_2 enumerate over the square grid, and A is the activity factor.

This derivation is easily computed numerically. According to [B33], significantly less than 15%[2] of land is used for residential areas and normally a significant fraction of the footprint covers water as well. Hence a Residential fraction of 0.05 is introduced, to simulate clusters of nodes spread out over the whole satellite footprint. The receiver sensitivity is, as discussed in B.2.2.2.2, chosen to be –75 dBm.

[2] Number includes land used for urban and other purposes, e.g., transport and recreation, and non-agricultural, semi-natural environments, e.g., sand dunes, grouse moors and non agricultural grasslands, and inland waters.

```
%Satellite specifications
Ga = 32.5;                % dBi   Antenna gain
lambda = 0.0566;          % m     Wavelength
L = -1;                   % dB    Insertion Loss
R = 1344;                 % km    Height
Int_limit = 88;           % dBm Interference limit
%Mesh specifications
Rbase = 0.5;              % km    Distance between two Mesh nodes
AntGain  = 8              % dBi   Mesh antenna gain (max)
AntTop   = -22            % dBi   Mesh antenna gain (top-lobe)
RxSens      =-105         % dBW Rx sensitivity Mesh
Pout       = 28;          % dBm Max. output power Mesh
Backoff   = 3;            % dB  Average Backoff
Activity    = 0.05;
pi = 3.1415;
pathloss = -20*log10(3E8/(4*pi*5.3E9))+2.3*10*log10(Rbase*1000);
PmGm = (pathloss - AntGain + FadingMargin + RxSens) + (AntTop-AntGain) -Backoff+ 30; % dBm
Residential = 0.15;       % fraction residential landuse
Pr1 = 0;nodes =0;
for r1 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
   for r2 = Rbase : Rbase/sqrt(Residential): R*sqrt(3)/2
      if( sqrt(r1*r1+r2*r2) < R*sqrt(3)/2)
         nodes = nodes+3;
         phi = atan( 2*sqrt(r1*r1+r2*r2)/R );
         Pr1 = Pr1 + sinc(2*phi/pi)*sinc(2*phi/pi);
      end;
   end;
end;
Pr2=10*log10(3*lambda*lambda*(1+4*Pr1*Activity)*10^((Ga+PmGm+L)/10)/...
        ((4*pi)*(4*pi)*R*R*1E6) );
sprintf('Distance between nodes: %d m\n',Rbase*1E3)
sprintf('Interference margin to altimeter: %d dB\n',Int_limit + Pr2)
```

Figure B.2—Mesh interference code sample

The result of the simulation, as shown above, is that over 30 million nodes can be supported under the footprint, with 6 dB in interference margin. In many cases shorter distances between the nodes will result in lower used power due to power control. Hence in practice many more nodes could be supported without violating the interference limit.

B.2.4.1.2 SAR satellites

In analogy with [B29], only the case for SAR-1 satellites is examined, since this provides the worst case analysis. However, contrary to this report, it will show that, using Mesh technology, an increase in network density actually reduces the interference into the SAR satellite, since the dynamic power-control reduces the power for shorter links. The receiver sensitivity is, as discussed in B.2.2.2.2, chosen to be –75 dBm.

As can be seen from Table B.15, a Mesh network has limitations both on the maximum distance and maximum density of the network. The maximum distance that can be achieved by the Mesh network using 4 Watts EIRP is about 1 km, which retains a margin of 10 dB to the interference threshold.

Deployments with distances between nodes of one km are however exceedingly sparse and not practical except in the very early stages of service rollout (i.e., when seeding the service area).

Reducing the distance increases the number of nodes, but reduces the necessary power levels, hence reducing the overall interference into the satellite. Increasing the density, and hence the number of nodes to very high levels, up to about one device per 92 m would still obtain tolerable interference levels. Deployment densities of this nature, especially in the areas of major interest to the satellite community (oceanic and agrarian), are extremely unlikely.

To allow an easier comparison with the RLAN results in [B29], Table B.15 computes the number of Mesh devices that can be situated in the SAR footprint without exceeding the interference limit.

Table B.15—WirelessHUMAN Mesh devices in the SAR footprint

Parameter	Value				
Node distance	1	0.5	0.25	0.1	km
Tx antenna gain	8				dBi
Rx sensitivity	–105				dBW
path loss	115.93	109.00	10.08	92.93	dB
P_{out} required (EIRP)	2.93	–4.00	–10.92	–20.07	dBW
P_{out} required (conducted)	–5.07	–12.00	–18.92	–28.07	dBW
Freespace distance	–160.8				dB
Building attenuation	0				dB
Tx antenna gain (top lobe)	–22				dBi
Polarization loss	–3				dB
Peak-to-Average ratio	–3				dB
Rx antenna gain (main lobe)	42.4				dBi
Rx Power	–224.90	–231.82	–238.74	–247.90	dBW/Hz
SAR threshold	–205				dBW/Hz
Margin	19.54	26.46	33.38	42.54	dB/Hz
SAR footprint	22.59				dB
Tx activity	–13.01				dB
Permissible density/km^2/ch	9.91	498.78	240.22	1976.39	nodes
Nodes within SAR footprint (CEPT region)	26967	132804	654001	5380723	nodes

In Table B.15, it is assumed that all Mesh devices are located in the boresight of the SAR satellite, which provides the worst case scenario.

B.2.4.1.3 FSS satellites

The bandwidth of the Mesh device is 21 MHz (73.2 dBHz). The maximum allowable interference power spectral density tolerated by the Telecom 3 network (see B.2.2.3.3) then becomes 27 dBW/Hz.

Appendix S8 of the ITU Radio Regulations [B32] gives the method to calculate the maximum interference power produced by an earth station to a satellite receiver. When calculating the maximum interference power from Mesh devices into a satellite receiver, consider all the Mesh devices under the satellite footprint as a single source. This means that the source is not specifically located, and only the direct top lobe of the Mesh antenna is taken into account.

Table B.16—Tolerable Mesh nodes for FSS operation

Parameter	Value				
Tx EIRP	–6	0	3	6	dBW
Tx antenna gain (main lobe)	8				dBi
Tx antenna gain (top lobe)	–22				dBi
Peak-to-Average Ratio	3				dB
Shielding effect	0				dB
Acceptable interference	27				dBW
Active users	1000	251	126	63	nodes (thousands)
Average Tx ratio	5				%
Tolerable nodes	300	75.4	37.8	18.9	nodes (millions)

From Table B.16, it shows that by using 4 W (6 dBW) EIRP, an enormous amount of Mesh nodes can be in operation within the FSS footprint.

B.2.4.2 Interference to RLANs

B.2.4.2.1 Immediate neighborhood analysis

B.2.4.2.1.1 ‘Same building’ analysis (1)

In the immediate neighborhood scenario, the interference from a Mesh node to a RLAN device in the same building is analyzed (link 1 in Figure B.3).

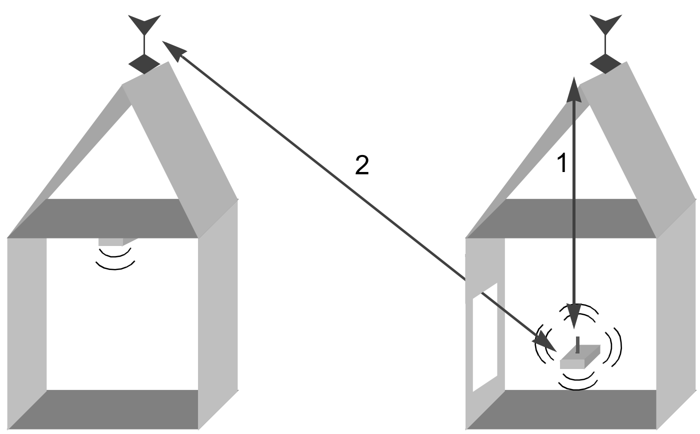


Figure B.3—Immediate neighborhood scenario

It is assumed for this scenario, that the distance between the Mesh node and the RLAN device in the same building is 5 m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 25 dB over that distance, based to Annex 2 of [B29]. Note that this is not the same as the average 13.4 dB assumed in [B29], since we consider only placement of Mesh devices on the roof, and not placement outside in general as in the outside RLAN case. This is likely to be a very modest value for a typical (European) home with concrete ceiling and stone tile roofing. The total attenuation is then $25 + 20*\log10(4*\pi*d*f_0/c) = 86$ dB. Given the radiation pattern of a Mesh node transmitting at full 28 dBm (i.e., 36 dBm EIRP), the interference level at the RLAN = 28-22-86= –80 dBm. Taking into account the backoff, 3 dB, and the effect of the Mesh activity factor, an additional 13 dB, brings the average interference level, –97 dBm, far below receiver sensitivity values. Operation of a Mesh device on the roof, while running an RLAN network inside is hence feasible, even in the same channel.

In this scenario, to operate the RLAN at its highest modulation and coding rate (64-QAM, 3/4 coding) while the Mesh device is transmitting, would require the separation to be at least 20 meters. (instead of the 5 meters used). For 16-QAM, 1/2 coding, the separation would be 10 meters.

B.2.4.2.1.2 'Across the street' analysis (2)

Another critical consideration is the analysis of illumination of indoor RLANs in adjacent buildings. This is due to the fact that despite the larger distance, normally only one isolating building layer (which may also be a window) is situated in-between, and the Mesh antenna gain increases with the angle from the vertical axis.

It is assumed for this scenario that the street is 10 m wide, which gives an antenna gain of –15 dBi and an outdoor distance of $\sqrt{125}$=11.2m. The structural isolation plus attenuation due to multipath/scattering is assumed to be 10 dB (window plus some indoor scattering). The total attenuation is then $10+20*\log10(4*\pi*d*f_0/c) = 78$ dB. Taking into account the antenna gain, the backoff and the Mesh activity factor of the Mesh node reduces the average level at the RLAN to –78 dBm.

Of course, the numbers in the above analysis fluctuate by a number of dB's for individual deployments. The average structural attenuation was quoted to be 13.4 dB in [B29], but there may be variations in building height or terrain sloping that increase the antenna gain in the direction of the RLAN by a few dBs. Typically the above results of this subclause are broadly applicable as conservative estimates to a wide range of deployment scenarios.

Power-control and DFS can assist in further reducing these interference levels. Note that the transmit probability of the RLAN device, (13 dB), has not been taken into consideration.

B.2.4.2.2 Outdoor RLAN analysis

An argument often used against the use of BWA devices in the 5-GHz bands is that it will interfere with outdoor deployments of RLAN devices. It is quite obvious that co-location of these two types of devices on a roof (or neighboring roofs) will cause severe interference when operating in the same channel; however, it should be realized that exactly the same issue exists when two RLAN APs on a roof (or neighboring roofs) are competing for the same channel. (To be specific, this is mostly the case for HIPERLAN/2, which is schedule based. Attempting to avoid this type of interference, which works well for low duty cycles, IEEE 802.11a uses CSMA/CD. In both cases, the requirement for a DFS mechanism can gracefully resolve the problem. In addition, outdoor RLAN deployments are predominantly used for hot-spot coverage and bridging, which implies the use of down-tilted antennas and oftentimes geographical isolation for hot-spot coverage and very directive antennas for bridging, each of which reduces the interference potential. In the cases where RLANs are currently used for access provisioning, WirelessHUMAN compliant systems will likely not be deployed or be used as more efficient substitutes.

BWA deployments require broad coverage and reasonable frequency re-use numbers to maintain sufficient Signal-to-Noise Ratio plus limited DFS flexibility to avoid local interference sources. Therefore, the likelihood of roof-mounted RLAN devices unable to find a sufficient noise-free channel for proper operation are rather small.

B.2.4.2.3 Network analysis

To illustrate the interference analysis further, a typical scenario consisting of a 4-node indoor RLAN network and a nearby 4-node Mesh network, is examined.

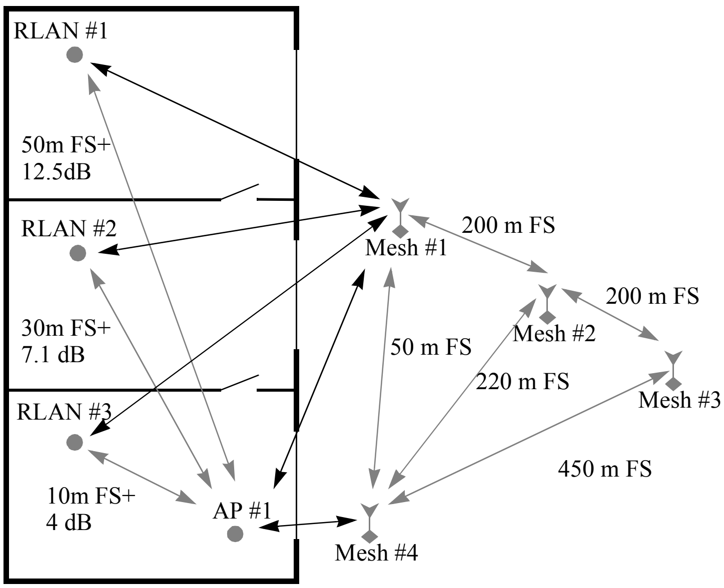
From Annex 2 of [B29], we extract that the typical indoor attenuation on top of free-space attenuation at 5 m is 4 dB for a mixture of line-of-sight through non-line-of-sight scenarios. The additional attenuation through 1 wall is 7.1 dB and the additional attenuation through 2 walls is 12.5 dB (the walls in these cases were breeze blocks and the rooms contained both wooden and metal furniture). The attenuation through a double-glazed window was found to be 7 dB.

In the case under study, a SU is assumed from each of these cases in a Small Office setting. The SU in the same room is assumed at 10 m; the SU in the adjacent room at 30 m; and the SU behind two walls at 50 m.

The Small Office is assumed to be a single-floor building with a flat roof. The attenuation through the roof is 22 dB. A typical indoor cross-floor attenuation according to Annex two of [B29] is 19 dB, which is probably a fairly pessimistic value. The Mesh #4 node is situated on the roof directly atop AP #1 and provides the 'Internet access' for the RLAN service within the building. The cabling distance between the data gathering point, the AP, and the access service, Mesh #4 node, is shortest. The distance between AP #1 and Mesh #4 is assumed to be 5 m.

The nearest neighboring node, Mesh #1, is 50 m away on an adjacent building. The building attenuation is 10 dB (a window plus indoor scattering, as in B.2.4.2.1.2. It is assumed that this building is lower than the building with the RLANs, resulting in an antenna gain of –10 dBi in the direction of the RLANs, rather than the –15 dBi specified in Table B.4). Two other nodes are each 200 m away as shown in Figure B.4. All Mesh nodes are on the roof and hence only have free-space (FS) attenuation to each other. Mesh #3 is assumed to have an additional 15 dB obstruction to the RLANs in the form of a building (basically the building on which Mesh #2 is located).

Note that in the Path Losses in Figure B.4, the antenna gain of the Mesh nodes (see Table B.4) in the direction of the RLANs has been included.



Path	Path Loss
Mesh#1 - AP#1	50m FS + 28dB
Mesh#1 - RLAN#1	60m FS + 28dB
Mesh#1 - RLAN#2	70m FS + 28dB
Mesh#1 - RLAN#3	80m FS + 28dB
Mesh#2 - AP#1	250m FS + 33dB
Mesh#2 - RLAN#1	250m FS + 33dB
Mesh#2 - RLAN#2	260m FS + 33dB
Mesh#2 - RLAN#3	270m FS + 33dB
Mesh#3 - AP#1	450m FS + 48dB
Mesh#3 - RLAN#1	450m FS + 48dB
Mesh#3 - RLAN#2	460m FS + 48dB
Mesh#3 - RLAN#3	470m FS + 48dB
Mesh#4 - AP#1	5m FS + 52dB
Mesh#4 - RLAN#1	52m FS + 48dB
Mesh#4 - RLAN#2	32m FS + 48dB
Mesh#4 - RLAN#3	12m FS + 52dB

Figure B.4—Example network scenario

In Table B.17, the ranges and corresponding total link attenuations, which are assumed to be symmetrical, are gathered. In general, it can be observed that only nodes that are really close or in line of sight through little attenuation (particularly windows) result in significant interference.

Table B.17—Link attenuations and ranges

	Link attenuation / Range							
	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	RLAN #1	RLAN #2	RLAN #3
Mesh#1	-----------	200 m	400 m	50 m	50 m	60 m	60 m	60 m
Mesh#2	94 dB	-----------	200 m	220 m	220 m	230 m	230 m	230 m
Mesh#3	100 dB	94 dB	-----------	450 m	450 m	460 m	460 m	460 m
Mesh#4	82 dB	94 dB	101 dB	-----------	5 m	52 m	32 m	12 m
AP#1	110 dB	127 dB	149 dB	106 dB	------------	50 m	30 m	10 m
RLAN#1	111 dB	128 dB	149 dB	130 dB	94 dB	------------	50 m	20 m
RLAN#2	111 dB	128 dB	149 dB	126 dB	84 dB	132 dB	------------	30 m
RLAN#3	111 dB	128 dB	149 dB	121 dB	72 dB	94 dB	107 dB	------------

In Table B.18, the maximum power and EIRP values for each of the devices is shown. For the RLAN devices and their AP, values are chosen that reflect implementations that are currently available in the market.

Table B.18— Tx Power, conducted and EIRP (regulatory limited)

	AP	RLAN	Mesh
Tx Power (mW)	200	200	500
Antenna (dBi)	2	0	8
EIRP (dBm)	25	23	35

In Table B.19, the resulting received signal strengths are shown assuming transmission with EIRP values as shown in Table B.18. Note that especially between the Mesh nodes, the Rx values are extremely high, which would automatically be reduced by the AGC. For simplicity of computation, this is however ignored. This table is not symmetric since different antenna gains at each end can affect the perceived signal level.

Table B.19—Received Signal Levels (dBm)

	Mesh #1	Mesh #2	Mesh #3	Mesh #4	AP #1	RLAN #1	RLAN #2	RLAN #3
Mesh #1	-----------	–54	–60	–42	–80	–83	–83	–83
Mesh #2	–54	-----------	–54	–54	–97	–100	–100	–100
Mesh #3	–60	–54	-----------	—61	–119	–121	–121	–121
Mesh #4	–42	–54	–61	-----------	–84	–102	–98	–93
AP #1	–76	–93	–115	–80	------------	–72	–62	–50
RLAN#1	–79	–96	–117	–98	–72	------------	–112	–74
RLAN#2	–79	–96	–117	–94	–62	–112	------------	–87
RLAN#3	–79	–96	–117	–89	–50	–74	–87	------------

Table B.20 shows resulting sustainable modulations. The top row in each box shows the actual communication direction, the used modulation and the Noise threshold. The next four rows illustrate the effect of interference from each source (using maximum allowed EIRP). If the modulation differs from the top box, then switch to a more robust modulation scheme was mandatory to maintain 3% PER. The last column defines the interference margin. A positive value means the threshold has been exceeded and is shown in bold.

Table B.20—Sustainable modulation during interference

RLAN#1 =>AP#1	3/4 QPSK	-90
Mesh #1	**PER>3%**	**4**
Mesh #2	3/4 QPSK	-13
Mesh #3	3/4 QPSK	-35
Mesh #4	**PER>3%**	**0**

RLAN#2 =>AP#1	2/3 64-QAM	-95
Mesh #1	1/2 QPSK	-5
Mesh #2	2/3 64-QAM	-22
Mesh #3	2/3 64-QAM	-44
Mesh #4	3/4 QPSK	-9

RLAN#3 =>AP#1	3/4 64-QAM	-95
Mesh #1	1/2 QPSK	-5
Mesh #2	2/3 64-QAM	-22
Mesh #3	3/4 64-QAM	-44
Mesh #4	3/4 QPSK	-9

AP#1 => RLAN#1	3/4 QPSK	-90
Mesh #1	**PER>3%**	**1**
Mesh #2	3/4 QPSK	-16
Mesh #3	3/4 QPSK	-37
Mesh #4	3/4 QPSK	-18

AP#1 => RLAN#2	2/3 64-QAM	-95
Mesh #1	3/4 QPSK	-8
Mesh #2	3/4 64-QAM	-25
Mesh #3	3/4 64-QAM	-46
Mesh #4	2/3 64-QAM	-23

AP#1 => RLAN#3	3/4 64-QAM	-95
Mesh #1	3/4 QPSK	-8
Mesh #2	3/4 64-QAM	-25
Mesh #3	3/4 64-QAM	-46
Mesh #4	3/4 16-QAM	-18

From Table B.20, two observations can be generalized. The first is that in certain scenarios interference is unavoidable if DFS is not used. The second is that interference only occurs when nodes are really close (such as Mesh #4) or have relatively good line of sight properties (such as Mesh #1, which only has a window in-between and a reduced height antenna) to the RLAN network. The later generalization means that very few nodes in a Mesh network will cause degradation of a RLAN network. Realizing that the interference excess is relatively low, and the Mesh network uses power-control to reduce the EIRP where possible, interference from a transmitting Mesh device will be very limited. Combined with the activity factors for both devices (on average 13 dB each) and DFS mechanisms, the likelihood of interference becomes so small that it is easily handled with Automatic Request (ARQ) causing minimal degradation of performance.

B.2.4.2.4 Adjacent channel issues

A feature of the OFDM technology used in both RLANs and Mesh technology at 5 GHz, is that the adjacent channel rejection is very high, at least 35 dB (see 8.4.10.2). Since the interference levels between RLANs and Mesh devices are relatively low compare to this, it is reasonable to assume that adjacent channels using RLAN and Mesh technology will not cause any noticeable interference to each other; therefore, this requires no further consideration.

B.2.4.3 Interference to RTTT

In accordance with [B29], and [B35], the cross-polarization is assumed to be 10–15 dB to the RSU and 6–10 dB to the OBU (Table B.21 uses the lower numbers).

Table B.21—Needed separation distance Mesh to RSU and OBU

Parameter	RSU		OBU
P_t	6		6
B_{Rx}	10	5	10
B_i	22		22
$I_{Rx}=Rx_{sens}-C/I_{8PSK}$	–117		–90
L	119.6	116.6	92.6
Cross-polarization	10		6
Antenna & feeder gain	8		8
Separation distance	553	394	53

It should be noted that in the above calculations of Table B.21, the duty cycle of the Mesh devices, which significantly reduces the interference scenario, has not been taken into consideration.

Especially for the RSU case, where the separation distance is fairly significant, it can be shown that the interference to the Mesh device is significantly larger than the other way around. Since RTTT devices normally have a fairly high duty cycle, a close Mesh device would not be able to operate properly in this channel and would need to use the DFS mechanisms to switch to another channel. therefore, for RSUs, proper operation is virtually guaranteed by virtue of its own interference potential.

B.2.4.4 Interference to radar

For radars, a somewhat similar situation exists as with RTTT RSUs. To show this, the interference distance from radars into Mesh devices is derived, followed by the derivation of the interference distance from Mesh devices into radars. Comparing Table B.22 and Table B.23, the interference distance from radars to Mesh is much larger than the interference distance from Mesh to radars.

For analysis of the minimum distance at which an Mesh device still operates, shown in Table B.22, the most robust modulation and coding mode is used.

Table B.22—Minimum separation distance of radar to Mesh

Radar type	A	B	C	D	E	
Peak EIRP	98.6	26	60	93	97	dBW
Antenna gain	40	0	46	43	43	dBi
P_t	58.6	26	14	50	54	dBW
BW_{radar}	3	15	30	14	3	MHz
$I_{mesh}=Rx_{sens}-C/I_{BPSK1/2}$	–116					dBW
L	174.6	142.0	131.3	166.0	170.0	dB
Gain and feeder loss	48	8	54	51	51	dB
Propagation loss	222.6	150	185.3	217	221	dB

Table B.22—Minimum separation distance of radar to Mesh *(continued)*

Radar type	A	B	C	D	E	
Distance @ 5.5 GHz	20693	137	497	11813	17630	km
Radio horizon	51.4	346.6	51.4	51.4	51.4	km (see [B36])
Separation distance	51.4	137	51.4	51.4	51.4	km

In Table B.23, the thermal noise level has been assumed –204 dB/Hz whereas the Rx noise factor is assumed to be 5 dB. The maximum I/N is –6 dB as specified by NATO (see [B29], [B36]).

Table B.23—Minimum separation distance of Mesh to radar

Radar type	A	B	C	D	E	
P_t mesh	–2					dBW
BW_{radar}	3	15	30	14	3	MHz
Noise (dBW)	–134.2	–127.2	–124.2	–127.5	–134.2	dBW
On-tune rejection	–8.9	–1.9	0.0	–2.2	–8.9	dB (see [B29])
Max. Interference	–131.3	–131.3	–130.2	–131.3	–131.3	dBW
L	129.3					dB
Gain + feeder loss	48	8	54	51	51	dB
Propagation loss	177.3	145.3	191.6	188.3	188.3	dB
Distance @ 5.5 GHz	220.1	79.4	916.3	662.7	662.0	km

Comparing the result of Table B.22 (line 10) and Table B.23 (line 10), it is shown that in all cases, the separation distance is larger for the BWA system, forcing it effectively out of the channel used by the radar. In all cases, the separation distance is effectively limited by the radio horizon.

In the case of radar type B, which is airborne, depending on the exact location of the radar, the gain+feeder loss will reduce from +8 to –22 dB, significantly reducing the necessary separation distance. Since the angle of detection (if any) is not known, this factor has not been used in the previous tables. For the other types, the distance is limited by the radio horizon, but in practice likely much lower due to obstructions and clutter.

From Table B.22 and Table B.23, similar conclusions to the RLAN analysis in [B29] can be drawn. Sharing with maritime radars (which are not likely operating anywhere near residential areas) and S5.452 meteorological radars in band B, and radiolocation radars in both band B and C is feasible when an effective DFS mechanism is employed by the Mesh system and the radar density isn't too high.

B.3 Performance Characteristics

B.3.1 WirelessMAN-SCa PHY throughput and modulation efficiency

Parameter settings for the SCa PHY that influence throughput and modulation efficiency calculations are summarized in Table B.24.

Table B.24—SCa parameters used in capacity calculations

Categorization of parameter	Parameter description	Parameter symbol	Parameter values
System-dependent parameter	Channel BW (MHz)	W	1.75, 3.5, 7, 14; 1.5, 3, 6, 12
	Maximum delay spread (μs)	d	4, 10, 20
	Spectral rolloff factor	α	0.18
Link-dependent parameter	QAM constellation size	M	4, 16, 64
	Inner (convolutional) code rate	r_I	1/2, 2/3, 3/4, 7/8
	Outer (Reed-Solomon) code rate	r_O	$239/255 \cong 0.937$
Traffic-dependent parameter	Data payload size [for burst uplinks] (bytes)	P_B	239, 717, 1195, 1673
	Data payload size [for continuous FDD downlinks]	P_C	1673, 2151, 2623, 3585
Derivative parameter	Symbol rate (Msymbol/s)	R	$R = W/(1+\alpha)$

Observe that the maximum delay spread is listed as a system-dependent parameter in Table B.24. This categorization is chosen because frame (and burst) preambles in the SC PHY are composed of Unique Words (UWs). Each UW has to be at least as long as the delay spread in the channel in order to effectively estimate the channel. The overhead associated with channel estimation (and all other frame format structures) are captured in capacity and spectral efficiency calculations.

In all calculations (namely, those in Table B.25 and Table B.26), the Unique Word length (in symbols), U, is chosen to be a power of 2, using the formula $U = 2^{\log 2(\lceil R \cdot d \rceil)}$ to achieve upward power of 2 rounding and symbol unit scaling. Moreover, all calculations assume the use of full (frame or burst) preambles are used to estimate the channel for each transmitted data block, which implies that the channel coherence time is assumed equal to the block period. In most broadband wireless access applications, coherence times are much longer than individual user transmissions. The use of full preambles is hence unnecessary as information derived from preambles from previous blocks may be used. In addition, several user data blocks may be multiplexed on a downlink transmission. For this reason, the spectral efficiency and throughput figures that are compiled should be considered conservative, particularly for downlink channels.

Burst transmissions (e.g., ones on an uplink) are assumed to use the frame format illustrated in Figure 128r. Applying the definitions found in Table B.24 to the frame format of Figure 128r with a burst preamble of length A symbols, and then subtracting away the associated overhead, the throughput for a burst transmission is found to be

$$T_B = \frac{8P_B R \log_2(M)}{\left(\frac{8P_B}{r_I r_O} + (A+U)\log_2(M)\right)} \tag{103}$$

Similarly, the throughput for a framed continuous transmission (e.g., transmission on an FDD continuous downlink) can be computed, using the continuous frame format. The resulting throughput is

$$T_C = \frac{8P_C R \log_2(M)}{\left(\frac{8P_C}{r_I r_O} + A\log_2(M)\right)}. \tag{104}$$

PHY modulation efficiency (in bits/s/Hz) is obtained by scaling the throughput by the BW efficiency. The resulting PHY modulation efficiencies for burst and continuous transmissions, parameterized, are, respectively,

$$E_B = \frac{T_B}{W} = \frac{T_B}{(1+\alpha)R} = \frac{8P_B \log_2(M)}{(1+\alpha)\left(\frac{8P_B}{r_I r_O} + (A+U)\log_2(M)\right)} \tag{105}$$

and

$$E_C = \frac{T_C}{W} = \frac{T_C}{(1+\alpha)R} = \frac{8P_C \log_2(M)}{(1+\alpha)\left(\frac{8P_C}{r_I r_O} + A\log_2(M)\right)}. \tag{106}$$

Table B.25 and Table B.26 contain the results of evaluating throughput and PHY efficiency expressions over a range of system and link parameters. Table B.25 focuses on burst-format transmission over a 1.75 MHz BW channel, such as one might see on the uplink of an FDD application, and assumes a burst preamble size of $A = 2U$. Table B.26 focuses on continuous-format transmission over a 6 MHz BW channel, such as one might see on the continuous downlink of a FDD application, and assumes longer frames and a frame preamble size of $A = 4U$. All calculations assume a spectral rolloff factor of $\alpha = 0.18$.

Table B.25—Throughput and PHY efficiency example: 1.75 MHz BW burst UL

System-dependent parameters		Link-dependent parameters		Throughput (Mbit/s)				PHY efficiency
Symbol rate (Msymb/s)	Max delay spread (Symbs)	QAM constel-lation size	Inner code rate	Packet payload size (bytes)				(Mbits/s/MHz)
				239	717	1195	1673	(P=1673)
1.5	8	4	1/2	1.37	1.38	1.39	1.39	0.79
			2/3	1.82	1.84	1.85	1.85	1.06
			3/4	2.05	2.07	2.08	2.08	1.19
			7/8	2.38	2.42	2.42	2.43	1.39
		16	1/2	2.72	2.76	2.77	2.77	1.58
			3/4	4.03	4.12	4.14	4.15	2.37
		64	2/3	5.31	5.47	5.51	5.52	3.16
			5/6	6.56	6.82	6.87	6.89	3.94
	16	4	1/2	1.36	1.38	1.38	1.39	0.79
			2/3	1.80	1.83	1.84	1.85	1.05
			3/4	2.01	2.06	2.07	2.07	1.19
			7/8	2.34	2.40	2.41	2.42	1.38
		16	1/2	2.66	2.74	2.75	2.76	1.58
			3/4	3.90	4.07	4.11	4.13	2.36
		64	2/3	5.08	5.39	5.46	5.49	3.13
			5/6	6.22	6.69	6.79	6.84	3.91
	32	4	1/2	1.33	1.37	1.38	1.38	0.79
			2/3	1.74	1.82	1.83	1.84	1.05
			3/4	1.95	2.04	2.06	2.06	1.18
			7/8	2.25	2.37	2.39	2.40	1.37
		16	1/2	2.54	2.70	2.73	2.74	1.57
			3/4	3.65	3.98	4.06	4.09	2.34
		64	2/3	4.68	5.23	5.36	5.41	3.09
			5/6	5.63	6.44	6.64	6.72	3.84

Table B.26—Throughput and PHY efficiency example: 6 MHz BW continuous DL

System-dependent parameters		Link-dependent parameters		Throughput (Mbit/s)				PHY efficiency
Symbol rate (Msym b/s)	Max delay spread (Symbs)	QAM constel-lation size	Inner code rate	Frame payload size (bytes)				(Mbits/s/MHz)
				1673	2151	2629	3585	(P=3585)
5.1	8	4	1/2	4.69	4.95	5.00	5.02	0.84
			2/3	6.22	6.58	6.66	6.69	1.12
			3/4	6.98	7.40	7.49	7.53	1.25
			7/8	8.12	8.62	8.73	8.78	1.46
		16	1/2	9.24	9.84	9.97	10.03	1.67
			3/4	13.65	14.68	14.90	15.00	2.50
		64	2/3	17.94	19.47	19.81	19.96	3.33
			5/6	22.10	24.21	24.68	24.89	4.15
	16	4	1/2	4.62	4.92	4.98	5.01	0.84
			2/3	6.10	6.54	6.63	6.67	1.11
			3/4	6.83	7.34	7.45	7.50	1.25
			7/8	7.91	8.54	8.68	8.74	1.46
		16	1/2	8.97	9.74	9.90	9.98	1.66
			3/4	13.07	14.45	14.76	14.90	2.48
		64	2/3	16.94	19.06	19.55	19.77	3.30
			5/6	20.60	23.58	24.29	24.60	4.10
	32	4	1/2	4.48	4.87	4.95	4.99	0.83
			2/3	5.86	6.44	6.57	6.63	1.11
			3/4	6.53	7.22	7.38	7.45	1.24
			7/8	7.51	8.38	8.58	8.67	1.45
		16	1/2	8.47	9.53	9.78	9.89	1.65
			3/4	12.03	14.00	14.48	14.69	2.45
		64	2/3	15.24	18.30	19.06	19.41	3.24
			5/6	18.14	22.42	23.53	24.04	4.01

B.3.2 WirelessMAN-SCa PHY link budget analysis

A link budget analysis was performed by combining various channel bandwidths and QAM constellations with the channel models found in [B41]. Figure B.5 and Figure B.6 provide two examples of the path loss versus propagation radius, using the NLOS Categories A, B and C propagation models of [B41], and assuming 3.5 GHz band operation, a 6.5 m SS antenna, and for a 30 m and 80 m BS antenna height, respectively. For reference, an example set of parameters that fully specify model Categories A, B, and C are listed in Table B.27.

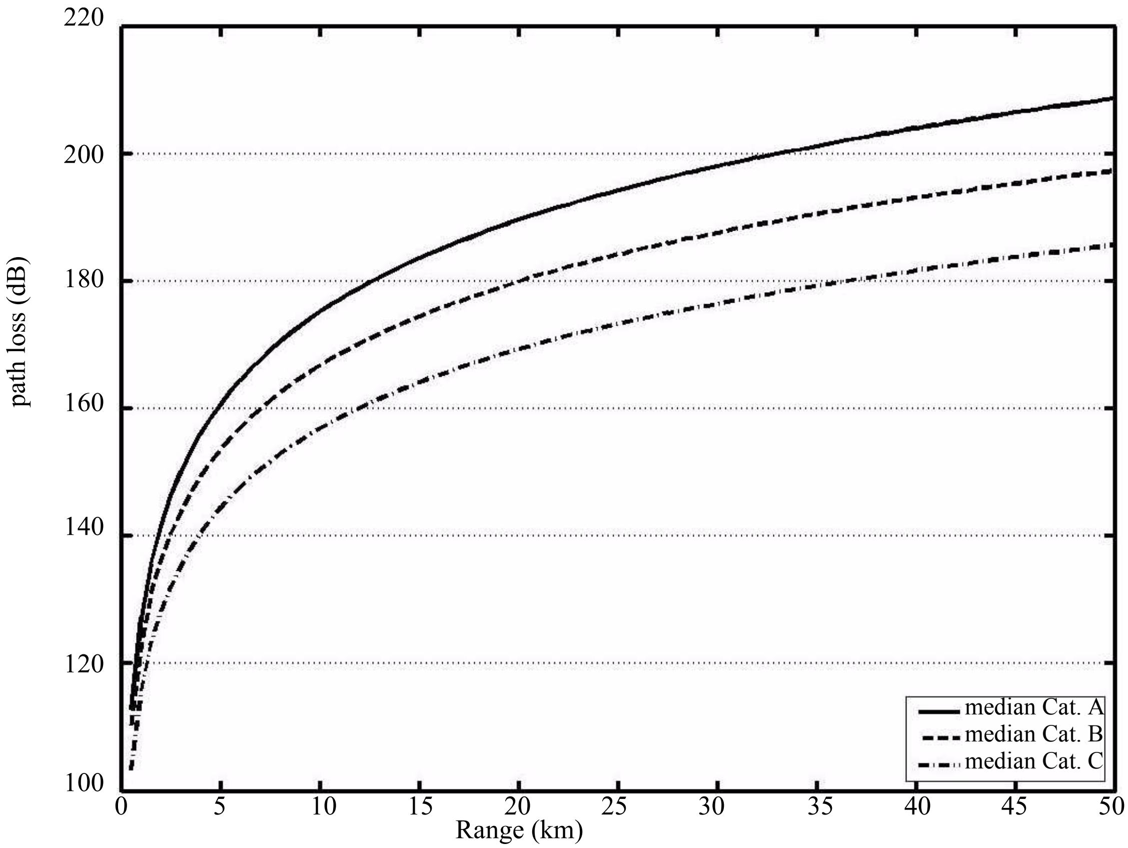


Figure B.5—Path loss model (30 m BS, 6.5 m SS antenna heights)

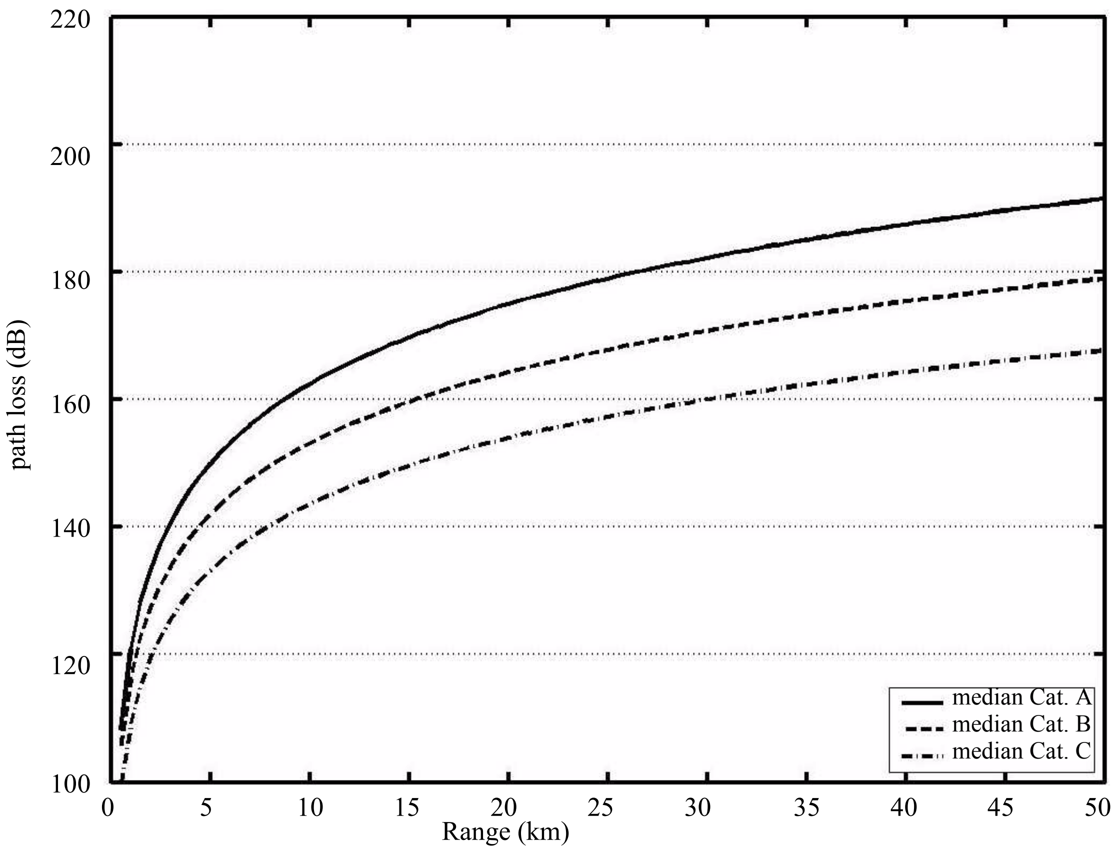


Figure B.6—Path loss model (80 m BS, 6.5 m SS antenna heights)

Table B.27—Sample parameters for A, B, and C channel model categories

Parameters	Category		
	C	B	A
	Flat few trees	Intermediate	Hilly heavy trees
a	3.6	4	4.6
b	0.005	0.0065	0.0075
c	20	17.1	12.6
Channel frequency (GHz)	3.5		
Wavelength λ (m)	0.085714		
Rx antenna height h(m)	6.5		
BS antenna height h_b(m)	30 or 80		
$\gamma = a - b \cdot h_b + c / h_b$	4.117	4.375	4.795

Table B.27—Sample parameters for A, B, and C channel model categories *(continued)*

Parameters	Category		
	C	B	A
	Flat few trees	Intermediate	Hilly heavy trees
$A = 20\log10(4\pi d_o / \lambda)$	83.32		
s(dB)	9.4		
$P_L = A + 10\gamma \cdot \log10(d/d_0) + DPI + DPh + s$			
4/3 Earth LOS (km)	32.5		

Evaluating, for example, median path loss figures as a function of distance, the minimum path length necessary to reliably deliver QPSK and 16-QAM, on both UL (1.75 MHz) channel and DL (7 MHz) channels may be computed by including **s** shadowing factor into path loss P_L calculation.

An alternate approach is to assume a cell radius, calculate budgets, and then assess link margins. Table B.28 through Table B.31 provide link budget calculations for a NLOS SCa system, with ‘median’ path loss, for UL and DL and, for 30 m and 80 m BTS antenna heights respectively. A 7 MHz DL using 16-QAM and a 1.75 MHz UL using QPSK are assumed in these calculations. Table B.32 and Table B.33 provides a similar analysis for the SCa system with 30 m BTS antenna height and for a 3.5 km coverage. For comparison purposes, corresponding link budget results for LOS scenarios are also provided in Table B.28 through Table B.33.

Table B.28—SCa DL link budget: example I

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	–150.5 dB	–160.0 dB	–167.7 dB	–120.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	–85.5 dBm	–94.0 dBm	–102.7 dBm	–55.2 dBm
Receiver NF	5 dB			

Table B.28—SCa DL link budget: example I *(continued)*

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Equivalent noise power in channel BW	–100.5 dBm			
SNR, calculated	15.0 dB	5.5 dB	–2.2 dB	45.3 dB
Fade margin	+1 dB	–8.5 dB	–16.2 dB	31.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Table B.29—SCa UL link budget: example II

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	–150.5 dB	–160.0 dB	–167.7 dB	–120.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	–92.5 dBm	–102.0 dBm	–109.7 dBm	–62.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	–107.6 dBm			
SNR, calculated	15.1 dB	5.6 dB	–2.1 dB	45.3 dB
Fade margin	3.1 dB	–6.4 dB	–14.1 dB	33.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Table B.30—SCa DL link budget: example III

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	–138.2 dB	–147.4 dB	–156.0 dB	–120.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	–73.2 dBm	–82.4 dBm	–91.0 dBm	–55.2 dBm
Receiver NF	5 dB			
Equivalent noise power in channel BW	–100.5 dBm			
SNR, calculated	27.3 dB	20.1 dB	9.5 dB	45.3 dB
Fade margin	13.3 dB	6.1 dB	–4.5 dB	31.3 dB
BTS antenna height = 80 m				
SS antenna height = 6.5 m				

Table B.31—SCa UL link budget: example IV

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	7 km			
Pathloss [48]	–138.2 dB	–147.4 dB	–156.0 dB	–120.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	–80.2 dBm	–89.4 dBm	–98.0 dBm	–62.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	–107.6 dBm			
SNR, calculated	27.4 dB	18.2 dB	10.4 dB	45.3 dB
Fade margin	15.4 dB	7.8 dB	–2.4 dB	33.3 dB
BTS antenna height = 80 m				
SS antenna height = 6.5 m				

Table B.32—SCa DL link budget: example V

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	7 MHz			
Modulation	16-QAM			
Target SNR with FEC	14 dB			
P_{1dB}	40 dBm			
Tx Antenna gain	15 dB			
Backoff	8 dB			
EIRP	47 dBm			
Cell radius for target SNR	3.5 km			
Pathloss [48]	–138.1 dB	–146.8 dB	–153.3 dB	–114.2 dB
Rx Antenna gain	18 dB			
Power at input to receiver	–73.1 dBm	–81.8 dBm	–88.3 dBm	–49.2 dBm
Receiver NF	5 dB			
Equivalent noise power in channel BW	–100.5 dBm			
SNR, calculated	27.4 dB	18.7 dB	12.2 dB	51.3 dB
Fade margin	13.4 dB	4.7 dB	–1.8 dB	37.3 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Table B.33—SCa UL link budget: example VI

Parameter	SCa(NLOS) category C	SCa(NLOS) category B	SCa(NLOS) category A	SCa(LOS)
Bandwidth	1.75 MHz			
Modulation	QPSK			
Target SNR with FEC	12 dB			
P_{1dB}	30 dBm			
Tx Antenna gain	18 dB			
Backoff	5 dB			
EIRP	43 dBm			
Cell radius for target SNR	3.5 km			
Pathloss [48]	–138.1 dB	–146.8 dB	–153.3 dB	–114.2 dB
Rx Antenna gain	15 dB			
Power at input to receiver	–80.1 dBm	–88.8 dBm	–95.3 dBm	–56.2 dBm
Receiver NF	4 dB			
Equivalent noise power in channel BW	–107.6 dBm			
SNR, calculated	27.5 dB	18.8 dB	12.3 dB	51.4 dB
Fade margin	15.5 dB	7.2 dB	1.7 dB	39.4 dB
BTS antenna height = 30 m				
SS antenna height = 6.5 m				

Note that:

— Target SNRs assume Concatenated RS-CC or BTC FEC delivers a BER of 10^{-6} with 6 dB coding gain.
— Tx Antenna gain in all above Tables include –1.5 dB RF loss.
— Link budget evaluations provided in Table B.28 through Table B.33 are for Median path loss cases. That is, the effect of Shadow Fading (e.g., S = 9.4 dB) is not included.

B.3.3 WirelessMAN-OFDM/OFDMA PHY symbol and performance parameters

The effective bandwidth of the transmitted signal is related to the carrier spacing and the number of carriers.

In order to calculate the sampling frequency for any bandwidth, we define the bandwidth efficiency:

$$BW_{Efficiency} = \frac{f_s}{BW} \cdot \frac{(N_{used}+1)}{N_{FFT}} = \frac{\Delta f \cdot (N_{used}+1)}{BW} \tag{107}$$

where

BW	is the Channel bandwidth (Hz)
f_s	is the Sampling frequency (Hz)
Δf	is the Carrier spacing (Hz)
$N_{used} + 1$	is the Number of active carriers used in the FFT (pilot and data carriers) + DC carrier
N_{FFT}	is the FFT size.

The bandwidth efficiency is designed to be in the range of 83–95%, depending mainly on the FFT size, in order to occupy the maximum usable bandwidth but still allow adequate RF filtering.

The following tables give some calculations of the carrier spacing, symbol duration and CP duration for different masks. The sampling rate is defined as $f_s = BW \cdot 8/7$, except for 256-OFDM (see 8.4.2.4) in licensed bandwidths, which are not a multiple of 1.75 MHz. In those cases, the sampling rate is $f_s = BW \cdot 7/6$.

Table B.34—OFDM channelization parameters for licensed bands

BW (MHz)		OFDM (N_{FFT} = 256)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
MMDS ($f_s/BW = 7/6$)	1.5	$6\frac{51}{61}$	$146\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$	$18\frac{2}{7}$	$36\frac{4}{7}$
	3.0	$13\frac{43}{64}$	$73\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$	$18\frac{2}{7}$
	6.0	$27\frac{11}{32}$	$36\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$	$9\frac{1}{7}$
	12.0	$54\frac{11}{16}$	$18\frac{2}{7}$	$\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$	$4\frac{4}{7}$
	24.0	$109\frac{3}{8}$	$9\frac{1}{7}$	$\frac{2}{7}$	$\frac{4}{7}$	$1\frac{1}{7}$	$2\frac{2}{7}$
ETSI ($f_s/BW = 8/7$)	1.75	$7\frac{13}{16}$	128	4	8	16	32
	3.5	$15\frac{5}{8}$	64	2	4	8	16
	7.0	$31\frac{1}{4}$	32	1	2	4	8
	14.0	$62\frac{1}{2}$	16	$\frac{1}{2}$	1	2	4
	28.0	125	8	$\frac{1}{4}$	$\frac{1}{2}$	1	2

Table B.34—OFDM channelization parameters for licensed bands *(continued)*

BW (MHz)		OFDM (N_{FFT} = 256)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
WCS ($f_s/BW = 7/6$)	2.5	$11\frac{35}{89}$	$87\frac{27}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$	$10\frac{34}{35}$	$21\frac{33}{35}$
	5.0	$22\frac{70}{89}$	$43\frac{31}{35}$	$1\frac{13}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$	$10\frac{34}{35}$
	10.0	$45\frac{55}{96}$	$21\frac{33}{35}$	$\frac{24}{35}$	$1\frac{13}{35}$	$2\frac{26}{35}$	$5\frac{17}{35}$
	15.0	$68\frac{23}{64}$	$14\frac{22}{35}$	$\frac{16}{35}$	$\frac{32}{35}$	$1\frac{29}{35}$	$3\frac{23}{35}$

Table B.35—OFDMA channelization parameters for licensed bands

BW (MHz)		OFDMA (N_{FFT} = 2048)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
MMDS ($f_s/BW = 8/7$)	1.5	$\frac{36}{43}$	$1194\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$	$149\frac{1}{3}$	$298\frac{2}{3}$
	3.0	$1\frac{60}{89}$	$597\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$	$149\frac{1}{3}$
	6.0	$3\frac{8}{23}$	$298\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$	$74\frac{2}{3}$
	12.0	$6\frac{39}{56}$	$149\frac{1}{3}$	$4\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$	$37\frac{1}{3}$
	24.0	$13\frac{11}{28}$	$74\frac{2}{3}$	$2\frac{1}{3}$	$4\frac{2}{3}$	$9\frac{1}{3}$	$18\frac{2}{3}$
ETSI ($f_s/BW = 8/7$)	1.75	$\frac{83}{85}$	1024	32	64	128	256
	3.5	$1\frac{61}{64}$	512	16	32	64	128
	7.0	$3\frac{29}{32}$	256	8	16	32	64
	14.0	$7\frac{13}{16}$	128	4	8	16	32
	28.0	$15\frac{5}{8}$	64	2	4	8	16

Table B.35—OFDMA channelization parameters for licensed bands *(continued)*

BW (MHz)		OFDMA (N_{FFT} = 2048)					
		$\Delta f(kHz)$	$T_b(\mu s)$	$T_g(\mu s)$			
				$T_b/32$	$T_b/16$	$T_b/8$	$T_b/4$
WCS ($f_s/BW = 8/7$)	2.5	$1\frac{32}{81}$	$714\frac{4}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$	$89\frac{3}{5}$	$179\frac{1}{5}$
	5.0	$2\frac{64}{81}$	$358\frac{2}{5}$	$11\frac{1}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$	$89\frac{3}{5}$
	10.0	$5\frac{47}{81}$	$179\frac{1}{5}$	$5\frac{3}{5}$	$11\frac{1}{5}$	$22\frac{2}{5}$	$44\frac{4}{5}$
	15.0	$8\frac{10}{27}$	$119\frac{7}{15}$	$3\frac{11}{15}$	$7\frac{7}{15}$	$14\frac{14}{15}$	$29\frac{13}{15}$

Table B.36—OFDM/OFDMA channelization parameters for license-exempt bands

			OFDM	OFDMA
	$f_s/(BW)$		8/7	8/7
BW(MHz)	N_{FFT}		256	2048
10	$\Delta f(kHz)$		$44\frac{9}{14}$	$5\frac{47}{81}$
	$T_b(\mu s)$		$22\frac{2}{5}$	$179\frac{1}{5}$
	$T_g(\mu s)$	$\frac{T_b}{32}$	$\frac{7}{10}$	$5\frac{3}{5}$
		$\frac{T_b}{16}$	$1\frac{2}{5}$	$11\frac{1}{5}$
		$\frac{T_b}{8}$	$2\frac{4}{5}$	$22\frac{2}{5}$
		$\frac{T_b}{4}$	$5\frac{3}{5}$	
20	$\Delta f(kHz)$		$89\frac{2}{7}$	$11\frac{9}{56}$
	$T_b(\mu s)$		$11\frac{1}{5}$	$89\frac{3}{5}$
	$T_g(\mu s)$	$\frac{T_b}{32}$		$2\frac{4}{5}$
		$\frac{T_b}{16}$	$\frac{7}{10}$	$5\frac{3}{5}$
		$\frac{T_b}{8}$	$1\frac{2}{5}$	$11\frac{1}{5}$
		$\frac{T_b}{4}$	$2\frac{4}{5}$	$22\frac{2}{5}$

In Table B.37, raw bit rates are shown for typical bandwidths. The raw bite rate is defined as $N_{used} \cdot b_m \cdot c_r / T_s$, where b_m is the number of bits per modulation symbol and c_r is the coding rate.

Table B.37—OFDM/OFDMA raw bitrates (Mbps)

BW (MHz)	T_g	QPSK 1/2	QPSK 3/4	16-QAM 1/2	16-QAM 3/4	64-QAM 2/3	64-QAM 3/4
OFDM 256-FFT							
6 MHz (MMDS)	$T_b/32$	5.09	7.64	10.18	15.27	20.36	22.91
	$T_b/16$	4.94	7.41	9.88	14.82	19.76	22.24
	$T_b/8$	4.67	7.00	9.33	14.00	18.67	21.00
	$T_b/4$	4.20	6.30	8.40	12.60	16.80	18.90
7 MHz (ETSI)	$T_b/32$	5.94	8.91	11.88	17.82	23.76	26.73
	$T_b/16$	5.76	8.65	11.53	17.29	23.06	25.94
	$T_b/8$	5.44	8.17	10.89	16.33	21.78	24.50
	$T_b/4$	4.90	7.35	9.80	14.70	19.60	22.05
20 MHz (U-NII)	$T_b/16$	16.13	24.20	32.27	48.40	64.54	72.61
	$T_b/8$	15.24	22.86	30.48	45.71	60.95	68.57
	$T_b/4$	13.71	20.57	27.43	41.14	54.86	61.71
OFDMA 2048-FFT							
6 MHz (MMDS)	$T_b/32$	4.99	7.48	9.97	14.96	19.95	22.44
	$T_b/16$	4.84	7.26	9.68	14.52	19.36	21.78
	$T_b/8$	4.57	6.86	9.14	13.71	18.29	20.57
	$T_b/4$	4.11	6.17	8.23	12.34	16.46	18.51
7 MHz (ETSI)	$T_b/32$	5.82	8.73	11.64	17.45	23.27	26.18
	$T_b/16$	5.65	8.47	11.29	16.94	22.59	25.41
	$T_b/8$	5.33	8.00	10.67	16.00	21.33	24.00
	$T_b/4$	4.80	7.20	9.60	14.40	19.20	21.60