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Title	IEEE 802.16m System Description Document [Draft]
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Re:	The Draft SDD
Abstract	This version is a revised version of IEEE 802.16m-08/003r5. The revision is based on comment resolution captured in the IEEE 802.16m-08/046r4.
Purpose	Draft for further development of the IEEE 802.16m SDD
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The Draft IEEE 802.16m System Description Document

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1

1 Scope

The IEEE 802.16m amendment shall be developed in accordance with the P802.16 project authorization request (PAR), as approved on 6 December 2006 [1], and with the Five Criteria Statement in IEEE 802.16-06/055r3 [2]. According to the PAR, the standard shall be developed as an amendment to IEEE Std 802.16 [3][4]. The resulting standard shall fit within the following scope:

This standard amends the IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for operation in licensed bands. It meets the cellular layer requirements of IMT-Advanced next generation mobile networks. This amendment provides continuing support for legacy WirelessMAN-OFDMA equipment.

And the standard will address the following purpose:

The purpose of this standard is to provide performance improvements necessary to support future advanced services and applications, such as those described by the ITU in Report ITU-R M.2072.

The standard is intended to be a candidate for consideration in the IMT-Advanced evaluation process being conducted by the International Telecommunications Union– Radio Communications Sector (ITU-R) [5][6][7]. This document represents the system description document for the IEEE 802.16m amendment. It describes the system level description of the IEEE 802.16m system based on the SRD developed by the IEEE 802.16 Task Group m[8]. All content included in any draft of the IEEE 802.16m amendment shall be in accordance with the system level description in this document as well as in compliance with the requirements in the SRD. This document, however, shall be maintained and may evolve.

2 References

[1] IEEE 802.16m PAR, December 2006, http://standards.ieee.org/board/nes/projects/802-16m.pdf

[2] IEEE 802.16 WG, "Five Criteria Statement for P 802.16m PAR Proposal," IEEE 802.16-06/055r3, November 2006, http://ieee802.org/16/docs/06/80216-06_055r3.pdf

[3] IEEE Std 802.16-2004: IEEE Standard for Local and metropolitan area networks – Part 16: Air Interface for Fixed Broadband Wireless Access Systems, June 2004

[4] IEEE Std. IEEE 802.16e-2005, IEEE Standard for Local and metropolitan area networks, – Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, – Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and IEEE Std. 802.16-2004/Cor1-2005, Corrigendum 1, December 2005

[5] Recommendation ITU-R M.1645: Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000, January 2003

[6] Draft New Report ITU-R M.[IMT.EVAL]: Guidelines for evaluation of radio interface technologies for IMT-Advanced (Doc ITU-R 5/69), Oct 2008

[7] Draft New Report ITU-R M.[IMT.TECH]: Requirements related to technical performance for IMT-Advanced radio interface(s) (Doc ITU-R 5/60), Aug 2008 [8] IEEE 802.16m System Requirements, IEEE 802.16m-07/002 <http://ieee802.org/16/tgm/#07_002>

[9] The WiMAX Forum Network Architecture Stage 2 - 3: Release 1, Version 1.2 http://www.wimaxforum.org/documents/documents/WiMAX_Forum_Network_Architecture_Stage_2-3_Rel_1v1.2.zip

[10] ITU-T Recommendation X.680 : Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation, July 2002.

[11] ITU-T Recommendation X.681 : Information technology - Abstract Syntax Notation One (ASN.1): Information object specification, July 2002.

[12] ITU-T Recommendation X.682 : Information technology - Abstract Syntax Notation One (ASN.1): Constraint specification, July 2002.

[13] ITU-T Recommendation X.683 : Information technology - Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications, July 2002.

[14] ITU-T Recommendation X.691 : Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER), July 2002.

[15] WiMAX Forum: WiMAX Network Protocols and Architecture for Location Based Services *Full Reference to be complete*

[16] Guidelines for use of a 48-bit Extended Unique Identifier (EUI-48™), http://standards.ieee.org/regauth/oui/tutorials/EUI48.html

3   Definitions, Symbols, Abbreviations

3.1 Definitions

1. WirelessMAN-OFDMA Reference System: A system compliant with a subset of the WirelessMAN-OFDMA capabilities specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005 and IEEE 802.16Cor2/D3, where the subset is defined by WiMAX Forum Mobile System Profile, Release 1.0 (Revision 1.4.0: 2007-05-02) [reference to said document], excluding specific frequency ranges specified in the section 4.1.1.2 (Band Class Index)

2. YMS(Yardstick Mobile Station) : A mobile station compliant with the WirelessMAN-OFDMA Reference System

3. RS : A relay station compliant with the IEEE 802.16 WirelessMAN OFDMA specification specified by IEEE 802.16-2004 and amended by IEEE 802.16e-2005, IEEE 802.16Cor2/D3 and IEEE 802.16j

4. YBS (Yardstick Base Station) : A base station compliant with the WirelessMAN-OFDMA Reference System

5. MRBS : A YBS implementing functionality to support RSs as defined in IEEE 802.16j

6. AMS: (Advanced Mobile Station) a mobile station capable of acting as a YMS and additionally implementing the protocol defined in IEEE 802.16m

7. ARS : A station implementing the relay station functionality defined in IEEE 802.16m

8. ABS: a base station capable of acting as a YBS and additionally implementing the protocol defined in IEEE 802.16m

9. LZone : A positive integer number of consecutive subframes where ABS communicates with RSs or YMSs, and where an ARS communicates with a YMS

10. 10. MZone : A positive integer number of consecutive subframes where an ABS communicates with an ARS or an AMS, and where an ARS communicates with another ARS, an AMS or an ABS.

11. Location-Based Service (LBS): A service provided to a subscriber based on the current geographic location of the MS.

12. LBS Application: The virtual entity that controls and runs the location based service, including location determination, and information presentation to the users.

13. Location Server (LS): A server which determines and distributes the location of the MS in the WiMAX network. It may reside in the WiMAX network CSN, as defined by [15].

14. Location Controller (LC): A controller which is responsible for coordinating the location measurements of the MS. It may reside in the WiMAX network ASN, as defined by [15].

15. Location Agent (LA): An agent which is responsible for the making measurements or optionally collecting and reporting of location related data to LC. LA function could reside entirely in the BS, in the MS or both, as defined by [15].

16. LBS Zone: A configurable amount of consecutive resource units which are reserved for LBS purposes.

17. LBS Pilots: A set of pilots which are periodically broadcasted by involved BSs for LBS purposes.

18. Downlink Silence Period: A downlink transmission period in which the transmission power is specially controlled.

19. Location Reference Signal Unit (LRSU): Any equipment which periodically or constantly broadcast pilot signals for positioning purposes.

20. Time difference of arrival (TDOA): The measurement of the difference in arrival time of received signals.

21. Time of arrival (TOA) : The time of arrival of a signal received by an MS or BS

22. Angle of arrival (AOA): The angle of arrival of a received signal relative to the boresight of the antenna.

23. Spatial Channel Information: Generalized set of measurements from the antennas (spatial channel estimation or a set of AOA's, which can be used for location estimation

24. Round trip delay (RTD): The time required for a signal or packet to transfer from a MS to a BS and back again.

25. Relative delay (RD): The delay of neighbor DL signals relative to the serving/attached BS.

3.2 Abbreviations

PBCH   Primary Broadcast Channel
RTD   Round Trip Delay
AMC adaptive modulation and coding
ARQ automatic repeat request
ASN access service network
BCH broadcast channel
BR bandwidth request
BS base station
BW bandwidth (abbreviation used only in equations, tables, and figures)
CC confirmation code
CID connection identifier
CINR carrier-to-interference-and-noise ratio
CLPC Closed-Loop Power Control
CMAC cipher-based message authentication code
Co-MD   Closed-Loop Macro Diversity
Co-MIMO   Collaboration MIMO
Co-Re Constellation Re-Arrangement
CP cyclic prefix
CPS common part sublayer
CQI channel quality information
CRC cyclic redundancy check
CSI channel state information
CSN Connectivity Service Network
CXCF Coordinated Coexistence Frame
DCD downlink channel descriptor
DL downlink
DRU Distributed Resource Unit
E-MBS Enhanced Multcast Broadcast Service
FA   Frequency Assignment
FCH frame control header
FDD   Frequency Division Duplex
FEC forward error correction
FFR Fractional Frequency Re-Use
FFS For Future Studying
FFT fast Fourier transform
FID flow identifier
FUSC full usage of subchannels
GPS global positioning system
GT Guard Time

1   HARQ hybrid automatic repeat request
2   HFDD Half-duplex Frequency Division Duplex
3   HMAC hashed message authentication code
4   HO handover
5   IP Internet Protocol
6   ITU International Telecommunication Union
7   ITU-R International Telecommunication Union -Radiocommunication Sector
8   LBS Location Based Service
9   LDPC low-density parity check
10 LDRU Logical Distributed Resource Unit
11 LLRU Logical Localized Resource Unit
12 LRU   Logical Resource Unit
13 MAC Medium Access Control
14 MBS   Multicast Broadcast Service
15 MC   Multi Carrier
16 MCS   Modulation Coding Scheme
17 MIMO multiple input multiple output
18 MS mobile station
19 MSDU MAC Service Data Unit
20 NSP network service provider
21 OFDM orthogonal frequency division multiplexing
22 OFDMA Orthogonal Frequency Division Multiple Access
23 OLPC Open-Loop Power Control
24 PAPR peak to average power ratio
25 PDU protocol data unit
26 PHY physical layer
27 PRU   Physical Resource Unit
28 PSCH Primary Synchronization Channel
29 PUSC partial usage of subchannels
30 QAM quadrature amplitude modulation
31 QoS quality of service
32 QPSK quadrature phase-shift keying
33 REQ request
34 RNG ranging
35 RRCM radio resource controller and management
36 RS Relay Station
37 RSP response
38 RSSI receive signal strength indicator
39 RU   Resource Unit
40 Rx receive (abbreviation not used as verb)
41 SCH synchronization channel
42 SBCH Secondary Broadcast Channel
43 SDU service data unit
44 SFH Superframe Header
45 SID Station Identifier
46 SM spatial multiplexing
47 SSCH Secondary Synchronization Channel
48 STC space time coding

1   TDD   Time Division Duplex
2   TDM time division multiplexing
3   TD-SCDMA Time Division-Synchronous Code Division Multiple Access
4   Tx transmit (abbreviation not used as verb)
5   UCD uplink channel descriptor
6   UL uplink
7   USCCH   Unicast Service Control Channel
8   UTRA Universal Terrestrial Radio Access
9   WARC World Administrative Radio Conference

1 # 4   Overall Network Architecture

2 <Editor's Note: This section will describe the overall network architecture applicable to IEEE 802.16m.

3 Editor's Note : Was not able to implement comment 14 as terms here sometimes are overloaded, i.e. it is
4 not always clear is a MS refers to MS as defined in .16 or in WMF NWG specs.>

5 The Network Reference Model (NRM) is a logical representation of the network architecture. The NRM
6 identifies functional entities and reference points over which interoperability is achieved between functional
7 entities. Figure 1 illustrates the NRM, consisting of the following functional entities: Mobile Station (MS),
8 Access Service Network (ASN), and Connectivity Service Network (CSN). The existing network reference
9 model is defined in WiMAX Network Architecture [9].

10

11
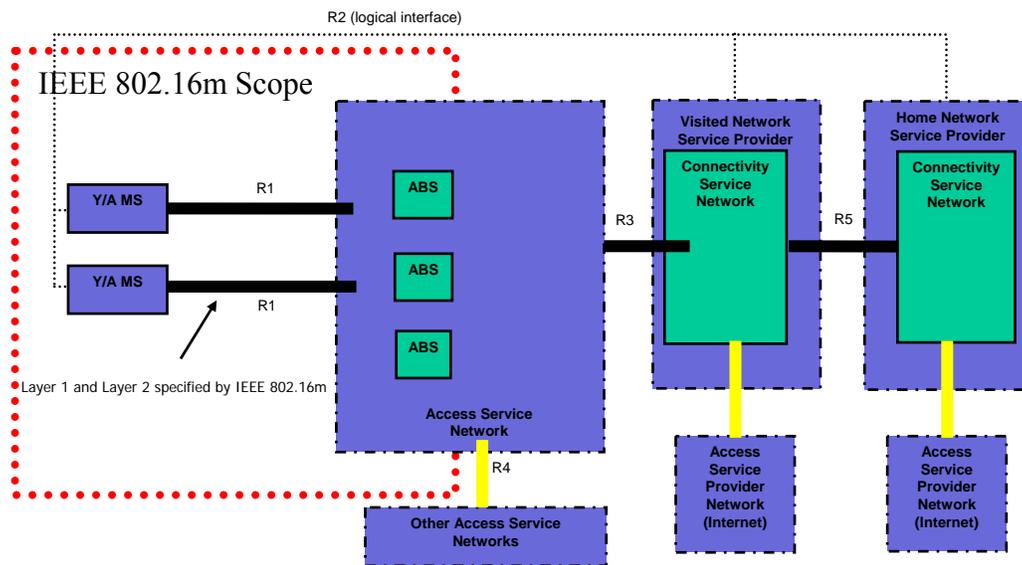
12 Figure 1 Example of overall network architecture

13

14 The ASN is defined as a complete set of network functions needed to provide radio access to an IEEE
15 802.16e/m subscriber. The ASN provides at least the following functions:

16 - IEEE 802.16e/m Layer-1 (L1) and Layer-2 (L2) connectivity with IEEE 802.16e/m MS

17 - Transfer of AAA messages to IEEE 802.16e/m subscriber's Home Network Service Provider (H-NSP)
18   for authentication, authorization and session accounting for subscriber sessions

19 - Network discovery and selection of the IEEE 802.16e/m subscriber's preferred NSP

20 - Relay functionality for establishing Layer-3 (L3) connectivity with an IEEE 802.16e/m MS (i.e. IP
21   address allocation)

22 - Radio Resource Management

23 In addition to the above functions, for a portable and mobile environment, an ASN further supports the
24 following functions:

25 - ASN anchored mobility

1   • CSN anchored mobility

2   • Paging

3   • ASN-CSN tunneling

4 The ASN comprises network elements such as one or more Base Station(s), and one or more ASN Gateway(s).
5 An ASN may be shared by more than one CSN. The CSN is defined as a set of network functions that provide
6 IP connectivity services to the IEEE 802.16e/m subscriber(s). A CSN may provide the following functions:

7   • MS IP address and endpoint parameter allocation for user sessions

8   • AAA proxy or server

9   • Policy and Admission Control based on user subscription profiles

10   • ASN-CSN tunneling support,

11   • IEEE 802.16e/m subscriber billing and inter-operator settlement

12   • Inter-CSN tunneling for roaming

13   • Inter-ASN mobility

14 The IEEE 802.16e/m CSN provides services such as location based services, connectivity for peer-to-peer
15 services, provisioning, authorization and/or connectivity to IP multimedia services.

16 CSN may further comprise network elements such as routers, AAA proxy/servers, user databases, Interworking
17 gateway MSs. A CSN may be deployed as part of a IEEE 802.16m NSP or as part of an incumbent IEEE
18 802.16e NSP.

19 Relay Stations (RSs) may be deployed to provide improved coverage and/or capacity.

20 A ABS that is capable of supporting a 16j RS, shall communicate with the 16j RS in the LZone. The ABS is not
21 required to provide 16j protocol support in the "16m zone". [The design of 16m relay protocols should be
22 based on the design of 16j wherever possible, although 16m relay protocols used in the "16m zone" may be
23 different from 16j protocols used in the LZone.]

24 Figure 2 and Table 1, show the IEEE 802.16m relay related interfaces that are to be supported and those which
25 are not required to be supported in the 802.16 specification. Only the interfaces involving RSs (IEEE 802.16m
26 and legacy RS) are shown.

27 Figure 2 and Table 1 also indicate the specific 802.16 protocol that is to be used for supporting the particular
28 interface.

1
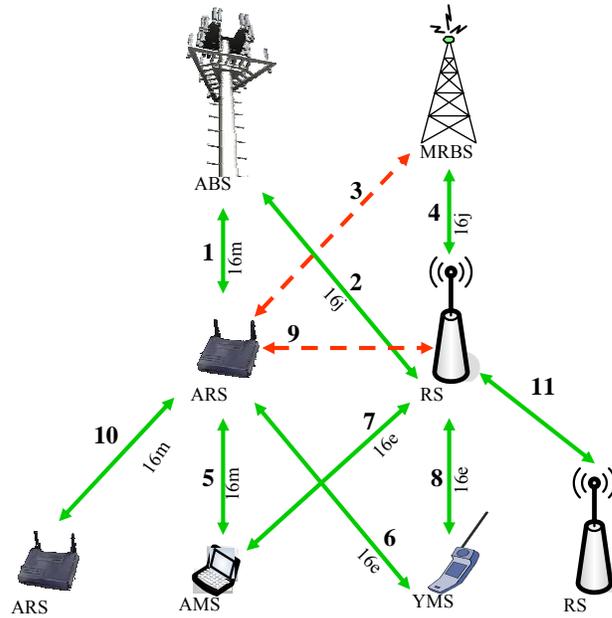
2				Figure 2 Diagram showing the relay-related connections.

3

4

Connection #	Connected Entities	Protocol used	Supported (Y/N)
1	AMS -ARS	16m	Y
2	AMS - RS	16j	Y
3	ARS – MRBS	N/A	N
4	MRBS - RS	16j	Y
5	ARS – AMS	16m	Y
6	ARS – YMS	16e	Y
7	AMS – RS	16e	Y
8	RS - YMS	16e	Y
9	ARS – RS	N/A	N
10	ARS – ARS	16m	Y
11	RS – RS	16j	Y

5				Table 1 Interconnections between the entities shown in Figure 2 and the protocol used.

Figure 2 and Table 1 capture the interfaces which may exist between the IEEE 802.16m and legacy stations. The figure and table are not intended to specify any constraints on the usage of these interfaces. For example, the figure and table do not provide rules for which interfaces a particular station can utilize at the same time, or how many connections a station can have over each of the specified interfaces.

The usage of the interfaces described in Figure 2 and Table 1 is constrained as follows: An may connect to a ABS either directly or via one or more ARSs. The number of hops between the ABS and a AMS can be two or greater than two. The topology between the ABS and the subordinate ARSs within a ABS cell shall be restricted to a tree topology. A YMS may connect to a ABS either directly or via one or more ARSs. Furthermore a YMS may connect to a ABS via one or more RSs. The topology between the ABS and the subordinate RSs within a ABS cell is specified in the IEEE 802.16j draft amendment.

Connection 10 indicates a connection between a ARS and another directly connected ARS. Such connections exist in order to support topologies in which the number of hops between the ABS and an AMS is greater than two hops.

Connection 11 indicates a connection between a RS and another directly connected RS. Such connections exist in order to support topologies in which the number of hops between the MRBS/ABS and an YMS/AMS is greater than two hops.

1   ## 5   IEEE 802.16m System Reference Model

2   <Editor's Note: This section describes system reference model in for those functions introduced in the
3   IEEE 802.16m air interface>

4   As shown in the following Figure 3, the proposed reference model for IEEE 802.16m is very similar to
5   that of IEEE 802.16e with the exception of soft classification of MAC common part sub-layer into
6   radio resource control and management functions and medium access control functions (i.e., no SAP
7   is required between the two classes of functions).

8

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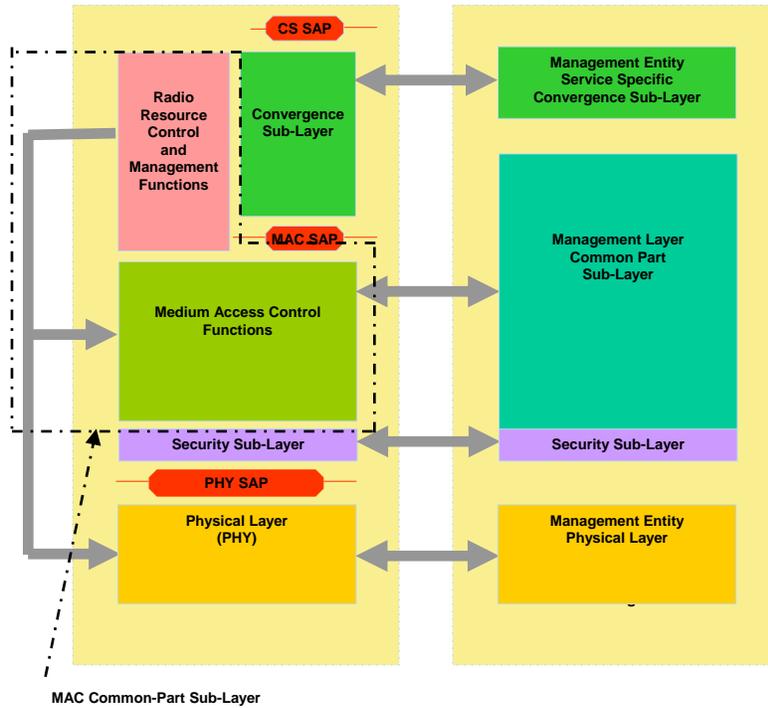
10   Figure 3 System Reference Model

11

12

6   Advanced Mobile Station State Diagrams

<Editor's Note: To capture only the top level states of the mobile stations, base stations. Detailed feature specific state diagrams will be captured elsewhere in the respective sections.>

The Figure 4 illustrates the mobile station state transition diagram for AMS. Mobile Station state diagram for IEEE 802.16m systems consists of 4 states, Initialization state, Access state, Connected state and Idle state.
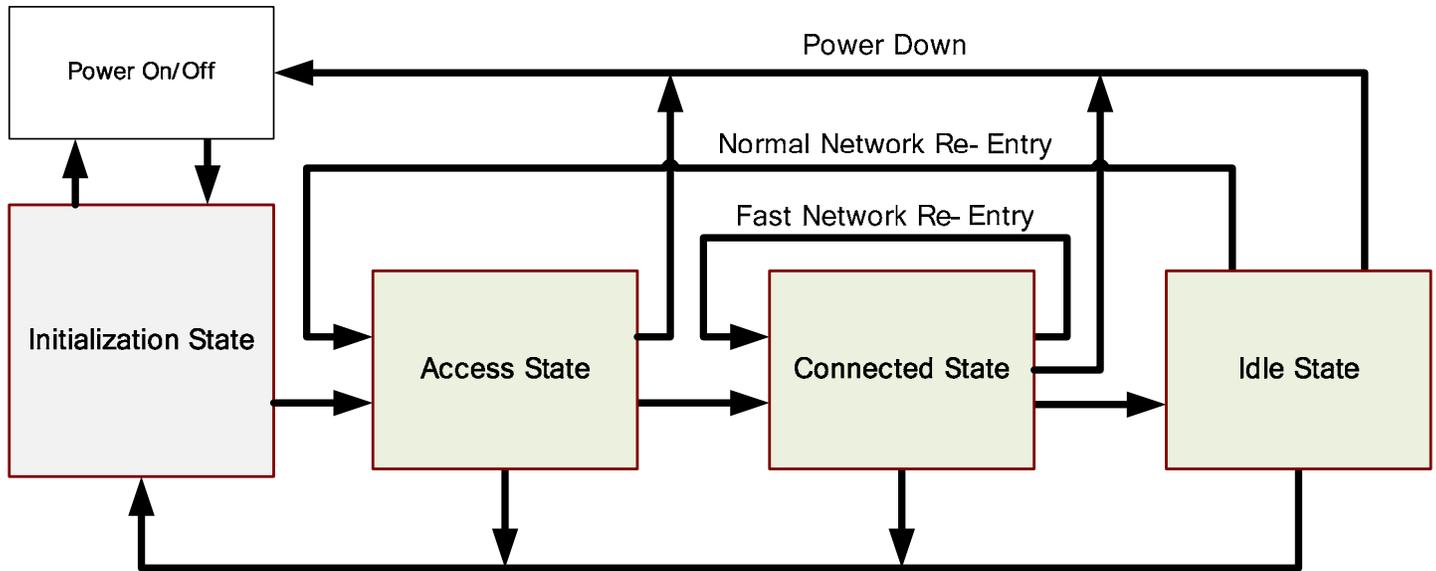
Figure 4 Mobile Station State Transition Diagram of IEEE 802.16m

6.1 Initialization State

In the initialization state, the AMS performs cell selection by scanning and synchronizing to a ABS SCH, and acquiring the system configuration information through BCH before entering Access State.
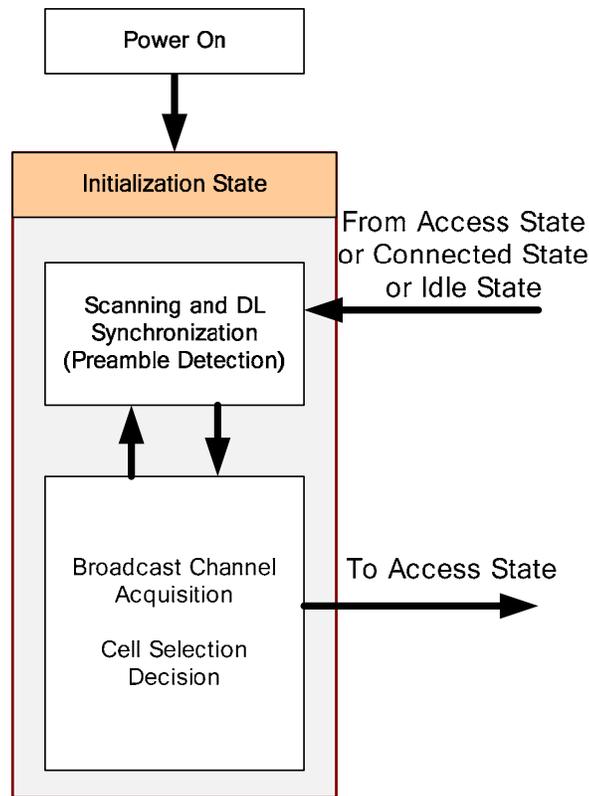
Figure 5 Initialization State Transition Diagram

During this state, if the AMS cannot properly perform the BCH information decoding and cell selection, it should return to perform scanning and DL synchronization. If the AMS successfully decodes BCH information and selects one target ABS, it transitions to the Access State.

6.2 Access State

The AMS performs attempts network entry with the target ABS while in the Access state. Network entry is a multi step process consisting of ranging, basic capability negotiation, authentication and authorization, and registration. The AMS receives its Station ID and establishes at least one connection using and transitions to the Connected state. Upon failure to complete any one of the steps of network entry the AMS transitions to the Initialization state.

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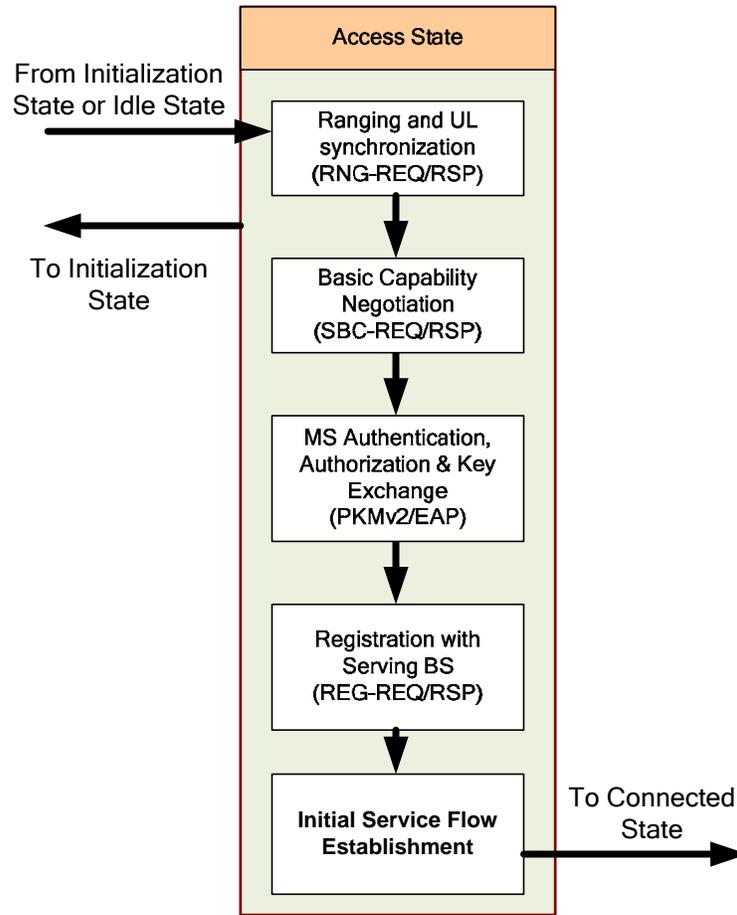
2   Figure 6 Access State Transition Diagram

3

4

6.3 Connected State

6   When in the Connected State a AMS operated in one of 3 modes; Sleep Mode, Active Mode and Scanning
7   Mode. During Connected State, the AMS maintains the one connection established during Access State.
8   Additionally the AMS and ABS may establish additional transport connections. The AMS may remain in
9   Connected state during a hand over. The AMS transitions from the Connected to the Idle state on a command
10   from the ABS. Failure to maintain the connections shall prompt the AMS to transition to the Initialization state.

1
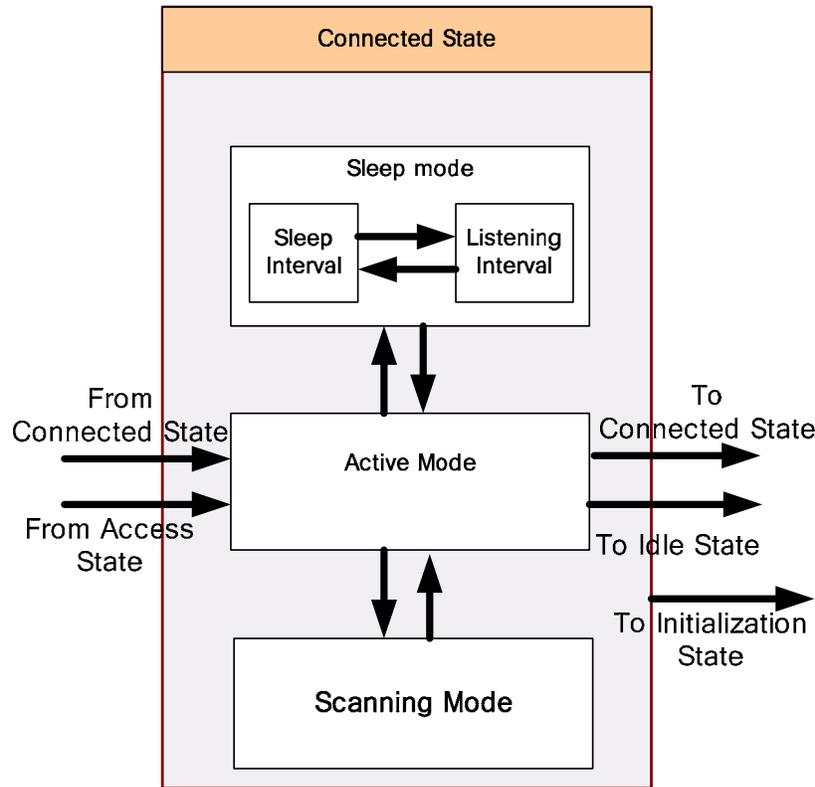
2   Figure 7 Connected State Transition Diagram

3

4   6.3.1   Active mode

5

6   When the AMS is in Active mode, ABS may schedule the AMS to transmit and receive at the earliest available
7   opportunity provided by the protocol, i.e. the AMS is assumed to be 'available' to the ABS at all times. The
8   AMS may request a transition to either Sleep or Scanning mode from Active mode. Transition to Sleep or
9   Scanning mode happens on command from the ABS.

10   6.3.2   Sleep mode

11

12   When in Sleep mode the AMS and ABS agree on a division of the resource in time into Sleep Intervals and
13   Listening Intervals. The AMS is only expected to be capable of receiving transmissions from the ABS during
14   the Listening Intervals and any protocol exchange has to be initiated during them. The AMS transition to
15   Active mode is prompted by control messages received from the ABS.

16   6.3.3   Scanning mode

17   When in Scanning mode the AMS performs measurements for as instructed by the ABS. The AMS is
18   unavailable to the ABS while in scanning mode. The AMS returns to active mode once the duration negotiated
19   with the ABS for scanning expires.

20

1   *6.4 Idle State*

2   The Idle state consists of 2 separated modes, paging available mode and paging unavailable mode based on its
3   operation and MAC message generation. During Idle State, the AMS may perform power saving by switching
4   between Paging available mode and Paging Unavailable mode.

5

6
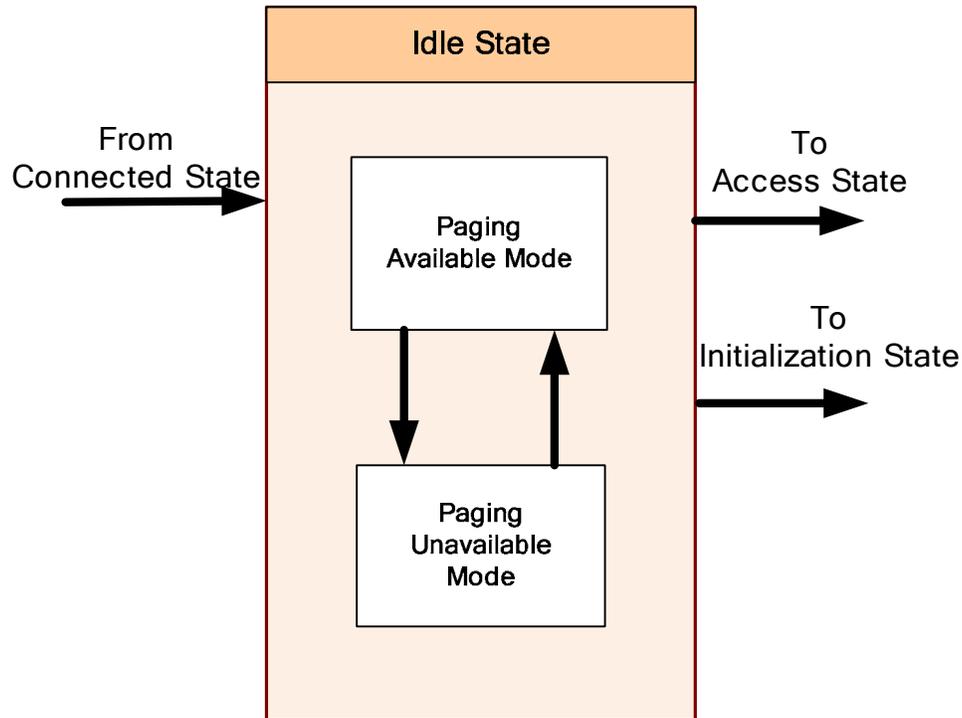
7   Figure 8 Idle State Transition Diagram

8

9   6.4.1   Paging Available Mode

10   The AMS may be paged by the ABS (MOB_PAG-ADV message is used in the Reference System) while it is in
11   the paging available mode. If the AMS is paged, it shall transition to the Access State for its network re-entry.
12   AMS may perform location update procedure during idle state.

13   6.4.2   Paging Unavailable Mode

14   During paging unavailable mode, AMS does not need to monitor the downlink channel in order to reduce its
15   power consumption.

16

7 Frequency Bands

<Editor's Note: This section will describe the frequency bands that are applicable to the IEEE 802.16m system>

IEEE 802.16m systems can operate in RF frequencies less than 6 GHz and are deployable in licensed spectrum allocated to the mobile and fixed broadband services. The following frequency bands have been identified for IMT and/or IMT-2000 by WARC-92, WRC-2000 and WRC-07

- 450-470 MHz
- 698-960 MHz
- 1710-2025 MHz
- 2110-2200 MHz
- 2300-2400 MHz
- 2500-2690 MHz
- 3400-3600 MHz

ITU-R has developed frequency arrangements for the bands identified by WARC-92 and WRC-2000, which are described in Recommendation ITU-R M.1036-3. For the frequency bands that were identified at WRC-07, further work on the frequency arrangements is ongoing within the framework of ITU-R.

8   IEEE 802.16m Air-Interface Protocol Structure

The functional block definitions captured in section 8.1 apply to the ABS and AMS. Definitions of functional blocks for the ARS are captured in section 8.2.

8.1   The IEEE 802.16m Protocol Structure

The IEEE 802.16m MAC is divided into two sublayers:

- Convergence sublayer (CS)
- Common Part sublayer (CPS)

MAC Common Part Sublayer is further classified into Radio Resource Control and Management (RRCM) functions and Medium Access Control (MAC) functions. The RRCM functions includes several functional blocks that are related with radio resource functions such as:

- Radio Resource Management
- Mobility Management
- Network-entry Management
- Location Management
- Idle Mode Management
- Security Management
- System Configuration Management
- MBS
- Connection Management
- Relay functions
- Self Organization
- Multi-Carrier

The Radio Resource Management block adjusts radio network parameters based on traffic load, and also includes function of load control (load balancing), admission control and interference control.

Mobility Management block supports functions related to Intra-RAT/ Inter-RAT handover. Mobility Management block handles the Intra-RAT/ Inter-RAT Network topology acquisition which includes the advertisement and measurement, manages candidate neighbor target YBSs/ABSs/RSs/ARSs and also decides whether AMS performs Intra-RAT/Inter-RAT handover operation.

Network-entry Management block is in charge of initialization and access procedures. Network-entry Management block may generate management messages which are needed during access procedures, i.e., ranging, basic capability negotiation, registration, and so on.

Location Management block is in charge of supporting location based service (LBS). Location Management block may generate messages including the LBS information.

The Idle Mode Management block manages location update operation during idle mode. Idle Mode Management block controls idle mode operation, and generates the paging advertisement message based on paging message from paging controller in the core network side.

Security Management block is in charge of authentication/authorization and key management for secure communication.

System Configuration Management block manages system configuration parameters, and system parameters and system configuration information for transmission to the AMS.

MBS (Multicast Broadcast Service) block controls management messages and data associated with broadcasting and/or multicasting service.

Service Flow and Connection Management block allocates station identifier and flow identifiers during access/handover/ service flow creation procedures. Connection Management block interacts with convergence sublayer to classify MAC Service Data Unit (MSDU) from upper layer, and maps MSDU onto a particular transport connection.

Relay Functions block includes functions to support multi-hop relay mechanisms. The functions include procedures to maintain relay paths between ABS and an access ARS.

Self Organization block performs functions to support self configuration and self optimization mechanisms. The functions include procedures to request RSs/MSs to report measurements for self configuration and self optimization and receive the measurements from the RSs/MSs.

Multi-carrier (MC) block enables a common MAC entity to control a PHY spanning over multiple frequency channels. The channels may be of different bandwidths (e.g. 5, 10 and 20 MHz), be non-contiguous or belong to different frequency bands. The channels may be of the same or different duplexing modes, e.g. FDD, TDD, or a mix of bidirectional and broadcast only carriers. For contiguous frequency channels, the overlapped guard sub-carriers shall be aligned in frequency domain in order to be used for data transmission.

The Medium Access Control (MAC) includes function blocks which are related to the physical layer and link controls such as:

- PHY Control

- Control Signaling

- Sleep Mode Management

- QoS

- Scheduling and Resource Multiplexing

- ARQ

- Fragmentation/Packing

- MAC PDU formation

- Multi-Radio Coexistence

- Data forwarding

- Interference Management

- Inter-ABS coordination

PHY Control block handles PHY signaling such as ranging, measurement/feedback (CQI), and HARQ

ACK/NACK. Based on CQI and HARQ ACK/NACK, the PHY Control block estimates channel quality as seen
by the AMS, and performs link adaptation via adjusting modulation and coding scheme (MCS), and/or power
level. In the ranging procedure, PHY contol block does UL synchronization with power adjustment, frequency
offset and timing offset estimation.

Control Signaling block generates resource allocation messages.

Sleep Mode Management block handles sleep mode operation. Sleep Mode Management block may also
generate MAC signaling related to sleep operation, and may communicate with Scheduling and Resource
Multiplexing block in order to operate properly according to sleep period.

QoS block handles QoS management based on QoS parameters input from Service Flow and Connection
Management block for each connection, and scheduler shall operate based on the input from QoS block in order
to meet QoS requirement.

Scheduling and Resource Multiplexing block schedules and multiplexes packets based on properties of
connections. In order to reflect properties of connections Scheduling and Resource and Multiplexing block
receives QoS information from QoS block for each connection.

ARQ block handles MAC ARQ function. For ARQ-enabled connections, ARQ block logically splits MAC SDU
to ARQ blocks, and numbers to each logical ARQ block. ARQ block may also generate ARQ management
messages such as feedback message (ACK/NACK information).

Fragmentation/Packing block performs fragmenting or packing MSDUs based on scheduling results from
Scheduler block.

MAC PDU formation block constructs MAC protocol data unit (PDU) so that ABS/AMS can transmit user
traffic or management messages into PHY channel. MAC PDU formation block adds MAC header and may add
sub-headers. MAC PDU formation block may also add MAC CRC if necessary.

Multi-Radio Coexistence block performs functions to support concurrent operations of IEEE 802.16m and non-
IEEE 802.16m radios collocated on the same mobile station.

The Data Forwarding block performs forwarding functions when RSs are present on the path between ABS and
AMS. The Data Forwarding block may cooperate with other blocks such as Scheduling and Resource
Multiplexing block and MAC PDU formation block.

Interference Management block performs functions to manage the inter-cell/sector interference. The operations
may include:

- MAC layer operation
    - o Interference measurement/assessment report sent via MAC signaling
    - o Interference mitigation by scheduling and flexible frequency reuse
- PHY layer operation
    - o Transmit power control
    - o Interference randomization
    - o Interference cancellation
    - o Interference measurement
    - o Tx beamforming/precoding

Inter-ABS coordination block performs functions to coordinate the actions of multiple ABSs by exchanging

1   information, e.g., interference management. The functions include procedures to exchange information for e.g.,
2   interference management between the ABSs by backbone signaling and by AMS MAC messaging. The
3   information may include interference characteristics, e.g. interference measurement results, etc.

4
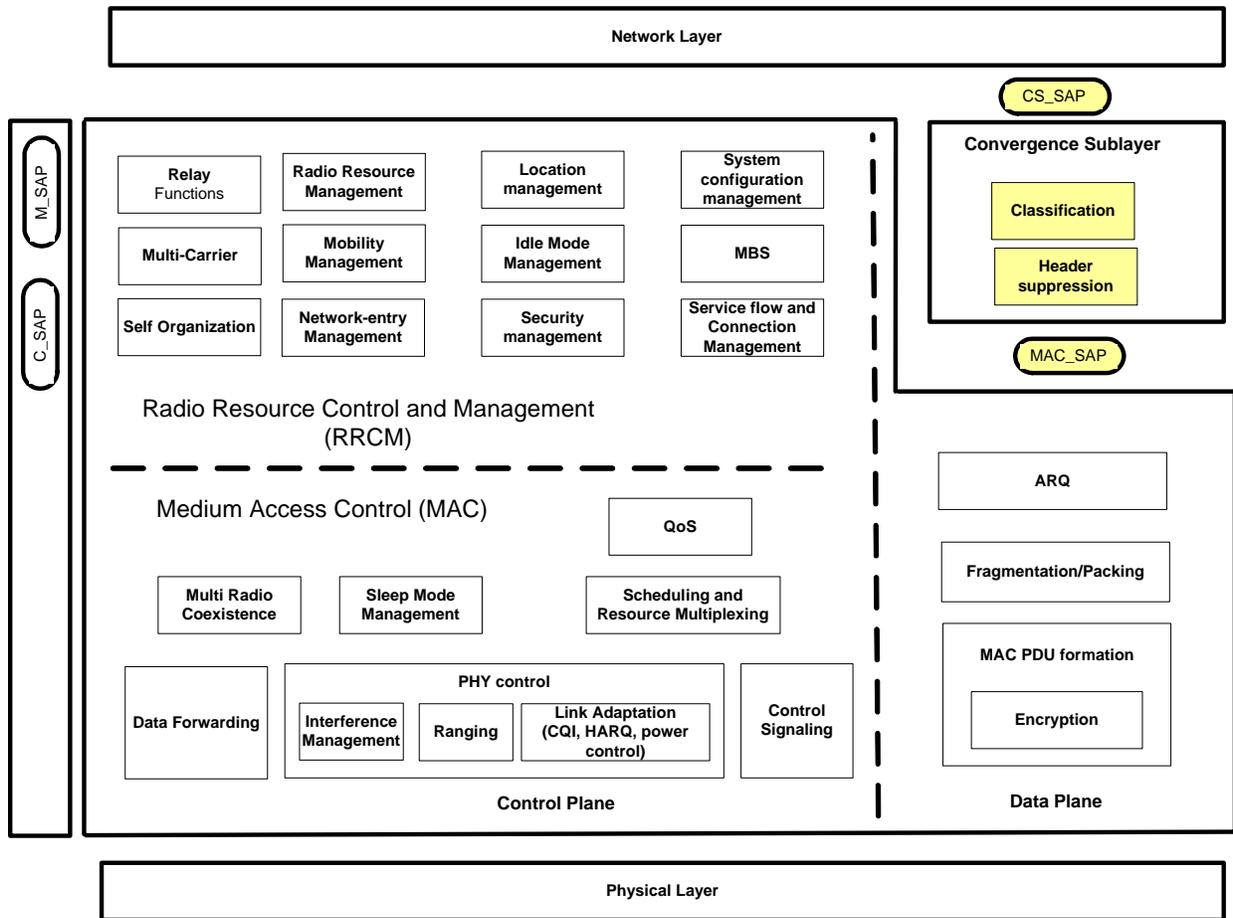
6   Figure 9 The IEEE 802.16m Protocol Structure

7   8.1.1   The AMS/ABS Data Plane Processing Flow

8   Figure 10 shows the user traffic data flow and processing at the ABS and the AMS. The red arrows show the
9   user traffic data flow from the network layer to the physical layer and vice versa. On the transmit side, a
10   network layer packet is processed by the convergence sublayer, the ARQ function (if present), the
11   fragmentation/packing function and the MAC PDU formation function, to form MAC PDU(s) to be sent to the
12   physical layer. On the receive side, a physical layer SDU is processed by MAC PDU formation function, the
13   fragmentation/packet function, the ARQ function (if present) and the convergence sublayer function, to form
14   the network layer packets. The black arrows show the control primitives among the MAC CPS functions and
15   between the MAC CPS and PHY that are related to the processing of user traffic data.

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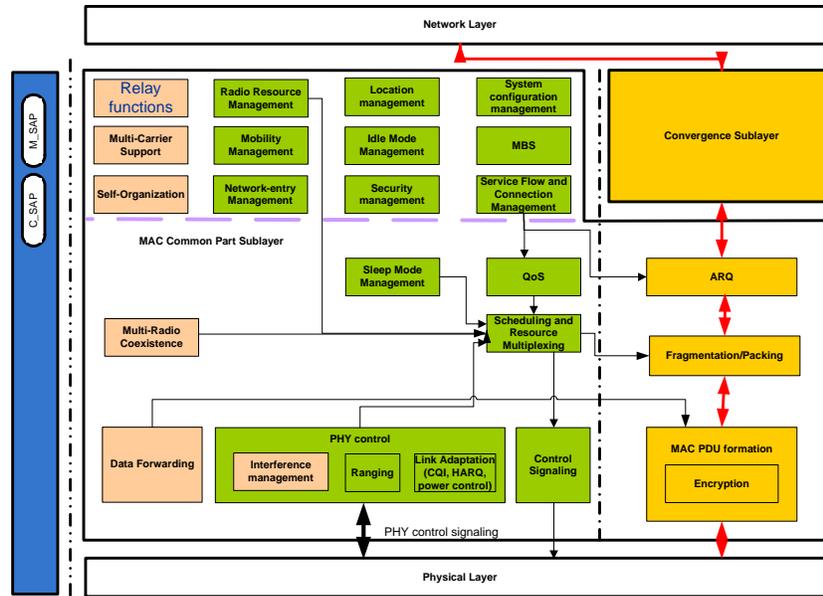
1

2 Figure 10 The IEEE 802.16m AMS/ABS Data Plane Processing Flow Note: The AMS may not utilize
3 all the blocks shown in this figure.

4

5 8.1.2   The AMS/ABS Control Plane Processing Flow

6 The following figure shows the MAC CPS control plane signaling flow and processing at the ABS and the
7 AMS. On the transmit side, the blue arrows show the flow of control plane signaling from the control plane
8 functions to the data plane functions and the processing of the control plane signaling by the data plane
9 functions to form the corresponding MAC signaling (e.g. MAC management messages, MAC header/sub-
10 header) to be transmitted over the air. On the receive side, the blue arrows show the processing of the received
11 over-the-air MAC signaling by the data plane functions and the reception of the corresponding control plane
12 signaling by the control plane functions. The black arrows show the control primitives among the MAC CPS
13 functions and between the MAC CPS and PHY that are related to the processing of control plane signaling. The
14 black arrows between M_SAP/C_SAP and MAC functional blocks show the control and management
15 primitives to/from Network Control and Management System (NCMS). The primitives to/from M_SAP/C_SAP
16 define the network involved functionalities such as inter-ABS interference management, inter/intra RAT
17 mobility management, etc, and management related functionalities such as location management, system
18 configuration etc.

19

20

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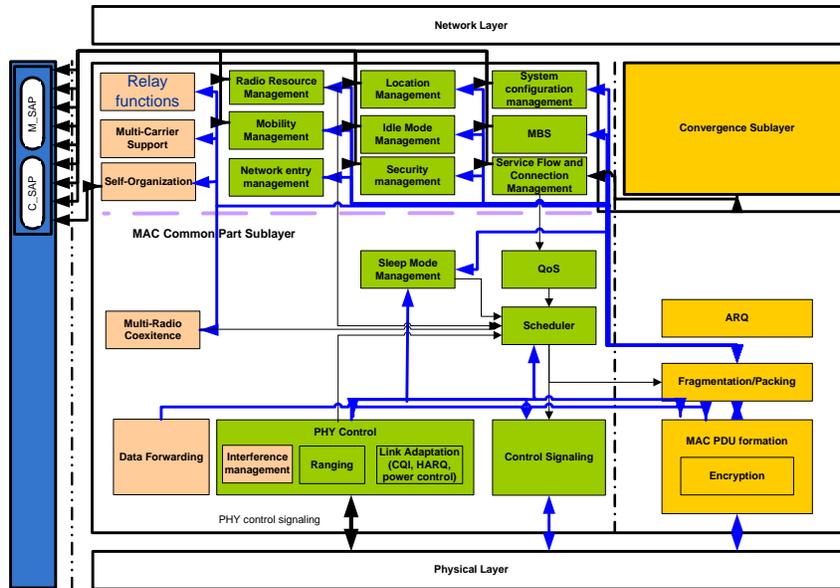
Figure 11 The IEEE 802.16m AMS/ABS Control Plane Processing Flow Note: The AMS may not utilize all the blocks shown in this figure.

8.1.3 Multicarrier Support Protocol Structure

Generic protocol architecture to support multicarrier system is illustrated in Figure 12. A common MAC entity may control a PHY spanning over multiple frequency channels. Some MAC messages sent on one carrier may also apply to other carriers. The channels may be of different bandwidths (e.g. 5, 10 and 20 MHz), be non-contiguous or belong to different frequency bands. The channels may be of different duplexing modes, e.g. FDD, TDD, or a mix of bidirectional and broadcast only carriers.

The MAC entity may support simultaneous presence of MSs with different capabilities, such as operation over one channel at a time only or aggregation across contiguous or non-contiguous channels.
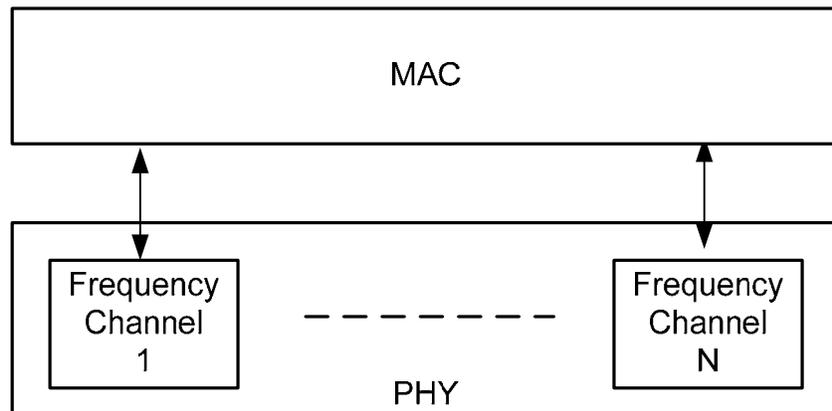
Figure 12 Multicarrier support protocol structure

1 8.1.4 Multi-Radio Coexistence Support Protocol Structure

2

3 Figure 13 shows an example of multi-radio device with co-located AMS, IEEE 802.11 station, and IEEE
4 802.15.1 device. The multi-radio coexistence functional block of the AMS obtains the information about other
5 co-located radio's activities, such as time characteristics, via inter-radio interface, which is internal to multi-
6 radio device and out of the scope of IEEE 802.16m.

7

8 IEEE 802.16m provides protocols for the multi-radio coexistence functional blocks of AMS and ABS to
9 communicate with each other via air interface. AMS generates management messages to report the information
10 about its co-located radio activities obtained from inter-radio interface, and ABS generates management
11 messages to respond with the corresponding actions to support multi-radio coexistence operation. Furthermore,
12 the multi-radio coexistence functional block at ABS communicates with the Scheduling and Resource
13 Multiplexing functional block to operate properly according to the reported co-located coexistence activities.
14 The multi-radio coexistence function can be used independently from sleep mode operation to enable optimal
15 power efficiency with a high level of coexistence support. However, when sleep mode provides sufficient co-
16 located coexistence support, the multi-radio coexistence function may not be used.
17

18
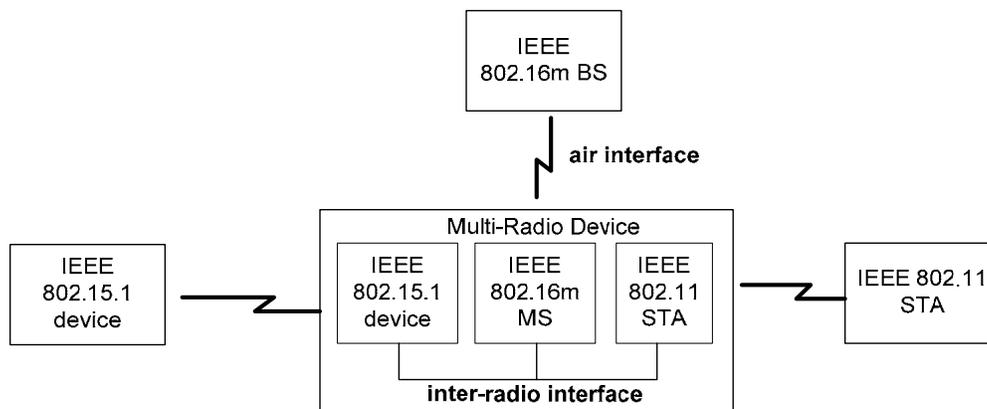
19   Figure 13 Example of Multi-Radio Device with Co-Located IEEE 802.16m AMS, IEEE 802.11 STA,
20   and IEEE 802.15.1 device

21

22 *8.2 Relay Protocol Structure*

23
24

25 Figure 14 shows the proposed protocol functions for an ARS. An ARS may consist of a subset of the protocol
26 functions shown in Figure 14. The subset of functions will depend on the type or category of the ARS.
27

28 The functional blocks and the definitions in this section do not imply that these functional blocks shall be
29 supported in all ARS implementations.
30

1
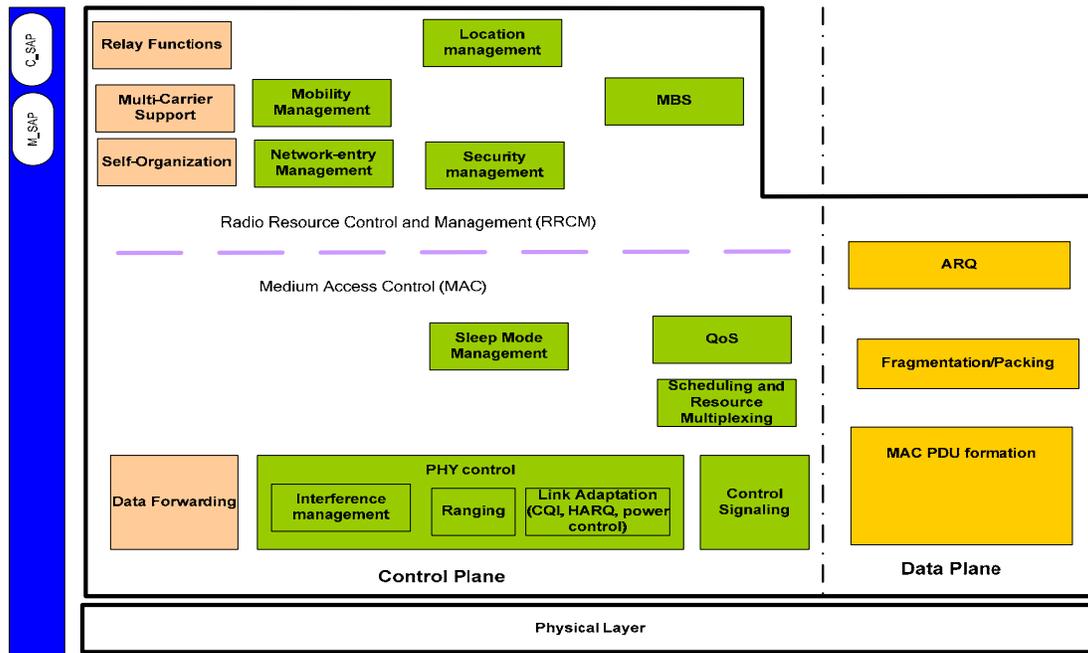
2   Figure 14 Protocol Functions of ARS

3

4

5   The ARS MAC is divided into two sublayers:

6   • Radio Resource Control and Management (RRCM) sublayer

7   • Medium Access Control (MAC) sublayer

8

9   The ARS RRCM sublayer includes the following functional blocks that are related with ARS radio resource

10   functions:

11   • Mobility Management

12   • Network-entry Management

13   • Location Management

14   • Security Management

15   • MBS

16   • Path Management functions

17   • Self Organization

18   • Multi-Carrier

19

20   The Mobility Management block supports AMS handover operations in cooperation with the ABS.

21

22   The Network-entry Management block is in charge of ARS/AMS initialization procedures and performing ARS

23   network entry procedure to the ABS. Network-entry Management block may generate management messages

needed during ARS/AMS initialization procedures and performing the network entry.

The Location Management block is in charge of supporting location based service (LBS), including positioning data, at the ARS and reporting location information to the ABS. Location Management block may generate messages for the LBS information including positioning data.

The Security Management block handles the key management for the ARS.

The MBS (Multicast and Broadcasting Service) block coordinates with the ABS to schedule the transmission of MBS data.

The Path Management Functions block includes procedures to maintain relay paths.

The Self Organization block performs functions to support ARS self configuration and ARS self optimization mechanisms coordinated by ABS. The functions include procedures to request ARSs/AMSs to report measurements for self configuration and self optimization and receive measurements from the ARSs/AMSs, and report measurements to ABS. The functions also include procedures to adjust ARS parameters and configurations for self configuration / optimization with / without the coordination with ABS.

The Multi-carrier (MC) block enables a common MAC entity to control a PHY spanning over multiple frequency channels at the ARS.

The ARS Medium Access Control (MAC) sublayer includes the following function blocks which are related to the physical layer and link controls:
- PHY Control
- Control Signaling
- Sleep Mode Management
- QoS
- Scheduling and Resource Multiplexing
- ARQ
- Fragmentation/Packing
- MAC PDU formation
- Data forwarding
- Interference Management

The PHY Control block handles PHY signaling such as ranging, measurement/feedback (CQI), and HARQ ACK/NACK at the ARS. Based on CQI and HARQ ACK/NACK, PHY Control block estimates channel environment of ARS/AMS, and performs link adaptation via adjusting modulation and coding scheme (MCS) or power level.

The Control Signaling block generates ARS resource allocation messages such as MAP as well as specific control signaling messages.

The Sleep Mode Management block handles sleep mode operation of its MSs in coordination with the ABS.

The QoS block handles rate control based on QoS parameters based on inputs from TBD functional blocks.

The Scheduling and Resource Multiplexing block schedules the transmission of MPDUs. The Scheduling and Resource Multiplexing block is present in the ARS in order to support distributed scheduling.

The ARQ block assists MAC ARQ function between ABS, ARS and AMS.

The Fragmentation/Packing block performs fragmenting or packing MSDUs based on scheduling results from Scheduling and Resource Multiplexing block. The Fragmentation/Packing block in an ARS includes the unpacking and repacking of fragments that have been received for relaying in order to adapt the size of MPDUs to the expected channel quality of the outgoing link.

The MAC PDU formation block constructs MAC protocol data units (PDUs) which contain user traffic or management messages. User traffic is assumed to have originated at either the ABS or AMS. The MAC PDU formation block may add or modify MPDU control information (e.g., MAC header).

The Data Forwarding block performs forwarding functions on the path between ABS and ARS/AMS. The Data Forwarding block may cooperate with other blocks such as Scheduling and Resource Multiplexing block and MAC PDU formation block.

The Interference Management block performs functions at the ARS to manage the inter-cell/sector and inter-ARS interference among ARS and ABS. This includes the collection of interference level measurements and selection of transmission mode used for individual MSs attached to the ARS.
Control functions can be divided among the ABS and RSs using a centralized model or a distributed model. In a centralized model, the ABS makes control decisions and the RSs relay control information between the ABS and
AMS. In a distributed model the ARS makes control decisions for MSs attached to it as appropriate, and optionally communicates those decisions to the ABS. The determination of whether a particular control function should be centralized or distributed is made independently for each control function. The classification of specific control functions as centralized or distributed is for further study.

8.3 E-MBS Protocol Structure

E-MBS or Enhanced Multicast and Broadcast Services consists of MAC and PHY protocols that define interactions between the MSs and the BSs.

While the basic definitions are consistent with IEEE802.16REV2 some enhancements and extensions are defined to provide improved functionality and performance.

The protocol structure for IEEE 802.16m E-MBS is described in Figure 15. The functional blocks describe both the data plane and control plane for E-MBS. The E-MBS protocol structure is a logical structure that describes MAC operations for E-MBS and complements the IEEE 802.16m protocol structure for unicast transmission in Figure 9 in the SDD.

The functional blocks on the left size of represent the control plane of the protocol structure in Figure 9. In the control plane, E-MBS MAC operates in parallel with the unicast MAC. The data plane for E-MBS shares some functionalities of the data-plane of unicast service. The EMBS protocol also has relationship with other upper MAC protocols such as Multicarrier Operation. Unicast MAC could operate independently from E-MBS MAC. E-MBS MAC may operate differently depending on whether unicast MAC is in active mode or idle mode.

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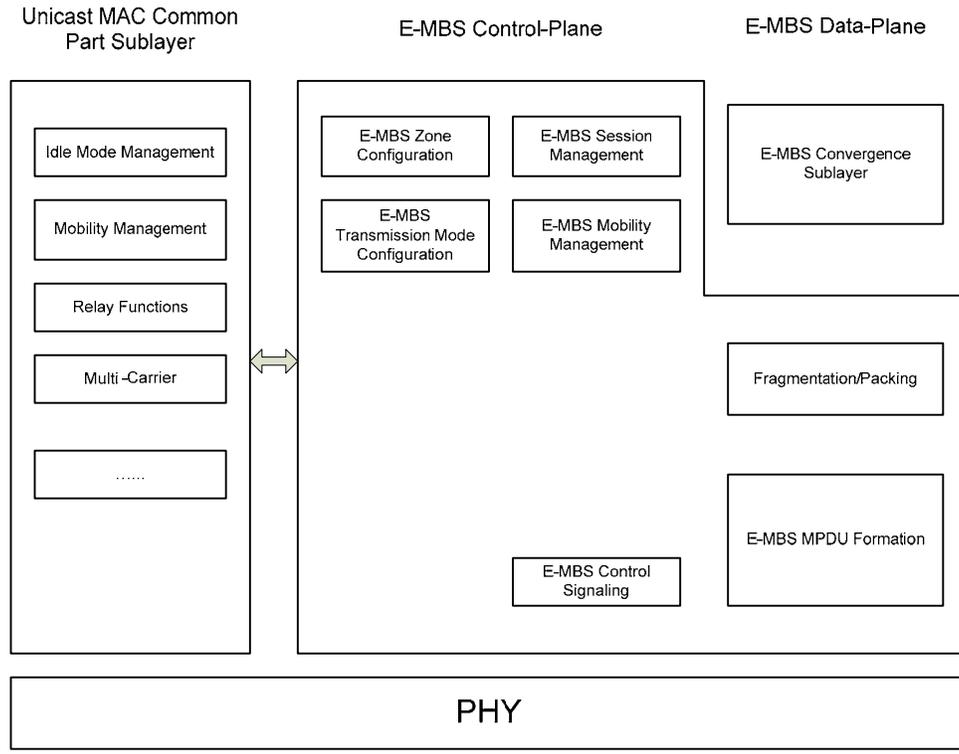
3   Figure 15 The IEEE 802.16m E-MBS Protocol Structure

4
5
6   The E-MBS MAC consists of the following functional blocks:
7   E-MBS Zone Configuration: This function manages the configuration advertisement of E-MBS zones. A ABS
8   could belong to multiple E-MBS zones.
9   E-MBS Transmission Mode Configuration: This function describes the transmission mode in which E-MBS is
10   delivered over air interface such as single-ABS and multi-ABS transmission.
11   E-MBS Session Management: This function manages E-MBS service registration / de-registration and session
12   start / update / termination.
13   E-MBS Mobility Management: This block manages the zone update procedures when a AMS crosses the E-
14   MBS zone boundary.
15   E-MBS Control Signaling: This block broadcasts the E-MBS scheduling and logical-to-physical channel
16   mapping to facilitate E-MBS reception and support power saving.
17

9   Convergence Sub-Layer

10 Medium Access Control Sub-Layer

10.1 Addressing

The AMS has a global address and logical addresses that identify the MS and connections during operation.

10.1.1 MS MAC Address

The AMS is identified by the globally unique 48-bit IEEE Extended Unique Identifier (EUI-48™) based on the 24-bit Organizationally Unique Identifier (OUI) value administered by the IEEE Registration Authority [16].

Insert the web reference into the references section and provide appropriate cross references.

10.1.2 Logical Identifiers

The following logical identifiers are defined in the following subsections.

10.1.2.1   Station Identifier (STID)

The ABS assigns aStation Identifier to the AMS during network entry, and, in some cases, network re-entry, that uniquely identifies the MS within the domain of the ABS. Each AMS registered in the network has an assigned Station Identifier. Some specific "Station Identifiers" are reserved, for example, for broadcast, multicast, and ranging.

10.1.2.2   Flow Identifier (FID)

Each AMS connection is assigned a Flow Identifier that uniquely identifies the connection within the AMS. Flow Identifiers identify management connections and transport connections. Some specific Flow Identifiers may be pre-assigned.

10.2 HARQ Functions

HARQ is mandatory for both downlink and uplink unicast data traffic at both ABS and AMS. Minimum agreed HARQ initial parameters are FFS and are mandatory for ABS and AMS. The exact configuration of HARQ for management messages is FFS.

10.2.1 HARQ in the Downlink

10.2.1.1   HARQ Timing and Protocol

IEEE 802.16m uses asynchronous HARQ scheme in the downlink.

The following HARQ parameters and their associated values are defined:

- Maximum retransmission delay.: FFS
- Maximum number of retransmissions: FFS
- Maximum number of HARQ processes FFS
- ACK/NACK delay: FFS

[Placeholder for figures illustrating the choice of HARQ scheme(s) in Downlink]

The HARQ ACK/NACK delay is defined for FDD and for each TDD DL/UL ratio and for each mixed mode scenario.
HARQ retry count is increased by one if maximum retransmission delay is reached. Discard un-decodable packets from soft buffer if retry count reaches maximum retransmission count.

10.2.1.2   HARQ Operation with Persistent Allocation

<Editor's note: This section is provided as place holder. This section will be filled when details of HARQ operation for persistent allocation is presented and discussed>

10.2.1.3   HARQ Re-transmissions

<Editor's note: the working assumption will depend on decision taken w.r.t. section 10.x.1.1>

IEEE 802.16m uses an adaptive HARQ scheme in the downlink. In adaptive asynchronous HARQ, the resource allocation and transmission format for the HARQ retransmissions may be different from the initial transmission. In case of retransmission, control signaling is required to indicate the resource allocation and transmission format along with other HARQ necessary parameters.

10.2.2 HARQ in the Uplink

10.2.2.1   HARQ Timing and Protocol

IEEE 802.16m uses synchronous HARQ scheme in the uplink.

The following HARQ parameters and their associated values are defined:

- Maximum retransmission delay: FFS
- Maximum number of retransmissions: FFS
- Maximum number of HARQ processes FFS

- ACK/NACK delay: FFS

[Placeholder for figures illustrating the choice of HARQ scheme(s) in Uplink]

10.2.2.2   HARQ Operation with Persistent Allocation

<Editor's note: This section is provided as place holder. This section will be filled when details of HARQ operation for persistent allocation is presented and discussed>

10.2.2.3   HARQ Re-transmissions

For synchronous HARQ, resource (block) allocation for the retransmissions in the uplink can be fixed or adaptive according to control signaling. The default operation mode of HARQ in the uplink is non-adaptive, i.e. the parameters and the resource for the retransmission is known a priori. The ABS can by means of signaling enable an adaptive UL HARQ mode. In adaptive HARQ the parameters of the retransmission are signaled explicitly.

10.2.3 HARQ and ARQ Interactions

When both ARQ and HARQ are applied for a flow, HARQ and ARQ interactions described here can be applied to the corresponding flow.

If the HARQ entity in the transmitter determines that the HARQ process was terminated with an unsuccessful outcome, the HARQ entity in the transmitter informs the ARQ entity in the transmitter about the failure of the HARQ burst. The ARQ entity in the transmitter can then initiate retransmission and re-segmentation of the appropriate ARQ blocks.

10.3 Handover

The following 4 cases are considered for handover in IEEE 802.16m:

Case-1: AMS handover from serving YBS to target YBS
Case-2: AMS handover from serving ABS to target YBS
Case-3: AMS handover from serving YBS to target ABS
Case-4: AMS handover from serving ABS to target ABS

The IEEE 802.16m network and mobile station uses legacy handover procedures for case-1.
Solutions for cases 2, 3 and 4 are FFS.

10.3.1 Network topology acquisition

10.3.1.1   Network topology advertisement

A ABS periodically broadcasts the system information of the neighboring ABSs using Neighbour

1   Advertisement message. The ABS formats Neighbour Advertisement message based on the cell types of
2   neighbor cells, in order to achieve overhead reduction and facilitate scanning priority for AMS. Neighbour
3   Advertisement message does not include information of neighbor femto cells. Special handling of neighbor
4   information of femto cell is described in section 10.3.3
5
6   A serving ABS may unicast the MOB_NBR-ADV message to a AMS.
7

8   ## 10.3.1.2   Scanning Procedure

9   The scanning procedure provides the opportunity for the AMS to perform measurement of the neighboring cells
10 for handover decision. The AMS may use any unavailable intervals assigned by the serving ABS to perform
11 scanning. In addition, the AMS may perform scanning procedure without interrupting its communication with
12 the serving ABS if the AMS supports such capability.
13
14 AMS selects the scanning candidate ABSs by information obtained from the ABS or information cached in the
15 AMSABS. The ABS or AMS may prioritize the neighbor ABSs to be scanned based on various metrics, such as
16 cell type, loading, RSSI and location.
17
18 AMS measures the selected scanning candidate ABSs and reports the measurement result back to the serving
19 ABS. The serving ABS defines triggering conditions and rules for AMS sending scanning report.
20

21 ## 10.3.2 Handover Process

22 ## 10.3.2.1   HO Framework

23 The handover algorithm is a network-controlled, AMS-assisted handover. Although handover procedure may be
24 initiated by either AMS or ABS, the final HO decision and target ABS(s) selection are performed by the serving
25 ABS or the network. AMS executes the HO as directed by the ABS or cancels the HO procedure through HO
26 cancellation message. The network re-entry procedure with the target ABS may be optimized by target ABS
27 possession of AMS information obtained from serving ABS over the backbone network. AMS may also
28 maintain communication with serving ABS while performing network re-entry at target ABS as directed by
29 serving ABS. Figure 16 shows a general call flow for handover.
30
31

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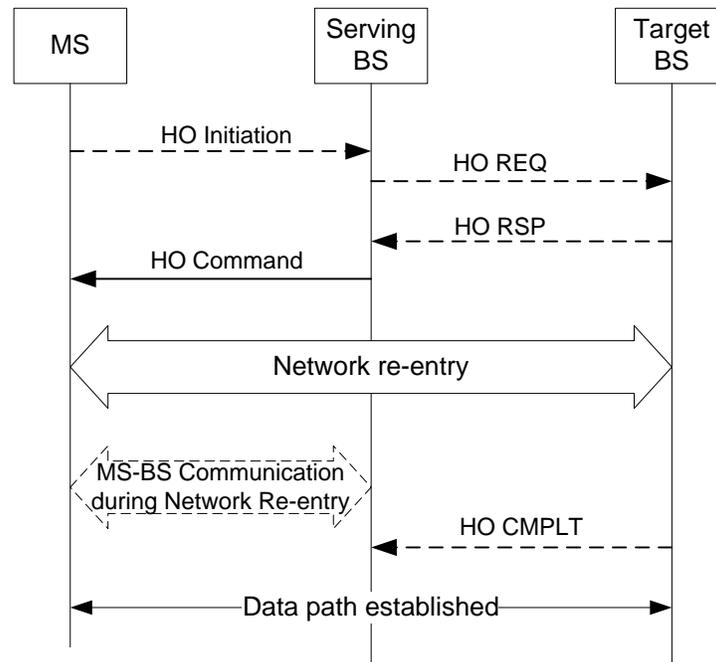
2   Figure 16 A general call flow for HO

3
4
5   The handover procedures are divided into three phases, namely, HO initiation, HO preparation and HO
6   execution. When HO execution is complete, the AMS is ready to perform Network re-entry procedures at target
7   ABS. In addition, HO cancellation procedure is defined to allow AMS cancel a HO procedure.
8

9   10.3.2.2   HO Procedure

10   *10.3.2.2.1   HO initiation*

11   Handover procedure may be initiated by either AMS or ABS and controlled by the ABS. When handover is
12   initiated by the AMS, the serving ABS defines the triggers and conditions based on which the AMS initiates a
13   handover. When multiple triggers and conditions are defined, the serving ABS may use combination of multiple
14   conditions to trigger HO. When HO is initiated by AMS, a HO Initiation control signaling is sent by the AMS
15   to start the HO procedure. In case of ABS initiated HO, HO initiation and HO preparation phases are carried out
16   together.
17

18   *10.3.2.2.2   HO preparation*

19   During HO preparation phase, the serving ABS communicates with target ABS(s) selected for HO. The target
20   ABS may obtain AMS information from the serving ABS via backbone network for HO optimization. If
21   ranging with target ABS not performed prior to or during HO preparation, dedicated ranging resource (e.g.
22   code, channel, etc.) at target ABS may be reserved for the AMS to facilitate non-contention-based HO ranging.
23   Information regarding AMS identity (e.g. TEK, STID, FIDs, etc.), may be pre-updated during HO preparation.
24   Any mismatched system information between AMS and the target ABS, if detected, may be provided to the
25   AMS by the Serving ABS during HO preparation.
26

1   HO preparation phase completes when serving ABS informs the AMS of its handover decision via a HO
2   Command control signaling. The control signaling may include dedicated ranging resource allocation and
3   resource pre-allocations for AMS at target ABS for optimized network re-entry. The control signaling includes
4   an action time for the AMS to start network re-entry at the target ABS and an indication whether AMS should
5   maintain communication with serving ABS during network re-entry. In the case that AMS maintains
6   communication with serving ABS during network reentry, the parameters associated with the scheme of
7   multiplexing transmission with serving and target ABS are determined by serving ABS based on the AMS
8   capability and negotiated between the serving and target BSs.
9
10 The control signaling indicates if the static and/or dynamic context and its components of the AMS is available
11 at the target ABS.

12 ### 10.3.2.2.3   *HO execution*

13 At the action time specified in the HO command control signaling, the AMS performs network re-entry at the
14 target ABS. If communication is not maintained between AMS and serving ABS during network re-entry at the
15 target ABS, serving ABS stops allocating resources to AMS for transmission at action time.
16 If directed by serving ABS via HO Command control signaling, the AMS performs network re-entry with the
17 target ABS at action time while continuously communicating with the serving ABS. However, the AMS stops
18 communication with serving ABS after network re-entry at target ABS is completed. In addition, AMS cannot
19 exchange data with target ABS prior to completion of network re-entry. Multiplexing of network re-entry
20 signaling with target ABS and communications with serving ABS is done by using negotiated intervals with
21 serving ABS for network re-entry signaling with target ABS, and the remaining opportunities with serving ABS
22 for data communication. If the negotiated interval is set to 0, the AMS communicates with the serving ABS
23 continuously while concurrently performing network re-entry with the target ABS.
24

25 ### 10.3.2.2.4   *HO cancellation*

26 After HO is initiated, the handover could be canceled AMSat any phase during HO procedure. After the HO
27 cancellation is processed, the AMS and serving ABS resume their normal operation.
28

29 ## 10.3.2.3   Network Re-entry

30 ### 10.3.2.3.1   *CDMA-based HO Ranging procedure*
31

32 If a dedicated ranging code is assigned to the AMS by target ABS, the AMS transmits the dedicated ranging
33 code to the target ABS during network re-entry. If a ranging channel is scheduled by the target ABS for
34 handover purpose only, the AMS should use that ranging channel in order to avoid excessive multiple access
35 interference. For CDMA-based HO ranging without AMS authentication, upon reception of the dedicated
36 ranging code, the target ABS should allocate uplink resources for RNG-REQ message and UL data if needed.
37
38 When the AMS handovers to the target ABS, CDMA-based HO ranging may be omitted if the ranging
39 parameters are valid.
40

41 ### 10.3.2.3.2   *Network Re-entry Procedure*
42   The network re-entry procedure is carried out as specified in IEEE P802.16Rev2 procedure unless otherwise

specified in this section.

10.3.3 Handover support for Femto ABS

[Editor's Note: This section is only related to intra-RAT IEEE 802.16m to IEEE 802.16m HO. The text
proposed in C80216m-MAC-08_022r2 is included with some modification.]
The network provides certain system information such as carrier frequency of the femto cell to AMS for
supporting handover between (macro/micro) ABS and femto ABS. AMS may cache this information for future
handover to the specific femto cell. At the time of handover preparation, the system information of a target
femto cell may be unicast or multicast to the AMS upon AMS request/network trigger or obtained by the AMS
monitoring the femto cell.

The HO procedure between femto ABS and macro ABS is FFS.

10.3.4 Handover Process supporting Legacy system

[Editor's Note: This section is only related to intra-RAT 16e/IEEE 802.16m HO.]

10.3.4.1   Network topology acquisition

10.3.4.2   Handover from 16e to IEEE 802.16m

10.3.4.3   Handover from IEEE 802.16m to 16e

10.3.5 Handover Process supporting Legacy system

10.3.5.1   Network topology acquisition

The 16e/16m co-existing system consists of 16e and 16m cells/sectors. A YBS advertises the system
information for its neighbor YBSs and the LZones of its neighbor ABSs. A ABS advertises the system
information for its neighbor YBSs in its both LZone and 16m zone. It also advertises the system information for
its neighbor ABSs in 16m zone only.
The ABS may indicate its 16m capability and information in its16e zone. The signaling for transmitting 16m
zone information is FSS. In addition, the MOB_NBR-ADV message in the LZone of ABS may contain
information of a neighboring 16m-only ABS or 16m zone of ABS.

[Editors note: the 16-m only BS definition is unclear. Since clearly 16m support is indicated the BS is
interpreted to be an ABS]

10.3.5.2   Handover from 16e to 16m

When a 16e-to-16m handover is triggered for a YMS, the YMS handover is from the serving YBS to the
LZone of the target ABS using 16e handover signaling and procedures.

When a 16e-to-16m handover is triggered for a AMS, the AMS may handover from the serving YBS to the
LZone of the target ABS using 16e handover signaling and procedures. The target YBS/ABS may direct the
AMS to switch to 16m zone. The detail procedure for zone switching is FFS .

1

2 A AMS may also handover from a YBS to a 16m only ABS or 16m zone of ABS directly if AMS is able to scan
3 16m-only ABS or 16m zone prior to handover. The detail procedure is FFS.

4

10.3.5.3   Handover from 16m to 16e

When a 16m-to-16e handover is triggered for a YMS, the YMS handover is from LZone of the serving ABS to
the target YBS using 16e handover signaling and procedures.
When a 16m-to-16e handover is triggered for a AMS, the serving ABS and AMS perform handover execution
using 16m handover signaling and procedures. The serving ABS performs context mapping and protocol inter-
working from 16m to 16e system. Then the AMS perform network re-entry to target YBS using 16e network re-
entry signaling and procedures.

12

10.3.6 Inter-RAT Handover Procedure

14

10.3.6.1   Network topology acquisition

IEEE 802.16m systems advertise information about other RATs to assist the MS with network discovery and
selection. IEEE 802.16m systems provide a mechanism for MS to obtain information about other access
networks in the vicinity of the MS from a BS either by making a query or listening to system information
broadcast. This mechanism can be used both before and after MS authentication. IEEE 802.16m system may
obtain the other access network information from an information server. The ABSs may indicate the boundary
area of the IEEE 802.16m network by advertising a network boundary indication. Upon receiving the
indication, the 16m MS may perform channel measurement to the non-IEEE 802.16m network.

10.3.6.2   Generic inter-RAT HO procedure

IEEE 802.16m system provides mechanisms for conducting inter-RAT measurements and reporting. Further,
IEEE 802.16m systems may specify a MAC container to forward handover related messages with other access
technologies such as IEEE 802.11, 3GPP and 3GPP2. The specifics of these handover messages may be defined
elsewhere, e.g. IEEE 802.21.

10.3.6.3   Enhance inter-RAT HO procedure

10.3.6.3.1   Dual Transmitter/Dual Receiver Support

In addition to the HO procedures specified in section 10.3.6.2, an MS with dual RF may connect to both a ABS
and a BS operating on other RAT simultaneously during handover. The second RF is enabled when inter-RAT
handover is initiated. The network entry and connection setup processes with the target BS are all conducted
over the secondary radio interface. The connection with the serving BS is kept alive until handover completes.

10.3.6.3.2   Single Transmitter/Single Receiver Support

An MS with a single RF may connect to only one RAT at a time. The MS will use the source RAT to prepare
the target RAT system. Once target RAT preparation is complete the MS may switch from source RF to target
RF and complete optimized network entry in target RAT. Only one RF is active at any time during the
handover.

39

[Editors note: in the above section it is not clear in all cases what MS and BS refers to thus no change was

implemented in unclear cases]

10.4 ARQ

An ARQ block is generated from one or multiple MAC SDU(s) or MAC SDU fragment(s). ARQ blocks can be variable in size. ARQ blocks are sequentially numbered. The location of this sequence number in the MAC PDU is FFS.

Retransmission of a failed ARQ block can be performed with or without rearrangement.

10.5 Power Management

IEEE 802.16m provides AMS power management functions including sleep mode and idle mode to alleviate AMS battery consumption.

10.5.1 Sleep Mode

10.5.1.1   Introduction

Sleep mode is a state in which an AMS conducts pre-negotiated periods of absence from the serving ABS air interface. Per AMS, a single power saving class is managed in order to handle all the active connections of the AMS. Sleep mode may be activated when an AMS is in the connected state. When Sleep Mode is active, the AMS is provided with a series of alternate listening window and sleep windows. The listening window is the time in which AMS is available to receive and send signaling and/or data from and to the ABS.

The IEEE 802.16m provides a framework for dynamically adjusting the duration of sleep windows and listening windows within a sleep cycle based on changing traffic patterns and HARQ operations. The length of successive sleep windows may remain constant or may be adaptive based on traffic conditions.

Sleep windows and listening windows can be dynamically adjusted for the purpose of data transportation as well as MAC control signaling transmission. AMS can send and receive data and MAC control signaling without deactivating the sleep mode.

10.5.1.2   Sleep mode entry

Sleep mode activation/entry is initiated either by a AMS or a ABS. When AMS is in Active mode, sleep parameters are negotiated between AMS and ABS. ABS makes the final decision and instructs the AMS to enter sleep mode. MAC control signaling can be used for sleep mode request/response signaling.

10.5.1.3   Sleep Mode Operations

10.5.1.3.1   Sleep cycle operation

Unit of sleep cycle is expressed in frames. The start of the listening window is aligned at the frame boundary.

1 The AMS shall ensure that it has up-to-date system information for proper operation. If the AMS detects that
2 the information it has is not up-to-date, then it shall not transmit in the listening window until it receives the up-
3 to-date system information.A sleep cycle is the sum of a sleep window and a listening window. AMS or ABS
4 may request change of sleep cycle through explicit MAC control signaling. Also, sleep cycle may change
5 implicitly. ABS keeps synchronizing with AMS on the sleep/listening windows' boundary. The synchronization
6 could be done either implicitly by following pre-determined procedure, or explicitly by using proper signaling
7 mechanism.
8

9 *10.5.1.3.2   Sleep Window Operation*

10 During the sleep window, the AMS is unavailable to receive any DL data and MAC control signaling from the
11 serving ABS. IEEE 802.16m provides a framework for dynamically adjusting the duration of the sleep
12 windows. If AMS has data or MAC control signaling to transmit to ABS during the sleep window, AMS can
13 interrupt the sleep window and request bandwidth for UL transmission with or without deactivating sleep mode
14 based on sleep mode configuration.
15

16 *10.5.1.3.3   Listening window operation*

17 During the listening window, the AMS can receive DL data and MAC control signaling from ABS. AMS can
18 also send data if any uplink data is scheduled for transmission. Listening window is measured in units of
19 subframes or frames. After termination (by explicit signaling or implicit method) of a listening window, the
20 AMS may go back to sleep for the remainder of the current sleep cycle.
21

22 10.5.1.3.3.1 Traffic Indication

23 During the AMS listening window, ABS may transmit the traffic indication message intended for one or
24 multiple AMSs. It indicates whether or not there is traffic addressed to one or multiple AMSs. The traffic
25 indication message is transmitted at pre-defined location. Upon receiving negative traffic indication in the
26 traffic indication message, the AMS can go to sleep for the rest of the current sleep cycle.
27

28 10.5.1.3.3.2 Listening Window Extension

29 The listening window duration can be dynamically adjusted based on traffic availability or control signaling in
30 AMS or ABS. The listening window can be extended through explicit signaling or implicit method. There may
31 be no sleep window within a sleep cycle due to extension of the listening window.
32

33 *10.5.1.3.4   Sleep Mode Exit*

34 Sleep mode termination/deactivation is initiated either by AMS or ABS. ABS makes the final decision and
35 instructs the AMS to de-activate sleep mode by using explicit signaling. MAC control signaling are used for
36 sleep mode request/response signaling.
37

38 10.5.2 Idle mode

39 Idle mode provides efficient power saving for the AMS by allowing the AMS to become periodically available
40 for DL broadcast traffic messaging (e.g. Paging message) without registration at a specific ABS.
41

42 The network assigns idle mode AMS to a paging group during idle mode entry or location update. The design

1   allows the network to minimize the number of location updates performed by the AMS and the paging signaling
2   overhead caused to the ABSs. The idle mode operation considers user mobility.
3
4   ABSs and Idle Mode AMSs may belong to one or multiple paging groups in order to minimize the number of
5   location updates and paging load without increasing average paging delay and without increasing the overhead
6   of transmitting of multiple paging IDs by the ABSs. Idle mode AMSs may be assigned paging groups of
7   different sizes and shapes based on user mobility.
8
9   The AMS monitors the paging message at AMS's paging listening interval. The start of the AMS's paging
10 listening interval shall be derived based on paging cycle and paging offset. Paging offset and paging cycle are
11 defined in terms of number of super-frames.
12
13 The AMSs are divided into logical groups to offer a scalable paging load-balancing distribution.

10.5.2.1   Paging Procedure

15 ABS transmits the list of PGIDs at the pre-determined location. The PGID information should be received
16 during AMS's paging listening interval.
17 Paging mechanism in 802.16m may use the two-step paging procedure that includes the paging indication
18 followed by the full paging message.
19

10.5.2.1.1   Paging Indication

21 Paging indications, if present, are transmitted at the pre-determined location. When paging indications are
22 transmitted, ABS transmits the list of PGIDs and associated paging indicator flag (the exact format of paging
23 indicator is TBD) indicating the presence of full paging messages for the corresponding PGIDs.
24

10.5.2.1.2   ABS Broadcast Paging message

26 Within a paging listening interval, the frame that contains the paging message for one or group of idle mode
27 AMSs is known to idle mode AMSs. Methods will be defined to determine the frame/subframe (within a super-
28 frame) that contains the paging message for one or group of idle mode AMSs.Paging message includes
29 identification of the AMSs to be notified of DL traffic pending or location update.
30

10.5.2.1.3   Operation during paging unavailable interval

32
33 ABS should not transmit any DL traffic or paging advertisement to AMS during AMS's paging unavailable
34 interval. During paging unavailable interval, the AMS may power down, scan neighbor ABSs, reselect a
35 preferred ABS, conduct ranging, or perform other activities for which the AMS will not guarantee availability
36 to any ABS for DL traffic.
37

10.5.2.1.4   Operation during paging listening interval

39
40 The AMS derives the start of the paging listening interval based on the paging cycle and paging offset. At the
41 beginning of paging listening interval, the AMS scans and synchronizes on the SCH of its preferred ABS. The
42 AMS decodes the BCH. The AMS shall confirm whether it exists in the same paging group as it has most

recently belonged by getting PGID information.

During paging listening interval, AMS monitors BCH. If BCH indicates change in system broadcast information (e.g. change in system configuration count) then AMS should acquire the latest system broadcast information at the pre-determined time when the system information is broadcasted by the ABS. Additionally, if paging indicators are present, AMS also monitors the paging indicators. If the paging indicator flag associated with its own PGID is set then AMS will subsequently decode the full paging message at the pre-determined location; otherwise AMS will return to paging unavailable interval. If paging indicators are not present, AMS decodes the full paging message at the predetermined location. If the AMS decodes a paging message that contains its identification, the AMS performs network re-entry or location update depending on the notification indicated in the paging message. Otherwise, AMS returns to paging unavailable interval.

10.5.2.2   Idle Mode Entry/Exit Procedure

10.5.2.2.1   *Idle mode initiation*

In order to reduce signaling overheads and provide location privacy, the paging controller may assign temporary identifier to uniquely identify the AMSs in the idle mode in a particular paging group. The AMS's temporary identifier remains valid as long as AMS stays in the same paging group. The temporary identifier assignment may happen during idle mode entry or during location update due to paging group change. Temporary identifier may be used in paging messages or during AMS's network re-entry procedure from idle mode as response to paging.

10.5.2.2.2   *Idle mode termination*

For termination of idle mode, AMS shall perform network re-entry with its preferred ABS. The network re-entry procedure can be shortened by the ABS possession of AMS information.

10.5.2.3   Location Update

10.5.2.3.1   *Location update trigger condition*

An AMS in idle mode shall perform a location update process operation if any of the following location update trigger condition is met.

- Paging group location update
- Timer based location update
- Power down location update

During paging group location update or timer based location update, AMS may update paging cycle and paging offset.

10.5.2.3.2   Location update procedure

If an AMS determines or elects to update its location, depending on the security association the AMS shares with its preferred ABS, the AMS shall use one of two processes: secure location update process or unsecure location update process.

Location update comprises of conditional evaluation and location update signaling.

10.5.2.3.2.1 Paging group location update

The AMS performs the Location Update process when the AMS detects a change in paging group. The AMS detects the change of paging group by monitoring the Paging Group IDs, which are transmitted by the ABS.

10.5.2.3.2.2 Timer based location update

AMS shall periodically perform location update process prior to the expiration of idle mode timer. At every location update including paging group location update, idle mode timer is reset to 0 and restarted.

10.5.2.3.2.3 Power down location update

The AMS attempts to complete a location update once as part of its orderly power down procedure.

10.6 Security

[Editors note: this section uses the term SS, believe the correct term should be AMS. However, this change has not been implemented]

10.6.1 Security Architecture

The security functions provide subscribers with privacy, authentication, and confidentiality across the IEEE 802.16m network. It does this by applying cryptographic transforms to transport and management MAC PDUs and standalone signaling headers carried across connections between AMS and ABS.
The security architecture of IEEE 802.16m system consists of the following functional entities; the AMS, the ABS, and the Authenticator.
Figure Figure 17 describes the protocol architecture of security services.
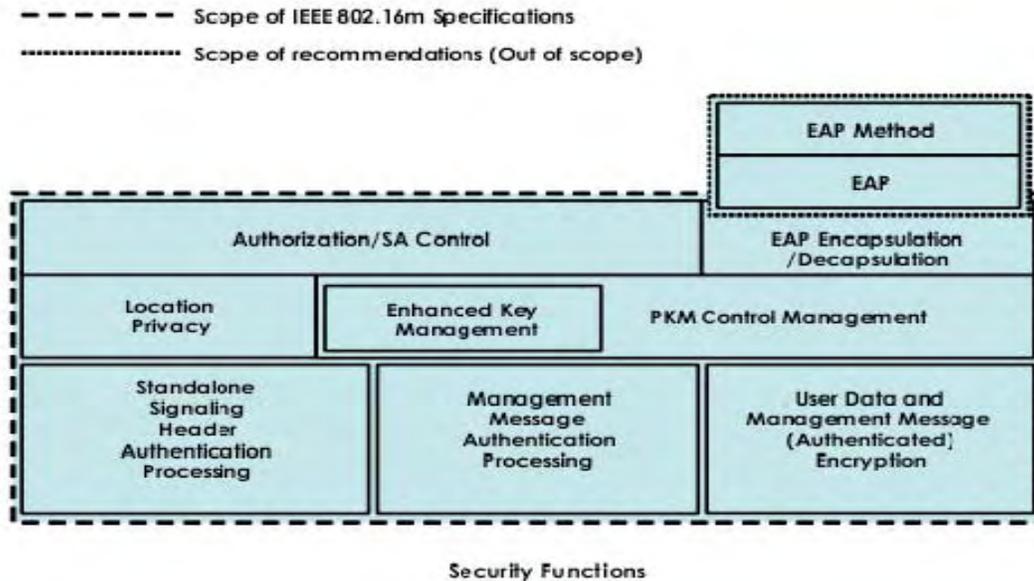
Figure 17 Functional Blocks of IEEE 802.16m Security Architecture

Within AMS and ABS the security architecture is divided into two logical entities:
- Security management entity
- Encryption and integrity entity

Security management entity functions includes :
- Overall security management and control
- EAP encapsulation/decapsulation for authentication & authorization
- Privacy Key Management (PKM) Control (e.g. Key Generation/Derivation/Distribution, Key State Management)
- Security Association (SA) management
- Identity/Location Privacy

Encryption and integrity protection entity functions include:
- Traffic Data Encryption/Authentication Processing
- Message authentication processing
- Message Confidentiality Protection

10.6.2 Authentication and Authorization Protocol

Authorization is the process of one station authenticating the identity of another. In the reference system this process is mutual, i.e. the ABS authenticates the identity of the SS and the SS authenticates the identity of the ABS. In the reference system, only EAP-based authentication is required. [However, in IEEE 802.16m, ECC (Elliptic Curve Cryptography)-based authorization should be supported as well.] Credentials used for RSA [and ECC] authorization will be based on X.509 certificates (IETF RFC 3279, 3280). RSA [or ECC]-based

47

authorization can be coupled with EAP authentication. EAP authentication (IETF RFC 3748) provides and additional level of authentication with an operator-selected EAP method (e.g EAP-TLS or EAP-SIM).

Execution of EAP methods and selection of credentials that are used during EAP authentication are outside the scope of this specification.

Authentication is executed during initial network entry after security capabilities and policies are negotiated. General SS capability negotiation shall be performed after authentication and authorization.

Re-authentication should be made before lifetime of authentication materials/credentials expires. Data transmission may continue during re-authentication process ,by providing SS with two sets of authentication/keying material with overlapping lifetimes. Authentication procedure is controlled by authorization state machine, which defines allowed operations in specific states.

10.6.2.1   AMS Privacy

In reference system there is no explicit means by which identity of user is protected. During initial ranging and certificate exchange during authorization AMS MAC Address (AMS ID) is transmitted in the clear. Hence, the identity or location information can be easily inferred from fixed AMS MAC address, result of which violates the security aspects of IEEE 802.16m SRD. Detailed method for providing AMS ID privacy is FFS.

[Editor's Note: During RG discussion support for Authorization was removed. However, this text remains, as there was no specific comment submitted to address it. It would be appropriate to remove Section 10.5.2.2 to make it consistent with the removal of the other authorization text.]
[

10.6.2.2   Elliptic Curve Cryptography-based Authorization

In addition to the current RSA-based authorization within the PKM protocol, Elliptic Curve Cryptography (ECC)-based authorization may be employed.

During initial and re-authorization, the SS can format the request in either one of two ways. The first way is to make use of a manufacturer-installed ECC certificate and public key that is associated with the SS in the initial authorization request. The other method is that the SS uses the elliptic curve domain parameters defined in its certificate to generate an ephemeral key pair.

Regardless of the method used, the ABS then verifies the domain parameters, the public key, and the signature over the request. If any of these checks fail, the then authorization request is rejected. When the ABS responds, it can choose between either of two methods (similar to SS initiation methods) when formatting the response.
]

10.6.3 Key Management Protocol

IEEE 802.16m inherits the key hierarchies of the reference system. The 802.16m uses the PKM protocol to achieve:
- Transparent exchange of authentication and authorization (EAP) messages (Chapter 10.6.2)
- Key Agreement (Chapter 10.6.3.2)

1   • Security material exchange (Chapter 10.6.3.2)
2

3   PKM protocol provides mutual and unilateral authentication and establishes shared secret between the AMS
4   and the ABS. The shared secret is then used to exchange or derive other keying material. This two-tiered
5   mechanism allows frequent traffic key refreshing without incurring the overhead of computation intensive
6   operations.
7

8   10.6.3.1   Key Derivation
9

10   All 802.16m security keys are either derived directly / indirectly from the MSK or generated randomly by the
11   ABS.
12

13   The Pairwise Master Key (PMK) is derived from the MSK and then this PMK is used to derive the
14   Authorization Key (AK).
15

16   Some IEEE 802.16m keys are respectively derived and updated by both the ABS and the SS.
17

18   *[Editor's Note: During RG discussion support for Authorization was removed. However, this text remains, as*
19   *there was no specific comment submitted to address it. It would be appropriate to remove the following text in*
20   *Section 10.5.3.1 to make it consistent with the removal of the other authorization text.]*
21

22   [Elliptic-Curve Diffie Hellman primitives (as defined in Section 5.4 of ANSI X9.62-2005) will be used to
23   generate the PMK if ECC authorization is used. Key hierarchy for keys derived from ECC generated PMK will
24   follow key hierarchy for keys derived from RSA certificates.]
25

26   The Authorization Key (AK) is used to derive other keys:
27   • Key Encryption Key (KEK)
28   • Transmission Encryption Key (TEK)
29   • Cipher-based Message Authentication Code (CMAC) key
30

31

32   After AK derivation, key agreement may be performed to verify the newly created AK and exchange other
33   required security parameters.
34

35   Alternatively ranging procedure may used to exchange nonce and other required security parameters.
36

37   KEK derivation follows procedures as defined in reference system.
38

39   TEK is derived at AMS and ABS by feeding identity parameters into a key derivation function. Parameters
40   such as AK, Security Association ID (SAID), NONCE, KEY_COUNT, BSID, AMS MAC address can be used.
41   NONCE is generated by ABS and distributed to SS.. If more than one TEK is to be created for an SA, separate
42   KEY_COUNTs are maintained for each TEK.
43

44   The CMAC key is derived locally by using the AK, the KEY_COUNT and SAID of SA concerned with control
45   plane/management signaling, as well as other identity parameters.
46

47   TEK(s) and the CMAC keys shall be derived in the following situations:

- Initial authentication
- Re-authentication
- Key update procedure for unicast connection.
- Handover to target ABS
- Re-entry to new ABS after connection loss / uncoordinated HO / idle mode re-entry.

In the last three cases, KEY_COUNT value is incremented prior derivation.

Group AK (GAK) is randomly generated at the ABS.

The GTEK is generated locally by using the GAK, the NONCE, the KEY_COUNT and other identity parameters.

New GTEK shall be derived in the following situations:
- AMS enters to multicast group (derived only in AMS side)
- Generation and transmission of new GAK
- Group key update procedure for multicast connection.

10.6.3.2   Key Exchange

The key exchange procedure is controlled by the security key state machine, which defines the allowed operations in the specific states. The key exchange state machine does not differ from reference system, except that instead of the exchanging the keys in reference system, a nonce is exchanged and used to derive keys locally.

Distribution mechanism for nonce is FFS. [In IEEE 802.16m, the nonce used to derive and update TEK is sent from ABS to AMS during authorization phase.]

The ABS and the AMS derive the TEK through the key derivation mechanism at each side respectively. Update mechanism for nonce is FFS.

The Nonce can be exchanged with the following messages:
- Key Request / Reply
- Key Agreement
- Ranging

1
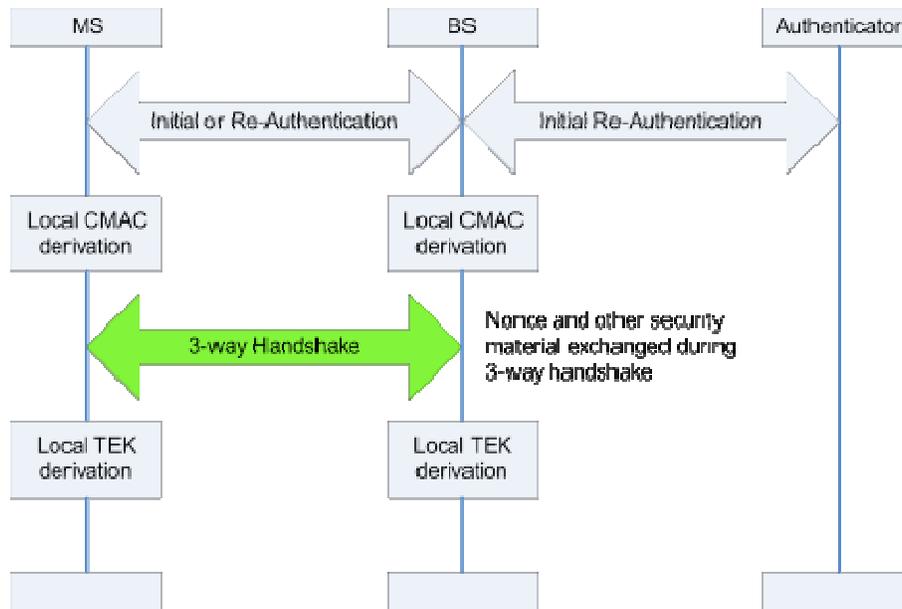
2　　Figure 18 Initial or Re-authentication - Key Derivation and Exchange

3
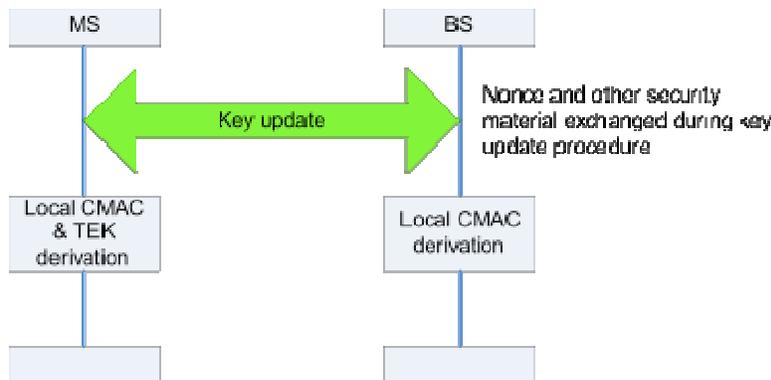
4

5　　Figure 19 Key Update Procedure

6　## 10.6.3.3　Key Usage

7

8　The TEK usage does not differ from 'Reference System'.

9

10　In encryption, used KEY_COUNT shall be identified by the receiver (AMS or ABS). EKS field carries the 2-bit
11　key sequence of associated TEK. Alternative EKS design and usage is FFS.

12

13　## 10.6.4 Security Association Management

14　A security association (SA) is the set of information required for secure communication between ABS and
15　AMSs. SA is identified using an SA identifier (SAID). In the reference system, the SA is applied to the
16　respective flows once an SA is established.

17

18　IEEE 802.16m supports two types of basic SA management:

51

1   • Unicast SA (SA)
2   • Group SA (GSA)
3

4   Unicast SA is used to provide keying material to unicast transport connections. As in the case of the reference
5   system, the data plane SA is applied to all messages exchanged within the same flow. Multiple flows may be
6   mapped to the same unicast SA. Unicast SA can be static or dynamic. Static SAs are assigned by the ABS.
7   Dynamic SAs are mapped to a particular service flow, and are taken down when that service-flow is no longer
8   in operation.
9

10   The unicast SA is used to provide keying material for management connections.
11

12   *[Editor's Note: The header design is ongoing in 802.16m, the EC bit seems unlikely to remain in the standard.*
13   *So, this text may need to be modified based on that decision.]*
14   However, SA is not equally applied to the messages within the same flow. According to the value of [MAC
15   header fields (e.g. EC or EKS)] [Flow ID], the SA is selectively applied to the management connections.
16

17   When a service flow is established between the ABS and the group of SS's, it is considered to be multicast and
18   it is serviced by a Group SA (GSA).
19

20   If SS and ABS decide "No authorization" as their authorization policy, no SAs will be established. In this case,
21   Null SAID shall be used as the target SAID field in DSA-REQ/RSP messages. If authorization is performed but
22   the AMS and ABS decide to create an unprotected service flow, the Null SAID may be used as the target SAID
23   field in DSA-REQ/RSP messages.

24   ## 10.6.5 Cryptographic Methods

25   Cryptographic methods specify the algorithms used in 802.16m for the following functions:
26   • User data and management data encryption/decryption methods and algorithms
27   • Key encryption/decryption methods and algorithms
28   • CMAC calculation algorithm for management message integrity protection
29

30   ## 10.6.5.1   Encryption methods

31   AMS and ABS may support encryption methods and algorithms for secure transmission of MPDUs. AES
32   algorithm is the only supported cryptographic method in 802.16m. The following AES modes are defined in
33   802.16m:
34   • AES-CCM mode - provides also integrity protection
35   • AES-CTR mode
36
37

38   ### *10.6.5.1.1   AES in CCM mode*

39   10.6.5.1.1.1 PDU payload format
40   The PN size is reduced in IEEE 802.16m from 4 bytes to 3 bytes. Further reduction in PN and supporting
41   methods are FFS. The nonce construction for the CCM algorithm defined in IEEE 802.16e is used also for
42   802.16m.
43

1   *[Editor's Note: During RG discussion detailed mechanisms for PDU payload format (Section 10.5.5.1.1) were*
2   *removed. However, this text remains, as there was no specific comment submitted to address it. This text*
3   *reflects a dependence on on PDU construction method. It would be appropriate to remove or modify the text for*
4   *Section 10.5.5.1.2 to be in accordance with the accepted text for PDU payload format.]*
5

6   ## 10.6.5.1.2   *Multiplexing MPDUs*

7   When some connections identified by flow ids are mapped to the same SA, their payloads can be multiplexed
8   together into one MPDU. The multiplexed payloads are encrypted together. In Figure 20, Flow_x and Flow_y
9   have payload x and y respectively which are mapped to the same SA. The MAC header provides the details of
10 payloads which are multiplexed.
11
12 Note that the multiplexed MPDU format in figure Figure 20 can be changed according to mechanism for single
13 MDPU encryption.
14
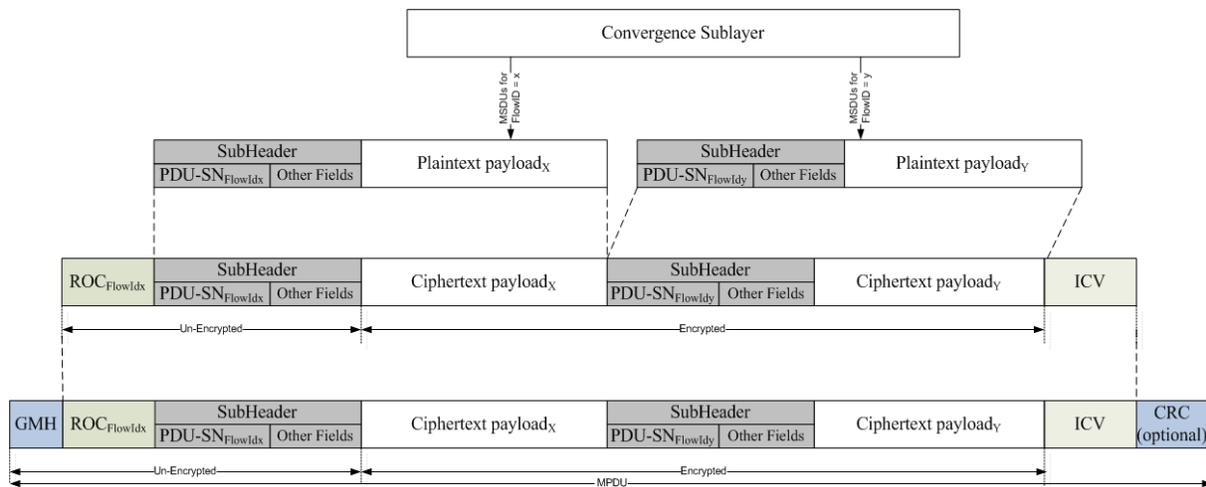
16   Figure 20 multiplexed MAC PDU format

17
18 In case of the multiplexed MPDU, the multiplexed MPDU is encrypted by using ROC and PDU_ SN of the first
19 flow PDU only. Hence the other flow's ROCs are to be omitted, but the ROCs are maintained per flow
20 implicitly. ROC and PDU_ SN of the first flow PDU is not encrypted.
21

22 ## 10.6.5.2   Key encryption methods

23 Key encryption method NIST AES key wrap shall be used to encrypt a key, when cryptographic key(s) is
24 needed to transmit from ABS to AMS.
25

26 ## 10.6.5.3   Control Plane Signaling Protection

27 Contrary to the legacy systems that do not define the confidentiality protection over control plane signaling,
28 IEEE 802.16m selectively protects the confidentiality of control plane signaling. The use of MAC (Message
29 Authentication Code) in legacy systems only proves the originator of messages and ensures integrity of the
30 messages.

1 *10.6.5.3.1   Management Message Protection*

2 IEEE 802.16m supports the selective confidentiality protection over MAC management messages. Through
3 capability negotiation, AMS and ABS know whether the selective confidentiality protection is applied or not. If
4 the selective confidentiality protection is activated, the negotiated keying materials and cipher suites are used to
5 encrypt the management messages. Information required for selective confidentiality support is contained in
6 FFS.
7 Figure Figure 21 presents three levels of selective confidentiality protection over management messages in
8 IEEE 802.16m.

9   • No authorization: If SS and ABS decide "No authorization" as their authorization policy, then the
10   management messages are neither encrypted nor authenticated. Management messages before the
11   authorization phase also fall into this category.
12   • CMAC based integrity protection; CMAC Tuple TLV is included to the end of management message as
13   a last TLV. CMAC integrity protects only payload, not header part. Actual management message is
14   plain text.
15   • AES-CCM based authenticated encryption; ICV field is included after encrypted payload and this ICV
16   integrity protects both payload and MAC header part.

17
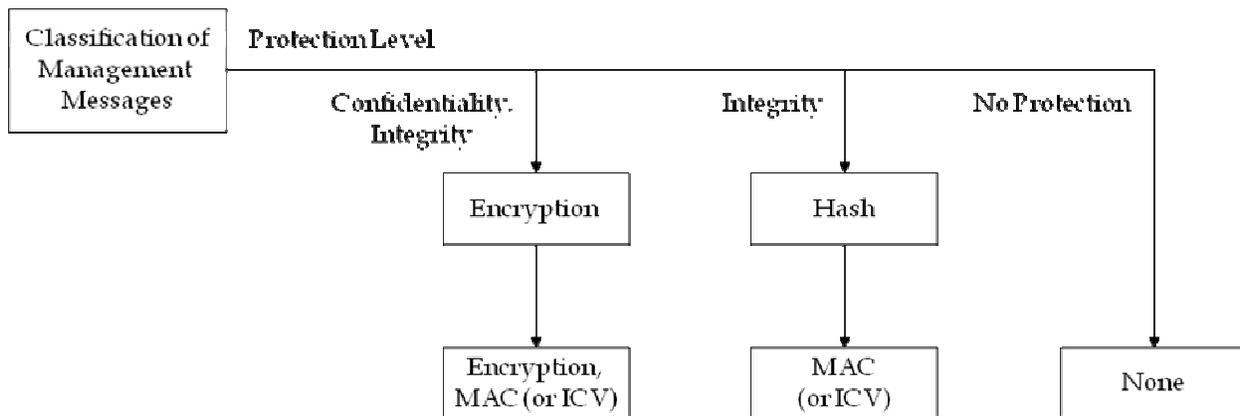
18
19   Figure 21 Flow of IEEE 802.16m Management Message Protection

20

21

22 *10.6.5.3.2   Standalone Signaling Header Authentication*

23 Integrity protection is applied to standalone MAC signaling header. Method for providing standalone signaling
24 header protection is FFS.

25

26 10.6.6 Certificate Profile

27

28 *[Editor's Note: During RG discussion support for Authorization was removed. However, this text remains, as*
29 *there was no specific comment submitted to address it. It would be appropriate to remove the following text in*
30 *Section 10.5.6 to make it consistent with the removal of the other authorization text.]*

31

32 This subclause describes the X.509 Version 3 certificate format and certificate extensions used in IEEE 802.16-
33 compliant SSs. The X.509 Version 3 format is defined in IETF RFC 3280. ASN.1 encoding of algorithms
34 object identifiers (OIDs) are also further described in IETF RFC 3279.

The basic X.509 Version 3 certificate format and set of ASN.1 encoded OIDs describing signature algorithms and public keys, is retained from the reference system for certificates used as credentials for RSA-based authorization (RSA signature algorithm and RSA public keys). RSA certificates will be based on keys that are no less than 1024 bits and no greater than 2048 bits.

ECC-based authorization requires credentials based on X.509 certificates that specify use of Elliptic Curve Digital Signature Algorithm (ECDSA) as the signature algorithm, define a set of elliptic curve domain parameters, and a public key generated from the set of domain parameters.

The elliptic curve domain parameters can be generated according to procedures defined in Section A.3 of ANSI X9.62-2005. Example parameters sets of parameters can be found in FIPS 186-3 and ANSI X9.63-2001. Domain parameters sets that are selected will produce keys of no less than 160 and no greater than 224 bits in length.

10.6.7 Mobility & Backward Compatibility

[Editor's Note: Text for this section is dependent upon work of other Rapporteur Groups.]

10.6.8 MBS Security

[Editor's Note: Text for this section is dependent upon work of MBS RG.]

10.7 Convergence Sublayer

GPCS is used to transport packet data over the air interface.This means that the classification is assumed to take place on layers above the MAC-CS. Relevant information for performing classification are transparently transported during connection setup or change.

10.8 Network Entry

Network entry is the procedure by which an AMS finds and establishes a connection with the network. The network entry has the following steps:
- AMS synchronizes with the ABS via synchronization channel (SCH).
- AMS obtains necessary information e.g. ABS ID, NSP ID for initial network entry, and performs network selection.
- AMS starts ranging process.
- Authentication and registration process.
- AMS enters 16m network and sets up service flows.

Neighbour BSs search is based on the same downlink signals as initial network search (eg: preamble) except some information can be provided by serving ABS (eg: NBR-ADV). Network re-entry from such procedures as handover, idle mode exit and so on, is based on initial network entry procedure with certain optimization procedures.

The ABS shall respond to the AMS' initial ranging code transmission by broadcasting a status indication

message (e.g.: Decoding Status Bitmap) in a following predefined DL frame/subframe. The initial ranging related messages (e.g.: RNG-RSP and BW Grant) can be embedded linked to the corresponding bit of the status indication message to reduce overhead.

10.9 Connection Management

Connections are identified by the combination of station identifier and flow identifier. Two types of connections are used – management connections and transport connections.
Management connections are used to carry MAC management messages. Transport connections are used to carry user data including upper layer signaling messages such as DHCP, etc and data plane signaling such as ARQ feedback.

Fragmentation is supported on transport connections. Fragmentation may be supported on unicast management connections.

10.9.1 Management connections:

Management connection is bi-directional and default values of flow identifier are reserved for unicast management connection(s). Management connections are automatically established after station identifier is assigned to an AMS during AMS initial network entry.

10.9.2 Transport connections:

Transport connection is uni-directional and established with unique flow identifier assigned during service flow establishment procedure. Each admitted/active service flow is uniquely mapped to a transport connection. Transport connection is released when the associated service flow is removed. To reduce bandwidth usage, ABS and AMS may establish/change/release multiple connections using single message transaction. Transport connections can be pre-provisioned or dynamically created. Pre-provisioned connections are those established by system for an AMS during the AMS network entry. On the other hand, ABS or AMS can create new connection dynamically if required. A connection can be created, changed, or torn down on demand.

10.9.3 Priority for Emergency service flows:

For handling Emergency Telecommunications Service and E-911, emergency service flows will be given priority in admission control over the regular service flows.
- Default service flow parameters are defined for emergency service flow, based on which the ABS can grant resource in response to the AMS's emergency service notification without going through the complete service flow setup procedure during initial network entry procedure or in normal state. Details of emergency service notification are FFS.

If a service provider wants to support National Security/emergency Preparedness (NS/EP) priority services, the ABS uses its own algorithm as defined by its local country regulation body. For example, in the US the algorithm to support NS/EP is defined by the FCC

10.10 QoS

In order to provide QoS, IEEE 802.16m MAC associates an uni-directional flow of packets which have a specific QoS requirement with a service flow. A service flow is mapped to one transport connection with one flow identifier. ABS and AMS provide QoS according to the QoS parameter sets, which are negotiated between

the ABS and the AMS during the service flow setup/change procedure. The QoS parameters can be used to schedule traffic and allocate radio resource. In addition, uplink traffic may be policed based on the QoS parameters.

10.10.1   Service Classes

IEEE802.16m supports following additional information field parameters:
Tolerated packet loss rate
The value of this parameter specifies the maximum packet loss rate for the service flow.
Indication of Associated Flows
A parameter that indicates the flow(s) that are associated with the current service flow if any.

10.10.2   Adaptive polling and granting

IEEE 802.16m supports adaptation of service flow QoS parameters. One or more sets of QoS parameters are defined for one service flow. The AMS and ABS negotiate the supported QoS parameter sets during service flow setup procedure. When QoS requirement/traffic characteristics for UL traffic changes, the ABS may autonomously switch the service flow QoS parameters such as grant/polling interval or grant size based on predefined rules. In addition, the AMS may request the ABS to switch the Service Flow QoS parameter set with explicit signaling. The ABS then allocates resource according to the new service flow parameter set.

10.10.3   Scheduling Services

In addition to the scheduling services supported by the legacy system, IEEE 802.16m provides a specific scheduling service to support realtime non-periodic applications such as on-line gaming. The detailed scheduling mechanism and the service flow parameters are FFS.

10.11 MAC Management

To meet the latency requirements for aspects of network entry, handover, state transition and so on, 802.16m supports the fast and reliable transmission of MAC management connections. Mechanism for providing reliable transport of fragments of a MAC management message is FFS.

The 16m MAC protocol peers communicate using a set of MAC Control Messages. These messages are defined using ASN.1 [10],[11],[12],[13]. The ASN.1 descriptions are written in way that provides future extension of the messages. The Packed Encoding Rules (PER) [14] are used to encode the messages for transmission over the air.

IEEE 802.16m provides a generic MAC management message at the L2 called L2_transfer that acts as a generic service carrier for various standards defined services including, but not limited to: Device provisioning bootstrap message to AMS, GPS assistance delivery to AMS, ABS(es) geo-location unicast delivery to AMS, 802.21 MIH transfer, EAP transfer etc. The exact standards based messages that will be supported in this manner is FFS.

10.12 *MAC PDU Formats*

Each MAC PDU contains a MAC header. The MAC PDU may contain payload. The MAC PDU may contain one or more extended headers.

Multiple MAC SDUs and/or SDU fragments from different unicast flows belonging to the same AMS can be multiplexed into a single MAC PDU

### 10.12.1	MAC header formats

### 10.12.1.1	Generic MAC Header

HT[TBD]	EH(1)	FlowID(4)		TBD
TBD		[EKS(2)]	Length (3)	
Length (8)				
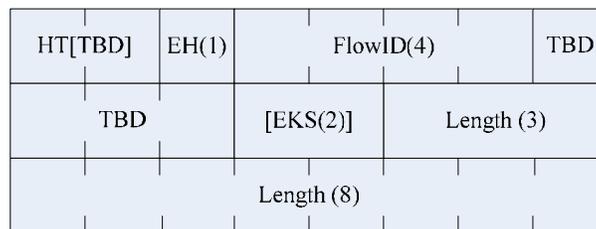
Figure 22 Generic MAC header format

- HT (Header Type): Indicates the type of the header. This field is TBD bits long.

- EH (Extended Header Presence Indicator): When set to '1", this field indicates that an Extended Header is present following this GMH.

- FlowID (Flow Identifier): This field indicates the flow that is addressed. This field is 4 bits long.

- [EKS (2bits):] Encryption Key Sequence

- Length: Length of the payload. This field is 11 bits long.

- FPI: The inclusion of FPI in GMH is FFS.

### 10.12.1.2	Compact Header

Compact header format is FFS.

1　10.12.1.3　Multicast/Broadcast MAC header

2

3　10.12.1.4　Multiplexing MAC Header

4

5　10.12.1.5　Signaling MAC Header

6

7　Signaling header format is FFS.

8

9　10.12.2　Extended header

10

11　The inclusion of extended header is indicated by EH indicator bit in MAC Header. The EH format is shown in
12　Figure 23 and will be used unless specified otherwise.

13

14
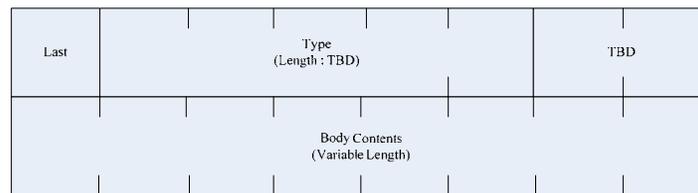
15　Figure 23 Extended Header Format

16

17　• Last: When the "Last" bit is set, another extended header will follow the current extended header. If this
18　　bit is not set this extended header is the last one.

19

20　• Type: indicates the type of extended header. The length is TBD.

21

22　• Body Contents: Type-dependent contents.

23

24

25　10.12.2.1　Fragmentation and packing extended header

26

27　Fragmentation and packing extended header format is FFS.

28

29　11 Physical Layer

30　*11.1 Duplex modes*

31

32　IEEE 802.16m supports TDD and FDD duplex modes, including H-FDD AMS operation, in accordance with
33　the IEEE 802.16m system requirements document [8]. Unless otherwise specified, the frame structure attributes
34　and baseband processing are common for all duplex modes.

11.2 Downlink and Uplink Multiple Access Schemes

IEEE 802.16m uses OFDMA as the multiple access scheme in the downlink and uplink.

11.3 OFDMA Parameters

The OFDMA parameters for the IEEE 802.16m are specified as follows:

Nominal Channel Bandwidth (MHz)		5	7	8.75	10	20
Over-sampling Factor		28/25	8/7	8/7	28/25	28/25
Sampling Frequency (MHz)		5.6	8	10	11.2	22.4
FFT Size		512	1024	1024	1024	2048
Sub-Carrier Spacing (kHz)		10.937500	7.812500	9.765625	10.937500	10.937500
Useful Symbol Time T_u (µs)		91.429	128	102.4	91.429	91.429
Cyclic Prefix (CP) $T_g=1/8\ T_u$	Symbol Time T_s (µs)	102.857	144	115.2	102.857	102.857
	Number of OFDM symbols per Frame	48	34	43	48	48
	Idle time (µs)	62.86	104	46.40	62.86	62.86
Cyclic Prefix (CP) $T_g=1/16\ T_u$	Symbol Time T_s (µs)	97.143			97.143	97.143
	Number of OFDM symbols per Frame	51			51	51
	Idle time (µs)	45.71			45.71	45.71

Table 2 OFDMA parameters for IEEE 802.16m

A CP size longer than 1/8 is used in channels with long delay spread.

11.4 Frame structure

11.4.1 Basic Frame structure

The IEEE 802.16m basic frame structure is illustrated in Figure 24. Each 20 ms superframe is divided into four equally-sized 5 ms radio frames each of those frames beginning with the superframe header (SFH). When using the same OFDMA parameters as in Table 2 with the channel bandwidth of 5 MHz, 10 MHz, or 20 MHz, each 5 ms radio frame further consists of eight subframes. A subframe shall be assigned for either DL or UL transmission. There are two types of subframes depending on the size of cyclic prefix: 1) the type-1 subframe which consists of six OFDMA symbols and 2) the type-2 subframe that consists of seven OFDMA symbols. In

1   both subframe types, some of symbols may be idle symbols.

2   The basic frame structure is applied to FDD and TDD duplexing schemes, including H-FDD MS operation. The
3   number of switching points in each radio frame in TDD systems is either two or four, where a switching point is
4   defined as a change of directionality, i.e., from DL to UL or from UL to DL.

5   When H-FDD mobile stations are included in an FDD system, the frame structure from the point of view of the
6   H-FDD mobile station is similar to the TDD frame structure; however, the DL and UL transmissions occur in
7   two separate frequency bands. The transmission gaps between DL and UL (and vice versa) are required to allow
8   switching the TX and RX circuitry.

9

10
11
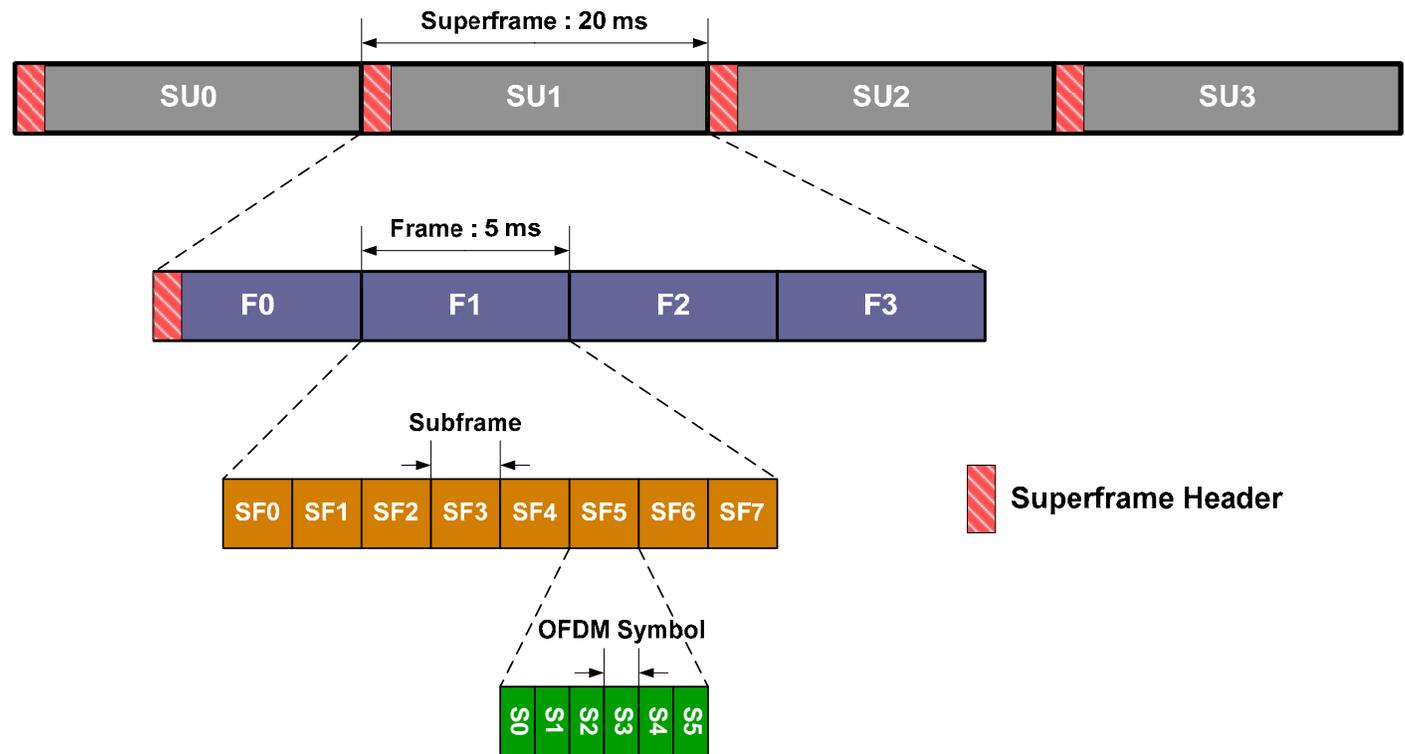
13   Figure 24 Basic frame structure

14

15   11.4.1.1   Frame Structure for CP=1/8 T_u

16
17   Figure 25 illustrates an example TDD frame structure with DL to UL ratio of 5:3. Assuming OFDMA symbol
18   duration of 102.857μs and a CP length of 1/8 T_u, the length of type-1 subframe is 0.617 ms. In Figure 25, the
19   last DL subframe, i.e., DL SF4, is a type-1 short subframe whose last OFDMA symbol is an idle symbol to
20   accommodate the gap required to switch from DL to UL. Other numerologies may result in different number of
21   subframes per frame and symbols within the subframes. Figure 26 shows an example of a frame structure in
22   FDD mode.

23
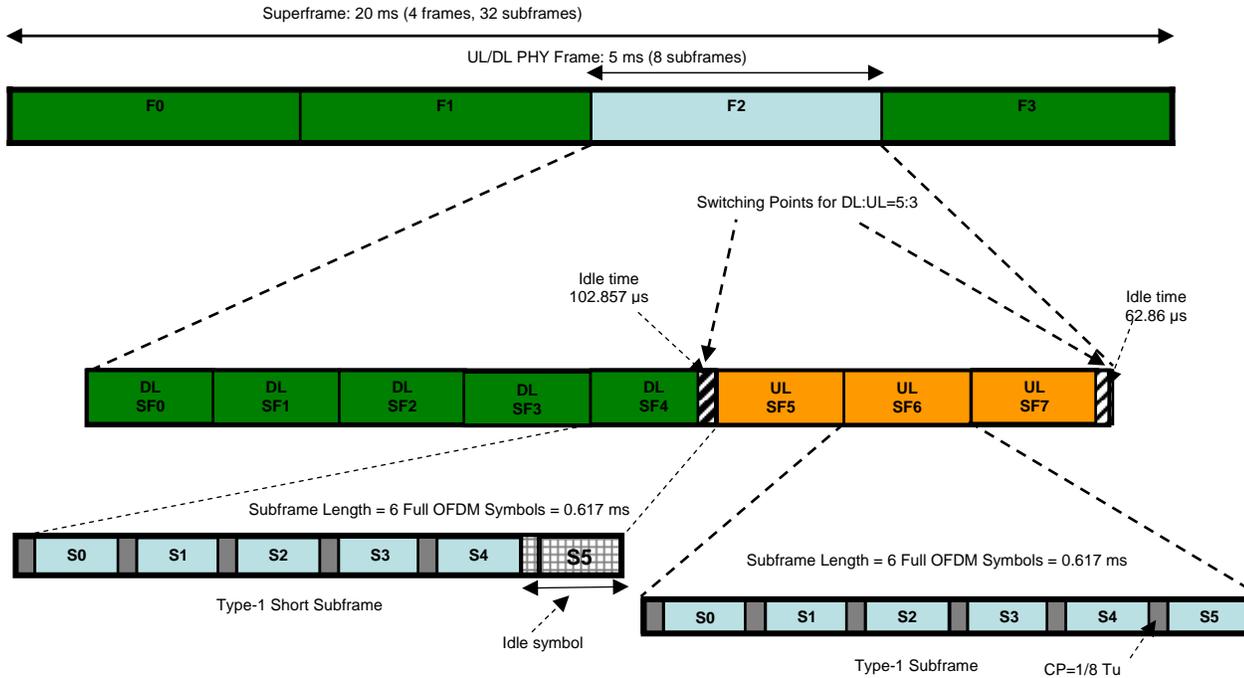
Figure 25 Frame structure with type-1 subframe in TDD duplex mode (CP=1/8 T_u)
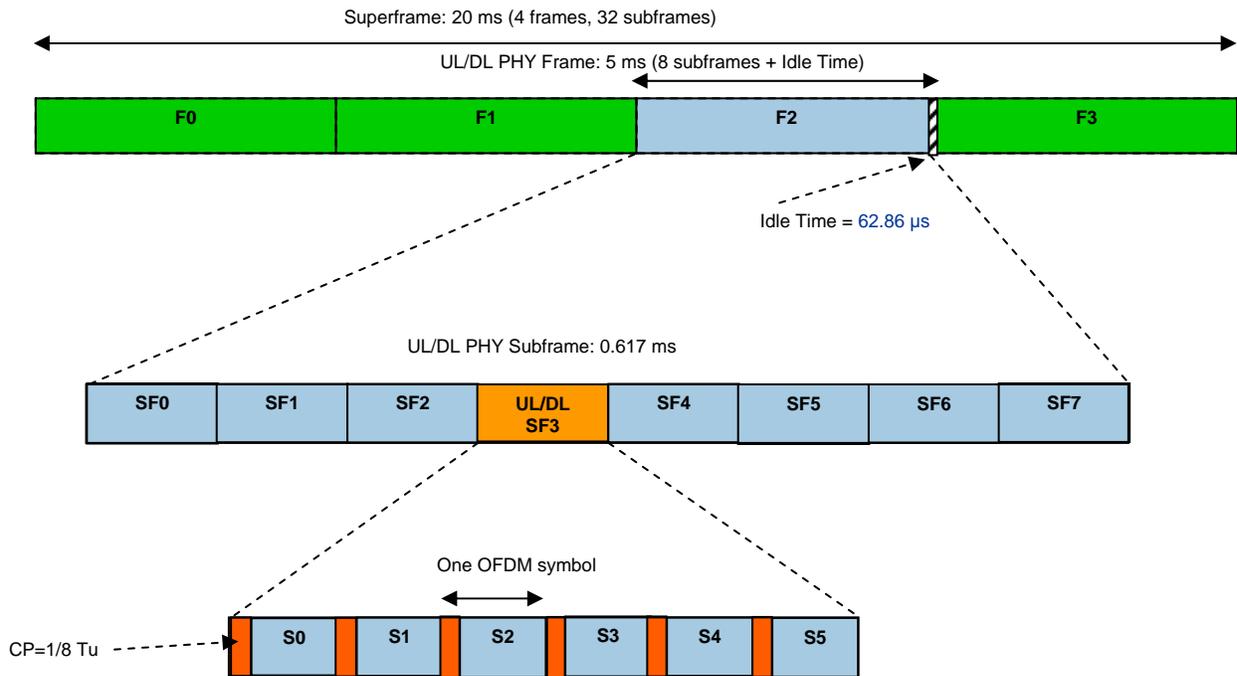
Figure 26 Frame structure with type-1 subframe in FDD duplex mode (CP=1/8 T_u)

1   11.4.1.2   Frame Structure for CP=1/16 T_u
2
3   For nominal channel bandwidths of 5, 10, and 20 MHz, an IEEE 802.16m frame for a CP of 1/16 T_u
4   shall have five type-1 subframes and three type-2 subframes.
5
6   Figure 27 illustrates an example of TDD and FDD frame structure with a CP of 1/16 T_u. Assuming
7   OFDM symbol duration of 97.143 µs and a CP length of 1/16 T_u, the length of type-1 and type-2
8   subframes are 0.583 ms and 0.680 ms, respectively. Other numerologies may result in different
9   number of subframes per frame and symbols within the subframes.
10
11

12
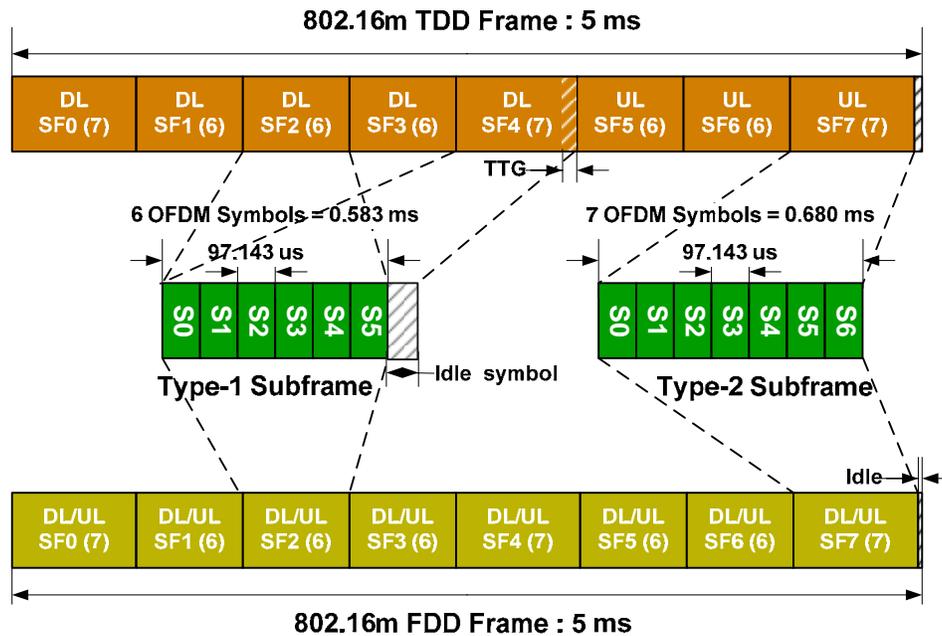
13   Figure 27 TDD and FDD Frame Structure with a CP of 1/16 T_u (DL to UL ratio of 5:3)
14

15   11.4.1.3   Superframe Header
16
17   As shown in Figure 24, each superframe begins with a DL subframe that contains a superframe header.

18   11.4.1.4   Transmission Time Interval
19
20   The transmission time interval (TTI) is the duration of the transmission of the physical layer encoded packet
21   over the radio air interface and is equal to an integer number of subframes. The default TTI is 1 subframe.

22   11.4.2 Frame Structure Supporting Legacy Frames
23
24   The legacy and IEEE 802.16m frames are offset by a fixed number of subframes to accommodate new features

1   such as the IEEE 802.16m synchronization channel (preamble), broadcast channel (system configuration
2   information), and control channels, as shown in Figure 28. The FRAME_OFFSET shown in Figure 28 is for
3   illustration. It is an offset between the start of the legacy frame and the start of the IEEE 802.16m frame
4   carrying the superframe header, defined in a unit of subframes. In the case where ABSs coexist with YBSs, two
5   switching points shall be selected in each TDD radio frame.

6

7   For UL transmissions both TDM and FDM approaches are supported for multiplexing of YMS ans AMS.

8
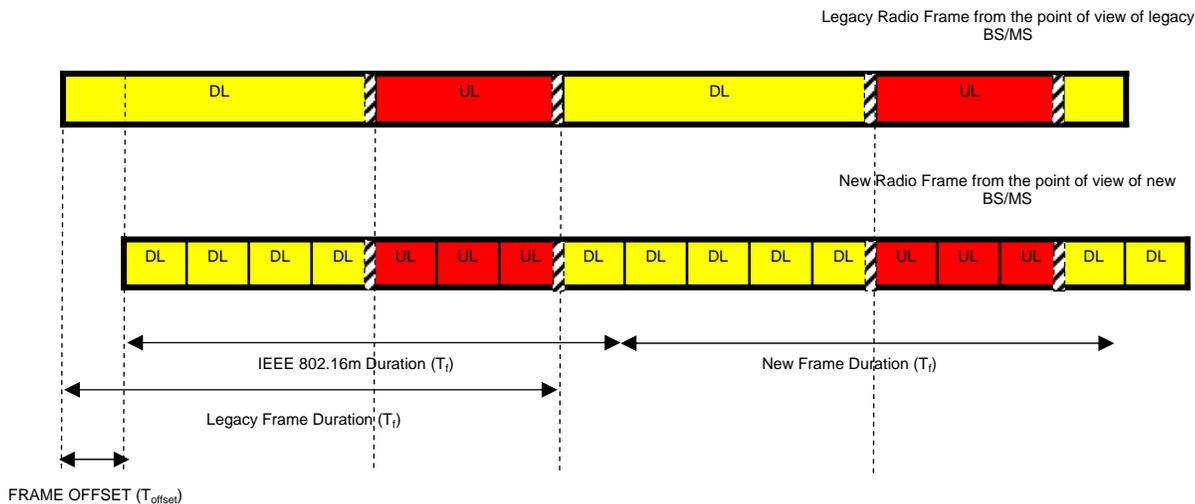
9
10   Figure 28 Relative position of the IEEE 802.16m and IEEE 802.16e radio frames (example TDD duplex mode)
11

11.4.2.1   The Concept of Time Zones

13

14   The time zone is defined as an integer number (greater than 0) of consecutive subframes. The concept of time
15   zones is introduced that is equally applied to TDD and FDD systems. The MZones and LZones are time-
16   multiplexed (TDM) across time domain for the downlink. For UL transmissions both TDM and FDM
17   approaches are supported for multiplexing of YMSs and AMSs. Note that DL/UL traffic for the AMS can be
18   scheduled in both zones whereas the DL/UL traffic for the YMS can only be scheduled in the LZones.

19   In the absence of any IEEE 802.16e system, the LZones will disappear and the entire frame will be allocated to
20   the MZones and thereby new systems.

11.4.2.1.1   Time Zones in TDD

22   In a mixed deployment of YMSs and new AMSs, the allocation of time zones in the TDD mode is as shown in
23   Figure 29 and Figure 30, which are examples for the two and four switching point case respectively. The
24   duration of the zones may vary. Every frame shall start with a preamble and the MAP followed by IEEE
25   802.16e DL zone since YMSs/relays expect LZones in this region. Similarly, in a mixed deployment of YMSs
26   and new AMSs, the UL portion shall start with IEEE 802.16e UL zone since YBS /YMS/RS expect IEEE
27   802.16e UL control information be sent in this region. Here the coexistence is defined as a deployment where
28   YBSs and ABSs co-exist on the same frequency band and in the same or neighboring geographical areas and in
29   this case, four switching points should not be used. In a green-field deployment where no YMS exists, the
30   LZones can be removed.

31   Switching points should be synchronized across network to reduce inter-cell interference.

1 The switching points would require use of idle symbols to accommodate the gaps. In case of TDD operation
2 with the generic frame structure, the last symbol in the slot immediately preceding a downlink-to-uplink/uplink-
3 to-downlink switching point may be reserved for guard time and consequently not transmitted.
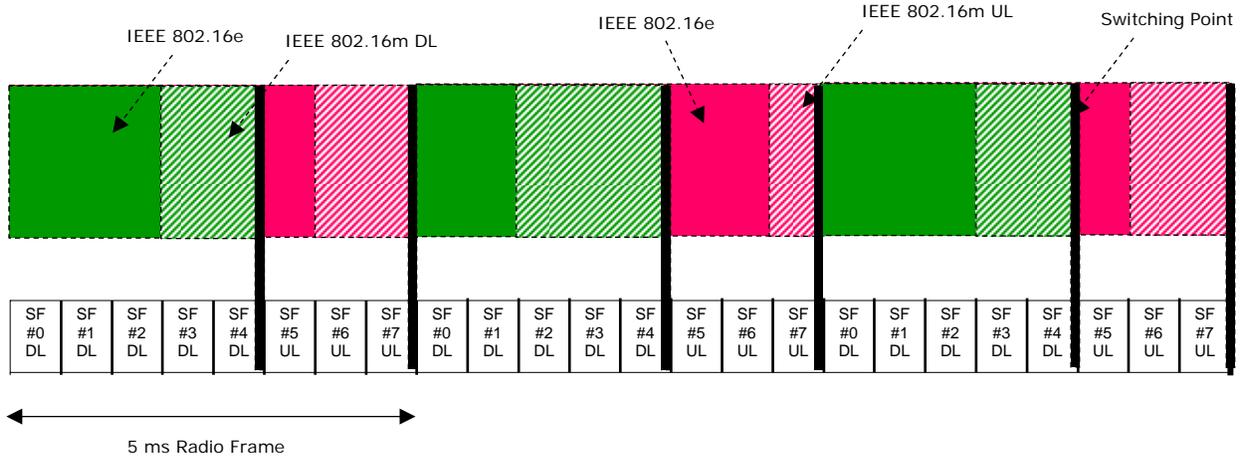
4
5   Figure 29 Example of Time zones in TDD mode
6
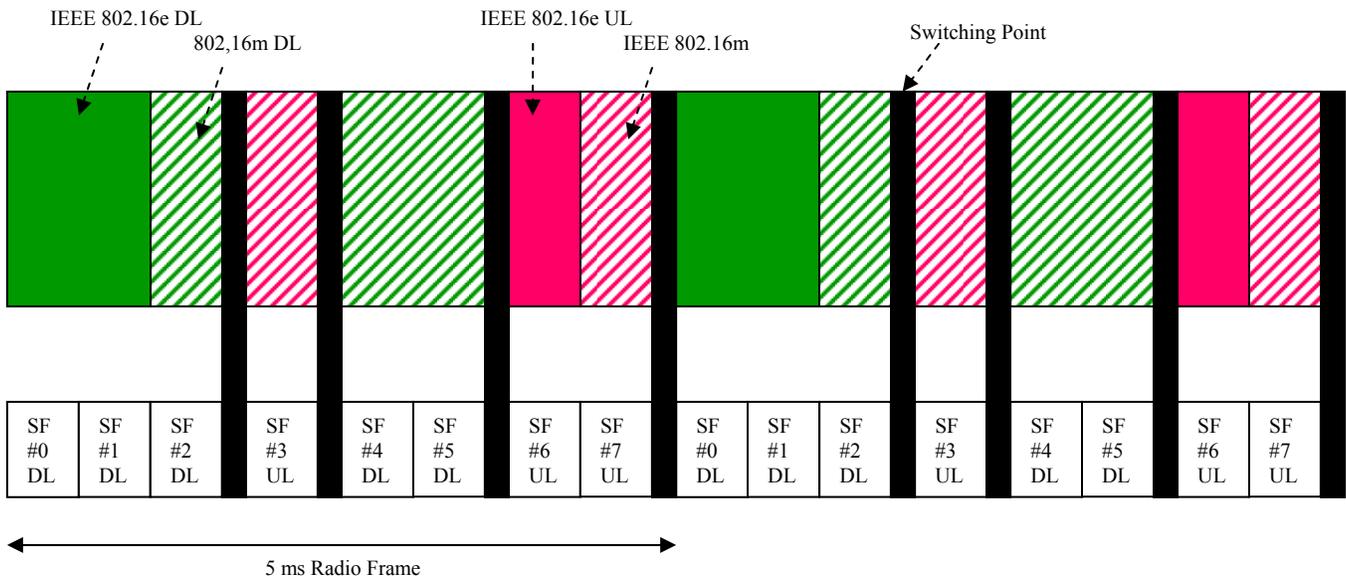
7

8   Figure 30 Example of Time zones in a TDD system with four switching points per radio frame.

9 *11.4.2.1.2   Time Zones in FDD*

10 In a mixed deployment of legacy terminals and new AMSs, an example of the allocation of time zones in the
11 FDD mode is shown in Figure 31.
12
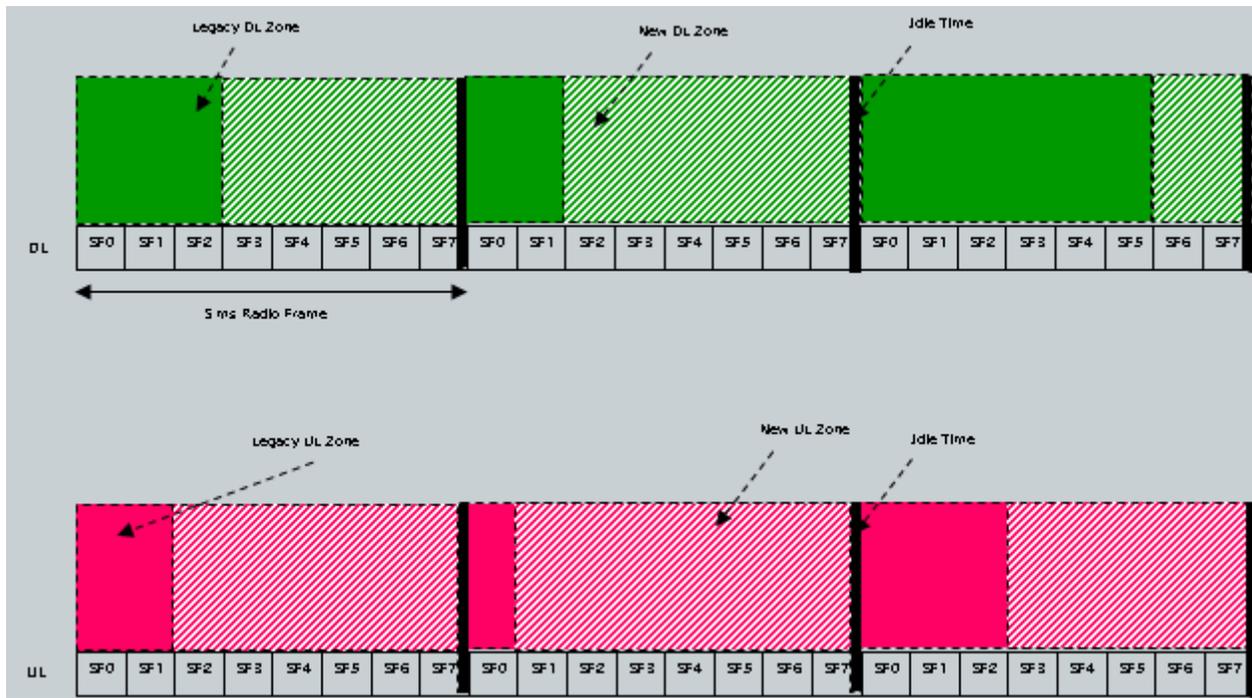
Figure 31 Example of Time zones in FDD mode

11.4.3 Frame Structure Supporting Legacy Frames in IEEE 802.16m Systems with Wider Channel Bandwidths

Figure 32 shows an example for the IEEE 802.16m frame structure supporting legacy frame in a wider channel. A number of narrow bandwidth carriers of the IEEE 802.16m can be aggregated to support wide bandwidth operation of AMSs. One or multiple of the carriers can be designated as the legacy carrier(s). When the center carrier spacing between two adjacent carriers is an integer multiple of subcarrier spacing, it is no necessary to reserve guard subcarriers for the IEEE 802.16m carriers. Different number of usable guard sub-carriers can be allocated on both sides of the carrier.

For UL transmissions both TDM and FDM approaches should be supported for multiplexing of legacy and AMSs in the legacy and IEEE 802.16m mixed carrier. The TDM in the figure is only for example.

In the case when the edge carrier is a legacy carrier, the impact of the small guard bandwidth on the edge of the wider channel on the filter requirements is FFS.
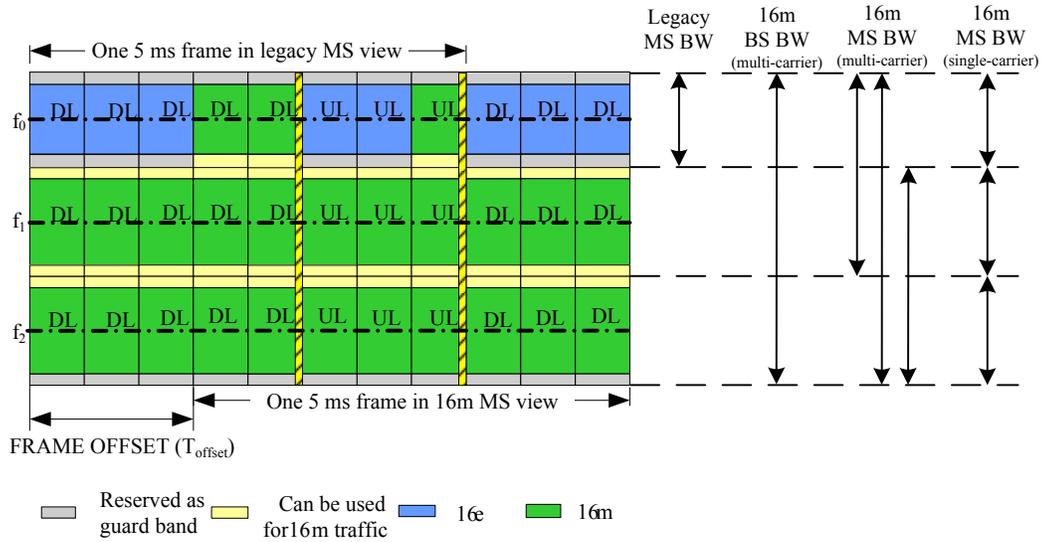
Figure 24 Illustration of frame structure supporting legacy frames with a wider channel

1

2   Figure 32 Illustration of frame structure supporting legacy frames with a wider channel

3

4   11.4.4 Relay Support in Frame Structure

5   A ABS that supports ARSs shall communicate with the ARS in the MZone. The ABS shall multiplex the LZone
6   and the MZone using TDM in the DL. In the UL, the ABS can support TDM as well as FDM for multiplexing
7   LZone and the MZone. The IEEE 802.16m specification shall not alter the LZone operation. The access link
8   and the relay link communications in the LZone shall be multiplexed in accordance with the IEEE 802.16j
9   specifications.

10   An RS radio frame may also define points where the RS switches from receive mode to transmit mode or from
11   transmit mode to receive mode, where the receive and transmit operations are both performed on either DL or
12   UL data. A ARS shall communicate with the YMS in the LZone.

13

14   The start of the LZone and MZone of the ABS and all the subordinate RSs/ARSs associated with the ABS shall
15   be time aligned. The duration of the LZone of the ABS and the RS may be different.

16   • 16e Access Zone

17   o where ABS, a RS or a ARS communicates with a 16e MS.

18   • 16j Relay Zone

19   o where ABS communicates with a RS.

20   There are two options for the Relay frame structure. These are captured in Figure 33 and Figure 34. Further
21   study is required to distill a single frame structure from among these two options.

Option 1:
Distinct DL/UL subframes (Uni-directional Zones)
Can Tx/Rx to/from MS in Relay Zone

Figure 33 *Relay Frame structure option 1*

Definitions corresponding to Option 1 shown in Figure 33

- 16m DL Access Zone: An integer multiple of subframes located in the MZone of the ABS frame, where a ABS can transmit to the AMSs.

- 16m UL Access Zone: An integer multiple of subframes located in the MZone of the ABS frame, where a ABS can receive from the AMSs.

- DL Relay Zone: An integer multiple of subframes located in the MZone of the DL of the ABS frame, where a ABS can transmit to the ARSs and the AMSs.

68

- UL Relay Zone: An integer multiple of subframes located in the MZone of the UL of the ABS frame, where a ABS can receive from the ARSs and the AMSs.

- DL Transmit Zone: An integer multiple of subframes located in the MZone of the DL of the ARS frame, where a ARS can transmit to subordinate ARSs and the AMSs.

- DL Receive Zone: An integer multiple of subframes located in the MZone of the DL of the ARS frame, where a ARS can receive from its superordinate station.

- UL Transmit Zone: An integer multiple of subframes located in the MZone of the UL of the ARS frame, where a ARS can transmit to its superordinate station.

- UL Receive Zone: An integer multiple of subframes located in the MZone of the UL of the ARS frame, where a ARS can receive from its subordinate ARSs and the AMSs.

Option 2:
Bi-Directional Zones
Distinct DL/UL Access Zone
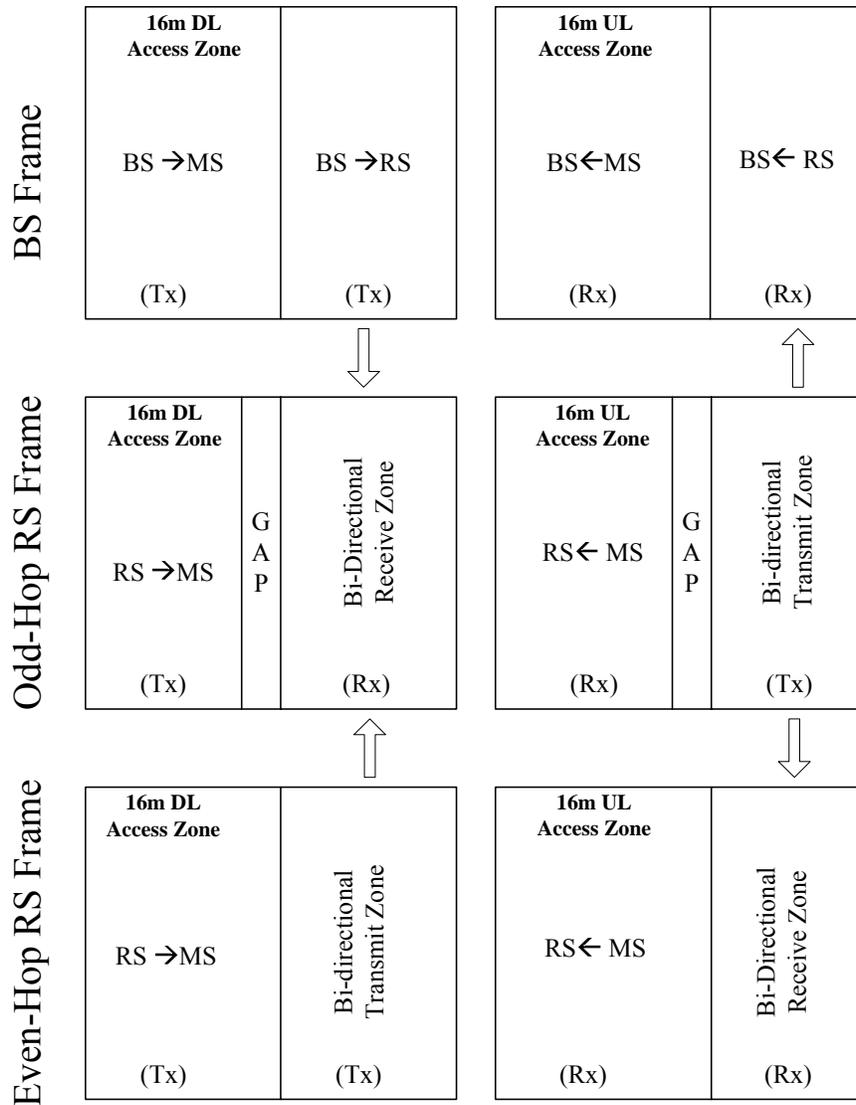
Figure 34 *Relay Frame structure option 2*

Notes related to Figure 34: An explicit access zone may or may not be present.

Definitions corresponding to Option 2 shown in Figure 34

- Bi-directional Transmit Zone: An integer multiple of subframes located in the MZone of the ARS frame where transmission to superordinate as well as subordinate station takes place.

- Bi-directional Receive Zone: An integer multiple of subframes located in the MZone of the ARS frame where reception from superordinate as well as subordinate station takes place.

- IEEE 802.16m DL Access Zone: An integer multiple of subframes in the MZone where ABS or a ARS transmits to the AMSs.

1 • IEEE 802.16m UL Access Zone: An integer multiple of subframes in the MZone where ABS or an ARS
2   receives from the AMSs.
3

4 11.4.5 Coexistence Support in Frame Structure
5
6 IEEE 802.16m downlink radio frame shall be time aligned with reference timing signal as defined in section
7 22.1 and should support symbol puncturing to minimize the inter-system interference.
8

8 11.4.5.1   Adjacent Channel Coexistence with E-UTRA (LTE-TDD)
9
10 Coexistence between IEEE 802.16m and E-UTRA in TDD mode may be facilitated by inserting either idle
11 symbols within the IEEE 802.16m frame or idle subframes, for certain E-UTRA TDD configurations. An
12 operator configurable delay or offset between the beginning of an IEEE 802.16m frame and an E-UTRA TDD
13 frame can be applied in some configurations to minimize allows the time allocated to idle symbols or idle
14 subframes to be minimized.IEEE 802.16mIEEE 802.16m Figure 35 shows two examples using frame offset to
15 support coexistence with E-UTRA TDD in order to support minimization of the number of punctured symbols
16 within the IEEE 802.16m frame.
17

19 Figure 35 Alignment of IEEE 802.16m frame and E-UTRA frame in TDD mode
20

1   11.4.5.2   Adjacent Channel Coexistence with UTRA LCR-TDD (TD-SCDMA)

2

3   Coexistence between IEEE 802.16m and UTRA LCR-TDD may be facilitated by inserting either idle symbols
4   within the IEEE 802.16m frame or idle subframes. An operator configurable delay or offset between the
5   beginning of an IEEE 802.16m frame and an UTRA LCR-TDD frame can be applied in some configurations to
6   minimize allows the time allocated to idle symbols or idle subframes to be minimized. Figure 36 demonstrates
7   how coexistence between IEEE 802.16m and UTRA LCR-TDD can be achieved to minimize the inter-system
8   interference.

9

10

11   Figure 36 Alignment of IEEE 802.16m frame with UTRA LCR-TDD frame in TDD mode

12 11.4.6 Frame Structure to support multi-carrier operation

13

14 The support for multiple RF carriers can be accommodated with the same frame structure used for single carrier
15 support, however, some considerations in the design of protocol and channel structure may be needed to
16 efficiently support this feature.

17 In general, each MS operating under IEEE 802.16m standard is controlled by one RF carrier, herein referred to
18 as the primary RF carrier. When multi-carrier operation feature is supported, the system may define and utilize
19 additional RF carriers to improve the user experience and QoS, or provide services through additional RF
20 carriers configured or optimized for specific services.

21 Figure 37 shows that the same frame structure would be applicable to both single carrier and multicarrier mode
22 of operation. A number of narrow BW carriers can be aggregated to support effectively wider BW operation.
23 Each carrier may have its own synchronization channel and superframe header. Further, some carriers may have
24 only part of superframe header. A multi-carrier AMS is an MS which can utilize radio resources across multiple
25 RF carriers under the management of a common MAC. Depending on MS's capabilities, such utilization may
26 include aggregation or switching of traffic across multiple RF carriers controlled by a single MAC instantiation.

27 The multiple carriers involved in multi-carrier operation may be in a contiguous or non-contiguous spectrum.
28 When carriers are in the same spectrum and adjacent and when the separation of center frequency between two
29 adjacent carriers is multiples of subcarrier spacing, no guard subcarriers are necessary between adjacent
30 carriers.

1
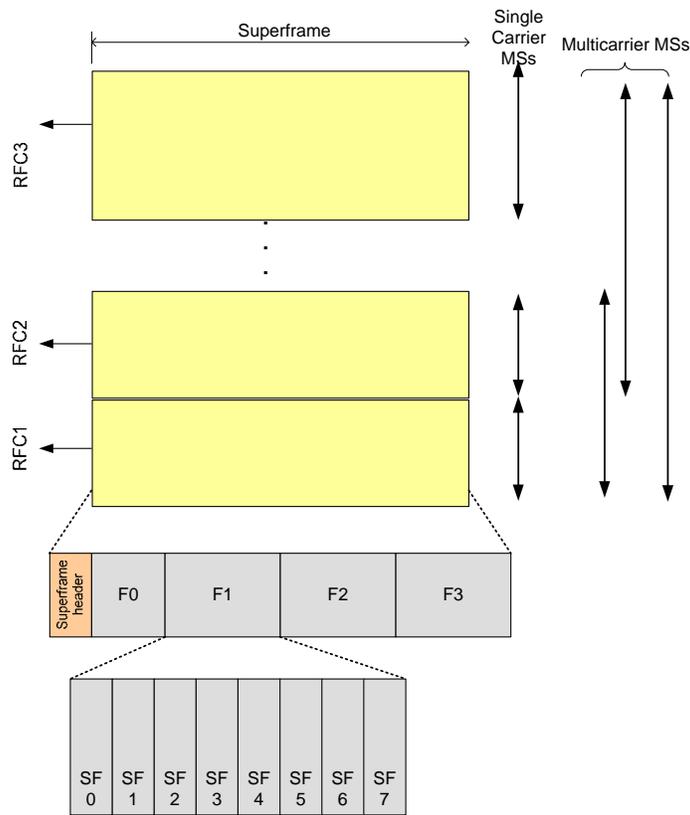
2
3
4   Figure 37 Example of the proposed frame structure to support multi-carrier operation
5
6

11.5 Downlink Physical Structure

8   Each downlink subframe is divided into a number of frequency partitions, where each partition consists of a set
9   of physical resource units across the total number of OFDMA symbols available in the subframe. Each
10 frequency partition can include contiguous (localized) and/or non-contiguous (distributed) physical resource
11 units. Each frequency partition can be used for different purposes such as fractional frequency reuse (FFR) or
12 multicast and broadcast services (MBS). Figure 38 illustrates the downlink physical structure in the example of
13 two frequency partitions with frequency partition 2 including both localized and distributed resource
14 allocations.

15

1
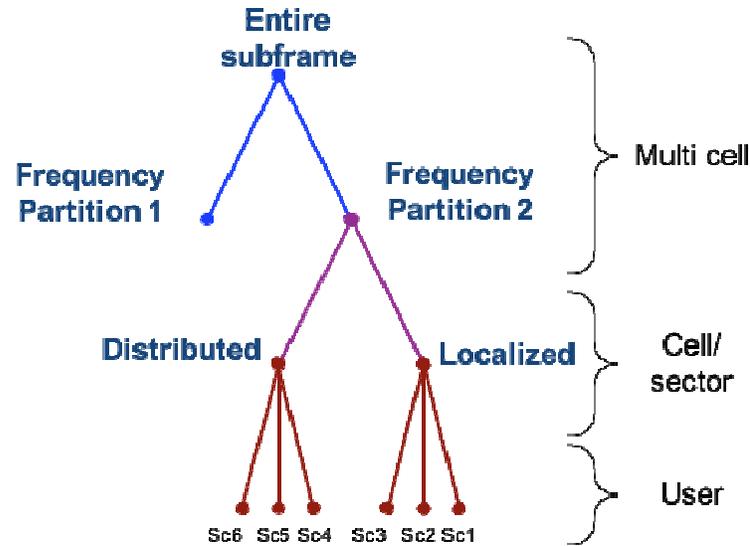
2   Figure 38 Hierarchical representation of the downlink physical structure

3

4   *11.5.1 Physical and Logical Resource Unit*

5

6   A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive
7   subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} is 6 OFDMA symbols for
8   type-1 subframes, and N_{sym} is 7 OFDM symbols for type-2 sub frames. A logical resource unit (LRU) is the
9   basic logical unit for distributed and localized groups. A LRU is 18*6 subcarriers for type-1 subframes and
10   18*7 subcarriers for type-2 subframes. Note that the LRU includes in its numerology the number of pilots that
11   are used in a PRU, and may include control information.

12   11.5.1.1   Distributed resource unit

13

14   The distributed resource unit (DRU) can be used to achieve frequency diversity gain. The DRU contains a
15   group of subcarriers which are spread across the distributed group within a frequency partition by the subcarrier
16   permutation. The size of the DRU equals the size of PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols. The
17   minimum unit for forming the DRU is equal to one subcarrier.

18   11.5.1.2   Localized/Contiguous resource unit

19

20   The localized resource unit, a.k.a. contiguous resource unit (CRU) can be used to achieve frequency-selective
21   scheduling gain. The CRU contains a group of subcarriers which are contiguous across the localized group
22   within a frequency partition. The size of the CRU equals the size of the PRU, i.e., P_{sc} subcarriers by N_{sym}
23   OFDMA symbols.

24   11.5.2 Subchannelization and Resource mapping

25

11.5.2.1   Basic Symbol Structure

The subcarriers of an OFDMA symbol are partitioned into $N_{g,left}$ left guard subcarriers, $N_{g,right}$ right guard subcarriers, and N_{used} used subcarriers. The DC subcarrier is not loaded. The N_{used} subcarriers are divided into PRUs. Each PRU contains pilot and data subcarriers. The number of used pilot and data subcarriers depends on MIMO mode, rank and number of multiplexed AMS as well as the type of the subframe, i.e., type-1 or type-2.

11.5.2.2   Downlink subcarrier to resource unit mapping

The DL subcarrier to resource unit mapping process is defined as follows and illustrated in the Figure 39:

1. Outer permutation is applied to the PRUs in the units of N1 and N2 PRUs, where N1=4 (TBD) and N2 =1 or 2 depending on system bandwidth (TBD). Direct mapping of outer permutation can be supported only for CRU.

2. Distributing the reordered PRUs into frequency partitions.

3. The frequency partition is divided into localized and/or distributed groups. Sector specific permutation can be supported and direct mapping of the resources can be supported for localized resources. The sizes of the distributed/localized groups are flexibly configured per sector (TBD). Adjacent sectors do not need to have same configuration for the localized and distributed groups;

4. The localized and distributed groups are further mapped into LRUs (by direct mapping of CRU and by "Subcarrier permutation" for DRUs) as shown in the following figure.
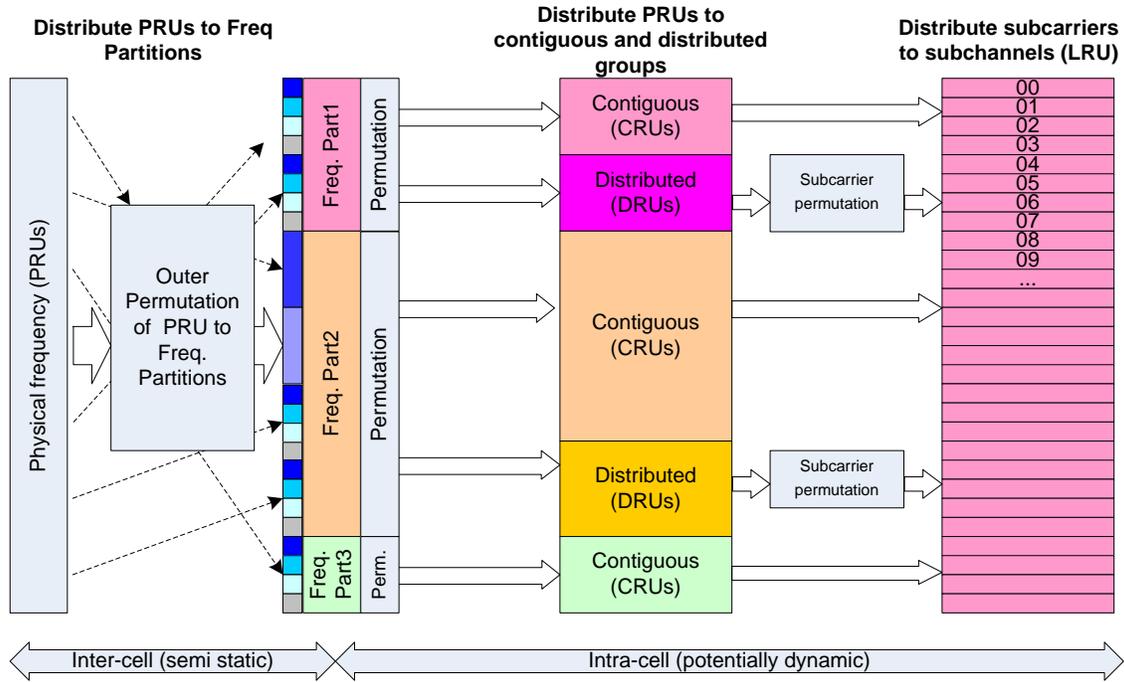
Figure 39 Illustration of the downlink subcarrier to resource unit mapping

11.5.2.3   Subchannelization for DL distributed resource

The Subcarrier permutation defined for the DL distributed group within a frequency partition spreads the subcarrriers of the DRU across the whole distributed group. The granularity of the subcarrier permutation is equal to a tone-pair defined as a pair of adjacent subcarriers in frequency.

Suppose that there are N_{RU} LRUs in a distributed group. A permutation sequence P (TBD) for the distributed group is provided. The subchannelization for DL distributed group spreads the subcarriers of LRUs into the whole available bandwidth of distributed resource, as indicated in the following procedure:

- Let n_k denote the number of pilot tones in the k-th OFDMA symbol within a PRU, and N_{RU} be the number of LRUs within the group.

- For each k-th OFDMA symbol in the subframe

    1. Allocate the n_k pilots in the I-th OFDMA symbol within each PRU;

    2. Renumber the remaining $N_{RU} * (P_{sc} - n_k)$ data subcarriers in order, from 0 to $N_{RU} * (P_{sc} - n_k)$-1 subcarriers. Apply the permutation sequence P (TBD) to form the permuted subcarriers 0 to $N_{RU} * (P_{sc} - n_k)$-1. The contiguous renumbered subcarriers are grouped into pairs/clusters before applying permutation, for example, to support Space Frequency Block Code (SFBC), renumbered subcarriers 0 to $N_{RU} * (P_{sc} - n_k)$-1 are first paired into $(N_{RU} * (P_{sc} - n_k)$-1)/2 clusters.

    3. Map each set of logically contiguous $(P_{sc} - n_k)$ subcarriers into distributed LRUs (i.e. subchannels) and form a total of N_{RU} distributed LRUs.

11.5.2.4   Subchannelization for DL localized resource

There is no Subcarrier permutation defined for the DL localizedgroup. The PRUs are directly mapped to CRUs within each frequency partition.

11.5.3 Pilot Structure

The transmission of pilot subcarriers in the downlink is necessary for enabling channel estimation, measurements of channel quality indicators such as the SINR, frequency offset estimation, etc. To optimize the system performance in different propagation environments and applications, IEEE 802.16m supports both common and dedicated pilot structures. The categorization in common and dedicated pilots is done with respect to their usage. The common pilots can be used by all AMSs. Dedicated pilots can be used with both localized and distributed allocations. Pilot subcarrriers that can be used only by a group of AMSs is a special case of common pilots and are termed shared pilots. The dedicated pilots are associated with a specific resource allocation, can be only used by the AMSs allocated to said specific resource allocation, and therefore can be precoded or beamformed in the same way as the data subcarriers of the resource allocation. The pilot structure is defined for up to four transmission (Tx) streams and there is a unified pilot pattern design for common and dedicated pilots. There is equal pilot density per Tx stream, while there is not necessarily equal pilot density per OFDMA symbol of the downlink subframe. Further, within the same subframe there is equal number of pilots for each PRU of a data burst assigned to one AMS.

Pattern A is used for 1 and 2 DL data streams dedicated and common pilot scenarios.
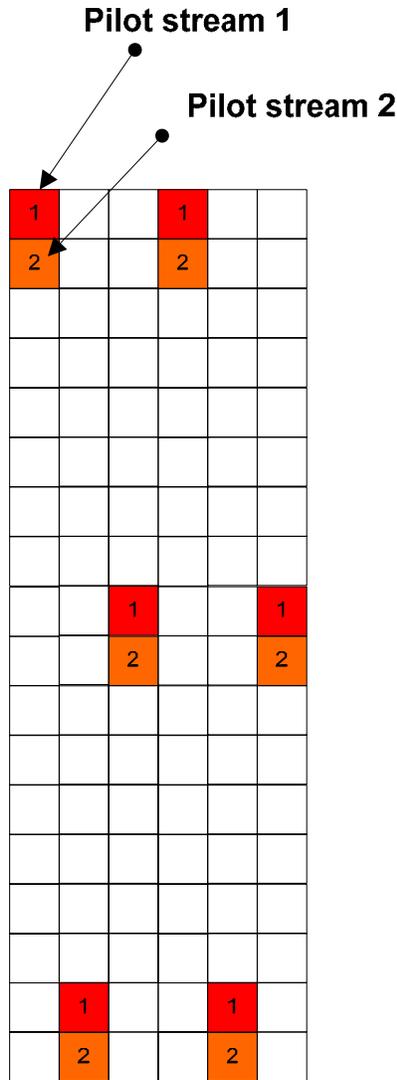
Figure 40 Pattern A for 1 or 2 pilot streams.

For the subframe consisting of 5 symbols, the last OFDM symbols in the figure is deleted. For the subframe consisting of 7 symbols, the first OFDM symbols in the figure is added as 7-th symbol.
The interlaced pilot patterns can be generated by cyclic shifting the base pilot pattern. The interlaced pilot patterns are shown in Figure 41 and can be optionally used by different ABSs. The use of interlaced pilot pattern is FFS. Pattern B is used for 4 data streams DL dedicated and common pilot pattern.

(a)   **(b)**   **(c)**
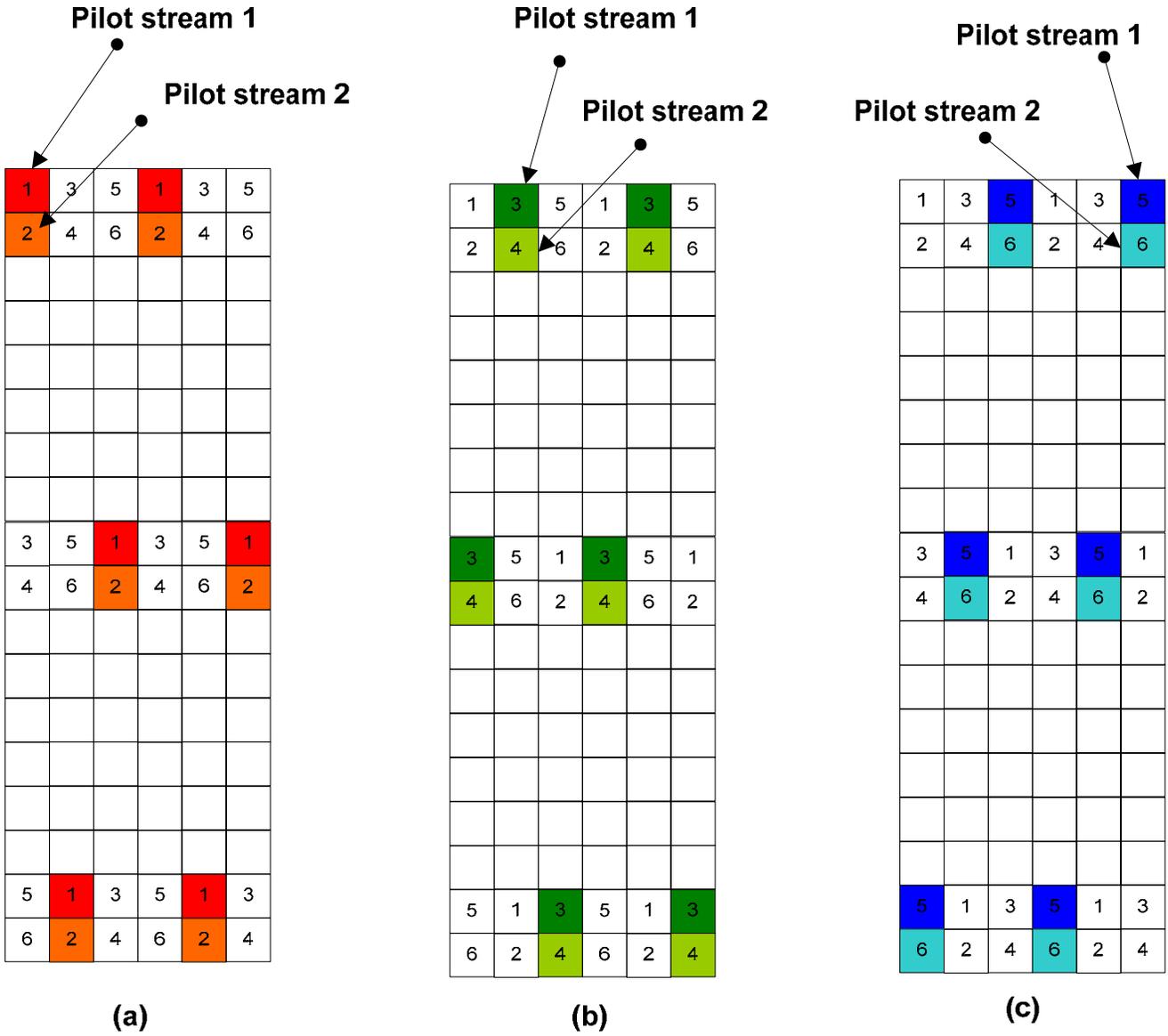
Figure 41 Interlaced Pattern A for 1 or 2 pilot streams.
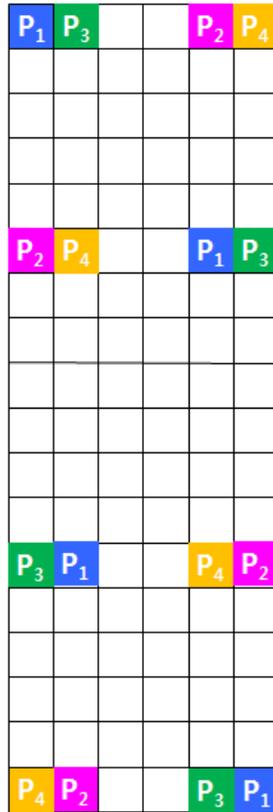
Figure 42 Pilot Pattern B for 4 stream pilots, P_k denotes pilot for stream k.

The pilot pattern of the subframe consisting of 5 OFDM symbols is obtained by deleting the third OFDM symbol of the type-1 subframe. The pilot pattern of the type-2 sybframe is obtained by adding the third OFDM symbol of the type-1 subframe to the end of the type-1 subframe.

11.5.3.1   E-MBS zone specific pilot for MBSFN

E-MBS zone specific pilot shall only be transmitted for MBSFN transmissions. An E-MBS zone is a group of ABSs involved in an SFN transmission. The E-MBS zone specific pilot, that's, common inside one E-MBS zone but different between neighboring E-MBS zones, is configured. Synchronous transmissions of the same contents with common pilot from multiple ABS in one MBS zone would result in correct MBSFN channel estimation.
The E-MBS zone specific pilot streams depends on the maximum number of streams within the E-MBS zone. Pilot structures/patterns should be supported up to two streams.
The definitions of the E-MBS zone specific pilots are FFS.

11.6 Uplink Physical Structure

Each UL subframe is divided into a number of frequency partitions, where each partition consists of a set of physical resource units across the total number of OFDMA symbols available in the subframe. Each frequency partition can include contiguous (localized) and/or non-contiguous (distributed) physical resource units. Each

1 frequency partition can be used for different purposes such as fractional frequency reuse (FFR). Figure 43
2 illustrates the uplink physical structure in the example of two FFR groups with FFR group 2 including both
3 localized and distributed resource allocations.
4
5
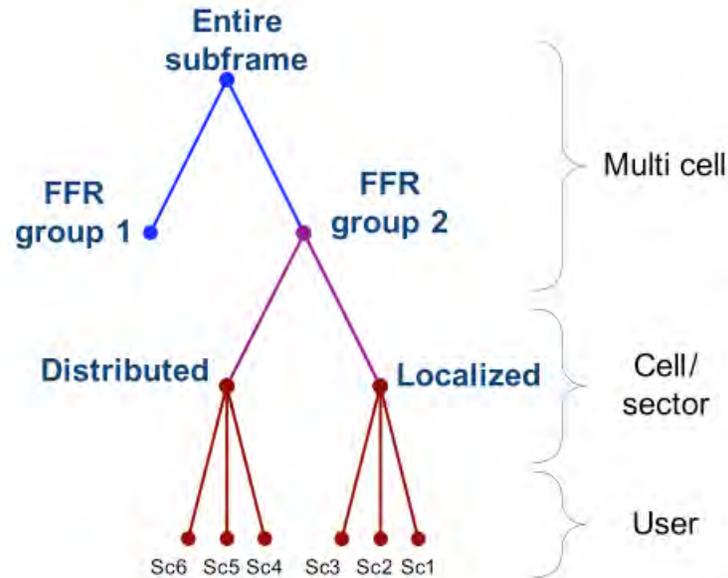
Figure 43 Example of uplink physical structure

8

9 11.6.1 Physical and Logical Resource Unit

10 A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive
11 subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} is the number of OFDMA
12 symbols depending on the subframe type. A logical resource unit (LRU) is the basic logical unit for distributed
13 and localized groups and its size is $P_{sc}*N_{sym}$ subcarriers for data transmission. Fortransmission, of control
14 information, the LRU size is the same as that used for data transmission and multiple users are allowed to share
15 one control LRU. The effective number of data subcarriers in an LRU depends on the number of allocated
16 pilots and control channel presence.
17

18 11.6.1.1   Distributed Resource unit

19 The distributed resource unit (DRU) can be used to achieve frequency diversity gain. The DRU contains a
20 group of subcarriers which are spread by the inner permutation across several PRUs that are part of a distributed
21 group. The size of the DRU equals the size of the LRU for distributed allocations. The minimum unit for
22 forming the DRU is a tile. The UL tile size is $6xN_{sym}$, where N_{sym} depends on the subframe type in section
23 11.4.1. 18x2 tile size for UL transmit power optimized distributed group and other tile sizes are FFS. Details of
24 the UL transmit power optimized distributed allocation are FFS.
25

26 11.6.1.2   Localized Resource unit

27 The Contiguous resource unit (CRU) can be used to achieve frequency-selective scheduling gain. The CRU
28 contains a group of subcarriers which are contiguous across the localizedgroup. The size of the CRU equals the

1   size of the LRU for localized allocations, i.e., Psc subcarriers by Nsym OFDMA symbols.
2

3   11.6.2 Subchannelization and Resource mapping

4   11.6.2.1   Basic Symbol Structure

5   The subcarriers of an OFDMA symbol are partitioned into $N_{g,left}$ left guard subcarriers, $N_{g,right}$ right guard
6   subcarriers, and N_{used} used subcarriers. The DC subcarrier is not loaded. The N_{used} subcarriers are divided into
7   PRUs. Each PRU contains pilot and data subcarriers. The number of used pilot and data subcarriers depends on
8   MIMO mode, rank and number of multiplexed AMS and the type of resource allocation, i.e., distributed or
9   localized resource allocations as well as the type of the subframe, i.e., type-1 or type-2.
10

11 11.6.2.2   Uplink Subcarrier to Resource Unit Mapping

12 The main features of resource mapping include:
13   1. Support of localized resource unit (CRU) and distributed resource unit (DRU) in an FDM
14   manner.
15   2. DRUs comprise multiple tiles which are spread across the distributed resource allocations to get
16   diversity gain.
17   3. FFR can be applied in UL.
18

19 Based on the main design concepts above, the UL subcarriers to resource unit mapping process is defined as
20 follows and illustrated in Figure 44:
21   1. First-level or outer permutation is applied to the PRUs in the units of N1 and N2 PRUs, where
22   N1=4 (TBD) and N2=1 (TBD). Direct mapping of outer permutation can be supported.
23   2. Distributing the reordered PRUs into frequency partitions.
24   3. The frequency partition is divided into localized (CRU) and/or distributed (DRU) resource
25   allocations. Using sector specific permutation can be supported; directly mapping of the
26   resources can be supported for localized resource. The sizes of the distributed/localized
27   resources are flexibly configured per sector. Adjacent sectors do not need to have same
28   configuration of localized and diversity resources.
29   4. The localized and distributed group resources are further mapped into LRUs. For the CRU
30   resources, the mapping is direct. For the DRU resources, a tile or hopping permutation is carried
31   out for permuting or hopping the tiles of the distributed groups.
32

1

1
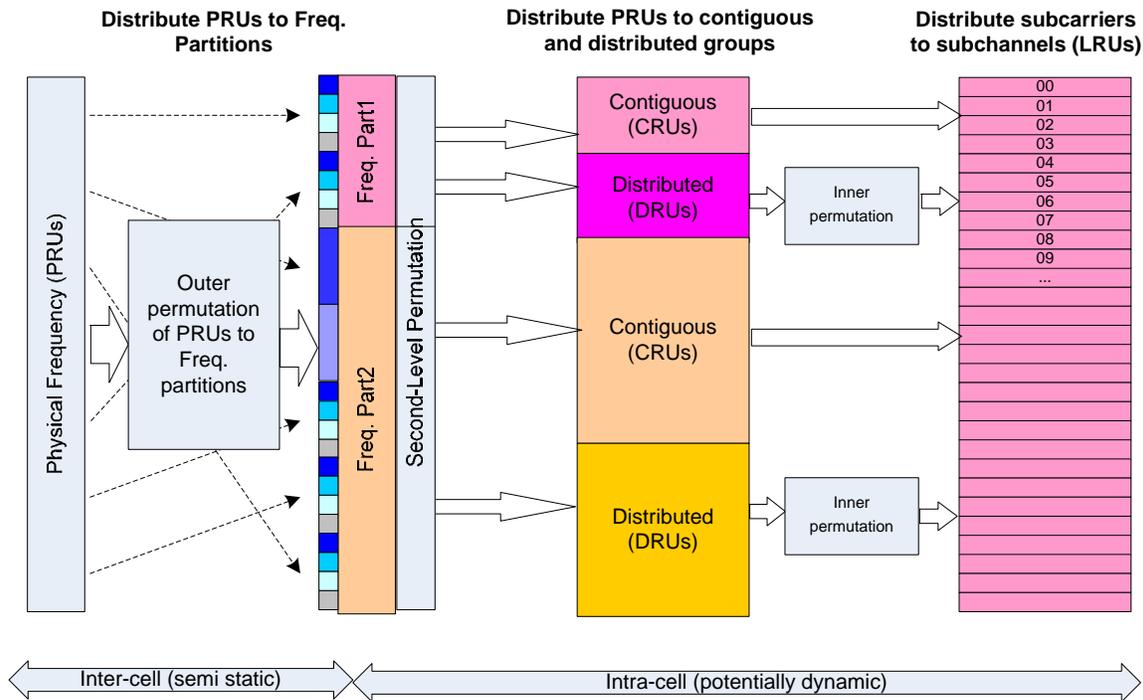
Figure 44 Illustration of the uplink subcarrier to resource unit mapping

11.6.2.3   Subchannelization for UL Distributed Resource

An inner permutation permutes PRUs within a frequency partition. The localized resource could be directly mapped. The tile permutation defined for the uplink distributed resource allocations spreads the tiles of the DRU across the whole allocated distributed resource allocations frequency band.

Two kinds of distributed resource allocation are used for UL distributed subchannelization, (1) regular distributed allocation (2) UL transmit power optimized distributed allocation. The UL transmit power optimized distributed resource is allocated first. The rest of the frequency resource is then allocated for regular distributed allocation. A hopping/permutation sequence (TBD) is defined for the power optimized allocation that spreads the hopping units across frequency. The second-level or inner permutation defined for the UL regular distributed resource allocations spreads the tiles of the DRU across the frequency band. The granularity of the inner permutation is equal to the tile size for forming a DRU according to section 11.6.1.1.

11.6.2.4   Subchannelization for UL Localized Resource

 Localized subchannels contain subcarriers which are contiguous in frequency. There is no inner permutation defined for the UL localized resource allocations. The CRU is directly mapped to localized LRU within each frequency partition. Precoding and/or boosting applied to the data subcarriers will also be applied to the pilot subcarriers.

1   ## 11.6.3 Pilot Structure

2   The transmission of pilot subcarriers in the uplink is necessary for enabling channel estimation, measurement of
3   channel quality indicators such as SINR, frequency offset and timing offset estimation, etc. The uplink pilots
4   are dedicated to localized and distributed resource units and are precoded using the same precoding as the data
5   subcarriers of the resource allocation. The pilot structure is defined for up to 4 Tx streams with orthogonal
6   patterns.
7
8   The pilot pattern may support variable pilot boosting. When pilots are boosted, each data subcarrier should have
9   the same Tx power across all OFDM symbols in a resource block. The boosting values are TBD.
10
11   The DL 18x6 pilot patterns defined in Section 11.5.3 are used for UL 18x6 pilots, which include pilots up to 4
12   TX streams.
13
14   For 6-by-6 UL tile, the UL pilot pattern for DRU is shown in Figure 45
15
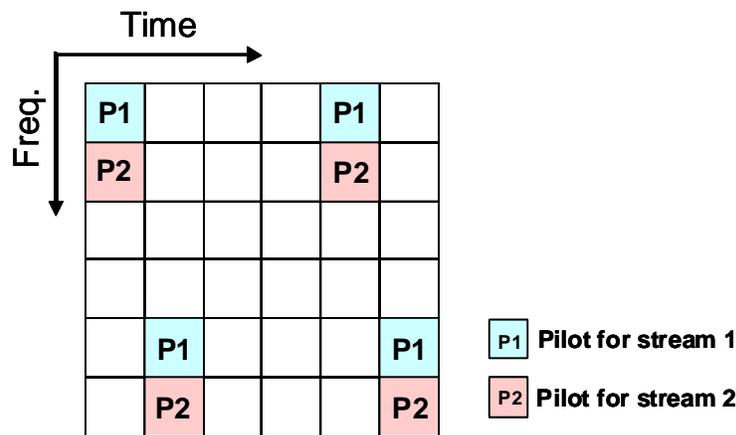
17   Figure 45 UL DRU tile structure.

18   ## 11.6.4 Uplink Physical Structure for Legacy Support
19
20   The IEEE 802.16m uplink physical structure supports both FDM (frequency division multiplexing) and TDM
21   (time division multiplexing) with the legacy system. When the legacy system operates in the PUSC mode, then
22   the type of multiplexing is FDM or TDM. If the legacy system operates in the AMC mode, then the uplink
23   resources for the legacy and the IEEE 802.16m system are multiplexed using FDM or TDM.
24
25   When the legacy system operates in the PUSC mode, a symbol structure according to 16m PUSC should be
26   used in order to provide FDM-based legacy support.
27

28   ### 11.6.4.1   Distributed Resource Unit for 16m PUSC

29   Unlike a DRU structure defined in 11.6.1.1, a DRU in 16m PUSC contains six tiles which size is 4xNsym
30   where Nsym depends on the subframe type. Figure 46 shows a tile structure when a subframe has 6 symbols.
31   Pilot pattern is TBD.
32
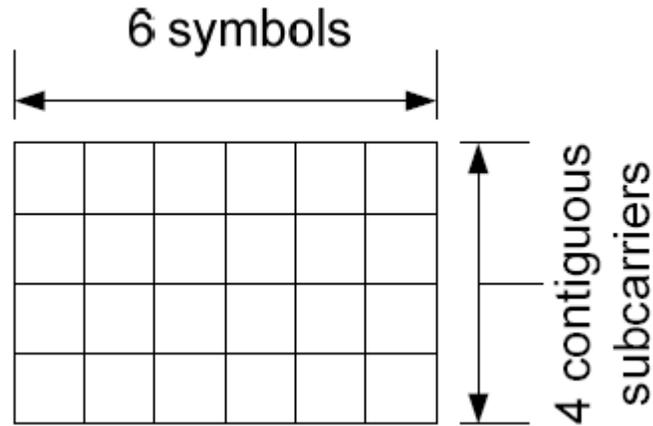
Figure 46 Tile structure in 16m PUSC

11.6.4.2   Subchannelization for 16m PUSC

A subchannelization for 16m PUSC is identical to legacy uplink PUSC [2]. For a given system bandwidth, total usable subcarriers are allocated to form tiles (four contiguous subcarriers) and every tiles are permuted according to permutation defined in uplink PUSC [2]. Once subchannelization is done, every subchannel is assigned to either legacy system or 16m system. Figure 47 shows the uplink frame which is divided in frequency domain into two logical regions – one is for legacy PUSC subchannels and the other is for 16m PUSC DRUs.
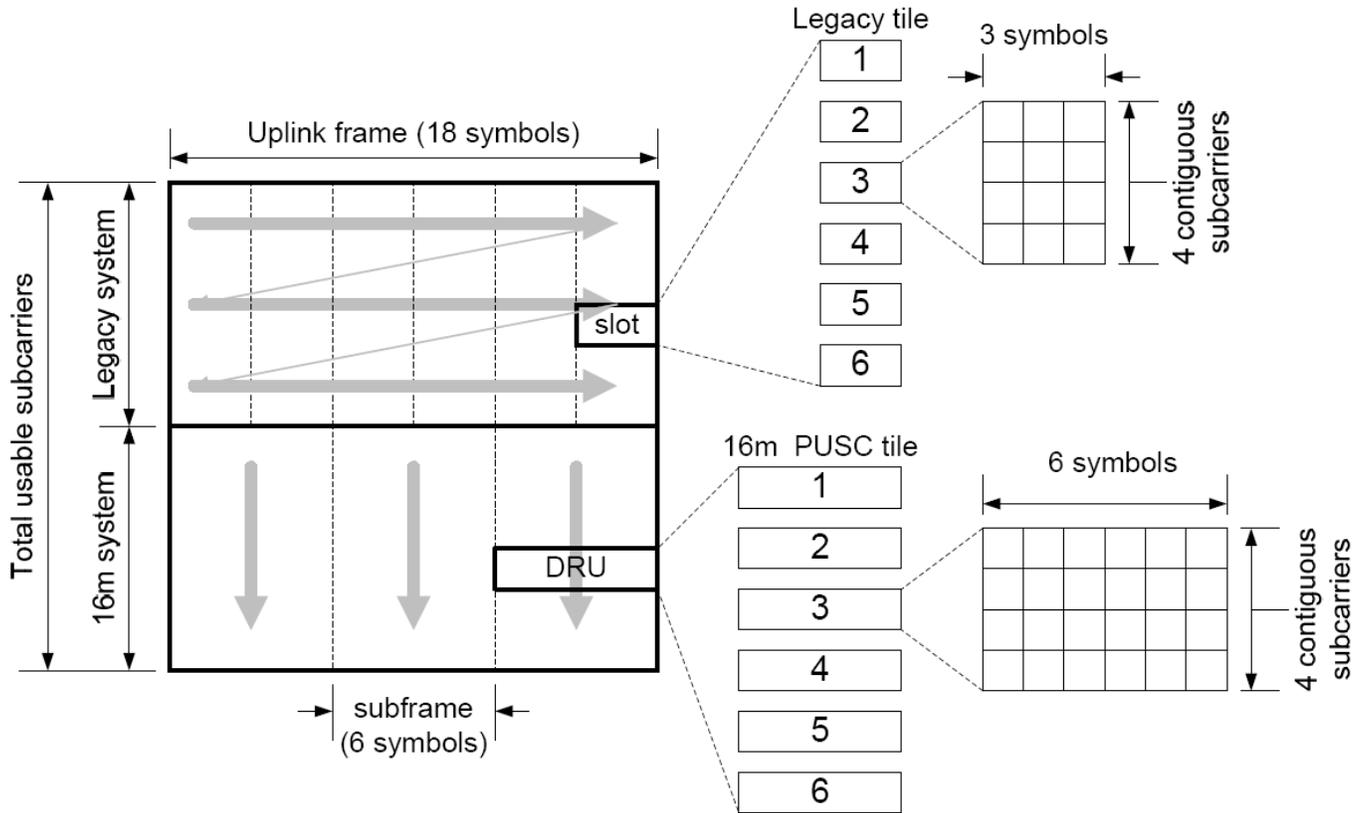
2   Figure 47 Subchannelization of 16m PUSC and DRU structure

3 *11.7 DL Control Structure*

4

5 DL control channels are needed to convey information essential for system operation. In order to reduce the
6 overhead and network entry latency, and improve robustness of the DL control channel, information is
7 transmitted hierarchically over different time scales from the superframe level to the subframe level. Broadly
8 speaking, control information related to system parameters and system configuration is transmitted at the
9 superframe level, while control and signaling related to traffic transmission and reception is transmitted at the
10 frame/subframe level.

11 In mixed mode operation (legacy/IEEE 802.16m), an AMS can access the system without decoding legacy FCH
12 and legacy MAP messages.

13 Details of the DL control structure are described in the following sections.

14 11.7.1   DL Control Information Classification

15

16 Information carried in the DL control channels is classified as follows.

17 11.7.1.1   Synchronization information

18 This type of control information is necessary for synchronization and system acquisition.

11.7.1.2   Essential system parameters and system configuration information

This includes a minimal set of time critical system configuration information and parameters needed for the mobile station (AMS) to complete access in a power efficient manner, including the following three types:

11.7.1.2.1   *Deployment-wide common information*

Deployment-wide common information and parameters such as downlink/uplink system bandwidth, TDD downlink/uplink ratio, and number of switching points.

11.7.1.2.2   *Downlink sector-specific information*

Downlink sector-specific essential information and parameters to enable AMS to further receive downlink extended broadcast information, control signaling and data. Examples of such information include antenna configuration, DL resource allocation configuration, pilot configuration.

11.7.1.2.3   *Uplink sector-specific information*

Uplink sector-specific essential information and parameters that are needed for the AMS to perform access on the uplink. Examples include UL resource allocation configuration, system configuration for initial ranging, UL channel parameters, UL power control parameters.

11.7.1.3   Extended system parameters and system configuration information

This category includes additional system configuration parameters and information not critical for access, but needed and used by all AMSs after system acquisition. Examples of this class include information required for handover such as handover trigger, neighbor ABS information, etc.

11.7.1.4   Control and signaling for DL notifications

Control and signaling information may be transmitted in the DL to provide network notifications to a single user or a group of users in the idle mode and sleep mode. Example of such notification is paging, etc.

11.7.1.5   Control and signaling for traffic

The control and signaling information transmitted in the DL for resource allocation to a single user or a group of users in active or sleep modes is included in this category. This class of information also includes feedback information such as power control and DL acknowledgement signaling related to traffic transmission/reception.

11.7.2   Transmission of DL Control Information

11.7.2.1   Synchronization Channel (SCH)

The synchronization channel (SCH) is a DL physical channel which provides a reference signal for time, frequency, and frame synchronization, RSSI estimation, channel estimation, and ABS identification.

11.7.2.1.1   *Synchronization channel requirements*

1   DEFINITIONS

Convergence time	Time interval for the probability of error in SCH index detection to be less than 1% under non-ideal assumptions on the timing and carrier synchronization, measured from the start of the acquisition process.
Correct detection	Choose a ABS among the co-channel ABS's whose received powers averaged over the convergence time are within 3 dB of the ABS with the highest received power
Coverage area	Area where the false detection probability is less than 1% within the convergence time
Overhead	Total radio resources (time and frequency) per superframe that can not be used for other purpose because of SCH
Cell ID set	The cell ID set is the set of unique SCH symbols for differentiating between macrocell/femtocell/sector/relay transmitters
Multi-bandwidth support	Design of SCH for different bandwidths as specified in Table 2
Multi-carrier support	Design of SCH to support functionality described in sections 8.1.3 and 11.4.6

2

3   11.7.2.1.1.1 Overhead

4   Mixed mode with legacy system

5   In mixed mode operation the SCH overhead shall be less than or equal to 4% per superframe including the
6   legacy preamble, where the 4% is calculated based on the ratio of SCH resource and that of usable resource for
7   transmitting data.

8   IEEE 802.16m only mode

9   In IEEE 802.16m only mode operation the SCH overhead shall be less than or equal to 2.6% per superframe,
10   where the 2.6% is calculated based on the ratio of SCH resource and that of usable resource for transmitting
11   data.

12   11.7.2.1.1.2 Synchronization

13   The SCH will provide synchronization for:

14   • Time, including frame and superframe

15   • Frequency

16   Synchronization performance must at least match that of IEEE 802.16e.

17   IEEE 802.16m SCH must enable system acquisition without knowledge of the full channel bandwidth.

18   The IEEE 802.16m SCH shall not cause degradation of synchronization for coexisting legacy systems.
19   Synchronization shall be robust for the full range of required mobile velocities as defined in the SRD (i.e. up to
20   350km/hr).

21   11.7.2.1.1.3 Coverage

22   The coverage area of IEEE 802.16m SCH shall not be worse than the minimum of the required coverage for
23   broadcasting channel, control channel and unicast data channel at channel conditions under considerations.

11.7.2.1.1.4 Cell IDs

The cell ID shall be obtained from the SCH. To support femto-cell deployments, the number of unique cell IDs conveyed by the SCH shall be greater than or equal to 512

11.7.2.1.1.5 MIMO support and channel estimation

The IEEE802.16m SCH supports multi-antenna transmissions. The number of supported antennas is 2. Channel estimation is supported from the SCH in order to support the control/data channel decoding.

11.7.2.1.1.6 Multi-carrier Multi-bandwidth support

IEEE 802.16m SCH shall support multi-bandwidth and multi-carrier operations as defined in the latest revision of the SDD.

11.7.2.1.1.7 Measurement Support

IEEE 802.16m SCH shall support noise power estimation.

11.7.2.1.1.8 Sequence requirements

The PAPR and peak power shall be no larger than those of the downlink signal (excluding SCH).

11.7.2.1.2   Synchronization channel architecture

11.7.2.1.2.1 Overview

11.7.2.1.2.1.1 Hierarchy

Two levels of synchronization hierarchy exist. These are called the primary synchronization channel (P-SCH) and secondary synchronization channel (S-SCH). The P-SCH is used for initial acquisition, superframe synchronization and sending additional information. The S-SCH is used for fine synchronization, and cell/sector identification (ID).

11.7.2.1.2.1.2 Multiplexing

P-SCH and S-SCH are TDM

11.7.2.1.2.1.3 Number of symbols in SCH

A complete instance of the SCH exists within a superframe. Multiple symbols within the superframe may comprise the SCH.

In mixed deployments, the presence of the IEEE 802.16e preamble is implicit.

11.7.2.1.2.1.4 Location of synchronization symbols

In mixed deployments, the presence of the IEEE 802.16e preamble in the first symbol of the IEEE 802.16e frame is implicit. The location of the SCH symbol(s) is fixed within the superframe.

For example, if 4 symbols per superframe are used for SCH, the 802.16m SCH can be transmitted in the first

1 subframe of every 802.16m frame as shown in Figure 48. The detailed allocation of SCH in time and frequency
2 for P-SCH and S-SCH within a superframe and a subframe are FFS.
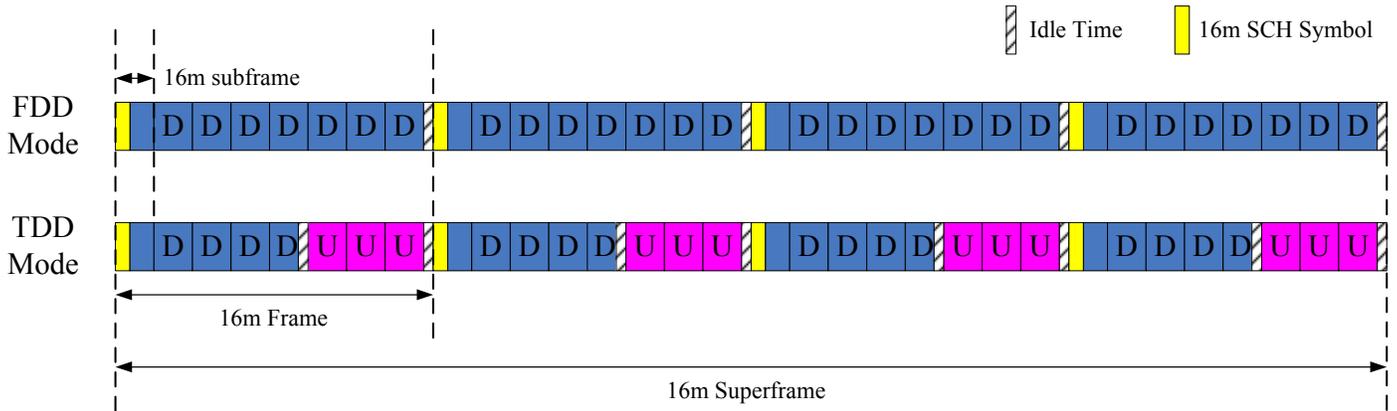
3

4 Figure 48 Example for location of IEEE 802.16m SCH symbols when 4 symbols per superframe are
5   used in 16m-only mode

6 11.7.2.1.2.1.5 Properties of P-SCH & S-SCH

7 The P-SCH has these properties:

8   • Common to a group of sectors/cells

9   • Partial cell ID information (e.g., ABS type, sector information, or grouping of cell ID)

10   • Supports limited signaling (e.g., system bandwidth, carrier information, etc.)

11   • Fixed bandwidth (5MHz)

12   • Support LBS (FFS)

13 The S-SCH has these properties:

14   • Full bandwidth

15   • Carries cell ID information

16 11.7.2.1.2.2 Description of legacy support/reuse
17 IEEE 802.16m system will exist in both greenfield and mixed (coexisting 16e and IEEE 802.16m equipment)
18 deployments. In mixed deployments the 16e preamble will be always present. As discussed in the requirements,
19 the IEEE 802.16m SCH is not to degrade the performance of legacy acquisition. The IEEE 802.16m SCH shall
20 enable AMSs to synchronize in frequency and time without requiring the IEEE 802.16e preamble.

21 The IEEE 802.16m P-SCH supports a timing synchronization by autocorrelation with a repeated waveform. The
22 structure of P-SCH is not identical to that of legacy preamble in the time domain.

23

24 11.7.2.1.2.3 Cell ID support
25 The number of IDs is at least 512.

26 Sectors are distinguished by the synchronization channel.

1 11.7.2.1.2.4 Multicarrier and multi-bandwidth support

2 The location of the SCH in frequency is FFS

3

4 11.7.2.1.2.5 MIMO support and channel estimation

5 Where employed, MIMO support is achieved by transmitting SCH subcarriers from known antennas. Antennas
6 are:

   (a) Cyclic delay diversity (with antenna specific delay values)

8 (b) Interleaved either within a symbol (multiple antennas can transmit within a single symbol but on distinct
9   subcarriers) or the different SCH sequences are transmitted from multi-antennas

10 (c) Across frames (only one antenna transmits in each symbol)

11 (d) Or some combination – actual approach is FFS.

12

13 The number of ABS antennas supported for MIMO channel measurements is FFS, depending on the
14 requirements of other IEEE 802.16m SDD content, such as DL MIMO and interference mitigation.

15 *11.7.2.1.3   Synchronization channel Sequence Design Properties*

16 The SCH enables timing synchronization by autocorrelation.

17 The power of synchronization channel can be boosted

18 The P-SCH is mapping with every other subcarrier on the frequency domain. Frequency reuse of 1 is applied to
19 P-SCH.

20 Frequency reuse of 3 is applied to S-SCH.

21 11.7.2.2   Broadcast Channel (BCH)

22

23 The Broadcast Channel (BCH) carries essential system parameters and system configuration information. The
24 BCH is divided into two parts: Primary Broadcast Channel (PBCH) and Secondary Broadcast Channel (SBCH).

25 *11.7.2.2.1   Primary Broadcast Channel (PBCH) and Secondary Broadcast Channel (SBCH)*

26

27 The Primary Broadcast Channel (PBCH) and the Secondary Broadcast Channel (SBCH) carry essential system
28 parameters and system configuration information. The PBCH is transmitted every superframe. The SBCH may
29 also be transmitted. When present, SBCH may be transmitted over one or more superframes. The information
30 contents of PBCH and SBCH is FFS

31 *11.7.2.2.2   Location of the BCH*

32

33 The SFH includes PBCH and the SBCH, and is located in the first subframe within a superframe. The PBCH
34 and SBCH occupy no more BW than 5 MHz, but the physical mapping (resource allocation) is FFS.

1 *11.7.2.2.3   Multiplexing of the PBCH and SBCH with other control channels and data channels*

2

3 The PBCH/SBCH is TDM with the SCH.

4 If SFH occupies narrower BW than system BW, the PBCH and SBCH in SFH are FDM with data within the
5 same subframe.

6 The PBCH is FDM with the SBCH within the first subframe.

7 *11.7.2.2.4   Transmission format*

8

9 The PBCH and SBCH are transmitted using predetermined modulation and coding schemes. The modulation
10 for the PBCH and the SBCH is QPSK.

11 The coding rate for PBCH and SBCH is FFS.

12

13 Multiple antenna schemes for transmission of the PBCH/SBCH are supported. Transmission of PBCH and
14 SBCH as one stream or two streams is FFS. The AMS is not required to know the antenna configuration prior to
15 decoding the PBCH.

16

17 If needed, signaling of the multiple antenna scheme used to transmit the PBCH/SBCH is TBD.

18 *11.7.2.2.5   Resource allocation*

19

20 The PBCH and SBCH are transmitted in a predefined frequency partition and PRUs of the frequency partition
21 used for PBCH and SBCH transmission span the available bandwidth for BCH.

22 The PHY structure for transmission of PBCH and SBCH is described in Section 11.5.1. The PBCH and SBCH
23 use distributed resource units.

24 11.7.2.3   Unicast Service Control Channels (USCCH)

25 *11.7.2.3.1   Unicast service control information/content*

26

27 Unicast service control information consists of both user-specific control information and non-user-specific
28 control information.

29 11.7.2.3.1.1 Non-user-specific control information

30 Non-user-specific control information consists of information that is not dedicated to a specific user or a
31 specific group of users. It includes information required to decode the user-specific control. Non-user-specific
32 control information that is not carried in the BCH may be included in this category.

33 11.7.2.3.1.2 User-specific control information

34 User specific control information consists of information intended for one user or more users. It includes

scheduling assignment, power control information, HARQ ACK/NACK information. HARQ ACK/NACK information for uplink data transmission is carried by DL ACK channel which is separated from control blocks for other user specific control information.

Resources can be allocated persistently to AMSs. The periodicity of the allocation may be configured.

Group control information is used to allocate resources and/or configure resources to one or multiple mobile stations within a user group. Each group is associated with a set of resources. The group message contains bitmaps to signal resource assignment, MCS, resource size etc. VoIP is an example of the subclass of services that use group messages.

11.7.2.3.2   Multiplexing scheme for data and unicast service control

Within a subframe, control and data channels are multiplexed using FDM. Both control and data channels are transmitted on logical resource units (LRU) that span all OFDM symbols in a sub-frame.

11.7.2.3.3   Location of control blocks

The first IEEE 802.16m DL subframe of each frame contains one USCCH region. Multiple USCCH regions in a subframe are FFS. A USCCH region can include both non-user specific and user specific control information.

USCCH regions are located 'n' IEEE 802.16m subframes apart. If a USCCH region is allocated in subframe N, the next USCCH region is in subframe N+n of the same frame. DL data allocations corresponding to the USCCH region can correspond to resources in any subframes between successive USCCH regions. The values of n can be 1 or 2. Other values of n (3 and 4) are FFS. For example, for n=2, USCCH region in subframe N can point to resource allocation in subframe N or N+1 and the next USCCH region is in subframe N+2. If a USCCH region is allocated in subframe N and contains the specification for UL data allocations, the corresponding UL data allocations occur in subframe TBD.

In the FDD mode, the first IEEE 802.16m DL subframe of each frame contains user-specific control information. In the TDD mode, the first IEEE 802.16m DL subframe after each UL to DL transition contains user-specific control information.

11.7.2.3.4   Transmission format

A unicast service control information element is defined as the basic element of unicast service control. A unicast service control information element may be addressed to one user using a unicast ID or to multiple users using a multicast/broadcast ID. It may contain information related to resource allocation, HARQ, transmission mode, power control, etc.

If each unicast service control information element is coded separately, this type of coding is referred to as "separate coding", whereas if multiple unicast service control information elements are coded jointly, this type of coding is referred to as "joint coding".

A coded control block is the output of separate coding or joint coding. The MCS of each coded control block may be controlled individually. Coded control blocks may all be transmitted at the same MCS and this transmission scheme is referred to as "fixed MCS". If each coded block may be transmitted at a different MCS, this scheme is referred to as "variable MCS".

1 Coding of multiple unicast service control information elements may therefore either be joint coding or separate
2 coding.

3 MCS of coded control blocks may either be with a fixed MCS or a variable MCS.

4 Non-user-specific control information is encoded separately from the user-specific control information.

5 For user-specific control information elements intended for a single user or a group of users, multiple
6 information elements are coded separately. The modulation and coding scheme (fixed/variable) of each
7 information element is FFS.

8 Non-user-specific control information in a USCCH region is transmitted at a fixed MCS for a given system
9 configuration.

10 *11.7.2.3.5   Resource allocation (physical to logical mapping, pilots, block size)*
11   <Editors' Notes: This section depends on SDD text included in the DL PHY Structure.>

12 11.7.2.3.5.1 Pilot structure for unicast service control channels
13   <Editors' Notes: This section depends on SDD text included in the DL PHY Structure.>

14 11.7.2.4   Multicast Service Control Channels
15   <Editors' Notes:This section is a placeholder for text to be developed based on SDD text that will be
16   added to Section 15 of the SDD (Support for Enhanced Multicast Broadcast Service). >

17 Multicast Service Control Channels are classified into cell specific and non-cell specific control channels.
18

19 *11.7.2.4.1   Multicast service control information/content*
20

21 Further details of multicast service control information/content are FFS.
22

23 *11.7.2.4.2   Multiplexing scheme of data and multicast service control and (e.g. TDM, FDM, Hybrid*
24   *TDM/FDM)*
25

26 Within a sub-frame where multicast data and control are carried, multicast service control and data channels are
27 multiplexed using FDM. Within a MBS scheduling interval, control is transmitted before MBS data in order to
28 decode the burst information.
29

30 *11.7.2.4.3   Location of control blocks within a frame/subframe*
31

32 The location of multicast service control blocks in a frame is FFS.
33

34 *11.7.2.4.4   Transmission format (e.g. modulation, coding, multiple antenna schemes)*
35 A multicast service control information element is defined as the basic element of the multicast service control.
36 A multicast service control information element is non-user specific and is addressed to all users in the cell. The
37 transmission format for multicast control is FFS.

1

11.7.2.4.5   Resource allocation (physical to logical mapping, pilots, block size)

11.7.2.5   Transmission of Additional Broadcast information on Traffic Channel

Examples of additional broadcast information include system descriptors, neighbor ABS information and paging information. The indication of the presence of additional broadcast information is FFS.

MAC management messages may be used to transmit additional broadcast information on traffic channel.

The essential configuration information about different RATs may be transmitted by a ABS. Such messages may be structured as broadcast or unicast messages.

The configuration of different RATs may be defined in a variable length MAC management message. This message should include information such as:

- RAT Logical Index

- RAT Type: 16m, 16e only, 3GPP/3GPP2, DVB-H, etc.

- If other RAT : List of configuration Parameters

The configuration parameters should include all information needed for efficient scanning and if needed handing over/switching to such RATs with minimal signaling with the target RAT.

11.7.3 Mapping information to DL control channels

Information	Channel	Location
Synchronization information	Synchronization Channel (SCH): Primary Synchronization Channel (P-SCH) and Secondary Synchronization Channel (S-SCH)	FFS
Essential system parameters and system configuration information	Primary Broadcast Channel (PBCH) and Secondary Broadcast Channel (SBCH)	Inside SFH
Extended system parameters and system configuration information	Additional Broadcast Information on Traffic Channel	Outside SFH
Control and signaling for DL notifications	Additional Broadcast Information on Traffic Channel	Outside SFH
Control and signaling for traffic	Unicast Service Control Channel	Outside SFH

Table 3 Mapping information to DL control channels

11.7.4 Multi-carrier Control Structure

<Editors' Notes:This section is a placeholders for text to be developed based on SDD text that will be added to Section 19 of the SDD (Support for Multi-carrier Operation). >

The carriers involved in a multi-carrier system, from one AMS point of view, can be divided into two types:

- A Primary carrier is the carrier used by the ABS and the AMS to exchange traffic and PHY/MAC control information defined in IEEE 802.16m specification. Further, the primary carrier is used for control functions for proper AMS operation, such as network entry. Each AMS shall have only one

1   carrier it considers to be its primary carrier in a cell.

2   • A Secondary carrier is an additional carrier which the AMS may use for traffic, only per ABS's specific
3   allocation commands and rules typically received on the primary carrier. The secondary carrier may also
4   include control signaling to support multi-carrier operation.

5   Based on the primary and/or secondary usage, the carriers of a multi-carriers system may be configured
6   differently as follows:

7   • Fully configured carrier: A carrier for which all control channels including synchronization, broadcast,
8   multicast and unicast control signaling are configured. Further, information and parameters regarding
9   multi-carrier operation and the other carriers can also be included in the control channels. Fully
10   configured carrier shall support both single carrier AMS and multicarrier AMS.

11   • Partially configured carrier: A carrier with only essential control channel configuration to support traffic
12   exchanges during multi-carrier operation.

13 A primary carrier shall be fully configured while a secondary carrier may be fully or partially configured
14 depending on usage and deployment model.

15

11.8 DL MIMO Transmission Scheme

17 11.8.1 DL MIMO Architecture and Data Processing

18
19 The architecture of downlink MIMO on the transmitter side is shown in the Figure 49.

20
21 In SU-MIMO, only one user is scheduled in one Resource Unit (RU). In MU-MIMO, multiple users can be
22 scheduled in one RU.

23
24 If vertical encoding is utilized, there is only one encoder block (one "layer"). If horizontal encoding is utilized,
25 there are multiple encoders (multiple "layers"). A "layer" is defined as a coding / modulation path fed to the
26 MIMO encoder as an input, and a "stream" is defined as each output of the MIMO encoder that is passed to the
27 beamformer / precoder.
28

1
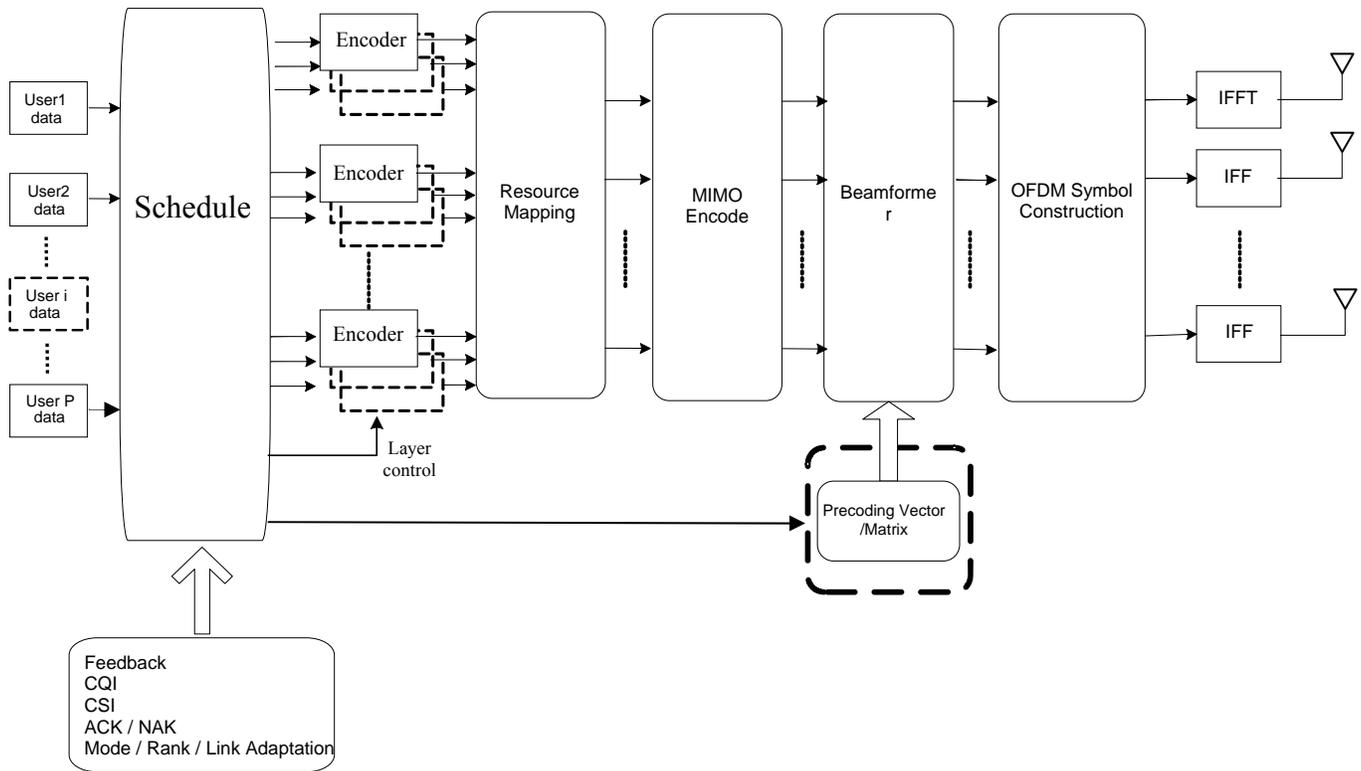
2   Figure 49 MIMO Architecture

3   The encoder block contains the channel encoder, interleaver, rate-matcher, and modulator for each layer.

4   The Resource Mapping block maps the modulated symbols to the corresponding time-frequency resources in
5   the allocated resource units (RUs).

6   The MIMO encoder block maps L (≥1) layers onto N_S (≥L) streams, which are fed to the Beamformer/Precoder
7   block.

8   The Beamformer/Precoder block maps streams to antennas by generating the antenna-specific data symbols
9   according to the selected MIMO mode.

10 The OFDM symbol construction block maps antenna-specific data to the OFDM symbol.

11 The feedback block contains feedback information such as CQI and CSI from the AMS.

12 The scheduler block will schedule users to resource units and decide their MCS level, MIMO parameters
13 (MIMO mode, rank). This block is responsible for making a number of decisions with regards to each resource
14 allocation, including:

15   • *Allocation type*: Whether the allocation should be transmitted with a distributed or localized allocation
16   • *Single-user (SU) versus multi-user (MU) MIMO*: Whether the resource allocation should support a
17   single user or more than one user
18   • *MIMO Mode*: Which open-loop (OL) or closed-loop (CL) transmission scheme should be used for the

97

1   user(s) assigned to the resource allocation.

2   • *User grouping*: For MU-MIMO, which users should be transmitted on the Resource Unit (RU)

3   • *Rank*: For the spatial multiplexing modes in SU-MIMO, the number of streams to be used for the user

4   allocated to the Resource Unit (RU).

5   • *MCS level per layer*: The modulation and coding rate to be used on each layer.

6   • *Boosting*: The power boosting values to be used on the data and pilot subcarriers.

7   • *Band selection*: If localized resource allocation is used, where in the frequency band should the

8   localized allocation be placed.

9

11.8.1.1   Antenna Configuration

11 The ABS employs a minimum of two transmit antennas. The AMS employs a minimum of two receive
12 antennas. The antenna configurations are $(N_T, N_R) = (2, 2), (4, 2), (4, 4), (8, 2), (8, 4)$, and $(8,8)$ where N_T
13 denotes the number of ABS transmit antennas and N_R denotes the number of AMS receive antennas.

14

15

11.8.1.2   Layer to Stream Mapping

17

18 For open-loop spatial multiplexing and closed-loop SU-MIMO, the number of streams is $N_S \leq \min(N_T, N_R)$,
19 where N_S is no more than 8. For open-loop transmit diversity modes, N_S depends on the STC schemes employed
20 by the MIMO encoder. MU-MIMO can have up to 2 streams with 2 Tx antennas, and up to 4 streams for 4 Tx
21 antennas and 8 Tx antennas.

22

23 For SU-MIMO, spatial multiplexing MIMO mode employs vertical encoding (SCW). [The support of
24 horizontal encoding (MCW) for SU-MIMO spatial multiplexing MIMO mode is FFS]. For SU-MIMO, transmit
25 diversity MIMO mode employs vertical encoding (SCW). For MU-MIMO, MCW (or horizontal) encoding is
26 employed at the base-station while only one stream is transmitted to each mobile station.

27

11.8.1.3   Stream to Antenna Mapping

29

30 The stream to antenna mapping depends on the MIMO scheme used. The mapping can be defined using the
31 following equation

$$\mathbf{y} = \mathbf{P} \times \mathbf{S(x)}, \text{ Equation 1}$$

33 where y is the output of the precoder/beamformer, P is a pre-coding matrix, S(x) is an STC matrix, and x is the
34 input layer vector.

35

11.8.1.4   Resource mapping

37

38 The MIMO mode permutation for various MIMO schemes is supported in either Distributed or Localized
39 resource mapping.

1 ## 11.8.1.5   Pilots

2 ## 11.8.1.6   Signaling support for MIMO

3 ### *11.8.1.6.1   Signaling support for SU MIMO*

4 In the downlink closed-loop SU-MIMO, the precoding matrix shall be signalled via explicit signaling if
5 common demodulated pilots are used, or via dedicated pilots.

6 ### *11.8.1.6.2   Signaling support for MU MIMO*

7 In the downlink MU-MIMO, the precoding matrix shall be signaled via explicit signaling if common
8 demodulation pilots are used, or via dedicated pilots.
9

10 ## 11.8.2 Transmission for Data Channels

11 ## 11.8.2.1   Single-user MIMO
12 Single-user MIMO schemes are used to improve per-link performance.
13
14 Both open-loop single-user MIMO and closed-loop single-user MIMO are supported for the antenna
15 configurations specified in Section 11.8.1.1.
16
17 For open-loop single-user MIMO, both spatial multiplexing and transmit diversity schemes are supported. Note
18 that in the case of open-loop single-user MIMO, CQI and rank feedback may still be transmitted to assist the
19 base station's decision of rank adaptation, transmission mode switching, and rate adaptation. Note that CQI, and
20 rank feedback may or may not be frequency dependent.
21
22 For closed-loop single-user MIMO, codebook based precoding is supported for both TDD and FDD systems.
23 CQI, PMI, and rank feedback can be transmitted by the mobile station to assist the base station's scheduling,
24 resource allocation, and rate adaptation decisions. Note that the CQI, PMI, and rank feedback may or may not
25 be frequency dependent.
26
27 For closed-loop single-user MIMO, sounding based precoding is supported for TDD systems.
28
29 As described in section 11.8.1, the overall structure of MIMO processing has two parts. The first part is the
30 MIMO encoder and second part is the precoder.
31
32 The MIMO encoder is a batch processor that operates on M input symbols at a time. The input to the MIMO
33 encoder is represented by an $M \times 1$ vector

34
$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_M \end{bmatrix}, \text{Equation 2}$$

35 where s_i is the *i*-th input symbol within a batch. The output of the MIMO encoder is an $N_S \times N_F$ MIMO STC
36 matrix $z = S(x)$, which serves as the input to the precoder. The output of the MIMO encoder is multiplied by N_T
37 $\times N_S$ precoder, P. The output of the precoder is denoted by a matrix $N_T \times N_F$ matrix

1
$$\mathbf{y} = P \times z = \begin{bmatrix} y_{1,1} & y_{1,2} & \cdots & y_{1,N_F} \\ y_{2,1} & y_{2,2} & \cdots & y_{2,N_F} \\ \vdots & \vdots & \ddots & \vdots \\ y_{N_T,1} & y_{N_T,2} & \cdots & y_{N_T,N_F} \end{bmatrix}, \text{Equation 3}$$

2 where $y_{j,k}$ is the output symbol to be transmitted via the *j*-th physical antenna on the *k*-th subcarrier. Note N_F is
3 the number of subcarriers used to transmit the MIMO signals derived from the input vector x. For open-loop
4 SU-MIMO, the rate of a mode is defined as $R = M / N_F$.

5 *11.8.2.1.1   Open-loop SU-MIMO*

6
7 A number of antenna configurations and transmission rates are supported in open-loop SU-MIMO. Among
8 them, 2Tx, 4Tx, and 8Tx antennas with rate 1 transmission are defined as Transmit Diversity modes. The
9 operation of these modes is specified in Section 11.8.2.1.1.1. The other modes, including 2Tx, 4Tx, and 8Tx
10 antennas with rate 2 transmission, 4Tx and 8Tx antennas with rate 3 transmission, 4Tx and 8Tx antennas with
11 rate 4 transmission, and 8Tx antennas with transmission up to rate 8, are defined as Spatial Multiplexing modes.
12 The operation of these modes is specified in Section 11.8.2.1.1.2. The dimensions of the vectors and matrices
13 for open-loop SU-MIMO are shown in the following table:

14

15

N_T	Rate	M	N_S	N_F
2	1	1	1	1
2	1	2	2	2
4	1	1	1	1
4	1	2	2	2
8	1	1	1	1
8	1	2	2	2
2	2	2	2	1
4	2	2	2	1
[4]	[2]	[4]	[4]	[2]
8	2	2	2	1
[8]	[2]	[4]	[4]	[2]
4	3	3	3	1
[4]	[3]	[6]	[4]	[2]
8	3	3	3	1
[8]	[3]	[6]	[4]	[2]
4	4	4	4	1
8	4	4	4	1

16   Table 4 Matrix dimensions for open-loop SU-MIMO modes

17   [Note : This table will be updated according to the decision of OL-SU-MIMO]
18
19 On a given subcarrier k, the precoding matrix P can be defined using the following equation:

1 $P(k) = W(k)$, Equation 4

2    $W(k)$ is an $N_T \times N_S$ matrix, where N_T is the number of transmit antennas and N_S is the numbers of streams. The
3   matrix W(k) is selected from a predefined unitary codebook, and changes every u subcarriers, and/or v OFDM
4   symbols. The matrix $W(k)$ can be identity matrix for 2Tx rate-2 and 4Tx rate-4. A codebook is a unitary
5   codebook if each of its matrices consists of columns of a unitary matrix. [The detailed unitary codebook, and
6   the parameter u and v are FFS. The CL SU MIMO and OL SU MIMO may use different unitary codebooks.]
7
8   For OL SU-MIMO, the following schemes are FFS: 4Tx rate-1 SFBC + Antenna hopping, 4Tx rate-2 Double
9   SFBC + Antenna hopping, 4Tx rate-2 SM + Antenna hopping, 4Tx rate-3 SM + Antenna hopping, 4Tx rate-3
10   hybrid SM + SFBC + Antenna hopping.
11   8Tx rate 5 to 8 schemes are FFS.

12   11.8.2.1.1.1 Transmit Diversity

13
14   The following transmit diversity modes are supported for open-loop single-user MIMO:
15   • 2Tx rate-1: For $M = 2$,SFBC, and for $M = 1$, a rank-1 precoder
16   • 4Tx rate-1: For $M = 2$,SFBC with precoder, and for $M = 1$, a rank-1 precoder
17   • 8Tx rate-1: For $M = 2$,SFBC with precoder, and for $M = 1$, a rank-1 precoder
18
19   For the transmit diversity modes with M=1, the input to MIMO encoder is x=s_1, and the output of the MIMO
20   encoder is a scalar, z=x. Then the output of MIMO encoder is multiplied by $N_T \times 1$ matrix W, where W is
21   described in section 11.8.2.1.1
22
23   For the transmit diversity modes with M=2, the input to the MIMO encoder is represented a 2×1 vector.

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$

24   , Equation 5
25
26   The MIMO encoder generates the SFBC matrix.

$$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$

27   , Equation 6
28   Then the output of the MIMO encoder is multiplied by $N_T \times 2$ matrix W, where W is described in section
29   11.8.2.1.1

30   11.8.2.1.1.2 Spatial Multiplexing

31
32   The following spatial multiplexing modes are supported for open-loop single-user MIMO:
33   • Rate-2 spatial multiplexing modes:
34   o 2Tx rate-2: rate 2 SM with precoding
35   o 4Tx rate-2: rate 2 SM with precoding
36   o 8Tx rate-2: rate 2 SM with precoding
37   • Rate-3 spatial multiplexing modes:
38   o 4Tx rate-3: rate 3 SM with precoding
39   o 8Tx rate-3: rate 3 SM with precoding
40   • Rate-4 spatial multiplexing modes:
41   o 4Tx rate-4: rate 4 SM
42   o 8Tx rate-4: rate 4 SM with precoding

1

2　For the rate-R spatial multiplexing modes, the input and the output of MIMO encoder is represented by an $R \times 1$
3　vector

$$\mathbf{x} = \mathbf{z} = \begin{bmatrix} s_1 \\ s_1 \\ \vdots \\ s_R \end{bmatrix}$$

4　, Equation 7
5　Then the output of the MIMO encoder is multiplied by $N_T \times R$ matrix W, where W is described in section
6　11.8.2.1.1.
7

8　*11.8.2.1.2　Closed-loop SU-MIMO*

9　11.8.2.1.2.1　Precoding technique
10　In FDD and TDD systems, unitary codebook based precoding is supported.
11
12　In TDD systems, sounding based precoding is supported.
13　For codebook based precoding, the base codebook will be an IEEE 802.16e-based and/or DFT-based codebook.
14

15　*11.8.2.1.3　Feedback for SU-MIMO*
16　In FDD systems and TDD systems, a mobile station may feedback some of the following information in Closed
17　loop SU-MIMO mode:
18　　• Rank (Wideband or sub-band)
19　　• Sub-band selection
20　　• CQI (Wideband or sub-band, per layer)
21　　• PMI (Wideband or sub-band for serving cell and/or neighboring cell)
22　　• Long-term CSI
23
24　For codebook based precoding, three different feedback modes for the PMI are supported:
25　　• The standard mode: The PMI feedback from a mobile station shall represent an entry of the base
26　　　codebook. It shall be sufficient for the base station to determine a new precoder.
27　　• The adaptive mode: The PMI feedback from a mobile station shall represent an entry of the
28　　　transformed base codebook according to long term channel information.
29　　• The differential mode: the feedback from a mobile station provides a differential knowledge of the
30　　　short-term channel information. This feedback represents information that is used along with other
31　　　feedback information known at the base station for determining a new precoder.
32　Mobile station shall support the standard and adaptive mode and may support the differential mode.
33　The feedback information may be transmitted via a physical layer control channel or via a higher layer
34　signaling message.
35
36　In TDD systems, a mobile station may transmit a sounding signal on the uplink.
37

38　11.8.2.2　Multi-user MIMO
39

1 Multi-user MIMO schemes are used to enable a resource allocation to communicate data to two or more AMSs.
2 IEEE 802.16m uses Multi-user MIMO to boost system throughput.
3
4 Multi-user transmission with one stream per user is supported for MU-MIMO. MU-MIMO includes the MIMO
5 configuration of 2Tx antennas to support up to 2 users, and 4Tx or 8Tx antennas to support up to 4 users.
6

7 *11.8.2.2.1   Precoding technique*

8 Up to four AMSs can be assigned to each resource allocation. Both unitary and non-unitary MU MIMO are
9 supported in IEEE 802.16m.
10 The base codebook can be an IEEE 802.16e-based and/or DFT-based codebook.
11

12 *11.8.2.2.2   Unification with SU*

13
14 Predefined and flexible adaptation between SU-MIMO and MU-MIMO are supported. The adaptation between
15 SU MIMO rank 1 and MU MIMO is dynamic by using the same feedback information.
16 The adaptation between feedback for SU MIMO rank 2 (or more) and feedback for MU MIMO is semi-static.

17 *11.8.2.2.3   Feedback for MU-MIMO*

18 11.8.2.2.3.1 CQI feedback

19 In FDD systems and TDD systems, a mobile station may feedback some of the following information in MU-
20 MIMO mode:
21 •   Sub-band selection
22 •   CQI (Wideband or sub-band, per layer)
23 •   PMI (Wideband or sub-band for serving cell and/or neighboring cell)
24 •   Long-term CSI
25
26 For CQI feedback, the mobile station measures the downlink pilot channel reference signal or the dedicated
27 pilots in the allocated resource unit, computes the channel quality information (CQI), and reports the CQI on
28 the uplink feedback channel. Both wideband CQI and subband CQI may be transmitted by a mobile station.
29 Wideband CQI is the average CQI of a wide frequency band. In contrast, sub-band CQI is the CQI of a
30 localized sub-band. The CQI is calculated at the mobile station assuming that the interfering users are
31 scheduled by the serving base station using precoders orthogonal to each other and orthogonal to the
32 reported PMI.
33

34 11.8.2.2.3.2 CSI feedback
35
36 Channel state information feedback may be employed for MU-MIMO. Codebook-based feedback is supported
37 in both FDD and TDD. Sounding-based feedback is supported in TDD.
38
39 For codebook based precoding, three different feedback modes for the PMI are supported:
40 ●   The standard mode: the PMI feedback from a mobile station shall represent an entry of the base
41   codebook. It shall be sufficient for the base station to determine a new precoder.
42 ●   The adaptive mode: The PMI feedback from a mobile station shall represent an entry of the
43   transformed base codebook according to long term channel information.

- The differential mode: the feedback from a mobile station provides a differential knowledge of the short-term channel information. This feedback represents information that is used along with other feedback information known at the base station for determining a new precoder.

Mobile station shall support the standard and adaptive mode and may support the differential mode.The unified codebook for SU and MU is employed. The MU MIMO codebook contains subsets of the unified codebook (including full set) to support both unitary and non-unitary precoding. When codebook-based feedback is used, the ABS indicates which codebook subset (including full set) will be used explicitly or implicitly.

An enhanced UL sounding channel is used to feedback CSI-related information by the AMS to facilitate vendor-specific adaptive closed-loop MIMO precoding. For sounding-based precoding, the enhanced UL sounding channel can be configured to carry a known pilot signal from one or more AMS antennas to enable the ABS to compute its precoding/beamforming weights by leveraging TDD reciprocity. The sounding waveform can be configured to occupy portions of the frequency bandwidth in a manner similar to the sounding waveform used in the legacy system. To facilitate analog-feedback-based precoding, the enhanced UL sounding channel can be configured to carry unquantized CSI-related information (e.g., an unquantized encoding of the DL spatial covariance matrix or an unquantized encoding of the eigenvectors of the DL spatial covariance matrix). The unquanitized CSI-related information can be specific to a particular specified portion of the band (narrowband feedback) or specific to the entire bandwidth (wideband feedback).

11.8.2.3   Rank and Mode Adaptation

To support the numerous radio environments for IEEE 802.16m systems, both MIMO mode and rank adaptation are supported. ABSs and AMSs may adaptively switch between DL MIMO techniques depending on parameters such as antenna configurations and channel conditions. Parameters selected for mode adaptation may have slowly or fast varying dynamics. By switching between DL MIMO techniques an IEEE 802.16m system can dynamically optimize throughput or coverage for a specific radio environment.

The MIMO modes include open-loop MIMO like transmit diversity, spatial multiplexing, and closed-loop MIMO, etc. The adaptation of these modes is related with the system load, the channel information, AMS speed and average CINR. Switching between SU-MIMO and MU-MIMO is also supported.

Both dynamic and semi-static adaptation mechanisms are supported in 16m. For dynamic adaptation, the mode/rank may be changed frame by frame. For semi-static adaptation, AMS may request adaptation. The decision of rank and mode adaptation is made by the ABS. The adaptation occurs slowly, and feedback overhead is less.

11.8.3 Transmission for Control Channel

11.8.3.1   Transmission for Broadcast Control Channel

A SU open-loop technique that provides diversity gain will be used for the Broadcast Control Channel. The detailed transmit diversity scheme for the Broadcast Control Channel is FFS.

11.8.3.2   Transmission for Unicast Control Channel

A SU technique that provides diversity or beamforming gain will be used for the Unicast Control Channel. The detailed transmit diversity scheme for Unicast Control Channels is FFS.

11.8.4 Advanced Features

11.8.4.1   Multi-BS MIMO

Multi-BS MIMO techniques are supported for improving sector throughput and cell-edge throughput through multi-BS collaborative precoding, network coordinated beamforming, or inter-cell interference nulling. Both open-loop and closed-loop multi-BS MIMO techniques can be considered. For closed-loop multi-BS MIMO, CSI feedback via codebook based feedback or sounding channel will be used. The feedback information may be shared by neighboring base stations via network interface. Mode adaptation between single-BS MIMO and multi-BS MIMO is utilized.

11.8.4.2   MIMO for Multi-cast Broadcast Services

Open-loop spatial multiplexing schemes as described in Section 11.8.2.1.1.2 are used for MBS. Support for SCW and MCW is FFS.
No closed loop MIMO scheme is supported in E-MBS.

11.9 UL Control Structure

Details of the UL control structure are described in the following sections.

11.9.1 UL Control Information Classification

The UL control channels carry multiple types of control information to support air interface procedures. Information carried in the control channels is classified as follows.

> <Editors' Notes: Text included in this section depends on SDD text being developed by other Rapporteur Groups (MIMO, HARQ).>

11.9.1.1   Channel quality feedback

Channel quality feedback provides information about channel conditions as seen by the AMS. This information is used by the ABS for link adaptation, resource allocation, power control etc. Channel quality measurement includes narrowband and wideband measurements. CQI feedback overhead reduction is supported through differential feedback or other compression techniques. Examples of CQI include Physical CINR, Effective CINR, band selection, etc. Channel sounding can also be used to measure uplink channel quality.

11.9.1.2   MIMO feedback

MIMO feedback provides wideband and/or narrowband spatial characteristics of the channel that are required for MIMO operation. The MIMO mode, precoder matrix index, rank adaptation information, channel covariance matrix elements, power loading factor, eigenvectors and channel sounding are examples of MIMO

1 feedback information.

11.9.1.3   HARQ feedback

HARQ feedback (ACK/NACK) is used to acknowledge DL transmissions. Multiple codewords in MIMO transmission can be acknowledged in a single ACK/NACK transmission.

11.9.1.4   Synchronization

Uplink synchronization signals are needed to acquire uplink synchronization during initial access or handover and also to periodically maintain synchronization. Reference signals for measuring and adjusting the uplink timing offset are used for these purposes.

11.9.1.5   Bandwidth request

Bandwidth requests are used to provide information about the needed uplink bandwidth to the ABS. Bandwidth requests are transmitted through indicators or messages. A bandwidth request indicator notifies the ABS of a UL grant request by the AMS sending the indicator. Bandwidth request messages can include information about the status of queued traffic at the AMS such as buffer size and quality of service, including QoS identifiers.

11.9.1.6   E-MBS feedback

<Editors' Notes : This section is a placeholder for text to be developed based on SDD text that will be added to Section 15 of the SDD (Support for Enhanced Multicast Broadcast Service). >

E-MBS feedback provides information for DL MBS transmission to one or multiple cells. Details are TBD.

E-MBS may employ a common uplink channel which is used by AMSs to transmit feedback. E-MBS feedback transmission through a dedicated channel is FFS. If a predefined feedback condition is met, a NACK is transmitted through a common E-MBS feedback channel. The feedback condition may be configured by either the ABS or the network.

During E-MBS service initiation, a common feedback channel per E-MBS service may be allocated. The allocation of more than one common E-MBS feedback channel per E-MBS service is FFS. The allocation of the common E-MBS feedback channel may be configured by the ABS. The allocation of the common E-MBS feedback channel configured by the network is FFS. Other methods for reducing E-MBS feedback overhead are FFS, e.g. probabilistic transmission. The use of the feedback channels for other purposes, (e.g., counting) is FFS.

The termination notification of MBS service is FFS.

11.9.2 UL Control Channels

<Editors' Notes: Text included in this section depends on SDD text being developed by other Rapporteur Groups (MIMO, HARQ).>

The UL subframe size for transmission of control information is 6 symbols.

11.9.2.1   UL Fast Feedback Channel

The UL fast feedback channel carries channel quality feedback and MIMO feedback. Transmission of BW REQ indicators on the UL fast feedback channel is FFS.

The mapping of UL fast feedback information into physical channels is described in Section 1.1.1.1.1.

There are two types of UL fast feedback control channels: primary and secondary fast feedback channels. The UL primary fast feedback control channel provides wideband feedback information including channel quality and MIMO feedback. It is used to support robust feedback reports. The UL secondary fast feedback control channel carries narrowband CQI and MIMO feedback information. The secondary fast feedback channel can be used to support CQI reporting at higher code rate and thus more CQI information bits.

11.9.2.1.1   Multiplexing with other control channels and data channels

The UL fast feedback channel is FDM with other UL control and data channels.

The UL fast feedback channel starts at a pre-determined location, with the size defined in a DL broadcast control message. Fast feedback allocations to an AMS can be periodic and the allocations are configurable. For periodic allocations, the specific type of feedback information carried on each fast feedback opportunity can be different.

The UL fast feedback channel carries one or more types of fast feedback information. The use of TDM/FDM or CDM to multiplex fast feedback channels from one or more users is FFS.

11.9.2.1.2   PHY structure

The secondary fast feedback channel can be allocated in a non-periodic manner based on traffic, channel conditions etc. The number of bits carried in the fast feedback channel can be adaptive.

A UL feedback mini-tile (FMT) is defined as 2 contiguous subcarriers by 6 OFDM symbols. A UL FMT of 6 contiguous subcarriers by 2 OFDM symbols is FFS. The primary and secondary fast feedback channels are comprised of N_{FMT} distributed FMTs, where N_{FMT} is FFS. One LRU consists of 9 FMTs and can be shared by multiple fast feedback channels.

11.9.2.2   UL HARQ Feedback Channel

This channel is used to carry HARQ feedback information.

11.9.2.2.1   Multiplexing with other control channels and data channels

The UL HARQ feedback channel starts at a pre-determined offset with respect to the corresponding DL transmission.

The UL HARQ feedback channel is FDM with other control and data channels.

Orthogonal signaling is used to multiplex multiple HARQ feedback channels.

11.9.2.2.2   PHY structure

The UL HARQ feedback channel is comprised of three distributed UL feedback mini-tiles (FMT), where the UL FMT is defined as 2 contiguous subcarriers by 6 OFDM symbols. A UL FMT of 6 contiguous subcarriers

by 2 OFDM symbols is FFS. One LRU consists of 9 FMTs and can be shared by multiple HARQ feedback channels.

11.9.2.3   UL Sounding Channel

The UL sounding channel is used by an AMS to send a sounding signal for MIMO feedback, channel quality feedback and acquiring UL channel information at the ABS. The sounding channel occupies specific UL sub-bands or whole UL OFDMA symbol(s).

11.9.2.3.1   *Multiplexing with other control information and data*

The ABS can configure an AMS to transmit an UL sounding signal on specific UL sub-bands or across the whole UL band. The sounding signal is transmitted over predefined subcarriers within the intended sub-bands. The periodicity of the sounding signal for each AMS is configurable.

The UL sounding channel is FDM and/or TDM with other control and data channels.

11.9.2.3.2   *Multiplexing sounding feedback for multiple users*

The ABS can configure multiple AMSs to transmit UL sounding signals on the corresponding UL sounding channels. The UL sounding channels from multiple users or multiple antennas per user can be CDM, FDM, or TDM.

Strategies for combating inter-cell-interference may be utilized to improve the sounding performance.

11.9.2.3.2.1 Opportunistic UL sounding

Opportunistic UL sounding may be needed for sounding channel quality. The usage of opportunistic UL sounding and the details of the scheme used are FFS.

11.9.2.3.3   *UL Sounding Channel Power Control*

Power control for the UL sounding channel is supported to manage the sounding quality. Each AMS's transmit power for UL sounding channel may be controlled separately according to its sounding channel target CINR value. The details of power control scheme are FFS.

11.9.2.3.4   *PHY structure*

Sounding from single or multiple antennas and multiple users are supported to provide MIMO channel information for DL transmission. Power allocation, sounding sequence design and mapping to subcarriers is TBD.

11.9.2.4   Ranging Channel

The UL ranging channel is used for UL synchronization. The UL ranging channel can be further classified into ranging channel for non-synchronized mobile stations and synchronized mobiles stations. A random access procedure, which can be contention based or non-contention based is used for ranging. Contention-based random access is used for initial ranging, periodic ranging and handover. Non-contention based random access is used for periodic ranging and handover.

11.9.2.4.1   *Ranging Channel for Non-Synchronized Mobile Stations*

The ranging channel for non-synchronized AMSs is used for initial access and handover.

1   11.9.2.4.1.1 Multiplexing with other control channels and data channels

2   The UL ranging channel for non-synchronized AMSs starts at a configurable location with the configuration
3   defined in a DL broadcast control message.

4

5   The UL ranging channel for non-synchronized AMSs is FDM with other UL control channels and data
6   channels.

7   11.9.2.4.1.2 PHY structure

8   The physical ranging channel for non-synchronized mobile stations consists of three parts: 1) ranging cyclic
9   prefix (RCP), 2) ranging preamble (RP) and 3) guard time (GT). The length of RCP shall not be shorter than the
10   sum of the maximum channel delay spread and round trip delay (RTD) of supported cell size. The length of GT
11   shall not be also shorter than the RTD of supported cell size. The length of ranging preamble shall be equal to
12   or longer than RCP length of ranging channel. The details on the length of each part and its configurations are
13   FFS. To support large cell sizes, the ranging channel for non-synchronized AMSs can span multiple
14   concatenated subframes.
15

16   The physical resource of ranging channel for non-synchronized mobile stations is consecutive Nr_{sc} ranging
17   subcarriers (BW_{RCH-NS} Hz corresponding to continuous Nr_{ru} CRUs) and Nr_{sym} OFDMA symbols (T_{RCH-NS} sec).
18   As a default configuration, Nr_{sc} and Nr_{sym} are equal to [TBD] ranging subcarriers and N_{sym} OFDMA symbols,
19   respectively, where N_{sym} depends on the subframe type as described in section 11.6.
20

21   Figure 50 shows the default ranging channel structure spanning one subframe. The ranging preamble is repeated
22   as a single opportunity. A single preamble can be used by different non-synchronized AMS for increasing
23   ranging opportunities. When the preamble is repeated as a single opportunity, the second RCP can be omitted
24   for coverage extension. The guard subcarriers shall be reserved at the edge of non-synchronized ranging
25   channel(s) physical resource. CDM allows multiple AMSs to share the same ranging channel. The details of the
26   ranging structure within the localized resource are FFS. In the TDD mode, the GT can be omitted for extending
27   the length of RCP.

28

29
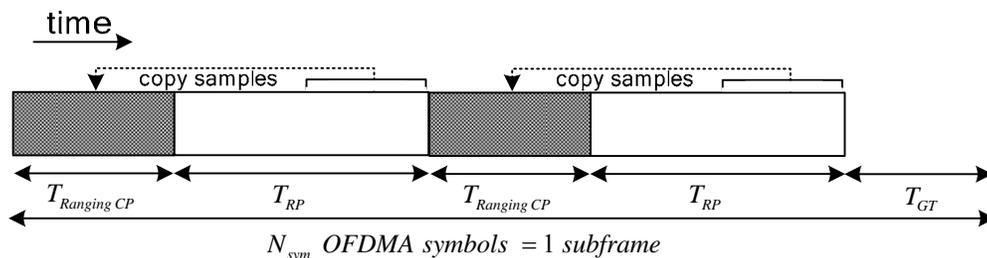
30   Figure 50 The default ranging structure for non-synchronized AMSs

31
32

33   Support for multi-antenna transmission is FFS. When multi-antenna transmission is supported by AMS, it can
34   be used to increase the ranging opportunity by spatial orthogonality.

35   *11.9.2.4.2   Ranging Channel for synchronized mobile stations*

36   The ranging channel for synchronized AMSs is used for periodic ranging. The use of the ranging channel for
37   synchronized AMSs for handover is FFS.

1   11.9.2.4.2.1 Multiplexing with other control channels and data channels

2   The UL ranging channel for synchronized AMSs starts at a configurable location with the configuration defined
3   in a DL broadcast control message.

4

5   The UL ranging channel for synchronized AMSs is FDM with other UL control channels and data channels.

6   11.9.2.4.2.2 PHY structure

7   The ranging sequence design and mapping to subcarriers are TBD.

8   11.9.2.5   Bandwidth Request Channel

9   Contention based or non-contention based random access is used to transmit bandwidth request information on
10 this control channel. Prioritized bandwidth requests are supported on the bandwidth request channel. The
11 mechanism for such prioritization is TBD.

12

13 The random access based bandwidth request procedure is described in Figure 51. A 5-step regular procedure
14 (step 1 to 5) or an optional 3-step quick access procedure (step 1,4 and 5) may be supported concurrently. Step
15 2 and 3 are used only in 5-step regular procedure. In step 1, AMS sends a bandwidth request indicator for quick
16 access that may indicate information such as AMS addressing and/or request size (FFS) and/or uplink transmit
17 power report (FFS), and/or QoS identifiers (FFS), and the ABS may allocate uplink grant based on certain
18 policy. The 5-step regular procedure is used independently or as a fallback mode for the 3-step bandwidth
19 request quick access procedure. The AMS may piggyback additional BW REQ information along with user data
20 during uplink transmission (step 5). In step 2 and step 4, ABS may send message to acknowledge the reception
21 status.

22
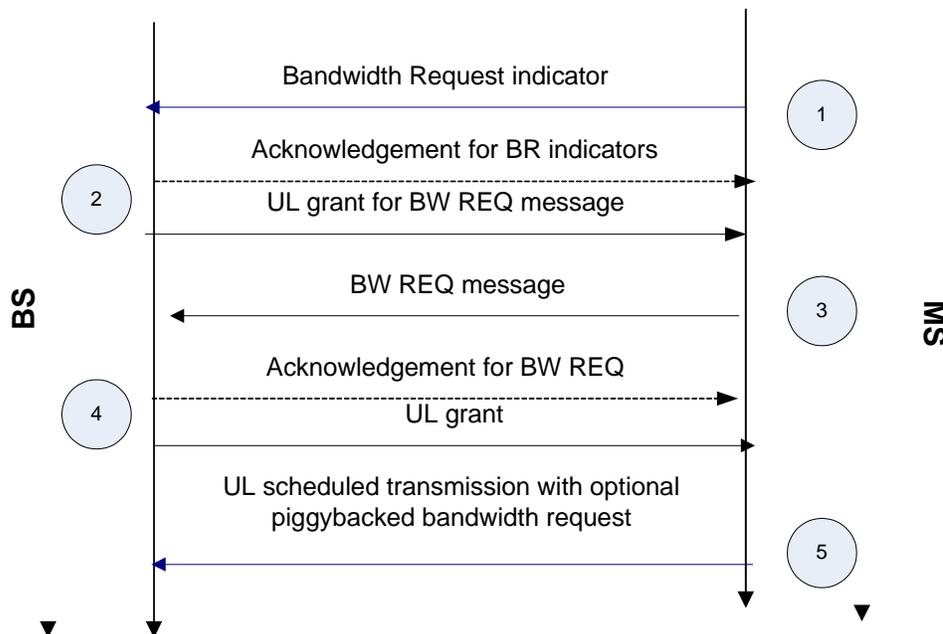
23   Figure 51 Bandwidth Request Procedure

24 *11.9.2.5.1   Multiplexing with other control channels and data channels*
25 The bandwidth request channel starts at a configurable location with the configuration defined in a DL

1 broadcast control message. The bandwidth request channel is FDM with other UL control and data channels.

2 *11.9.2.5.2   PHY structure*

3 The bandwidth request (BW REQ) channel contains resources for the AMS to send in BW REQ access
4 sequence at the step-1 of the bandwidth request procedure shown in Figure yyy.
5
6 A BW REQ tile is defined as 6 contiguous subcarriers by 6 OFDM symbols. Each BW REQ channel consists of
7 3 distributed BW-REQ tiles.
8

9 CDM allows multiple bandwidth request indicators to be transmitted on the same BW REQ channel. In
10 addition, multiple BW REQ channels may be allocated per subframe using FDM. The ranging sequence design
11 and mapping to subcarriers are TBD.

12 11.9.3 UL Inband Control Signaling

13 Uplink control information can be multiplexed with data on the UL data channels as MAC headers or MAC
14 management messages. Inband control signaling can contain information such as uplink bandwidth requests or
15 bandwidth assignment updates.

16 11.9.4 Mapping of UL control information to UL control channels

17
18   <Editors' Notes: This table needs to be updated as the mapping of UL control information to UL control
19   channels is developed.>
20

Information	Channel
Channel quality feedback	UL Fast Feedback Channel UL Sounding Channel
MIMO feedback	UL Fast Feedback Channel UL Sounding Channel
HARQ feedback	UL HARQ Feedback Channel
Synchronization	UL Ranging Channel
Bandwidth request	Bandwidth Request Channel UL Inband Control Signaling UL Fast Feedback Channel*(FFS)
E-MBS feedback	FFS

21

22 ** Transmission of BW REQ indicators on the UL Fast Feedback Channel is FFS*

23 *11.10 Power Control*

24 The power control scheme shall be supported for DL and UL based on the frame structure, DL/UL control
25 structures, and fractional frequency reuse (FFR).

26 11.10.1   Downlink Power Control

27 The ABS should be capable of controlling the transmit power per sub-frame and per user. With downlink power
28 control, each user-specific information or control information would be received by the AMS with the
29 controlled power level. DL unicast service control channel (USCCH) should be power controlled based on

AMS UL channel quality feedback.

The per pilot tone power and the per data tone power can jointly be adjusted for adaptive downlink power control. In the case of dedicated pilots this is done on a per user basis and in the case of common pilots this is done jointly for the users sharing the pilots.

Power Control in DL supports Single-User MIMO and Multi-User MIMO applications.

11.10.2   Uplink Power Control

Uplink power control shall be supported to compensate the path loss, shadowing, fast fading and implementation loss. Uplink power control should also be used to control inter-cell and intra-cell interference level. Uplink power control should also consider optimization of overall system performance and the reduction of battery consumption. Uplink power control consists of two different modes: open-loop power control (OLPC) and closed-loop power control (CLPC). ABS can transmit necessary information through control channel or message to AMSs to support uplink power control. The parameters of power control algorithm are optimized on system-wide basis by the ABS, and broadcasted periodically or trigged by events.

AMS can transmit necessary information through control channel or message to the ABS to support uplink power control. ABS can exchange necessary information with neighbor ABSs through backbone network to support uplink power control.

In high mobility scenarios, power control scheme may not be able to compensate the fast fading channel effect because of the very dynamic changes of the channel response. As a result, the power control shall be used to compensate the distance-dependent path loss, shadowing and implementation loss only.

Uplink power control should consider the transmission mode depending on the single- or multi-user support in the same allocated resource at the same time.

11.10.2.1   Open-loop Power Control (OLPC)

The OLPC compensates the channel variations and implementation loss without frequently interacting with ABS. The AMS can determine the transmit power based on the transmission parameters sent by the ABS, uplink channel transmission quality (e.g. indicated as ACK or NACK), downlink channel state information and interference knowledge obtained from downlink. Mobile stations use uplink open loop power control applying channel and interference knowledge to operate at optimum power settings.

Open-loop power control could provide a coarse initial power setting of the terminal at the beginning of a connection.

As for mitigating inter-cell interference, power control may consider serving ABS link target SINR and/or target Interference to other cells/sectors. In order to achieve target SINR, the serving ABS path-loss can be fully or partially compensated for a tradeoff between overall system throughput and cell edge performance. When considering target interference to other cells/sectors, mobile station TX power is controlled to generate less interference than the target interference levels. The compensation factor for each frequency partition and interference targets for each frequency partition are determined and broadcasted by ABS, with considerations including FFR pattern, cell loading and etc. More details can be referred to section 20.3.

11.10.2.2   Closed-loop Power Control (CLPC)

The CLPC compensates channel variation with power control commands from ABS. Base station measures uplink channel state information and interference information using uplink data and/or control channel transmissions and sends power control commands to AMSs while minimizing signaling overhead.

According to the power control command from ABS, AMS adjust its UL transmission power. The adjustment step of CLPC is FFS.

11.10.2.3   Coupling of Open Loop and Closed Loop Power Control

OLPC and CLPC can be combined into a unified power control procedure that uses both AMS measurements and ABS corrections for efficient operations. Closed loop power control is active during data transmission. Base Station measures uplink power using uplink data and/or control channel transmissions and sends control command. Moreover, the AMS could request to change the power control mode from open-loop to closed-loop and vice versa. The ABS could also send the unsolicited power control mode change command to the AMS.

11.11 Link Adaptation

This section introduces the Link Adaption schemes which will adaptively adjust radio link transmission formats in response to change of radio channel for both downlink and uplink.

11.11.1   DL Link Adaptation

11.11.1.1   Adaptive modulation and channel coding scheme

IEEE 802.16m shall support the adaptive modulation and channel coding (AMC) scheme for DL transmission. The serving ABS can adapt the modulation and coding scheme (MCS) level based on the DL channel quality indicator (CQI) reported from AMS. The definition of CQI is FFS. DL control channel transmit power should also be adapted based on DL channel quality indicator (CQI) reported from AMS.

11.11.2   UL Link Adaptation

11.11.2.1   Adaptive modulation and channel coding scheme

IEEE 802.16m shall support the adaptive modulation and channel coding (AMC) scheme for UL transmission. The serving ABS can adapt the modulation and coding scheme (MCS) level based on the UL channel quality estimation and the maximum transmission power by AMS. The definition of UL channel quality indicator is FFS. Note that the UL AMC may be integrated with UL power control and interference mitigation schemes to further achieve higher spectral efficiency. UL control channel (excluding initial ranging channel) transmit power should also be adapted based on UL power control.

11.11.3   Transmission Format

[Note: The content of this section shall not contradict with the transmission format determined by HARQ RG and PHY text RG]

IEEE 802.16m system should support the transmission format used in legacy system for the purpose of legacy support. IEEE 802.16m can have transmission format independent of legacy transmission format, and IEEE

1   802.16m transmission format is FFS.

2   *11.12 UL MIMO Transmission Scheme*

3   11.12.1   UL MIMO Architecture and Data Processing

4   The architecture of uplink MIMO on the transmitter side is illustrated in Figure 52.

5

6   In SU-MIMO, only one user is scheduled in one Resource Unit (RU). In MU-MIMO, multiple users can be
7   scheduled in one RU.

8   If vertical encoding is utilized, there is only one encoder block (one "layer"). If horizontal encoding is utilized,
9   there are multiple encoders (multiple "layers"). A "layer" is defined as a coding / modulation path fed to the
10   MIMO encoder as an input, and a "stream" is defined as each output of the MIMO encoder that is passed to the
11   beamformer / precoder.

12
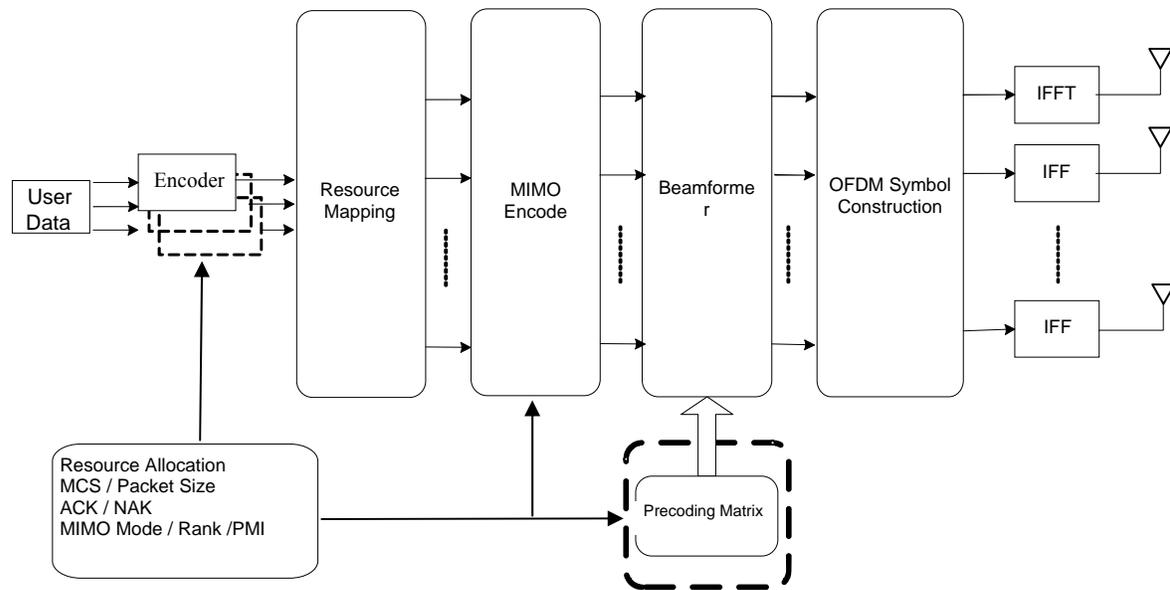
Figure 52 MIMO Architecture

1

2   The encoder block contains the channel encoder, interleaver, rate-matcher, and modulator for each layer.

3   The Resource Mapping block maps the modulated symbols to the corresponding time-frequency resources in
4   the allocated resource units (RUs).

5   The MIMO encoder block maps L ($\geq$ 1) layers onto N_S ($\geq$L) streams, which are fed to the precoding block.

6   The precoding block maps streams to antennas by generating the antenna-specific data symbols according to the
7   selected MIMO mode. Power balancing functionality in the beamformer/pre-coder block is FFS

8   The OFDM symbol construction block maps antenna-specific data to the OFDM symbol.

9   If only one transmit antenna is used, the codeword to stream mapping, MIMO encoding and precoder are
10   removed in Figure 52.

11   The ABS will schedule users to resource blocks and decides their MCS level, MIMO parameters (MIMO mode,
12   rank). PMI may be calculated at the ABS or AMS.

13   Decisions with regards to each resource allocation include:

14   • *Allocation type*: Whether the allocation in question should be transmitted with a distributed or localized
15   allocation

16   • *Single-user (SU) versus multi-user (MU) MIMO*: Whether the resource allocation should support a
17   single user or more than one user

18   • *MIMO Mode*: Which open-loop (OL) or closed-loop (CL) transmission scheme should be used for the
19   user(s) assigned to the resource allocation.

20   • *User grouping*: For MU-MIMO, which users are allocated to the resource allocation

21   • *Rank*: For the spatial multiplexing modes in SU-MIMO, the number of streams to be used for the user
22   allocated to the resource allocation.

23   • *MCS level per layer*: The modulation and coding rate to be used on each layer.

1 • *Boosting*: The power boosting values to be used on the data and pilot subcarriers.

2 • *Band selection*: If localized resource allocation is used, the frequency band location.

3

11.12.1.1 Antenna Configuration

5

6 The antenna configurations are denoted by (N_T, N_R) where N_T denotes the number of AMS transmit antennas
7 and N_R denotes the number of ABS receive antennas. The supported antenna configurations are $N_T = 1, 2,$ or 4
8 and $N_R \geq 2$. Support of $N_T = 3$ is FFS.

11.12.1.2 Layer to Stream Mapping

10

11 For open-loop spatial multiplexing and closed-loop SU-MIMO, the number of streams is $N_S \leq \min(N_T, N_R)$.
12 For open-loop transmit diversity modes, N_S depends on the STC schemes employed by the MIMO encoder and
13 its value is specified in 11.12.2.1.1.1. For SU-MIMO and MU-MIMO, Vertical encoding (SCW) is employed
14 [Support for MCW is FFS pending decisions in DL MIMO].

15 The layer to stream mapping depends on the MIMO scheme used. The mapping can be defined using the
16 following equation:

17 $$z = S(x), \text{ Equation 8}$$

18 where z is the output of the MIMO encoder, S(x) is an STC matrix, and x is the input layer vector.

11.12.1.3 Stream to Antenna Mapping

20

21 The stream to antenna mapping depends on the MIMO scheme used. The mapping can be defined using the
22 following equation

23 $$\mathbf{y} = \mathbf{P} \times z, \text{ Equation 9}$$

24 where P is a pre-coding matrixand z is the output of the MIMO encoder.

25

11.12.1.4 Resource mapping

27

28 The MIMO mode permutation for various MIMO schemes is supported in either Distributed or Localized
29 resource mapping.

30

11.12.1.5 Signaling support for MIMO

32

33 One or both of the following approaches for TDD and FDD will be supported:

1. Downlink reference signals. These reference signals (e.g. Common Pilots or a Midamble) shall support measurements at the AMS of the channel from the physical antennas of the ABS.

2. A downlink control channel may carry one or more of the following information computed based on uplink reference signals. Such information can include but is not limited to the following:

   a. MIMO mode

   b. Precoding matrix index (PMI)

In FDD systems and TDD systems, a base station may transmit the following uplink MIMO transmission parameters:

- Rank

- Sub-band selection

- MCS / packet size

- PMI

The uplink MIMO transmission parameters may be transmitted via a physical layer control channel or via a higher layer signaling message.

11.12.2   Transmission for Data Channels

11.12.2.1   Single-user MIMO

Single-user MIMO schemes are used to improve per-link performance in the uplink.

Both open-loop single-user MIMO and closed-loop single-user MIMO are supported for the antenna configurations specified in Section 11.12.1.1.

For open-loop single-user MIMO, both spatial multiplexing and transmit diversity schemes are supported.

For closed-loop single-user MIMO, codebook based precoding is supported for both TDD and FDD systems.

For closed-loop single-user MIMO, downlink pilot based precoding is supported for TDD systems.

As described in section 11.12.1, the overall structure of MIMO processing has two parts. The first part is the MIMO encoder and second part is the precoder.

The MIMO encoder is a batch processor that operates on M input symbols at a time. The input to the MIMO encoder is represented by an $M \times 1$ vector

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_M \end{bmatrix}, \text{Equation 10}$$

where s_i is the i-th input symbol within a batch. The output of the MIMO encoder is an $N_S \times N_F$ MIMO STC matrix $z = S(x)$, which serves as the input to the precoder. The output of the MIMO encoder is multiplied by $N_T \times N_S$ precoder, P. The output of the precoder is denoted by a matrix $N_T \times N_F$ matrix

$$\mathbf{y} = \mathrm{P} \times \mathrm{z} = \begin{bmatrix} y_{1,1} & y_{1,2} & \cdots & y_{1,N_F} \\ y_{2,1} & y_{2,2} & \cdots & y_{2,N_F} \\ \vdots & \vdots & \ddots & \vdots \\ y_{N_T,1} & y_{N_T,2} & \cdots & y_{N_T,N_F} \end{bmatrix}, \text{Equation 11}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers or symbols used to transmit the MIMO signals derived from the input vector x. For open-loop SU-MIMO, the rate of a mode is defined as $R = M / N_F$.

11.12.2.1.1   Open-loop SU-MIMO

A number of antenna configurations and transmission rates are supported in uplink open-loop SU-MIMO. Among them, 2Tx and 4Tx antennas with rate 1 transmission are defined as Transmit Diversity modes. The operation of these modes is specified in Section 11.12.2.1.1.1. The other modes, including 2Tx and 4Tx antennas with rate 2 transmission, 4Tx antennas with rate 3 transmission, and 4Tx antennas with rate 4 transmission, are defined as Spatial Multiplexing modes. The operation of these modes is specified in Section 11.12.2.1.1.2. The dimensions of the vectors and matrices for open-loop SU-MIMO are shown in the following table:

1   Table 5 Matrix dimensions for open-loop SU-MIMO modes

N_T	Rate	M	N_S	N_F
2	1	1	1	1
2	1	2	2	2
4	1	1	1	1
4	1	2	2	2
2	2	2	2	1
4	2	2	2	1
[4]	[2]	[4]	[4]	[2]
4	3	3	3	1
[4]	[3]	[6]	[4]	[2]
4	4	4	4	1

2   [Note : This table will be updated according to the decision of OL-SU-MIMO]

3

4   On a given subcarrier k, the precoding matrix P can be defined using the following equation:

5                 $P(k) = W(k)$, Equation 12

6   $W(k)$ is an $N_T \times N_S$ matrix, where N_T is the number of transmit antennas and N_S is the number of streams. The
7   matrix $W(k)$ is selected from a predefined unitary codebook, and changes every u subcarriers, and/or v OFDM
8   symbols. The matrix $W(k)$ can be identity matrix for 2Tx rate-2 and 4Tx rate-4 spatial multiplexing case. A
9   codebook is a unitary codebook if each of its matrices consists of columns of a unitary matrix. [The detailed
10   unitary codebook, and the parameter u are FFS.]

11   For OL SU-MIMO, the following schemes are FFS: 4Tx rate-1 SFBC + Antenna hopping, 4Tx rate-2 Double
12   SFBC + Antenna hopping, 4Tx rate-2 SM + Antenna hopping, 4Tx rate-3 SM + Antenna hopping, 4Tx rate-3
13   hybrid SM + SFBC + Antenna hopping.

14

15   11.12.2.1.1.1   Transmit Diversity

16

17   The following transmit diversity modes are supported for open-loop single-user MIMO:

18   •   2Tx rate-1: For $M = 2$, SFBC, and for $M = 1$, a rank-1 precoder

19   •   4Tx rate-1: For $M = 2$SFBC with precoder, and for $M = 1$, a rank-1 precoder

20

21   For the transmit diversity modes with M=1, the input to MIMO encoder is x=s_1, and the output of the MIMO
22   encoder is a scalar, z=x. Then the output of MIMO encoder is multiplied by $N_T \times 1$ matrix W, where W is
23   described in section 11.12.1.1.1.

24   For the transmit diversity modes with M=2, the input to the MIMO encoder is represented a 2×1 vector

$$\mathbf{X} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$$, Equation 13

The MIMO encoder generates the SFBC matrix.

$$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$, Equation 14

Then the output of the MIMO encoder is multiplied by $N_T \times 2$ matrix W, where W is described in section 11.12.1.1.1.

11.12.2.1.1.2   Spatial Multiplexing

The following spatial multiplexing modes are supported for open-loop single-user MIMO:

- Rate-2 spatial multiplexing modes:
    o   2Tx rate-2: rate 2 SM
    o   4Tx rate-2: rate 2 SM with precoding
- Rate-3 spatial multiplexing modes:
    o   4Tx rate-3: rate 3 SM with precoding
- Rate-4 spatial multiplexing modes:
    o   4Tx rate-4: rate 4 SM with precoding

For the rate-R spatial multiplexing modes, the input and the output of MIMO encoder is represented by an $R \times 1$ vector

$$\mathbf{X} = \mathbf{z} = \begin{bmatrix} s_1 \\ s_1 \\ \vdots \\ s_R \end{bmatrix}$$, Equation 15

Then the output of the MIMO encoder is multiplied by $N_T \times R$ matrix W, where W is described in section 11.12.1.1.1.

11.12.2.1.2   Closed-loop SU-MIMO

11.12.2.1.2.1   Precoding technique

In FDD and TDD systems, unitary codebook based precoding is supported. In this mode, a mobile station transmits a sounding pilot in the uplink to assist the uplink scheduling and precoder selection in the base station. The base station signals the resource allocation, MCS, rank, preferred precoder index, and packet size to the mobile station. The codebook on the uplink shall be the same or a subset of the SU-MIMO codebook in the downlink.

In TDD systems, downlink pilot based precoding is supported. In this mode, a mobile station transmits a

1 sounding pilot in the uplink to assist the uplink scheduling in the base station. The base station signals the
2 resource allocation, MCS, rank, and packet size to the mobile station. The mobile station chooses the precoder
3 based on the downlink CQI measurement pilot. The precoder is vendor-specific. It is FFS whether the mobile
4 station will feedback the rank and MCS to assist the uplink scheduling in the base station.

5 The support of transmit antenna selection is FFS.

11.12.2.1.3   *Uplink overhead channels for uplink SU-MIMO*

7 In FDD systems and TDD systems, a mobile station may transmit a sounding signal on the uplink.

11.12.2.2   Multi-user MIMO

9 Uplink Multi-user MIMO is supported to enable multiple AMSs spatially multiplexed on the same radio
10 resources (e.g. the same time and the same frequency allocation) for uplink transmission.

11 Both open-loop and closed-loop MU-MIMO are supported.

12 AMS precoding and/or beamforming is supported.

11.12.2.2.1   *Precoding techniques*

14 In MU-MIMO systems, the received signal of the *f*-th subcarrier at the ABS can be represents as follows.

$$\mathbf{r}_f = \sum_{j=1}^{K} \mathbf{H}_{j,f} \mathbf{V}_{j,f} \mathbf{x}_{j,f} + \mathbf{n}_f$$

15 , Equation 16

16 where *K* is the number of the allocated users on one resource unit, $H_{j,f}$ is the uplink channel response of the *f*-
17 th subcarrier from the *j*-th AMS to the ABS; $\mathbf{V}_{j,f}$ is the precoding matrix of the *f*-th subcarrier from the *j*-th
18 AMS; $\mathbf{x}_{j,f}$ is the transmit signal of the *f*-th subcarrier from the *j*-th AMS; and $\mathbf{n}_f$ is the noise of the *f*-th
19 subcarrier received at the ABS.

20 In FDD and TDD systems, unitary codebook based precoding is supported. In TDD systems, downlink pilot
21 based precoding is supported and the precoder is vendor-specific. The number of AMSs or streams to support
22 on the same time-frequency resource is also vendor/implementation specific. Different pilot patterns may be
23 employed on different streams. Specific pilot patterns are FFS. The maximum number of pilot streams is limited
24 to 4.

11.12.2.2.2   *Open-loop MU-MIMO*

26 AMSs with single transmit antenna are supported in open-loop MU-MIMO transmissions. AMSs with multiple
27 transmit antennas are also supported in open-loop MU-MIMO transmissions. Uplink open-loop SU-MIMO
28 spatial multiplexing modes of all rates, and transmit diversity mode with rank 1, are supported in open loop
29 MU-MIMO for AMSs with more than one transmit antenna.

30 The ABS is responsible for scheduling users and the number of transmitted streams such that it can
31 appropriately decode the received signals according to the number of transmitted streams and to the number of
32 receive antennas. The total number of transmitted streams shall not exceed the number of receive antennas at
33 the ABS.

11.12.2.2.3   *Closed-loop MU-MIMO*

1   Unitary codebook based precoding is supported for both TDD and FDD. In this case, the AMS shall follow
2   indication of PMI from the ABS in a downlink control channel and perform codebook based precoding.

3   Downlink pilot based precoding is supported in TDD systems. In this case, the precoder may be vendor-
4   dependent.

5   Non-unitary precoding is FFS.

6   *11.12.2.2.4   Unification with SU-MIMO*
7   Unified codebook for SU and MU may be supported.

8   *11.12.2.2.5   Feedback for MU-MIMO*
9   Feedback with an uplink sounding signal is supported.

11.13 Channel coding and HARQ

11 11.13.1   Channel coding

12 11.13.1.1   Block diagram
13
14
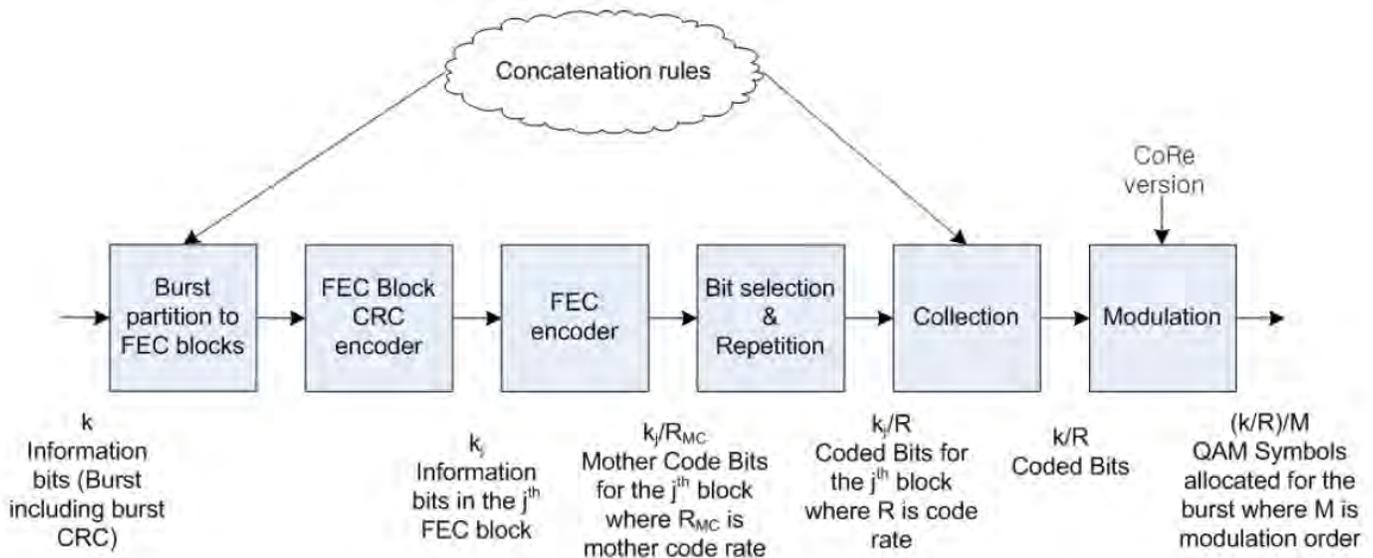
16   Figure 53 Channel coding block diagram

17 11.13.1.2   Partition into FEC blocks

18 A burst CRC is appended to a burst before the burst is further processed by burst partition. The burst CRC is
19 calculated based on all the bits in the burst.When the burst size exceeds the maximum FEC block size, the burst
20 is partitioned into a number of smaller blocks, each of which is encoded separately. If a burst is partitioned into
21 more than one FEC blocks, an FEC block CRC is appended to each FEC block before the FEC encoding. The
22 FEC block CRC of an FEC block is calculated based on all the bits in that FEC block. The maximum FEC

1   block size is 4800 bits. Concatenation rules are based on the number of information bits and do not depend on
2   the structure of the resource allocation (number
3   of LRUs and their size). The concatenation rules are FFS.

11.13.1.3   FEC encoding

5   IEEE 802.16m uses the CTC (convolutional turbo code) of code rate 1/3 defined in the IEEE 802.16e standard
6   where the CTC inner interleaver parameters for additional FEC block sizes are FFS while maintaining IEEE
7   802.16e CTC interleaver. The code rate of the "FEC Encoder" block in Figure 53 is termed mother code rate
8   (R_{MC}). The use of
9   other coding schemes like CC and LDPC are FFS.
10 The CTC scheme is extended to support additional FEC block sizes. FEC block sizes larger than the legacy
11 ones
12 are supported. The FEC block sizes are FFS and they are independent of the transmission format, including
13 code rate, modulation order, and resource allocation. Further, the FEC block sizes are regularly increased with
14 pre-determined block size resolutions. The FEC block sizes which are multiple of 7 shall be removed for the
15 tail-biting encoding structure.
16 The encoder block depicted in Figure 53 includes the sub-block interleavers. The interleaving details
17 are FFS.

11.13.1.4   Bit selection and repetition

19 Bit selection and repetition are used in 802.16m to achieve rate matching. Bit selection adapts the number of
20 coded bits to the size of the resource allocation (in QAM symbols) which may vary depending on the LRU and
21 subframe type. The total subcarriers in the allocated LRU are segmented to each FEC block. Mother Code Bits,
22 the total number of information and parity bits generated by FEC encoder, are considered as a maximum size of
23 circular buffer. In case that the size of the circular buffer N_{buffer} is smaller than the number of Mother Code Bits,
24 the first N_{buffer} bits of Mother Code Bits are considered as selected bits. Repetition is performed when the
25 number of transmitted bits is larger than the number of selected bits. The selection of coded bits is done
26 cyclically over the buffer.

11.13.1.5   Modulation

28 Modulation constellations of QPSK, 16 QAM, and 64 QAM are supported as defined for the legacy system.
29 The
30 mapping of bits to the constellation point depends on the constellation-rearrangement (CoRe) version used for
31 HARQ re-transmission as described in Section 11.13.2.2 and may depend on the MIMO stream. QAM
32 Symbols are mapped to the input of the MIMO encoder.
33

11.13.2   HARQ

11.13.2.1   HARQ type

36 Incremental redundancy Hybrid-ARQ (HARQ IR) is used in 802.16m by determining the starting position of
37 the bit selection for HARQ retransmissions. Chase Combining is supported and treated as a special case of IR.
38 The rule for determining the starting position is FFS.
39

11.13.2.2   Bit re-arrangement

41 Bit re-arrangement (BitRe) is supported in 802.16m. Bit re-arrangement includes a bit-level interleaver and an

1 inverter. For each transmitted burst, the BitRe-version is selected by the transmission number of this burst. The
2 specific bit-level interleaver and invreter mechanism is FFS.
3

11.13.2.3   Adaptive HARQ

5 The resource allocation and transmission formats in each retransmission in downlink can be adaptive
6 according to control signaling. The resource allocation in each retransmission in uplink can be fixed or
7 adaptive according to control signaling. The support of adaptive HARQ and the specific mechanism for
8 adaptive HARQ are FFS,
9 while the reduction of signaling overhead should be considered as an important criterion for those studies.

11.13.2.4   Exploitation of frequency diversity

11 In HARQ re-transmissions, the bits or symbols can be transmitted in a different order to exploit the frequency
12 diversity of the channel. The mechanism is FFS.

11.13.2.5   MIMO HARQ

14 For HARQ subpacket retransmission, the mapping of bits or modulated symbols to spatial streams may be
15 applied to exploit spatial diversity with given mapping pattern, depending on the type of IR. In this case, the
16 predefined set of mapping patterns should be known to both transmitter and receiver. The specific mechanism is
17 FFS and it should be determined with the consideration of MIMO architecture and data processing.

11.13.2.6   HARQ feedback

19 A basic ACK/NAK channel to transmit 1-bit feedback is supported.
20
21 An enhanced ACK/NAK control channel with some additional information is FFS.

12 Inter-Radio Access Technology Functions

13 Support for Location Based Services

24 The IEEE 802.16m system supports MAC and PHY features needed for accurate and fast estimation and
25 reporting of AMS location. Such location capabilities defined in 802.16m when combined with appropriate
26 network level support allows enhanced location based services as well as emergency location services, such as
27 E911calls.
28 In addition to native location capabilities the system also supports additional timing and frequency parameters
29 needed to assist GPS or similar satellite based location solutions.
30 This section described enhancements to MAC and PHY features to support Location Based Service.

13.1 Location Based Services Overview

32 IEEE 802.16m shall support Location Based Services. LBS include all services that make use of the AMS
33 location.
34
35 Location determination can be made by either:
36   • AMS managed location, in which the mobile measures, calculates and uses the location information
37   with minimal interaction with the network
38   • Network managed location, in which the location is determined by the network and the network reports
39   the location to requesting entities. The location process may be triggered by the network or the

application on the AMS.

IEEE 802.16m supports basic MAC and PHY features to support both use cases, with or without use of GPS or equivalent satellite based location solution.

The service can be provided to:
- The end user providing the AMS with value added services
- External emergency or lawful interception services.
- The network operator using the location information for network operation and optimization

IEEE 802.16m system entities will support LBS applications by providing them with:
- Relevant measurements, periodic or event driven
- Resources (time and frequency slots) to perform the relevant measurements
- Communication channels (unicast and broadcast), as allocated to higher layer applications of any type.

It should be emphasized that the actual implementation of the LBS application or method of location determination is out of the scope of IEEE 802.16m.

In order to enhance location based service, AMS should send report location-related information which includes the location information or the measurement for determining location in response to the request of ABS or according to the location information report condition to measure its location. In addition, LBS is supported for AMS in connected state as well as idle state. For the connected state, AMS can report location information when it is needed. For the idle state, AMS should perform location information reporting when it is paged, and report location information when it is needed.

The AMS positioning is performed by using measurements methods, such as TDOA, TOA, AOA, and etc., whose relevant location-related parameters may includes cell-ID, RSSI, CINR, RD, RTD, angle, and Spatial Chanel Information. These parameters are exchanged between the AMS and its serving/attached and neighboring ABSs/ARSs. These measurements of these parameters are extracted by processing DL and/or UL signals at the AMS and ABSs, respectively. Positioning algorithms that depend on such measurements have certain performance tradeoffs in terms of positioning accuracy, latency, and signaling overhead. Two or more measurements can be utilized to provide higher accuracy estimate of the AMS position.

13.1.1 LBS Network Reference Model

LBS architecture is a functional model consistent with the WiMAX network reference model (NRM) [10]. LBS architecture is shown in Figure 54. The architecture has support for
- Both periodic and event based location information services
- Both user initiated and network initiated location procedure with the same functional decomposition
- Basic cell/sector based location information services
- Enhanced sub-sector location based on mobile based or network based calculation
- GPS capability detection and utilization when supported by the AMS

The end to end LBS system architecture is out of the scope of IEEE 802.16m. However the standard supports underlying MAC and PHY features to allow location related measurement and signaling both in the control

1 plane and in the user plane.
2

3
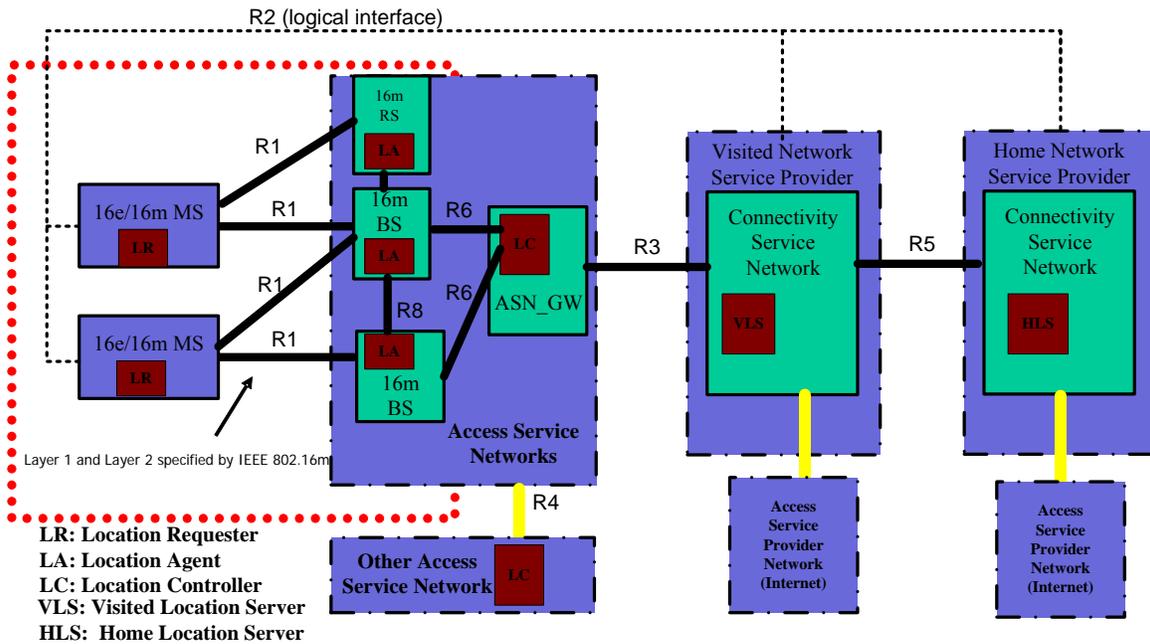
4 Figure 54 LBS Network Reference Model

5
6

7 **13.1.2 LBS Applications**

8 A user is subscribed to a set of LBS applications. Applications differ by the type of service they provide, the
9 location determination technique they use, and where the LBS system elements reside. An LBS application
10 shall be defined by the following:
11   1.   List of AMS's subscribed to it.
12   2.   Type of 802.16m PHY measurements it needs, by which update rate and as a response to which
13   event.
14   3.   What kind of communication channels it needs (unicast downlink and/or uplink, multicast or
15   broadcast)
16   4.   QoS requirement (priority, data rate, latency) for each requested uplink and downlink channel.
17
18

19 *13.2 Location Determination methods for LBS*

20 **13.2.1 GPS-Based Method**

21

22 An AMS, which is equipped with GPS capability can utilize IEEE 802.16m MAC and PHY features to estimate
23 its location when GPS is not available, e.g. indoors, or be able to faster and more accurately acquire GPS
24 signals for location determination.
25 The network shall make the GPS assistance data, including GPS Almanac data and Ephemeris data, available

126

1 through broadcast and/or unicast air interface messages to AMS's. The delivery of GPS assistance data from the
2 network to AMS's can be realized by enhanced GPS broadcast and/or unicast messages and enhanced LBS
3 management messages.
4 Enhanced GPS broadcast and/or unicast messages, containing GPS Ephemeris data and GPS Almanac data, are
5 the messages assisting AMS's to do GPS based positioning.
6
7 Assisted GPS (A-GPS) Method
8 Assisted GPS (A-GPS), consisting of the integrated GPS receiver and network components, assists a GPS
9 device to speed up GPS receiver "cold startup" procedure. In order to achieve this goal, the ABS shall provide
10 the 16m AMS with the GPS Almanac and Ephemeris information downloaded from the GPS satellites. By
11 having accurate, surveyed coordinates for the cell site towers, the ABS can also provide better knowledge of
12 ionospheric conditions and other errors affecting the GPS signal than the device alone, enabling more precise
13 calculation of position.

14 ## 13.2.2   Non-GPS-Based Method
15
16 Non-GPS-Based methods rely on the role of the serving and neighboring ABSs/ARSs. LBS related
17 measurements may be supported in the DL and UL as follows.
18
19   *a) Location Measurements in Downlink*
20 In DL, the AMS receives signals which are existing signals (e.g. preamble sequence) or new signals designed
21 specifically for the LBS measurements, if it is needed to meet the requirement from the serving/attached ABS
22 and multiple neighboring ABSs/ARSs. The ABSs/ARSs are able to coordinate transmission of their sequences
23 using different time slots or different OFDM sub-carriers. The AMS accurately calculates the required
24 measurements, even in the presence of multi-path channel and heavy interference environment, and then
25 estimates its location accordingly.
26
27   *b) Location Measurements in Uplink*
28 Various approaches can be utilized at the serving/attached ABS/ARS to locate the AMS such as TOA and
29 AOA. These measurements are supported via existing UL transmissions (e.g. ranging sequence) or new signals
30 designed specifically for the LBS measurements.
31
32 The ARSs support a set of PHY and MAC features to assist serving ABS in LBS and may be used in
33 cooperation with serving ABS and other ARS to make LBS measurements. In addition to TDOA measurements
34 the ARSs support Round Trip Delay(RTD)/Time of arrival (TOA) measurements using DL and UL frame
35 resources, which may be designated for to LBS purposes. Optionally ARSs may perform AOA measurements.

36 ## 13.2.3   Hybrid Methods
37
38 Hybrid method combines at least two kinds of measurement methods to perform location estimation.
39 To improve the LBS performance, different types of downlink and uplink measurements such as RSSI, TDOA,
40 TOA, and AOA can be combined. A combination metric needs to be considered, which takes into consideration
41 the contributions from the utilized methods. Details of the considered DL/UL LBS measurements methods
42 along with the combining metrics are FFS.
43 The specific location algorithms or how IEEE 802.16m based metrics can be combined with GPS to improve
44 location is outside the scope of this standard.
45
46 For the combination methods, measurement-based scheme, such as TDOA and TOA, can be consolidated to

1   estimate AMS's position.

2   ### 13.2.3.1   AMS assisted positioning

3

4   Hybrid method may be implemented by combination of measurement-based methods or AMS assisted
5   positioning method.

6

7   For AMS assisted positioning method, the GPS position (if capable) and ranging signal measurements reported
8   from assisting AMSs, and ranging signal measurements at ABSs (such as TDOA and AOA) are utilized to
9   determine the location of a positioned AMS. AMS assisted positioning is optional for AMS. The possibility of a
10   GPS capable AMS assisting ABS to locate the non-GPS AMS's is FFS.
11   If AMS is aware of its current location and has received ranging signal from positioned AMS above a quality
12   threshold, then the AMS should report to ABS with information related to the signal received from the
13   positioned AMS, and its own GPS location.
14

15   ## 13.3 Reporting methods for LBS

16   For E911 services, the AMS location can be reported to ABS through UL inband signaling. Other reporting
17   methods are FFS.

18   ### 13.3.1   Reporting Types

19   According to the measurement methods of LBS, some location information or some LBS measurement
20   parameters such as CINR/RSSI/RD/RTD/Angle is transmitted to the ABS to measure the location.

21   ### 13.3.2   Reporting Mode

22

23   An AMS supported LBS shall report location information if any of following location information reporting
24   condition is met.
25   -Timer based location information reporting
26   -Threshold based location information reporting
27

28   An LBS-capable AMS should support the following reporting modes: per-request, periodic, and event-triggered
29   reporting modes. The event-triggered reporting mode is a variation of the periodic reporting mode with
30   reporting criteria, such as a moving distance threshold and updated timer expiration. For example, the AMS will
31   report the location when the distance between the current location and the last reported location beyond the
32   "moving distance threshold".

33   ## 13.4 LBS operation

34   16m utilizes protocols carried in user plane for transferring location information (e.g. GPS assistance, position
35   information, WiMAX measurements) between an AMS and the location server. 16m may utilize a service flow,
36   with needed QoS, for transferring location information.
37

38   ### 13.4.1 Connected State

39   The system should be able to locate the mobile when in connected state.
40

41   For connected state, LBS can be initiated by the ABS or the AMS. LBS message contains some LBS

information, which may include identifier of the AMS, and indicator of LBS measurement method. Other associated parameters for LBS measurement are FFS. Indicator of LBS measurement is used to instruct the ABS and/or the AMS to perform LBS measurement and report location information.

13.4.2 Idle State

The system should be able to locate the mobile when in idle state. In some use cases the AMS may not need to enter the connected state to be located. The ABS may use paging or other network initiated multicast signaling to initiate a location process on the AMS.

The AMS in idle mode can receive a paging message which may include identifier of the AMS and indicator for LBS measurement method; other associated parameters for LBS measurement are FFS. AMS should perform LBS measurement with attached ABS and neighbor ABSs in terms of LBS measurement method that indicated by paging message for the AMS. When AMS gets LBS measurement parameters, AMS may report them as location information to attached ABS.

14 Support for Enhanced Multicast Broadcast Service

14.1 General Concepts

Enhanced multicast and broadcast services (E-MBS) are point-to-multipoint communication systems where data packets are transmitted simultaneously from a single source to multiple destinations. The term broadcast refers to the ability to deliver contents to all users. Multicast, on the other hand, refers to contents that are directed to a specific group of users that have the associated subscription for receiving such services.

Both Static and Dynamic Multicast are supported.

The E-MBS content is transmitted over an area identified as a zone. An E-MBS zone is a collection of ABSs transmitting the same content. The contents are identified by the same identifiers (IDs). Each ABS capable of E-MBS service can belong to one or more E-MBS zones. Each E-MBS Zone is identified by a unique E-MBS_Zone ID.

An AMS can continue to receive the E-MBS within the E-MBS zone in Connected State or Idle State. The definitions of E-MBS service area and E-MBS region are FFS.

A ABS may provide E-MBS services belonging to different MBS zones (i.e. the ABS locates in the overlapping MBS zone area).

MBS data bursts may be transmitted in terms of several sub-packets, and these sub-packets may be transmitted in differeent subframe and to allow AMSs combining but without any acknowledgement from AMSs.

14.1.1 Relationship to Basic MBS in Reference System

1 The basic concepts and procedures in EMBS are consistent with MBS definitions in 802.16REV2, but the
2 concepts have been adapted to the new MAC and PHY structure.
3 EMBS refers to a data service offered on multicast connection using specific (E-)MBS features in MAC and
4 PHY to improve performance and operation in power saving modes. A ABS may allocate simple multicast
5 connections without using E-MBS features.
6
7

8 ## 14.2 E-MBS Transmission Modes

9

10 Two types of access to E-MBS may be supported: single-ABS access and multi-ABS access. Single-ABS
11 access is implemented over multicast and broadcast transport connections within one ABS, while multi-ABS
12 access is implemented by transmitting data from service flow(s) over multiple ABSs. AMS may support both
13 single-ABS and multi-ABS access. E-MBS service may be delivered either via a dedicated carrier or a mixed
14 unicast-broadcast carrier.

15 ### 14.2.1 Non-Macro Diversity Support

16
17 Non-macro diversity support is provided by frame level coordination in which the transmission of data across
18 ABS's in an E-MBS Zone is not synchronized at the symbol level. However, such transmissions are
19 coordinated to be in the same frame. This MBS transmission mode is supported when macro-diversity is not
20 feasible.
21

22 ### 14.2.2 Macro Diversity Support

23
24 The macro diversity operating mode for E-MBS shall be as a wide-area multi-cell multicast broadcast single
25 frequency network (MBSFN). A single-frequency network (SFN) operation can be realized for broadcast traffic
26 transmitted using OFDMA from multiple cells with timing errors within the cyclic prefix length. An MBS zone
27 with SFN is illustrated is illustrated in Figure 55.
28
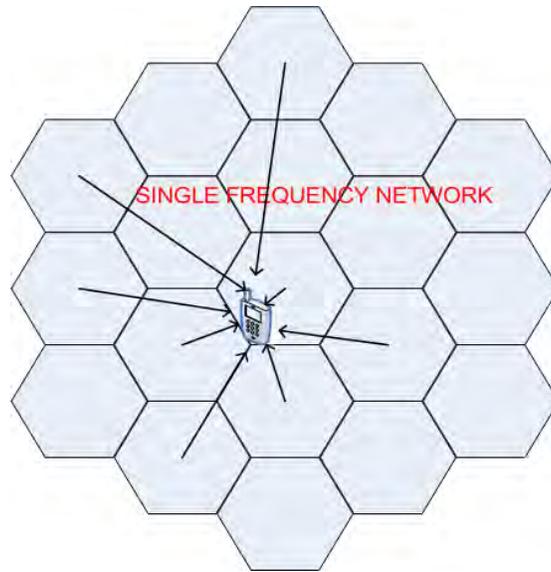
Figure 55 A single frequency network where multiple ABSs transmit the same content.

An multi-ABS MBS in which the transmission of data across ABS's in an E-MBS Zone are synchronized at the symbol level allowing Macro-diversity combining of signals and higher cell edge performance. It requires the multiple ABS participating in the same Multi-ABS-MBS service to be synchronized in the transmissions of common multicast/broadcast data. Each ABS shall transmit the same PDUs, using the same transmission mechanism (symbol, subchannel, modulation, and etc.) at the same time.

14.3 E-MBS Operation

14.3.1 E-MBS Service Initiation, Acquisition, and Update

MBS flows are initiated by the ABS but may be requested by AMS. For Static Multicast the service may be initiated without request from a user. The AMS may join an ongoing service and request for initiation of a new service.
Information about available MBS services and their changes may be. The ABS can notify users in power saving modes of such changes to ensure service consistency.

14.3.2 E-MBS Operation in Connected State

Details on E-MBS Operation in Connected State is FFS.

14.3.3 E-MBS Operation in Idle State

An idle AMS is notified for the commencement of a certain E-MBS service the AMS has subscribed to including emergency broadcast. Not all E-MBS services require notification.
Details on E-MBS Operation in Idle State is FFS.

1 14.3.4 E-MBS Operation with HARQ retransmission

2 Details on E-MBS Operation with HARQ retransmission is FFS.

3

4 14.3.5 E-MBS Operation with Link Adaptation

5 Details on E-MBS Operation with Link Adaptation is FFS.

6 *14.4 E-MBS Protocol Features and Functions*

7

8 14.4.1 E-MBS PHY Support

9 14.4.1.1   Multiplexing of Unicast Data and E-MBS Data

10 E-MBS service can be time domain multiplexed (TDM) with unicast service by sub-frames. The MBS sub-
11 frames are put contiguously at the end of DL sub-frames.

12

13 Both TDM and FDM are supported for the mixed unicast and E-MBS. E-MBS service is time domain
14 multiplexed (TDM) with unicast service at the sub-frame level. E-MBS service is frequency domain
15 multiplexed at the LRU level.

16

17

18 14.4.1.2   Enhanced Schemes

19

20 14.4.1.3   Frame and Control Channel Structure

21 In unicast/multicast mixed carrier, EMBS uses the same frame structure used for unicast carrier. The EMBS
22 data is multiplexed with Unicast traffic. The SBCH indicates E-MBS region which may span over multiple
23 subframes. If a super-frame contains MBS subframes, MBS sub-frames are allocated with fixed pattern within
24 super-frame. The pattern may vary between super-frames. The Figure 56 below illustrates the frame structure
25 when MBS subframes are present in super-frames.
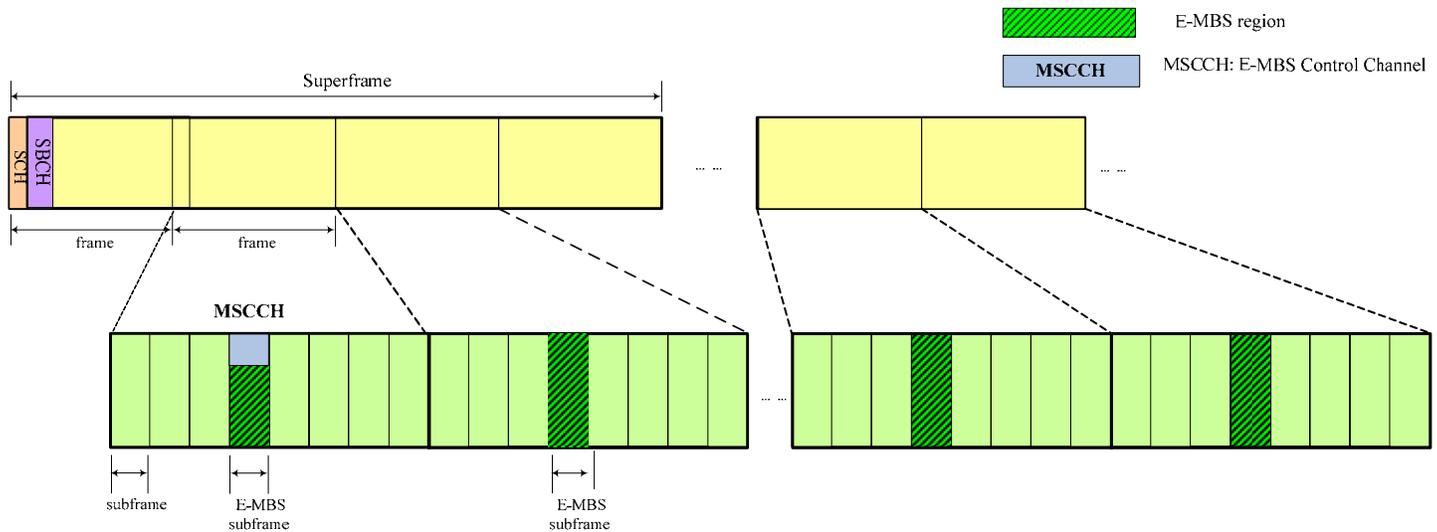
26

27

28

Figure 56 Illustration for EMBS Channel support in Mixed Broadcast/Unicast Carrier

For unicast/multicast mixed carrier, the control channel design to support E-MBS is as follows
- It is FFS to use BCH or reserved SCH to indicate if a carrier is broadcast only or cannot be used for AMS entry to the network.
- SBCH
    - Provides pointers to help AMS find the location of the MSCCH.

- *MSCCH (MBS Service Control Channel)*
    - *Indicates physical layer parameters of MBS data channels for each service using joint coding.*
    - *MSCCH is transmitted at the beginning of MBS resource during one MBS transmission cycle.*
    - *MSCCH can point to burst locations in up to N super-frames later within the transmission cycle*

The control channel structure for an EMBS dedicated carrier is FFS.

The use of greater FFT size or CP length to support large call radius in dedicated carrier is FFS.

14.4.2 E-MBS MAC Support

14.4.2.1   E-MBS Zone Configuration

Each E-MBS zone has a unique zone ID. All the ABSs in an E-MBS zone shall broadcast the same E-MBS zone ID. If a ABS belongs to several E-MBS zones, it shall broadcast all the zone IDs with which it is associated.

### 14.4.2.2   E-MBS Scheduling Interval

E-MBS scheduling interval can span several super-frames. The length of the E-MBS scheduling interval may be constrained by the SRD channel switching time requirements.
For each MBS Zone there is an MBS Scheduling Interval (MSI), which refers to a number of successive frames

1   for which the access network may schedule traffic for the streams associated with the MBS Zone prior to the
2   start of the interval. The length of this interval depends on the particular use case of MBS. An MBS MAP
3   message addresses the mapping of MBS data associated with an MBS Zone for an entire MSI.
4   The MBS MAP message is structured such that it may be used to efficiently define multiple transmission
5   instances for a given stream within an MSI.
6

7   14.4.2.3   Mapping of E-MBS Data for Power Saving

8   An AMS decodes only a specific EMBS data burst during the majority of the time when the user is watching a
9   certain EMBS program. The AMS wakes up in each E-MBS Scheduling interval in order to decode the data
10 burst (see Figure 57). This results in the maximum power saving in EMBS service.
11
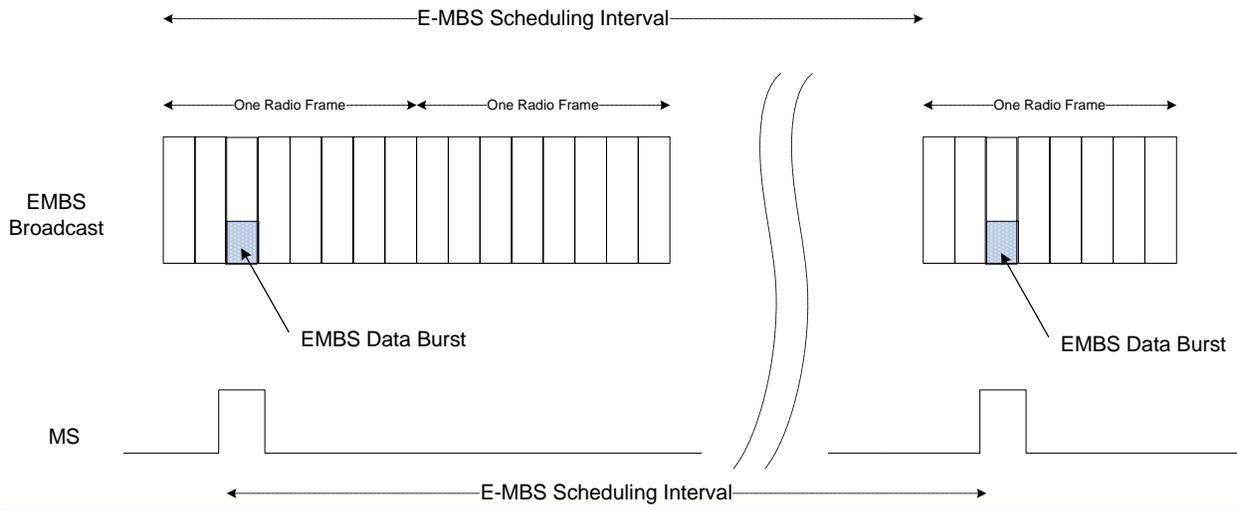
13   Figure 57 EMBS Power Saving

14
15

16   14.4.2.4   E-MBS Mobility Management

17   When an AMS moves across the MBS zone boundaries, it can continue to receive MBS data from the ABS in
18   Connected State or Idle State. In Connected State, the AMS performs handover procedure for MBS.
19
20   During MBS zone transition in Idle State, the AMS may transit to Connected State to perform handover or it
21   may initiate MBS location update process for the purpose of MBS zone transition.
22

23   14.4.3 E-MBS CS Layer Support

24

25   14.4.3.1   Header Compression

26

14.4.3.2   Forward Error Correction

The Convergence Sub-Layer provides forward error correction (FEC), which complements the FEC provider by the PHY layer. The FEC provided by the convergence sub-layer takes advantage of extended time diversity and deeper interleaving in order to achieve adequate IP packet error rates.

14.5 E-MBS Transmission on Dedicated Broadcast Carriers

E-MBS could be transmitted in a dedicated carrier, or a unicast/EMBS mixed carrier.

14.5.1 Deployment mode for E-MBS transmission on dedicated broadcast carrier

IEEE 802.16m system may designate the carriers for E-MBS only. The multi-carrier AMS which is capable of processing multiple radio carriers at the same time may perform normal data communication at one carrier while receiving the E-MBS content over another carrier.

14.5.2 E-MBS Dedicated Carrier

EMBS data can be transmitted in broadcast only carrier. In this case a fully configured unicast or unicast/E-MBS mixed carrier could be used to provide signaling support needed for service initiation, and additions and terminations as well as other service and security related exchanges between the AMS and the ABS or the MBS servers in the network. The Broadcast Only carrier, may be transmitted at higher power and be optimized for improve performance.
The multi-carrier AMS which is capable of processing multiple radio carriers at the same time may perform normal data communication at one carrier while receiving E-MBS data over another carrier. It may also receive multiple E-MBS streams from multiple carriers simultaneously.

Transmission of indications to all AMSs or those in the same paging Group on the E-MBS Dedicated Carrier is FFS.
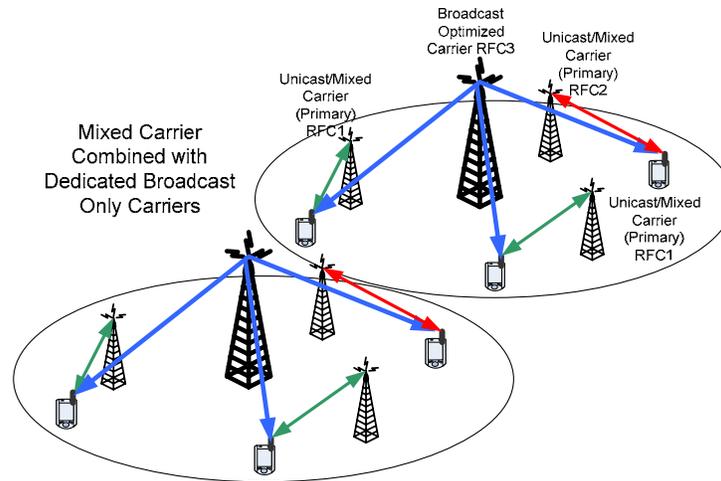
Figure 58 E-MBS Deployment with on Broadcast Only and Mixed Carrier

14.5.2.1   Channel coding

FEC with large block size should be supported in E-MBS. LDPC code support is FFS.

15 Support for multi-hop relay

16 Solutions for Co-deployment and Co-existence

17 Support for Femtocell

18   Support for Self-organization

SON functions are intended for ABSs (e.g. macro, relay, Femto) to automate the configuration of ABS parameters and to optimize the network performance, coverage, and capacity. The scope of SON is limited to the measurement and reporting of air interface performance metrics from AMS / ABS, and the subsequent adjustments of ABS parameters.

18.1 Self-configuration

Self-configuration is the process of initializing ABSs automatically with minimum human intervention.

18.2 Self-optimization

Self-optimization is the process of analyzing the reported SON measurements from the ABS / AMS and utilizing them to fine-tuning the ABS parameters in order to optimize the network performance, coverage, and capacity.

19 Support for Multi-carrier Operation

19.1 Multi-carrier operation Principles

The following is common in all modes of multi-carrier operation:

- The system defines N standalone fully configured RF carriers as defined in section 11.7.4, each fully configured with all synchronization, broadcast, multicast and unicast control signaling channels. Each AMS in the cell is connected to and its state is controlled through only one of the fully configured carriers as its primary carrier.

- The system defines M (M >= 0) partially configured RF carriers as defined in section 11.7.4, each configured with the essential control channel configuration to support traffic exchanges during multicarrier operation.

- In the multicarrier operation a common MAC can utilize radio resources in one or more of the secondary carriers, while maintaining full control of AMS mobility, state and context through the primary carrier.

- Some information about the secondary carriers including their presence and location shall be made available to the AMS through the primary carriers. The primary carrier may also provide AMS the information about the configuration of the secondary carrier.

- The resource allocation to a AMS can span across a primary and multiple secondary RF carriers. Link adaptation feedback mechanisms should incorporate measurements relevant to both primary and secondary carriers.

- A multi-carrier system may assign secondary carriers to an AMS in the downlink and/or uplink asymmetrically based on system load (i.e., for static/dynamic load balancing), peak data rate, or QoS demand.

- In addition to its primary RF carrier data transfer between a ABS and itself, an AMS may dynamically utilize resources across multiple secondary RF carriers. Multiple AMSs, each with a different primary RF carrier may also share the same secondary carrier.

- The multiple carriers may be in different parts of the same spectrum block or in non-contiguous spectrum blocks. The use of non-contiguous spectrum blocks may require additional control information on the secondary carriers.
- Each AMS will consider only one fully configured RF carrier to be its primary carrier in a cell. A secondary carrier for an AMS, if fully configured, may serve as primary carrier for other AMSs.

There are two scenarios to multicarrier deployment.

Scenario 1: All carriers in the system are fully configured to operate standalone and may support some users as their primary carrier and others as their secondary carrier. AMS can, in addition, access on secondary channels for throughput improvement, etc.

Scenario 2: In addition to fully configured and standalone RF carriers the system also utilizes additional partially configured supplementary radio carriers optimized as data pipes for certain services or traffic types using limited control signaling capability. Such supplementary carriers may be used only in conjunction with a primary carrier and cannot operate standalone to offer IEEE 802.16m services for a AMS.

In multi-carrier operation, an AMS can access multiple carriers. The following multi-carrier operations are identified:

- Carrier aggregation

1   o AMS shall always maintain its physical layer connection and monitor the control
2   information on the primary carrier.

3 • Carrier switching
4   o AMS can switch its physical layer connection from the primary to the secondary carrier per
5   ABS's instruction. When the AMS is connected to the secondary carrier, the AMS doesn't
6   need to maintain its physical layer connection to the primary carrier.
7   o This mode may be used for the cases of single radio AMS.
8

19.2 Subcarrier Alignment for Utilization of Guard Subcarriers of Adjacent Frequency Channels

11 When multiple contiguous frequency channels are available, the guard sub-carriers between contiguous
12 frequency channels can be utilized for data transmission only if the sub-carriers from adjacent frequency
13 channels are well aligned. In order to align those sub-carriers from adjacent frequency channel, a frequency
14 offset ($\Delta f'$) can be applied to its FA. The basic idea is shown by the example in Figure 59.
15
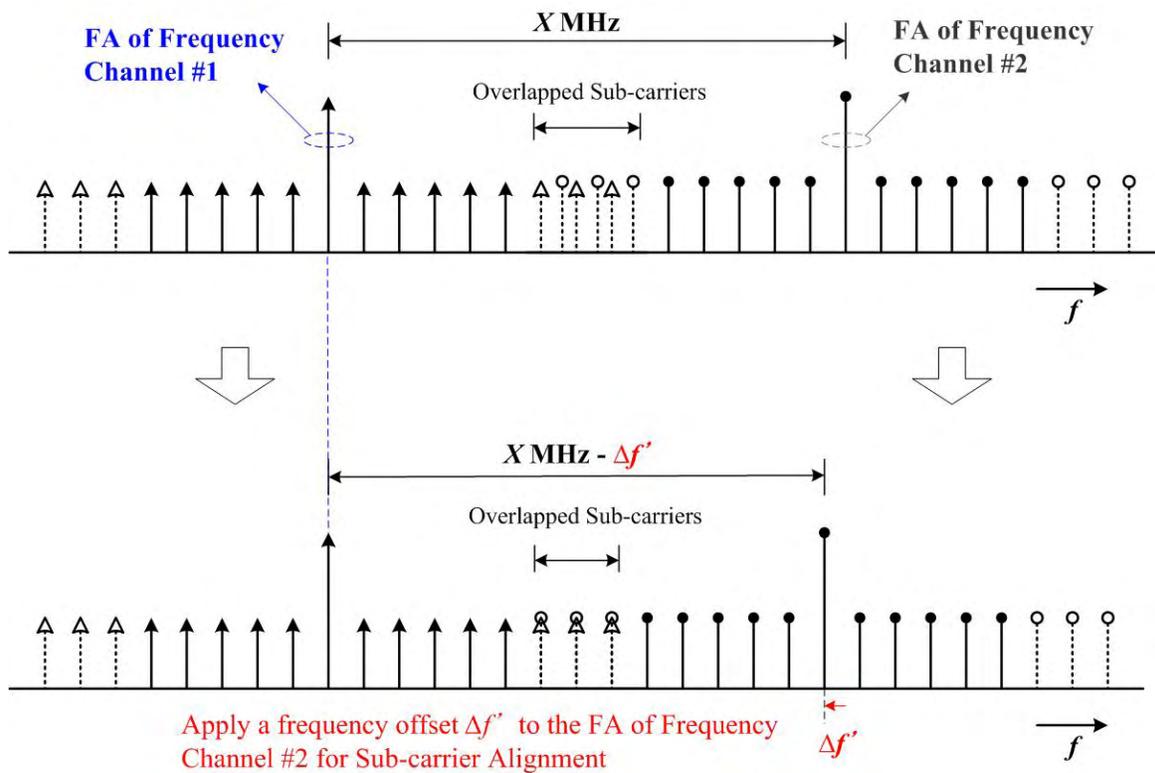
Figure 59 Sub-carrier alignment by applying a fraction of sub-carrier spacing to the FA of adjacent frequency channel

19   In order to utilize the guard sub-carrier for data transmission, the information of the available guard sub-
20 carriers eligible for data transmission shall be sent to AMS. This information shall include the numbers of
21 available sub-carriers in upper side and in lower side with respect to the DC sub-carrier of carrier.

1   *19.3 PHY Aspects of OFDMA Multi-carrier Operation*

2

3   Physical layer to support OFDMA multi-carrier operation is shown in Figure 60. A single MAC PDU or a
4   concatenated MAC PDUs is received through the PHY SAP and they can form a FEC block called PHY PDU.
5   The figure shows that the physical layer performs channel encoding, modulation and MIMO encoding for a
6   PHY PDU and generates a single modulated symbol sequence. Any one of the multiple carriers (primary or
7   secondary carriers) can deliver a modulated symbol sequence. Or, in case of allocation on DRU, a single
8   modulated symbol sequence may be segmented into multiple segments where each segment can be transmitted
9   on a different carrier. The same MCS level and MIMO scheme are used for all segments of a PHY PDU.
10   However, different PHY PDUs transmitted on the same or different carriers may have different MCS and
11   MIMO schemes. The physical layer performs subcarrier mapping for a modulated symbol sequence or a
12   segment of the sequence relevant to the given carrier.

13
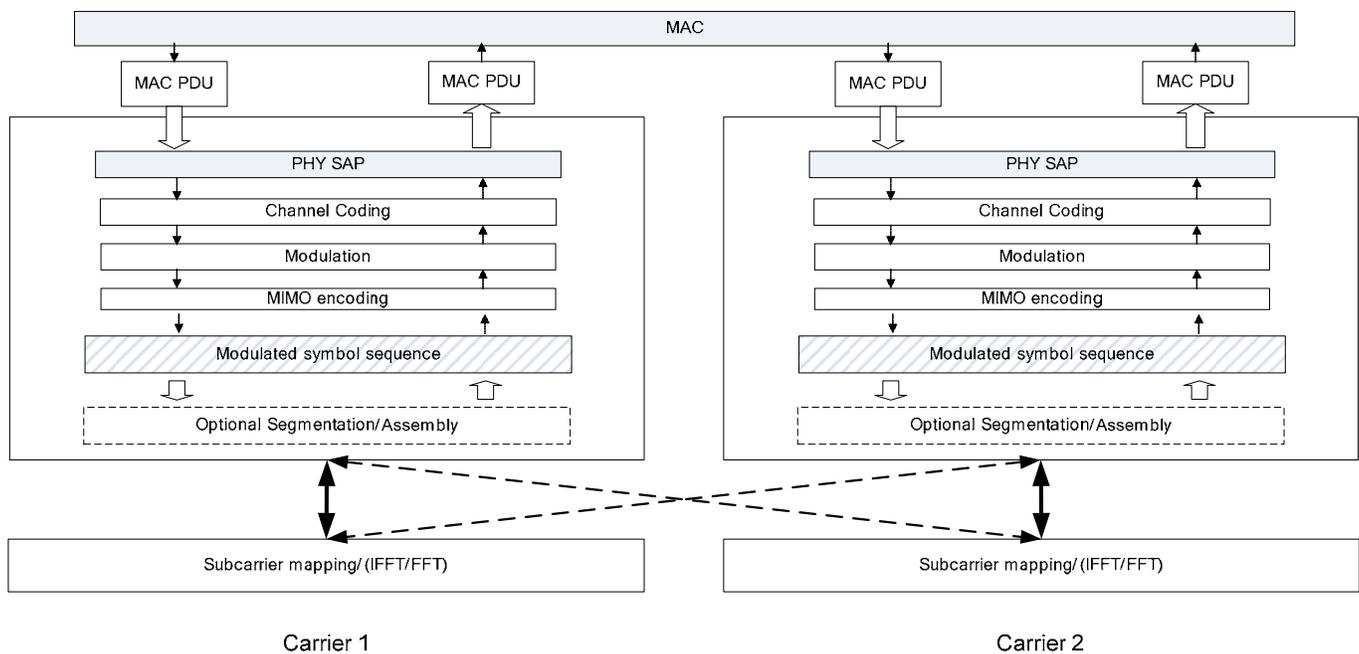
14   Figure 60 An example of physical layer structure to support multi-carrier operation

15

16   The following describes the details of the PHY PDU transmission operation:

17   1. For a PHY PDU, the PHY delivers a single modulated symbol sequence. This modulated symbol
18   sequence, is regarded as a single HARQ packet the same as in a single carrier system.

19   2. A modulated symbol sequence of a PHY PDU can be transmitted as follows:

20   A. Transmitting the modulated symbol sequence on a single RF carrier. Note that in the same time,
21   different PHY bursts may be transmitted to an AMS from different RF carriers.

22   B. Transmitting the modulated symbol sequence on DRUs across several RF carriers at the same sub-
23   frame, via PHY burst segmentation and mapping to different RF carriers, by using the same MCS
24   and MIMO scheme.

25   3. In the multi-carrier system, an LRU is defined independently per carrier. The RF carrier specific

1   physical layer performs subcarrier mapping based on the LRU per carrier. It must be noted that the radio
2   resource utilization on each RF carrier may be different.

3   PHY segmentation, i.e. transmitting one PDU across multiple carriers is FFS.

19.3.1 Frame Structure

5   The frame structures to support multi-carrier can be found in 11.4.3 and 11.4.6.

19.3.2 Channel Coding, Modulation and HARQ

7   For a PHY PDU, channel encoding, modulation and MIMO encoding are performed as in a single carrier
8   operation to generate a single modulated symbol sequence. The modulated symbol sequence can be segmented
9   and transmitted over DRUs in multiple carriers as shown in Figure 60.

10   The modulated symbol sequence is regarded as a single HARQ packet. HARQ feedback for PHY PDU sent
11   across primary and secondary carriers can be carried in the primary carrier. HARQ feedback for PHY PDU sent
12   only in the secondary carrier can be carried in the secondary carrier.

19.3.3 Data Transmission over Guard Resource

14   The guard sub-carriers between contiguous RF carriers in the new zone can be utilized for data transmission if
15   the sub-carriers on contiguous RF carriers are well aligned. The serving ABS and the AMS need to negotiate
16   their capability to support guard sub-carrier data transmission. The set of guard sub-carriers utilized for data
17   transmission is defined as guard resource.

19.3.3.1   PHY Structure Support

19   Each carrier can exploit subcarriers at band edges as its additional data subcarriers. The guard resource forms
20   integer multiples of PRUs. The resulting data subcarriers (including guard resource) form PRUs. The PRU
21   structure used for guard resource is the same as the structure of the ordinary PRU in 11.5 and 11.6. For the
22   carrier, CRUs may be constructed from the PRUs including PRUs from guard resource. Support of DRU is FFS.

23   The ABS provides information regarding the use of guard resource for data channels. Guard resource is not
24   used for control channels transmission.

25   Figure 61 illustrates example of exploiting guard subcarriers for data transmission.

26
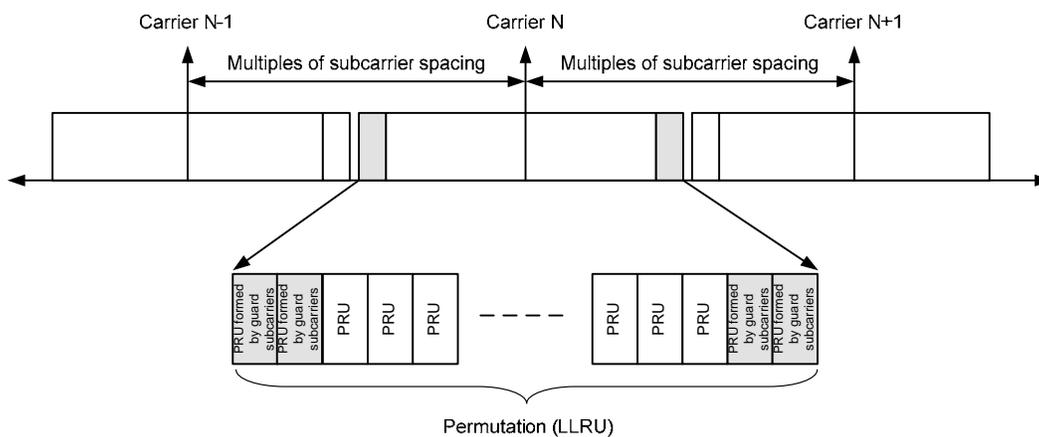
Figure 61 Example of data transmission using the guard subcarriers

140

1

19.3.4 Allocation Scheme for OFDMA Multi-carrier

Allocation signaling is made to indicate the allocation of OFDMA data regions which is defined as a set of LRUs. A modulated symbol sequence of a PHY PDU can be sent through a single carrier (primary or secondary). In this case, there is only one data region for the modulated symbol sequence in a carrier. Additionally, a modulated symbol sequence of a PHY PDU can be segmented for the allocation in DRU and multiple carriers can deliver the segments through each carrier. In this case, there are multiple data regions for the modulated symbol sequence across multiple carriers. The segmentation is only allowed for the allocation in DRU. Allocation information indicates a data region or multiple data regions with other parameters like MCS level. When multiple PHY PDUs are transmitted over multiple carriers in a sub-frame, the delivery order is FFS.

For each AMS the allocation information for both its Primary and secondary carriers is sent through the primary carrier, or the allocation information for each carrier is sent through the carrier itself.

19.3.5 Data Regions and Sub-carrier Mapping for OFDMA Multi-carrier Operation

When a modulated symbol sequence is transmitted through one carrier, the sequence is mapped using the same mapping rule of the single carrier mode. When a modulated symbol sequence is segmented, each segment can be mapped to OFDMA data regions over multiple carriers using the algorithms defined below, where logical carrier index is defined as FFS.

   a) Segment the modulated symbol sequence into blocks sized to fit into a single LRU.

   b) Map each segmented block onto one LRU from the lowest LRU index in the OFDMA data region of the carrier with the lowest logical carrier index.

   c) Continue the mapping so that the LRU index increases. When the edge of the data region is reached, continue the mapping from the lowest LRU index in the OFDMA data region of the carrier with the next available logical carrier index.

   d) Continue the mapping until the all modulated data symbols are mapped.

An example is shown in Figure 62. Within the LRU, subcarrier mapping follows the mapping rule for a single carrier case.
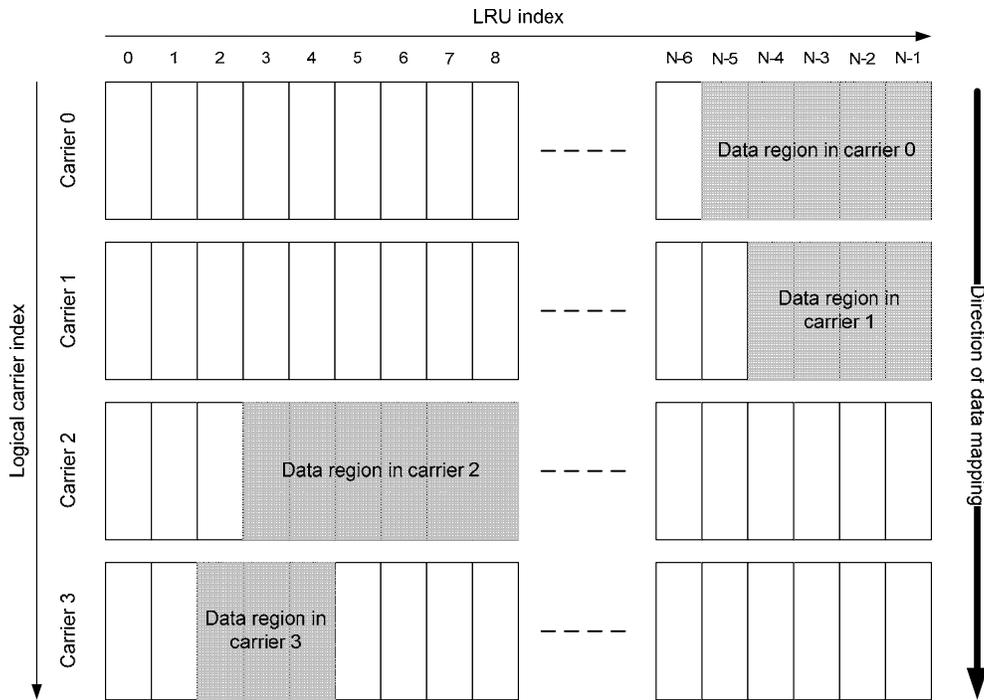
Figure 62 Example of modulated symbol sequence mapping in OFDMA multi-carrier operation

19.3.6 DL Control Structure

All DL controls channel needed for single carrier operation are needed for the fully configured carrier. For partially configured carrier, the BCH, additional broadcast information, USCCH and SCH may have different configuration from those of the fully configured carrier.

Obtaining System Information of Secondary Carriers

- For the case where the AMS can simultaneously decode multiple carriers, the AMS can decode the broadcast channels of its secondary carriers. ABS may instruct the AMS, through control signaling on the primary carrier, to decode broadcast channels of specific set of secondary carriers.

- When the AMS cannot simultaneously decode multiple carriers, the ABS can convey the system information of secondary carriers to AMS, through control signaling on the primary carrier.

19.3.6.1   SCH

Primary and Secondary SCHs are present in a fully configured carrier. In a fully configured carrier, the location and transmission format of SCH is the same as that of the single carrier described in 11.7.2.1. SCH configuration in the partially configured carrier is FFS.

19.3.6.2   19.3.6.2 BCH

BCH is present in a fully configured carrier. In a fully configured carrier, the location and transmission format of PBCH/SBCH is the same as that of single carrier described in section 11.7.2.2. Configuration of BCH in a

partially configured carrier is FFS.

19.3.6.3   USCCH

USCCH is present in a fully configured carrier. The location and transmission format of USCCH on the fully configured carrier is the same as that defined in 11.7.2.3.

The presence and use of USCCH on the partially configured carrier is FFS.

19.3.6.4   Additional Broadcast Information

All additional broadcast information related to multicarrier operation which can be provided on the fully configured carrier should not be transmitted on the partially configured carrier

19.3.7 UL Control Structure

All UL controls channel needed for single carrier operation are supported for the fully configured carrier. A partially configured carrier may not have any uplink capability, e.g. a secondary carrier configured to be optimized for downlink only multicast and broadcast services.

19.3.7.1   UL Fast Feedback Channel

The ABS configures the set of carriers for which the AMS reports fast feedback information. The ABS may only allocate resource to the AMS on a subset of those configured carriers. Fast feedback information for link adaptation for SIMO and information for MIMO operation can be sent through the primary carrier. The fast feedback information related to the assigned secondary carriers can be carried in those carriers if supported by their configuration.

19.3.7.2   UL HARQ Feedback Channel

HARQ feedback for PHY PDU sent across primary and secondary carriers can be carried in the primary carrier. HARQ feedback for PHY PDU sent in secondary is carried in the secondary if supported by the secondary carrier configuration

19.3.7.3   UL Ranging Channel

UL initial ranging for non-synchronized AMS is conducted on a fully configured carrier. UL periodic ranging for synchronized AMS is conducted on the primary carrier but may also be performed in a secondary carrier if supported by the secondary carrier. The issue of periodic ranging on the secondary carrier, autonomously performed by the AMS or directed by the ABS, is FFS. The serving ABS transmits the ranging response on the same carrier that the UL ranging is received.

19.3.7.4   UL sounding channel

UL sounding is conducted on the primary and secondary carrier.

19.3.7.5   Bandwidth Request Channel

BW request channel is transmitted only on the primary carrier.

19.3.8 UL Power Control

Depending on the correlation between RF carriers, separate controls of UL power for different RF carriers are necessary. Thus, one or multiple power control commands for multiple carriers are supported. Although multiple power control commands are allowed, the power control commands or messages can be sent to AMS through the primary carrier. When a AMS switches to a secondary carrier in carrier switching mode, the secondary carrier can carry power control commands or messages if supported by its configuration.

19.4 MAC Aspect of OFDMA Multi-carrier Operation

The MAC layer in OFDMA multi-carrier mode will operate in the same way as single carrier MAC.

19.4.1 Addressing

There is no difference between a single carrier and OFDMA multi-carrier operation from an addressing perspective as described in sub-clause 10.1.

19.4.2 Security

All the security procedures between AMS and ABS are performed using only the AMS's primary carrier. The security context created and maintained by the procedures is managed per ABS through the primary carrier.

19.4.3 Initial Entry

The AMS attempts initial ranging and network entry only with a fully configured carrier. An AMS needs to know which carrier(s) of the ABS are fully configured carriers. The use of SCH or BCH to indicate whether a carrier is fully or partially configured is FFS.

The following options can be used to help AMS with determining whether it can use a carrier for network entry:

1) A carrier which does not have a SCH can not be used as primary carrier by a AMS. So when an AMS detects a carrier without a SCH the AMS skips the carrier and proceed with scanning and network entry procedure with another carrier.

2) When partially configured carrier includes the SCH, the ABS may use a preamble sequence selected from a predefined set of sequences reserved for partially configured carriers. By detecting a preamble sequence designated for partially configured carrier the AMS skips that carrier and proceed with scanning and selection of alternative carrier.

Once the AMS detects the SCH on a fully configured carrier, the AMS may proceed with reading BCH or Extended system parameters and system configuration information where the ABS indicates its configuration, its support for multicarrier feature, as well as other carriers configuration information, which are FFS. The AMS can decide on proceeding with network entry with the current carrier or going to alternative carriers based on this information.

Once a candidate primary carrier is determined the initial network entry procedures are the same as in single carrier mode. The carrier on which the AMS successfully performs initial network entry becomes the primary carrier of the AMS. After successful ranging, the AMS follows the capability negotiation procedure in which it provides ABS with its OFDMA multi-carrier capabilities, such as carrier aggregation or carrier switching. The ABS may provide configuration parameters of other carriers to the AMS. The ABS may assign secondary

1   carriers to the AMS, through negotiation with the AMS.

2   The AMS may omit UL ranging (for time/frequency synchronization and power adjustment purpose) with
3   secondary carrier. In this case, AMS uses the same timing, frequency and power adjustment information for the
4   secondary carrier as in the primary carrier. The AMS may perform fine timing/frequency/power adjustment on
5   the secondary carrier through measuring the sync channel and/or pilot on the secondary carrier. The AMS may
6   perform UL ranging with secondary carrier. In this case, power adjustment results in the primary carrier may be
7   used as initial transmission power for UL ranging over the secondary carrier. The use of dedicated ranging
8   resource received from the primary carrier to enhance the ranging in the secondary carrier is FFS.

9   ## 19.4.4 MPDU Processing

10   The construction and transmission of MAC PDU in OFDMA multi-carrier operation mode is the same as that in
11   single carrier operation mode.

12   ## 19.4.5 Bandwidth Request and Allocation

13   All bandwidth requests are transmitted on the AMS's primary carrier using the assigned UL control channels
14   following the same procedures as single carrier mode. Bandwidth request using piggyback scheme is also
15   allowed in the secondary carriers. The ABS may allocate UL resources which belong to a specific carrier or a
16   combination of multiple carriers.

17   ## 19.4.6 QoS and Connection Management

18   QoS and Connection management in multicarrier mode are based on single carrier mode. The Station ID and all
19   the Flow IDs assigned to an AMS are unique identifiers for a common MAC and used over all the carriers. The
20   followings are also applicable:

21   1. The connection setup signaling is performed only through the AMS's primary carrier. The connection is
22   defined for a common MAC entity.

23   2. AMS's QoS context is managed per service flow for each AMS, and is applicable across primary carrier
24   and secondary carriers and collectively applied to all carriers.

25   3. Flow ID is maintained per AMS for both primary carrier and secondary carriers.

26   4. The required QoS for a service flow may be one of the parameters considered in order to determine the
27   number of secondary carriers assigned to the AMS.

28   ## 19.4.7 Carrier Management

29   The ABS may instruct the AMS, through control signaling on the current primary carrier, to switch its primary
30   carrier to one of the available fully configured carriers within the same ABS for load balancing purpose,
31   carriers' varying channel quality or other reasons. AMS switches to the target fully configured carrier at action
32   time specified by the ABS. The carrier switch may also be requested by the AMS through control signaling on
33   the current primary carrier. Given that a common MAC manages both serving and target primary carriers,
34   network re-entry procedures at the target primary carrier is not required. ABS may direct an AMS to perform
35   the primary carrier switching without scanning.

36   ABS may also assign different secondary carriers to the AMS, through control signaling on the current primary
37   carrier.

38   The ABS may instruct AMS to perform scanning on other carriers which are not serving the AMS. In this case,
39   if the target carrier is not currently serving the AMS, the AMS may perform synchronization with the target

carrier if required.

19.4.7.1   Carrier switching between a primary carrier and a secondary carrier

Primary to secondary carrier switching in multi-carrier mode is supported when secondary carrier is partially configured. The carrier switching between a primary carrier and a secondary carrier can be periodic or event-triggered with timing parameters defined by multi-carrier switching message on the primary carrier. When an AMS switches to a secondary carrier, its primary carrier may provide basic information such as timing and frequency adjustment to help with AMS's with fast synchronization with the secondary carrier. The details are FFS.

19.4.8 Handover Support

An AMS in multi-carrier operation follows the handover operation in single carrier mode of IEEE 802.16m. MAC management messages in relation with handover between an AMS and a ABS are transmitted over the AMS's primary carrier. Similar to the procedure defined in 10.3.2.2.3, if directed by serving ABS via HO Command control signaling, the AMS performs network re-entry with the target ABS on the assigned fully configured carrier at action time while continuously communicating with serving ABS. However, the AMS stops communication with serving ABS on primary/secondary carriers after network re-entry at target ABS is completed. In addition, AMS cannot exchange data with target ABS prior to completion of network re-entry. Multiplexing of network re-entry signaling with target ABS and communications with serving ABS is FFS.

To facilitate AMS's scanning of neighbor ABS's fully configured carriers, the serving ABS may broadcast/multicast/unicast the neighbor ABS's multi-carrier configuration information to the AMS.

When an AMS receives handover notification from a ABS or when an AMS sends HO notification to a ABS, the AMS may get the information on OFDMA multi-carrier capabilities of one or more possible target ABSs in the handover transaction.

After handover to a certain target ABS is determined, the AMS conducts network re-entry through its target primary carrier. After the completion of network re-entry procedure, the AMS and the ABS may communicate over AMS's primary and/or secondary carriers.

Regardless of multi-carrier support, an AMS capable of concurrently processing multiple radio carriers, may perform scanning with neighbor ABSs and HO signaling with the target ABS using one or more of its available radio carriers, while maintaining normal operation on the primary carrier and secondary carriers of the serving ABS. The AMS may negotiate with its serving ABS in advance to prevent allocation over those carriers used for scanning with neighboring ABSs and HO signaling with the target ABS.

19.4.9 Power Management

The AMS is only assigned to one or more secondary carrier during the active/normal mode. Therefore, the power saving procedures in OFDMA multi-carrier mode of operation are the same as single carrier mode and all messaging including idle mode procedures and state transitions are handled by the primary carrier.

In active/normal mode AMS can be explicitly directed through the primary carrier to disable reception on some secondary carriers to satisfy the power saving. When reception is disabled, no allocation can be made on those secondary carriers. When the primary carrier indicates that there is no allocation in secondary carriers, the AMS can disable reception on that carrier.

19.4.9.1   Sleep Mode

When an AMS enters sleep mode, the negotiated policy of sleep mode is applied to a common MAC regardless

of OFDMA multi-carrier mode and all carries shall power down according to the negotiated sleep mode policy. During the listening window of sleep mode, the traffic indication is transmitted through the primary carrier. Data transmission follows the normal operation (no sleep) defined for multiple carriers.

- One set of unified sleep mode parameters (i.e., sleep window and listening window configuration) are configured for a AMS regardless of single carrier or multi-carrier operation.

- During listening window, AMS monitors the traffic indication on the primary carrier. If traffic indication is negative, AMS goes back to sleep. If traffic indication is positive, AMS continues to monitor the primary carrier control channel to know if it has traffic scheduled for transmission on the primary carrier and/or secondary carrier. Note that the serving ABS may request AMS to switch its primary carrier during the listening window for load balancing or power saving.

19.4.9.2   Idle Mode

During paging listening interval, AMS monitors paging notification on a fully configured carrier. The procedure for paging is the same as defined for single carrier. The selection of the carrier for paging is FFS. When paged, the AMS can perform network re-entry procedure with the paged carrier.

Messages and procedures to enter the idle mode between AMS and ABS are processed through the primary carrier. The network re-entry procedure from idle mode is similar to those of initial network entry. One set of unified idle mode parameters (i.e., paging listening interval and paging unavailable interval configuration) is configured for a AMS regardless of single carrier or multi-carrier operation.

19.4.10   EMBS Support

IEEE 802.16m system may designate the partially configured carriers for E-MBS only. The multi-carrier AMS which capable to process multiple radio carriers at the same time may perform normal data communication at one carrier while receiving the E-MBS content over another carrier.

20 Support for Interference Mitigation

This section introduces the interference mitigation schemes by using fractional frequency reuse (FFR), advanced antenna technology, power control and scheduling.

20.1 Interference Mitigation using Fractional Frequency Reuse (FFR)

IEEE 802.16m shall support the fractional frequency reuse (FFR) to allow different frequency reuse factors to be applied over different frequency partitions during the designated period for both DL and UL transmissions, note that the frequency partition is defined in 11.5.2.2 and in 11.6.2.2 for DL and UL respectively. The operation of FFR is usually integrated with other functions like power control or antenna technologies for

1   adaptive control and joint optimization. The basic concept of FFR is introduced by the example in Figure 63.

2
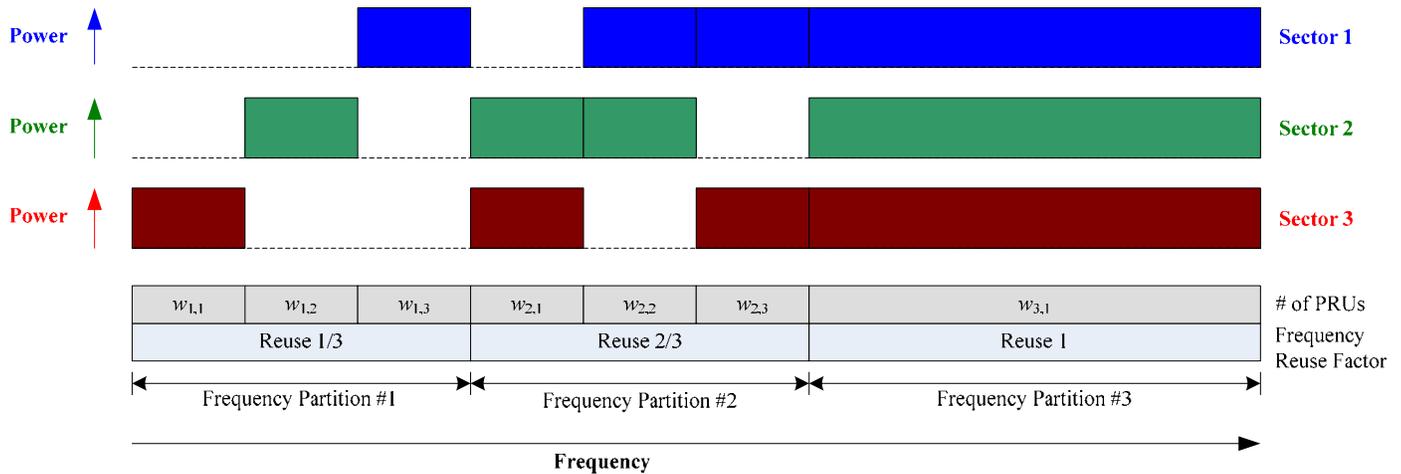
4   Figure 63 Basic Concept of Fractional Frequency Reuse (FFR)

5

6   In basic FFR concept, subcarriers across the whole frequency band are grouped into frequency partitions with
7   different reuse factors. In general, the received signal quality can be improved by serving AMSs in the
8   frequency partitions with lower frequency reuse factor, due to lower interference levels. This will be helpful for
9   the AMSs located around cell boundary or for the AMSs suffering severe inter-cell interference. On the other
10   hand, ABS may apply higher frequency reuse factor for some frequency partitions to serve the AMSs which do
11   not experience significant inter-cell interference. This will be helpful for ABS to serve more AMSs and achieve
12   better spectral efficiency.

13   Resource allocation in an FFR system takes several factors into consideration such as reuse factor in partition,
14   power at partition, available multi-antenna technologies, as well as interference-based measurements taken at
15   AMS.

16   20.1.1 Downlink (DL) FFR

17

18   20.1.1.1   Interference Measurement and Signaling Support

19

20   For DL FFR, the AMSs shall be capable of reporting the interference information to serving ABS. The serving
21   ABS can instruct AMS to perform interference measurement over the designated radio resource region in
22   solicited/unsolicited manner, or the AMS may perform the autonomous interference measurement without the
23   instruction by ABS. Examples of interference measurement include SINR, SIR, interference power, RSSI,
24   etc. The AMS can also recommend the preferred frequency partition to serving ABS based on considerations
25   such as interference measurements, resource metric of each partition, etc. The measurement results can then be
26   reported by message and/or feedback channel.

27   The ABS can transmit necessary information through a signaling channel or message to facilitate the
28   measurement by AMS. The information includes the frequency reuse parameters of each frequency partitions,

1 the corresponding power levels and associated metric for each partition. Resource metric of each FFR partition
2 is the measure of the overall system resource usage by the partition (such as effective bandwidth due to reuse,
3 transmission power, multi-antennas, and interference to other cells and so on). The use of resource metric is
4 FFS.

5

20.1.1.2   Inter-ABS Coordination

7

8   In order to support FFR, the ABSs shall be capable of reporting interference statistics and exchanging its FFR
9   configuration parameters which may include FFR partitions, power levels of each partition, associated metric of
10 each partition with each other or with some control element in the backhaul network. Note that some of the
11 coordination may be achieved by signaling over air-interface and the configuration format for FFR coordination
12 is FFS.

13 The Figure 64 shows an example to integrate FFR with DL power control. This allows the system to adaptively
14 designate different DL power boosting over different PRUs in each frequency partition. The power allocation of
15 each PRU may be higher or lower than normal level, it should be well coordinated from system-wide
16 consideration.

17
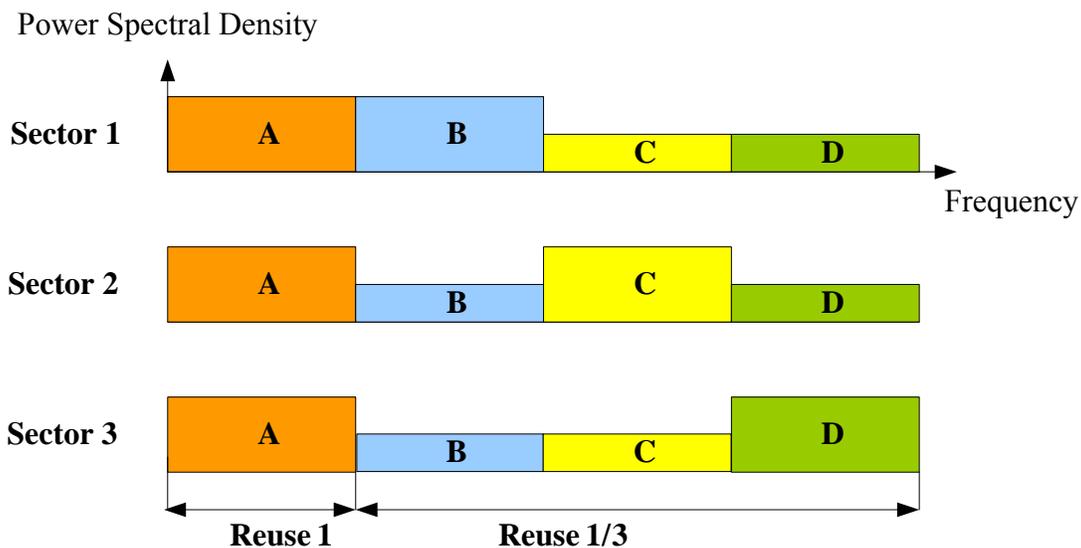
19   Figure 64 Example to integrate FFR and DL power control

20

21 20.1.2 Uplink (UL) FFR

22

20.1.2.1   Interference Measurement and Signaling Support

24

25 For UL FFR, the ABSs shall be capable to estimate the interference statistics over each frequency partitions. In

order to support UL FFR, the ABS can transmit necessary information through a feedback channel or message to the AMS. The information can include the frequency reuse parameters of each frequency partitions and the corresponding UL power control target.

20.1.2.2   Inter-ABS Coordination

In order to support UL FFR, the ABSs shall be capable of reporting its interference statistics and to exchange its FFR configuration and corresponding UL power control target with each other or with some control element in the backhaul network. Note that some of the coordination may be achieved by signaling over air-interface and the configuration format for FFR coordination is FFS.

The Figure 65a and Figure 56b shows examples of integration of FFR with UL power control (Section 11.10.2). In Figure 65a, system adaptively designates different IoT targets for UL power control over different PRUs in each frequency partition. A AMS assigned for a partition needs to do power control properly considering the target IoT level of other cells for that partition. If the target IoT level of other cells for a partition is low, for example, a AMS assigned for that partition should transmit with lower power not to interfere other cell users. If the target IoT level of other cells for a partition is high, then a user assigned for that partition may transmit with a higher power. To control system-wide interference, the ABS can adjust the frequency partitions and the corresponding target IoT level in coordination with other ABSs.

Another example for SINR based UL power control is given in Figure 65(b), where different target SINR level may be designated for different frequency partitions.
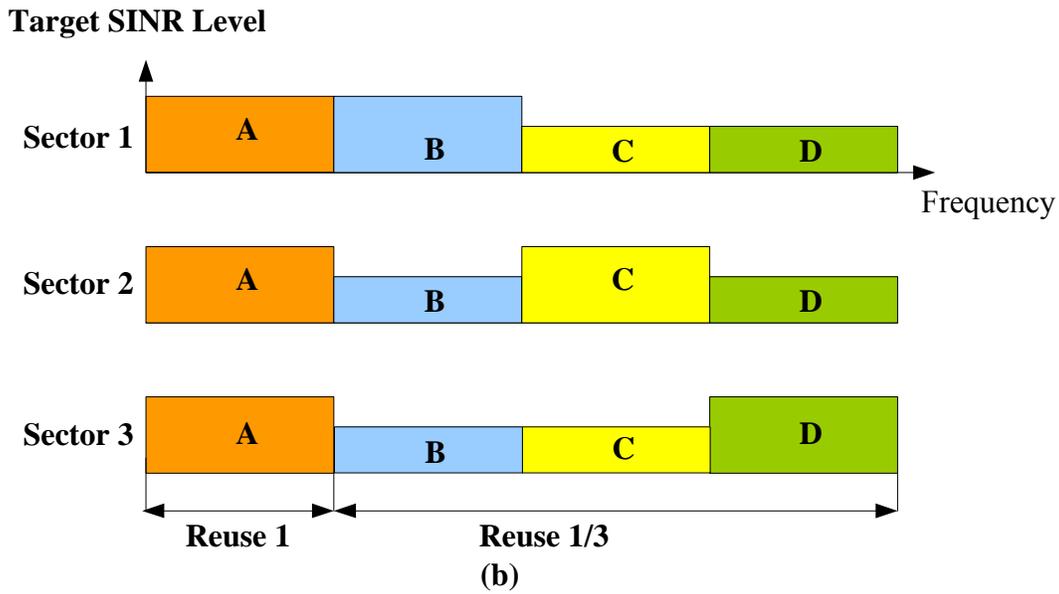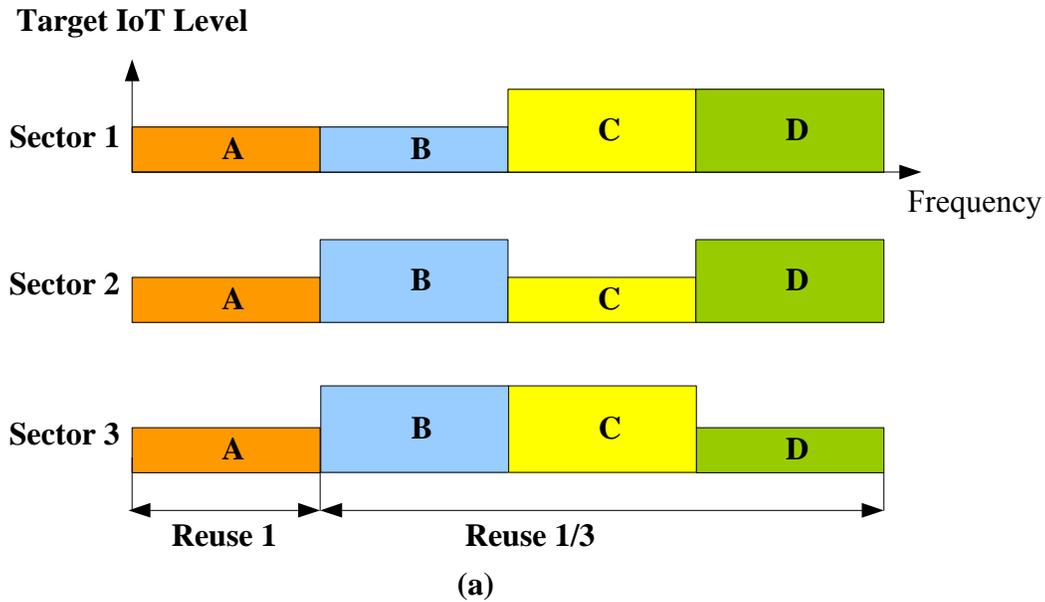
Figure 65 Example to integrate FFR and UL power control

20.2 Interference Mitigation using Advanced Antenna Technologies

[Note: The content of this section shall not contradict with the content of "11.8.4.1 Multi-ABS MIMO" in IEEE 802.16m-08/003r4]

IEEE 802.16 should support the advanced antenna technologies to mitigate inter-cell interference.

20.2.1 Single Cell Antenna Processing with Multi-ABS Coordination

The details of single cell antenna processing are defined in "11.8 DL MIMO Transmission Scheme". This sub-section introduces the interference mitigation techniques based on the MIMO schemes defined in Section 11

with extended inter-ABS coordination mechanisms and interference measurement support. Note that the inter-ABS coordination mechanisms in this sub-section do not require data forwarding between different cells, i.e. different ABS will not transmit the same data to a AMS.

When precoding technique is applied in neighboring cells, the inter-cell interference can be mitigated by coordinating the PMIs (Precoding Matrix Indexes) applied in neighboring cells. For example, the AMS can estimate which PMIs in neighboring cell will result in severe interference level and report the PMI restriction or recommendation to the serving ABS. The serving ABS can then forward this information to recommend its neighboring ABSs a subset of PMIs to use or not to use. Based on this information, the neighboring ABS can configure the codebook and broadcast it.

In addition, the PMI coordination can also be applied in UL. One example is that the neighboring ABSs can estimate the sounding signal transmitted by specific AMS and identify which PMIs may result in significant interference. By forwarding this information over the backhaul network, the serving ABS can instruct the AMS to choose the proper PMI or the combination of PMIs for maximizing SINR to its own cell and minimizing the interference to neighboring cells.

Precoding with interference nulling can also be used to mitigate the inter-cell interference. For example, additional degrees of spatial freedom at a ABS can be exploited to null its interference to neighboring cells.

20.2.1.1   Inter-ABS Coordination

In order to support PMI coordination to mitigate inter-cell interference, the ABSs shall be capable of exchanging the interference measurement results such as the recommended PMI subset to be restricted or to be applied in neighboring cells with each other or with some control element in the backhaul network. For UL PMI coordination, this subset is estimated by ABS through estimating the sounding signals transmitted by specific AMSs. In order to facilitate the PMI coordination and interfering PMIs estimation, the information on the PMI and the associated resource allocation applied in each cell should also be exchanged.

In order to support precoding with interference nulling, the associated resource allocation and some control element should be exchanged between neighboring ABSs.

Note that the PMI coordination may also be integrated with the FFR defined in 20.1. For example, the ABS may apply FFR to isolate some of the interference sources if the PMIs restrictions recommended by different AMSs are contradicted with each other.

20.2.1.2   Interference Measurement

In order to support DL PMI coordination to mitigate inter-cell interference, the AMS shall be capable of measuring the channel from the interfering ABS, calculates the worst or least interfering PMIs, and feedbacks the restricted or recommended PMIs to the serving ABS together with the associated ABS IDs or information assisting in determining the associated ABS IDs. The measurement can be performed over the region implicitly known to AMS or explicitly designated by ABS. The PMIs can then be reported to ABS by UL control channel and/or MAC layer messaging in solicited/unsolicited manner.

For UL PMI coordination, the ABS shall be capable of measuring the channel from the interfering AMS using

1   sounding signals. Neighboring ABS should calculate the PMIs with least interference and forward them to the
2   serving ABS. The mechanism to identify the interfering AMS is FFS.

3   The priority of selection of PMIs forwarded from neighboring ABS is set in DL/UL. For priority of selection of
4   PMIs, measurements such as SINR, normalized interference power, or IoT for each resource unit (e.g., a
5   subchannel, a fraction of PRU) is required, and it should be forwarded from neighboring ABS. The measured
6   CINR should provide an accurate prediction of the CINR when the transmission happens with coordinated DL
7   closed loop transmission. In order to mitigate UL interference, corresponding to each sub-band, or RB(s), ABSs
8   may send an indication to neighbor base stations if the IoT is above the thresholds.

9   In addition to PMIs, additional interference measurements may need to be reported to resolve conflicting
10 requests from different AMSs. More details are FFS.

11 In order to support precoding with interference nulling to mitigate inter-cell interference, a ABS shall be
12 capable to measure the channel from an interfering AMS.

13 ## 20.2.2 Multi-ABS Joint Antenna Processing

14

15 This sub-section introduces the techniques to use joint MIMO transmission or reception across multiple ABSs
16 for interference mitigation and for possible macro diversity gain, and the Collaborative MIMO (Co-MIMO) and
17 the Closed-Loop Macro Diversity (CL-MD) techniques are examples of the possible options. For downlink Co-
18 MIMO, multiple ABSs perform joint MIMO transmission to multiple AMSs located in different cells. Each
19 ABS performs multi-user precoding towards multiple AMSs, and each AMS is benefited from Co-MIMO by
20 receiving multiple streams from multiple ABSs. For downlink CL-MD, each group of antennas of one ABS
21 performs narrow-band or wide-band single-user precoding with up to two streams independently, and multiple
22 ABSs transmit the same or different streams to one AMS. Sounding based Co-MIMO and CL-MD are
23 supported for TDD, and codebook based ones are supported for both TDD and FDD.

24

25 ## 20.2.2.1   Closed-loop Multi-ABS MIMO

26 For the uplink, macro-diversity combining, cooperative beamforming and interference cancellation can be used
27 across multiple base stations to mitigate inter-cell interference.

28

29 ### *20.2.2.1.1   Inter-ABS Coordination*

30 For macro-diversity combining, soft decision information in the form of log-likelihood ratios is generated at
31 different base stations and combined. This will require the exchange of non-persistent allocations of scheduling
32 information and soft-decision information across base stations.

33 For cooperative beamforming, joint multi-antenna processing is carried out across multiple base stations. This
34 will require the exchange of non-persistent allocations of channel state information, scheduling information and
35 quantized versions of received signals across base stations.

36 For interference cancellation, a ABS that is unable to decode data for a particular user may request a
37 neighboring ABS to exchange the decoded data of the interfering users along with scheduling and transmission
38 format related information. The information exchanged may be used in conjunction with channel state
39 information for the purpose of interference cancellation.

1   Cooperative cells can have same permutation for resource allocation.

2   For all of these uplink multi-ABS MIMO techniques, channel state information can be derived either through
3   different pilots or sounding channels per sector or cell.

4   The ABSs can coordinate transmission of their beams, so that interference from neighboring cells can be almost
5   completely eliminated. Furthermore, if ABSs cannot coordinate, then the sequence in which beams are served
6   can be chosen randomly and independently at each ABS.

7   In order to support CL-MD, the associated resource allocation and some control element should also be
8   exchanged between neighboring ABSs. For codebook-based cases, the AMSs involved in coordination
9   determines precoding matrix index (PMI) for each coordinating ABS, and reports them to the serving ABS,
10   which in turn forwards the corresponding PMI to the relevant ABS via the network interface. For sounding
11   based cases, the ABSs involved in coordination obtain precoding matrix based on uplink sounding.

12   Note that the CL-MD may also be integrated with the FFR defined in 20.1.

13   In order to support Co-MIMO, the associated resource allocation and some control element should also be
14   exchanged among coordinating ABSs. For codebook-based cases, the AMS involved in coordination determines
15   narrow precoding matrix index (PMI) for each coordinating ABS, and reports these to the serving ABS, which
16   in turn forwards the corresponding PMI to the relevant ABS via the network interface. For sounding based
17   cases, the ABS involved in coordination estimates the channel state information (CSI) using uplink sounding for
18   all AMSs involved in coordination, and calculates multiuser precoding matrixes for these users.

19   *20.2.2.1.2   Measurement Support*

20   A ABS that senses high levels of interference may send a request for inter-cell interference reduction to a
21   neighboring ABS along with identification of dominant interfering AMSs. Once a neighboring ABS with
22   dominant interfering AMSs accepts the inter-cell interference reduction request, the measurement process will
23   be started. The measurement process requires estimation of channel state information for AMSs involved in
24   multi-ABS joint antenna processing.

25   ABS can request multiple uplink sounding signals per AMS during a Frame to enable the measurement of CQI
26   on a per beam basis.

27   In order to support codebook based CL-MD, the AMS shall be capable to measure the channel from the
28   interfering ABS, and calculate the PMI for it. In order to support sounding based CL-MD, the ABS shall be
29   capable to measure the channel from an interfering AMS, and calculates the precoding matrix for it.

30   In order to support codebook based Co-MIMO, the AMS shall be capable to measure the channel from the all
31   ABSs involved in coordination, and calculates the PMIs for them. In order to support sounding based Co-
32   MIMO, the ABS shall be capable to measure the channel from all AMSs involved in coordination, and
33   calculates the precoding matrixes for these users.

34

35   ## 20.3 Interference Mitigation using Power Control and Scheduling

36

37   ABS may use various techniques to mitigate the interference experienced by AMS or to reduce the interference
38   to other cells. The techniques may include sub-channels scheduling, dynamic transmit power control, dynamic
39   antenna patterns adjustment, and dynamic modulation and coding scheme. As an example, ABS may allocate
40   different modulation and coding schemes (MCS) to mobiles through UL scheduling which indirectly controls

1   mobile transmit power and the corresponding UL interference to other cells. ABS can exchange information
2   related to UL power control schemes with other neighbor ABSs. AMS may use interference information and its
3   downlink measurements to control the uplink interference it causes to adjacent cells.

4   Using interference information ABS may attempt intra-ABS techniques such as alternative traffic scheduling,
5   adjustment of MCS to avoid interference and ABS may also use inter-ABS techniques such as the examples
6   depicted in sections 20.1 and 20.2.

7   DL interference mitigation may be achieved by allocating different DL power boosting over different sub-
8   channels, while the UL interference mitigation may also be achieved by setting different power control schemes
9   (Section 11.10.2). Both the UL and DL power control techniques may be further cooperated with the   FFR
10   (20.1) and the advanced antenna technologies (20.2) for better performances.

11   ABS can schedule AMSs with high mutual interference potential on different subchannels or frequency
12   partitions, e.g. by exchanging scheduling constraints between coordinating ABSs. The necessary interference
13   prediction may be based on the interference measurement mechanisms defined in 20.1 and 20.2.

14   *20.4 Interference Mitigation to Support Co-deployment with other Networks*

15

16   This sub-section addresses the coexistence problems which may appear between wireless networks deployed by
17   different operators. IEEE 802.16m deployment addresses the licensed spectrum allocations, which generally
18   enjoy low interference levels. Problems may arise in the case of co-deployment of FDD and TDD networks or
19   of un-synchronized TDD networks.

20   In order to resolve the potential interference due to the coexistence between wireless networks, the technique of
21   Coordinated Coexistence Frame (CXCF) may be applied.

22   - When enabling the CXCF technique, the following allocations will be identified:

23   A. Protected allocations, having as scope to protect the receive operation of AMS, ABS or a combination of
24   them; in some cases such allocations involve the creation of the silence intervals, during which there are no
25   transmissions.

26   B. Un-protected allocations, during which the interference is not mitigated by especial   measures. The existing
27   licensed operation is based on this approach.

28   - Synchronization by using GPS or similar synchronization sources in order to achieve the absolute time
29   synchronization of the Coordinated Coexistence Frame

30   - Scheduling among wireless communications to reduce the experienced interference

31

32   The Coordinated Coexistence Frame period is based on the IEEE 802.16m superframe structure, further
33   including frames and sub-frames. The CXCF duration and structure depends on the air-interfaces deployed by
34   other wireless networks.

35

1 # 21 RF Requirements

2 # 22 Inter-ABS Synchronization

3 ## 22.1 Network synchronization

4 For TDD and FDD realizations, it is recommended that all ABSs should be time synchronized to a common
5 timing signalABSs. In the event of the loss of the network timing signal, ABSs shall continue to operate and
6 shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing
7 reference shall be a 1 pps timing pulse and a 10 MHz frequency reference. These signals are typically provided
8 by a GPS receiver but can be derived from any other source which has the required stability and accuracy. For
9 both FDD and TDD realizations, frequency references derived from the timing reference may be used to control
10 the frequency accuracy of ABSs provided that they meet the frequency accuracy requirements of [tbd]. This
11 applies during normal operation and during loss of timing reference.

12 ## 22.2 Downlink frame synchronization

13 At the ABS, the transmitted downlink radio frame shall be time-aligned with the 1pps timing pulse with a
14 possible delay shift of n micro-seconds (n being between 0 and 4999). The start of the preamble symbol,
15 excluding the CP duration, shall be time aligned with 1pps plus the delay of n micro-seconds timing pulse when
16 measured at the antenna port.

17 # Appendix 1 IEEE 802.16e Protocol Structure

18 Figure 66 shows the protocol architecture of IEEE 802.16e which will be used as reference system. The MAC
19 layer is composed of two sub-layers: Convergence Sublayer (CS) and MAC Common Part Sublayer (MAC
20 CPS).

21
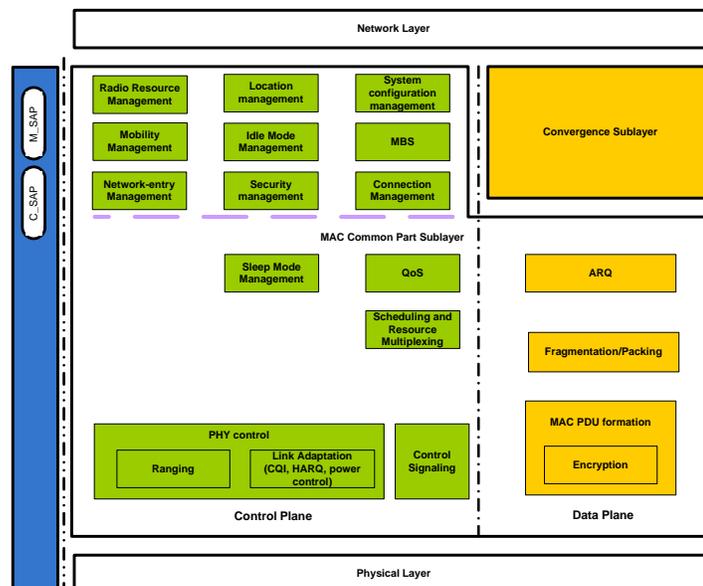
23 Figure 66 The IEEE 802.16e protocol architecture

24

For convenience, the MAC CPS functions are classified into two groups based on their characteristics. The upper one is named as resource control and management functions group, and the lower one is named as medium access control functions. Also the control plane functions and data plane functions are also separately classified.

The resource control and management functional group includes several functional blocks that relates to radio resource functionalities such as:

- Radio Resource Management

- Mobility Management

- Network-entry Management

- Location Management

- Idle Mode Management

- Security Management

- System Configuration Management

- MBS

- Connection Management

Radio Resource Management block adjusts radio network parameters related to the traffic load, and also includes function of load control (load balancing), admission control and interference control.

Mobility Management block handles processes related to handover procedure. Mobility Management block manages candidate neighbor target ABSs based on some criteria, e.g. PHY signaling report, loading, etc. and also decides whether AMS performs handover operation.

Network-entry Management block is in charge of initialization procedures. Network-entry Management block may generate management messages which are needed during the initialization procedures, i.e., ranging (this does not mean physical ranging, it implies the ranging messages needed to in order to assist in the identification, authentication, and CID allocation), basic capability, registration, and so on.

Location Management block is in charge of supporting location based service (LBS). Location Management block may generate messages including the LBS information. The Idle Mode Management block manages location update operation during idle mode.

Idle Mode Management block controls idle mode operation, and generates the paging advertisement message based on paging message from paging controller in the core network side.

Security Management block is in charge of key management for secure communication. Using managed key, traffic encryption/decryption and authentication are performed.

System Configuration Management block manages system configuration parameters, and generates broadcast control messages such as downlink/uplink channel descriptor (DCD/UCD).

MBS (Multicast and Broadcasting Service) block controls management messages and data associated with broadcasting and/or multicasting service.

Connection Management block allocates connection identifiers (CIDs) during initialization/handover/ service flow creation procedures. Connection Management block interacts with convergence sublayer to classify MAC Service Data Unit (MSDU) from upper layer, and maps MSDU onto a particular transport connection.

The medium access control functional group includes function blocks which are related with physical layer and

link controls such as:

- PHY Control

- Control Signaling

- Sleep Mode Management

- QoS

- Scheduling and Resource Multiplexing

- ARQ

- Fragmentation/Packing

- MAC PDU formation

PHY Control block handles PHY signaling such as ranging, measurement/feedback (CQI), and HARQ ACK/NACK. Based on CQI and HARQ ACK/NACK, PHY Control block estimates channel environment of AMS, and performs link adaptation via adjusting modulation and coding scheme (MCS) or power level.

Control Signaling block generates resource allocation messages such as DL/UL-MAP as well as specific control signaling messages, and also generates other signaling messages not in the form of general MAC messages (e.g., DL frame prefix also known as FCH).

Sleep Mode Management block handles sleep mode operation. Sleep Mode Management block may also generate management messages related to sleep operation, and may communicate with Scheduler block in order to operate properly according to sleep period.

QoS block handles rate control based on QoS parameters input from Connection Management function for each connection, and scheduler shall operate based on the input from QoS block in order to meet QoS requirement.

Scheduling and Resource and Multiplexing block schedules and multiplexes packets based on properties of connections. In order to reflect properties of connections Scheduling and Resource and Multiplexing block receives QoS information from QoS block for each connection.

ARQ block handles MAC ARQ function. For ARQ-enabled connections, ARQ block logically splits MAC SDU to ARQ blocks, and a sequence number is assigned to each logical block. ARQ block may also generate ARQ management messages such as feedback message (ACK/NACK information).

Fragmentation/Packing block performs fragmenting or packing MSDUs based on scheduling results from Scheduler block.

MAC PDU formation block constructs MAC protocol data unit (PDU) so that ABS/AMS can transmit user traffic or management messages into PHY channel. MAC PDU formation block may add sub-headers or extended sub-headers. MAC PDU formation block may also add MAC CRC if necessary, and add generic MAC header.

A1.1 The IEEE 802.16e AMS/ABS Data Plane Processing Flow

The following figure describes data transmission flow in the IEEE 802.16e. On the transmitter side, after a packet arrives from higher layer, Convergence Sublayer classifies a packet according to classification rules, and maps a packet onto a particular transport connection. If a packet is associated with ARQ connection, then ARQ block logically splits a packet into ARQ blocks. After scheduling, a packet may be fragmented or packed, and a sub-header is then added if necessary. A packet including sub-headers may be encrypted if negotiated. MAC PDU formation block adds generic MAC header, then MAC Protocol Data Unit (MPDU) is constructed.

1   Several MPDUs may be concatenated according to the size of the data burst.

2   On the receiver side, after a packet arrives from physical layer, MAC PDU formation block constructs MPDU,
3   and Fragmentation/Packing block defragments/unpacks MPDU to make MSDU. After reconstituted in
4   Convergence Sublayer, MSDU is transferred to higher layer.

5
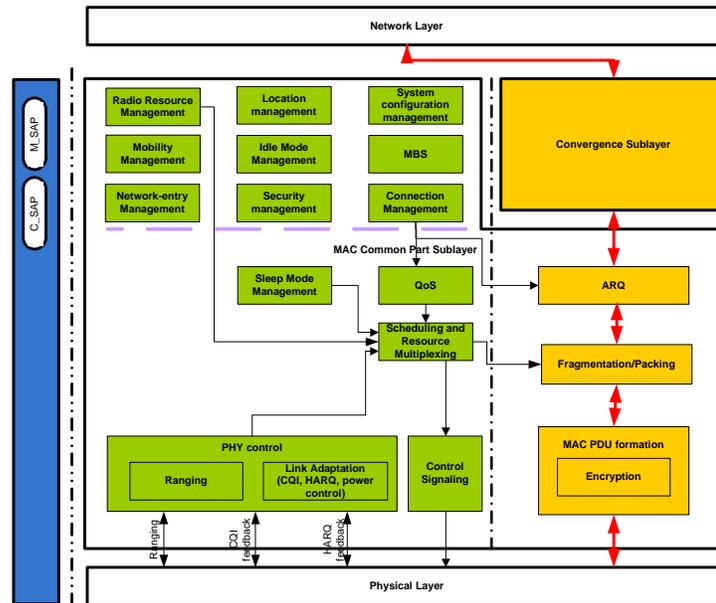
6

7   Figure 67 The IEEE 802.16e AMS/ABS Data Plane Processing Flow

8

A1.2 The IEEE 802.16e AMS/ABS Control Plane Processing Flow

10 Figure 68 describes the MAC message transmission flow in IEEE 802.16e. Most of the MAC functional block
11 generates its own management messages, and these messages are transported to Fragmentation/Packing block.
12 Basically the MAC management message does not use ARQ block (Management messages will be operated in
13 request-and-response manner, that is, if there is no response, sender retransmits request. Therefore additional
14 ARQ operation is not required). Management message may be fragmented or packed, and authentication
15 information (e.g., CMAC/HMAC in IEEE 802.16e) may be appended to the management message if necessary.
16 Some of MAC messages may be transmitted via Control Signaling block in the form of control message (e.g.,
17 MAP). On the receiver side, most of MAC functional block also receives and handles MAC management
18 messages from the MAC functional block of the opposite side (AMS to ABS, ABS to AMS).
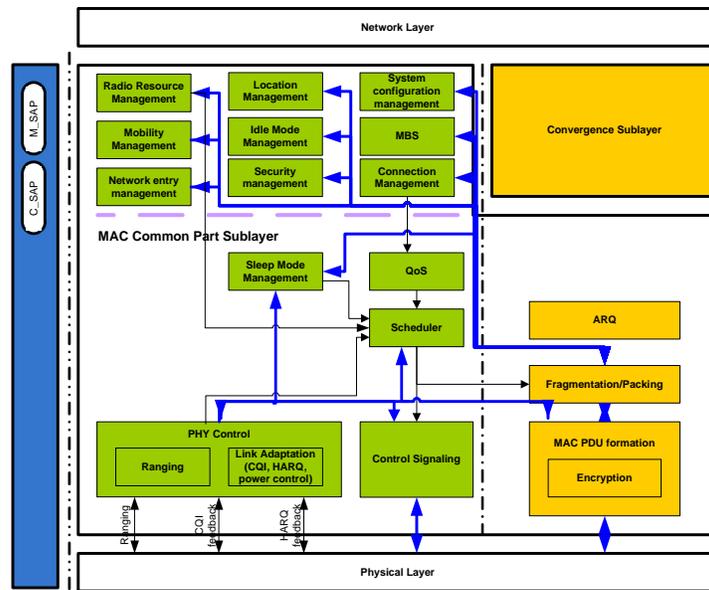
19

20

Figure 68 The IEEE 802.16e AMS/ABS Control Plane Processing Flow

<Editor note: the following text has been generated based on minority opinion and the TBD responses from a large number of members to latency attributes of the frame structure in the Excel Sheet [CIEEE 802.16m-08/096r10] and the necessity to demonstrate the frame structure compliance with the IEEE 802.16m SRD [8]. The content of the following tables will be updated based on the ultimate decisions that will be made in the group on the frame structure parameters.>

Appendix 2. Data Plane and Control Plane Access Latencies

[In order to justify the choice of parameters for the proposed frame structure, it is imperative to demonstrate that the frame structure and associated parameters satisfy the IEEE 802.16m system requirements. In the following sections, the break down of the data and control planes access latencies is provided for the reference and the IEEE 802.16m systems.

A2.1 Data Plane Access Latency

The break down of the components of data plane access latency is shown in Table 6. The access latency with 30% frame error rate over the airlink is 4.67 AMS which is less than 10 AMS limit specified by the IEEE 802.16m SRD.

| Step	Description	IEEE 802.16e Value	IEEE 802.16m Value
0	MS wakeup time	Implementation Dependent	Implementation Dependent
1	MS Processing Delay	2.5 ms	1.23 ms
2	Frame Alignment	2.5 ms	0.31 ms
3	TTI for UL DATA PACKET (Piggy back scheduling information)	5 ms	0.617 ms
4	H-ARQ Retransmission (FER = 30%)	0.3*20 ms	0.3* 4.3 ms
5	BS Processing Delay	2.5 ms	1.23 ms
6	R6 Transfer delay	T_{R6}	T_{R6}
7	ASN-GW Processing delay	T_{ASN_GW}	T'_{ASN_GW}
	Total one way access delay	18.50 ms + T_{ASN_GW}+T_{R6}	4.67 ms + T'_{ASN_GW}+T_{R6}
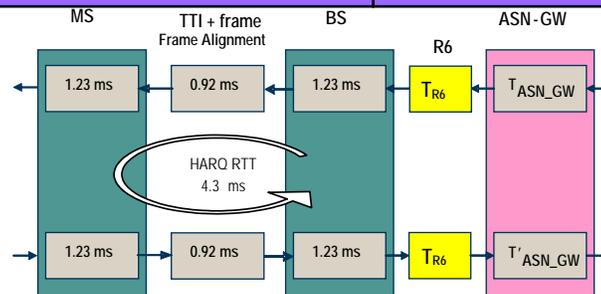
Table 6 Data plane access latency. The above processing time is FFS.

A2.2 Control Plane Access Latency

The break down of system entry procedure from DL scanning and synchronization to the point where the radio resource control (RRC) connection is established is shown in Table 7. Note that the use of superframe header, that encompasses the system configuration information, would significantly reduce the time spent in step 1. Also, since the probability of error required for transmission of some of the MAC control messages is typically 10^{-3}, H-ARQ is used to ensure more reliability. The use of shorter TTI and faster transmissions would enable shorter H-ARQ retransmission, consequently reducing the total time for IDLE_STATE to ACTIVE_STATE transition.

In addition, we assume that the base station, relay station, or mobile station processing time is approximately 2*TTI = 1.23 AMS, that further reduces the total delay budget. It is shown that the IDLE_STATE to ACTIVE_STATE transition time of less than 80 AMS is achievable through the use of proposed frame structure which is less the 100 ms value specified by the SRD.

It must be noted that some of the radio resource control and management messages require probability errors in the order of 10^{-6}; ARQ is used in conjunction with H-ARQ to achieve higher transmission reliability.

Step	Description	IEEE 802.16e Value	IEEE 802.16m Value
0	MS wakeup time	Implementation dependent	Implementation dependent
1	DL scanning and synchronization + DL MAP acquisition + DCD/UCD acquisition	> 300 ms (Assuming 0.5 s DCD/UCD interval)	20 ms
2	Random Access Procedure (UL CDMA Code + BS Processing + DL CDMA_ALLOC_IE)	> 15 ms	< 5 ms
3	Initial Ranging (RNG-REQ + BS Processing + RNG-RSP)	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ
4	Capability Negotiation (SBC-REQ + BS Processing + SBC-RSP) + H-ARQ Retransmission @ 30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
5	Authorization and Authentication/Key Exchange (PKM-REQ + BS Processing + PKM-RSP + …) +H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
6	Registration (REG-REQ + BS/ASN-GW Processing + REG-RSP) + H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
7	RRC Connection Establishment (DSA-REQ + BS Processing + DSA-RSP + DSA-ACK) + H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
	Total C-plane connection establishment Delay	> 90 ms	< 30 ms
	Total IDLE_STATE –> ACTIVE_STATE Delay	> 390 ms	< 50 ms

Table 7 Control plane access latency. The above processing time is FFS.