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Abstract	This version is a revised version of IEEE 802.16m-08/003r3. The revision is based on comment resolution captured in the IEEE 802.16m-08/025r2.	
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 Scope

The 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 802.16m amendment. It describes the system level description of the 802.16m system based on the SRD developed by the IEEE 802.16 TGM[8]. All content included in any draft of the 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. The system described herein is defined to ensure competitiveness of the evolved air interface with respect to other mobile broadband radio access technologies as well as to ensure support and satisfactory performance for emerging services and applications.

2 References

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- [2] IEEE 802.16 WG, "Five Criteria Statement for P802.16m PAR Proposal," IEEE 802.16-06/55r3, November 2006, http://ieee802.org/16/docs/06/80216-06_055r3.pdf
- [3] IEEE Std 802.16-2004: Part 16: IEEE Standard for Local and metropolitan area networks: Air Interface for Fixed Broadband Wireless Access Systems, June 2004
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3 Definition, Symbols, Abbreviation

FA	Frequency Assignment
FDD	Frequency Division Duplex
HFDD	Half-duplex Frequency Division Duplex
LRU	Logical Resource Unit
LDRU	Logical Distributed Resource Unit
LLRU	Logical Localized Resource Unit
MCS	Modulation Coding Scheme
OFDMA	Orthogonal Frequency Division Multiple Access
PRU	Physical Resource Unit
TDD	Time Division Duplex

4 Overall Network Architecture

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

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

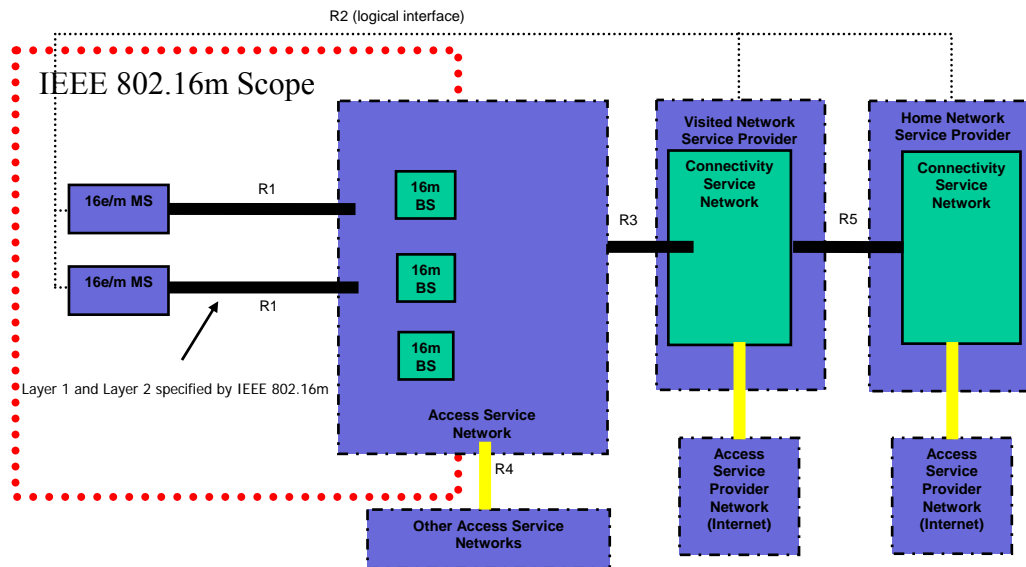


Figure 1 Example of overall network architecture

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

- IEEE 802.16e/m Layer-1 (L1) and Layer-2 (L2) connectivity with IEEE 802.16e/m MS
- Transfer of AAA messages to IEEE 802.16e/m subscriber's Home Network Service Provider (H-NSP) for authentication, authorization and session accounting for subscriber sessions
- Network discovery and selection of the IEEE 802.16e/m subscriber's preferred NSP
- Relay functionality for establishing Layer-3 (L3) connectivity with an IEEE 802.16e/m MS (i.e. IP address allocation)
- Radio Resource Management

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

- ASN anchored mobility
- CSN anchored mobility
- Paging

- ASN-CSN tunneling

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

- MS IP address and endpoint parameter allocation for user sessions
- AAA proxy or server
- Policy and Admission Control based on user subscription profiles
- ASN-CSN tunneling support,
- IEEE 802.16e/m subscriber billing and inter-operator settlement
- Inter-CSN tunneling for roaming
- Inter-ASN mobility

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

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

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

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

Figure 2 and Table 1, show the 16m relay related interfaces that are to be supported and those which are not required to be supported in the 802.16 specification. Only the interfaces involving RSs (16m and legacy RS) are shown.

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

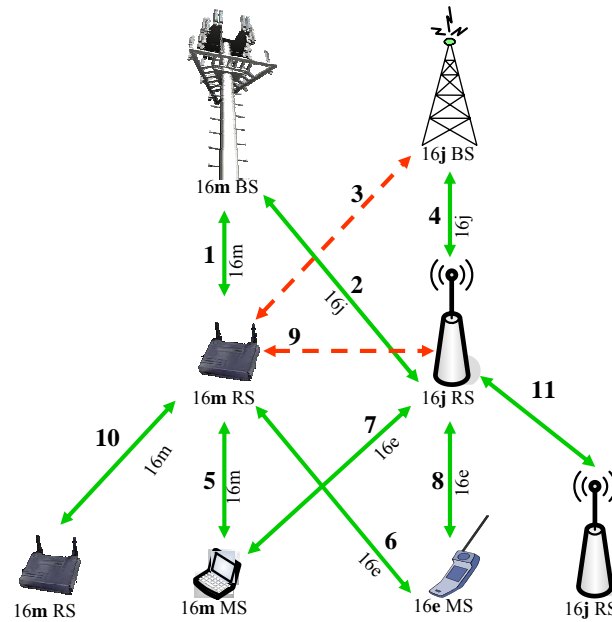


Figure 2 Diagram showing the relay-related connections.

The entities shown in Figure 2 and referred to in Table 1 are defined as follows:

- 16m BS – A base station that supports the base station functionality specified in the IEEE 802.16m draft amendment including the optional relay functionality.
- 16j BS – A base station that supports the base station functionality specified in the IEEE 802.16j draft amendment. This type of base station is referred to as an MR-BS in the IEEE 16j draft amendment.
- 16m RS – A relay station that supports the relay station functionality specified in the IEEE 802.16m draft amendment.
- 16j RS – A relay station that supports the relay station functionality specified in the IEEE 802.16j draft amendment.
- 16m MS – An MS which supports the mobile station functionality specified in the IEEE 802.16m draft amendment.
- 16e MS – An MS which supports the mobile station functionality compliant with the WirelessMAN-OFDMA Reference System, as specified in IEEE 802.16m System Requirements [8].

Connection #	Connected Entities	Protocol used	Supported (Y/N)
1	16m BS -16m RS	16m	Y
2	16m BS - 16j RS	16j	Y
3	16m RS – 16j BS	N/A	N
4	16j BS - 16j RS	16j	Y
5	16m RS - 16m MS	16m	Y
6	16m RS - 16e MS	16e	Y
7	16m MS – 16j RS	16e	Y
8	16j RS - 16e MS	16e	Y
9	16m RS – 16j RS	N/A	N
10	<u>16m RS – 16m RS</u>	16m	Y
11	<u>16j RS – 16j RS</u>	16j	Y

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 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: A 16m MS may connect to a 16m BS either directly or via one or more 16m RSs. The number of hops between the 16m BS and a 16m MS can be two or greater than two. The topology between the 16m BS and the subordinate 16m RSs within a 16m BS cell shall be restricted to a tree topology. A 16e MS may connect to a 16m BS either directly or via one or more 16m RSs. Furthermore a 16e MS may connect to a 16m BS via one or more 16j RSs. The topology between the 16m BS and the subordinate 16j RSs within a 16m BS cell is specified in the IEEE 802.16j draft amendment.

Connection 10 indicates a connection between a 16m RS and another directly connected 16m RS. Such connections exist in order to support topologies in which the number of hops between the 16m BS and an MS is greater than two hops.

Connection 11 indicates a connection between a 16j RS and another directly connected 16j RS. Such connections exist in order to support topologies in which the number of hops between the 16j MR-BS and an MS is greater than two hops.

5 IEEE 802.16m System Reference Model

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

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

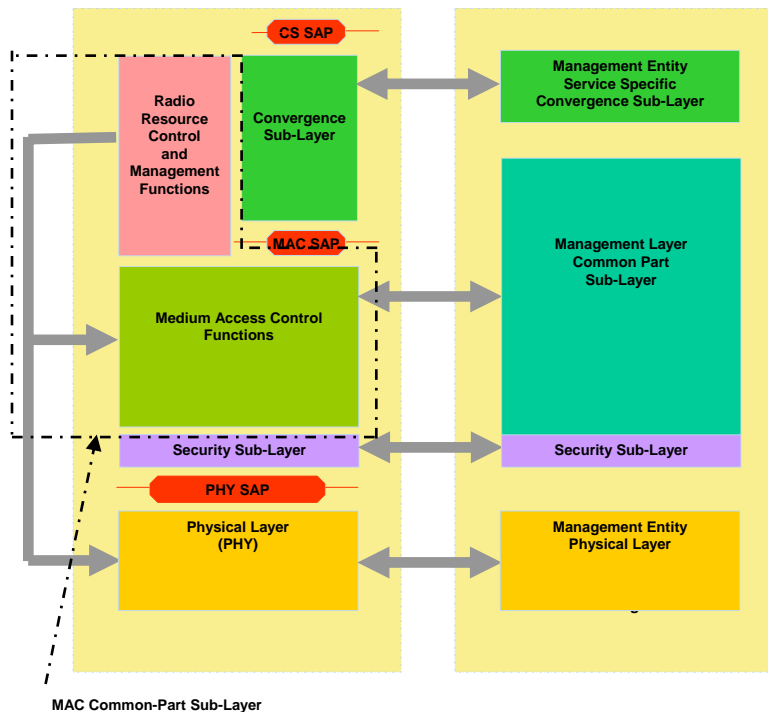


Figure 3 System Reference Model

6 IEEE 802.16m 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 following Figure 4 illustrates the mobile station state transition diagram for IEEE802.16m MS. Mobile Station state diagram for IEEE802.16m systems consists of 4 states, Initialization state, Access state, Connected state and Idle state.

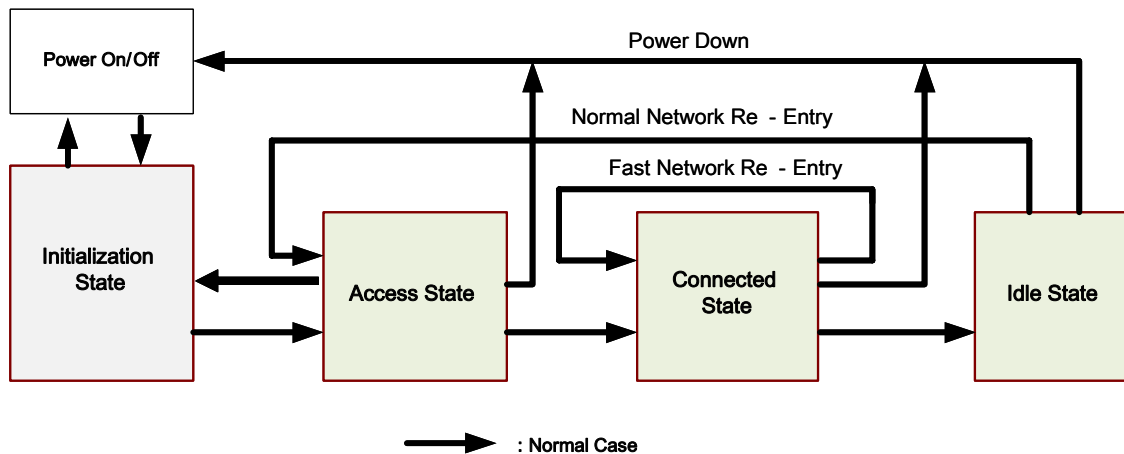


Figure 4 System State Transition Diagram of IEEE802.16m

6.1 Initialization State

Initialization State is where an MS without any connection with BS performs cell selection by scanning and synchronizing to a BS preamble, and acquiring the system configuration information through BCH before entering Access State. The MS can return back to the scanning step in case it fails to perform the actions required in next step.

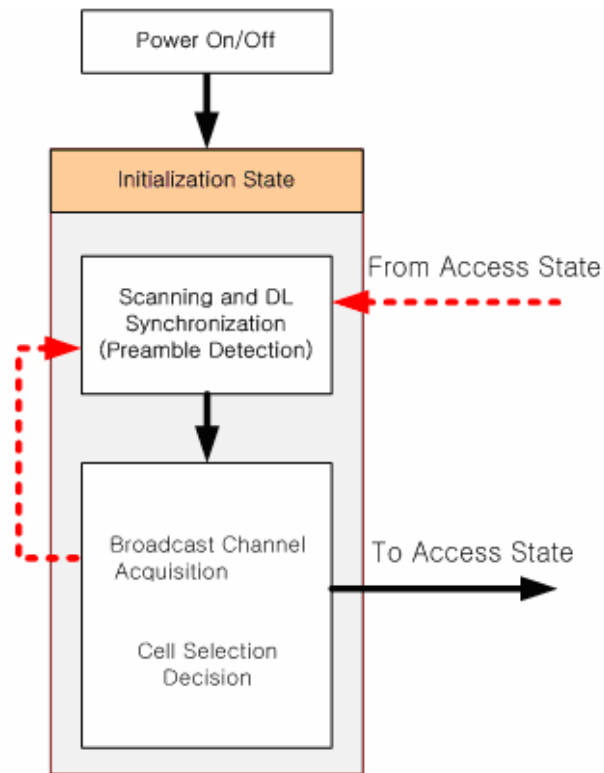


Figure 5 Initialization State Transition Diagram

During this state, if the MS cannot properly perform the BCH information decoding and cell selection, it should return to perform scanning and DL synchronization. The red dashed line represents the abnormal case. If the MS successfully decodes BCH information and selects one target BS, it goes to the Access State. The MS can transit from any state to the initialization state under abnormal conditions..

6.2 Access State

Access State is where the MS performs network entry to the selected BS by going through several processes. The MS performs the ranging process (initial ranging code and RNG-REQ/RSP MAC message is used in the Reference System) in order to obtain UL synchronization. Next, the MS performs basic capability negotiation with the BS (SBC-REQ/RSP MAC message is used in the Reference System). The MS then performs the authentication and authorization process.. Next, the MS performs the registration process (REG-REQ/RSP MAC message is used in the Reference System). MS receives the 802.16m specific IDs as part of Access State procedures. IP address assignment may follow using appropriate procedures.

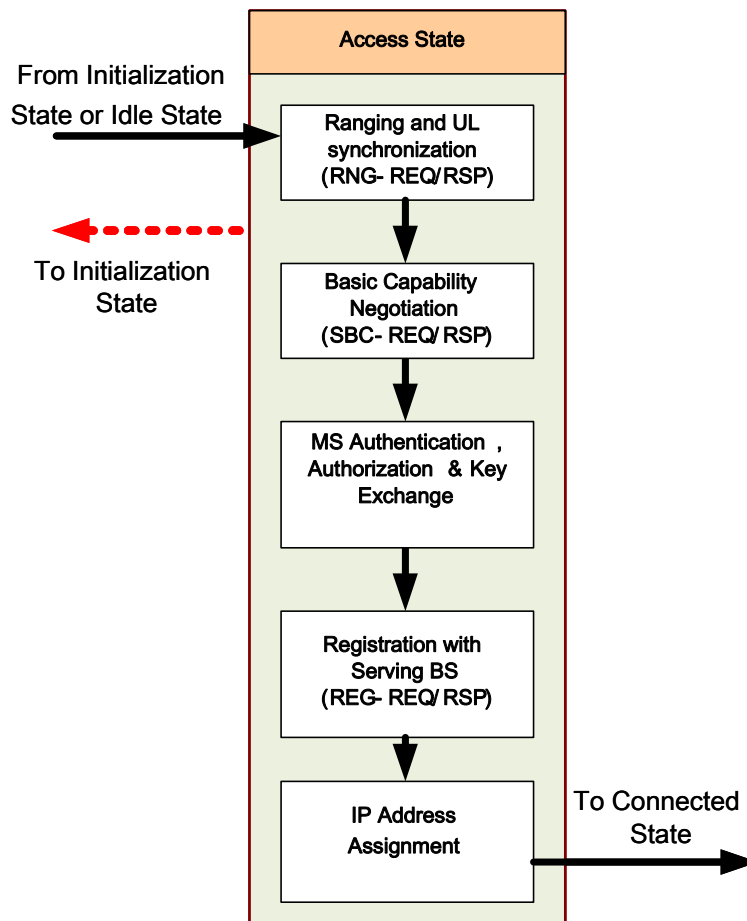


Figure 6 Access State Transition Diagram

<Editor's note: This figure identifies the access state transitions consistent with IEEE 802.16e. These procedures may be modified for IEEE 802.16m. Further updates are likely necessary. In addition the names of the messages in the parenthesis are the ones used in the Reference System>

Upon successfully performing the Access State operation, the MS goes to the Connected State. Otherwise, in case of abnormal operation, the MS goes back to the Initialization State.

6.3 Connected State

The Connected State consists of 3 modes; Sleep Mode, Active Mode and Scanning Mode. During Connected State, the MS maintains at least one connection as established during Access State, while MS and BS may establish additional transport connections. In addition, to reduce power consumption of the MS during user data exchange, the MS or BS can request a transition to sleep mode. And also, MS can scan neighbor cell's signal to reselect a cell which provides robust and reliable services.

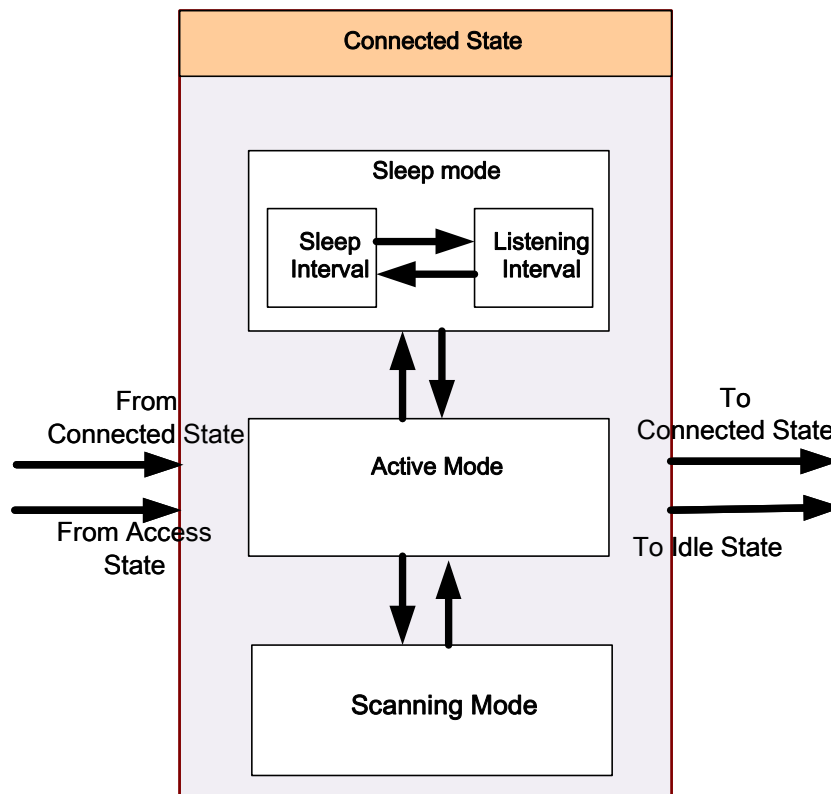


Figure 7 Connected State Transition Diagram

6.3.1 Active mode

During Active Mode, the MS and BS perform normal operations to exchange the DL/UL traffic transaction between the MS and BS. MS can perform the Fast network re-entry procedures after handover: while in handover, MS maintains any 802.16m specific IDs required for handover (FFS) and its IP address in accordance with upper layer protocols. Without going through Access State, MS may remain in Connected State with target BS.

6.3.2 Sleep mode

During Sleep mode, MS may enable power saving techniques. MS in Active mode transitions to sleep mode through sleep mode MAC signaling management messages (MOB_SLP-REQ/RSP message is used in the Reference System). MS does not transmit and receive any traffic to/from its BS during the sleep interval. An MS can receive an indication message (MOB_TRF-IND message is used in the Reference System) during listening interval and then based on the message content to decide whether it should transit to active mode or to stay in sleep mode. During the sleep interval, MS may choose to transit to active mode.

6.3.3 Scanning mode

During scanning mode, the MS performs scanning operation and may be temporarily unavailable to the BS. While in active mode, MS transitions to scanning mode via explicit MAC signaling (MOB_SCN-REQ/RSP message is used in the Reference System) or implicitly without scanning management messages generation. In scanning intervals, MS is unavailable to BS.

6.4 Idle State

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

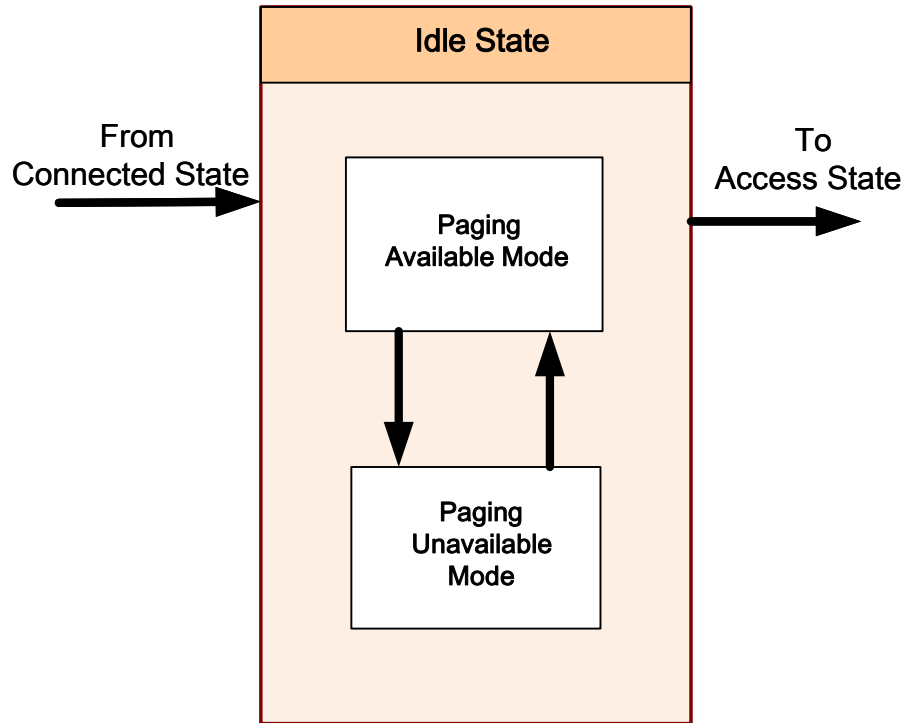


Figure 8 Idle State Transition Diagram

6.4.1 Paging Available Mode

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

6.4.2 Paging Unavailable Mode

During paging unavailable mode, MS does not need to monitor the downlink channel in order to reduce its power consumption. While in this mode, MS can also transition to Access State if required.

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

8.1 The IEEE 802.16m Protocol Structure

The 802.16m MAC is divided into two sublayers:

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

MAC Common Part Sublayer is further classified in to Radio Resource Control and Management (RRCM) functions and Medium Access Control (MAC) functions. The RRCM sublayer 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 functional block definitions captured in section 8.1 apply to the BS and MS. Definitions of functional blocks for the RS are captured in section 8.2.

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 BSs/RSs and also decides whether MS 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 initialization procedures, i.e., ranging (this does not mean physical ranging, but ranging message in order to identification, authentication, and CID allocation), basic capability negotiation, registration, and so on.

Location Management block is in charge of supporting location based service (LBS). Location Management

1 block may generate messages including the LBS information.

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

5 Security Management block is in charge of key management for secure communication.

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

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

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

14 Relay Functions block includes functions to support multihop relay mechanisms. The functions include
15 procedures to maintain relay paths between BS and an access RS.

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

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

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

- 26 • PHY Control
- 27 • Control Signaling
- 28 • Sleep Mode Management
- 29 • QoS
- 30 • Scheduling and Resource Multiplexing
- 31 • ARQ
- 32 • Fragmentation/Packing
- 33 • MAC PDU formation
- 34 • Multi-Radio Coexistence
- 35 • Data forwarding
- 36 • Interference Management
- 37 • Inter-BS coordination

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

1 ACK/NACK. Based on CQI and HARQ ACK/NACK, PHY Control block estimates channel environment of
2 MS, and performs link adaptation via adjusting modulation and coding scheme (MCS) or power level. In the
3 ranging procedure, PHY control block does UL synchronization with power adjustment, frequency offset and
4 timing offset estimation.

5 Control Signaling block generates resource allocation messages. Sleep Mode Management block handles sleep
6 mode operation. Sleep Mode Management block may also generate MAC signaling related to sleep operation,
7 and may communicate with Scheduler and Resource Multiplexing block in order to operate properly according
8 to sleep period.

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

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

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

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

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

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

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

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

- 30 • MAC layer operation
 - 31 ○ Interference measurement/assessment report sent via MAC signaling
 - 32 ○ Interference mitigation by scheduling and flexible frequency reuse
- 33 • PHY layer operation
 - 34 ○ Transmit power control
 - 35 ○ Interference randomization
 - 36 ○ Interference cancellation
 - 37 ○ Interference measurement
 - 38 ○ Tx beamforming/precoding

39 Mobility Management block supports functions related to Intra-RAT/ Inter-RAT handover. It handles the Intra-
40 RAT/ Inter-RAT Network topology acquisition which includes the advertisement and measurement, and also

decides whether MS performs Intra-RAT/ Inter-RAT handover operation.

Inter-BS coordination block performs functions to coordinate the actions of multiple BSs by exchanging information for e.g., interference management. The functions include procedures to exchange information for e.g., interference management between the BSs by backbone signaling and by MS MAC messaging. The information may include interference characteristics, e.g. interference measurement results, etc.

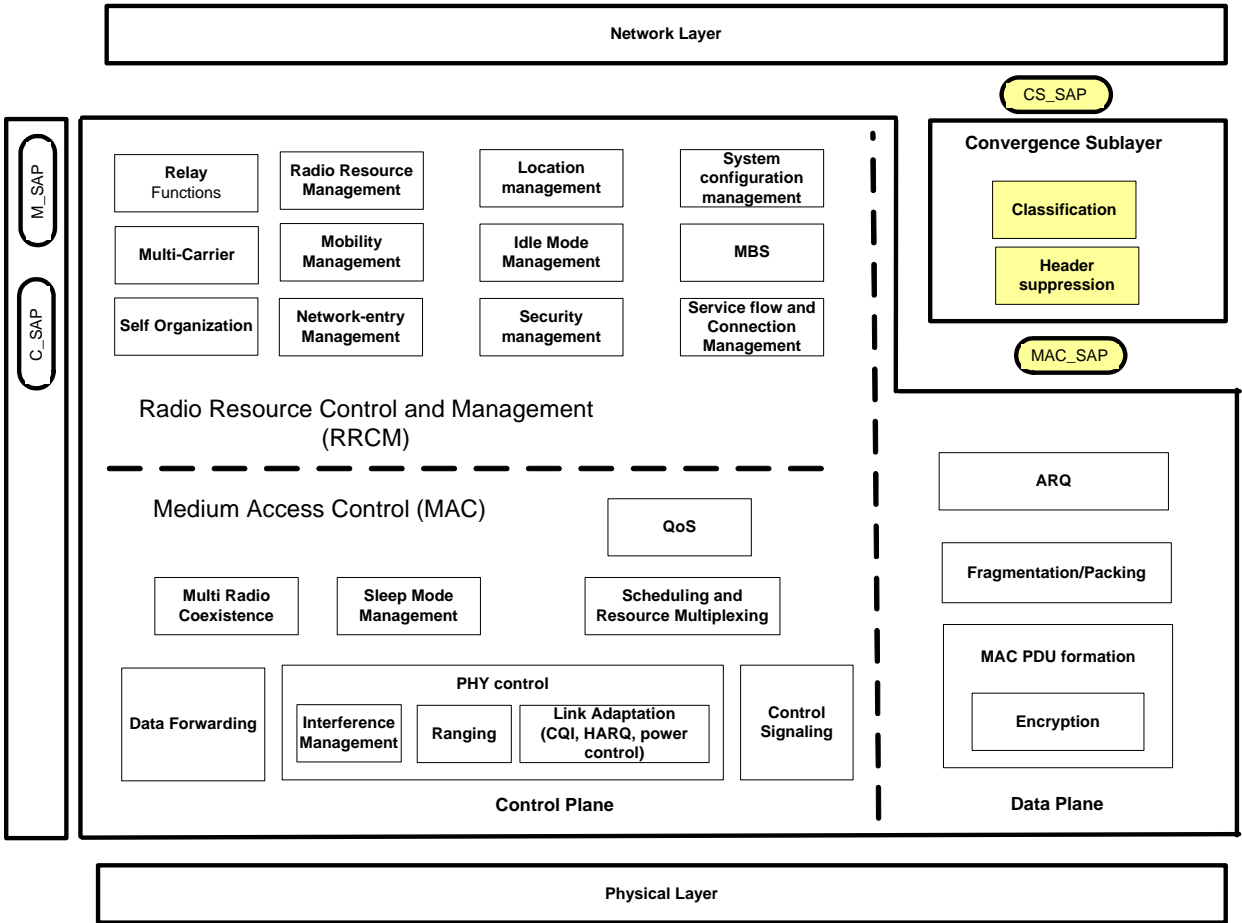


Figure 9 The IEEE 802.16m Protocol Structure

8.1.1 The IEEE 802.16m MS/BS Data Plane Processing Flow

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

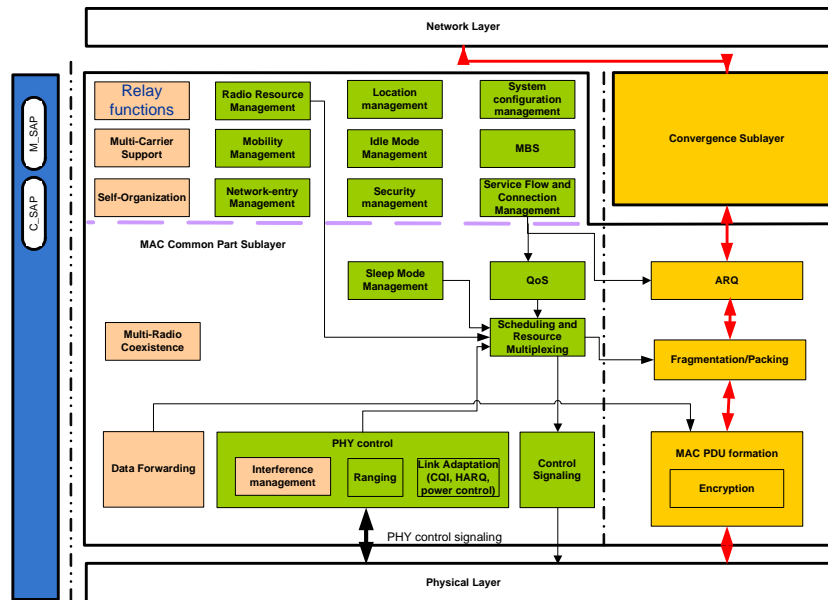


Figure 10 The IEEE 802.16m MS/BS Data Plane Processing Flow Note: The MS may not utilize all the blocks shown in this figure.

8.1.2 The IEEE 802.16m MS/BS Control Plane Processing Flow

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

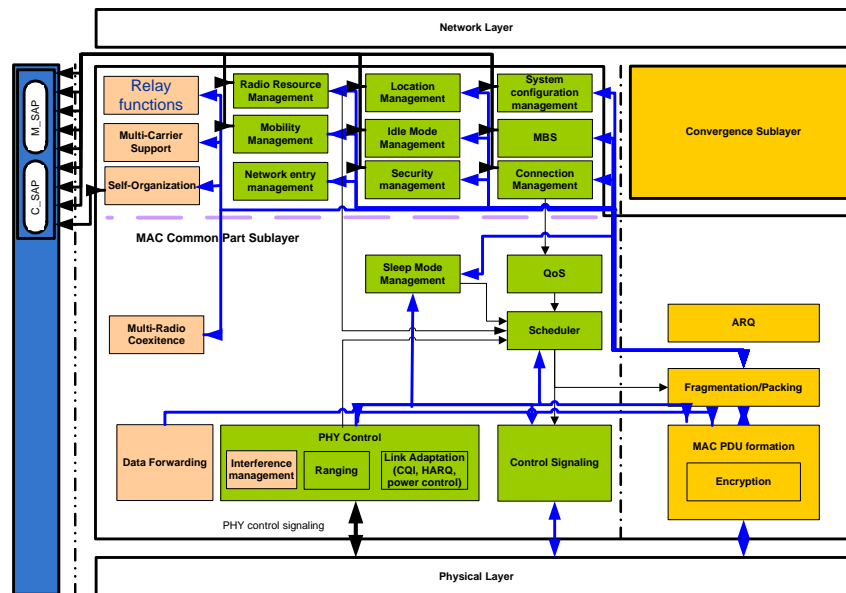


Figure 11 The IEEE 802.16m MS/BS Control Plane Processing Flow Note: The MS may not utilize all the blocks shown in this figure.

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.

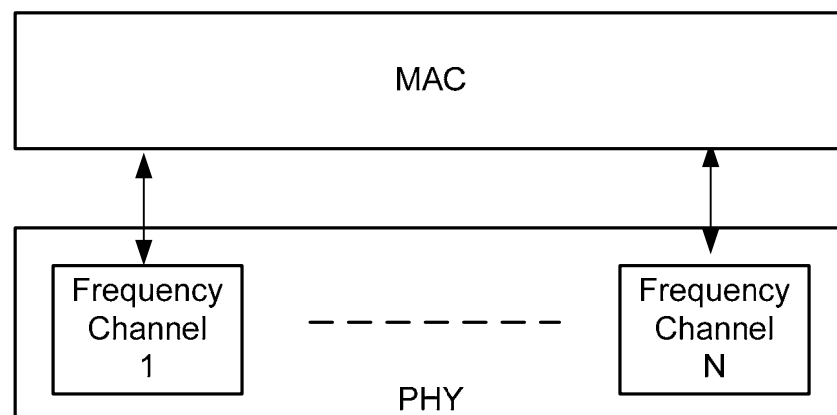


Figure 12 Multicarrier support protocol structure

8.2 Relay Protocol Structure

The protocol partitioning for the BS and MS is shown in Figure 9 and the data plane and control plane processing flow is described in sub-clauses 8.1.1 and 8.1.2, respectively.

Figure 13 shows the proposed protocol functions for an RS. An RS may consist of a subset of the protocol functions shown in Figure 13. The subset of functions will depend on the type or category of the RS.

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

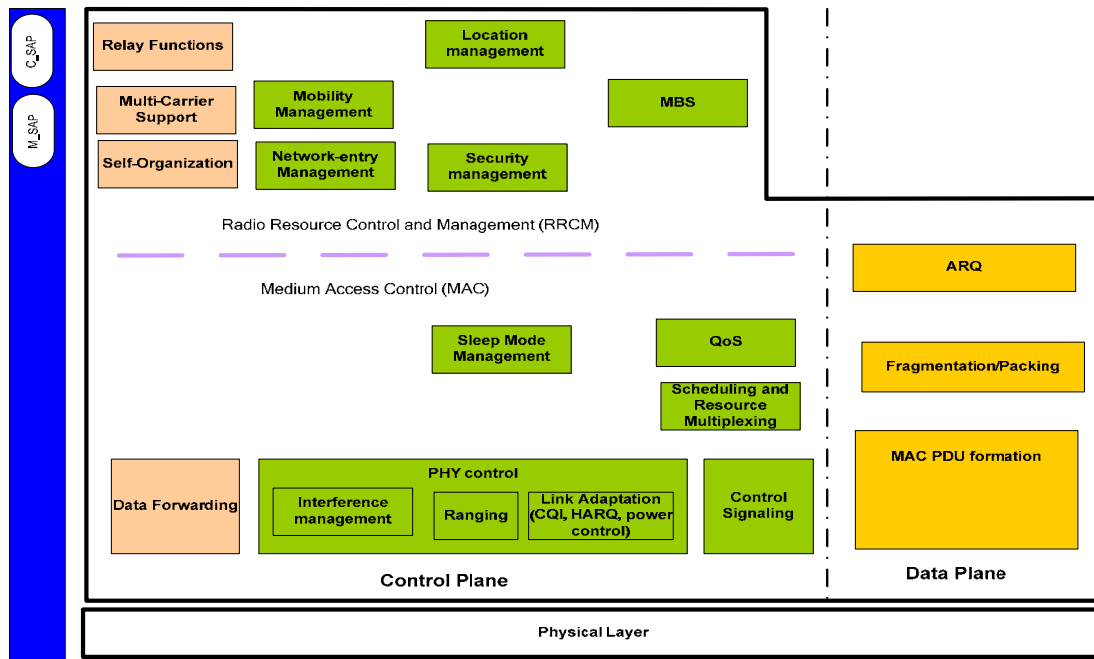


Figure 13 Protocol Functions of RS

The 802.16m RS MAC is divided into two sublayers:

- Radio Resource Control and Management (RRCM) sublayer
- Medium Access Control (MAC) sublayer

The 802.16m RS RRCM sublayer includes the following functional blocks that are related with RS radio resource functions:

- Mobility Management
- Network-entry Management

- Location Management
- Security Management
- MBS
- Path Management functions
- Self Organization
- Multi-Carrier

The Mobility Management block supports MS handover operations in cooperation with the BS.

The Network-entry Management block is in charge of RS/MS initialization procedures and performing RS network entry procedure to the BS. Network-entry Management block may generate management messages needed during RS/MS 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 RS and reporting location information to the BS. Location Management block may generate messages for the LBS information including positioning data.

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

The MBS (Multicast and Broadcasting Service) block coordinates with the BS 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 RS self configuration and RS self optimization mechanisms coordinated by BS. The functions include procedures to request RSs/MSs to report measurements for self configuration and self optimization and receive measurements from the RSs/MSs, and report measurements to BS. The functions also include procedures to adjust RS parameters and configurations for self configuration / optimization with / without the coordination with BS.

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

The 16m RS 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 RS. Based on CQI and HARQ ACK/NACK, PHY Control block estimates channel environment of RS/MS, and performs link adaptation via adjusting modulation and coding scheme (MCS) or power level.

1
2 The Control Signaling block generates RS resource allocation messages such as MAP as well as specific control
3 signaling messages.
4

5 The Sleep Mode Management block handles sleep mode operation of its MSs in coordination with the BS.
6

7 The QoS block handles rate control based on QoS parameters based on inputs from TBD functional blocks.
8

9 The Scheduling and Resource Multiplexing block schedules the transmission of MPDUs. The Scheduling and
10 Resource Multiplexing block is present in the RS in order to support distributed scheduling.
11

12 The ARQ block assists MAC ARQ function between BS, RS and MS.
13

14 The Fragmentation/Packing block performs fragmenting or packing MSDUs based on scheduling results from
15 Scheduler block. The Fragmentation/Packing block in an RS includes the unpacking and repacking of fragments
16 that have been received for relaying in order to adapt the size of MPDUs to the expected channel quality of the
17 outgoing link.
18

19 The MAC PDU formation block constructs MAC protocol data units (PDUs) which contain user traffic or
20 management messages. User traffic is assumed to have originated at either the BS or MS. The MAC PDU
21 formation block may add or modify MPDU control information (e.g., MAC header).
22

23 The Data Forwarding block performs forwarding functions on the path between BS and RS/MS. The Data
24 Forwarding block may cooperate with other blocks such as Scheduling and Resource Multiplexing block and
25 MAC PDU formation block.

26 The Interference Management block performs functions at the RS to manage the inter-cell/sector and inter-RS
27 interference among RS and BS. This includes the collection of interference level measurements and selection of
28 transmission mode used for individual MSs attached to the RS.

29 Control functions can be divided among the BS and RSs using a centralized model or a distributed model. In a
30 centralized model, the BS makes control decisions and the RSs relay control information between the BS and
31 MS. In a distributed model the RS makes control decisions for MSs attached to it as appropriate, and optionally
32 communicates those decisions to the BS. The determination of whether a particular control function should be
33 centralized or distributed is made independently for each control function. The classification of specific control
34 functions as centralized or distributed is for further study.
35
36

9 Convergence Sub-Layer

10 Medium Access Control Sub-Layer

10.1 MAC Addressing

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

10.1.1 IEEE 802 MAC Address

The 48-bit globally-unique IEEE 802 MAC address uniquely identifies the MS.

10.1.2 MAC Logical Addresses

MAC logical addresses are assigned to the MS by management messages from the BS. Logical addresses are used for resource allocation and management of the MS.

10.1.2.1 “Station Identifier”

The BS assigns a “Station Identifier” to the MS during network entry to uniquely identify the MS to the BS. Each MS 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”

Each MS connection is assigned a “Flow Identifier” that uniquely identifies the connection within the MS. “Flow Identifiers” identify management connections and active transport Service Flows.

10.2 HARQ Functions

HARQ is supported in downlink and uplink packet (re)transmissions in both BS and MS to improve robustness and performance.

The HARQ operation relies on N-process (multi-channel) stop-and-wait protocol.

10.2.1 HARQ in the Downlink

10.2.1.1 HARQ Timing and Protocol

<Editor’s note: Decision could not be made on the choice of HARQ schemes for downlink, currently 3 options are being considered 1) synchronous, 2) asynchronous, and 3) combination of the previous schemes>

Option1:

1 IEEE 802.16m uses synchronous HARQ scheme in the downlink.

2
3 Option 2:

4 IEEE 802.16m uses asynchronous HARQ scheme in the downlink.

5
6 Option 3:

7 IEEE 802.16m uses both asynchronous and synchronous HARQ schemes in the downlink.

8
9 The following HARQ parameters and their associated values are defined:

- 10
- 11 • Maximum retransmission delay.: FFS
- 12 • Maximum number of retransmissions: FFS
- 13 • Maximum number of HARQ processes FFS
- 14 • ACK/NACK delay: FFS
- 15

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

17
18
19 The HARQ ACK/NACK delay is defined for FDD and for each TDD DL/UL ratio and for each mixed mode
20 scenarios
21

22 **10.2.1.2 HARQ Operation with Persistent Allocation**

23 <Editor's note: This section is provided as place holder. This section will be filled when details of
24 HARQ operation for persistent allocation is presented and discussed>
25

26 **10.2.1.3 HARQ Re-transmissions**

27 <Editor's note: the working assumption will depend on decision taken w.r.t. section 10.x.1.1>
28

29 Option-1: For synchronous HARQ, resource at the retransmissions in the downlink can be fixed or adaptive
30 according to control signaling.
31

32 Option-2: For asynchronous HARQ, IEEE 802.16m uses an adaptive HARQ scheme in the downlink. In
33 adaptive asynchronous HARQ, the resource allocation and transmission format for the HARQ retransmissions
34 may be different from the initial transmission. In case of retransmission, control signaling is required to indicate
35 the resource allocation and transmission format along with other HARQ necessary parameters.
36

37 Option-3: For synchronous HARQ, resource at the retransmissions in the downlink can be fixed or adaptive
38 according to control signaling. For asynchronous HARQ, IEEE 802.16m uses an adaptive HARQ scheme in the
39 downlink. In adaptive asynchronous HARQ, the resource allocation and transmission format for the HARQ
40 retransmissions may be different from the initial transmission. In case of retransmission, control signaling is
41 required to indicate the resource allocation and transmission format along with other HARQ necessary
42 parameters.
43

10.2.2 HARQ in the Uplink

10.2.2.1 HARQ Timing and Protocol

<Editor's Note: Decision could not be made on the choice of HARQ schemes for uplink, currently 3 options are being considered, 1) synchronous, 2) asynchronous, and 3) combination of the previous schemes>

Option 1:

IEEE 802.16m uses synchronous HARQ scheme in the uplink.

Option 2:

IEEE 802.16m uses asynchronous HARQ scheme in the uplink.

Option 3:

IEEE 802.16m uses both asynchronous and synchronous HARQ schemes 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

<Editor's note: Option will depend on decision taken w.r.t. section 10.x.2.1>

Option-1: For synchronous HARQ, resource at the retransmissions in the uplink can be fixed or adaptive according to control signaling.

Option-2: For asynchronous HARQ, IEEE 802.16m uses an adaptive HARQ scheme in the uplink. 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.

Option-3: For synchronous HARQ, resource at the retransmissions in the uplink can be fixed or adaptive according to control signaling. For asynchronous HARQ, IEEE 802.16m uses an adaptive HARQ scheme in the uplink. 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.

10.2.3 HARQ and ARQ Interactions

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

10.3 Handover

The following 4 cases are considered for handover in 802.16m

Case-1: 16m MS handover from legacy serving BS to legacy target BS

Case-2: 16m MS handover from 16m serving BS to legacy target BS

Case-3: 16m MS handover from legacy serving BS to 16m target BS

Case-4: 16m MS handover from 16m serving BS to 16m target BS

The 16m network and mobile station uses legacy handover procedures for case-1.

Solutions for cases 2, 3 and 4 are FFS.

11 Physical Layer

11.1 Duplex modes

IEEE 802.16m supports TDD and FDD duplex modes, including H-FDD MS operation, in accordance with the IEEE 802.16m system requirements document [8]. Unless otherwise specified, the frame structure attributes 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 (μ s)		91.429	128	102.4	91.429	91.429
Cyclic Prefix (CP) $T_g=1/8 T_u$	Symbol Time T_s (μ s)	102.857	144	115.2	102.857	102.857
	Number of OFDM symbols per Frame	48	34	43	48	48
	Idle time (μ s)	62.86	104	46.40	62.86	62.86
	Symbol Time T_s (μ s)	97.143			97.143	97.143
Cyclic Prefix (CP) $T_g=1/16 T_u$	Number of OFDM symbols per Frame	51			51	51
	Idle time (μ s)	45.71			45.71	45.71

Table 2 OFDMA parameters for IEEE 802.16m

A longer CP size 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 14. Each 20 ms superframe is divided into four equally-sized 5 ms radio frames. 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 (some of which may be idle symbols) and 2) the type-2 subframe that consists of seven OFDMA symbols.

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

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

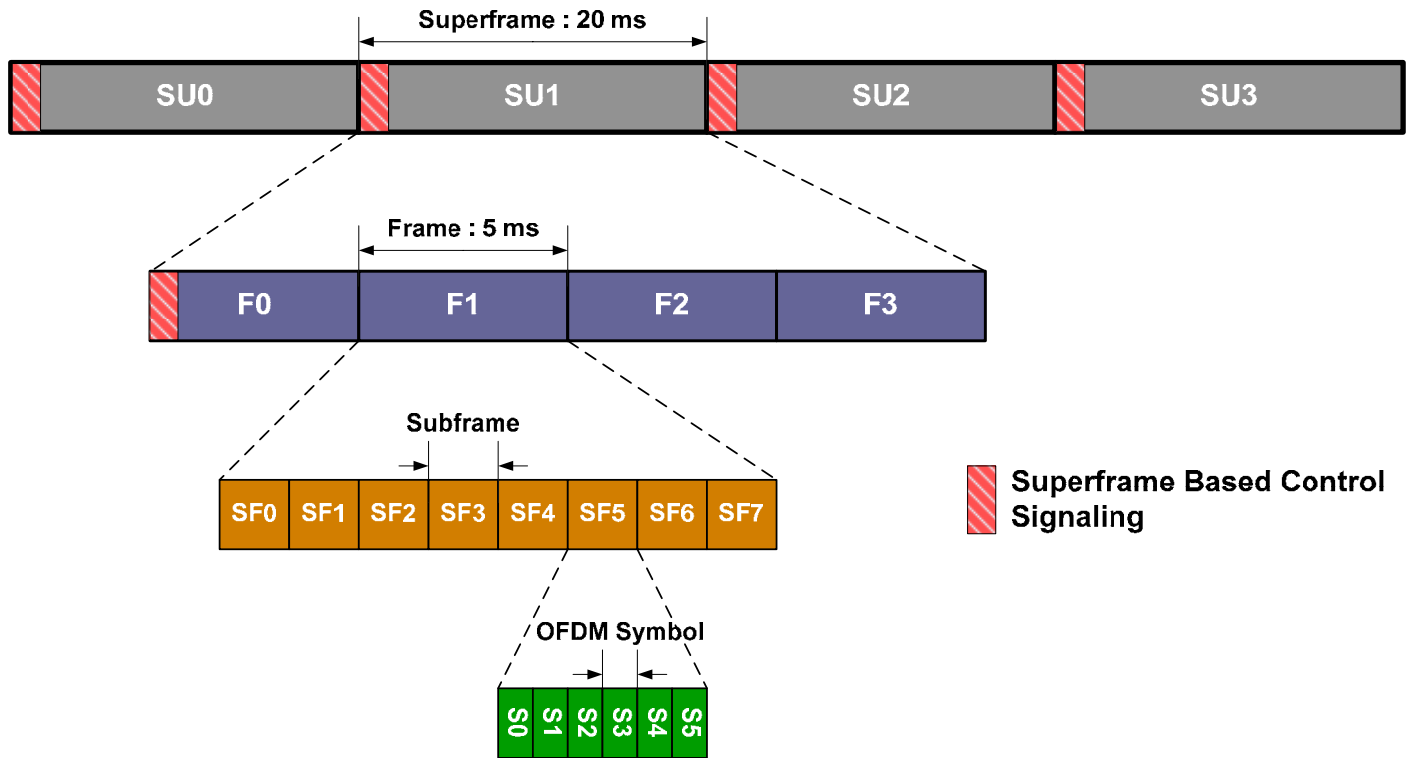


Figure 14 Basic frame structure

11.4.1.1 Frame Structure for $CP=1/8 T_u$

Figure 15 illustrates an example TDD frame structure with DL to UL ratio of 5:3. Assuming OFDMA symbol duration of $102.857\mu s$ and a CP length of $1/8 T_u$, the length of type-1 subframe is 0.617 ms. In Figure 15, the last DL subframe, i.e., DL SF4, is an type-2 subframe whose last OFDMA symbol is an idle symbol to accommodate the gap required to switch from DL to UL. Other numerologies may result in different number of subframes per frame and symbols within the subframes. Figure 16 shows an example of a frame structure in FDD mode, and Figure 17 shows an example of a frame structure with CP of $1/16 T_u$.

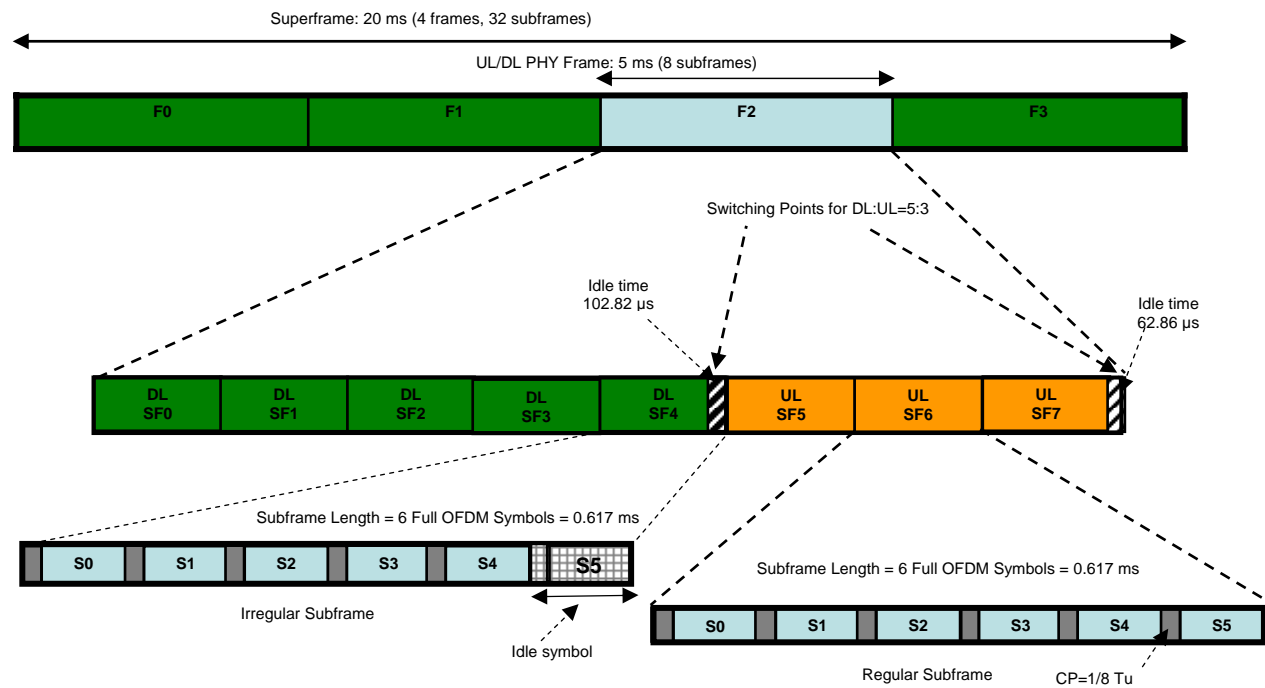


Figure 15 Frame structure with type-1 subframe in TDD duplex mode ($CP=1/8 T_u$)

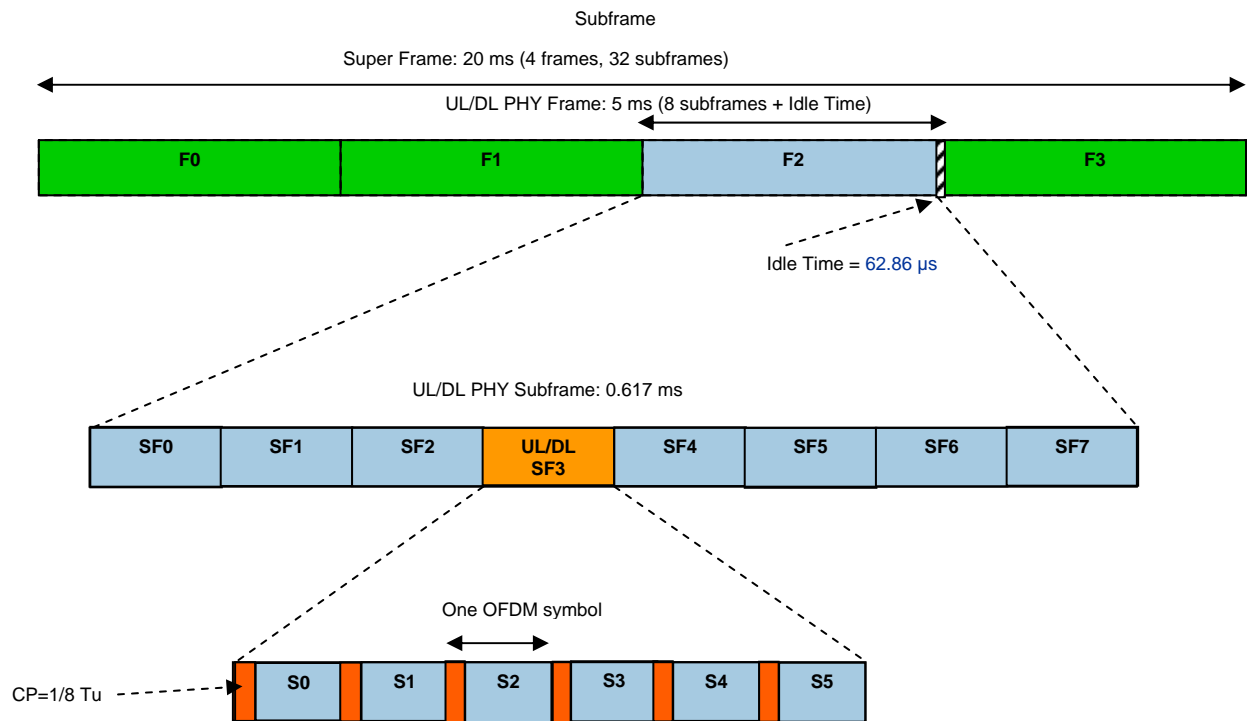


Figure 16 Frame structure with type-1 subframe in FDD duplex mode ($CP=1/8 T_u$)

11.4.1.2 Frame Structure for CP=1/16 T_u

Figure 17 illustrates an example of TDD and FDD frame structure with a CP of 1/16 T_u . Assuming OFDMA symbol duration of 97.11 μ s and a CP length of 1/16 T_u , the length of type-1 and type-2 subframes are 0.583 ms and 0.680 ms, respectively. Other numerologies may result in different number of subframes per frame and symbols within the subframes.

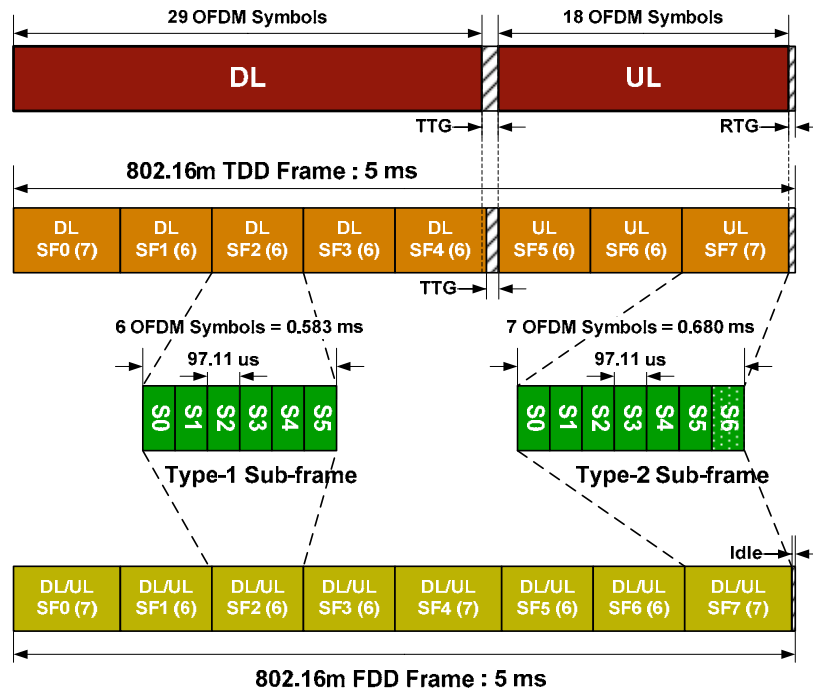


Figure 17 TDD and FDD Frame Structure with a CP of 1/16 T_u (DL to UL ratio of 5:3)

11.4.1.3 Superframe Header

As shown in Figure 14, each superframe shall begin with a DL sub frame that contains a superframe header.

11.4.1.4 Transmission Time Interval

The transmission time interval (TTI) is the duration of the transmission of the physical layer encoded packet over the radio air interface and is equal to an integer number of subframes (default one subframe).

11.4.1.5 Frame Structure to support multi-carrier operation

The support for multiple RF carriers can be accommodated with the same frame structure used for single carrier

support, however, some considerations in the design of protocol and channel structure may be needed to efficiently support this feature.

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

Figure 18 shows that the same frame structure would be applicable to both single carrier and multicarrier mode of operation. A number of narrow BW carriers can be aggregated to support effectively wider BW operation. Each carrier may have its own synchronization channel and superframe header. Further, some carriers may have only part of superframe header.

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

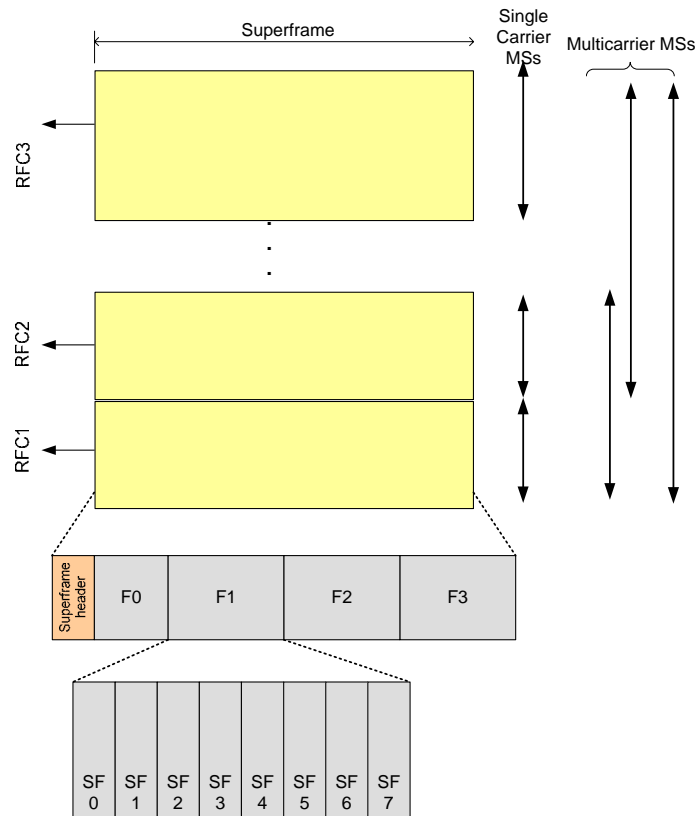


Figure 18 Example of the proposed frame structure to support multi-carrier operation

11.4.2 Frame Structure Supporting Legacy Frames

The legacy and IEEE 802.16m frames are offset by a fixed number of subframes to accommodate new features

such as new synchronization channel (preamble), broadcast channel (system configuration information), and control channels, as shown in Figure 19. The FRAME_OFFSET shown in Figure 19 is for illustration. It is an offset between the start of the legacy frame and the start of the new frame carrying the superframe header, defined in a unit of subframes. In the case where 16m BSs coexist with legacy BSs, two switching points shall be selected in each TDD radio frame.

For UL transmissions both TDM and FDM approaches are supported for multiplexing of legacy and 16m mobiles.

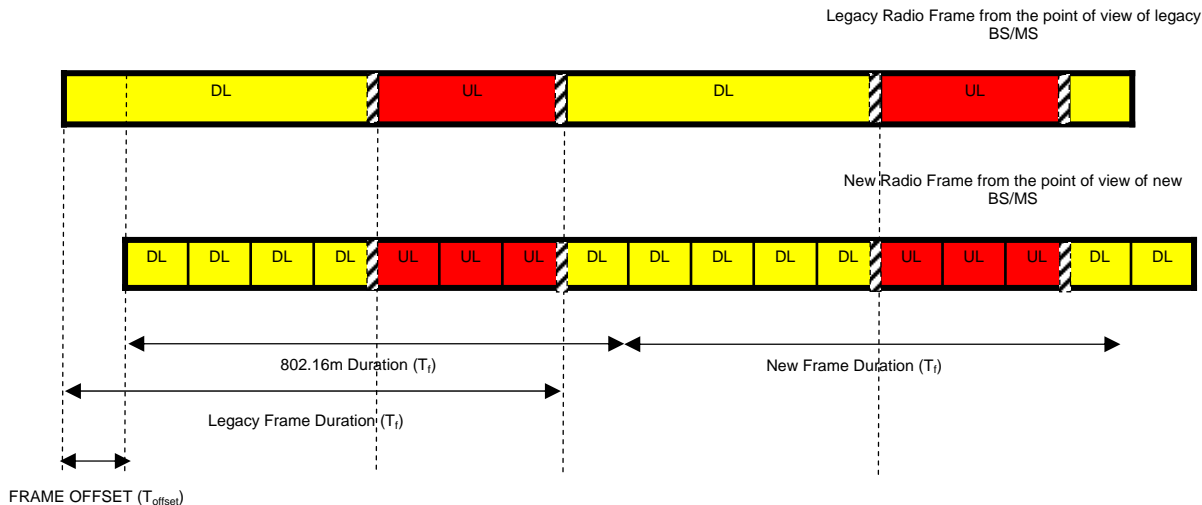


Figure 19 Relative position of the new and legacy radio frames (example TDD duplex mode)

11.4.2.1 The Concept of Time Zones

The time zone is defined as an integer number (greater than 0) of consecutive subframes. The concept of time zones is introduced that is equally applied to TDD and FDD systems. The new and legacy time zones are time-multiplexed (TDM) across time domain for the downlink. For UL transmissions both TDM and FDM approaches are supported for multiplexing of legacy and new terminals. Note that DL/UL traffic for the new MS can be scheduled in both zones whereas the DL/UL traffic for the legacy MS can only be scheduled in the legacy zones.

In the absence of any legacy system, the legacy zones will disappear and the entire frame will be allocated to the new zones and thereby new systems.

11.4.2.1.1 Time Zones in TDD

In a mixed deployment of legacy terminals and new IEEE 802.16m terminals, the allocation of time zones in the TDD mode shall be as shown in **Error! Reference source not found.** and **Error! Reference source not found.**, which are examples for the two and four switching point case respectively. The duration of the zones may vary. Every frame shall start with a preamble and the MAP followed by legacy DL zone since legacy terminals/relays expect IEEE 802.16e zones in this region. Similarly In a mixed deployment of legacy terminals and new IEEE 802.16m terminals, the UL portion shall start with legacy UL zone since legacy BS/terminals/relays expect IEEE 802.16e UL control information be sent in this region. Here the coexistence is defined as a deployment where legacy and new BSs co-exist on the same frequency band and in the same or

1 neighboring geographical areas and in this case, four switching points should not be used. In a green-field
2 deployment where no legacy terminal exists, the legacy zones can be removed.

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

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

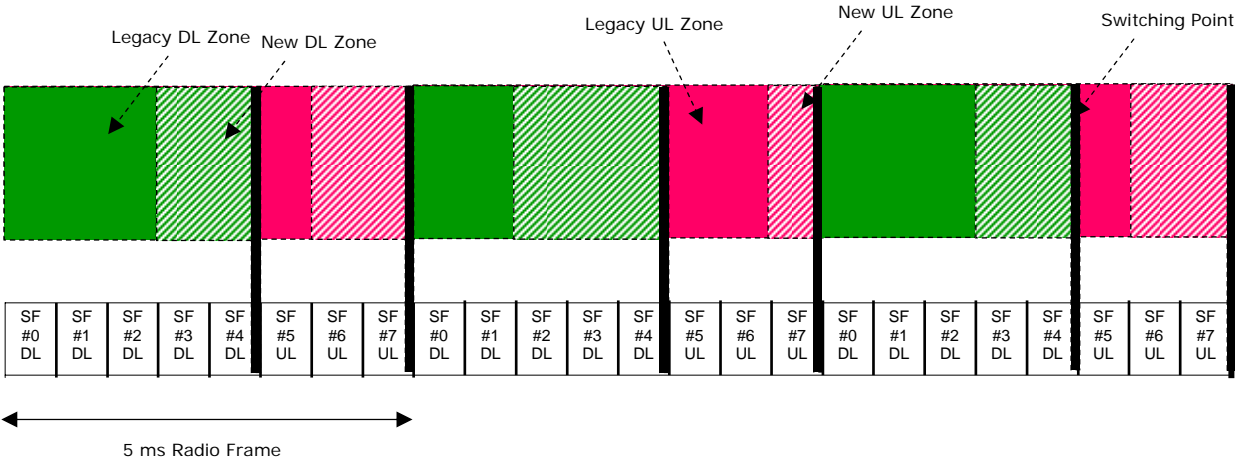


Figure 20 Example of Time zones in TDD mode

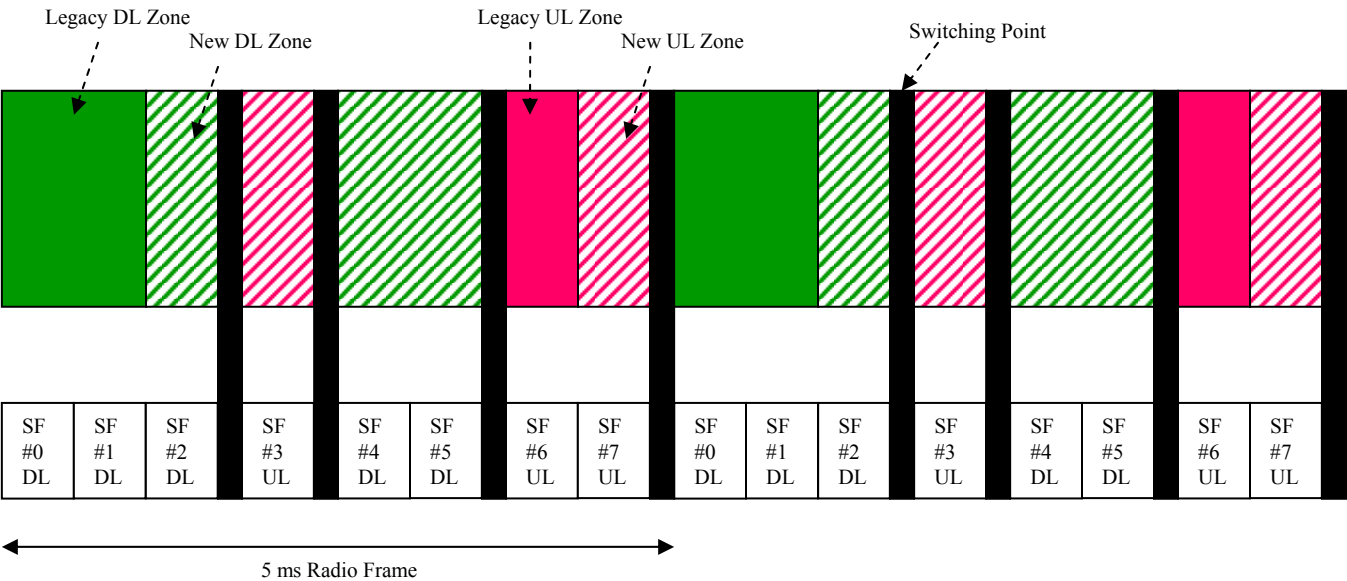


Figure 21 Example of Time zones in a TDD system with four switching points per radio frame.

11.4.3 Frame Structure Supporting Legacy Frames with a Wider Channel for the IEEE 802.16m

Figure 22 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 IEEE 802.16m MSs. One or multiple of the narrowband 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, there is no necessity 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 IEEE 802.16m MSs 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.

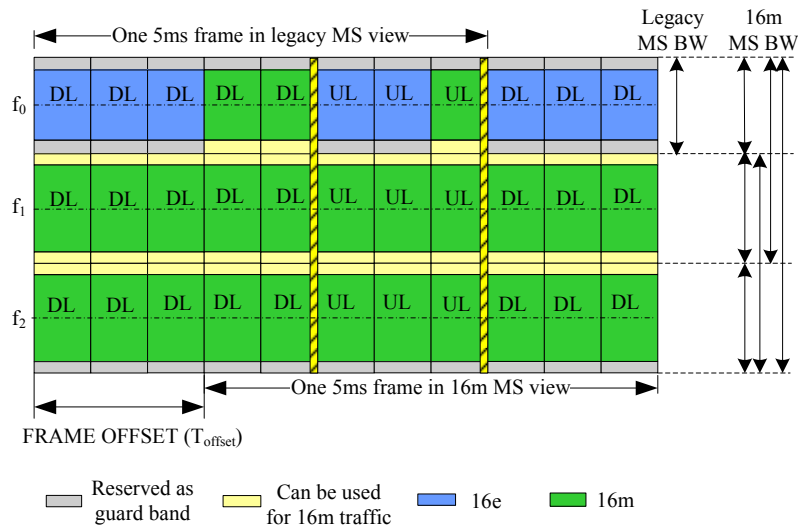


Figure 22 Illustration of frame structure supporting legacy frames with a wider channel

11.4.4 Relay Support in Frame Structure

A 16m BS that supports 16m relay stations shall communicate with the 16m RS in the 16m zone. The 16m BS shall multiplex the legacy zone and the 16m zone using TDM in the DL. In the UL, the 16m BS can support TDM as well as FDM for multiplexing legacy zone and the 16m zone. The 16m specification shall not alter the legacy zone operation. The access link and the relay link communications in the legacy zone shall be multiplexed in accordance with the IEEE 802.16j specifications.

A 16m RS shall communicate with the 16e MS in the "legacy zone".

The start of the legacy zone and 16m zone of the BS and all the subordinate RSs associated with the BS shall be time aligned. The duration of the legacy zone of the BS and the RS may be different.

- Legacy Zone
 - where 16m BS communicates with 16j RS or 16e MS, and where 16m RS communicates with a 16e MS.
- 16e Access Zone

1 ○ where 16m BS, a 16j RS or a 16m RS communicates with a 16e MS.

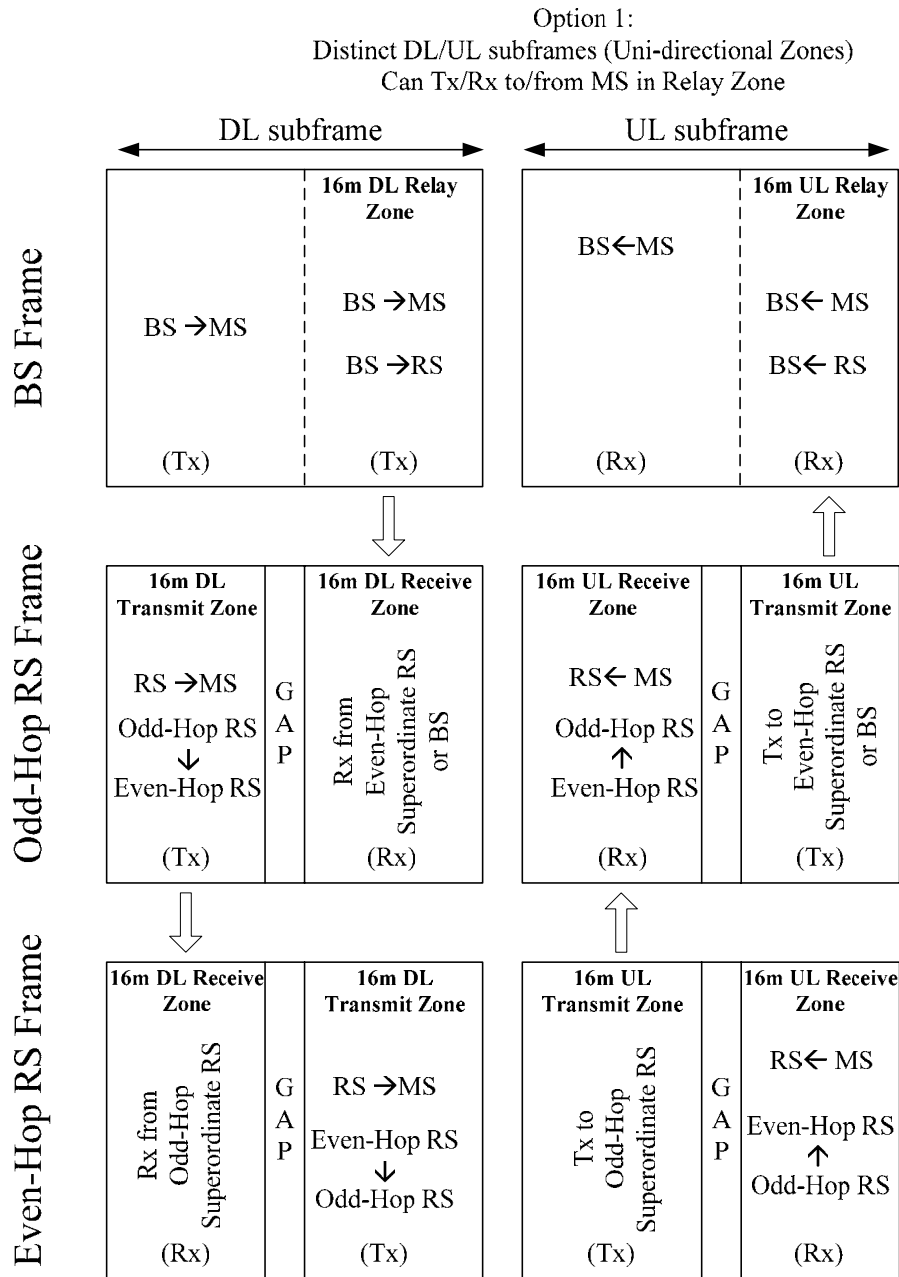
2 • 16j Relay Zone

3 ○ where 16m BS communicates with a 16j RS.

4 • 16m Zone

5 ○ where 16m BS communicates with 16m RS or 16m MS, and where 16m RS communicates with
6 other 16m entities (i.e. 16m BS, 16m RS or 16mMS).

7 There are two options for the Relay frame structure. These are captured in Figure 23 and Figure 24. Further
8 study is required to distill a single frame structure from among these two options.

Figure 23 *Relay Frame structure option 1*

Definitions corresponding to Option 1 shown in Figure 23

- DL Relay Zone: An integer multiple of subframes located in the 16m zone of the DL of the BS frame, where a 16m BS can transmit to the 16m RSs and the 16m MSs.
- UL Relay Zone: An integer multiple of subframes located in the 16m zone of the UL of the 16m BS frame, where a 16m BS can receive from the 16m RSs and the 16m MSs.
- DL Transmit Zone: An integer multiple of subframes located in the 16m zone of the DL of the 16m RS frame, where a 16m RS can transmit to subordinate 16m RSs and the 16m MSs.

- 1 • DL Receive Zone: An integer multiple of subframes located in the 16m zone of the DL of the 16m RS
2 frame, where a 16m RS can receive from its superordinate station.
- 3 • UL Transmit Zone: An integer multiple of subframes located in the 16m zone of the UL of the 16m RS
4 frame, where a 16m RS can transmit to its superordinate station.
- 5 • UL Receive Zone: An integer multiple of subframes located in the 16m zone of the UL of the 16m RS
6 frame, , where a 16m RS can receive from its subordinate 16m RSs and the 16m MSs.

7

Option 2:
Bi-Directional Zones
Distinct DL/UL Access Zone

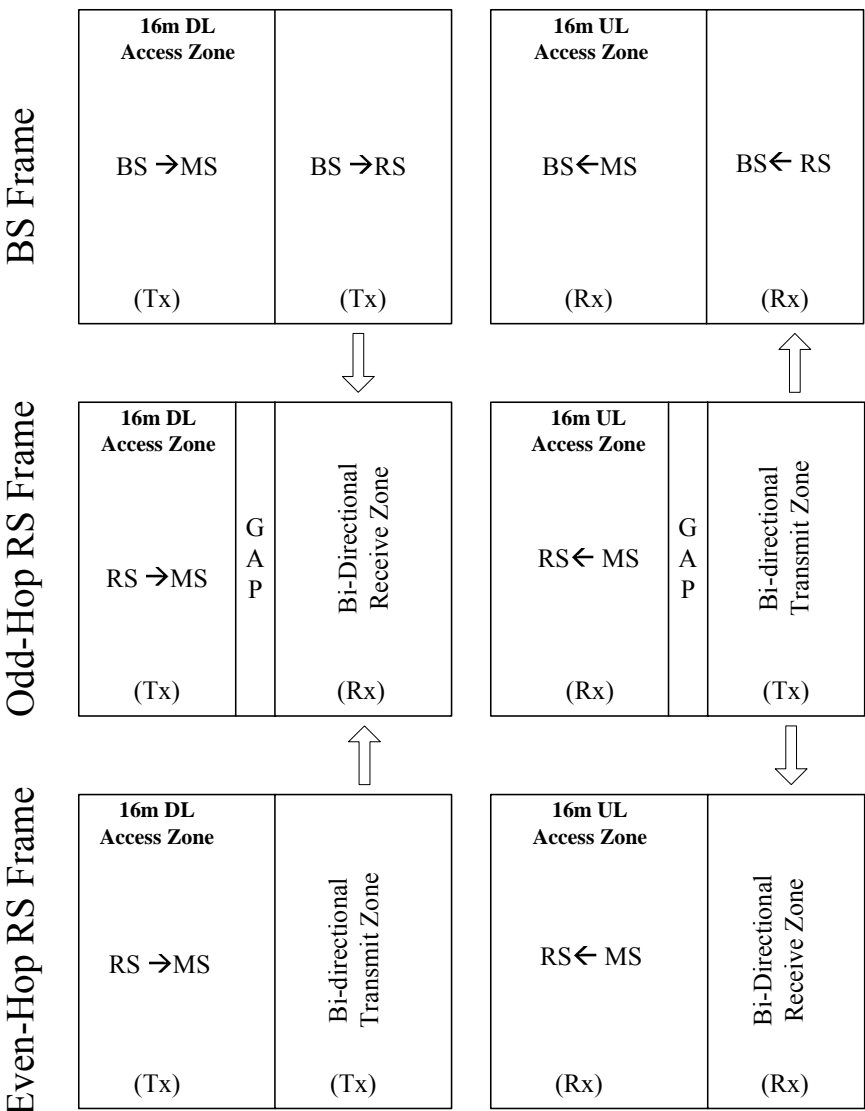


Figure 24 *Relay Frame structure option 2*

Notes related to Figure 24: An explicit access zone may or may not be present.

Definitions corresponding to Option 2 shown in Figure 24

- Bi-directional Transmit Zone: An integer multiple of subframes located in the 16m zone of the RS frame where transmission to superordinate as well as subordinate station takes place.
- Bi-directional Receive Zone: An integer multiple of subframes located in the 16m zone of the RS frame where reception from superordinate as well as subordinate station takes place.
- 16m DL Access Zone: An integer multiple of subframes in the 16m zone where 16m BS or a 16m RS transmits to the 16m MSs.

- 16m UL Access Zone: An integer multiple of subframes in the 16m zone where BS or an RS receives from the MSs.

11.4.5 Coexistence Supports in Frame Structure

IEEE 802.16m downlink radio frame shall be time aligned with reference timing signal as defined in section 21.1 and should support symbol puncturing to minimize the inter-system interference.

11.4.5.1 Adjacent Channel Coexistence with E-UTRA (LTE-TDD)

Coexistence between IEEE 802.16m and E-UTRA in TDD mode may be facilitated by inserting either idle symbols within the IEEE 802.16m frame or idle subframes, for certain E-UTRA TDD configurations. The IEEE 802.16m system shall be able of applying an operator configurable delay or offset between the beginnings of the IEEE 802.16m frame and the E-UTRA TDD frame in some configurations allows the time allocated to idle symbols or idle subframes to be minimized. Figure 25 shows two examples using frame offset to support coexistence with E-UTRA TDD in order to support minimization of the number of punctured symbols within the IEEE 802.16m frame.

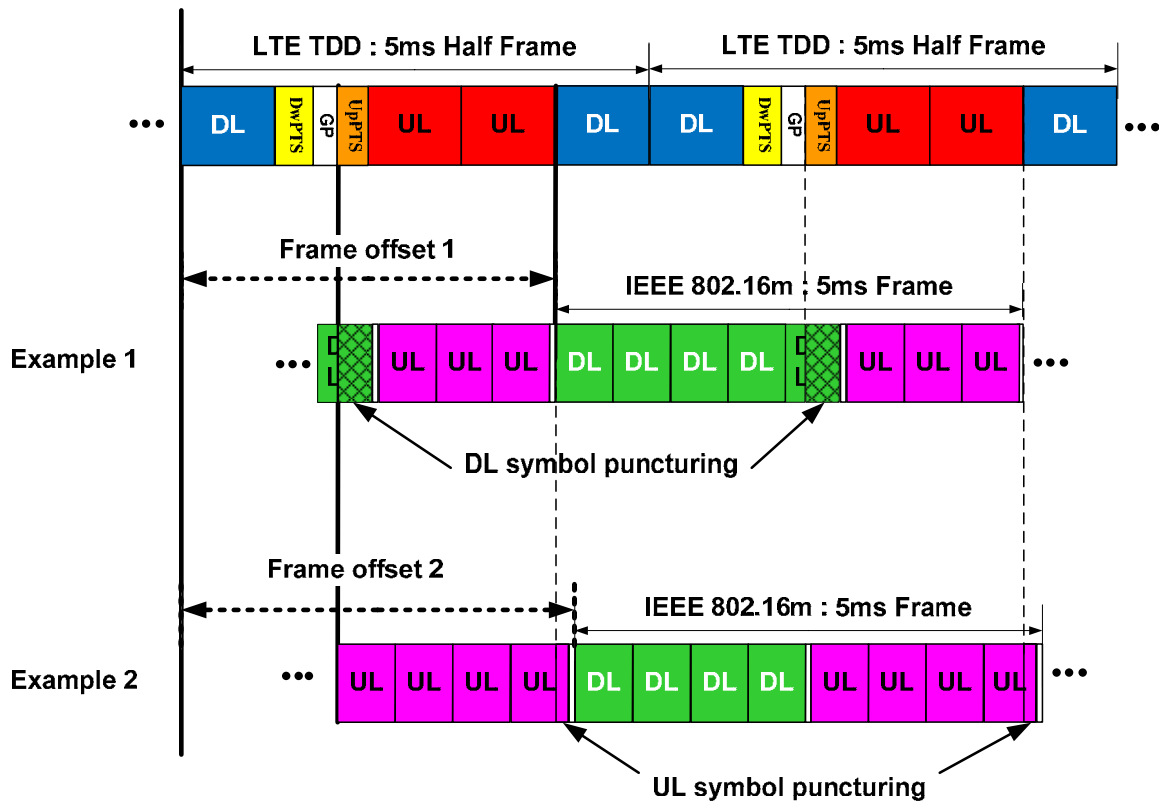


Figure 25 Alignment of IEEE 802.16m frame and E-UTRA frame in TDD mode

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

Coexistence between IEEE 802.16m and UTRA LCR-TDD may be facilitated by inserting either idle symbols within the IEEE 802.16m frame or idle subframes. The IEEE 802.16m system shall be able of applying an operator configurable delay or offset between the beginnings of the IEEE802.16m frame and the UTRA LCR-TDD frame may allow the time allocated to idle symbols or idle subframes to be minimized. Figure 26 demonstrates how coexistence between IEEE802.16m and UTRA LCR-TDD can be achieved to minimize the inter-system interference.

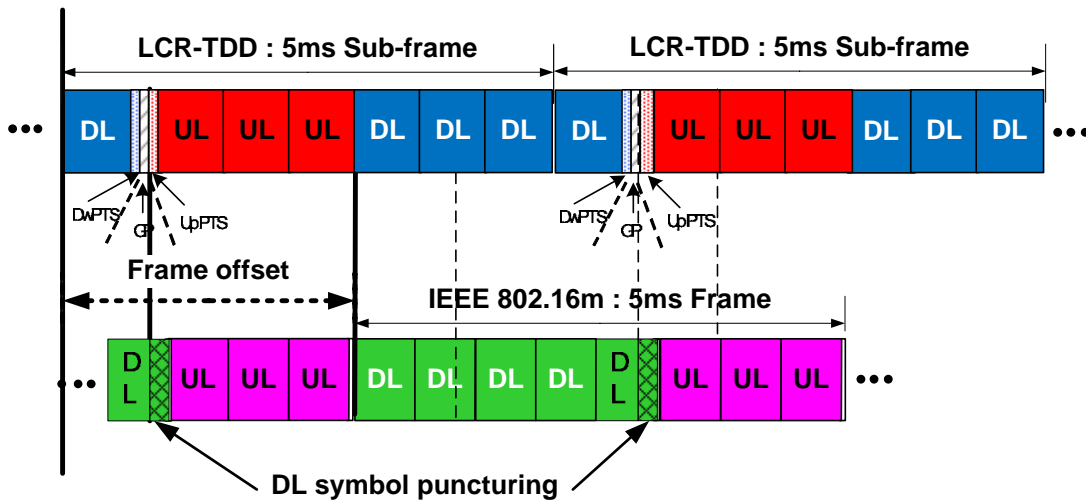


Figure 26 Alignment of IEEE 802.16m frame with UTRA LCR-TDD frame in TDD mode

11.5 Downlink Physical Structure

As described in section 11.4, the 5 ms radio frame is divided into 8 subframes. Each of the subframes can be allocated for downlink transmission. Each 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 frequency partition can be used for different purposes such as fractional frequency reuse (FFR) or multicast and broadcast services (MBS). Figure 27 illustrates the downlink physical structure in the example of two frequency partitions with frequency partition 2 including both localized and distributed resource allocations.

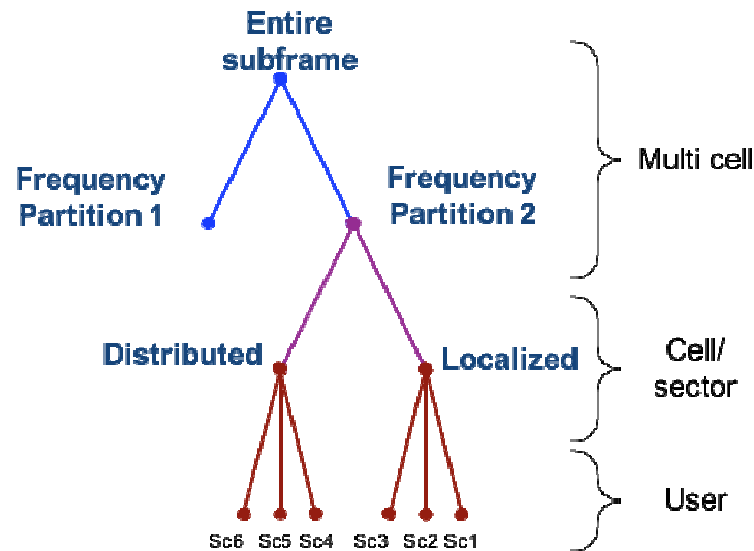


Figure 27 Hierarchical representation of the downlink physical structure

11.5.1 Physical and Logical Resource Unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} is 6 OFDMA symbols for type-1 subframes, and N_{sym} is 5 OFDM symbols for type-1 short subframe or 7 OFDM symbols for type-2 subframes. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. A LRU is $P_{sc} * N_{sym}$ subcarriers for type-1 subframes and type-2 subframes. Note that the LRU includes in its numerology the number of pilots that are used in a PRU, and may include control information. So, the effective number of data subcarriers in an LRU depends on the number of allocated pilots and control channel presence.

11.5.1.1 Distributed resource unit

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

11.5.1.2 Localized resource unit

The logical localized resource unit (LLRU) can be used to achieve frequency-selective scheduling gain. The LLRU contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the LLRU equals the size of the PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

11.5.2 Subchannelization and Resource mapping

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 the type of resource allocation, i.e., distributed or localized resource allocations, 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 28:

1. First-level or outer permutation is applied to the PRUs in the units of N_1 and N_2 PRUs, where $N_1=4$ (TBD) and $N_2=1$ or 2 depending on system bandwidth (TBD). Direct mapping of outer permutation can be supported.
2. Distributing (TBD) the reordered PRUs into frequency partitions.
3. The frequency partition is divided into localized(LLRU) and/or distributed(DRU) resources for each resource group. Using sector specific permutation can be supported; directly mapping of the resources can be supported for localized resource. The sizes of the groups are flexibly configured per sector (TBD). Adjacent sectors do not need to have same configuration of localized and distributed resources;
4. The localized and distributed groups are further mapped into LRUs (by direct mapping of LLRU and by “Subcarrier permutation” on DRUs) as shown in the following figure.

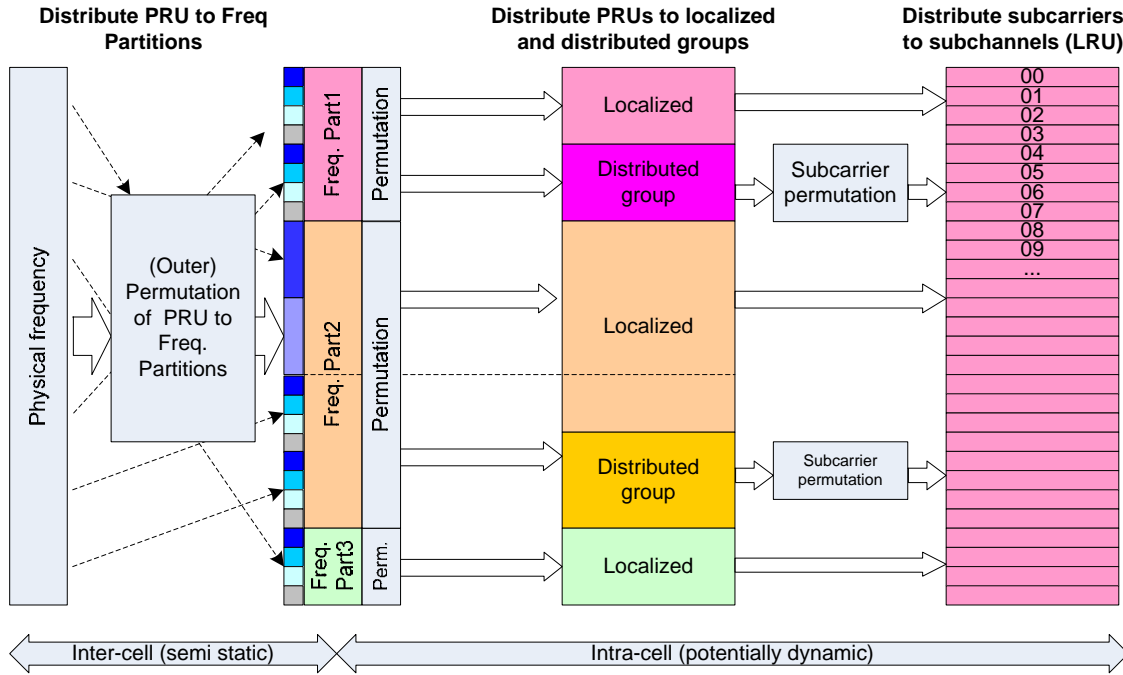


Figure 28 Illustration of the downlink subcarrier to resource unit mapping

11.5.2.3 Subchannelization for DL distributed resource

The second-level or inner permutation defined for the DL distributed resource allocations within a frequency partition spreads the subcarriers of the DRU across the whole distributed resource allocations. The granularity of the inner permutation is equal to the minimum unit for forming a DRU according to 11.5.1.1.

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 resource 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 each OFDMA symbol within a PRU, and N_{RU} be the number of LRUs within the distributed resource.
- For each k -th OFDMA symbol in the subframe
 1. Allocate the n_k pilots in each 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 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 second-level or inner permutation defined for the DL localized resource allocations. The PRUs are directly mapped to LLRUs within each frequency partition defined in 11.5.

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 MSs. Dedicated pilots can be used with both localized and diversity allocations. Pilot subcarriers that can be used only by a group of MSs 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 MSs 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] [a non-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, there is equal number of pilots for each PRU of a data burst assigned to one MS.

The pilots can be used for channel estimation, measurements (CQI and interference mitigation/cancellation), frequency offset estimation and time offset estimation. The pilots will be dedicated to localized and distributed subchannels. The pilots will be pre-coded, using the same pre-coding and/or boosting of the information burst(s) when such pre-coding is applied. The pilot patterns are optimized for both regular and type-2 subframes.

Pilot patterns are proposed for efficiency and performance. Pattern A is used for 1 and 2 data streams DL dedicated and common pilot pattern.

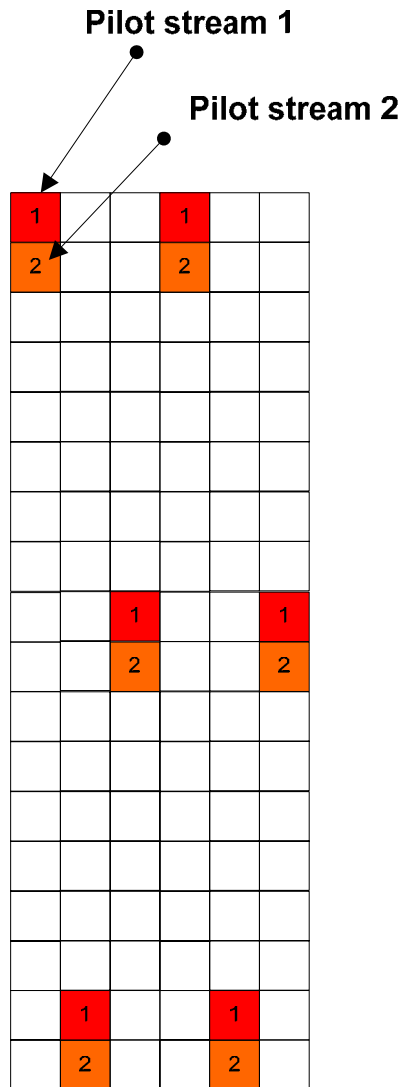


Figure 29 Pattern A for 1/2 pilot streams.

For type-2 subframe of 5 or 7 OFDMA symbol, the first or last OFDMA symbols will be deleted or added. The interlaced pilot patterns can be generated by cyclic shifting the base pilot pattern. The interlaced pilot patterns are shown in Figure 30 and can be optionally used by different BSs. The use of interlaced pilot pattern is FFS.

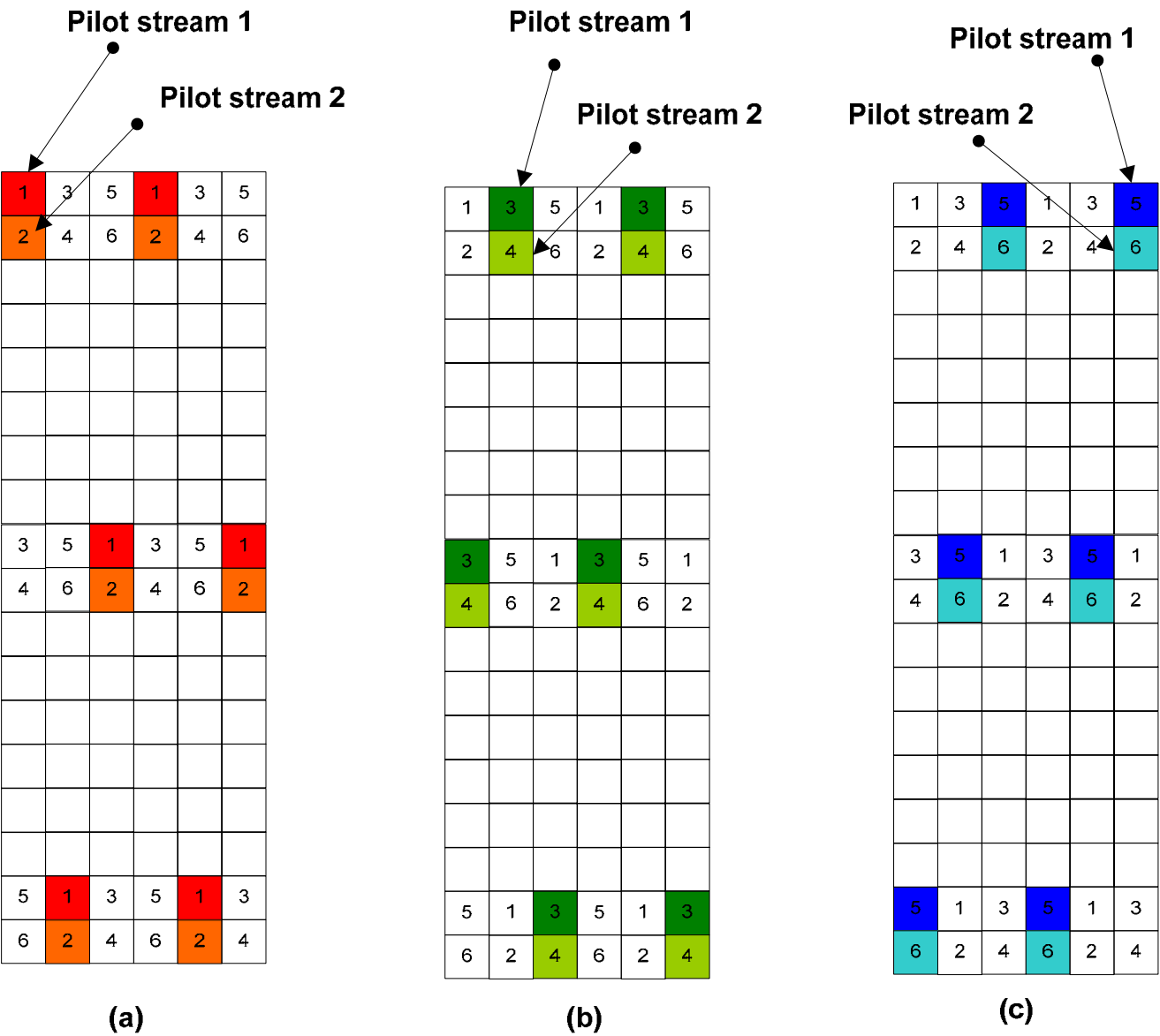


Figure 30 Interlaced Pattern A for 1/2 pilot streams.

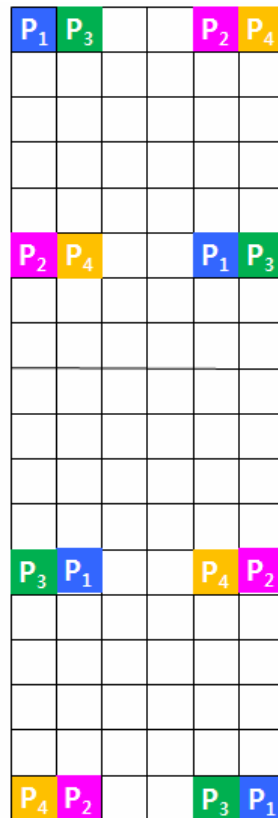


Figure 31 Pilot pattern for 4 stream pilots, pilot k denotes pilot for transmit antenna k.

11.5.3.1 Common pilot structure

11.5.3.2 Dedicated pilot structure

11.6 Uplink Physical Structure

As described in section 11.4, the 5 ms radio frame is divided into 8 subframes. Each of the subframes can be allocated for uplink transmission. Each 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 frequency partition can be used for different purposes such as fractional frequency reuse (FFR). Figure 32 illustrates the uplink physical structure in the example of two FFR groups with FFR group 2 including both localized and distributed resource allocations.

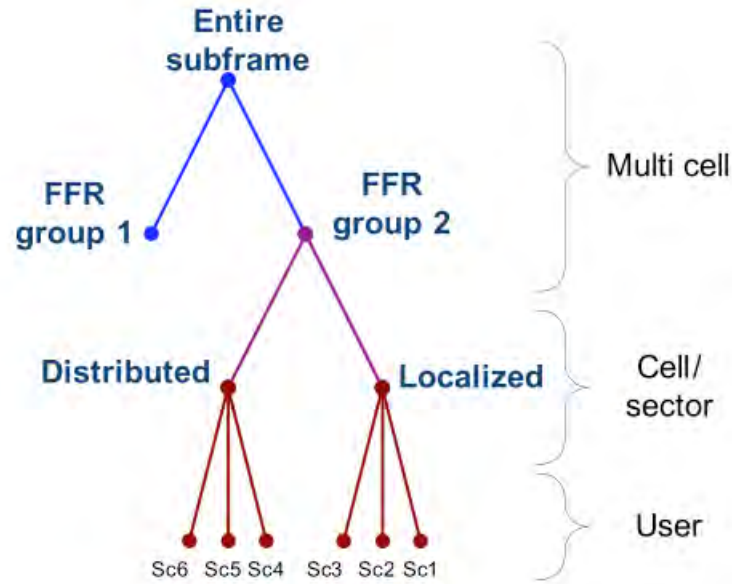


Figure 32 Example of uplink physical structure

11.6.1 Physical and Logical Resource Unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} the number of OFDMA symbols depending on the subframe type. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations and its size is $P_{sc} \cdot N_{sym}$ subcarriers for data transmission. For control channel/message transmission, the size is TBD. The LRU includes in its numerology the number of pilots that are used in a PRU, and may include control information. So, the effective number of data subcarriers in an LRU depends on the number of allocated pilots and control channel presence.

11.6.1.1 Distributed Resource unit

The distributed resource unit (DRU) can be used to achieve frequency diversity gain. The DRU contains a group of subcarriers which are spread across the distributed resource allocations. The size of the DRU equals the size of the LRU for distributed allocations. The minimum unit for forming the DRU is a tile. T different types of tiles are defined, where T is TBD. The minimum unit for forming the UL DRU is a UL tile; the UL tile sizes are $6 \times N_{sym}$, where N_{sym} depends on the subframe type. 18×2 for UL transmit power optimized distributed allocation and other tile sizes are FFS.

11.6.1.2 Localized Resource unit

The localized resource unit (LLRU) can be used to achieve frequency-selective scheduling gain. The LLRU contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the LLRU equals the size of the LRU for localized allocations, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

11.6.2 Subchannelization and Resource mapping

11.6.2.1 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 the type of resource allocation, i.e., distributed or localized resource allocations.

11.6.2.2 Uplink Subcarrier to Resource Unit Mapping

The main features of resource mapping include:

1. Support of localized resource unit (LLRU) and distributed resource unit (DRU) in an FDM manner.
2. DRUs comprise multiple tiles which are spread across frequency partitions to get diversity gain.
3. FFR can be applied in UL.

Based on the main design concepts above, the UL subcarriers to resource unit mapping process is defined as follows and illustrated in Figure 33:

1. First-level or outer permutation is applied to the PRUs in the units of $N1$ and $N2$ PRUs, where $N1=4$ (TBD) and $N2=1$ (TBD). Direct mapping of outer permutation can be supported.
2. Distributing (TBD) the reordered PRUs into frequency partitions.
3. The frequency partition is divided into localized (LLRU) and/or distributed (DRU) resources for each resource. Using sector specific permutation can be supported; directly mapping of the resources can be supported for localized resource. The sizes of the distributed/localized resources are flexibly configured per sector (TBD). Adjacent sectors do not need to have same configuration of localized and diversity resources.
4. The localized and distributed groups resources are further mapped into 1 LRUs. For the LLRU resources, the mapping is direct. For the DRU resources, a tile or hopping permutation is carried out for permuting or hopping the tiles of the distributed groups.

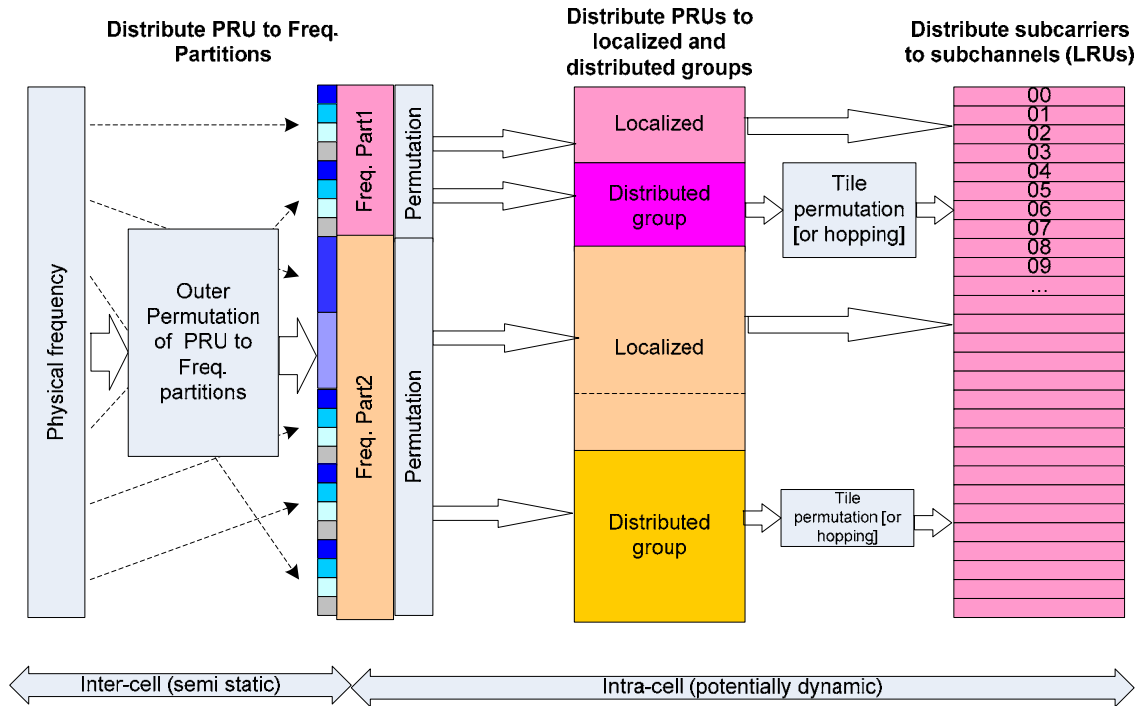


Figure 33

11.6.2.3 Subchannelization for UL Distributed Resource

A second-level 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 frequency band. The granularity of the inner permutation is equal to the minimum resource unit for forming a DRU as defined in Section 11.6.1.1.

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 allocation will be allocated first. The rest of the frequency resource will be regular distributed allocation. A second level 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 second-level or inner permutation defined for the UL localized resource allocations. The LLRU 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.

Uplink LLRUs frequency allocations can match that of downlink LLRUs such that channel reciprocity traits can be exploited.

11.6.3 Pilot Structure

The transmission of pilot subcarriers in the uplink is necessary for enabling channel estimation, measurement of channel quality indicators such as SINR, frequency offset and timing offset estimation, etc. The uplink pilots will be dedicated to localized and distributed resource units and will be precoded using the same precoding with the data subcarriers of the resource allocation. The pilot structure is defined for up to 4 Tx streams with orthogonal patterns..

Pilot patterns shall have a mode which enables active interference suppression algorithms to be employed. This includes:

- Pilot locations fixed within each DRU and LRU
- Pilot sequences with low cross correlation

The pilot pattern may support variable pilot boosting. The boosting values are TBD.

11.6.4 Uplink Physical Structure for Legacy Support

The 802.16m uplink physical structure supports both FDM (frequency division multiplexing) and TDM (time division multiplexing) with the legacy system. When the legacy system operates in the PUSC mode, then the type of multiplexing is TBD. If the legacy system operates in the AMC mode, then the uplink resources for the legacy and the 802.16m system are multiplexed using FDM or TDM.

11.7 DL Control Structure

DL control channels are needed to convey information essential for system operation. The basic frame structure is illustrated in Figure 14 in Section 11.4.1. In order to reduce the overhead and network entry latency, and improve robustness of the DL control channel, information is transmitted hierarchically over different time scales from the superframe level to the subframe level. Broadly speaking, control information related to system parameters and system configuration is transmitted at the superframe level, while control and signaling related to traffic transmission and reception is transmitted at the frame/subframe level.

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

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

11.7.1 DL Control Information Classification

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

11.7.1.1 Synchronization information

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 (MS) 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 switching point number.

11.7.1.2.2 Downlink sector-specific information

Downlink sector-specific essential information and parameters to enable MS 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 MS 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 MSs after system acquisition. Examples of this class include information required for handover such as handover trigger, neighbor BS 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 BS identification.

11.7.2.1.1 Synchronization channel requirements (Informative)

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 BS among the co-channel BS's whose received powers averaged over the convergence time are within [3] dB of the BS 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 11.4.1.5

11.7.2.1.1.1 Overhead

Mixed mode with legacy system

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

16m only mode

In 16m only mode operation the SCH overhead shall be less than or equal to [2] % per super frame, where the [2]% is calculated based on the ratio of SCH resource and that of usable resource for transmitting data.

11.7.2.1.1.2 Synchronization

The SCH will provide synchronization for:

- Time, including frame and superframe
- Frequency (up to [20]ppm initial tolerance of carrier frequency)

Synchronization performance must at least match that of 802.16e.

16m SCH must enable system acquisition without knowledge of the full channel bandwidth.

The 16m SCH shall not cause degradation of synchronization for coexisting legacy systems. Synchronization shall be robust for the full range of required mobile velocities as defined in the SRD (i.e. up to 350km/hr).

11.7.2.1.1.3 Coverage

The coverage area of IEEE 802.16m SCH shall not be worse than the minimum of the required coverage for 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 FFS

11.7.2.1.1.5 MIMO support and channel estimation

IEEE802.16m SCH may support multi-antenna transmissions. The number of supported antennas is FFS.

Channel estimation supported from the SCH is FFS.

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 structures are possible:

- Non-hierarchical, where only a single type of 16m synchronization symbol exists, which may be in addition to the legacy 16e preamble. Where a new 16m SCH is defined, the 16e preamble is not required as part of the SCH functionality (as defined in the SCH Requirements).
- Hierarchical, where more than one type of SCH symbol exists within the superframe. They may or may not use the legacy 16e preamble as one level of hierarchy.

The decision of hierarchy or non-hierarchy structure of the synchronization channel is FFS.

[Option 1. No hierarchy of synchronization channel (SCH) exists. The SCH is transmitted with a span of one OFDM symbol, in order to enable time- and frequency-synchronization and cell-ID detection.]

[Option 2. 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. The S-

SCH is used for fine synchronization, and cell/sector identification (ID). The use of P-SCH to carry ID information is also FFS.]

11.7.2.1.2.1.2 Multiplexing

Synchronization symbols 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 legacy preamble is implicit.

The number of synchronization channel symbols in each superframe is FFS.

11.7.2.1.2.1.4 Location of synchronization symbols

In mixed deployments, the presence of the 16e preamble in the first symbol of the 16e frame is implicit. The location of the SCH symbol(s) is fixed within the superframe.

The location of SCH is FFS. [Where a SCH hierarchy exists, the time separation between the P-SCH and S-SCH is fixed.]

11.7.2.1.2.1.5 Properties of P-SCH & S-SCH (if they exist)

<Editors' note: This section only applies if the P-SCH/S-SCH hierarchy is agreed. Square bracketed items are for further discussion.>

The P-SCH has these properties:

- Common to all sectors/cells
- [Optionally supports limited signalling (e.g. mode, bandwidth, etc)]
- Fixed bandwidth (5MHz or less)
- [Carries ID information (e.g. group ID, femto ID) - FFS]

The S-SCH has these properties:

- [Same bandwidth as P-SCH | Full bandwidth]
- Carries ID information

11.7.2.1.2.2 Description of legacy support/reuse

16m system will exist in both greenfield and mixed (coexisting 16e and 16m equipment) deployments. In mixed deployments the 16e preamble will be always present. As discussed in the requirements, the 16m SCH is not to degrade the performance of legacy acquisition.

The 802.16m SCH shall enable 802.16m MSs to synchronize in frequency and time without requiring the legacy preamble.

11.7.2.1.2.3 Cell ID support

The number of IDs is at least *[TBD]*.

Sectors are distinguished by the synchronization channel; the number of sectors is *[FFS]*.

11.7.2.1.2.4 Multicarrier and multi-bandwidth support

The location of the SCH in frequency is FFS

11.7.2.1.2.5 MIMO support and channel estimation

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

- (a) Cyclic delay diversity (with antenna specific delay values
- (b) Interleaved either within a symbol (multiple antennas can transmit within a single symbol but on distinct subcarriers) or the different SCH sequences are transmitted from multi-antennas
- (c) Across frames (only one antenna transmits in each symbol)
- (d) Or some combination – actual approach is FFS.

The number of BS antennas supported for MIMO channel measurements is FFS, depending on the requirements of other 16m SDD content, such as DL MIMO and interference mitigation.

11.7.2.1.3 Synchronization channel Sequence Design Properties

The SCH enables timing synchronization by autocorrelation.

The power of synchronization channel can be boosted

The SCH (non-hierarchical) or P-SCH (hierarchical) is mapping with every other subcarrier on the frequency domain.

The S-SCH (hierarchical) is mapping with every *[FFS]* subcarriers on the frequency domain

11.7.2.2 Broadcast Channel (BCH)

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

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

The Primary Broadcast Channel (PBCH) and the Secondary Broadcast Channel (SBCH) carry essential system parameters and system configuration information. The PBCH carries deployment wide common information. The SBCH carries sector specific information. The information in the PBCH and SBCH may be transmitted over one or more superframes.

11.7.2.2.2 *Location of the BCH*

11.7.2.2.3 *The SFH includes PBCH and the SBCH, and is located in the first subframe within a superframe. Multiplexing of the PBCH and SBCH with other control channels and data channels*

The PBCH/SBCH is TDM with the SCH.

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

11.7.2.2.4 *Transmission format*

The PBCH and SBCH are transmitted using predetermined modulation and coding schemes.

The modulation and coding rate for PBCH and the modulation and coding rate for SBCH are TBD.

Multiple antenna schemes for transmission of the PBCH/SBCH are supported.

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

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

<Editors' Notes: This section depends on SDD text included in the DL PHY Structure.>

11.7.2.3 **Unicast Service Control Channels**

11.7.2.3.1 *Unicast service control information/content*

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

11.7.2.3.1.1 **Non-user-specific control information**

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

11.7.2.3.1.2 **User-specific control information**

User specific control information consists of information intended for one user or more users. Examples of this subclass of information include scheduling assignment, power control information, ACK/NACK information.

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

A group message 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. 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

11.7.2.3.3 Within a sub-frame, 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. Location of control blocks

The first 802.16m DL sub-frame of each frame contains user-specific control information.

The location of control blocks for non-user specific control information is TBD.

Control blocks for user specific control information are located 'n' 802.16m subframes apart. If a USCCH is allocated in subframe N, DL data allocations corresponding to the USCCH occur in either subframe N, N+1, ..., N+(n-1). The next USCCH is in subframe N+n of the same frame. The values of n can be 1 or 2. Other values of n (3 and 4) are FFS. For example, for n=2, USCCH in subframe N can point to resource allocation in subframe N or N+1 and the next USCCH is in subframe N+2. 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 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".

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

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

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

For user-specific control information intended for a single user, multiple information elements are coded separately. The modulation and coding scheme (fixed/variable) is FFS.

The transmission format (joint/separate and fixed/variable MCS) for non-user-specific control information is FFS

1 **11.7.2.3.4 Resource allocation (physical to logical mapping, pilots, block size)**

2 <Editors' Notes: This section depends on SDD text included in the DL PHY Structure.>

3 **11.7.2.3.4.1 Pilot structure for unicast service control channels**

4 <Editors' Notes: This section depends on SDD text included in the DL PHY Structure.>

5 **11.7.2.4 Multicast Service Control Channels**

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

8 **11.7.2.4.1 Multicast service control information/content**

9 **11.7.2.4.2 Multiplexing scheme of data and multicast service control and (e.g. TDM, FDM,**
10 **Hybrid TDM//FDM)**

11 **11.7.2.4.3 Location of control blocks within a frame/subframe**

12 **11.7.2.4.4 Transmission format (e.g. modulation, coding, multiple antenna schemes)**

13 **11.7.2.4.5 Resource allocation (physical to logical mapping, pilots, block size)**

14 **11.7.2.5 Transmission of Additional Broadcast information**

15
16 Examples of additional broadcast information include system descriptors, neighbor BS information and paging
17 information. The indication of the presence of additional broadcast information is FFS.

18 MAC management messages may be used to transmit additional broadcast information.

19 **11.7.3 Mapping information to DL control channels**

Information		Channel	Location
Synchronization information		Synchronization Channel (SCH)	FFS
	Deployment-wide common information	Primary Broadcast Channel (PBCH)	Inside of SFH
Essential system parameters and system configuration information	Downlink sector-specific information	Secondary Broadcast Channel (SBCH)	Inside of SFH
	Uplink sector-specific information		
Extended system parameters and system configuration information		FFS	Outside of SFH
Control and signaling for DL notifications		FFS	FFS
Control and signaling for traffic		Unicast Service Control Channel	Outside of SFH

Table 3 Mapping information to DL control channels

11.7.4 Multi-carrier Control Structure

<Editors' Notes: This section is a placeholder 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 MS point of view, can be divided into two types:

- A Primary carrier is the carrier used by the BS and the MS to exchange traffic and full PHY/MAC control information defined in 16m specification. Further, the primary carrier is used for control functions for proper MS operation, such as network entry. Each MS shall have only one carrier it considers to be its primary carrier in a cell.
- A Secondary carrier is an additional carrier which the MS may use for traffic, only per BS's specific allocation commands and rules, typically received on the primary carrier. The secondary carrier may also include control signaling to support multi-carrier operation..

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

- Fully configured carrier: A carrier for which all control channels including synchronization, broadcast, multicast and unicast control signaling are configured. Further, information and parameters regarding multi-carrier operation and the other carriers can also be included in the control channels.
- Partially configured carrier: A carrier with only essential control channel configuration to support traffic exchanges during multi-carrier operation.

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

11.8 DL MIMO Transmission Scheme

11.8.1 DL MIMO Architecture and Data Processing

The architecture of downlink MIMO on the transmitter side is shown in the Figure 34. In SU-MIMO, only one user is scheduled in one Resource Unit (RU). In MU-MIMO, multiple users can be scheduled in one RU. If vertical encoding is utilized, there is only one encoder/modulator block (one “layer”). If horizontal encoding is utilized, there are multiple encoders / modulators (multiple “layers”). A “layer” is defined as a coding / modulation path fed to the MIMO encoder as an input, and a “stream” is defined as each output of the MIMO encoder that is passed to the beamformer / precoder.

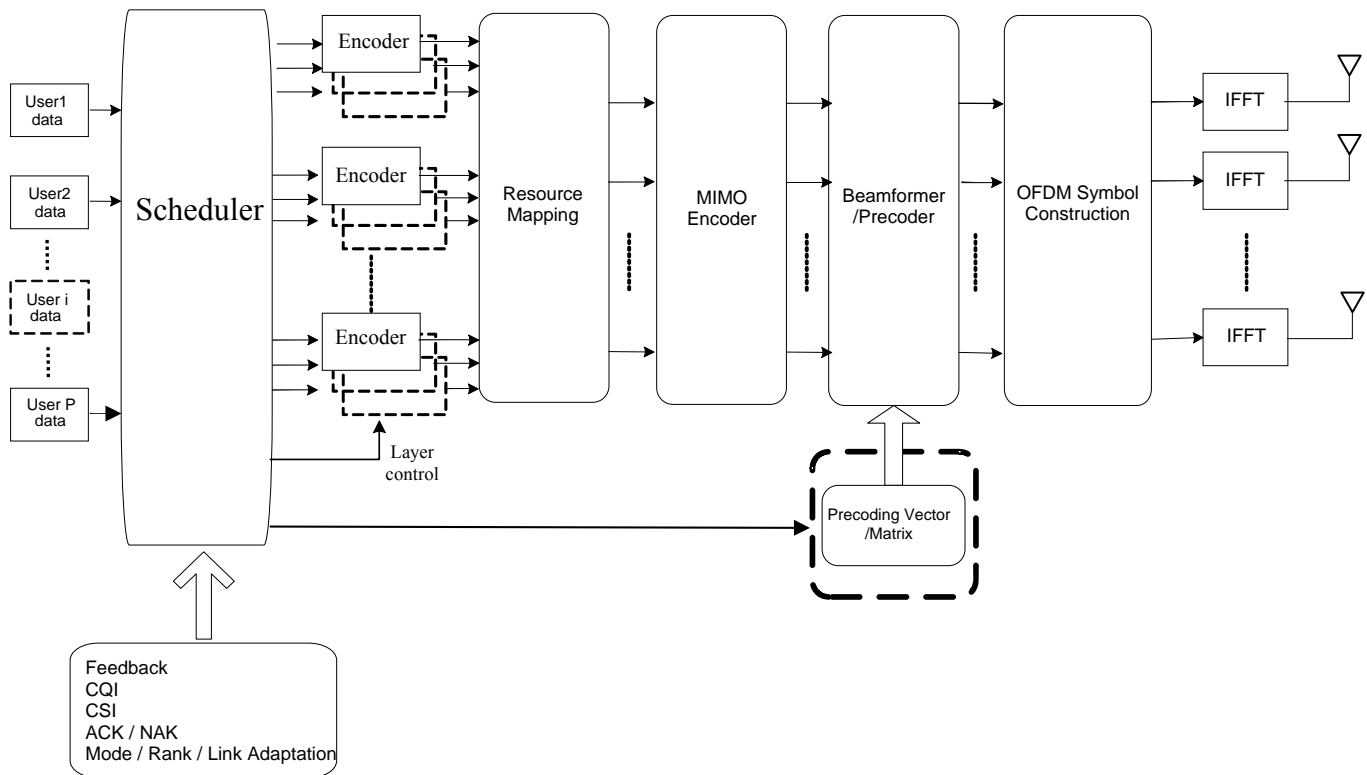


Figure 34 MIMO Architecture

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

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

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

The precoding block maps streams to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

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

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

The scheduler block will schedule users to resource blocks and decide their MCS level, MIMO parameters

(MIMO mode, rank). This block is responsible for making a number of decisions with regards to each resource allocation, including:

- **Allocation type**: Whether the allocation in question should be transmitted with a distributed or localized allocation
- **Single-user (SU) versus multi-user (MU) MIMO**: Whether the resource allocation should support a single user or more than one user
- **MIMO Mode**: Which open-loop (OL) or closed-loop (CL) transmission scheme should be used for the user(s) assigned to the resource allocation.
- **User grouping**: For MU-MIMO, which users should be transmitted to on the resource allocation
- **Rank selection**: For the spatial multiplexing modes in SU-MIMO, the number of streams to be used for the user allocated to the resource allocation.
- **MCS level per layer**: The modulation and coding rate on each layer must be determined.
- **Boosting**: The power boosting values to be used on the data and pilot subcarriers.
- **Band selection**: If localized resource allocation is used, where in the frequency band should the localized allocation be placed.

11.8.1.1 Antenna Configuration

The BS employs a minimum of two transmit antennas. The MS employs a minimum of two receive antennas. The antenna configurations are $(N_T, N_R) = (2, 2), (4, 2), (4, 4), (8, 2),$ and $(8, 4)$, where N_T denotes the number of BS transmit antennas and N_R denotes the number of MS receive antennas. (8,8) with 8 streams is FFS.

11.8.1.2 Layer to Stream Mapping

The number of streams, M , for SU-MIMO is $M \leq \min(N_T, N_R)$, where M is no more than 4 (8 streams are FFS). MU-MIMO can have up to 2 streams with 2 Tx antennas, and up to 4 streams for 4 Tx antennas and 8Tx antennas.

For SU-MIMO, Vertical encoding (SCW) is employed. [The support of horizontal encoding (MCW) for SU-MIMO is FFS]. For MU-MIMO, MCW (or horizontal) encoding is employed at the base-station while only one layer is transmitted to each mobile station.

11.8.1.3 Stream to Antenna Mapping

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

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

where \mathbf{P} is a pre-coding matrix, $\mathbf{S}(\mathbf{x})$ is an STC matrix, and \mathbf{x} is the input layer vector.

11.8.1.4 Resource mapping

The following table illustrates the MIMO mode permutation for various MIMO schemes.

MIMO Scheme	Resource Mapping
Open-loop SU-MIMO	Distributed or Localized
Closed-loop SU-MIMO	Distributed or Localized
MU-MIMO	Distributed or Localized

Table 4 Supported resource channels in MIMO

11.8.1.5 Pilots**11.8.1.6 Signaling support for MIMO****11.8.1.6.1 Signaling support for SU MIMO****11.8.1.6.2 Signaling support for MU MIMO**

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

11.8.2 Transmission for Data Channels**11.8.2.1 Single-user MIMO**

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

Both open-loop single-user MIMO and closed-loop single-user MIMO are supported for the antenna configurations specified in Section 11.8.1.1.

For open-loop single-user MIMO, both spatial multiplexing and transmit diversity schemes are supported. Note that in the case of open-loop single-user MIMO, CQI and rank feedback may still be transmitted to assist the base station's decision of rank adaptation, transmission mode switching, and rate adaptation. Note that CQI, and rank feedback may or may not be frequency dependent.

For closed-loop single-user MIMO, codebook based precoding is supported for both TDD and FDD systems. CQI, PMI, and rank feedback can be transmitted by the mobile station to assist the base station's scheduling, resource allocation, and rate adaptation decisions. Note that the CQI, PMI, and rank feedback may or may not be frequency dependent.

For closed-loop single-user MIMO, sounding based precoding is supported for TDD systems. As described in section 11.8.1, 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

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

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

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

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

11.8.2.1.1 Open-loop SU-MIMO

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

N_T	Rate	M	N_F
2	1	1	1
2	1	2	2
4	1	1	1
4	1	2	2
8	1	1	1
8	1	2	2
2	2	2	1
4	2	2	1
8	2	2	1
4	3	3	1
8	3	3	1
4	4	4	1
8	4	4	1

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

On a given frequency resource k [size is FFS], the precoding matrix \mathbf{P} can be defined using the following

equation:

$$\mathbf{P}(k) = \mathbf{D}(k)\mathbf{W}(k), \text{ Equation 4}$$

The precoder is composed of two matrices. The first matrix $\mathbf{W}(k)$ is an $N_T \times M$ matrix, where N_T is the number of transmit antennas and M is the numbers of streams. The matrix $\mathbf{W}(k)$ is selected from a predefined unitary codebook, and changes every u subcarriers. A codebook is a unitary codebook if each of its matrices consists of columns of a unitary matrix. [The detailed unitary codebook, and the parameter u are FFS.] The second matrix $\mathbf{D}(k)$ is an $N_T \times N_T$ diagonal matrix as follows,

$$\mathbf{D}(k) = \begin{bmatrix} e^{j\theta_0 k} & 0 & \dots & 0 \\ 0 & e^{j\theta_1 k} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & e^{j\theta_{(N_T-1)} k} \end{bmatrix}, \text{ Equation 5}$$

where k denotes frequency resource index and $\theta_i, i=0, 1, 2, \dots, N_T-1$ denotes the phase shift for the i -th transmit antenna across two adjacent frequency resources. [The value of θ_i is FFS.]

For OL SU-MIMO, the following schemes are FFS: rate-1 STBC/SFBC and rate-2 Double STBC/SFBC, 2-D POD for rate-1 and rate-2, rate-3 hybrid SM+STBC/SFBC, differential STBC/SFBC, SM+Antenna hopping.

11.8.2.1.1.1 Transmit Diversity

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

- 2Tx rate-1: STBC/SFBC, and rank-1 precoder
- 4Tx rate-1: STBC/SFBC with precoder, and rank-1 precoder
- 8Tx rate-1: STBC/SFBC with precoder, and rank-1 precoder

In Transmit Diversity mode, the MIMO encoder generates 2Tx STBC/SFBC, and then multiplied by $N_T \times 2$ matrix and $N_T \times N_T$ diagonal matrix as described in section 11.8.2.1.1.

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

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \text{ Equation 6}$$

The output of the MIMO encoder is a 2×2 matrix

$$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}, \text{ Equation 7}$$

For the 2Tx rate-1 mode, the output of the precoder is a 2×2 matrix

$$\mathbf{y} = \mathbf{z}, \text{ Equation 8}$$

For the 4Tx rate-1, the output of the precoder is a 4×2 matrix

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 9}$$

where \mathbf{W} is a 4×2 precoder and \mathbf{D} is a 4×4 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

For the 8Tx rate-1, the output of the precoder is a 8×2 matrix

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 10}$$

where \mathbf{W} is a 8×2 precoder and \mathbf{D} is a 8×8 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

11.8.2.1.1.2 Spatial Multiplexing

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

- Rate-2 spatial multiplexing modes:
 - 2Tx rate-2: rate 2 SM
 - 4Tx rate-2: rate 2 SM with precoding
 - 8Tx rate-2: rate 2 SM with precoding
- Rate-3 spatial multiplexing modes:
 - 4Tx rate-3: rate 3 SM with precoding
 - 8Tx rate-3: rate 3 SM with precoding
- Rate-4 spatial multiplexing modes:
 - 4Tx rate-4: rate 4 SM
 - 8Tx rate-4: rate 4 SM with precoding

For the rate-2 spatial multiplexing modes, the input to the MIMO encoder is represented as a 2×1 vector

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \text{ Equation 11}$$

The output of the MIMO encoder is a 2×1 vector

$$\mathbf{z} = \mathbf{x}, \text{ Equation 12}$$

For the 2Tx rate-2 mode, the output of the precoder is a 2×1 vector

$$\mathbf{y} = \mathbf{z}. \text{ Equation 13}$$

For the 4Tx rate-2 mode, the output of the precoder is a 4×1 vector

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z} \text{ Equation 14}$$

where \mathbf{W} is a 4×2 precoder and \mathbf{D} is a 4×4 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

For the 8Tx rate-2 mode, the output of the precoder is a 8×1 vector

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 15}$$

where \mathbf{W} is a 8×2 precoder and \mathbf{D} is a 8×8 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

For the rate-3 spatial multiplexing modes, the input to the MIMO encoder is represented as a 3×1 vector

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}, \text{ Equation 16}$$

The output of the MIMO encoder is a 3×1 vector

$$\mathbf{z} = \mathbf{x}, \text{ Equation 17}$$

For the 4Tx rate-3 mode, the output of the precoder is a 4×1 vector

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 18}$$

where \mathbf{W} is a 4×3 precoder and \mathbf{D} is a 4×4 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

For the 8Tx rate-3 mode, the output of the precoder is a 8×1 vector

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 19}$$

where \mathbf{W} is a 8×3 precoder and \mathbf{D} is a 8×8 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

For the rate-4 spatial multiplexing modes, the input to the MIMO encoder is represented as a 4×1 vector

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix}, \text{ Equation 20}$$

The output of the MIMO encoder is a 4×1 vector

$$\mathbf{z} = \mathbf{x}, \text{ Equation 21}$$

For the 4Tx rate-4 mode, the output of the precoder is a 4×1 vector

$$\mathbf{y} = \mathbf{z}, \text{ Equation 22}$$

For the 8Tx rate-4 mode, the output of the precoder is a 8×1 vector

$$\mathbf{y} = \mathbf{D} \times \mathbf{W} \times \mathbf{z}, \text{ Equation 23}$$

where \mathbf{W} is a 8×4 precoder and \mathbf{D} is a 8×8 diagonal phase matrix. Note that \mathbf{W} and \mathbf{D} may be frequency dependent as described in section 11.8.2.1.1.

11.8.2.1.2 Closed-loop SU-MIMO

11.8.2.1.2.1 Precoding technique

In FDD and TDD systems, unitary codebook based precoding are supported.

In TDD systems, sounding based precoding is supported.

11.8.2.1.2.2 Power Loading Technique

11.8.2.1.3 Feedback for SU-MIMO

In FDD systems and TDD systems, a mobile station may feedback some of the following information in Closed loop SU-MIMO mode:

- Rank (Wideband or sub-band)
- Sub-band selection
- CQI (Wideband or sub-band, per layer)
- PMI (Wideband or sub-band for serving cell and/or neighboring cell)
- Doppler estimation

For codebook based precoding, the feedback from a mobile station shall be based on the same codebook as used by base station for transmission.

The feedback information may be transmitted via a physical layer control channel or via a higher layer signaling message.

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

11.8.2.2 Multi-user MIMO

Multi-user MIMO schemes are used to enable a resource allocation to communicate data to two or more MSs. 802.16m uses Multi-user MIMO to boost system throughput.

Multi-layer transmission with one stream per user is supported for MU-MIMO. MU-MIMO includes the MIMO configuration of 2Tx antennas to support up to 2 users, and 4Tx or 8Tx antennas to support up to 4 users.

11.8.2.2.1 Precoding technique

The precoding for MU-MIMO can be either standardized or vendor-specific. Up to four MSs can be assigned to each resource allocation.

In MU-MIMO systems, the received signal of the f -th subcarrier in the i -th MS (without considering co-channel interference) can be described as:

$$\mathbf{y}_{i,f} = \mathbf{H}_{i,f} \sum_{j=1}^K \mathbf{v}_{j,f} \mathbf{x}_{j,f} + \mathbf{n}_{i,f}, \text{ Equation 24}$$

where K is the number of the allocated users, $\mathbf{v}_{j,f}$ is the precoding vector of the f -th subcarrier for the transmit signal to the j -th MS, $\mathbf{x}_{j,f}$ is the transmit signal of the f -th subcarrier to the j -th MS and $\mathbf{n}_{i,f}$ is the noise of the f -th subcarrier in the j -th MS.

If dedicated pilots are used, the form and derivation of the assembled precoding matrix, $\mathbf{V}_f = [\mathbf{v}_{1,f} \dots \mathbf{v}_{K,f}]$, can be either standardized or vendor-specific. If the columns of the assembled precoding matrix are orthogonal to each other, it is defined as unitary MU-MIMO. Otherwise, it is defined as non-unitary MU-MIMO. Note that beamforming is enabled with this precoding mechanism. Non-linear precoding is FFS.

11.8.2.2.2 Unification with SU

Predefined and flexible adaptation between SU-MIMO and MU-MIMO are supported.

11.8.2.2.3 Feedback for MU-MIMO

11.8.2.2.3.1 CQI feedback

For CQI feedback, the mobile station measures the downlink pilot channel, computes the channel quality information (CQI), and reports the CQI on the uplink feedback channel. Both wideband CQI and subband CQI may be transmitted by a mobile station. Wideband CQI is the average CQI of a wide frequency band. In contrast, sub-band CQI is the CQI of a localized sub-band.

11.8.2.2.3.2 CSI feedback

Channel state information feedback may be employed for MU-MIMO. Codebook-based feedback is supported in both FDD and TDD. Sounding-based feedback is supported in TDD.

The unified codebook for SU and MU is employed.

An enhanced UL sounding channel is used to feedback CSI-related information by the MS 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 MS antennas to enable the BS 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 unquantized 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 802.16m systems, both MIMO mode and rank adaptation are supported. BSs and MSs 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 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, MS 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, MS may request adaptation. The decision of rank and mode adaptation is made by the BS. 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 here. 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 here. The detailed transmit diversity scheme for Unicast Control Channels is FFS.

11.8.4 Advanced Features

11.8.4.1 Multi-cell MIMO

Multi-cell 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-cell MIMO techniques can be considered. For closed-loop multi-cell 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-cell MIMO and multi-cell 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.

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 layer 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 MS. This information is used by the BS 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 spatial characteristics of the channel that are required for MIMO operation. The precoder matrix index, precoding vector index, rank adaptation, channel covariance matrix elements, power loading factor, eigenvectors and channel sounding are examples of MIMO feedback information.

11.9.1.3 HARQ feedback

HARQ feedback (ACK/NACK) is used to acknowledge DL transmissions. Multiple codewords 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. This includes reference signals for measuring and adjusting the uplink timing offset.

11.9.1.5 Bandwidth request

Bandwidth requests are used to provide information about the needed uplink bandwidth to the BS. Bandwidth requests are transmitted through indicators or messages. Bandwidth request messages can include information about the status of queued traffic at the MS 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.

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).>

11.9.2.1 UL Fast Feedback Channel

The UL fast feedback channel carries channel quality feedback and MIMO feedback. Transmission of other feedback information on the UL fast feedback channel is FFS.

The UL fast feedback channel is classified into multiple logical channels per user. The mapping of these logical channels into one or multiple physical channels is FFS.

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 MS 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*

Transmission on the fast feedback channel can be event-driven. The transmission format of the fast feedback channel can be adaptive.

The structure of the resource blocks, pilots and resource mapping for the UL fast feedback channel are TBD.

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 structure of UL HARQ feedback channel resource blocks, pilots and resource mapping are TBD.

11.9.2.3 UL Sounding Channel

The UL sounding channel is used by an MS to send a sounding signal for MIMO feedback, channel quality

1 feedback and acquiring UL channel information at the BS.

2 **11.9.2.3.1 Multiplexing with other control information and data**

3 The BS can configure an MS to transmit an UL sounding signal on specific UL sub-bands. The sounding signal
4 is transmitted over predefined subcarriers within the intended sub-bands. The periodicity of the sounding signal
5 for each MS is configurable.

6 The UL sounding channel is FDM with other control and data channels.

7 **11.9.2.3.2 PHY structure**

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

11 **11.9.2.4 UL Ranging Channel**

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

17 **11.9.2.4.1 Ranging Channel for non-synchronized mobile stations**

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

19 **11.9.2.4.1.1 Multiplexing with other control channels and data channels**

20 The UL ranging channel for non-synchronized MSs starts at a configurable location with the configuration
21 defined in a DL broadcast control message.

22
23 The UL ranging channel for non-synchronized MSs is FDM with other UL control channels and data channels.

24 **11.9.2.4.1.2 PHY structure**

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

26 **11.9.2.4.2 Ranging Channel for synchronized mobile stations**

27 The ranging channel for synchronized MSs is used for periodic ranging. The use of the ranging channel for
28 synchronized MSs for handover is FFS.

29 **11.9.2.4.2.1 Multiplexing with other control channels and data channels**

30 The UL ranging channel for synchronized MSs starts at a configurable location with the configuration defined
31 in a DL broadcast control message.

32
33 The UL ranging channel for synchronized MSs is FDM with other UL control channels and data channels.

34 **11.9.2.4.2.2 PHY structure**

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

11.9.2.5 Bandwidth Request Channel

Contention based or non-contention based random access is used to transmit a bandwidth request indicator on this control channel. To support different levels of QoS, the bandwidth request channel provides a mechanism for prioritized bandwidth requests. Inclusion of additional information in a bandwidth request indicator such as bandwidth request size, MS-ID, flow identifier, uplink transmit power report and CINR report is FFS.

The random access bandwidth request procedure is described in Figure 35. A 5-step regular procedure (step 1 to 5) or an optional quick access procedure (step 1, 4 and 5) may be supported concurrently. Step 2 and 3 are used only in 5-step regular procedure. In step 1, MS sends a bandwidth request indicator that may indicate information such as MS addressing and/or request size (FFS) and/or uplink transmit power report (FFS), and the BS may allocate uplink grant based on certain policy. The 5-step regular procedure is used independently or as fallback mode for quick access procedure. The MS may piggyback additional BW-REQ information along with user data during uplink transmission (step 5).

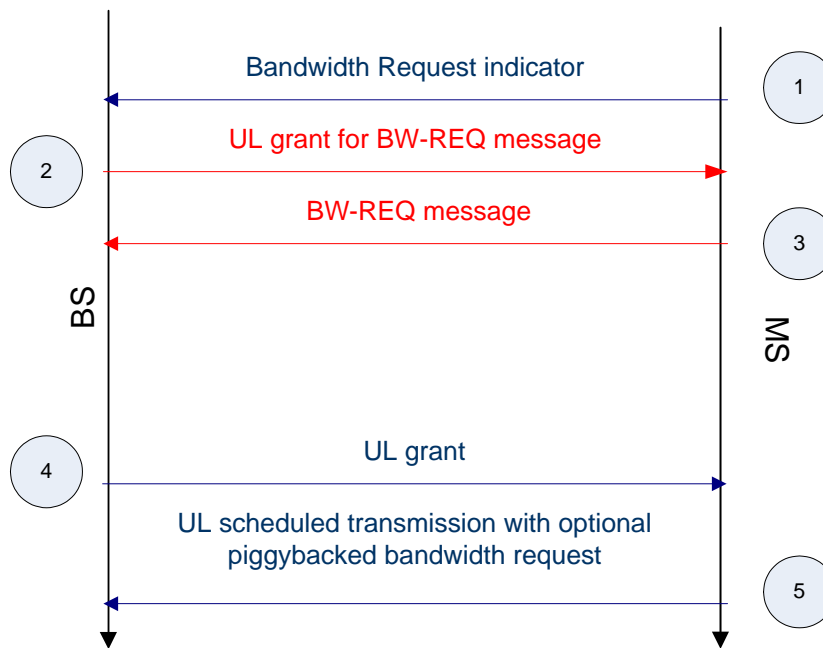


Figure 35 Bandwidth Request Procedure

11.9.2.5.1 Multiplexing with other control channels and data channels

The bandwidth request channel starts at a configurable location with the configuration defined in a DL broadcast control message. The bandwidth request channel is FDM with other UL control and data channels.

11.9.2.5.2 PHY structure

The structure of bandwidth request channel resource blocks, pilots and resource mapping are TBD. The ranging sequence design and mapping to subcarriers are TBD. The ranging sequence can be configured per user class, per service class and per sector. Users can be classified based on operator-specific network performance requirements and service level agreements.

11.9.3 UL Inband Control Signaling

Uplink control information can be multiplexed with data on the UL data channels as MAC headers or MAC

management messages. Inband control signaling can contain information such as uplink bandwidth requests or bandwidth assignment updates.

11.9.4 Mapping of UL control information to UL control channels

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

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

12 Security

13 Inter-Radio Access Technology Functions

14 Support for Location Based Services

15 Support for Enhanced Multicast Broadcast Service

16 Support for multi-hop relay

17 Solutions for Co-deployment and Co-existence

18 Support for Self-organization

19 Support for Multi-carrier

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 MS in the cell is connected to and its state being controlled through only one of the fully configured carriers as its primary carriers.
- The system defines M ($M \geq 0$) partially configured RF carriers as defined in section 11.6.4, 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 MS 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 user through the primary carriers. The primary carrier may also provide user the information about the configuration of the secondary carrier.
- The resource allocation 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 MS 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 BS and an MS may dynamically utilize resources across multiple secondary RF carriers. Multiple MS, 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 MS will consider only one fully configured RF carrier to be its primary carrier in a cell. A secondary carrier for an MS, if fully configured, may serve as primary carrier for other MS's.

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.

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 MS.

In multi-carrier operation, an MS can access multiple carriers. The following multi-carrier operations are identified:

- Carrier aggregation
 - MS shall always maintain its physical layer connection and monitor the control information on the primary carrier.
- Carrier switching
 - MS can switch its physical layer connection from the primary to the secondary carrier per BS' instruction. When the MS is connected to the secondary carrier, the MS doesn't need to maintain its physical layer connection to the primary carrier.
 - This mode may be used for the cases of single radio MS.

19.2 Subcarrier Alignment for Utilization of Guard Subcarriers of Adjacent Frequency Channels

When multiple contiguous frequency channels are available, the guard sub-carriers between contiguous frequency channels can be utilized for data transmission only if the sub-carriers from adjacent frequency channels are well aligned. In order to align those sub-carriers from adjacent frequency channel, a frequency

offset ($\Delta f'$) can be applied to its FA. The basic idea is shown by the example in Figure 36.

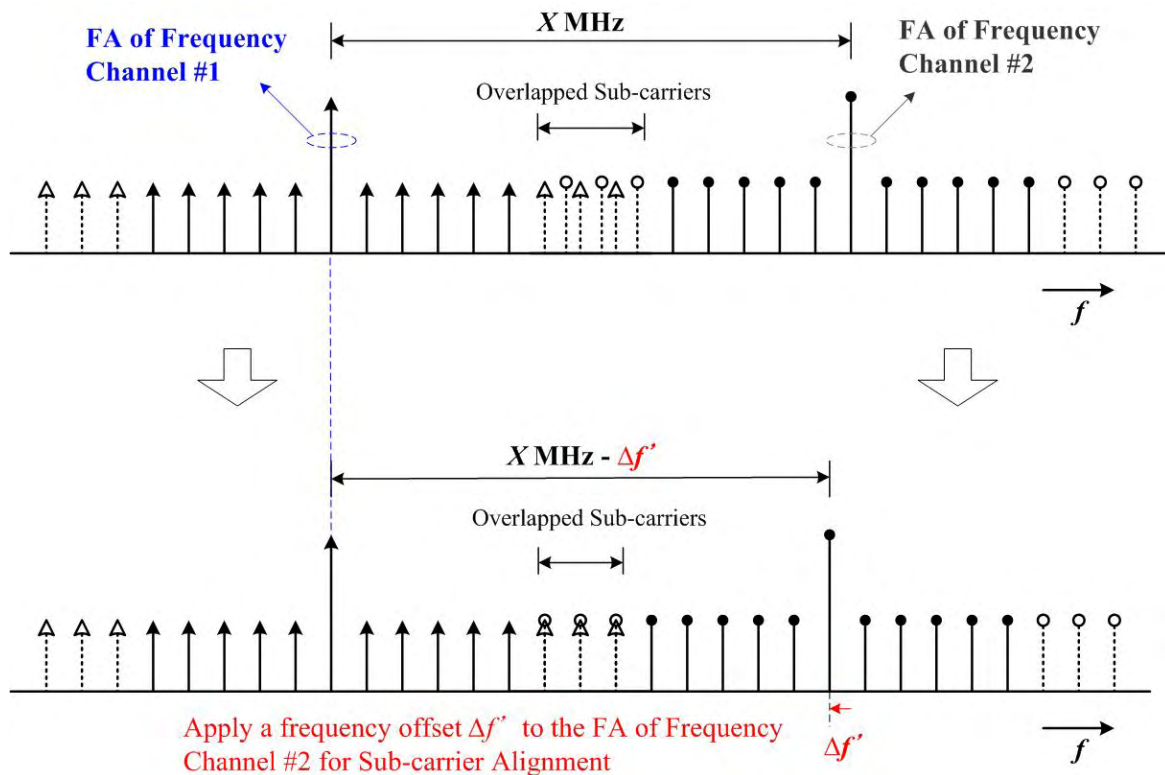


Figure 36 Sub-carrier alignment by applying a fraction of sub-carrier spacing to the FA of adjacent frequency channel

In order to utilize the guard sub-carrier for data transmission, the information of the available guard sub-carriers eligible for data transmission shall be sent to MS. This information shall include the numbers of available sub-carriers in upper side and in lower side with respect to the DC sub-carrier of carrier.

20 RF Requirements

21 Inter-BS Synchronization

21.1 Network synchronization

For TDD and FDD realizations, it is recommended that all BSs be time synchronized to a common timing signal. In the event of the loss of the network timing signal, BSs shall continue to operate and shall automatically resynchronize to the network timing signal when it is recovered. The synchronizing reference shall be a 1 pps timing pulse and a 10 MHz frequency reference. These signals are typically provided by a GPS receiver but can be derived from any other source which has the required stability and accuracy. For both FDD and TDD realizations, frequency references derived from the timing reference may be used to control the frequency accuracy of BSs provided that they meet the frequency accuracy requirements of [tbd]. This applies

during normal operation and during loss of timing reference.

21.2 Downlink frame synchronization

At the BS, the transmitted downlink radio frame shall be time-aligned with the 1pps timing pulse with a possible delay shift of n micro-seconds (n being between 0 and 4999). The start of the preamble symbol, excluding the CP duration, shall be time aligned with 1pps plus the delay of n micro-seconds timing pulse when measured at the antenna port.

Appendix 1 IEEE 802.16e Protocol Structure

The following Figure 37 shows the protocol architecture of IEEE 802.16e which will be used as reference system. The MAC layer is composed of two sub-layers: Convergence Sublayer (CS) and MAC Common Part Sublayer (MAC CPS).

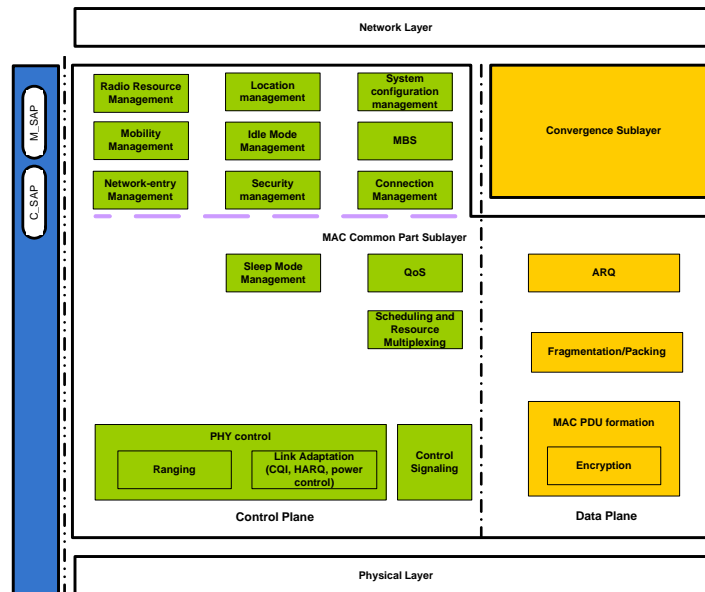


Figure 37 The IEEE 802.16e protocol architecture

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 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

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 related to handover procedure. Mobility Management block manages candidate neighbor target BSs based on some criteria, e.g. PHY signaling report, loading, etc. and also decides whether MS performs handover operation.

Network-entry Management block is in charge of initialization procedures. Network-entry Management block may generate management messages which needs during initialization procedures, i.e., ranging (this does not mean physical ranging, but ranging message in order to 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 MS, 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 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 BS/MS 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 MS/BS Data Plane Processing Flow

The following figure describes data transmission flow in the 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 add sub-header 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. Several MPDUs may be concatenated according to the size of the data burst.

On the receiver side, after a packet arrives from physical layer, MAC PDU formation block constructs MPDU, and Fragmentation/Packing block defragments/unpacks MPDU to make MSDU. After reconstituted in Convergence Sublayer, MSDU is transferred to higher layer.

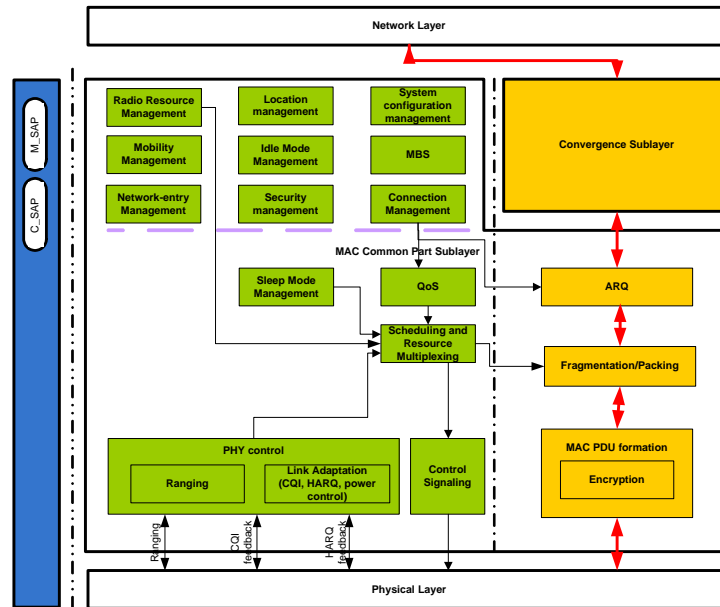


Figure 38 The IEEE 802.16e MS/BS Data Plane Processing Flow

A1.2 The IEEE 802.16e MS/BS Control Plane Processing Flow

The following Figure 39 describes the MAC message transmission flow in IEEE 802.16e. Most of the MAC functional block generates its own management messages, and these messages are transported to Fragmentation/Packing block. Basically the MAC management message does not use ARQ block (Management messages will be operated in request-and-response manner, that is, if there is no response, sender retransmits request. Therefore additional ARQ operation is not required). Management message may be fragmented or packed, and authentication information (e.g., CMAC/HMAC in IEEE 802.16e) may be appended to the management message if necessary. Some of MAC message may be transmitted via Control Signaling block in the form of control message (e.g., MAP). On the receiver side, most of MAC functional block also receives and handles MAC management messages from the MAC functional block of the opposite side (MS to BS, BS to MS).

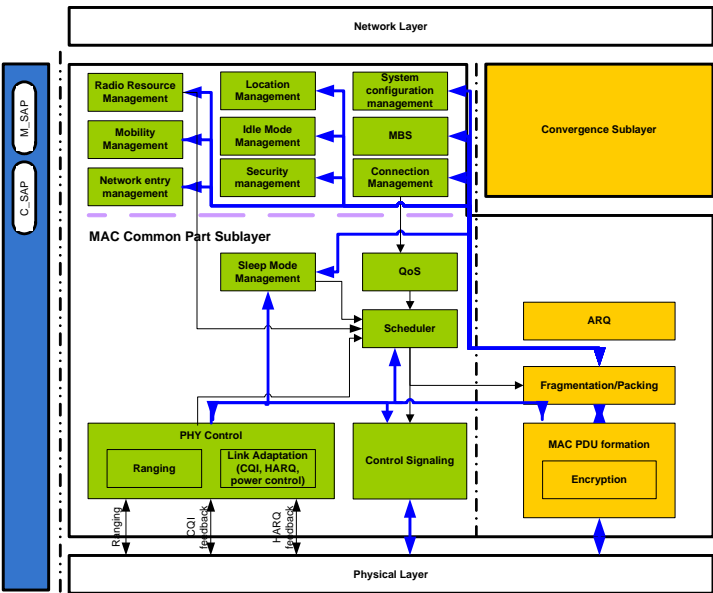


Figure 39 The IEEE 802.16e MS/BS Control Plane Processing Flow

<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 [C802.16m-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 ms which is less than 10 ms 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 + $T'_{ASN_GW} + T_{R6}$

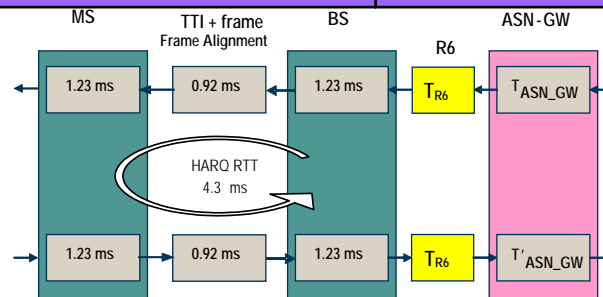


Table 6 Data plane access latency. The above processing time is FFS.

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 $2 \times \text{TTI} = 1.23$ ms, that further reduces the total delay budget. It is shown that the IDLE_STATE to ACTIVE_STATE transition time of less than 80 ms 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.