**Radiocommunication Study Groups**

Source: Revision 1 to Document 5D/TEMP/174

**17 February 2009**
**English only**

## Working Party 5D

# STATUS OF DRAFT REVISION 9 OF RECOMMENDATION ITU-R M.1457

## I) Current status

Working Party 5D has reviewed the submissions to the 4th meeting regarding the radio interface technology revisions under the Circular Letter 8/LCCE/95 process.

WP 5D concludes the following, as further detailed in the remainder of this document:

| M.1457 Section | Technology | Document | Circular Letter 95 | Notes |
|---|---|---|---|---|
| 5.1 | CDMA-DS | 5D/401 | Section 4 | |
| 5.2 | CDMA-MC | 5D/406 | Section 4 | Additional TDD component of the SRTT for inclusion in draft Revision 9 to M.1457 subject to Note 1. |
| 5.3 | CDMA TDD | 5D/401 | Section 4 | |
| 5.4 | TDMA-SC | 5D/340 | Section 4 | Deletion of TDD from the indoor component of the SRTT |
| 5.5 | FDMA/TDMA | 5D/338 | Section 4 | |
| 5.6 | OFDMA-TDD-WMAN | 5D/357, 5D365 | Section 4 | Additional FDD component of the SRTT for inclusion in draft Revision 9 to M.1457 subject to Note 2. |

**Note 1 Section 5.2**

In Section 6 of Circular Letter 8/LCCE/95 with regard to meeting X+2 in the process, it is noted that:

> **Meeting "x+2"** – The evaluation is completed for the proposed update to Recommendation ITU-R M.1457, except for exceptional circumstances.

Some administrations have raised a point as an exceptional circumstance that they need to have further investigation into the areas indicated in Section II (Areas of investigation) of this document in order to reach a conclusion on this technology submission.

The additional TDD component of an SRTT proposed for inclusion in the CDMA-MC technology is at this time proposed to be included in draft Revision 9 of Recommendation ITU-R M.1457 subject to achieving a satisfactory conclusion to the exceptional circumstances points that have been raised.

In order to clearly distinguish the existing FDD and proposed additional TDD component in the draft revision of Section 5.2 of Recommendation ITU-R M.1457-8, WP 5D has developed the structure for Section 5.2 drawing from the submitted materials to the 4th meeting as shown in the draft Revision 9 of Recommendation ITU-R M.1457 in Section IV of this TEMP document.

**Note 2 Section 5.6**

In Section 6 of Circular Letter 8/LCCE/95 with regard to meeting X+2 in the process it is noted that:

> **Meeting "x+2"** - The evaluation is completed for the proposed update to Recommendation ITU-R M.1457, except for exceptional circumstances.

Some administrations have raised a point as an exceptional circumstance that they need to have further investigation into the areas indicated in Section II (Areas of investigation) of this document in order to reach a conclusion on this technology submission.

The additional FDD component of an SRTT proposed for inclusion in the OFDMA-TDD-WMAN technology is at this time proposed to be included in draft Revision 9 of Recommendation ITU-R M.1457 subject to achieving a satisfactory conclusion to the exception circumstances points that have been raised.

In order to clearly distinguish the existing TDD and proposed additional FDD component in the draft revision of Section 5.6 of Recommendation ITU-R M.1457-8, WP 5D has developed the structure for Section 5.6 drawing from the submitted materials to the 4th meeting as shown in the draft Revision 9 of Recommendation ITU-R M.1457 in Section IV of this TEMP document.

## II) Areas of investigation

a) The German Administration is of the view that the integration of a TDD interface into a FDD interface and vice versa could significantly impact on spectrum related matters, which also include certain coexistance aspects.

Germany therefore requests that at least those issues are addressed by WP 5D before the modified Recommendation is adopted, that could cause interference between different services and applications in the relevant frequency bands and impact on spectrum related matters.

Some of those issues are already addressed in contribution 5D/389 in a general manner. For a more detailed description of those as well as other spectrum related issues, where Germany had expected that they would be addressed by the procedures as described in CL/95, Germany will examine the contributions to WP 5D provided by the proponents of the modified interfaces, to identify those items that could have an impact on the usage of the spectrum.

b) Based on the content of contribution 5D/399, France explained the reasons why an evaluation for new interfaces was considered as appropriate. Since WP 5D has decided not to evaluate the proposals for FDD in Documents 5D/357 and 5D/365, and TDD in Document 5D/406 as new interfaces (according to the definitions of an evaluation in the CL 8/LCCE/95), France explained that its main concern is relating to CL 8/LCCE/95, Sect. 9.1 (Benefits of the proposed enhancement): the proponent should show the added value of going ahead with the enhancement. Specifically, additional service capabilities (e.g. bit rate, multimedia), QoS, performance capabilities, and reduction in complexity should be explained.

## III) Timelines for conclusion

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In order for WP 5D to meet the schedule for draft Revision 9 of Recommendation ITU-R M.1457 to be submitted to Study Group 5 at its 7-8 December 2009 meeting, it is noted that the external organizations would provide certifications of references and transposition as well as final references and other administrative information called for in the original schedule by 3 August 2009 (see Document 5D/97 Chapter 6 Attachment 6.9).

Consequently WP 5D seeks to complete draft Revision 9 of Recommendation ITU-R M.1457 *for all the technology proposals* at the 5th meeting of WP 5D (10-17 June 2009). To this end the following plan is agreed by WP 5D:

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1) The concerned administrations as per Documents 5D/389 and 5D/399 seeking information in the "Areas of investigation" are to provide an early input contribution to WP 5D through the normal means by no later than 25 March 2009 to provide specific guidance to the technology proponents on what additional information is required to satisfactorily agreed and conclude the additional radio transmission technologies proposed for Sections 5.2 and 5.6.

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2) The proponents are requested to provide inputs to the June meeting of WP 5D towards closure of this open area.

3) The administrations and the proponents are encouraged to conduct dialog in the intervening period to promote understanding and a positive closure of this open area.

4) Working Party 5D intends to conclude on these remaining areas in its 10-17 June 2009 meeting.

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5) The fourth meeting of Working Party 5D will provide a liaison to the proponents informing them of the situation, the way forward and the timelines.

## IV) Draft Revision 9 of Recommendation ITU-R M.1457

NOTE – Included as embedded file :

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**Document 5D/TEMP/182-E**
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**Working Party 5D**
**SWG M.1457**

PROPOSED UPDATE OF SECTION 5.6 OF M.1457-8

## 5.6 IMT-2000 OFDMA TDD WMAN

## 5.6a TDD component

### 5.6a.1 Overview of the radio interface

#### 5.6a.1.1 Introduction

The IEEE standard relevant for IMT-2000 OFDMA TDD WMAN, designated as IEEE Std 802.16, is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. It is published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE).

The radio interface technology specified in IEEE Standard 802.16 is flexible, for use in a wide variety of applications, operating frequencies, and regulatory environments. IEEE 802.16 includes multiple physical layer specifications, one of which is known as WirelessMAN-OFDMA. OFDMA TDD WMAN is a special case of WirelessMAN-OFDMA specifying a particular interoperable radio interface. The component of OFDMA TDD WMAN defined here operates in TDD mode.

The OFDMA TDD WMAN radio interface comprises the two lowest network layers – the physical layer (PHY) and the data link control layer (DLC). The lower element of the DLC is the medium access control layer (MAC); the higher element in the DLC is the logical link control layer (LLC). The PHY is based on orthogonal frequency division multiple access (OFDMA) suitable for use in a 5 MHz, 10 MHz, 7 MHz, or 8.75 MHz channel allocation. The MAC is based a connection-oriented protocol designed for use in a point-to-multipoint configuration. It is designed to carry a wide range of packet-switched (typically IP-based) services while permitting fine and instantaneous control of resource allocation to allow full carrier-class Quality of Service (QoS) differentiation.

#### 5.6a.1.2 Radio access network architecture

The OFDMA TDD WMAN radio interface is designed to carry packet-based traffic, including IP. It is flexible enough to support a variety of higher-layer network architectures for fixed, nomadic, or fully mobile use, with handover support. It can readily support functionality suitable for generic

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data as well as time-critical voice and multimedia services, broadcast and multicast services, and mandated regulatory services.

The radio interface standard specifies Layers 1 and 2; the specification of the higher network layers is not included. It offers the advantage of flexibility and openness at the interface between Layers 2 and 3 and it supports a variety of network infrastructures. The radio interface is compatible with the network architectures defined in ITU-T Recommendation Q.1701. In particular, a network architecture design to make optimum use of IEEE Standard 802.16 and the OFDMA TDD WMAN radio interface is described in the "WiMAX End to End Network Systems Architecture Stage 2-3", available from the WiMAX Forum[1].

The protocol layering is illustrated in Fig. 70. The MAC comprises three sub-layers. The service-specific convergence sublayer (CS) provides any transformation or mapping of external network data, received through the CS service access point (SAP), into MAC service data units (SDUs) received by the MAC common part sublayer (CPS) through the MAC SAP. This includes classifying external network SDUs and associating them to the proper MAC service flow identifier (SFID) and connection identifier (CID). It may also include such functions as payload header suppression (PHS). Multiple CS specifications are provided for interfacing with various protocols. The internal format of the CS payload is unique to the CS, and the MAC CPS is not required to understand the format of or parse any information from the CS payload.

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**Deleted:** The core radio interface is defined in the data/control plane. Layer 1 comprises the PHY, which interfaces with the MAC at Layer 2 through the PHY service access point (SAP). The MAC includes three separate sub-layers. The lowest of these is the security sub-layer, which provides security mechanisms providing authentication, encryption, and key exchange for data privacy and to limit service to authorized use. Above the security sub-layer is the core MAC functionality, known as the MAC Common Part Sub-layer (MAC CPS). This interfaces, via the MAC SAP, with the Service-Specific Convergence Sub-layer (CS), which provides an interface to the IP network via the CS SAP.

1 http://www.wimaxforum.org/technology/documents/

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FIGURE 70

**OFDMA TDD WMAN protocol layering, showing service access points (SAPs)**

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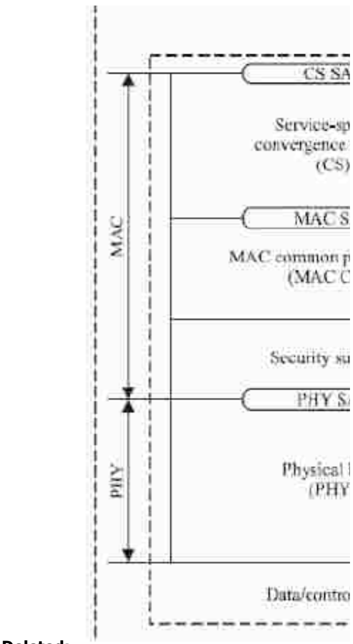


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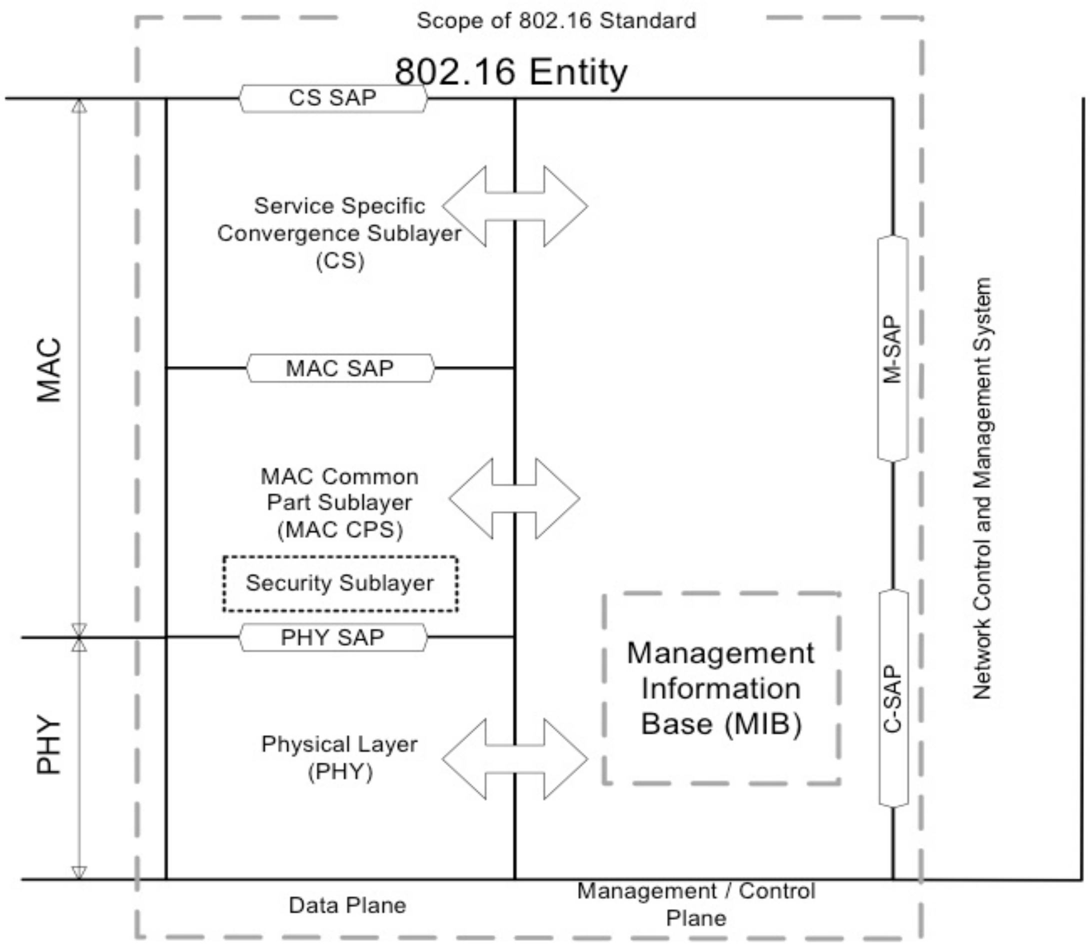


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The MAC CPS provides the core MAC functionality of system access, bandwidth allocation, connection establishment, and connection maintenance. It receives data from the various CSs, through the MAC SAP, classified to particular MAC connections.

Quality of service (QoS) is applied to the transmission and scheduling of data over the PHY.

The MAC also contains a separate security sublayer providing authentication, secure key exchange, and encryption.

Data, PHY control, and statistics are transferred between the MAC CPS and the PHY via the PHY SAP (which is implementation specific).

The 802.16 devices can include Mobile Stations (MS) or Base Stations (BS). As the 802.16 devices may be part of a larger network and therefore would require interfacing with entities for management and control purposes, a Network Control and Management System (NCMS) abstraction has been introduced in this standard as a "black box" containing these entities. The NCMS abstraction allows the PHY/MAC layers specified in 802.16 to be independent of the network architecture, the transport network, and the protocols used at the backend and therefore allows greater flexibility. NCMS logically exists at BS side and MS side of the radio interface, termed NCMS(BS) and NCMS(MS), respectively. Any necessary inter-BS coordination is handled through the NCMS(BS).

This specification includes a Control SAP (C-SAP) and Management SAP (M-SAP) that expose control plane and management plane functions to upper layers. The NCMS uses the C-SAP and M-SAP to interface with the 802.16 entity. In order to provide correct MAC operation, NCMS shall be present within each MS. The NCMS is a layer independent entity that may be viewed as a management entity or control entity. General system management entities can perform functions through NCMS and standard management protocols can be implemented in the NCMS.

**5.6a.1.2.1 BS and MS Functionality**

The system architecture consists of two logical entities, the base station (BS) and the mobile station (MS). The basic architectural assumption is of a base station (BS) communicating in point-to-multipoint fashion with a number of fixed or mobile stations (MSs). The BS is connected to an IP-based backhaul network. It controls and allocates the resources in spectrum and time. Transmissions on the downlink (BS to MS) are divided in both time and frequency (using the multiple sub-carriers provide by OFDMA) for assigning communications to individual MSs. Transmissions on the uplink (from MS to BS) take place according to the schedule and in the sub-channels assigned by the BS.

In brief, the BS is responsible for:

– configuring and updating basic parameters;

– performing bandwidth allocation for DL (per connection) and UL traffic (per MS) and performing centralized QoS scheduling, based on the QoS/service parameters and the active resource requests from the MS;

– communicating to all MSs, through the maps, the schedule of each frame and supporting other data and management broadcast and multicast services;

– transmitting/receiving traffic data and control information as MAC protocol data units (PDUs);

– performing connection admission control and other connection management functions;

– providing other MS support services such as ranging, clock synchronization, power control, and handover.

The MS is responsible for:

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**Deleted:** The MAC is connection-oriented. Each service, including inherently connectionless services, is mapped to a connection. Various mechanisms, known as scheduling services, are available for the SS to communicate to the BS the resource requirements of its connections. Each connection is assigned a specific scheduling service. The BS is required to manage a variety of simultaneous connections with disparate QoS requirements.

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– identifying the BS, obtaining MAC parameters, and joining the network;

– establishing basic connectivity, setting up additional data and management connections, and negotiating any optional parameters as needed;

– generating resource requests for connections that require them, based on the connection profiles and traffic;

– receiving broadcast/multicast PDUs and unicast PDUs and forwarding them appropriately;

– making local scheduling decisions based on the current demand and history of resource requests/grants;

– transmitting only when instructed by the BS to do so or the MS has some information that qualifies for transmission in one of the allowed contention slots;

– unless in sleep mode, receiving all schedule and channel information broadcast by the BS and obeying all medium access rules;

– performing initial ranging, maintenance ranging, power control, and other housekeeping functions.

Figure 70 is limited to describing a system including a BS and the MSs with which it communicates. However, the radio interface also provides specifications to allow handover of an MS from one BS to another. Such handover would typically occur as a mobile device moves toward an adjacent cell. However, it might also occur due to system-wide efforts at load balancing.

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#### 5.6a.1.3 Layer 1: Physical layer (PHY)

The radio interface is a special case of the Wireless MAN-OFDMA air interface specified in § 8.4 of IEEE Standard 802.16. It uses orthogonal frequency-division multiple access (OFDMA), which is an extension of orthogonal frequency-division multiplexing (OFDM).

##### 5.6a.1.3.1 OFDMA technology overview

OFDM divides the channel by frequency into orthogonal sub-carriers. Data to be transmitted is divided into parallel streams of reduced data rate (and therefore longer symbol duration) and each stream is modulated and transmitted on a separate sub-carrier. The lengthened symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of a cyclic prefix (CP) eliminates intersymbol interference if the CP duration is longer than the channel delay spread.

In a typical OFDM implementation, all of the transmitter’s sub-carriers are, at any given time, addressed to a single receiver; multiple access is provided solely by TDMA time slotting. OFDMA, however, divides the sub-carrier set into subsets, known as sub-channels. Each sub-channel can address a different receiver at any given time. In the downlink, each sub-channel may be intended for a different receiver or group of receivers. In the uplink, multiple MSs may transmit simultaneously as long as they are assigned different sub-channels.

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Sub-carriers are used for three purposes:

– Data transmission

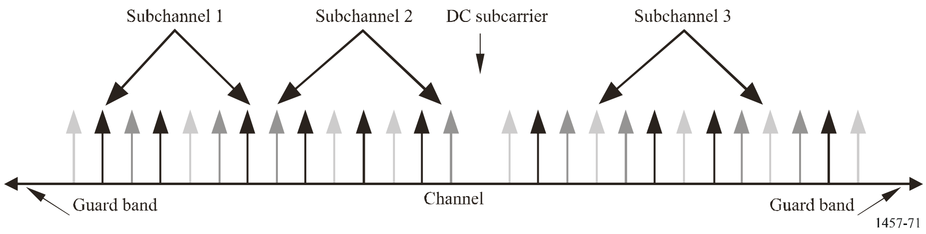
– Pilot transmission, for various estimation purposes

– Null transmission, for guard bands and at DC.

The concept is illustrated in Figure 71. As indicated, the sub-carriers forming one sub-channel need not be adjacent.

FIGURE 71

**OFDMA frequency description, schematically showing three sub-channels**




Sub-channelization is a multiple access technique. It provides OFDMA systems increased scheduling flexibility and a number of performance advantages, including enhanced scalability and advanced antenna array processing capabilities.

### 5.6a.1.3.2 OFDMA TDD WMAN physical layer details

The PHY utilizes OFDMA with either 512 sub-carriers in a 5 MHz channel or 1 024 sub-carriers in a 7 MHz or 10 MHz channel. In addition, 1 024 sub-carriers in a 8.75 MHz channel is also utilized for TDD. The primitive PHY parameters for TDD mode are listed in Table 10A.

TABLE 10A

**OFDMA TDD WMAN primitive PHY parameters, TDD mode**

| | | | | |
|---|---|---|---|---|
| FFT size ($N_{FFT}$) | 512 | 1 024 | 1 024 | 1024 |
| System channel bandwidth ($BW$) | 5 MHz | 10 MHz | 8.75 MHz | 7 MHz |
| Sampling frequency ($F_s$) | 5.6 MHz | 11.2 MHz | 10 MHz | 8 MHz |
| Sub-carrier frequency spacing ($\Delta f = F_s/N_{FFT}$) | 10.9375 kHz | | 9.77 kHz | 7.8125 kHz |
| Useful symbol time ($T_b = 1/\Delta f$) | ~91.43 µs | | ~102.4 µs | 128 µs |
| Guard (CP) time ($T_g = T_b/8$) | ~11.43 µs | | ~12.8 µs | 16 µs |
| OFDMA symbol duration ($T_s = T_b + T_g$) | ~102.9 µs | | ~115.2 µs | 144 µs |
| Frame duration | 5 ms | | 5 ms | 5 ms |
| OFDMA symbols per frame (including TTG and RTG) | ~48 | | ~43 | ~34 |
| OFDMA symbols per frame (excluding TTG and RTG) | 47 | | 42 | 33 |

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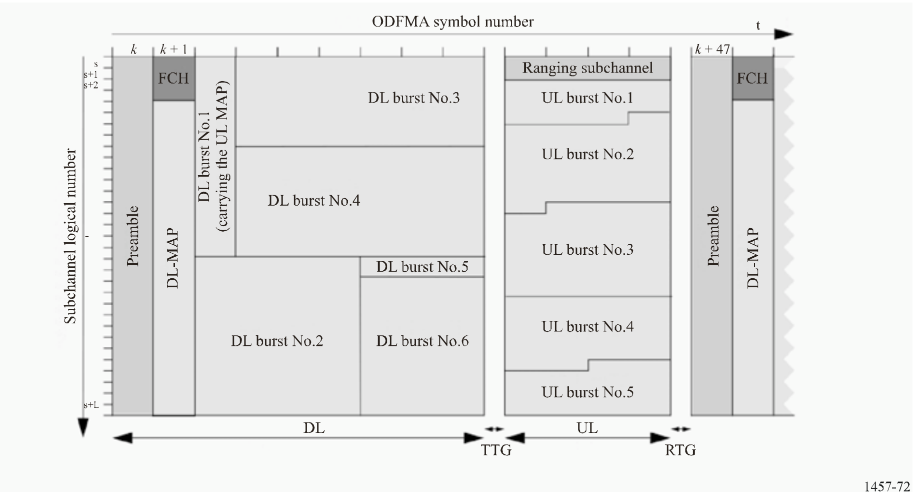
### 5.6a.1.3.3 Framing and sub-channelization

In the case of TDD, OFDMA TDD WMAN PHY utilizes a 5 ms TDD frame. The frame includes first downlink and then uplink sub-frames, divided by time gaps to allow the transceivers to switch between receive and transmit. The two gaps (TTG and RTG) are both included in the 5 ms duration. The asymmetry between the uplink and downlink sub-frame durations is configurable on a system-wide basis.

The TDD frame structure is illustrated schematically in Fig. 72A.

FIGURE 72A

**Schematic illustration of TDD frame structure**




The frame is shown in two dimensions. The horizontal dimension represents time, which maps directly into the OFDM symbol sequence. The vertical dimension represents the list of available logical sub-channels. This maps into frequency, although only indirectly, since the sub-carriers in a given logical channel are not arranged in sequential order.

The frame begins with a preamble for synchronization. The following OFDM symbol contains the frame control header (FCH) and the downlink map (DL_MAP), transmitted simultaneously on different sub-channels. The FCH includes frame configuration data. The DL-MAP indicates the use of the DL sub-frame, in time and sub-channel allocation. The UL-MAP that follows provides similar information for the uplink, though the allocation is relevant not to the current frame but to a subsequent one, in order to allow the MS time to prepare an appropriate transmission or in accordance with the UL-MAP.

The construction of the sub-channel from individual sub-carriers is called the permutation. OFDMA TDD WMAN provides a number of possible permutations. The optimal choice depends on the deployment scenario and instantaneous circumstances; therefore, the permutation may differ from one ODFM symbol to the next. The specification supports a sequence of permutation zones in the frame, so that different mobile stations can be served with different permutations.

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#### 5.6a.1.3.4 Adaptive modulation and coding

OFDMA TDD WMAN supports a variety of modulation and coding alternatives. The control is adaptive and dynamic, so that the BS may select different options for communicating with different MSs and may order the MS to alter the choices in order to optimize the trade-off of robustness versus capacity.

The BS selects the modulation from among QPSK, 16-QAM, and 64-QAM. For forward error correction, Convolutional Coding and Convolutional Turbo Coding with variable code rate and repetition coding are specified. Block Turbo Code and Low Density Parity Check Code (LDPC) are supported as optional features.

Data randomization is specified in order to reduce the peak-to-average power ratio. Interleaving is specified to increase frequency diversity.

#### 5.6a.1.3.5 Fast feedback and hybrid ARQ

OFDMA TDD WMAN specifies an uplink fast-feedback channel to provide time-critical PHY parameter data to the BS. Parameters include signal-to-noise ratio, MIMO coefficients, and MIMO configuration parameters.

Additional UL acknowledgment channels may be allocated by the BS to support hybrid automatic repeat request (HARQ).

### 5.6a.1.4 Layer 2: Medium access control layer (MAC)

The medium access control layer (MAC) functionality controls access to the medium, which in this case is the radio spectrum. The MAC is also responsible for basic functions such as data encapsulation, fragmentation, radio resource control, radio link control, error detection and retransmission, QoS, security, sleep mode, and handover.

Although the radio interface is designed primarily to support a connectionless network layer, such as IP, the MAC is connection-oriented. All services, including inherently connectionless services, are mapped to a connection. The connection provides a mechanism for requesting resource allocation, associating QoS and traffic parameters, transporting and routing data, and all other actions associated with the terms of the service. A 16-bit connection identifier (CID) is assigned to designate each connection. The MAC uses the CID to identify all information exchanged between BS and MS, including management and broadcast data. The CID provides a simple and direct way to differentiate traffic. All MAC-level QoS functions, such as the classifier and QoS scheduler, use the CID to identify and differentiate traffic in order to maintain the service level and fairness among connections.

#### 5.6a.1.4.1 Convergence sub-layer (CS)

At the transmitter side, the Convergence sub-layer is responsible for transforming packet-based protocol data units from the higher layer protocol into MAC service data unit (SDUs), possibly using payload header suppression (PHS) to suppress some of the packet headers and reduce the burden of carrying them over the air. The CS then classifies each MAC SDU, assigning it to a particular connection, and passes it to the MAC CPS. At the receiver side, the CS is responsible for the inverse operations, including reassembly of packets into their original format with complete headers.

The CS contains a classification function that determines on which connection a particular packet shall be carried and which PHS rule applies for that packet. The operation is illustrated in Fig. 73, which shows the downlink case. Classifier parameters are configured during dynamic service signalling.

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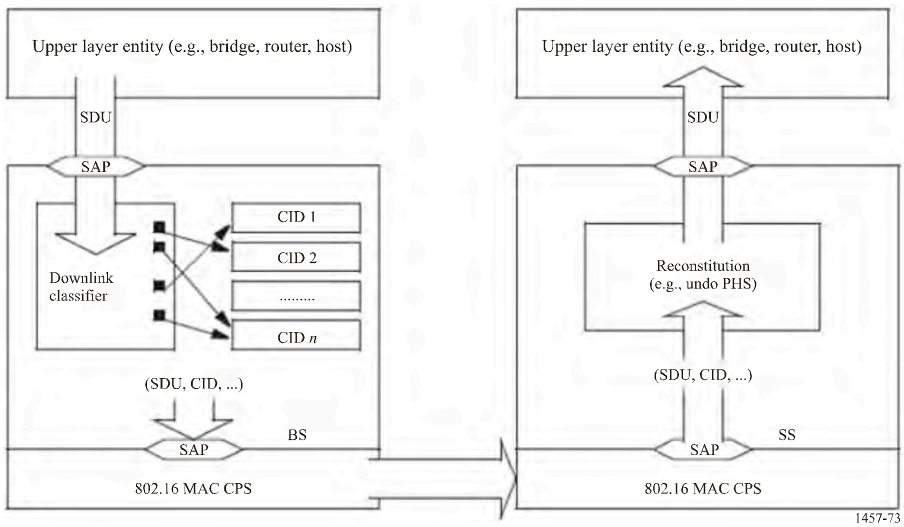
FIGURE 73

**Classification and CID mapping (downlink)**




### 5.6a.1.4.2 MAC common part sub-layer (CPS)

The MAC CPS is responsible for performing the core MAC functions. It receives MAC service data units (SDUs) from the CS and encapsulates them in its native MAC PDU format for transmission over the PHY. The MAC CPS also manages the transport connections and QoS, controlling access to the radio spectrum by the MSs.

Encapsulation may be as simple as adding necessary information to the SDU. However, the MAC CPS also has the possibility of dividing a single SDU into multiple fragments before transmission, for reassembly at the receiving MAC CPS. Fragmentation allows more efficient support of higher layer protocols with variable-size SDUs, given that the underlying PHY used a fixed frame size. The MAC CPS also has the complementary option to pack multiple higher layer payloads into a single PDU. Since MAC encapsulation introduces some fixed overhead per PDU, this can improve the efficiency of carrying small SDUs.

A MAC PDU consists of a six-byte MAC header, a variable-length payload, and an optional cyclic redundancy check. Four header formats, distinguished by the HT field, are defined. The generic header is shown in Fig. 74.

MAC PDUs generally contain either MAC management messages or convergence sub-layer data. However, one header type is reserved for uplink PDUs that contain no payload, conveying their information (such as a resource request) in the content of the header itself. Additional sub-headers are also defined. For example, the MS can use the grant management sub-header to convey bandwidth management needs to the BS. The fragmentation sub-header contains information that indicates the presence and orientation in the payload of any fragments of SDUs. The packing subheader is used to indicate the packing of multiple SDUs into a single PDU. The grant management and fragmentation sub-headers may be inserted in MAC PDUs immediately following the generic header if so indicated by the Type field. The packing sub-header may be inserted before each MAC SDU if so indicated by the Type field.

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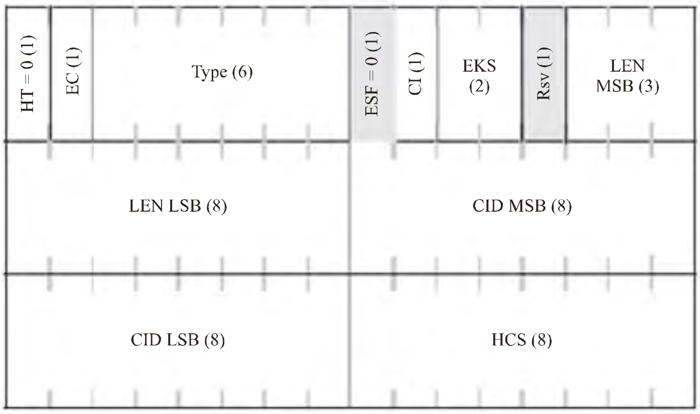
FIGURE 74

**Generic MAC header format**

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### 5.6a.1.4.2.1 Uplink scheduling services

The scheduling algorithm is not specified in the standard but is critical to efficient multimedia delivery when the BS supports a variety of disparate connections. The BS is presumed capable of scheduling its own downlink transmissions based on QoS information developed in the CS. Uplink scheduling is more complicated because, while resource allocation is under the control of the BS, only the MSs know in real time their immediate transmission demands.

In order to allow efficient QoS-based scheduling, a number of uplink scheduling services are defined, with a specific service assigned to each connection. The QoS categories are summarized in Table 11.

Resource requests, for transmission slots, are initiated by a specific connection at the MS. However, grants are allocated not to the connection but to the supporting MS. The MS is required to manage the slots allocated to it, assigning them to the multiple connections it supports. By distributing the management and permitting local resource allocation, over-the-air negotiation is minimized and rescheduling decisions are made more quickly and effectively.

### 5.6a.1.4.2.2 Radio link control

As noted in § 5.6.1.3.2, OFDMA TDD WMAN supports adaptive modulation and coding. The MAC CPS is responsible for radio link control. This involves managing the modulation and coding selection at the MS through interactive message exchange based on monitoring the ratio of carrier signal to noise and interference.

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TABLE 11

**OFDMA TDD WMAN Uplink scheduling services**

| QoS category | Typical applications | QoS specifications |
|---|---|---|
| **UGS**<br>Unsolicited grant service | VoIP | – Maximum sustained rate<br>– Maximum latency tolerance<br>– Jitter tolerance |
| **rtPS**<br>Real-time packet service | Streaming audio or video | – Minimum reserved rate<br>– Maximum sustained rate<br>– Maximum latency tolerance<br>– Traffic priority |
| **ErtPS**<br>Extended real-time packet service | Voice with activity detection (VoIP) | – Minimum reserved rate<br>– Maximum sustained rate<br>– Maximum latency tolerance<br>– Jitter tolerance<br>– Traffic priority |
| **nrtPS**<br>Non-real-time packet service | File transfer protocol (FTP) | – Minimum reserved rate<br>– Maximum sustained rate<br>– Traffic priority |
| **BE**<br>Best-effort service | Data transfer, web browsing, etc. | – Maximum sustained rate<br>– Traffic priority |

**5.6a.1.4.2.3 Energy conservation in the MS**

The MAC CPS controls two energy-saving modes – Sleep Mode and Idle Mode – to conserve energy in the MS. During Sleep Mode, the MS observes pre-negotiated periods without transmission. Idle Mode is intended as a mechanism to allow the MS to become periodically available for DL broadcast messaging without registration at a specific BS as the MS traverses an air link environment populated by multiple BSs, typically over a large geographic area.

**5.6a.1.4.2.4 Handover**

The MAC CPS supports optimized hard handover.

**5.6a.1.4.3 Security sub-layer**

The security sub-layer, which operates between the PHY and the MAC CPS, is responsible for providing strong encryption, decryption, mutual authentication, and secure key exchange. Security is maintained as a separate sub-layer so that it may be upgraded as necessary. Also, the key functionality internal to the sub-layer is also modular, to provide easy maintenance upgrade. For example, the protocol provides a means of identifying one from a set of supported cryptographic suites, each of which specifies data encryption and authentication algorithms, and the rules for applying those algorithms to a MAC PDU payload.

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The security sub-layer utilizes a security association (SA), which is a set of information shared between the transmitter and receiver. Each SA contains information on the cryptographic suite used for that SA and may also contain keys, such as the traffic encryption keys (TEKs), along with the key lifetimes and other associated state information. Prior to transmission, the MAC PDUs are mapped to an SA. The receiver uses the CID to determine the correct SA and applies the corresponding processing to the received PDU.

Device and user authentication use the IETF EAP protocol. OFDMA TDD WMAN encrypts user data using the AES-CCM cryptographic suite, with the Advanced Encryption Standard (AES) algorithm in the counter with CBC-MAC (CCM) mode, with 128-bit keys. The keys are generated using EAP authentication and managed by a Traffic Encryption Key (TEK) state machine. MAC management messages are AES encrypted and authenticated. A three-way handshake scheme is supported to optimize re-authentication during handover.

### 5.6a.1.5 Smart antennas

OFDMA TDD WMAN specifies the use of smart antenna technologies, including antenna beamforming, space-time coding, and spatial multiplexing, which increase the cell size, data throughput, and spectral efficiency. These techniques reduce the sensitivity of the system to fading and multipath transmission effects.

### 5.6a.1.6 Summary of major technical parameters

TABLE 12A

**OFDMA TDD WMAN parameters and capabilities, TDD mode**

| Parameter/Capability | Value | | | | IEEE 802.16 Subclause |
|---|---|---|---|---|---|
| Duplex method | TDD | | | | § 8.4.4 |
| Physical layer mode | OFDMA | | | | § 8.4 |
| System channel bandwidth | 5 MHz | 10 MHz | 8.75 MHz | 7 MHz | § 8.4.1 |
| FFT size | 512 | 1 024 | 1 024 | 1024 | |
| Frame duration | 5 ms | | 5 ms | 5 ms | § 8.4.5.2 |
| Transmit transition gap (TTG) | 105.714 µs | | 87.2 µs | 188 µs | § 8.4.5.2 |
| Receive transition gap (RTG) | 60 µs | | 74.4 µs | 60 µs | § 8.4.5.2 |
| Modulation, downlink | QPSK, 16-QAM, 64-QAM | | | | § 8.4.9.4.2 |
| Modulation, uplink | QPSK, 16-QAM | | | | § 8.4.9.4.2 |
| Forward error correction coding | Convolutional Coding and Convolutional Turbo Coding | | | | § 8.4.9.2.1; § 8.4.9.2.3 excluding § 8.4.9.2.3.5 |
| Encryption | AES-CCM, AES Key Wrap, 128-bit keys | | | | § 11.9.14 |
| Authentication | EAP | | | | § 11.8.4.2 |
| Privacy key management | PKMv2 | | | | § 7.2.2 |
| Management message integrity protection | CMAC | | | | § 7.5.4.4 |

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***[Editor's note: the following text is new text]***

***[Editor's note: any content TDD specific should be deleted from this section]***

***[Editor's note: tables and figure numbering needs to be updated]***

## 5.6b FDD component

### 5.6b.1 Overview of the radio interface

#### 5.6b.1.1 Introduction

The IEEE standard relevant for IMT-2000 OFDMA TDD WMAN, designated as IEEE Std 802.16, is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. It is published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE).

The radio interface technology specified in IEEE Standard 802.16 is flexible, for use in a wide variety of applications, operating frequencies, and regulatory environments. IEEE 802.16 includes multiple physical layer specifications, one of which is known as WirelessMAN-OFDMA. OFDMA TDD WMAN is a special case of WirelessMAN-OFDMA specifying a particular interoperable radio interface. The component of OFDMA TDD WMAN defined here operates in FDD mode.

The OFDMA TDD WMAN radio interface comprises the two lowest network layers – the physical layer (PHY) and the data link control layer (DLC). The lower element of the DLC is the medium access control layer (MAC); the higher element in the DLC is the logical link control layer (LLC). The PHY is based on orthogonal frequency division multiple access (OFDMA) suitable for use in a 5 MHz ,10 MHz, or 7 MHz channel allocation. The MAC is based a connection-oriented protocol designed for use in a point-to-multipoint configuration. It is designed to carry a wide range of packet-switched (typically IP-based) services while permitting fine and instantaneous control of resource allocation to allow full carrier-class Quality of Service (QoS) differentiation.

#### 5.6b.1.2 Radio access network architecture

The OFDMA TDD WMAN radio interface is designed to carry packet-based traffic, including IP. It is flexible enough to support a variety of higher-layer network architectures for fixed, nomadic, or fully mobile use, with handover support. It can readily support functionality suitable for generic data as well as time-critical voice and multimedia services, broadcast and multicast services, and mandated regulatory services.

The radio interface standard specifies Layers 1 and 2; the specification of the higher network layers is not included. It offers the advantage of flexibility and openness at the interface between Layers 2 and 3 and it supports a variety of network infrastructures. The radio interface is compatible with the network architectures defined in ITU-T Recommendation Q.1701. In particular, a network architecture design to make optimum use of IEEE Standard 802.16 and the OFDMA TDD WMAN radio interface is described in the "WiMAX End to End Network Systems Architecture Stage 2-3", available from the WiMAX Forum[2].

The protocol layering is illustrated in Fig. 70. The MAC comprises three sub-layers. The service-specific convergence sublayer (CS) provides any transformation or mapping of external network data, received through the CS service access point (SAP), into MAC service data units (SDUs) received by the MAC common part sublayer (CPS) through the MAC SAP. This includes

2 http://www.wimaxforum.org/technology/documents/

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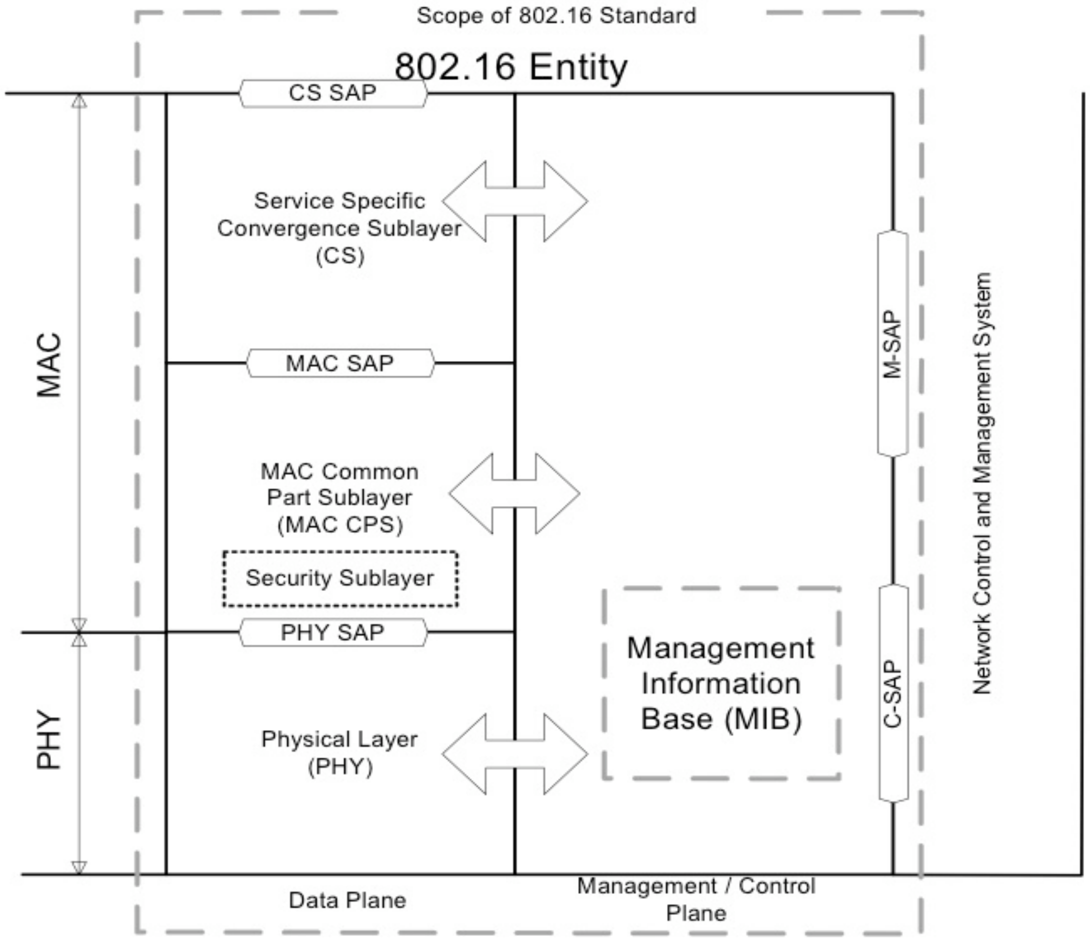
classifying external network SDUs and associating them to the proper MAC service flow identifier (SFID) and connection identifier (CID). It may also include such functions as payload header suppression (PHS). Multiple CS specifications are provided for interfacing with various protocols. The internal format of the CS payload is unique to the CS, and the MAC CPS is not required to understand the format of or parse any information from the CS payload.

FIGURE 70

**OFDMA TDD WMAN protocol layering, showing service access points (SAPs)**


Scope of 802.16 Standard
802.16 Entity
CS SAP
Service Specific
Convergence Sublayer
(CS)
MAC SAP
MAC Common
Part Sublayer
(MAC CPS)
Security Sublayer
PHY SAP
Physical Layer
(PHY)
MAC
PHY
Management
Information
Base (MIB)
M-SAP
C-SAP
Network Control and Management System
Data Plane
Management / Control
Plane

The MAC CPS provides the core MAC functionality of system access, bandwidth allocation, connection establishment, and connection maintenance. It receives data from the various CSs, through the MAC SAP, classified to particular MAC connections.

Quality of service (QoS) is applied to the transmission and scheduling of data over the PHY.

The MAC also contains a separate security sublayer providing authentication, secure key exchange, and encryption.

Data, PHY control, and statistics are transferred between the MAC CPS and the PHY via the PHY SAP (which is implementation specific).

The 802.16 devices can include Mobile Stations (MS) or Base Stations (BS). As the 802.16 devices may be part of a larger network and therefore would require interfacing with entities for management and control purposes, a Network Control and Management System (NCMS) abstraction has been introduced in this standard as a "black box" containing these entities. The NCMS abstraction allows the PHY/MAC layers specified in 802.16 to be independent of the network architecture, the transport network, and the protocols used at the backend and therefore allows greater flexibility. NCMS logically exists at BS side and MS side of the radio interface, termed NCMS(BS) and NCMS(MS), respectively. Any necessary inter-BS coordination is handled through the NCMS(BS).

This specification includes a Control SAP (C-SAP) and Management SAP (M-SAP) that expose control plane and management plane functions to upper layers. The NCMS uses the C-SAP and M-SAP to interface with the 802.16 entity. In order to provide correct MAC operation, NCMS shall be present within each MS. The NCMS is a layer independent entity that may be viewed as a management entity or control entity. General system management entities can perform functions through NCMS and standard management protocols can be implemented in the NCMS.

**5.6b.1.2.1 BS and MS Functionality**

The system architecture consists of two logical entities, the base station (BS) and the mob ile station (MS). The basic architectural assumption is of a base station (BS) communicating in point-to-multipoint fashion with a number of fixed or mobile stations (MSs). The BS is connected to an IP-based backhaul network. It controls and allocates the resources in spectrum and time. Transmissions on the downlink (BS to MS) are divided in both time and frequency (using the multiple sub-carriers provide by OFDMA) for assigning communications to individual MSs. Transmissions on the uplink (from MS to BS) take place according to the schedule and in the sub-channels assigned by the BS.

In brief, the BS is responsible for:

– configuring and updating basic parameters;

– performing bandwidth allocation for DL (per connection) and UL traffic (per MS) and performing centralized QoS scheduling, based on the QoS/service parameters and the active resource requests from the MS;

– communicating to all MSs, through the maps, the schedule of each frame and supporting other data and management broadcast and multicast services;

– transmitting/receiving traffic data and control information as MAC protocol data units (PDUs);

– performing connection admission control and other connection management functions;

– providing other MS support services such as ranging, clock synchronization, power control, and handover.

The MS is responsible for:

– identifying the BS, obtaining MAC parameters, and joining the network;
– establishing basic connectivity, setting up additional data and management connections, and negotiating any optional parameters as needed;
– generating resource requests for connections that require them, based on the connection profiles and traffic;
– receiving broadcast/multicast PDUs and unicast PDUs and forwarding them appropriately;
– making local scheduling decisions based on the current demand and history of resource requests/grants;
– transmitting only when instructed by the BS to do so or the MS has some information that qualifies for transmission in one of the allowed contention slots;
– unless in sleep mode, receiving all schedule and channel information broadcast by the BS and obeying all medium access rules;
– performing initial ranging, maintenance ranging, power control, and other housekeeping functions.

Figure 70 is limited to describing a system including a BS and the MSs with which it communicates. However, the radio interface also provides specifications to allow handover of an MS from one BS to another. Such handover would typically occur as a mobile device moves toward an adjacent cell. However, it might also occur due to system-wide efforts at load balancing.

**5.6b.1.3 Layer 1: Physical layer (PHY)**

The radio interface is a special case of the Wireless MAN-OFDMA air interface specified in § 8.4 of IEEE Standard 802.16. It uses orthogonal frequency-division multiple access (OFDMA), which is an extension of orthogonal frequency-division multiplexing (OFDM).

**5.6b.1.3.1 OFDMA technology overview**

OFDM divides the channel by frequency into orthogonal sub-carriers. Data to be transmitted is divided into parallel streams of reduced data rate (and therefore longer symbol duration) and each stream is modulated and transmitted on a separate sub-carrier. The lengthened symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of a cyclic prefix (CP) eliminates intersymbol interference if the CP duration is longer than the channel delay spread.

In a typical OFDM implementation, all of the transmitter’s sub-carriers are, at any given time, addressed to a single receiver; multiple access is provided solely by TDMA time slotting. OFDMA, however, divides the sub-carrier set into subsets, known as sub-channels. Each sub-channel can address a different receiver at any given time. In the downlink, each sub-channel may be intended for a different receiver or group of receivers. In the uplink, multiple MSs may transmit simultaneously as long as they are assigned different sub-channels.

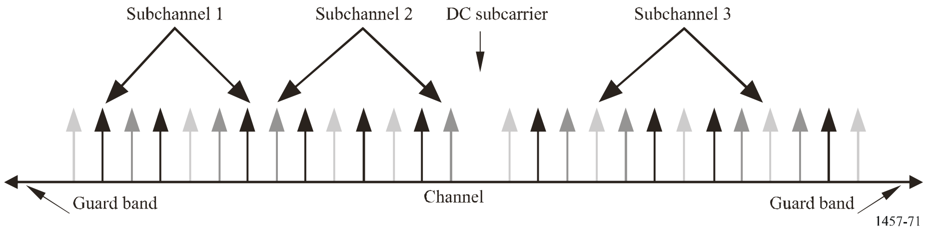
Sub-carriers are used for three purposes:

– Data transmission
– Pilot transmission, for various estimation purposes
– Null transmission, for guard bands and at DC.

The concept is illustrated in Figure 71. As indicated, the sub-carriers forming one sub-channel need not be adjacent.

FIGURE 71

**OFDMA frequency description, schematically showing three sub-channels**




Sub-channelization is a multiple access technique. It provides OFDMA systems increased scheduling flexibility and a number of performance advantages, including enhanced scalability and advanced antenna array processing capabilities.

### 5.6b.1.3.2 OFDMA TDD WMAN physical layer details

The PHY utilizes OFDMA with either 512 sub-carriers in a 5 MHz channel or 1 024 sub-carriers in a 7 MHz or 10 MHz channel. The primitive PHY parameters for FDD mode are listed in Table 10B.

TABLE 10B

**OFDMA TDD WMAN primitive PHY parameters, FDD mode**

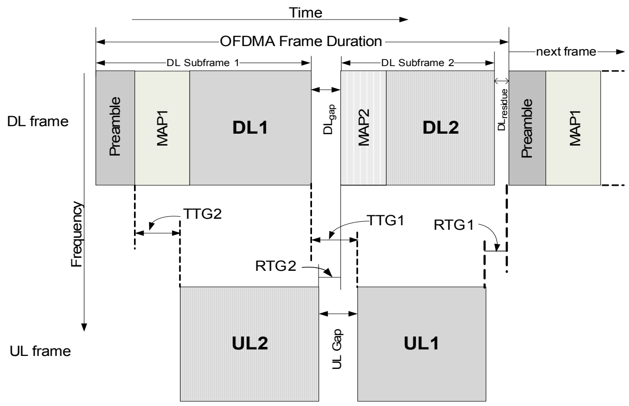
| | | | |
|---|---|---|---|
| FFT size ($N_{FFT}$) | 512 | 1 024 | 1024 |
| System channel bandwidth ($BW$) | 5 MHz | 10 MHz | 7 MHz |
| Sampling frequency ($F_s$) | 5.6 MHz | 11.2 MHz | 8 MHz |
| Sub-carrier frequency spacing ($\Delta f = F_s/N_{FFT}$) | 10.9375 kHz | | 7.8125 kHz |
| Useful symbol time ($T_b = 1/\Delta f$) | ~91.43 µs | | 128 µs |
| Guard (CP) time ($T_g = T_b/8$) | ~11.43 µs | | 16 µs |
| OFDMA symbol duration ($T_s = T_b + T_g$) | ~102.9 µs | | 144 µs |
| Frame duration | 5 ms | | 5 ms |
| OFDMA symbols per frame | ~48 | | ~34 |

### 5.6b.1.3.3 Framing and sub-channelization

The FDD frame structure is illustrated in Fig. 72B. This frame structure can concurrently supports both Full Duplex FDD (F-FDD) and Half Duplex FDD (H-FDD) Mobile Stations. The frame is partitioned using MAP1 and MAP2 control structures for H-FDD Mobile Stations.

FIGURE 72B

**Schematic illustration of FDD frame structure**




For systems that serve only F-FDD MSs, the frame structure is configured by allocating the whole down link and uplink frames to the F-FDD MSs without partitioning of frames.

### 5.6b.1.3.4 Adaptive modulation and coding

OFDMA TDD WMAN supports a variety of modulation and coding alternatives. The control is adaptive and dynamic, so that the BS may select different options for communicating with different MSs and may order the MS to alter the choices in order to optimize the trade-off of robustness versus capacity.

The BS selects the modulation from among QPSK, 16-QAM, and 64-QAM. For forward error correction, Convolutional Coding and Convolutional Turbo Coding with variable code rate and repetition coding are specified. Block Turbo Code and Low Density Parity Check Code (LDPC) are supported as optional features.

Data randomization is specified in order to reduce the peak-to-average power ratio. Interleaving is specified to increase frequency diversity.

### 5.6b.1.3.5 Fast feedback and hybrid ARQ

OFDMA TDD WMAN specifies an uplink fast-feedback channel to provide time-critical PHY parameter data to the BS. Parameters include signal-to-noise ratio, MIMO coefficients, and MIMO configuration parameters.

Additional UL acknowledgment channels may be allocated by the BS to support hybrid automatic repeat request (HARQ).

### 5.6b.1.4 Layer 2: Medium access control layer (MAC)

The medium access control layer (MAC) functionality controls access to the medium, which in this case is the radio spectrum. The MAC is also responsible for basic functions such as data encapsulation, fragmentation, radio resource control, radio link control, error detection and retransmission, QoS, security, sleep mode, and handover.

Although the radio interface is designed primarily to support a connectionless network layer, such as IP, the MAC is connection-oriented. All services, including inherently connectionless services, are mapped to a connection. The connection provides a mechanism for requesting resource allocation, associating QoS and traffic parameters, transporting and routing data, and all other actions associated with the terms of the service. A 16-bit connection identifier (CID) is assigned to designate each connection. The MAC uses the CID to identify all information exchanged between BS and MS, including management and broadcast data. The CID provides a simple and direct way to differentiate traffic. All MAC-level QoS functions, such as the classifier and QoS scheduler, use the CID to identify and differentiate traffic in order to maintain the service level and fairness among connections.

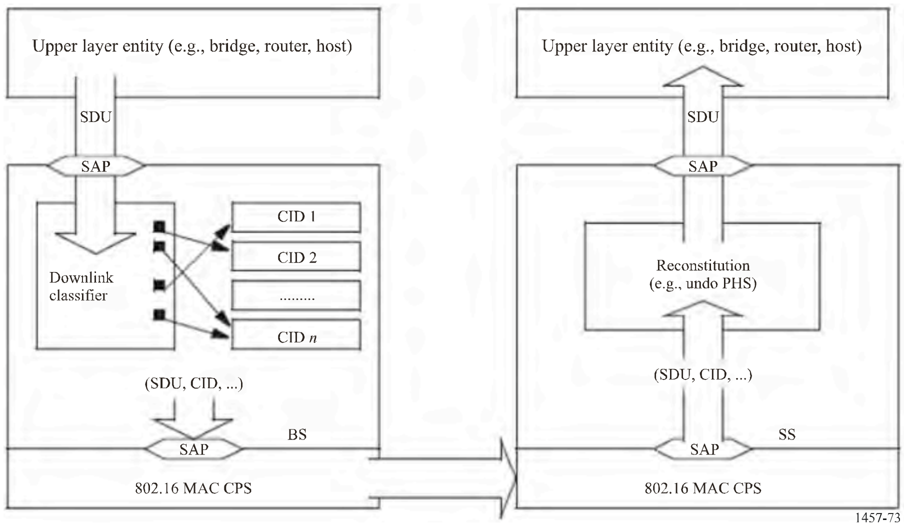
**5.6b.1.4.1 Convergence sub-layer (CS)**

At the transmitter side, the Convergence sub-layer is responsible for transforming packet-based protocol data units from the higher layer protocol into MAC service data unit (SDUs), possibly using payload header suppression (PHS) to suppress some of the packet headers and reduce the burden of carrying them over the air. The CS then classifies each MAC SDU, assigning it to a particular connection, and passes it to the MAC CPS. At the receiver side, the CS is responsible for the inverse operations, including reassembly of packets into their original format with complete headers.

The CS contains a classification function that determines on which connection a particular packet shall be carried and which PHS rule applies for that packet. The operation is illustrated in Fig. 73, which shows the downlink case. Classifier parameters are configured during dynamic service signalling.

FIGURE 73

**Classification and CID mapping (downlink)**



**5.6b.1.4.2 MAC common part sub-layer (CPS)**

The MAC CPS is responsible for performing the core MAC functions. It receives MAC service data units (SDUs) from the CS and encapsulates them in its native MAC PDU format for transmission over the PHY. The MAC CPS also manages the transport connections and QoS, controlling access to the radio spectrum by the MSs.

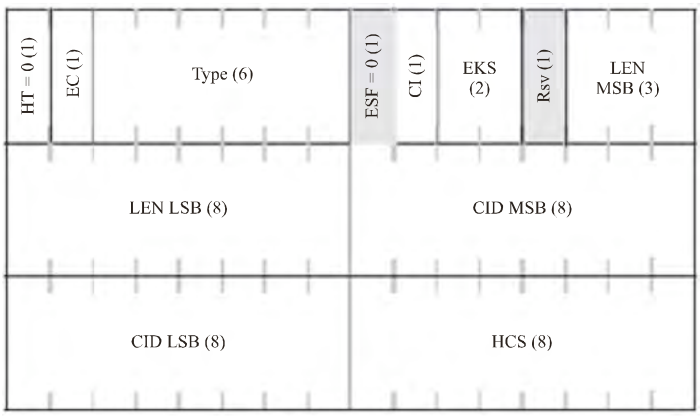
Encapsulation may be as simple as adding necessary information to the SDU. However, the MAC CPS also has the possibility of dividing a single SDU into multiple fragments before transmission, for reassembly at the receiving MAC CPS. Fragmentation allows more efficient support of higher layer protocols with variable-size SDUs, given that the underlying PHY used a fixed frame size. The MAC CPS also has the complementary option to pack multiple higher layer payloads into a single PDU. Since MAC encapsulation introduces some fixed overhead per PDU, this can improve the efficiency of carrying small SDUs.

A MAC PDU consists of a six-byte MAC header, a variable-length payload, and an optional cyclic redundancy check. Four header formats, distinguished by the HT field, are defined. The generic header is shown in Fig. 74.

MAC PDUs generally contain either MAC management messages or convergence sub-layer data. However, one header type is reserved for uplink PDUs that contain no payload, conveying their information (such as a resource request) in the content of the header itself. Additional sub-headers are also defined. For example, the MS can use the grant management sub-header to convey bandwidth management needs to the BS. The fragmentation sub-header contains information that indicates the presence and orientation in the payload of any fragments of SDUs. The packing subheader is used to indicate the packing of multiple SDUs into a single PDU. The grant management and fragmentation sub-headers may be inserted in MAC PDUs immediately following the generic header if so indicated by the Type field. The packing sub-header may be inserted before each MAC SDU if so indicated by the Type field.

FIGURE 74

**Generic MAC header format**

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#### 5.6b.1.4.2.1 Uplink scheduling services

The scheduling algorithm is not specified in the standard but is critical to efficient multimedia delivery when the BS supports a variety of disparate connections. The BS is presumed capable of scheduling its own downlink transmissions based on QoS information developed in the CS. Uplink scheduling is more complicated because, while resource allocation is under the control of the BS, only the MSs know in real time their immediate transmission demands.

In order to allow efficient QoS-based scheduling, a number of uplink scheduling services are defined, with a specific service assigned to each connection. The QoS categories are summarized in Table 11.

Resource requests, for transmission slots, are initiated by a specific connection at the MS. However, grants are allocated not to the connection but to the supporting MS. The MS is required to manage the slots allocated to it, assigning them to the multiple connections it supports. By distributing the management and permitting local resource allocation, over-the-air negotiation is minimized and rescheduling decisions are made more quickly and effectively.

#### 5.6b.1.4.2.2 Radio link control

As noted in § 5.6.1.3.2, OFDMA TDD WMAN supports adaptive modulation and coding. The MAC CPS is responsible for radio link control. This involves managing the modulation and coding selection at the MS through interactive message exchange based on monitoring the ratio of carrier signal to noise and interference.

TABLE 11

**OFDMA TDD WMAN Uplink scheduling services**

| QoS category | Typical applications | QoS specifications |
|---|---|---|
| **UGS**<br>Unsolicited grant service | VoIP | – Maximum sustained rate<br>– Maximum latency tolerance<br>– Jitter tolerance |
| **rtPS**<br>Real-time packet service | Streaming audio or video | – Minimum reserved rate<br>– Maximum sustained rate<br>– Maximum latency tolerance<br>– Traffic priority |
| **ErtPS**<br>Extended real-time packet service | Voice with activity detection (VoIP) | – Minimum reserved rate<br>– Maximum sustained rate<br>– Maximum latency tolerance<br>– Jitter tolerance<br>– Traffic priority |
| **nrtPS**<br>Non-real-time packet service | File transfer protocol (FTP) | – Minimum reserved rate<br>– Maximum sustained rate<br>– Traffic priority |
| **BE**<br>Best-effort service | Data transfer, web browsing, etc. | – Maximum sustained rate<br>– Traffic priority |

#### 5.6b.1.4.2.3 Energy conservation in the MS

The MAC CPS controls two energy-saving modes – Sleep Mode and Idle Mode – to conserve energy in the MS. During Sleep Mode, the MS observes pre-negotiated periods without transmission. Idle Mode is intended as a mechanism to allow the MS to become periodically available for DL broadcast messaging without registration at a specific BS as the MS traverses an air link environment populated by multiple BSs, typically over a large geographic area.

#### 5.6b.1.4.2.4 Handover

The MAC CPS supports optimized hard handover.

### 5.6b.1.4.3 Security sub-layer

The security sub-layer, which operates between the PHY and the MAC CPS, is responsible for providing strong encryption, decryption, mutual authentication, and secure key exchange. Security is maintained as a separate sub-layer so that it may be upgraded as necessary. Also, the key functionality internal to the sub-layer is also modular, to provide easy maintenance upgrade. For example, the protocol provides a means of identifying one from a set of supported cryptographic suites, each of which specifies data encryption and authentication algorithms, and the rules for applying those algorithms to a MAC PDU payload.

The security sub-layer utilizes a security association (SA), which is a set of information shared between the transmitter and receiver. Each SA contains information on the cryptographic suite used for that SA and may also contain keys, such as the traffic encryption keys (TEKs), along with the key lifetimes and other associated state information. Prior to transmission, the MAC PDUs are mapped to an SA. The receiver uses the CID to determine the correct SA and applies the corresponding processing to the received PDU.

Device and user authentication use the IETF EAP protocol. OFDMA TDD WMAN encrypts user data using the AES-CCM cryptographic suite, with the Advanced Encryption Standard (AES) algorithm in the counter with CBC-MAC (CCM) mode, with 128-bit keys. The keys are generated using EAP authentication and managed by a Traffic Encryption Key (TEK) state machine. MAC management messages are AES encrypted and authenticated. A three-way handshake scheme is supported to optimize re-authentication during handover.

### 5.6b.1.5 Smart antennas

OFDMA TDD WMAN specifies the use of smart antenna technologies, including antenna beamforming, space-time coding, and spatial multiplexing, which increase the cell size, data throughput, and spectral efficiency. These techniques reduce the sensitivity of the system to fading and multipath transmission effects.

### 5.6b.1.6 Summary of major technical parameters

TABLE 12B

**OFDMA TDD WMAN parameters and capabilities, FDD mode**

| Parameter/Capability | Value | | | IEEE 802.16 Subclause |
|---|---|---|---|---|
| Duplex method | FDD | | | § 8.4.4 |
| Physical layer mode | OFDMA | | | § 8.4 |
| System channel bandwidth (Uplink/Downlink) | 5 MHz | 10 MHz | 7 MHz | § 8.4.1 |
| FFT size | 512 | 1024 | 1024 | |
| Frame duration | 5 ms | | | § 8.4.5.2 |
| Modulation, downlink | QPSK, 16-QAM, 64-QAM | | | § 8.4.9.4.2 |
| Modulation, uplink | QPSK, 16-QAM | | | § 8.4.9.4.2 |
| Forward error correction coding | Convolutional Coding and Convolutional Turbo Coding | | | § 8.4.9.2.1; § 8.4.9.2.3 excluding § 8.4.9.2.3.5 |
| Encryption | AES-CCM, AES Key Wrap, 128-bit keys | | | § 11.9.14 |
| Authentication | EAP | | | § 11.8.4.2 |
| Privacy key management | PKMv2 | | | § 7.2.2 |
| Management message integrity protection | CMAC | | | § 7.5.4.4 |

### 5.6a.2 Detailed specification of the radio interface - TDD

The standards contained in this section are derived from the global core specifications for IMT-2000 contained at http://ties.itu.int/u/itu-r/ede/rsg8/rwp8f/wp8f-tech/GCSrev7/5-6/. The following notes apply to the sections below, where indicated: (1) The relevant SDOs should make their reference material available from their website. (2) This information was supplied by the recognized external organizations and relates to their own deliverables of the transposed global core specification.

*Note by the Secretariat: In accordance with the established procedure for updating this Recommendation, the SDO's information regarding the development of standards transposed from the global core specifications will be submitted to ITU by 3 August 2009 and included in the sections below when the final text is sent out for approval.*

The entries in the Tables in the elements of §5.6a.2.x.2 that contain "Y" or interoperable options (IO-BF or IO-MIMO) are part of the detailed specifications for OFDMA TDD WMAN. The "N" entries in the Tables in the elements of §5.6a.2.x.2 are for information only and are not included in the OFDMA TDD WMAN specification. The specifications for OFDMA TDD WMAN are provided in the elements of Section 5.6a.2.x.1 that are specifically included in the corresponding elements of Section 5.6a.2.x.2. Anything in Section 5.6a.2.x.1 that is not mentioned in Section 5.6a.2.x.2 is excluded.

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IEEE 802.16-2004 Published 01/10/2004 http://standards.ieee.org/getieee802/802.16.html
IEEE 802.16e-2005 and Cor1 Published 28/02/2006 http://standards.ieee.org/getieee802/802.16.html
IEEE 802.16f-2005 Published 01/12/2005 http://standards.ieee.org/getieee802/802.16.html
The Tables in § 5.6.2.1 provide specific definition of which portions of the stated reference links are to be considered as the specifications for OFDMA TDD WMAN. These Tables have been derived from the WiMAX Forum system profile document WiMAX Forum Mobile System Profile Rel 1.0 Approved Specifications (Rev 1.2.2, 2006/11/17) (http://www.wimaxforum.org/technology/documents/WiMAX_Forum_Mobile_System_Profile_v1_2_2.pdf).

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### 5.6a.2.1 Release 1

#### 5.6a.2.1.1 IEEE Std 802.16:Standard for Local and Metropolitan Area Networks – Air Interface for Broadband Wireless Access Systems

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This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

##### 5.6a.2.1.1.1 IEEE Std 802.16-2004

**IEEE Standard for Local and metropolitan area networks – Part 16: Air Interface for Fixed Broadband Wireless Access Systems**

This revised standard specifies the air interface, including the medium access control layer and multiple physical layer specifications, of fixed BWA systems supporting multiple services. It consolidates IEEE Std 802.16™, IEEE Std 802.16a™, and IEEE Std 802.16c™, retaining all modes and major features without adding modes. Content is added or revised to improve performance, ease deployment, or replace incorrect, ambiguous, or incomplete material, including system profiles."

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##### 5.6a.2.1.1.2 IEEE Std 802.16e-2005 and Cor1

**IEEE Standard for Local and metropolitan area networks – Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems – Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands**

This document provides enhancements to IEEE Std 802.16-2004 to support subscriber stations moving at vehicular speeds and thereby specifies a system for combined fixed and mobile broadband wireless access. Functions to support higher layer handover between base stations or sectors are specified. Operation is limited to licensed bands suitable for mobility below 6 GHz. Fixed IEEE 802.16 subscriber capabilities are not compromised. In addition to mobility enhancements, this document contains substantive corrections to IEEE 802.16-2004 regarding fixed operation

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##### 5.6a.2.1.1.3 IEEE Std 802.16f-2005

**IEEE Standard for Local and metropolitan area networks – Part 16: Air Interface for Fixed Broadband Wireless Access Systems – Amendment 1: Management Information Base)**

This document provides enhancements to IEEE Std 802.16-2004 to define a management information base (MIB) for the MAC and PHY and associated management procedures.

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#### 5.6a.2.1.2 WiMAX Forum® Mobile System Profile

The complete WiMAX Forum® Mobile System Profile, Release 1 is included in the following volume.

##### 5.6a.2.1.2.1 WiMAX Forum® Mobile System Profile Release 1 – IMT-2000 Edition

This provides the complete WiMAX Forum® Mobile System Profile, Release 1.

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### 5.6a.2.2 Release 1.5

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**5.6a.2.2.1** IEEE Std 802.16:Standard for Local and Metropolitan Area Networks – Air Interface for Broadband Wireless Access Systems

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

**5.6a.2.2.1.1 IEEE P802.16Rev2**

**(Draft) Standard for Local and metropolitan area networks – Part 16: Air Interface for Broadband Wireless Access Systems**

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

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**5.6a.2.2.2 WiMAX Forum® Mobile System Profile**

The complete WiMAX Forum® Mobile System Profile, Release 1.5 is included in the following volumes.

**5.6a.2.2.2.1 WiMAX Forum® Mobile System Profile Specification: Release 1.5 - Common Part**

This specification describes the features of the WiMAX Forum® Mobile System Profile, Release 1.5. It includes the features common to both the TDD and FDD operational modes. It has the following table of contents:



**5.6a.2.2.2.2 WiMAX Forum® Mobile System Profile Specification: Release 1.5 – TDD Specific Part**

This specification describes the features of the WiMAX Forum® Mobile System Profile, Release 1.5. It includes the features specific to the TDD operational mode. The content refers to the physical layer.

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**5.6a.2.2.2.3 WiMAX Forum® Mobile Radio Specification**

This specification describes the radio features of the WiMAX Forum® Mobile System Profile, Release 1.5.

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[***The remainder of Section 5.6.2 is deleted***]

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**5.6b.2 Detailed specification of the radio interface - FDD**

The standards contained in this section are derived from the global core specifications for IMT-2000 contained at http://ties.itu.int/u/itu-r/ede/rsg8/rwp8f/wp8f-tech/GCSrev7/5-6/. The following notes apply to the sections below, where indicated: (1) The relevant SDOs should make their reference material available from their website. (2) This information was supplied by the recognized external organizations and relates to their own deliverables of the transposed global core specification.

*Note by the Secretariat: In accordance with the established procedure for updating this Recommendation, the SDO's information regarding the development of standards transposed from the global core specifications will be submitted to ITU by 3 August 2009 and included in the sections below when the final text is sent out for approval.*

The entries in the Tables in the elements of §5.6b.2.x.2 that contain "Y" or interoperable options (IO-BF or IO-MIMO) are part of the detailed specifications for OFDMA TDD WMAN. The "N" entries in the Tables in the elements of §5.6b.2.x.2 are for information only and are not included in the OFDMA TDD WMAN specification. The specifications for OFDMA TDD WMAN are provided in the elements of Section 5.6b.2.x.1 that are specifically included in the corresponding elements of Section 5.6b.2.x.2. Anything in Section 5.6b.2.x.1 that is not mentioned in Section 5.6b.2.x.2 is excluded.

**5.6b.2.1 Release 1**

(this section is intentionally left blank)

**5.6b.2.2 Release 1.5**

**5.6b.2.2.1 IEEE Std 802.16: Standard for Local and Metropolitan Area Networks – Air Interface for Broadband Wireless Access Systems**

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

5.6b.2.2.1.1 **IEEE P802.16Rev2**

**(Draft) Standard for Local and metropolitan area networks – Part 16: Air Interface for Broadband Wireless Access Systems**

This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband wireless access

(BWA) systems providing multiple services. The MAC is structured to support multiple PHY specifications, each suited to a particular operational environment.

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#### 5.6b.2.2.2 WiMAX Forum® Mobile System Profile

The complete WiMAX Forum® Mobile System Profile, Release 1.5 is included in the following volumes.

##### 5.6b.2.2.2.1 WiMAX Forum® Mobile System Profile Specification: Release 1.5 - Common Part

This specification describes the features of the WiMAX Forum® Mobile System Profile, Release 1.5. It includes the features common to both the TDD and FDD operational modes. It has the following table of contents:

1. Scope
   ***<hyperlink>***
2. References
   ***<hyperlink>***
3. Definitions
   ***<hyperlink>***
4. PHY profile
   ***<hyperlink>***
5. MAC profile
   ***<hyperlink>***
6. Security
   ***<hyperlink>***
7. Radio profile
   ***<hyperlink>***
8. Power class profile
   ***<hyperlink>***

##### 5.6b.2.2.2.2 WiMAX Forum® Mobile System Profile Specification: Release 1.5 – FDD Specific Part

This specification describes the features of the WiMAX Forum® Mobile System Profile, Release 1.5. It includes the features specific to the FDD operational mode. The content refers to the physical and the MAC layers.

***<hyperlink PHY>***

***<hyperlink MAC>***

##### 5.6b.2.2.2.3 WiMAX Forum® Mobile Radio Specification

This specification describes the radio features of the WiMAX Forum® Mobile System Profile, Release 1.5.

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