

Radiocommunication Study Groups



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TECHNOLOGY ASPECTS

Institute of Electrical and Electronics Engineers (IEEE)

**UPDATED MATERIAL ON IMT-2000 OFDMA TDD WMAN FOR
REVISION 9 OF RECOMMENDATION ITU-R M.1457**

1 Source information

This contribution was developed by IEEE Project 802®, the Local and Metropolitan Area Network Standards Committee (“IEEE 802”), an international standards development committee organized under the IEEE and the IEEE Standards Association (“IEEE-SA”).

The content herein was prepared by a group of technical experts in IEEE 802 and industry and was approved for submission by the IEEE 802.16™ Working Group on Wireless Metropolitan Area Networks, the IEEE 802.18 Radio Regulatory Technical Advisory Group, and the IEEE 802 Executive Committee, in accordance with the IEEE 802 policies and procedures, and represents the view of IEEE 802.

2 Discussion

Following Document 5D/122, this contribution contains updated material on IMT-2000 OFDMA TDD WMAN for revision 9 of Recommendation ITU-R M.1457 in line with Circular Letter 8/LCCE/95 and the schedule received from ITU-R WP 5D ([IEEE L802.16-08/003](#)). This material will be further updated in time for the final meeting addressing the development of revision 9.

In particular, the material required as specified in the update procedure for revisions of Recommendation ITU-R M.1457 (8/LCCE/95) is addressed in the following Annexes:

[Annex 1](#): Update of Section 5.6.2

[Annex 2](#): Modifications to Section 5.6.1

[Annex 3](#): Updated GCS

[Annex 4](#): Summary and rationale of the proposed update

[Annex 5](#): Self-evaluation of the proposed update against the evaluation criteria

[Annex 6](#): Self-declaration that the proposed amendments are self-consistent between Section 5.6.1, Section 5.6.2, and the GCS

[Annex 7](#): Summary of the material that is planned to be submitted to the final meeting for revision 9

3 Proposal

We propose that the amendments shown in the electronic attachments in Annexes 1 and 2 be agreed for incorporation in revision 9 of M.1457.

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Annex 1

Update of Section 5.6.2

See electronic attachment.

Annex 1-Section
5.6.2

Annex 2

Modifications to Section 5.6.1

See electronic attachment.

Annex 2-Section
5.6.1

Annex 3

Updated GCS

It is anticipated that the updated set of the Global Core Specifications (GCS) for IMT-2000 OFDMA TDD WMAN will be submitted as per established procedures.

Annex 4

Summary and rationale of the proposed update

The main purpose of this update is to align Recommendation ITU-R M.1457 to the most updated versions of the specifications underlying the radio interface IMT-2000 OFDMA TDD WMAN. Furthermore, alignment is made by incorporating the FDD mode of IEEE Std 802.16. The main enhancements are in VoIP capacity, MIMO, load balancing, and handover latency.

Annex 5

Self-evaluation of the proposed update against the evaluation criteria

The self-evaluation of the “total” radio interface update of IMT-2000 OFDMA TDD WMAN has been made against all evaluation criteria listed in the update procedure contained in Circular Letter 8/LCCE/95. The results are that the proposed updates meet the evaluation criteria as follows:

7.1 “The evaluation criteria” (Section 7.1 in Circular Letter 8/LCCE/95)

The “requirements and objectives of IMT-2000” and the “Minimum performance capabilities for IMT-2000” as per Attachments 4 and 6 of Circular Letter 8/LCCE/47 were considered. The values included in Circular Letter 8/LCCE/47 were used. The proposed update consists of enhancements to the existing IMT-2000 OFDMA TDD WMAN radio interface. The evaluation of the proposed update was done in the context of the “total” radio interface. As shown in the tables below, the conclusion is that the IMT-2000 OFDMA TDD WMAN radio interfaces with the proposed enhancements continues to meet all evaluation criteria in “Requirements and objectives of IMT2000” and “Minimum performance capabilities for IMT-2000”.

TABLE 1

Requirements and objectives relevant to the evaluation of candidate radio transmission technologies

IMT-2000 Item description	Obj/Req	Source	Meets
Voice and data performance requirements			
1. One-way end to end delay less than 40 ms	Req	G.174, § 7.5	Yes
2. For mobile videotelephony services, the IMT-2000 terrestrial component should operate so that the maximum overall delay (as defined in ITU-T Recommendation F.720) should not exceed 400 ms, with the one way delay of the transmission path not exceeding 150 ms	Req	Suppl. F.720, F.723, G.114	Yes
3. Speech quality should be maintained during $\leq 3\%$ frame erasures over any 10 second period. The speech quality criterion is a reduction of ≤ 0.5 mean opinion score unit (5 point scale) relative to the errorfree condition (G.726 at 32 kbit/s)	Req	G.174, § 7.11 and M.1079 § 7.3.1	Yes
4. DTMF signal reliable transport (for PSTN is typically less than one DTMF error signal in 10^4)	Req	G.174, § 7.11 and M.1079 § 7.3.1	Yes
5. Voiceband data support including G3 facsimile	Req	M.1079, § 7.2.2	Yes
6. Support packet switched data services as well as circuit switched data; requirements for data performance given in ITUTG.174	Req	M.1034, §§ 10.8, 10.9	Yes
Radio interfaces and subsystems, network related performance requirements			

IMT-2000 Item description	Obj/Req	Source	Meets
7. Network interworking with PSTN and ISDN in accordance with Q.1031 and Q.1032	Req	M.687-1, § 5.4	Yes
8. Meet spectral efficiency and radio channel performance requirements of M.1079	Req	M.1034, § 12.3.3/4	Yes
9. Provide phased approach with data rates up to 2 Mbit/s in phase 1	Obj	M.687, § 1.1.14	Yes
10. Maintain bearer channel bit-count integrity (e.g. synchronous data services and many encryption techniques)	Obj	M.1034, § 10.12	Yes
11. Support for different cell sizes, for example: Mega cell Radius~100-500 km Macro cell Radius ≤35km, Speed ≤500 km/h Micro cell Radius ≤1km, Speed ≤100 km/h Pico cell Radius ≤50m, Speed ≤10 km/h	Obj	M.1035, § 10.1	Yes
Application of IMT-2000 for fixed services and developing countries			
12. Circuit noise- idle noise levels in 99% of the time about 100pWp	Obj	M.819-1, § 10.3	Yes
13. Error performance - as specified in ITU-R F.697	Obj	M.819-1, § 10.4	Yes
14. Grade of service better than 1%	Obj	M.819-1, § 10.5	Yes

TABLE 2

**Generic requirements and objectives relevant to the evaluation of
candidate radio transmission technologies**

IMT-2000 Item description	Obj/Req	Source	Meets
Radio interfaces and subsystems, network related performance requirements			
1. Security comparable to that of PSTN/ISDN	Obj	M.687-1, § 4.4	Yes
2. Support mobility, interactive and distribution services	Req	M.816, § 6	Yes
3. Support UPT and maintain common presentation to users	Obj	M.816, § 4	Yes
4. Voice quality comparable to the fixed network (applies to both mobile and fixed service)	Req	M.819-1, Table 1, M.1079, § 7.1	Yes
5. Support encryption and maintain encryption when roaming and during handover	Req	M.1034, § 11.3	Yes
6. Network access indication similar to PSTN (e.g. dialtone)	Req	M.1034, §§ 11.5	Yes
7. Meet safety requirements and legislation	Req	M.1034, § 11.6	Yes
8. Meet appropriate EMC regulations	Req	M.1034, § 11.7	Yes
9. Support multiple public/private/residential IMT-2000 operators in the same locality	Req	M.1034, § 12.1.2	Yes
10. Support multiple mobile station types	Req	M.1034, § 12.1.4	Yes

IMT-2000 Item description	Obj/Req	Source	Meets
11. Support roaming between IMT-2000 operators and between different IMT-2000 radio interfaces/environments	Req	M.1034, § 12.2.2	Yes
12. Support seamless handover between different IMT-2000 environments such that service quality is maintained and signaling is minimized	Req	M.1034, § 12.2.3	Yes
13. Simultaneously support multiple cell sizes with flexible base location, support use of repeaters and umbrella cells as well as deployment in low capacity areas	Req	M.1034, § 12.2.5	Yes
14. Support multiple operator coexistence in a geographic area	Req	M.1034, § 12.2.5	Yes
15. Support different spectrum and flexible band sharing in different countries including flexible spectrum sharing between different IMT-2000 operators (see M.1036)	Req	M.1034, § 12.2.8	Yes
16. Support mechanisms for minimizing power and interference between mobile and base stations	Req	M.1034, § 12.2.8.3	Yes
17. Support various cell types dependent on environment (M.1035 § 10.1)	Req	M.1034, § 12.2.9	Yes
18. High resistance to multipath effects	Req	M.1034, § 12.3.1	Yes
19. Support appropriate vehicle speeds (as per § 7) Note: Applicable to both terrestrial and satellite proposals	Req	M.1034, § 12.3.2	Yes
20. Support possibility of equipment from different vendors	Req	M.1034, § 12.1.3	Yes
21. Offer operational reliability at least as good as 2nd generation mobile systems	Req	M.1034, § 12.3.5	Yes
22. Ability to use terminal to access services in more than one environment, desirable to access services from one terminal in all environments	Obj	M.1035, § 7.1	Yes
23. End-to-end quality during handover comparable to fixed services	Obj	M.1034-1 § 11.2.3.4	Yes
24. Support multiple operator networks in a geographic area without requiring time synchronization	Obj		Yes
25. Layer 3 contains functions such as call control, mobility management and radio resource management some of which are radio dependent. It is desirable to maintain layer 3 radio transmission independent as far as possible	Obj	M.1035, § 8	Yes
26. Desirable that transmission quality requirements from the upper layer to physical layers be common for all services	Obj	M.1035, § 8.1	Yes
27. The link access control layer should as far as possible not contain radio transmission dependent functions	Obj	M.1035, § 8.3	Yes
28. Traffic channels should offer a functionally equivalent capability to the ISDN B channels	Obj	M.1035, § 9.3.2	Yes
29. Continually measure the radio link quality on forward and reverse channels	Obj	M.1035, § 11.1	Yes
30. Facilitate the implementation and use of terminal battery saving techniques	Obj	M.1035, § 12.5	Yes
31. Accommodate various types of traffic and traffic mixes	Obj	M.1036, § 1.10	Yes
Application of IMT-2000 for fixed services and developing countries			
32. Repeaters for covering long distances between terminals and base stations, small rural exchanges with wireless trunks etc.	Req	M.819-1, Table 1	Yes

IMT-2000 Item description	Obj/Req	Source	Meets
33. Withstand rugged outdoor environment with wide temperature and humidity variations	Req	M.819-1, Table 1	Yes
34. Provision of service to fixed users in either rural or urban areas	Obj	M.819-1, § 4.1	Yes
35. Coverage for large cells (terrestrial)	Obj	M.819-1, § 7.2	Yes
36. Support for higher encoding bit rates for remote areas	Obj	M.819-1, § 10.1	Yes
Satellite component (Not required for RTT submission)			
37. Links between the terrestrial and the satellite control elements for handover and exchange of other information	Req	M.818-1, § 3.0	N/A
38. Take account for constraints for sharing frequency bands with other services (WARC-92)	Obj	M.818-1, § 4.0	N/A
39. Compatible multiple access schemes for terrestrial and satellite components	Obj	M.818-1, § 6.0	N/A
40. Service should be comparable quality to terrestrial component as far as possible	Obj	M.818-1, § 10.0	N/A
41. Use of satellites to serve large cells for fixed users	Obj	M.819-2, § 7.1	N/A
42. Key features (e.g. coverage, optimization, number of systems)	Obj	M.1167, § 6.1	N/A
43. Radio interface general considerations	Req	M.1167, § 8.1.1	N/A
44. Doppler effects	Req	M.1167, § 8.1.2	N/A

TABLE 3

**Subjective requirements and objectives relevant to the evaluation
of candidate radio transmission technologies**

IMT-2000 Item description	Obj/Req	Source	Meets
1. Fixed Service- Power consumption as low as possible for solar and other sources	Req	M.819-1, Table 1	Yes
2. Minimize number of radio interfaces and radio sub-system complexity, maximize commonality (M.1035, § 7.1)	Req	M.1034, § 12.2.1	Yes
3. Minimize need for special interworking functions	Req	M.1034, § 12.2.4	Yes
4. Minimum of frequency planning and inter-network coordination and simple resource management under time-varying traffic	Req	M.1034, § 12.2.6	Yes
5. Support for traffic growth, phased functionality, new services or technology evolution	Req	M.1034, § 12.2.7	Yes
6. Facilitate the use of appropriate diversity techniques avoiding significant complexity if possible	Req	M.1034, § 12.2.10	Yes
7. Maximize operational flexibility	Req	M.1034, § 12.2.11	Yes
8. Designed for acceptable technological risk and minimal impact from faults	Req	M.1034, § 12.2.12	Yes
9. When several cell types are available, select the cell that is the most cost and capacity efficient	Obj	M.1034, § 10.3.3	Yes
10. Minimize terminal costs, size and power consumption, where appropriate and consistent with other requirements	Obj	M.1036, § 1.12	Yes

TABLE 4

Minimum performance capabilities

Test environments	Indoor office	Outdoor to indoor and pedestrian	Vehicular
Mobility considerations	Mobility type (Low)	Mobility type (Medium)	Mobility type (High)
Handover	Yes	Yes	Yes
Support of general service capabilities			
Packet data	Yes	Yes	Yes
Asymmetric services	Yes	Yes	Yes
Multimedia	Yes	Yes	Yes
Variable bit rate	Yes	Yes	Yes

8.1 Compatibility with the existing IMT-2000 radio interfaces

The proposed update fits well within the framework of the existing IMT-2000 OFDMA TDD WMAN radio interface. All features supported in the existing IMT-2000 OFDMA TDD WMAN are still supported in the proposed update.

8.2 Harmonization within multiple proposals

See Section 9.2.

“Other considerations” (Section 9 in 8/LCCE/95)

9.1 Benefits of the proposed enhancement

The proposed enhancements improve the performance of IMT-2000 OFDMA TDD WMAN radio interface.

9.2 Harmonization and consensus building

Through their membership and through liaison communications, the SDO stakeholders, the IEEE and the WiMAX Forum, have established harmonization and consensus building. IEEE expects that the system profile submitted by the WiMAX Forum will be fully consistent with IEEE Std 802.16.

9.3 Enhanced performance capabilities

The proposed update is fully in line with the ongoing activities on the vision for the enhancements of IMT-2000, also reflected in the Roadmap for the future updates of Recommendation ITUR M. 1457.

Annex 6

Self-declaration that the proposed amendments are self-consistent between Section 5.6.1, Section 5.6.2, and the GCS

A formal statement will be provided stating that the proposed amendments are self-consistent between Sections 5.6.1, 5.6.2, and the GCS, as per established procedures.

Annex 7

Summary of the material that is planned to be submitted to the final meeting for revision 9

It is planned that the following material will be submitted in its final form to ITU-R for the final meeting for revision 9, as per established procedures.

The understanding of IEEE is that the following material received in its final form by the established deadlines, together with the other material contained in the present contribution, is fully compliant with the established procedures.

- 1) Final version of revised Section 5.6.2; all reference links – including the SDO doc/version number, status and issued date – will be submitted by SDOs to ITU-R BR Counsellor by the established deadline, when the transposition process has to be completed; by the same deadline also the certifications of references and transposition will be submitted.
- 2) Final version of revised Section 5.6.1.
- 3) New set of global core specifications.
- 4) Summary and rationale of the proposed update.
- 5) The self-evaluation (as per Annex 5 of the current contribution).
- 6) Formal self-declaration of consistency between Section 5.6.1, Section 5.6.2, and the GCS.

SDOs will also submit the Letters of Conveyance to ITU-R BR Counsellor, as per established procedures.

5.6 IMT-2000 OFDMA TDD WMAN

5.6.2 Detailed specification of the radio interface

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/rsg5/IMT-2000/GCS/GCSrev9/5-6> ~~<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 ??? and included in the sections below when the final text is sent out for approval.

~~The Tables in § 5.6.2.1 provide specific definition of which portions of the stated reference links are to be considered as t~~The specifications for OFDMA TDD WMAN are provided in the elements of Section 5.6.2.1 that are specifically included in Section 5.6.2.2. 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). The entries in the Tables in § 5.6.2.1 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 5.6.2.1 are for information only and are not included in the OFDMA TDD WMAN specification. Anything in in the attached references Section 5.6.2.1 that is not mentioned in the ~~Tables in §~~Section 5.6.2.1 is excluded.

5.6.2.1 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.

5.6.2.2 WiMAX Forum Mobile System Profile

The WiMAX Forum Mobile System Profile specification is complementary to IEEE Std 802.16, primarily for the purpose of certification of conformant Mobile Stations and Base Stations.

[Editor's Note: The remainder of Section 5.6.2 is deleted]

5.6 IMT-2000 OFDMA TDD WMAN

5.6.1 Overview of the radio interface

5.6.1.1 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. OFDMA TDD WMAN as defined here operates ~~only~~ in TDD [and FDD modes](#)¹.

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 either a 5 MHz or a 10 MHz, [or a 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.

5.6.1.2 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 Forum².

The protocol layering is illustrated in Fig. 70. ~~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. The MAC comprises three sub-layers. The~~

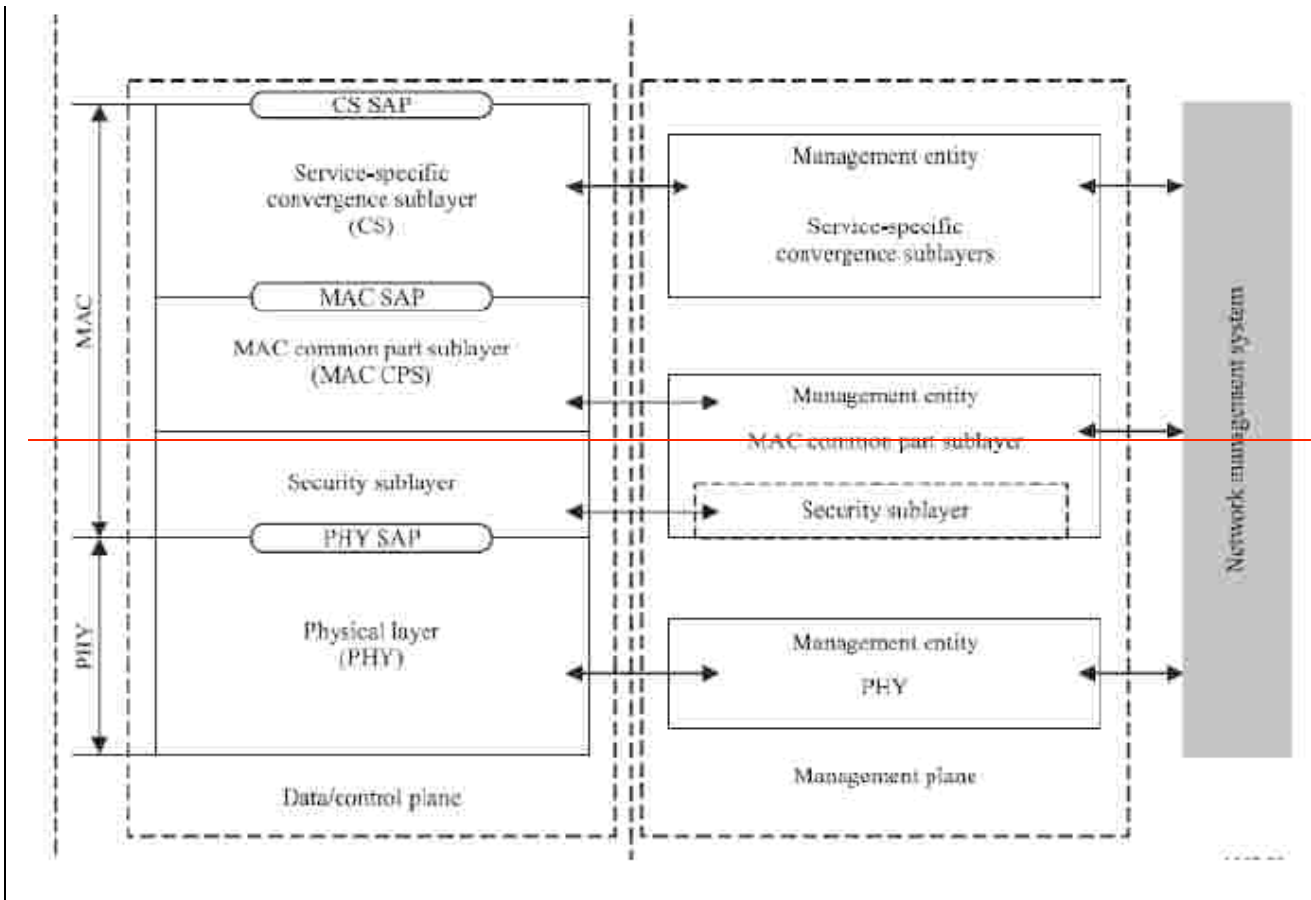
¹ [Unless stated otherwise, the overview of this radio interface applies to both modes.](#)

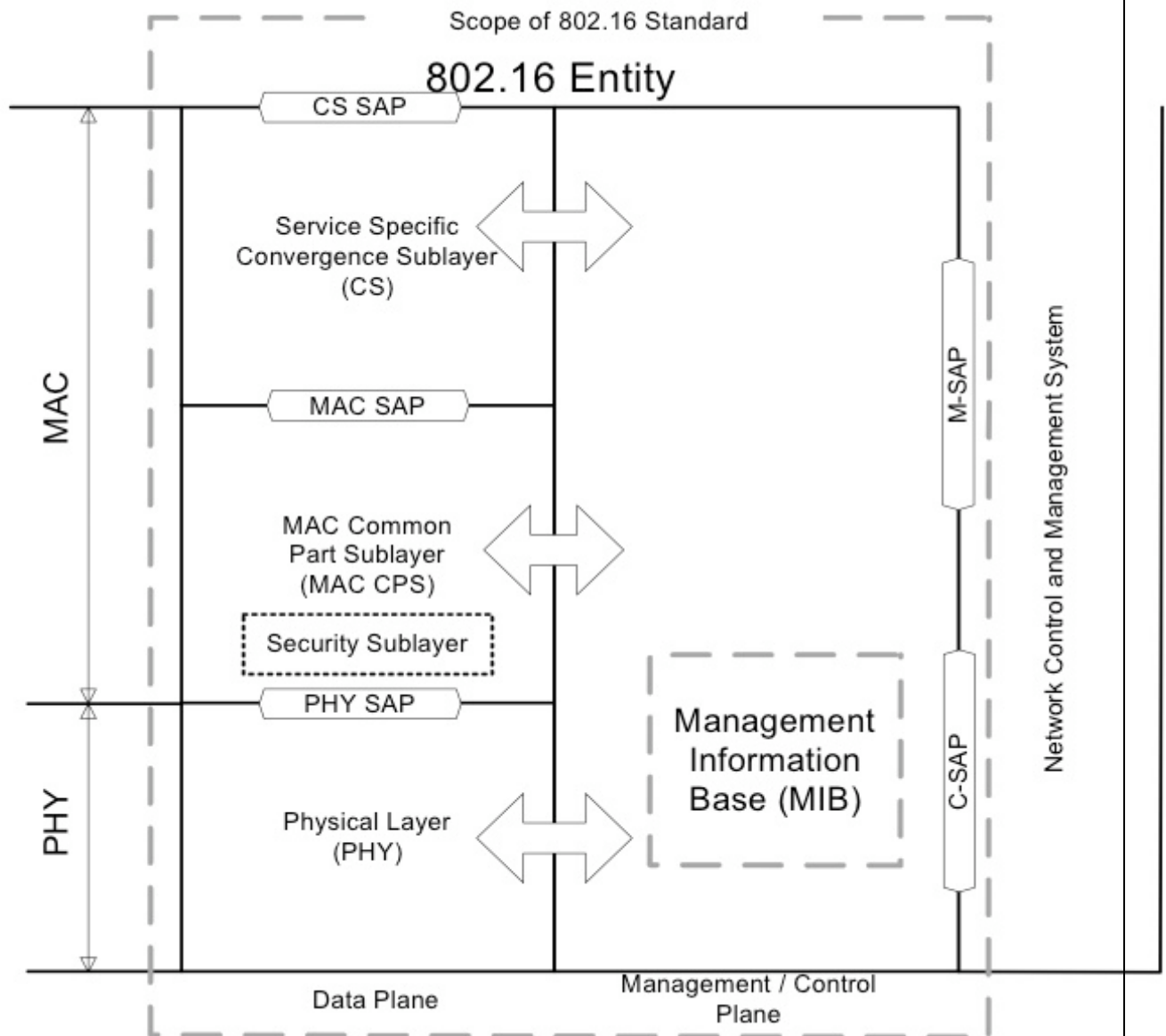
² <http://www.wimaxforum.org/technology/documents/>

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.

FIGURE 70

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





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.

~~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.~~

5.6.1.2.1 BS and **SSMS** Functionality

The system architecture consists of two logical entities, the base station (BS) and the **mobile subscriber** station (**SSMS**). The basic architectural assumption is of a base station (BS) communicating in point-to-multipoint fashion with a number of fixed or mobile **subscriber** stations (**SSMS**s). 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 **SSMS**) are divided in both time and frequency (using the multiple sub-carriers provide by OFDMA) for assigning communications to individual **SSMS**s. Transmissions on the uplink (from **SSMS** 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 **SSMS**) and performing centralized QoS scheduling, based on the QoS/service parameters and the active resource requests from the **SSMS**;
- communicating to all **SSMS**s, 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 **SSMS** support services such as ranging, clock synchronization, power control, and handover.

The **SSMS** 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 **SSMS** 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 **SSMS**s with which it communicates. However, the radio interface also provides specifications to allow handover of an **SSMS** 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.

5.6.1.3 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).

5.6.1.3.1 OFDMA technology overview

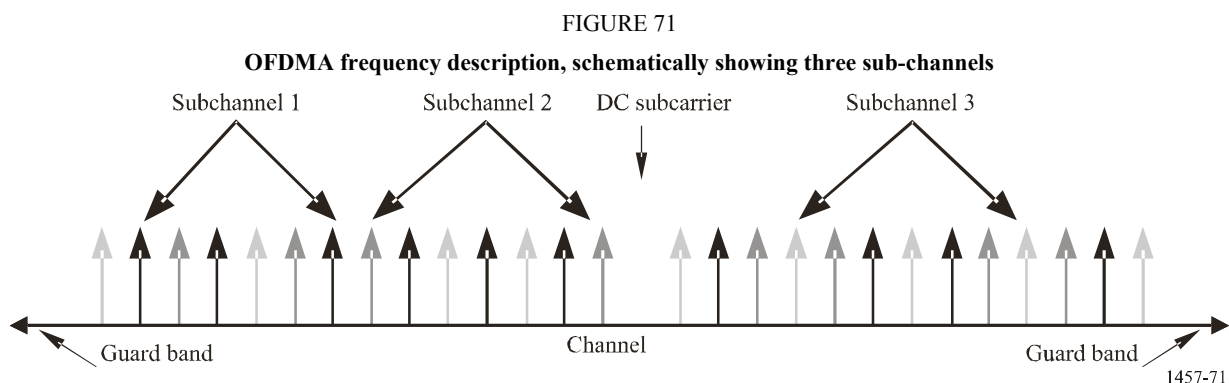
OFDM divides the channel by frequency into orthogonal sub-carriers. Data to be transmitted is divided into parallel streams of reduced data rate (and therefore longer symbol duration) and each stream is modulated and transmitted on a separate sub-carrier. The lengthened symbol duration improves the robustness 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 **SSMS**s 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.



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.

5.6.1.3.2 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 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 and those for Full-FDD (F-FDD) mode are listed in Table 10B.

TABLE 10A

OFDMA TDD WMAN primitive PHY parameters, [TDD mode](#)

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

TABLE 10B

OFDMA TDD WMAN primitive PHY parameters, [F-FDD mode](#)

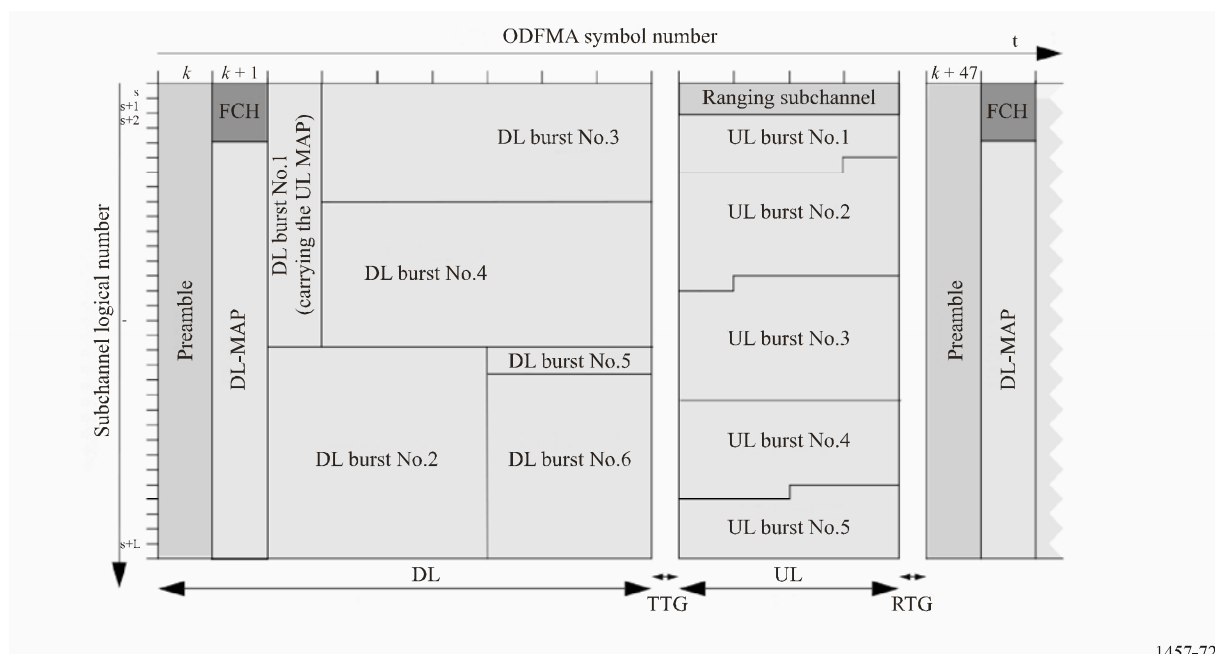
FFT size (N_{FFT})	512	1 024
System channel bandwidth (BW)	5 MHz	10 MHz
Sampling frequency (F_s)	5.6 MHz	11.2 MHz
Sub-carrier frequency spacing ($\Delta f = F_s/N_{\text{FFT}}$)	10.9375 kHz	
Useful symbol time ($T_b = 1/\Delta f$)	~91.43 μs	
Guard (CP) time ($T_g = T_b/8$)	~11.43 μs	
OFDMA symbol duration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

5.6.1.3.3 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



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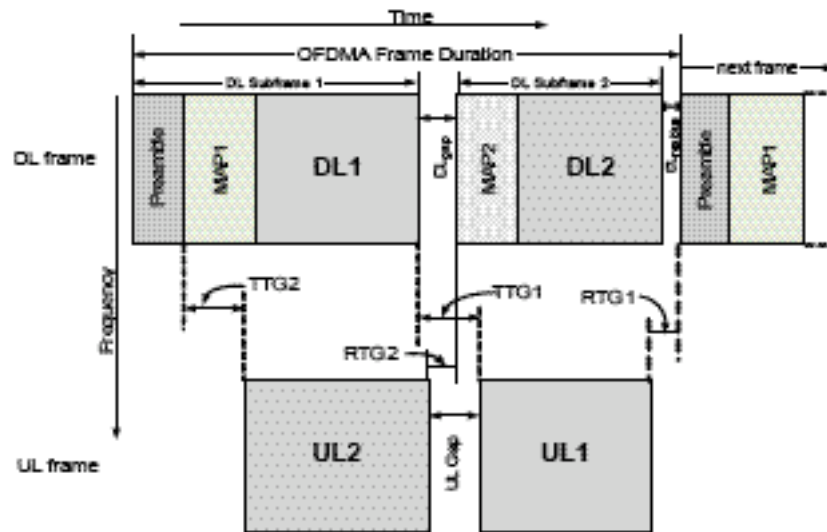
The frame is shown in two dimensions. The horizontal dimension represents time, which maps directly into the OFDM symbol sequence. The vertical dimension represents the list of available logical sub-channels. This maps into frequency, although only indirectly, since the sub-carriers in a given logical 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 **SSMS** 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 OFDM symbol to the next. The specification supports a sequence of permutation zones in the frame, so that different **subscriber/mobile** stations can be served with different permutations.

[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.

5.6.1.3.4 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 **SSMS**s and may order the **SSMS** 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.

5.6.1.3.5 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).

5.6.1.4 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 SSMS, 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.

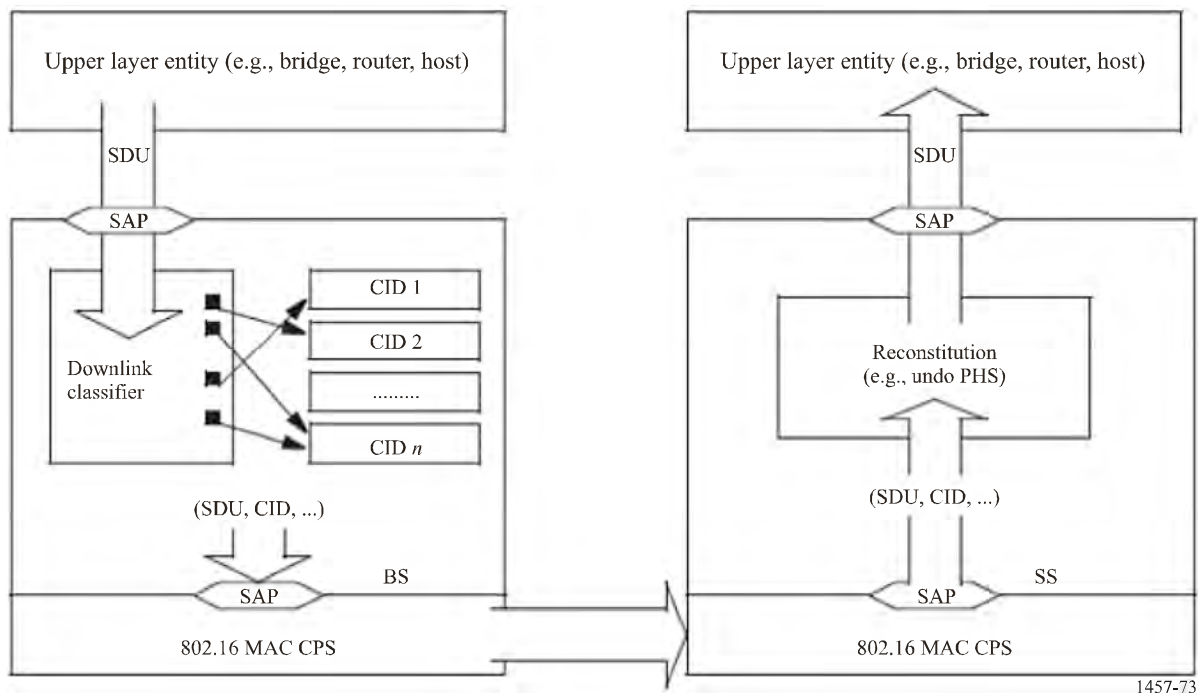
5.6.1.4.1 Convergence sub-layer (CS)

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)



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5.6.1.4.2 MAC common part sub-layer (CPS)

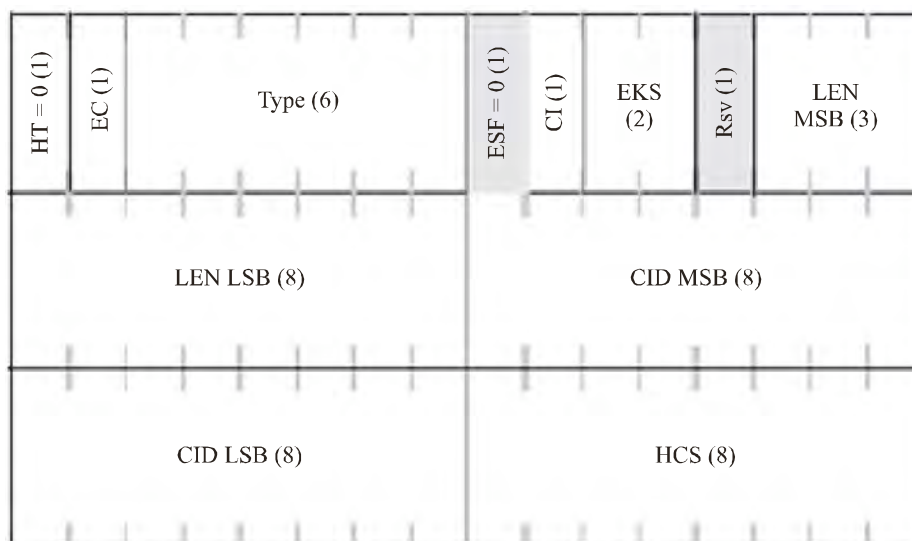
The MAC CPS is responsible for performing the core MAC functions. It receives MAC service data units (SDUs) from the CS and encapsulates them in its native MAC PDU format for transmission over the PHY. The MAC CPS also manages the transport connections and QoS, controlling access to the radio spectrum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

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 [SSMS](#) 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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5.6.1.4.2.1 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 [SSMS](#)s 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 [SSMS](#). However, grants are allocated not to the connection but to the supporting [SSMS](#). The [SSMS](#) 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.

5.6.1.4.2.2 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 [SSMS](#) 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 Unsolicited grant service	VoIP	<ul style="list-style-type: none"> – Maximum sustained rate – Maximum latency tolerance – Jitter tolerance
rtPS Real-time packet service	Streaming audio or video	<ul style="list-style-type: none"> – Minimum reserved rate – Maximum sustained rate – Maximum latency tolerance – Traffic priority
ErtPS Extended real-time packet service	Voice with activity detection (VoIP)	<ul style="list-style-type: none"> – Minimum reserved rate – Maximum sustained rate – Maximum latency tolerance – Jitter tolerance – Traffic priority
nrtPS Non-real-time packet service	File transfer protocol (FTP)	<ul style="list-style-type: none"> – Minimum reserved rate – Maximum sustained rate – Traffic priority
BE Best-effort service	Data transfer, web browsing, etc.	<ul style="list-style-type: none"> – Maximum sustained rate – Traffic priority

5.6.1.4.2.3 Energy conservation in the ~~mobile-SSMS~~

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

5.6.1.4.2.4 Handover

The MAC CPS supports optimized hard handover.

5.6.1.4.3 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.

5.6.1.5 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.

5.6.1.6 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 1-3.2
Physical layer mode	OFDMA			§ 8.4
System channel bandwidth	5 MHz	10 MHz	8.75 MHz	§ 8.4.1
FFT size	512	1 024	1 024	
Frame duration	5 ms		5 ms	§ 8.4.5.2
Transmit transition gap (TTG)	105.714 μ s		87.2 μs	§ 8.4.5.2
Receive transition gap (RTG)	60 μ s		74.4 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

TABLE 12B

OFDMA TDD WMAN parameters and capabilities, FDD mode

<u>Parameter/Capability</u>	<u>Value</u>		<u>IEEE 802.16 Subclause</u>
<u>Duplex method</u>	<u>FDD</u>		<u>§ 8.4.4</u>
<u>Physical layer mode</u>	<u>OFDMA</u>		<u>§ 8.4</u>
<u>System channel bandwidth (Uplink/Downlink)</u>	<u>5 MHz</u>	<u>10 MHz</u>	<u>§ 8.4.1</u>
<u>FFT size</u>	<u>512</u>	<u>1 024</u>	
<u>Frame duration</u>	<u>5 ms</u>		<u>§ 8.4.5.2</u>
<u>Modulation, downlink</u>	<u>QPSK, 16-QAM, 64-QAM</u>		<u>§ 8.4.9.4.2</u>
<u>Modulation, uplink</u>	<u>QPSK, 16-QAM</u>		<u>§ 8.4.9.4.2</u>
<u>Forward error correction coding</u>	<u>Convolutional Coding and Convolutional Turbo Coding</u>		<u>§ 8.4.9.2.1; § 8.4.9.2.3 excluding § 8.4.9.2.3.5</u>
<u>Encryption</u>	<u>AES-CCM, AES Key Wrap, 128-bit keys</u>		<u>§ 11.9.14</u>
<u>Authentication</u>	<u>EAP</u>		<u>§ 11.8.4.2</u>
<u>Privacy key management</u>	<u>PKMv2</u>		<u>§ 7.2.2</u>
<u>Management message integrity protection</u>	<u>CMAC</u>		<u>§ 7.5.4.4</u>