The Role of IEEE802.16e Mobile WiMAX

Rachana Khanduri
Department of electronics
GRD-IMT,Dehradun

Chhavi Chaudhary
Department of electronics
GRD-IMT, Dehradun

Vishal Gupta, PhD.
Department of electronics
GRD-IMT, Dehradun

ABSTRACT
A recent technology for the next generation (fourth generation [4 G]) of mobile broadband networks is commonly known as Worldwide Interoperability for Microwave Access (WiMAX) that is designed to provide high bandwidth over long range transmission. IEEE 802.16e mobile WiMAX is accountable for the job of establishing interoperability and conformance between products. This paper provides an brief overview of mobile WiMAX, its features and challenges on the wireless local and Metripolitan Area Network (MAN) standards IEEE 802.16 and IEEE 802.16e.

Keywords
WiMAX, IEEE 802.16, Mobile WiMAX, IEEE 802.16e, OFDM.

1. INTRODUCTION
IEEE 802.16- 2004 [1] Air Interface standard, commonly known as WiMAX play an important role in fixed broadband wireless metropolitan area networks. The standard specifies fixed broadband wireless access (BWA) techniques for point to point and point to multipoint links. IEEE 802.16e- 2005 [2], adds the features and attributes to the standard necessary to support mobility. IEEE 802.16e is a recent wireless broadband standard, provide a solution to broadband (high speed) wireless access in a metropolitan area [3]. Several WiMAX profiles have been developed by WiMAX forum for testing of interoperability. Two system profiles based on IEEE 802.16 and IEEE 802.16e [4], called fixed and mobile system profiles designed by the WiMAX forum include mandatory and optional physical (PHY) layers and medium access control (MAC), of BWA. For improving multipath performance in non-line- of-sight environments, the mobile WiMAX Air interface adopts Orthogonal Frequency Division Multiple access (OFDM). In order to empower fast growth in manufactured quantities, market share and interoperability, the WiMAX forum provide the Network Working Group (NWG) for developing an end-to-end network reference model architecture based on IP supporting both fixed and mobile WiMAX [5,6].
The IEEE 802.16e defines scalable OFDMA (SOFDMA) [7] to support scalable channel bandwidths from 1.25 to 20 MHz. Significant enhancements adds by Mobile WiMAX:

- By using advanced antenna diversity schemes and hybrid automatic repeat request (HARQ) it improves NLOS coverage.
- System gain and indoor penetration improve by utilizing dense subchannelization.
- To improve coverage, it adopts multiple input multiple output (MIMO) and adoptive antenna system (AAS) [8].
- For enabling better coverage and capacity trade-off, it defines a downlink subchannelizes scheme.

2. MOBILE WIMAX
Mobile WiMAX provides high throughput broadband connections over long distance. It supports WiMAX base station on the average can cover between 5 to 10Km and wireless Metropolitan Area Network (MAN) connectivity at speed up to 70 Mbps. Overview of the WiMAX is shown in table 1.

Table 1. Overview of the WiMAX

802.16a	**802.16REVd**	**802.16e**
Fixed Outdoor	Fixed Outdoor	Limited Mobility
Applications • El/Tl service for enterprises • Backhaul for hotspots • Limited residential Broadband Access	**Applications** • Indoor Broadband access for residential users (High Speed Internet, VoIP,..)	**Applications** • 'Portable' Broadband access for consumers • Always Best Connected
CPE • External box connected to PC with outside antenna	**CPE** • External box connected to PC with built-in antenna	**CPE** • PC Card

2.1 Physical Layer Description
By using OFDM symbol and is of variable size [9,10] each 802.16e frame contains downlink (DL) and an uplink (UL) part discriminated in time. The downlink or uplink frames consist of control information for users to synchronize and to know about the receiving or transmitting information. Transmission or reception occurs in blocks that are organized by basic units called slots. Each slot includes a two dimensional block, one dimension persisting the frequency and the other persisting the time. Depending on the permutation scheme, a slot expands over 1 to 3 OFDM symbols in the time direction and over 1 subchannel in the frequency direction. Downlink and uplink subframes can be distributed into different zones where different permutation schemes are used [11,12]. Permutation schemes are employed to decide the number of subcarriers per subchannel and the

allocation of the subcarrier that construct a subchannel in the OFDM symbol.

The IEEE 802.16e contains support for MIMO (Multiple Input Multiple Output) downlink and uplink transmission. Present mobile WiMAX profiles involves support for upto 2 transmit antennas despite the IEEE 802.16e standard allows up to 4 spatial streams. One of the main aim of next generation WiMAX system is to allow at least up to 8 transmit antennas at the base station, 4 streams and space-time coding. Table 2 gives the system requirements of mobile-WiMAX standards.

Table 2. Most important features and system requirements of mobile WiMAX standards

Requirement	IEEE 802.16e	IEEE802.16m
Aggregate Data Rate	63 Mbps	100 Mbps for mobile stations, 1 Gbps for fixed
MIMO support	up to 4 streams, no limit on antennas	4 or 8 streams, no limit on antennas
Duplexing Schemes	TDD and FDD	TDD and FDD
Operating Radio Frequency	2.3 GHz, 2.5-2.7 GHz, 3.5 GHz	< 6 GHz
Handover Intrafrequency Interruption Time	Not Specified	30 ms
Handover Interfrequency Interruption Time	35-50 ms	depending on scenario
Handover between 802.16 standards (for corresponding mobile station)	From 802.16e serving BS to 802.16e target BS	100 ms
Handover with other technologies	Not Specified	From legacy serving BS to legacy target BS From 802.16m serving BS to legacy target BS From legacy serving BS to 802.16m target BS
		From 802.16m serving BS to 802.16m target BS
Mobility Speed	Vehicular: 120 km/h	IEEE 802.11, 3GPP2, GSM/EDGE, (E-)UTRA (LTE TDD) Using IEEE 802.21 Media Independent Handover (MIH)
Coverage	10 km	3 km, 5-30 km and 30-100 km
Position accuracy	Not Specified	Indoor: 10 km/h Basic Coverage Urban: 120 km/h High Speed: 350 km/h Location Determination Latency: 30 s

2.2 OFDM Technology

The IEEE 802.16e wireless MAN OFDM mode is based on the scalable OFDM (S-OFDM) that supports a wide range of bandwidths to flexibly address the need for various spectrum allocation and usage model requirements. By adjusting the FFT size while fixing the sub-carrier frequency spacing at 10.94 KHz, the scalability is supported. The S-OFDM parameters for mobile WiMAX [13,14,15] are listed in table 3.

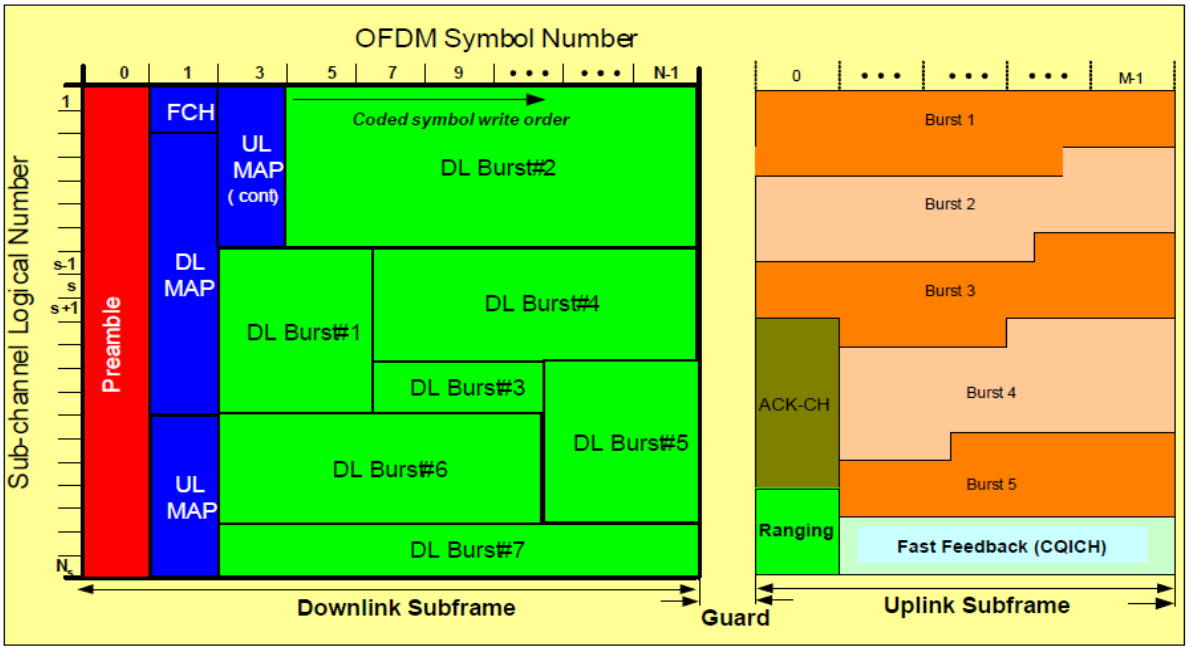
Table 3. OFDMA Scalability Parameters

Parameters	Values
Guard Time ($T_g = T_b/8$)	11.4 microseconds
OFDMA Symbol Duration (Ts = Tb + Tg)	102.9 microseconds
Number of OFDMA Symbols (5 ms Frame)	48

The IEEE 802.16e PHY [16] supports TDD (Time Division Duplex) and half duplex FDD (Frequency Division Duplex) operation. TDD does require system wide synchronization to counter interference issues. Figure 1 illustrates the OFDM frame structure for a TDD implementation. To prevent DL and UL transmission collisions, each frame is divided into DL and UL sub-frames separated by Transmit/Receive and Receive/Transmit Transition Gaps (TTG and RTG, respectively). In a frame, the following control information is used to ensure optimal system peration.

- Preamble: The preamble is the first OFDM symbol of the frame, used for synchronization.
- Frame Control Header (FCH): The FCH follows the preamble that provides the frame configuration information such as MAP message length and coding scheme and usable sub-channels.

Figure 1. WiMAX OFDMA Frame Structure

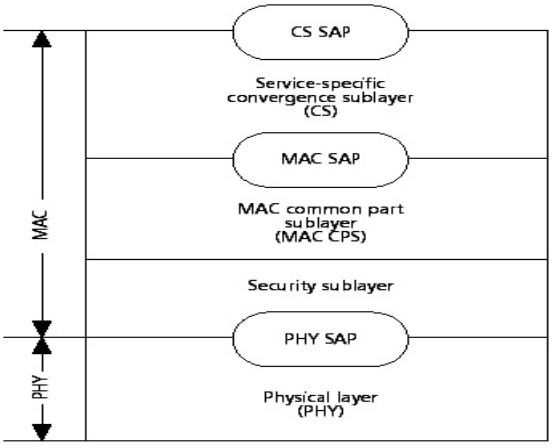


- DL-MAP and UL-MAP: Sub-channel allocation and other control information for DL and UL sub-frames respectively, provided by the DL-MAP and UL-MAP.
- UL Ranging: To perform closed loop time, frequency and power adjustment as well as bandwidth requests, the UL ranging sub-channel is allocated for mobile stations (MS).
- UL CQUICH: The UL CQUICH channel is allocated for the MS to feedback channel-state information.
- UL ACK: The UL ACK is allocated for the MS to feedback DL HARQ acknowledge.

2.3 Functionality of MAC layer

The MAC layer contains three sublayers: the service specific convergence sublayer (CS), MAC common part sublayer (MAC CPS) and security sublayer. The reference model in IEEE 802.16 is shown in figure 2.

Figure 2. IEEE 802.16 reference model



The CS is used to transform or map external data from the upper layers into appropriate MAC service data units (SDUs) for the MAC CPS. This consists of external data with the proper MAC service flow identifier (SFID) and connection identifier (CID). An SDU data unit exchanged between two adjacent protocol layers [16,17]. The core functionality for system access, allocation of bandwidth, connection establishment and maintenance is provided by the MAC CPS. The QoS aspect of data transmission also handles by this sublayer. The security sublayer provides functionalities such as authentication, secure key exchange and encryption. The IEEE 802.16d MAC consist of two modes of operation: point to multipoint (PMP) and multipoint to multipoint (mesh). The IEEE 803.16e defines two different types of addresses in the MAC sublayer to identification of individual stations. These addresses are utilized for resource allocation and management of the mobile station and are called "station identifiers" (assigned during network entry) and "flow identifiers" (assigned for QoS purposes).

2.4 Quality of service (QoS) support

In the mobile WiMAX, QoS needs for a wide range of data services and applications with fast air link, asymmetric downlink/uplink capability, fine resource granularity and a flexible resource allocation mechanism. Mobile WiMAX applications and quality of service requirements are summerized in table 4.

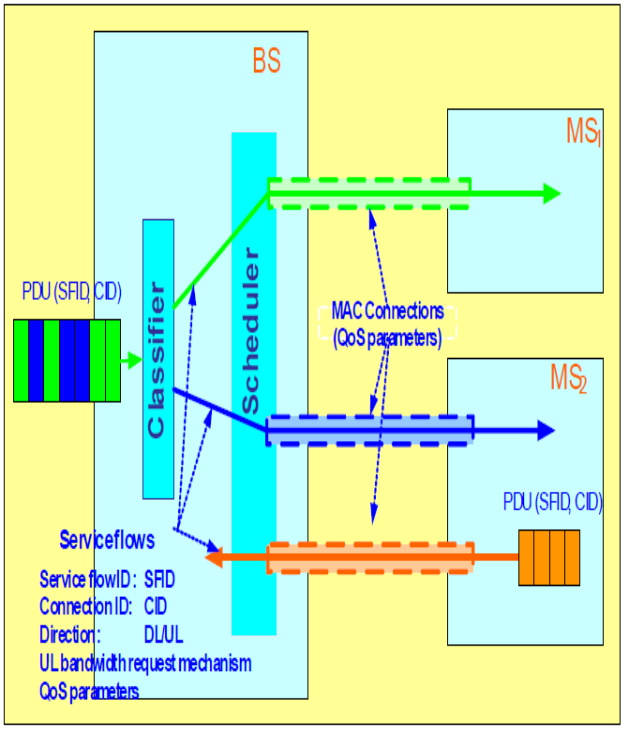
Table 4. Mobile WiMAX Applications and Quality of Service

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP	• Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance

rtPS Real-Time Polling Service	Streaming Audio or Video	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Traffic Priority
ErtPS Extended Real-Time Polling Service	Voice with Activity Detection (VoIP)	• Minimum Reserved Rate • Maximum Sustained Rate • Maximum Latency Tolerance • Jitter Tolerance • Traffic Priority
nrtPS Non-Real-Time Polling Service	File Transfer Protocol (FTP)	• Minimum Reserved Rate • Maximum Sustained Rate • Traffic Priority
BE Best-Effort Service	Data Transfer, Web Browsing, etc.	• Maximum Sustained Rate • Traffic Priority

Figure 3 shows mobile WiMAX QoS support. With a particular set of QoS parameters, a unidirectional flow of packets are obtained. The base station and user terminal first establish a unidirectional logical link between the peer MACs called a connection. The QoS parameters define the transmission ordering and scheduling on the air interface.

Figure 3. Mobile WiMAX QoS Support



3. ADVANCED FEATURES OF MOBILE WIMAX

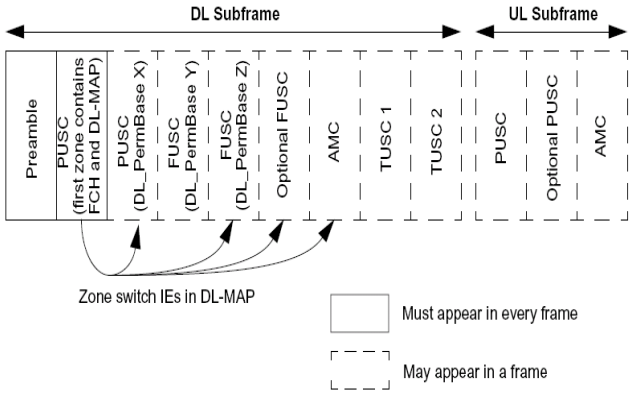
Mobile WiMAX IEEE 802.16e consist of following advanced features.

3.1. Fractional frequency reuse

To enhance spectral efficiency, all sectors perform on the same frequency in IEEE 802.16e. Edge users may undergo the degeneration in connection as a result of excessive co-channel interface (CCI) in frequency reuse one deployment. With mobile WiMAX, users operated on channels, take up a limited fraction of the entire channel bandwidth. In mobile WiMAX IEEE 802.16e, sub-channel segmentation and permutation section simplify the flexible sub-channel reuse. Subdivision of the accessible OFDMA sub-channels is known as segment. A number of adjacent OFDMA symbols in downlink or uplink that employ same modification is a permutation section.

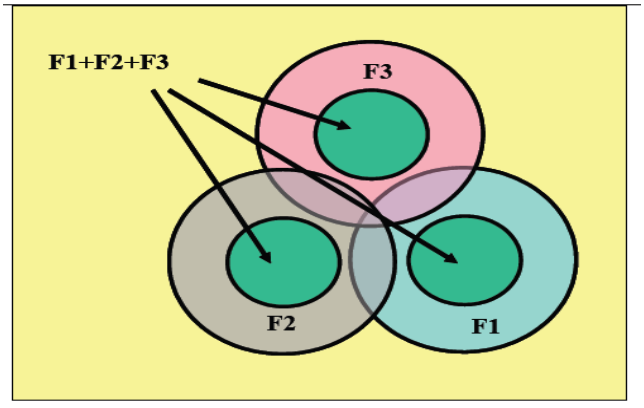
The DL or UL sub-frame may include more than one permutation zone as shown in the figure 4.

Figure 4. Multi-Zone Frame Structure



Different sets of sub-channels in the same frequency channel indicated by F_1, F_2 and F_3 in figure 5. To ensure throughput and connection feature for users at the cell edge, the entire load reuse one is provided for center users to improve spectral efficiency and fractional frequency reuse with this arrangement.

Figure 5. Fractional Frequency Reuse



3.2. Smart antenna technologies

Smart antenna application to be accomplished on vector flat sub carriers, provided by OFDMA. For next generation broadband communication systems, MIMO-OFDM/OFDMA is conceptualized as a keystone [18,19]. To upgrade system accomplishment, mobile WiMAX IEEE 802.16e holds up a entire domain of smart antenna technologies. The smart antenna technologies sustained consist of:

- Beamforming: The system utilizes several-antennas to transmit weighted signals to upgrade range and strength of the system and minimize outage probability [20].
- Space- Time Code (STC): To support spatial diversity and reduce fade margin, transmit diversity such as Alamouti code [21,22] is accommodated.
- Spatial Multiplexing (SM): Spatial multiplexing [23,24] is provided to take advantage of higher peak rates and increased throughput. several streams are transmitted over several antennas with spatial multiplexing.

The supported features in the mobile WiMAX performance profile are listed in the table 5.

Table 5. Advanced Antenna Options

Link	**Beamforming**	**Space Time Coding**	**Spatial Multiplexing**
DL	Nt≥2, Nr≥15	Nt=2, Nr≥1 Matrix A	Nt=2, Nr≥2 Matrix B, vertical encoding
UL	Nt ≥1, Nr≥2	N/A	Nt=1, Nr≥2 Two-user collaborative SM

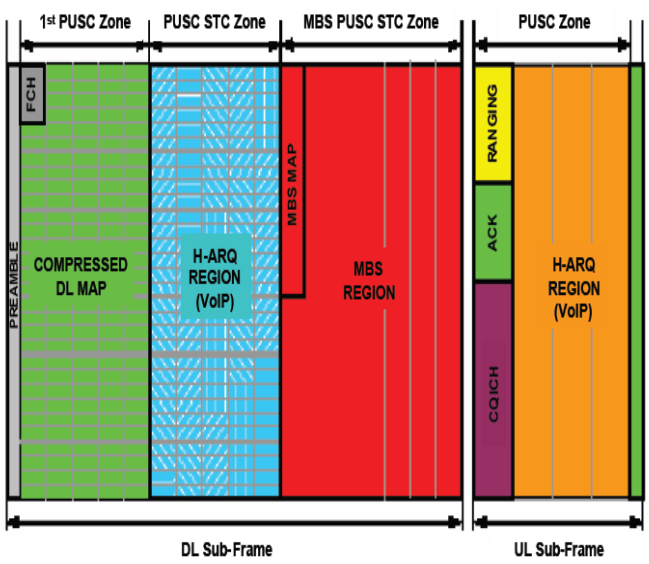
3.3. Multicast and Broadcast Service (MBS)

The optimum characterstics of Media FLO, 3GPP E-UTRA and DVB-H are incorporated by Multicast and Broadcast Service (MBS). MBS fascinates the following specifications:

- By using a Single Frequency Network (SFN) supports tremendous data rate and broadcasting.
- Small MS power utilization.
- Short duration of switching time.
- Extensible allotment of transmission resources.
- With audio and video streams sustain data casting.

The DL and UL region configuration is shown in figure 6, when a mix of unicast and broadcast services are sustained. With SFN performance, the MBS segment holds various BS MBS mode. As well as, scalable responsibilities of broadcast resources to MBS traffic are granted by adaptable period of MBS areas. To primarily recognize MBS sections and position of the correlated MBS MAPs in each zone, the multicast service approaches the DL MAP. Through OFDM symbol offset specification the position of every MBS region and MBS section PHY arrangement are designated by the MBS MAP IE. At the first sub-channel of the first OFDM symbol of the correlated MBS region locates the MBS MAP.

Figure 6. Embedded MBS Support with Mobile WiMAX – MBS Zones



4. CONCLUSIONS

In this paper, the main features of IEEE 802.16e Mobile WiMAX are explained and present an overview of the IEEE 802.16e PHY layer issues, MAC protocol and QoS provisioning. For high quality voice and video, internet, mobility and demand for bandwidth, the IEEE 802.16e appears as a strong candidate for providing aggregate rates to high-speed mobile users at the range of Gbps. WiMAX technology based on IEEE 802.16e standard will ensure that multiple vendors produce interoperable equipment. It will help in bridging the digital divide and will ensure faster roll out in areas where the low POTS penetration, high DSL costs or poor copper quality have acted as a barrier in providing high speed, broadband internet access.

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