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Mobile WiMAX and It Comparison with other Next Generation Wireless Network Technologies

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Abstract: In the next generation networks (4G) for Wireless Metropolitan area technology, the Mobile Wi-max (Wireless Interoperability Wireless Access) is one of the outstanding technologies that have promised to offer broadband wireless access (BWA) over long distance. The Mobile WiMAX was successfully adopted by ITU (International Telecommunication Union) as one of the IMT2000 (International mobile Telecommunications) technologies in November-2007. Mobile WiMAX, based on the IEEE 802.16e standard (release 1), supports a several types of handovers and allows fully mobility of users. Today the IEEE 802.16 Working Group (WG) has formed the IEEE 802.16m (release 2) and IEEE 802.16j. The IEEE 802.16j will provide relay functionality and IEEE 802.16m (Advance Air Interface) will provide high data rates and additional functionalities to meet the requirements for IMT-Advanced defined by ITU-R (ITU-Radio communication Sector) for 4G system. Another technology considered by IMT-Advanced for the 4G Radio Access Technology is LTE-Advanced. This paper provides vast overview of IEEE 802.16e and its comparison with other wireless technologies.

Keywords*:* Mobile WiMAX, IEEE 802.16e, PHY-layer, MAC-layer, Handover, IEEE 802.16m**.**

1. INTRODUCTION

Today the increasing demand for mobile broadband, internet and multimedia application a user can use all these services anytime and anywhere. IEEE802.16 [1] WG (Working Group) provide a solution for broadband wireless access (BWA) technologies i.e. called IEEE 802.16e or Mobile WiMAX. Mobile WiMAX is one of the outstanding BWA technologies that can provide high data rate and cover wider area than WLAN system. Mobile WiMAX combines both OFDMA (Orthogonal Frequency-Division Multiple Access) and advance MIMO (Multiple Input and Multiple Output) technologies.

The IEEE 802.16 [1] WG established by the IEEE standards board in 1999 has developed and published several version of Air Interface Standard for Wireless Metropolitan Area Networks (WMANs). The IEEE WG first standard was published in 2001, i.e. IEEE 802.16 standard providing Air Interface for fixed BWA system in 10-66 GHz band with a theoretical maximum bandwidth of 120Mb/s and maximum transmission range 50 Km. This standard only supports line-of-sight (LOS) transmission and thus does not seem to favor deployment in urban areas. A variant of the standard, IEEE 802.16 (i.e. IEEE 802.16a,.16b,.16c,.16d) that support only for fixed BWA system, not for mobility. This is the main problems in the earlier draft of IEEE 802.16 but the IEEE 802.16 WG is solve this problem by developing a standard that is IEEE 802.16e [2] is called Mobile WiMAX (WiMAX).

The WiMAX adopt OFDMA and SOFDMA (Scalable OFDMA) at the physical layers for easy and fast transmission. The IEEE 802.16e [2] amendment include many new features and functionality needed to support enhanced quality of service (QoS) and mobility. The QoS are providing by MAC layers in WiMAX. IEEE 802.16e is fully supported via multimedia transmission with different QoS requirements through the use of scheduling mechanisms. The increasing demand of multimedia applications in the internet, IEEE 802.16 provides new wireless services such as multimedia streaming, real-time surveillance, Voice over IP (VoIP) and multimedia conferencing. The WiMAX adds significant enhancement [3].

(1) PHY layers adopt OFDMA with scalable bandwidth from 1.25-20 MHz.

(2) It uses of MIMO antenna technologies (i.e. Adaptive antenna system, AAS) to supports both downlink and uplink high data rates.

(3) It improves multipath performance in NLOS environments by using OFDMA technologies.

(4) Its use S-OFDMA to support by adjusting the FFT (Fast Fourier Transform) size from 128 to 512, 1024, 2048, to supports channel bandwidth of 1.25 MHz, 5 MHz, 10 MHz and 20 MHz respectively.

TABLE I. IEEE 802.16 STANDARDS

Standard	Description	Status
802.16-2001	Fixed Broad Band Wireless Access (10-63 GHz)	Supersede
802.16.2-2001	Recommended Practice for Coexistence	Supersede
802.16c-2002	System Profile for 10 – 63 GHz	Supersede

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802.16a-2003	Physical Layer and MAC definition for 3-11 GHz	Supersede
P802.16c	License exempt Frequencies (Project withdrawn)	Withdrawn
P802.16d	Maintenance and system profile for 2-11 GHz (Project merged into 802.16-2004)	Merged
802.16-2004	Air interference with fixed Broad Band Wireless Access system (Roll up of 802.16-2001, 802.16a, 802.16c, and P802.16d)	Superseded
P802.16.2a	Coexistence with 2-11 GHz and 23.5-43.5 GHz (Project merged into 802.16,2-2004).	Merged
802.16.2-2004	Recommended Practice for Coexistence (Maintenance and roll up of 802.16.2-2001 and P802.16.2a)	Current
802.16f-2005	MIB for 802.16-2004	Superseded
802.16-2004/core1-2005	Correction for fixed operations (Co-published with 802.16e-2005).	Superseded
802.16e-2005	Mobile Broad Band Wireless Access System.	Superseded
802.16k-2007	Bridging of 802.16 (An amendment to IEEE 802.1D)	Current
802.16g-2007	Management plane Procedure and System	Superseded
P802.16i	Mobile Management Information Base (Project Merged into 802.16-2009)	Merged
802.16-2009	Air interface for fixed and mobile Broadband wireless access system (Rollup of 802.16-2004, 802.16-2004/ Core 1, 802.16e, 802.16f, 802.16g and P802.16i)	Current
802.16j-2009	Multihop Relay	Current
802.16h-2010	Improved Coexistence Mechanism for Latescence Exempt Operation	Current
P802.16m	Advance Air Interface with Data Rate 100 Mb/s Mobile and 1Gb/s fixed.	In progress
P802.16n	Higher Reliability Networks.	In progress

II PHY LAYER OF IEEE 802.16e

IEEE 802.16e air interface adopts OFDMA for improved multipath performance in NLOS environments. The OFDMA in PHY layer of mobile WiMAX based on scalable-OFDMA i.e. called SOFDMA [4]. The SOFDMA support a wide range of operating scalable channel bandwidths from 1.25 to 20 MHz to flexibly address the need for various spectrum allocation and application requirement, when the operating bandwidth increase the FFT size is also increased to maintain a fixed subcarrier frequency spacing of 10.94 KHz. This ensures a fixed OFDMA symbol duration. Since the basic resource unit (i.e. the OFDMA symbol duration) is fixed, the impact of bandwidth scaling is minimized to the upper layers [5], [6]. Table II shows the relevant parameters for the OFDMA PHY layer [5], [6].

TABLE II. PARAMETERS FOR OFDMA PHY

Parameter	***Value***			
FFT Size	128	512	1024	2048
Channel Bandwidth (MHz)	1.25	5	10	20
Subcarrier Frequency Spacing (KHz)	10.94			
Useful Symbol Period	91.4			
Guard Time	1/32, 1/6, 1/8, 1/4			

In the Mobile WiMAX for producing higher code rates, the channel coding stage includes randomization; convolution coding (native code rate is 1/2) and puncturing to produce higher code rates. The modulation scheme used in Mobile WiMAX is QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation) or 64QAM. The modulation data are mapped by segmenting the sequence of modulated symbols into a sequence of slots. A guard interval is also inserted at this stage [5], [6].

III MAC LAYAER IN WIMAX

Figure 1 shows the reference model of IEEE 802.16 layers [3]. In this figure the MAC layer consists of three sub layers: (1) The service-specific convergence sub layers (CS), (2) MAC common part sub layer (MAC CPS) and (3) Security sub layer

F. Service-Specific Convergence Sub layer (CS):

The main function of CS is to transform or map external data from the upper layers into appropriate MAC service data units (SDUs) for the MAC CPS. This includes classification of external data with the proper MAC service flow identifier (SFID) and connection identifier (CID). An SDU is the basic data unit exchanged between two adjacent protocol layers.

G. *MAC Common Part Sub layer (MAC CPS):*

The MAC CPS provides the core functionality for system access, allocation of bandwidth, and connection establishment and maintenance. This sub layer also handles the QoS aspect of data transmission.

H. Security Sub layer:

The security sub layer provides functionalities such as authentication, secure key exchange, and encryption. For the PHY layer, the standard supports multiple PHY specifications, each handling a particular frequency range. IEEE 802.16e provides Point-to-Multipoint (PMP) modes of operation.

D. *Point-to-Multipoint:* WiMAX is connection oriented technology which means that all data service are mapped to a connection between the SS and The BS. In other words, a connection between the entities must be established before

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any uncast traffic can be transmitted. The DL direction from BS to SS operates on a PMP basis in which a central BS is able to provide independent, frequency-separated sectors and serve multiple SSs located in the sectors [7].

E. *MAC Management messages:* The management message are designed for controlling actions at SS, RS or BS on request/ response/ acknowledgment basis: Some of the events triggered or executed by the management message exchanges are the following [2].

1 Network entry and registration.
2 Handover.
3 Privacy service addition, modification and removal.
4 UL(Uplink) and DL(Downlink) physical channel Description on DCD/UCD messages.
5 Delivery of UL and DL user access information on DL-/UL-MAP messages.
6 Multicast polling.

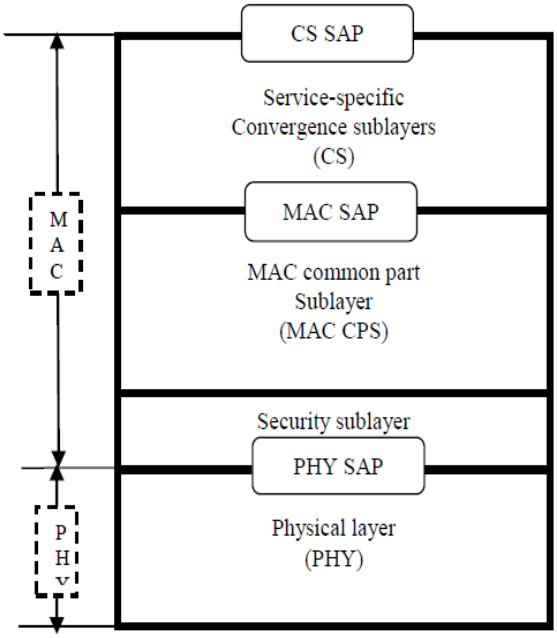

Figure.1 IEEE 802.16 Reference Model

IV HAND OVER IN MOBILE WIMAX

IEEE 802.16WG has defined three types of handover or IEEE 802.16e technologies [2]: the Hard Handover (HHO), the Fast Base Station Switching (FBSS), and the Micro Diversity Handover (MDHO). The first one is required while the others are optional types.

In WiMAX a handover initiation decision by a wireless terminal or BS is dependent on the Received Signal Strength (RSS) from the current serving BS (SBS) and neighboring BS (NBS). The MS and the SBS both decide on when to initiate a handover activity whenever the RSS from the SBS drops below a certain threshold, which might hamper an ongoing communication session, the MS goes for a handover with one of the chosen NBS, called the target BS(TBS).

I. Hard Handover

The Hard handover is a process to change the serving BS using a "break-before-make" way in other words connection to the old BS is broken before a new BS is connected. The process of HHO in IEEE 802.16e is broadly divided into Network Topology Acquisition Phase (NTAP) and Actual Handover Phase (AHOP).

J . Micro Diversity Handover and Fast Base Station Switching

The MDHO and the FBSS are consider as soft handover method and both are optional handover scheme for the Mobile WiMAX and therefore needs to be supported by both the MS and the BS. The MS keep a list of BSs capable to the MDHO on its coverage area. This group is called Diversity Set (DS), or in some source in Active Set (AS). There is always one BS in the DS that is defined as an Anchor BS (ABS). In the MDHO the MS is able to communicate in DL and UL with all the BSs in the DS simultaneously instead of only one. In the FBSS the MS communicate only with one ABS over UL and DL channel. So, signal strength of neighboring BSs are continuously monitored by each MS for efficient updating of its DS and ABS.

K . Comparison Between HHO and MDHO and FBSS

The HHO mechanism used in now day beyond 3G (B3G) technologies but it cannot handle voice-centric application with high speed mobility. On the other hand the MHDO and FBSS are provide full seamless mobility at high speed (up to 120 km/s) with very low (less than 1%) packet loss, very fast switching and low handover latency (less then 50ms). These two handover technologies can also supports high speed real-time voice centric application like VoIP and provide better performance with respect to multi-access interference, flexibility and coverage than their CDMA(Code Division Multiple Access) competitors do [8]. It means the MDHO and the FBSS provide better handover performance in comparison to HHO, there is still a long way to go before adequate support measures for these two techniques can be developed and deployed in WiMAX networks

TABLE. III COMPARISON OF THE MWIMAX HANOVER TECHNIQUES

Parameter	Handover	MDHO	FBSS
Latency	High	Low	Medium
Complexity	Low	High	Medium
Reliability	Low	High	Medium
Packet Losses	High	Low	Low
Cost	Low	High	Medium
Support for delay sensitive Application	Low	High	High
Speed	Low	High	Medium
Link quality	Low	High	Medium

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In the WiMAX handover enhanced by integrating fixed relay station in WiMAX networks [9]. In this paper author proposed fast HO scheme called Passport Handover along with Transport CID(Connection Identifier) mapping strategy for real-time application and by this method the HO latency for both downlink and uplink service is greatly reduced [10]. In this paper author discus main issues in WiMAX handover and also has highlight those cross-layer (L2+L3) challenges that demand more attention [8]. In this paper proposed a new metrology for reduce latency for both DL and UL during scan and handover procedure [11].

V. ADVANCE MWIMAX AND COMPARISON WITH OTHER TECHNOLOGIES

Today, IEEE 802.16 WG is developing two new standards that is 802.16j and 802.16m [12], [13]. The 802.16j will provide relay functionality and 802.16m (Advance Air Interface) will provide higher data rates and additional functionalities to meet the requirements for IMT-Advance defined by ITU-R for 4G system [14].

The 4G wireless technology describes mobile wireless services which have been defined by the ITU-R and IMT-Advanced. These are mobile system that include the new capabilities of IMT that go beyond those of IMT-200. Long Term Evolution-Advanced (LTE-Advanced) [15] and IEEE 802.16m are the two main candidate technologies submitted for IMT-advanced certification. In order to meet IMT-Advanced goals, several enhancement and new capabilities are being studied for inclusion source more efficiently, increase capability, improve reliability in highly mobile environments, and accommodate users with different requirements. The goal is to reduce overhead, improve flexibility and facilitate channel estimation. The IEEE 802.16m allows handover with service continuity for Radio Access Technologies (specific interest being paid on IEEE 802.11, 3GPP, GSM/EDGE, UTRA, E-UTRA and 3GPP2 CDMA2000) and support of IEEE 802.21 Media Independent Handover (MIH) standard. IEEE 802.21: Media Independent Handover that enable the optimization of handover between heterogeneous IEEE 802 networks and facilities handover between IEEE 802 networks and cellular networks.

IEEE 802.16m will comprise three documents: A system Requirement Document (SRD) [16], a System Description Document (EMD), and an Evaluation Methodology Document (EMD) [17]. As its name suggests, the System Requirements Document contains high-level requirements for 802.16m- compliment system, including, among others, rates throughput, coverage, mobility support, operating bandwidths and frequency, QoS, latency, handover and security. The main goal is to meet the cellular layer demands of IMT-Advanced and, at same the time, support latency WMAN-OFDMA equipment. A list of some of main requirements for IEEE 802.16m is given in Table V. These requirements are compared with IEEE 802.16e, the latency standard for Mobile WiMAX.

TABLE IV. .IMPORTANT FEATURES AND REQUIREMENTS OF MOBILE WIMAX STANDARDS

Requirement	***IEEE 802.16e***	***IEEE 802.16m***
Aggregate Data Rate	63 Mbps	100 Mbps for mobile station, 1 Gbps for fixed
Operating Radio Frequency	2.3 GHz, 2.5-2.7 GHz, 3.5 GHz	< 6 GHz
MIMO Support	TDD and FDD	4 or 8 stream. No limit on antenna
Coverage	10 Km	3 Km, 5-30 Km,, 30 -100 Km depending on scenario
HO Inter-frequency Interruption Time	30- 50 ms	30 ms
HO Intra-frequency Interruption Time	Not specified	100 ms
HO between 802.16 Standard (For corresponding Mobile station)	From 802.16e serving BS to 802.16e target BS	From legacy SBS to legacy TBS From 802.16m SBS to ligancy TBS from legacy 802.16 SBS to 802.16 TBS From 802.16m SBS to 802.16 m TSB
HO with other Technologies	Not specified	IEEE 802.11, 3GPP2, GSM/EDGE, (E-) UTRAN (LTE TDD) Using 801.21 MIH
Mobility Speed	Vehicular 120 km/h	Indoor 10 km/h Basic coverage Urban: 120 km/h High speed 350 km/h
Potion Accuracy	Not specified	Location Determination latency: 30s Hand set based: 50 m (67- percentile) Network based: 100 m (67 percentile), 300 m (95 percentile)
IDEL to ACTIVE State Transition	390 ms	50 ms
\QOS Classes	UGS,nrt PS.ert PS, rtPs.BE	UGS, ,nrt PS.ert PS, rtPs.BE

A *Comparison between WiMAX and UMTS/HSDPA*

WiMAX and UMTS/HSDPA(Universal Mobile Telecommunication System/High Speed Downlink Packet Access) are both system able to provide high data rates to several users. Although the main purpose is the same, there are some differences regarding technical issues used by each one of the system. Table V summarizes the main differences between them:

TABLE V. COMPARISON BETWEEN MWIMAX AND UMTS/HSDPA

Attributes	Mobile WiMAX	UMTS/HSDPA
Standards	IEEE 802.16e	WCDMA

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Duplex method	TDD	FDD
Multiple Access	SOFDMA	CDMA
Frequency (GHz)	2.5,3.5,5.8	2
Frame Size (ms)	5	2
Modulation	QPSK/16QMA/64QMA	QPSK/16QMA
DL PHY Peak Data Rate (Mbps)	31.68 (For a 10 MHz channel)	14.4
Coverage (km)	Up to 5 km	Typically 2 to 5 km
HARQ	Yes	Yes
Fast Scheduling	Yes	Yes
AMC	Yes	Yes

B. Comparison between IEEE 802.16m and LTE Advance in accordance to IMT-Advanced

IMT-Advanced is the ITU description for system beyond IMT-2000 as discussed in much detail earlier. In the previous the two main candidates for IMT-Advanced certification (LTE-Advanced and IEEE 802.16m) have been presented along with the steps taken to satisfy the requirements for IMT-Advanced. IEEE 802.16m has similar performance capabilities as LTE-Advanced technologies. With 802.16e operators can deliver upwards of 3.5 bps today (35 Mbps per sector for a 10MHz channel) while 802.16m and LTE will advance that to over 5.0 bits per hertz (greater than 100Mbps per sector for a 20 MHz channel). In Table VII summarizes the some difference between the two technologies

TABLE VI. COMPARISON BETWEEN IEEE 802.16M AND LTE-ADVANCED

Parameter	IEEE 802.16M	LTE-Advance
MIMO Technique	DL: upto 8x8 UL: upto 4x4	DL: upto 8x8 UL: upto 4x4
Latency (ms)	C-Plane: 100 (Idle to Active) U-Plane : 10	C-Plane:50 U-Plane :10
Duplex Scheme	TDD,FDD and HFDD	TDD,FDD
Mobility Support	Up to 500 km/hr	Max at speed < 15 km/hr High Performance (120 km/hr) Maintain link 350 km/hr
Modulation	BPSK,QPSK, 16QAM,64 QMA, SC.	QPSK,16QAM,64 QMA
Multicarrier Support	Up to 100 MHz with channel aggregation	100 MHz with channel aggregation.
Saleable Bandwidth support (MHz)	5, 7, 8.75, 10, 20 and 40.	20-100
Peak Spectral Efficiency bps/Hz	DL: 15(4x4) MIMO UL: 6.75 (2x4) MIMO	DL:30 (8X8) MIMO UL:15 (4x4) MIMO
Peak Data Rate (Mbps)	DL: 1000 (Low mobility) DL: 100 (High mobility) UL:130	DL:1000 UL: 500
Access Scheme	DL:OFDMA UL:OFDMA	DL:OFDMA UL: SC-OFDMA
Cell Edge Spectral Efficiency (bps/Hz)	DL:0.09 (2x2) UL:0.05 (1x2)	DL:0.12 (4X4) UL: 0.07 (2X4)

V. CONCLUSION

The demand for high speed broadband services set to grow constantly the ITU's Radio communication sector (ITU-R) came up with recommendation for the design of a new air interface which would support this growing demand. Such system would be considered 4G or IMT-Advanced from 3GPP and IEEE 802.16m. IEEE WG is developed new standard to meet the requirement for IMT-Advanced for 4G system. IEEE 802.16m and LTE-Advanced are the two main candidate technologies submitted for IMT-Advanced certification. IEEE 802.216m and LTE-Advanced would merge into one as they target IMT-Advanced status is quelled because towards 4G certification, both these standards share a great deal of similar technological aspects and will certainly both qualify for 4G status.

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BIOGRAPHIES

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