A Study on WiMAX: IEEE 802.16 Standard

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ABSTRACT
WiMAX (IEEEE802.16 standard) is abbreviation of worldwide Interoperability for Microware access, and it means exchanging and using information in the World Wide Web by accessing microwave waves (electromagnetic waves in radio frequency spectrum). WiMAX is a telecommunication protocol and this technology provides broadband wireless access. The first version was published in 2001. WiMAX can provide services in areas having physical limitations such as tradition wired infrastructures. WiMAX supports a wide area in comparison to WAN, and it supports mobile and fixed services.

Keywords
Wireless**,** WiMAX, Network, QOS, IEEEE802.16

1. INTRODUCTION
wireless refers to communication technology, and radio waves, infrared and microwave are used to transmit signals between two devices instead of cable and wire, with regard to advantages and disadvantages of wired and wireless networks and comparing it with wired networks, network providers try a take the best actions to select the best one. Wireless technology is divided into fixed, portable and infrared technologies. Wireless networks are divided to WPAN, WLAN, WMAN and WGAN in terms of dimensions. Due to accessing wireless networks easily and widely, the number of users using such networks increases. Users advocate the network having higher and suitable speed to transmit information. Also, its effective range must be appropriate, and it shouldn't limit them to geographical situation and width. Infrared networks are the first wireless networks used to transmit information; such networks did not have higher and suitable range. In beginning of 90 decades, Wi-Fi wireless networks were introduced. They had suitable speed and range in comparison to infrared networks, but they are not favorable for users. They were suitable and useful for small or medium environments. Then new wireless network having suitable range and speed were introduced. They were called WiMAX. WiMAX can provide services by two methods involving LOS (line of sight) and NLOS (non line of sight). During the years, amendments have been applied to WiMAX standard. WiMAX forum group is one of the main groups and founder of WiMAX networks. This group has various programs for wide accessing to such as wireless network. IEEEE802.16 was presented in 2001 with frequency range of 66-10 GHZ and maximum bandwidth of 120 Mbit/s and it only supported LOS transmission.

IEEE802.16d was presented in 2003. It is a fixed WiMAX. Then, 802.16-2004 standard was considered as a substitution for all previous versions of WiMAX in 2004 [1]. One of the limitations of this standard development is lack of supporting its mobility. IEEE 802.16e [2] (improved 2004-802.16) was introduced in2005 and it was called mobile WiMAX. Mobile WiMAX improves NLOS, and uses adaptive antenna system. IEEE 802.16j was developed in 2009. IEEE802.16m standard was introduced in 2011. This standard provided minimum fixed speed of 1Gbit/s and 100Mbit/s for users.

In this paper, WiMAX technology is reviewed, and then mobile WiMAX characteristics and features are studied. Finally, it is concluded.

2. VARIOUS WIRELESS NETWORKS IN TERMS OF DIMENSIONS
WPAN (Wireless Personal Area Network) covers a small area, and it uses IEEEE802.15 standard. It allows devices to provide communication with each other in a small area. The best simple is Bluetooth. WLAN (wireless local area network) allows sharing information between different equipment located in a limited distance, and it uses IEEEE 802.11.WLAN covers a relatively small area, and uses Wi-Fi technology. In WMAN (Wireless Metropolitan Area Network), IEEEE 802.16 standard is used. WMAN networks use WiMAX technology to connect to wide areas (metropolitan width). The final step is wireless Global Area Network or WGAN. The proposed design is IEEEE 802.20. A WGAN network can perform like cell phone network, and the users can travel in countries, while all of them are connected to a network.

3. WiMAX TECHNOLOGY
WiMAX developed increasingly due to its high bandwidth in remote distances, the quality of service, flexibility and other capabilities. WiMAX involves key features so is distinct from other technologies of metropolitan area wireless access. These features are as follows [3].

- Its use of Orthogonal Frequency Division Multiple Access (OFDMA).
- Scalable use of any spectrum width (varying from 1.25 MHz to 28 MHz).
- Time and Frequency Division Duplexing (TDD and FDD).
- Advanced antenna techniques such as beam forming, multiple input multiple output (MIMO).
- Per subscriber adaptive modulation.
- Advanced coding techniques such as space-time coding and turbo coding.
- Strong security.
- Multiple QOS classes suitable not only for voice but designed specifically for a combination of data, voice and video services.

WiMAX presents IPTV and VOIP services in addition to high speed and band width, so it was considered as a substitution for DSL and telephone services [1]. Features of Fixed WiMAX and Mobile WiMAX are presented in table 1. Also, the main features of IEEE 802.16, 802.16-2004 and 802.16e-2005standards are summarized in table 2.

Table 1. Fixed WiMAX and Mobile WiMAX [4, 5].

Parameter	Fixed WiMAX	Mobile WiMAX
Definition	Only allow BWA (Broadband Wireless Access)when subscriber is in the range of a WiMAX BS.	Allows Handoff of data sessions as the user moves between radio towers.
Standard	802.16d	802.16e
Frequency	2-11 GHz	2-6 GHz
Key features	Allows LOS and NLOS Selectable channel bandwidth ranging from 1.25 to 20MHz	Provide mobile wireless broadband up to vehicular speed.
Application	Fixed and nomadic access	Mobility and nomadic access

Wireless communications are described as LOS or NLOS. In Line of Sight (LOS) link, a signal travels over direct path from the transmitter to a wireless signal receiver without passing obstructions. In Non Line of Sight (NLOS) link, a signal passes various obstructions from the transmitter to a wireless signal receiver. When a signal is transmitted, it may be reflected, refracted, diffracted, absorbed or scattered. Thus, multiple signals could be made, and these signals are received by a receiver at various times via various paths. Also, these signals have different strength [4, 6]. LOS and NLOS are shown in figure 1.

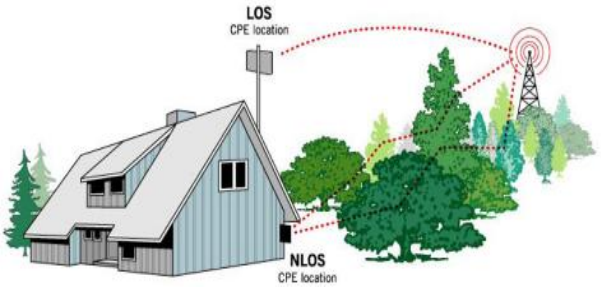

Fig1. LOS and NLOS [7].

3.1 Physical Layer

WiMAX standard 2004 (IEEE 802.16 a-d) has presented three physical layers involving a new single carrier (SCA), 256 Point EFT OFDM and 2048Point EFT OFDM. Two last items are suitable for NLOS operations, but the second design is used more than others due to Faster Fourier transform (FFT) and etc. [10].

3.2 MAC layer (Media Access Control)

MAC layer (Media Access Control) is composed of three sub-layers involving common part(CPS), convergence sub-layer [11] and security sub-layer [12]. CS classifiers data receives from top layers, and then payload header is added to the frame. It is transferred to CPS sub-layer. CPS manages general functions like channel accessing, QOS and network entry initialization. Security sub-layer is protected against the attacks by wireless networks toward the users. Security sub-layer is used to store information about how transmission is secured through using secure key exchanges during authentication, and which encryption tool is used during data transmit [4].

Mac layer is designed for very high data rate applications and QOS requirements. Mac layer protocol must be flexible and effective in wide range of various data traffic model, because users required services have different delays and band width [10]. IEEE 802.16d MAC supports two methods of point to multipoint (PMP) and multipoint to multipoint. In PMP, uplink transmissions from subscriber station to base station occur in separate timeframes. In sub-frame of downlink, BS can transmit a sequence of protocol data units. Sub-frames of uplink and downlink can be duplex by using frequency dividing duplex (FDD) or time dividing duplex (TDD). PMP method can support mobile WiMAX. Unlike PMP model, there is no separate downlink and uplink sub-frame in PMP model. Each station can provide direct connection with some station is system. In mesh model, distributed and centralized scheduling methods are used for transmission scheduling. Also, this model has coordinate and uncoordinated distributed scheduling. Both of them use three-route handshake method [12].

3.3 WiMAX network model

WiMAX model is composed of mobile station [13], network access provider (NAP), network service provider (NSP) and Internet. MS is mobile equipment used by the end used. There are fixed and mobile devices such as wireless laptops, cell phones and etc. NAP is used for QOS to apply the poling and to select special CSN. It involves base stations, ASN-GW and foreign agent components. NAP includes several ASN involving one or more base stations and one or more ASNs. Also, it involves a set of functionalities, and radio access is provided for WiMAX subscribers. In the mobile network, ASN is responsible of paging and location management and radio resource management mechanisms like handover control and execution. Various BSs are connected to ASN involving base station and ASN-GW through reference point R4. ASN gateway acts like a traffic aggregation in ASN. Tasks of ASN involve paging and location management, Radio Resource Management mechanisms like handover control and execution. Connection of various ASN-GW is required for redundancy and loud balance. Network service provider provides IP connection services for users and CSN organization. IP connection is provided for users through CSN [14].

Table 2. Basic characteristics of IEEE 802.16, 802.16-2004 and 802.16e-2005standards [8, 9].

Parameters	802.16	802.16-2004	802.16e-2005
Status	Completed December 2001	Completed June 2004	Completed December 2005
Frequency band	10GHz–6GHz	2GHz–11GHz	2GHz–11GHz for fixed;

			2GHz–6GHz for mobile applications
Application	Fixed LOS	Fixed NLOS	Fixed and mobile NLOS
MAC architecture	Point-to- multipoint, mesh	Point-to-multipoint, mesh	Point-to-multipoint, mesh
Transmission scheme	Single carrier only	Single carrier, 256 OFDM or 2,048 OFDM	Single carrier, 256 OFDM or scalable OFDM with 128, 512, 1,024, or 2,048 subcarriers
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
Gross data rate	32–134.4Mbps	1–75Mbps	1–75Mbps
Multiplexing Burst	Burst TDM/TDMA	Burst TDM/TDMA/OFDMA	Burst TDM/TDMA/OFDMA
Duplexing	TDD and FDD	TDD and FDD	TDD and FDD
Channel bandwidths	20MHz, 25MHz, 28MHz	1.75MHz, 3.5MHz, 7MHz, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz	1.75MHz, 3.5MHz, 7MHz, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz
Air-interface designation	Wireless MAN-SC	Wireless MAN-SCa Wireless MAN-OFDM Wireless MAN-OFDMA	Wireless MAN-SCa Wireless MAN-OFDM Wireless MAN-OFDMA
implementation	None	256 - OFDM as Fixed WiMAX	Scalable OFDMA as Mobile WiMAX

4. MOBILE WiMAX

Figure 2 shows the structure of mobile WiMAX frame. Each frame involves two sub-frames of downlink and uplink. Initialization of each frame involves Preamble, FCH (frame control header) and Map message. In mobile WiMAX, each data channel is called data burst [15].The preamble is the first symbol of the frame that is used for synchronization. It is followed by FCH [16, 17]. It provides the frame configuration information such as MAP message length and etc. DL-MAP and UL-MAP provide sub-channel allocation and control information for the DL and UL. UL ACK is allocated for the MS to feedback DL HARQ acknowledgement. UL CQICH channel and UL ACK are allocated for the MS to feedback channel state information and DL HARQ acknowledgement respectively[17].

The following key features must exist in mobile WiMAX network [4]:

1 In a mobile WiMAX network, all networks must be based on IP protocol that is based on IEEE 802.16.

2 The network core is a multi- service core network, and it is not organized as a special service like a video or voice.

3 QOS is based on policy functions.

4 Support Fixed network, nomadic or mobile usage.

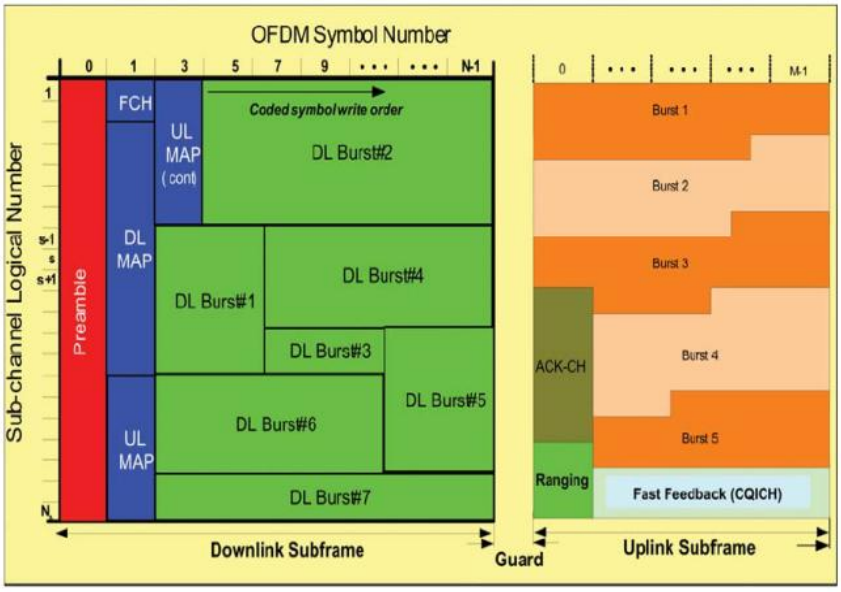

Fig2.Mobile WiMAX frame [15].

The architecture of mobile WiMAX network has been shown in figure 3. Connectivity service network involves a server of AAA (Authentication, Authorization, Accounting) and performs policy functions. It provides an authentication framework for mobile station.

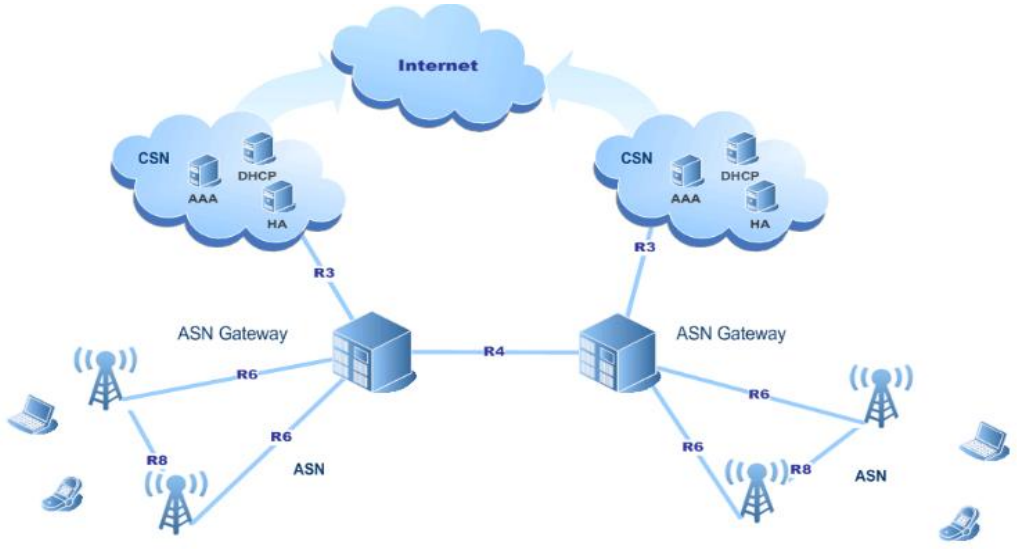

Fig3. Network Architecture of Mobile WiMAX [4].

Power consumption and handoff are related to mobile WiMAX applications. Mobile WiMAX uses sleep and idle model for operations of power efficiency. In sleep mode, power consumption of mobile user decreases, and it allows mobile user to scan BS to collect information of handoff. In idle mode, user can traverse multiple BSs, and can access to downlink broadcast messages without registering it in BS. In this case, handoff is not required for inactive mobile user [12].

There are three handoff methods in mobile WiMAX [12]:

- hard handoff (HHO)
- fast base station switching (FBSS)
- Macro diversity handover (MDHO)

HHO is compulsory, while MDHO and FBSS are arbitrary. In FBSS, mobile user communicates with anchor BS only. In handoff, it is transferred to new reference BS. In MDHO, mobile user communicates with all BSS in active set [12].

There are different multi antenna technologies in mobile WiMAX, and it is classified as two types [16].

- Open loop MIMO: involves coding time- space black, multiplex of open loop (SM-MIMO or MIMO-BS) and selecting adaptive models between both of them.
- Close loop MIMO: In this technology, transmitter forms antenna beams adaptively based on channel

side information. It is called transmitter adaptive antenna array (TX-AA).

5. WIMAX AUTHENTICATION

In order to confront with the attacks in base station, mutual authentication between the network and device is essential [18]. In WiMAX, authentication is performed by access service network-Gateway and AAA (authentication, authorization and accounting) server. Also, WiMAX uses EAP presenting multiple standards of authentication. In addition, users are authorized by network access identifier in WiMAX [19].

6. WIMAX APPLICATIONS

WiMAX applications are numerous. this applications include the following programs [20]:

- *Internet access:* It is considered as the main demands in WiMAX networks, and it can be presented for users who are not satisfied of wired broadband.
- *Group communications:* WiMAX networks involve group communications such as video conferences, and multicast is very important to support it.
- *Metropolitan Area Distributed service:* WiMAX is a wireless communication system, and it provides communications with high data rate in urban areas. Customers use distributed services in WiMAX network, and they can access to services by each network server. Carter et al. proposed a design for distributed services. In this design, the service of accessing is only determined instead of determining exact server address. Also, in this design, the user communicates with the subset of servers to access the high security and reliability [21].
- *Content-based Distribution:* In this design proposed by Carzaniga et al., it's not necessary to determine destination by message sender. It is automatically transferred to all receivers interested in receiving the message content by network layer [22].
- *Quality Guaranteed Applications:* In applications, it's necessary that the network layer guarantees the quality of services sufficiently, but such guarantee is difficult in wireless networks. Zhang and Mouftah studied multipath routing, and it has better QOS than one-route routing [23].
- *Multi-homing applications:* In multi-homing technology, a station has two or more IP addresses and interfaces. In addition, routing of application layer must be taken into account in designing the network layer [24].

7. CONCLUSION

In this paper, we presented overview of WiMAX standard (IEEEE 802.16) and its features. WiMAX is standard for wireless broadband. Its high band width along with high data transferring allows using it in companies and residential areas.

Service providers prefer WiMAX technology due to required hand width, power, user location, network owner and service type. WiMAX can be used with other services. Hence, WiMAX is not a threat for service of DSL and cable modem. WiMAX supports WMAN networks completely. Mobile WiMAX is OFDM-based technology, and it has decreased the cost in comparison to 3G. In future, we will carry out comprehensive study on MAC layer and QOS.

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