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Mobile WiMAX as a Next Generation Broadband Wireless Networks

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ABSTRACT

Worldwide interoperability for microwave access (WiMAX) is a wireless standard that introduces orthogonal frequency division multiple access (OFDMA) and other key features to enable mobile broadband services at a vehicular speed of up to 350 km/h. WiMAX complements wireless local area networks (WLANs) and competes with other third generation (3G) and forth generation(4G) wireless standards such as 3GPP-LTE Advanced on coverage and data rate. More specifically, WiMAX supports a much larger coverage area than WLAN, does not require line of sight for a connection, and is significantly less costly compared to the current 3G and 4G cellular standards. Although the WiMAX standard supports both fixed and mobile broadband data services, the latter (mobile WiMAX-IEEE 802.16m) have a much larger market. Therefore, this article will briefly compare both the Fixed and Mobile WiMAX standard, the technologies deployed for the air interface and the network, and its potential for successful deployment in the next generation of broadband wireless networks.

Keywords: *4G (Fourth Generation), WLAN, Mobile Broadband Wireless,WiMAX*

1. INTRODUCTION

WiMAX stands for Worldwide Interoperability for Microwave Access formed by WiMAX forum in 2001. It provides wireless broadband to fixed and mobile terminals in a large geographical area. The 2005 version of WiMAX provides data rate up to 40Mbits/s and 2011 version can support data rate up to 1 Gbit/s for fixed stations [1]. It is one of the latest developments and considered as a 4G (Fourth Generation) technology. Wimax supports data rate up to 75 Mbit/s which is higher than conventional cable modem and digital subscriber line (DSL) connections which are all wired access technologies. DSL has practical difficulties in providing broadband services in many urban and suburban areas because it can provide services into three miles of region. Other than this, in cable networks there does not exists any return channel and hence there is no provision for internet access. Conventional high speed internet broadband solution is difficult in remote rural areas and it does not provide good support for terminal mobility. To overcome these problems, Mobile Broadband Wireless Access (BWA) is introduced to provide flexible and cost effective solution [2]. It has many advantages as high speed, flexibility and easier to scale. It has the potential to serve customers that are unsatisfied or unserved by wired broadband services. WiMAX is based on Wireless Metropolitan Area Network (WMAN). IEEE 802.16 group developed WMAN and it is adopted by ETSI (European Telecommunication Standard Institute) in HiperMAN group i.e. High Performance Radio Metropolitan Area Network [3]. Although the work on IEEE standard started in 1999, it was only during 2003 that the standard received wide attention when the IEEE 802.16a standard was ratified in January. Mobile WiMAX scenario is shown in Figure 1 [4].

WiMAX system uses OFDM in the physical layer. OFDM is based on the adaptive modulation technique in non-line-of–sight (NLOS) environments. Base stations of WiMAX can provide communication without the need of line-of-sight (LOS) connection. WiMAX base station has enough available bandwidth so at a time it can serve large number of subscribers and also cover large area range. WiMAX standard have two versions: IEEE 802.16-2004 and IEEE 802.16e. IEEE 802.16-2004 standard supports for fixed applications so it is called as fixed WiMAX or IEEE 802.16d. It supports OFDM (Orthogonal Frequency Division Multiplexing) in physical layer. It provides wireless DSL technology where broadband cables are not available. WiMAX standard 802.16e uses OFDMA (Orthogonal Frequency Division Multiplexing Access) technique. It provides support for nomadic and mobility services so it also known as Mobile WiMAX [5].

2. WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WiMAX) NETWORKS

Worldwide Interoperability for Microwave Access (WiMAX) defines an air interface and medium access control (MAC) protocol for wireless metropolitan area networks (WMAN) intended for providing high bandwidth wireless voice, data, video and multimedia applications for residential and enterprise link to core telecommunications networks. It also serves as an alternative to cabled access networks, such as fiber optics, coaxial systems using cable modems and digital subscriber lines (DSL). Established in 1999, the WiMAX forum is an industrial consortium promoting the IEEE 802.16 standards profile for broadband wireless access systems. Variants of the IEEE 802.16 specifications include the initial IEEE 802.16 specifications that addressed line-of-sight (LOS) environments at high frequency bands (10 – 66 GHz) via conventional quadrature amplitude modulation (QAM) single carrier techniques. The limited potentials of LOS systems resulted in the development of IEEE 802.16d amendment to support non-LOS modes in radio bands of 2 to 11 GHz. Other amendment of the IEEE 802.16d resulted in the IEEE 802.16a with enhanced physical (PHY) layer operation in the same frequency bands by adding two additional PHY modes [6]:

- A 256-point fast Fourier transform (FFT) orthogonal frequency division multiplexing (OFDM) PHY mode.
- A 2048-point FFT orthogonal frequency-division multiple access (OFDMA) PHY mode. It was understood that developments were to use OFDM for both downlink (DL) and uplink (UL) to enable high performance receiver structures in the presence of frequency-selective fading channels [7]. The new PHY capability was augmented by addition of other enhancements.
- Efficient multicast-broadcast transmission schemes using single frequency network (SFN) concepts.
- Variable frame sizes (example - 2ms, 2.5ms, 5ms).
- Fast scheduling based on flexible channel quality indication (CQI).
- New forward error correction schemes including convolution turbo code (CTC) and low density parity check (LDPC) codes.
- Support for multi-antenna operation including optional advanced antenna subsystem (AAS) modes, open-loop space time coding (STC) modes (supporting two-four transmit antennas), closed-loop multiple input multiple output (MIMO) modes, and uplink coordinated space-division multiple access (SDMA).
- Frequency-diverse and frequency-specific sub-channelization schemes where respective groups of physically distributed and physically adjacent subcarriers are used to construct sub-channels.
- Adaptive modulation and coding based on hybrid automatic repeat request (HARQ) techniques.

The IEEE 802.16e mobile specification provided improved support for intercell handoff, directed adjacent-cell measurement, and sleep modes to support low-power mobile station (MS) operation. An important factor in the IEEE 802.16e is the introduction of OFDMA PHY of FFT sizes of 128, 256, 512 and 1024 in addition to the original length of 2048. This enables scalable deployment, wherein the OFDM symbol duration and inter-subcarrier separation is constant regardless of carrier bandwidth [8]. The next-generation mobile WiMAX, the IEEE 802.16m specification added FDD (frequency-division duplex) configuration, enabling multiple input multiple output (MIMO)/beamforming (BF) under frequency division duplex (FDD), adding persistent allocation to improve efficiency for VoIP (Voice over Internet Protocol) and data traffic, reducing MAP (multiple access point) control access message overhead, and reducing handoff latency. It is expected that these enhancements will meet the requirements of International Telecommunications (ITU) IMT-Advanced or the fourth generation (4G) network. The targeted performance for IEEE 802.16m includes: Backward compatibility with current mobile and fixed WiMAX systems, provision of more than twice the spectral efficiency of mobile IEEE 802.16e WiMAX in both downlink and uplink for metrics like average sector throughput, average user throughput and cell edge user throughput, provision of more than 1.5 times the VoIP capacity of 802.16e mobile WiMAX, provision of lower latency than for the 802.16e mobile WiMAX [9]. The technical profile of the evolving IEEE 802.16m mobile WiMAX is expected to include: Improved and backward compatible frame structure and system protocol, Smaller frame/sub-frame size to reduce latency, New multi-antenna technologies, Improved interference coordination and management schemes for both downlink and uplink, New control channel design with better system coverage and reduced overhead, Persistent scheduling for VoIP and real-time video services, Optimized handover, more efficient paging and random access, and a lot other enhancements.

Table 1: WiMAX Network Specification [9]

Technology	Fixed WiMAX	Fixed WiMAX	Mobile WiMAX	Mobile WiMAX
Standard	IEEE 802.16d	IEEE 802.16a	IEEE 802.16e	IEEE 802.16m
Air Interface	TDD	FDD	OFDMA/FDD	OFDMA/FDD
Throughput	≤ 75 Mbps	75 Mbps	75 Mbps	≤ 200 Mbps
Multiplexing	OFDM	OFDM	OFDMA	OFDMA
Frequency	2-11 GHz	2-11 GHz	2-11 GHz	2-11 GHz
Usage	WMAN	WMAN	WMAN	WMAN
Coverage	≤ 10 Km	10 Km	50 Km	≥50 Km
Services	Fixed Wireless Multimedia	Fixed Wireless Multimedia	Fixed Wireless Multimedia	Fixed Wireless Multimedia

Mobile broadband network evolution started in the early 1970s with the International Telecommunications Union – Radio Standardization Sector (ITU-R), First Generation (1G- analog cellular radio) network technology, generally known as the International Mobile Telecommunication (IMT) specification -1G. 1G basically uses analog cellular radio technology to transmit cells of information from mobile phones to other subscribers through transmitting towers at frequencies of up to 150 MHz implemented on Frequency Division Multiple Access (FDMA). FDMA is an access technology that allocates users with different carrier frequencies in a shared radio spectrum. The need for simultaneous voice and data transfer, single tandardization of the various country's 1G networks and improvement in overall throughput led to the advent of the IMT –2G networks in the 1980s [10]. The Second Generation (2G) broadband mobile etworks employ circuit-switched digital communication technology to transmit voice and data at low speed. The 2G networks use either Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA) to transmit/modulate radio signals. The 2G networks have throughput of up to 500 Kbps at 300 – 600 MHz. There were some inherent problems with the 2G networks which includes signal fluctuations and inconsistency in transit cells, and equipment incompatibility from different manufacturer which led to a variety of proprietary standards generally referred to as the intermediary networks (2.5G and 2.75G). 2.5G and 2.75G broadband wireless networks are enhancements of the 2G technologies to provide increased data capacity and better Quality of Service (QoS) on the 2G networks. The 2.5G networks are 2G networks that have implemented a packet-switched domain in addition to the circuit-switched domain. These intermediary networks have been integrated into the ITU's IMT-2000 family known as the 3G networks [11]. The IMT-2000 Third Generation (3G) mobile networking systems have gradually replaced the 2G, 2.5G and 2.75G networks. The 3G systems have higher quality voice channels, as well as broadband data capabilities up to 2 Mbps, with multimedia cellular radio (voice, data, audio entertainment, images, video clips, etc), at frequencies of 900, 1800, 2100 MHz. The 3G networks started with the vision to develop a single global standard for highspeed data and high-quality voice services. The goal was to have all users' worldwide use a single standard that would allow for true global roaming, but an agreement on a single 3G implementation could not be reached. Thus, all 3G technologies do not possess the same performance capabilities and 3G technologies can be split into: High Speed Downlink Packet Access (HSDPA), Code Division Multiple Access (CDMA2000), 1 x EV-DV (Evolution Data and Voice) and WCDMA (Wideband-CDMA) [12]. As the intention to have all cellular users worldwide use a single standard that would allow true global roaming was not possible with the IMT-2000 3G networks, the evolution of ITU 4G network was inevitable. The Fourth Generation (4G), IMT-Advanced is a new generation of wireless broadband network intended to complement and replace the 3G systems. This is to allow accessing information anywhere, anytime, seamless connection to a wide range of information and services that will include large volumes of information, data, pictures, video, and so on. The future 4G infrastructures will consist of a set of various networks using IP (Internet Protocol) as a common protocol with broader bandwidth, higher data rate, smoother and quicker handoff, and will focus on ensuring seamless systems and networks. The key concept is integrating the 4G capabilities with all of the existing mobile technologies [12, 13].

Table 3: Specifications for Mobile Broadband Wireless Networks [10]

Technology	1G	2G	3G	4G
standard	IIMT-1G	IEEE 802.16a	IEEE 802.16e	IEEE 802.16m
Air Interface	FDMA	TDMA/CDMA	WCDMA, CDMA2000 etc	OFDM,OFDMA, MIMO, etc
Throughput	< 400 Kbps	600 Kbps	Above 2 Mbps	Up to 200 Mbps
Coverage	<10 Km	<10 Km	Up to 10 Km	Above 50 Km
Frequency	150 MHz	300-600 MHz	900,1800, and 2100 MHz	2 to 8 GHz
Coverage	≤ 10 Km	10 Km	50 Km	≥50 Km
Services	Mobile Wireless	Mobile Wireless	Mobile Wireless, Multimedia	Mobile Wireless, Multimedia

3. CONCLUSION

WiMAX is primarily a metropolitan area network (MAN) technology and the 4G is being proposed as a universal technology that will encompass LAN, MAN, WAN, cellular and other mobile networks with backward compatibility. The 3GPP LTE Advanced is the current main contender of the Mobile WiMAX, because they share many common technologies and architectures, but also exhibit differences. One of the main differences is in the uplink, where the single-carrier FDMA (SC-FDMA) is being adopted for LTE. However, Mobile WiMAX(IEEE 802.16m) and LTE-Advanced (Release 10) remain the dominant technologies proposed to meet specification for ITU 4G broadband next generation of mobile networks.

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