

# AN ANALYSIS OF THE EXISTING TECHNOLOGY AND COMPARE WITH CELLULAR NETWORKS: WiMAX

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**Abstract:** *Broadband access technology has significant influences in the telecommunication industry. Worldwide Interoperability for Microwave Access (WiMAX) is a broadband wireless technology which brings broadband experience to a wireless context. There are two different types of broadband wireless services. One is fixed wireless broadband which is similar to the traditional fixed line broadband access technology like DSL or cable modem but using wireless as a medium of transmission. Another type is broadband wireless known as mobile broadband which has additional functionality of portability, mobility and nomad city. The IEEE 802.16 family WiMAX is designed to accommodate both fixed and mobile broadband application. WiMAX promises to solve the last mile problem which refers to the expense and time needed to connect individual homes and offices to trunk route for communications. WiMAX also offer higher peak data rates and greater flexibility than 3G networks and Wi-Fi. This thesis is provides the analysis of the broadband wireless access (BWA) technology with a focus on WiMAX and compare it with the other wireless technology like Wireless Fidelity (Wi-Fi) and third-generation (3G).*

**Keywords:** *WiMAX, Broadband, Third Generation, Wi-Fi.*

## 1. Introduction

Broadband access technology has significant influences in the telecommunication industry. It is not only provides faster web surfing but also quicker file downloads, several multimedia applications and reliable voice communications. Today broadband users are restricted to digital subscriber line (DSL) technology, which provide broadband over twisted-pair wires and cable modem technology. Both wire lines are highly

expensive and time consuming to deploy compare to the wireless technology. Another way of getting broadband access is satellite service but it is costly. Wireless technology has also clear advantage in rural areas and developing countries. Worldwide interoperability for microwave access (WiMAX) is a broadband wireless technology which brings broadband experience to a wireless context. There are two different types of broadband wireless services. One is fixed wireless broadband which is similar to the traditional fixed line broadband access technology like DSL or cable modem. Another type is broadband wireless, also known as mobile broadband which has additional functionality of portability, mobility and nomad city. WiMAX is a next generation broadband wireless technology that offers high speed, last mile broadband services. It can also use as a cellular backhaul and Wi-Fi hotspots[1],[2],[3],[14].

## 2. History of WiMAX

The history of WiMAX began several years ago to find suitable alternative of traditional wire line broadband technology that can serve wireless internet access and other broadband services and can easily deploy in rural and under developing areas where wired infrastructure was difficult to install and economically not suitable. In June 2001, a private organization named WiMAX forum was established to coordinate the components and equipment development so that company equipment will compatible and interoperate. It also began certifying the products and in January 2006 it announced its first

certified product for fixed application. In February 2006, WiMAX forum established its second lab in Seoul, South Korea to certify interoperability of WiMAX product. In 2007, Mobile WiMAX equipment which is based on IEEE802.16e got certificate and it is expected that in 2008, mobility and nomad city supported advance WiMAX equipment will get certificate and WiMAX will spread widely[5].

### 3. WiMAX Standards: IEEE 802.16 Extensions

The IEEE 802.16 group was formed in 1998 to develop the radio air interface for wireless broadband. The first version of the 802.16 completed in December 2001 which is based on the single-carrier physical layer and the burst time division multiplexed (TDM) MAC layer. Due to the technological advances, the IEEE 802.16 standards have seen many changes and adopted several extensions. The family of IEEE 802.16 standards offers enormous design flexibility, licensed and license-exempt frequency bands, QoS establishment, strong security measurements, low packet loss handovers and multicast support.

**3.1 IEEE 802.16 a:** The IEEE has developed 802.16a which is optimized for operation between frequencies from 2 to 11 GHz. This lower range of frequencies can easily penetrate barriers and thus do not require a line of sight. This version attracts most commercial interest because its range covers a number of popular bands around the world.

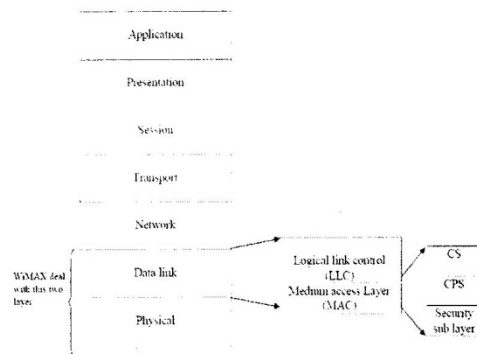


Fig. 1: OSI Reference Model where WiMAX Defined Only First Two Layer

**3.2 IEEE 802.16 b:** IEEE 802.16b extension increases the spectrum of 5 and 6 GHz frequency

bands and provides quality of service which ensures priority transmission for real time voice and video.

**3.3 IEEE 802.16 c:** In January 2003 IEEE published the version 802.16c which aimed to develop the 10-66 GHz BWA system profiles to aid interoperability specification. This version has been replaced by IEEE 802.16-2004.

**3.4 IEEE 802.16d:** IEEE 802.16d extension supports both time division duplex (TDD) and frequency division duplex (FDD) transmission.

**3.5 IEEE 802.16 e:**

IEEE 802.16 e has multicast and broadcast service feature. It also enhances the techniques of Multiple-Input Multiple-Output (MIMO) and adaptive antenna system (AAS).. It has also introduced power save modes for mobility supporting MSs.

**3.6 IEEE 802.16f:** Improve the coverage area by using the mesh networking. Mesh networking has the ability to bypass obstacles and only a small amount of meshing can largely improve the coverage area of base station.

**3.7 IEEE 802.16 g:** This technology support mobility at higher layer and across backhaul. It's not yet fixed whether OFDM or OFDMA will be the transmission technique[10].

### 4. Protocol layers of WiMAX

WiMAX/802.16 is based on the physical and data link layer of the OSI reference model where physical layer is single-carrier (PHY) layer and the data link layer is subdivided into logical link control (LLC) and the medium access control (MAC) sub layer. MAC layer is based on burst Time Division Multiplexing (TDM) layer and is again subdivided into Convergence sub layer (CS), Common part sub layer (CPS) and finally the security sub layer[14]. Figure 1 shows the OSI seven layer model where WiMAX particularly deals with the Physical and the MAC portion of the Data link layer since it is a connection oriented technology.

#### 4.1 WiMAX Physical Layer

Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. It also defines the type of modulation and demodulation as well as transmission power. WiMAX physical layer is based on the orthogonal frequency division multiplexing (OFDM). OFDM is a good choice

of high speed data transmission, multimedia communication and digital video services. It even can maintain very fast data rate in a non line of sight condition and multipath environment. In the following subsection we provide a detailed description of the OFDM. WiMAX 802.16 physical layer considers two types of transmission techniques OFDM and OFDMA. Both of these techniques have frequency band below 11 GHz and use TDD and FDD as its duplexing technology. MAC layer provides an interface between the physical layer and the upper layer. It takes packets from the upper layer and prepares it for the transmission over the air. It also maintains the scheduling and multiple access connection[14].

#### OFDM Basics

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers as shown in Figure 3.4. In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread[5].

#### OFDMA Symbol Structure and Sub-Channelization

Sub channel is created by the group of sub carriers and in frequency domain modulated symbols are mapped onto this sub channel. There are four types of sub carriers in OFDM where only data sub carrier carries the useful data. The other types of sub carriers are pilot sub carrier, null sub carrier and the direct current sub carrier. Data sub-carriers for data transmission Pilot sub-carriers for estimation and synchronization purposes Null sub-carriers for no transmission; used for guard bands and DC carriers[5].

#### OFDM Multiple-Access Strategies

OFDM multiple-access strategies provide no interfering orthogonal communication channels. Usually Frequency division multiple access (FDMA), Time division multiple access

(TDMA) and code division multiple access (CDMA) handle multiple users by dividing the available size. In FDMA, each user gets unique carrier frequency. In TDMA, user can send and receive data in a unique time slot. In orthogonal CDMA each user can share both bandwidth and time slots with other users but each user is separated by unique orthogonal code. So in this technique if there are for example five users, there would be five frequency slots in FDMA. In TDMA, individual user can use all five frequency slots but only one fifth of the time and in CDMA, each user can use all five frequency slot in all the time but use only a unique orthogonal code out of the five codes. The reason for this separation is to eliminate the interference among the individual user. OFDM achieved most of the best features of the multiple access techniques[5].

#### 4.2 WiMAX MAC layer

The different sub layer of the MAC layer has performed different functions. The convergence sub layer (CS) takes higher layer protocol data unit (PDU) and process it. The common part sub layer (CPS) is responsible for connection setup, bandwidth allotment and the connection maintenance. The security sub layer of the MAC layer provides authentication, encryption and the integrity of the data. WiMAX MAC layer set an interface between the physical layer and the higher transport layer. It takes MAC Service Data Units (MSDUs) packets from the higher layer and prepares it for transmission over the air[4]. Figure 2 shows MAC layer.

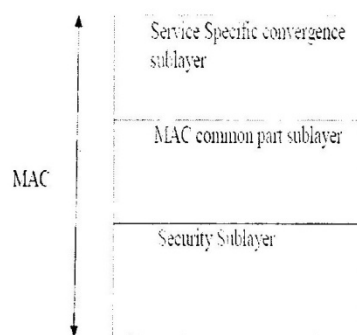


Fig. 2: WiMAX MAC Layer[3]

### 5. WiMAX Modulation Technology

Modulation is a process where carrier wave carries the digital signal or message. There are three basic types of modulation, Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK). WiMAX technology combined ASK and PSK and formed Quadrature Amplitude Modulation (QAM) where both the amplitude and phase are changed. WiMAX supports adaptive modulation and coding which can increase the system capacity and range when necessary. Higher order modulation such as 64 QAM has higher throughput but lower range[15]. On the other hand lower order modulation like 16 QAM has lower throughput but higher range from the same base station.

### 6. Design of WiMAX

WiMAX is designed to support high speed broadband services. Usually it has two parts:

1. WiMAX base station
2. WiMAX receiver

#### WiMAX Base Station

WiMAX base station is similar to a cellular network base station which consists of a WiMAX tower and indoor electronics. Base station performs the MAC and PHY features. It also handles the signaling and user scheduling. It is also responsible for uplink and downlink bandwidth management on a real time basis and frequency reuse.

#### WiMAX Receiver

WiMAX receiver could be a WiMAX enabled computer, PCMCIA card, WiMAX modem, mobile internet devices or a standalone box. It works like a Wi-Fi network but in a broader coverage area[12].

### 7. Mechanism of WiMAX Technology

Depending on the frequency range WiMAX can provide two types of Wireless services, Line of sight (LOS) and Non line of sight (NLOS).

Fig. 3 represents how WiMAX works and shows LOS and NLOS.

#### 7.1 Line of Sight (LOS)

LOS operates in higher frequencies between 10-66 GHz. This frequency range is called millimeter bands. Since line of sight uses higher frequencies, it can provide higher bandwidth

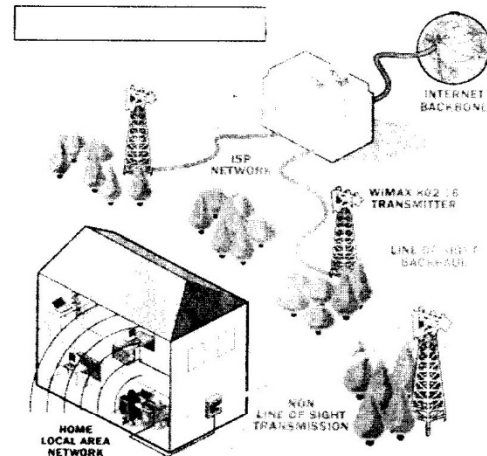


Fig. 3: How WiMAX Works

with less interference. Its coverage area also huge. Theoretically it is 30 mile radius. For LOS there should be direct contact between the WiMAX tower

and the dish antenna from the customer sight which could be placed in the rooftop or a pole. In this way subscriber can get great data capacity.

#### 7.2 Non Line of Sight (NLOS)

NLOS uses lower frequencies between 2 GHz to 11 GHz. This lower frequency range is called centimeter band. The advantage of these lower frequencies is, it can bend or diffract around obstacles. This advantage helps the multipoint communication, so more customers can get the services from a single tower which reduces the service cost also. Usually it is 4 to 6 mile radius which is similar to a cell phone coverage area [12].

### 8. Power Control and Management in WiMAX

Modulation method BPSK is use for serving long distance subscriber station. This scheme takes higher power but data efficiency is less. On the other hand, 64 QAM is best for providing greater quality data but it usually served the closest subscriber station.

WiMAX follows two types of power saving method: Sleep mode and Idle mode.

#### Sleep mode

In sleep mode, MS breaks its connection with the BS for a particular amount of time. This time is selected by the MS by negotiating with the BS..

During sleep time MS can minimize its power consumption as well as radio resource of BS. In this time period, it can also look for the handoff information from the other BS.

#### Idle mode

In idle mode, mobile station turns off completely which saves greater power than the sleep mode. In this mode MS don't need to register itself to the BS, but still it receives downlink data transmission. Several base station forms the phase group and before going to the idle mode, BS assigns the MS to a particular phase group. MS awake from time to time to see at which phase group it resides. If it goes to a new phase group, it updates the other phase group in the network about its current location. So if and downlink data comes in the idle mode, it goes to its current phase group. Since in idle mode MS does not maintain any active connection to the BS, so it don't need to handoff and it can save the PHY and MAC layer resources also[15].

### 9. WiMAX Network Topology

WiMAX deals with both point-to-point (P-P) and point-to-multipoint (P-MP) networks. PP networks can easily deploy and it can provide high speed data with minimum interference. It can provide last mile solution. This P-P network usually takes less operating and maintenance cost and can provide direct services to the end users. On the other hand P-MP network can provide services to hundreds of subscribers within a single radio environment. Here by using multiplexing and queuing method, many

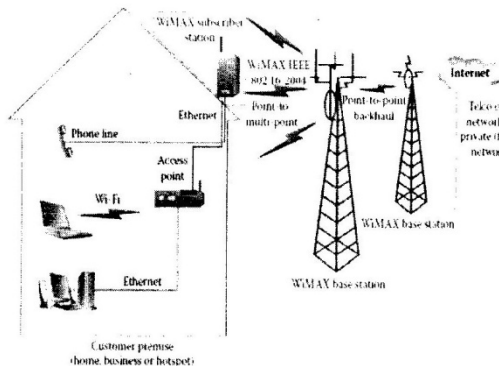


Fig. 4: WiMAX Network Topology [7]

subscribers uses the single radio channel for its Communication.

Fig. 4: shows the network topology of WiMAX where two WiMAX base stations are connected with point-to-point microwave link. Base station is usually connected with the core network by fiber optic cable. WiMAX subscriber station could be mounted on the rooftop of the customer premises equipment which can establish high speed line of sight connection with the base station or the base station could provide point to multipoint link which is cost effective and work even in obstructed environment. WiMAX has NRM(Network Reference Model) and Mesh network for better performance.

### 10. Quality of Services

WiMax Technology has a powerful QoS feature which ensures better quality of interactive and real time audio and video services. WiMAX Protocol gives the option to the service provider to maintain QoS. Provider can give priority to a particular data or dedicated bandwidths for real time traffic while properly maintain the normal data on the other line. Following are the variety of QoS.

**Unsolicited Grant Service (UGS):** It provides constant bit rate (CBR) as VOIP does.

**Real time polling service (rtPS):** It provides real time variable bit rate (VBR) like teleconference or MPEG video.

**Non real time polling service (nrtPS):** It provides non-real time services like bandwidth indifferent file transfer that need better QoS.

**Best effort services (BE):** It provides best effort data like HTTP traffic. BE traffic don't required guaranteed QoS and **Enhance real-time polling service (ertPS):** It is designed to support real time services with variable bit rate like VOIP[9].

### 11. WiMAX Security

IEEE 802.16 standard clearly describes the security issues for fixed and mobile WiMAX network. It also shows how to secure the physical and MAC layer. In this security mechanism, security sub layer is responsible for authentication and encryption processes and privacy and key management protocol (PKM) is responsible for user privacy from theft of services. This security sub layer use authenticated key management protocol where BS is responsible for distributing keying data to the SS. On the whole, WiMAX security architecture deals with all of the basic wireless



security requirements like authentication, authorization, access control, data integrity and privacy[11].

## 12. Comparison among the Technologies

Here we will compare the technologies, especially WiMAX, Cellular and Wi-Fi.

### 12.1 WiMAX versus Cellular Technology 3G

WiMAX throughput capabilities depend on selectable channel bandwidth between 1.25 MHz to 20 MHz which is very much effective for the flexible deployment of WiMAX network. On the other hand 3G system uses fixed channel bandwidth. WiMAX uses OFDM as a modulation technique which is suitable for very high peak rate but 3G systems uses CDMA where achieving very high data rate is more difficult. WiMAX offer higher spectral efficiency than the 3G system. Its multiple antenna technique raises the spectral efficiency. Its OFDM based physical layer is more tractable in MIMO implementation. Compare to the CDMA based 3G system where achieving higher gain arise complexity. It is also improve the capacity by taking the advantage of multi user diversity and frequency diversity. WiMAX system has the ability to support more symmetric links which is useful for dynamically adjust the downlink to uplink ration. It is also useful for the fixed application. WiMAX is a better technology for multimedia application than the 3G[2]. Its MAC layer is designed to support various types of traffic. Its strong quality of service mechanism is useful for real time and non real time data, best effort and priority based data. An important advantage of WiMAX is its light-weight IP architecture. Using one IP architecture make it easier for WiMAX core network, on the other hand 3G technology use different core network for voice and data which increases the operating cost. Moreover WiMAX can serve greater number of users with optimum performance which reduces the cost and improved the operational efficiencies. Though WiMAX added mobility functionalities but it is not proves yet how much mobility it can support. On the other hand 3G technologies have inherent functionally for supporting roaming and mobility. Rate of CDMA2000 (3G) rate is 2Mbps but WiMAX is 72Mbps. Bandwidth of WiMAX is larger than 3G.

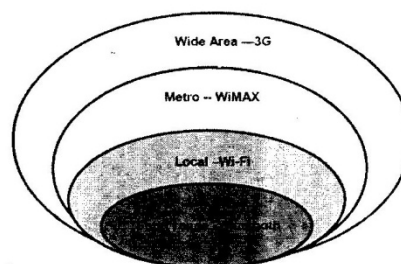


Fig. 5: Technology Range [13]

Fig. 5 shows the ranges of different technology. Here we see that 3G cover the greatest distance and WiMAX sits in the middle.

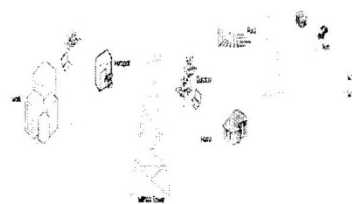


Fig. 6: WiMAX vs. Wi-Fi Coverage Area[13]

### 12.2 WiMAX vs. Wi-Fi

WiMAX and Wi-Fi both are wireless broadband technology but Wi-Fi signal has a very limited range. So if a user's move from one place to another, H/She must find the hotspot or access point and set up a new connection. On the other hand, WiMAX cover metropolitan size areas so there is no need of hotspot. Wi-Fi network power level is lower. On the other hand WiMAX power level is one to two orders of magnitude greater than Wi-Fi. This advantage allows WiMAX system to cover far greater distances. For covering larger area, Wi-Fi should setup lots of Access point which increases the cost, On the other hand WiMAX sectorized antenna can be placed in the existing cell phone tower which reduces the cost. Further, by using array of tower, wider coverage area of many miles can be achieved. WiMAX can tolerate extended multipath signal delays which are up to 10

microseconds versus Wi-Fi which can tolerate just 0.5 microseconds. WiMAX works both license and unlicensed bandwidth and it range 2-30 miles. Its speed is 70Mbps. On the other hand Wi-Fi works unlicensed bandwidth and it range 50-1500ft. Its speed is 6-54Mbps[2].

Fig. 6 shows the typical distances covered by the WiMAX and Wi-Fi network. Wi-Fi is suitable for small home or office environment whereas WiMAX can cover many miles and filling the gap between the Wi-Fi hotspots. In this sense Wi-Fi and WiMAX is not a competitor rather a friendly technology. The biggest difference isn't speed; it's distance. WiMAX outdistances Wi-Fi by miles.

Wi-Fi's range is about 100 feet (30 m). WiMAX will blanket a radius of 30 miles (50 km) with wireless access. WiMAX is not designed to clash with Wi-Fi, but to coexist with it. WiMAX coverage is measured in square kilometers, while that of Wi-Fi is measured in square meters. The original WiMax standard (IEEE 802.16) proposes the usage of 10-66 GHz frequency spectrum for the WiMAX transmission, which is well above the Wi-Fi range (up to 5GHz maximum). But 802.16a added support for 2-11 GHz frequency also. One WiMax base station can be accessed by more than 60 users. WiMAX can also provide broadcasting services also.

### 13. Conclusions

During the last few years, broadband wireless technology growth significantly which results the emergence of WiMAX. It can be used to deliver variety of services and applications. IEEE 802.16 standard WiMAX has different versions from 802.16a to 802.16h where each new version has come with new features and solve some difficulties and restrictions of the previous version. The other features of WiMAX include strong quality of service, robust security, scalability, mobility support, high data rate and flexible architecture. WiMAX has a very robust and flexible air interface. Its physical layer is based on OFDM modulation technology. OFDM uses cyclic prefix and Inverse Fast Fourier

Transform which is very much effective for overcoming multipath distortion and intersymbol interference. The other feature of WiMAX PHY layer is its multiple antenna support which is used for special multiplexing, beam forming and diversity. Another important feature of WiMAX PHY layer is its powerful error correcting coding. WiMAX MAC layer architecture supports various types of QoS requirements. Based on the QoS needs, it can handle the data packets differently. Another WiMAX MAC layer advantage is its power saving operation. Its sleep mode and idle mode operation saves the battery power[16].

Moreover, like the cellular network, it supports full mobility which can be switched off in fixed application. It is also responsible for PDU construction, ARQ and its powerful authentication and encryption scheme provides some sort of security to the user data. WiMAX network architecture supports all usage models (fixed, mobile & nomadic). It also support high capacity real time and non real time voice, data and multimedia services while maintaining the appropriate QoS. Moreover it supports idle mode operation and paging for the mobile station. Its network reference model support interoperability. WiMAX has very powerful security architecture. It uses Advance Encryption Standard (AES) for its encryption mechanism which is very fast and efficient computational capability for both hardware and software operation. By comparing the WiMAX, Wi-Fi and 3G technology, we observe that WiMAX offers better services than the Wi-Fi and 3G. WiMAX network can be a good choice to fill up the gap between the Wi-Fi hotspots. It also resolves some of the technical difficulties of Cellular network. Moreover it is highly flexible and spectrally efficient. It also offers both LOS and NLOS data transmission, extensible security mechanism and broad bandwidth. It is not far away where everybody will be able to access the high speed internet connectivity at any time at any place like the mobile phone we use today.

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