WX-E - WiMAX - The Essentials for Engineers and Technicians

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Short Description

WiMAX - The Essentials provides a snapshot of all aspects of mobile WiMAX networks, beginning with a discussion of the current state of wireless networks and a definition as to where WiMAX fits in. The WiMAX network architecture and its components are introduced to provide an end-to-end view of the WiMAX network.

Description

WiMAX - The Essentials provides a snapshot of all aspects of mobile WiMAX networks, beginning with a discussion of the current state of wireless networks and a definition as to where WiMAX fits in. The WiMAX network architecture and its components are introduced to provide an end-to-end view of the WiMAX network.

It also provides an overview of important WiMAX operations such as connection setup, bandwidth allocation schemes and mobility. It contains the essentials - easy to use, easy to refer to, easy to implement.

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1 Introduction to WiMAX

1.1 Introduction

WiMAX (Worldwide Interoperability for Microwave Access) has become synonymous with the IEEE 802.16 Wireless Metropolitan Area Network (WMAN) air interface standard.

WiMAX can be used for wireless networking like the popular Wi-Fi. It is a second-generation protocol, partially a successor to the Wi-Fi protocol. Wi-Fi distances are measured in feet and works over shorter distances, whereas WiMAX allows higher data rates over longer distances, efficient use of bandwidth, and reduces interference to a minimum.

In the areas where the conventional wire-line DSL and cable are NOT readily available, WiMAX-compliant systems will provide a cost-effective fixed wireless alternative. The evolution of IEEE 802.16 will expand the standard to address mobile applications thus enabling broadband access directly to WiMAX-enabled portable devices ranging from smart phones and PDAs (Personal Digital Assistants) to notebook and laptop computers. The latest 802.16e amendment supports the mobility in WiMAX system.

1.1.1 WiMAX abilities

The principle of operation of WiMAX is same as the Wi-Fi. The data transmission from one computer to another is via radio signals. A computer (either a desktop or a laptop) equipped with WiMAX would receive data from the WiMAX transmitting station, probably using encrypted data keys to prevent unauthorized users from stealing access.

Under optimal conditions, the fastest Wi-Fi connection can transmit up to 54Mbps (megabits per second). It should be able to handle up to 70Mbps. It will provide at least the equivalent of cable-modem transfer rates to each user, even if those 70MB is split up between several dozen businesses or a few hundred home users.

Visual representation of WiMAX setup is shown in Figure 1.1. The main difference between WiMAX and Wi-Fi is the distance but not the speed. Wi-Fi's range is about 100 feet (30m) whereas WiMAX will cover a radius of 30 miles (50km) with wireless access. The increased range is due to the frequencies used and the power of the transmitter. At that distance, terrain, weather and large buildings will act to reduce the maximum range in some circumstances, but the potential is there to cover huge tracts of land.

Figure 1.1

Visual representation of WiMAX setup

1.2 WiMAX broadband services

The term broadband commonly refers to high-speed Internet access. The FCC (Federal Communications Commission) defines broadband service as data transmission speeds exceeding 200Kbps (kilobits per second), or 200,000bps (bits per second), in at least one direction i.e. downstream (from the Internet to the user's computer) or upstream (from the user's computer to the Internet).

1.2.1 Differences between broadband and dial-up service

Here is a list of the major differences between these two services:

- Broadband is always ON (does not block phone lines and no need to reconnect to network after logging OFF).
- Broadband service provides higher speed of data transmission.
- It provides access to the highest quality Internet services (streaming media, VoIP (Internet phone), gaming, and interactive services).
- Delay in transmission is less.
- The newly developing services require the transfer of large amounts of data, which may not be technically feasible with dial-up service. Therefore, broadband service may be increasingly necessary to access the full range of services and opportunities that the Internet can offer.

1.2.2 Types of broadband connections

Broadband connections include several high-speed transmission technologies such as:

- Satellite
- Cable Modem
- Digital Subscriber Line (DSL)
- Broadband over Power Lines (BPL)
- Fiber
- Wireless

The choice of the broadband technology will depend on number of factors such as:

- Users located in urban or rural area.
- How broadband Internet access is packaged with other services (like voice telephone and home entertainment).
- Price
- Availability

In remote or sparsely populated areas DSL or cable modem service will be costly, therefore Wireless technologies using longer range directional equipment will be effective in providing broadband services. Speeds are generally comparable to DSL and cable modem, an external antenna is usually required.

Wireless broadband connection to the internet is through a radio link between the customer's location and the service provider's facility. Wireless broadband can be mobile or fixed.

Fixed wireless broadband service is becoming more widely available at airports, city parks, bookstores, and other public locations called "hot spots." Hot spots generally provide speeds up to 54Mbps. Wireless-Fidelity (Wi-Fi) technology is also often used in conjunction with DSL or cable modem service to connect devices within a home or business to the Internet via a broadband connection.

Mobile wireless broadband services are mostly available in moving buses, trains etc. These services are also becoming available from mobile telephone service providers and others. These require a special PC card with built in antenna that plugs into a user's laptop and are generally appropriate for highly mobile customers.

1.3 Wi-Fi – an introduction

Wi-Fi is a brand originally licensed by the Wi-Fi Alliance to describe the underlying technology of Wireless Local Area Networks (WLAN) based on the IEEE 802.11 specifications.

Wi-Fi was developed for use in mobile computing devices, such as laptops and in LANs as shown in Figure 1.2, but is now increasingly used for more services, including Internet and VoIP phone access, gaming, and basic connectivity of consumer electronics such as televisions and DVD players, or digital cameras. More standards are in development that will allow Wi-Fi to be used by cars in highways in support of an Intelligent Transportation System to increase safety, gather statistics, and enable mobile commerce (IEEE 802.11p exclusively covers this aspect of technology).

Wi-Fi and the Wi-Fi certified logos are registered trademarks of the Wi-Fi alliance – the trade organization that tests and certifies equipment compliance with the 802.11x standards.

Figure 1.2

A basic Wi-Fi network diagram

1.3.1 Advantages of Wi-Fi

Here are some of the advantages of Wi-Fi:

- Built into all modern laptops, IDE (Integrated Device or Drive Electronics) cards are available for desktop machines and other PC devices to use the Wireless Communication.
- Allows LANs to be deployed without cabling, typically reducing the cost of network deployment and expansion. Spaces where cables cannot be run, such as outdoor areas and historical buildings, can host wireless LANs.
- Wi-Fi chipset pricing continues to reduce, making it a very economical networking option and driving inclusion of Wi-Fi in an ever-widening array of devices.
- Different brands of Access Points and client network interfaces are interoperable at a basic level of service. Wi-Fi products are widely available in the market. Products designated as Wi-Fi certified by the Wi-Fi alliance are interoperable and include WPA2 security.
- Wi-Fi is a global set of standards. Unlike cellular carriers, the same Wi-Fi client works in different countries around the world.
- Widely available in a large number of public hot spots, millions of homes, corporate and university campuses. Wi-Fi is becoming popular and the numbers are increasing.
- If strong passwords are used, Wi-Fi Protected Access (WPA and WPA2)

encryption is not easily crackable.

- New protocols for Quality of Service (QoS) (like 802.11e for Wi-Fi Multimedia (WMM) standards) and power saving mechanisms (WMM Power Save) make Wi-Fi even more suitable for latency-sensitive applications (such as voice and video) and small form-factor.

1.3.1 Wi-Fi – the disadvantages

Of course there are always going to be some disadvantages with any technology. Those for Wi-Fi include the following:

- Spectrum assignments and operational limitations are not consistent worldwide; most of Europe allows for an additional two channels beyond those permitted in the US (1-13 vs. 1-11); Japan has 1-14 channels. Some countries, like Spain, prohibit use of the lower-numbered channels.
- Wi-Fi networks can be monitored and are used to read/copy data (including personal information) transmitted over the network unless encryption such as WPA (Wi-Fi Protected Access) or VPN (Virtual Private Network) is used.
- Wi-Fi Access Points typically default to an open (encryption-free) mode. Novice users benefit from a zero configuration device that works out of the box but might not intend to provide open wireless access to their LAN.
- Many 2.4GHz 802.11b and 802.11g Access Points default to the same channel, contributing to congestion on certain channels.
- Wi-Fi networks have limited range. A typical Wi-Fi home router using 802.11b or 802.11g with a stock antenna might have a range of 45m (150ft) indoors and 90m (300ft) outdoors. 2.4GHz frequency block has better range than 5GHz frequency block, and less range than the oldest Wi-Fi (and pre-Wi-Fi) 900MHz block. Outdoor range with improved antennas can be several kilometers or more with LOS (Line of Sight).
- It is also an issue when municipalities or other large entities such as universities seek to provide large area coverage. Everyone is considered equal during band usage (except for amateur radio operators who are the primary licensee). This openness is also important to the success and widespread use of Wi-Fi, but makes it unsuitable for must have public service functions.
- 11b and 802.11g standards use the 2.4GHz band. Due to this choice of frequency band, 802.11b and 802.11g equipment will suffer interference from microwave ovens, cordless telephones, Bluetooth devices, baby and security monitors, amateur radio and other appliances using this band.

1.4 Modulation schemes

1.4.1 Frequency-Shift keying (FSK)

Frequency-Shift keying (FSK) is a frequency modulation scheme in which some characteristics (frequency) of the high frequency sine wave (carrier) is varied in accordance with the discrete modulating signal (data). Figure 1.3 shows binary states Zero (low) and one (high) represented by an analog waveform. Binary FSK (BFSK) is the simplest FSK. Binary “1" is called the mark frequency and the binary "0" is called the space frequency. Figure 1.3 shows FSK waveforms.

Binary data from a computer is converted in to FSK by a modem for transmission over telephone lines, cables, optical fiber, or wireless media. The modem also converts incoming FSK signals to digital low and high states, for the computer to understand.

Figure 1.3

Frequency-Shift Keying

1.4.2 Quadrature Amplitude Modulation (QAM)

QAM (Quadrature Amplitude Modulation) is modulation in which two Amplitude-Modulated (AM) signals are combined into a single channel, hence doubles the effective bandwidth. Especially in wireless applications, QAM is used with Pulse Amplitude Modulation (PAM) in digital systems. Figures 1.4 and 1.5 show analog and digital waveforms of QAM respectively.

Figure 1.4

QAM Analog Modulation

Figure 1.5

QAM Digital Modulation

In a QAM signal two sinusoidal carriers each having the same frequency but, one exactly 90 degrees out of phase with respect to the other. Since two sinusoidal carriers, are out of phase with each other by 90° they are called Quadrature carrier. One signal is called the I signal, and the other is called the Q signal. These two signals can be represented mathematically, one by a sine wave, and the other by a cosine wave. The two modulated carriers are combined at the source for transmission. At the destination, the carriers are separated, the data is extracted from each, and then the data is combined into the original modulating information.

QAM enables data transmission at twice the rate of standard Pulse Amplitude Modulation (PAM) without any degradation in the Bit Error Rate (BER). QAM and its derivatives are used in both mobile radio and satellite communication systems.

Most common forms of QAM are 16-QAM, 32-QAM, and 64-QAM. In 16-QAM four different phases and four different amplitudes are used for 16 different symbols. This means such a coding is able to transmit 4bps, same principle for 32 QAM.

1.4.3 Phase-Shift keying (PSK)

Phase-Shift keying (PSK) is a digital modulation in which phase of the carrier is varied in accordance with the modulating signal (data). Figure 1.6 shows PSK waveforms.

PSK uses a finite number of phases in which each phase is assigned a unique pattern of binary bits, which represents digital data. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The original signal is recovered by the demodulator, which determines the phase of the received signal and maps it back to the symbol it represents. This requires the receiver to be able to compare the phase of the received signal to a carrier signal; such a system is known as Coherent Phase-Shift Keying (CPSK).

Figure 1.6

Phase -Shift Keying

1.4.4 Binary Phase-Shift keying (BPSK)

Binary Phase-Shift keying (BPSK) is a modulation in which the phase of the RF carrier is shifted 180 degrees in accordance with a digital bit stream. Since it uses two phases, which are separated by 180º it is termed as 2-PSK. BPSK follows NRZ-M (Non-Return-to-Zero-Mark) digital coding scheme. Digital '1' causes a phase transition, and a digital '0' does not produce a transition. This avoids the confusion about the polarities of the signal. Figure 1.7 shows Binary Phase-Shift Keying waveforms.

Differentially coherent detection process is performed by the receiver, in which the phase of each bit is compared to the phase of the preceding bit. BPSK offers a 6-dB advantage in signal-to-noise ratio over on-off keying for a given carrier level.

Figure 1.7

Binary Phase-Shift Keying

1.4.5 Quadrature Phase-Shift keying (QPSK)

Quadrature Phase-Shift keying (QPSK) is a phase modulation algorithm. In this form of Phase-Shift Keying four different phase angles are used. In QPSK, the four angles are usually separated by 90° spacing. Figure 1.8 shows phase of the carrier wave is modulated to encode bits of digital information in each phase change.

Figure 1.8

Quadrature Phase-Shift Keying

1.5 WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless broadband technology, which supports Point-to-Multi-Point (PMP) broadband wireless access as shown in Figure 1.9.

There are two main applications of WiMAX:

- Fixed WiMAX applications are point-to-multipoint enabling broadband access to homes and businesses.
- Mobile WiMAX offers the mobility of cellular networks at true broadband speeds. Both fixed and mobile applications of WiMAX are engineered to help deliver ubiquitous, high-throughput broadband wireless services at a low cost.

As stated in the 802.16 standard, fixed wireless is the base concept for the Metropolitan Area Networking (MAN). In fixed wireless, a backbone of base stations is connected to a public network. Each of these base stations supports many fixed subscriber stations, either public Wi-Fi hot spots or firewalled enterprise networks; Media Access Control (MAC) is also used for these base stations. Uplink and downlink bandwidth is allocated to subscribers as per their individual needs and is based on real-time need.

Figure 1.9

WiMAX has the potential to affect all forms of telecommunications

WiMAX systems typically consists of two parts:

- A WiMAX base station: Base station consists of WiMAX tower and indoor electronics. Typically, a base station can cover up to 10km radius (Theoretically, it can cover up to 50km radius or 30 miles, however practical considerations limit it to about 10km or 6 miles). Any wireless node would be able to access the Internet within the coverage area.
- A WiMAX receiver - The receiver and antenna could be a stand-alone box or a PCMCIA (Personal Computer Memory Card International Association) card that sits in a laptop or computer. Access to WiMAX base station is similar to accessing a Wireless Access Point (WAP) in a Wi-Fi network, but the coverage and speeds are more.

By using high-speed backhaul microwave links, several base stations can be connected with one another. This would allow for roaming by a WiMAX subscriber from one base station to another base station area, similar to cellular phone companies.

Important Wireless MAN IEEE 802.16 (WiMAX) specifications:

- Range can cover 30 mile (50km) radius from base station.

- Speed: Up to 70Mbps
- Non-Line-of-sight (NLOS) between user and base station.
- Frequency bands: 2 – 11 GHz and 10 – 66 GHz (licensed and unlicensed bands)

Both MAC and PHY layers are defined in 802.16 standards and allows multiple PHY-layer specifications. The subscriber stations might also be mounted on rooftops of the users. The MAC layer is a common interface that makes the networks interoperable. In the future, 802.11 hot spots might be hosted by 802.16 MANs. These would serve as wireless Local Area Networks (LANs) and would directly serves the end users.

WiMAX supporters are focusing on the broadband last mile in unwired areas, and on backhaul for Wi-Fi hot spots. WiMAX is expected to support mobile wireless technology and wireless transmission directly to mobile end users. Wi-Fi has changed the last hundred feet of networking similarly WiMAX would change the last mile problem for broadband.

Range of WiMAX is up to 30 miles, which can be used to provide both campus-level network connectivity and a wireless last-mile approach. This can bring high-speed networking and Internet service directly to customers. This is especially useful in the areas where the DSL or cable services are not available or the deployment of the broadband services takes a long time.

WiMAX 802.16 standard published in March 2002 provides information on the Metropolitan Area Network (MAN) technology. The LOS fixed wireless MAN standard is extended, mainly focusing on the spectrum from 10 – 60 GHz, in the extension given in the March publication. This extension provides for NLOS access in low frequency bands like 2 – 11 GHz. These bands are sometimes unlicensed. This support PMP (Point to Multipoint) and mesh technologies and boosts the maximum distance from 30 – 50 miles.

IEEE approved the 802.16 standards in June 2004, and three working groups were formed to evaluate and rate the standards.

802.16's predecessors (like 802.11a) were not very accommodative of the European standards; the devices based on 802.11a had to undergo major modifications to work in Europe. European HiperLAN standard was issued to compete with the US-centric 802.11 series of standards. However, as the Wi-Fi exploded, the European HiperLAN standards failed to get popularity.

Today’s WiMAX standard incorporates Europe’s newer HiperMAN standard as well as the Korean WiBro, which is a version of Mobile WiMAX or 802.16e. The IEEE wireless standard 802.16e has a range of up to 30 miles, and can deliver broadband at around 70Mbps. This is theoretically twenty times faster than a commercially available wireless broadband.

1.5.1 The WiMAX system

Figure 1.10 shows some of the applications that WiMAX networks can provide. It shows that WiMAX systems can be used for Point-to-Point links, residential broadband or high-speed business connections. It also shows that the Point-to-Point (PtP) connection may be independent from all other systems or networks. The Point-to-Multi-Point (PMP) system allows a radio system to provide services to multiple users. WiMAX systems can also be setup as mesh networks allowing it to forward packets between base stations and subscribers without having to install communication lines between base stations.

Figure 1.10

WiMAX system types

1.5.2 Radio channels

The key components of a basic WiMAX radio system are shown in Figure 1.11. This diagram shows that the major components of a WiMAX system include a Subscriber Station (SS), a Base Station (BS) and interconnection gateways to datacom (e.g. Internet) and telecom (e.g. PSTN). An antenna and receiver (subscriber station) in the home or business converts the microwave radio signals into broadband data signals for distribution in the home. In this example, a WiMAX system is being used to provide telephone and broadband data communication services. WiMAX system converts broadcast signals to an audio format (such as VoIP) when used for telephone services for distribution to IP telephones or Analog Telephone Adapter (ATA) boxes. When WiMAX is used for broadband data, the WiMAX system also connects the Internet through a gateway to the Internet. This example also shows that the WiMAX system can reach distances of up to 50km when operating at lower frequencies (2–11 GHz).

Figure 1.11

WiMAX radio channel

1.5.3 WiMAX Standards

Figure 1.12 shows the evolution of 802.16 broadband wireless systems. This Figure 1.12 shows that the original 802.16 specification defined fixed broadband wireless service operates in the 10-66 GHz frequency band. 802.16A specification was created to provide wireless broadband service in lower frequency range i.e. 2–11 GHz frequency band. 802.16e was developed to provide both fixed and mobile service.

Figure 1.12

WiMAX standards evolution

1.5.4 Comparison with Wi-Fi

There is a possibility of comparison and confusion between WiMAX and Wi-Fi as both begin with the same two letters, and are based upon IEEE standards beginning with 802, and are both to do with wireless connectivity and the Internet. Despite this, both standards are aimed at different applications.

WiMAX is a long-range (many kilometers) system that uses licensed spectrum to deliver a PtP connection to the Internet from an ISP (Internet Service Provider) to an end user. Different types of accesses provided by different 802.16 standards, from mobile (analogous to access via a cell phone) to fixed (an alternative to wired access, where the end user's wireless termination point, fixed in location.)

Wi-Fi is a shorter-range (hundreds of meters) system that uses unlicensed spectrum to provide access to Internet or intranet resources. Wi-Fi is frequently used to provide Internet access to third parties within a single room or building, sometimes informally and sometimes as part of a business relationship due to its ease and low cost.

1.5.5 WiMAX vs Wi-Fi Scalability

The standard supports flexible RF channel bandwidths and reuse of these channels (frequency reuse) at the PHY layer to increase cell capacity as the network grows. The standard also specifies support for automatic transmit power control and channel quality measurements as additional PHY layer tools to support cell planning/deployment and efficient spectrum use. As the number of subscribers grows, operators can re-allocate spectrum through sectorization and cell splitting. In addition, support for multiple channel bandwidths enables equipment makers to provide a means to address the unique government spectrum use and allocation regulations faced by operators in diverse international markets. The IEEE 802.16a standard specifies channel sizes ranging from 1.75MHz up to 20MHz with many options in between.

Wi-Fi based products have a minimum requirement of 20MHz per channel. This is 22MHz in case of 2.4GHz band for 802.11b. Here, the license exempt bands are 2.4GHz, 5GHz and Unlicensed National Information Infrastructure (U-NII) for operation.

The MAC layer of 802.11 functions as effectively as Ethernet. However, as the users increase, In the MAC layer, the CSMA/CA foundation of 802.11(a wireless Ethernet protocol) scales about as well as does Ethernet. Just as in an Ethernet LAN, more users results in a geometric reduction of throughput, same as CSMA/CA MAC for WLANs. In contrast, the MAC layer in the 802.16 standard has been designed to scale from one up to 100s of users within one RF channel, which was never designed and was incapable of supporting with 802.11 MAC.

Coverage Comparison

WLANs and 802.11 systems are designed based on a CDMA approach or an OFDM design different from that used in WiMAX, and have as a requirement low power consumption limiting the range. OFDM in the WLAN was expected to provide a maximum coverage of a few hundred meters.

The ODFM designed for 802.16 is expected to cover something in the range of tens of kilometers. The Broadband Wireless Access standard provides optimal performance in all types of propagation environments. These include Line of Sight, Near Line of Sight and Non Line of Sight environments. For distances of up to 40 km, the OFDM waveform supports 70Mbps in a single RF channel. Deployment of mesh networks and antenna techniques like the beam forming, STC and antenna diversity will enhance the coverage, yet providing this high spectral efficiency. In addition, the OFDM designed for BWA can support longer-range transmissions and the multi-path or reflections encountered.

Quality of Service

The contention based access techniques used for Wireless LANs have limitations that are overcome by the 802.16a MAC layer designed for WiMAX. The protocol used by the MAC layer in WiMAX supports differentiated service levels depending on the customer needs. Dedicated T1/E1 level services are provided to business customers, while best effort services are provided to residential users. TDMA on the uplink and TDM data streams on the downlink with hooks for a centralized scheduler support delay sensitive services like voice and video. This also provides an assured bounded delay on the data.

1.6 The history of WiMAX

Table 1.1 shows a timeline of the history of WiMAX.

Table 1.1

WiMAX events

Date	**Event**
June 2001	WiMAX Forum established
December 2001	IEEE 802.16 10 – 66 GHz Line of Sight Up to 134Mbps (28MHz channelization)
December 2002	802.16 Interoperability
January 2003	IEEE 802.16a 2 - 11 GHz Non Line of Sight Up to 75MHz (20MHz channelization)
June 2004	802.16-2004 Standard 256 OFDM (Orthogonal Frequency Division Multiplexing) PHY modes of the 802.16-2004 standards, which was ratified by the IEEE.
July 2005	Fixed WiMAX Certification; Cetecom began testing WiMAX Forum member companies’ products to certify that they meet WiMAX Forum conformance and interoperability standards.

End of 2005	Mobile WiMAX Standard
2006	WiMAX Forum Certified Products
October 2007	The WiMAX Forum is pleased to recognize the decision of the Radio communication Sector of the International Telecommunication Union (ITU-R) to include WiMAX technology in the IMT-2000 set of standards

1.7 Competing technologies

WiMAX was specifically designed for outdoor network access. WiMAX has provisions at the physical layer for optimizing symbol rate. This makes it robust in the presence of increased delay spread, which is prevalent outdoors. WiMAX can deliver more reliable QoS and per client bandwidth assignments, as it does not use contention based MAC protocol.

It is the fact that Wi-Fi is well in terms of end user adoption and reduced cost metrics. Therefore, it is likely that WiMAX and Wi-Fi will coexist with each other. WiMAX is poised to become the outdoor wireless network access of choice, with Wi-Fi being the prevalent indoor wireless network.

Table 1.2 shows the comparison of WiMAX with other technologies. Wi-Fi alliance started certifying IEEE 802.11n Draft 2.0 products in June ’07 and vendors like Cisco have recently announced commercial availability of 802.11n “pre-standard” products. Hence, there is a lot of customer/end-user interest (and confusion) in this version of Wi-Fi and its comparison with WiMAX. Especially since both standards use MIMO technologies for enhanced throughput.

Table 1.2

Technology comparisons

Parameters	**Wi-Fi 802.11**	**Wi-Fi 802.11n**	**WiMAX 802.16a**	**Mobile-Fi 802.20**	**Cellular**
Speed	6–54Mbps	300Mbps	70Mbps	16Mbps	2Mbps
Band	Unlicensed	Unlicensed	Both	Licensed	Licensed
Coverage	50-1500ft	230-820ft	2-30 miles	3–6 miles	1–3 miles

1.7.1 Technology comparison

As WiMAX was formed to complement Bluetooth and Wi-Fi technologies, Table 1.3 is a list of the differences in each of these.

Table 1.3

Differences between WiMAX, WLAN and Bluetooth

Parameters	**WiMAX**	**WLAN**	**Bluetooth**
Frequency Band	2-11 GHz	2.4 GHz	Varies
Range	~30 miles	~100 m	~10 m
Data Transfer Rate	70 Mbps	11-55 Mbps	20 Kbps-55 Mbps
Users	Thousands	Dozens	Dozens

802.11 Standards are based on distributed architecture, whereas WiMAX is based on a centrally controlled architecture. In this, the wireless media access is in complete control of the scheduler residing in the Base station (BS). WiMAX can support multiple connections conforming to a set of QoS parameters and provides the packet classifier ability to map the connections to many user applications and interfaces. Figure 1.13 shows comparison of WiMAX with other wireless technologies.

Figure 1.13

Comparison of WiMAX with other wireless technologies

WiMAX main competition within the market comes from widely deployed wireless systems with overlapping functionality such as UMTS and CDMA2000, as well as a number of Internet oriented systems such as HIPERMAN and WiBro.

3G and 4G Cellular Systems

CDMA2000 and UMTS (Universal Mobile Telecommunications System) are two of the major 3G systems, which compete with WiMAX. In addition to phone service, both offer DSL-class Internet access. UMTS has been enhanced to UMTS-TDD, to compete with WiMAX. This can use WiMAX oriented spectrum and provides more consistent user experience than WiMAX.

When users move out of range of upgraded equipment, they usually fall back to older systems. Being upgrades from earlier systems, 3G cellular phone systems usually benefit from already having entrenched infrastructure.

Some of the services of 4G cellular system are:

- High bandwidth,
- Low latency,
- All-IP networks with voice, etc.

With GSM/UMTS, the move to 4G is the 3GPP (3rd Generation Partnership Project) Long Term Evolution effort. For AMPS/TIA (Advanced Mobile Phone System) derived standards such as CDMA2000, a replacement called UMB (Ultra Mobile Broadband) is under development. However, in favor of OFDMA for the downlink and a variety of OFDM based solutions for the uplink existing air interfaces are being discarded. These will bring Internet access speeds comparable to, or better than, WiMAX.

Internet Oriented Systems

WMAN standards, the European standard HIPERMAN and Korean standard WiBro are no longer seen as competition, but as complementary. Wi-Fi 802.11g system is widely deployed as a short-range mobile Internet solution, such as in cafes and at transportation hubs like airports. This provides enough coverage for some users to feel subscription to a WiMAX service as unnecessary.

1.8 Advantages of WiMAX

- A single WiMAX main station can serve hundreds of users.
- Endpoints install within days instead of the weeks required for wired connections.
- Data rates as high as 70Mbps and distances of 30 miles are possible.
- Users can operate mobile within 3 - 5 miles of a base station at data rates up to 70Mbps.
- No FCC radio licensing is required.
- WiMAX provides NLOS/LOS coverage advantage.
- Simplified internetworking with other IP technologies.
- WiMAX fits easily into wired and wireless ecosystem.
- WiMAX will deliver high speed data communications across wide distances.

1.9 WiMAX Version II

802.16m is the new version of WiMAX 802.16 standards which IEEE has begun working. 802.16m (WiMAX version II) could increase the data transfer speeds up to 1Gbps and maintain backward compatibility with existing WiMAX devices. It also appears to provide compliance with the ITU's requirements for 4G. However, due to convergence between VoIP and various forms of multimedia (IPTV, streaming video, digital downloads, etc.), the increased bandwidth is supposedly needed. By the end of 2009, IEEE hopes to have this standard come together.

The 1GB speed expected out of the 802.16m is based on the MIMO technology. It is important to note that some 802.11g/n routers are using this technology and theoretically capable of providing 108Mbps speeds. Committee assures of compatibilities between IEEE 802.16m and WiMAX standards though 802.16m is not a part of WiMAX standard yet. It will also be 4G compatible with the future wireless networks offering much higher speeds.

Current 802.16m specifications include:

- Very low rate Data (16kbps)

- Low rate Data and Low Multimedia (144kbps)
- Medium multimedia (2Mbps)
- High multimedia (30Mbps)
- Super high multimedia (30Mbps ~ 100Mbps / 1Gbps)

1.9.1 Future development

Achieving 100Mbps mobile and 1Gbps, fixed-nomadic bandwidth is the goal for the long-term evolution of both WiMAX and LTE (Long Term Evolution). 3GPP LTE and WiMAX-m are concentrating much effort on MIMO-AAS (Adaptive Antenna System), mobile multi-hop relay networking and related developments needed to deliver 10X and higher Co-Channel re-use multiples.

IEEE would like to create a standard as much backwards compatible as possible to the current version of the WiMAX (802.16e or 820.16-2005) along with peak data rates of up to 1Gbps (that's around 1,000Mbps).

Systems such as WiMAX and LTE promises faster data rates than those available today by mainly doing the following:

- **Increase the channel bandwidth:**WiMAX and LTE provide flexible channel bandwidths from 1.25 – 20 MHz, today HSDPA uses 5MHz channel. Therefore, by using a channel that is four times as broad as today, data rates can be increased four times.
- **Multiple Inputs, Multiple Output (MIMO):**Independent data streams are sent over each antenna by using multiple antennas at both the transmitting and receiving end. This is possible as signals bounce of buildings, trees and other obstacles and thus form independent data paths. Both LTE and WiMAX currently foresee two transmitting and two receiving antennas (2x2 MIMO). In the best case, this doubles data rates.
- **Higher Order Modulation:**WiMAX and LTE uses 64QAM modulation under ideal transmission conditions, which packs six bits into a single transmission step. While the modulation used by HSDPA is 16QAM which packs four bits into a single transmission step.

LTE and WiMAX will be able to increase today's 2Mbps to about 20 - 25 Mbps by using the techniques above. That is still far away from the envisaged 1,000Mbps. However, as of now, the primary focus is in making the LTE and WiMAX a reality.

1.9.2 Femtocells

A femtocell is a two-way communication device extending a typical base station by incorporating all of the major components of the telecommunications infrastructure. Femtocell is also called Access Point Base Station. Access Point Base Stations are stand-alone units that are typically deployed in hot spots, in buildings and homes. Femtocells are an alternative way to deliver the benefits of Fixed Mobile Convergence (FMC). Femtocell-based deployment will work with existing handsets.

Simplicity of ultra low cost, scalable deployment are the main benefits of an Access Point Base Station. Access Point Base Stations can be designed from simple hot spot coverage to large deployments by racking such units into full-scale base-stations. For connectivity, Access Point Base Stations can reduce deployment costs but may introduce security risks as they depend on the Internet.

1.9.3 Solar-powered WiMAX base station

A solar-Powered WiMAX base station is an option for remote locations where electricity is not available due to lack of infrastructure or very expensive. Generators can be used, but they are becoming more expensive to operate due to increasing oil prices. Figure 1.14 is an example of an installation of a solar powered WiMAX base station.

Likewise, disaster recovery operations are often conducted where electric power is unavailable from the grid, and WiMAX has already proven valuable in several recovery missions. Finally, solar power provides a readily available, inexpensive and environmentally friendly power source.

Figure 1.14

Solar Powered WiMAX (source: Sunwize)

Target Configuration

A single-sector WiMAX base station is called target configuration. Primary components are the WiMAX Baseband Card, a chassis and a remote radio head. The baseband card implements the IEEE 802.16 standard and can be programmed to operate in 802.16e mode for mobile access (with software upgrade) or in 802.16-2004 mode for fixed wireless access.

The baseband card is implemented on a full-height, double-width Advanced

Mezzanine Card (Advanced MC) compliant with the PICMG (PCI Industrial Computers Manufacturers Group) standard. The remote radio head consists of an omni-directional broadband antenna and RF circuitry. It can transmit in SISO (Single Input Single Output) mode where a single data stream is transferred between the transmitter and the receiver, or in MIMO mode, where multiple data streams are transmitted concurrently.

The solar-powered system consists of solar panel modules, battery array and charger controller. The battery array powers the base station while the charger controller regulates power to the base station and controls charging of the battery. Solar panels provide power to charge the battery.

1.10 Conclusion

Intel and its ecosystem vendors are making to operate a base station powered solely on solar technology in both economically and technologically feasible way. Specifically, the Intel NetStructure® WiMAX Baseband Card, along with advances in radio technology, enables operators to deploy and operate a fully functioning solar powered base station. While the capital costs may initially appear high, these costs are, in fact, comparable if not lower than electric grid extension or fossil fuel generation alternatives. In addition, at the times of disaster solar power may be the only source of power available. Consequently, the solar-powered alternative offers great potential to improve power efficiency and availability, and lower operating expenses while supplying power to remote locations and disaster recovery operations.