WIMAX TECHNOLOGY AND ITS APPLICATIONS

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1. Abstract
This paper presents the features of the Worldwide Interoperability for Microwave Access (WiMAX) technology and future applications of WiMAX. A discussion is given by comparing WIMAX with DSL(Digital subscriber line) & Cable and Wireless Fidelity (Wi-Fi). Several references have been included at the end of this paper for those willing to know in detail about certain specific topics.

2. Introduction
WiMAX is an IP based, wireless broadband access technology that provides performance similar to 802.11/Wi-Fi networks with the coverage and QOS (quality of service) of cellular networks. WiMAX is also an acronym meaning "Worldwide Interoperability for Microwave Access (WiMAX). WiMAX is a wireless digital communications system, also known as IEEE 802.16, that is intended for wireless "metropolitan area networks". WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In contrast, the WiFi/802.11 wireless local area network standard is limited in most cases to only 100 - 300 feet (30 - 100m).

WiMAX operates on both licensed and non-licensed frequencies, providing a regulated environment and viable economic model for wireless carriers. The average cell ranges for most WiMAX networks will likely boast 4-5 mile range (in NLOS capable frequencies) even through tree cover and building walls. Service ranges up to 10 miles (16 Kilometers) are very likely in line of sight (LOS) applications (once again depending upon frequency).

Mobile WiMAX capabilities on a per customer basis are much better than competing 3G technologies. WiMAX is often cited to possess a spectral efficiency of 5 bps/Hz, which is very good in comparison to other broadband wireless technologies, especially 3G.

3. Will WiMAX replace DSL and Cable?
It is important to remember that WiMAX is a global broadband wireless standard. The question of whether or not it could replace either DSL or Cable will vary from region to region. Many developing countries simply do not have the infrastructure to support either cable or DSL broadband technologies. In fact, many such countries are already widely using proprietary broadband wireless technologies. Even in such regions however, it is very unlikely that either Cable or DSL technologies would disappear. The business case and basic infrastructure often dictates that the cheapest solutions will predominate. In many areas in developing nations, it may be cheaper to deploy Cable and DSL in the cities at least for fixed applications, whereas WiMAX will dominate outside of major towns.

In the US, both Cable and DSL are growing extremely fast, but are not available for all customers. Rural and remote areas often lack broadband choices if any are available at all. When they are available, the DSL or cable plant may only exist within the town limits with no service outside the city limits. This offers a compelling argument that low-cost WiMAX gear can leverage access to many new customers. WiMAX also promises a whole new level of data access flexibility that will be much less location specific for customers. This type of robust mobile, portable or fixed broadband access will be unprecedented.

In addition, WiMAX will provide competitive options for carriers and users that will benefit traditional wireline carriers and customers by encouraging innovation and improved services.

With the advent of IPTV fiber plays are enjoying resurgence. It does not appear that WiMAX or broadband wireless will be ready to deliver IPTV in the immediate future. However, fixed WiMAX may offer the best potential for delivery of this potential content juggernaut. More recently some promising new compression technologies have reached the market. These technologies, while still new, allow the delivery of true IP-based TV signals to cellular devices. One company asserts that it could deliver high definition TV (HDTV) in as little as 2.5 Mbps of bandwidth, with standard resolution signal

requiring 1.5 Mbps. These speeds are within the potential reach of WiMAX.
Qualcomm and its MediaFlo system are one good example of such technologies. It is important to note that the resolution of this TV or video system is not at the level of standard TV, but progress is occurring rapidly.

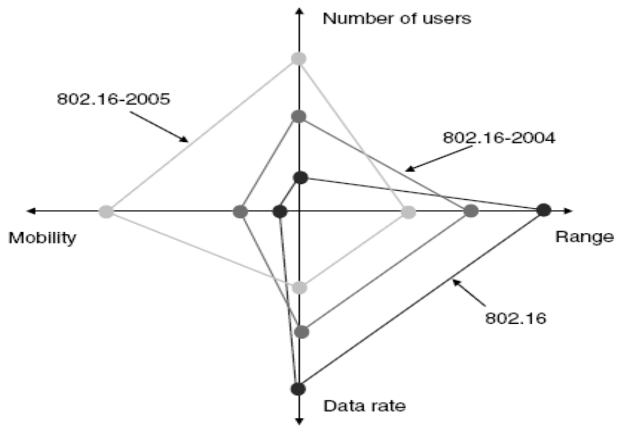
4. IEEE 802.16

The IEEE developed the 802.16 in its first version to address line of sight (LOS) access at spectrum ranges from 10 GHz to 66 GHz. The technology has evolved through several updates to the standard such as 802.16a, 802.16c, the Fixed WiMAX 802.16d (802.16-2004) specification and lastly the mobile 802.16e set that are currently commercially available. The upcoming 802.16m standard is due to be ratified in 2010. The first update added support for 2 GHz through 11 GHz spectrum with NLOS capability. Each update added additional functionality or expanded the reach of the standard.
For example, the 802.16c revision added support for spectrum ranges both licensed and unlicensed from 2 GHz to 10 GHz. It also improved quality of service (QOS) and certain improvements in the media access control (MAC) layer along with adding support for the HiperMAN European standard. The number of supported physical (PHY) layers was increased. Transport mediums such as IP, Ethernet and asynchronous transfer mode (ATM) were added.
Concentrated in 2- to 11-GHz WMAN, with the following set of features:

- Service area range 50 km
- NLoS
- QoS designed in for voice/video, differentiated services
- Very high spectrum utilization: 3.8 bit/Hz
- Up to 280 Mbps per BS
- Speed - 70 Mbps

5. WiMAX—Evolution of the Technology

As the envisioned usage scenario has evolved over time, so has evolved the technological basis of WiMAX. The IEEE 802.16 technical specification has now evolved through three generations:
• IEEE 802.16: High data rate, highpower, PTP, LOS, fixed SSs
• IEEE 802.16-2004: Medium data rate, PTP, PMP, fixed SSs
• IEEE 802.16-2005: Low-medium data rate, PTP, PMP, fixed or mobile SSs.



6. WiMAX System

A WiMAX system consists of two parts:
• A **WiMAX tower - s**imilar in concept to a cell-phone tower- A single WiMAX tower can provide coverage to a very large area as big as 3,000 square miles (~8,000 square km).
• A **WiMAX receiver** – The receiver and antenna could be a small box or PCMCIA card, or they could be built into a laptop the way WiFi access is today.
A WiMAX tower station can connect directly to the Internet using a high bandwidth, wired connection (for example, a T3 line). It can also connect to another WiMAX tower using a line-of-sight, microwave link. This connection to a second tower (often referred to as a **backhaul**), along with the ability of a single tower to cover up to 3,000 square miles, is what allows WiMAX to provide coverage to remote rural areas.
Compared to the complicated wired network, a WiMAX system only consists of two parts:
The WiMAX base station (BS) and WiMAX subscriber station (SS), also referred to as customer premise equipments (CPE). Therefore, it can be built quickly at a low cost. Ultimately, WiMAX is also considered as the next step in the mobile technology evolution path. The potential combination of WiMAX and CDMA standards is referred to as 4G.

6.1 System Model

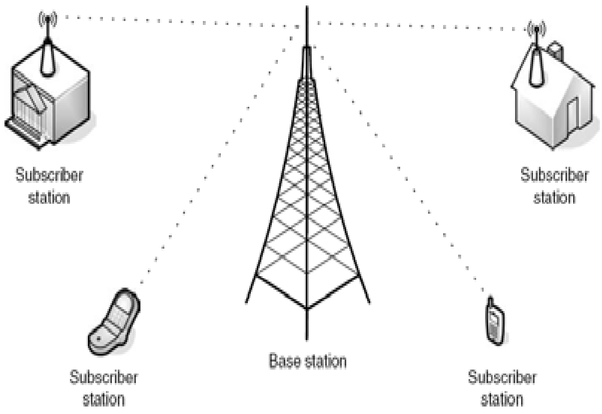
IEEE 802.16 supports two modes of operation: PTP and PMP.

6.1.1 Point-to-point (PTP)

The PTP link refers to a dedicated link that connects only two nodes: BS and subscriber terminal. It utilizes resources in an inefficient way and substantially causes high operation costs. It is usually only used to serve high-value customers who need extremely high bandwidth, such as business high-rises, video postproduction houses, or scientific research organizations. In these cases, a single connection contains all the available bandwidth to generate high throughput. A highly directional and high-gain antenna is also necessary to minimize interference and maximize security.

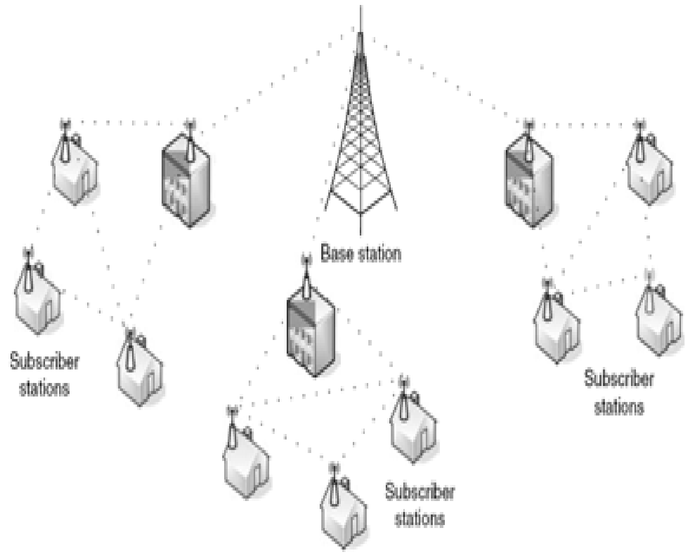
6.1.2 Point-to-multipoint (PMP)

The PMP topology, where a group of subscriber terminals are connected to a BS separately (shown in Figure), is a better choice for users who do not need to use the entire bandwidth. Under PMP topology, sectoral antennas with highly directional parabolic dishes (each dish refers to a sector) are used for frequency reuse. The available bandwidth now is shared between a group of users, and the cost for each subscriber is reduced.



6.1.3 Mesh Topology

In addition to PTP and PMP, 802.16a introduces the mesh topology, which is a more flexible, effective, reliable, and portable network architecture based on the multihop concept. Mesh networks are wireless data networks that give the SSs more intelligence than traditional wireless transmitters and receivers. In a PMP network, all the connections must go through the BS, while with mesh topology, every SS can act as an access point and is able to route packets to its neighbors by itself to enlarge the geographical coverage of a network. The architecture of a mesh system is shown in Figure. The routing across the network can be either proactive (using predetermined routing tables) or reactive (generating routes on demand).



7. WiMAX as a Metro-Access

Deployment Option

WiMAX is a worldwide certification addressing interoperability across IEEE 802.16 standards-based products. The IEEE 802.16 standard with specific revisions addresses two usage models:

- Fixed (IEEE 802.16d)
- Portable (IEEE 802.16e)

7.1 Fixed (IEEE 802.16d)

Fixed WiMAX is the 802.16d standards or as it is sometimes called 802.16-2004. Its product profile utilizes the OFDM 256-FFT (Fast Fourier Transform) system profile, which is just different enough from its sister standard of Mobile WiMAX (802.16e) that the two are incompatible. Interestingly, both standards support both protocols within the technology protocol as well as the one chosen for Mobile WiMAX and the Korean WiBro/Mobile WiMAX standard. If the Forum had elected to use an OFDMA version in Fixed WiMAX, it would have been far easier to provide an upgrade path.

This particular disconnect likely points to the emerging understanding of the marketplace power of WiMAX. More importantly, it indicates the power of the Korean WiBro/Mobile WiMAX persuasion, which heavily influenced the use of OFDMA® in the Mobile Standard.

The Fixed WiMAX 802.16-2004 standard supports both time division duplex (TDD) and frequency division duplex (FDD) services---the latter of which is far more popular with mobile wireless providers than the newer TDD

approach.
At this point, Fixed WiMAX 802.16d systems are widely deployed in both Europe and Asia, but it is clear that for many vendors the adoption of the Mobile WiMAX 802.16e is the option of choice.
Having said this, the opening of the US 3.65 GHz spectrum range has opened up a 802.16d opportunity in the US as vendors adapt existing 3.5 GHz systems (and mostly Fixed WiMAX based built for International use) radio systems to use in this band.

7.2 Portable (IEEE 802.16e)

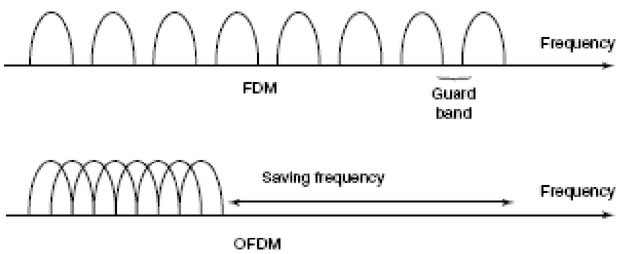
The true Mobile WiMAX standard of 802.16e is divergent from Fixed WiMAX. It attracted a significant number of Forum members towards an opportunity to substantively challenge existing 3G technology purveyors. While clearly based on the same OFDM base technology adopted in 802.16-2004, the 802.16e version is designed to deliver service across many more sub-channels than the OFDM 256-FFT. It is important to note that both standards support single carrier, OFDM 256-FFT and at least OFDMA 1K-FFT.
The 802.16e standard adds OFDMA 2K-FFT, 512-FFT and 128-FFT capability. Sub-channelization facilitates access at varying distance by providing operators the capability to dynamically reduce the number of channels while increasing the gain of signal to each channel in order to reach customers farther away. The reverse is also possible.
For example, when a user gets closer to a cell site, the number of channels will increase and the modulation can also change to increase bandwidth. At longer ranges, modulations like QPSK (which offer robust links but lower bandwidth) can give way at shorter ranges to 64 QAM (which are more sensitive links, but offer much higher bandwidth) for example. Each subscriber is linked to a number of subchannels that obviate multi-path interference. The upshot is that cells should be much less sensitive to overload and cell size shrinkage during the load than before. Ideally, customers at any range should receive solid QOS without drops that 3G technology may experience. Here is an in-depth Q&A on OFDMA®.
The 802.16e version of WiMAX also incorporates support for multiple-input-multiple-output (MIMO) antenna technology as well as Beamforming and Advanced Antenna Systems (AAS), which are all "smart" antenna technologies that significantly improve gain of WiMAX systems as well as throughput.
The 802.16e standard is being utilized primarily in licensed spectrum for pure mobile applications. Many firms have elected to develop the 802.16e standard exclusively for both fixed and mobile versions. The 802.16e version of WiMAX is the closest comparable technology to the emerging LTE mobile wireless standard. Or rather, it is more proper to say that LTE is the most comparable to Mobile WiMAX in terms of capabilities as well as technology. The two competing technologies are really very much alike technically.

8. WiMAX Physical Layer

The WiMAX physical layer is based on orthogonal frequency division multiplexing. OFDM is the transmission scheme of choice to enable high-speed data, video, and multimedia communications and is used by a variety of commercial broadband systems, including DSL, Wi-Fi and Digital Video. Broadcast-Handheld (DVB-H), and MediaFLO, besides WiMAX. OFDM is an elegant and efficient scheme for high data rate transmission in a non-line-of-sight or multipath radio environment.

8.1 OFDM Technology

Orthogonal frequency division multiplexing (OFDM) technology provides operators with an efficient means to overcome the challenges of NLOS propagation. OFDM is based on the traditional frequency division multiplexing (FDM), which enables simultaneous transmission of multiple signals by separating them into different frequency bands (subcarriers) and sending them in parallel. In FDM, guard bands are needed to reduce the interference between different frequencies, which causes bandwidth wastage .Therefore, it is not a spectrum-efficient and cost-effective solution. However, OFDM is a more spectrum-efficient method that removes all the guard bands but keeps the modulated signals orthogonal to mitigate the interference level.

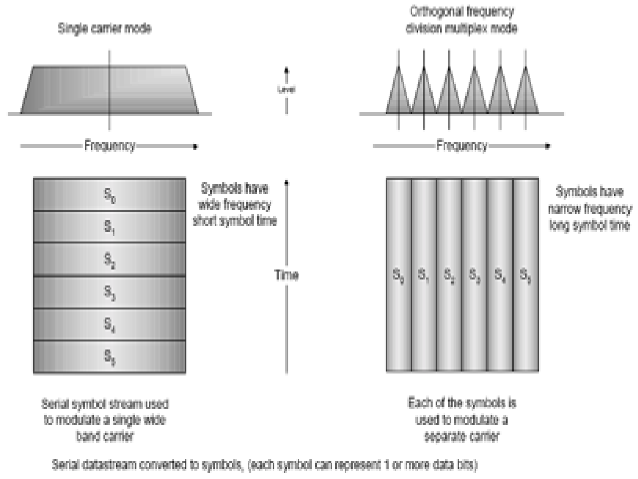


Comparison between FDM and OFDMA

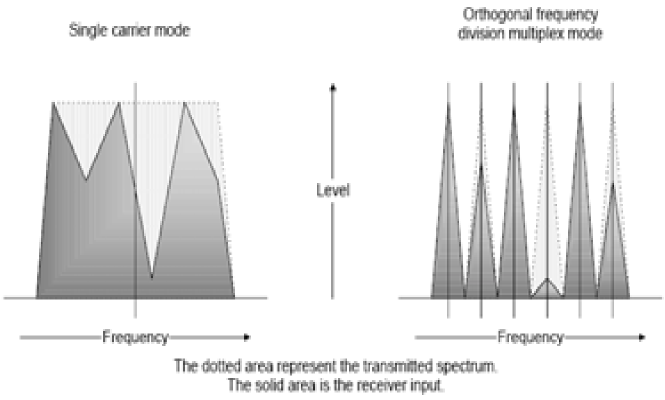
As shown in figure the required bandwidth in OFDM is significantly decreased by spacing multiple modulated carriers closer until they are actually overlapping.OFDM uses fast Fourier transform (FFT) and inverse FFT to convert serial data to multiple channels. The FFT size is

256, which means a total number of 256 sub channels (carriers) are defined for OFDM. In OFDM, the original signal is divided into 256 subcarriers and transmitted in parallel. Therefore, OFDM is referred to as a multicarrier modulation scheme. Compared to single-carrier schemes, OFDM is more robust against multipath propagation delay owing to the use of narrower subcarriers with low bit rates resulting in long symbol periods. A guard time is introduced at each OFDM symbol to further mitigate the effect of multipath delay spread.

The WiMAX OFDM waveform offers the advantage of being able to operate with the larger delay spread of the NLOS environment. By virtue of the OFDM symbol time and use of a cyclic prefix, the OFDM waveform eliminates the inter-symbol interference (ISI) problems and the complexities of adaptive equalization. Because the OFDM waveform is composed of multiple narrowband orthogonal carriers, selective fading is localized to a subset of carriers that are relatively easy to equalize. An example is shown below as a comparison between an OFDM signal and a single carrier signal, with the information being sent in parallel for OFDM and in series for single carrier.



The ability to overcome delay spread, multi-path, and ISI in an efficient manner allows for higher data rate throughput. As an example it is easier to equalize the individual OFDM carriers than it is to equalize the broader single carrier signal.



For all of these reasons recent international standards such as those set by IEEE 802.16, ETSI BRAN, and ETRI, have established OFDM as the preferred technology of choice.

8.2 OFDM Parameters in WiMAX

As mentioned previously, the fixed and mobile versions of WiMAX have slightly different implementations of the OFDM physical layer. Fixed WiMAX, which is based on IEEE 802.16- 2004, uses a 256 FFT-based OFDM physical layer. Mobile WiMAX, which is based on the IEEE 802.16e-20055 standard, uses a scalable OFDMA-based physical layer. In the case of mobile WiMAX, the FFT sizes can vary from 128 bits to 2,048 bits.

8.2.1 Fixed WiMAX OFDM-PHY:

For this version the FFT size is fixed at 256, which 192 subcarriers used for carrying data, 8 used as pilot subcarriers for channel estimation and synchronization purposes, and the rest used as guard band subcarriers.6 Since the FFT size is fixed, the subcarrier spacing varies with channel bandwidth. When larger bandwidths are used, the subcarrier spacing increases, and the symbol time decreases. Decreasing symbol time implies that a larger fraction needs to be allocated as guard time to overcome delay spread. WiMAX allows a wide range of guard times that allow system designers to make appropriate trade-offs between spectral efficiency and delay spread robustness. For maximum delay spread robustness, a 25 percent guard time can be used, which can accommodate delay spreads up to 16 µs when operating in a 3.5MHz channel and up to 8 µs when operating in a 7MHz channel. In relatively benign multipath channels, the guard time overhead may be reduced to as little as 3 percent.

8.2.2 Mobile WiMAX OFDMA-PHY:

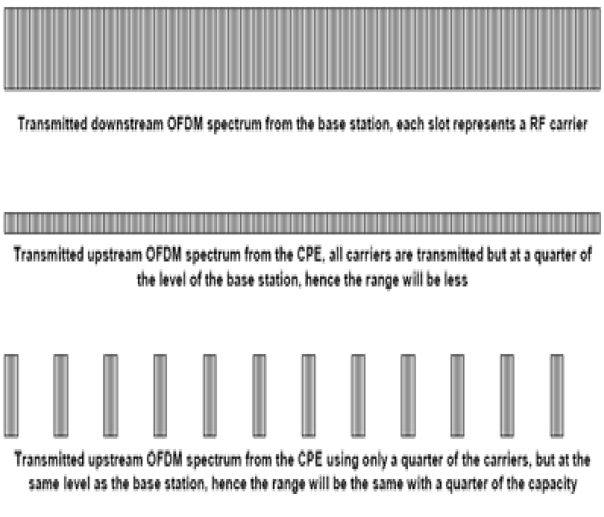
In mobile WiMAX, the FFT size is scalable from 128 to 2,048. Here, when the available bandwidth increases, the FFT size is also increased such that the subcarrier spacing is always 10.94 kHz. This keeps the OFDM symbol duration, which is the basic resource unit, fixed and therefore makes scaling have minimal impact on higher layers. A scalable design also keeps the costs low. The subcarrier spacing of 10.94 kHz was chosen as a good balance between satisfying the delay spread and Doppler spread requirements for operating in mixed fixed and mobile environments. This subcarrier spacing can support delay spread values up to 20µs and vehicular mobility up to 125 kmph when operating in 3.5GHz. A subcarrier spacing of 10.94 kHz implies that 128, 512, 1,024, and 2,048 FFT are used when the channel bandwidth is 1.25MHz, 5MHz, 10MHz, and 20MHz, respectively. It should, however, be noted that mobile WiMAX may also include additional bandwidth profiles. For example, a profile compatible with WiBro will use an 8.75MHz channel bandwidth and 1,024 FFT. This obviously will require different subcarrier spacing and hence will not have the same scalability properties.

8.3 Sub Channelization OFDMA

Sub Channelization in the uplink is an option within WiMAX. Without sub channelization, regulatory restrictions and the need for cost effective CPEs, typically cause the link budget to be asymmetrical, this causes the system range to be up link limited. Sub channeling enables the link

budget to be balanced such that the system gains are similar for both the up and down links. Sub channeling concentrates the transmit power into fewer OFDM carriers; this is what increases the system gain that can either be used to extend the reach of the system, overcome the building

penetration losses, and or reduce the power consumption of the CPE. The use of sub channeling is further expanded in orthogonal frequency division multiple access (OFDMA) to enable a more flexible use of resources that can support nomadic or mobile operation.



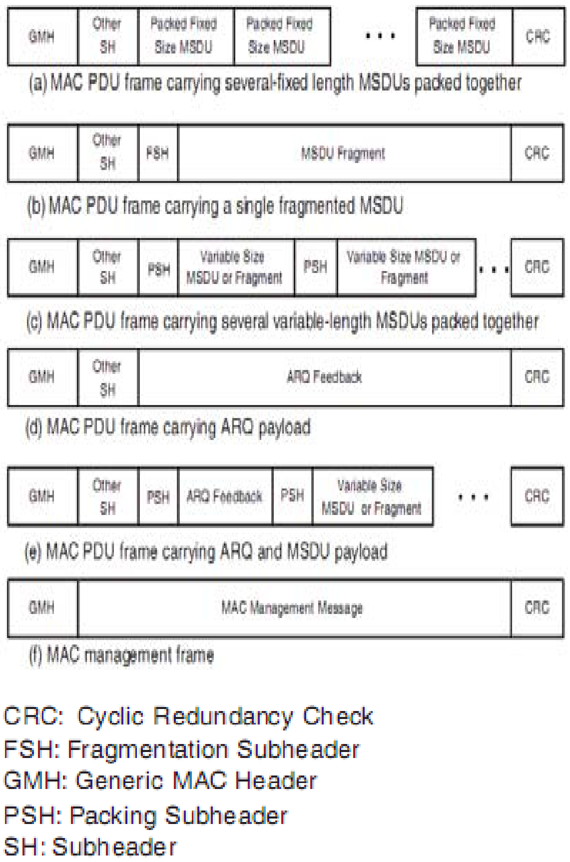
8.4 MAC-Layer Overview

The primary task of the WiMAX MAC layer is to provide an interface between the higher transport layers and the physical layer. The MAC layer takes packets from the upper layer—these packets are called MAC service data units (MSDUs)—and organize them into MAC protocol data units (MPDUs) for transmission over the air. For received transmissions, the MAC layer does the reverse. The IEEE 802.16- 2004 and IEEE 802.16e-2005 MAC design includes a convergence sub layer that can interface with a variety of higher-layer protocols, such as ATM, TDM Voice, Ethernet, IP, and any unknown future protocol. Given the predominance of IP and Ethernet in the industry, the WiMAX Forum has decided to support only IP and Ethernet at this time. Besides providing a mapping to and from the higher layers, the convergence sub layer supports MSDU header suppression to reduce the higher layer overheads on each packet. The WiMAX MAC is designed from the ground up to support very high peak bit rates while delivering quality of service similar to that of ATM and DOCSIS. The WiMAX MAC uses a variable-length MPDU and offers a lot of flexibility to allow for their efficient transmission. For example, multiple MPDUs of same or different lengths may be aggregated into a single burst to save PHY overhead. Similarly, multiple MSDUs from the same higher-layer service may be concatenated into a single MPDU to save MAC header overhead. Conversely, large MSDUs may be fragmented into smaller MPDUs and sent across multiple frames. Each MAC frame is prefixed with a generic MAC header (GMH) that contains a connection identifier (CID), the length of frame, and bits to qualify the presence of CRC, sub headers, and whether the payload is encrypted and if so, with which key. The MAC payload is either a transport or a management message. Besides MSDUs, the transport payload may contain bandwidth requests or retransmission requests. The type of transport payload is identified by the sub header that immediately precedes it. Examples of sub headers are packing sub headers and fragmentation sub headers. WiMAX MAC also supports ARQ, which can be used to request the retransmission of unfragmented MSDUs and fragments of MSDUs. The maximum frame length is

2,047 bytes, which is represented by 11 bits in the GMH.

8.4.1 Channel-Access Mechanisms

In WiMAX, the MAC layer at the base station is fully responsible for allocating bandwidth to all users, in both the uplink and the downlink. The only time the MS has some control over bandwidth allocation is when it has multiple sessions or connections with the BS. In that case, the BS allocates bandwidth to the MS in the aggregate, and it is up to the MS to apportion it among the multiple connections. All other scheduling on the downlink and uplink is done by the BS. For the downlink, the BS can allocate bandwidth to each MS, based on the needs of the incoming traffic, without involving the MS. For the uplink, allocations have to be based on requests from the MS. The WiMAX standard supports several mechanisms by which an MS can request and obtain uplink bandwidth. Depending on the particular QoS and traffic parameters associated with a service, one or more of these mechanisms may be used by the MS. The BS allocates dedicated or shared resources periodically to each MS, which it can use to request bandwidth. This process is called polling. Polling may be done either individually (unicast) or in groups (multicast). Multicast polling is done when there is insufficient bandwidth to poll each MS individually. When polling is done in multicast, the allocated slot for making bandwidth requests is a shared slot,



which every polled MS attempts to use. WiMAX defines a contention access and resolution mechanism for the case when more than one MS attempts to use the shared slot. If it already has an allocation for sending traffic, the MS is not polled. Instead, it is allowed to request more bandwidth by

(1) Transmitting a stand-alone bandwidth request MPDU,

(2) Sending a bandwidth request using the ranging channel, or

(3) Piggybacking a bandwidth request on generic MAC packets.

8.5 Power Control

Power control algorithms are used to improve the overall performance of the system, it is implemented by the base station sending power control information to each of the CPEs to regulate the transmit power level so that the level received at the base station is at a predetermined level. In a dynamical changing fading environment this pre-determined performance level means that the CPE only transmits enough power to meet this requirement. The converse would be that the CPE transmit level is based on worst-case conditions. The power control reduces the overall power consumption of the CPE and the potential interference with other co-located base stations. For LOS the transmit power of the CPE is approximately proportional to its distance from the base station, for NLOS it is also heavily dependent on the clearance and obstructions.

8.6 Adaptive Modulation

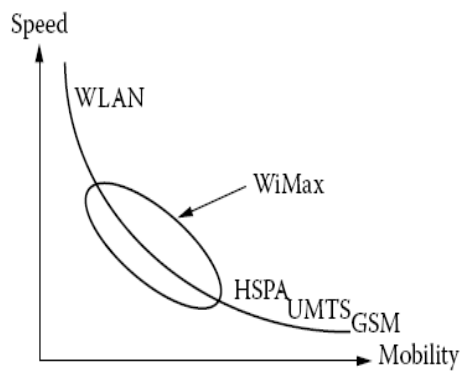
Adaptive modulation allows the WiMAX system to adjust the signal modulation scheme depending on the signal to noise ratio (SNR) condition of the radio link. When the radio link is high in quality, the highest modulation scheme is used, giving the system more capacity. During a signal fade, the WiMAX system can shift to a lower modulation scheme to maintain the connection quality and link stability. This feature allows the system to overcome time-selective fading. The key feature of adaptive modulation is that it increases the range that a higher modulation scheme can be used over, since the system can flex to the actual fading conditions, as opposed to having a fixed scheme that is budgeted for the worst case conditions.

8.7 Error Correction Techniques

Error correction techniques have been incorporated into WiMAX to reduce the system signal to noise ratio requirements. Strong Reed Solomon FEC, convolution encoding, and interleaving algorithms are used to detect and correct errors to improve throughput. These robust error correction techniques help to recover error frames that may have been lost due to frequency selective fading or burst errors. Automatic repeat request (ARQ) is used to correct errors that cannot be corrected by the FEC, by having the error information resent. This significantly improves the bit error rate (BER) performance for a similar threshold level.

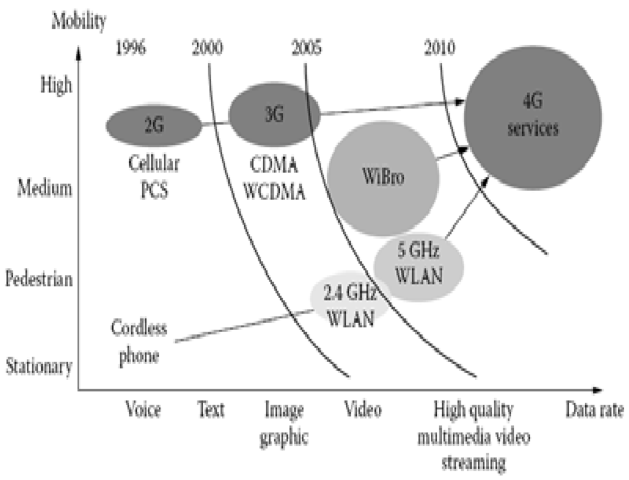
9. Competing technologies

Within the marketplace, WiMAX's main competition 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 .Both of the two major 3G systems, CDMA2000 and UMTS, compete with WiMAX. Both offer DSL-class Internet access, in addition to phone service. UMTS has also been enhanced to compete directly with WiMAX in the form of UMTS-TDD, which can use WiMAX-oriented spectrum, and it provides a more consistent (lower bandwidth at peak) user experience than WiMAX (Figure). Moving forward, similar air interface technologies to those used by WiMAX are being considered for the 4G evolution of UMTS.



9.1 WiBro

WiBro (wireless broadband) is an Internet technology being developed by the Korean telecom industry (Figure). In February 2002, the Korean government allocated 100 MHz of electromagnetic spectrum in the 2.3-GHz band, and in late 2004, WiBro Phase 1 was standardized by the TTA (Telecommunications Technology Association) of Korea. WiBro is the newest variety of mobile wireless broadband access. It is based on the same IEEE 802.16 standard as WiMAX but is designed to maintain connectivity on the go, tracking a receiver at speeds of up to 37 mi per hr (60 km/hr). WiMAX is the current standard in the United States, offering wireless Internet connectivity to mobile users at fixed ranges of up to 31 mi (50 km) from the transmitting base. However, it is not designed to be used while the receiver is in motion. WiBro can be thought of as mobile WiMAX, though the technology and its exact specifications will change as it undergoes refinements throughout its preliminary stages.



10. Will WiMAX compete with Wi-Fi?

Clearly, WiMAX and Wi-Fi are complementary technologies and will remain so for the foreseeable future. The widely available Wi-Fi technology used in hotspots in hotels, restaurants, airports and even larger Wi-Fi zones in some cities will continue to grow for many years. The recent flurry of municipal Wi-Fi mesh networks has only served to cement the technology into the wireless equation. Wi-Fi is not going away any time soon.

As the WiMAX standard grows into its first highs scale deployment with Clear wire in 2009 and continues to gain acceptance and drive cost reductions, new chipsets that incorporate the ability to function across multiple platforms will become more common in general with the MAN portion of this network technology slowly being converted to the more robust WiMAX systems, as the business cases for hotspot venues merit. Basically, this means that WiMAX users in a few years will be able to not only access Wi-Fi hotspots at a café, but could also have mobile citywide WiMAX access as well, along with access to other existing cellular technologies.

Multiple network capability in a single device is gaining traction and should be the norm in only a few years. Once again, this points towards a complementary aspect to the two technologies. True mobile access users in many cases will not require the level of bandwidth that they may need when in a fixed location. The two technologies will fulfill differing needs for consumers.

However, other LAN technology standards such as Bluetooth, UHF Whitespace frequencies, Ultrawideband and the 802.11n specification that offer value in shorter range hotspot networks will all grow and necessitate chipsets and laptop radios that will eventually be able to seamlessly cross these shorter range data networks as well as cellular networks and WiMAX citywide networks. The WiMAX standard is a major part of the very bright vision of the broadband wireless future that flexibility like this promises. Though leaders in the industry often cite the potential for true software defined radio systems, wherein a user's handset, laptop or other devices essentially scan for the best connection for the location and spectrum available. The industry is slowly moving in this direction; however, expect the full development of this type of seamless technology to be a few years away. Even moderate incremental improvements in this direction could afford consumers benefits that are essentially impossible with wireline technologies.

11. Benefits of WiMAX

Component Suppliers
• Assured wide market acceptance of developed and components
• Lower production costs due to economies of scale
• Reduced risk due to interoperability Equipment Manufacturers
• Stable supply of low cost components and chips
• Freedom to focus on development of network elements consistent with core competencies, while knowing that equipment will interoperate with third party products
• Engineering development efficiencies
• Lower production costs due to economies of scale Operators and Service Providers
• Lower CAPEX – with lower cost base station, customer premises equipment (CPE), and network deployment costs
• Lower investment risk due to freedom of choice among multiple vendors and solutions
• Ability to tailor network to specific applications by mixing and matching equipment from different vendors
• Improved operator business case with lower OPEX End Users
• Lower subscriber fees
• Wider choice of terminals enabling cost performance analysis
• Portability of terminals when moving locations/networks from WiMAX operator “A” to operator “B”
• Lower service rates over time due to cost efficiencies in the delivery chain.

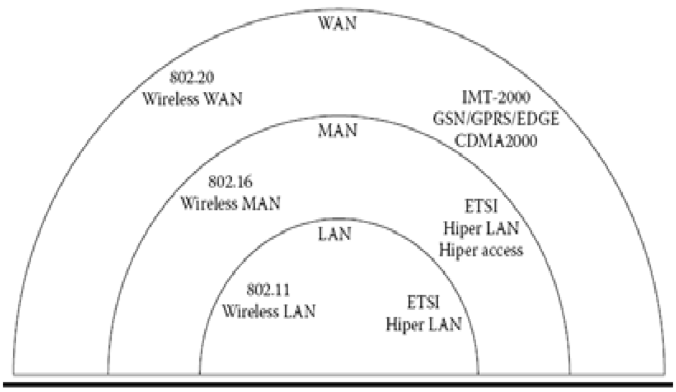
12. Limitations

A commonly-held misconception is that WiMAX will deliver 70 Mbit/s over 50 kilometers. In reality, WiMAX can do one or the other — operating over maximum range (50 km) increases bit error rate and thus must use a lower bitrate. Lowering the range allows a device to operate at higher bitrates. Typically, fixed WiMAX networks have a higher-gain directional antenna installed near the client (customer) which results in greatly increased range and throughput. Mobile WiMAX networks are usually made of indoor "*customer premises equipment*" (CPE) such as desktop modems, laptops with integrated Mobile WiMAX or other Mobile WiMAX devices. Mobile WiMAX devices typically have an omni-directional antenna which is of lower-gain compared to directional antennas but are more portable. In practice, this means that in a line-of-sight environment with a portable Mobile WiMAX CPE, speeds of 10 Mbit/s at 10 km could be delivered However, in urban environments they may not have line-ofsight and therefore users may only receive 10 Mbit/s over 2 km. Higher-gain directional antennas can be used with a Mobile WiMAX network with range and throughput benefits but the obvious loss of practical mobility. Like most wireless systems, available bandwidth is shared between users in a given radio sector, so performance could deteriorate in the case of many active users in a single sector. In practice, many users will have a range of 2-, 4-, 6-, 8-, 10- or 12 Mbit/s services and additional radio cards will be added to the base station to increase the capacity as required.
Because of this, various granular and distributed network architectures are being incorporated into WiMAX through independent development and within the 802.16j mobile multi-hop relay (MMR) task group. This includes wireless mesh, grids, network remote station repeaters which can extend networks and connect to backhaul.

13. Future of WiMAX

13.1 The IEEE 802.20 Standard

The IEEE 802.20 standard is a broadband wireless networking technology that is being standardized for deployment by mobile communications service providers, in portions of their licensed spectrum. The capacity of 802.20 is projected to be 2 Mbps per user, and its range is comparable to 3G cellular technologies, namely, up to 5 km. More typical deployments will be in the neighborhood of 1 to 3 km. Finalization of the 802.20 standard is not expected soon. The 802.20 standard has been under development since late 2002, but the going has been slow, to say the least. 802.20 and 802.16e, the mobile WiMAX specification, appear similar at first glance but differ in the frequencies they will use and the technologies they are based on. Standard 802.20 will operate below 3.5 GHz, whereas mobile WiMAX will work within the 2-GHz to 6-GHz bands. Further, as the name suggests, 802.16e is based on WiMAX, with the goal of having WiMAX transmitters being able to support both fixed and mobile connections. Although the 802.20 group will be back at work later, the 802.20 technology is alluring, with promises of low-latency 1-Mbps connections being sustained even at speeds of up to 150 mph, but we are going to have to wait a couple of years for it.



13.2 IEEE 802.16m

The 802.16m mobile WiMAX standard is a follow-on to 802.16e standard and is a candidate to the International Telecom Union's (ITU) consideration as an IMT advanced (4G) technology - specifically, providing downlink speeds of at least 100 Mbps in a wide area with high-mobility. The new 802.16m standard will provide increased performance advantages over 802.16e. From a technological perspective, 802.16m is capable of providing up to 120 Mbps down and 60 Mbps up in an urban setting, using 4x2 MIMO antennas on a single 20MHz-wide channel. Even higher data rates can be achieved with additional spectrum resources or more complex antenna schemes. Actual commercial performance will be considerably less based on spectrum used and other factors. While 802.16m will provide increased performance for users, the main, driving factor for operators adopting the technology will be increased network capacity to accommodate the massive bandwidth increases driven by smart phones, tablets and other wireless devices. In addition to capacity and performance advantages, 802.16m will be backward compatible with existing WiMAX networks, providing ease-of-mind for operators deploying networks today. Most mobile WiMAX operators can easily convert from 802.16e to 802.16m by updating some circuit plate units and software in their bases stations.

14. CONCLUSION

It is expected that WiMAX becomes the dominant standard for Wireless MAN networks in the world market, at least, in fixed broadband networks. A brief comparison between 802.16 and 802.16a has been provided and also it has been shown the advantage by using adaptive modulation. It has been explained that the key difference between the initial 802.16 standard and the 802.16a consists of the modulation scheme. The importance of OFDM has also been analyzed and this becomes an important feature that makes the difference between the 802.16 and 802.16a standard. More about this topic can be found in the literature provided. PHY and MAC layers of WiMAX have been Discussed Future possible applications have been discussed. WiMAX mobility standard is the next step. However, it will have its competition too with the 802.20 standard that in short is called Mobility-Fi. We will have to wait for the products and their performance in real environments in order to evaluate what the standard addresses and the real performance of these products. There are already prototypes and also development kits using WiMAX standard that are used for education and mainly for research. Nowadays, there are also some products that have been introduced into the market that already contains the WiMAX standard presented here. Market is the key word to take into account. Products will have to be delivered according to the market needs and those for end-users will have to be extremely easy to install. Experience from DSL and cable modems services shows this drawback. Of course, in addition to be easy to install and provide good technical features, these products have to provide low-cost or at least a clear advantage over other technologies that are, at this moment,
already matured in the market like xDSL and cable modem.

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