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"WiMAX": Promising Wireless Technology to Make Internet Access Decelerates a Thing of the Past

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Abstract: New and increasingly advanced data services are driving up wireless traffic, which is being further boosted by growth in voice applications in advanced market segments as the migration from fixed to mobile voice continues. This is already putting pressure on some networks and may be leading to difficulties in maintaining acceptable levels of service to subscribers.
For the past few decades the lower band width applications are growing but the growth of broad band data applications is slow. Hence we require technology which helps in the growth of the broad band data applications. WiMAX is such a technology which helps in point-to-multipoint broadband wireless access without the need of direct line of sight connectivity with base station.
This paper explains about the WiMAX technology, its additional features in physical layer and MAC layer and the benefits of each feature.
This paper focuses on the major technical comparisons (like QOS and coverage) between WiMAX and other technologies. It also explains about the ability of the WiMAX to provide efficient service in multipath environment.

Keywords: WiMax, QoS, DSL, OFDM, OFDMA, MAN, LOS, NLOS, CDMA

I. INTRODUCTION

For the past couple decades, low-bandwidth applications such as downloading ring tones and SMS are experiencing sharp growth, but the growth of broadband data applications such as email and downloading/ uploading files with a laptop computer or PDA has been slow. The demand for broadband access

Continues to escalate worldwide and lower-bandwidth wire line methods have failed to satisfy the need for higher bandwidth integrated data and voice services. WiMAX is radio technology that promises two-way Internet access at several megabits per second with ranges of several miles. It is believed that the technology can challenge DSL (Digital Subscriber Line) and cable broadband services because it offers similar speeds but is less expensive to set up. The intention for WiMAX is to provide fixed, nomadic, portable and, eventually, Mobile wireless broadband connectivity without the need for Direct line-of-sight with a base station.

II. WHAT IS WIMAX?

WiMAX is an acronym that stands for **"Worldwide Interoperability for Microwave Access". IEEE 802.16** is working group number 16 of IEEE 802, specializing in point-to-multipoint broadband wireless access. It also is known as WiMAX. There are at least four 802.16 standards: 802.16, 802.16a, 802.16-2004 (802.16), and 802.16e.

WiMAX does not conflict with WiFi but actually complements it. WiMAX is a wireless metropolitan area network (MAN) technology that will connect IEEE 802.11 (WiFi) hotspots to the Internet and provide a wireless extension to cable and DSL for last km broadband access. IEEE 802.16 provides up to 50 km of linear service area range and allows user's connectivity without a direct line of sight to a base station. The technology also provides shared data rates up to 70 Mbit/s.

The portable version of WiMAX, IEEE 802.16 utilizes Orthogonal Frequency Division Multiplexing Access (OFDM/OFDMA) where the spectrum is divided into many sub-carriers. Each sub-carrier then uses QPSK or QAM for modulation. WiMAX standard relies mainly on spectrum in the 2 to 11 GHz range. The WiMAX specification improves upon many of the limitations of the WiFi standard by providing increased bandwidth and stronger encryption

For years, the wildly successful 802.11 x or WiFi wireless LAN technology has been used in BWA applications. When the WLAN technology was examined closely, it was evident that the overall design and feature set available was not well suited for outdoor Broadband wireless access (BWA) applications. WiMAX is suited for both indoor and outdoor BWA; hence it solves the major problem.[1]

In reviewing the standard, the technical details and features that differentiate WiMAX certified equipment from WiFi or other technologies can best be illustrated by focusing on the two layers addressed in the standard, the physical (PHY) and the media access control (MAC) layer design.

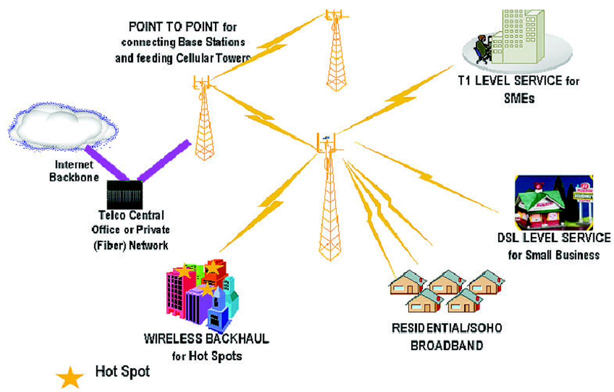


Figure 1. BWA (IEEE 802.16) Everywhere

A. Wimax phy layer

The first version of the 802.16 standard released addressed Line-of-Sight (LOS) environments at high frequency bands operating in the 10-66 GHz range, whereas the recently adopted amendment, the 802.16a standard, is designed for systems operating in bands between 2 GHz and 11 GHz. The significant difference between these two frequency bands lies in the ability to support Non-Line -of-Sight (NLOS) operation in the lower frequencies, something that is not possible in higher bands. Consequently, the 802.16a amendment to the standard opened up the opportunity for major changes to the PHY layer specifications specifically to address the needs of the 2-11 GHz bands. This is achieved through the introduction of three new PHY-layer specifications (a new Single Carrier PHY, a 256 point FFT OFDM PHY, and a 2048 point FFT OFDMA PHY);

Some of the other PHY layer features of 802.16a that are instrumental in giving this technology the power to deliver robust performance in a broad range of channel environments are; flexible channel widths, adaptive burst profiles, forward error correction with concatenated Reed-Solomon and convolutional encoding, optional AAS (advanced antenna systems) to improve range/capacity, DFS (dynamic frequency selection)-which helps in minimizing interference, and STC (space-time coding) to enhance performance in fading environments through spatial diversity. Table 1 gives a high level overview of some of the PHY layer features of the IEEE 802.16a standard.

Table 1. 802.16a PHY Features

Feature	***Benefit***
256 point FFT OFDM waveform	• Built in support for addressing multipath in outdoor and NLOS environments
Adaptive Modulation and variable error correction encoding per RF burst	• Ensures a robust RF link while maximizing the number of bits/ second for each subscriber unit.
TDD and FDD duplexing support	• Address varying worldwide regulations where one or both may be allowed.
Flexible Channel sizes (e.g. 3.5MHz, 5MHz, 10MHz,Etc)	• Provides the flexibility necessary to operate in many different frequency bands with varying channel requirements around the world.
Designed to support smart antenna systems	• Smart antennas are fast becoming more affordable, and as these costs come down their ability to suppress interference and increase system gain will become important to BWA deployments.

While all the features listed above are necessary requirements for basic outdoor BWA operation, flexible channel sizes is required if a standard is to truly address worldwide deployment. This is because the regulations governing what frequency equipment can operate in, and as a result the size of the channels used, can vary country by country. In the case of licensed spectrum where an operator had to pay for every MHz granted, it is imperative that the system deployed use all the allocated spectrum and provide flexibility in either cellular or "big stick" deployments. Thus if an operator has been granted and paid for 14MHz, they do not want a system that has 6MHz channels, wasting 2MHz of spectrum. They want a system that can be deployed with 7MHz, 3.5MHz or even 1.75MHz channels for maximum adaptability.

B. IEEE 802.16A MAC LAYER

Every wireless network operates fundamentally in a shared medium and as such that requires a mechanism for controlling access by subscriber units to the medium. The 802.16a standard uses a slotted TDMA protocol scheduled by the BTS to allocate capacity to subscribers in a point-to-multipoint network topology. While this on the surface sounds like a one line, technical throwaway statement, it has a huge impact on how the system operates and what services it can deploy.

By starting with a TDMA approach with intelligent scheduling, WiMAX systems will be able to deliver not only high speed data with SLAs, but latency sensitive services such as voice and video or database access are also supported.

The standard delivers QoS beyond mere prioritization, a technique that is very limited in effectiveness as traffic load and the number of subscribers' increases. The MAC layer in WiMAX certified systems has also been designed to address the harsh physical layer environment where interference, fast fading and other phenomena are prevalent in outdoor operation.

Table 2. 802.16a MAC Features

Feature	***Benefit***
TDM/TDMA Scheduled Uplink/Downlink frames	• Efficient bandwidth usage
Scalable from 1 to hundreds of subscribers	• Allows cost effective deployments by supporting enough subs to deliver a robust business case
Connection-oriented	• Per Connection QoS • Faster packet routing and forwarding
QoS supportContinuous GrantReal Time Variable Bit RateNon Real Time Variable Bit RateBest Effort	• Low latency for delay sensitive services (TDMVoice, VoIP) • Optimal transport for VBR traffic(e.g., video)·Data prioritization
Automatic Retransmission request (ARQ)	Improves end-to-end performance by hiding RF layer induced errors from upper layer protocols
Support for adaptive modulation	• Enables highest data rates allowed by channel conditions, improving system capacity
Security and encryption (Triple DES)	• Protects user privacy
Automatic Power control	• Enables cellular deployments by minimizing self interference

III. WIMAX SCALABILITY

- **Differentiating the IEEE 802.16a and 802.11 Standards - WiFi versus WiMAX Scalability**

At the PHY layer the standard supports flexible RF channel bandwidths and reuse of these channels (frequency reuse) as a way 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. Operators can re-allocate spectrum through sectorization and cell splitting as the number of subscribers grows.

In the MAC layer, the CSMA/CA foundation of 802.11, basically a wireless Ethernet protocol, scales about as well as does Ethernet. That is to say - poorly. Just as in an Ethernet LAN, more users results in a geometric reduction of throughput, so does the CSMA/CA MAC for WLANs. In contrast the MAC layer in the 802.16 standard has been designed to scale from one up to 100's of users within one RF channel, a feat the 802.11 MAC was never designed for and is incapable of supporting.[6]

A. Coverage

The BWA standard is designed for optimal performance in all types of propagation environments, including LOS, near LOS and NLOS environments, and delivers reliable robust performance even in cases where extreme link pathologies have been introduced. The robust OFDM waveform supports high spectral efficiency over ranges from 2 to 40 kilometers with up to 70 Mbps in a single RF channel. Advanced topologies (mesh networks) and antenna techniques (beam-forming, STC, antenna diversity) can be employed to improve coverage even further. These advanced techniques can also be used to increase spectral efficiency, capacity, reuse, and average and peak throughput per RF channel. In addition, not all OFDM is the same. The OFDM designed for BWA has in it the ability to support longer range transmissions and the multi-path or reflections encountered. In contrast, WLANs and 802.11 systems have at their core either a basic CDMA approach or use OFDM with a much different design, and have as a requirement low power consumption limiting the range. OFDM in the WLAN was created with the vision of the systems covering tens and maybe a few hundreds of meters versus 802.16 which is designed for higher power and an OFDM approach that supports deployments in the tens of kilometers.

IV. QUALITY OF SERVICE

The 802.16a MAC relies on a Grant/Request protocol for access to the medium and it supports differentiated service The protocol employs TDM data streams on the DL (downlink) and TDMA on the UL (uplink), with the hooks for a centralized scheduler to support delay-sensitive services like voice and video. By assuring collision-free data access to the channel, the 16a MAC improves total system throughput and bandwidth efficiency, in comparison with contention-based access techniques like the CSMA-CA protocol used in WLANs. The 16a MAC also assures bounded delay on the data. The TDM/TDMA access technique also ensures easier support for multicast and broadcast services. With a CSMA/CA approach at its core, WLANs in their current implementation will never be able to deliver the QoS of a BWA, 802.16 systems.

IV. ROLE OF 'OFDMA' IN MULTIPATH ENIRONMENT

Technologies using DSSS (802.11b, CDMA) and other wide band technologies are very susceptible to multipath fading, since the delay time can easily exceed the symbol duration, which causes the symbols to completely overlap (ISI). The use of several parallel sub-carriers for OFDMA enables much longer symbol duration, which makes the signal more robust to multipath time dispersion.

A. Multipath: frequency selective fading

This type of fading affects certain frequencies of a transmission and can result in deep fading at certain frequencies. One reason this occurs is because of the wide band nature of the signals. When a signal is reflected off a surface, different frequencies will reflect in different ways. In Figure below, both CDMA (left) and OFDMA (right) experience selective fading near the center of the band. With optimal channel coding and interleaving, these errors can be corrected. CDMA tries to overcome this by spreading the signal out and then equalizing the whole signal. OFDMA is therefore much more resilient to frequency selective fading when compared to CDMA.

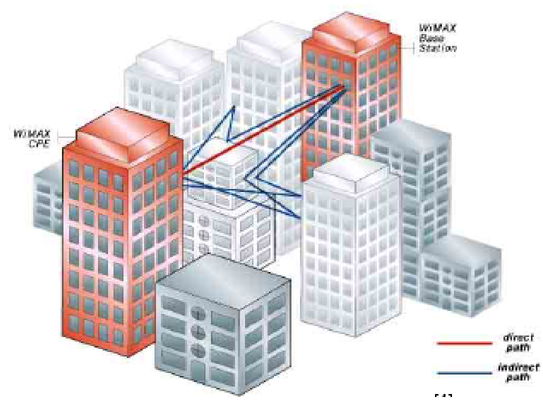


Figure 2. Multipath Frequency fading

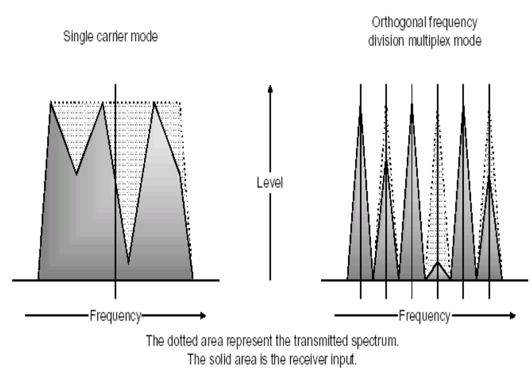


Figure 3. Single and OFDM frequency mode

V. OFDMA WITH ADAPTIVE MODULATION AND CODING (AMC)

Both W-CDMA (HSDPA) and OFDM utilize Quadrature Phase Shift Keying (QPSK) and Quadrature

Amplitude Modulation (QAM). It should be noted here that for WCDMA, AMC is only used on the downlink, since the uplink still relies on WCDMA which uses QPSK but not QAM. Modulation and coding rates can be changed to achieve higher throughput, but higher order modulation will require better Signal to Noise Ratio. Figure illustrates how higher order modulations like QAM 64 are used closer to the base station, while lower order modulations like QPSK are used to extend the range of the base station . Performance results conducted for one of the 3GPP Working Groups [2], show that while OFDM is able to achieve the maximum throughput of 9.6 Mbps (16QAM), WCDMA does not exceed 3 Mbps. From these results, it appears that even higher discrepancy may be found when utilizing higher modulation and code rates to yield even higher throughput for OFDM.

Adaptive Modulation and Coding (AMC) in a multipath environment may give OFDMA further advantages since the flexibility to change the modulation for specific sub-channels allows you to optimize at the frequency level. Another alternative would be to assign those sub channels to a different user who may have better channel conditions for that particular sub-channel. This could allow users to concentrate transmit power on specific sub-channels, resulting in improvements to the uplink budget and providing greater range. This technique is known as Space Division Multiple Access (SDMA).

In Figure below, you can see how sub-channels could be chosen depending on the received signal strength. The sub-channels on which the user is experiencing significant fading are avoided and power is concentrated on channels with better channel conditions. The signals on the top indicate the received signal strength, while the bottom part of the figure indicates which sub-carriers are then chosen for each signal.[7]

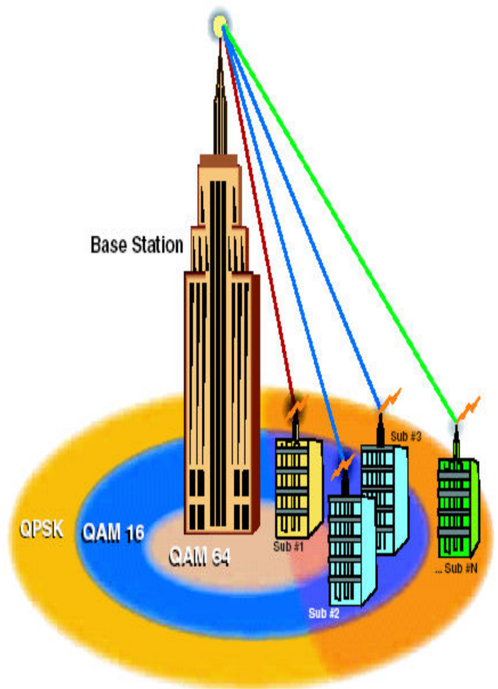


Figure 4. Adaptive PHY

With OFDMA, the client device could choose sub channels based on geographical locations with the potential of eliminating the impact of deep fades. CDMA-based technologies utilize the same frequency band regardless of where the user is.

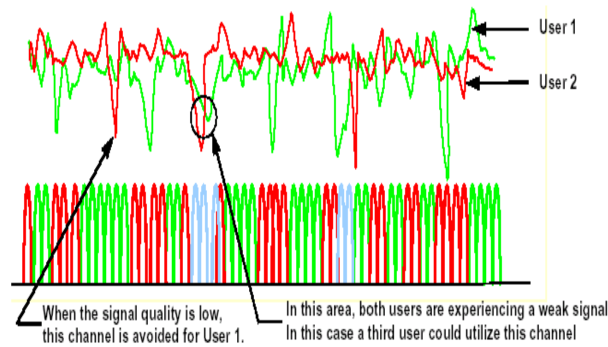
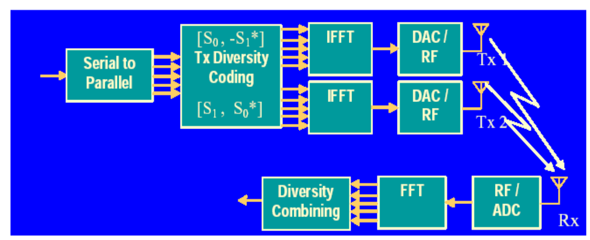


Figure 5. Signal Quality Analogy

VI. ADVANCED RADIO TECHNIQUES:

A. Transmit and receive diversity schemes

Transmit and Receive Diversity schemes are used to take advantage of multipath and reflected signals that occur in NLOS environments. By utilizing multiple antennas (transmit and/or receive), fading, interference and path loss can be reduced. The OFDMA transmit diversity option uses space time coding. For receive diversity, techniques such as maximum ratio combining (MRC) take advantage of two separate receive paths.



Space-Time TX mapping and the appropriate MISO channel estimate at the TX achieves full 2nd order diversity in the link stabilizing the channel response and reducing the required fading margin by 5-10 dB depending on the environment

Figure. 6. Adv. Radio Techniques

B. Smart antenna technology

Adaptive antenna systems (AAS) are an optional part of the 802.16 standard. AAS equipped base stations can create beams that can be steered, focusing the transmit energy to , greater range as shown in the figure. When receiving, they can focus in the particular direction of the receiver. This helps eliminate unwanted interference from other locations.

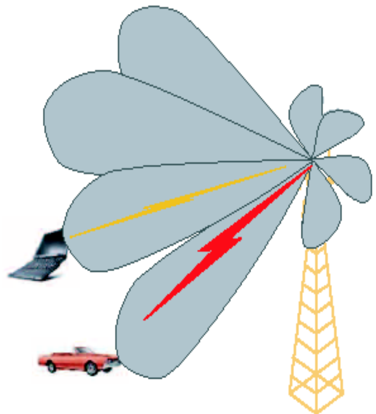


Figure. 7

VI. CONCLUSION

Thus WiMAX systems for portable/nomadic use will have better performance, interference rejection, multipath tolerance, high data quality of service support (data oriented MAC, symmetric link) and lower future equipment costs i.e., low chipset complexity, high spectral efficiencies. And hence WiMAX can complement existing and emerging 3G mobile and wireline networks, and play a significant role in helping service provides deliver converged service offerings.

VII. IEEE 802.16 MAC – COMMONLY USED TERMS

BS – Base Station
SS – Subscriber Station, (i.e., CPE)
DL – Downlink, i.e. from BS to SS
UL – Uplink, i.e. from SS to BS
FDD – Frequency Division Duplex
TDD – Time Division Duplex
TDMA – Time Division Multiple Access
TDM – Time Division Multiplexing
OFDM – Orthogonal Frequency Division Multiplexing
OFDMA -Orthogonal Frequency Division Multiple Access
QoS – Quality of Service

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