A Performance Study of Wireless Broadband Access (WiMAX)

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Abstract-- WiMAX (worldwide interoperability for microwave access) is one of the wireless broadband access technologies which supplies broadband services to clients, but it surpasses other technologies by its coverage area, where one base station can cover a small city. In this paper, WiMAX technology is studied by exploring its basic concepts, applications, and advantages / disadvantages. Also a MATLAB simulator is used to verify the operation of the WiMAX system under various channel impairments and for variety of modulation schemes. From the simulation results, we found that WiMAX system works well in both AWGN and multipath fading channels, but under certain constraints that are addressed in this paper.

Keywords: WiMAX, IEEE 802.16, simulation.

I. INTRODUCTION

In the last few years, WiMAX has been proposed as a promising wireless communication technology due to the fact that it can provide high data rate communications in metropolitan area networks (MANs). Until now, a number of specifications for WiMAX were standardized by the IEEE 802.16 working group. In 2001, the first IEEE 802.16 standard was published, which aimed to support the communications in the 10-66 GHz frequency band. Two years later, IEEE 802.16a was introduced to provide additional physical layer specifications for the 2-11 GHz frequency band. These two standards were revised further in 2004 to introduce IEEE 802.16-2004 standard, where QoS (Quality of Service) provisioning was one of its essential features [1, 2]. In 2005, IEEE 802.16e was approved as the official standard for mobile applications. In addition to the IEEE 802.16 working group, companies in the industry also have formed the WiMAX forum to promote the development and deployment of WiMAX systems.

However, till day there are many technical challenges to wide adaptation of WiMAX, in particular its coexistence and interoperability with other wireless technologies [3].

In general WiMAX has two hardware components, a WiMAX tower and a WiMAX receiver. The tower is like a cell tower, but can provide coverage to an estimated 30-mile radius. The tower connects to the Internet using a high-bandwidth wire line connection (e.g., T3), or it provides a wireless backhaul to other WiMAX towers with LOS (Line Of Sight) microwave links. The receiver can be anything from a large building-mounted antenna to a small appliance, a laptop card, or even a built-in chip, like the WiFi (Wireless Fidelity) receivers in PCs and laptops today (see fig. 1).

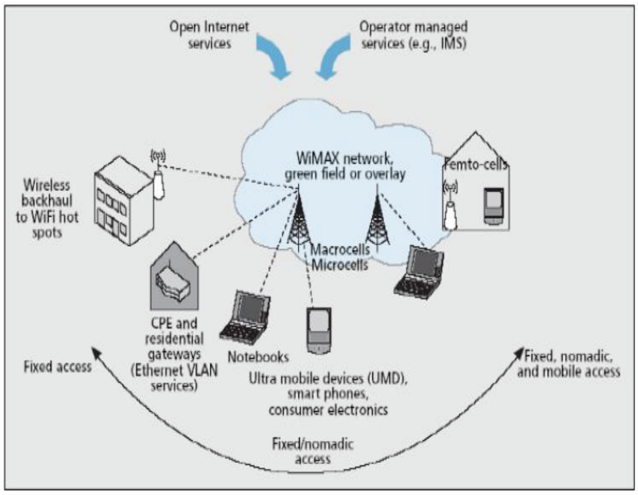

Figure 1. WiMAX technology enabling a variety of usage models in the same network.

However, in this paper, WiMAX technology is studied in detail. Also a simulator is used to verify the operation of WiMAX system for variety of modulation schemes and under various channel impairments.

Our paper is organized as follows: section II clarifies the types of WiMAX, and section III gives a comparison between WiMAX and WiFi. In section IV, the disadvantages of WiMAX are stated. While section V involves a detailed explanation of WiMAX physical layer. The results and discussion are addressed in section VI, and finally; the conclusions are drawn in section VII.

II. Types of WiMAX

In general, WiMAX can be divided into two types: fixed and portable [4].

A. Fixed WiMAX

The IEEE 802.16-2004 standard is designed for fixed-access usage models because it uses a mounted antenna at the subscriber's site. It is optimized for long-distance links because it is designed to tolerate longer delays and delay variations. However, fixed WiMAX operates in the licensed 2.5 GHz, 3.5 GHz and license-exempt 5.8 GHz bands. This technology provides a wireless alternative to the cable modem, digital subscriber lines of any type (xDSL), transmit/exchange (Tx/Ex) circuits and optical carrier level (OC-x) circuits. The fixed profiles have channel sizes of 3.5 MHz, 5 MHz, 7 MHz, and 10 MHz. Typically, fixed WiMAX networks have a higher-gain directional antenna which greatly increases range and throughput.

B. Portable (Mobile) WiMAX

Mobile WiMAX, also known as IEEE 802.16e standard, is designed for mobile users. Its channel sizes are of 5 MHz, 8.75 MHz and 10 MHz. However, mobile WiMAX adds significant enhancements over fixed WiMAX, such as [5]:

1. It improves NLOS (None Line Of Sight) coverage by utilizing advanced antenna diversity schemes such as adaptive antenna system (AAS) and multiple input multiple output (MIMO) technologies.
2. It adopts dense subchannelization, thus increasing system gain and improving indoor penetration.
3. It is based on OFDM/OFDMA technology.

These features bring potential benefits in terms of coverage, power consumption, frequency reuse, and bandwidth efficiency.

III. Comparison and Confusion between WiMAX and WiFi

In WiMAX systems, licensed spectrum is used to deliver the internet from an ISP (Internet Service Provider) to an end user. While WiFi uses unlicensed spectrum to provide access to a network. The notable advantage of WiMAX comes from combining OFDMA technologies in conjunction with smart antennas. Based on the proven technology of OFDM; WiMAX is better able to address significant challenges within an NLOS (Non-Line of Sight) environment than WiFi because WiMAX uses more subcarriers during wireless transmission, that are typically 256 subcarriers against 64 subcarriers for WiFi.

Also, WiMAX supports higher throughput and longer distance than many competitive wireless technologies, where the distance reached by a WiMAX network is tens of kilometers, compared to a maximum of 100 meters by WiFi.

Furthermore, in WiMAX, the ratio of cyclic prefix (or non-useful data) to the total number of subcarriers is much smaller than with WiFi. Thus WiMAX has higher efficiency and better NLOS performance.

IV. WiMAX Disadvantages

Although WiMAX has its own competitive advantages, but still has some disadvantages; such as:

1. Line of site is needed for longer distances.
2. Weather conditions like rain could interrupt the signal.
3. 0ther wireless equipments could cause interference.
4. WiMAX is very power intensive technology and requires strong electrical support.
5. Big installation and operational cost.

V. WiMAX Physical Layer

WiMAX physical layer is based on various communication techniques including coding, interleaving, QPSK modulation, and OFDM transmission. In this section, we elaborate the physical layer of WiMAX downlink system by exploring the WiMAX simulator. Fig. 2 shows the WiMAX simulator which represents a downlink baseband model of the physical layer of a wireless metropolitan area network (WMAN) according to the IEEE 802.16 standard. The tasks performed in the communication system model include [6]:

1. Generation of random bit data which models a downlink burst consisting of an integer number of OFDM symbols.
2. Forward Error Correction coding (FEC).
3. Data interleaving.
4. Modulation, using one of the BPSK, QPSK, 16-QAM or 64-QAM modulation schemes.
5. Orthogonal Frequency Division Multiplexed (OFDM) transmission using 192 sub-carriers, 8 pilots, 256-point FFTs, and a variable cyclic prefix length.
6. A choice of non-fading, flat-fading or selective multipath fading channel.
7. OFDM receiver which includes channel estimation using the inserted preambles.
8. Gain and phase compensation.
9. Data carrier extraction.
10. Hard-decision demodulation followed by deinterleaving and Viterbi decoding.

The following paragraphs clarify the function of each block of the simulator.

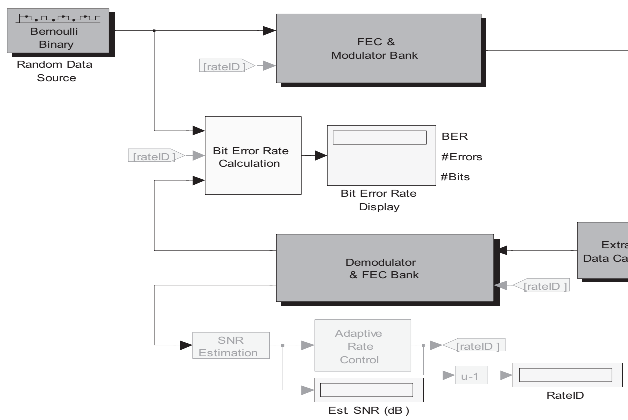

Figure 2. Simulator of WiMAX downlink system.

A. *Random Data Generator*

The first block of the simulator is the random data generator which generates data with the required speed.

B. *Forward Error Correction*

The second block is the Forward Error Correction block which is used to improve the capacity of a channel by adding some carefully designed redundant information to the data being transmitted through the channel. The process of adding this redundant information is known as channel coding, where convolutional coding is the major form of channel coding.

C. *Orthogonal Frequency-Division Multiplexing*

Orthogonal Frequency Division Multiplexing (OFDM) is a communication transmission technique which divides a communication channel into a number of equally spaced frequency bands. A subcarrier carrying a portion of the user information is transmitted in each band. Each subcarrier is orthogonal with every other subcarrier, differentiating OFDM from the commonly used frequency division multiplexing (FDM). OFDM is a very effective way of protecting data transmitted over communication channels that experience narrow-band fading. Each subcarrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. This is because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate intersymbol interference (ISI). Although OFDM has great advantages but it is sensitive to Doppler shift and frequency synchronization problems. Also it has another disadvantage which is the high peak-to-average-power ratio (PAPR), requiring linear transmitter circuitry, which suffers from poor power efficiency. It is worth to mention that OFDM can be easily implemented using IFFT (Inverse Fast Fourier Transform) on the sender side, and the FFT algorithm on the receiver side.

D. *Radio Communication Channel*

The radio wave transmitted from a base station radiates in all directions, and hence the subscriber station will receive radio waves including reflected waves that are reflected from various obstacles, diffracted waves, scattering waves, and the direct wave from the base station to the subscriber station. In this case, since the path lengths of the direct, reflected, diffracted, and scattering waves are different, the time each it takes to reach the mobile station will be different. In addition the phase of the incoming wave varies because of reflections. As a result, the receiver receives a superposition consisting of several waves having different phase and times of arrival which is called a multipath propagation environment. In a multipath propagation environment, the received signal is sometimes intensified or weakened. This phenomenon is called multipath fading and the signal level of the received wave changes from moment to moment. However, multipath fading raises the error rate of the received data. A compensation method for this multipath fading must be used to ensure a high transmission performance.

E. *WiMAX Receiver*

At the reception side, reciprocal processes are done in order to recover the transmitted symbols. These processes are: FFT, channel estimation and compensation, QPSK demodulation, and decoding.

However, in this simulator, the received estimated bits are compared with the transmitted bits using BER (Bit Error Rate) block which calculates the number of errors received and the BER.

VI. Results and Discussion

In this section we evaluate the performance of WiMAX downlink system via examining its BER at the receiver end. The effect of various channel impairments such as channel noise and multipath fading are investigated. Also, the impact of various modulation techniques; such as BPSK, QPSK, 16QAM, and 64QAM is addressed.

Fig. 3 illustrates the effect of SNR (signal to noise ratio) on system BER for BPSK modulation. It is clear that in general the system BER decreases as SNR increases that is because increasing SNR means increasing symbol energy with respect to noise energy within symbol time period; this will enhance the ability of the WiMAX receiver to detect the received data more precisely and hence decreasing the BER.

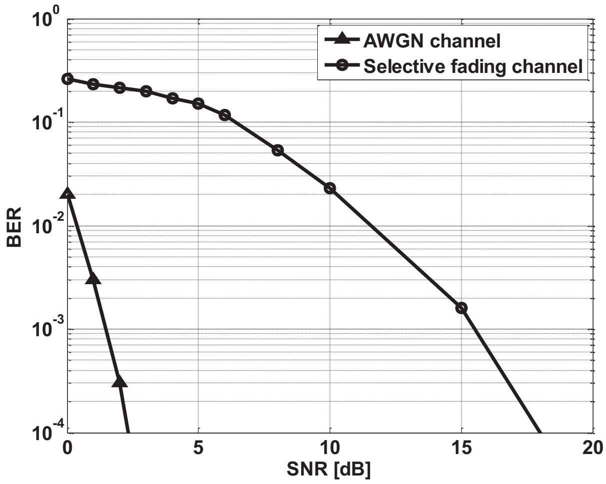

Figure 3. Variations of BER with respect to SNR for BPSK modulation.

Also, we can observe that at certain SNR; the effect of selective fading channel on system BER is severe comparing to that of AWGN channel. This may be due to the notches at the power spectrum of the selective fading channel, where at these notches; the transmitted signal is attenuated severely which leads to increasing BER. Also, in order to achieve a reasonable BER of 10^{-4}; it is required an SNR of no less than 2.5 dB for AWGN channel, and no less than 18 dB for selective fading channel.

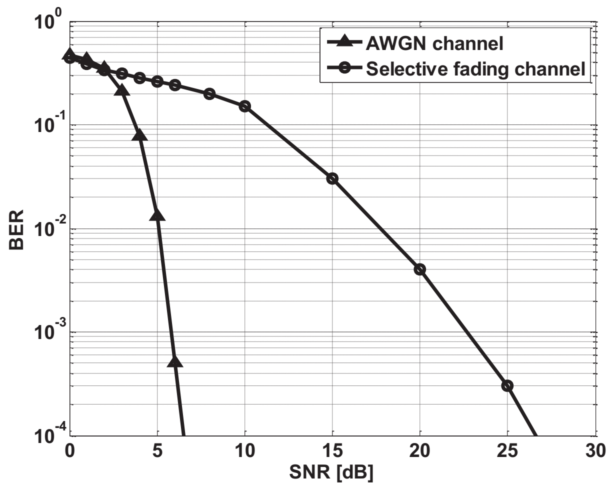

Figure 4. Variations of BER with respect to SNR for QPSK modulation.

Fig. 4 depicts the effect of SNR on the system BER but for QPSK modulation which shows the same behavior as in fig. 3 except that the required SNR to achieve the same BER is larger. For instance, in fig. 4, the required SNR's to achieve BER of 10^{-4} are 6.5 dB, and 27 dB for AWGN and selective fading channels respectively. We can note that these values are larger than the corresponding values in fig. 3. However, this is expected; because in general as we increase the modulation efficiency from BPSK to QPSK, and in order to keep the BER constant, we need to propagate the signal in less channel impairments, or instead we need to increase the SNR.

By the same way; fig. 5 shows that the required SNR's to achieve the target BER for 16 QAM modulation are 13 dB and 31 dB for AWGN and selective fading channels respectively. While 20 dB and 40 dB are required for 64 QAM modulation as shown in fig. 6.

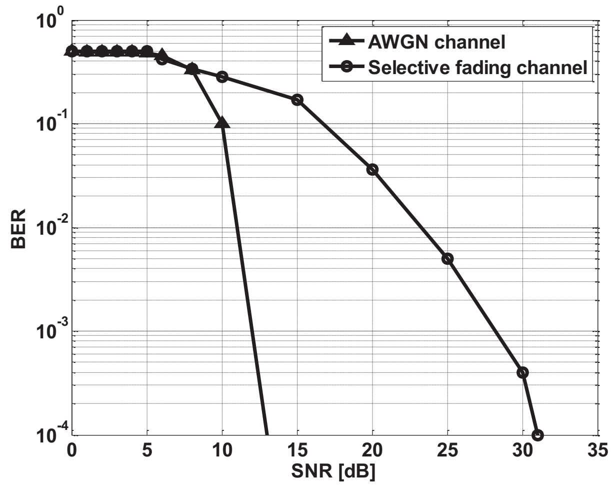

Figure 5. Variations of BER with respect to SNR for 16QAM modulation.

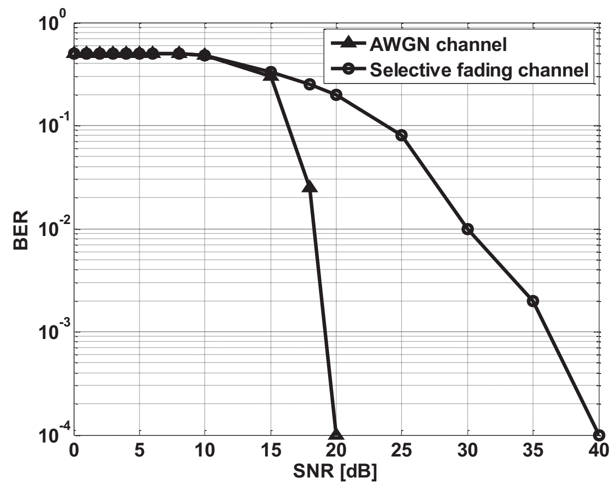

Figure 6. Variations of BER with respect to SNR for 64QAM modulation.

VII. Conclusions

Recently, WiMAX has been proposed as an attractive wireless communication technology for providing broadband access for metropolitan areas. Despite its salient features from the technical perspective, the success of the WiMAX network depends on its capability of providing cost-effective solutions for a variety of existing and potential services. Also, WiMAX has several advantages over the existing wireless techniques; of these are the using of OFDM transmission with larger number of subcarriers to combat multipath fading, and the wide coverage area achieved. However, according to the simulation results, we can conclude that WiMAX system works well in both AWGN and multipath fading channels and for variety of modulation schemes, but under certain SNR constraints that are addressed in this paper.

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