Wi-Max Physical Layer Simulator Using Different Modulation Schemes

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Abstract
Wi-MAX is a wireless technology which offers high data rate transmission in broadband. The Worldwide interoperability for microwave access (Wi-MAX) based on IEEE 802.16, has been one of the most important technologies in communication networks providing voice, data and video services with different type of QoS (Quality of Service) during last few years. In this paper, the architecture of the Wi-MAX physical layer simulator is presented. The main blocks are implemented with the aid of the Matlab Simulink and the bit error rate (BER) curves are presented with varying SNR under different digital modulations in AWGN channel.

Keywords – Wi-MAX, Physical layer, QoS, OFDM

1. Introduction

Wi-MAX (Worldwide Interoperability for Microwave Access) is based on the IEEE802.16 standard for Metropolitan Area Networks (MAN). Its goal is to deliver wireless broadband access to customers using base stations with coverage distances in the order of miles. Originally, the standard considered only fixed and nomadic links (802.16-2004) that could be used for "last mile" connectivity providing an alternate to T1 and DSL wired lines or as a back-haul for cellular or Wi-Fi networks. In order to address mobile subscribers, Wi-MAX was expanded to include portable devices (802.16e) such as personal digital assistants (PDAs), laptops, or phones. Requirements for mobility support include provisions for roaming, also inter-cell handoff and incorporating more flexibility into the standard to sustain multiple users demanding various types of services[1] [2].In mobile Wi-Max, the system's resources are dynamically allocated to deliver high data rates seamlessly to terminals traveling at vehicular speeds. The frequencies allocated for Wi-Max span the 2-66 GHz range. The exact frequency of operation for any given system is dependent on the propagation conditions that are encountered during its use. The frequencies higher than 10 GHz are practical only for fixed line-of-sight (LoS) type services. Non-line of sight (NLoS) communications perform better when the frequencies of operation are kept under 10 GHz. The frequencies below 6 GHz have better propagation properties and are better suited for mobile communications because they most likely guarantee service to all the niches of the coverage area[3] [4].Wi-Max is a part of the evolution from voice-only wireless communications systems to ones that provide additional services like web browsing, streaming media, gaming, instant messaging, and other content. Being able to deliver a wide variety of services also requires a delivery system that is flexible and can efficiently allocate system resources. The 802.16 standard offers adjustable data rate to and from each user while maintaining the required quality of service (QoS). Certain applications require higher error resilience and latency requirements that directly factor into the QoS. Real-time services, for example, have strict latency tolerances.

The system resources are allocated and scheduled dynamically by the base station on a frame by frame basis to keep up with the need of the users in the environment. To approach the theoretical capacity of the system, Wi-Max uses a combination of adaptive modulation schemes and coding ranging from rate QPSK to 5/6 rate 64QAM.The amount of error correction applied to each transmission is adjustable and can be changed depending on the required QoS and based on the reliability of the link between each user and the base station. The higher modulation constellations offer a larger throughput per frequency-time slot but not all users receive adequate signal levels to reliably decode all modulation types. Users that are close to the base station that exhibit good propagation and interference characteristics are assigned with higher modulation constellations to minimize the use of system resources. While users that are in less favourable areas use the lower order modulations for communications to ensure data is received and decoded correctly at the expense of additional frequency/time slots for the same amount of throughput. Assigning modulations based on the link conditions increases the overall capacity of the system. The use of variable or adaptive modulations to increase capacity is a trend also observed in other recently developed mobile phone and data standards like WCDMA[5] [6].Rest of this paper is organized as follows: Section II gives a brief overview about different Wi-Max standards. In Section III detailed study about the Wi-Max physical layer is presented. Section IV shows our simulation results. Finally conclusion and future work are presented in section V.

2. IEEE 802.16

IEEE 802.16 is a series of Wireless Broad band standards authored by the Institute of Electrical and Electronics Engineers (IEEE). The IEEE Standards Board in established a working group in 1999 to develop standards for broadband Wireless Metropolitan Area Networks. The Forum promotes and certifies compatibility and interoperability of products based on the IEEE 802.16 standards.

IEEE 802.16a

The second version of Wi-Max standard 802.16a was an amendment of 802.16 standards and has the capability to broadcast point-to-multi point in the frequency range 2 to 11 GHz. It was established in January 2003 and assigned both licensed and unlicensed frequency bands. Unlicensed bands cover maximum distance from 31 to 50 miles. It improves the Quality of Service (QoS) features with supporting protocols for instance Ethernet, ATM or IP.

IEEE 802.16b

IEEE 802.16b extension clarifies broadband wireless access metropolitan network functions and capabilities of the radio-air interface. License-exempt BWA metropolitan networks support multimedia services. It also increases the spectrum of 5 and 6 GHz frequency bands and provides quality of service which ensures priority transmission for real time voice and video.

IEEE 802.16c

The third version of Wi-Max standard 802.16c was also an amendment of 802.16 standards which mostly dealt with frequency ranging 10 to 66 GHz. This standard addressed various issues, for instance, performance evaluation, testing and detailed system profiling. The system profile is developed to specify the mandatory features to ensure interoperability and the optional features that differentiate products by pricing and functionality.

IEEE 802.16d

In September2003, a revision project known as 802.16d began which aimed to align with a particular view of European Telecommunications Standards Institute (ETSI) Hiper-MAN. This project was deduced in 2004 with the release of 802.16d-2004 including all previous versions' amendments. This standard supports mandatory and optional elements along with TDD and FDD technologies. Theoretically, its effective data rate is 70 Mbps but in reality, the performance is near about 40 Mbps. This standard improves the Quality of Service (QoS)by supporting very large Service Data Units (SDU) and multiple polling schemes.

IEEE 802.16e

802.16e was an amendment of 802.16d standard which finished in 2005 and known as 802.16e-2005. Its main aim is mobility including large range of coverage. Sometimes it is called mobile Wi-Max. This standard is a technical updates of fixed Wi-Max which has robust support of mobile broadband. Mobile Wi-Max was built on Orthogonal Frequency Division Multiple Access (OFDMA). It mentioned that, both standards (802.16d-2004 and 802.16e-2005) support the 256-FFTsize.The OFDMA system divides signals into sub-channels to enlarge resistance to multipath interference. For instance, if a 30MHz channel is divided into 1000 sub-channels, each user would concede some sub-channels which are based on distance.

3. Wi-Max PHYSICAL LAYER

Physical layer is the most important layer. The role of the physical layer is to encode the binary digits that represent MAC frames into signal and transmit and receive these signals across the communication media. The Wi-Max physical layer is based on OFDM which is used to enable high speed data, video and multimedia used by a variety of commercial application. Now we discuss about the Wi-Max physical layer.

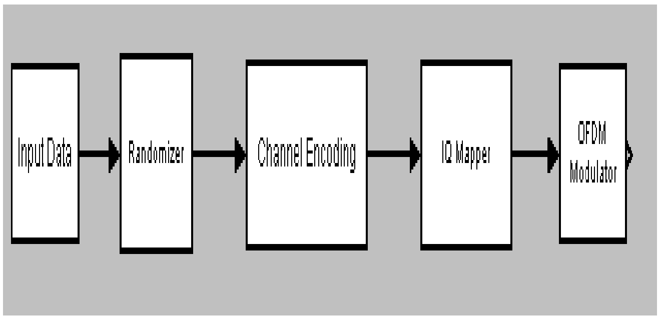

Fig.1 Physical Layer (Transmitter Side)

Randomizer

Randomization is the first process carried out in the physical layer after the data packet is received from the higher layers. The randomization process is used to minimize the possibility of transmissions of non-modulated subcarriers.

Channel Encoding

The encoding process consists of a concatenation of an outer Reed-Solomon (RS) code and an inner convolutional code (CC) as a FEC scheme. That means that first data passes in block format through the RS encoder, and then, it goes across the convolutional encoder. The last part of the encoder is a process of interleaving to avoid long error bursts. Now we consider various blocks of channel encoder in detail.

RS Encoder

A Reed-Solomon code is specified as RS (n, k, t) with l-bit symbols. This means that the encoder takes k data symbols of l bits each and adds 2t parity symbols to construct an n-symbol codeword. Thus, n, k and t can be defined as:

- n: number of bytes after encoding,
- k: number of data bytes before encoding,
- t: number of data bytes that can be corrected.

The error correction ability of any RS code is determined by (n − k), the measure of redundancy in the block. If the location of the erroneous symbols is not known in advance, then a Reed-Solomon code can correct up to t symbols, where t can be expressed as t = (n − k)/2.

Convolutional encoder

After the RS encoding process, the data bits are further encoded by a binary convolutional encoder, which has a native rate of 1/2andaconstraintlengthof7.A convolutional code is a type of FEC code that is specified by CC (m, n, k), in which each m-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n> m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code [7].

Puncturing Process

Puncturing is the process of systematically deleting bits from the output stream of a low-rate encoder in order to reduce the amount of data to be transmitted, thus forming a high-rate code.

Interleaver

Interleaving does not change the state of the bits but it works on the position of bits. Interleaving is done by spreading the coded symbols in time before transmission. The incoming data into the interleaver is randomized in two permutations. First permutation ensures that adjacent bits are mapped onto non-adjacent subcarriers. The second permutation maps the adjacent coded bits onto less or more significant bits of constellation thus avoiding long runs of less reliable bits. The block interleaver interleaves all encoded data bits with a block size corresponding to the number of coded bits per OFDM symbol. The number of coded bits depends on the modulation technique used in the Physical layer. Wi-Max 802.16e supports 4 modulation techniques and is adaptive in the selection of a particular technique based on the channel conditions and data rate.

IQ Mapper

Once the signal has been coded, it enters the modulation block. All wireless communication systems use a modulation scheme to map coded bits to a form that can be effectively transmitted over the communication channel. Thus, the bits are mapped to a subcarrier amplitude and phase, which is represented by a complex in-phase and quadrature-phase (IQ) vector. QPSK,16QAM and 64QAM modulations are supported by the system.

There are three important types of digital modulation which are used as follows:

- Binary Phase Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- Quadrature Amplitude Modulation (QAM)
- Binary Phase Shift Keying (BPSK): The BPSK is a binary level digital modulation scheme of phase variation which has two theoretical phase angle i.e. +90 and -90. This gives high immunity against the interference and noise and a robust modulation which gives improved BER performance.
- Quadrature Phase Shift Keying (QPSK): If there are 4 phases that consists of 0, 90, -90 and 180 then the M-ary PSK is termed as Quadrature Phase Shift keying (QPSK). It uses more symbols as compared to BPSK. In QPSK, the number of bits used per symbol is two-bit of modulation symbols.
- Quadrature Amplitude Modulation: Quadrature Amplitude Modulation (QAM) uses different kind of phases which are 16, 32, 64, and 256. Each single state is defined as a specific phase and amplitude. This proves the detection of symbols and generation is much more complex than amplitude device or a simple phase. In QAM, two sinusoidal carriers are transmitted that change their amplitude depending on the digital sequence; these carriers are out of phase to each other by 90. QPSK and QAM–4 are referred as the same modulation which is consider as the complex

symbols of data. The most efficient modulation of 802.16 is 64-QAM, in which 6 bits modulation symbol are transmitted. The IQ plot for a modulationschemeshowsthetransmittedvectorforalldatawordcombinations.The use of variable or adaptive modulations to increase capacity is a trend also observed in other recently developed mobile phone and data standards like WCDMA [8], [9]. The constellation mapped data are assigned to all allocated data subcarriers of the OFDM symbol in order of increasing frequency offset index.

IFFT

This block implements the OFDM modulation. The IQ mapped data are sent to IFFT for time domain mapping. Mapping to time domain needs the application of Inverse Fast Fourier Transform (IFFT). In our case we have incorporated the MATLAB ´IFFT´ function to do so.

Cyclic Prefix Insertion

Cyclic prefix [10] must be added after the IFFT operation to combat the effect of multipath. Four different duration of cyclic prefix are available in the standard. Being G the ratio of CP time to OFDM symbol time, this ratio can be equal to 1/32, 1/16, 1/8 and 1/4.

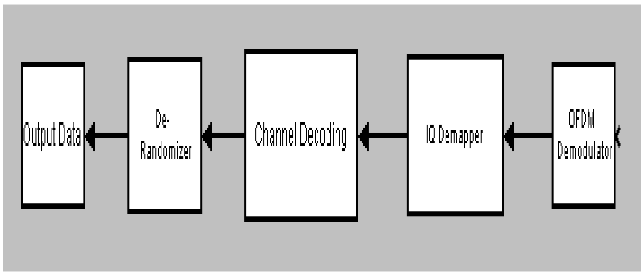

Fig.2 Physical Layer (Receiving side)

Channel: The channel that we used is pure AWGN .This is a noise channel. This channel effects on the transmitted signals when signals passes through the channel. It adds white Gaussian noise to the input signal. After adding Gaussian noise data is then passed to the receiver.

Receiver: The complementary blocks are implemented in the receiver. The CP is removed, sub-carriers are demodulated via the FFT transform, and then sub-carrier de-mapping is performed. After that Channel decoding process is performed with the help of de-interleaver, convolution decoder and RS decoder. Data is then de randomized and in last we get final data.

4. Model Simulation Results

The Model for the Wi-Max is built from the standard documents [11, 12]. The performance of the Wi-Max-PHY layer was tested and evaluated at different noise levels. We performed our simulation in Matlab Simulink version 7.4. We have preferred the Matlab because it is adequate for the simulation of different signal processing methods used in wireless networks [13].The simulation result based on the adaptive modulation technique for BER calculation was observed in this section. The adaptive modulation techniques used in the Wi-Max are QPSK, 16-QAM and 64-QAM respectively. Various BER vs. SNR plots are presented for all these modulation techniques.

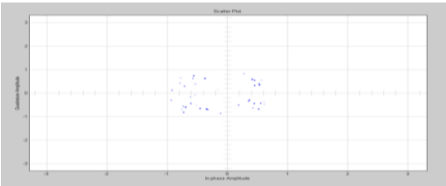

Fig.3 QPSK Modulation Scatter Plot at SNR=10

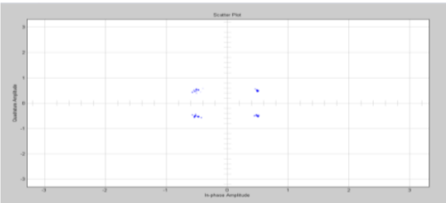

Fig.4 QPSK Modulation Scatter Plot at SNR= 15

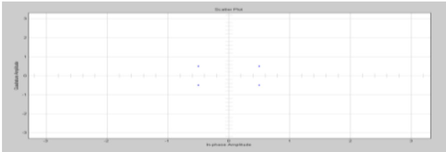

Fig.5 QPSK Modulation Scatter Plot at SNR=20

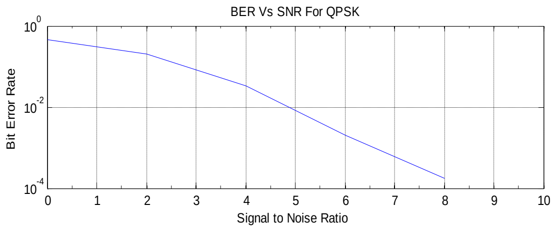

Fig.6 BER Vs SNR Plot for QPSK

Fig. 3, 4 and 5 shows the constellation points of the receiving data at different SNR using QPSK at coding rate 1/2 in pure AWGN. It is clear from fig. 3, 4 and 5 that increasing the value of SNR decreases the spread of constellation points. Our results show that at SNR value 20constellation points of receiving data match with the constellation points of sending data. Fig. 6 shows the BER Vs SNR plot for QPSK in pure AWGN. Our result shows that increasing the value of Signal to Noise Ratio (SNR) decreases Bit Error Rate (BER) and at SNR value 9 it is zero

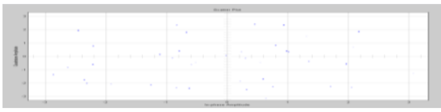

Fig.7 16-QAM Modulation Scatter Plot at SNR=10

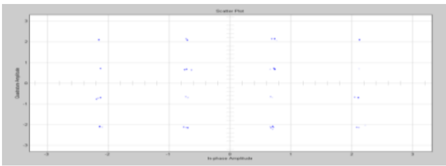

Fig.8 16-QAM Modulation Scatter Plot at SNR=20

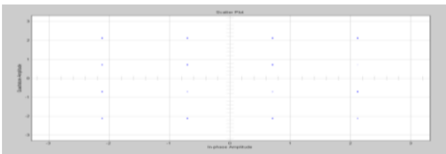

Fig.9 16-QAM Modulation Scatter Plot at SNR=30

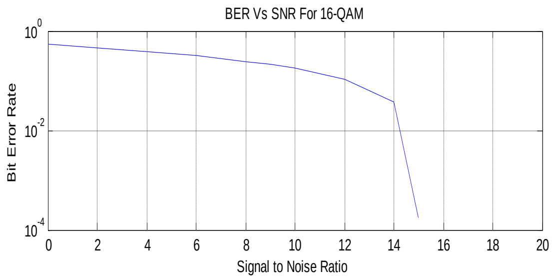

Fig.10 BER Vs SNR Plot for 16-QAM

Fig. 7, 8 and 9 shows the constellation points of the receiving data at different SNR using 16-QAM at coding rate 1/2 in pure AWGN. It can be observed from the Figs. 7, 8 and 9 that spread reduction is taking place with the increasing values of Signal to noise ratio. Our results show that at SNR value 30constellation points of receiving data match with the constellation points of sending data. Fig. 10 shows the BER Vs SNR plot for 16-QAM in pure AWGN. Our result shows that increasing the value of Signal to Noise ratio (SNR) decreases Bit Error Rate (BER) and at SNR value 15 it is zero.

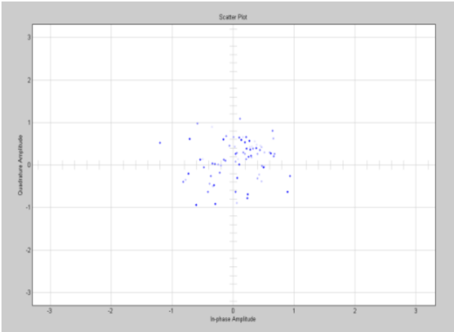

Fig.11 64-QAM Modulation Scatter Plot at SNR=15

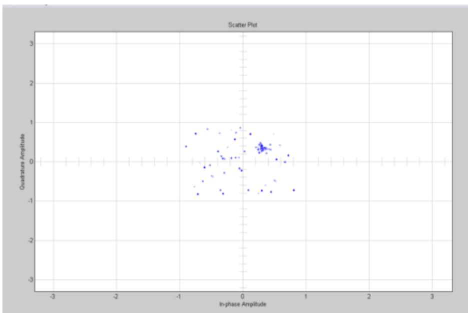

Fig.12 64-QAM Modulation Scatter Plot at SNR=25

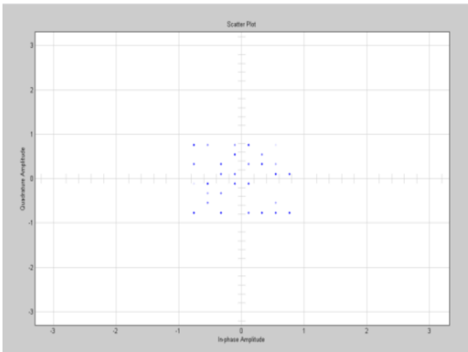

Fig.13 64-QAM Modulation Scatter Plot at SNR=40

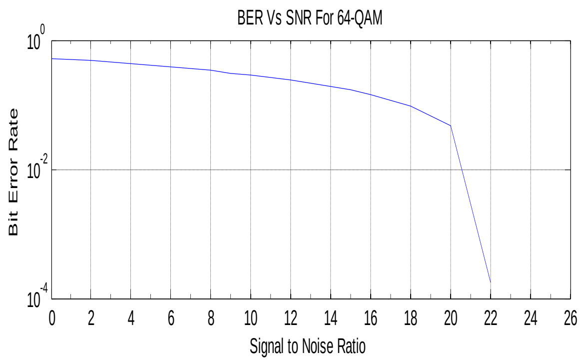

Fig.14 BER Vs SNR Plot for 64-QAM

Fig. 11, 12 and 13 shows the constellation points of the receiving data at different SNR using 64-QAM at coding rate 1/2 in pure AWGN. It is clear from fig. 11, 12 and 13 that increasing the value of SNR decreases the spread of constellation points. Our results show that at SNR value 40 constellation points of receiving data match with the constellation points of sending data. Fig. 14 shows the BER Vs SNR plot for 64-QAM in pure AWGN. Our result shows that increasing the value of Signal to Noise Ratio (SNR) decreases Bit Error Rate (BER) and at SNR value 23 it is zero.
Fig. 15 Compares the Bit Error Rate (BER) for all three modulation schemes implemented in our physical layer modal of Wi-Max.

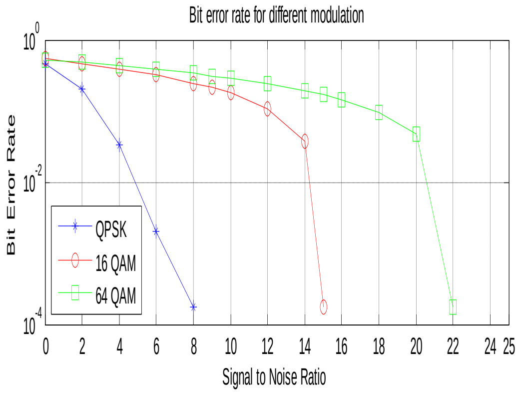

Fig.15 Bit Error rate (BER) for different modulations techniques.

5. CONCLUSIONS

The main objective of this paper is to implement the Wi-Max physical layer using MATLAB in order to evaluate the physical layer performance. The performance of the Wi-Max-PHY layer based on the IEEE 802.16e standard was evaluated and assessed at different modulation schemes and noise levels. Scatter plots are generated to validate the model in terms of general trends in reception quality as we perturb different parameters. A key performance measure of a wireless communication system is the BER. The BER curves are used to compare the performance of different modulation techniques. Thus we can conclude, lower modulation and coding scheme provides better performance with less SNR. As a result of the comparative study, it was found that: when channel conditions are poor, energy efficient schemes such as QPSK were used and as the channel quality improves, 16-QAM or 64-QAM was used.

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