Performance Evaluation and Analysis of Wi-MAX Technology and 802.16 OFDM Physical Layer

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Abstract—*The recent trends in broadband wireless communication systems are demand for high data rates, large transmission range and minimum end to end delay. This is Necessary to access the services such as Internet, Video conferences, and Multimedia applications. Wi-Max (Worldwide Interoperability for Microwave Access) technology provides Broadband Wireless Access (BWA) in metropolitan areas with a simpler installation and lower cost compare to wired networks. To understand the working of Wi-Max system and the role of various parameters on the system performance, the simulation model of Wi-Max physical layer using MatLab developed. Efforts have been taken to study the Bit Error Rate (BER) performance of this model under different channel conditions. Efforts are also taken to understand the effect of various Modulation techniques, Coding rates, cyclic prefix factors and FFT size on the system performance. The idea is to help the beginner to understand the system and to make the best possible system selection under different propagation conditions. Wi-Max's competitiveness in the marketplace largely depends on the actual data rates and ranges that are achieved, but this has been difficult to judge due to the large number of possible options and competing marketing claims.*

Keywords—Worldwide Interoperability for Microwave Access (WI-MAX), Broadband Wireless Access (BWA), Bit Error Rate (BER).

I. INTRODUCTION

Worldwide interoperability for microwave access (Wi-MAX) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates. Wire line infrastructures are considering more costly and time consuming than a wireless one. Broadband wireless access (BWA) provides us promising solution for "last-mile" access technology to provide high speed connections [2]. IEEE 802.16 standard for BWA and its associated industry consortium, worldwide interoperability for microwave access (WI-MAX) forum promise to offer high data rate over large areas to a large number of users where broadband is unavailable [5]. This is the first industry wide standards that can be used for fixed wireless access with substantially higher bandwidth than most cellular networks.

Worldwide interoperability for microwave access (Wi-MAX) technology is based on IEEE-802.16-2004 and 802.16e-2005 standards for fixed and mobile wireless access in metropolitan area network (MAN).It can deliver data rates of 70 Mbps, cover ranges in excess of 30 km, and it can provide secure delivery of content and support mobile users at vehicular speeds [1]. Wi-MAX physical (PHY)-layer uses adaptive modulation based on orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA)[7]. Adaptive modulation is used to achieve the highest possible data rate for a given link quality. Modulation can be adjusted at very short time intervals, to provide robust transmission links and high system capacity. The higher modulation constellations offer a larger throughput per frequency-time slot but not all users receives 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 constellation to minimize the use of system resources. While users that are in less favorable areas used the lower order modulations for communications to ensure data is received and decoded correctly at the expense of additional frequency/time slot for the same amount of throughput.

In order to investigate how well OFDM performs in Wi-MAX signal when transmitted over an additive white Gaussian noise (AWGN) channel only a simulation model was created and implemented using MATLAB and different SNR values. In the BER calculation we use different SNR values in urban and sub urban area. For BER calculation we use BPSK, QPSK, 16-QAM and 64-QAM modulation techniques [4].

II. NETWORK ARCHITECTURE

An IEEE 802.16 network is consists of fixed infrastructural sites. In fact, the IEEE802.16 network is resembled to cellular phone network. Each cell consists of a Base Station (BS) and one or more subscribe station (SS), depending on the implementation of the topology. Therefore, the BS provides Point to Point (PTP) service or Point to Multipoint (PMP) service in order to serve multiple SSs. BSs provides connectivity to core networks.

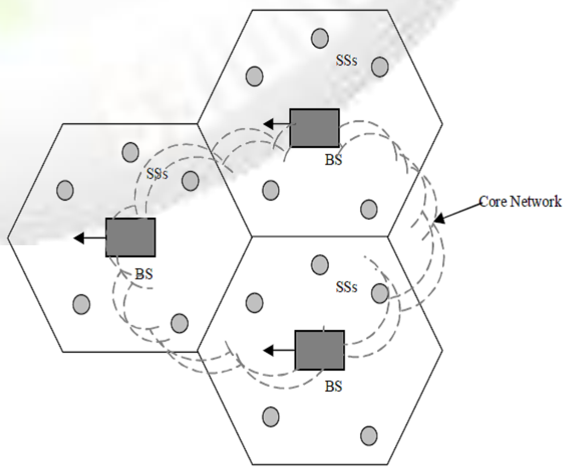

Fig. 1: A typical IEEE 802.16 Network Architecture

The SS can be a roof mounted or wall mounted customer premises equipment (CPE) or a standalone hand held device like Mobile phone, personal digital assistant (PDA) or peripheral component interconnect (PCI) card for PC or Laptop [3]. In case of outside CPE, the users inside the building are connected to a conventional network like Ethernet Local Area Network (IEEE 802.3 for LAN) or Wireless LAN (IEEE 802.11b/ WAN) which have access to the CPE[8]. A group of cells can be grouped together to form a network, where BSs are connected through a core network, as shown in Figure 1. The IEEE 802.16 network also support mesh topology, where SSs are able to communicate among themselves without the need of a BS.

BSs typically employ one or more wide beam antennas that may be partitioned into several smaller sectors, where all sectors sum to complete 360 degree coverage. CPEs typically employ highly directional antennas that are pointed towards the BS. Depending on the need, IEEE 802.16 networks can be deployed in different forms [6].

Wi-MAX architectures use either Point to Multipoint (PMP), Mesh, or Mobile Multihop Relay (MMR) mode. PMP architecture was introduced as the first standard of Wi-MAX in 2001. In this mode subscriber stations connect to the base station in a single hop route. In Mesh mode subscriber stations can communicate in an ad-hoc fashion. Mesh mode gained too much attention by researchers but was not much deployed in the real world because it supports only OFDM version and is not compatible with PMP with completely different frame structure and network entry procedure. The mobile multi hop relay (MMR) mode in 802.16j was introduced as an extension for PMP mode in IEEE 802.16e. MMR outperforms PMP but its achieving higher throughput and enhancing coverage Unlike PMP mode, MMR Supports both OFDM and OFDMA operations and is backward compatible with a PMP mode. MMR differs from PMP by introducing the Relay Stations in which mobile station can use as an intermediate route forwarders to the BS in a like tree topology rather than a PMP or MESH topology. MMR consist of three network entities BS, relay station (RS) and mobile station (MS). RSs have the functionality of playing and intermediate forwarder to forwards traffic between any MS and the BS. RS was classified to work in two modes transparent or non transparent. In transparent mode only data signals are forwarded and no control signals are allowed to pass. RS In non transparent is being also divided according to the scheduling role they play and follow as distributed or centralized. Distributed if they are allowed to share any scheduling decision and bandwidth allocation with the BS or centralized if RS are just forwarder and scheduling decisions are made by the BS. Radio links between entities in the MMR mode are named Access links (AL) if it connects MSs with RS and are called relay links (RL) if the radio link is between the RS and the BS.

The WiMAX base station on the tower is physically wired to the ISP (Internet Service Provider) network through fiber optic cables. At the ISP network terminus, data aggregated from all base stations are sent to the internet backbone through high-speed and high-capacity of “thick” fiber-optic cables. The Figure 2 shows the general block schematic of Wi-MAX system.

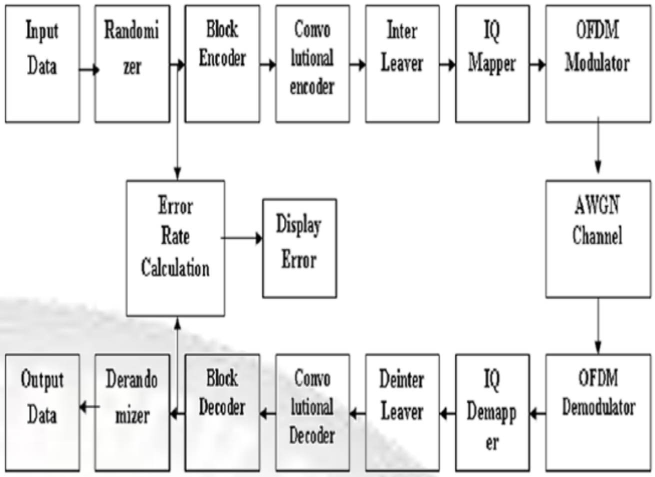

Fig. 2:Block Schematic of WiMAX System

III. SIMULATION RESULT

In simulation results, first we will present the structure of implemented simulator and then we will present the simulation results of both in terms of validation of implementation and values for various parameters that characterize the performance of the physical layer.

We have developed the simulator in Matlab™ using modular approach. Each block of the transmitter, receiver and channel is written in separate ´m´ file. The main procedure call each of the block in the manner a communication system works. The main procedure also contains initialization parameters, input data and delivers results. The parameters that can be set at the time of initialization are the number of simulated OFDM symbols, CP length, modulation and coding rate, range of SNR values for simulation. The input data stream is randomly generated. Output variables are available in Matlab™ workspace while BER and BLER values for different SNR are stored in text files which facilitate to draw plots. Each single block of the transmitter is tested with its counterpart of the receiver side to confirm that each block works perfectly.

The objective behind simulating the physical layer in Matlab™ was to study BER and BLER performance under different channel conditions and varying parameters that characterize the performance. But, in order to relay on any results from PHY layer simulation we must have some results that can do some validation in terms of general trends.

IV. SCATTER PLOTS

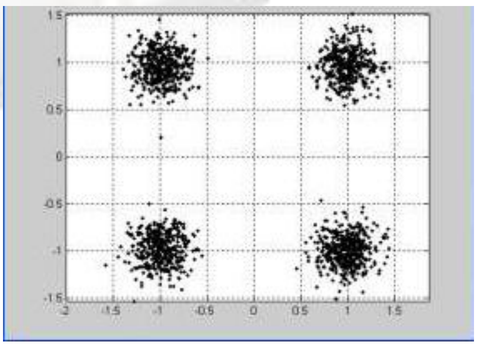

Fig. 3:16 QAM Scatter plot

The figure 3 shows the scatter plots for 16-QAM modulation technique. These plots are obtained by sending the same frame data from transmitter to receiver through the channel repeatedly 1000 times.

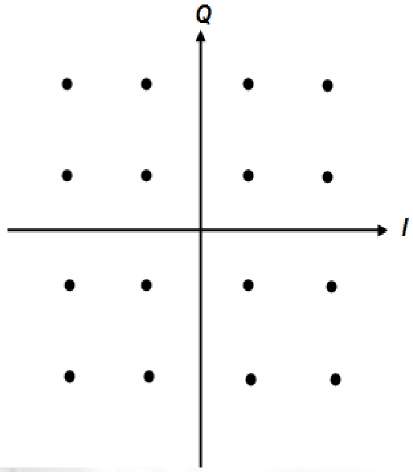

Fig. 4:16 QAM constellation

It can be observed from these plots that spread reduction is taking place with the increasing values of SNR. It is also very important to note that the scatter spread gives a strong hint about the BER/BLER statistics as SNR values are varied.

V. BER PLOT

The lower modulation and coding scheme provides better performance with less SNR. This can be easily visualized if we look at constellation mapping; larger distance between adjacent points can tolerate larger noise (which makes the point shift from the original place) at the cost of coding rate. By setting threshold SNR, adaptive modulation schemes can be used to attain highest transmission speed with a target BER.

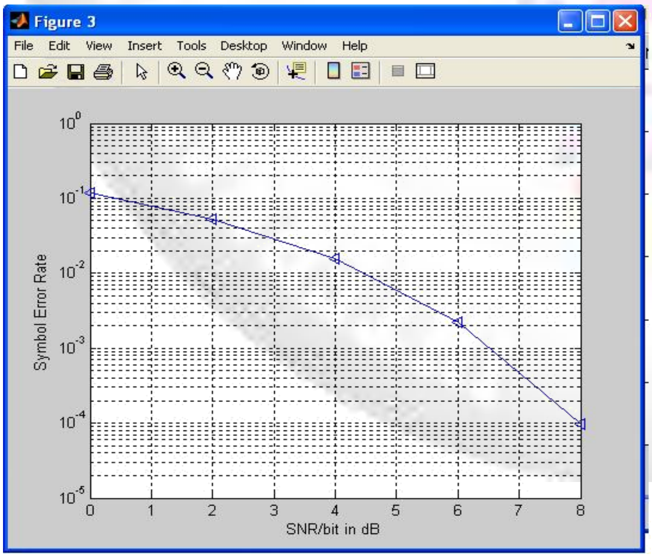

Fig. 5:BER Plot

VI. CONCLUSION

The model presented will be used to implement coding and modulations schemes. The simulation results will enable user to select the best option to suit their requirements. For good propagation conditions a high order modulation scheme with low coding redundancy such as 16 QAM will used in order to increase the transmission data rate. During fading signal the system selects an energy efficient modulation scheme such as BPSK or QPSK. This helps in making efficient use of the bandwidth and increases overall system capacity. In addition, higher values of cyclic prefix factor helps to improve the signal strength. Apart from QAM 256, higher size of FFT will also be chosen to upgrade the performance of the system in concern with system complexity.

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