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Performance Analysis of IEEE 802.16e Wimax Physical Layer

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ABSTRACT
WiMAX (worldwide inter-operability for microwave access) is an emerging technology for global broadband wireless system offering high speed access to mobile and broadband services. It is based on IEEE 802.16e standard. This standard only deals with MAC and PHY layer specification of network architecture. Considerable research has been done on performance analysis of PHY layer model of WiMAX system over AWGN channel model. This paper attempts performance analysis of IEEE 802.16e PHY layer model over AWGN as well as SUI channel models as SUI channel models are more realistic models based on empirical results. Different modulation schemes, coding rates, and different values of cyclic prefix are considered for comparison using BER (Bit error rate) ratio and SNR (Signal to Noise ratio) as performance parameters.
Keywords – Adaptive Modulation, AWGN channel, OFDM, SUI channel models, WiMAX.

I. INTRODUCTION

Nowadays people are enjoying wireless internet access for telephony, radio and television services when they are in fixed or mobile conditions. The rapid growth of wireless internet causes a demand for high-speed access to the World Wide Web. To serve the demand for access to the internet "any where any time" and ensure quality of service, the IEEE802.16 working group brought out a new broadband wireless access technology called "WIMAX" meaning Worldwide Interoperability for Microwave Access. WiMAX is a new broadband wireless access technology that provides very high data throughput over long distance in a point-to-multipoint and line of sight (LOS) or non-line of sight (NLOS) environments [1]. In terms of the coverage, WiMAX can provide services up to 20 or 30 miles away from the base station. WiMAX standards were developed by IEEE 802.16 group. These standards are based on wireless metropolitan area networking (WMAN) standards [2]. The WiMAX Forum has two different system profiles: one based on IEEE 802.16-2004 OFDM PHY, called the fixed system profile; the other is based on IEEE 802.16e- 2005 scalable OFDMA PHY, called the mobility system profile. The majority of aspects which make WiMAX technology different from others that can be applied to the same scenario reside in its physical layer [4]. To this level, many numerical approximation models which are able to predict the behavior of radio channels can be found [5]. However, this work contains the description of mandatory and optional features of WiMAX PHY layers and simulates them in fading environment. The rest of this document is structured as follows: some of the basic features for fixed WiMAX PHY layer are described. Various propagation models using the SUI based channel scenarios along with path loss and delay spread for arbitrary transmitter/receiver is explained in section. The Section four and five are explaining structure of SUI channels and their implementation on 802.16d system, basic idea about path loss and delay spread are presented in section. The section is about simulation models and its parameter, section eight of paper discussion about the simulation result and experimental test carried out, finally section nine is about conclusion of the paper and directions for the future work. The rest of this paper is organized as follows: Section II briefly explains WIMAX PHY model and OFDM modulation technique. A comprehensive description of SUI channel has been presented in section III. The simulation model and results have been presented in section IV. This paper is concluded with section V.

II. WIMAX PHY LAYER FEATURE

In fixed WiMAX profile, the size of OFDM symbols are fixed at 256, 192 subcarriers are using for carrying data, for channel estimation and synchronization purposes 08 subcarriers used as pilot, and the rest symbols used as guard band. Since the FFT symbols are fixed in size, the spacing between subcarrier varies with channel bandwidth. When larger bandwidths are in use subcarrier spacing increases and symbol time decreases. According to [1], decreasing symbol time implies a larger fraction needs to be allocated as guard time to overcome delay spread. To allow system designers to make appropriate trade-offs between spectral efficiency and delay spread robustness IEEE 802.16 OFDM-PHY allows a wide range of guard times[5].

III. SYSTEM MODEL

The MATLAB simulation model consists of random data generator, channel encoding, digital modulation, IFFT, cyclic prefix insertion blocks in the transmitter side and cyclic pre fix remover, FFT, digital demodulator, channel decoder blocks in the receiver side as shown in fig. 1 and system model parameters are listed in table I. Channel coding part is composed of three steps of randomization, Forward Error Correction (FEC) and interleaving [6]. FEC is done in two phases through the outer Reed Solomon (RS) and inner Convolutional Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. Reed Solomon Encoder that encapsulates the data with coding blocks and these coding blocks are helpful in dealing with the burst errors.

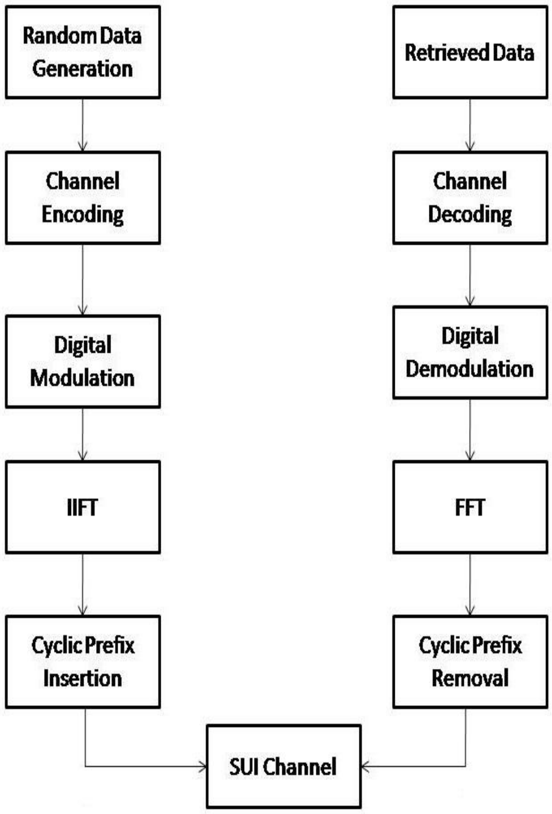

Fig.1 WIMAX Communication System Model

A. SUI CHANNEL MODEL

The term channel refers to the medium between the transmitting antenna and the receiving antenna .The characteristics of wireless signal changes as it travels from the transmitter antenna to the receiver antenna. These characteristics depend upon the distance between the two antennas, the path taken by the signal, and the environment around the path. The profile of received signal can be obtained from that of the transmitted signal if we have a model of the medium between the two. The wireless channel is characterized by: Path loss, Multipath delay Spread, Fading characteristics, Doppler spread, Co-channel and adjacent channel interference. All the model parameters are random in nature and only a statistical characterization of them is possible. They are dependent upon terrain, tree density, antenna height and beam width, wind speed. In practice, most simulation studies use empirical models like Hata Model, CO ST 231 Extension to Rata Model, COST 231-Walfish-Ikegami Model, Erceg Model, Stanford University Interim (SUI) Channel Models, ITU Path Loss Models that have been developed based on measurements taken in various real environments. For our analysis we considered the SUI channel model. In this model a set of six channels was selected to address three different terrain types that are typical of the continental US. This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications [4]. The table 1 below depicts the parametric view of the SUI channels.

Table 1: SUI channels

Terrain type	SUI Channel
C (Mostly flat terrain with light tree densities)	SUI-1, SUI-2
B (Hilly terrain with light tree density or flat terrain with moderate to heavy tree density)	SUI-3, SUI-4
A (Hilly terrain with moderate to-heavy tree density)	SUI-5, SUI-6

Some of the important characteristics of SUI channel are as follows:

a) It has a higher path loss as compared to super cell architecture.
b) It includes both macroscopic and microscopic fading effects.
c) It considers both co-channel and adjacent channel interference.
d) It takes account of high multipath delay and doppler spread.

The SUI channel also includes many diversified parameters such as terrain, antenna specification, wind speed or traffic range, and bandwidth. Erceg path loss model has been used to represent a real world scenario. The *K* factor is a very important parameter of this channel model, it is the ratio of power in the fixed component to the power in the variable component. The *K* factor depends upon BTS and CPE heights, bandwidth, distance from the antenna, environmental condition including wind, traffic, and season. However, SUI channel has much more realistic approach as the *K* factor for all these 6 channels namely SUI-1, SUI-2, SUI- 3, SUI-4, SUI-5, and SUI-6 are very different [4].

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K-Factor

The narrow band received signal fading can be characterized by a Ricean distribution. The key parameter of this distribution is the K-factor, defined as the ratio of the "fixed" component power and the "scatter" component power. In [7], an empirical model was derived from a 1.9 GHz experimental data set collected in typical suburban environments for transmitter antenna heights of approximately 20 m. In [8], an excellent agreement with the model was reported using an independent set of experimental data collected in San Francisco Bay Area at 2.4 GHz and similar antenna heights. The narrowband K-factor distribution was found to be lognormal, with the median as a simple function of season, antenna height, antenna beam-width, and distance. The standard deviation was found to be approximately 8 dB. The model presented in [7] is as follows:

$$K=F_s\,F_h\,F_b\,K_o\,d^{\gamma}\,u$$

Where,

Fs is a seasonal factor; Fs =1.0 in summer (leaves), 2.5 in winter (no leaves).

F_h is the receive antenna height factor; $F_h= (h/3)^{0.46}$, (h is the receive antenna height in meters).

F_b is the beam-width factor; $F_b = (b/17)^{-0.62}$ (b in degrees).

K_o and γ are regression coefficients; $K_o = 10$, $\gamma = -0.5$.

u is a lognormal variable which has zero dB mean and a std. deviation of 8.0 dB.

Using this model, one can observe that the K-factor decreases as the distance increases and as antenna beam-width increases. We would like to determine K-factors that meet the requirement that 90% of all locations within a cell have to be serviced with 99.9% reliability. The calculation of K-factors for this scenario is rather complex since it also involves path loss, delay spread, antenna correlation (if applicable), specific modem characteristics, and other parameters that influence system performance. However, we can obtain an approximate value as follows: First we select 90% of the users with the highest K-factors over the cell area. Then we obtain the approximate value by selecting the minimum K-factor within the set. For a typical deployment scenario this value of K-factor can be close or equal to 0.7. BTS antenna height is 30 m. Receive antenna height is 6m. BTS antenna beam-width is 120 degrees. Receive antenna beam-width is Omni-directional polarization. 90% cell coverage with 99.9% reliability at each location covered. Table 1 and Table 2, shown below; depict various SUI channels in terms of K-factor.

Table 2: SUI channel with low K-factor

Doppler	Low delay spread	Moderate delay spread	High delay spread
Low	SUI-3		SUI-5
High		SUI-4	SUI-6

Table 3: SUI channel with high K-factor

Doppler	Low delay spread	Moderate delay spread	High delay spread
Low	SUI-1,2		SUI-5
High		SUI-4	SUI-6

The SUI channel model can also be represented in matrix form as shown below in fig. 2.

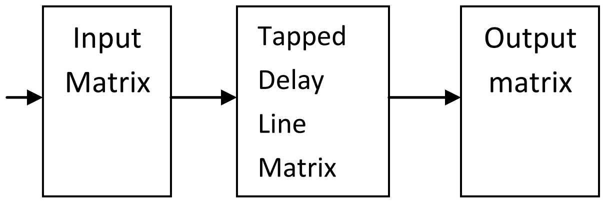

Fig. 2: SUI CHANNEL MODEL

Input Matrix

This block correlation between input signals if multiple transmitting antennas are used.

Tapped Delay Line Matrix

This part models the multipath fading of the channel. The multipath fading is modeled as a tapped delay line with 3 taps with non-uniform delays. The gain associated with each tap is characterized by a distribution (Rician with a K-factor > 0, or Raleigh with K-factor = 0) and the maximum Doppler frequency.

Output Matrix

This block the correlation between output signals if multiple receiving antennas are used.

IV. SIMULATION RESULTS

In this section, the simulation results obtained will be discussed. To evaluate the performance, we used varying channel models such as SUI-1, SUI-2, SUI-3, SUI-4, SUI-5, SUI-6 and different modulation, techniques. For experimentation purposes, simulation is done in

MATLAB over hundred iterations. Table 4 shows the various parameters used in simulation.

Table 4: Simulation parameters

Standard	**802.16e**
Data Rate	**70 Mbps**
Modulation Schemes	**BPSK, QPSK, 16-QAM, 64-QAM**
Carrier Frequency	**11 GHz**
Channel Size (Bandwidth)	**1.5 MHz**
Radio Technology	**OFDM & OFDMA**
Channel Models	**SUI-1, SUI-2, SUI-3, SUI-4, SUI-5, SUI-6**

The output for the performance of mobile WiMAX is estimated by the BER and the SNR plot. Figure 3 shows the BER v/s SNR plot for different SUI channel models with BPSK as the modulation scheme.

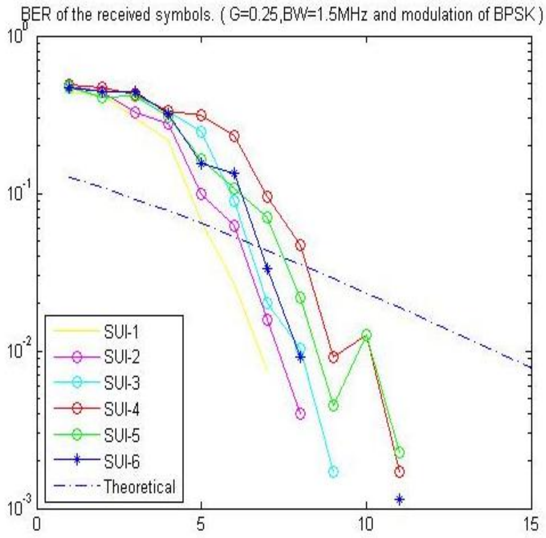

Fig. 3: BER v/s SNR for BPSK

The output for the performance of mobile WiMAX, estimated by the Bit Error Rate and the Signal to Noise Ratio plot using the MATLAB coding with Quadrature Phase Shift Keying modulation technique is given below in figure 4.

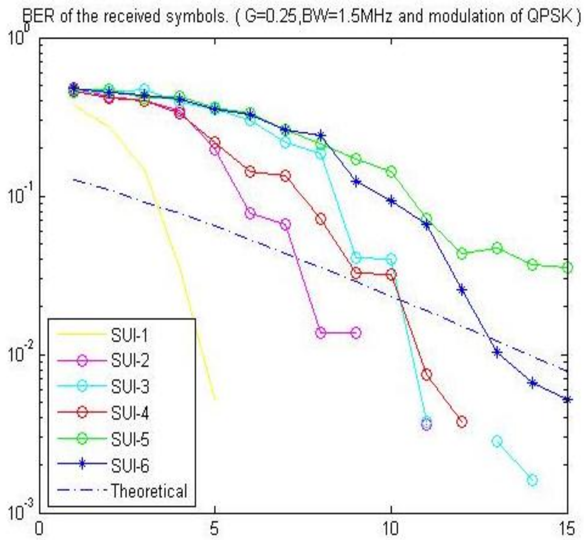

Figure 4: BER v/s SNR for QPSK

The output for the performance of mobile WiMAX was estimated by the BER and the SNR plot using the MATLAB coding with 16QAM modulation. It is illustrated in the figure 5.

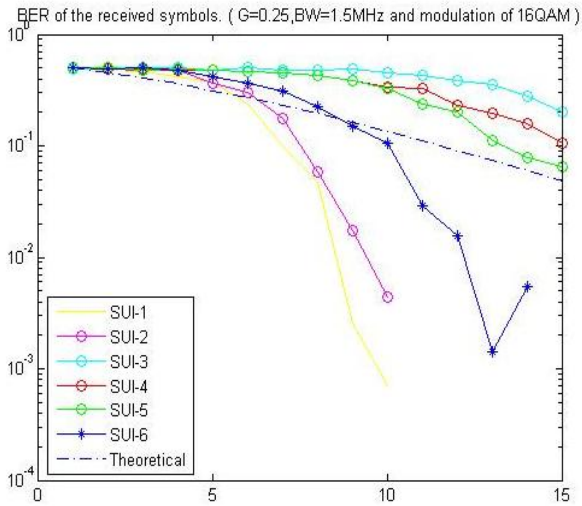

Figure 5: BER v/s SNR for 16-QAM

The output for the performance of mobile Wimax was estimated by the BER and the SNR plot using the MATLAB coding with 64-QAM modulation and graphical illustration in figure 6.

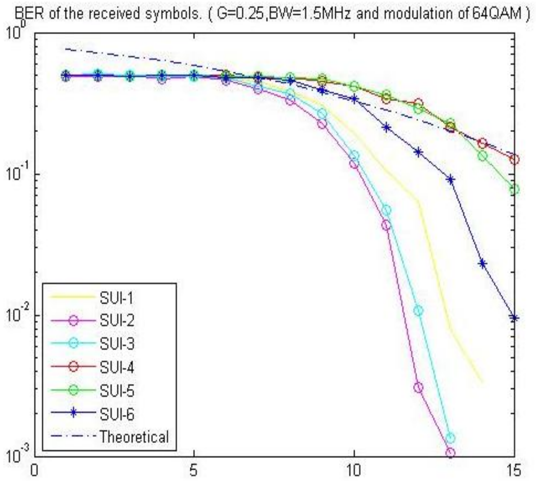

Figure 6: BER v/s SNR for 64-QAM

V. CONCLUSION

A comparative study between different SUI channels model implemented with WiMAX, each one of them is described by appropriate parameters and specified for specific environment of propagation, these channels have been implemented using different modulation schemes. Analysis demonstrated that the modulation and coding rate have a considerable impact on the relative performance between the different channel conditions. It has been also observed that, lower modulation and coding scheme provides better performance with less SNR.

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