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Performance Evaluation of WiMAX-OFDM System over different SUI Channels

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Abstract –**At present, telecommunication industries are highly concerned with the wireless transmission of data which can use various transmission modes, from point- to-multipoint links. It contains full mobile internet access. Various applications have already been applied so far using WiMAX, as alternative to 3G mobile systems in developing countries. The paper built a simulation model based on 802.16 OFDM-PHY baseband and demonstrated in different simulation scenarios with different modulation techniques; BPSK, QPSK, 16-QAM and 64-QAM to find out the best performance of physical layer for WiMAX Mobile. The Stanford University Interim (SUI) channel model under varying parameters is selected for the wireless channel in the simulation. The performance is recorded on the basis of BER, and SNR output through MATLAB Simulation.**

Keywords –**BER, OFDM, QAM, QPSK, SNR, SUI channel and WiMAX.**

I. Introduction to WiMAX

WiMAX is called the next generation broadband wireless technology which offers high speed, secure, sophisticate and last mile broadband services along with a cellular back haul and Wi-Fi hotspots. The development of WiMAX began a few years ago when scientists and engineers felt the need of having a wireless Internet access and other broadband services which works well everywhere especially the rural areas or in those areas where it is hard to establish wired infrastructure and economically not feasible [1].

IEEE 802.16, also known as IEEE Wireless-MAN, explored both licensed and unlicensed band of 2-66 GHz which is standard of fixed wireless broadband and included mobile broadband application. WiMAX forum, a private organization was formed in June 2001 to coordinate the components and develop the equipment those will be compatible and inter operable. After several years, in 2007, Mobile WiMAX equipment developed with the standard IEEE 802.16e got the certification and they announced to release the product in 2008, providing mobility and nomadic access. The IEEE 802.16e air interface based on Orthogonal Frequency Division Multiple Access (OFDMA) which main aim is to give better performance in non-line-of-sight environments. IEEE 802.16e introduced scalable channel bandwidth up to 20 MHz, Multiple Input Multiple Output (MIMO) and AMC enabled 802.16e technology to support peak Downlink (DL) data rates up to 63 Mbps in a 20 MHz channel through Scalable OFDMA (S-OFDMA) system [2].

IEEE 802.16 has strong security architecture as it uses Extensible Authentication Protocol (EAP) for mutual authentication, a series of strong encryption algorithms, CMAC or HMAC based message protection and reduced key lifetime [3].

The aim of this study is to implement the OFDM Physical layer specification of IEEE 802.16. Using different Modulation Techniques. We analyze the performance of OFDM physical layer in mobile WiMAX based on the simulation results of Bit-Error-Rate (BER) and Signal-to-Noise Ratio (SNR).

II. WiMAX OFDM System

WiMAX's main objectives are to cover those remote areas where cable connection is not feasible or expensive and for better coverage especially for mobile networks where users are always moving than the other broadband technologies like, Wi-Fi, UWB and DSL. This subsection describes the network architecture, mechanism and some technical issues of WiMAX mobile in brief with potential diagrams.

A. WiMAX Architecture

WiMAX architecture comprises of several components but the basic two components are BS and SS. Other components are MS, ASN, CSN and CSN-GW etc. The WiMAX Forum's Network Working Group (NWG) has developed a network

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reference model according to the IEEE 802.16 air interface to make sure the objectives of WiMAX are achieved. To support fixed, nomadic and mobile WiMAX network, the network reference model can be logically divided into three parts [4].

B. Mobile Station (MS)

It is for the end user to access the mobile network. It is a portable station able to move to wide areas and perform data and voice communication. It has all the necessary user equipment such as an antenna, amplifier, transmitter, receiver and software needed to perform the wireless communication. GSM, FDMA, TDMA, CDMA and W-CDMA devices etc. are the examples of Mobile station.

C. Access Service Network (ASN)

It is owned by NAP, formed with one or several base stations and ASN gateways (ASN-GW) which creates radio access network. It provides all the access services with full mobility and efficient scalability. Its ASN-GW controls the access in the network and coordinates between data and networking elements.

D. Connectivity Service Network (CSN)

It Provides IP connectivity to the Internet or other public or corporate networks. It also applies per user policy management, address management, location management between ASN, ensures QoS, roaming and security [5].

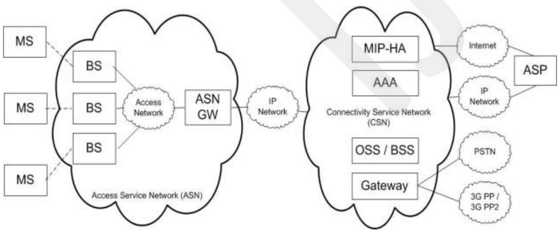

Figure 1: WiMAX Network Architecture

E. Mechanism

WiMAX is capable of working in different frequency ranges but according to the IEEE 802.16, the frequency band is 10 GHz - 66 GHz. A typical architecture of WiMAX includes a base station built on top of a high rise building and communicates on point to multi-point basis with subscriber stations which can be a business organization or a home. The base station is connected through Customer Premise Equipment (CPE) with the customer. This connection could be:

1. Line-of-Sight (LOS) or
2. Non-Line-of-Sight (NLOS) [6].

D. Practical Scenarios

WiMAX comprises of two main parts; WiMAX base station and WiMAX receiver.

1. WiMAX base station

It is often called WiMAX tower or booster. The base station broadcasts radio frequencies to the receiver end. This station consists of electronic devices and WiMAX tower - works as like GSM network. The WiMAX base station may be connected with other base stations by high speed microwave link which is called backhaul [7].

Responsible for: Providing air interface to the MS and it performs in MAC and PHY.

Additional functions: Frequency reuse, handoff, tunnel establishment, QoS &classification of traffic etc.

Management: Session management, bandwidth management for uplink and downlink and multicast group management etc.

Practical Face: Tower in outdoor environment and electronic equipment in indoor environment.

2. WiMAX receiver (CPE)

WiMAX receiver receives the radio frequency from the WiMAX base station and makes sure the connectivity of WiMAX network is in range. This receiver and antenna could be stand alone in a small box or PCMCIA slot card or built in a computer (either laptop or desktop). WiMAX tower may connect directly to the internet using higher bandwidth and also connect to another tower using non line of sight microwave link which is known as backhaul. This base station might allow the WiMAX subscriber one base station to another which is similar to GSM networks [8].

Responsible for: Providing connectivity between subscriber equipment (such as mobile phone or laptop) and a WiMAX base station.

Additional function: Packet priority, network interoperability and QoS.

Connection: Backhaul, high speed microwave link which is also referred to a connection between core network and WiMAX system.

Provides User: VoIP, multimedia and Internet access and many mobile applications.

Practical face: Customer Premises Equipment (CPE) for indoor and outdoor purposes.

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III. METHODOLOGY

Figure 2 shows a baseband transceiver structure for proposed work utilizing the Fourier transform for modulation and demodulation. Here the encoded serial data is modulated to complex data symbols (BPSK/QPSK/16-QAM/64-QAM) with a symbol rate of $\frac{1}{T_s}$. The data is then $T_s$demultiplexed by a serial to parallel converter resulting in a block of N complex symbols, X_0 to X_{N-1}. The parallel samples are then passed through a N point IFFT (in this case no oversampling is assumed) with a rectangular window of length $N.T_s$, resulting in complex samples x_0 to x_{N-1}. Assuming the incoming complex data is random it follows that the IFFT is a set of N independent random complex sinusoids summed together. The samples, x_0 to $x_{N-1}$are then converted back into a serial data stream producing a baseband transmit symbol of length $T = N.T_s$.

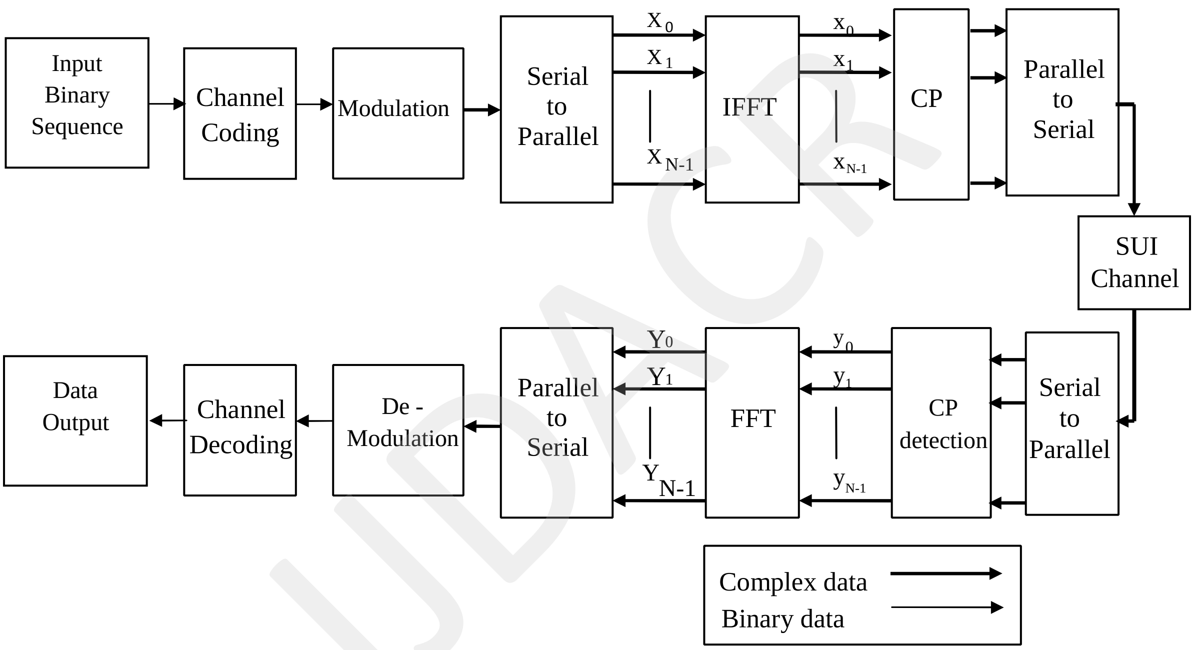

Figure 2: Basic block diagram for proposed work

A Cyclic Prefix (CP), which is a copy of the last part of the samples is appended to the front of the serial data stream before Radio Frequency (RF) up conversion and transmission. The CP combats the disrupting effects of the channel which introduce Inter Symbol Interference (ISI). In the receiver the whole process is reversed to recover the transmitted data, the CP is removed prior to the FFT which reverses the effect of the IFFT. The complex symbols at the output of the FFT, $Y_0 \, .. Y_{N-1}$ are then demodulate and the original bit steam recovered [9].

Mathematically the demodulation process (assuming no CP and no channel impairments) using the FFT is equation (1),

$$Y_{m,k} = FFT\{x_{m,n}\}$$

$$= \frac{1}{N} \sum_{n=0}^{N-1} x_{m,n} e^{-j2\pi nk/N}$$

$$= \frac{1}{N} \sum_{n=0}^{N-1} \sum_{d=0}^{N-1} X_{m,d} e^{j2\pi n(d-k)/N}$$

$$= \frac{1}{N} \sum_{d=0}^{N-1} X_{m,d} \sum_{n=0}^{N-1} e^{j2\pi n(d-k)/N}$$

$$= \frac{1}{N} \sum_{d=0}^{N-1} X_{m,d} \, N\delta[d-k]$$

$$= X_{m,k} \qquad (1)$$

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A. Channel Coding

Channel coding is done by three steps, Randomization, Forward Error Correction (FEC) and Interleaving [10].

1. Randomization

Randomization is performed on data transmitted on the downlink and uplink. This is implemented with a Pseudo Random Binary Sequence (PRBS) generator which uses a 15-stage shift register with a generator polynomial of $1+x^{14}+x^{15}$ with XOR gates in feedback configuration.

2. Forward Error Correction (FEC)

Forward error correction (FEC) or channel coding is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The central idea is the sender encodes their message in a redundant way by using an error-correcting code (ECC). Here, FEC is done using the following phases:

- Reed Solomon code and
- Convolution Code

3. Interleaving

After channel coding, the next step is interleaving. It is a technique used as an alternative technique for correcting the burst error.

B. Modulation

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. This is achieved by modulating the data by a desirable modulation technique. After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel to serial converter. In order to avoid ISI we provide a cyclic prefix to the signal. Following are the modulation techniques which have used in the paper:

- Binary Phase-Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- Quadrature Amplitude Modulation (16-QAM and 64-QAM)

C. Serial to Parallel Convertor

Data to be transmitted is typically in the form of a serial data stream. Serial to parallel conversion block is needed to convert the input serial bit stream to the data to be transmitted in each OFDM symbol. The data allocated to each symbol depends on the modulation scheme used and the number of subcarriers.

Cyclic prefix is inserted in every block of data according to the system specification and the data is multiplexed to a serial fashion.

D. Cyclic Prefix

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation.

E. Communication Channel (SUI Channel)

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

SUI or, the Stanford University Interim Channel Model is a set of 6 channel models for three different terrain types and also provide a variety of Doppler spreads, delay spreads and line-of-sight/non-line-of-site conditions (LOS/NLOS). It defines six channels to address three different terrain types.

These three terrain types are defined as A, B and C; Terrain A is hilly terrain with moderate to heavy tree density and high path loss; Terrain B is hilly terrain with light tree density or flat terrain with moderate to heavy tree density and moderate path loss; and C is mostly flat terrain with light tree density and has low path loss.

Table 1: SUI Channels and their characteristic parameters

Channel	Terrain Type	Doppler Spread	Spread	LOS
SUI-1	C	Low	Low	High
SUI-2	C	Low	Low	High
SUI-3	B	Low	Low	Low
SUI-4	B	High	Moderate	Low
SUI-5	A	Low	High	Low
SUI-6	A	High	High	Low

F. Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver

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end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial to parallel converter. A demodulator is used, to get back the original signal.

The bit error rate and the signal–to–noise ratio is calculated by taking into consideration the unmodulated signal data and the data at the receiving end (Sink).

IV. Simulation and Results

Simulation is carried out using MATLAB 2010a:

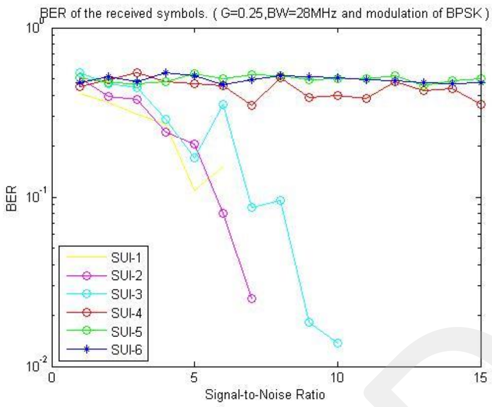

Figure 3: BER performance of WiMAX in BPSK modulation scheme for different SUI channel

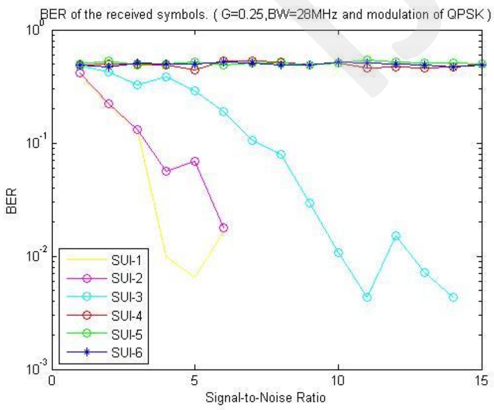

Figure 4: BER performance of WiMAX in QPSK modulation scheme for different SUI channel

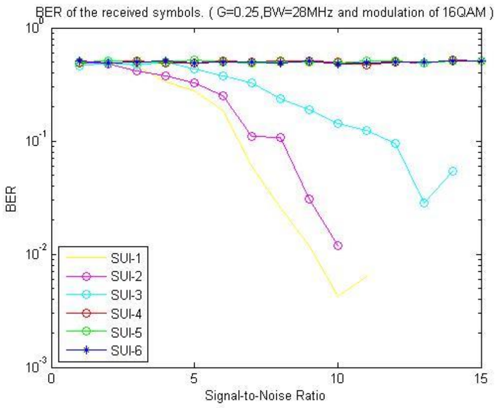

Figure 5: BER performance of WiMAX in 16-QAM modulation scheme for different SUI channel

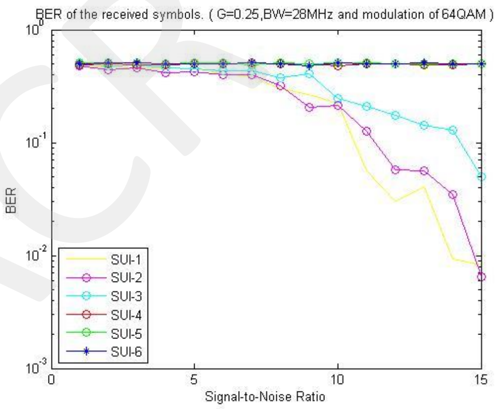

Figure 6: BER performance of WiMAX in 64-QAM modulation scheme for different SUI channel

V. Conclusion

This research work firstly discusses the OFDM WiMAX 802.16 system, then the implementation of IEEE 802.16 model is presented with the analysis of the capabilities of WiMAX in different SUI channel. The simulation uses MATLAB and the effect of different modulation schemes has been evaluated over OFDM system.

With the help of simulation results, it was found that,

- SUI-3 channel shows better BER performance for BPSK modulation scheme.
- For QPSK scheme, SUI-3 channel shows better BER performance.
- For 16-QAM scheme, SUI-1 channel shows better BER performance.
- For 64-QAM scheme, SUI-2 channel shows better BER performance.

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