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Reducing Bit Error Rate in WiMAX using Spread Spectrum Techniques in Comparison with OFDM based Modulations

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Abstract: This research investigated the Bit Error Rate (BER) performance of the WiMAX(Worldwide Interoperability for Microwave Access), a wireless system which uses IEEE 802.16 standard. For the implementation of OFDM model and analyzing the performance of WiMAX system using the Bit Error Rate (BER) and Signal to Noise Ratio (SNR) MATLAB software tool is used. We have used different adaptive modulation techniques such as QPSK, 16-QAM and 64-QAM and spread spectrum techniques such as FHSS (Frequency Hopping Spread Spectrum) and DSSS (Direct Sequence Spread Spectrum). In the current research the Bit Error Rate is improved by using spreading signals. Spread spectrum enables a signal to be transmitted across a frequency band that is much wider than the minimum bandwidth required by the information signal. The simulation results of this research show that FHSS and DSSS have given low BER at low SNR as compared to other modulation techniques.

Keywords: Performance, Evaluation, Bit Error, WiMAX, Standards, OFDM, FHSS, DSSS, OFDM.

I. INTRODUCTION

WiMAX (World Wide Interoperability for Microwave Access) is an IEEE standard (IEEE 802.16) which offers high bandwidth solution with long range for metropolitan area networks. The IEEE 802.16 standard allows for extensive coverage over a wide geographical area. The distance between the Base Station (BS), which broadcasts WiMAX signals, and the Subscriber Station (SS), which receives signals from the base station and connects to the WiMAX network, can reach up to 50km (30 miles) for fixed stations and 5-15km for mobile stations [1]. WiMAX technology enables the delivery of wireless broadband access as an alternative to cable and DSL (Digital subscriber line). WiMAX refers to interoperable implementations of the IEEE 802.16 family of wireless-networks standards ratified by the WiMAX Forum.

LAYERS OF WIMAX: Two layers of WiMAX are:

1. Physical Layer

The physical layer is based on OFDM (orthogonal frequency division multiplexing), which offers a good resistance to multipath and allows WiMAX to operate in NLOS (non line of site) conditions [6]. The physical interfaces are defined in the 802.16 standard are:

1. Wireless MAN-SC (using as single carrier (SC) in the 10–66 GHz band)

2. Wireless MAN-OFDMA (using OFDM transmission and orthogonal frequency division multiple access (OFDMA) in the 2–11 GHz band)

The use of OFDM increases the data capacity and bandwidth efficiency with respect to classical SC transmission. In OFDMA, the subcarriers are divided into subsets, each subset representing a subchannel. The standard indicates that the OFDM symbol is divided into logical subchannels to support scalability, multiple access and advanced antenna array processing capabilities [6]. The OFDM physical layer model will be considered due to its frequent use and implementation simplicity. WiMAX transmitter consists of several blocks: a randomizer, forward error correction (FEC), an interleaver and a modulator. They are applied in this order at transmission. The corresponding operations at the receiver are applied in reverse order. FEC is essential for OFDM systems since it compensates for the bit errors that are inevitable due to the deep fades of the channel. The standard supports four different modulation schemes. It supports higher order 16-QAM and 64-QAM schemes to maximize link throughput and also supports BPSK and QPSK for robustness and reliability **[**6]. The WiMAX 802.16 standard includes the two main duplexing modes: time division duplexing (TDD) and frequency division duplexing (FDD).

2. Media Access Control (MAC)

The functions MAC layer of IEEE 802.16e are described as both Internet Protocol (IP) and synchronous Transfer Mode (ATM) traffic are supported by convergence sublayer**.** This layer transforms the incoming traffic into MAC data units. Broadband access is provided by the WiMAX network to services that have distinct QoS (quality of service) demands and traffic priorities [2]. The MAC layer is responsible for managing the scheduling of traffic flows and allocating bandwidth in a way that meets the quality of service (QoS) criteria for each flow[2]. IEEE 802.16e should offer QoS to both stationary and mobile users.

Since the BS has to manage several SSs, the MAC layer of WiMAX has some sophisticated bandwidth reservation and resource allocation mechanisms. WiMAX has divided the MAC layer into three sublayers: convergence sublayer (CS), common part sublayer (CPS), and security sublayer. The service-specific CS resides on the top of the MAC layer and mainly performs classification of higher-layer packet data units (PDUs) and payload header suppression (optional function). The CPS resides in the middle of the MAC layer and is responsible for connection establishment, resource allocation and scheduling between the BS and SS. The security sublayer provides authentication, secure key exchange, encryption and integrity control across the BWA(Broadband Wireless access) system. The SS establishes a connection with the BS using the contention slots in the uplink subframe.

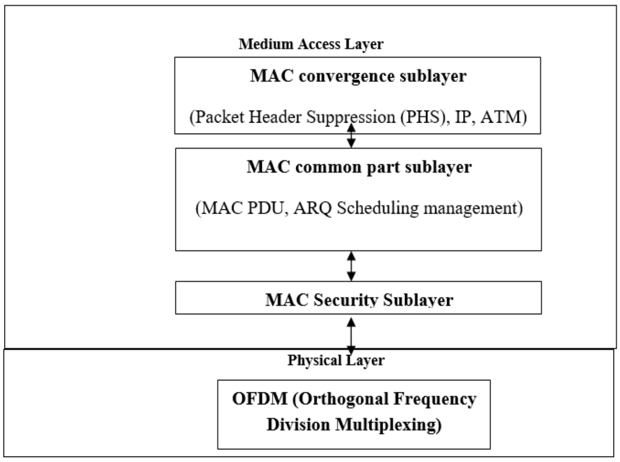

Figure 1: WiMAX Layers

BIT RATE

Bit rate specifies how much data is sent in a certain amount of time by counting the number of bits that are sent from one place to another. Generally, Bit rate is measured in bits per second (bps), kilobits per second (Kbps), or megabits per second (Mbps).

1. Bit Error Rate (BER)

The BER is calculated from the number of bits received with error divided by the total number of bits transferred [3].

BER= (No. of Bits in Error) / (Total bits number of bits transferred)

In digital transmission, the number of bit errors is the number of received bits that has been changed because of noise, interference, distortion or bit synchronization errors over a communication channel [3]. BER unit is represented with percentage. BER performance is also reduced by quantization errors such as incorrect or ambiguous reconstruction of the digital waveform. The accuracy of the analog modulation process and the effects of the filtering on signal and noise bandwidth also effect quantization errors [10].

2. Signal to Noise Ratio (SNR)

This is the ratio of the received signal strength over the noise strength in the frequency range of the operation. Noise strength can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR which means high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput [10]. Signal to noise ratio (SNR) is often used to check the quality of a communication link and measured in decibels and represented by Eq. (1).

$\text{SNR} = 10 \log_{10}$ (Signal Power / Noise Power) dB …(1)

3. BER VS SNR Process

Phase modulation schemes encode information by varying the phase of the carrier signal. The phase of the carrier signal is altered in accordance with the incoming binary data. BPSK, which stands for Binary Phase Shift Keying, is a form of phase shift keying where the phase of the radio carrier is set to either 0 or π based on the value of the incoming bit [5]. Each bit in the digital signal creates a send symbol that lasts for the same amount of time (Ts) as the bit itself (Tb). QPSK stands for four-state or quadrature PSK. It uses two bits together and changes the radio carrier's phase based on the four patterns of two bits. The transmission of a symbol requires double the time compared to a bit, resulting in QPSK having twice the bandwidth efficiency of BPSK [10]. There are many ways of reducing BER. Here, we focus on spreading spectrum and modulation techniques. In our case, we have considered the most commonly used channel: Additive White Gaussian Noise (AWGN) channel where the noise gets spread over the whole spectrum of frequencies. BER has been measured by comparing the transmitted signal with the received signal and computing the error count over the total number of bits. For any given modulation, the BER is normally expressed in terms of signal to noise ratio (SNR) [3].

II. SPREAD SPECTRUM

Spread spectrum is a type of digital modulation technique which is based upon the principle of disseminating a signal across multiple frequencies in order to hinder interference and the interception of the signal. A signal is dispersed across a broad frequency range in order to utilize a larger bandwidth than the data bandwidth, while maintaining the same power. Both the spread signal and the noise signal appear similar within the same frequency band, making it challenging to distinguish the signal. This characteristic of spreading enhances the security of the transmission. Spread spectrum, in contrast to narrowband signals, distributes the power of the signal across a wide range of frequencies. This results in an enhanced signal-to-noise ratio (SNR) because only a tiny portion of the spread spectrum signal is impacted by interference.

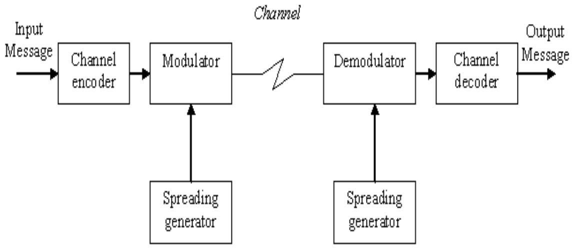

Figure 2: General Model of Spread Spectrum [4]

On both the sender and receiver sides of a communication system, a spreading generator is positioned to synchronize the modulated spectrum that is received, using the spreading technique. The Shannon capacity equation serves as the foundation for spread spectrum systems, which operate under extremely low signal-to-noise ratios (SNR) while utilizing a significantly wide bandwidth to achieve a satisfactory data rate per user [4].

There are two techniques to spread the bandwidth:

1. Frequency Hopping Spread Spectrum (FHSS)
2. Direct Sequence Spread Spectrum (DSSS)

1. Frequency Hopping Spread Spectrum (FHSS):

Frequency hopping spread spectrum is a transmission mode employed in wireless networks to achieve spread spectrum by continuously hopping the carrier frequency. FHSS works on narrow band signal with a bandwidth of less than 1 MHz. This approach involves the modulation of a data transmission with a narrowband carrier signal that randomly changes frequencies in a predictable sequence at regular intervals. The frequency hopping is synchronized between both ends of the communication [4]. FHSS enhances privacy and an effective solution to prevent interference and multi-path fading (distortion). It declines narrowband interference, inclines signal capacity, and improves the signal to noise ratio. The bandwidth efficiency is high due to which it is hard to intercept. In order to implement frequency hopping, it is necessary to establish a mechanism that allows for the transmission of data over clear channels while avoiding those that are busy. The spread-spectrum signals include minimum noise to the narrow-frequency communications, and vice versa. As a result, bandwidth can be used more efficiently [4]. Transmission of the same data using a single carrier frequency requires a substantially smaller total bandwidth than frequency hopping. The effective interference bandwidth is actually the same, though, because transmission only uses a small percentage of this bandwidth at any given time. While providing no extra protection against wideband thermal noise, the frequency hopping approach does reduce the degradation caused by narrowband interferers. For frequency hopping spread spectrum (FHSS) systems, the total bandwidth is divided into multiple narrower channels, each with a lesser bandwidth, and separated by guard spaces [9]. The transmitter and receiver remain on a specific channel for a certain duration before switching to a different channel.

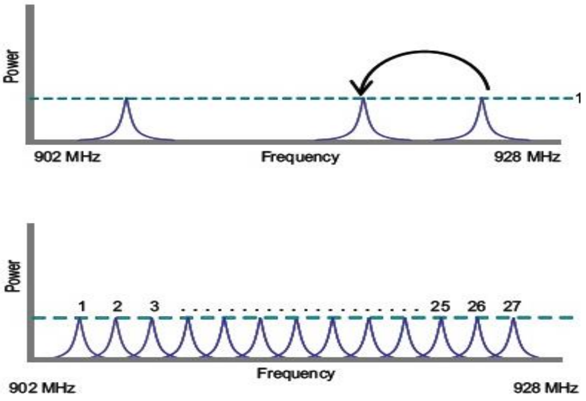

Figure 3: Frequency range is divided into channels [9]

The frequency-hopping technique does not spread the signal, as a result, there is no processing gain. The processing gain is the increase in power density when the signal is de-spread and it will improve the received signal's Signal-to-noise ratio (SNR). In other words, the frequency hopper needs to put out more power in order to have the same SNR as a direct-sequence radio. The frequency hopper, however, is more difficult to synchronize. In these architectures, the receiver and the transmitter must be synchronized in time and frequency in order to ensure proper transmission and reception of signals. In a direct-sequence radio, however, only the timing of the chips needs to be synchronized.

2. Direct Sequence Spread Spectrum (DSSS)

The DSSS encoder uses a mathematical key to spread the data across a wide range of frequencies. Same key is used to decode the data at the receiver end. DSSS uses a lower power density (power/frequency), which makes it harder to detect. DSSS also sends redundant copies of the encoded data to ensure reception. Narrowband interference appears to the receiver as another narrowband transmission [7]. Upon decoding the overall received signal, the transmission with a broader bandwidth (DSSS encoded data) is converted back to its initial narrowband format, while the interference is transformed into a signal with reduced power density, thereby reducing its effects. When broadband interference is present, but the resulting decoded broadband interference can give a much higher noise floor, almost as high as the decoded signal.

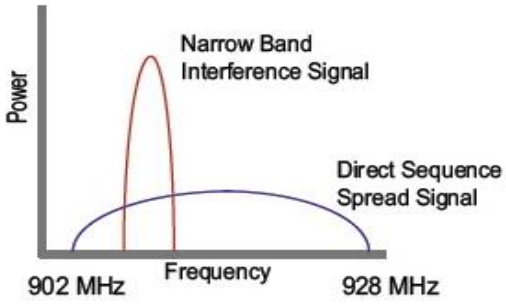

Figure 4: Converted Narrowband signal into DSSS signal [7]

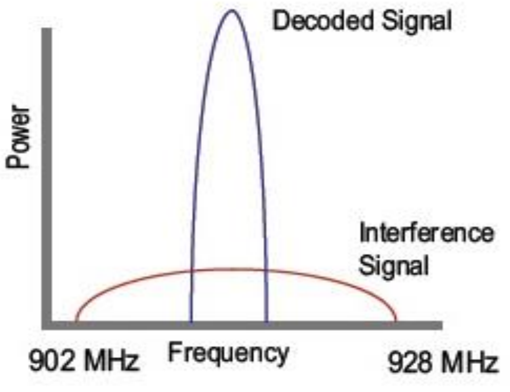

Figure 5: DSSS signals is decoded into original signal [7]

Due to this factor, Direct Sequence Spread Spectrum (DSSS) is most effective for transmitting extensive data packets in an environment with minimal to moderate interference. However, its performance is not as optimal in industrial applications with higher levels of interference. As a general rule, FHSS can resist interference from spurious RF signals ten times better than DSSS.

III. PROBLEM DEFINITION

To reduce the bit error rate in existing method only OFDM (Orthogonal Frequency Division Multiplexing) is used in WiMAX using various modulation techniques such as QPSK, 16-QAM, 64-QAM. In the current research the Bit Error Rate is to be improved by using the spread spectrum techniques such as FHSS (frequency hopping spread spectrum) and DSSS (Direct sequence spread spectrum).Spread spectrum enables a signal to be transmitted across a frequency band that is much wider than the minimum bandwidth required by the information signal. The transmitter spreads the energy, originally concentrated in narrowband across a number of frequency band channels on a wider spectrum. So chances of interference are low. Spread spectrum includes improved privacy, decreased narrowband interference and increased signal capacity. The main objective of this research is to implement the spread spectrum techniques for reducing the bit error rate in WiMAX using spreading signals. The already existing methods reduce the bit rate but the proposed technique improves the bit error rate as compared to existing.

IV. DESIGN METHODOLOGY

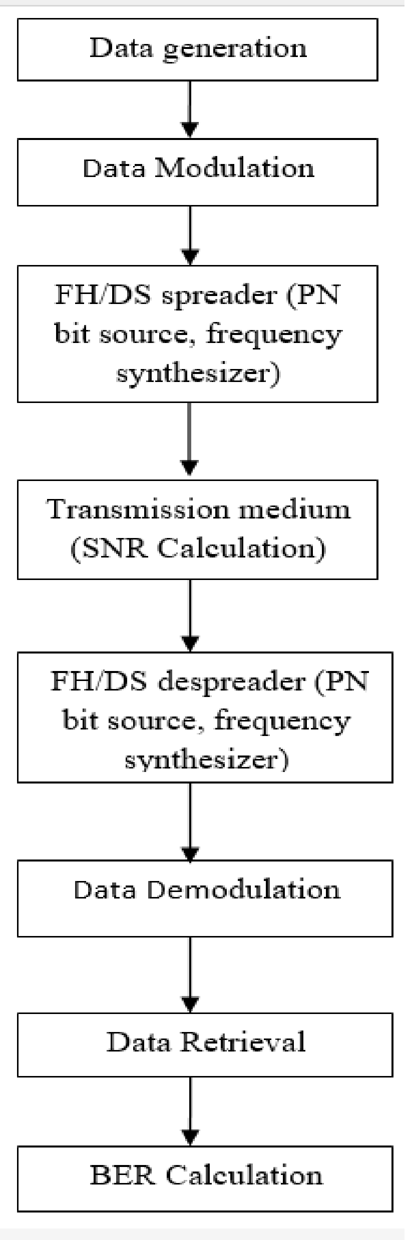

Figure 6: Steps of implementation

V. RESULTS AND DISCUSSION

Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS) techniques are used to reduce the bit error rate in the WIMAX during transmission channel using the MATLAB simulator. The bit error rate is reduced by FHSS and DSSS, because they send the data after creating small chipping data streams over frequency spectrum. These frequencies are transmitted over the WIMAX channel and the bit error rate is recorded. The bit error rate is significantly lower in the final results than the OFDM modulation only. We have implemented these two techniques on the WIMAX platform along with the existing OFDM modulation technique.

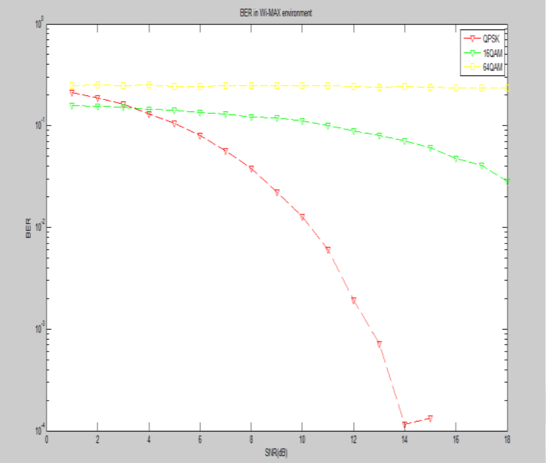

Figure 7: Simulation of QPSK,16-QAM,64-QAM modulation.

Figure 7 describes the three modulation signals QPSK, 16-QAM,64-QAM modulation. The signals shows BER (Bit error rate) v/s SNR(Signal to noise ratio).

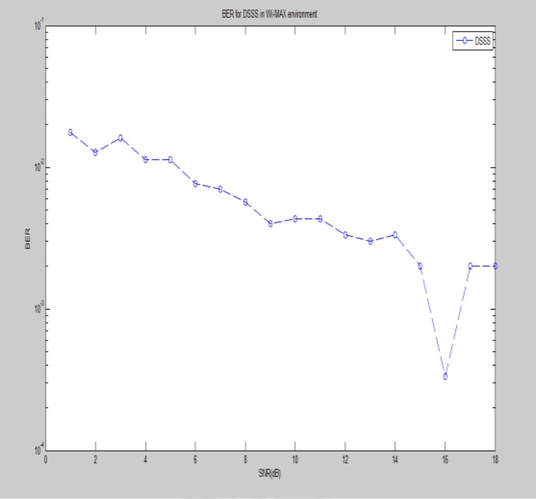

Figure 8: DSSS signal with BER v/s SNR

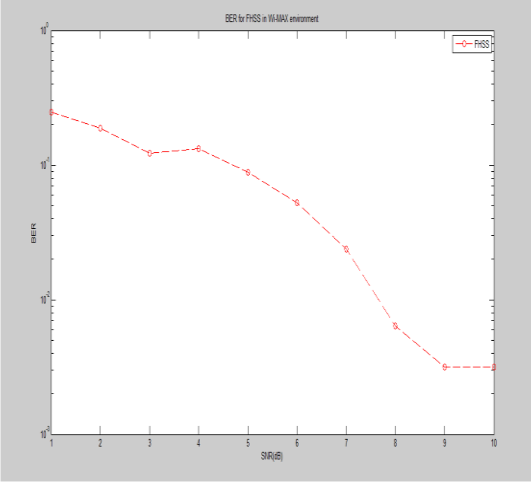

Figure 9: FHSS signal with BER v/s SNR

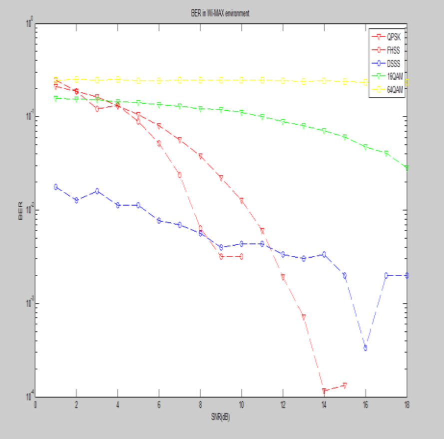

Figure 10: Comparison of QPSK, 16QAM, 64QAM, FHSS, DSSS

Figure 10 describes the comparison of existing modulations with proposed methods FHSS and DSSS and shows that FHSS gives low BER at low SNR as compared to other methods.

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