

# Performance Evaluation of WiMAX (IEEE 802.16)

Priyanka Shitole<sup>1</sup>, Anshuj Jain<sup>2</sup>

<sup>1</sup>M. Tech. Scholar, Scope College of Engineering, Bhopal, India

<sup>2</sup>Assistant Professor, Scope College of Engineering, Bhopal, India

**Abstract:** In this paper, the review of the multiple input multiple output using space time block code on WiMAX (IEEE 802.16) system. The Worldwide Interoperability for Microwaves Access technology which can offer high speed voice, image, and video and data service up to base on standard 802-16 wireless MAN is configured in the same way as a traditional cellular network. The range of WiMAX makes the system very attractive for users, but there will be slightly higher BER at low SNR.

**Keywords:** WiMAX, OFDM, RAYLEIGH CHANNEL, MIMO-OFDM, BER

## 1. Introduction

The growth in the use of the information networks lead to the need for new communication networks with higher data rates. The telecommunication industry is also going to change, with a demand for a greater range of services, such as video conferences, or applications with multimedia contents, wireless communication has permeated nearly all acts of human life.

WiMAX (Worldwide Interoperability for Microwave Access) is a 4G technology and wireless communications standard designed to provide 28to 40 megabit-per-second data rates. Error free transmission is one of the main aims in wireless communications. With the increase in multimedia applications, large amount of data is being transmitted over wireless communications. This requires error free transmission more than ever and to achieve error free transmission multiple antennas can be implemented on both stations i.e. base station and user terminal with proper modulation scheme and coding technique. The 4th generation of wireless communications can be attained by Multiple-Input Multiple-Output (MIMO) in combination with Orthogonal Frequency Division Multiplexing (OFDM) [1]. MIMO multiplexing (spatial multiplexing) and diversity (space time coding) having OFDM modulation scheme are the main areas of focus in our thesis study. MIMO multiplexing increases a network capacity by splitting a high signal rate into multiple lower rate streams. MIMO allows higher throughput, diversity gain and interference reduction. It also fulfills the requirement by offering high.

Alamouti Space Time Block Code (STBC) scheme is used with orthogonal designs over multiple antennas which showed simulated results are identical to expected theoretical results. With this technique both Bit Error Rate (BER) and maximum

diversity gain are achieved by increasing number of antennas on either side. This scheme is efficient in all the applications where system capacity is limited by multipath fading [2].

Because of the characteristics of WiMAX system itself, and the problems of OFDM system which is sensitive to the timing and the frequency compensation. The OFDM system of the WiMAX adopts abruptly deliver mode, reliability, good efficiency and High data rate is achieved between the transmitter and the receiver if they are ideally synchronized. However, there usually exists a small timing and frequency offset whose exists will dramatically degrade the performance of the whole OFDM systems. Hence, before signals can be demodulated, OFDM symbols have to be time-synchronized and carrier frequency offset compensated. This puts forward very high request to the mode piece of the synchronization system. In order to realize the synchronization, it must adopt synchronization algorithm of smaller calculation quantity. In the meantime, it should have higher examination of the first moment. Characteristics of WiMAX simulation model as shown in Table 1.

Table 1  
Key Characteristics of WiMAX (IEEE 802.16) Standard [3]

Characteristic	Description
Physical layer	Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), Orthogonal Frequency Division Multiplexing (OFDM).
Standard	802.16e
Frequency band s	2.4 GHz, 3.5GHz, 5GHz
Topology	Mesh,
Modulation scheme	BPSK, QPSK, QAM
Data rates	5.5 to 70 Mbps

### A. Features of WiMAX [3]

- **Interoperability:** The IEEE 802.16 standard is internationally accepted and the standard is maintained and certified by WiMAX forum covers fixed, portable and mobile deployments.
- **Long Range:** It covers up to 30 miles but in practice, it covers only 6 miles.
- **QoS:** QoS of WiMAX media access control (MAC) is designed to support a large number of users, with multiple connections per terminal.

- *Mobility:* WiMAX offers immense mobility especially IEEE 802.16e-2005.

This paper is organized as follows: In section II, the orthogonal frequency division multiplexing system and peak average peak ratio is formulated. Multiple input multiple outputs OFDM system is introduced in section III. In section IV discuss about IEEE 802.16 reference model. In section V explain the space time block code and simulation result. Finally, the conclusions are given in section VI.

## 2. Orthogonal frequency division multiplexing

The OFDM (Orthogonal Frequency Division Multiplexing) is a wide band wireless digital communication technique that is based on block modulation, with the wireless multimedia application becoming more and more popular, the required bit rate are achieved due to OFDM multicarrier transmission for video communication, very high bit rate/high-speed communication is required.

OFDM has been popularly standardized in many applications such as high performance wireless LAN, IEEE 802.11 (Wi-Fi), in Asynchronous Digital Subscriber Line (ADSL) and in power line communication. It uses in military application. It has great importance in wireless internet service. It used in WiBRO and WiMAX services [5].

$$\tilde{S} = x(t) + jy(t) \dots \dots \dots (1)$$

$$= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} A_k e^{j2\pi(\frac{k}{T_s})t} \dots \dots \dots (2)$$

Where  $A_k$  is the complex data of the  $k^{th}$  subcarriers and  $T$  is the OFDM symbol period [6]. Low let us discuss some advantages of OFDM: It has maximum spectral efficiency according to Nyquist rate. It controls overlapping of bands in channels. Its implementation technique is easier because it uses IFFTs. It has perfect synchronization of transmitter and receiver. It is well suited for high bit rate applications. In OFDM system timing recovery is very straight forward. In this system effects of delay spread can be easily compensated using cyclic prefix. It uses efficient bandwidth range.

OFDM also has some disadvantages. The main disadvantage of multicarrier modulation is that it exhibits a high peak to average power ratio. Because of high PAPR two problems occur which are: Problem 1- It increased the complexity of A/D and D/A converters and problem 2- It reduced the efficiency of RF power amplifier. The other disadvantages are OFDM system is very sensitive for frequency errors, it causes carrier offset problem. It needed higher input back off factor before the peaks in the signal experience significant distortion.

The PAPR of the discrete time base band OFDM signal is defined as the ratio of the maximum peak power divided by the average power of the OFDM signal [6].

$$PAPR(a_n) = \frac{\max |a^2|}{P^{av}(a_n)} \dots \dots \dots (3)$$

$$P^{av}(a_n) = \frac{1}{N} \sum_{n=0}^{N-1} E\{|a_n^2|\} \dots \dots \dots (4)$$

Where  $E\{.\}$  denotes the expected value. The PAPR (in dB) of the OFDM signal can be defined as,

$$PAPR = 10 \log_{10} \left\{ \frac{P^{peak}}{P^{avg}} \right\} \dots \dots \dots (5)$$

Where, is the average power consumed by each frame, and is the maximum of power for one OFDM frame. When BPSK modulation is used on each sub carrier, binary block coding can be directly implemented before modulation. If the power in each sub carrier is normalized to 1 W, is  $NW$ .

## 3. MIMO-OFDM

Multiple-Input Multiple-Output uses multiple antennas at both sides which provides transmit diversity and receiver diversity. It's applicable in every kind of networks like PAN, LAN, WLAN, WAN, MAN. MIMO system can be applied in different ways to receive either a diversity gain, capacity gain or to overcome signal fading.

The quality of a wireless link can be described by three basic parameters, namely the transmission rate, the transmission range and the transmission reliability. Conventionally, the transmission rate may be increased by reducing the transmission range and reliability. By contrast, the transmission range may be extended at the cost of a lower transmission rate and reliability, while the transmission reliability may be improved by reducing the transmission rate and range. However, with the advent of MIMO assisted OFDM systems, the above-mentioned three parameters may be simultaneously improved. Initial field tests of broadband wireless MIMO-OFDM communication systems have shown that an increased capacity, coverage and reliability achievable with the aid of MIMO techniques.

Furthermore, although MIMOs can potentially be combined with any modulation or multiple access technique, recent research suggests that the implementation of MIMO aided OFDM is more efficient, as a benefit of the straight forward matrix algebra invoked for processing the MIMO OFDM signals. MIMO OFDM, which is claimed to be invented by Airgo Networks, has formed the foundation of all candidate standards proposed for IEEE 802.11n. In recent years, this topic has attracted substantial research efforts, addressing numerous aspects, such as system capacity, space/time/frequency coding, Peak-to- Average Power Ratio (PAPR) control, channel estimation, receiver design, etc. Recently, Paulraj et al. and Stuber et al provided compelling overviews of MIMO-OFDM Communications. Furthermore, Nortel Networks has developed a MIMO OFDM prototype, which demonstrates the superiority of MIMO OFDM over today's networks in terms of the achievable data rate.

**4. IEEE 802.16 reference model**

In Fig. 1, there are four types of sub layer are used in IEEE 802.16 reference model.

- Convergence Sub layer (CS)
- MAC common part sub layer • Security sub layer
- Physical sub layer

In convergence sub layer classification of the higher-layer protocol PDU into the appropriate connection- Suppression of payload header Information- Delivery of the resulting CS PDU to the MAC SAP associated with the service flow for transport to the peer MAC SAP- Receipt of the CS PDU from the peer MAC SAP- Rebuilding of any suppressed pay load header information [7]. MAC common part sub layer (MAC CPS) classification of the system access - Bandwidth request/allocation - Connection establishment/maintenance- Quality of service - Power saving mechanisms and handover mechanism Security sub layer classification of the authentication- Secure key exchange and encryption.

The IEEE 802.16 group has introduced new standard under the rules of WiMAX forum and named it IEEE 802.16e in December 2005. 802.16e was the updated version of IEEE 802.16-2004 which established the basis for first fixed WiMAX solution. IEEE 802.16e was addressing the wireless MANs. There were some challenges for mobile wireless environment. Mobile devices receive signal which vary over shorter distances and can be affected by serious errors so there must be some protocols to deal this issue.

There must be a control of Peak to Average Power Ratio (PAPR) in wireless environment. The Mobile WiMAX must be working on a licensed bands rather than unlicensed bands. The main purpose of this standard was to provide platform for interoperability between vendors. WiMAX forum works similarly to Wi-Fi forum which provide standard to business organizations and manufacturers to recommend standards of equipment interoperability.

**5. Space time block code**

Space-Time Codes (STCs) have been implemented in cellular communications as well as in wireless local area networks. Space time coding is performed in both spatial and temporal domain introducing redundancy between signals transmitted from various antennas at various time periods. It can achieve transmit diversity and antenna gain over spatially un-coded systems without sacrificing bandwidth. The research on STC focuses on improving the system performance by employing extra transmits antennas. Alamouti STBC uses two transmit antennas regardless of the number of receive antennas. The Alamouti scheme encoding operation is given by (8). In this paper, the rows of each coding scheme represents a different time instant, while the columns represent the transmitted symbol through each different antenna. In this case, the first and second row represents the transmission at the first and second time instant respectively.

$$G_2 = \begin{pmatrix} S_1 & S_2 \\ -S_2^* & S_1^* \end{pmatrix}$$

The reception and decoding of the signal depends on the number of receive antennas available.

$$r^{(1)} = r_1(t) = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)} \dots\dots\dots(7)$$

$$r_1 = r_1(t+T) = -h_{1,1}s_2 + h_{1,2}s_1 + n_1 \dots\dots\dots(8)$$

$$\underline{s} = (\alpha_{1,1} s_1 + \alpha_{1,2} s_2) + h^* n^{(1)} + h n^{(2)} \dots\dots\dots(9)$$

$$\underline{s} = (\alpha_{2,1} s_1 + \alpha_{2,2} s_2) - h n^{(2)} + h^* n^{(1)} \dots\dots\dots(10)$$

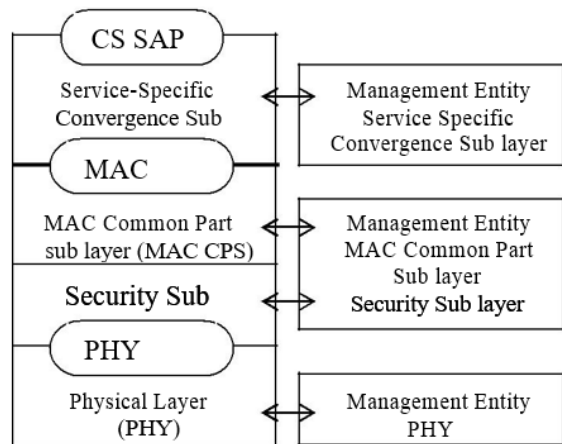


Fig. 1. IEEE 802.16 reference model

**6. Conclusion**

WiMAX-OFDM in the 3.5 GHz band is of practical interest due to the potential for large-scale WiMAX deployment. Communication system can operate with a lower transmit power, transmit over longer distances, tolerate more interference, use smaller antennas and transmit at a higher data rate. These properties make the code energy efficient. Hence, new codes were sought that would allow for easier decoding and encoding. The task of the decoder and encoder is using a code with mostly high-weight code words. Error detection and correction techniques are essential for reliable communication over a noisy channel.

In Fig. 2, the simulation results are presented along with the theoretical results. The theoretical results are presented while considering the 1 Tx and 1 Rx, 1 Tx and 2 Rx using maximum ratio combining technique. As shown in the Fig. 2, the performance in term of BER improves significantly for example for Eb/N0 equals to 10 db the BER improves by a factor of 10. Hence, MRC schemes provide very good results; this is also an agreement with theoretical results. However, in MRC scheme, to receive better signal quality more than two receivers may require. To counteract this Alamouti proposed a scheme in which more than one transmitter can be used to transmit signals, as signal generated from these antennas will travel different

path, hence may provide better quality signal at the receiver. As this scheme is somewhat compromising scheme, therefore results may not be up to the level of MRC. However, this scheme is very simple and has potential to combat with fading of the channel.

Fig. 3, simulation results for the Alamouti scheme are presented. Here, the simulation results exactly matched with theoretical results. In Fig. 3, Alamouti results are presented while considering, 2 Tx and 2 Rx. It is evident from (Fig. 2 and Fig. 3) as the number of receiver increased from 1 to 2 the BER improves. This is understandable as the number of receiver increases the performance should improve. Comparing Fig. 2 and 3 it is noticeable that in case of 2 Tx and 2 Rx the results are better in comparison to 1Tx and 2 Rx MRC scheme. This 2 Tx and 2 Rx, scheme avails the advantage MRC as well as Alamouti scheme.

The STBC coding method leads to reduce BER as compare to convolution coding method. Although coding is a simple, having good PAPR reduction performance and blessed with unique advantage of error correction, but finding the best suited coding technique and the optimal coding rate is very iterative process.

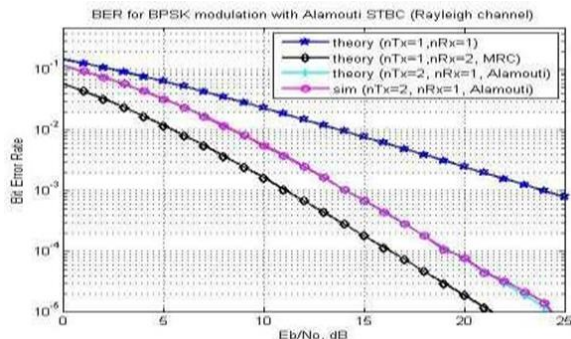


Fig. 2. BER performance of SISO, SIMO and MISO system

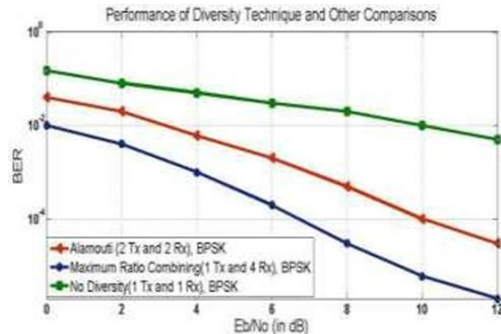


Fig. 3. Performance analysis of SISO (No diversity (1Tx, 1Rx), BPSK), MIMO (Alamouti (2Tx, 2Rx), BPSK) and Maximum ratio combining (1Tx, 4Rx), BPSK) system.

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