

Implementation of Quality Based Algorithm for Wimax Simulation Using SISO and SIMO Techniques

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Abstract-This paper presents the designing of more primitive algorithm of WiMAX (Worldwide Interoperability for Microwave Access) system simulation for lower Bit Error Rate Perspective. WiMAX is considered today the most interesting opportunity, able to provide radio coverage distances of almost 50 kilometers and data throughput up to 70 Mbps, and to complete wired network architectures, ensuring a flexible and cheap solution for the last-mile. In its mobile variant, WiMAX has the potential to replace cellular networks. In this way, the WiMAX may be seen as the fourth generation (4G) of mobile communications systems. The vital aspect of simulation of WiMAX system is to achieve the lower Bit Error Rates, higher Signal to Noise Ratio and there by higher system capacity. There is one fundamental aspects of wireless communication that make the problem challenging and interesting, that is the phenomenon of fading. The technique called diversity, can dramatically improve the performance over fading channels. The main objective of this research paper is to achieve the greater reduction in bit error rate for wireless system by implementing antenna diversity principle like SIMO (Single Input Multiple Outputs) and to compare the performance analysis of same.

Keywords-AWGN, BER, SISO, SIMO and WiMAX

I. INTRODUCTION TO WIMAX

The experienced growth in the use of digital networks has led to the need for the design of new communication networks with higher capacity. The telecommunication industry is also changing, with a demand for a greater range of services, such as video conferences, or applications with multimedia contents. The increased reliance on computer networking and the Internet has resulted in a wider demand for connectivity to be provided "any where, any time", leading to a rise in the requirements for higher capacity and high reliability broadband wireless telecommunication systems. Wireless access to data networks is expected to be an area of rapid growth for mobile communication systems. The huge uptake rate of mobile phone technologies, WLANs and the exponential growth that is experiencing the use of the internet have resulted in an increased demand for new methods to obtain high capacity wireless networks.

WiMAX methods to obtain high capacity wireless networks. WiMAX is considered today the most interesting opportunity, able to provide radio coverage distances of almost 50 kilometers and data throughput up to 70 Mbps and to complete wired network architectures, ensuring a flexible and cheap solution for the last-mile. The interoperability is a very strategic issue, on which equipment cost and volume of sales will be based. Operators will not be bound to a unique equipment supplier, as the radio base stations will be able to interact with terminals produced by different suppliers. Operators can benefit of suppliers' competition in terms of costs and innovation. The existing technologies such as Wireless Fidelity (Wi-Fi), Digital Subscriber Line (DSL), Global System for Mobile communications (GSM), Integrated Services Digital Network (ISDN), and the relatively new 3G technologies have not been able to provide higher capacity along with high bit rate and wide coverage areas. WiMAX provides an appropriate solution to certain rural access zones that are today prevented from having access to broadband internet because of cost consideration. WiMAX has the potential to impact all forms of telecommunications. In a fixed wireless communication, WiMAX can replace the telephone company's copper wire networks, the cable TV's coaxial cable infrastructure while offering Internet Service Provider services. In its mobile variant, WiMAX has the potential to replace cellular networks. In this way, as shown in figure 1 the WiMAX may be seen as the fourth generation (4G) of mobile communications system as the convergence of cellular telephony, computing, internet access, and potentially many multimedia applications become a real fact. [4] In comparison with Wi-Fi and Cellular technology, Wi-Fi provides a high data rate, but only on a short range of distances and with a slow movement of the user. On the other hand, Cellular offers larger ranges and vehicular mobility, but instead, it provides lower data rates, and requires high investments for its deployment. WiMAX tries to balance this situation. WiMAX fills the gap between Wi-Fi and Cellular, thus providing vehicular mobility, and high service areas and data rates as shown in figure 2

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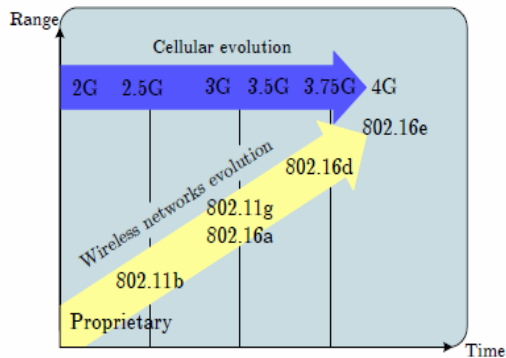


Figure 1 Cellular evolution Vs. Wireless network Evolution

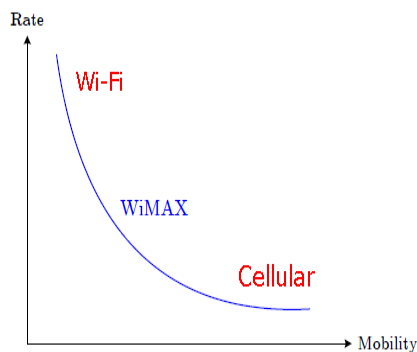


Figure 2 Data rate and Mobility

WiMAX is a standards based technology for wireless MANs conforming to parameters which enable interoperability. WiMAX developments have been moving forward at a rapid pace since the initial standardization efforts in IEEE 802.16. Standards for Fixed WiMAX (IEEE 802.16-2004) were announced as final in 2004, followed by Mobile WiMAX (IEEE 802.16e) in 2005. The WiMAX standards are mentioned in table 1.

WiMAX Standard	Definition Year	Frequency Band
802.16	2002	10-66 GHz
802.16(a)	2003	2-11 GHz
802.16(b)	2003	5-6GHz
802.16(c)	2003	10-66GHz
802.16(d)	2003	2-11GHz
802.16-2004	2004	2-66GHz
802.16(e)	2005	2-11GHz

Table 1 WiMAX Standards

In Europe, the standards for wireless MANs were formalized under the ETSI as HiperMANs. These were also based on IEEE 802.16 standards but did not initially use the same parameters (such as frequency or number of

subcarriers). These were later harmonized with the WiMAX standards. The IEEE 802.16d standards provide for fixed and nomadic access, while the 802.16e standards also provide mobility up to speeds of 120 kilometers per hour.

II. PROBLEM DOMAIN

In 4G transmission system, link reliability and maximum data throughput is the need for transmitting real time data at high speed. However when the path is in a deep fade, any communication scheme will likely suffer from errors. The phenomenon of fading; that makes the time-variation of the channel strengths due to the small-scale effect of multi path fluctuation, as well as larger scale effects such as path loss via distance attenuation and shadowing by obstacles. Antenna diversity principle is one of the promising solutions for this. Traditionally the design of wireless systems has been focused on increasing the reliability of the air interface; in this context, fading and interference are viewed as nuisances that are to be countered. Recent focus has shifted more towards increasing the spectral efficiency; associated with this shift is a new point of view that **fading can be viewed as an opportunity** to be exploited. **The main objective of this work is to provide a unified treatment of wireless communication from both these points of view.** There are many ways to obtain diversity. Diversity over time can be obtained via coding and interleaving; information is coded and the coded symbols are dispersed over time in different coherence periods so that different parts of the code-words experience independent fades. Analogously, one can also exploit diversity over frequency if the channel is frequency-selective. In a channel with multiple transmit or receive antennas spaced sufficiently far enough, diversity can be obtained over space as well. In a 4G wireless network, macro-diversity can be exploited by the fact that the signal from a base station can be received by two receiving antennas at mobile station. This type of diversity is known as Single Input Multiple Outputs antenna diversity technique. Also diversity is such an important resource; a wireless system typically uses several types of diversity such as Multiple Inputs Single Output, Multiple Inputs Multiple Outputs etc.

III. ANTENNA DIVERSITY TECHNIQUES

A natural solution to improve the performance of system in fading environment is to ensure that the information symbols pass through multiple signal paths, each of which fades independently, making sure that reliable communication is possible as long as one of the paths is strong. This technique is called **diversity**, and it can dramatically improve the performance over fading channels. Antenna diversity can be obtained by placing multiple antennas at the transmitter and/or the receiver

Single Input Single Output Antenna System (SISO)

The main fundamental behind advance antenna system implementation is the diversity. In the initially stages, the various modulation schemes like coherent BPSK, coherent

QPSK, coherent 4-PAM, coherent 16-QAM were in which error probability decay very slowly proportional to $1/\text{SNR}$. [1]

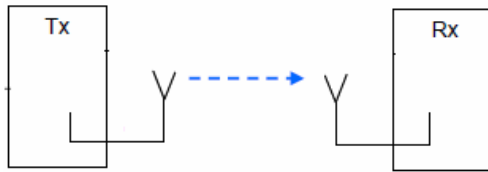


Figure 3 (a) Single Input Single Output Antenna System

Basically the above mention modulation techniques did not use diversity principle that is the single antenna system were used at transmitter and receiver in both the side as shown in figure 3 (a), anticipating lower poor spectral efficiency and lesser capacity. However in such a scenario, diversity can be obtained by implementing the OFDM technique i.e. frequency diversity during the transmission of symbols.

Single Input Multiple Output Antenna Diversity Technique

The first step toward using diversity is to use a single input multiple output configurations, e.g., one transmit and two receive antennas as shown in figure 3 (b). This configuration is called single input multiple output (SIMO). For example, a base station with one transmit and two receive antennas would be SIMO ($1 \times L$ system).

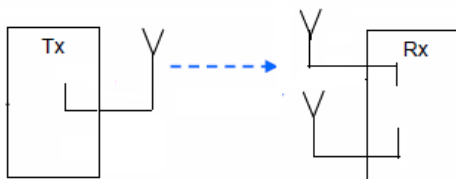


Figure 3 (b) Single Input Multiple Outputs Antenna System

In a flat fading channel with 1 transmit antenna and 2 (L) receive antennas, the channel model is as follows:

$y_l[m] = h_l[m]x[m] + w_l[m]$, Where $l = 1, \dots, L$ The noise $w_l[m]$ independent across the antennas. We would like to detect $x[1]$ based on $y_1[1], \dots, y_L[1]$. If the antennas are spaced sufficiently far apart, then we can assume that the gains $h_l[1]$ are independent Rayleigh, and we get a diversity gain of L . With receive diversity; there are actually two types of gain as we increase L . This can be seen by considering the expression for the error probability of BPSK conditioned on the channel gains: [1]

$$Q\left(\sqrt{2\|h\|^2\text{SNR}}\right)$$

We can break up the total received SNR conditioned on the channel gains into a product of two terms:

$$\|h\|^2\text{SNR} = L\text{SNR} \cdot \frac{1}{L}\|h\|^2$$

The first term corresponds to a power gain (also called array gain): by having multiple receive antennas and coherent combining at the receiver, the effective total received signal power increases linearly with L : doubling L yields a 3 dB power gain. The second term reflects the diversity gain and by averaging over multiple independent signal paths, the probability that the overall gain is small is decreased and BER is reduced. [1]

Multiple Inputs Single Outputs Antenna Diversity Technique

The next step toward using diversity is to use a multiple input single output configurations, e.g., two transmit antennas and one receive antenna. This configuration is called multiple inputs single output (MISO) as shown in figure 3 (c). For example, a base station with two transmit and one receive antennas would be MISO ($L \times 1$ system).

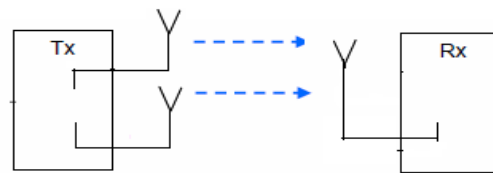


Figure 3 (c) Multiple Inputs Single Output Antenna System

Now consider the case when there are L transmits antennas and 1 receive antenna, the MISO channel. This is common in the downlink of a cellular system since it is often cheaper to have multiple antennas at the base station than to having multiple antennas at every handset. It is easy to get a diversity gain of L : simply transmit the same symbol over the L different antennas during L symbol times. Generally, any time block length L can be used on this transmit diversity system which simply use one antenna at a time and transmit the coded symbols of the time diversity code successively over the different antennas. This provides a coding gain over the repetition code. Coding scheme can also be designed for the transmit diversity system. Space Time Code is one of the most elegant, so-called Alamouti scheme. This is the transmit diversity scheme proposed in several third generation cellular standards.

Multiple Input Multiple Output Antenna Diversit Technique

MIMO involves the transmission of two streams using two or more than two spatially separated antennas. The streams are received at the receiver by using spatially separated antennas. The streams are then separated by using the space time processing, which forms the core of the MIMO technology as shown in figure 3 (d). A base station using two transmit antennas and two receive antennas is referred to as MIMO ($n \times n$).



Figure 3 (d) Multiple Inputs Multiple Outputs Antenna System

In addition to provide diversity, MIMO channels also provide additional degree of freedom for communication. The main advantages of MIMO channels over SISO channels are the array gain, the diversity gain, and the multiplexing gain

IV. IMPLEMENTATION OF QUALITY BASED ALGORITHM FOR Wi-MAX SIMULATION.

For the implementation of WiMAX simulation algorithm as shown in figure 4, MATLAB simulation is carried out strictly as per the IEEE standards 802.16d [8]. Also the resultant BER is calculated using WiMAX SISO (no diversity) and WiMAX SIMO (diversity method) techniques. Finally Comparative analysis is displayed for the performance evaluation of different WiMAX systems. Basically the simulation algorithm contains three major parts of WiMAX system.

1. Transmitter
2. Channel
3. Receiver

Users can input their own choice about the inclusion of diversity techniques by entering the number of receiving antennas i.e. 1 for SISO or 2 for SIMO. In the next step, rate_id and selection of cyclic prefix for Orthogonal Frequency Division Multiplexing Technique (OFDM) in the range of 1/4, 1/8, 1/16, 1/32 is defined as per IEEE standards 802.16. The BER performance is carried out with number of OFDM symbols for e.g. 50, 100, 500, 1000, etc. User define input is required before the simulation process for the number of transmitting and receiving antennas i.e. the choice of diversity scheme. Randomly generated data stream by Pseudo Random Binary Sequence Generator is produced for the simulation process. FEC (Forward Error Correction) coding is applied to the randomized stream of data for coding Purpose. As an outer code Read Solomon coding is applied in the first phase for different rate_ids, using inbuilt function 'rsenc' of MATLAB. The RS encoded data is applied to the convolutional coder for much transparency. Block interleaving is applied to the coded stream to protect the information from data loss errors. After that the modulation schemes like QPSK $\frac{3}{4}$ or 16 QAM $\frac{1}{2}$ is applied to interleaved data. At last before the transmission of symbols through the wireless Additive channel, IFFT is performed on the stream to realize OFDM.

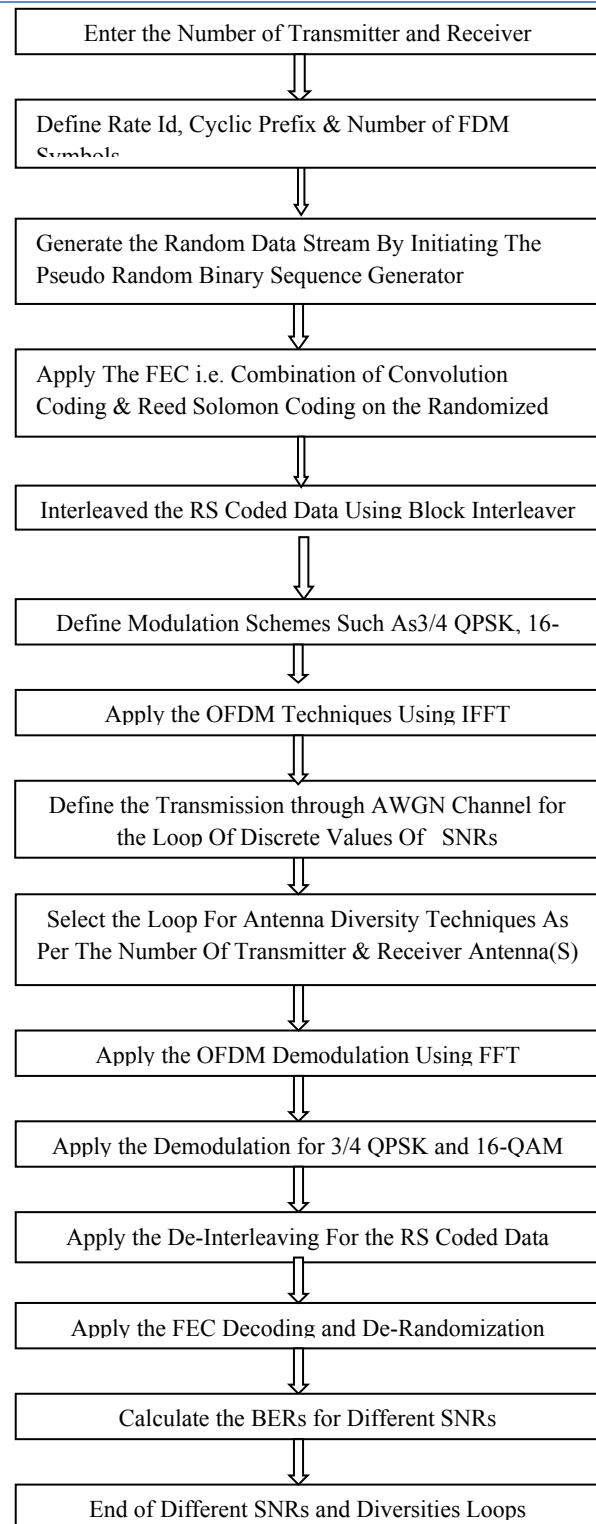


Figure 4 WiMAX Simulation Algorithm

In the next phase, AWGN (Additive White Gaussian Noise Channel) channel is defined as per the type of diversity scheme. For SISO scheme, single AWGN channel between one transmitting antenna and one receiving antenna is realized. For SIMO diversity technique, single AWGN channel and two noise matrixes are defined between one Transmitting antenna and two receiving antennas. At

receiving side, OFDM demodulation is carried out by taking FFT of the received data frame. After that the Demodulation and De-interleaving of the frequency domain symbols is carried out. At last FEC de-coding is performed to rearrange the data stream to the original fashion. In the final phase of simulation, the decoded data stream of last step will be compared with Original randomized data stream of the transmitter side and BER will be calculated by inbuilt MATLAB function `_BITERR_`. Also simulation graphs are plotted for SNRs v/s BER.

V. SIMULATION RESULTS

The BER v/s SNR relationship for the WiMAX system with the Single Input Single Output Antenna technique is shown in figure 5 with the value of cyclic prefix = $\frac{1}{4}$ and QPSK $\frac{3}{4}$ as the modulation scheme. As can be seen from graph, in case of no diversity, i.e. using single transmitting and single receiving antenna, initially the BER can be obtained around **0.48** and at higher value of SNR, the achievable BER decreases around **0.009 for 8 dB SNR**. Also the values of BER are high as there is no implementation of numbers of antennas in either transmitter or receiver side and throughput of the system totally depends on the channel SNR.

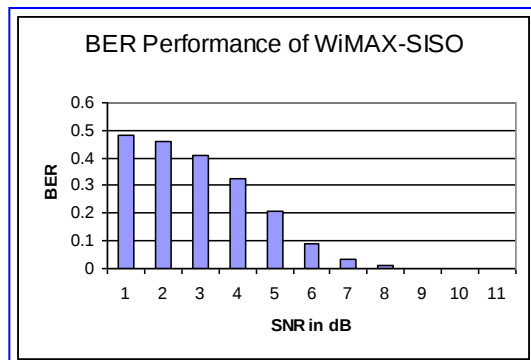


Figure 5 BER Performance of Single Input Single Output Antenna System

The BER v/s SNR relationship for the WiMAX system with the Single Input Multiple Output Antenna system is shown in figure-6 with the value of cyclic prefix = $\frac{1}{4}$ QPSK $\frac{3}{4}$ as the modulation scheme.

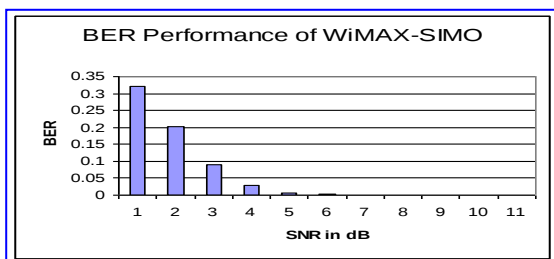


Figure 6 BER Performance of Single Input Multiple Outputs Antenna Diversity Technique

As can be seen from the graph, in case of receive diversity, i.e. using single transmitting and two receiving antennas, initially the BER can be obtained around 0.322 and at higher value of SNR, the achievable BER decreases around 0.00018 for 8 dB SNR.

Comparative Analysis

From the comparison of simulation results of WiMAX SISO and WiMAX SIMO, it can be observed that with the implementation of receiving diversity (SIMO), BER performance is improved compared to SISO antenna system. It is due to the fact that by averaging over multiple independent signal paths, the probability of error is decreased and BER is reduced for the same value of SNR. In this way, by using SIMO diversity technique, **the received signal quality gets enhanced by averaging over multiple independent signals.**

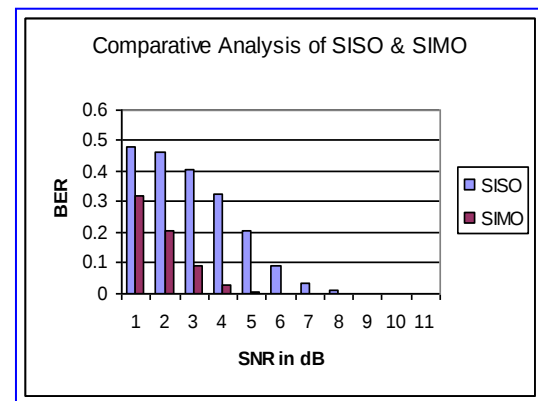


Figure 7 Comparisons between WiMAX SISO and WIMAX SIMO

VI. SIMULATION RESULTS OF VARIATION IN MODULATION ORDER

Figure 8 shows the BER performance of WiMAX system for 16-QAM $\frac{1}{2}$ with cyclic prefix $\frac{1}{4}$. It can be observed that by changing the order of modulation scheme, the BER of the system is also affected. As the modulation order M increases, the BER of the system also increases.

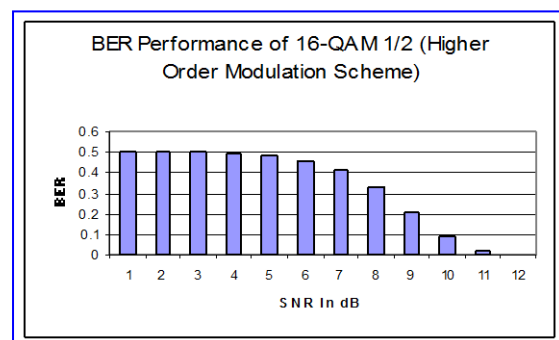


Figure 8 Effect of variation in modulation order

This is due to the fact that for fixed number of transmitting and receiving antennas, as the modulation order increases

i.e. in turn the no. of bits per symbol increases for that modulation scheme, due to the variation in their spatial position as well overlapping, the loss of bits will be encountered which is the main cause behind the degradation of BER. The degradation of BER can be more specifically observed by analyzing the comparison of BER performance of QPSK $\frac{3}{4}$ Vs. 16 QAM $\frac{1}{2}$. The comparative analysis is shown in figure 9.

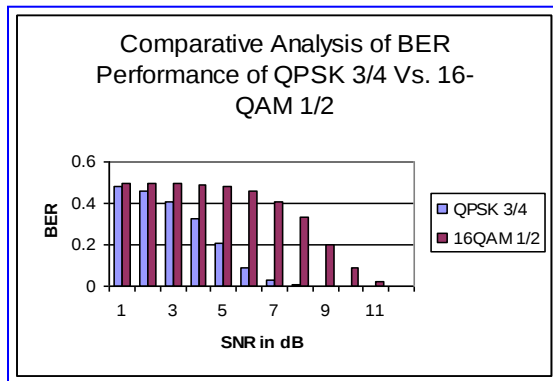


Figure 9 Comparative analysis of QPSK $\frac{3}{4}$ Vs. QAM $\frac{1}{2}$

When the lower order modulation scheme QPSK $\frac{3}{4}$ has been applied, the BER is approximately 0.2048 at 5dB SNR and which is quite lower as compared to higher order modulation 16 QAM $\frac{1}{2}$ for which BER = 0.4817 at the same value of 5dB SNR. In this way, it can be concluded that the diversity technique with lower order modulation also give the excellent throughput of the system. However when the order of modulation is low, it also causes the degradation in the data rates of the systems. So there is always trade-off in the selection of order of modulation and in practice, it totally depends on the application.

VII. CONCLUSION

WiMAX may be seen as the fourth generation of mobile communications systems as WiMAX is an evolving wireless networking standard for point to multipoint wireless networking which works for the 'lastmile' connections. The key problem with the wireless channels is impairment of the channel by fading and interference. The major goal of this research paper is to develop the quality based algorithm for WiMAX system in antenna diversity environment for lower BER Perspective. Conventional single-antenna transmission techniques aiming at an optimal wireless system performance operate in the time domain and/or in the frequency domain. In particular, channel coding is typically employed, so as to overcome the detrimental effects of multipath fading. However, with regard to the ever-growing demands of wireless services, the time is now ripe for evolving the antenna part of the 4G radio system. In fact, when utilizing multiple antennas, the unused spatial domain can be exploited. Simulation of WiMAX along with the implementation of Antenna Diversity Technique (SIMO) achieves the drastic improvement in performance regarding

to Bit Error Rates as compared to conventional antenna system. (SISO). For SISO WiMAX system, the attainable BER is 0.407 at 3dB SNR while for SIMO WiMAX system, the achievable BER is 0.089 at same value of SNR. Hence by averaging over multiple independent signal paths, the probability that the overall gain is small is decreased and BER of the system is enhanced. Also it can be observed that by increasing the modulation order M, BER of the system also increases for the same value of SNR. When the lower order modulation scheme has been applied, the BER is approximately 0.2048 at 5dB SNR, while for the higher order modulation scheme, BER = 0.4817 for the same value of SNR. More specifically, this paper examines the simulation of WiMAX system in antenna diversity environment on the platform of MATLAB 2007a.

VIII. FUTURE ENHANCEMENT

In this research paper, the performance analysis and simulation results are presented using SIMO diversity technique. However in future a quality based algorithm can be implemented using MISO (Multiple Input Single Output) and MIMO (Multiple Input Multiple Output) diversity techniques for better system throughput. In such a case, two efficient wireless channels must be defined for the transmission of two independent information signals through two transmitting antennas. With MISO diversity technique, two independent channels are defined, signal fades independently; making sure that reliable communication is possible as long as one of the paths is strong and received signal quality will get enhanced. Also with the implementation of transmit diversity and received diversity i.e. MIMO, the lowest BERs can be achieved and performance can be dramatically improved compared to other system. It is due to the fact that MIMO technique exploits the advantages of MISO and SIMO diversity techniques.

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