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Performance Evaluation of Adaptive Modulation Techniques of WiMAX System with Optimized Cyclic Prefix

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Abstract: Orthogonal frequency division multiple access uses adaptive modulation technique on the physical layer of WiMAX and it uses the concept of cyclic prefix that adds additional bits at the transmitter end. The signal is transmitted through the channel and it is received at the receiver end. Then the receiver removes these additional bits in order to minimize the inter symbol interference, to improve the bit error rate and to reduce the power spectrum. In this paper, we have investigated the physical layer performance on the basis of bit error rate vs. signal to noise ratio by varying cyclic prefix of adaptive modulation techniques (BPSK, QPSK, 16-QAM and 64-QAM). These parameters are discussed with two different channel Models (AWGN Channel model and Rayleigh Channel model). The BER curves were used to compare the performance of different modulation techniques with optimized cyclic prefix. BPSK modulation technique under different channels provides satisfactory performance among the four considered modulation techniques.

Keywords : Adaptive Modulation techniques, IEEE-802. 16, OFDMA

I. INTRODUCTION

WiMAX (worldwide interoperability for microwave access) represents an IEEE metropolitan access standard (IEEE 802.16) that provides wireless broadband to fixed CPEs (customer premises equipment) and mobile terminals. The system offers a wide variety of services including voice, data and multimedia. The full potential of the WiMAX network standard will be realized as the recent nomadic and mobile extensions are deployed. Given the finalization of the IEEE 802. 16 standard [1], and the upcoming test and certification of WiMAX network products [2][3], mobile broadband services are about to become a reality. Mobile WiMAX network integrates a rich set of features that offer considerable flexibility in terms of deployment options, as well as potential applications. Mobile WiMAX network can provide tens of megabits per second of capacity per channel from each base station with a baseline configuration. WiMAX operation is currently active in a number of licensed bands at 2-4 GHz. Unlicensed operation (at significantly lower transmit powers) is also ermitted at the top end of the 5 GHz band. In the licensed case, reliable non-line-of-sight (NLoS) operation can be achieved to mobile users over a number of kilometres. Within the standard, multiple FFT sizes are specified {128, 512, 1024 & 2048}and this facilitates scalable channel bandwidths from 1.25 MHz to 20 MHz[2][4]. The performance of mobile WiMAX has been widely evaluated in The 802. 16 standard that supports a number of advanced physical layer techniques, such as adaptive modulation and coding (AMC), multiple-input multiple-output (MIMO) transmission modes and scalable orthogonal frequency division multiple access[5][6] (SOFDMA). These can be used intelligently to enhance diversity gain and multi-user performance . There are a number of ways to take advantage of multi-user diversity, AMC and flexible resource allocation [4][7].

The basic idea of Adaptive Modulation is to adapt different order modulations allow to send more bits per symbol and thus achieve higher throughputs or better spectral efficiencies. However, it must also be noted that when using a modulation technique such as 64-QAM, better signal-to-noise ratios (SNRs) are needed to overcome any interference and maintain a certain bit error ratio (BER). The use of adaptive modulation allows a wireless system to choose the highest order modulation depending on the channel conditions. We can see a general estimate of the channel conditions needed for different modulation techniques. As the range increase, modulation step down to lower modulations (in other words, BPSK), but as you are closer you can utilize higher order modulations like QAM for increased throughput. In addition, adaptive modulation allows the system to overcome fading and other interference. [8]

The rest of the paper is organized as follows: Section 2 explain system model. Section 3 describes coding results. Finally, conclusion and future work are presented in section 4.

II. SYSTEM DESCRIPTION

In our system we investigated the behaviour of adaptive modulation technique of WiMAX network. The adaptive modulation used following modulation techniques for modulating and demodulating the signal:

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

Based on these modulation techniques the following parameters were investigated.

- Bit Error Rate (BER)
- Signal to Noise Ratio (SNR)

In this model noise is characterised as Gaussian and two types of channels (AWGN and Rayleigh) are used. Besides of this, we used cyclic prefix to evaluate the performance of the channel on the basis of BER Vs SNR. There are two types of model that were used in the system. The first model is a

OFDM Based AWGN Channel model while the other comprises Rayleigh Channel model both are having Cyclic prefix (CP) blocks. In this coding we use BPSK, QPSK, 16-QAM and 64-QAM modulation techniques. The Cyclic Prefix is used to reduce the effect of fading in the channel and improve the performance of the channel and also improve Bit Error Rate. Cyclic prefix acts as a buffer region where delayed information from the previous symbols can get stored. Transmission of cyclic prefix reduces the data rate, the system designers will want to minimize the cyclic prefix duration. Typically, cyclic prefix duration is determined by the expected duration of the multipath channel in the operating environment. In the simulation model data is modulated and then Cyclic Prefix is added to it to reduce the effect of fading and to give sufficient time to the receiver for storage of signal. In this model two types of channels[9-14] (AWGN and RAYLEIGH) are considered and Gaussian noise is used in simulation. In receiver side cyclic prefix is removed and after demodulation we compare transmitted data and demodulated data to calculate Bit Error Rate.

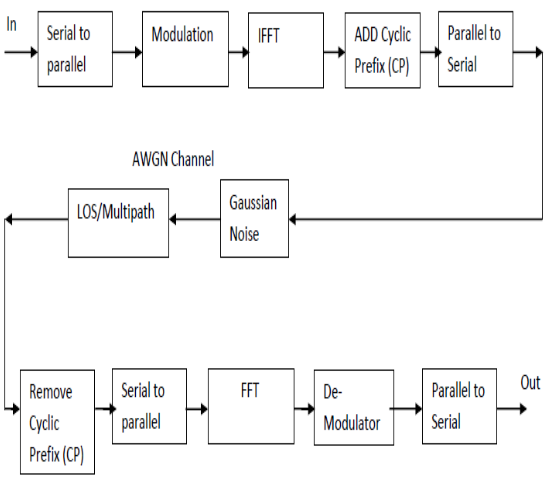

Figure 1. OFDM transmitter with Cyclic Prefix using AWGN channel.

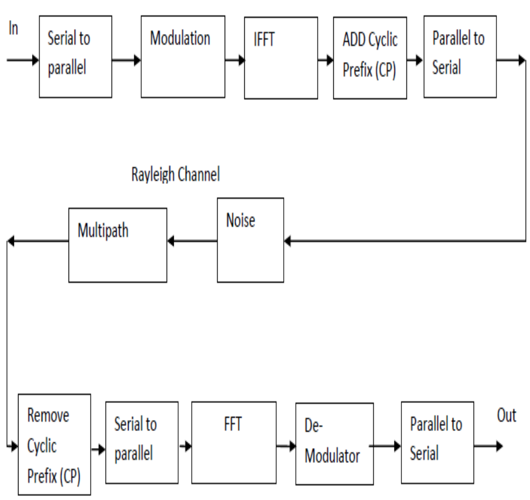

Figure 2. OFDM transmitter with Cyclic Prefix using Rayleigh channel

III. RESULTS AND DISCUSSION

In this section, we have presented various BER vs. SNR plots for all the essential modulations in the standard on different channel models. Figure 3 and 4 display the performance on Additive White Gaussian Noise (AWGN) and Rayleigh channel models respectively. The simulation result based on the adaptive modulation technique for BER calculation was observed in this section. The adaptive modulation techniques used in the WiMAX network are BPSK, QPSK, 16-QAM, 64-QAM respectively. We use all modulation techniques in order to get the results on different models. OFDM with Adaptive Modulation Techniques in AWGN. The initial results observed in the AWGN channel condition using adaptive modulation techniques and compared the performance of these techniques while using the 256 multicarrier OFDM waves. In the figure-3 we compare different modulation techniques with different values of Cyclic Prefix. We choose the most suitable values of Cyclic Prefix that give good results of Bit Error rate. The Bit Error Rate with high Cyclic Prefix are very good but as we increase the Cyclic Prefix the data rate decreased so we can say Cyclic Prefix and data rate are inversely proportional to each other. So it is difficult choose the suitable value of Cyclic Prefix.

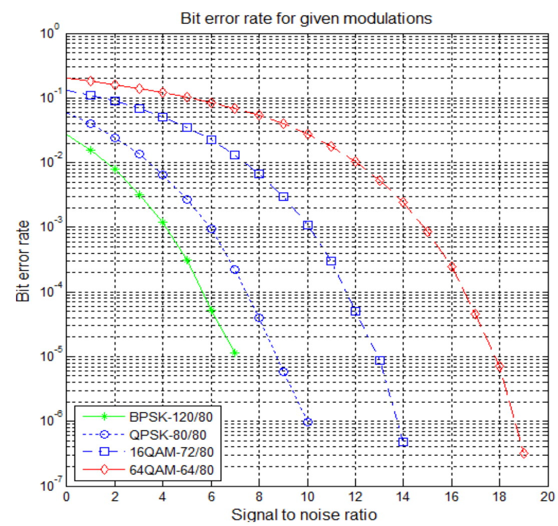

Figure 3. Adaptive Modulation Techniques in AWGN channel with Cyclic Prefix (CP)

The table-1 as follows shows the values of the given graph of figure-3 in WiMAX under AWGN channel. These are the values of the system with various cyclic prefix.

Table-1. WiMAX system under AWGN channel with various cyclic prefix values.

BPSK 120/80	QPSK-80/80	16QAM-72/80	64QAM-64/80
0.0269	0.0581	0.1309	0.2016
0.0155	0.0394	0.1094	0.1796
0.0079	0.0241	0.0886	0.1582
0.0032	0.0134	0.0686	0.1387
0.0012	0.0065	0.0509	0.1199
3.0577E-4	0.0027	0.0354	0.102
5.1923E-5	9.3077E-4	0.0226	0.085
1.1538E-5	2.1827E-4	0.0131	0.0688
0	4.0385E-5	0.0068	0.0535

0	5.7692E-6	0.003	0.0395
0	9.6154E-7	0.0011	0.0273
0	0	3.0288E-4	0.0176
0	0	5.0481E-5	0.0102
0	0	8.6538E-6	0.0053
0	0	4.8077E-7	0.0024
0	0	0	8.4199E-4
0	0	0	2.4583E-4
0	0	0	4.5513E-5
0	0	0	7.0513E-6
0	0	0	3.2051E-7

There is another model which consists on Rayleigh Fading Channel with the addition of Cyclic Prefix (CP) at the transmitter as well as receiver end. Figure-4 we show the effect of CP on WiMAX network under Rayleigh fading channel. We investigate the effects of CP while using adaptive modulation techniques and compared the performance of OFDM symbols in terms of BER and SNR. In Rayleigh channel BPSK and QPSK both give the good results at lower SNR but 16-QAM and 64-QAM give results at higher SNR. The distance in which we can use 16-QAM and 64-QAM is lesser in Rayleigh channel than the distance calculated in AWGN channel. The graph shows that lower order modulation is less effected than the higher order modulation even by using CP.

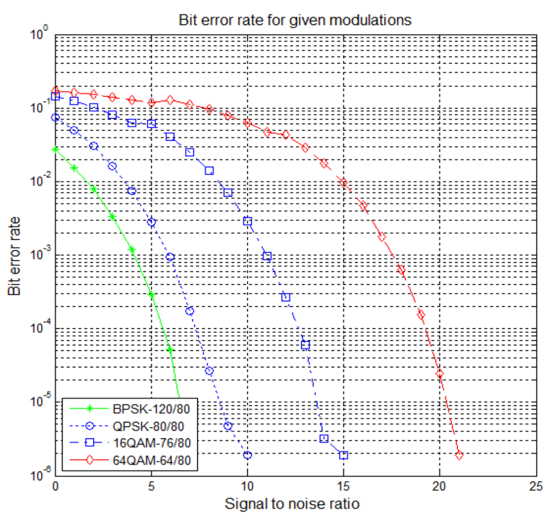

Figure 4.Adaptive Modulation Techniques in Rayleigh Channel with Cyclic Prefix (CP)

The table-2 shows the values of the given graph of figure-4 in WiMAX under Rayleigh channel. These are the values of the system with various cyclic prefix.

Table-2. WiMAX system under Rayleigh channel with various cyclic prefix values.

BPSK-120/80	**QPSK-80/80**	**16QAM-76/80**	**64QAM-64/80**
0.0153	0.0502	0.123	0.1604
0.0079	0.0304	0.102	0.1508
0.0033	0.0163	0.0816	0.1406
BPSK-120/80	**QPSK-80/80**	**16QAM-76/80**	**64QAM-64/80**
0.0012	0.0075	0.0625	0.13
2.8846E-4	0.0028	0.0605	0.1188
5.1923E-5	9.3077E-4	0.041	0.1277
1.9231E-6	1.7115E-4	0.0252	0.1119
0	2.6923E-5	0.0141	0.0951
0	4.8077E-6	0.007	0.0784
0	1.9231E-6	0.0029	0.0625
0	0	9.6667E-4	0.0476
0	0	2.6346E-4	0.0426
0	0	5.9615E-5	0.0285
0	0	3.2051E-6	0.0176
0	0	1.9231E-6	0.0176
0	0	0	0.0096
0	0	0	0.0047
0	0	0	0.0018
0	0	0	6.3173E-4
0	0	0	1.5288E-4
0	0	0	2.4519E-5
0	0	0	1.9231E-6

We study the Bit Error Rate with different CP and analyze the effect of that on Bit Error rate with AWGN and Rayleigh channel. The Bit Error Rate under BPSK modulation technique is smaller than that of other modulation techniques under AWGN and Rayleigh channel. Table-3 gives the best suited values for adaptive modulation and also gives the idea of adaptive cyclic prefix.

Table-3. CP values for different modulations under AWGN and Rayleigh channel

Sr. No.	**Modulation Type**	**Channel Type**	**Cyclic Prefix**
1.	BPSK	AWGN	120/80
2.	QPSK	AWGN	80/80
3.	16-QAM	AWGN	72/80
4.	64-QAM	AWGN	64/80
5.	BPSK	Rayleigh	120/80
6.	QPSK	Rayleigh	80/80
7.	16-QAM	Rayleigh	76/80
8.	64-QAM	Rayleigh	64/80

IV. CONCLUSION AND FUTURE WORK

We concluded CP play an important role in WiMAX system. We use various CP values and select suitable for each modulation technique. Actually we give idea for adaptive CP as like the adaptive modulation. CP limits the speed of transmission but we required due to the multipath communication. As the distance increases signal strength decreases and SNR also, so we switch from higher modulation level to lower modulation level. At low SNR fading is more and signal strength is also low. To overcome this problem we choose higher value of CP. Large CP means large time gap between two frames. Large value give extra time receive signal from maximum multipath signals. We also conclude that although large CP reduces data rate but it increases coverage upto low level of SNR. The BER curves were used to compare the performance of different modulation. BPSK modulation technique under different channels provides satisfactory performance among the four considered modulations. We concluded that BPSK is more power efficient and need less bandwidth amongst all other modulation techniques used in an OFDM adaptive modulation. In case of bandwidth utilization the 64-QAM modulation requires higher bandwidth and gives an excellent data rates as compared to others.

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