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PERFORMANCE ENHANCEMENT OF IEEE 802.16E (MOBILE WI-MAX) SYSTEM WITH ADAPTIVE MODULATION AND CODING TECHNIQUES

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ABSTRACT

WI-MAX is an efficient technology which offers high speed voice, video and data services based on OFDM based adaptive physical layer. WI-MAX is introduced by the institute of electrical and electronics engineers (IEEE) which is used in fixed and mobile wireless applications. This standard only deals with MAC and PHY layer specification of network architecture. This research has already been done on performance analysis of physical layer of WI-MAX system with the help of different modulation techniques such as BPSK, QPSK and QAM. In this thesis work, the performance of WI-MAX system has been analyzed with the help of BPSK, QPSK, QAM-8, QAM-16, QAM-64, QAM-256 and an adaptive modulation and coding scheme (AMC) modulation techniques to find out the best performance of physical layer for 802.16e WI-MAX. The MATLAB simulation has been observed based on performance of different modulation techniques using Bit Error Rate (BER), Signal to Noise Ration (SNR) and Spectral Efficiency as performance parameters. This research proposes that the higher modulation coding techniques such as QAM-256 provides better performance with highest SNR near the base station but as range increases, the lower modulation coding techniques such as BPSK can be adjusted to perform better with lowest SNR using Adaptive modulation coding.

KEYWORDS: WI-MAX, OFDM, IEEE 802.16e, AMC, BER, SNR

INTRODUCTION

WI-MAX stands for "Worldwide Interoperability for Microwave Access". It is a new wireless OFDM-based technology, provides high quality broadband services long distances.

- It is based on IEEE.802.16 wireless (Metropolitan Area Network) MAN air interface standard to fixed, portable and mobile users.
- The WI-MAX standard air interface includes the definition of both the medium access control (MAC) and the physical (PHY) layers for the subscriber station and base station.
- WI-MAX promises to combine high data rate services with wide area coverage (in frequency range of 10 – 66 GHZ (Line of sight) and 2 -11 GHZ (Non Line of Sight)) and large user densities with a variety of Quality of Service (QoS) requirements.
- It can easily provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed station and 3 to 10 miles (5-15 km) for mobile stations with theoretical data rates between 1.5 and 75 Mbps per channel.

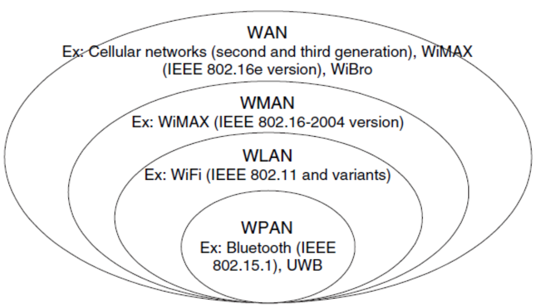

Fig: 1. Classical representation of wireless technologies

The revisions of the IEEE 802.16 standard fall into two categories.

1. **The Fixed WI-MAX:** IEEE 802.16-2004 standard is called the Fixed WI-MAX, provides for a fixed-line connection with an antenna mounted on a rooftop, like a TV antenna. This Fixed WI-MAX operates in the 2.5 GHZ and 3.5 GHZ frequency bands.
2. **The Mobile WI-MAX:** IEEE 802.16e is called the Mobile WI-MAX, allows mobile client machines to be connected to the Internet. It includes the following features:

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- Network Architecture - Portable, Mobile.
- PHY Technology - OFDMA 128, 512, 1024, 2048.
- Duplexing Format - TDD, FDD, HD-FDD.
- Modulation - 64QAM, 16QAM, QPSK, and BPSK.
- Channel Size - 1.25 - 14 MHZ.

METHODOLOGY

Simulation model is used to investigate the PHY layer performance of IEEE 802.16e WI-MAX using physical layer setup.

Physical Layer Setup

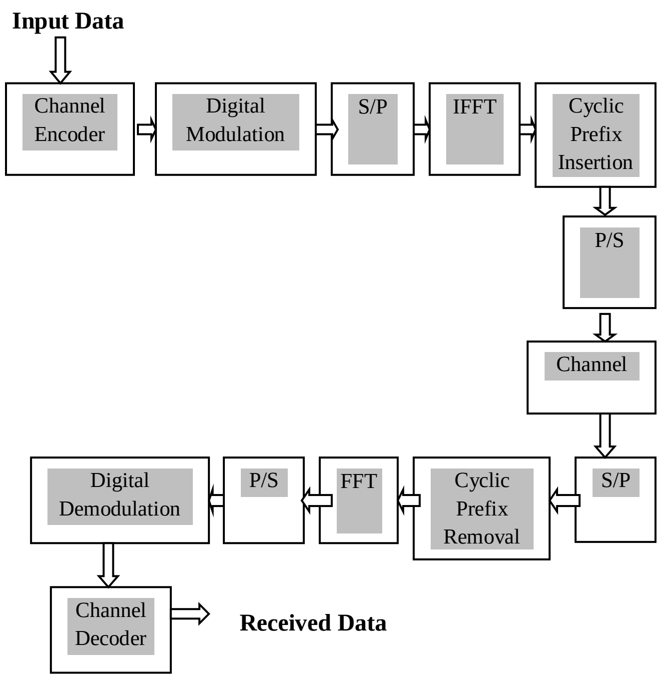

Fig: 2. Simulation Setup

The structure of the baseband part of the implemented transmitter and receiver is shown in Figure 2. In this set up, Channel coding part is composed of three steps- randomization, Forward Error Correction (FEC) and interleaving. FEC is worked in two phases using the outer Reed-Solomon (RS) and inner Convolutional Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver side.

Channel Encoder: In order to meet the BER requirements under moderate C/N conditions, channel coding is mandatory. There are two main types of coding schemes: block coding and convolutional coding. Block coding operates on finite length blocks and convolutional code works often in a continuous manner. A combination of these is proposed for the down link. Reed-Solomon forward error code is proposed as the outer code owing to its excellent distance properties. Channel coding involves three steps:

1) Randomization
2) Forward Error Correction (FEC)
3) Interleaving

They are applied in this order at transmission. The inverse operations then performed, in the reverse order, at the receiver side.

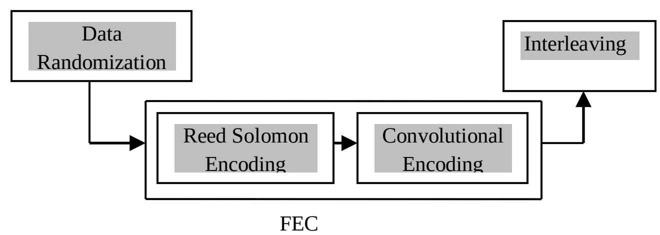

Fig: 3. Channel Encoding Setup

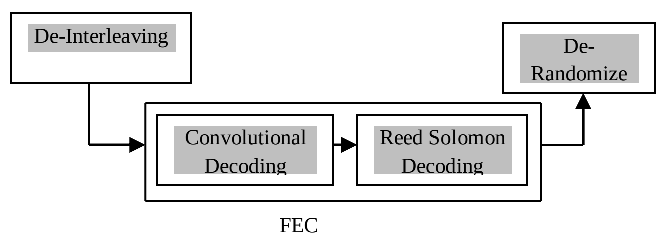

Fig: 4. Channel Decoding Setup

1) Randomization: Randomization is done to avoid long sequences of consecutive ones or consecutives zeros. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF (1 only) is added to the end of the transmission block, for the unused integer bytes. The pseudorandom Binary Sequence (PBRS) generator used for randomization.

2) Forward Error Correction: FEC introduces redundancy in the data before it is transmitted. The redundant data (check symbols) are transmitted with the original data to the receiver. There are three methods of channel coding specified by OFDM PHY:

1) Reed Solomon concatenated with Convolutional Coding(RS-CC)
2) Block Turbo Codes(BTCs)
3) Convolutional Turbo Codes(CTCs)
4) Puncturing Process

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1) **Reed Solomon concatenated with Convolutional Coding:** The Reed-Solomon encoding is derived from a systematic RS (N ¼ 255, K ¼ 239, T ¼ 8) code using GF(28), where N is the number of overall bytes after encoding, K is the no. of data bytes before encoding and T is the number of data bytes which can be corrected. This code is then shortened and punctured to enable variable block sizes and variable error-correction capability. The code after this is reduced to K data bytes. Then, add 239-K' zero bytes as a prefix. After encoding abondon these 239-K' zero bytes. When a codeword is punctured to permit T' bytes to be revised, only the first 2T' of the total 16 parity bytes is employed.
2) **Block Turbo Codes:** In IEEE 802.16, for OFDM PHY, the BTC is based on the product of two simple component codes, which are binary expanded Hamming codes or parity check codes. It should be also noted that the codes are not the same for the two PHYs. Data bit ordering for the composite BTC matrix is defined such that the first bit in the first row is the LSB (Least Significant Byte) and the last data bit in the last data row is the MSB.
3) **Convolutional Turbo Codes:** The outer RS encoded block is fed to inner binary Convolutional encoder. Convolutional codes are used to correct the random errors in the data transmission. A convolution code is a type of FEC code that is specified by CC (m, n, k), in which each m-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n m) and the transformation is a function of the last k information signs, where k is the constraint length of the code . To encode data, start with k memory registers, each holding I input bit. All memory registers start with a rate of 0. The encoder has n modulo- 2 summers, and n generator polynomials, one for each summer.
4) **Puncturing Process:** Puncturing is the process of systematically deleting bits from the output stream of a low-rate encoder in order to reduce the amount of data to be transferred, thus making a high-rate code. The mechanism of puncturing is applied to generate the variable coding rates needed to provide various error protection levels to the users of the system.

Interleaving: Interleaving is a technique where sequential data words or packets are spread across several transmitted data bursts. It is used to protect the transmission against long sequences of consecutive errors. All encoded data bits are interleaved by a block inter leaver with a block size corresponding to the number of coded bits per the allocated sub channels per OFDM symbol, Ncbps. The inter leaver is defined by a two step permutation. The first confirms that neighbor coded bits are mapped onto non-neighbor subcarriers. The second permutation confirms that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation.

Modulation: After bit interleaving, the data bits are entered serially to the constellation map per. The OFDM PHY mandates BPSK as well as Gray-mapped QPSK, 16-QAM, and 64-QAM as shown in Figure 4.8. The 64-QAM constellation is optional for license-exempt bands. This is to allow use of IEEE 802.11 RF components as they do meet the 64-QAM performance needs of IEEE 802.16 standard.

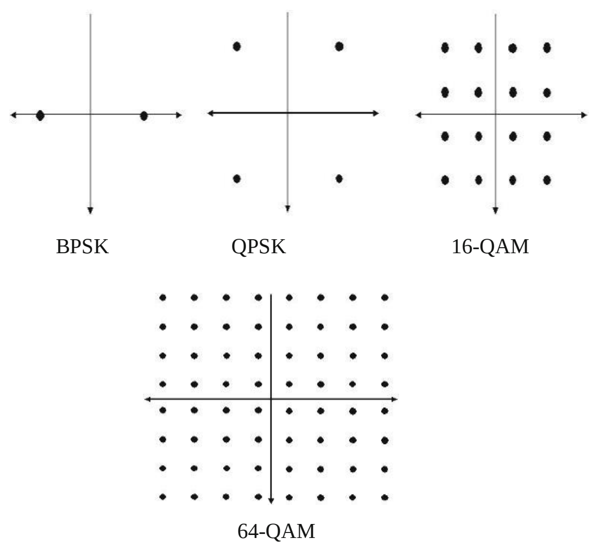

Fig: 5. BPSK, QPSK, 16-QAM, and 64-QAM constellations

Inverse FFT: The OFDM symbol threats the source symbols to perform frequency-domain into time domain. If we select the N number of subcarriers for the system to evaluate the performance of WI-MAX the basic function of IFFT receives the N number of sinusoidal and N symbols at a time.

Cyclic Prefix Insertion: To maintain the frequency orthogonality and reduce the delay due to multipath propagation, cyclic prefix is added in OFDM signals. To do so, before sending the signal, it is summed at the starting of the signal. In wireless transmission the transferred signals might be distort by the effect of

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echo signals due to presence of multipath delay. The ISI is completely deleted by the design when the CP length L is greater than multipath delay.
The receiver blocks are basically the inverse of the sender blocks. At the destination side, a reverse mechanism (including de-interleaving and decoding) is executed to obtain the real data bits. As the de-interleaving mechanism only varies the order of received data, the error probability is flawless. When fleeting through the CC Decoder and the RS-decoder, few errors may be revised, which results in lower error rates.

RESULTS AND DISCUSSION

Physical layer performance results

The objective behind simulating the physical layer in MATLAB™ is to study BER performance under different modulation techniques by using different channel conditions. But, in order to relay on any results from PHY layer simulation we must have some results that can do some validation in terms of general trends.

Table 1 . Performance evaluation using different modulation techniques under AWGN channel at various BER levels

Modulation	BPSK	QPSK	8-QAM	16-QAM	64-QAM	256-QAM
Bits/Symbol	**1**	**2**	**3**	**4**	**6**	**8**
Code Rate	1/2	1/2	1/2	1/2	1/2	1/2
SNR (dB) at BER 10^{-1}	---	3	7	9	15	21
SNR (dB) at BER 10^{-2}	2	5	9	12	18	24
SNR (dB) at BER 10^{-3}	3	7	12	14	20	26
SNR (dB) at BER 10^{-4}	5	9	14	16	22	28

BER Vs SNR Performance combined plot of mobile WI-MAX with different modulation scheme on AWGN channel

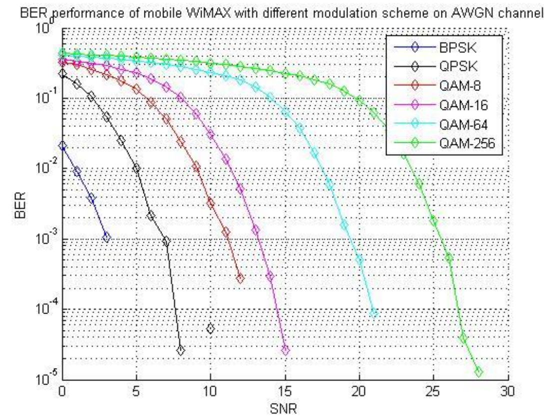

Fig: 6. Plot for theoretical value of BER Vs SNR under AWGN

During all simulations, BPSK has the lowest BER and QAM-256 has the highest BER than other modulation techniques. By using Adaptive modulation coding (AMC), the modulation order and the forward error correction (FEC) schemes are varied by adjusting their code rate to the variations in the communication channel.

Table 2. Performance evaluation on Spectral Efficiency using different modulation techniques under AWGN channel

Modulation	BPSK	QPSK	8-QAM	16-QAM	64-QAM	256-QAM
Bits/Symbol	**1**	**2**	**3**	**4**	**6**	**8**
Code Rate	1/2	½	½	1/2	1/2	1/2
Spectral Efficiency	0.5	1	1.5	2	3	4
SNR (dB)	For all values	From 5 onwards	From 10 onwards	From 12 onwards	From 19 onwards	From 25 onwards

Spectral Efficiency Vs SNR Performance combined plot of mobile WI-MAX with different modulation scheme on AWGN channel

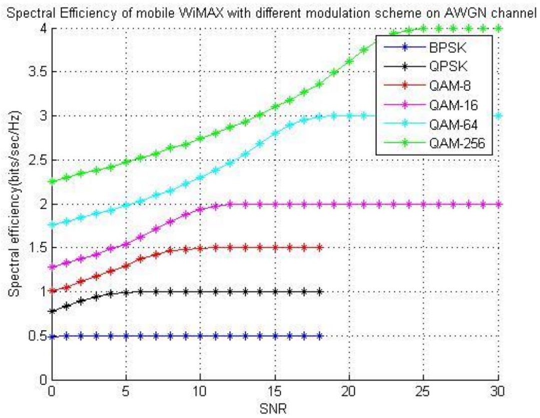

Fig: 7. Plot for theoretical value of Spectral Efficiency Vs SNR under AWGN

It can be seen from these above figures that the higher order modulation scheme such as QAM-256 has high spectral efficiency because of using more information for transmitting over a distance and has strong SNR. The lower order modulation scheme such as BPSK has very less spectral efficiency and poor SNR. It means QAM-256 can be used for transmitting maximum amount of data with the fewest transmission error.

CONCLUSION

In all aspects of adaptive modulation technique, the performance of Mobile WI-MAX can be concluded as follows,

- The higher order modulation scheme such as QAM-256 has strong SNR and the lower order modulation scheme such as BPSK has poor SNR.
- BPSK has the lowest BER and QAM-256 has the highest BER than other modulation techniques.
- In BER plots, By using Adaptive modulation coding (AMC), the higher modulation coding techniques such as QAM-256 has provided better performance with highest SNR near the base station but as range increases, the lower modulation coding techniques such as BPSK can be adjusted to perform better with lowest SNR.
- In Spectral Efficiency plots, QAM-256 can be used for transmitting maximum amount of data with the fewest transmission error.

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