Performance Analysis of Cyclic Redundancy Check(CRC) encoded Fixed WiMAX Wireless Communication System under Implementation of M-ary Quadrature Amplitude Modulation(QAM) Technique

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ABSTRACT

IEEE802.16 known as WiMAX technology is a promised broadband wireless technology that promises high-speed data services up to the costumer end. The aim of this paper is the performance evaluation of Cyclic Redundancy Check (CRC) encoded fixed WiMAX system under different combinations of M-ary quadrature amplitude modulation techniques (QAM, 16-QAM and 64-QAM) and different communication channels AWGN and fading channels (Rayleigh and Rician). It offers both line of sight and non-line of sight wireless communication. In our research work, we investigated the physical layer performance on the basis of bit error rate (BER) and signal to noise ratio (SNR). This research work demonstrates that QAM modulations is better than the 16-QAM and 64-QAM modulations schemes of AWGN channels as it has the lowest bit error rate (BER).

Keywords – **AWGN, CRC, Fixed WiMAX, Fading Channel, M-ary QAM**

I. INTRODUCTION

Worldwide Interoperability for Microwave Access, or WiMAX for short, is a next generation open standard that seeks to serve users' increasing demands for high data throughput (broadband) services such as streaming media on the internet, live video conferencing, and mobile TV on computers as well as handsets and PDAs. WiMAX is expected to be integrated into the next generation mass market consumer devices and to offer something that does not exist today – speeds similar to cable and metropolitan area coverage while on the move, all for a much lower cost than we are used to today. WiMAX already offers broadband services in many emerging and rural markets which are not supported by wireline-based technologies and started its first deployment in developed countries replacing both commonly used Wi-Fi on one hand and traditional cellular standards such as 3G.
WiMAX technology is broadband wireless technology, which transmitted on the line-of-sight (LOS) and non line-of-sight (NLOS) transmission, operating in the 2 GHz to 11 GHz range and 10 GHz to 66 GHz range respectively. Furthermore, WiMAX systems, that support air interfaces access for fixed, nomadic, and mobile wireless communications. The operation is wildly coverage area LOS: 2-5 km and NLOS : 5-50 km [1-3]. IEEE 802.16 is the standard to state the radio frequency of fixed Broadband Wireless Access. WiMAX is the trade name of “IEEE 802.16 Standard”. IEEE 802.16 was first planned offer the last mile for Wireless Metropolitan Area Network (WMAN) with the line of sight (LOS) of 30 – 50 km.

Basically the goal of WIMAX is to provide high speed internet access to home and business subscribers without wires. It supports legacy voice systems, voice over IP, TCP/IP, and Application with different QoS requirements. 802.16 consist of the access point, base station and subscriber station. During a communication, all the information coming from a subscriber station go to the base station and retransmitted back to subscriber station. Base station can handle multiple of subscriber station. Two types of links are defined in this:-
The downlink: From base station to the subscriber station.
The uplink: From subscriber station to the base station. [4] In this paper, we focus on the physical layer of WiMAX system simulating on IEEE802.16 standards, which data transmitted on the transmission channel. The transmission channel component of AWGN**(**Additive white Gaussian Noise) channel and Rician fading channel with concatenated

II. SIMULATION MODEL

The transmitter and receiver sections of the WiMAX Physical layer are shown in the block diagram of Figure-a. In this setup, we have just implemented the mandatory features of the specification, while leaving the implementation of optional features for future work. The channel coding part is composed of coding techniques of the Cyclic Redundancy Check (CRC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. We do not explain each block in details. Here we only give the emphasis on M-ary quadrature amplitude modulation Cyclic Redundancy Check (CRC) coding techniques.

In this section, the WiMAX PHY layer simulation model with Cyclic Redundancy check(CRC) encoded to be implemented has been discussed thoroughly and all related assumptions have been stated clearly and justified. The implemented model needs to be realistic as possible in order to get reliable results. It is ought to be mentioned here that the real communication systems are very much complicated and due to non availability of the algorithms to simulate the performance evaluation of their various sections, generally, simulations are made on the basis of some assumptions to simplify the communication system(s) concerned. It consists of various sections. A brief description of the simulated model is given below [5]

The block diagram of the simulated system model is shown in Figure-a. The synthetically generated input binary bit stream is ensured against transmission errors with a Cyclic Redundancy Check (CRC). In CRC channel coding scheme, a Cyclic Redundancy Check (CRC) is applied to the input binary data. The Cyclic Redundancy Check (CRC) encoded bits are prior to convert into each of the either complex digital modulation symbols in QAM, 16-QAM, 64-QAM modulations and fed to an OFDM modulator for transmission. The simulated coding and modulation schemes used in the present study are shown in Table-1.In OFDM modulator, the digitally modulated information symbols are transmitted in parallel on sub carriers through implementation as an inverse First Fourier transform (IFFT) on a block of information symbols followed by an analog-to-digital converter (ADC). To mitigate the effects of inter-symbol interference (ISI) caused by channel time spread, each block of IFFT coefficients is typically preceded by a cyclic prefix. At the receiver side, the received signal is OFDM demodulated, de-mapped, and then decoded in order to recover the data transmitted.

The default use of the Cyclic Redundancy Check (CRC) component is to compute CRC from a serial bit stream of any length. The input data is sampled on the rising edge of the data clock. A cyclic redundancy check (CRC) is an error-detecting code commonly used in digital networks and storage devices to detect accidental changes to raw data. Blocks of data entering these systems get a short check value attached, based on the remainder of a polynomial division of their contents; on retrieval the calculation is repeated, and corrective action can be taken against presumed data corruption if the check values do not match. CRCs are based on the theory of cyclic error-correcting codes. The use of systematic cyclic codes, which encode messages by adding a fixed-length check value, for the purpose of error detection in communication networks. Cyclic codes are not only simple to implement but have the benefit of being particularly well suited for the detection of burst errors, contiguous sequences of erroneous data symbols in messages. This is important because burst errors are common transmission errors in many communication channels, including magnetic and optical storage devices. Typically an n-bit CRC applied to a data block of arbitrary length will detect any single error burst not longer than n bits and will detect a fraction $1-2^{-n}$ of all longer error bursts.[6] Specification of a CRC code requires definition of a so-called generator polynomial. This polynomial resembles the divisor in a polynomial long division, which takes the message as the dividend and in which the quotient is discarded and the remainder becomes the result, with the important distinction that the polynomial coefficients are calculated according to the carry-less arithmetic of a finite field. The length of the remainder is always less than the length of the generator polynomial, which therefore determines how long the result can be. In practice, all commonly used CRCs employ the finite field GF(2). This is the field of two elements, usually called 0 and 1, comfortably matching computer architecture. The rest of this article will discuss only these binary CRCs, but the principles are more general. The simplest error-detection system, the parity bit, is in fact a trivial 1-bit CRC: it uses the generator polynomial x+1. A CRC-enabled device calculates a short, fixed-length binary sequence,known as the check value or improperly the CRC, for each block of data to be sent or stored and appends it to the data, forming a codeword. When a codeword is received or read, the device either compares its check value with one freshly calculated from the data block, or equivalently, performs a CRC on the whole codeword and compares the resulting check value with an expected residue constant. If the check values do not match, then the block contains a data error. The device may take corrective action, such as rereading the block or requesting that it be sent again. Otherwise, the data is assumed to be error-free (though, with some small probability, it may contain undetected errors; this is the fundamental nature of error-checking). The CRC value is reset to 0 before starting or can optionally be seeded with an initial value. On completion of the bit stream, the computed CRC value may be read out.[7] Cyclic redundancy codes add bits to the end of a message transaction for the purpose of error detection. The message information is divided by a generator polynomial. The remainder is then appended to the message and transmitted. The receiver divides the message and remainder by the same generator polynomial. If no errors have occurred, the remainder is zero. The process is as follows:

1. The original message polynomial is shifted to the left by the order of the generator polynomial
2. The shifted message is divided by the generator polynomial, producing a remainder
3. The remainder is appended to the message and transmitted.
4. The receiver divides the transmitted message by the generator polynomial
5. If a remainder occurs, the message is deemed in error and retransmission is requested
6. If no remainder exists, the message is shifted to the right by the order of the generator polynomial

In the case of QAM (quadrature amplitude modulation), a finite number of at least two phases, and at least two amplitudes are used. QAM is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (*modulating*) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components — hence the name of the scheme. In the case of QAM, the amplitude of two waves, 90 degrees out-of-phase with each other

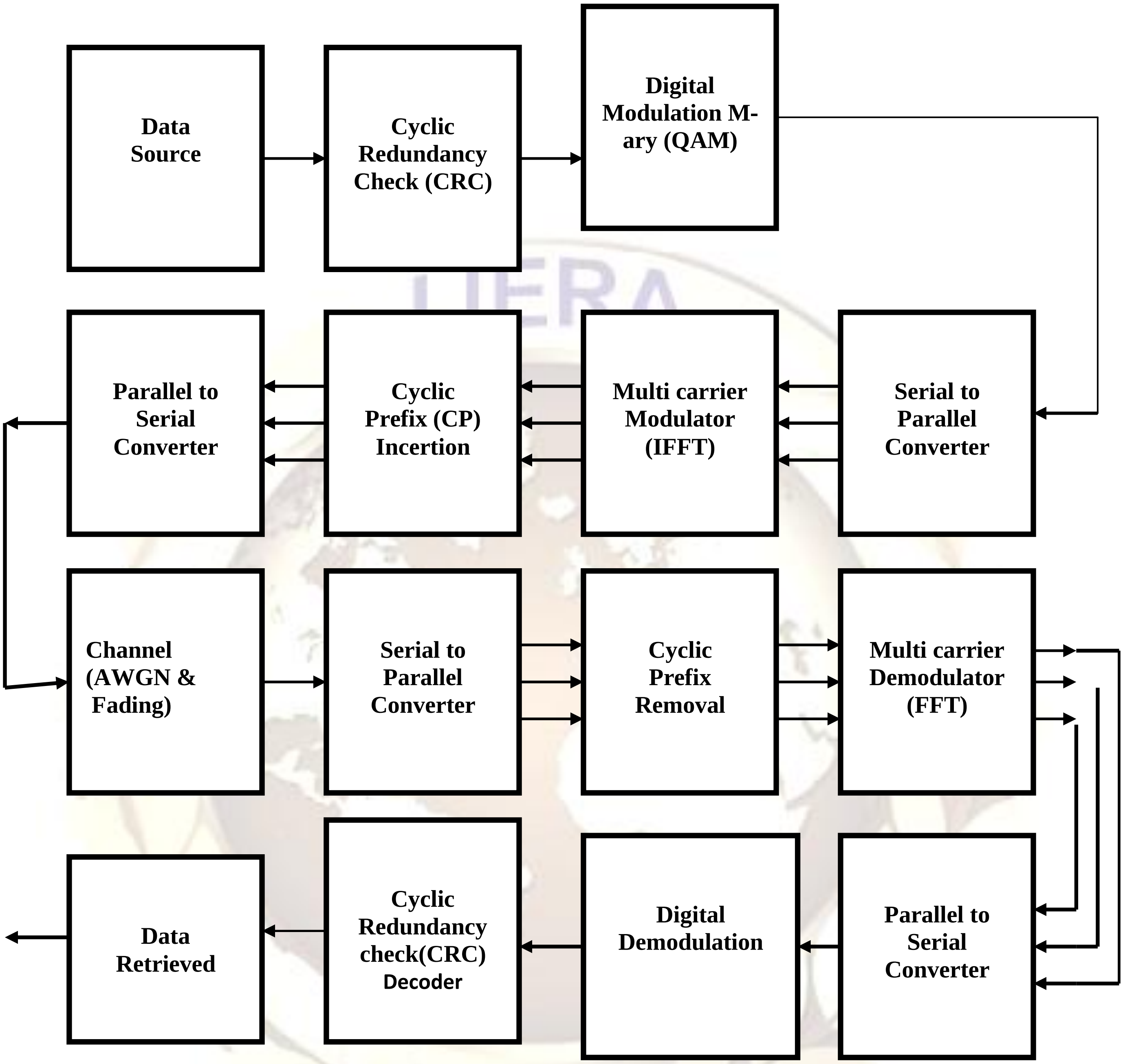

Figure-a: A block diagram of Cyclic Redundancy Check (CRC) encoded WiMAX communication system (in quadrature) are changed (modulated or keyed) to represent the data signalMany modern fixed microwave communication systems are based on quadrature amplitude modulation (QAM). These systems have various levels of complexity. Even though QPSK uses no state changes in amplitude, it is sometimes referred to as 4-QAM. When four levels of amplitude are combined with the four levels of phase, we get 16-QAM. In 16 QAM, 2 bits are encoded on phase changes, and 2 bits are encoded on amplitude changes, yielding a total of 4 bits per symbol. The general form of an M-ary QAM signal can be defined as

$$S_i(t) = \sqrt{\frac{2E_{min}}{T_s}}\, a_i \cos(2\pi f_c t) + \sqrt{\frac{2E_{min}}{T_s}}\, b_i \sin(2\pi f_c t)$$

$0 \le t \le T$;   i 1,2,….M   (i)

Where E_{min} is the energy of the signal with the lowest amplitude, a and b are a pair of independent integers chosen according to the location of the particular signal point. It is to be noted here that M-ary QAM does not have constant energy per symbol, nor does it have constant distance between possible symbol states. It reasons that particular values of (t) will be detected with higher probability than others.

If rectangular pulse shapes are assumed, the signal $S_i(t)$ may be expanded in of pair of basis functions defined as

$$\phi_1(t) = \sqrt{\frac{2}{T_s}} \cos(2\pi f_c t) \quad 0 \le t \le T_s \qquad \text{(ii)}$$

$$\phi_2(t) = \sqrt{\frac{2}{T_s}} \sin(2\pi f_c t) \quad 0 \le t \le T_s \qquad \text{(iii)}$$

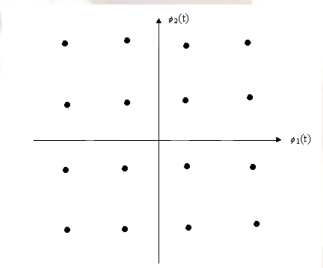

Figure-b: Constellation diagram of an M-ary QAM (M=16) signal set [8].

The co-ordinate of the i th message point are $a_i\sqrt{E_{min}}$ and $b_i\sqrt{E_{min}}$ where (a_i, b_i) is an element of the L by L matrix given by

$$\{a_i, b_i\} = \begin{bmatrix} (-L+1, L-1) & (-L+3, L-1) & \ldots (L-1, L-1) \\ (-L+1, L-3) & (-L+3, L-3) & \ldots (L-1, L-3) \\ . & . & . \\ . & . & . \\ (-L+1, -L+1) & (-L+3, -L+1) & (L-1, -L+1) \end{bmatrix} \qquad \text{(iv)}$$

Where $L = \sqrt{M}$. For a 16-QAM with signal constellation as shown in figure 3, the L by L matrix is

$$\{a_i, b_i\} = \begin{bmatrix} (-3,3) & (-1,3) & (1,3) & (3,3) \\ (-3,1) & (-1,1) & (1,1) & (3,1) \\ (-3,-1) & (-1,-1) & (1,-1) & (3,-1) \\ (-3,-3) & (-1,-3) & (1,-3) & (3,-3) \end{bmatrix} \qquad \text{(v)}$$

Table-1: Summary of Model Parameters

Parameters	values
Number Of Bits	44000
Number Of Subscribers	200
FFT Size	256
CP	1/4
Coding	Cyclic Redundancy Check (CRC)
Code rate	2/3
Constraint length	7
K-factor	3
Maximum Doppler shift	100/40Hz
SNR	0-20
Modulation	QAM, 16-QAM, 64-QAM
Noise Channels	AWGN, Rayleigh and Rician

At the receiving section we have just reversed the procedures that we have performed at the transmission section. After ensuring that the WiMAX PHY layer simulator is working properly we started to evaluate the performance of our developed system. For this purpose we have varied encoding techniques and digital modulation schemes under AWGN and frequency-flat fading (Rayleigh/ Rician) channels. Bit Error Rate (BER) calculation against different Signal-to-Noise ratio (SNR) was adopted to evaluate the performance.

III. SIMULATION RESULT

This section presents and discusses all of the results obtained by the computer simulation program written in Matlab following the analytical approach of a wireless communication system considering AWGN, Rayleigh Fading and Rician Fading channel. A test case is considered with the synthetically generated data. The results are represented in terms of signal to noise ratio (SNR) and the bit error rate (BER) for practical values of system parameters.

From figure-c we can see that, the bit error rate(BER) performance of QAM modulation scheme has lower than 16-QAM and 64-QAM modulation scheme under the AWGN channel. For an example, while using the, for SNR value 13dB, BER for QAM modulation remains 0, where BER for 16-QAM and 64-QAM modulation remains 0.00256 and 0.00519 respectively. After SNR value 13dB, BER for QAM remains zero for the rest of the SNR values. But 16-QAM and 64-QAM modulation has more non-zero BER values than that of QAM modulation.

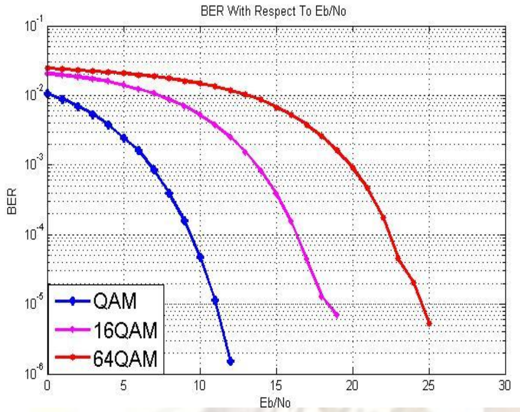

Figure-c: BER simulation of an Cyclic Redundancy Check (CRC) encoded in QAM,16-QAM and 64-QAM modulation schemes in an AWGN channel

From figure-d we can see that, the bit error rate (BER) performance of QAM modulation scheme has lower than 16-QAM and 64-QAM modulation scheme under the Rayleigh fading channel. For an example, while using the, for SNR value 15dB, BER for QAM modulation remains 0, where BER for 16-QAM and 64-QAM modulation remains 0.00311 and 0.01218 respectively. After SNR value 15dB, BER for QAM remains zero for the rest of the SNR values. But 16-QAM and 64-QAM modulation has more non-zero BER values than that of QAM modulation.

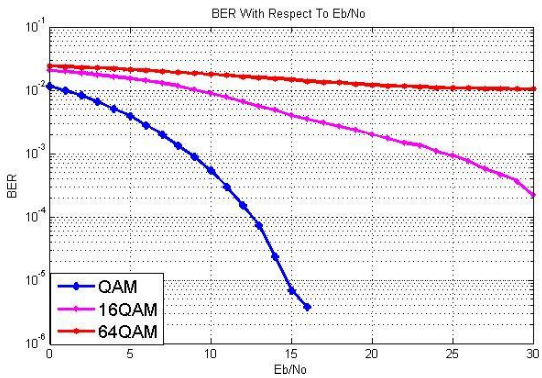

Figure-d: BER simulation of an Cyclic Redundancy Check (CRC) encoded in QAM,16-QAM and 64-QAM modulation schemes in an Rayleigh channel

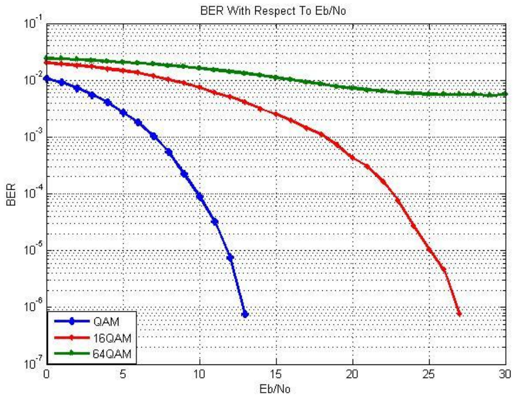

Figure-e: BER simulation of an Cyclic Redundancy Check (CRC) encoded in QAM,16-QAM and 64-QAM modulation schemes in an Rician channel.

From figure-e we can see that, the bit error rate(BER) performance of QAM modulation scheme has lower than 16-QAM and 64-QAM modulation scheme under the Rician fading channels channel. For an example, while using the, for SNR value 19dB, BER for QAM modulation remains 0, where BER for 16-QAM and 64-QAM modulation remains 0.00262 and 0.01289 respectively. After SNR value 19dB, BER for QAM remains zero for the rest of the SNR values. But 16-QAM and 64-QAM modulation has more non-zero BER values than that of QAM modulation.

IV. CONCLUSION

In this research work, it has been studied the performance of an OFDM based wireless WiMAX communication system adopting the Cyclic Redundancy Check (CRC) channel coding and different digital modulation schemes. A range of system performance results highlights the impact of digital modulations under Cyclic Redundancy Check (CRC) coding in AWGN and fading channels (Rayleigh and Rician).

The research work focuses on the performance investigation by BER against Eb/No of coded and uncoded WiMAX system under AWGN, Rayleigh and Rician fading channels using different digital modulations namely QAM ,16-QAM and 64-QAM. The BER values are always in between 0 to 0.02433. The BER curves were used to compare the performance of different modulation techniques and coding scheme. The effects of the Cyclic Redundancy Check (CRC) coding and different communication channels were also evaluated in the form of BER. The effects of the Cyclic Redundancy Check (CRC) coding were also evaluated in the form of BER and we conclude that the performance three modulation order are better performance to given that QAM modulation with respect to 16-QAM and 64-QAM modulation schemes.

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