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Bit Error Rate analysis of efficient wireless channels in WiMAX for an image transmission using concatenated RS-LDPC coding techniques

Rekha S M[1], Manoj P B[2]

M.tech, IV Semester, DEC, AMC Engineering College, Bangalore, India [1]

Associate Prof, Dept. Electronics & Communication, AMCEC, Bangalore, India [2]

Abstract: Wireless technologies offer significant benefits over wired, such as including low installation cost, rapid deployment, and mobility and so on. Wireless technologies are suitable for remote end applications. It is a challenging task to successfully transmit an image to the receiver with a very low bit error rate (BER) because of the presence of the noise in wireless channels. According to the user needs such as requirement of smaller bandwidth, high data rates, the wireless communication has undergone through the significant developments. In order to overcome the limitations of current technologies such as the presence of Inter Symbol Interference (ISI), multipath fading, availability of scarce resources, use of more efficient wireless systems is necessary. WiMAX is the most promising and upcoming 4G wireless transmission technologies that fulfil the user needs. Application of concatenated Reed Solomon-Low density Parity Check (RS-LDPC) codes with the WiMAX system ensures the reliability and efficiency of the system. This paper analyses the WiMAX system performance under various channel scenarios (Additive White Gaussian Noise (AWGN), Rayleigh and Rician fading channels) by applying concatenated RS-LDPC coding technique. The performance is evaluated by calculating the BER for different values of Signal to Noise Ratio (SNR).

Keywords: BER, WiMAX, RS, LDPC, concatenated code

I. INTRODUCTION

Since the final decades of 20th century, the need of wireless transmission has grown tremendously with a high speed wireless data access i.e. in Mbps with fewer errors to a very long distance. WiMAX is a future 4G wireless data transmission technique covers a data range up to 50km, and provides a data rate of 70Mbps. WiMAX is an IEEE 802.16 standard based technology responsible for bringing the broadband wireless access to the world as an alternative to wired broadband. Non line of sight communication is also possible in WiMAX. WiMAX requires employing forward Error correction (FEC) methods on the data transferred in order to avoid the burst errors that occur in the PHYsical channel. The FEC codes used in this paper are RS and LDPC. These codes can be applied independently or they can be concatenated together to provide a more efficient system with minimum BER. RS and LDPC codes have the capability to reach the Shanon channel capacity. In order to eliminate the Inter Symbol Interference (ISI) in the channel, an efficient technique known as Orthogonal Frequency Division Multiplexing (OFDM) has been used, thus by increasing the bandwidth efficiency. This paper presents the performance evaluation of the WiMAX under the different efficient wireless channels along with concatenated RS-LDPC coding technique using the samples of real time image and speech transmission in terms of BER in the physical layer of WiMAX system using MATLAB.

II. METHODOLOGY

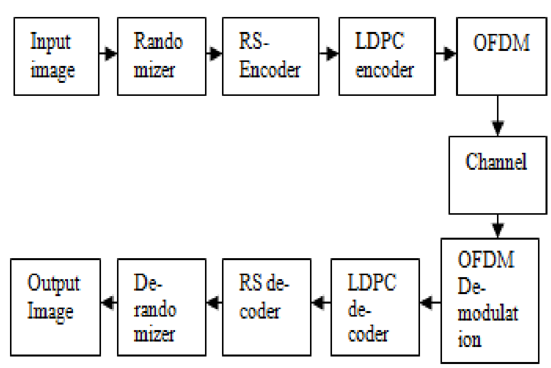

Fig. 1 Block diagram of WiMAX system with concatenated RS-LDPC coding technique. Channel may be AWGN, Rayleigh, Rician fading channel.

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The Fig. 1 shows the block diagram of the complete WiMAX system with concatenated RS-LDPC coding technique. The channel can be modelled as an AWGN or Rayleigh or Rician. First the channel is modelled as AWGN channel for the practical channel conditions like high quality long distance communication channel. A 128X128 image is taken as input and applied to the randomizer. The randomization introduces the protection through the information theoretic uncertainty. The output of the randomizer is applied to the encoder part. The encoder of the WiMAX system is the combination of Reed-Solomon (RS) code as an outer code and LDPC code as an inner code. The encoded baseband data is modulated by means of QAM which is applied for OFDM process as the physical layer of WiMAX system is made up of OFDM. In OFDM process, the in phase and quadrature phase components of the symbols will undergo through the process of IFFT so that requirement of effective bandwidth can be made approximately half without any inter symbol interference. At first the channel is modelled as an AWGN channel, which is considered to be suitable for long distance communication. This is the simplest type of channel that is having the noise distribution with a constant power spectral density with Gaussian nature of PDF over the whole channel bandwidth. [1] In urban areas where the availability of line of sight path is very difficult, fading comes into picture. At that time AWGN channel can be replaced by Rayleigh channel to model the system. In metropolitan areas where there would be a possibility of having at least one line of sight path along with multipath structure, the wireless channel can be modelled as the Rician channel. Here the multipath variations of the signals are superimposed over the line of sight component which increases the overall strength of the whole information at the receiver.

III. IEEE 802.16/ WiMAX TECHNOLOGY

WiMAX is wireless broadband solution based on the IEEE 802.16 standard. WiMAX offers rich features with a lot of flexibility in terms of deployment options and potential service offerings. Some of the salient features of WiMAX are:

- The physical layer is based on OFDM, which offers a good resistance to multipath, and allows WiMAX to operate in NLOS conditions.
- WiMAX supports a very high data rate up to 70Mbps.
- WiMAX has a scalable physical layer architecture that allows for the data rate to scale easily witha available channel bandwidth.
- WiMAX supports a number of modulations and forward error correction (FEC) coding schemes.
- Supports for Time Division Multiplexing (TDD) and frequency Division multiplexing (FDD).
- WiMAX is designed to supports a variety of applications, including voice and multimedia services.

IV. FADING CHANNELS

Fading is the result of multipath structure of the signal components, i.e. the signal components take different paths to reach towards the receiver. The actual received signal at the receiver is the vector sum of all the signals. In multipath, some signals add the direct path and some others subtract it. There are two types of fading; a) Large scale fading and b) small scale fading Rayleigh, Rician and AWGN are most widely used fading channels which come under the category of small scale fading.

A. Rayleigh fading channel

The multipath propagation of the signal will cause the Rayleigh fading [3], because of the infrequent availability of the line of sight path in between the transmitter and receiver in urban areas, Rayleigh channel modelling [4] is the best choice to model the WiMAX system.

B. Rician fading channel

In metropolitan areas where there would be a possibility of having at least one line of sight path along with multipath structure, the wireless channel can be modelled as the Rician channel. Here the multipath variations of the signals are superimposed over the line of sight component which increases the overall strength of the whole information at the receiver.

C. Additive White Gaussian Noise (AWGN) channel

For the simulation purpose, the communication medium is considered to be suitable for long distance system wherein average fading is assumed to be constant throughout the path. To characterize the above system, the channel has been modelled as an additive white Gaussian noise (AWGN) channel. This is the simplest type of channel that is having the noise distribution with a constant power spectral density with Gaussian nature of (probability density function) PDF over the whole channel bandwidth. [5]

V. CODING TECHNIQUES

A. Reed Solomon Code

The RS code is one of linear block codes which were proposed in 1960 [6]. Reed–Solomon (RS) codes are cyclic error correcting codes invented by Irving S.Reed and Gustave Solomon. Reed-Solomon codes have found important applications from deep-space communication to consumer electronics. They are prominently used in consumer electronics such as CDs, DVDs, Blue-ray Discs, in data transmission technologies such as DSL & WiMAX. It is vulnerable to the random errors but strong to burst errors [7].

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Hence, it has good performance in fading channel which have more burst errors. The Reed-Solomon code is a [n, k, n-k+1] code, in other words, it is a linear block code of length n with dimension k and minimum Hamming distance n-k+1. The Reed-Solomon code is also called a maximum distance separable code. Reed–Solomon code can correct up to (n − k) / 2 erroneous symbols, i.e., it can correct half as many errors as there are redundant symbols added to the block. For practical uses of Reed–Solomon codes, it is common to use a finite field F with 2^m elements. In this case, each symbol can be represented as an m-bit value. The sender sends the data points as encoded blocks, and the number of symbols in the encoded block is n = 2m− 1. The number k, with k < n, of data symbols in the block is a design parameter. The Reed-Soloman decoder does the following: Compute the syndrome (s1, s2, s3, s4, … , s2t); Determine the error location polynomial σ(X); Determine the error value evaluator; Evaluate the error location number and error values and perform error correction.

B. Low density Parity Check Code (LDPC)

LDPC code is a kind of block codes that exhibit near Shannon limit performance. It was first introduced by Gallager in his thesis in 1960' and rediscovered by D. J. C. Mackay [8]. In this paper we adopt an iterative decoding method introduced by D. J. C. Mackay. Here are some notations in the algorithm: Rj= the set of column locations of 1's in the j^{th} row; Rj\i= the set of column locations of the 1's in the j^{th} row excluding location i; Ci= the set of row locations of the 1's in the i^{th} column; Ci\j= the set of row locations of the 1's in the ith column excluding location j; $r_{ji}(b)$ = the probability of the jth check equation being satisfied given bit c_i= b and the other bits have distribution given by {qij}j'≠j; qij(b) = probability that c_i= b given extrinsic information from all check nodes except the j^{th} node. The algorithm iterates back and forth between {qij} and {rji} using formulas given below.

$$r_{ij}(0) = \frac{1}{2} + \frac{1}{2}\prod_{i' \epsilon v_j \backslash i}(1 - 2q_{i'j}(1))$$

$$r_{ij}(1) = 1 - r_{ij}(0)$$

$$q_{ij}(0) = K_{ij}(1 - P_i)\prod_{j' \in C_i \backslash j} r_{j'i}(0)$$

$$q_{ij}(1) = K_{ij}P_i\prod_{j' \in C_i \backslash j} r_{j'i}(1)$$

In equation shown below Pi is the probability that the i^{th} bit is 1. Q({q_{ij}}) was initialized to P({Pi}) to complete the iteration loop. In 16QAM modulation there is a different method to compute Pi. At first, we compute the received symbol probability conditioned on the transmitted symbol.

$$p(c_i = 1) = \sum_{x:x_i=1} P(y|x)P(x)$$

$$p(y_k|x_k) = \frac{1}{\sqrt{2\pi}\sqrt{No/2}}$$

Where P (Ci=1) is the probability of the i^{th} bit in the symbol x is 1 and P(x) is a priori probability of symbol x for which the i^{th} bit is 1.

V CODE CONCATENATION

Code Concatenation [9] is used to avoid the decoding complexity (and hence cost) of long codes. As the required error probability decreases the length of the code must increase which intern decreases the code rate. In concatenation, two codes are combined together to achieve the performance level of a long code without the corresponding increase in hardware complexity normally expected of a code of that length [10]. Furthermore, by combining two codes with different error-correcting properties, we can hope to address both random and burst error sources simultaneously. Thus in concatenation, the digital signal is subjected to two encoding operations before being transmitted over some channel. The first encoding is usually performed using a non-binary code and the result is then passed to a second encoder which encodes via a binary code. As RS code is strong to both burst errors and random errors, RS code is being widely used in the applications of communication and data storages. Recently, with the intense interests on LDPC codes, a concatenation coding scheme with LDPC codes as inner codes while RS codes as outer codes is accepted [11].

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Number of bits	262144
Number of sub carriers	24480
FFT size	128
CP (cyclic prefix)	22
Modulation	16 QAM
Noise channels	AWGN, Rayleigh, Rician

VI. SIMULATION RESULTS

This section presents the results obtained by the computer simulation program written in MATLAB for AWGN, Rician, Rayleigh fading channels. An image is taken as an input to the WiMAX system to analyse the performance. The bit error rates (BER) for the different values of SNR are recorded for different fading channels.

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TABLE II
SIMULATION RESULTS

SNR	BER (AWGN)	BER (Rayleigh)	BER (Rician)
1	0	0.18562	0.015442
3	0	0.12933	0.0026687
5	0	0.033791	0
7	0	0	0
10	0	0	0
12	0	0	0
15	0	0	0

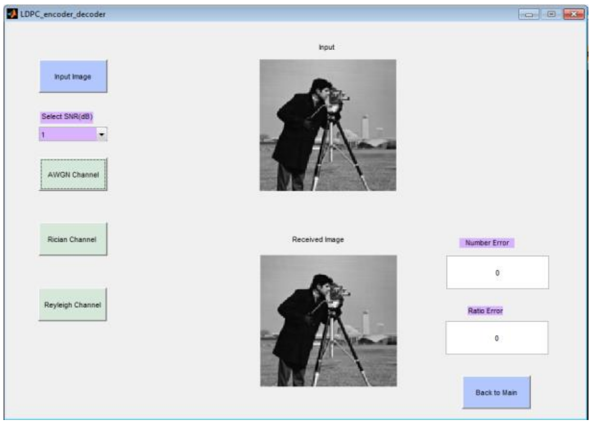
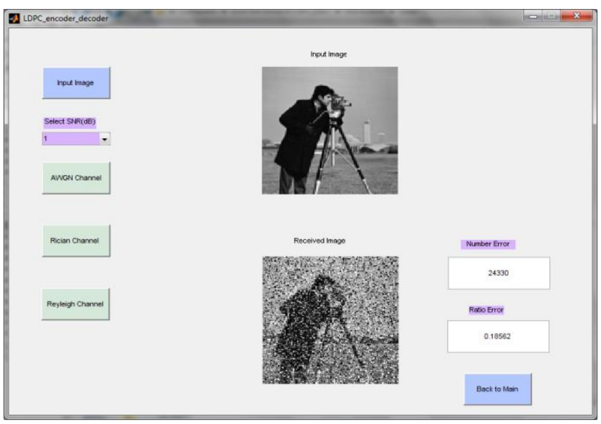
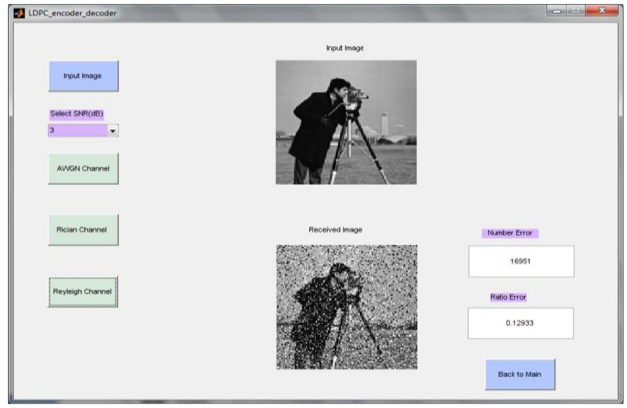


Fig. 2 A sample line graph using colors which contrast well both on screen and on a black-and-white hardcopy

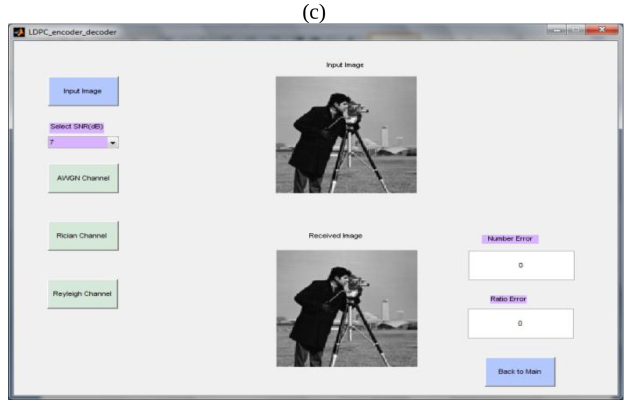


(a)



(b)

(c)



(d)

Fig. 3 Simulation results for WiMAX Rayleigh
(a) BER= 0.18562 for SNR =1dB, (b) BER= 0.12933 for SNR =3dB, (c) BER= 0.033791 for SNR = 5dB, (d) BER= 0 for SNR=7dB

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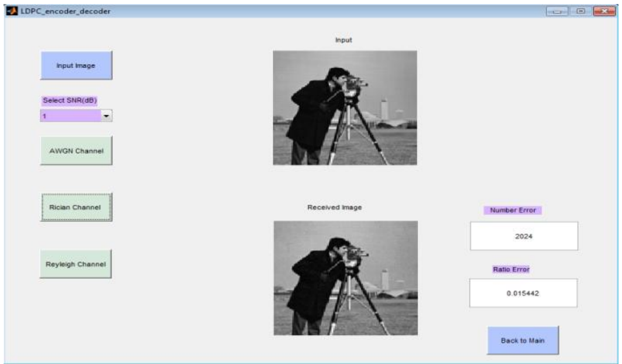
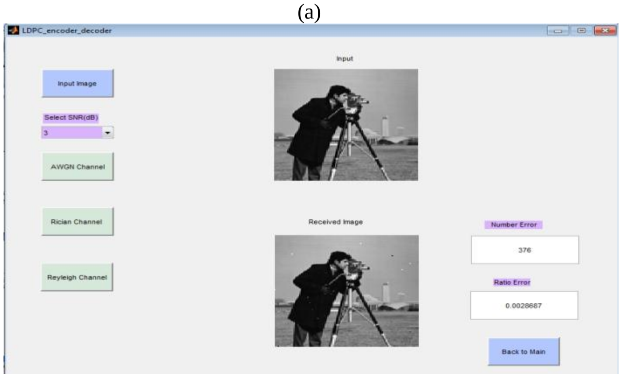
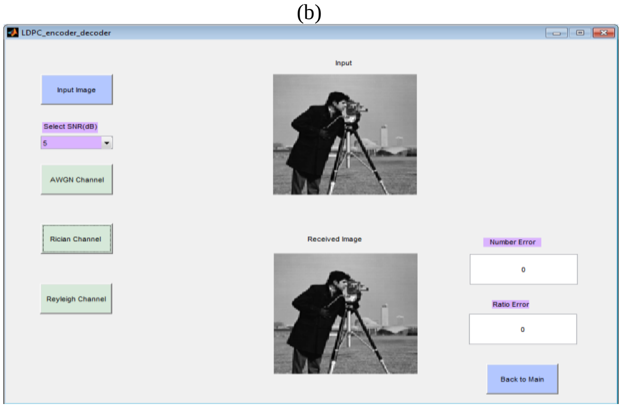


(a)



(b)



(c)

Fig. 4 Simulation results for WiMAX Rayleigh
(a) BER= 0.015442 for SNR =1dB, (b) BER= 0.0026687 for SNR =3dB, (c) BER= 0 for SNR = 5dB

VII. CONCLUSION

The simulation of Physical layer of WiMAX along with the concatenated scheme of RS-LDPC codes is carried out for an image transmission over the fading channels considering the Quality of Service (QoS) performance metrics such as BER, SNR. The simulation system is implemented using MATLAB. The simulation results of the WiMAX system with concatenated RS-LDPC coding technique using AWGN, Rayleigh, Rician channels, for different values of SNR=1, 3, 5, 7, 10, 12, 15dBs are recorded. From the results obtained, it is clear that, in an AWGN channel the image can be reconstructed for SNR ≥ 1dB. WIMAX system with Rayleigh channel can reconstruct the image at SNR=5dB and WiMAX system with Rician channel can reconstruct the image at SNR=7dB.

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BIOGRAPHY

Rekha S .M. presently perusing M.Tech in Digital Electronic and Communication, at AME Engineering College, Bangalore, Karnataka, India. She was a student of S. J. M. I. T., Chitradurga, Karnataka, India during her B.E in the stream of Electronics and Communication from VTU University, Belgaum. Her Area of research interest includes Advanced digital image processing, Wireless Communication and Networking.

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Mr. P. B. Manoj received his Master's degree in Information technology from Visvesvaraya Technological University, Belgaum, Karnataka, India, and pursuing is his Ph.D. under VTU, Karnataka, India. His research interests include mobile wireless networks, sensor networks, parallel and clustering computing, and performance modeling and evaluation. He has authored/co-authored several technical papers in the areas of computer networking, performance evaluation, and parallel and distributed computing. He is currently an Associate Professor in the Department of Electronics and Communication Engineering, AMC Engineering college,Bangalore, VTU, Karnataka.