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Performance Improvement of WIMAX with FEC Zigzag Code Using MIMO Technique

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Abstract-*The telecommunication industry has been developing at a very fast rate. This paper presents the performance enhancement of the WiMAX system (Worldwide Interoperability for microwave Access) by using MIMO Technique. WiMAX an emerging global broadband wireless OFDM-based technology that provide high quality broadband services. Mobile WiMAX is a wireless networking system which provides wireless broadband to fixed and mobile terminals. In this paper, we investigated the performance of WiMAX system for different modulation technique Quadrature Phase Shift keying (QPSK) and Quadrature Amplitude Modulation (QAM). In this paper, we evaluate bit-error rate performance of WiMAX system with zigzag coded modulation with different code rate and code length. The results show that the proposed zigzag-coded modulation presents a stronger error correcting capability as compared to the Reed Solomon with Convolutional code.*
Index Terms- *WiMAX, OFDM, Zigzag codes, RS codes, CC codes*

I. Introduction

Wireless is a spectrum of opportunities. IEEE 802.16 is officially called wireless MAN in IEEE. The IEEE 802.16 standard is based on the Wireless Metropolitan Area Network. It supports multiple frequency allocation from 2-66GHz.Wimax is one of the various areas of research that is started with 802.16 on developing its performance in variable environments.

Broadband Wireless Access (BWA) has emerged as a promising solution for last mile access technology to provide high speed internet access in the residential as well as small and medium sized enterprise sectors. As discussed above section, cable and digital subscriber line (DSL) technologies are providing broadband service. But due to the practical difficulties many urban and suburban locations may not be served by DSL connectivity as it can only reach about three miles from the central office switch.On Broadband wireless Access, because of its wireless nature, it can be faster to deploy, easier to scale and more flexible, thereby giving it the potential lto serve customers not served or not satisfied by their wired broadband alternatives. IEEE 802.16standard for BWA and its associated industry consortium, Worldwide Interoperability for Microwave Access (WiMAX) forum promise to offer high data rate over large areas to a large number of users where broadband is unavailable.

This is the first industry wide standard that can be used for fixed wireless access with substantially higher bandwidth than most cellular networks. Wireless broadband systems have been in use for many years, but the development of this standard enables economy of scale that can bring down the cost of equipment, ensure interoperability, and reduce investment risk for operators. The first version of the IEEE 802.16 standard operates in the 10–66GHz frequency band and requires line-of-sight (LOS) towers. Later the standard extended its operation through different PHY specification 2-11 GHz frequency band enabling non line of sight (NLOS) connections, which require techniques that efficiently mitigate the impairment of fading and multipath. Taking the advantage of OFDM technique the PHY is able to provide robust broadband service in hostile wireless channel. The OFDM based physical layer of the IEEE802.16 standard has been standardized in close cooperation with the European

Telecommunications Standards Institute (ETSI) High Performance Metropolitan Area Network (HiperMAN). Thus, the HiperMAN standard and the OFDM based physical layer of IEEE802.16 are nearly identical. Both OFDM based physical layers shall comply with each other and a global OFDM system should emerge. The WiMAX forum certified products for BWA comply with the both standards. Communications with direct visibility in the frequency band from 10 to 66 GHz, were dealt by IEEE 802.16 standard, the amendment IEEE 802.16a specifies working in a lower frequency band 2- 11 GHz. IEEE 802.16d a variation of IEEE 802.16a was basically about optimizing the power consumption of mobile device. IEEE 802.16e is an amendment to IEEE 802.16-2004 and added portability and is oriented to both stationary and mobile deployments. WiMAX standards based projects can work equally well with both the above IEEE standard.

OFDM- Multicarrier transmission, also known as OFDM is a technique with a long history back to 1960that has recently seen rising popularity in wireless and wire line applications. The recent interest in this technique is mainly due to the recent advances in digital signal processing technology. International standards making use of

OFDM for high-speed wireless communications are already established or being established by IEEE 802.11, IEEE, 802.16, IEEE 802.20 and ETSIBRAN committees. For wireless applications, an OFDM-based system can be of interest because it provides greater immunity to multipath fading and impulse noise, and eliminates the need for equalizers, while efficient hardware implementation can be realized using FFT techniques.

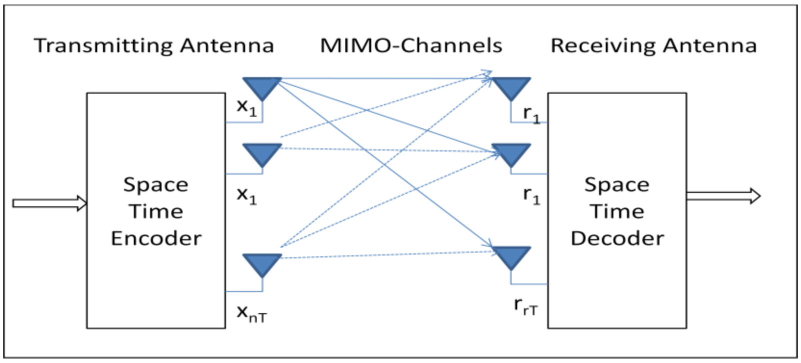
OFDM is a multi-carrier modulation technique where data symbols modulate a parallel collection of regularly spaced sub-carriers. The sub-carriers have the minimum frequency separation required to maintain orthogonally of their corresponding time domain waveforms, yet the signal spectra corresponding to the different sub-carriers overlap in frequency. The spectral overlap results in a waveform that uses the available bandwidth with very high bandwidth efficiency.

OFDM is simple to use on channels that exhibit time delay spread or, equivalently, frequency selectivity. Frequency selective channels are characterized by either their delay spread or their channel coherence bandwidth which measures the channel de-correlation in frequency. The coherence bandwidth is inversely proportional to the root-mean-square (rms) delay spread.

By choosing the sub-carrier spacing properly in relation to the channel coherence bandwidth, OFDM can be used to convert a frequency selective channel into a parallel collection of frequency flat sub-channels. Techniques that are appropriate for flat fading channels can then be applied in a straight forward fashion.

MIMO system model- Multi-antenna systems can be classified into three main categories. Multiple antennas at the transmitter side are usually applicable for beam forming purposes. Transmitter or receiver side multiple antennas for realizing different (frequency, space) diversity schemes. The third class includes systems with multiple transmitter and receiver antennas realizing spatial multiplexing (often referred as MIMO by itself).

In radio communications MIMO means multiple antennas both on transmitter and receiver side of a specific radio link. In case of spatial multiplexing different data symbols are transmitted on the radio link by different antennas on the same frequency within the same time interval. Multipath propagation is assumed in order to ensure the correct operation of spatial multiplexing, since MIMO is performing better in terms of channel capacity in a rich scatter multipath environment than in case of environment with LOS. This fact was spectacularly shown in



Concatenated zigzag-coded modulation- Channel coding represents the source information over the channel in such a manner that minimizes the error probability in decoding by adding the redundant bits systematically with the data. Channel coding is important for wireless channel because it reduces the bit error rate at the receiver. Hence in this way the reception quality improves. In general channel coding can be performed by error detecting and correcting codes. Coding methods are based on logical or mathematical operations. Zigzag code has a big advantage, in that it can choose a higher code rate. Modulation used here is of the M-QAM modulation type, and possesses such advantages as small radiation outside the band and higher bandwidth efficiency. It is robustly applicable in practical communication systems.

A. Encoding of Zigzag Codes

A coded modulation scheme is used for ultra-high speed transmission. This paper introduces a family of error-correcting codes called zigzag codes. A zigzag code is described by a highly structured zigzag graph [2]. A zigzag code is a type of linear error-correcting code. In this coding the input data is partitioned into segments of fixed size and the sequence of check bits to data is added, where each check bit is the exclusive OR of the bits in a single segment and of the previous check bit in the sequence. Zigzag codes show upto 0.5 dB performance gain over structured low density parity check codes (LDPC). This paper deals with bit-error-rate (BER) performance of WiMAX systems that uses the various coding and modulation schemes [1]. The structure of zigzag code is shown in Fig. 2, where node represents the modulo-2 summation. An (I,J)-zigzag code is a systematic code with I parity bits in the form of a column vector p, and I.J information bits in the form of an I×J matrix D [4] , where p and D are given by,

$$D = \begin{bmatrix} d(1,1) & d(1,2) & \dots & d(1.J) \\ \vdots & \vdots & \dots & \vdots \\ d(I,1) & d(I,2) & \dots & d(I,J) \end{bmatrix}_{I\times J} \quad \text{and} \quad \begin{bmatrix} p(1) \\ \vdots \\ p(I) \end{bmatrix}_{I\times 1} \qquad (1)$$

The parity check bits are generated according to

$$P(i) = \left(p(i-1) + \sum_{j=1}^{J} d(i,j)\right) \bmod 2, \qquad 1 \le I \le I, \qquad (2)$$

With the initial value $p(0) = 0$

B. Concatenated (I,J) Zigzag Codes

If we concatenate several component zigzag codes then a stronger code can be obtained. The first constituent code encodes the original data $\Pi 1(D) = D$,and the remaining K-1 constituent codes encode K-1 different interleaved versions of D using K-1 length (I×J) random interleaves. The k^{th} constituent code generates a parity check vector $pk = [pk(1), \dots, pk(I)]T$ and the parity check matrix is denoted by [1]

$$P = \begin{bmatrix} p1(1) & \dots & pk(1) \\ \vdots & \ddots & \vdots \\ P1(I) & \dots & pk(I) \end{bmatrix}_{I\times K}$$

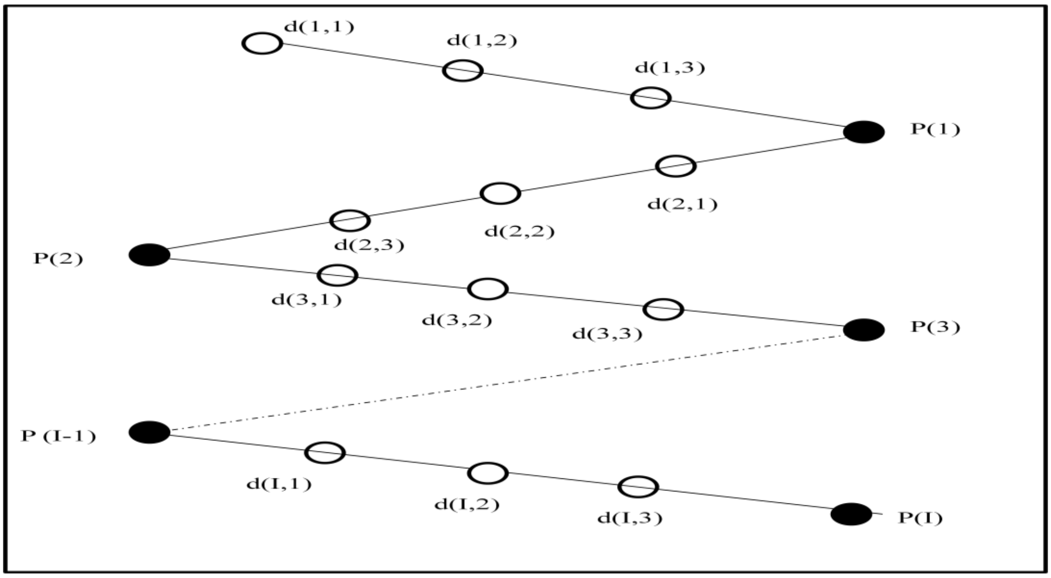


Fig:- The structure of zigzag codes.

II. Decoding Of Zigzag Codes

We perform the A Posterior Probability (APP) decoding of zigzag codes, this process starts with the information of posterior probabilities for each data bit then the data bit value is chosen which corresponds to the MAP probability for that data bit, after reception of a corrupted code-bit sequence, the process of decision making with APPs allows the MAP algorithm to determine the most likely information bit that have been transmitted at each bit time [4].

For each constituent code, based on the parity check relation, this algorithm performs forward and backward recursions and updates the log-likelihood ratio (LLR) of the information bits periodically. To perform the forward and backward recursions and update the LLR of the information bits, each decoder uses the output LLR of the information bits from the previous decoder [4]. LLR is a statistical test that is used to compare the fit of 2 models one of which is a special case of the other. This test is based on likelihood ratio, which defines how many times more likely the data bits are less than one model than the other. This ratio can be used to compare a critical value to decide whether to reject the model or to accept it [4]. Decoding of concatenated (I,J)-zigzag codes

Like that of the LDPC codes, the a posteriori probability (APP) decoding of zigzag codes involves non-linear operation at the parity check nodes, which is computationally complex and is less attractive from the implementation point of view. We next describe allow- complexity iterative Max-Log-MAP (MLM) –based decoding algorithm for concatenated zigzag codes, which is of the same natures the min-sum decoding of LDPC codes. For each constituent code, based on the parity check relation the algorithm performs forward and backward recursions and updates the log-likelihood ratio (LLR) of the information bits. To combine the LLR of the information bits from all constituent codes, the algorithm performs turbo processing, i.e., the decoders of all constituent codes are placed in loop. Each constituent decoder uses the output LLR of the information bits. from the previous decoder to perform the forward and backward recursions and update the LLR of the information bits. The structure of the turbo processing Note that the LLRs of the parity check bits of each constituent code are not updated in the turbo processing, and thus remain unchanged in the decoding process. In the first turbo iteration, the LLRs of the information bits computed based on the channel outputs and their a priori LLRs are input to the loop (to decoder 1). In the following,

We elaborate on the decoding procedure for the K-dimensional concatenated(I,J)- zigzag codes. Given the channel output y, the LLR of an information bit is given by

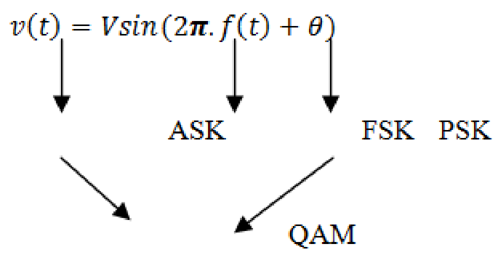
$$l^a(d(i,j)) = \log\frac{P(d(i,j)=0|y)}{P(d(i,j)=0|y)} + \frac{P(d(i,j)=0)}{P(d(i,j)=1)}, \qquad 1 \le i \le I, 1 \le j \le J \qquad (3)$$

Where the first term is the posterior LLR given the channel output, and the second term is the a priori LLR of the information bit. Typically the information bits are assumed equiprobable and therefore the second term is zero. The LLR of a parity check bit is given by

$$l^a(p_k(i)) = \log\frac{P(p_k(i)=0|y)}{P(p_k(i)=0|y)}, \qquad 1 \le i \le I, 1 \le k \le K \qquad (4)$$

Convolution- Convolution codes were first mentioned by Elias in 1955. They can be seen as an attempt to generate the random codes that were successfully used by Shannon. Convolution codes differ from block codes in that the encoder contains memory and the n encoder outputs at any given time unit depend not only on the k inputs at that time unit but also on m previous input blocks .An (n, k, m) convolution code can be implemented with a k-input, n-output linear sequential circuit with input memory m. typically, n and k are small integers with k < n, but the memory ordm must be made large to achieve low error probabilities.

Quadrature Amplitude Modulation (QAM)- ASK is also combined with PSK to create hybrid systems such as amplitude and phase shift keying or Quadrature Amplitude Modulation (QAM) where both the amplitude and the phase are changed at the same time. QAM is a modulation scheme which conveys data by changing (modulating) the amplitude of two carrier waves.[14] These two waves, usually sinusoids, are out of phase with each other by 90° and are thus called Quadrature carriers hence the name of the scheme .



(2)

As for many digital modulation schemes, the constellation diagram is a useful representation. In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, although other configurations are possible. Since in digital telecommunications the data is usually binary, the number of points in the grid is usually a power of 2 (2, 4, 8...). Since QAM is usually square, some of these are rare—the most common forms are 16-QAM, 64-QAM, 128-QAM and 256-QAM. By moving to a higher-order constellation, it is possible to transmit more bits per symbol. However, if the mean energy of the constellation is to remain the same (by way of making a fair comparison), the points must be closer together and are thus more susceptible to noise and other corruption; this results in a higher bit error rate and so higher-order QAM can deliver more data less reliably than lower-order QAM.

QAM principa- In general terms, QAM can be defined as the digital modulation format where information is conveyed in the amplitude and phase of a carrier signal. This scheme combines two carriers whose amplitudes are modulated independently with the same frequency and whose phases are shifted by 90 degrees with respect to each other. These carriers are called in-phase carriers (I) and Quadrature phase carriers (Q).

An M-ary Quadrature amplitude modulation (M-QAM) signal can be defined by the following equation.

$$S_m(t) = A_m . g(t). \cos(2\pi f_c + \theta_m) \qquad m=1,2,\ldots..M \qquad (6)$$

Where $s_m(t)$ represents the band pass signal chosen from the M possible waveforms, f_c symbolizes the carrier frequency, g(t) is a real-valued signal pulse whose shape influences the spectrum of the transmitted signal and A_m and θ_m denote the amplitude and phase angel of the m[th] symbol ,given by

$$A_m = \sqrt{(A_m^I)^2 + (A_m^Q)^2} \qquad (7)$$

$$= \tan^{-1}\left(\frac{A_m^Q}{A_m^I}\right) \qquad m=1,2,\ldots M \qquad (8)$$

In these equations, A_m^I and $A_m^Q \in \{\pm 1d, \pm 3d, \ldots \pm (M-1)d\}$ indicate the I and Q amplitudes corresponding to the M possible symbols in the two-dimensional space and d is a constant whose value is determined by the average transmitted power.

Additive white Gaussian noise (AWGN)- In the study of communication systems, the classical (ideal) additive white Gaussian noise (AWGN) channel, with statistically independent Gaussian noise samples corrupting data samples free of inter symbol interference (ISI), is the usual starting point for understanding basic performance relationships.[15] An AWGN channel adds white Gaussian noise to the signal that passes through it.
In constructing a mathematical model for the signal at the input of the receiver, the channel is assumed to corrupt the signal by the addition of white Gaussian noise as below, therefore the transmitted signal, white Gaussian noise and received signal are expressed by the following equation with s (t), n (t) and r (t) representing those signals respectively:

r(t) = s (t) + n (t)
S (t) ⇒⊕⇒r (t)
⇑
n(t)

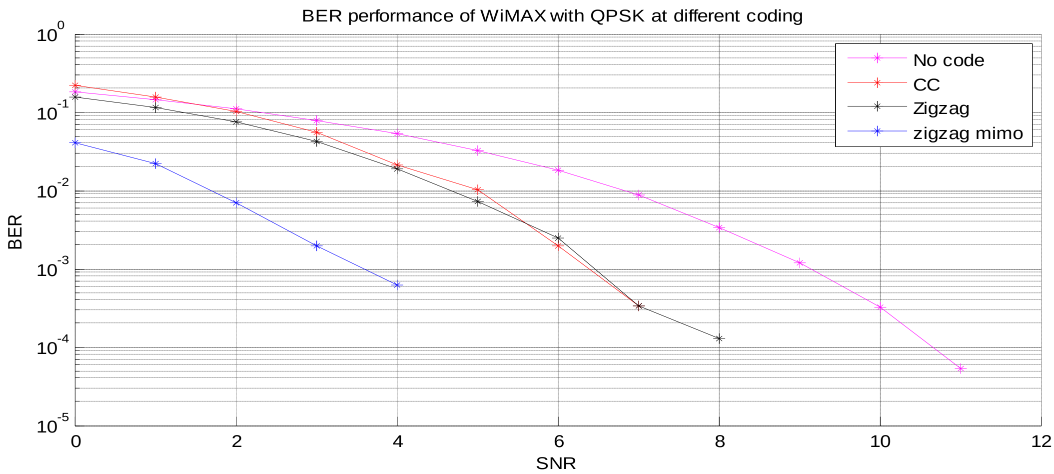
Where n (t) is a sample function of the AWGN process with probability density function (pdf) and power spectral density as follows.

$$\theta nm = 0.5 N_0 \left[W / H_z \right]$$

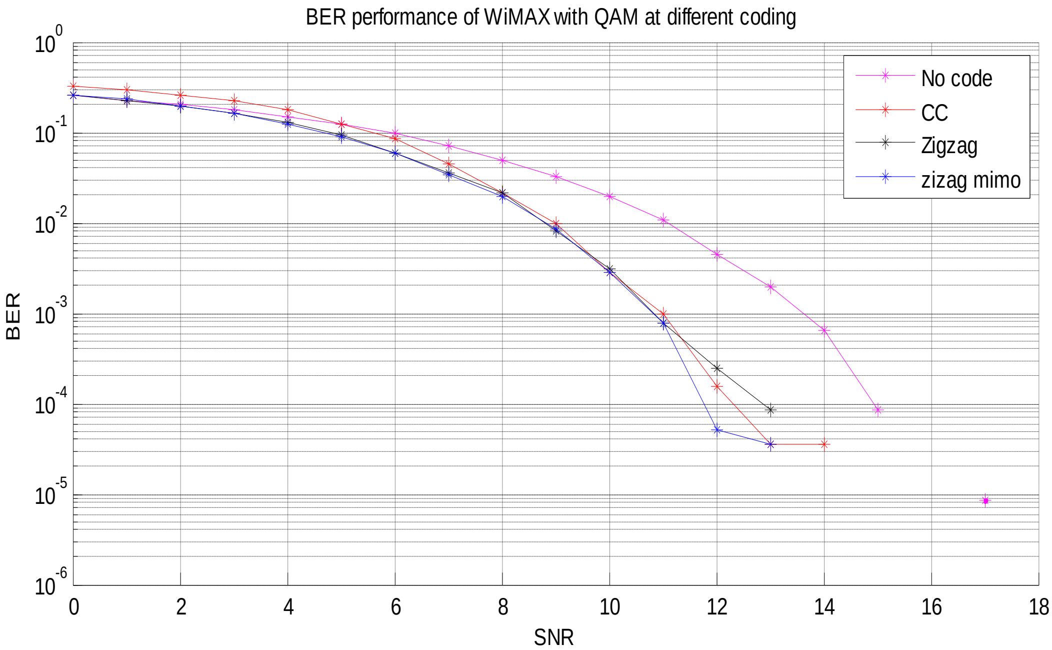
Where N is a constant and called the noise power density.

III. Results

The results of the simulation are presented in this section. At the time of simulation some parameters are set like CP length, coding rate, code length, modulation and range of SNR values. The input is generated randomly.. We have plotted the BER to SNR figures for different modulation and zigzag coding.



BER performance evaluation of different code and QPSK modulation for WiMAX



BER performance evaluation of different code and QAM modulation for WiMAX

IV. Conclusion

In this paper, performance enhancement of WiMAX system is done with MIMO. BER for different adaptive modulation techniques are evaluated in slow frequency selective fading channel. In frequency selective fading, channel is affected by more ISI and noise then in flat fading. The performance of WiMAX system and FEC coding, for the transmission of reliable data over communication channel Forward- Error- Correction techniques are necessary. The redundant bits are added to the data stream before its transmission so the effect of error which may occur during transmission can be reduced. In the receiver side system is enabled by the redundancy to detect and correct the errors. The simulation results we can conclude in zigzag codes with modulation techniques type performs better and gives a stronger error detecting.

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