Performance Analysis of Zigzag with RS coded WiMAX System

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Abstract: ***The Worldwide Interoperability for Microwave Access is the IEEE 802.16 family of standard. The IEEE 802.16 standard defines Wireless MAN (metropolitan area network). The IEEE WiMAX/802.16 standard for broadband wireless metropolitan area networks (WMANs) can deliver high throughput over long distances, and support different qualities of services, offers a wireless backhaul network that enables high speed internet access to residential, small and medium business customers. This promising and cost-effective technology can also support internet access for Wi-Fi hot spots and cellular base stations through their respective access points [1]. It has been designed to provide high data rate communication in metropolitan area wireless networks [2]. The WiMax, for broadband wireless access is employed for high speed and low cost, which is easy to deploy, and provides a better alternative for extension of fiber-optic backbone. The base stations of WiMAX can provide greater wireless coverage of about 5 miles, with LOS (line of sight) transmission within the bandwidth of up to 70 Mbps. In this paper, we evaluate bit-error rate performance of WiMAX system using zigzag with RS coded modulation for different code rate and code length. The results show that the proposed zigzag-coded modulation combined with RS coding presents a stronger error correcting capability as compared to the Reed Solomon with Convolutional code or only zigzag code.***

Keywords: WiMAX, OFDM, Zigzag codes, RS codes, CC codes.

1. Introduction

WiMAX is a telecommunication protocol that provides fixed and mobile internet access. This protocol combines a number of wireless technologies that have emerged from IEEE to face the rapid demand of higher data rate and longer transmission range in wireless access and to enable a high speed connection to the Internet in terms of education, multimedia service, commerce, trade , research and other applications.

1.1 WiMAX Architecture

WiMAX is based on the standard IEEE 802.16, which consist of one Base Station (BS) and one or more Subscriber Stations (SSs), as shown in Figure 1, the BS is responsible for data transmission from SSs through two operational modes: Mesh and Point-to-multipoint (PMP), this transmission can be done through two independent channels: the Downlink Channel (from BS to SS) which is used only by the BS, and the Uplink Channel (from SS to BS) which is shared between all SSs, in Mesh mode, SS can communicate by either the BS or other SSs, in this mechanism the traffic can be routed not only by the BS but also by other SSs in the network, this means that the uplink and downlink channels are defined as traffic in both directions; to and from the BS. In the PMP mode, SSs can only communicate through the BS, which makes the provider capable of monitor the network environment to guarantee the Quality of Service Quos to the customers [3].

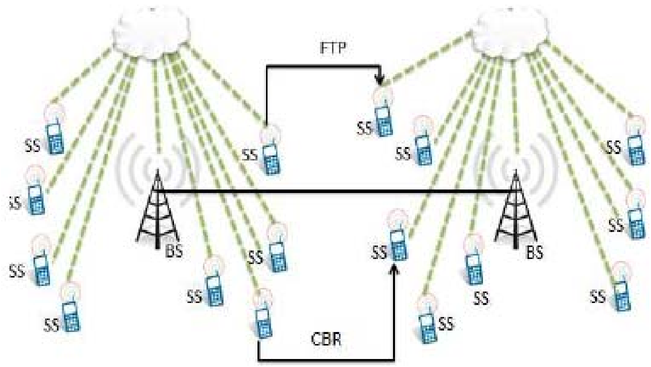

Figure 1: WiMAX Architecture

1.2 WiMAX Promises

- The maximum values are 8 km under NLOS conditions and 50 km coverage under LOS conditions.
- In practice probably 200m-1km coverage is possible in portable devices and 70-10km in fixed broadband accesses.
- Support for both frequency-division duplex (FDD) and time-division duplex (TDD).
- Support for point-to-point multi-point mesh topology.
- IEEE 802.16-2005 standard offers support both fixed and mobile access over the same infrastructure.

1.3 IEEE 802.16 Protocol Layers

The IEEE 802.16 standard is structured in the form of a protocol stack with well defined interfaces. The MAC layer is composition of three sub layers:
1. Service Specific Convergence Sub-layer (CS)
2. MAC Common Part Sub-layer (CPS) and
3. Privacy Sub-layer.

The MAC CS receives higher level data through CS Service Access Point (SAP) and provides transformation and mapping into MAC Service Data Unit (SDU). MAC SDUs are then received by MAC CPS through MAC SAP. The specification targeted 2 types of traffic transported through IEEE 802.16 networks: Asynchronous Transfer Mode (ATM) and Packets. Therefore, Multiple CS specifications are available for interfacing with various protocols.

The MAC CPS is the core part of the MAC layer which defines medium access method. The CPS can provide functions related to duplexing and channelization, channel access, network entry, PDU framing, and initialization. This provides the rules and mechanism for system access, connection maintenance and bandwidth allocation. For transmission scheduling QoS decisions are also performed within the MAC CPS.

The Privacy layer lies between the MAC CPS and the PHY layer. For public networks security is a major issue. This sub layer provides the mechanism for encryption and decryption of data transferring to and from PHY layer and can also be used for secure key exchange and authentication. PHY control, data statistics are transferred between the MAC CPS and the PHY through the PHY SAP.

2. The WiMAX Model

The modeling setup includes MATLAB R2010a and communications block set running on windows XP. The model shown in Fig. 2 consists of three main components transmitter, receiver and channel.

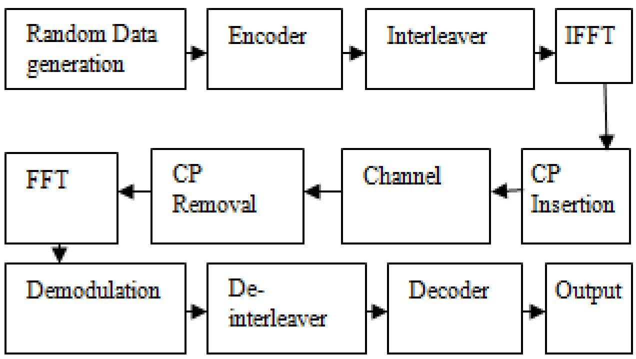

Figure 2: WiMAX (IEEE 802.16) Model

The binary data after randomization is fed into the forward error correction (FEC) encoder. We consider convolutional turbo codes (CTCs), convolutional codes (CC), Reed-Solomon (RS) and especially concatenated zigzag codes. After bitwise interleaving the bits, they are fed into the modulator. Where mapping the bits to QPSK, 16-QAM, 64-QAM and 8-QAM symbols are performed. According to the IEEE 802.16 standard, a special sub-carrier allocation pattern is used to account for the specialties dealing with an OFDMA uplink. The OFDM signal in the time domain is computed via the inverse fast Fourier transform (IFFT). Finally, the cyclic prefix (CP) is added for the guard band. Here the channel is assumed to be a time-variant multi-path channel, modeling mobile users in an NLOS scenario. The receiver noise is modeled by an additive white Gaussian noise (AWGN) process which is added to the received signal [4].

Assuming perfect synchronization, the receiver removes the cyclic prefix and extracts the useful symbol time. The receiver extracts the user-specific information after the computation of the frequency domain signal via the FFT. With the assumption that the delay spread of the channel is smaller than the Cyclic prefix (CP) and the time variance of the channel during one OFDM symbol is negligible [4].

Orthogonal frequency-division multiplexing (OFDM) scheme is used in most wireless communications systems due to its high spectrum efficiency and robustness in multi-path propagation. OFDM is a special form of multi-carrier modulation and mitigate inter symbol interference (ISI) by multiplexing the data on orthogonal property. Moreover, it is, spectrally, more sufficient technique as compared to a conventional single carrier modulation technique.

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation scheme which is suited for high data rate transmission in delay dispersive environments. It converts a high data rate stream into a number of low data rate streams that are transmitted over parallel, narrowband channels which can be easily equalized. OFDM provides high bandwidth efficiency because in this scheme the carriers are orthogonal to each other and multiple carriers share the data among themselves. The most important advantage of this transmission technique is their robustness to channel fading in wireless communication environment. The model presented in this paper is built on the following parameters:

Modulation: QPSK, M-QAM
Bandwidth: 15MHz
$N_{FFT:}$ 2048
Sampling factor: 7/6
Length of Cyclic prefix: 1/8
$F_{s:}$ 2075 MHz
Symbol Time (T_b): 79.5
Length of Cyclic Prefix (T_g):10.2

3. Coding Theory

According to Hoffman, coding theory is “the study of methods for efficient and accurate transfer of information from one place to another”. From mathematical point of view coding is injection that assigns to every symbol of the set A a symbol from the set Y. In this way a codeword $\mathbf{C_i}$ is created. Code is a set of all code words. Code words Ci is represented by a –m-tuple sequence, where every of m-objects may be assigned z-states. The length of the code ***L*** is the number of code words Ci**.** This length for binary codes is defined by the relation $1 \leq L \leq 2m$ [5]. 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 [6].

3.1 Description of Zigzag Codes

A zigzag code is described by a highly structured zigzag graph [7]. 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 up-to 0.5 dB performance gain over structured low density parity check codes (LDPC).
Let D= {d(i, j)}, i= 1,2….,I , j=1,2,…,J, denote an I×J information bits and P= {p(i)}, i =1,2,…,I, denotes a parity check matrix column vector. Let

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

The parity check bits are generated such that each segment consists of even number of ones. Thus the codeword contains I×J information bits and P parity check bits.
The parity bits are generated as follows [7]:

$$P(i)= (p(i-1) + \sum_{j=1}^{J} d(i,j))\ mod2,\ 1 \le i \le I,$$

With the initial value p (0)=0.
For 1 ≤ i ≤ I, we define
[p(i-1),d(i,1)d(i,2),…,d(i,J),p(i)] as the ith segment of the (I,J)-zigzag code.

Note that the zigzag code is completely parameterized by the pair (I,J).The zigzag code has weaker error correcting capability because it has a minimum distance d_{min}=2 for any pair(I,J).However it is very useful in case of concatenated construction.

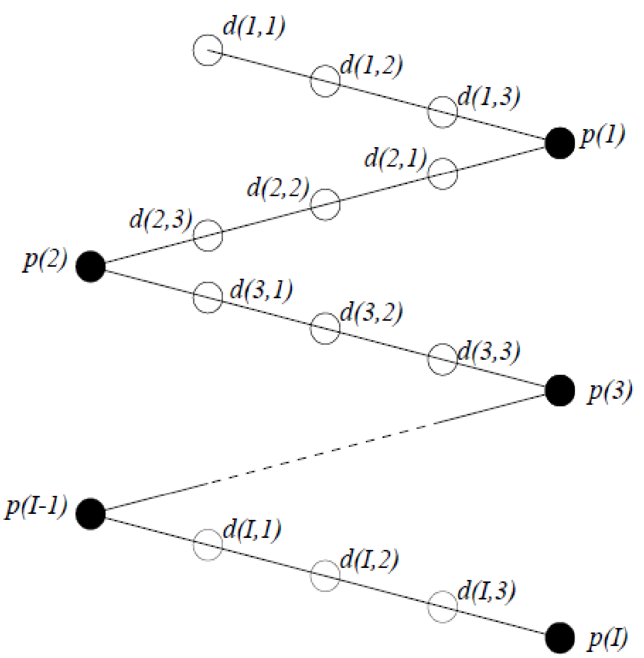

Figure 3: Graphical representation of Zigzag Code, White nodes represent information bits, black nodes represent parity bits.

3.2 Decoding of concatenated (I, J)-zigzag codes

Like that of the LDPC codes, a posteriori probability (APP) decoding of zigzag codes involves a nonlinear operation at the parity check nodes, which is computationally complex and is less attractive from the implementation point of view. We next describe a low- complexity iterative Max-Log-MAP (MLM)-based decoding algorithm for concatenated zigzag codes, which is of the same nature as 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 a 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. 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 [5].

Log-Likelihood test is a statistical test used to compare the fit of 2 models, one of which is a special case of the other. The test is based on likelihood ratio, which expresses how many times more likely the data are under one model than the other. This ratio can be used to compute or compare with a critical value to decide whether to accept the model or to reject.

3.3 Reed-Solomon (RS) Code

The Reed-Solomon error correction codes were introduced by Irving S. Reed and Gustavo Solomon in 1960. Their work was independent of other similar works like the work by Bose, Chaudhurj and Hocquenghem (i.e., the BCH codes). Even though the RS codes are a subgroup of the BCH codes, RS codes have pillaged and burned many of its forbearers and peers in efficiency, practicality, and rates. RS codes have generated many useful and widespread applications. A lot of credit goes to Reed and Solomon [8].

Reed-Solomon codes are codes for forward-error correction that are used in data transmission vulnerable to channel noise. Reed-Solomon codes are block codes that by adding redundant data before transmission are capable of detection and correction of errors within the block of data [9]. Reed-Solomon codes are non-binary codes, i.e. signal elements are represented by group of bits.

4. Simulation Results

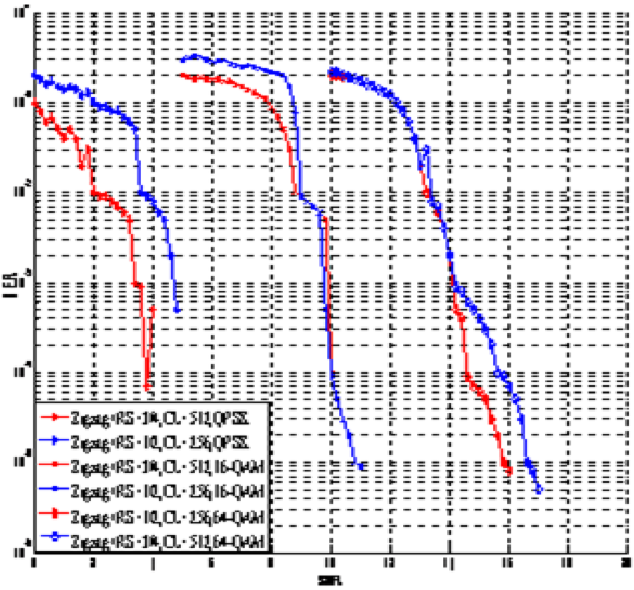

Figure 4: BER performance evaluation of different rate/modulation for WiMAX.

From the above simulation results, it can be clearly seen that in QPSK modulation with rate-3/4 we get a BER of $5*10^{-4}$ at a SNR of about 4 dB and with rate-1/2 we get a BER of $8*10^{-3}$ at a SNR of 4 dB. In case of 16-QAM type modulation with code rate-3/4 we get a BER of $1*10^{-4}$ at a SNR of 10 dB and with rate-1/2 we get a BER of $9*10^{-5}$ dB at a SNR of 10 dB. In case of 64-QAM type modulation with code rate-3/4 we get a BER of $7*10^{-5}$ dB at a SNR of 16 dB and with code rate -1/2 we get a BER of $8*10^{-6}$ at a SNR of 16 dB. The graph shows that the performance of zigzag with RS coded modulation scheme with code rate ¾ for QPSK and 16-QAM types are better than the code rate-1/2 but in case of 64-QAM it is seen that the performance of WiMAX for zigzag coding for code rate- ½ is better than code rate-3/4.

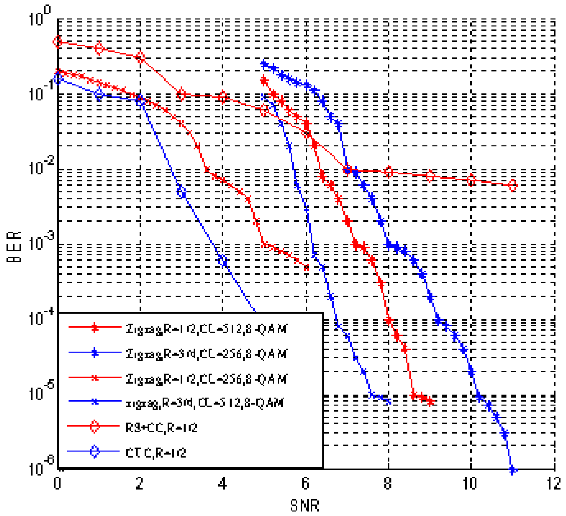

Figure 5: BER performance evaluation for R=1/2 and ¾, N=256 and 512 respectively, for 8-QAM modulation.

From the above simulation results, it can be clearly seen that in case of 8-QAM modulation with code length-512 and at rate-1/2 we get a BER of $4*10^{-2}$ at a SNR of about 6 dB and at rate-3/4 we get a BER of 3 $*10^{-3}$at a SNR of 6 dB. For code length-256 and rate-1/2 we get a BER of 5 $*10^{-4}$ at a SNR of 6 dB and at rate-3/4 we get a BER of $1.3*10^{-1}$ at a SNR of 6 dB. It is seen that 8-QAM modulation with code length-256, rate-1/2 performs better than code length-512, rate-3/4.

5. Conclusion

For the transmission of reliable data over communication channel Forward- Error- Correction techniques are necessary. If 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. The receiver in the system is enabled by the redundancy to detect and correct the errors. By the simulation results we can conclude that the zigzag with RS codes with M-QAM modulation type performs better and gives a stronger error detecting and correcting capabilities.

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Author Profile

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