

## Performance Evaluation of a Concatenated FEC Scheme Based WiMAX System with Application to the Digital Image Transmission over White Gaussian Noise and Fading Channels

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**Abstract:** The WiMAX technology based on air interface standard 802-16 wireless MAN is configured in the same way as a traditional cellular network with base stations using point to multipoint architecture. WiMAX (Worldwide Interoperability for Microwave Access) is a promising technology which can offer high speed voice, video and data service up to the customer end. In this study, the performance of a concatenated interleaved FEC (Forward Error Correction) scheme based WiMAX communication system on digital image transmission under different combinations of digital modulation (BPSK, 4-QAM and 16-QAM) over both Additive White Gaussian Noise (AWGN) and fading (Rician and Rayleigh) channels have been discussed. The simulation study is made with the processing of a black and white (monochrome) digital image under AWGN and different fading channels. It is observed from the simulation study that the modulation technique used is robust in discrimination of the transmitted digital image in both AWGN and fading environments.

**Key words:** OFDM, block coding, concatenated code, additive white gaussian noise, fading channel, digital image transmission

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### INTRODUCTION

Wireless and mobile communications has become one of the fastest growing areas in our modern life and it has an enormous impact on almost every aspect of the daily life (Tran *et al.*, 2008). The IEEE WiMAX/802.16 is a promising technology for broadband Wireless Metropolitan Area Networks (WMANs) as it can provide high throughput over long distances and can support different qualities of services. WiMAX/802.16 technology ensures broadband access for the last mile. It provides a wireless backhaul network that enables high speed Internet access to residential, small and medium business customers, as well as Internet access for WiFi hot spots and cellular base stations (El-Najjar *et al.*, 2008). It supports both point-to-multipoint (P2MP) and multipoint-to-multipoint (mesh) modes.

Worldwide Interoperability for Microwave Access, known as WiMAX, is a wireless networking standard which aims for addressing interoperability across IEEE 802.16 standard-based products. WiMAX defines a WMAN, a kind of a huge hot-spot that provides interoperable broadband wireless connectivity to fixed, portable and nomadic users (Intel White Paper, 2004). The present study is intended to investigate the performance

of a digital image transmission for WiMAX communication system with the deployment of different modulation techniques in various noisy environments. In designing a wireless communication system, generally the effect of noise in the mobile channel and the effects of multipath fading during propagation of radio wave through free space are crucial issue. In Additive White Gaussian Noise (AWGN) channel, the desired signal is degraded by thermal noise generated in the electronic circuits of transmitting and receiving sections of a communication system. Rayleigh fading characterizes a situation of a number of indirect multipath signals with no distinct dominant direct line of sight transmission. On the other hand, Rician fading is characterized by the presence of the direct line of sight transmission in addition to a number of indirect multipath signals (Stallings, 2004; Semmar *et al.*, 1997). This study deals with the analysis of the digital image transmission through a typical transmission channel. Usually image transmission has to pay enormous cost of bandwidth and need to have lossless reproduction. Hence, we are going to evaluate the performance of a communication channel under certain environment when dealing with digital images. The simulation deals with non-compressed digital image transmission by a model of the digital transmission

channel baseband. The whole simulation is aimed at the research and education area of the digital signal transmission in baseband and quantification and evaluation of the distortion that may have influence on the transmitted digital signal according to the time and frequency domain. The main goal is to evaluate the performance different modulation scheme for digital image transmission over both AWGN and fading (Rician and Rayleigh) channels through Wimax communication system and assess the performance of concatenated interleaved transmission. In fading channel, the errors in mobile radio systems tend to arrive in blocks and a burst of errors is reduced in block interleaver which essentially mixes up the RS-CC encoded bit stream in a set of symbols before transmission and reorders them in reception.

**MATERIALS AND METHODS**

**Simulation model:** This structure corresponds to the physical layer of the WiMAX/IEEE 802.16 WirelessMAN-OFDM air interface. In this setup. The input binary data stream obtained from a segment of recorded audio signal is ensured against errors with Forward Error Correction Codes (FECs) and interleaved. The complementary operations are applied in the reverse order at channel decoding in the receiver end. The complete channel encoding setup is shown in Fig. 1.

FEC techniques typically use error-correcting codes (e.g., RS, CC) that can detect with high probability the error location. These channel codes improve the bit error rate performance by adding redundant bits in the transmitted bit stream that are employed by the receiver to correct errors introduced by the channel. Such an approach reduces the signal transmitting power for a given bit error rate at the expense of additional overhead and reduced data throughput (even when there are no errors) (Bing, 2003). The Forward Error Control (FEC) consists of a Reed-Solomon (RS) outer code and a rate-compatible Convolutional Code (CC) inner code. A block Reed Solomon (255,239,8) code based on the Galois field GF (2<sup>8</sup>) with a symbol size of 8 bits is chosen that processes a block of 239 symbols and can correct up to 8 symbol errors calculating 16 redundant correction symbols.

Reed Solomon Encoder that encapsulates the data with coding blocks and these coding blocks are helpful in dealing with the burst errors (Khan and Ghauri, 2008). The block formatted (Reed Solomon encoded) data stream is passed through a convolutional interleaver. Here a code

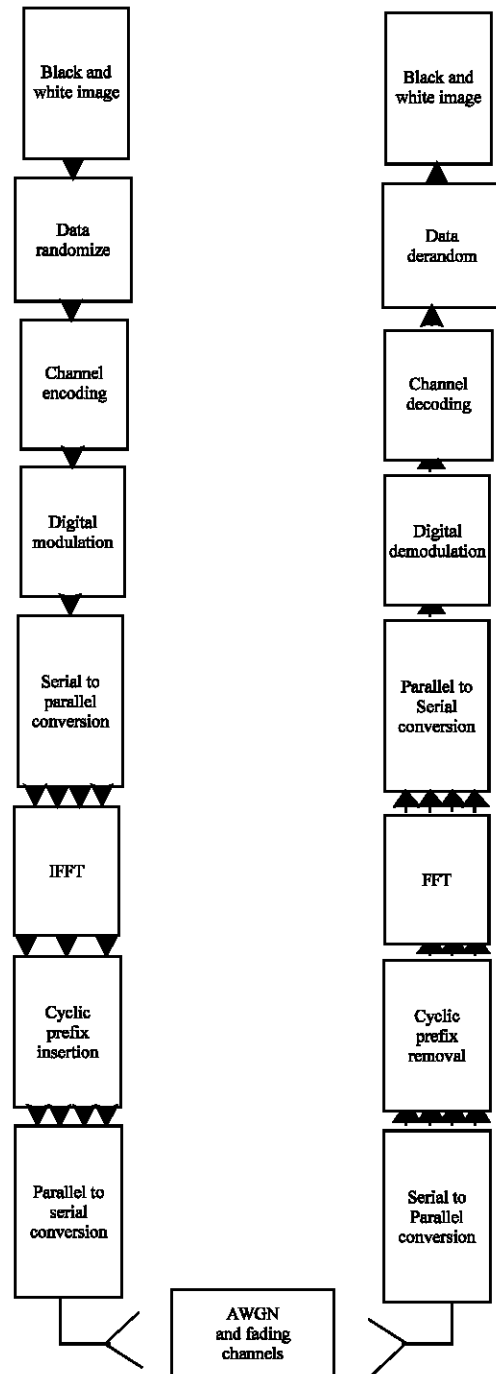


Fig. 1: Wimax Communication system model based with interleaved concatenated channel coding

rate can be defined for convolutional codes as well. If there are k bits per second input to the convolutional encoder and the output is n bits per second, the code rate is k/n. The redundancy is on not only the incoming k bits but also several of the preceding k bits. Preceding k bits

**Table 1: Simulated coding, modulation schemes and noisy channels**

Modulation	RS code	CC code rate	Noise channels
BPSK			
QPSK	(255,239,8)	1/2	AWGN channel
4-QAM			
16-QAM			
BPSK			
QPSK	(255,239,8)	1/2	Rayleigh channel
4-QAM			
16-QAM			
BPSK			
QPSK	(255,239,8)	1/2	Rician channel
4-QAM			
16-QAM			

used in the encoding process is the constraint length  $m$  that is similar to the memory in the system (Pahlavan and Krinshnomurthy, 2006), where  $k$  is the input bits and  $n$  is the number of output bits is equal to  $\frac{1}{2}$  and the constraint length  $m$  of 7.

The convolutionally encoded bits are interleaved further prior to convert into each of the either four complex modulation symbols in BPSK, QPSK, 4-QAM, 16-QAM modulation and fed to an OFDM modulator for transmission. The simulated coding modulation schemes and also noisy fading channels used in the present study is shown in Table 1.

In OFDM modulator, the digitally modulated symbols are transmitted in parallel on subcarriers through implementation as an Inverse Fast 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 presented by a cyclic prefix. At the receiving side, a reverse process (including deinterleaving and decoding) is executed to obtain the original data bits. As the deinterleaving process only changes the order of received data, the error probability is intact. When passing through the CC-decoder and the RS-decoder, some errors may be corrected, which results in lower error rates (Xiao, 2008).

**RESULTS AND DISCUSSION**

Here an attempt has been made to evaluate the performance of the Wimax systems by varying the modulation techniques and AWGN and fading channels.

For image transmissions, a compressed black and white image is reconverted into a Binary image in Monochrome Bitmap (BMP) format containing 256 X 239 pixels. Each pixel value of the image is multiplexed column

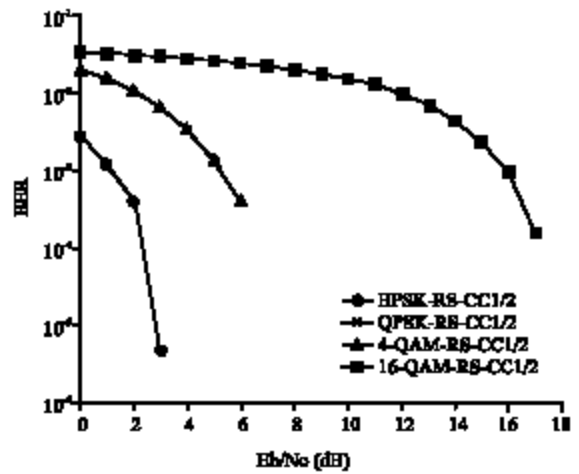


Fig. 2: Bit error rate performance between different modulation techniques of an  $\frac{1}{2}$ -rated RS-CC coded image signal under AWGN channel



Fig. 3: Performance study of a communication system in AWGN channels (SNR = 15 dB). (a) Transmitted image, (b) Received image in 2-PSK modulation techniques, (c) Received image in QPSK and 4-QAM modulation techniques and (d) Received image in 16-QAM modulation techniques

wise into serial binary stream and is RS-CC encoded. In Fig. 2, the Bit Error Rate under QPSK and 4-QAM modulation technique over AWGN channel with 8 dB SNR value is 0.0000021 which is almost 0 and 16-PSK SNR value of 15 dB is 0.0041952.

And it is observed from Fig. 3 that the received image in QPSK and 4-QAM is retrieved almost the same as the original image.

In Fig. 4, the bit error rate under QPSK and 4-QAM modulation technique over Rayleigh channel with 9 dB SNR value is 0.0000327 which is almost 0 and 16-PSK SNR value of 15 dB is 0.0070378 and retrieved the noisy image. And it is observed from Fig. 5 that the received image in

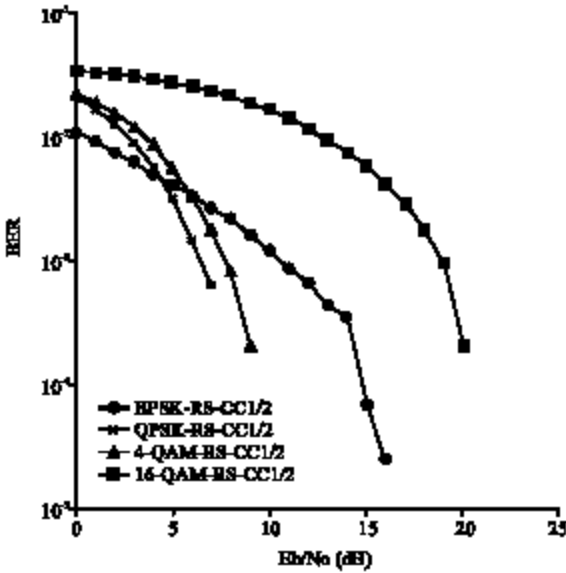


Fig. 4: Bit Error Rate Performance between different modulation techniques of an  $\frac{1}{2}$ -rated RS-CC coded image signal under Rayleigh channel



Fig. 5: Performance study of a communication system in Rayleigh channels (SNR = 15 dB). (a) Transmitted image, (b) Received image in 2-PSK modulation techniques, (c) Received image in QPSK and 4-QAM modulation techniques and (d) Received image in 16-QAM modulation techniques

QPSK and 4-QAM is retrieved almost the same as the original image. In Fig 6, the bit error rate under QPSK and 4-QAM modulation technique over AWGN channel with SNR value of 10 and 14 dB is almost 0 and 16-QAM SNR value of 20 dB is  $1.2422 \times 10^{-5}$  and retrieved the noisier image.

And it is observed from Fig 7 that the received image in QPSK and 4-QAM is retrieved almost the same as the original image.

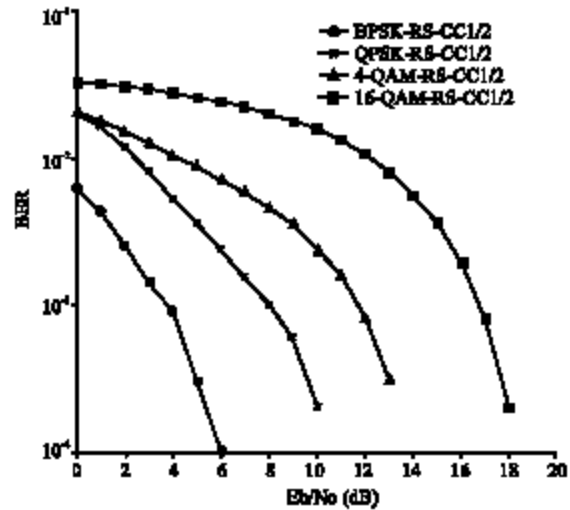


Fig. 6: Bit error rate performance between different modulation techniques of an  $\frac{1}{2}$ -rated RS-CC coded image signal under Rician channel



Fig. 7: Performance Study of a communication system in Rician channels (SNR = 15 dB). (a) Transmitted image, (b) Received image in 2-PSK modulation techniques, (c) Received image in QPSK and 4-QAM modulation techniques and (d) Received image in 16-QAM modulation techniques

### CONCLUSION

On the basis of results in the present study, it may be concluded that the performance of the Wimax system in digital image transmission over AWGN channel is comparatively better as compared to Rayleigh and Rician fading channels. And it is also observed from the earlier discussion, the performance of QPSK and 4-QAM modulation technique is the same and retrieved image signal is the same as the original image. So, this two modulation techniques is efficiently used rather than BPSK because QPSK is double bandwidth efficiency. In absence of any fading effects, the Quadrature Phase Shift

Keying based modulation/demodulation scheme shows unique performance in proper identification and retrieval of transmitted digital image.

### RECOMMENDATIONS

The future systems should be characterized by significantly enhanced spectral efficiency in order to increase linking throughput and network capacity. There should be a further learning process on how to develop a system the throughput can be increased by simultaneously transmitting different streams of data on the different transmit antennas but at the same carrier frequency.

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