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Spectral Efficiency and Bit Error Rate Measure of Wireless OFDM System Using Raptor Codes with SUI-3 channel models

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Abstract:- In this paper, we presents the performance measure of the wireless Orthogonal Frequency Division Multiplexing (OFDM) system based on Raptor codes. Different coding techniques are used for the performance evaluation such as convolution code; turbo codes, RS codes and Low density parity check (LDPC) codes. We are using the Raptor codes to evaluate the performance of the wireless OFDM system. Raptor code is new emerging rateless code which has shown amazing performance over variety of channels. Different channel model are used for the performance measure. We use the Stanford University Interim (SUI-3) channel models. Two performance measure parameters are bit error rate and spectral efficiency. Simulation results are presented for the effectiveness of the proposed Raptor codes with Stanford University Interim (SUI-3) channel. The simulation result based on 16-QAM and 64-QAM modulation technique using Raptor codes for BER and spectral efficiency measure. Result also reveals that the performance improves with different modulation techniques.

Keywords: **Rapter codes, Stanford University Interim (SUI-3), Low density parity check (LDPC) codes, Luby Transform Code, 16-QAM, 64- QAM.**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) technique has been accepted for many applications such as mobile and indoor wireless communications. If the OFDM signal is amplified by the high power amplifier (HPA) with nonlinear characteristics, the resultant spectrum may exhibit severe in-band and out-of-band radiation of the distortion components. In modern wireless communication systems, forward error correcting codes are employed for efficient transmission of data in noisy environments. Achieving a very less bit error rate (BER) has been the major task in the field of error control coding.

Several research works has been carried out on the performance evaluation of an OFDM system [1]-[6]. The BER performance results for OFDM system over fading channels are reported in [1]-[4]. The performance of non-coherently detected BFSK/OFDM over multipath fading channels with noise is investigated. This analysis demonstrates that it is possible to transmit information in selective channels with no symbol interference.

Fountain codes [8] are a concept of forward error correcting codes, recently developed by Digital Fountain Inc. specifically for such broadcast networks. The first realization of Fountain codes was Luby Transform (LT) codes [9]. The encoding and decoding times of these were later improved, and this new version was named Raptor codes [10]. The recently developed Raptor codes, which are a class of Fountain codes and the extension of LT codes, tend to give better performance than the low density parity check (LDPC) codes [7] on burst error channels [11][12].

Raptor Codes is an extension of LT-Codes [9] with linear time encoding and decoding. Raptor codes produces, for a given integer k, and any real $\delta > 0$, a potentially infinite stream of symbols such that any subset of symbols of size $k(1+\delta)$ is sufficient to recover the original k symbols with high reliability.

Raptor code [13] has the properties of linear time, linear time decoding, and very close to ideal code performance under any channel loss conditions. We start with LT codes, the basic Fountain codes and move on to Raptor codes. In Raptor codes, we first deal with a non-systematic code and then finally develop a Systematic Raptor code [14].

In this paper, we present the performance measure of the wireless Orthogonal Frequency Division Multiplexing (OFDM) system based on Raptor codes. Different coding techniques are used for the performance evaluation such as convolution code; turbo codes, RS codes and Low density parity check (LDPC) codes. We are using the Raptor codes to evaluate the performance of the wireless OFDM system. Raptor code is new emerging rate less code which has shown amazing performance over variety of channels. Different channel model are used for the performance measure. We use the Stanford University Interim (SUI-3) channel models.

The rest of the paper is organized as follows: In Section II, basic of Orthogonal Frequency Division Multiplexing (OFDM) is explained. In section III, Fountain Codes, Raptor Codes and Luby Transform code are explained. In section IV, performance measure parameters are explained in detail. In Section V, simulation results will be presented for wireless OFDM system using raptor code with 16-QAM and 64-QAM

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modulation Scheme. Section VI, conclusions will be made.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

In a OFDM system, the total signal frequency band is divided into N non-overlapping frequency sub channels. Each sub channel is modulated with a separate symbol, and then the N sub channels are frequency multiplexed. It seems good to avoid spectral overlap of channels to eliminate inter-channel interference. However, this leads to inefficient use of the available spectrum. To cope with the inefficiency, the ideas proposed in the mid-1960s were to use parallel data and FDM with overlapping sub channels, in which each, carrying a signalling rate b, is spaced b apart in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion, as well as to use the available bandwidth fully. By using the overlapping multicarrier modulation technique, almost 50% of bandwidth can be saved.

Basic Principal of OFDM system [7] is to divide high data rate transmission into lower data rate and that are transmitted simultaneously over number of subcarriers. Each of these signal are individually modulated and transmitted over the channel. And at the Receiver and signal will be demodulated and recombine to recover the Original Signal. As shown in figure given below each subcarrier arranged orthogonally in spectrum. Periodic signal are orthogonal when integral of their product is zero. Fig. 1 shows the block diagram of the OFDM system.

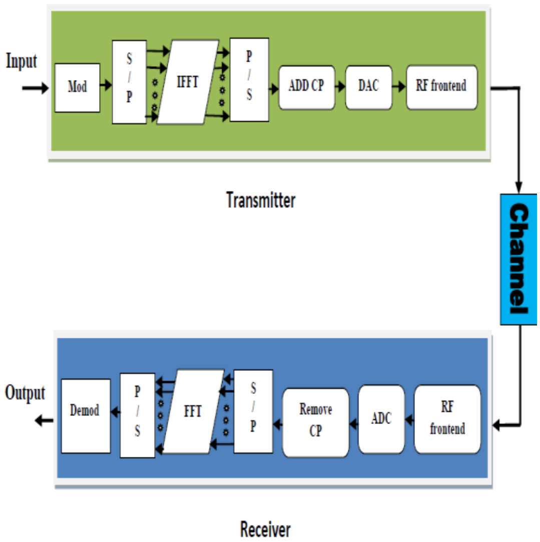

Fig. 1 Block Diagram of OFDM

Modulation: Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique (QPSK). After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel to serial converter. In order to avoid ISI we provide a cyclic prefix to the signal.

Communication Channel: This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

Demodulation: Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial to parallel converter. A demodulator is used, to get back the original signal. The bit error rate and the signal to noise ratio is calculated by taking into consideration the unmodulated signal data and the data at the receiving end.

III. FOUNTAIN CODES

Digital Fountain Codes has promising performance for erasure channel which is suitable model for packet switching networks. The first practical realization of the Fountain codes was introduced by M Luby in [3] and was further improved in [4]. Raptor code [4] is a class of Digital Fountain Codes, can be used independently of channel loss rate of erasure channel and near optimal performance for every erasure channel. Digital Fountain Codes are considered as "rate less", which means, unlike the traditional block codes such as LDPC codes and RS codes, Digital Fountain Codes do not have a fixed code rate and the rate is determined by the number of transmitted codeword symbols required before the decoder is able to decode. The rate is then not known a priori as it is in traditional fixed-rate block codes. It can generate as many codeword symbols as needed to recover all the message bits regardless of the channel performances. Existing rate less codes has the ability to adapt itself according to the channel conditions without knowing the channel knowledge at the transmitter.

A. LUBY TRANSFORM CODE

The Luby Transform code introduced by M.Luby [3] is the first practical realization of the Digital Fountain concept. The length of codeword symbol is arbitrary i.e. encoding symbols can be generated on y, as few or as many as needed depending upon the quality of the channel. The decoder can retrieve original data from any set of the transmitted codeword symbols that are only slightly longer than original data [3]. Regardless of the statistics of the erasure events on the channel, we can send as many encoded symbols unless decoder become able to recover original data from the encoded symbols, so LT code is optimal for any erasure channel. Encoding

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and decoding time is function of original data. It can recover k symbols from $k + O(\sqrt{k} * ln(\frac{k}{\delta}))$ encoding symbols with probability $1-\delta$ on average $k + O(\sqrt{k} * ln(\frac{k}{\delta}))$ symbol operations [3]. Because of the high complexity of the LT codes, Raptor code was proposed as an extension of LT code to achieve linear increase in complexity by using some appropriate pre-coding methods, but Raptor code also requires extra memory to store the pre-code output. The family of Digital Fountain Code has received many designers' attention and have been used in many applications on Transport layer.

B. RAPTOR CODES

The results of the previous section imply that LT-Codes cannot be encoded with constant cost if the number of collected output symbols is close to the number of input symbols. One of the many advantages of the new construction is that it allows for encoding and decoding with constant cost, as we will see below. The reason behind the lower bound of *log(k)* for the cost of LT-Codes is the information theoretic lower bound of Proposition 1.

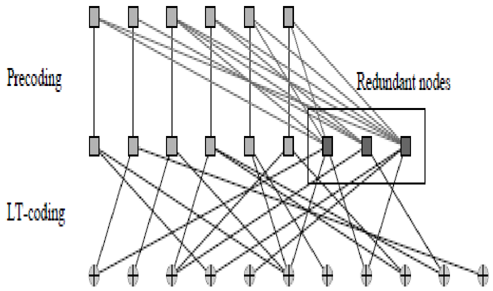

Fig. 2 Raptor Codes: the input symbols are appended by redundant symbols

The decoding graph needs to have of the order of *klog(k)* edges in order to make sure that all the input nodes are covered with high probability. The idea of Raptor Coding is to relax this condition and require that only a constant fraction of the input symbols be recoverable. Then the same information theoretic argument as before shows only a linear lower bound for the number of edges in the decoding graph.

IV. PERFORMANCE PARAMETERS FOR RAPTOR CODES

Space: Since Raptor Codes require storage for the intermediate symbols, it is important to study their space consumption. We will count the space as a multiple of the number of input symbols. The space requirement of the Raptor Code is *1/R* where *R* is the rate of the pre-code.

Overhead: The overhead is a function of the decoding algorithm used, and is defined as the number of output symbols that the decoder needs to collect in order to recover the input symbols with high probability. We will measure the overhead as a multiple of the number *k* of input symbols, so an overhead of $1-\varepsilon$ for example, means that $(1-\varepsilon)k$ output symbols need to be collected to ensure successful decoding with high probability.

Cost: The cost of the encoding and the decoding process

V. EXPERIMENTAL RESULTS

In this section, we present the wireless OFDM system using Raptor Code with Stanford University Interim (SUI-3) channel models and 16-QAM and 64-QAM.

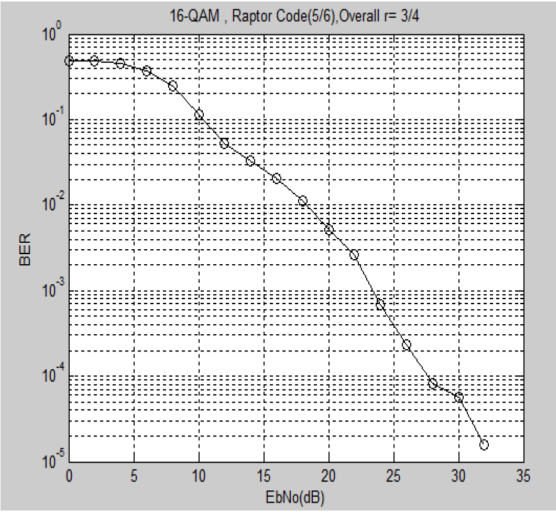

Fig. 3 BER vs EbNo for 16-QAM using Raptor codes with (r=3/4)

Simulation has been done in MATLAB and control parameters are used to evaluate the performance of wireless OFDM system namely Bit error rate (BER) and Spectral Efficiency. Fig.3 shows the BER vs EbNo for Raptor codes with (r=3/4) using 16-QAM Modulation Techniques. Fig. 4 demonstrates the Spectral Efficiency vs EbNo for Raptor codes with (r=3/4) using 16-QAM Modulation Techniques. Fig.5 depicts the BER vs EbNo for Raptor codes with (r=3/4) using 64-QAM Modulation Techniques. Fig.6 indicates the Spectral Efficiency vs EbNo for Raptor codes with (r=3/4) using 64-QAM Modulation Techniques.

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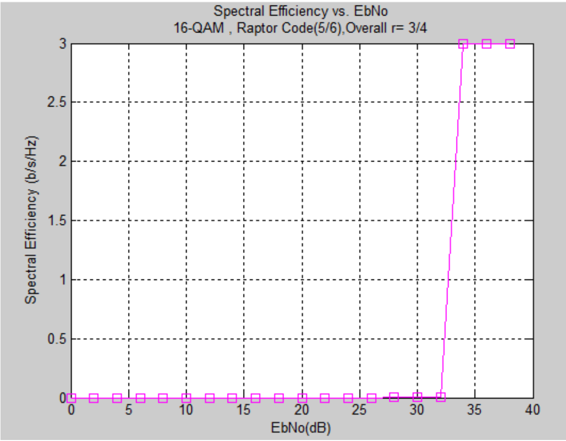

Fig. 4 Spectral Efficiency vs EbNo for 16-QAM using Raptor codes with (r=3/4)

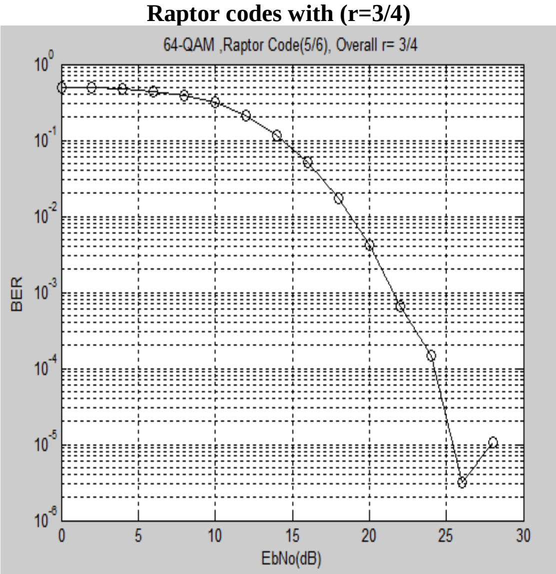

Fig. 5 BER vs EbNo for 64-QAM using Raptor codes with (r=3/4)

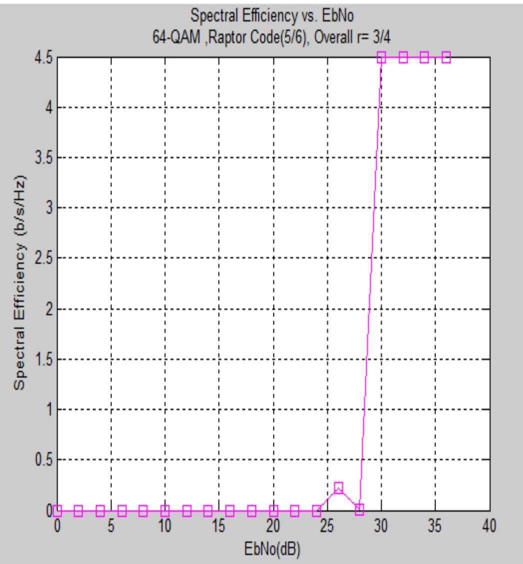

Fig. 6 Spectral Efficiency vs EbNo for 64-QAM using Raptor codes with (r=3/4)

VI. CONCLUSIONS

Different coding techniques are used for the performance evaluation such as convolution code; turbo codes, RS codes and Low density parity check (LDPC) codes. We are using the Raptor codes to evaluate the performance of the wireless OFDM system. Raptor code is new emerging rate less code which has shown amazing performance over variety of channels. Different channel model are used for the performance measure. We use the Stanford University Interim (SUI-3) channel models. Two performance measure parameters are bit error rate and spectral efficiency. Simulation results are presented for the effectiveness of the proposed Raptor codes with Stanford University Interim (SUI-3) channel. The simulation result based on 16-QAM and 64-QAM modulation technique using Raptor codes for BER and spectral efficiency measure.

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