IOP Conference Series: Materials
Science and Engineering

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To cite this article: Awatif A Jafaar *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **870** 012127

Performance Optimization of Image Transmission based Turbo and Precoder codes

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Abstract. The amazing performance of the concatenated codes led to attract many researchers to study these characteristics and use theme in many applications in recent years. Because the concatenated code theory is not built from the previous theories, so the characteristics of these codes remain under study and clarification. Recently, the concatenated codes became one of the main options for forward error correcting codes (FEC) in third generation mobile standards such as Universal Mobile Telecommunications System UMTS. This paper investigates the effect joint source –and channel coding which is considered a proficient system for wireless transmission. A new class of FEC is used which is known as a precoder of rate 1 as inner code and non recursive turbo code as outer encoder for hybrid system and then compared with the performance of UMTS turbo code standard for DCT compressed image.

1. Introduction

In wireless transmission, the signal distorts as a result of the channel impairment so high errors will be occur. From this standpoint, the great challenge when sending an image wirelessly has become achieving reliable, transmission for high quality recovered image. Many generations of networks has been adopted to achieve those factors, such as 3G, 4G and 5G [1].

Compression technology is considered one of the most techniques used in many applications that require storage of large amounts of data such as storage devices, multimedia and medical imaging. The reason for this is the fact that non-compressed images require a large storage capacity and channel bandwidth. Image compression technique is done by reducing the redundancy of the information according to certain algorithms hence reducing the file size, leading to the storage of larger amounts of data [2]. The Discrete Cosine Transform (DCT) was adopted in 1986 under the joint auspices of the ISO and ITU, in order to be used in standard image compression format known as Joint Photographic Experts Group (JPEG) [3]. When the channel unknown or varying with time which is the situation of the real time case, these schemes are not sufficient. Therefore, in order to solve this problem ,combining Systems of source coding and channel coding have been proposed to strengthen the technology of source coding which is sensitive to errors that occur through the transmission[4]. V.Aarthi and S.Navaneetha proposed a system compares between three types of decoder algorithms which are used for decoding process at receiver side [5]. In [6], the research suggested system that based Forward error correcting code (FEC) which known as Turbo code with image compression for OFDM system. Another type of FEC code which is used in [7] for image transmission known as a product code has been evaluated. In this paper the researchers suggested a scheme uses Low Density Parity Check code (LDPC) with Reed Solomon code as a channel coding technique for image transmission.

In this paper, the effect of using a new hybrid codes in UMTS application has been examined. This examination is done by coded the compressed image by a combination of parallel convolutional codes as outer encoder and precoder as inner encoder. The precoder which is a binary inverse filter used in this paper as error correcting codes to improves error correction capability without adding any redundant bits. The performance of this system is evaluated comparing with the UMTS Turbo code system in terms of Peak Signal to Noise Ratio PSNR, Bit Error Rate BER and image quality.

2. Forward Error Correcting Technique (FEC)

FEC is usually realized by adding redundant bits into the transmitted information bits. The detection and correction of errors in the received information stream can be done by utilizing these extra bits, so more reliable information transmission can be accomplished. The drawback of using channel coding to protect the information is a reduction in data rate or an expansion in bandwidth.

Error-correction coding theory was suggested in 1948. Turbo codes are attractive class of error correcting codes which were presented with a practical decoding algorithm.

To increase the code rate, a specific process which is called puncturing is used. Puncturing is the procedure of deleting some bits from the codeword according to a specific matrix called puncturing matrix. The puncturing matrix consists of zeros and ones where the zero refers to an omitted bit and the one refers to an emitted bit. Puncturing process can be considered for both block and convolutional codes [8].

An interleaver is a device that organizes the arrangement of data stream in a deterministic manner. The inverse of this process can be achieved by deinterleaver to restore the original data stream. Interleaving is usually used to spread out the errors occurring in burst. In this paper, interleaving is also used to provide the encoder with permutations so that the obtained redundancy sequence can be considered independent [9].

3. Overview of Precoders

Precoder is a specific class of synchronous sequential machines. It consists of two main parts: unit tap delay and modulo 2 adders. The important property of the precoder that it is correct errors without adding redundant bits to the data. Precoder is a binary inverse filter used to produce and check error correcting codes in communication scheme with transfer function shown in equation 1.

$$X/Z = 1/\,[\boldsymbol{h_0} + \boldsymbol{h_1 D^1} + h_2 D^2 + \boldsymbol{h_3 D^3} + \ldots\ldots\ldots\ldots \boldsymbol{h_n D^n}] \qquad (1).$$

Where + represents modulo 2 adder.

The circuit of precoder is satisfied the principle of superposition which is condition of any linear system. There are many types of precoder circuit which depend on the number of shift register, adders and the feedback connection. The general circuit diagram of precoder is shown in Fig (1).

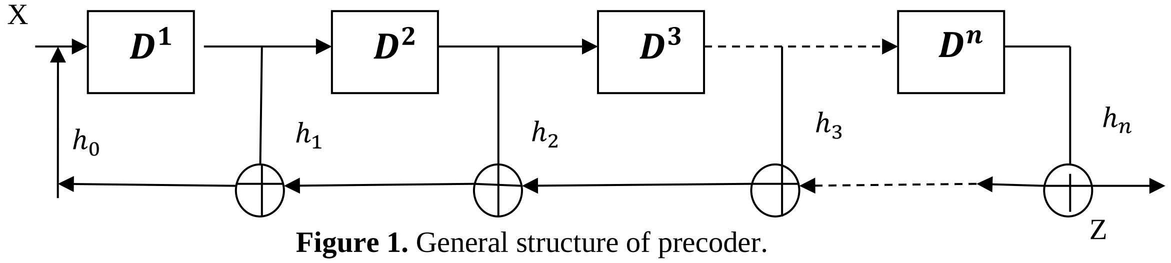

Figure 1. General structure of precoder.

There are many types of precodes such as $\boldsymbol{P_{r1}(D)/P_{r2}(D)}$ where $\boldsymbol{P_r(D)}$ is a finite field polynomial [10]. Although some of them are used to support the inner encoder by recursive characteristics, but they also increase the complexity. So, in this paper, a precoder with $\boldsymbol{1/1+D+D^3}$polynomial is used. The

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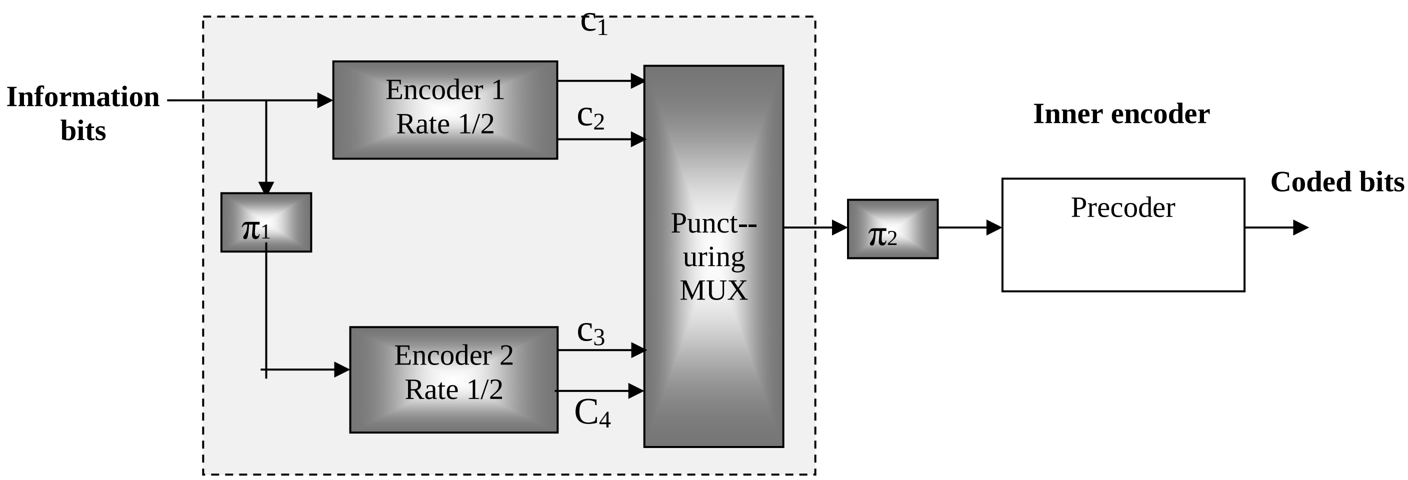
structure and the decoding algorithm are explained in [11]. The researcher examines the performance of serial concatenated convolutional code with convolutional code as outer encoder and precoder as inner encoder.

In this work, the concatenation between parallel convolutional codes are used as outer encoder and the inner is the precoder. The proposed system shown in Fig (2), consists of Turbo code of two convolutional encoder with rate 1/2 connected by a random interleaver ($\pi 1$) of length N. The data sequence and the two parity sequences result in a rate 1/4 code which is punctured to the desired rate by omitting specific bits to achieve the desired rate. Rate 1/3 is achieved by omitting 3 bits from various locations in codewords. The MUX purpose is to convert two or more parallel sequences to a single serial sequence. This sequence is then passed through a second interleaver $\pi 2$ and precoder of rate 1 to improve the error correction capability of the scheme.

The decoding process of the proposed scheme has been performed by iterative decoding using Soft Input Soft Output (SISO) Log-MAP decoder. The decoder circuit consists of three SISO detector, the outer one is designed according to precoded trellis and the other for outer parallel convolutional encoders. The DEMUX-puncture block has opposite function of MUX-puncture block. It is converting the serial sequence to parallel sequences, and adding 0's or 1's if it is necessary in position of the punctured bits. The LOG MAP decoding is explained in detail in [12].



(a)

Inner decoder

Outer decoder

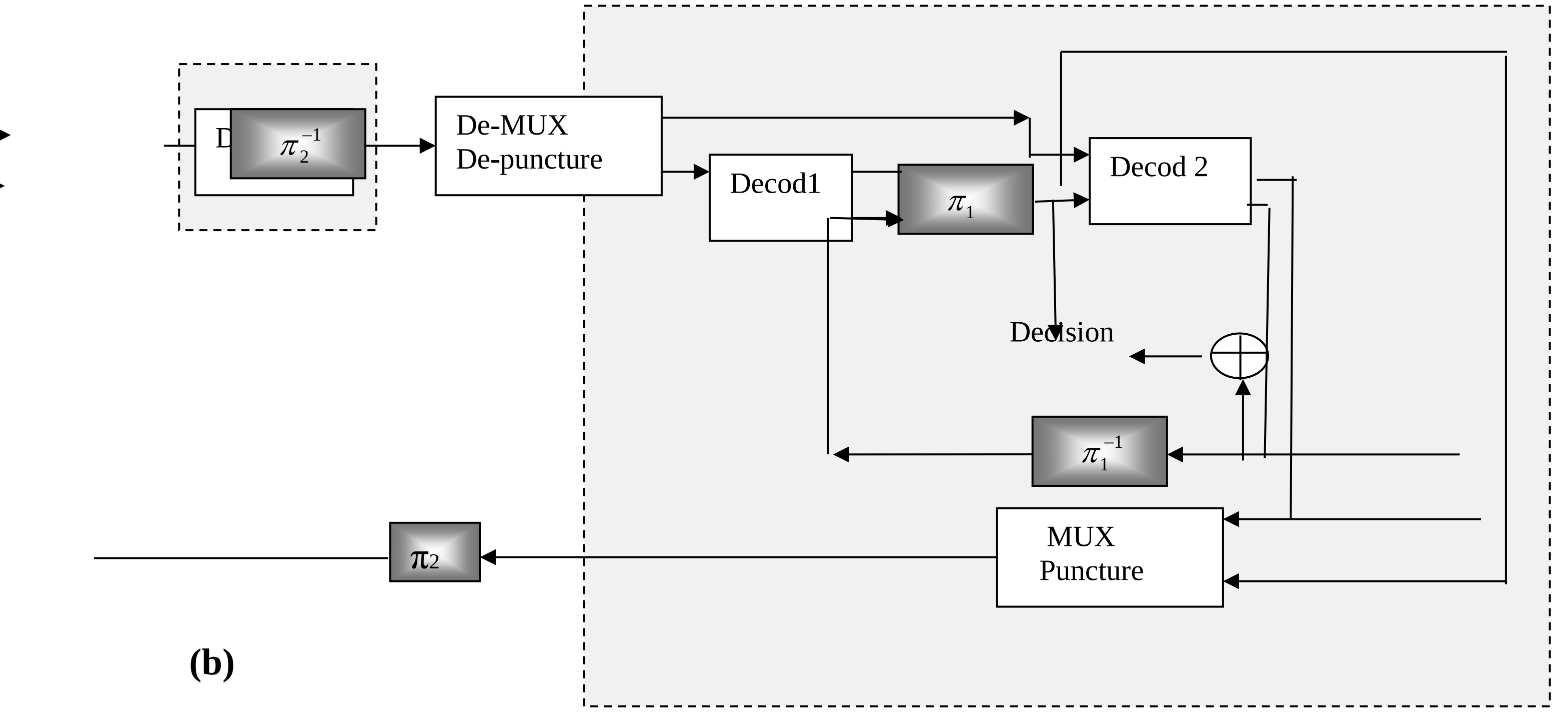


Figure 2. The Proposed Precoded channel: (a) encoder structure (b) decoder structure**.**

4. The Proposed System

The source image is divided into 8x8 pixel blocks and each block is transformed to frequency domain using DCT which separates image into variable frequency parts. Each block is divided into two parts: low frequency part at the upper left corner which contains the important information of the image. The other part contains high frequency coefficients which contain details. DCT enable us to separate high frequency from low frequency coefficients to select which values to cancel or maintain. Then the coefficients have been adaptively quantized by dividing each element in each block by quantization table Fig (3). The quantized coefficients then be entropy coded by Huffman code.

150	80	40	14	4	2	1	0
92	75	36	10	6	1	0	0
52	38	26	8	7	4	0	0
12	8	6	4	2	1	0	0
4	3	2	0	0	0	0	0
2	2	1	1	0	0	0	0
1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(a)

1	1	2	4	8	16	32	64
1	1	2	4	8	16	32	64
2	2	2	4	8	16	32	64
4	4	4	4	8	16	32	64
8	8	8	8	8	16	32	64
16	16	16	16	16	16	32	64
32	32	32	32	32	32	32	64
64	64	64	64	64	64	64	64

(b)

150	80	20	4	1	0	0	0
92	75	18	3	1	0	0	0
29	19	13	2	1	0	0	0
3	2	2	1	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(c)

Figure 3. Quantization of DCT coefficients (a) DCT coefficients (b) quantization table (c) quantized coefficients.

The compressed image then has been coded using FEC after binary transformation using two types of FEC, the first code is UMTS standard turbo code with structure of two systematic convolutional codes in parallel each of 4 constraint length and the generator polynomial are 15 and 13 in octal form. The second precoded proposed system which hybrid scheme of parallel turbo code of rate 1/3 as outer encoder and precoder rate 1 as inner encoder as shown in Fig(2a). Then, the coded data are modulated using Binary Phase Shift Keying (BPSK) modulation before being transmitted over AWGN and fading channel. The transceiver coded system is shown in Fig (4).

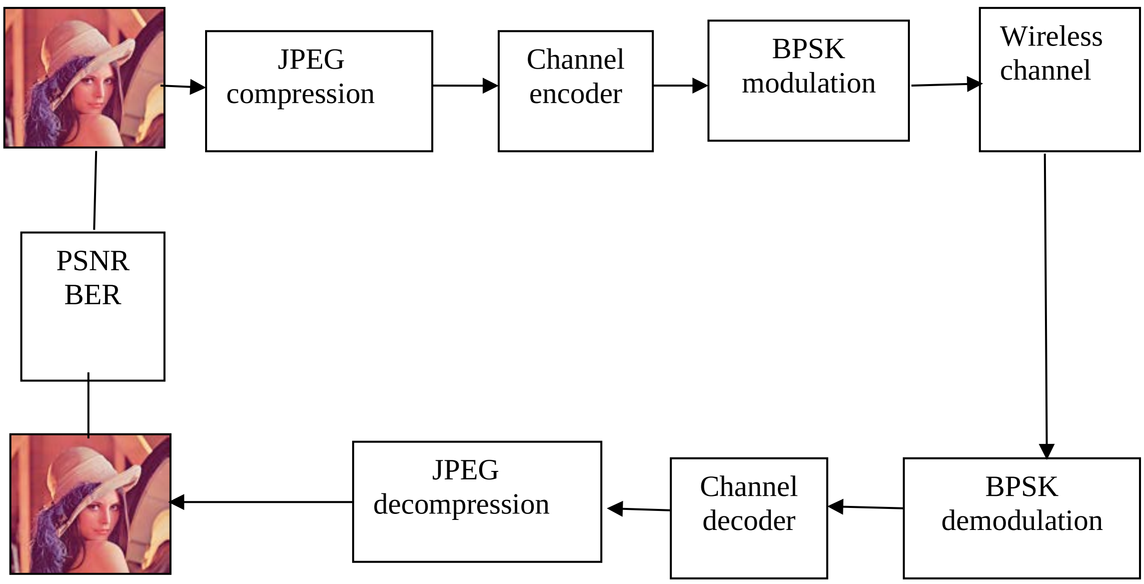


Figure 4. Image transceiver system.

5. Simulation Results:

The simulation results for wireless system are expressed in terms of PSNR, BER and image quality of the reconstructed images using MATLAB program. Performances of the UMTS turbo code standard system and the precoded proposed system have been examined. To get a fair evaluation, the same code rate is considered of the two systems which is equal to 1/3. The Soft Input Soft Output (SISO) LOG MAP decoding will be used and for three iteration.

The comparison between these systems over AWGN channel is shown in Fig (5). From this comparison it can be observed that the precoded system performs better BER than the other system where BER = 0 at 3dB for proposed system while for UMTS system BER= 0.412*10^-4.

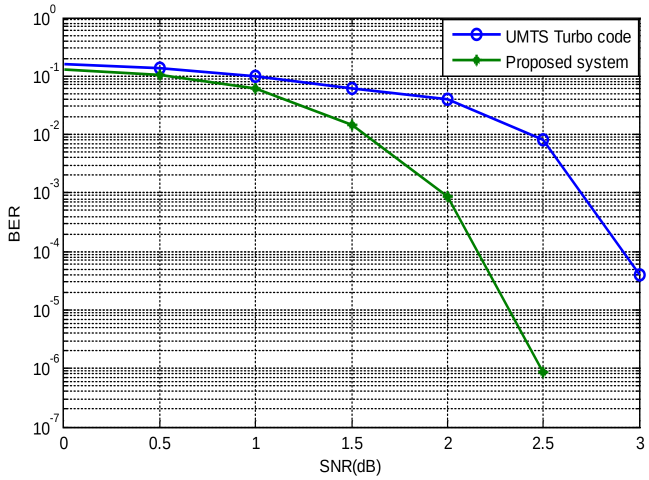


Figure 5. BER performances of UMTS turbo code and precoded systems.

The results of PSNR of recovered image are shown in table below. PSNR is a measure of how the quality of the reconstructed image is varying. It is the ratio between the maximum powers of a signal to the distorting noise that affects the fidelity of its representation [13].

$$\text{PSNR}=10log_{10}(\frac{255^2}{MSN}) \qquad (2)$$

Where MSE means mean squared error between the original and the reconstructed images.

Table 1. Comparison of PSNR of recovered image for UMTS Turbo coded and precoded systems

SNR	UMTS Turbo code	Precoded system
0	9.43	13.55
0.5	11.68	14.67
1	15.77	16.77
1.5	17.92	23.02
2	25.54	35.55
2.5	34.69	65.24
3	43.23	inf

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From this table it is clear that the proposed scheme gives low BER and high PSNR at low SNR which is considered as important goal for image transmission through a wireless channel.

From applying the proposed algorithm to transmission of the image besides precoder, the following figures are produced. The ability of the system to correct the errors at different SNRs can be shown.

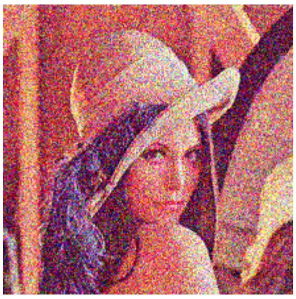

Figure 6. Received image at 0dB**.**

Figure 7. Received image at 2dB.

Figure 8. Received image at 2.5dB.

Figures 6, 7 and 8 give the recovered image of the precoded system at different values of SNR over AWGN channels. As shown from these figures, a small change in SNR gives high quality in the reconstructed image.

To evaluate the performance of the precoded system compared with UMTS turbo code system over fading channel, the following comparison curve is obtained. This comparison is done for three iteration and code rate 1/3 for both types of systems. It can be observed from the figure below that the precoded system improves the error rate at the receiver side with the same code rate for the both systems i.e. the precoder add no redundancy on UMTS turbo code system but improves BER.

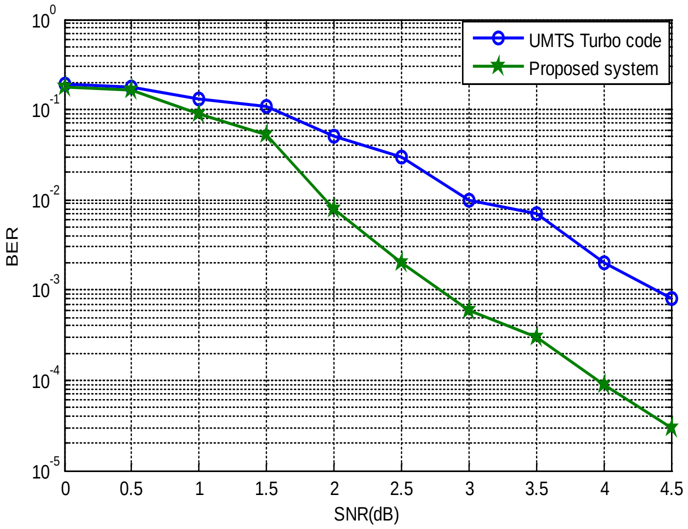

Figure 9. BER performances of UMTS turbo code and precoded systems over fading channel.

To explain the advantage of the proposed system, the comparison of PSNR value of recovered image compared to other methods is done. The comparison is achieved with the proposed systems in reference 5 at SNR =2dB.

Table 2. Comparison between the precoded system and the proposed systems in reference 5.

The proposed system	PSNR for recovered image(dB)
Proposed system	35.55
Enhanced LOG MAP	15.924
Modified LOG MAP	15.09
LOG MAP	14.9

From this table, the advantage of the proposed system can be clearly seen from the improvement of PSNR value compared to other methods

6. Conclusions

This paper described the concept of precoded system, whose basic structure depends on the concatenation of convolutional codes. This code is proposed in order to get an improvement in the recovered image at low signal-to-noise ratio. The AWGN and fading channel is used in the simulation and the results are presented in term of BER and PSNR of the reconstructed images. The precoded scheme has better performances in terms of BER and PSNR of the recovered image than the turbo coded system.

The interleaving stage is important to minimize the effect of burst errors. This improvement is obtained by spreading of burst errors. The decoding process is done for three iteration and this provided better coding gain at the decoder.

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Acknowledgments
We would like to express our thanks of gratitude to our college and university, Al- Mustansiriyah university, college of engineering for their encouragement and support in completing this research.