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LDPC Codes based Error Resilient Image Transmission over AWGN Channel

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***Abstract* - Error-resilient schemes have been developed in order to reliably transmit multimedia over unreliable channels. This paper presents the application of LDPC codes to the problem of reliable image transmission over wireless channels. Binary input additive white Gaussian noise (AWGN) channel is used in this paper. Pixels in error (PE) is evaluated for three different values of signal to noise ratio. The image is recovered with PE equal to zero at signal to noise ratio equals 1.5dB.**

Keywords - low-density parity-check (LDPC) codes, additive white Gaussian noise (AWGN) channel, image transmission, pixel in error

I. INTRODUCTION

The widespread deployment of wireline/wireless communication systems and the proliferation of digital media created the recent surge in multimedia transmission research. Since all communication channels suffer from errors, error-resilient schemes have been developed in order to reliably transmit multimedia over unreliable channels. High quality images are a crucial requirement in most wireless multimedia communications. Such applications require efficient error correction techniques for controlling errors introduced by noisy communication channels. Low-Density Parity-Check (LDPC) codes have received intense research attention lately due to their ability to achieve reliable transmission at rates approaching the channel capacity. This paper presents the application of LDPC codes to the problem of reliable image transmission over wireless channels.

The rest of the paper is organized as follows. Section II, briefs about the related work. We present an overview of LDPC codes in Section III. The proposed wireless image transmission system is described in Section IV. The simulation and results are given in Section V and Section VI concludes the paper.

II. RELATED WORK

Forward error-correction (FEC) code namely Low-Density Parity-Check codes were invented by Gallager in 1962 [1]. MacKay and Neal rediscovered LDPC codes exhibiting good error correcting capability [2]. LDPC codes are broadly classified into regular and irregular codes. Richardson and Urbanke proposed in [3], design of LDPC codes based on irregular bipartite graph that perform extremely close to Shannon limit. An efficient encoding algorithm for LDPC codes is developed in [4].

A number of schemes relating to reliable image transmission using LDPC codes have been investigated in the literature. Zhong*et al*. [5] were the first to propose a scheme based on LDPC codes for channel coding in a robust wireless image transmission system. Ma *et al*. [6] proposed an LDPC coded BICM scheme in image transmission system to improve both efficiency and reliability. Thomos*et al*. [7] proposed a novel scheme for error-resilient image transmission by employing a product coder consisting of LDPC codes and RS codes. Pan *et al*. [8] proposed a combined source-channel coding scheme for image transmission over fading channels by employing rate compatible LDPC codes along with embedded image coders. Ma *et al*. [9] proposed a method to design UEP-LDPC codes based on Gaussian approximation (GA) algorithm over AWGN channel for uncompressed image transmission.

III. LDPC CODES OVERVIEW

LDPC codes with uniform variable node degree and uniform check node degree are of type regular whereas codes with non-uniform degree are of type irregular. The degree distribution pair (λ, ρ) of the bipartite graph known as Tanner graph are expressed as follows.

$$\lambda(x) = \sum_{i=2}^{dv} \lambda_i \, x^{i-1}$$

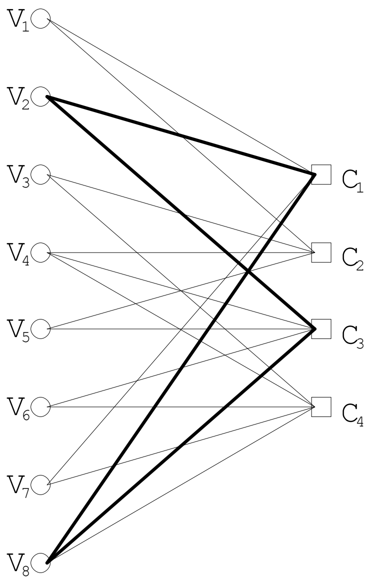
$$\rho(x) = \sum_{i=2}^{dc} \rho_i \, x^{i-1}$$

where $\lambda(x)$ and $\rho(x)$ represent variable node degree distribution with maximum variable node degree dv and check node degree distribution with maximum check node degree dc respectively.

For example, the parity check matrix H and the corresponding Tanner graph with code rate of one-half $(1/2)$ and code length $n = 8$ is as shown in Fig. 1. This Tanner graph contain 8 variable node and 4 check node. Six variable nodes

$$H = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}$$

(a)



(b)

Fig. 1. A (8,4) LDPC code: (a) parity check matrix (b) Tanner graph.

are of degree 2 and two variable nodes are of degree 3 whereas two check nodes are of degree 4and two check nodes are of degree 5. Hence the degree distribution pair for this example are $\lambda(x) = 0.75x + 0.25x^2$and $\rho(x) = 0.5x^3 + 0.5x^4$.The shor-test cycle in the Tanner graph is of length four (bold lines).

To encode, the parity check matrix H is transformed into lower triangular like matrix by using row and column permutations, and then the matrix is partitioned into sub-matrices. Then sub-matrices are used in the encoding procedure proposed in [4] to encode the input data message. For iterative decoding of LDPC codes, message passing algorithms [11] are generally used. The algorithm aspects the $a\ proiri$ probabilities in the form of log likelihood ratios which represent a level of belief about the value of the codeword bits.

IV. SYSTEM FOR WIRELESS IMAGE TRANSMISSION

A. Image Fundamentals

Each pixel of color image comprises of three color components red, green and blue whereas black and white (b/w) image pixel contain greyscale component only. The intensity of each color component is in range 0 to 255, so the binary equivalent of greyscale pixel and color pixel is of size 1 byte and 3 bytes respectively. The uncoded color image is converted into binary at rate of 24 bits per pixel (bpp).

B. Image Transmission System

Communications system for transmission of image over binary input additive white Gaussian noise (AWGN) channel is shown in Fig. 2. In forward error correction coding, to an uncoded image bit stream extra bits are added for the correction of errors at the decoding end. FEC codes such as LDPC codes

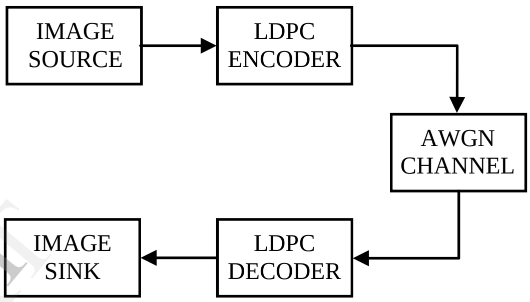


Fig. 2. Block Diagram of Image Transmission System.

have been used for error correction. The uncompressed image is read from the source and converted into binary equivalent for encoding and then transmitted over the channel. The received codeword bits are decoded before the reconstructing of the original image.

V. SIMULATION AND RESULTS

Degree distribution based on density evolution can be used to obtain LDPC codes with optimal performance. We use the variable node degree distribution sequence in the LDPC code construction algorithm proposed in [10]. The LDPC code is constructed for a maximum variable node degree of 10. The Tanner graph associated with constructed LDPC code parity check matrix is of type irregular and is free from short cycle of length-4 resulting in a girth-6 irregular LDPC code. The code rate is one-half $(r = 1/2)$ and code length is $n = 512$. The code has the following degree distribution pair.

$$\lambda(x) = 0.252x + 0.3086x^2 + 0.002x^3 + 0.4375x^9$$

$$\rho(x) = 0.375x^{10} + 0.625x^{11}$$

All the simulations are done using MATLAB platform. Table I list out the parameters used in the simulation. The soft decision decoding algorithm known as sum-product algorithm (SPA) is used in this paper for decoding purpose. The color image *Lena* of size 512×512 pixels used in simulation is shown in Fig. 3. The uncompressed image in binary format is of size 6291456 bits at the rate of 24 bpp. Before the transmission of image bit stream an equal amount of redundant bits are added to the bit stream as the rate of the LDPC code is $1/2$. Hence the total number of bits transmitted$N_t = 12582912$.The recovered images over AWGN channel at signal to noise ratio (E_b/N_0) equals $0.5dB$ is shown in Fig. 4.

TABLE I. SIMULATION PARAMETERS

LDPC Code	(512,256)
Code Rate	1/2
Maximum Iteration for Decoding	10, 25, 50
Modulation	BPSK
Channel	AWGN
E_b/N_0 in dB	0.5 , 1 , 1.5

Fig. 3. Original *Lena* image.

Fig. 4. Recovered image at E_b/N_0 equals $0.5dB.I_{max} = 10$.

The bit error rate (BER) is evaluated by the relation $BER = bits\ in\ error/N_t$. The pixels that remained uncorrected after the decoding i.e. pixels in error (PE) is calculated for various maximum decoding iteration(I_{max}). The BER and PE of recovered images over wireless channel at different values of signal to noise ratio (E_b/N_0) is tabulated in Table II.

TABLE II. ERROR PERFORMANCE OF IMAGE TRANSMISSION SYSTEM. IMAGE SIZE IS 512 × 512.

E_b/N_0 (dB)	BER $I_{max} = 10$	Pixels in Error		
		$I_{max} = 10$	$I_{max} = 25$	$I_{max} = 50$
0.5	8.728×10^{-4}	3987	1832	1169
1	6.938×10^{-5}	313	124	52
1.5	0	0	0	0

VI. CONCLUSION

We have simulated LDPC codes based wireless image transmission system. Simulation results for a color image of 512×512 pixels shows that at a specific value of E_b/N_o the pixels in error decreases with the increase in the maximum value of decoding iteration. As well as in the recovered image pixels in error is reduced to zero at E_b/N_0 equal to $1.5dB$.

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