Unequal Error Protection applied to JPEG Image Transmission using Turbo Codes

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Abstract — **An investigation of unequal error protection (UEP) methods applied to JPEG image transimmision using turbo codes is presented. The JPEG image is partitioned into two groups, i.e., DC components and AC components according to their respective sensitivity to channel noise. The highly sensitive DC components are better protected with a lower coding rate, while the less sensitive AC components use a higher coding rate. Simulation results are given to demonstrate how the UEP schems outperforms the equal error protection (EEP) scheme in terms of bit error rate (BER) and peak signal to noise ratio (PSNR).**

I. INTRODUCTION

Visual signals such as compressed still images are very vulnerable to channel noise. Usually, channel coding is utilized to protect the transmitted visual signals. The Joint Photograph Experts Group (JPEG) standard [1] proposed in 1992 is widely used for still image compression and transmission. Turbo codes [2] are suitable for protecting multimedia signals such as images since these visual signals are characterised by a large amount of data, even after compression. In this paper, we address the special case of JPEG still image transmission over noisy channels in which turbo codes are used for channel coding. UEP, which involves data partition with different coding rates, is a method used to protect different components of an image “unequally” according to their respective sensitivity to channel errors.

II. MOTIVATION AND GOAL

In a JPEG coded image, the coded bits are composed mainly of two types of bits, DC bits and AC bits. There are two justifications in applying UEP to JPEG coded images. First, in the two dimension discrete cosine transform (DCT) adopted by JPEG coding, the DC coefficient is a measure of the average value of the 64 image samples and contains a significant fraction of total image energy. Thus, the DC coefficients are treated separately from the AC coefficients in various source coding stages of JPEG. Secondly, due to strong correlation in adjacent DC bits, differential coding is applied to DC components. Thus, for DC bits, decoding errors in one block will lead to decoding errors in subsequent blocks. Conversely, for AC bits, decoding errors only affect local blocks.

Observing the output bits from a JPEG image encoder, we found AC bit number is around 6-12 times that of DC. This gives us a large space for applying UEP turbo coding on the output bits of a JPEG source encoder.

We allocate a lower coding rate to highly sensitive DC components and a higher coding rate to less sensitive AC components, while keeping the UEP coding rate the same as that of EEP. We will show how sensitive the BER and PSNR of an image is to different protection levels for DC and AC components. Ideal synchronization is assumed in the simulation results.

III. IMAGE COMMUNICATION SYSTEM

In the proposed image communication system, the JPEG still image compression standard is used as the source coding scheme. Turbo codes are used as the error control code.

The JPEG source encoder used in this study partitions the output bits into two groups of bits, i.e., DC bits and AC bits. Both are sent into a multi-rate turbo encoder. The multi-rate turbo encoder applies different coding rates to the DC and AC bits according to the particular UEP scheme. We assume that the channel is a binary input channel with additive white Gaussian noise. QPSK modulation is used. The turbo decoder decodes the UEP coded bits from the noisy channel output. The JPEG image decoder integrates the two groups of DC and AC bits into a standard image coded stream and outputs the reconstructed image.

IV. UEP SCHEME

The multi-rate turbo encoder used for UEP is capable of implementing two different code rates for the DC and AC components. Two different interleaver structures were examined. We denote DC bit number and AC bit number in a JPEG image by L_{DC} and L_{AC}. In the first interleaver structure, the DC and AC blocks are joined together to form a single block of the same size as that of the EEP scheme. Each block has its own interleaver. Figure 1 shows the structure of the first interleaver type.

The second interleaver structure design is to break the larger interleaver of size $L_{DC}+L_{AC}$ into x smaller pieces, each having an identical size of y bits. z is the number of buffer bits. We have

$$x = \left\lfloor \frac{L_{AC}}{L_{DC}} \right\rfloor + 1 \tag{1}$$

$$y = \left\lceil \frac{L_{DC} + L_{AC}}{x} \right\rceil \tag{2}$$

$$z = xy - (L_{DC} + L_{AC}). \tag{3}$$

The DC block contains L_{DC} DC bits and $y - L_{DC}$ AC bits. This is followed by $x - 2$ blocks containing AC bits. The last block contains $y - z$ AC bits and z buffer bits. Each block has the same interleaver size. The interleaver structure is showed in Figure 5. Using the same interleaver size for EEP and UEP simplifies the turbo encoder which is desirable from the point of view of hardware implementation.

Through varying the number of coded bits associated with each information bit, a multi-rate turbo encoder is obtained.

V. Simulation Results

In this section, we present some simulation results from transmitting JPEG coded "Lena" over the AWGN channel.

In JPEG image source coding, quality factor Q is used to control the compression ratio and thus the compressed image quality. In order to make the performance comparison independent of Q, average energy per pixel to noise ratio, E_p/N_o, is used instead of E_b/N_o as normally used in other data communication systems. The advantage of using E_p/N_o is to allow for fair comparison for systems with various source coding rates. Typically, PSNR has been used as the objective measurement of the reconstructed image quality. For the objective measurement, the average PSNR of the reconstructed image is plotted against E_p/N_o.

A 16 state multi-rate systemetic turbo codec with codes 35/23 in octal notation is used in the simulations. S-random interleaving is used. The PSNRs of "Lena" 64×64 and 256×256 images are 30.2643 and 34.1613, respectively. They are the highest PNSRs the receiver can obtain without any transmission errors.

Synchronisation is an issue when variable length coded (VLC) signals such as JPEG images are transmitted through noisy channels. In order to distinguish synchronisation errors from decoding errors, we assume ideal synchronisation within the DCT operational 8×8 subblock in our simulations. In [3], the authors investigated the UEP method applied to header bits and all the other image bits. In this study, we assume all the header bits are transmitted correctly.

UEP schemes using the first interleaver structure were simulated for the 64×64 "Lena" image. L_{DC} is 667 and L_{AC} is 9829. Three different coding rate allocations for DC and AC components were tried while keeping the total turbo coded bits the same as in the EEP case, i.e., overall rate 1/2 coding regardless of the code rate allocation between the DC and AC components. Figures 2 to 4 give BER performance comparisons while Figure 6 gives PSNR performance comparisons for three different UEP schemes. From these figures, we can see that the average PSNRs of UEP outperform that of EEP for low E_p/N_o, but is worse than that of EEP for high E_p/N_o.

An UEP scheme using the second interleaver structure was also simulated for the 256×256 "Lena" image. L_{DC} is 8910 and L_{AC} is 82578. x, y and z are 10, 9149 and 2, respectively. Figure 7 gives BER performance comparisons while Figure 8 gives PSNR performance comparisons. In this case, the average PSNRs of UEP outperform that of EEP in all interesting E_p/N_o regions.

For the first interleaver type, the PSNR performance of the UEP schemes are worse than that of the EEP scheme for high E_p/N_o. The underlying justification is that the interleavers of the DC and AC block are of different size. The interleaver size of the AC block is more than 10 times larger than that of the DC block. Thus the AC interleaver gain for high E_p/N_o is much larger than that of DC. Conversely, for the second interleaver type, the interleaver size of the DC and AC blocks are of the same size. Therefore the interleaver gain has the same influence on both DC and AC blocks.

VI. Conclusion

UEP methods applied to JPEG image transmission using turbo codes are investigated in this paper. The DC and AC components are protected with different coding rates. Different UEP schemes are compared to that of EEP in terms of both BER and PSNR. The simulation results revealed:

1. The BER of highly sensitive DC bits is very sensitive to channel coding rate allocation. A slightly lower coding rate for DC components will lead to significant DC BER drop while keeping the corresponding AC BER close to that of EEP.

2. For very noisy channels, where E_p/N_o is relatively low, UEP schemes are better than EEP in terms of BER and PSNR. For higher E_p/N_o, the average BER of the most important DC component is much lower than that of EEP. The average PSNR of UEP schemes is slightly worse than that of EEP for the first interleaver structure but slightly better for the second interleaver structure.

References

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[3] X. Fei and T. Ko, "Turbo-codes used for compressed image transmission over frequency selective fading channel," *IEEE Globecom'97*, New York, NY, USA, vol. 2, pp. 629–633, Nov. 1997.

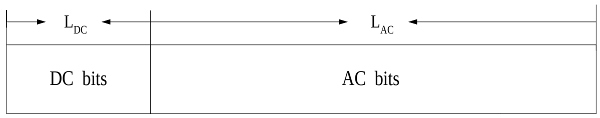

Fig. 1: the first interleaver structure type

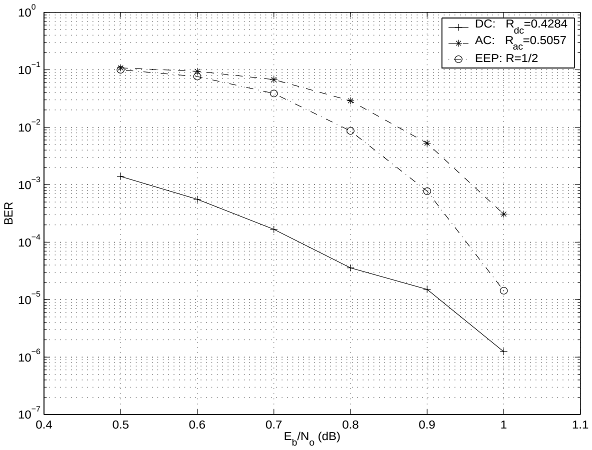

Fig. 2: BER performance comparison of EEP and 1st UEP scheme for LENA64 (1st interleaver type)

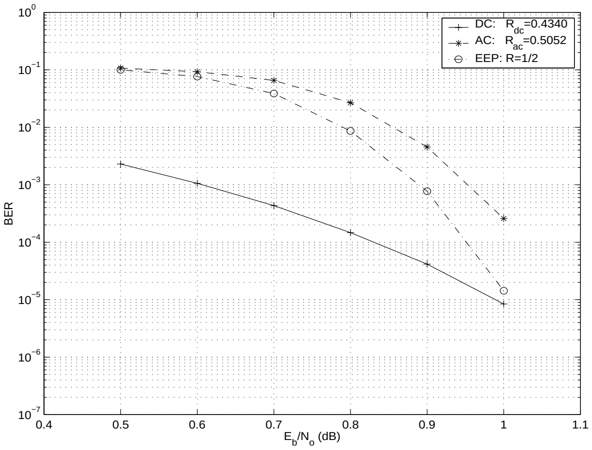

Fig. 3: BER performance comparison of EEP and 2nd UEP scheme for LENA64 (1st interleaver type)

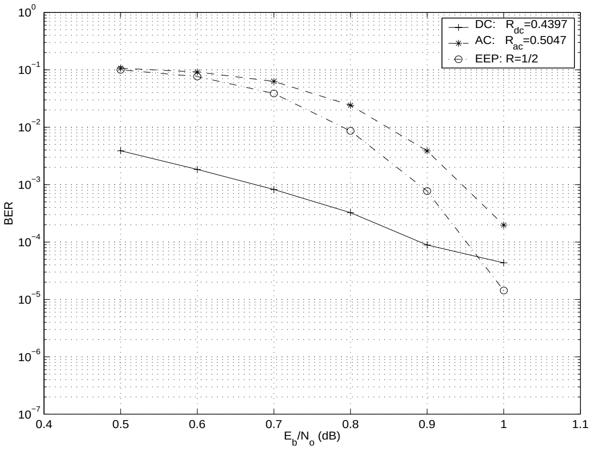

Fig. 4: BER performance comparison of EEP and UEP 3rd scheme for LENA64 (1st interleaver type)

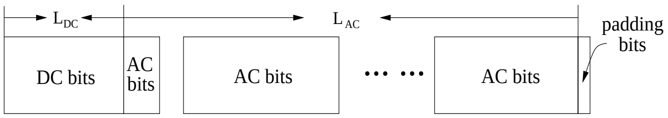

Fig. 5: the second interleaver structure type

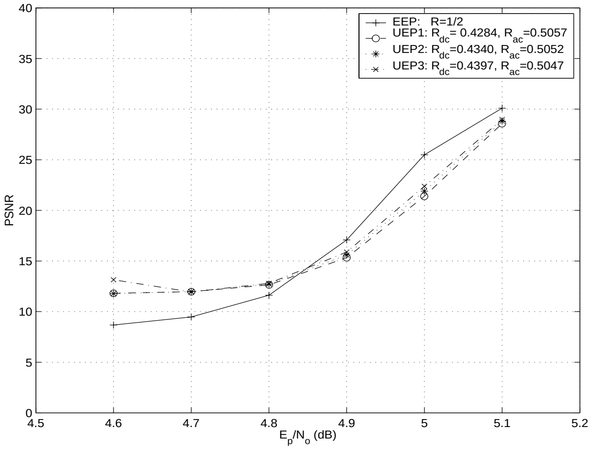

Fig. 6: PSNR performance comparison of EEP and UEP schemes for LENA64 (1st interleaver type)

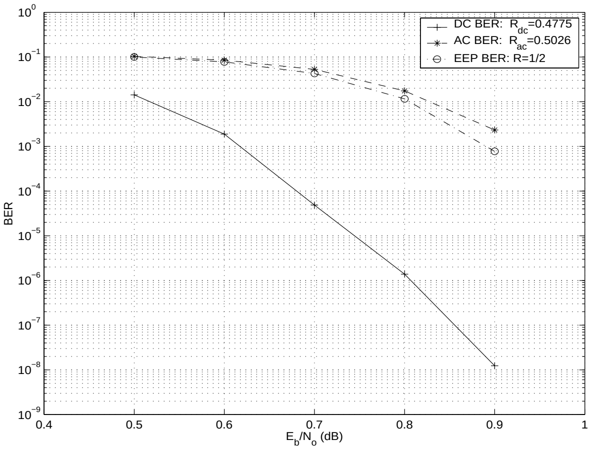

Fig. 7: BER performance comparsion of EEP and UEP scheme for LENA256 (2nd interleaver type)

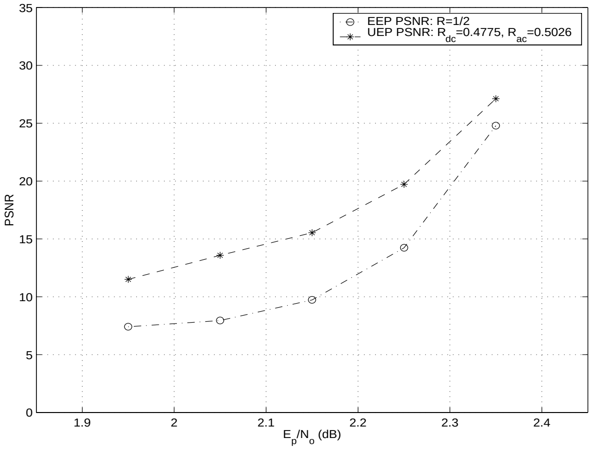

Fig. 8: PSNR performance comparison of EEP and UEP scheme for LENA256 (2nd interleaver type)