An Adaptive UEP_BTC_STBC System for Robust H.264 Video Transmission

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Abstract

A new adaptive UEP_BTC_STBC scheme is proposed to guarantee the robust video transmission according to the channel conditions. This scheme enhanced STBC (space- time block coding) by concatenating BTC code (block turbo code), both the good error correcting capability of BTC and the concurrent large diversity gain characteristic of STBC can be achieved simultaneously. Furthermore, by employing different BTC codes together with different modulation approaches, the scheme is capable of adapting to channel conditions and maximize end-to-end QoS of video transmission. Simulation result shows that the proposed adaptive scheme achieved significant improvement in delivered video quality according to channel condition.

1. Introduction

With the development of multimedia communication services, robust video transmission over wireless environment poses many challenges. The lossy wireless channel causes high transmission errors of the compressed video data and thus results in deterioration of video reconstruction quality.

STBC for wireless communications has drawn enormous attention since 1998 [1]. STBC not only can exploit the spatial diversity and the temporal diversity simultaneously, but also can be easily implemented with a linear decoding complexity. Those features have made it applicable in wireless channel. While because the decoding performance of the STBC decoder couldn't be improved by soft decoding, its error correcting capability is limited. To improve the bit error rate (BER) performance, it is conceivable to concatenate STBC with a code design that has a high error correcting capability and acceptable decoding complexity, which motivates a flurry of interest in searching for a good concatenating scheme [2-7].

Among the many kinds of error correcting codes, turbo block code (BTC) [8], also known as turbo product code, has attracted keen research interest recently. It is a multiple dimensional code and can even achieve a smaller distance from the Shannon limit with iterative decoding than the convolutional turbo code (CTC) [8], which is generally regarded as the best linear code. The proposed BTC can guarantee a minimum distance of 9 [8] while the minimum distance of a CTC can be as low as 2 [9]. Hence we propose an STBC decoder concatenating with a BTC decoder, the former acts as the inner code while the latter acts as the outer code. Thus the large diversity gain offered by STBC and the superior error correcting capability of BTC can be achieved simultaneously. In this paper, we proposed a new adaptive UEP_BTC_STBC scheme to provide robust video transmission over Rayleigh fading channel. According to channel conditions the scheme can switch to different BTC codes together with different modulation modes to maintain the video quality at acceptable levels over a relatively wide range of SNR.

2. Video Transmission System

2.1 Source Video Coding

H.264 is the newest video coding standard. In this paper, according to the importance of the coded video stream we use data partition to put the encoded data into three different streams. Each stream carries certain syntactical elements of coded video stream.

Table 1. Data partition for H.264 element syntax

Partition	Syntax element
Partition A (Stream 1)	SE_HEADER, SE_MBTYPE, SE_CBP_INTRA, SE_MVD, SE_INTRAPREDMODE, SE_REFFRAME, SE_PTYPE, SE_BFRAME, SE_EOS, SE_DELTA_QUANT_INTRA
Partition B (Stream 2)	SE_LUM_DC_INTRA, SE_CHR_DC_INTRA,SE_LUM_AC_INTRA, SE_CHR_AC_INTRA,SE_CBP_INTER, SE_DELTA_QUANT_INTER
Partition C (Stream 3)	SE_LUM_DC_INTER, SE_LUM_AC_INTER, SE_CHR_DC_INTER, SE_CHR_AC_INTER

There are 20 syntactical elements defined in [10], in table 1 we category those elements into three partitions. The partition A contains the most important information needed to decode picture frames thus it needs highest level of error protection. Partition C requires least protection since information in partition A and B is used to decode data in partition C.

2.2 Adaptive UEP_BTC_STBC System

Our system model is shown in Fig.1. H.264 source encoder partitions the output information into three different streams according to the Table 1. Those three streams are channel encoded by the different BTC

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codes according to the importance of streams and the channel state information (CSI), and then those three streams are modulated one by one by the most appropriate mode based on CSI and integrated into one stream. After STBC encoder, the stream is sent into wireless channel. Here, BTC acts as an inner code while STBC acts as an outer code. At the receiver, after STBC decoder, demodulation, BTC decoder, three streams finally are sent into H.264 decoder to get reconstructed video sequence.

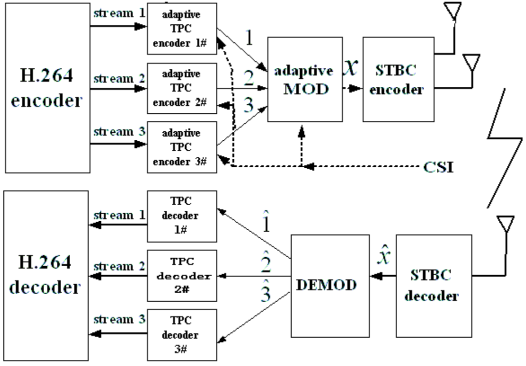

Fig.1 adaptive UEP_TBC_STBC system structure

2.3 Transmitter and receiver

An example of a two-dimensional BTC encoding scheme is a row BCH code multiplied by a column BCH code : BCH(n_1,k_1,δ_1)× BCH(n_2,k_2,δ_2) [8], where n_i, k_i and δ_i (i=1,2) stand for the length of a codeword, the length of information bits and the minimum Hamming distance respectively. The data rate of this BTC encoder is $(k_1 \times k_2)/(n_1 \times n_2)$ and its minimum Hamming distance is $\delta = \delta_1 \times \delta_2$. Thus a long block code with a large Hamming distance can be constructed by combining short codes with small Hamming distances and the resulting error correction capability will be strengthened significantly. Another attractive feature of this BTC is that the decoding speed can be increased by employing a bank of parallel elementary decoders for the rows and columns of the product code since they are independent but with same structure.

Subsequent to the BTC encoder, the information stream is modulated by PSK or QAM constellations and then sent to the STBC encoder, where it is subdivided into N streams according to the STBC encoding matrix and then transmitted from N transmit antennas separately. The diversity gain is N times compared with only one transmit antenna if the appropriate design criteria have been satisfied [11, 12].

Assuming that the STBC design in [1] is adopted, the full rate oding matrix for an encoder with two transmit antennas can be represented as:

$$\mathcal{G}_2 = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} = \begin{bmatrix} c_1^1 & c_1^2 \\ c_2^1 & c_2^2 \end{bmatrix} \qquad (1)$$

where the superscript '*' denotes the conjugation operation, x_1 and x_2 are the symbols to be transmitted per block, i.e., the number of symbols per block is K_0=2. The symbols c_t^i (i=1, 2,…, N and t=1,2,…,P) in the i_{th} column are transmitted by the i_{th} transmit antenna. In this example, the number of transmit antennas is N=2 and the number of time slots occupied by one block is P=2.The normalized data transmission rate of the system with this combined BTC_STBC encoding scheme is:

$$R = \frac{k_1 k_2 K_0}{n_1 n_2 P} Q_0 \qquad (2)$$

where Q_0 is the number of bits per symbol and its value therefore depends on the modulation scheme adopted.

In the receiver, the signal detected by the j_{th} antenna is:

$$r_t^j = \sum_{i=1}^{N} h_{i,j} c_t^i + \eta_t^j \qquad (3)$$

Again, all path gains $h_{i,j}$ have zero mean and a variance of 0.5 per dimension for Rayleigh flat fading channels.

The detected signals given by the expression in (3) are firstly STBC decoded in the symbol level. Applying the linear maximal likelihood detection results [1,11,12], the output of the STBC decoder will be those signals with the minimal Euclidean distance from the received codewords for each symbol assuming perfect channel state information. After STBC decoder, the output is then demodulated and decoded by the soft BTC detection. The detail description of BTC soft decoding can be found in [8][13].

3. Simulation

We investigate our adaptive UEP_BTC_STBC video transmission system in a Rayleigh flat fading channel. At the source coding side, H.264 encoder software is based on the platform of the reference software JM8.6. The Foreman sequence with 100 frames at QCIF resolution are encoded with IBPBP structure. Period of I-Frames is 15 and frame rate is 30fbs. Each frame is used as one slice and partitioned into three streams as table 1.

After H.264 encoder, the output three compressed streams are sent into the different BTC encoders to provide different error protection, each BTC code is a row BCH code multiply a column BCH code, here we all use the same row and column BCH code. Then the three streams are modulated one by one. In our simulation, the symbol transmission rate is set to be 128Ksps. If the modulation mode is BPSK, the message bitrate (after channel coding) r_{s+c} is 128Kbps.

While if QPSK or 8PSK is selected, the message bitrate r_{s+c} will be 256Kbps or 384Kbps. After modulation, the G_2 STBC coding is selected with two transmitter antennas (N=2) and one receives antennas (M=1). For soft detections, the parameters are: γ=[0 0.2 0.3 0.5 0.7 0.9 1 1 1 1], β=[0.2 0.4 0.6 0.8 1 1 1 1 1 1], p=2 and four times of iterations. At each SNR value, at least 30 simulations were run. Table 2 gives the different BTC schemes of error protection.

Table 2. different schemes

Scheme	Streams (str.)	BTC code	Code rate
UEP-1	UEP1-str1	$(15,7,5)^2$	0.22 (bits/s/Hz)
	UEP1-str2	$(31,21,5)^2$	0.46 (bits/s/Hz)
	UEP1-str3	$(31,26,3)^2$	0.70 (bits/s/Hz)
UEP -2	UEP2-str1	$(31,21,5)^2$	0.46 (bits/s/Hz)
	UEP2 -str2	$(63,51,5)^2$	0.65(bits/s/Hz)
	UEP2 -str3	(63,57,3)	0.80 (bits/s/Hz)
EEP1	Three streams	$(15,11,3)^2$	0.54 (bits/s/Hz)
EEP2	Three streams	$(31 ,21,5)^2$	0.46 (bits/s/Hz)
EEP3	Three streams	$(63,51,5)^2$	0.65(bits/s/Hz)
BM [4], Turbo+STBC, transmission rate: 0.33 bits/s/Hz			
HL [5], Convolutional+*DSTBC, transmission rate: 0.5 bits/s/Hz			

*DSTBC: differential STBC

Figure 2 shows the BER performance of the three encoded H.264 streams under two unequal error protection schemes together with BPSK modulation mode. We can see that those two schemes all can protect the H.264 encoded video streams at different level. Stream 1 is the most important information in the H.264 decoding process, so we give it the highest protection, and its BER curve is the lowest. Theoretically, partition C is less important than partition A and B, hence it requires the lowest level of error protection and its BER curve is the highest. From Figure 2 we also can see that different protection scheme can lead to different BER performance. The higher the protection levels the better BER performance.

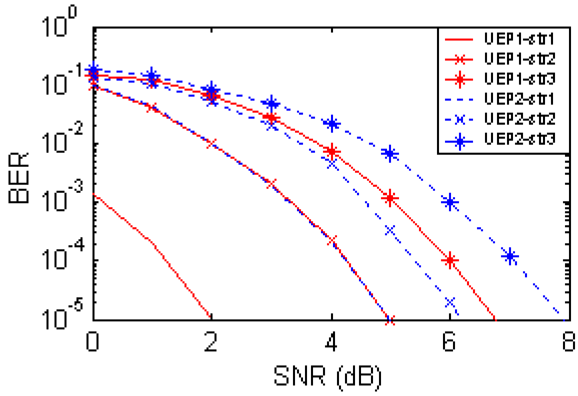

Fig. 2 BER performance of different streams

Figure 3 shows the BER performance of UEP schemes, EEP schemes. Here we also compared our system with other reported concatenating schemes [4, 5], which can be regarded as equal error protection and are comparable with our EEP1 scheme. From Figure 3 we can see that our BTC_STBC scheme is better than other reported concatenating schemes. When BER is 10^{-3} and code rate is about 0.5bits/s/Hz our scheme outperforms the BM scheme 3dB and the HL scheme 1.6dB respectively in terms of SNR improvement.

Now let's look at the PSNR of H.264 reconstructed video sequence under various BTC protection schemes when the modulation mode is BPSK. We use the same error concealment method at the H.264 decoding process. Figure4 shows the average PSNR of the reconstructed Foreman equence under different schemes. We can see clearly that unequal error protection's performance is better than equal error protection at the most of the SNR. The reason of UEP scheme outperforming EEP scheme is that UEP scheme give different level of protection according to different importance of the streams. Stream1 carries the most important information; its error bits will greatly degrade the decoder's performance and directly influence the decoding of stream2 and stream3. So in UEP scheme, it has the highest protection. While stream3 only includes the inter DCT coefficients which don't need too much protection, once it is corrupted, we still can do error concealment according to the correct information of stream1 and stream2, thus weak protection is applicable. On the other hand, EEP scheme can't use this characteristic of the streams. The protection of stream1 is not enough while stream3 is over protected, which leads to bad decoding performance.

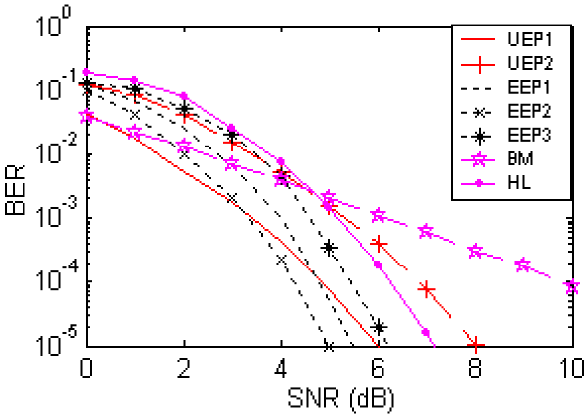

Fig. 3 BER performance of various protection schemes together with BPSK

From Figure 4 we also can see that when SNR range is low, UEP1'performance is better than UEP2. However as channel conditions improve (i.e. SNR increase) the PSNR will saturate quickly at lower level, which makes the system very inefficient for large SNR. On the other hand, UEP2 will provide better efficiency for larger SNR by allowing larger r_{s+c}, but at the expense of poorer performance as SNR decreases compared with UEP1. Thus we want to design an adaptive UEP system to maintain the video quality at acceptable levels over a relatively wide range of SNR according to channel condition.

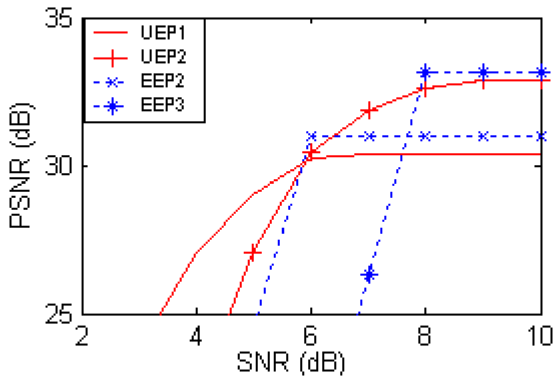

Fig. 4 the average PSNR of Foreman sequence under various protection schemes together with BPSK

Figure 5 shows the average PSNR of the Forman sequence at various UEP protection schemes. Here, to make the system's performance more efficient, we also employ the different modulation approaches. In Fig.5, it is clear that UEP1 with BPSK scheme can provide the highest protection and achieve the best PSNR performance at lower value of SNR, but its PSNR will saturate at low level quickly, thus lead to inefficiency in the high range of SNR. On the other hand, at higher range of SNR, UEP2 with QPSK, 8PSK or 16QAM can achieve better efficiency and better video reconstructed performance but at the cost of rapidly degradation of video quality as SNR decreases.

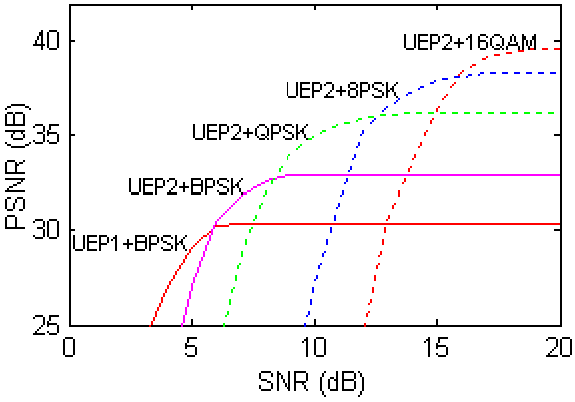

Fig.5. The average PSNR of Foreman sequence under various UEP protection schemes

Thus, we want to design an adaptive UEP scheme, which can switch between these different UEP schemes according to CSI. Here, we suppose that CSI is known at the transmitter. Then according to CSI, we can get the SNR value. When SNR is lower than 6dB ($SNR \leq 6dB$), UEP1 with BPSK scheme is employed, while when the SNR is from 6dB to 8dB ($6dB < SNR \leq 8dB$), we switch to UEP2 with BPSK. Then when the SNR is from 8dB to 12dB ($8dB < SNR \leq 12dB$), UEP2 with QPSK is used. When the SNR is from 12dB to 16dB ($12dB < SNR \leq 16dB$), we employ UEP2 with 8PSK. At last, when SNR is higher than 16dB ($SNR > 16dB$), we can use UEP2 with 16QAM to provide better efficiency and better video quality.

4.Conclusion

A new adaptive UEP_BTC_STBC system to transmit the video sequence over wireless channels is proposed. The simulation result ensures that the performance of this system is highly effective and efficient according to the channel state information and can guarantee high video transmission quality over a large range of SNR. Furthermore, simple structure and linear processing characteristics of STBC and the fast decoding speed of BTC makes our system more attractive and applicable. Our method also can apply to the scalable video transmission.

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