WIRELESS VIDEO TRANSPORT USING CONDITIONAL RETRANSMISSION AND LOW-DELAY INTERLEAVING

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ABSTRACT

We consider the scenario of using Automatic Repeat reQuest (ARQ) retransmission for two-way low-bit-rate video communications over wireless Rayleigh fading channels. Low-delay constraint may require that a corrupted retransmitted packet not be retransmitted again, thus there will be packet-errors at the decoder which results in video quality degradation. In this paper, we propose a scheme to improve the video quality. First, we propose a low-delay interleaving scheme that combines the interleaving memory with the video encoder buffer. Second, we propose a conditional retransmission strategy that reduces the number of retransmissions. Simulation results show that our proposed scheme can effectively reduce the number of packet errors and improve the channel utilization. As a result, we obtain PSNR (Peak Signal to Noise Ratio) improvement up to about 4 dB compared to H.263 TMN8.

1. INTRODUCTION

In this paper, we consider the scenario of using the ARQ retransmission scheme for two-way low-bit-rate video communications over wireless Rayleigh fading channels.

For two-way video communications over a narrow-band wireless channel with burst-error nature, the video is usually encoded with a low-bit-rate low-delay video coding standard such as H.263 [1]. H.263 applies motion-compensated prediction, Discrete Cosine Transform (DCT), and variable-length coding to reduce the temporal, spatial, and statistical redundancy between the video frames. This scheme achieves good compression ratios but also makes the signal susceptible to transmission errors.

Since a feedback channel is available in two-way communications applications and the communication channels of our consideration have short and constant end-to-end delays, Selective Repeat ARQ schemes can be used to obtain reliable communications [2]. However, during retransmissions, the effective channel bandwidth is reduced which results in lower PSNR [3,4]. Also, in two-way interactive applications, low-delay constraint may require that a corrupted transmitted packet may only be retransmitted a limited number of times, implying possibly a greater degree of packet loss in lossy channel conditions. We have investigated the effects of retransmission and packet-errors at the video decoder when we allow only retransmission once. The results show significant PSNR drop due to the packet errors.

To reduce the packet errors, interleaving can be used that converts burst errors to random errors for correction using a Forward Error Correction (FEC) code. However, in two-way video communications, the end-to-end delay constraint places a limitation on the use of interleaving. In this paper, we propose a low-delay interleaving scheme which combines the video encoder buffer with the interleaving memory so that the interleaving does not increase the delay and the memory in the video encoder.

In addition to the interleaving, the retransmission strategy itself could be improved. We propose a conditional retransmission scheme to reduce the number of retransmissions to improve the effective channel throughput. We use the concealment error and the channel condition to determine whether it is worthwhile to retransmit an incorrectly received packet. We also investigate the trade-off between the saved-bits due to the reduced retransmission and the distortion resulting from the concealment error due to corrupted packets that are not re-transmitted.

In the following sections, we discuss the low-delay interleaving and condition retransmission scheme we proposed and show simulation results.

2. LOW-DELAY INTERLEAVING

An Interleaving scheme with a BCH error-correction code has been shown to provide good performance in improving BER [5]. However, applying interleaving has two negative aspects: increasing end-to-end delay and increasing the required memory at the encoder and the decoder.

To alleviate the negative aspects of interleaving, we propose to combine the interleaving memory with the encoder buffer. The block diagram of incorporating the interleaving buffer into the encoder buffer is shown in Fig. 1. If the encoder buffer-size is M bits (corresponds to M/R_c ms delay where R_c is the channel rate in kbits/s), the interleaving memory size is set to be $X\%$ of the video encoder buffer size M. The interleaving is performed only when the video encoder buffer fullness is greater than $X\%$ (in order not to introduce interleaving delay into the system, since the data is already in the buffer) and when the channel is in the bad state (in order to save overheads when the channel condition is in the good

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state). If the encoder buffer fullness is low or the channel condition is good, we will rely only on retransmissions without the interleaving. The algorithm can be summarized as follows:

If (Buffer_fullness_level $\geq$ X% of the encoder_buffer_size) and (Current_State = S_b) {
Mark the boundary of data and Perform Interleaving;
}
else {
Rely on retransmissions only;
}

where S_b is the bad channel state which can be determined as described in [3,4] (e.g. by the ratio of averaged number of retransmitted bits to the average number of transmitted bits in the past N coded frame-intervals).

From our proposed algorithm, we could save the encoder interleaver delay of ~ $k\lambda/R_c$ seconds where R_c is the channel rate. No extra memory is required at the encoder since we use the encoder buffer for the interleaving memory.

In the simulations, $k\lambda$ was set to 50% of the video encoder buffer size. Since in TMN8, the encoder buffer size is M = 3200 bits (corresponds to 100 ms delay), $k\lambda$ is set to be 1600 bits. Several choices of BCH(n,k) which can correct one-bit error were investigated. Fig. 2 shows the simulation results of different BCH (n,k) codeword and interleaving degree λ on video quality for the test sequence "Claire". When a shorter codeword with a larger interleaving degree is used, the overhead is larger but the PER is reduced, and vice versa. The effects of reduced PER on the video quality is usually stronger than the effects of reduced channel throughput caused by the overhead. From the simulation results, we choose BCH(25,20) code with a block interleaving depth λ = 80 bits. The simulation results are discussed in Section 4.

3. CONDITIONAL RETRANSMISSION BASED ON CONCEALMENT ERROR

To further improve the channel bandwidth utilization, we propose a conditional retransmission strategy based on the concealment error motivated by the observation that it is not worth retransmitting packets for which the concealment at the decoder is adequate as indicated by a sufficiently low concealment error. To calculate the concealment error when a packet is lost, the same concealment mechanism used at the decoder is implemented at the encoder so that there is no mismatch between the encoder and the decoder.

We consider the case where the low-delay constraint allows only one retransmission which results in packet errors at the video decoder. These packet errors will cause errors to propagate. Since the GOB is the synchronization unit in H.263, at the receiving end, if the H.263 decoder detects a packet error, the decoder will give up decoding the corresponding macroblock and the following macroblocks in that GOB, and seek the next GOB sync-word. The corrupted macroblocks in the GOB will be discarded and replaced by the macroblocks at the same location in the previous decoded-frame.

If an error packet is not resent, the mean-square concealment error (MSE) caused by replacing the damaged area with the content from the previous frame is:

$$D_{CE} = \frac{1}{N_L} \sum_{(x,y)\in L} (\hat{f}_k(x,y) - \hat{f}_{k-1}(x,y))^2 \qquad (1)$$

where D_{CE} is the concealment MSE of the damaged area, frames k and k-1 are the current frame and the previous frame respectively, $\hat{f}(x,y)$ is the reconstructed pixel value at the coordinate (x,y), L is the damaged area due to the error packet, N_L is the number of pixels in the damaged area. This can also be calculated at the encoder when a NAK is received and after completing the encoding of the corresponding GOB.

The decision rule for retransmitting a packet or not is as follows:

If ($NAKPacket_j \in GOB_i$) and ($NAKPacket_{j-1} \in GOB_i$) {
Decision_as_previous_packet;
}
else {
If ($D_{CE} < T$) and (*Current_State* = S_b){
do not retransmit;
}
else {
retransmit;
}
},

where S_b is the bad channel state, and T is a threshold. The same threshold is used in all of the simulations. Based on this decision rule, if a packet is not retransmitted, the succeeding packets in the same GOB will also not be retransmitted since the concealment will be used for the area of that GOB. Also, when D_{CE} is less than T and the channel condition is bad, we will not retransmit that packet because either the concealment can do a good job and there is a high probability that the retransmitted packets will be corrupted again due to the bad channel condition.

4. SIMULATION RESULTS

We perform simulations to show the effects of packet errors on the video quality. The video encoder and decoder used in this study are based on TMN8, a test model for the H.263+ standard [6]. A wireless channel simulator simulating Rayleigh fading channels as described in [3,4],[7] is used in our study. Selective Repeat ARQ with a wireless channel roundtrip-delay of 30 ms is assumed. A delay constraint is set such that if a packet arrives at the decoder too late to meet the delay constraint, it is considered a lost packet.

Test video sequences including "Claire", "Car phone", "Miss America", and "Suzie" in the QCIF format (176x144 pixels/frame) were encoded at 32 kb/s with a target frame-rate of 10 frames/s using TMN8 and our proposed scheme. Simulations were performed with channel parameters corresponding to a BER of 0.01, a packet error-rate of 0.17, and an average burst-length of 19 packets, which corresponds to a slow-fading environment.

Fig. 3 shows the results of our proposed interleaving scheme for "Claire". Our scheme shows an improvement of about 2 dB compared to TMN8 under the same condition. Fig. 4 shows the simulation results for the same sequence with the PSNR comparisons among TMN8 with clean channel, TMN8 with packet-errors and concealment, and our proposed low-delay interleaving and conditional retransmission scheme. Our overall scheme shows an improvement of about 4 dB compared to TMN8. Table 1 shows the average channel throughput and PSNR comparison for all video sequences tested. The PSNR improvement is up to about 3 dB for our proposed interleaving scheme and up to about 5.5 dB for our conditional retransmission and interleaving schemes. Fig. 5 gives a subjective evaluation of the video quality for the "Carphone" sequence of our proposed scheme compared to TMN8 where a frame with significant PSNR improvement in video sequence is shown. The improvement is due to the reduced packet errors and retransmissions.

5. SUMMARY

In this paper, we proposed a low-delay interleaving and conditional retransmission scheme to improve the video quality for wireless video. We also discussed the tradeoff between the saved bits (from the conditional retransmission) and the concealment error. Simulation results show improvement in PSNR of up to about 4 dB for our scheme compared to H.263 TMN8. Subjective evaluation also confirms the significant video quality improvement.

6. REFERENCES

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Table 1. Comparison of the average throughput and PSNR for TMN8 under clean channel, channel errors, and using our proposed scheme

Video Sequence	Total Frames	Clean Channel		TMN8 with packet loss and concealment		Proposed Interleaving Scheme		Conditional Retransmission	
		Average Throughput (kbps)	PSNR (dB)	Average Throughput (kbps)	PSNR (dB)	Average Throughput (kbps)	PSNR (dB)	Average Throughput (kbps)	PSNR (dB)
"Claire"	162	32.0	39.51	28.1	32.68	29.0	34.58	29.9	36.48
"Car phone"	124	32.0	30.81	27.3	24.41	28.5	26.09	29.3	27.12
"Miss America"	49	32.0	39.86	25.5	32.00	28.0	34.31	30.2	36.46
"Suzie"	49	32.0	34.16	25.5	27.09	29.1	29.74	30.9	32.65

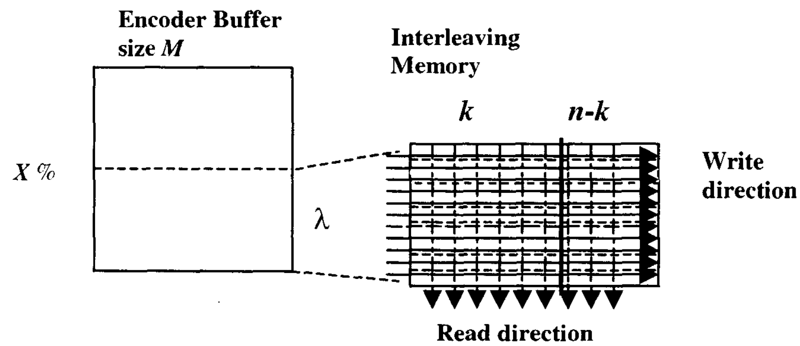

Figure 1. Block Diagram for the combined encoder buffer and the interleaver

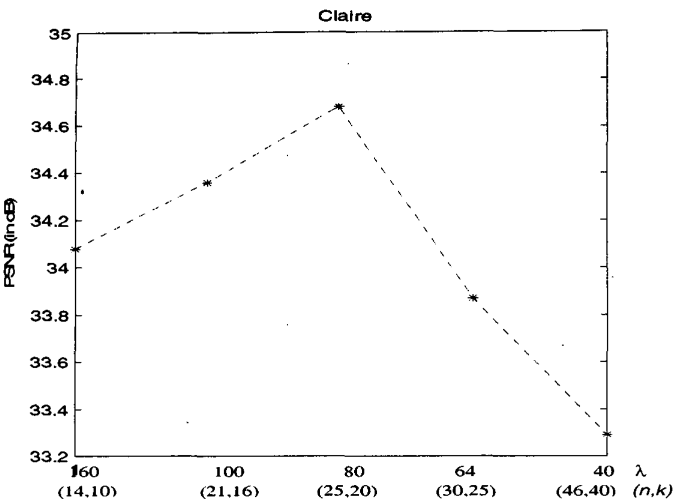

Figure 2. Effects of different interleaving degree (λ) and BCH code (n,k) on video quality. Test sequence is "Claire".

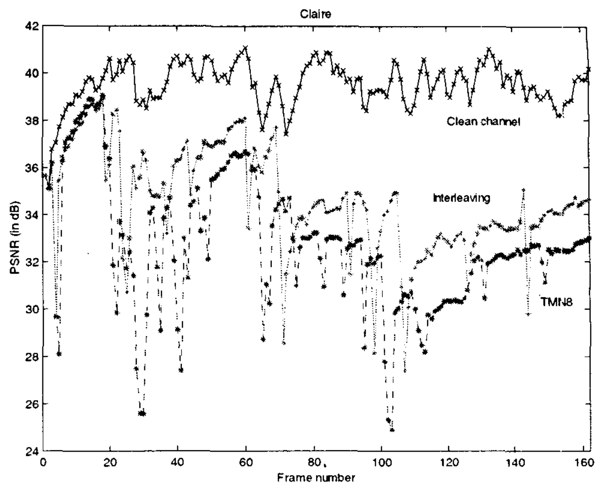

Figure 3. PSNR comparison for the "Claire" sequence between TMN8 in clean channel (-x- line), TMN8 with packet loss and concealment (dashed -*- line), and our proposed interleaving scheme (solid -*-line).

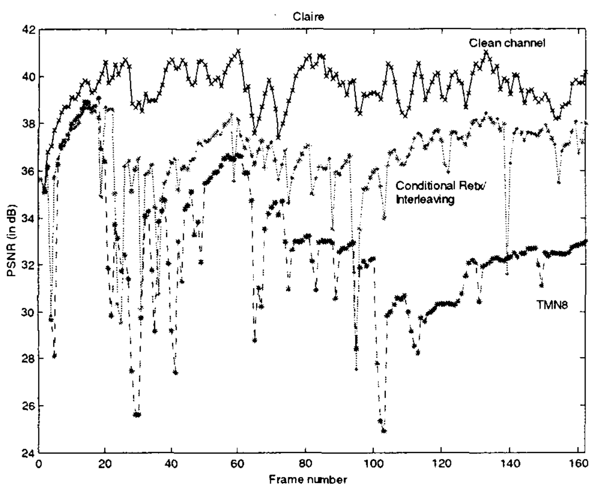

Figure 4. PSNR comparison for the "Claire" sequence between TMN8 in clean channel (-x- line), TMN8 with packet loss and concealment (dashed -*- line), and our proposed conditional retransmission and interleaving scheme (solid -*-line).

Figure 5. Subjective evaluation for 32 kb/s Carphone sequence. Reduce number of packet errors from interleaving with PSNR improvement of 4.5 dB for frame number 21. TMN8 shown in (a) and proposed conditional retransmission and interleaving scheme shown in (b).