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Burst-aware Adaptive Forward Error Correction in Video Streaming over Wireless Networks

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Abstract

Video streaming over wireless networks have many challenges due to the high error rate and burst packet error characteristic. Forward error correction (FEC) is a method commonly used to handle losses in real-time communication. Conventional FEC mechanisms provide redundancy by an averaged packet loss rate and performance decreases by burst packet losses. However, the average packet loss rate cannot give any indication of burst packet loss. Hence, the conventional FEC mechanisms cannot recover original source data over wireless networks. In this paper, we propose a burst-aware adaptive FEC (BAFEC) control mechanism to overcome burst packet losses. We will therefore be able to take account of average burst packet loss length. The sender can rely on this information in order to adjust the FEC redundancy. The experimental result shows that compared to the conventional FEC mechanisms, our proposed mechanism achieved better recovery performance in terms of packet loss rate and PSNR.

Keyword: Forward Error Correction, Adaptive, Burst packet losses, Wireless Networks, Quality of Service.

1. Introduction

Wireless video streaming poses great challenges due to the time-varying characteristics of wireless channels. However, the current wireless networks and existing mechanisms deployed on the Internet are lacking in quality of service (QoS) for video streaming. Random and burst errors occur frequently in wireless channels. Once bit errors occur during the transmission, the error will propagate due to the dependency among the compressed video streaming. As a result, the reconstructed video quality degrades severely. Therefore, how to protect the compressed video streaming data from channel errors is very important.

There are two commonly used error control schemes, automatic retransmission request (ARQ) and forward error correction (FEC) [1] [2]. In ARQ, missing data packets are retransmitted during timeouts or explicit receiver requests. Retransmitting lost packets in large-scale video streaming transmission is often unfeasible as retransmission incurred delay is unacceptable [3] [4]. FEC is thought to be more suitable for video streaming transmission due to its small transmission delay whilst it can also improve the reliability of transmission through adding extra redundancy information. FEC recovery for video delivered over a wireless network is the focus of this paper.

However, varying channel conditions will affect its effectiveness. Therefore, FEC should be designed in an adaptive scheme to overcome the transmission errors that occur in a wireless channel. Intelligent FEC redundancy adjustment has been an important issue in previous FEC studies [5] [6] [7] [8] [9]. In this previous work, they consider not only congestion losses but also wireless losses and packet loss rate to adaptive FEC redundancy. For example, when congestion losses happen, FEC redundancy must be decreased. On the other hand, when wireless packet losses happen, FEC redundancy must be increased. Nevertheless, they only considered packet loss rate to adjust FEC redundancy. In wireless networks, continuous packet losses were frequently lost [10] [11]. However, the burst loss induced by congestion losses or wireless errors decreases the recovery efficiency of FEC [12]. The average packet loss rate cannot give any indication of channel burst packet loss.

In this paper, we propose a burst-aware adaptive FEC (BAFEC) control scheme to overcome burst packet loss over wireless networks. We counted continuous packet losses, called “burst packet loss length”. Our proposed control scheme will statistically average packet loss rate to calculate FEC redundancy and burst packet loss length in order to

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adjust FEC redundancy at receiver to feedback to sender. Thus, sender can rely on this information to adapt FEC redundancy. When burst packet loss length is high, the FEC redundancy is increased. On the other hand, when burst packet loss length is low, the FEC redundancy is decreased.

The remainder of this paper is organized as follows. Our proposed BAFEC control scheme concept and algorithm is introduced in section 2. Section 3 discusses experimental setting and wireless error models. Section 4 analyzes simulation results. Finally, the paper is summarized.

2. Burst-aware Adaptive Forward Error Correction (BAFEC)

2.1 Adaptive FEC (AFEC) mechanism problem

In conventional FEC transmitting h FEC packets in an FEC block of k source data provides an error recovery against a packet loss rate of h/(h + k). For adaptive FEC algorithms, redundant data is added to transmission data relying on average packet loss rate [6]. When the error rate is low, the FEC redundancy is lower. On the other hand, when the error rate is high, the FEC redundancy is larger.

To analyze the effects of FEC for simplicity, the sending of packets is regarded as a series of independent Bernoulli trials. Therefore, the loss recovery function of the FEC scheme can be modeled as:

$$F(n, k, p) = \sum_{i=k}^{n} \binom{n}{i} (1-p)^{i} p^{n-i} \quad (1)$$

where p is the average packet loss rate. The recovery rate R can be thus attained by calculating the probability that more than k packets out of n are successfully received while given the degree of redundancy h. Depending on the selection of h, the FEC model could achieve the desired quality of service level for robust data transmission.

Unfortunately, the burst packet loss length may be more than that calculated by packet loss rate FEC redundancy. Because the FEC recovery performance formulation is based on average packet loss rate, the performance is decreased by burst packet loss length in wireless networks.

2.2 BAFEC

The proposed BAFEC control scheme algorithm is shown in figure 1. When an FEC block of packets are received, the receiver calculates the average packet loss rate and burst packet loss length. The receiver then calculates FEC redundancy relying on average packet loss rate by Eq. (1).

If the calculated FEC redundancy is more than the burst packet loss length, the receivers can feedback the calculated FEC redundancy to the sender side. On the other hand, if the burst packet loss length is more than the calculated FEC redundancy, the FEC redundant packets will be set to burst packet loss length and then feedback to the sender side.

FEC mechanism recovery performance will decrease by burst packet loss length. Therefore, if burst packet loss length is more than FEC redundancy calculated relying on average packet loss rate, the FEC mechanism recovery performance will be decreased. Hence, we will adjust the FEC redundancy to protect the original video source data. If the burst packet loss length is less than FEC redundancy calculated relying on average packet loss rate, the FEC mechanism recovery performance will not be decreased. Therefore, we will keep the calculated FEC redundancy to protect the original video source data.

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When a block of packets arrive:

if ( calculated FEC redundancy > burst placket loss length )

    No_FEC = calculated FEC redundancy;

else

    No_FEC = burst packet loss length
```

Figure 1: BAFEC pseudo code

3. Experiment setting

3.1 Experiment environment

The platform of evaluation is shown in Figure 2. The configuration included a video sender and a video receiver in our evaluation. In this evaluation, the video server transmits video streams over the Internet and the video receiver is connected using wireless links.

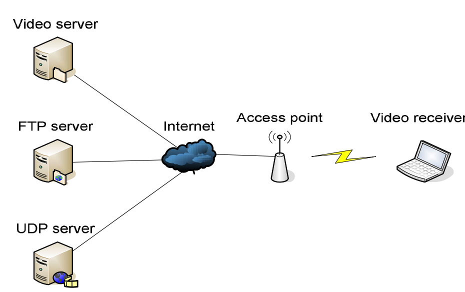

Figure 2: Evaluation topology

The sender sends a video stream to video client. The video clip is “Foreman” encoded in MPEG-4

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CIF format (352×288). For video quality comparison, we encoded the test sequence with a codec at 960 Kbps and 30 frames per second [13]. There are two traffic flows in our evaluation. One is FTP traffic, transmitted by using TCP packets. The second one is Poisson traffic transmitted by using UDP packets. We present our results in terms of packet loss rate and average video quality. We use the peak signal-to-noise ratio (PSNR) to measure the reconstructed quality at the receiver. For the evaluation, we adopt Reed-Solomon (RS) code as a robust symbol oriented error correction coding system [14] [15].

3.2 Wireless error model

In order to describe the burst error property, the two-state Markov model is used in evaluation. The two-state Markov has two states of the model which are defined by G and B. State G denotes that a packet is received correctly and state B denotes that a packet is lost. The two-state Markov model is given in Figure 3.

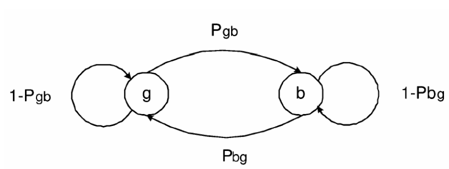

Figure 3: Two-state Markov model

4. Experiment results

We observe the average packet loss rate of wireless loss for different error controlled schemes of the evaluation scenario and compare with varying burst packet loss length.

According to the experimental results in Table 1, our proposed BAFEC control scheme can dynamically adjust FEC redundancy to protect video streaming data when burst packet loss length increases which achieves a lower packet loss and higher PSNR. These results demonstrate our proposed BAFEC control scheme can improve the video quality successfully when burst packet loss length increases.

According to the experimental results in Table 2, our proposed BAFEC control scheme also achieves the lower packet loss rate and higher PSNR as the burst length increases. The conventional AFEC control scheme can obtain better recovery performance when packet loss rates increase as FEC redundant packets are increased. Unfortunately, the FEC recovery performance decreases when burst packet loss length is greater than the FEC redundant packets. Our proposed BAFEC also can dynamically adjust FEC redundancy relying on burst packet loss length information. These results demonstrate our proposed BAFEC control scheme also can enhance the video quality successfully.

According to the experimental results in Table 3, the conventional AFEC control scheme can obtain still better FEC recovery performance by packet loss rate increase when FEC redundant packets are increased. All the same, when the burst packet loss length is more than the FEC redundant packets, the FEC recovery performance will decrease. Our proposed BAFEC control scheme can obtain recovery performance even though burst packet loss length increases. Our proposed BAFEC control scheme achieves a lower packet loss rate as the burst length increases. Our proposed BAFEC control scheme achieves a higher PSNR as the burst length increases.

5. Conclusions

In wireless networks, the burst packet losses problem always exists. The burst packet losses problem decreases the FEC recovery performance because the number of lost packets could be larger than the number of FEC redundancy, leading to an FEC decoder being unable to reconstruct the original source data.

In order to solve the burst losses effect on the FEC recovery performance, we propose a BAFEC control scheme. In our proposed BAFEC control scheme, we will take account of burst packet loss length. In our proposed mechanism, we will feedback average burst packet loss length to the sender. The sender can then rely on this information to adjust the FEC redundancy. According to the experimental results, our proposed BAFEC control scheme can overcome burst packet loss length much more effectively. According to the experimental results, our proposed BAFEC control scheme achieves higher PSNR values and thus provides better quality than conventional FEC mechanisms.

Table 1: Average packet loss rate of wireless = 10% vs. burst packet loss length

Burst loss length	AFEC		BAFEC	
	PLR	PSNR	PLR	PSNR
2	0.2 %	34.5 dB	0.2 %	34.5 dB
4	1.2 %	33.8 dB	0.5 %	34.3 dB
6	3.5 %	32.0 dB	0.8 %	34.1 dB
8	5.5 %	30.3 dB	1.1 %	33.9 dB
10	8.6 %	28.0 dB	1.3 %	33.8 dB

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Table 2: Average packet loss rate of wireless = 20 % vs. burst packet loss length

Burst loss length	AFEC		BAFEC	
	PLR	PSNR	PLR	PSNR
2	0.6 %	34.2 dB	0.6 %	34.2 dB
4	1.1 %	33.9 dB	1.1 %	33.9 dB
6	5.8 %	29.8 dB	1.5 %	33.5 dB
8	9.1 %	26.7 dB	1.7 %	33.3 dB
10	10.0 %	26.1 dB	1.9 %	33.0 dB

Table 3: Average packet loss rate of wireless = 30 % vs. burst packet loss length

Burst loss length	AFEC		BAFEC	
	PLR	PSNR	PLR	PSNR
2	0.9 %	33.9 dB	0.9 %	33.9 dB
4	1.3 %	33.8 dB	1.3 %	33.8 dB
6	1.9 %	33.0 dB	1.9 %	33.0 dB
8	12.3 %	25.8 dB	2.3 %	32.5 dB
10	15.2 %	23.5 dB	2.7 %	32.1 dB

Reference

[1] M. Elaoud, “Adaptive use of error-correction codes for real-time communication in wireless networks,” IEEE INFOCOM, pp. 548-555, April 1998.

[2] L. Rizzo, “Effective erasure codes for reliable computer communication protocols,” Computer Communication Review, volume 2, pp. 426-432, June 1999.

[3] K. Park, “QoS-sensitive transport of real-time MPEG video using adaptive forward error correction,” IEEE MMCS, pp. 426-432, June 1999.

[4] K. Park, “AFEC: an adaptive forward error correction protocol for end-to-end transport of real-time traffic,” IEEE ICN, pp. 196-205, 1998.

[5] Song Cen, “End-to-end differentiation of congestion and wireless losses,” IEEE/ACM Transactions on Networking, volume 11, pp. 703-717, Oct. 2003.

[6] Syed A. Khayam, “Performance analysis and modeling of errors and losses over 802.11b LANs for High-bit-rate real-time multimedia,” Signal Processing: Image Communication, volume 18, pp. 575-595, Aug. 2003.

[7] C. H. Shih, “A self-regulated redundancy control scheme for wireless video transmission,” IEEE WirelessCom, pp. 439-444, June 2005.

[8] C. H. Lin, “An enhanced adaptive FEC mechanism video delivery over wireless networks,” IEEE ICNS, pp. 106-111, July 2006.

[9] Tong Gan, “Reducing video-quality fluctuations for streaming scalable video using unequal error protection, retransmission, and Interleaving,” IEEE Transactions on Image Processing, volume 15, pp. 819-832, April 2006.

[10] Masayuki Arai, “Measurement and modeling of burst packet losses in Internet end-to-end communications,” Pacific Rim International Symposium on Dependable Computing, pp. 260-267, December 1999.

[11] Jianwei Niu, “A robust error concealment algorithm in wireless networks,” International Advanced Information Networking and Applications Workshops, pp. 386-389, May 2007.

[12] Abdelhamid Nafaa, “Forward error correction strategies for media streaming over wireless networks,” IEEE Communications Magazine, volume 46, pp. 72-79, December 2007.

[13] MPEG-4 and H.263 Video Traces for Network Performance Evaluation, http://www.tkn.tu-berlin.de/research/trace/trace.html

[14] Philip K. McKinley, “A study of adaptive forward error correction for wireless collaborative computing,” IEEE Transactions on Parallel and Distributed Systems, volume 13, pp. 936-947, September 2002.

[15] L-J Chen, “Improving wireless link throughput via interleaved FEC,” International Symposium on Computers and Communications, pp. 539-544, June 2004.

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