An Enhanced Adaptive FEC Mechanism for Video Delivery over Wireless Networks

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Abstract

This paper proposes an Enhanced Adaptive FEC (EAFEC) algorithm implemented in the Access Point (AP) to improve video delivery over wireless networks. Unlike traditional static FEC mechanisms, which add redundant data to transmission data in a fixed number, the number of redundant FEC data for the EAFEC mechanism is determined by the AP, which is based on both network traffic load and wireless channel state. The algorithm is based on two factors. One of them is the queue length in the access point, indicating network traffic load; the second factor is packet retransmission times, indicating wireless channel state. EAFEC usage would tune FEC data number generated in such a way that it wouldn’t unnecessarily add more traffic to network in already congested scenario. Our work shows that the EAFEC algorithm improves system performance by dynamically tuning FEC strength to the current loss in wireless channel. We use NS-2 simulation experiments to prove our algorithm.


1. Introduction

Increasing numbers of Internet users connect to Internet services with wireless components, like laptop computers and PDAs, due to their convenience. Unfortunately, wireless network packet error is unavoidable and more serious than in wired networks. Unavoidable packet errors however, are usually recovered using ARQ (Automatic Repeat reQuest) or FEC (Forward Error Correction) techniques [1-2]. In ARQ, missing packets are retransmitted during timeouts or explicit receiver requests. In FEC, the sender prevents packet losses by transmitting redundant information, allowing reconstruction of a certain amount of missing data at the receiver without the need for retransmissions. Retransmitting lost packets in large-scale multimedia video transmission is often unacceptable as retransmission incurred delay is unacceptable [3-4]. FEC recovery for video delivered over wireless network is the focus of this paper.

Intelligent FEC packet adjustment has been an important issue in previous FEC studies [4-6]. For example, more redundant FEC packets have greater opportunity to recover erroneous packets, but those packets may overload wireless networks when traffic load is high; fewer FEC packets, on the other hand, may fail to recover erroneous packets when wireless error rate is high. Improving network performance by dynamically tuning FEC strength to the current rate of wireless channel loss is the objective of this paper.

An intelligent FEC mechanism, Enhanced Adaptive FEC (EAFEC), is proposed to provide improved video delivery over wireless networks. The redundant FEC packets are dynamically added based on both network traffic load and wireless channel state. EAFEC algorithm usage would tune FEC packet numbers generated in such a way that they wouldn’t unnecessarily add to network congestion.

The remainder of this paper is organized as follows. The EAFEC concept and algorithm is introduced in section 2. Section 3 discusses experimental settings and wireless error models. Section 4 analyzes simulation results. Finally, the paper is summarized and possible future work presented.
2. Enhanced Adaptive Forward Error Correction (EAFEC)

2.1 The static FEC mechanism problem

For static FEC algorithms, redundant data is added to transmission data in a fixed number. The static FEC advantage is easier to implement. However, the static FEC disadvantage is that it does not flexibly adapt network condition variations. When error rate is low, static FEC algorithms can create a large overhead. On the other hand, when network traffic load is high, static FEC algorithms result in additional packet loss because of network congestion. Thus, static FEC can degrade system performance by poorly matching overhead to the degree of underlying channel error, especially when the channel path rate fluctuates widely.

For example, for every eight video packets (a block), the fixed number of FEC redundant packets are added. Here, the number is from 0 to 8, and other experiment settings are similarly described as in section 3. When redundant packet numbers increase, packet loss numbers decrease, as shown in figure 1. Nevertheless, when too many redundant packets are added (more than 6), packet loss increases. The same result also occurs in video transmission quality, shown in figure 2.

2.2 EAFEC

In the infrastructure mode, when every wired and wireless node wants to send data packets to other wireless nodes, data must first be sent to the Access Point (AP). The AP then forwards packets to the corresponding node. Therefore, AP is a good place for adding the FEC mechanism for improving video delivery quality. Video data transmitted over the network as shown in figure 3. Here the video delivered path wired segment is assumed to have no packet loss.

For EAFEC, the AP dynamically determines how many redundant FEC packets should be generated, based on the current network condition. First, AP queue length is a good indicator for estimating network traffic load. For example, if network load is high, queue length is long; otherwise, queue length is short. When queue length is long, more redundant FEC packets can be generated, but when queue length increases, fewer FEC packets are generated to avoid unnecessary network congestion. On the other hand, packet retransmission time also indicates wireless channel status. When the wireless channel is good, packet retransmission is less; otherwise, packet retransmission is more. When the wireless channel is experiencing more losses, more redundant FEC packets will be generated, but when the channel is good, fewer FEC packets are generated. In a conclude, the EAFEC algorithm not only uses wireless AP queue length, but also MAC layer retransmission times to determine how many redundant packets should be added to video transmission packets.

![Figure 1: Static FEC mechanism – packet loss.](image1)

![Figure 2: Static FEC mechanism – PSNR.](image2)

![Figure 3: Wireless AP adds redundant FEC data to video transmission data.](image3)
2.2.1 The EAFEC algorithm

The EAFEC algorithm is shown in figure 5. When a block of packets are first received, the AP calculates queue length with weight value (qweight). Then AP compares queue length with threshold values. If queue length is smaller than low_threshold value (threshold_1), the maximum FEC packets are generated. If it is larger than high_threshold value (threshold_2), none FEC packets is generated. Otherwise, FEC packets are generated based on data size fraction in the queue. FEC packet number is then calculated again according to packet retransmission time. If retransmission time is less than low_threshold value (threshold_3), FEC packet number is set to zero. If retransmission time is greater than high_threshold value (threshold_4), FEC packet number does not change. Otherwise, FEC packet number increases with retransmission time. FEC redundant packet number changes in the EAFEC algorithm are shown in figure 4.

3. Experiment setting

3.1 Simulation topology and setting

The proposed FEC algorithm was verified and compared with other FEC mechanisms using NS-2 [7] simulator. The simulation topology we used in this paper is shown in figure 6. In this simulation, video server transmits video streams over the Internet and the video receivers are connected using wireless links. The video traffic trace we used for the experiment is “Highway” video using H.264 video coding with JM 1.7 codec [8]. The “Highway” format is QCIF and the GOP structure is IPPPPPPPPPPPPPPPPPPPPP (Simple Profile). Highway video trace is composed of 2000 frames, with each frame divided into transmitting slices. A slice is about 500 bytes and is transmitted via RTP/UDP/IP packet by unicast transmission. The
Table 1: The Notation of EAFEC algorithm.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>qlen</td>
<td>weighted moving average queue length</td>
</tr>
<tr>
<td>qweight</td>
<td>queue weight</td>
</tr>
<tr>
<td>current_q</td>
<td>current queue length</td>
</tr>
<tr>
<td>threshold1</td>
<td>low threshold for queue</td>
</tr>
<tr>
<td>threshold2</td>
<td>high threshold for queue</td>
</tr>
<tr>
<td>no_FEC</td>
<td>number of redundant FEC packets that will be generated</td>
</tr>
<tr>
<td>Max_FEC</td>
<td>the maximum number of redundant FEC packets</td>
</tr>
<tr>
<td>rT</td>
<td>weighted moving average retransmission time</td>
</tr>
<tr>
<td>current_rT</td>
<td>current retransmission time</td>
</tr>
<tr>
<td>threshold3</td>
<td>low threshold for retransmission time</td>
</tr>
<tr>
<td>threshold4</td>
<td>high threshold for retransmission time</td>
</tr>
</tbody>
</table>

3.2 Comparison with static FEC

EAFEC performance with other static FEC mechanisms is evaluated in these experiments, including 4_FEC and 0_FEC cases. In 4_FEC, for every eight video packets (a block), four FEC packets are generated to video recovery. In 0_FEC, when video packets are transmitted through AP, no FEC packets are generated. For EAFEC setting, the queue length low_threshold is ten packets and high_threshold is forty packets. Additionally, packet retransmission time low_threshold is five times and high_threshold is ten times. Both qweight and rweight are 0.1, and the maximum number of FEC packets sent is set as four. The access point queue size (queue limit) of all FEC cases is set as fifty packets. Video recovery assumes that if the sum of packet numbers in a block and FEC packet numbers for this block is greater or equal to eight, the original eight video packets can be restored. Otherwise, video packets alone are sent to receiver applications and FEC packets become useless.

3.3 Wireless error model

In this paper, we adopt the random uniform model as wireless error model. The random uniform model provides the distributed packets with an error rate $p$. In the wireless network, there are no retransmissions in broadcasting and multicasting, so the packet error rate of network-level is the same as the application-level. However, in unicasting transmission MAC layer senders can transmit a packet at a maximum of $N$ times before it discards the packet. The perceived correct rate at application-level is given by

$$P_{\text{CORRECT}} = \sum_{i=1}^{N} (1-p)^{i-1} = 1 - p^N$$

where $N$ is the maximum number of retransmission at the MAC layer (DCF mode) and $p$ is the packet error rate at physical layer. Consequently, the application-level error rate is

$$P_{\text{effective}} = p^N$$

In the following simulations, we set the parameters of the packet error rate based on the characteristic of the error model.

4. Result analysis

4.1 Static FEC vs. EAFEC

Static FEC mechanism and EAFEC performance are compared and analyzed in the first experiment. The packet error rates are set as 0.6 and 0.7, which means $P_{\text{effective}}$ are 0.12 and 0.24. Video transmission...
quality evaluated by packet loss and PSNR improved when redundant packet numbers increase, as shown in figure 7 and 8. When redundant packets are added to video transmission packets, there is no additional packet loss, according to the results. The EAFEC mechanism improved the additional packet loss problem caused by network congestion.

4.2 EAFEC performance

EAFEC mechanism performance was evaluated in the second experiment. The packet error rate was set as 0.1 to 0.7 with 0.1 intervals. The maximum retransmission number is also assumed at four times of RTT. Hence $P_{\text{effective}}$ corresponds to 0.0001, 0.0016... 0.2401. Redundant FEC packet numbers
for static FEC mechanisms remained constant as shown in figure 9; on the other hand, with EAFEC mechanism redundant FEC packet numbers increase with packet error rate. This is due to the fact that high packet error rate leads to a high probability of packet retransmission until the packet has been correctly received at the receiver. Thus the EAFEC mechanism generates redundant FEC packets based on network condition is validated in these results. Moreover, video delivered quality according to packet loss numbers and PSNR is presented in figure 10 and 11. EAFEC can achieve similar video quality to 4_FEC without sending unnecessary FEC packets, as shown in figures 10 and 11.

5. Conclusions and future work

This paper proposes an Enhanced Adaptive FEC (EAFEC) algorithm implemented in the wireless AP to improve video delivery over lossy networks. The number of redundant FEC data for the EAFEC mechanism is determined by the AP, which is based on both network traffic load and wireless channel state. EAFEC algorithm usage would tune FEC packet numbers generated in such a way that they wouldn’t unnecessarily add to network congestion. Our work shows that the EAFEC improves system performance by dynamically tuning FEC strength to the current amount of wireless channel loss, using simulation experiments. In our future work, we will consider the effect of packet loss from wired network segment on the video recovery. Besides, the optimum threshold values in EAFEC algorithm is also an important research issue.

6. References

[7] NS-2 Multimedia Communication tool
http://140.116.72.80/~smallko/ns2/MultimediaComm_en.html
http://www.tkn.tu-berlin.de/research/trace/trace.html