Improving the quality of H.264 video transmission using the Intra-Frame FEC over IEEE 802.11e networks

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Abstract. Video streaming is one of the most popular application services for the Internet users. Efficient coding standards such as H.264 offers better quality of video streams, and wireless network standards like IEEE 802.11e provide a quality of service mechanism. On the contrary, transmission errors, especially in wireless networks, degrade the video quality, which can be recovered by the FEC mechanism. This paper proposes an efficient FEC recovery algorithm which greatly enhances the video quality in error-prone wireless networks. The FEC algorithm gives a priority to specific video frames such as I frames for the loss recovery in order to improve the received video quality. The simulation results prove that it is necessary to adapt to the changing wireless environment, and generating FEC packets only for I frames are sufficient to improve the video quality in wireless networks.

Keywords: H.264, Video Transmission, Intra-Frame FEC, 802.11e network.

1 Introduction

In recent years, an increasing number of multimedia-enabled mobile device users connect to the Internet service via wireless communications. Moreover, efficient coding standards such as H.264 provide better video quality than before. For provisioning the quality of service (QoS) in wireless networks, IEEE 802.11e standards introduce differentiated service by mapping different types of packets to different levels of transmission priority queues.

Wireless networks offer mobility to users, which becomes one of the advantages to connect to the Internet. However, it suffers from transmission errors and provides low bandwidth compared to the wired networks. Forward Error Correction (FEC) helps alleviating packet losses from the errors by delivering redundant packets along with the original packets. For the delay sensitive communication, FEC works better than the retransmission mechanism which causes longer end-to-end delay.

In general, many research works assume that the FEC packets are generated for all video frames. This paper proposes an efficient FEC packet generation approach in which packets are generated for some important frames only. This approach results in maintaining high quality of video streams as well as using small amount of network resources.

The rest of this paper is organized as follows. Section 2 explains related work. The proposed approach is described in section 3. Simulation environment and results are in section 4. Finally, section 5 presents the conclusion.

2 Background and Related Work

2.1 Background

H.264 is a video coding standard published in 2003 [1]. The picture frame in H.264 composes one or more slices whose types include I, P, B, SI, and SP. The pictures are encoded constraining the dependencies within the Group of Pictures (GOP). Fig. 1 shows a typical GOP with 3 types of slices. I slice, called an intra frame slice, is a self-decodable unit that can be decoded independently without referencing any neighbor slices. P slice, called an inter frame slice, requires a referencing at least one previous I or P slice. B slice depends on the closest both I and P slices or two P slices.

Fig. 1. GOP of the H.264 encoding example

In order to support QoS requirements, IEEE 802.11e has been specified to satisfy QoS requirements by providing differentiated classes of services at the medium access control (MAC) layer [2]. Enhanced Distributed Channel Access (EDCA) classifies the traffic into four access categories (AC) which include AC[3] for voice traffic, AC[2] for video traffic, AC[1] for best effort traffic, and AC[0] for background traffic. Each AC has its own queue and independent backoff parameters.

Forward error correction (FEC) such as using Reed-Solomon (RS) code [3] becomes suitable for delay-sensitive communications by transmitting some redundant data as well as the original data. An application may transmit a video frame of K packets. The FEC codec generates H error correction packets by using block-based error corrections such as a simple parity check or RS codes. As a result, an (N, K) block erasure code converts K source packets into a group of N (= $K + H$) coded packets which will be transmitted over the error-prone networks. When a receiver receives any K of the N packets, it is able to rebuild the original source packets.

2.2 Related Work

Many research works introduce FEC to enhance the quality of video stream transmitted over error-prone wireless networks. FEC packets are generated depending on the current queue length [4] or the wireless channel status [5]. In addition, the transmission of H.264 video streams over 802.11e network provides QoS by mapping different types of frames to the corresponding AC queues [6]. In [7], the backoff parameters CW dynamically changes in order to adapt to the network link status. Each type of frames is mapped to multiple ACs and selected to one of them based on the shortest waiting time in the queue [8].

There are few papers dealing with generating FEC packets for H.264 video streams over 802.11e networks. This paper introduces an efficient FEC algorithm for two purposes. First, this algorithm adapts to generating proper amount of FEC packets by detecting the wireless MAC status. Second, it generates FEC packets not for all video frames but for the selected types of frames such as I-frames which is the most important frame type in the video sequence. This algorithm results in using less network resources and providing better video quality.

3 Proposed approach

Our approach considers two points of views to generate FEC packets for H.264 video frames over 802.11e networks. First point is that which video frames are used to generate FEC packets. Our proposed approach uses Intra frames among the video frames in order to efficiently utilize the wireless network resources. Second point is that which factors are involved for deciding how many FEC packets to generate.

The proposed algorithm measures both the length of the queue that the intra frames are stored and the MAC channel error rates. The queue defines two thresholds, *th1* and *th2*. When the average queue length is less than *th1*, the predefined number of FEC packets is generated. When the average length is in between *th1* and *th2*, MAC-level transmission failure rate is measured. The number of FEC packets increases proportional to the transmission failure rate up to the maximum number. When the average queue length exceeds above *th2*, no FEC packets are generated. The FEC packets are inserted at the same AC queue where the intra frames are stored.

4 Simulation and Results

4.1 Simulation Environment

We implemented the approach explained in section 3 using ns-2 simulator [9]. The network topology used in the simulation is displayed in Fig. 2.

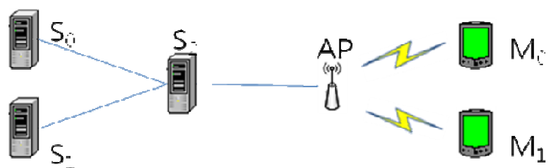

Fig. 2. The network topology of the simulations

There are three wired nodes and two mobile nodes. The AP places in between the two groups of nodes. Station S_0 creates three traffic flows all destined to M_0: 64 Kbps VoIP voice traffic assigned to AC[3], 125 Kbps CBR/UDP traffic mapped to AC[1], and FTP/TCP traffic to AC[0]. Station S_1 transmits a foreman video stream with qcif format. The video is encoded with IPPP sequence. The video frames are segmented and packed into the 512 byte packets. AP generates FEC packets on behalf of S_1 based on measuring the queue length and the wireless transmission errors. The I-frame packets are assigned to AC[2] and the P-frame packets are to AC[1]. The corresponding FEC packets are mapped to the same queue. The packet error rate varies from 5% to 20%. The value K is defined by the number of encoded I frame packets in a GOP. The value H is set by the two equations: $H = K$ and $H = K/2$. The proposed approach was compared with both the no FEC algorithm and static FEC algorithm in which K=8 and H=2 for all video frames. The remaining parameters of the simulation environment are specified in Table 1.

Table 1. Simulation parameter settings for ns-2

Parameter	Setting
MAC Protocol	802.11e
Bandwidth (wired)	10 Mbps
Bandwidth (wireless)	2 Mbps
AP queue length	100 packets
AP queue *th1*	20 packets
AP queue *th2*	80 packets
Number of video frames	400
Number of video packets	1456

4.2 Analysis of Simulation Results

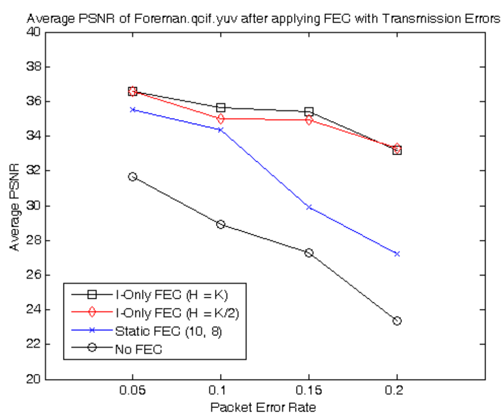

Fig. 3. Average PSNR value for the four algorithms with varying packet transmission errors

Fig. 3 shows the average PSNR values of the four algorithms. When a mobile device receives both I-frame video packets as well as FEC packets and the total number of received packets is greater than K in a GOP, the I frame will be completely recovered. According to the figure, as the transmission error rate increases, the average PSNR decreases for all algorithms. However, no FEC algorithm shows the worst performance in terms of the PSNR because there is no recovery mechanism for the lost video packets. Static FEC algorithm works better than that of no FEC algorithm, but not good when compared to the results of the I-only FEC algorithms. The average PSNR of the two I-only FEC algorithms shows little differences. However, I-only FEC with $H = K/2$ generates smaller number of FEC packets generated than that of $H = K$ FEC algorithm, which relieves the wireless network congestion.

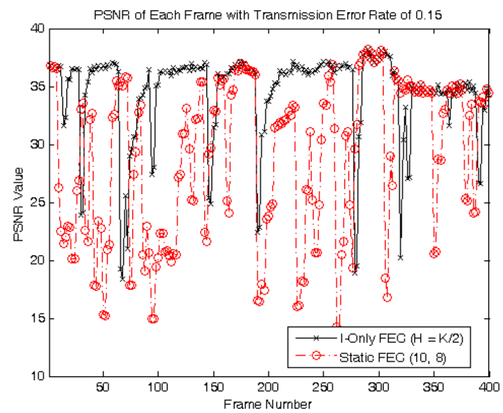

Fig. 4. The PSNR value of each frame after recovered by the two FEC approaches

Fig. 4 displays PSNR values of each video frame with 15% transmission error rate. Static FEC fluctuates for the PSNR values because several I-frames are lost and not recovered by the FEC mechanism. Static FEC generates FEC packets regardless of the video frame types. Recovered I frames help increasing the PSNR significantly, but recovered P frames partially improve the video quality.

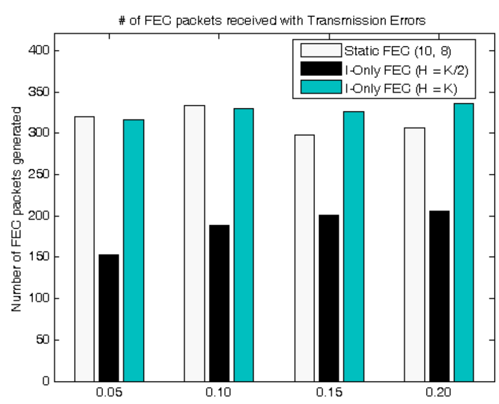

Fig. 5. Number of FEC packets received with varying transmission errors

Fig. 5 illustrates the number of received FEC packets by the receiver. The number of FEC packets generated by the static algorithm with $K = 8$ and $H = 2$ is similar to that of the I-only FEC with $H = K$. The I-only FEC with $H = K/2$ generated the smallest number of FEC packets to transmit to the receiver. Even though it does not much FEC packets generated, the quality of the received video reaches to almost similar level of the I-only FEC with $H = K$ algorithm shown in Fig. 3. This implies that generating FEC packets for I frames are sufficient enough to improve the video quality in wireless error-prone network environment.

5 Conclusions

H.264 provides an efficient way of coding video streams and the IEEE 802.11e network enables for video streams to differentiate transmission services by assigning the video traffic to the high priority queue. Forward error correction is a very effective mechanism for delay sensitive applications when the network is error-prone and the end-to-end delay is unaffordable. This paper proposes an efficient FEC mechanism that generates FEC packets only for I frames in order to save the wireless network resources without degrading the video quality. The simulation results show that the I-only FEC with $H = K/2$ algorithm produces similar PSNR values to that of the I-only FEC with $H = K$ algorithm using smaller amount of FEC packets.

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