A Study of Improvements on FEC Efficiency

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Abstract

Forward Error Correction (FEC) plays an increasingly important role in communication systems. It will improve the capacity of a channel via adding some carefully designed redundant packet with the source data being transmitted through the channel. In this paper, the performance of packet-level forward error correction schemes that include end-system and network centric are in terms of both packet loss rate and average PSNR of video streaming transmission after error recovery. We describe about the based on end-system centric are MAC retransmission and packet-size adaptation, and then describe about based on network centric are multi-path transmission and multi-hop transmission.

Keyword: Forward Error Correction, Heterogeneous links, QoS, Multi-hop FEC

I. INTRODUCTION

The quality of multimedia communication over the Internet is influenced by delay constraints, and loss-tolerant. For the multimedia applications over the best-effort network, most of them are running on top of UPD/IP protocol, and some critical problems such as high bit error rate, time-varying property, and burst error property would lead to difficulties to deploy multimedia services [3]. Some error control schemes can reduce the effective packet loss. One general knowledge way observed by the receiver is to add redundant information at the sender.

A common method to add redundancy is Forward error correction (FEC) [4], which transmits redundant information of each packet in addition to source data. In this sender-based scheme, the receiver can recover the loss or corrupted data by receiving the enough number of total sending data. Moreover, in this scheme, FEC needs additional bandwidth and loss recovery is performed at the cost of higher latency.

Transmission over Internet network could affect the efficiency of FEC schemes. High packet loss rate could need more redundant data to protect source data. On the other hand, more redundancy requires more bandwidth. However, the increase of packet loss always goes along with loss of successive packets. For example, in wired network, the condition of burst loss usually due to the network congestion and the router buffers overflow. In wireless network, a transmission error loss is usually followed by an amount of burst error loss, e.g. radio inference, fading, and shadowing, which will decrease the efficiency of FEC schemes. For instance, there are four redundant packets, which can recover the loss packets at the receiver when the burst loss length is less than four. If the burst loss length is more than four, the FEC schemes cannot effectively protect source data. Hence, this scheme also decreases the efficiency of bandwidth on this condition. If we can use some approaches to reduce packet loss and burst length, it can help us by using the similar redundancy to achieve the better FEC performance.

Some enhancement schemes are proposed to improve the original techniques for multimedia transmission over wireless network, such as hybrid automatic retransmission request (ARQ) [12] which combines ARQ and FEC in order to decrease the times of retransmission and to improve the network efficiency. In end-system centric [11], there are two kind of basic approaches to improving FEC efficiency which would be popularly discussed: one is MAC retransmission, which retransmits the lost packets according to the acknowledgement packets at MAC layer, but it is just for unit-cast transmission over wireless network. However, on the scenario of using the MAC retransmission scheme, it would bring about the striking delay since the times of retransmission can be many due to the higher error rate on the wireless network or the round trip time on the wireless connection is long. According to the foregoing properties of the multimedia streaming, the long delay might degrade the quality of the multimedia streaming [7, 8].

The other basic approaches in end-system centric are packet size adaptation [5, 6], which could adjust the packet size or the MAC frame size to reduce the error rate over the burst error channel. There are some researches to discuss the effect of packet size [6]. The smaller packet size seems to get the better quality of service of multimedia streaming, but could spend more time in the transmit queue. Furthermore, it is showed that too small packets size would be dropped by the access point due to overflowing the queuing buffer [1]. Therefore, an efficient error control scheme aiming at solving the burst error problem and improving the quality of service for multimedia streaming would take account of not only the packet size control method but also the effect of delay for the multimedia streaming. Wen, Dai, and Jin designed and formulated their adaptive algorithm for robust video using the hybrid ARQ scheme to control the error correction [2], but it might be unsuitable for the high burst error environment due to using the byte-level FEC protection. This conclusion is also shown in [8], which compares the efficiency of three error control schemes including the hybrid ARQ, the byte-level FEC, the packet-level FEC. The results demonstrate that the packet-level FEC protection could get better efficiency than the byte-level FEC protection over the higher burst error situation.

In network centric, path diversity and multi-hop FEC scheme are able to improve FEC efficiency. Path diversity is a transmission technique that sends data simultaneously through two or more paths in a packet-based network. Changing economics and an increased emphasis on end-to-end fault tolerance have brought path diversity within the purview of the transport layer. The use of multiple paths through the transport network for streaming has been to help overcome the loss and delay problems that afflict streaming media and low latency communication. In addition, it has long been known that multiple paths can improve fault tolerance and link recovery for data delivery, as well as provide larger aggregate bandwidth, load balancing, and faster bulk data downloads [16].

More important, path diversity reduces the frequency and length of burst losses, i.e., losses of consecutive packets. Distributing packet across multiple paths increases the inter-packet spacing on each path, and therefore for a network congestion event of a given duration fewer packets are lost [17]. It is easier for FEC to recover from multiple isolated losses than from an equal number of consecutive losses. For two paths with equal average packet loss rates, sending even packets on one path and odd packets on the other has no effect on the end-to-end loss rate but does reduce burst losses. Hence, reducing burst losses provides performance of error recovery for FEC.

The other approach in network centric is Multi-hop FEC. The Multi-hop FEC scheme partitions the end-to-end internet path into segments according to the error characteristic of the sub-internet path, and provides amounts of FEC over those segments.

The conventional end-to-end FEC protection mechanisms would collect packet loss information of every link along the transmission data path in the receiver, and determines the desired redundancy for the loss recovery purpose in the sender based on the feedback from the receiver. On the other hand, the Multi-hop FEC protection mechanism needs intermediate nodes to perform FEC encoding/decoding function individually for each link. By isolating and recovering packet losses within the link, the Multi-hop FEC protection mechanism is shown to be more effective than the conventional end-to-end FEC protection mechanisms in improving video quality in error-prone environments [18]. The Multi-hop FEC protection mechanism can be realized by active networks [18], wireless networks [19] and overlay network networks [20] [21], where intermediate nodes are able to perform basic FEC encoding/decoding operations.

The end-system centric not only reduces the average burst loss data but also decrease the packet loss rate, but these schemes will increase delay. The additional delay will decrease the quality of multimedia communication. The conventional end-to-end FEC protection mechanisms will not only over-allocate the desired redundancy for each link but also leads to the critical network effects such as congestion loss. Hence, Multi-hop FEC protection mechanism addresses this problem for reducing packet loss rate and burst loss length provides performance of error recovery for FEC.

This remaining paper is organized as followed. Section 2 provides the overview of end-system centric and experimental related results are given. The network centric is presented in detail in Section 3. We present the summary evaluation in Section 4. Finally, conclusions and future works are pointed out in Section 6.

II. END-SYSTEM CENTRIC

In this section, we evaluate the different schemes via the NS2 tools, and then via simulation results considering the performance of PSNR.

2.1 Experiment setup

In end-system centric, we established an experimental platform on the NS2. On this platform, we emulated a real-time video streaming application over UDP. Our simulation setup of NS2 employed an IEEE 802.11b WLAN operating and two wireless stations communication in the ad-hoc network configuration [10].

We tested two approaches: (i) MAC retransmission scheme, (ii) packet size adaptation. Initially, the wireless server was forced to transmit at 11 Mbps. And then, a two-state Markov model is used to simulate burst loss patterns over a wired/wireless channel [14]. We setup the wireless packet loss rate is 35.8% and average burst loss data is about 3.15 kbytes [9, 15]. RS stands for Reed-Solomon which was a robust symbol oriented error correction coding system. We set different packet size (1000, 500, and 250 bytes) to simulate. In 1000 bytes, the number of source packets in block is eight, and we add four redundant packets in each block (12, 8). In others, we ensure the amount of source and redundant data was the same in different packet size. The distance between the two wireless stations is 20 meters. The packets could be missed because of the decoding deadlines, i.e., late packets. In order to compensate for one-way delay jitter and allow some time for MAC retransmissions, a playout delay, which was used in the decoding process to improve the decodability of the predictively-encoded frames, was 500 ms.

For video quality comparison, we encoded the test sequence Foreman (352 × 288) with a standard MPEG-4 codec at 960 Kbps and 30 frames per second. We present our result in average burst loss data, packet loss rate, end-to-end delay and average video quality. For the latter, we used the peak signal-to-noise ratio (PSNR) measure the quality of reconstruction in image compression.

2.2 Experiment results

In this section, we discuss the burst loss data, packet loss rate, end-to-end delay, and PSNR in view of two different approaches individually.

Figure 1 reveals the average burst loss data for different packet size with seven different MAC retransmission times. The result demonstrates that an amount of average burst loss data decreases with increasing MAC retransmission times, but the decreasing rage isn’t obvious. According to our experiment results, small packet sizes help to reduce the burst loss data.

Packet loss rate results are shown in Figure 2. It’s clearly shown that end-system centric can conduce to reduce packet loss rate. In addition, when we use the same protection rate in different packet sizes, increasing MAC retransmission times and decreasing the packet size can improve FEC efficiency in evidence.

Another important problem is delay. As everyone knows, delay will increase with increasing retransmission times. Figure 3 displays that the end-to-end delay of FEC schemes is distinctly longer than UDP links. This is because all FEC schemes need some time to encode and decode. “No FEC, 1000 bytes” case is shown that increasing MAC retransmission times

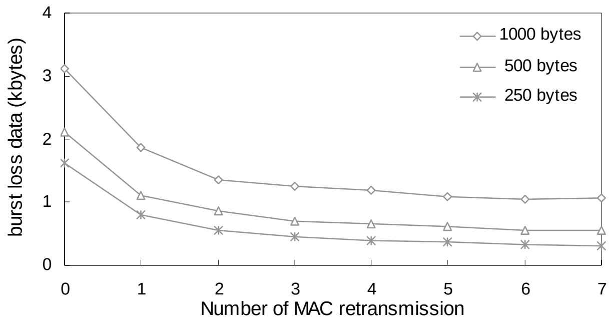

Figure 1. Average burst loss data of no FEC vs. the number of MAC retransmission

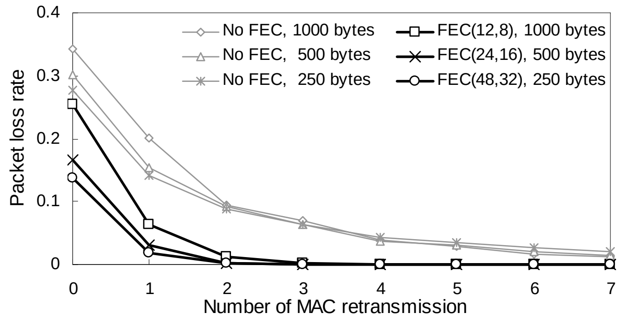

Figure 2. Packet loss rate vs. the number of MAC retransmission

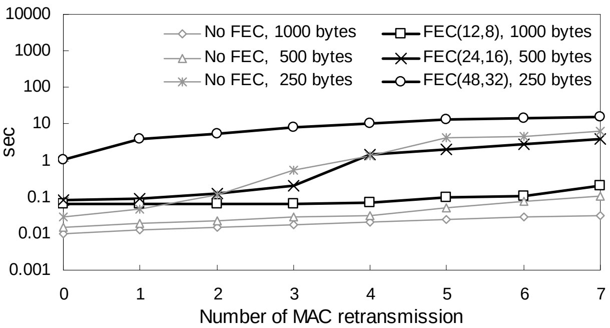

Figure 3. End-to-end delay vs. the number of MAC retransmission

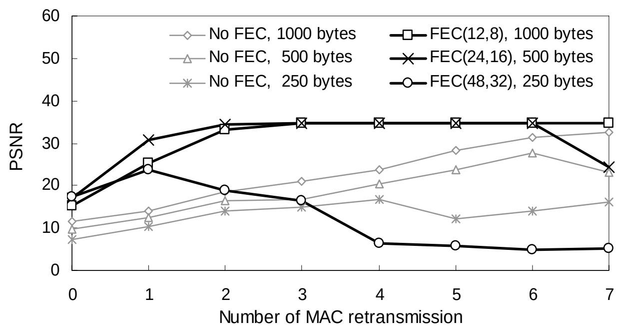

Figure 4. PSNR vs. the number of MAC retransmission

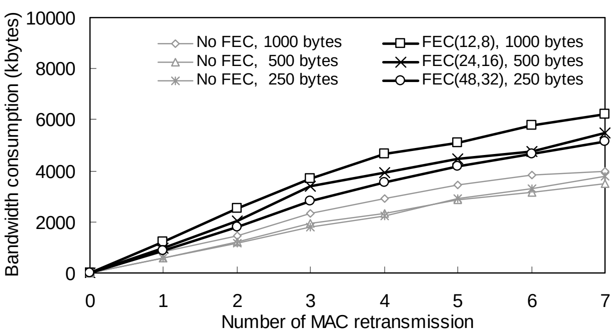

Figure 5. Bandwidth consumption-retransmission only vs. the number of MAC retransmission

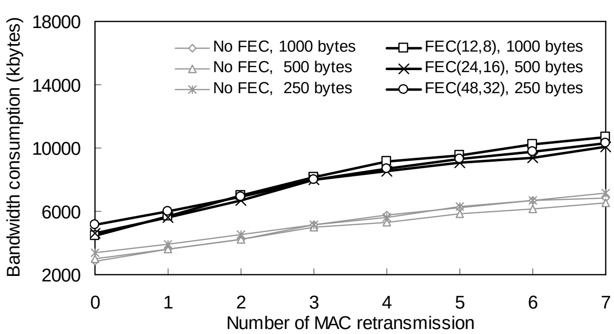

Figure 6. PSNR vs. the number of MAC vs. the MAC retransmission

don’t increase delay time obviously. However, the delay will rise quickly with smaller packet sizes and longer retransmission times because of smaller packet sizes cause to produce more headers overhead and longer retransmission also cause others overhead. At these conditions, although FEC efficiency can be improved, the delay is so long that it isn’t suit to multimedia communication, i.e., “FEC (48, 32), 250 bytes” case.

The PSNR results for different control schemes are shown in Figure 4. In “No FEC” cases, although packet loss rate will decrease with smaller packet size, the PSNR in these cases also decrease. This is because that smaller packet sizes make some burst error become uniform random error, and this kind of change is bad to multimedia communication. The smaller packet size adaptation causes every frame to need more packets to transmit. Therefore, it is easy for the frame error rate to rise. In other words, the frame error rate of the random uniform error distribution is higher than the burst error distribution. However, in FEC scheme, the random uniform error condition is more favorable than burst error condition. In Figure 4, the PSNR of “FEC (24, 16), 500 bytes” case is better than “FEC (12, 8), 1000 bytes” case in evidence. Furthermore, some PSNR of these cases suddenly decrease because of the late packets weren’t able to arrive in time with delay increasing and these will miss their decoding deadlines. In another interesting result, in “No FEC, 250 bytes”, the PSNR rise slightly at the 5, 6, and 7 transmission times. At three conditions, these delays are almost the same with each other in Figure 3, but higher transmission times led to higher decodable frame rate. Hence, the late packets are similar to each other at three conditions, and the PSNR will increase with increasing transmission times.

Figure 5 shows bandwidth consumption of retransmission only for these different methods. The bandwidth consumption increases with higher retransmission times, but the consumption of smaller packet sizes is lower than larger packet size. As a result of smaller packet size isn’t easier to occur error in wireless bit error model.

More specifically, Figure 6 displays the total bandwidth consumption for all. The total source data is about 2827 kbytes, and the FEC protection rate is about 50%. Therefore, the bandwidth consumption in “FEC” cases is about 1.5 times in “No FEC” cases. In contrast, regardless of the “FEC” or “No FEC” cases, the bandwidth consumption of different packet sizes is close to each other. It is due to the smaller packet size that will increase additional bandwidth consumption of header overhead even though it can decrease the bandwidth consumption of retransmission. As a result, if we can combine with two approaches of end-system centric timely, we don’t cost the header overhead of the smaller packet sizes.

III. NETWORK CENTRIC

In network centric, path diversity and multi-hop FEC are evaluated over real network environment.

3.1 Path Diversity

In our path diversity scenario shown in Figure 7, the video server is sending video source packets through two paths relying on the path diversity selector. We compare three FEC protect mechanism transmission policies which are single-path (SP), multipath distributed (MPD) and multipath per path (MPP).

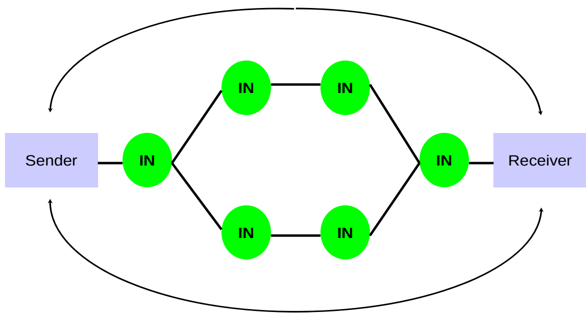

Figure 7. Path diversity

FEC	Single-path	Multi-path
1	24.35 ms	22.68 ms
2	28.05 ms	24.53 ms
3	32.25 ms	26.63 ms
4	36.58 ms	28.79 ms
5	41.20 ms	31.10 ms
6	45.88 ms	33.39 ms
7	50.75 ms	35.82 ms
8	55.65 ms	38.25 ms

Figure 8. Path diversity End-to-end delay

FEC		MPD		SP		MPP	
SP,MPP	**MPD**	FLR	PSNR	FLR	PSNR	FLR	PSNR
(8,8)	**(16,16)**	0.617	12.126	0.53	10.780	0.617	12.126
(9,8)	**(18,16)**	0.433	14.196	0.27	15.880	0.310	15.320
(10,8)	**(20,16)**	0.357	16.717	0.246	19.224	0.282	17.540
(11,8)	**(22,16)**	0.313	16.616	0.2175	18.943	0.256	17.879
(12,8)	**(24,16)**	0.240	17.573	0.182	19.201	0.206	18.787
(13,8)	**(26,16)**	0.156	26.049	0.142	26.184	0.134	27.832
(14,8)	**(28,16)**	0.132	25.257	0.1055	28.076	0.123	25.309
(15,8)	**(30,16)**	0.079	31.966	0.095	29.260	0.101	29.720
(16,8)	**(32,16)**	0.036	33.665	0.045	31.507	0.062	31.490

Figure 9. Path diversity frame loss rate and PSNR

In our single-path policy, FEC redundant packets rely on RS-code. The clip is foreman and setup the packet loss rate is 35.8% and average burst loss packet length is 3.15 over the default path.

In our multipath distributed policy, FEC redundancy encoding before deliver packets over multipath by RS-code. The odd number packets and even number packets are transmission distributed. The video clip still is foreman and also setup the packet loss rate is 35.8% and average burst loss packet length is 3.15 over per path.

In multipath per path, the odd number packets and even number packets are encoding FEC redundant packets independent by RS-code. The odd number packets and even number packets are also transmission distributed. The video clip still is foreman and also setup the packet loss rate is 35.8% and average burst loss packet length is 3.15 over per path.

In our experimental results as shown in Figure 8, multipath transmission policies that no matter multipath distributed policy or multipath per path policy will reduce the video transmission end-to-end delay very well.

In our experimental results as shown in Figure 9, the frame error rate and PSNR value that no matter multipath distributed policy or multipath per path policy is better than single-path policy.

As our experimental results shows, multipath per path policy is better than multipath distributed policy from FEC parameter (8, 8) to FEC parameter (14, 8) that is because multipath per path has higher probability to recovery loss packet, like packet size control scheme. Moreover, at this time, multipath distributed policy and multipath per path policy will still influence burst loss packet length which will lead to FEC recovery performance down. When FEC parameter on (15, 8) and (16, 8) that multipath distributed policy will better than multipath per path that because burst loss packet length will not influence the FEC recovery performance but already influences multipath per path policy.

3.2 Multi-hop FEC Protection

In our multi-hop FEC scenario as shown in Figure 10, we define a FEC-aware overlay network as a network that is built on existing networks such as the Internet as shown in Figure. In the FEC-aware overlay network, a lot of intermediate nodes supporting FEC encoding/decoding function are installed in the network, and they are connected by some network protocols such as the IP protocol. The video clip is still foreman and setup the packet loss rate is 13%. During the 60 seconds of experiment time in scenario, the background UDP traffic both in wired and wireless links is applied at [0, 20] and [40, 60], and at [20, 40] the background UDP traffic in wired links is stopped.

In our experimental results as shown in Figure 11, multi-hop FEC protection transmission policies will increase the video transmission end-to-end delay very well. In our experimental results as shown in Figure 12, as the PSNR value increase as the hop number increases.

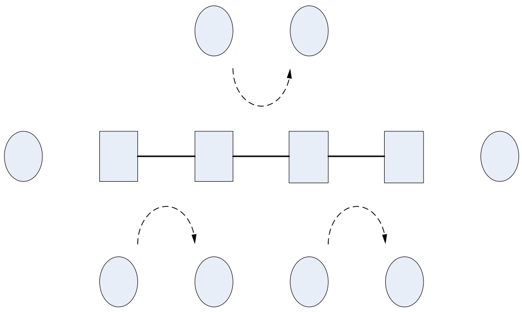

Figure 10. FEC-aware overlay network

FEC	One hop	Two hop	Three hop	Four hop	Five hop
0	89.25 ms	156.66 ms	223.95 ms	291.35 ms	358.65 ms
1	89.98 ms	158.23 ms	226.50 ms	295.71 ms	362.96 ms
2	90.71 ms	159.85 ms	228.99 ms	298.13 ms	367.27 ms
3	91.43 ms	161.51 ms	231.50 ms	301.55 ms	371.57 ms
4	92.16 ms	163.85 ms	235.52 ms	307.21 ms	375.88 ms
5	92.89 ms	165.65 ms	236.55 ms	308.37 ms	380.19 ms
6	93.62 ms	166.35 ms	239.06 ms	311.78 ms	384.50 ms
7	94.33 ms	167.95 ms	241.57 ms	315.19 ms	388.81 ms
8	95.08 ms	169.59 ms	245.01 ms	318.60 ms	393.11 ms

Figure 11. Multi-hop FEC End-to-end delay

FEC	One hop	Two hop	Three hop	Four hop	Five hop
0	20.58	20.58	20.59	20.61	20.62
1	21.87	22.06	22.39	22.55	22.88
2	22.33	22.98	23.62	24.05	24.95
3	23.61	24.06	24.75	25.53	25.98
4	24.05	24.89	25.58	27.96	28.15
5	25.11	25.88	28.02	31.68	23.66
6	22.19	22.08	21.95	21.77	21.56
7	20.68	20.55	20.36	20.13	19.85
8	20.33	20.15	19.95	19.73	19.45

Figure 12. Multi-hop FEC PSNR

IV. CONCLUSIONS

In this paper, the performance of FEC control schemes for video streaming transmission is analyzed. Both the packet loss rate and average PSNR as perceived by multimedia application are computed for a two-state Markov model loss process. Experimental simulations validate the analytical results. Our main results can be summarized in Figure 13.

	End-to-end delay	Bandwidth consume	Issue
Retransmission	Variation	Trouble-free	Queue buffer
Packet size adaptation	Long	Header	Packet size choose
Multi-path	Short	Trouble-free	Out-of-order
Multi-hop FEC	Variation	Redundancy	Intermediate nodes

Figure 13. Summary

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