Multi-path Forward Error Correction Control Scheme with Path Interleaving

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Abstract

Several research studies have been devoted to improving the reliability and performance of the Internet by utilizing redundant communication paths. Multihoming and overlay networks are two main streams in this area of research which attempt to leverage redundant connections of the Internet for increased reliability and performance. Furthermore, the quality of video transmission can be improved when path diversity is combined with the error control scheme such as forward error correction. Nevertheless, in the general networks, losses are burst due to network congestion and channel errors in wireless communication and this property of burst losses decreases the efficiency of FEC. In this thesis, a novel multi-path FEC control scheme with path interleaving is proposed for improving the quality of video transmission. Our scheme aims at dispersing the burst losses to different FEC blocks and therefore the efficiency of FEC can be improved. The experimental results shows that compared to the traditional multi-path FEC schemes, the experimental results show that the proposed scheme achieves better performances in terms of packet loss rate and video PSNR.

Keyword: Multi-path, Forward Error Correction, Wireless Network, QoS.

I. Introduction

Along with rapid development of the multimedia communications, like video streaming, many multimedia services become popular on the Internet. However, the current Internet infrastructure and existing mechanisms deployed in the Internet are lack of quality of service for media streaming. Multimedia communication over best effort packet networks such as the Internet is quite challenging because of the dynamic and unpredictable available bandwidth, loss rate, and delay. Recently, multimedia communication over multiple paths to provide path diversity has emerged as an approach to help overcome these problems.

Path diversity is a transmission technique that sends source data packets simultaneously through two or more paths in packet-based network [1] [11]. The paths may originate from single source [2-6] or multiple sources [7-8]. Using path diversity through the transport network for multimedia communication has been proposed to help overcome the loss [2] and delay [3] problems that afflict video streaming and low-latency communication. In addition, path diversity has long been know that can improve fault tolerance and link recovery for packet delivery, as well as provide larger aggregate bandwidth, load balancing, and faster bulk data downloads.

Path diversity can reduced variability of packet losses, for example, reduced excursions between periods of no loss and high loss that are common on the Internet. The end-to-end application sees the average network behavior across the paths, which generally has reduced variability. This reduced variability enables methods of combating losses, such as forward error correction (FEC), to become more effective [9-10]. In the literature on the multi-path with FEC, we can generalize two basic schemes from a collection of related works: the path-dependent scheme and the path-independent scheme. The path-dependent FEC scheme splits source data to different paths and then produces different redundant data for each path. According to different network environment, applications can produce the different amount of redundant data for different paths in order to overcome the loss of individual path. The path-independent FEC scheme generates the enough redundant data at sender, and then to distribute total data to different paths for network transmission. In this scheme, the receiver observes the average network condition across these paths, and the loss recovery is performed for losses on all paths.

However, the burst loss induced by congestion losses or wireless errors decreases the efficiency of FEC since the receiver may not receive the enough number of packets in a FEC block for loss recovery. For two traditional multi-path FEC schemes, burst loss of the individual path would decrease the efficiency of FEC. In this paper, we propose a novel multi-path FEC control scheme with path interleaving to overcome burst loss problem for video streaming. Path interleaving aims at dispersing burst loss to overcome the burst losses effect on FEC efficiency by crisscross sending data of the same FEC block to different paths. The goal of the proposed scheme is to avoid decreasing the efficiency of FEC due to burst losses in multi-path transmission environment for video streaming.

The remaining of the thesis organized as follows: in Section II, we describe the related works; in Section III, we describe the novel multi-path FEC control scheme with path interleaving; results of video experiments are presented in Section IV. Finally, we conclude the paper in Section V.

II. Related works

In this section, we briefly describe related works about multi-path FEC. We compartmentalize multi-path schemes to path-dependent FEC scheme and path-independent FEC scheme.

II.1. Path-department FEC scheme

One of the multi-path FEC schemes employs path-dependent coding [9]. Figure 1 shows the path-dependent FEC scheme. The applications would send source data to different paths, and then the FEC encoder will encode redundant data for each path. Different paths have different number of redundant packets because loss patents of each path are different and independent. This scheme could overcome the losses for each individual path. However, burst losses of the individual path would decrease the efficiency of FEC.

II.2. Path-independent FEC scheme

The path-independent FEC scheme is shown in Figure 2 [10]. In Figure 2, the sender encodes redundant data and than sends all data over multiple paths. This scheme can overcome the losses of all paths because the receiver observes the average losses of multiple paths. For the burst losses in multiple paths, the FEC recovery could fail and this reduces the FEC efficiency.

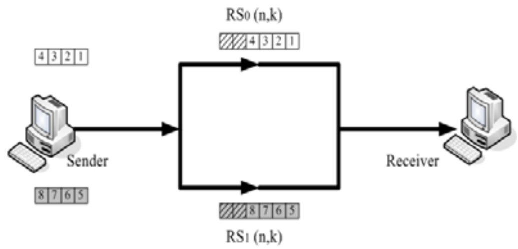


Figure 1 Path-dependent FEC scheme

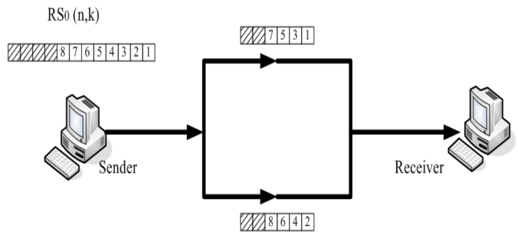


Figure 2 Path-independent FEC scheme

III. Multi-path system implementation

In this paper, we implement multi-path system using divert socket. Divert socket is a tool which is used in Linux operating system that can intercept packets traveling up or down in Internet Protocol layer. We will illustrate the detail of the multi-path system implementation of our method in the following.

We implement the striping method at the Internet Protocol layer. To use striping transparently, we use the tunnel network provided on overlay network. First, we need to set up a firewall chain in Linux operating system. Linux operating system provide three default chains: input, output and forward. We need to set up output chain and bound to a port. When transmission packets travel down from application layer, divert socket will first divert those packets to a port which is determined in first phase. Second, it intercepts and gets the contents of this packet including IP header, transport protocol header and payload. Third, we modified the destination IP address in IP header and recalculate the checksum value of IP header. Last, reinject those packets back to the Internet protocol layer. So, those packets will arrive to the modified destination.

According to this method, we can implement multi-path topology in our method. The benefit of our method is that we only need one network card in one device instead of using multiple network cards, but can also achieve the same effects. In traditional IP tunneling method such as IP in IP tunneling will increase additional overhead in bandwidth because of adding other headers in original packet. So, the benefit of our method is that we will not increase the load of bandwidth, but only need some other mathematic calculating. Multi-path system architecture is shown in Figure 3.

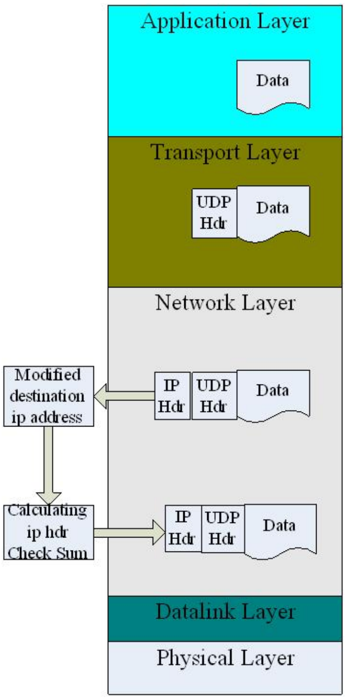


Figure 3 Multi-path system architecture

Because overlay networks will maintain the routing table on each intermediate node, our method without adding of packet sizes to label the destination address of next hop. Based on our method, each intermediate node on overlay networks only need to modify the destination address change into the destination address of next hop.

IV. Multi-path FEC control scheme with path interleaving

Due to the burst error property, the efficiency of FEC would be decreased. Our proposed scheme could disperse the burst losses and transform the burst network condition to uniform one. Uniform loss condition is helpful to improve the efficiency of FEC. The main of our scheme aims at dispersing the burst losses to different FEC blocks. When sending the data packets of FEC blocks over multiple paths, the scheme would change the transmission order of FEC blocks and send them using path interleaving. The receiver has a packet buffer to absorb the impact of packet disordering. Path interleaving is shown in Figure 4. It aims at striping two or more FEC block packets to multiple paths in order to share the burst to different blocks.

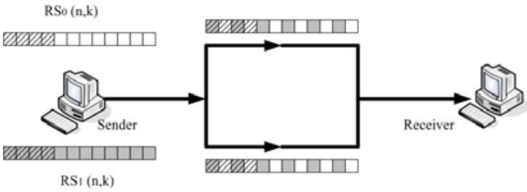


Figure 4 Path interleaving

V. Experiment results

In this section, the experiment environment containing the burst error model and parameters of simulation is described in subsection V.2. We compare the different multi-path FEC schemes that including path-dependent, path-independent and the proposed scheme via evaluate the performances in terms of receiver packet loss rate and video PSNR. The experimental results are given in subsection V.2.

V.1 Experiment environment

The platform of evaluation is shown in Figure 5-1. The configuration included a video sender and a video receiver in our evaluation. We set two paths between the sender and the receiver via two intermediate nodes over overlay network. Each path is labeled with path packet loss rate and burst length respectively.

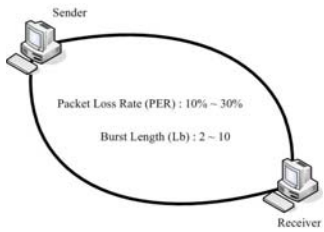


Figure 5-1 Experiment platform

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. The state G is denoted that a packet is received correctly, and the state B is denoted that a packet is lost. Two-state Markov model is shown in Figure 5-2.

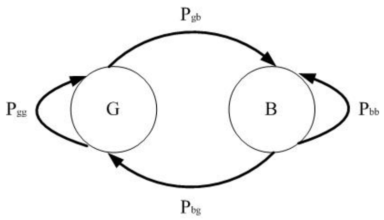


Figure 5-2 Two-state Markov model

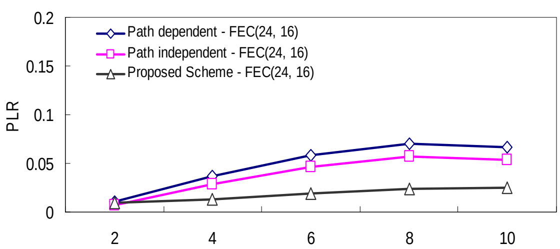
The sender sends a video stream to video client. The video clip is “Foreman” encoded in MPEG-4 CIF format (352 × 288). For video quality comparison, we encoded the test sequence “Foreman” with a standard MPEG-4 codec at 960 Kbps and 30 frames per second. We present our results in terms of packet loss rate and average video quality. For the latter, we use the peak signal-to-noise ratio (PSNR) to measure the reconstructed quality at the receiver.

For the evaluation adopts Reed-Solomon (RS) code as a robust symbol oriented error correction coding system. The coding rate of FEC is fixed to 1/3. That is, the number of source packets n is 16, and the number of redundant packets is set to 8.

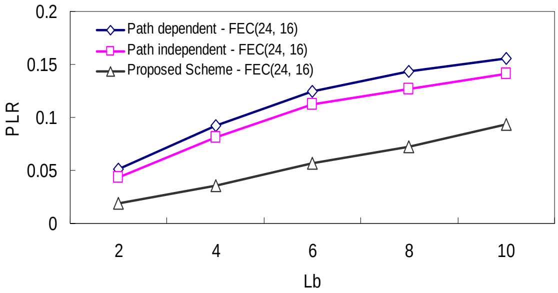
We would present the results of receiver packet loss rate and PSNR when two paths have the same path loss rate and the corresponding burst lengths are different.

V.2 Experimental results

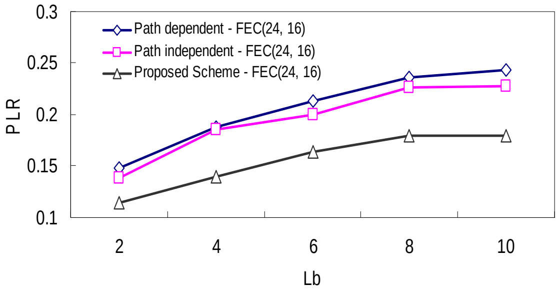
And then, we observe the packet loss rate (PLR) for different error control schemes of the simulation scenario is to fix the path packet loss rate and vary the burst length from two to ten. According to Figure 5-3(a), (b), and (c), our proposed scheme achieves the lower packet loss rate as the burst length increases. These results demonstrate our proposed scheme can reduce the packet loss rate successfully.



(a) Path packet loss rate = 10%



(b) Path packet loss rate = 20%



(b) Path packet loss rate = 30%

Figure 5-3 Receiver packet loss rate vs. burst length (Lb)

VI. Conclusion

In the wired or wireless network, the burst loss problem always exists. In the wire network, the congestion causes the buffer overflow. In the wireless network, fading and signal failure also cause the successive packet to be dropped. Generally, the multi-path FEC schemes are apply for enhancing the quality of video streaming. The burst loss problem decreases the FEC efficiency because the number of lost packets could be larger than the number of redundant packet and the FEC decoder can not reconstruct the original source data.

In order to solve the burst losses effect on the FEC efficiency, we propose a multi-path FEC control scheme. Our proposed scheme aims at dispersing the burst losses to different FEC blocks, and the FEC efficiency can be improved. According to the experimental results, our scheme achieves higher PSNR values and thus provides better quality than traditional multi-path FEC schemes.

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