A Real-time Streaming Media Transmission Protocol for Multi-hop Wireless Networks

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***Abstract-* Time delay as well as error accumulation makes transmission of high-quality streaming media over multi-hop wireless networks more challenging. Since conventional TCP/IP-based protocol drops and retransmits the whole packet once error(s) occur above Physical Layer, which leads to long time delay and low efficiency in transmission, a new protocol for real-time streaming media transmission is proposed in this paper. A packet control layer (PCL) is added between Data Link and Network Layer to enable error-polluted data be transmitted continuously while an error control layer (ECL) is inserted between Transport and Application Layer to further correct errors in data stream. Moreover, a robust header conversion method is applied to PCL to shorten time delay by reducing packet retransmission probability and decrease the redundancy of packet header. And an error-CRC-erasure coding scheme embedded with CRC error correcting algorithm is adopted in ECL. Simulations on DSP show that the proposed protocol can greatly reduce time delay and obtain better error correction performance compared with traditional protocol in BSC channel.**

I. INTRODUCTION

Transmission of streaming media over multi-hop wireless networks has been still facing challenges: high end-to-end delay and high packet loss rate. In order to achieve good streaming services, several error control techniques are commonly adopted: Automatic Repeat reQuest (ARQ), Forward Error Correction (FEC) and Hybrid ARQ (HARQ). Under the ARQ, the receiver notifies the sender with the information of lost packets and the sender then retransmits the packets until they are received successfully, which increases delay rapidly. With the FEC, the receiver not only detects the error, but also corrects the errors by adding redundancy on streaming data. This leads to less retransmission than ARQ. However, FEC decreases the data rate and the ability of error correction is limited by the amount of redundancy. Hybrid ARQ is a joint method of ARQ and FEC.

The ARQ is used in the TCP/IP protocol stack, so TCP/IP protocol is hardly adopted in streaming services which request low delay. Otherwise, the RTP/RTCP protocol is widely used in streaming services because it doesn't need to retransmit the lost packets. But, the TCP/IP can guarantee higher successful transmission rate than RTP/RTCP. As known, a reason that the packets become lost is the packets are dropped by protocol stack if they are checked still error by Cyclic Redundancy Check (CRC).

Some researches try to increase the ability of error correction of CRC[1,2]. Because the CRC is often performed after FEC in the protocol stack, other researches focus on improving the performance of FEC to decrease the error rate before being checked by CRC. The RS, LDPC and Turbo code are main FEC methods [3-5]. The RS code is widely used in applications because of easy implementation. ShokroHahi proposed a new erasure code, called Raptor code[6]. Raptor code has good performance when the number of packets is much large. However, although FEC methods achieve good performance to resist bits error, they have high complexity and have to add redundancy to the streaming data which decrease the efficiency of data transmission[7-9].

A new protocol is proposed in this paper to achieve high successful packet transmission rate while keeping low delay. This proposed protocol is used to transmit streaming media packets over multi-hop wireless networks by adding a packet control layer (PCL) between data link layer and network layer and an error control layer (ECL) between transport layer and application layer. This new protocol enables error-polluted data keep being transmitted by PCL and correct error by ECL. Moreover, a robust header conversion method is applied to PCL to reduce the probability of error in header. The simulations on DSP show that the proposed protocol can obtain better error correction performance.

The next contents are organized as follows: the framework of the protocol is introduced in section II; the error control method is illustrated in section III; and the simulation results are shown in section IV.

II. THE FRAMEWORK OF THE PROPOSED PROTOCOL

The new protocol is designed based on TCP/IP protocol. In the original TCP/IP protocol stack, there are five layers. From top to bottom, they are Application layer, Transport Layer, Internet Layer, Datalink Layer and Physical Layer. When one below layer is checked error by CRC, the packet will not be passed to the up layer and the packet is dropped. Next, the receiver signals the sender which packet is not received successfully. And then, the sender retransmits the lost packet.

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Even though retransmission leads to reliable delivery, the procedure causes high delay, so it is not appropriate for real-time application such as streaming service. In the new protocol framework, as shown in Fig.1, two new layers are inserted: PCL layer and ECL layer.

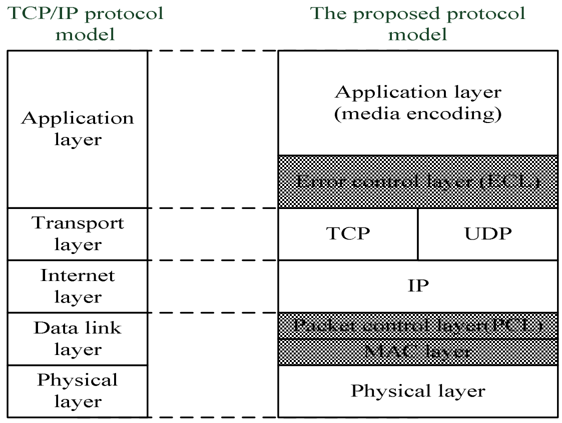


Fig.1 The framework of the proposed protocol

PCL layer: this layer is designed to offer extra protection on the header of TCP/IP layer in order to keep transmitting packet even when the packet is checked error by CRC, instead of dropping it. This can decrease the amount of retransmission and obtain low delay. When the header of a packet is correct, the packet will be passed continuously. Thus, the PCL works to guarantee a correct header. In other words, PCL adds redundancy to header and performs FEC when error occurs in header.

ECL layer: this layer is designed to perform error correction for the packets which are passed from TCP layer with error. Through this layer, the packet data can be received by application layer with no error.

Since the two layers are added into the protocol stack, the ability of network error correction is enhanced and retransmission is reduced.

III. ERROR CONTROL IN PROPOSED PROTOCOL

The PCL and the ECL jointly achieve error control for streaming data packets. The detailed error control method is illustrated in this section.

A. The protection of TCP/IP layer header by PCL

If TCP/IP layer header is checked error, the packet is going to be dropped in traditional protocol stack and waiting to be retransmitted. This results in high delay.

In the new protocol, some redundant bits of error correction code are added to TCP/IP layer header to offer enhanced error correction. When the header of a packet is checked to contain error bits during transmission, the PCL tries to recover the original header through the error correction bits. If the header is recovered successfully, the packet is going on being transmitted. Otherwise, the packet is dropped.

After adding the redundancy, the header is split up into multiple parts and interleave with the data information in the data frame to resist burst error. The structure of data frame is shown in Fig.2.

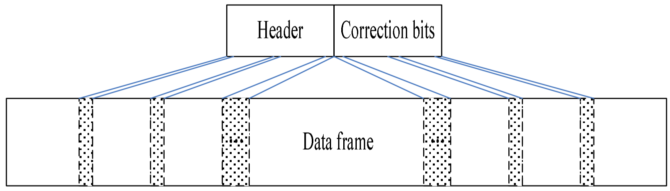


Fig.2 The structure of data frame

B. The header conversion

In order to reduce the probability of error in header and decrease the header redundancy, a shorten header format is adopted. In this paper, a 7-byte header is applied which structure is shown in Fig 3.

3 bits address	16 bits sequence number	16 bits confirmed sequence number	URG	ACK	PUH	RST	SYN	FIN	16 bits check sum

Fig.3 The structure of shorten header

In the header, 3 bits are used for address. The sequence number and the confirmation sequence number both adopt 16 bits. From URG to FIN, the same bits as traditional TCP header are filled. And then the 16 bits check sum follows.

The new header can be performed conversion to compatible with the traditional TCP layer header by PCL layer. It is necessary that each section is just filled out and the CRC is recalculated. The header conversion is used to shorten the length of header so as to decrease the probability of error in header and easy to be protection by PCL.

C. The correction of packet erasure by ECL

Even though burst error is the main error model in the multi-hop wireless networks, the random error still often occurs. According to the error model, an error-CRC-erasure method is proposed in this paper. This method adopts multi-level correction to enhance the probability of successful transmission. The code structure of the method is shown in Fig.4.

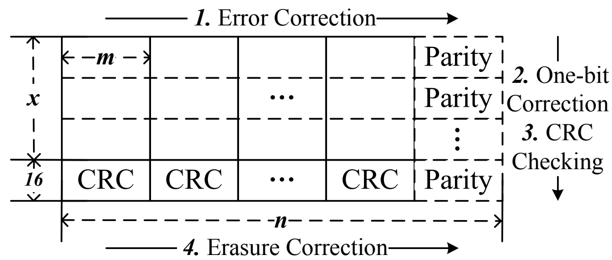


Fig.4 The code structure of the error–CRC-erasure

In the row direction, RS code is adopted to correct error and packet erasure. In the column direction, CRC-16 is used to check error. The sender encodes packet data with RS code in row direction and then calculates the CRC bits in column direction. Afterwards, multiple codes are interlaced to transmit.

When packets arrive at the receiver, it is first de-interlaced, and then corrected in row direction. If successful, the correct codes are output. Otherwise, it is performed CRC correction in column direction. The CRC can achieve one-bit error correction. If there is still error in the packets, the erasure correction is applied.

D. The channel multiplexing

In the multi-hop wireless networks, the conflict often occurs at nodes which send data and receive data at the same time. In order to reduce this conflict, a channel multiplexing techniques is introduced in the proposed protocol.

Firstly, the time is divided into slots. Then, in each slot, some nodes only send data and the other nodes only receive data. The different types of nodes are selected according to distance from which no conflict happens.

For example, if five nodes arranged in a line is a multi-hop wireless network in Fig.5. At slot 1, the node A and the node D send data, while the nodes B, C, E receive data without conflict. At slot 2, the node C sends data and the nodes B, D receive data, while the nodes A, E are set idle. At slot 3, the nodes B, E send data and the nodes A, C, D receive data. Consequently, after 3 time slots, each node sends once and receive once, which composes a cycle. Because the TCP protocol requests ACK from receiver after successful transmission, the multiplexing technique can simultaneously complete ACK feedback in one cycle. In this way, conflict is reduced and the transmission efficiency is improved. Moreover, the cycle is streamline which is appropriate for implementation on hardware system.

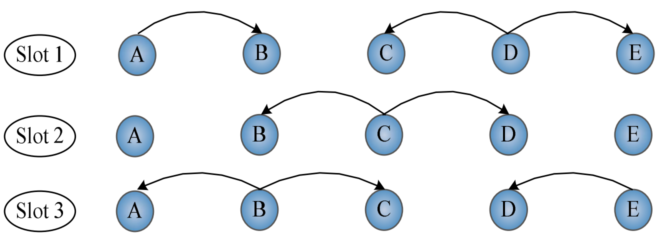


Fig.5 Slots multiplexing technique

IV. SIMULATION RESULTS

In the simulation, a five-node multi-hop wireless network is set as Fig.6. These nodes are arranged in a line. The maximum data rate is 10Mbps for point-to-point transmission. The error bit rates are all 1×10^{-5} in data linker layer between two neighbor nodes.

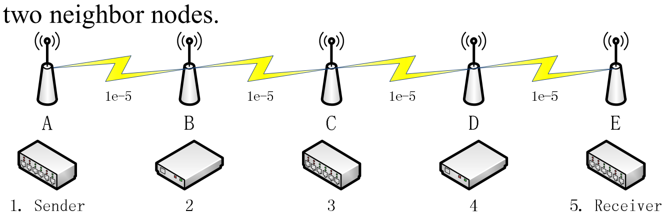
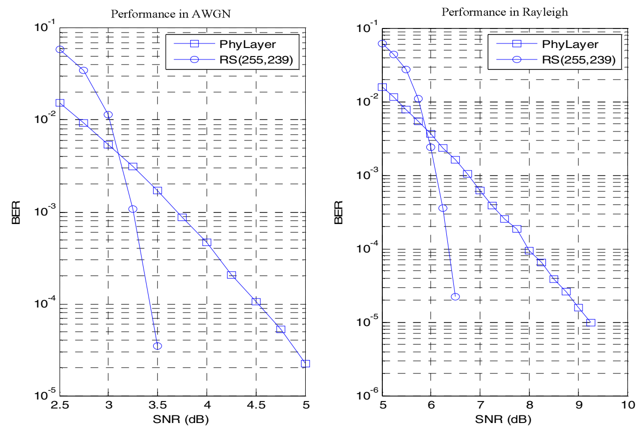


Fig.6 The simulation scene

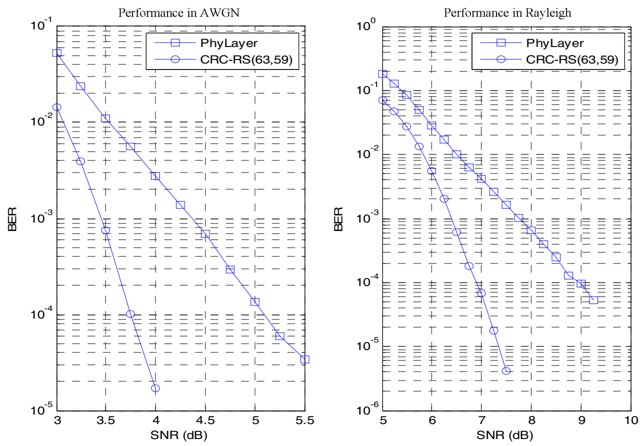
At nodes A and C, the PCL and ECL work to encode and add redundancy. At nodes C and E, the PCL and ECL work to decode and correct error. At nodes B and D, only PCL work. Some parameters setup are listed in Table 1 below.

The channel is selected AWGN and Rayleigh. For AWGN, the SNR is set from 3dB to 5.5dB with interval 0.25dB. For Rayleigh, the SNR is set from 5dB to 9.25dB with interval 0.25dB. When the first hop received up to 100 error code blocks, the simulation terminates.

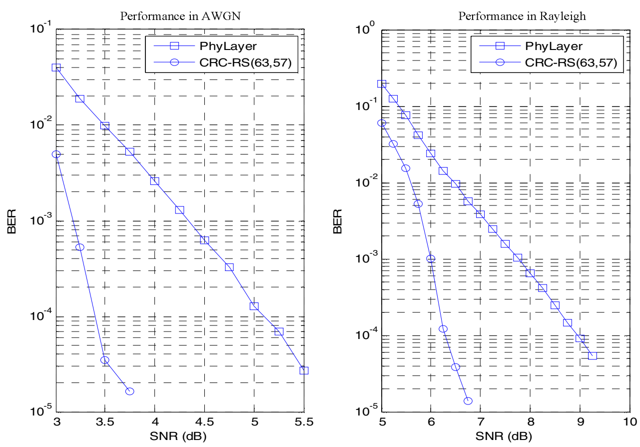
The comparison of performance for traditional RS code and the proposed method is shown in Fig.7.From the figure, it can be seen when bits error rate is between 10^{-4} and 10^{-5}, the traditional RS method and the proposed method have both good performance for error correction and no failure happen. When SNR is small, lower than 3dB, the traditional RS method has higher bit error rate than the proposed method. This shows that the proposed method has better performance than RS method.



(a) Traditional RS(255,239) method



(b) error-CRC-erasure with RS(63,59)



(c) error-CRC-erasure with RS (63,57)

Fig.7 The BER comparison of traditional RS and the proposed method

Table 1 Parameters setup at nodes

node	Physical Layer	PCL layer	ECL layer	
Node A	(2,1,7) Convolution code, 48*60 interlaced	Header conversion, BCH(120,57) code	RS(255,239) code, 255*12 interlaced	CRC-RS(63,59) code, 24*63 interlaced
Node B	60*48 de-interlaced, (2,1,7) Convolution code	BCH(120,57) decode, header conversion	-	-
Node B	(2,1,7) Convolution code, 48*60 interlaced	Header conversion, BCH(120,57) code	-	-
Node C	60*48 de-interlaced, (2,1,7) Convolution code	BCH(120,57) decode, header conversion	255*12 de-interlaced, RS(255,239) decode	24*63 de-interlaced, CRC-RS(63,59) decode
Node C	(2,1,7) Convolution code, 48*60 interlaced	Header conversion, BCH(120,57) code	RS(255,239) code, 255*12 interlaced	CRC-RS(63,59) code, 24*63 interlaced
Node D	60*48 de-interlaced, (2,1,7) Convolution code	BCH(120,57) decode, header conversion	-	
Node D	(2,1,7) Convolution code, 48*60 interlaced	Header conversion, BCH(120,57) code	-	
Node E	60*48 de-interlaced, (2,1,7) Convolution code	BCH(120,57) decode, header conversion	255*12 de-interlaced, RS(255,239) decode	24*63 de-interlaced, CRC-RS(63,59) decode

Fig.8 shows the delay at each node. The blue bars indicate the delay with proposed error-CRC-erasure method and the brown bars designate the delay with traditional RS method. It can be seen from the Fig.7 that error-CRC-erasure has lower delay than the traditional RS method. Especially at node 1, 3, 5, the proposed method has nearly half delay as RS method. This performance owes to the new protocol stack which reduces the retransmission and shortens the TCP layer header.

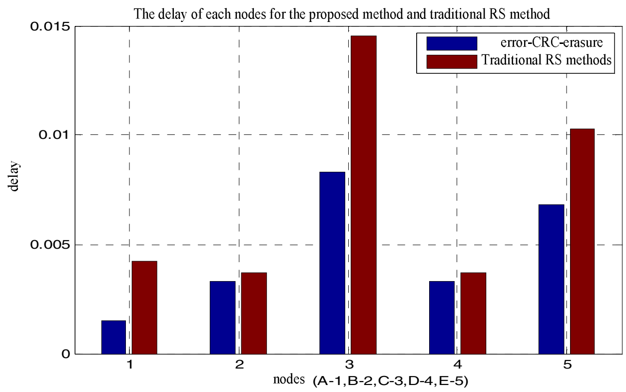


Fig.8 The delay comparison of traditional RS and the proposed method

V. CONCLUSION

In this paper, we proposed a new protocol which is designed to transmit streaming data packet over multi-hop wireless networks. Based on TCP/IP , the proposed protocol adds two layers of PCL and ECL to control error, in order to decrease retransmission and offer real-time service for media applications. Moreover, a channel multiplexing technique is proposed to reduce conflict and make full use of the channel resource, which can complete once data transmission and once ACK feedback in one cycle. The simulation results are shown to demonstrate the performance of the proposed protocol. It shows that the proposed protocol can decrease error transmission rate and reduce delay.

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