SCTP Performance Analysis based on ROHC

Byung-Cheol Shinn and Bai Feng, *Member, KIMICS*

Abstract—In this paper, an analysis has been done on the performance of SCTP header compression by using Robust Header Compression (ROHC) [1] method. And it is assumed that the operating mode for ROHC is unidirectional mode (U-Mode) and the possible states are IR and SO states. The throughput of SCTP packets in wireless link and the impact of size of W-LSB encoding window on throughput are discussed.

Index Terms—SCTP, ROHC, performance analysis, W_LSB, context.

I. INTRODUCTION

With the development of Internet technology, SCTP (Stream Control Transmission Protocol) [2] is replaced with existing transmission protocol TCP (Transport Control Protocol) and UDP (User Datagram Protocol) for a real-time multimedia application service. SCTP is a new transmission protocol and is specified in RFC (Request for Comments) 2960 of IETF (Internet Engineering Task Force). In addition, it spreads the bound of using application for various kinds of service.

However, the encapsulation process of SCTP/IP layers produces packets whose payload size, for particular services, is a little percentage of the whole packet size and the header sizes are relatively a large percentage (high overhead services), so that, a significant part of radio channel bandwidth (the most expensive and limited resource of the whole wireless system) is used for header transmission. For these reasons it is of primary importance the adoption of a header compression scheme can be able to reduce the protocol overhead with the aim to make economically feasible and physically realizable the implementation of such high overhead-services.

The header compression work has been studied from 1984 and several header compression protocols such as Thin-wire I and II, CTCP (Compressed TCP) [3], IPHC (IP Header Compression) [4] and CRTP (Compressed RTP) [5] have been proposed. However, none of them can work well over the wireless link due to error propagation. To solve the problem, the ROHC working group in IETF proposed a new header compression framework, named as ROHC. The most significant feature of the protocol is the robustness. ROHC successfully reduces the error propagation by a special encoding mechanism, known as Windows-based Least Significant Bits (W-LSB) encoding method.

The paper is organized as follows. Following the introduction, in the section II, we will briefly describe the SCTP and ROHC; in section III, the analysis model is described; performance analysis results are presented in section IV. Finally, we give a conclusion of the paper in section V.

II. SCTP AND ROHC

TCP [6] has performed immense service as the primary means of reliable data transfer in IP networks. As the number of application increases recently, it is found that the role of TCP is limited and they have incorporated their own reliable data transfer protocol on top of UDP. Such a trend in application directly motivated the development of SCTP.

A. SCTP

SCTP is a reliable transport protocol operating on top of a connectionless packet network such as IP network. It transfers a message with a function of multiple paths or multiple streams between two nodes connected by "SCTP association".

As shown in Fig.1, we assume SCTP runs on top of IP. The basic service offered by SCTP is the reliable transfer of user messages between peer SCTP users. It performs this service within the context of an association between two SCTP endpoints.

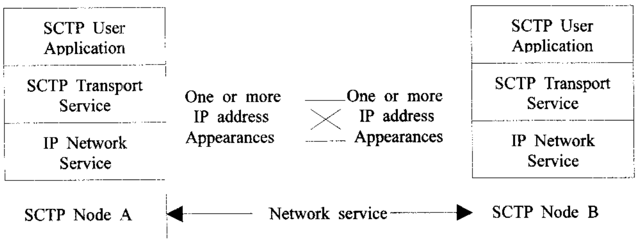


Fig. 1 An SCTP association.

The characteristics of SCTP are the transmission of various kinds of application data over just one session. When the session is initialized, the sender gives the number of stream to the receiver. In transmission time, ordering function is provided for each stream of independently. Data recovery and retransmission processes

---

Manuscript received June 28, 2007.

Byung-Cheol Shinn is with the Department of Radio Engineering, Chungbuk National University, Cheongju, 361-763, Korea (Tel: +82-43-261-2389, Fax: +82-43—271-4647, Email: bcshin@cbu.ac.kr)

are also performed on each stream ID. The SCTP packet format is shown in Fig. 2. The SCTP packet format is divided into a common header and several chunks, and each chunk has its own independence as shown in Fig. 2.

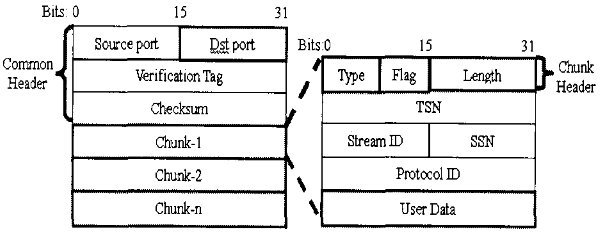


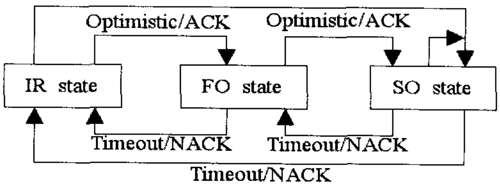
Fig. 2 SCTP packet format.

B. ROHC

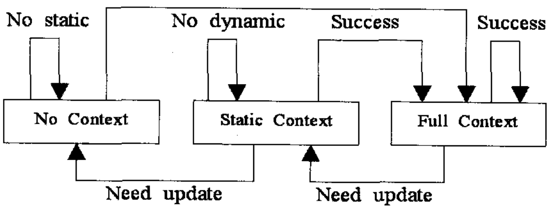
ROHC is developed which is adaptable to the characteristics of wireless links which can compress the 40 octets IPv4/UDP/RTP headers to 1-3 octets. And SCTP/IP headers can also be processed on ROHC platform [7].

Header compression with ROHC can be characterized as an interaction between two state machines, one compressor machine and one decompressor machine, each of them instantiated once per context. The compressor bases on the state machine in Fig. 3(a), and each state represents different level of compression. Transition conditions between the three states are defined by the modes of operation.

The compressor starts from the initialization and refresh (IR) state with the transmission of all static and dynamic header fields allowing the decompressor the correct context acquisition. In the first order (FO) state, the compressor considers only the dynamic fields that have been changed with respect to the header of the previous packet and transmits only encoded variations of these dynamic fields. In the second order (SO) state, where we have the highest level of compression, the compressor enters into it only when the stream becomes regular.



(a) State transition of compressor.



(b)State transition of decompressor.

Fig. 3 State transition of ROHC protocol.

The decompressor is based on the state machine in Fig. 3(b), each state representing different level of decompression according to context state. Initially, the decompressor works in the no context (NC) state. Once a packet has been decompressed correctly, the decompressor transmits all the way to the full context (FC) state. When the dynamic fields of context needs to update, the decompressor transits back to the static context (SC) state. Only when the static field of context needs to update the decompressor will go all the way back to the NC state. By updating context in step-by-step, ROHC can further reduce the size of compressed headers and the possibility of context out of sync between the compressor and decompressor.

In addition, ROHC can get further compression gain due to the synergy between the sophisticated encoding methods and the wide availability of formats needed for sending compressed header. ROHC derives from the concept of the compression profiles.

III. THE ANALYSIS MODEL

In this section, we develop an analysis model for the ROHC-SCTP profile based on [7] together with some assumptions.

A. Assumptions

We make the following assumptions in our model:

1) Mode

The compressor and decompressor can work in three modes. They are named as unidirectional (U), optimization (O) and reliable (R) mode. In U-mode, the communication between compressor and decompressor is only proceeding in one direction. In O-mode and R-mode, the communication between compressor and decompressor is bidirectional.

In order to simplify the model, we assume the compressor and decompressor only work in U- mode.

2) State

Assume the compressor only works in IR and SO [1] states.

3) Packet types

Assume only two types of packet in our defined packet stream: IR is for context refreshment and compressed header (CH) is packet with compressed header.

4) Channel

Assume the corruptions of packets are independent of each other through the channel.

B. Analysis Model [13]

Table 1 shows the parameters which are used in our analysis model. SCTP can divide data into a number of streams, each stream can be transferred according to its characteristics, and each stream can be handled without any relation with other streams. So we define a SCTP packet stream as shown in Fig. 4, and there are N packets in the stream including IR and CH packets.

Table 1 Parameters utilized in analysis model

Symbol	Meaning
N	Number of packets in a stream
ir	Index of Initializtion Refreshment packet in a stream
ch	Index of packet with Compressed Header in a stream
p(ir)	Probability of decompressing an IR packet
p(ch)	Probability of decompressing an CH packet
c(ch)	Possibility that the context is valid on i^{th} CH packet
n_{ir}	Index of the i^{th} IR packet in a stream
n_i	Index of the i^{th} packet in a stream
E	Bandwidth Efficiency
T(N)	Throughput for N IR or CH packet
w	Size of W-LSB encoding window
e(ir)	FBE probability of IR packet.
e(ch)	FBE probability of CH packet.
L_p	The length of payload in each packet
L_{ir}	The length of IR packet
L_{ch}	the length of CH packet
L_{link}	the length of link layer header
b	Bit error rate

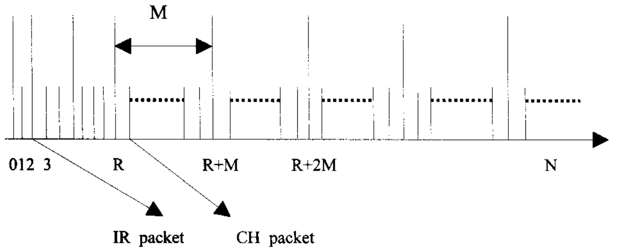


Fig. 4 The SCTP packet stream.

As we know, the IR packet is larger than the CH packet because the header of CH packet is compressed. So we use the long line to represent the IR packet, and use the short line to represent the CH packet as shown in Fig. 4. We use a sequence number $\{n_i \mid n_i=0,1,2, \ldots N\}$ to index the packets in the stream. And we use *ir* to index the IR packet, *ch* to index the CH packet.

The compressor works from IR state, where the context refreshment period exponentially increased. The output packets are seldom compressed until reaches a predefined value, R. Then the compressor goes to the SO state, where the IR packet is transmitted at a fixed interval of M packets. The relation of R and M can be described as

$$R = \lfloor \log_2 M \rfloor \tag{1}$$

As we know, the packet stream includes two types of packet, IR and CH packets. So we can represent the index of IR packets in IR and SO state.

$$n^{ir} = \begin{cases} 2^{ir} + ir - 1 & IR\ state, 0 \le ir < R+1 \\ (ir-R) * M + 2^{R+1} + R - 1 & SO\ state, R+1 \le ir < N \end{cases} \tag{2}$$

We can calculate the position of IR packet from above equation. The result is shown in Table 2.

Table 2 Position of IR packets in the packet stream

Packet number	Position of IR packet
1	2
2	5
3	10
4	19
5	36
…	…

As we defined previously, the SCTP packets stream contains IR and CH packet. So, except IR packets, the remaining positions are the index to CH packets, as shown in Table 3.

Table 3 Position of CH packets in the packet stream

Packet number	Position of CH packet
1	1
2	3
3	4
4	6
5	7
…	…

For a given compressed packet stream, we use '*p*( )' to represent the probability of decompressing a given packet successfully. The successful decompression of a packet depends on two conditions. First, the packet itself should not contain any bit error that causes the decompression failure. We use '*e*( )' to represent the probability of fatal bit error (FBE). Second, the context should be valid. We use '*c*( )' to represent the possibility that the context is valid on CH packet. We use *w* to represent the size of W-LSB encoding window.

1) For IR Packet

IR packet is independent from the context and can be decompressed if no FBE happens. So we can get the probability of decompressing an IR packet successfully through Eq (3):

$$p(ir) = 1 - e(ir) \qquad ir \in \{n_{ir}\} \tag{3}$$

The throughput of IR packets can be calculated as in Eq (4) and the unit is (packets).

$$T(ir) = \sum_{ir=0}^{N-1} p(ir) = \sum_{ir=0}^{N-1} (1 - e(ir)) \qquad ir \in \{n_{ir}\} \tag{4}$$

2) For CH Packet

The *p* not only depends on FBE, but also depends on context. So the *p* of CH packet can be calculated as:

*p(ch)=p(i^{th} packet is not corrupted)*p(context is valid)*

And we can get the equation as in Eq (5).

$$p(ch) = (1 - e(ch)) * c(ch) \qquad ch \notin \{n_{ir}\} \tag{5}$$

The throughput of CH packets can be calculated as in Eq (6) and the unit is (packets).

$$T(ch)=\sum_{ch=0}^{N-1}p(ch)=\sum_{ch=0}^{N-1}(1-e(ch))*c(ch) \qquad ch\notin\{n_{ir}\} \quad (6)$$

where the *c(ch)* can be calculated as follows:

$$c(ch)=1-\prod_{ch\in\{n_k^{o,i-1}\}}e(ch)-\sum_{j=o}^{i-w-1}\left(p(i)*\prod_{ch=j+1}^{j+w}e(ch)\right) \quad (7)$$

For a packet stream, the general equation for total throughput T over N packets can be obtained as follows:

$$T(N)=\sum_{i=0}^{N-1}p(i) \quad (8)$$

In order to represent the bandwidth efficiency, we derive a parameter E, and it can be described as in Eq (9).

E= number of successful decompressing packets/number of transmitted packets

$$=T(N)/N \quad (9)$$

We employed a simple Bernouilli model for FBE of IR and CH packets. We assume that the link layer drops all the corrupted packets. With such a model, the packet corruption is independent of each other and the *e* can be calculated as:

$$\begin{aligned} e(ir)&=1-(1-b)^{(L_{ir}+L_p+L_{link})} && ir\in\{n_{ir}\} \\ e(ch)&=1-(1-b)^{(L_{ch}+L_p+L_{link})} && ch\notin\{n_{ir}\} \end{aligned} \quad (10)$$

where, L_p is the length of payload in each packet. L_{ir} is the length of IR packet header; L_{ch} is the length of CH packet header; L_{link} is the length of the link layer header.

We analyze the performance on SCTP agent. So we set L_{ir} to 18 octets and L_{ch} to 2 octets from [7]. We assume PPP protocol is used in link layer and thus L_{link} is set to be 7 octets. The value of M will be assumed to be 64. And *b* is set to represent the bit error rate (BER). We set the SCTP packet stream as 1000 packets per second. Two nodes are connected through the wireless link. One works as compressor and the other works as the decompressor.

IV. PERFORMANCE ANALYSIS

In this section, we present some performance results based on the analytical model specified by Eq (1) to (10). And the performance results will be divided into three parts: First, we analyze the relationship of the throughput and bit error rate. Then we describe the impact between bit error rate and bandwidth efficiency. Finally, we present the throughput as a function of window size *w*.

A. Throughput vs BER

In order to get the numerical result, we define a SCTP packet stream with 1000 packets. And it is composed of IR packet and CH packet. So we will give the throughput performance on the two types of packet respectively.

1) For IR packet

Fig. 5 shows a direct view of the throughput of IR packet with the payload as a parameter result and can be calculated from Eq. (4).

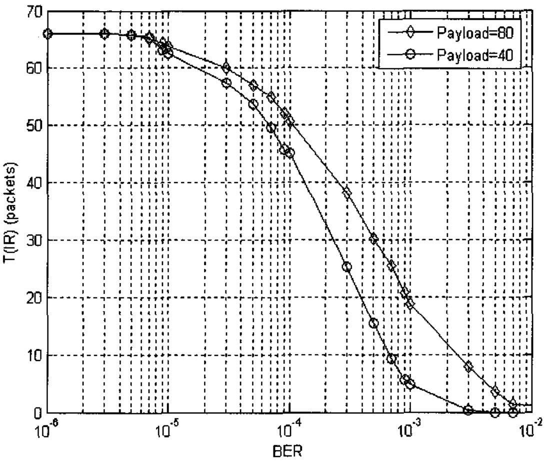


Fig. 5 Throughput of IR packet with different payloads (when window size is *w*= 64).

With the increase of BER, the throughput decreases. It is obvious that the throughput of IR packet is almost same for the BER in the range of 1.0E-06 to 6.0E-06. With the increase of BER, the throughput of IR packet decreases for the BER above 6.0E-06.

In addition, it is also observed that the throughput of IR packet increases as the payload increases.

2) For CH packet

We can get the numerical results for CH packets from Eq (5) and they are shown in Fig. 6. The throughput of CH packet has comparability with IR packet.

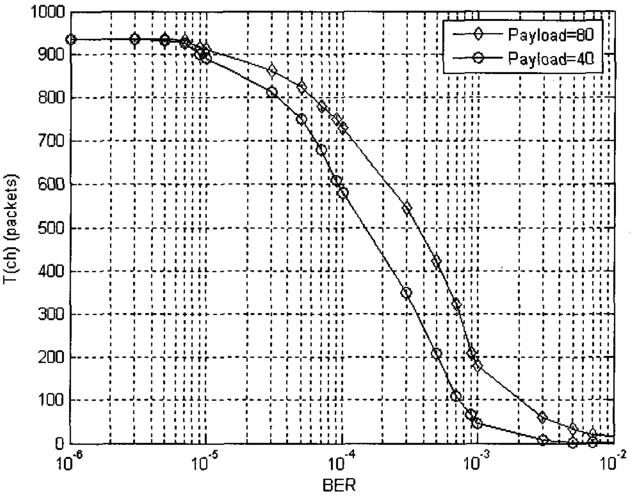


Fig. 6 Throughput of CH packet with different payloads (when window size is *w*= 64).

Fig.5 and Fig.6 show that the throughput of CH packet is much higher than IR packet. It means that during a transmission, most of the bandwidth is used to transmit CH packet. As we know, CH is the packet with compressed headers. So it is smaller than IR packet.

B. Bandwidth Efficiency vs BER and throughput vs window size

Fig.7 presents the relationship between BER and efficiency. The efficiency of IR and CH packets become lower by increasing the BER. Under a high BER (1.00E-01), the throughput of IR and CH packets can be presented in Fig.8 with different values of w. With the increasing of BER, the throughput of IR packet become decreasing under the high BER period. But the decreasing tendency will be reduced by increasing the value of w.

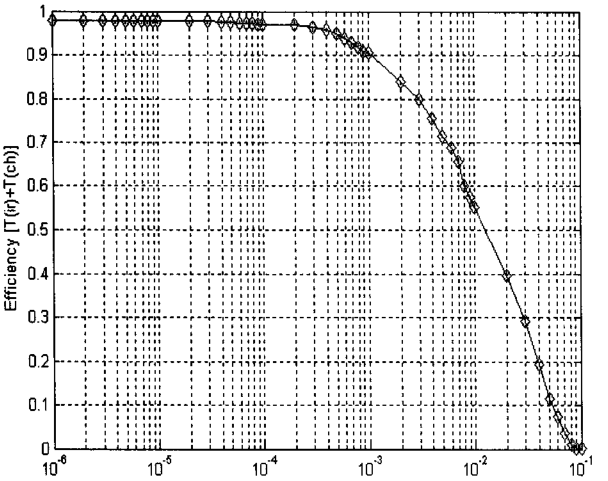


Fig. 7 Bandwidth Efficiency.

We use Eq (7) to get result as shown in Fig. 8. In order to present this phenomenon directly, we fix the BER to be a high value. So Fig. 8 gives a direct view about it. The throughput of CH packet increases as the window size w increases. The throughput of IR packet, however, does not change as a function of window size *w*.

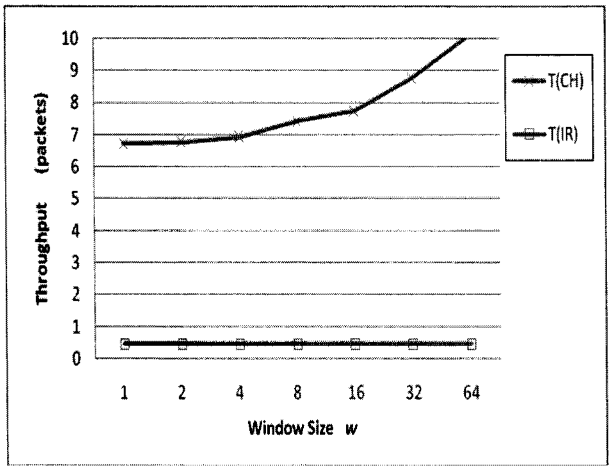


Fig. 8 Throughput with different *w* values (where BER=1.00E-01).

V. CONCLUSIONS

In this paper, we developed an analytical model to analyze the performance of SCTP when ROHC header compression is applied. The throughput of SCTP packets in wireless link and the impact of window size *w* of W-LSB encoding window scheme on throughput in IR and SO states under U-mode is discussed.

From this analysis, it is found that the throughput of IR packet is almost same for the BER in the range of 1.0E-06 to 6.0E-06. With the increase of BER, the throughput of IR packet decreases for the BER above 6.0E-06. And we also perform the impact of window size for W-LSB encoding on ROHC robustness.

To simplify the analysis, the performance analysis in IR and SO state under U-mode has been done in the work. The complementary analysis under O-mode/R-mode can be mentioned as the future work area.

REFERENCES

[1] C. Bormann, C. Burmeister, M. Degermark, H. Fukushima, H. Hannu, L-E. Jonsson, R. Hakenberg, T. Koren, K. Le, Z. Liu, A. Martensson, A. Miyazaki, K. Svanbro, T. Wiebke, T. Yoshimura, and H. Zheng, "Robust header compression: ROHC: Framework and four profiles: RTP, UDP, ESP, and uncompressed," RFC 3095, IETF, July 2001.

[2] R. Stewart et al., "Stream control transmission protocol," RFC 2960, IETF, Oct. 2000.

[3] V. Jacobson, "Compressing TCP/IP headers for low speed serial lines," RFC 1144, IETF, 1990.

[4] M. Degermark, B. Nordgren, S. Pink, "IP header compression", RFC 2507, IETF, 1999.

[5] S. Casner, V. Jacobson, "Compressing IP/UDP/RTP headers for low-Speed serial links," RFC 2508, IETF, 1999.

[6] A. Calveras, J. Paradells. "TCP/IP over wireless link: performance evaluation," Proc. IEEE, VTC'98. Ottawa, Ontario, Canada, May 1998.

[7] Hee-Ok Song, Seong-Gun Choi, Byung-Cheol Shin, Insung Lee, "A study on SCTP header compression using the ROHC method," vol.9, no.1, The Korea Institute of Maritime Information & Communication Sciences, Feb. 2005, pp76-87.

[8] G. Boggia, P. Camarda, and V.G. Squeo, "ROHC+: A new header compression scheme for TCP streams in 3G wireless systems," in Proceedings of the IEEE ICC, vol. 5, 2002, pp. 3271-3278.

[9] Pelletier, G., "Robust header compression (ROHC): context replication for ROHC profiles," Internet Draft (work in progress), <draft-ietf-rohc-context-replication-03.txt>, IETF, Jul. 2004.

[10] Armando L. Caro Jr, Janardhan R. Iyengar, Paul D. Amer, Sourabh Ladha, Gerard J. Heinz II, Keyur C, Shah, "SCTP:A proposed standard for robust internet data transport", IEEE Comp. Mag., vol. 36, no.11, pp.56-63, Nov. 2003.

[11] G. Pelletier, L-E. Jonsson, M. West, R. Price, K. Sandlund, "Robust Header Compression (ROHC): A profile for TCP/IP (ROHC-TCP)" <draft-ietf-rohc-tcp-07.txt>, IETF, Jul. 2004.
[12] Hui Wang, J.S. Li and P.L. Hong, “Performance analysis of ROHC U-mode in wireless links,” IEEE Proc. Commun., vol. 151, no. 6, Dec. 2004.
[13] H. Wang and K.G. Seah, “An analytical model for the ROHC RTP profile,” WCNC, 2004.

ACKNOWLEGMENT

This work was supported by the research grant of the Chungbuk National University in 2007.

Byung-Cheol Shinn
1975: Bachelor, Department of Electrical, Seoul National University, Korea.
1977 : Master, Department of Electronics, KAIST, Korea.
1984 : Ph.D., Department of Electronics, KAIST, Korea.
1984-1998 : Professor in KAIST.
1998-Present : Professor in Chungbuk National University.

Bai Feng
2004 : Bachelor of Computer Science in Zhengzhou University, China.
2006-Present : Graduate student of Bioinformatics in Chungbuk National University, Korea.