Improving the Performance of SCTP Transport Protocol over Wireless Networks

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Abstract

Stream Control Transmission Protocol(SCTP) is a reliable transport protocol combining the advantages of TCP and UDP. SCTP has many desirable features including multihoming, multistreaming, and partial data reliability. These features have made SCTP perform much more effectively in multimedia networking applications. They have also worked better in wireless environment which traditional transport protocols are ineffective and cumbersome.

Before the transmission, an application using SCTP needs to establish an association between the client and the server. The establishment of association requires a number which will be used to create multiple streams. However, SCTP has not specified a method or suggested any ideas of determine the number.

In our paper, we focus on the performance of SCTP protocol over the wireless networks. The ideas is to extend the SCTP with a process of determining an optimal number prior to the association establishing. We examine the modified SCTP on a simulated wireless networks, and the experiment results of simulation using NS2 have shown the modified SCTP is feasible and also demonstrated the modified SCTP's superiority of performance over TCP and UDP over the wireless networks.

1. Introduction

The Stream Control Transmission Protocol (SCTP) has many attractive features such as multi-streaming and multi-homing. These features enable many multimedia network applications on the wireless networks [8], on which traditional transport protocols such as TCP and UDP perform unsatisfactorily.

One problem which severely impacts on TCP performance over wireless network is so-called head-of-line blocking. SCTP solves the problem of head-of-line blocking by using multiple streams. However, The problem associated with using multiple streams is that if too many streams are used over a network with low traffic, it wastes our resources. If the network traffic is high, but we start with just few streams, we will experience a bad delay performance. This problem motivates us to find a way of finding out an optimal number which just makes SCTP work as efficient as possible [3].

There are many trial-and-error approaches to find such an optimal number for SCTP to exploit in the association establishment [6]. Our approach is to modify the SCTP protocol by integrating one more step prior to the four-way handshake procedure to collect parameters for determining a stream number.

In this paper, we present the modification necessary to improve the performance of SCTP over the wireless networks, and then test this modified protocol on the simulated network. The rest of paper is organized as follows. In Section 2, we provide an overview of SCTP routing protocols. In Section 3, we describe the modification and improvement to current SCTP protocol. The implementation of modified SCTP protocol is illustrated in Section 4. Results and discussions are presented in Section 5. Conclusions are given in Section 6.

2. SCTP protocol

SCTP was initially developed for telephony signalling for the purpose of transmitting voice data and control signal at separate streams. But today it can be adopted to transmit Internet data using more than one stream for the robustness and efficiency purpose.

A SCTP packet consists of a common header and a number of chunks. The common header is usually followed by one or more concatenated chunks, which contain control or data information.

2.1. SCTP association

Different than TCP which provides a byte-stream data service, SCTP provides a message-oriented data delivery service. SCTP uses a new concept of four way handshake association to perform three way handshake in TCP to establish a connection and UDP needs no connection.

This four way handshake and oriented message mechanism provide resilience against the Denial of Service attacks to which TCP is prone.[7]. Similar to TCP, an SCTP association is terminated with the sending of three messages. Note that graceful shutdown is the preferred method of terminating an association.

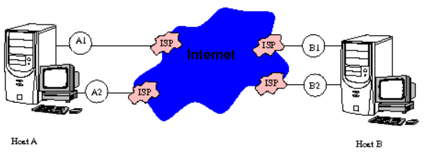

Figure 1. A Network with multihomed addresses

2.2. SCTP features

SCTP has some novel features to improve performance in wireless and mobile environment. Like the most popular TCP algorithms — TCP Reno and TCP Reno with Eifel, SCTP also suffers from spurious timeouts when delay spikes occurs in wireless mobile environment. However, when an end point uses mobile IP, SCTP performance better than TCP Reno and TCP SACK during hand-offs.

In detailed, SCTP provides the following services and features [3]:

- Multi-homing, or the ability for a single SCTP endpoint to support multiple IP addresses. Using multi-homed SCTP, redundant LANs can be used to reinforce the local access, while various options are possible in the core network to reduce the dependency of failures for different addresses.

- Multi-streaming function provided by SCTP allows data to be partitioned into multiple streams that have the property of being delivered independently, so that message loss in any of the streams will only affect delivery within that stream, and not in other streams.

- SCTP provides reliable transmission, detecting when data is discarded, reordered, duplicated or corrupted, and retransmitting damaged data as necessary.

- SCTP is message oriented and supports framing of individual message boundaries. In comparison, TCP is stream oriented and does not preserve any implicit structure within a transmitted byte stream.

- SCTP is rate adaptive similar to TCP, and will scale back data transfer to the prevailing load conditions in the network. It is designed to behave cooperatively with TCP sessions attempting to use the same bandwidth.

Some of these features are very useful for the wireless networks where the link error rates are much larger than that on the traditional wired networks. For example, SCTP uses the similar congestion control algorithms, but the packet lose is not the only indicator of the congestion.

3. Modification to SCTP Protocol

The original association establishment of SCTP can be viewed in [2]. Here we show the modified association establishment in Figure 2.

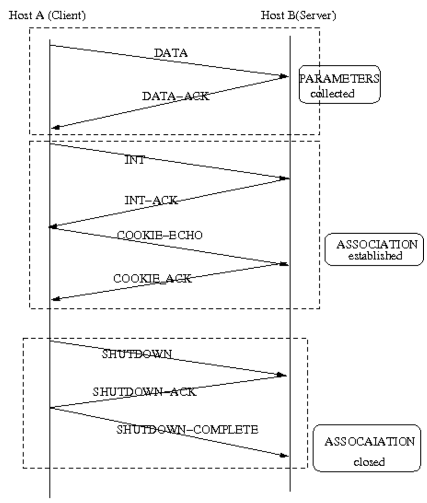

Figure 2. Modified SCTP: Parameter collecting, association establishment and shutdown

To find out optimal number of streams in SCTP association, a parameter collection handshake is introduced before the association establishment so that the sender collects the real-time parameters of network and receiver and packet the optimal stream number into INIT message. More precisely, the modified association of SCTP is described as follows.

- Host A sends an DATA chuck with time-stamp to host B.
- When host B receives DATA chuck, it generates a DATA-ACK chuck which consists of original time-stamp from DATA chuck and buffer size of host B, then sends the DATA-ACK chuck to host A.
- Host A uses the data in DATA-ACK chuck to evaluate parameters (such as RTT, propagation delay, etc.) and determine the optimal number of streams. Then host A generates INT packet and send it to host B.
- Follow SCTP protocol to establish an association.

Only at this point does SCTP establish the association and allocate resources at host B.

3.1. Determining the Stream Number of Association in SCTP

We have seen that the number of streams in a SCTP association can affect on the performance of a network. It is obvious that the best selection of stream number may save the precious network resource without affecting the performance of data transmission. As stated in [1], the number of streams is determined when the association is made. Once the number of streams is negotiated, it is impossible to change stream number without reestablishing another association. It should be noted that network traffic can be variable as time goes on [9].

As analyzed in [1], the stream number of an association relies on many factors. In other words, the stream number of an association is a function of multiple variables or the optimal stream number is affected by many conditions. Note that these conditions and factors likely interact with each other rather than being independent with each other, while the impact of an individual factor is diverse in different circumstances. we first investigate three factors which are irrespective and independent with each other though, as follows:

1. receiver buffer size (b). Bigger the receiver buffer size is, less streams we need to establish.
2. round trip time (r). If the RTT value is considerable long, more streams should be established for quick transmission.
3. link error rate (e). Higher link error rate will result in the increase of stream number.

Apparently, the optimal stream number of an association has a relation with these three factors as follows: $S \propto \frac{e}{b \times r}$

From this relationship, we can see that the optimal stream number of an association is in direct proportion to the link error rate (e), but in inverse proportion to the receiver buffer size (b) and round trip time (r). This relation is certainly not simple or straight forward.

4. Implementation of Modified SCTP

In the past, Fuzzy logic theory has been applied in many problems like this where the relationship between the ultimate results is determined by a few factors with uncertainty. The application of fuzzy logic theory in modelling those complex systems has been very successful [5]. In this section, we attempt to take advantage of fuzzy logic theory in the modelling of optimal stream number in SCTP.

4.1. Structure of Fuzzy logic system

This relation can be modelled using fuzzy logic as follows. First we define the receiver buffer size b, round trip time r, and link error rate e as the antecedent sets of fuzzy logic system, which has been associated with optimal stream number S as consequent set. Then we define the fuzzy membership functions for both of antecedent sets and consequent set as below [3]:

1. Fuzzy membership function (B) of receiver buffer size (b). Three fuzzy sets, *small*, *normal* and *big* are defined in Equation 1 and shown in Figure 3.

$$B = \begin{cases} small & \text{if } b \text{ is less than 5KB} \\ normal & \text{if } b \text{ is between 5KB and 40KB} \\ big & \text{if } b \text{ is more than 40KB} \end{cases} \tag{1}$$

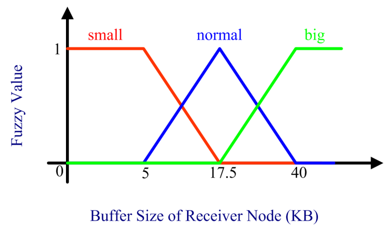

Figure 3. Fuzzy membership function (B) of receiver buffer size (b)

2. Fuzzy membership function (R) of round trip time (r). Two fuzzy sets, *short* and *long*, are defined in Equation 2 and shown in Figure 4.

$$R = \begin{cases} short & \text{if } r \text{ is less than 50ms} \\ long & \text{if } r \text{ is more than 100ms} \end{cases} \tag{2}$$

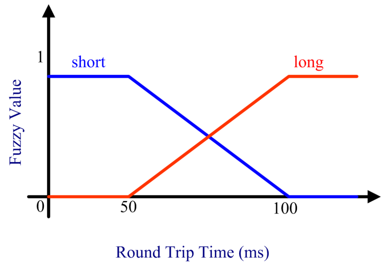

Figure 4. Fuzzy membership function (R) of round trip time (r)

3. Fuzzy membership function (E) of link error rate (e). Two fuzzy sets, *low* and *high*, are defined in Equation 3 and shown in Figure 5.

$$E = \begin{cases} low & \text{if } e \text{ is less than } 0.1\% \\ high & \text{if } e \text{ is more than } 5\% \end{cases} \quad (3)$$

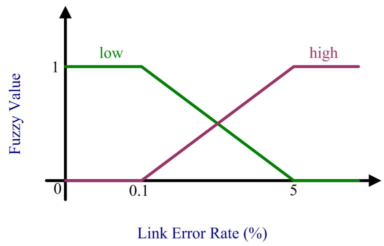

Figure 5. Fuzzy membership function (E) of link error rate (e)

4. Fuzzy membership function (S) of optimal stream number (n). Five fuzzy sets, *least*, *less*, *normal*, *more*, and *most* are defined in Equation 4 and shown in Figure 6.

$$S = \begin{cases} least & \text{if } n \text{ is less than 2} \\ less & \text{if } n \text{ from 2 to 4} \\ normal & \text{if } n \text{ from 4 to 6} \\ more & \text{if } n \text{ from 6 to 8} \\ most & \text{if } n \text{ greater than 8} \end{cases} \quad (4)$$

After an investigation and deliberation, we identified the relation between S and factors that can be described using fuzzy rules and illustrated in Table 1.

4.2. Fuzzy Logic Based Stream Number Determination

For given input variables b, e, r, there must be a unique membership function associated with each input parameter. Based on the membership function, the

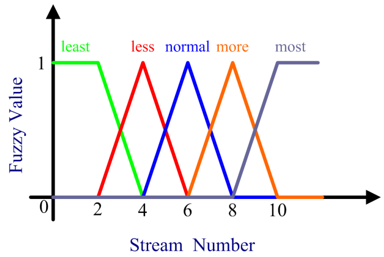

Figure 6. Fuzzy membership function (S) of optimal stream number(n)

Table 1. Fuzzy logic system rules

Input			Output
B	E	R	S
small	low	short	more
small	low	long	less
small	high	short	most
small	high	long	more
normal	low	short	normal
normal	low	long	less
normal	high	short	more
normal	high	long	normal
big	low	short	less
big	low	long	least
big	high	short	more
big	high	long	less

membership degree values $F(B)$, $F(E)$, $F(R)$ can be determined. In our implementation of stream number rules, the membership degree values should be:

1. for member function B

$$F_i(B) = F_{L-rule_i}(B), i \in \{1, 2, \ldots, 12\} \quad (5)$$

2. for member function R

$$F_i(R) = F_{F-rule_i}(R), i \in \{1, 2, \ldots, 12\} \quad (6)$$

3. for member function E

$$F_i(E) = F_{N-rule_i}(E), i \in \{1, 2, \ldots, 12\} \quad (7)$$

Moreover, the membership functions associate a weighting factor, W_i, with values of each input and the effective rules. These weighting factors determine the degree of influence or degree of membership (DOM) each active rule has. The weighting factor, W_i, for each entry of current rules should be:

$$W_i = \min\{F_i(B), F_i(R), F_i(E)\}, i \in \{1, 2, \ldots, 12\} \quad (8)$$

By computing the logical product of the membership weights for each active rule, a set of fuzzy output, S_i, response magnitudes are produced by using Equation 9.

$$S_i = F_{S-rule_i}(W_i), i \in \{1, 2, \ldots, 12\} \quad (9)$$

Finally, all that remains is to combine and defuzzify these output responses. The optimal stream number can be computed by:

$$S = \frac{\sum_{i=1}^{12} W_i S_i}{\sum_{i=1}^{12} W_i} = \frac{W_1 S_1 + W_2 S_2 + \ldots + W_{12} S_{12}}{W_1 + W_2 + \ldots + W_{12}} \quad (10)$$

5. Experiment Results

In this section, we test the modified SCTP protocol on a simulated network using NS2 [4]. We used the simplest network to investigate the multi-streaming features. Our approach has been tested on a network as illustrated in Figure 7. The detailed parameters are shown in Table 2.

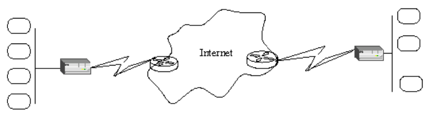

Figure 7. Network used in simulation

Table 2. Parameters used in experiment scenario

Parameter	Value
Application traffic	FTP/CBR
Initial RTT	100 ms
Packet Size	512 bytes
Simulation time	5 minutes
Number of nodes	2
Available bandwidth	8 Mb/s

The objective of this experiment is to:

- demonstrate the feasibility of the modified SCTP protocol.
- prove the fuzzy logic can be deployed in the network.
- show the goodput which have been generated by using the modified SCTP is always the best among other the situations.
- demonstrate the effects of different parameters to the optimal number of streams.

The SCTP protocol and modified SCTP protocol were tested on the network for three different scenarios. In each scenario, we carried experiments for the number of stream are 1, 2, 3 and 4 and a number which is determined by the fuzzy system before the SCTP association is established. Especially, if there is one stream used in SCTP, it is actually the TCP/UDP connection.

5.1. Different Buffer Sizes

In scenario 1, the buffer size on the receiver is different. We can image that the bigger the buffer size, the better the goodputs for the reason that the receiver has enough buffer size to store many packets while waiting on a lost packet.

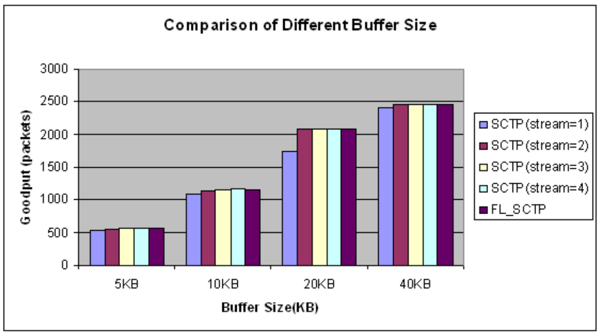

Figure 8. The comparison of SCTP and modified SCTP with different buffer size (*b*)

Figure 8 shows that the modified SCTP in which the fuzzy system determines an optimal number always perform the best for all buffer sizes.

5.2. Different Link Error Rates

For wired networks, the link error rates are always same or fixed. However, on the wireless networks, the link error rates could be dramatically different. In scenario 2, we deliberately change the link error rates, and then carry out a number of experiments. Figure 9 shown the experiment results that higher link error rates need more streams. If the link has a higher error rate, it leads to head-of-line blocking more frequently; therefore, additional streams may be helpful to reduce this problem. In all five comparisons, the modified SCTP exactly optimized the number of streams, as shown in Figure 9.

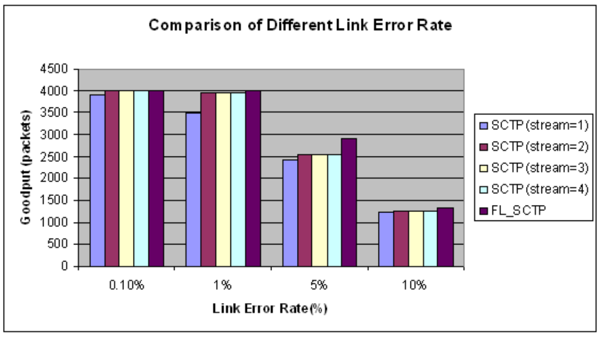

Figure 9. The comparison of SCTP and modified SCTP with different link error rate (e)

5.3. Different RTTs

Round Trip Time (RTT) is an indicator that the total propagation delay of a transmission. For a satellite communication, it might take a few seconds, it will have a huge impact on the goodput. For each RTT value, more streams are helpful to increase goodputs because more packets cause increased amounts of link error and the possibility of the head-of-line blocking is higher than other cases. In this scenario, the fuzzy system also determine the optimal number of stream for all given round trip times, as shown in Figure 10.

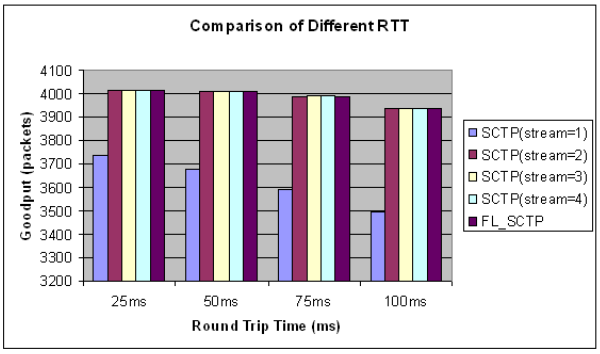

Figure 10. The comparison of SCTP and modified SCTP with different round trip time (r)

6. Conclusion

In this paper we proposed a modified SCTP protocol that can be used in wireless networks in which many TCP algorithms such as TCP-Reno can not be used. The modified SCTP protocol allows the sender to collect and analyze the real-time data from network and receiver before an association establishment so that the sender may evaluate the optimal number of streams. We also demonstrated our implementation of modified SCTP protocol in NS-2 platform. Simulation demonstrated the feasibility and the performance of modified SCTP protocol is affordable and comparable but more intelligent than other original SCTP protocol in which the number of streams is not determined, but left to people to guess.

There are, however, many issues and problem for further study in this area for the future. For instance, we can

- take into consideration more factors which may affect the optimal number of streams while designing the fuzzy logic system;
- explore more opportunities using the modified SCTP in the multimedia applications such as teleconference, video/audio streaming, etc.

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