멀티홈잉 기반 SCTP 성능 실험 및 비교 분석

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요 약

SCTP(Stream Control Transmission Protocol) 프로토콜의 '멀티홈잉(multi-homing)' 특성을 통해 SCTP 응용은 두 개 이상의 IP 주소를 통해 데이터를 전송할 수 있다. 본 논문에서는 리눅스 기반 테스트베드 환경에서 SCTP 멀티홈잉 특성이 처리율 성능에 미치는 영향을 분석한다. 실험을 위해 NISTNET 에뮬레이터를 활용하여 다양한 패킷손실율, 링크대역폭, 및 전송지연 환경을 구성하여 SCTP 처리율을 비교 분석 하였다. 실험 결과, 패킷 손실이 존재하는 망 환경에서 SCTP 멀티홈잉은 단일홈잉 경우에 비해 높은 성능을 보이며, 이는 SCTP 멀티홈잉에서 대체경로 재전송에 의한 효과로 볼 수 있다. 반면에, 링크대역폭 및 전송지연 요소는 상대적으로 SCTP 처리율 성능에 미치는 효과가 미미하였다.

키워드 : SCTP, 멀티홈잉, 처리율, 성능분석

Experimentation and Analysis of SCTP Throughput by Multi-homing

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ABSTRACT

Stream Control Transmission Protocol (SCTP) provides the multi-homing feature, which allows each SCTP endpoint to use two or more IP addresses for data transmission. In this paper, the SCTP multi-homing feature is experimented and analyzed in terms of throughput over Linux platforms based on the NISTNET network emulator. We perform the experimental analysis of SCTP throughputs by SCTP multi-homing for the various network conditions: different packet loss rates, network bandwidths, and transmission delays. From the experimental results, it is shown that the SCTP multi-homing gives much better throughput gain over the SCTP single-homing case in the networks with a high packet loss rate. In the meantime, the other factors including network bandwidth and transmission delay do not seem to give a significant impact on the performance of the SCTP multi-homing.

Key Words : SCTP, Multi-homing, Throughput, Performance Analysis

1. Introduction

The Stream Control Transmission Protocol (SCTP) is the 3rd transport protocol next to TCP and UDP, which was standardized in the IETF[1]. Similarly to TCP, the SCTP is a connection-oriented reliable transport protocol. Differently from TCP, the SCTP uses the four-way connection establishment and the three-way connection shutdown mechanisms. In particular, the SCTP provides the 'multi-streaming' and 'multi-homing' features.

In particular, the SCTP multi-homing feature allows SCTP endpoints to use two or more IP addresses for data transmissions. An SCTP endpoint can thus use a primary IP address in the SCTP association, along with one or more secondary IP address. In the data transmission, the SCTP primary IP address is mainly used to transmit and receive the data packets, whereas the secondary IP address(es) will be used as backup path(s) in the event of the packet loss in the network. On the other hand, the use of the SCTP multi-homing to the transport layer mobility or handover is under further study, as seen in [2, 3].

Some studies on SCTP [4, 5] show that SCTP could provide a performance gain over TCP. However, their study usually focuses on comparison of the basic SCTP features such as connection management and multi-streaming. In [6], the performance of SCTP has been evaluated by using a network simulator (ns-2), rather than the Linux platform.

In this paper, we analyze the SCTP performance over

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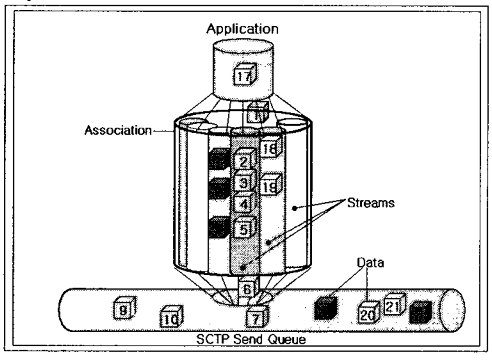
Linux platforms using the LK-SCTP toolkit [7, 8], under a variety of network environments using the NISTNET network emulator [9]. In particular, we deal with the issue on "the performance gain of SCTP multi-homing over SCTP single-homing" for the different network environments such as packet loss rate, network bandwidth, and delays in the network.

This paper is organized as follows. Section 2 briefly describes the SCTP features such as SCTP multi-streaming and multi-homing. In Section 3, we briefly compare the SCTP and TCP throughputs over the Linux platform. In Section 4, we present the network configuration for the test experimentations of SCTP multi-homing based on the Linux platform. Section 5 discusses the experimental results for each of the test scenarios. Section 6 concludes this paper.

2. SCTP Features

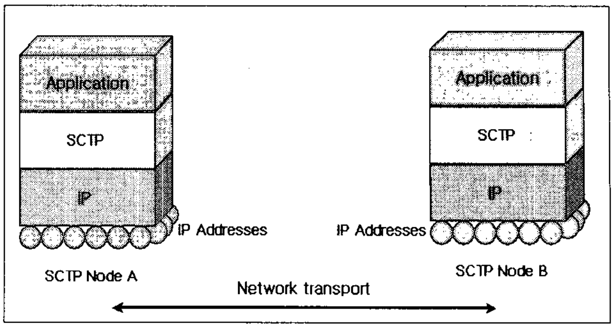
The SCTP provides the distinctive features over TCP: multi-streaming and multi-homing. The multi-streaming is a distinctive feature of SCTP. The SCTP application may multiple *streams* within an association. In the association establishment phase, the two SCTP endpoints will be informed of the number of streams used in the association, as shown in (Figure 1).



(Figure 1) SCTP Multi-streaming

The SCTP performs the in-sequence delivery per stream. This mechanism helps to avoid the head-of-line (HoL) blocking of TCP, since each stream data can be independently delivered to the peer endpoint within one association. A more detailed description on the SCTP features is found in the IETF RFC 2960 [1].

The SCTP also provides the distinctive multi-homing feature over the TCP. From the multi-homing feature, the SCTP endpoint can use two or more IP addresses in the association, as shown in (Figure 2).



(Figure 2) SCTP Multi-homing

The SCTP multi-homing feature can be used to protect an association from the potential network failure by steering traffic to alternate IP addresses. During the initiation of an association, SCTP endpoints exchange the list of IP addresses that will be used in the association. One of the listed IP addresses will be designed as the primary address. If the primary address repeatedly drops chunks, all the data chunks will be transmitted to an alternate address. The SCTP multi-homing can be implemented with the help of the heartbeat mechanism. This heartbeat mechanism will be used to detect a failure of each IP address used in the association.

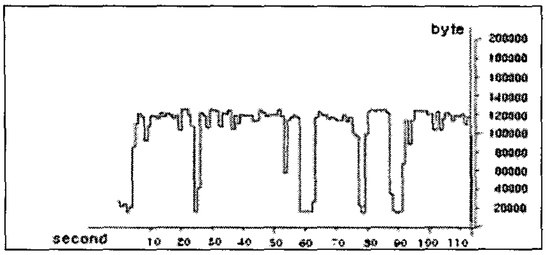
3. Comparison of SCTP and TCP by Throughput

In this section, we describe some preliminary results of experimentations for performance comparison of the SCTP and TCP over Linux platform. To compare the SCTP and TCP in the throughput perspective, we construct a small testbed, which consists of the two end hosts (client and server) in the subnet environment. In the test configuration, the SCTP client and server are equipped with Linux-Kernel 2.6.10 and LK-SCTP toolkit [7].

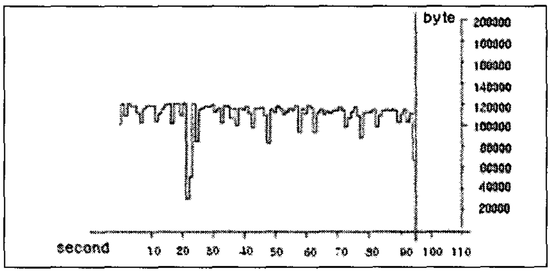
In the test scenario, we have measured throughputs of SCTP and TCP for the different size of the user data using the socket '*send()*' system call. After establishing an SCTP association or a TCP connection with the server, the client begins to download a file of 100 Mbytes from the server. As a performance metric, we measured the throughput of data transmission (i.e., the totally transmitted data bytes during the association period).

(Figure 3) and (Figure 4) show the throughput results for the different sizes of user input data for each *send()* socket system call.

(Figure 3) shows the data packets transmitted (in byte) over the association period for SCTP (Fig. 3) (a) and for TCP (Fig. 3) (b), in which the user input data of 2,048 bytes are sent by the socket *send()* call.



(a) Throughput of SCTP



(b) Throughput of TCP

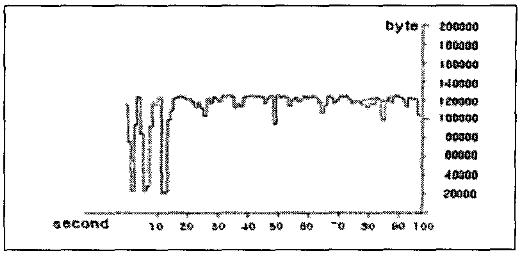
(Figure 3) SCTP and TCP with user data of 2,048 bytes

In (Fig. 3) (a), we see that the SCTP transmits the total 198,514 packets and 114,079,092 bytes (including the data and control packets) over the association period of 114 seconds, which corresponds to the average throughput of 999,811 bytes per second. In the meantime, we see in (Fig. 3) (b) that the TCP sends 101,387 packets over the connection period of 95 second, with the average throughput of 1,100,614 bytes per second. In summary, from the figure we see that the TCP provides better throughput than the SCTP for the user data of 2,048 bytes.

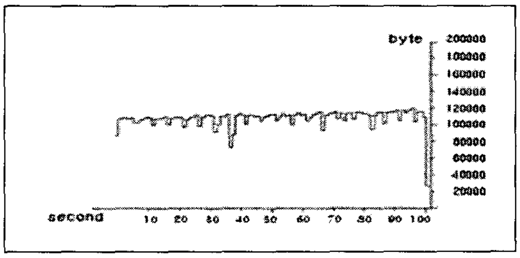
On the other hand, (Figure 4) shows the results of the SCTP throughput (Fig. 4) (a) and for TCP throughput (Fig. 4) (b) with a larger data of 8,192 bytes.

It is noted that the results of (Figure 4) are different from those in (Figure 3). In (Fig. 4) (a), the SCTP gives the average throughput of 1,126,167 bytes per second, whereas (Fig. 9) (b) shows that the TCP provides the throughput of 1,076,685 bytes per second, for the large user data.

From the results of (Figure 3) and (Figure 4), it is interesting to note that the SCTP tends to provide better throughput performance over the TCP, when the size of the user input data for each socket system call gets larger. That is, the SCTP performance will be improved for the bulk data transport, compared to TCP. This performance gain of SCTP over TCP may come from the respective congestion control schemes. That is, the TCP starts with an initial Congestion Window (CWND) as 1*MTU, whereas the SCTP starts from the CWND of 2*MTU. Overall, the SCTP tends to provide better throughput than TCP for the large bulk data transport.



(a) Throughput of SCTP



(b) Throughput of TCP

(Figure 4) SCTP and TCP with user data of 8,192 bytes

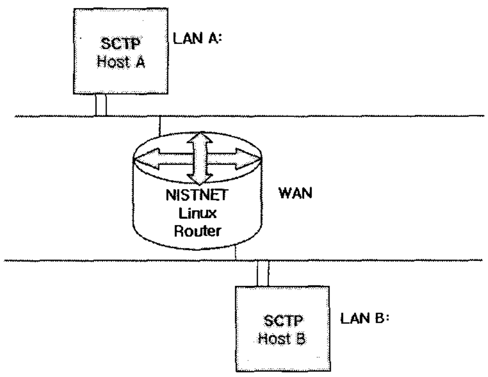
4. Experimentations for SCTP Multi-homing Feature

Now, we will focus on the experimental analysis of throughput by the SCTP multi-homing feature. For this purpose, we describe the network configuration and test scenarios that are employed for experimentations of the SCTP multi-homing.

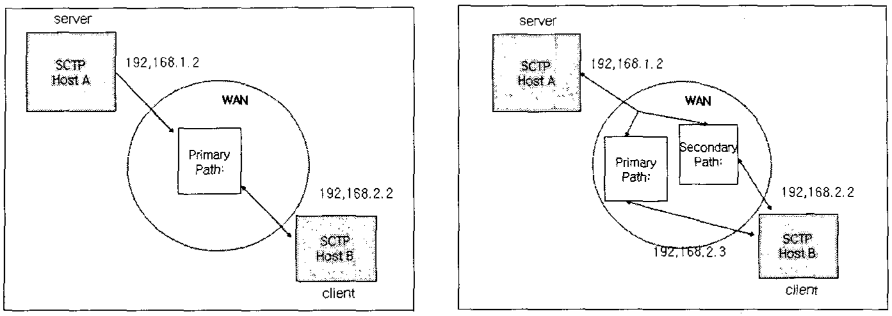
4.1 Network Configuration

(Figure 5) shows the network topology used for the experimentation of the SCTP multi-homing.

In the figure, the two SCTP hosts are all equipped with Linux 2.6.10 and LK-SCTP toolkit [7] and are configured together with the network emulation tool of NISTNET [9]. We configure a variety of the network situations with different packet loss rate, different network bandwidth, and different transmission delay between the two SCTP endpoints.



(Figure 5) Test Network based on NISTNET



(a) SCTP Single-homing (b) SCTP Dual-homing

(Figure 6) SCTP Single-homing and Dual-homing

To experiment the SCTP multi-homing feature, we configured two different networks: SCTP single-homing and dual-homing cases, as shown in (Figure 6).

(Figure 6) (a) is for experimentation of the SCTP single-homing, whereas (Figure 6) (b) is for the SCTP dual-homing. It is noted in (Figure 6) (b) that the host A is still in the single-homing sate (i.e., it uses one IP address to receive the data packets), whereas the host B is in the dual-homing state where the primary and backup paths are used for the data transport. For each experiment, the client will download a data file of 10 Mbytes from the server. The dual-homing endpoint will use the primary IP address (192.168.2.2) and the secondary IP address (192.168.2.3).

4.2 Test Scenarios

As a performance metric, we employ the throughput of data transmission (i.e., the totally transmitted data packets in bytes during the overall association period). It is noted that the main objective of this paper is to see how much the SCTP multi-homing could give the performance gain, compared to the SCTP single-homing case, under the various network conditions.

For this purpose, we analyze the following three test scenarios by configuring the NISTNET software:

a) Scenario A: Network with different packet loss rate ranged from 0 to 10 %;
b) Scenario B: Network with different bandwidths of 0.5 Mbps, 0.8 Mbps, and 1.0 Mbps;
c) Scenario C: Network with different transmission delay ranged from 50 ms to 200 ms.

For each of the test scenarios, we compare the throughput of the SCTP single-homing and dual-homing cases. The results are captured and traced using 'Ethereal' tool [10]. For all the experimentation, the SCTP client begins to download a data file of 10 Mbytes from the SCTP server after establishing an association with the server.

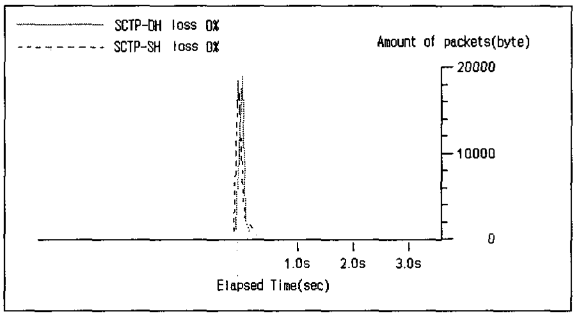
5. Numerical Results

5.1 Performance by Packet Loss Rate

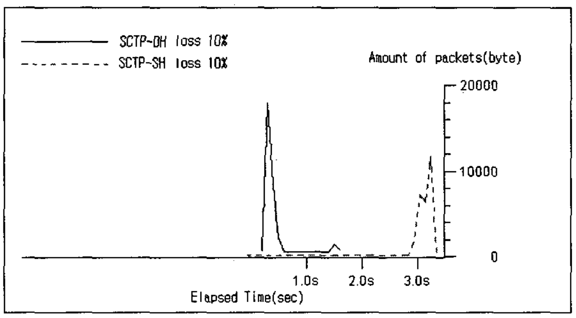
(Figure 7) shows the SCTP performance for the network with the packet loss rates of 0 % (Fig. 7) (a) and 10% (Fig. 7) (b). The other network conditions are equally applied, such as bandwidth and delay.

It is shown in the figure that the SCTP multi-homing gives almost the same throughput as the SCTP single-homing case, when the packet loss rarely occurs in the network, as shown in Fig. 7(a). However, when the packet losses occur more frequently in the network, the SCTP multi-homing provides a better throughput over the SCTP single-homing case, as shown in Fig. 7(b).

In particular, we see that the SCTP dual-homing case completes the file transmission (SCTP-DH = 1.8 seconds)



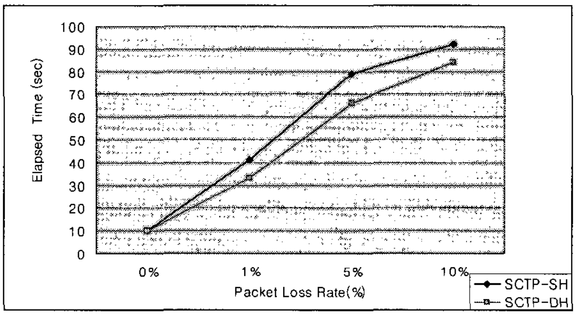
(a) Throughput with Packet Loss Rate of 0 %



(b) Throughput with Packet Loss Rate of 10 %

(Figure 7) SCTP Performance with Different Packet Loss Rates earlier than the SCTP single-homing case (SCTP-SH = 3.5 seconds). This throughput gap comes because the SCTP dual-homing host uses the secondary IP address for recovery of the lost data packets.

(Figure 8) shows the experimental results of the SCTP throughput (measured as the completion time of the file transmission) with a variety of the packet loss rates of 0%, 1%, 5%, and 10%. In this experiment, a large data file is employed with 10 Mbytes. In the figure, the time elapsed for completion of 10 Mbytes data file transmission is plotted for each of the test cases.

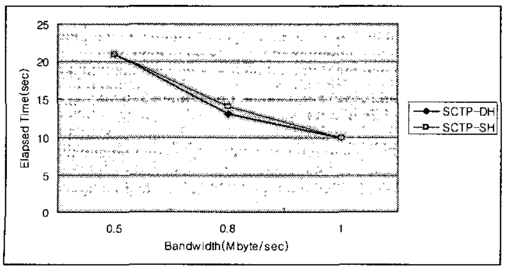


(Figure 8) SCTP Performance by Packet Loss Rates

From the figure, it is shown that the throughput gap between the SCTP multi-homing and single-homing cases tends to get larger, as the packet loss rate increases in the network, until the loss rate reaches 5%. This implies that the SCTP multi-homing gain could increase in the network with a certain loss rate, since the data retransmissions are required more frequently.

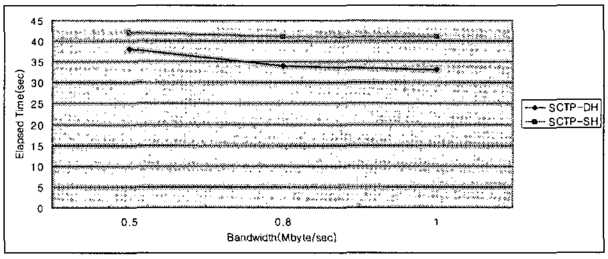
5.2 Performance by Network Bandwidth

(Figure 9) shows the SCTP throughput performance for different network bandwidth of 0.5 Mbps, 0.8 Mbps, and 1.0 Mbps, in which the packet loss does not occur in the network. From the figure, it is shown that the SCTP multi-homing gives slightly better throughput over the SCTP single-homing case. However, the gap is not significant, compared to the cases in (Figure 7) and (Figure 8).



(Figure 9) SCTP Performance by Bandwidths without Packet Loss

(Figure 10), on the other hand, shows the SCTP throughputs for different bandwidths, in which the packet losses occur with the rate of 1%. From the figure, it is shown that the throughput gap between the SCTP multi-homing and single-homing cases gets larger, as the network bandwidth increases along with the effect of some packet losses.

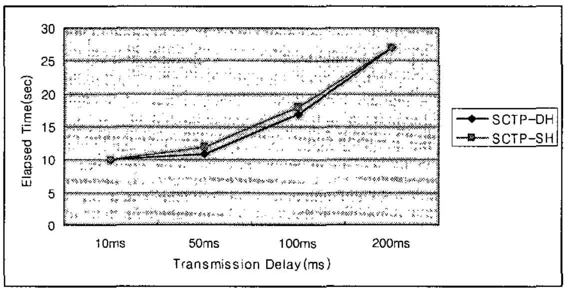


(Figure 10) SCTP Performance by Bandwidth with Packet Loss

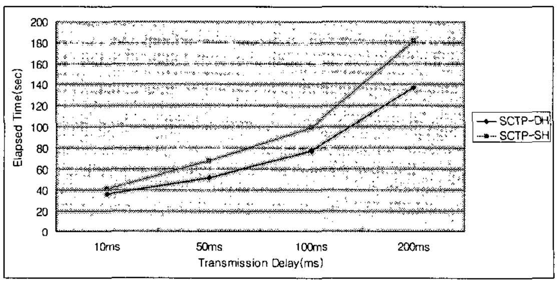
From (Figure 9) and (Figure 10), we see that the SCTP multi-homing gain can be affected by the packet loss rate rather the network bandwidth in the network.

5.3 Performance by Transmission Delay

(Figure 11) shows the SCTP performance for different network transmission delays of 10 ms through 200 ms, in which the packet loss does not occur in the network. From the figure, it is shown that the SCTP multi-homing gives slightly better throughput over the SCTP single-homing case. However, the performance gap is not significant, compared to those in (Figure 7) and (Figure 8).



(Figure 11) Performance by Transmission Delay without Packet Loss

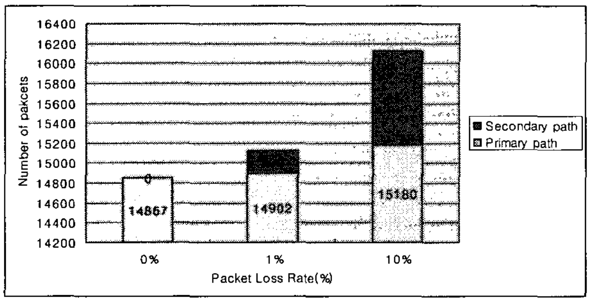


(Figure 12) Performance by Transmission Delay with Packet Loss

(Figure 12) shows the SCTP throughput for the scenarios with different network delays, where the packet losses occur with the rate of 1%. From the figure, it is shown that the throughput gap between the SCTP multi-homing and single-homing cases gets larger, as the network delays increases along with the effect of some packet losses.

From (Figure 11) and (Figure 12), we see that the SCTP multi-homing gain can be affected by the packet loss rate rather the transmission delay in the network.

(Figure 13), on the other hand, shows how much the SCTP primary and secondary IP addresses are used in the association for the dual-homing host. From the figure, we see that the secondary IP address is used more frequently when the packet loss rate gets larger to deliver the retransmitted data packets.



(Figure 13) Usage of Secondary IP Address for SCTP Dual-homing Host

6. Conclusions

In this paper, we have analyzed the throughput performance of the SCTP multi-homing and single-homing cases over Linux platform under the various network conditions such as packet loss rate, network bandwidth, and transmission delays.

From the experimental results, it is shown that the SCTP multi-homing gives much better throughput gain over the single-homing case, when packet losses occur in the network. Moreover, the performance gap between the SCTP multi-homing and single-homing cases gets larger, when the packet loss rates increase. In the meantime, the network bandwidth and transmission delay factors do not give a significant impact on the performance of the SCTP multi-homing and single-homing cases, compared to the factor of the packet loss rates in the network.

In the meantime, this paper focuses on experimentation of the SCTP dual-homing host for performance analysis of SCTP multi-homing over the simple test network. For further study, the experimentation for the host with more than two IP addresses may need to be performed for additional analysis of the SCTP multi-homing performance under the more various network environments.

References

[1] R. Stewart, *et al.*, 'Stream Control Transmission Protocol,' IETF RFC 2960, October, 2000.

[2] S. Koh, *et al.*, "mSCTP for Soft Handover in Transport Layer," IEEE Communications Letters, Vol. 8, No.3, pp. 189~191, March, 2004.

[3] S. Koh, *et al.*, "mSCTP for Vertical Handover between Heterogeneous Networks," LNCS, Vol.3597, pp.28~36, July, 2005.

[4] A. Jungmajer, M. Schopp, and M. Tuexen, "Performance Evaluation for the Stream Control Transmission Protocol," IEEE ATM Workshop 2000, June, 2000.

[5] T. Ravier, *et al.*, "Experimental Studies of SCTP Multi-homing," First Joint IEI/IEE Symposium on Telecommunications Systems Research, 2001.

[6] J. Song, *et al.*, "Performance Evaluation on SCTP Multi-homing Feature," Vol.11-C, No.2, Journal of KIPS (Korea Information Processing Society), April, 2004.

[7] Linux Kernel SCTP Project, Available from http://lksctp.sourceforge.net/

[8] R. Stewart, *et al.*, 'Sockets API Extensions for Stream Control Transmission Protocol', IETF Internet Draft, draft-ietf-tsvwg-sctpsocket-10.txt, Working in Progress, Feb., 2005.

[9] NISTNET, Available from http://snad.ncsl.nist.gov/itg/nistnet/install.html

[10] Ethereal, Available from http://www.ethereal.com

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