mSCTP for Vertical Handover Between Heterogeneous Networks

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Abstract. Stream Control Transmission Protocol (SCTP) is a new end-to-end transport protocol that is featured 'multi-homing.' The mSCTP (mobile SCTP) is defined as SCTP with the capability of dynamic address reconfiguration. This paper describes a framework of mSCTP handover for supporting vertical handover between heterogeneous IP networks such as WLAN and 3G Cellular systems. We show some experimental results of the mSCTP vertical handover on Linux platforms. From the experimental results, we see that the handover latency of mSCTP depends on Round Trip Time (RTT) between two SCTP endpoints, possibly with the handover latency of 1 second below.

1 Introduction

In the next-generation wireless mobile networks, the vertical handover between heterogeneous IP networks is one of the challenging issues, as shown in the example of the handover between WLAN and 3G Cellular systems. Mobile IP (MIP) has so far been considered as an IP mobility scheme [1, 2]. MIP is a network-layer mobility protocol and requires the support of the special agents such as Home Agents and Foreign Agents in the network.

Stream Control Transmission Protocol (SCTP) [3] is a new end-to-end transport layer protocol next to TCP and UDP. In particular, the SCTP multi-homing feature enables SCTP endpoints to support multiple IP addresses. Each SCTP endpoint can send and receive messages from any of the several IP addresses. One of the several IP addresses is designated as the primary address during the initiation.

The recent works on SCTP include the capability of dynamic IP address reconfiguration during an association, which is called ADDIP extension [4]. While an SCTP association goes on, the ADDIP extension enables the SCTP to add a new IP address, to delete an unnecessary IP address and to change the primary IP address used for the association. In this paper we define mSCTP (or mobile SCTP) as the SCTP with the ADDIP extension.

In this paper, we describe a framework of the mSCTP handover. The mSCTP can be used to provide the vertical handover for Mobile Terminals that are moving between heterogeneous IP networks. The mSCTP could also be used along with MIP for mobile sessions that require the location management. Some related studies on mSCTP [5, 6] include the experimentations of mSCTP using Network Simulator (ns-

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2) [7, 8], where the mSCTP performance is compared to the MIP. On the other hand, in this paper, the mSCTP handover is experimented over a real testbed based on Linux Platform using the recently released Linux Kernel SCTP codes [9, 10, 11].

This paper is organized as follows. Section 2 describes an overview of mSCTP handover. In Section 3, we describe some experimental results of mSCTP vertical handover that have been performed on the Linux testbed, in which the performance of mSCTP will be analyzed in terms of handover latency. Section 4 concludes this paper.

2 mSCTP Handover

The mSCTP is defined as SCTP with the capability of dynamic address reconfiguration that has recently been made in IETF [4]. The mSCTP can be used to support the vertical handover of mobile terminals, as illustrated in Figure 1.

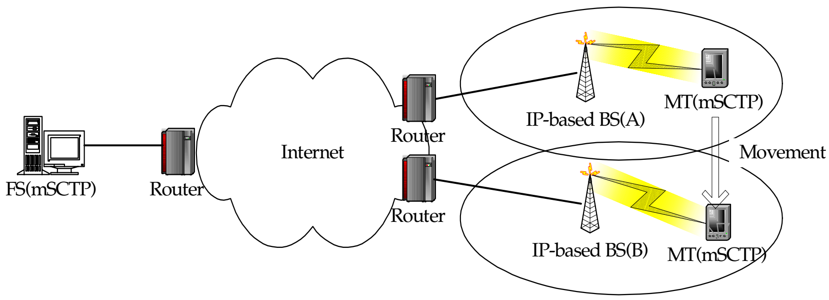

Fig. 1. mSCTP Handover

In this figure, it is assumed that a Mobile Terminal (MT) initiates an SCTP session with a Fixed Server (FS). After initiation of an SCTP association, the MT moves from Base Station (BS) A to BS B, as shown in the figure.

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Then, the overall mSCTP handover procedures could be done as follows:

(1) Session is initiation by MT
In the initial stage, we assume that FS has 'IP address 1', whereas MT uses 'IP address 2'. Note in this phase that the MT is in the single-homing state, and it uses IP address 2 as its primary IP address in the SCTP association.

(2) Obtaining a new IP address
Now, the MT is moving from A to B and it is now in the overlapping region. In this phase, the MT will obtain a new address 'IP address 3' from the BS B by using any scheme for address configuration such as Dynamic Host Configuration Protocol (DHCP).

(3) Adding the new IP address to SCTP association
After obtaining a new IP address, the MT informs FS that it will use a new IP address. This will be done by sending SCTP Address Reconfiguration (ASCONF) chunk [4] to FS. The MT may receive the responding ASCONF-ACK chunk from the FS. The MT is now in the dual homing state. The old IP address (IP address 2) is still used as the primary address, until the new IP address 3 will be set to be "Primary Address" for MT.

(4) Changing the primary IP address
While the MT further continues to move toward BS B, it will set the primary address as the new IP address according to an appropriately configured rule. Once the primary address is changed, the FS will send the outgoing data to the new primary IP address of MT, whereas the old IP address may be used as a backup address to recover the lost data chunks.

(5) Deleting the old IP address from the SCTP association
As the MT progresses to move toward BS B, if the old IP address gets inactive, the MT will delete it from the association.

The procedural steps for handover described above will be repeated each time the MT moves to a new BS, until the SCTP association will be terminated.

3 Experimental Analysis of mSCTP Handover

In this section, we describe some experimental results of the mSCTP vertical handover that have been performed over Linux platform.

3.1 Test Environment

We consider the handover of MT that is moving between two heterogeneous IP networks. The mobility pattern tested in this paper is shown in Figure 2. In this figure, an MT is moving to a new area via the overlapping region where the MT is temporarily in the dual-homing state.

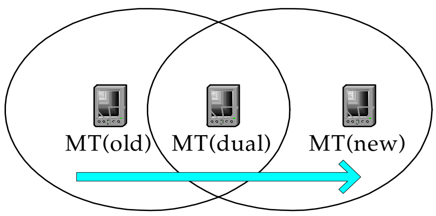

Fig. 2. Mobility Pattern for mSCTP Handover

To simulate the vertical handover of mSCTP over Linux testbed, we construct a small test network as shown in Figure 3. The test network consists of two terminals (FS and MT) and a router. Those two terminals are equipped with the mSCTP implementations given in the Linux Kernel 2.6.8 [9, 10]. The MT has the two network interfaces (i.e., two NICs), and thus it can be attached to the router in the dual-homing state.

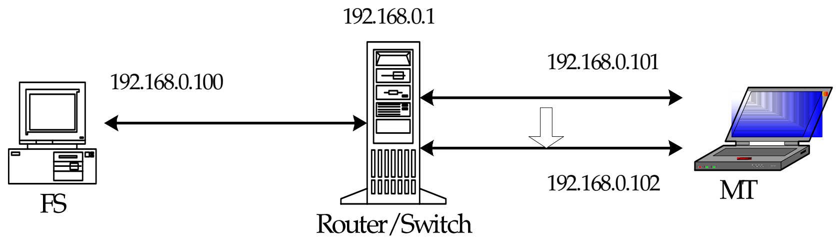

Fig. 3. Mobility Pattern for mSCTP Handover

Over the testbed, the mSCTP handover of MT proceeds as follows:

(1) Session Initiation
The MT initiates an SCTP session with FS. Initially, the MT uses IP address 192.168.0.101, and the FS binds to 192.168.0.100. After initiation, two endpoints exchange data packets.

(2) Add-IP
When the MT is going to a new network area (i.e., overlapping region), it enables the second network interface and obtains a new IP address (192.168.0.102), and then adds the new IP address to the SCTP association. This Add-IP functionality is triggered when the MT calls the socket API of "sctp_bindx()" function [11].

(3) Primary-Change
In the meantime, the MT informs the FS about the change of the primary IP address. Now, the FS will send the data to the new primary address. Note that this Primary-Change is triggered when the MT calls the appropriate "setsockopt()" function [11].

(4) Delete-IP
After a pre-specified time period, the MT deletes the old IP address from the SCTP association. Note that this Delete-IP functionality is also triggered by calling the socket API of "sctp_bindx()" function.

In the test experiments, FS transmits data packets of 1,000 bytes to the MT periodically, and the MT also sends a few data to the FS. By using the 'ethereal' [12], we captured the trace of the packets that have been exchanged between FS and MT.

From such the packet trace, we measured the 'handover latency' as a performance metric of mSCTP [5, 6]. More specifically, in this paper, the handover latency is defined as the gap of 'the time when the MT received the last data packet over the old IP address' and 'the time when the MT received the first data packet over the new IP address'.

3.2 Results and Discussion

It is noted that the handover performance may be affected by the time when the link-down of the old network link occurs. So, we measured the performance of the mSCTP handover for the two scenarios, as shown in Figure 4.

Figure 4 illustrates those two scenarios. Fig. 4(a) shows the case in which the MT performs Add-IP before the Link-Down event, whereas in Fig. 4(b) the Link-Down occurs almost the same time with the Add-IP.

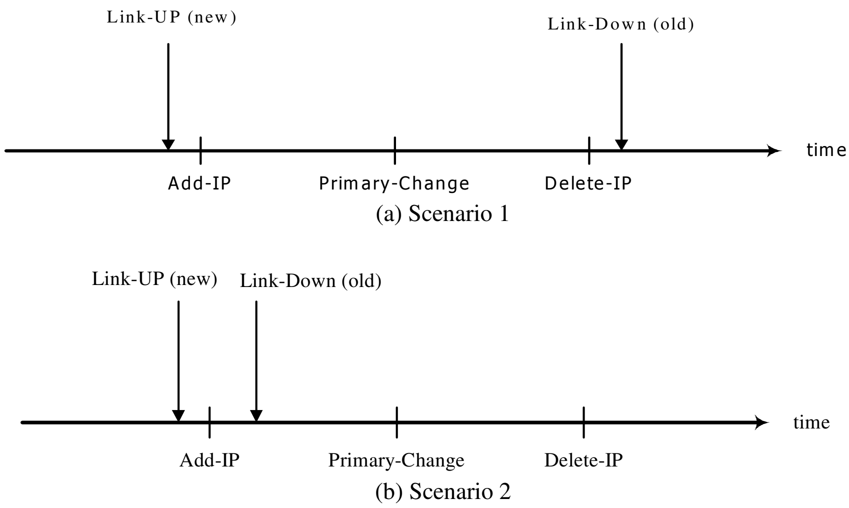

Fig. 4. mSCTP Handover Scenarios

① Scenario 1(Fig. 4(a)):
When Link-Down of the old link occurs after the Delete IP. This scenario simulates the case in which the MT moves relatively in a slower speed.

② Scenario 2 (Fig. 4(b):
When Link-Down of the old link occurs just after Add-IP. This scenario simulates the case in which the MT moves relatively in a faster speed.

A. Results for Scenario 1

Figure 5 shows the experimental result of Scenario 1, in which all the SCTP control and data packets for the association are captured using Ethereal.

In the figure we see that FS (192.168.0.100) and MT (192.168.0.101) establish an SCTP association through the packets 1 to 4. Then those two endpoints begin the data transport.

Packet 6 contains the ASCONF chunk of MT, which is used to ass the new IP address '192.168.0.102' to the association. FS responds with the ASCONF-ACK chunk at Packet 8. Packet 17 is used for MT to request the change of Primary Address to the FS. It is in the packet 18 noted that FS responds with ASCONF-ACK chunk over the new IP address (192.168.0.102). After that the FS sends DATA packets to MT over the new IP address, as shown in Packet 23. As per Scenario 1, MT performs the Delete-IP operation at Packet 27 before the Link-Down of the old network link occurs.

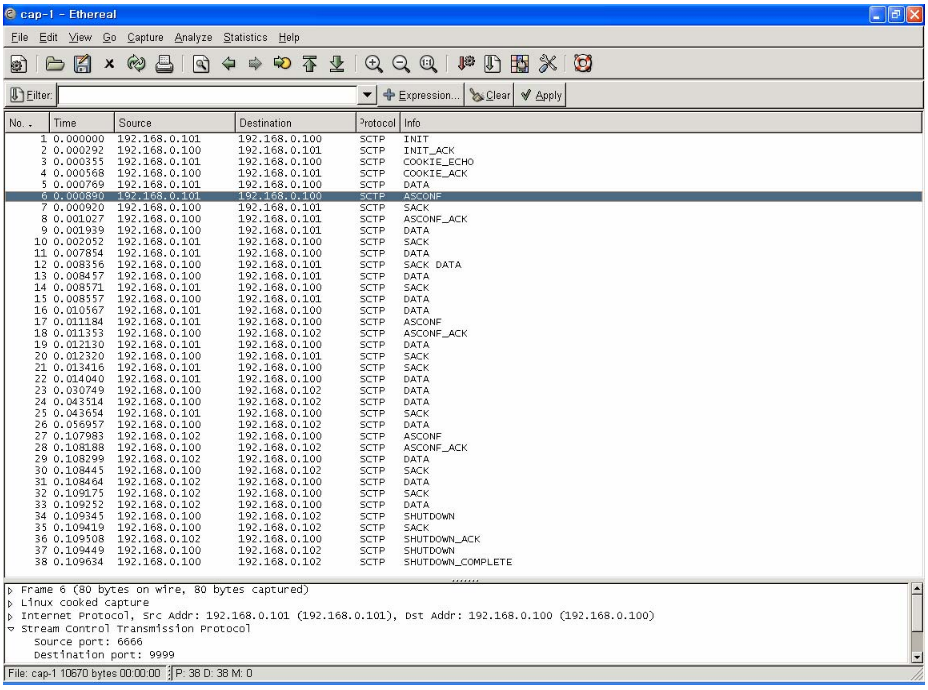

Fig. 5. Result of mSCTP Handover for Scenario 1

From the result, we also note that even after the Primary-Change, the MT still uses its old IP address as the source IP address of the DATA packets (see Packets 19 and 22). This is because the Primary-Change operation is applied to the FS, rather than MT. That is, the source IP address of DATA packets transmitted by MT is not affected by the Primary-Change operation. Only after the Delete-IP operation, MT uses the new IP address as its source IP address (see Packets 29 and 31).

In Figure 5, the handover latency of mSCTP is measured as "0.030 – 0.008 = 0.022 (sec.) = 22 (ms) ", which corresponds to the gap of the times recorded at Packet 15 (last data packet of old IP address) and 23 (first data packet of the new IP address). Seeing the packets between Packet 15 and 23, we can divide the overall handover latency into the following components:

- Time duration required for exchanging ASCONF and ASCONF-ACK for the Primary-Change operation (see Packets 17 and 18), which is roughly equal to the Round Trip Time (RTT).
- Kernel processing time at FS for changing the primary address and setting the address as the primary destination address (see Packets 20 ~ 23).

We note that the kernel processing time (the second component) is usually a constant value, independently of the RTT and the network condition. In particular, the processing time may be relatively a small value compared to the RTT in the legacy large networks, Accordingly, we may state that the overall mSCTP handover latency is proportional to the RTT between two SCTP endpoints in the network.

B. Results for Scenario 2

Figure 6 shows the experimental result of Scenario 2, in which all the SCTP control and data packets for the association are captured.

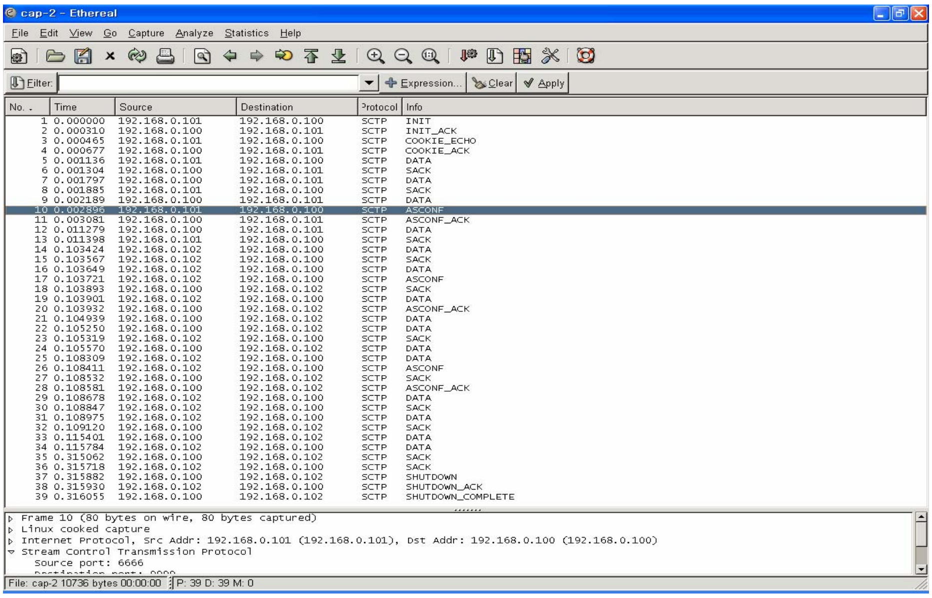

Fig. 6. Result of mSCTP Handover for Scenario 2

Figure 6 shows the same result as Figure 5, other than the following differences:

- Differently from Figure 6, the MT uses the new IP address as its source IP address of the DATA packets (see Packet 14). This is because the Link-Down of the old link occurs just after the Add-IP operation (see Packet 10 and 11).
- After Packet 17 for Primary-Change, all the packets for MT use only the new IP address (192.168.0.102).

From the figure, the mSCTP handover latency is measured as "0.104 – 0.011 = 0.093 (sec.) = 93 (ms)", which corresponds to the gap of the times recorded at Packet 12 (last data packet of old IP address) and 21 (first data packet of the new IP address). Scenario 2 requires the handover latency greater than Scenario 1 by 70 (ms), which is approximately equal to the time taken for processing the Link-Down event at MT (see Packets 13 and 14). If this processing time is relatively a small constant value, we can see that the mSCTP handover latency depends on the RTT between two SCTP end-points, as done in Scenario 1.

Another interesting point of Figure 6 is that FS cannot send any DATA packet to MT until the Primary-Change is performed (Packet 17), since the old IP address has already been deleted by the Link-Down event at the time of the Add-IP operation (see Packet 11 and 12). Accordingly, we can recommend in this case that the fast-moving MT should perform the Primary-Change operation as soon as possible (hopefully at the same time of the Add-IP operation). This will be helpful to further reduce the handover latency of mSCTP.

4 Conclusions

In this paper, we described a new handover scheme based on SCTP, which is called mSCTP. The mSCTP can be used for vertical handover between heterogeneous IP networks such as WLAN and 3G systems. The mSCTP can also be used together with Mobile IP for the sessions that require the location management.

We have described some experimental analysis of the mSCTP handover, which is performed over a Linux testbed network. In the testebd, we experimented the mSCTP handover for the Mobile Terminal that is dual-homed to two different network interfaces. From the experimental results, it is shown that the SCTP handover performance mainly depends on the RTT (round trip time) between two SCTP terminals, possibly with the handover latency of 1 second below.

For further study, the mSCTP handover experimentations need to be performed on the real large-scale networks, so as to analyze the handover performance in a more realistic manner.

Acknowledgement

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References

1. Perkins, C., et al., "IP Mobility Support for IPv4", IETF RFC 3344, August 2002
2. Johnson, D., et al., "Mobility Support in IPv6", IETF RFC 3775, June 2004
3. Stewart R., et al., "Stream Control Transmission Protocol", IETF RFC 2960, October 2000
4. Stewart, R., et al., "Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration", IETF Internet Draft, draft-ietf-tsvwg-addip-sctp-08.txt, June 2004
5. Chang M., et al., "A Transport Layer Mobility Support Mechanism", LNCS 3090, pp. 287 - 296, May 2004.
6. Chang M., et al., "Transport Layer Mobility Support Utilizing Link Signal Strength Information", IEICE Transactions on Communications, Vol. E87-B, No. 9, pp. 2548-2556, September 2004.
7. Network Simulator 2, Available from http://www.isi.edu/nsnam/ns/
8. ns-2 modules for SCTP, Available from http://www.cis.udel.edu/~iyengar/research/

9. Linux Kernel Archives, Available from http://www.kernel.org/
10. Linux Kernel SCTP Project, Available from http://lksctp.sourceforge.net/
11. Stewart, R., et al., "Sockets API Extensions for Stream Control Transmission Protocol", IETF Internet Draft, draft-ietf-tsvwg-sctpsocket-09.txt, September 2004
12. Ethereal, Available from http://www.ethereal.com/