mSCTP-DAC: Dynamic Address Configuration for mSCTP Handover+

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Abstract. This paper proposes a dynamic IP address configuration (DAC) scheme for mSCTP handover, which exploits the information from the link layer to support SCTP handover between heterogeneous access networks. The proposed DAC scheme enables a mobile terminal to automatically add a new IP address in the newly visited region, change the primary path, and delete the old IP address so as to support the mSCTP handover. For experimental analysis of mSCTP handover, we consider the handover scenarios for 3G-BWA and 3G-WLAN over Linux platforms. From experimental results, it is shown that the throughput and handover latency of the mSCTP handover would be affected by the timing of primary-change and the overlapping period.

Keywords: mSCTP, Link Layer, Handover, Mobility, Latency

1 Introduction

Stream Control Transmission Protocol (SCTP), as defined in the IETF RFC 2960 [1], is an end-to-end, connection-oriented transport layer protocol, next to TCP and UDP. In particular, the SCTP multi-homing feature enables SCTP endpoints to support multiple IP addresses in an association. Each SCTP endpoint can send and receive messages from any of the several IP addresses. One of the several IP addresses is designed as the primary address during the SCTP initiation.

On the other hand, IP handover has been one of the challenging issues to support mobility between heterogeneous networks such as 3G-BWA (Broadband Wireless Access; IEEE 802.16(e)) and 3G-WLAN(Wireless LAN; IEEE 802.11) [2]. The mobile Stream Control Transmission Protocol (mSCTP) [3] can be used to support the soft handover for mobile terminals with the help of the SCTP multi-homing feature and ADDIP extension [4].

This paper describes a scheme of Dynamic IP Address Configuration using the link layer information for mSCTP handover (mSCTP-DAC). We especially propose the mSCTP-DAC scheme that can be used to dynamically and automatically configure the relevant IP addresses for the on-going SCTP session by using the status

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information of network interface, whenever a mobile terminal moves into a new region.

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

Figure 1 sketches the mSCTP handover for a Mobile Terminal (MT) between two different IP networks, where the MT is moving from Base Station (BS) A to B [3].

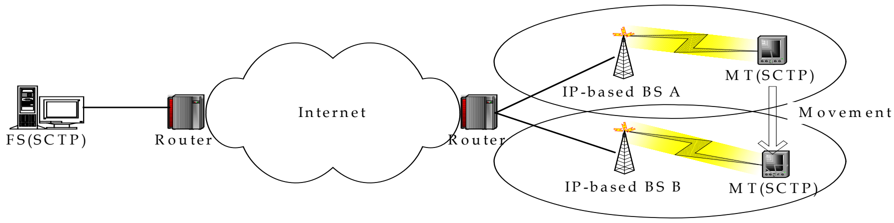


Fig. 1. mSCTP handover

In the figure, it is assumed that an MT initiates an SCTP session with a Fixed Server (FS). After initiation of an SCTP association, the MT moves from BS A to BS B, as shown in the figure. Refer to [4] for details of mSCTP handover procedures.

Some works [5-8] have been made on mSCTP handvoer. Those works in [5, 6, 7] have experimented the mSCTP handover by using manual (static) IP configuration. More especially, the works in [8] performed the experimental analysis by using the NS-2 simulator about when to add a new IP address and when to delete the existing IP address.

In this paper, we describe a ‘dynamic (automaic)’ IP address configuration scheme, rather than a ‘manual (static)’ scheme, for mSCTP handover. For experimental analysis, we use the NISTNET [9] network emulator to perform the mSCTP handover across heterogeneous networks such as 3G-BWA and 3G-WLAN. We consider the handover latency and throughput as the performance metrics.

This paper is organized as follows. In Section 2, we present the proposed dynamic IP address configuration scheme for mSCTP handover. Section 3 describes the mSCTP handover based on the proposed mSCTP-DAC scheme. Section 4 describes the experimental analysis of mSCTP handover over Linux platforms. Finally, Section 5 concludes this paper.

2 Dynamic IP Address Configuration Scheme for mSCTP Handover

To support the mSCTP handover for an MT, we need to detect movement of an MT and to determine when to perform the handover. This section describes the dynamic IP address configuration scheme for mSCTP handover (mSCTP-DAC). mSCTP-DAC interacts with the data link, IP and transport (SCTP) layer. More especially, mSCTP-DAC monitors status information on the attached link, determines when to trigger the handover, and then enables mSCTP to dynamically configure the IP addresses required for handover.

Figure 2 shows an overview of mSCTP-DAC operations. In the figure, mSCTP-DAC consists of three modules: Link Layer Information Monitoring (LLM), Dynamic IP Address Configuration (DAC), and Handover Processing (HOP). The LLM module collects state information at the link layer and IP layer, and sends it to the DAC module. DAC determines when to trigger HOP to perform mSCTP handover. HOP performs mSCTP handover at the transport layer with the SCTP protocol stack. The specific description for each module is given in the succeeding sections.

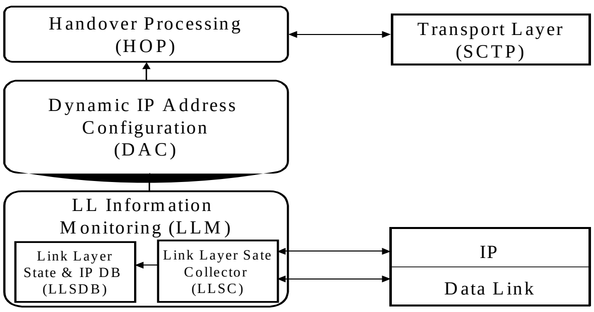


Fig. 2. Overview of mSCTP-DAC operations

2.1 Link Layer Information Monitoring (LLM)

The Link Layer information Monitoring (LLM) consists of the following two sub-modules: Link Layer State Collector (LLSC) and Link Layer State DB (LLSDB).

LLSC gathers state information of network links, and LLSDB contains the gathered information, and then transmits the state information, including IP addresses, to the DAC. In LLSC, it is assumed that MT has two different NIC (Network Interface Cards). LLSC first probes all the network interfaces attached to MT. It then monitors the status of link-up/down of the detected network interfaces. For example, if ‘link-up’ of 1st network interface is detected by LLSC, the corresponding link information and IP address will be recorded into LLSDB. In addition, the same procedures are applied to the link-down of network interfaces.

On the other hand, LLSDB transmits the information into the DAC module. It may include the following four fields: Interface ID, IP address, Signal Strength, and Link State. Interface ID indicates the interface name of the network link. IP address and Signal Strength field indicate the IP address and signal strength of link-up interface. In addition, Link State indicates whether the network interface is up or down. This information will be used to determine when to perform mSCTP handover by MT.

2.2 Dynamic IP Address Configuration (DAC)

The Dynamic IP Address Configuration (DAC) module can be used to determine when to perform mSCTP handover by analyzing state transition of link status, and requests the HOP module to trigger mSCTP handover. In order to determine when to perform mSCTP handover, the DAC module refers to link states of network interface.

The description of the associated states and events is given in Table 1.

Table 1. States and events used to trigger handover

STATE	DESCRIPTION	EVENT	DESCRIPTION
CLOSED	No link is up.	IF1_UP	LLM detects link-up of IF1
		IF2_UP	LLM detects link-up of IF2
IF1_SH	IF1 link is only link-up.	IF1_DOWN	LLM detects link-down of IF1
		IF2_DOWN	LLM detects link-down of IF2
IF2_SH	IF2 link is only up.	IF1_INIT_REQ	DAC request initiation of IF1 to HOP
		IF2_INIT_REQ	DAC request initiation of IF2 to HOP
		IF1_ADD_REQ	DAC request ADD-IP of IF1 to HOP
		IF2_ADD_REQ	DAC request ADD-IP of IF2 to HOP
IF_DH	Both IF1 and IF2 links are up.	IF1_DEL_REQ	DAC request DEL-IP of IF1 to HOP
		IF2_DEL_REQ	DAC request ADD-IP of IF1 to HOP
		IF1_P-C_REQ	DAC request P-C to HOP
		IF2_P-C_REQ	DAC request P-C to HOP

In Table 1, DAC defines four states and nine events used for handover. In the table, ‘state’ indicates the current link state of network interface, and ‘event’ indicates link state information of the corresponding interface, or message generated while the state is transited. In the table, CLOSED state means that there is no link-up of network interface. IF1_SH and IF2_SH mean that either 1st network or 2nd network interface is link-up. In addition, IF_DH means that both two network interfaces are link-up at the same time. For example, IF1_UP or IF1_DOWN event makes the 1st network interface link-up or link-down.

Based on these states and events, Figure 3 shows the state transition diagram used for mSCTP handover. As seen in Figure 3, the state transition diagram starts at the CLOSE state. CLOSE state means that the communication between MT and FS has not been initiated yet. DAC receives the link state event from LLSDB, and then makes state transmit from CLOSED into IF1_SH or IF2_SH state, if LLM detects a new link-up. When the state moves from CLOSED into IF1_SH or IF2_SH, either IF1_INIT_REQ or IF2_INIT_REQ event is generated and sent to the HOP module for initializing an SCTP session with the corresponding IP address. After that, if the DAC detects IF1_UP or IF2_UP event from the IF1_SH or IF2_SH state, the state moves into IF_DH. At this point, IF1_ADD_REQ or IF2_ADD_REQ event will be generated and sent to the HOP module for requesting addition of a newly assigned IP address to the SCTP session.

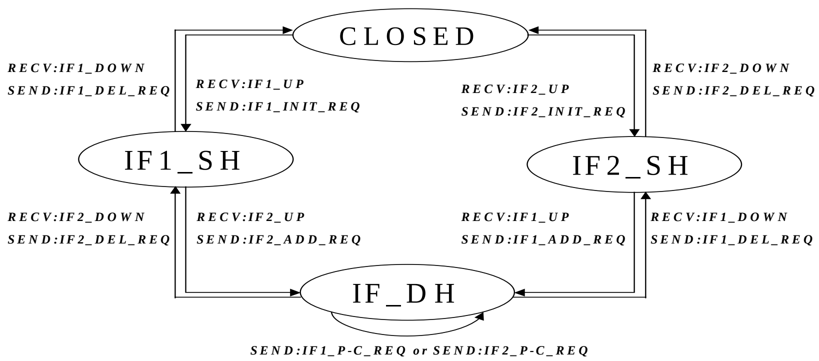


Fig. 3. State Transition Diagram of mSCTP-DAC

In the IF_DH state, the MT is in the overlapping area between the existing region and the new region. Moreover, when the signal strength of the new link-up interface is stronger than the threshold configured by system administrator, the IF1_P-C_REQ or IF2_P-C_REQ event may be generated and sent to the HOP module for requesting change of primary path, which will occur when the MT continuously moves toward the new region. From these events, MT uses the new IP address as the primary path.

After then, if the IF1_DOWN or IF2_DOWN event is sent from LLSDB, the state of DAC transits from IF_DH into IF1_SH or IF2_SH. In this case, the IF1_DEL_REQ or IF2_DEL_REQ is generated and sent to the HOP module for requesting deletion of the old IP address. At this state, it is considered that MT just left the existing region and is in the new region.

2.3 Handover Processing (HOP)

Handover Processing (HOP) is used to handle the SCTP ASCONF/ASCONF-ACK chunks required for mSCTP handover, with the help of the SCTP APIs. Initially, HOP initiates an SCTP association. If IF1_ADD or IF2_ADD, and IF1_DEL_REQ or IF2_DEL_REQ event are delivered from DAC, the HOP then sends the ASCONF (Address Configuration) chunk by calling sctp_bindx(). It then processes the corresponding ASCONF-ACK, and will call the sctp_recvmsg(). Moreover, when IF1_P-C_REQ or IF2_P-C_REQ events are received, the HOP module sends an ASCONF chunk for changing the primary path by calling setsockopt().

3 mSCTP Handover with mSCTP-DAC

To describe the operations of the mSCTP handover with mSCTP-DAC, we assume that an MT with the two different network interfaces tries to move across between heterogeneous networks.

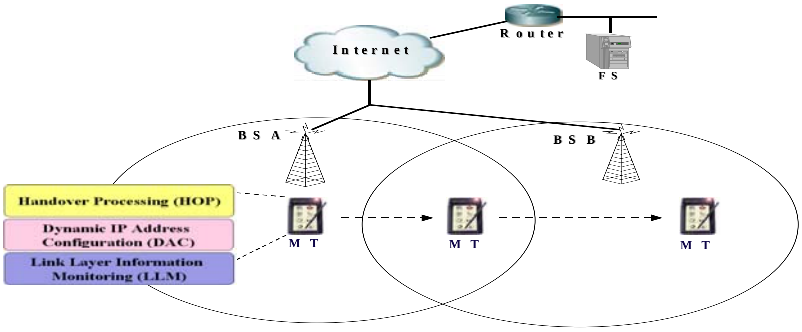


Fig. 4. The mSCTP handover with mSCTP-DAC module

In Figure 4, there are two heterogeneous networks, and an MT communicates with FS through Internet. Both MT and FS have the SCTP stack, and the MT additionally has the mSCTP-DAC module proposed in this paper. The mSCTP handover is performed as follows:

① When an MT enables the mSCTP-DAC mdule, an mSCTP session is initiated by MT. LLM Firstly collects the link-up of 1st network interface and records the information into DB. The state of mSCTP-DAC is transited from CLOSED to IF1_SH, and sends then the IF1_INIT_REQ event to the HOP module for adding the correspondent IP address. HOP then tries to initiate an SCTP association with the FS.

② When the MT moves toward a new region and then detects the new signal from the BS B, the 2nd network interface is link-up. The correspondent link state information is recorded into DB, and the state is transited from IF1_SH into IF_DH. At this time, DAC sends IF2_ADD_REQ event to HOP for adding the correspondent IP address to the SCTP session. The HOP generates an ASCONF chunk and sends it to the FS for ADD-IP, and receives the ASCONF-ACK chunk from the FS.

③ When the MT continuously moves toward the new region, and then the signal strength gets stronger than the pre-configured threshold, DAC sends IF2_P-C_REQ event to HOP module for requesting Primary-Change. HOP then sends ASCONF to FS for Primary-Change, and receives the ASCONF-ACK. If once the primary address is changed, the FS will send the outgoing data over the new primary IP address.

④ When LLM detects the link-down of 1st network interface as the MT progresses to move toward the new region, DAC transits the state from

IF_DH to IF2_SH, and then sends IF1_DEL_REQ to HOP for DEL-IP. The HOP module sends ASCONF to FS, and receives ASCONF-ACK.

⑤ The procedural steps for seamless handover described above will be repeated, whenever the MT moves to a new region.

4 Experimental Analysis of mSCTP-DAC

This section describes the experimental analysis for mSCTP handover over Linux platform. For experiments, we implemented the proposed mSCTP-DAC modules using C language.

4.1 Test Scenarios

To experiment the mSCTP handover, we use Linux kernel 2.6.8 [10] and LKSCTP [11] tool on an MT and FS. In addition, Two NICs were used for the MT that is moving between two different IP networks, and the NISTNET [9] network emulator was used to simulate the handover between two networks such as 3G-BWA and 3G-WLAN.

We have experimented the following two test scenarios, as shown in Figure 5.

A. Scenario A: mSCTP handover between 3G and BWA (see Fig. 5(a))
For the 3G-BWA scenario, an MT has two NICs and goes from 3G to BWA networks. When MT moves from 3G to BWA network, it tries to add the new IP address assigned from BWA, and delete the existing IP address assigned from 3G networks. In this case, the primary-change is performed in the overlapping region.

B. Scenario B: mSCTP handover between 3G and WLAN (see Fig. 5(b))
For the 3G-WLAN scenario, an MT has two NICs and goes from 3G to WLAN networks, and then it also goes from WLAN to 3G. It is noted that the primary-change for 3G-WLAN is performed twice in the experiments.

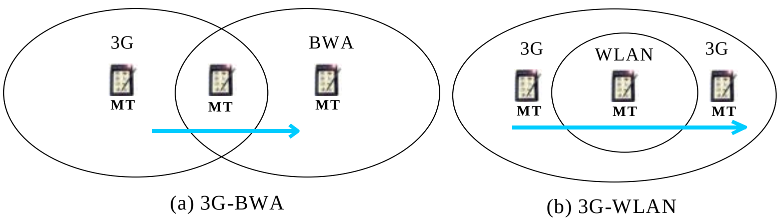


Fig. 5. mSCTP handover scenarios

On the other hand, the testbed environment consists of two hosts, one router for DHCP server, and a PC router for NISTNET. PC router has two NICs, which have an

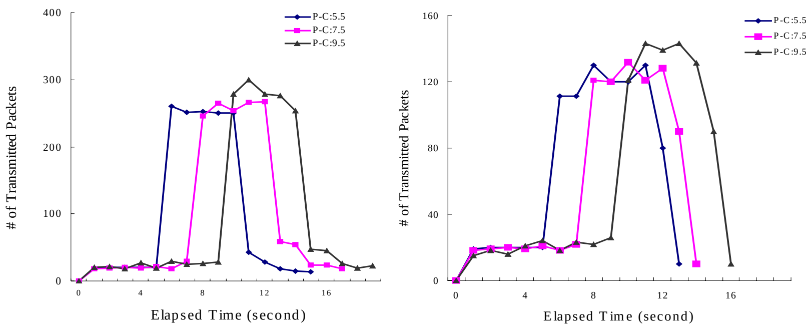
IP address "192.168.62.1" for 192.168.62.0 network and an IP address "192.168.1.1" for 192.168.1.0 network. An FS has an IP address "192.168.1.2". IP addresses of the MT are assigned from the DHCP server connected to the PC router. In the testbed network, the MT is initially connected to the 3G networks with the link bandwidth of 1.2 Mbps. After handover, the MT has the bandwidth of 5.4 Mbps to BWA or 8 Mbps to WLAN.

4.2 Experimental Results

We consider the throughput and handover latency as the performance metrics. We will analyze how the primary-change timing and the overlapping period can affect the mSCTP throughput and handover latency, respectively.

A. Throughput of mSCTP-DAC by Primary-Change

Figure 6 shows the experimental results of mSCTP-DAC handover in terms of the throughput for the two test scenarios: 3G-BWA and 3G-WLAN. In the figure, the number of transmitted packets exchanged between MT and FS are plotted, as the elapsed time goes on. For each experiment, we performed the primary-change (P-C) operations at three different time 5.5, 7.5, and 9.5 second. It is noted that the ADD-IP is performed at the time of 4.5 second for all the experiments.



(a) 3G-BWA (b) 3G-WLAN

Fig. 6. Results on Throughput by mSCTP-DAC

Figure 6(a) depicts the results of throughput by mSCTP-DAC for three different Primary-Change scenarios. In the figure, we note that the # of transmitted packets rapidly increases after the primary-change operation (i.e., the transmitted packet count gets much larger after the P-C operation). This is because the MT moves from the old link of 3G with bandwidth of 1.2 Mbps to the new link of BWA with bandwidth of 5.4Mbps. We also note that the case with an earlier P-C operation has completed the data transmission faster.

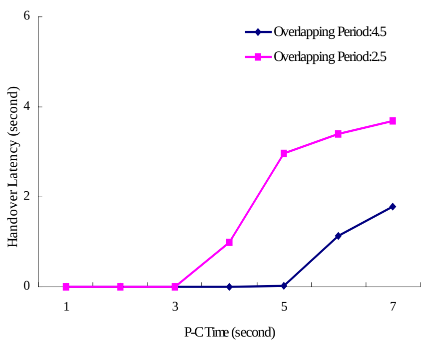
On the other hand, Figure 6(b) shows the results on throughput by mSCTP-DAC for handover from 3G to WLAN, and again to 3G, for three different P-C scenarios. It is shown in the figure that the # of transmitted packets gets larger just after the primary-change operation (when the MT is in the WLAN network), and then falls back to the normal throughput of 3G Network.

In summary, we can see from Figure 6 that the mSCTP throughput is affected by the time when the primary-change operation is performed. It is better to perform the primary-change operation quickly when the MT goes into the network with a higher bandwidth.

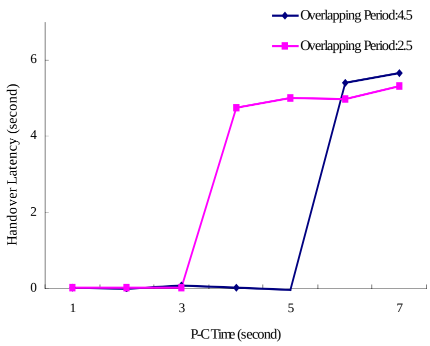
B. Handover Latency of mSCTP-DAC by Overlapping Period

Figure 7 compares the handover latency of the mSCTP-DAC handover for the different times of the primary-change operation, given that the MT is staying in the overlapping region at the fixed period of 4.5 or 2.5 second. Figure 7(a) and 7(b) show the handover latency of the mSCTP handover between 3G and BWA, and between 3G and WLAN, respectively. As shown in the figure, the handover latency of mSCTP gets larger, as the time for the primary-change operation is delayed (after the ADD-IP operation). This implies that it is better for the MT to perform the primary-change operatin as soon as possible, in order to reduce the handover latency.

On the other hand, we can also see in the figure that the handover latency can be reduced for the larger overlapping period. In particular, when the MT is staying in the overlapping region enough to complete the primary-change operation (or when the MT is moving with a slower speed), the handover latency becomes nearly ‘zero’ if the primary-change operation is completed within the overlapping period, as shown at the P-C time of 1-3 second in Figure 7(a) and 7(b).



(a) 3G-BWA



(b) 3G-WLAN

Fig. 7. Handover Latency by Primary-Change

As shown in the figure, the handover latency of mSCTP gets larger, as the time for the primary-change operation is delayed (after the ADD-IP operation). This implies that it is better for the MT to perform the primary-change operatin as soon as possible, in order to reduce the handover latency.

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5 Conclusions

In this paper, we proposed a dynamic IP address configuration scheme using link-layer information for mSCTP handover (mSCTP-DAC), and performed the experimental analysis of mSCTP handover. The proposed dynamic IP address configuration scheme can be used to configure dynamically and automatically the relevant IP addresses for the on-going SCTP session by using the status information of network interface during the movement of an MT. For these experiments, we implemented mSCTP-DAC under Linux platform, and made some scenarios to show performance of mSCTP handover. Moreover, we used NISTNET network emulator to simulate the handover for 3G-BWA and 3G-WLAN environments.

From the experiments, it is shown that the throughput of the mSCTP handover becomes degraded, as the primary-change is delayed. We can also see that the handover latency of mSCTP becomes nearly zero if the primary-change operation can be completed within the overlapping period. Accordingly, we note that it is better to perform the primary-change operation as quickly as possible, when the MT goes into the network with a higher bandwidth.

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