# Performance Improvements of Mobile SCTP during handover period

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***Abstract*—Handling mobility at the transport layer is an interesting approach to attain seamless handover in the context of heterogeneous access networks. To support terminal mobility, an extension of SCTP called SCTP-DAR (SCTP Dynamic Address Reconfiguration) (a.k.a. mobile SCTP) has been defined allowing SCTP endpoints to update IP address and inform the remote peer about primary address change. However, mobile SCTP suffers from performance degradation during handover. In this paper, we investigate two handover-related issues: reduction of data rate immediately after handover and packet reordering. The first issue is caused by the congestion control mechanism, which forces the ongoing traffic to enter the slow-start phase when moving into the new path after handover. The second issue is caused by the asymmetric characteristics of access networks such as the different bandwidths and delays in heterogeneous access networks. In order to solve these issues, we propose to use a combination of two mechanisms, congestion control parameter update and buffer retransmission.**

***Keywords*-SCTP; mSCTP handover; multi-homing; congestion control; vertical handover.**

## I. INTRODUCTION

Stream Control Transmission Protocol [1] has been designed by the IETF SIGTRAN (Signaling Transport) working group as a transport protocol for the delivery of packet-based PSTN (Public Switched Telephone Network) signaling over IP networks. Similar to TCP (Transmission Control Protocol), SCTP offers reliable data transfer and has mechanisms for congestion control, data duplication detection and data retransmission. In addition, it supports two new features, which are multi-streaming and multi-homing. Even though SCTP was explicitly designed for signaling transport, the multi-homing feature of this protocol can be used for broader applications and becomes an interesting solution to support multi-homing in multi-interface mobile terminals [2]. Each SCTP endpoint owns a list of IP addresses. During the initial phase of the association, SCTP endpoints have to exchange their lists of addresses. Among these IP addresses, the endpoint chooses one address as primary address. The others are secondary ones. Based on this principle, an SCTP association has a primary path and several secondary paths. If a failure occurs along the primary path, SCTP switches to an alternative path to maintain the communication.

To support the mobility of a mobile terminal, an extension of SCTP called mobile SCTP (mSCTP) [3] using SCTP Dynamic Address Reconfiguration [4], allows endpoints to update the IP address lists in an SCTP association. Each endpoint can update its address list if a new address is received or a current address becomes obsolete. This update procedure typically happens during the handover of a mobile terminal. For example, an endpoint moving from one access point to another may receive a new IP address from the new access point and the old IP address is no longer reachable. Thus, the endpoint needs to add a new IP address and deletes the old one from the address list of the association [5]. Mobile SCTP also allows an endpoint to inform the remote peer about its primary address change. For updating address lists and changing the primary address, mSCTP defines two new chunks: AddresS CONFiguration Change Chunk (ASCONF) and AddresS CONFiguration ACKnowledgment Chunk (ASCONFACK) [4].

However, in the context of heterogeneous networks with the existing congestion control mechanism and multi-homing feature, mSCTP has to suffer from two problems: (i) entrance into slow-start phase of new primary path just after handover, and (ii) packet reordering problem occurring in handover between heterogeneous access networks. These problems seriously cause mSCTP performance reduction after handover.

Some existing studies have already tried to improve handover performance of the mSCTP handover in the context of heterogeneous wireless networks. To provide a better throughput in handover procedure, [6] proposes to duplicate data on both existing primary path and new added one. This proposition is only useful in high loss rate environment, but it will create redundancy in stable context. In [7], the authors present a SCTP Efficient Flow Control (SCTP EFC) mechanism in order to minimize the change of traffic rate during handover. SCTP EFC updates new primary path with the same information of the old one to bypass slow-start phase. However, in heterogeneous networks environment, access network features such as bandwidth and delay may be different, so using the same information for new primary path update is not efficient. Another interesting approach named Buffer retransmission, which is introduced in [8], aims to ameliorate mSCTP handover performance but this solution can resolve only the packet reordering problem. In this paper, we propose to use a combination of two

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mechanisms: congestion control parameter update and buffer retransmission. The main contribution is a new congestion control parameter update mechanism based on bandwidth estimation to avoid the slow-start phase in the new primary path after handover. Buffer retransmission proposed in [8] is used to overcome the packet reordering problem.

The remainder of this paper is organized as follows. Section II studies the two problems encountered in SCTP handover procedure. In Section III, we present the details of our proposition on congestion control parameter update and the use of this mechanism in combination with buffer retransmission. Section IV describes the simulation scenario and results. Finally, we conclude the paper in Section V.

## II. PROLEM DESCRIPTION

Two main problems that the SCTP protocol can have in a handover between heterogeneous wireless networks are performance degradation due to the slow-start phase and packet reordering. These problems cause SCTP performance reduction after handover period. This section explains the reasons and the conditions, in which these problems can occur.

### A. Problem related to the slow-start phase

The entrance in slow-start phase can reduce throughput after handover. Like TCP, SCTP also supports flow control and congestion control mechanisms such as slow-start, congestion avoidance, fast recovery, etc. In terms of control variables, endpoint maintains only one receiver window (rwnd) for the whole association. Other control variables such as congestion window (cwnd), slow-start threshold (ssthresh) and RTT (Round-Trip Time), are kept on a per destination address basis. Because SCTP uses only one address at a time for transmission, SCTP handover can be understood as a procedure, in which an endpoint replaces the primary address with another one and redirects data flows from the old path to the new one. Since the ssthresh variable is controlled on a per destination address basis, the ongoing traffic must enter the slow-start phase on the new primary path after handover. This procedure leads to an immediate throughput reduction.

Figure 1 illustrates the effect of slow-start phase to mSCTP handover performance. We use Cumulative Transmission Sequence Number Acknowledgement (TSN Ack), which represents the last data sequence number received successfully, as a performance metric. As seen in Figure 1, handover execution takes place at 41.9 seconds. After that, ongoing traffic enters slow-start phase on the new primary path and its congestion control parameters start with initial values. Therefore, right after handover procedure, cumulative TSN Ack increases slowly, which proves a throughput reduction.

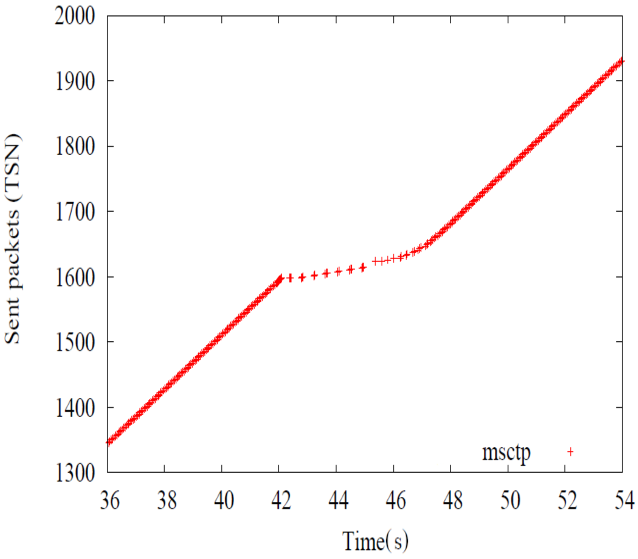

Figure 1. Throughput reduction after handover

### B. Problem related to packet reordering

In the SCTP primary path switching operations, the packet reordering problem may occur due to the asymmetric characteristics of access networks such as bandwidth and delay [8][9]. When a Mobile node (MN) moves between heterogeneous wireless networks (e.g from 3G to WLAN), the mSCTP endpoint should change its primary address to a newly received IP address. It is obvious that characteristics of heterogeneous access networks are not symmetric. If SCTP endpoints switch the primary path into a new path with higher bandwidth (or smaller delay), data chunks sent over the new path can arrive at peer endpoint earlier than those sent to the old path with lower bandwidth (or bigger delay). Therefore, packet may arrive at peer endpoint out-of-order, which is referred to the packet reordering problem. Consequently, endpoint can evoke spurious fast retransmission and unnecessarily reduce congestion window, which causes degradation of throughput in handover period.

Figure 2 shows an example of packet reordering problem due to the asymmetric characteristics between paths in one association. Each endpoint has two interfaces, interface 1 and interface 2. At the beginning, they use interface 1 (path 1) for their communication. When handover happens, the traffic is switched to interface 2 (path 2). We assume that the bandwidth of path 2 via interface 2 is higher than the one of path 1. As shown in Figure 2, endpoint S sends 4 data packets (TSNs 1-4) to endpoint R via path 1 just before the handover operation. After the handover, endpoint S uses the new path, path 2, to send new data packets. Because of the different bandwidths, data packets sent via path 2 (TSNs 5-6) arrive at endpoint R earlier than ones sent via

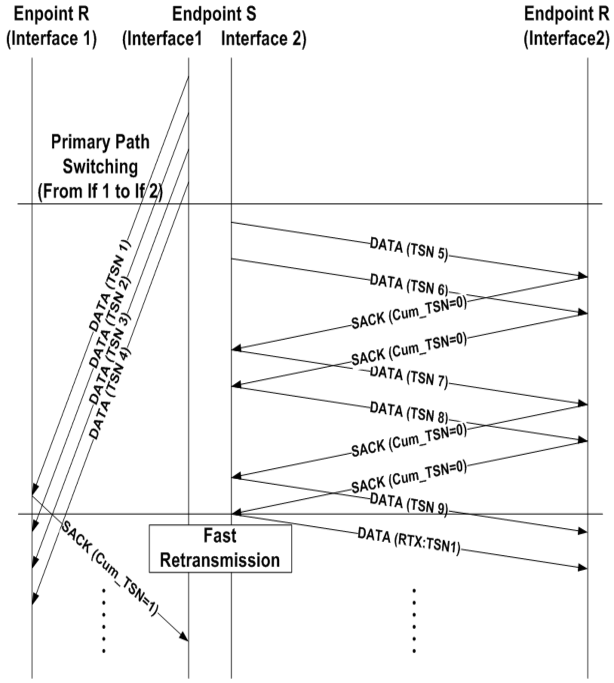

Figure 2. Packet reordering problem in mSCTP handover [8]

path 1. Therefore, a notification about packet reordering is sent to endpoint S via SACK chunk. When the accumulation of duplicate SACKs of the same gap received at endpoint S equals four, endpoint S triggers spurious fast retransmission immediately.

To solve this problem, the authors of [8] propose a buffer retransmission mechanism, which retransmits all outstanding data over the new primary path. All outstanding data are packets that have been transmitted over the old primary path but have not been acknowledged. It means that, after primary path change, endpoint will not send new data until all outstanding data are transmitted and acknowledged. Consequently, spurious fast retransmission and unnecessary reduction of congestion window may be avoided.

## III. PROPOSED SCHEMES

In order to deal with these problems of performance reduction, we present a solution combining two mechanisms: congestion control parameter update and buffer retransmission proposed in [8]. Although each mechanism helps to solve only one problem described above, we will show in the following of this section that the combining of both has better results.

### A. Proposal of congestion control parameter update

In order to bypass slow-start phase after the change of primary path in handover, we propose a mechanism named congestion control parameter update. The mechanism principle is forcing the new primary path to update its congestion control parameters using the old ones information. Just after the primary path switching operation, the congestion window (cwnd) and threshold (ssthresh) parameters of new primary path are calculated by the following formulas:

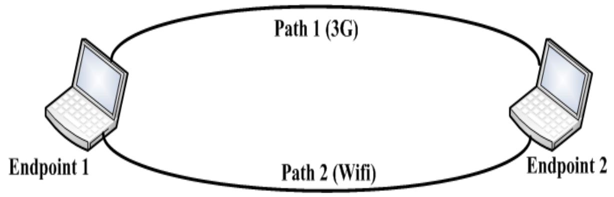

Figure 3. Network topology

$$cwnd_{new} = \alpha \times cwnd_{old} \tag{1}$$

$$ssthresh_{new} = \alpha \times ssthresh_{old} \tag{2}$$

$$\alpha = \frac{bandwidth_{new}}{bandwidth_{old}} \tag{3}$$

in which $\alpha$ is the bandwidth ratio of the two networks concerning handover.

With this mechanism, the new primary path will conserve the old ones status. For example, if the old primary path is in congestion avoidance status before the handover, the new primary path will be also in congestion avoidance status after handover. Therefore, mSCTP may avoid entering slow-start phase and its performance can be improved.

For bandwidth estimation purpose, in the old primary path, we use available bandwidth, which is equal to $\frac{cwnd}{RTT}$. This estimation reflects real bandwidth that the old path can support for data transfer. In the new primary path after handover, bandwidth is estimated thanks to Packet Pair algorithm [10]. It means that, sender sends two HeartBeat packets back-to-back via the new primary path. The size of probe HeartBeat packet is set to the Maximum Transfer Unit (MTU) [9]. Therefore, the available bandwidth estimation (ABE) of new primary path is calculated by

$$ABE = \frac{S_{HB}}{\Delta_T} \tag{4}$$

in which $S_{HB}$ is the size of probe HeartBeat packet, and $\Delta_T$ is the disperse time between the probe HeartBeat acks.

## IV. SIMULATION AND RESULTS

In this section, we present the performance evaluation of the proposed solution. In order to analyze mSCTP handover performances, we use the network simulator ns-2.33 [11].

### A. Simulation scenarios

In this simulation, each endpoint has two interfaces: one representing 3G interface, which has a bandwidth of 384Kbps and a delay time of 150 ms, and one representing Wi-Fi interface, which has a bandwidth of 11 Mbps and a delay time of 4 ms. Although we use wired interfaces

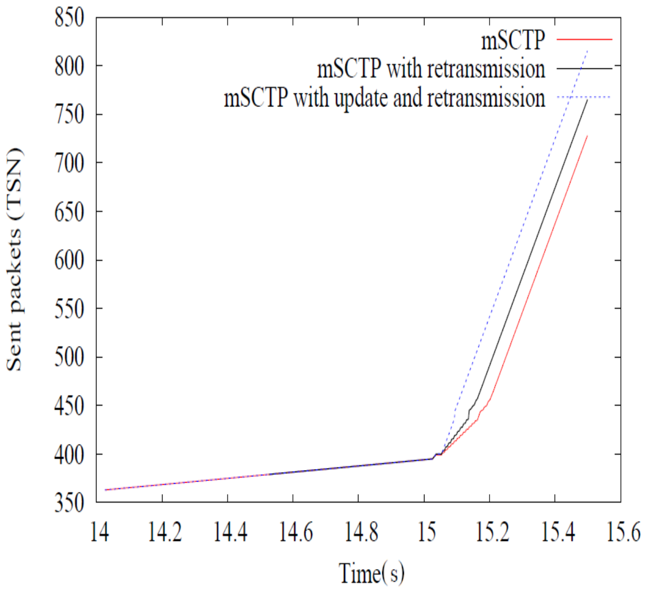

Figure 4. Handover from low to high bandwidth access network

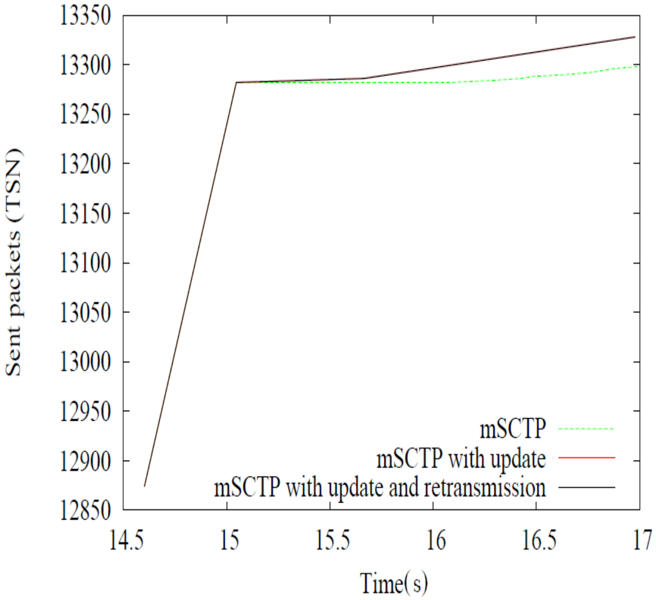

Figure 5. Handover from high to low bandwidth access network

in simulation, our proposition can be applicable for general interfaces with any technology type. In order to investigate our proposed scheme efficiencies, we execute two different scenarios. In the first one, endpoint executes handover from the 3G interface to the Wi-Fi interface, in which packet reordering problem happens. In the second one, handover is carried out, in inverse direction, from the Wi-Fi interface to the 3G interface. In the both scenarios, we have implemented bandwidth estimation mechanisms, which are presented above, to calculate the bandwidth ratio of the two networks $\alpha$.

### B. Simulation results

*1) Scenario 1-Handover from low to high bandwidth access network (from 3G to Wi-Fi interface):* In this scenario, SCTP primary switching operation occurs at 15.1 seconds. Figure 4 illustrates three curves corresponding to the handover performances of three schemes: the red one for original mSCTP, the black one for mSCTP with buffer retransmission mechanism and the blue one for mSCTP with the combination of both congestion control parameter update and buffer retransmission. Cumulative TSN Ack value, which represents the last Transmission Sequence Number (TSN) of Data chunk successfully received in sequence, is used to measure the mSCTP handover performance.

As shown in Figure 4, mSCTP including our proposed schemes has the best handover performance as the accumulated TSN of the blue line increases most quickly. The handover performance of the original mSCTP is the worst among these three handover schemes, proved by the fact that the accumulated TSN of the red line increases most slowly. The performance of mSCTP integrated two mechanisms is also better than the one of mSCTP only including buffer retransmission mechanism. Enven though mSCTP with buffer retransmission can overcome the packet reordering problem, ongoing traffic has to still enter into slow-start phase in the new primary path after the primary path switching operation, causing performance degradation. The performance of mSCTP including buffer retransmission mechanism is better than the one of the original mSCTP because at least packet reordering problem is solved.

*2) Scenario 2- Handover from high to low bandwidth access network (from Wi-Fi to 3G interface):* In Figure 5, the handover performances of three schemes are presented by three curves: the green one for original mSCTP, the red one for mSCTP with congestion control parameter update and the black one for mSCTP with the combination of both mechanisms, congestion control parameter update and buffer retransmission. The handover occurs at 15.1 seconds. We also use the Cumulative TSN Ack value to represent the mSCTP handover performance. As shown in Figure 5, mSCTP integrating two proposed mechanisms has the best handover performance. The accumulated TSN of the black line increases most quickly. The original mSCTP gets the worst handover performance among these three handover schemes. The accumulated TSN of the green line increases most slowly. The red curve and the black one are almost the same. It means that, performance of mSCTP integrated two mechanisms is the same as the one of mSCTP with only update parameter congestion control mechanism. The fact is that mSCTP does not suffer from packet reordering problem in this handover scenario (from high to low bandwidth access network). As described above, packet reordering problem happens when endpoint executes handover to a higher bandwidth (or smaller delay) network.

## V. CONCLUSION

In this paper, we have presented problems, which reduce mSCTP performance in handover procedure: slow-start phase and packet reordering problem. In order to solve these problems, we have proposed to combine congestion control parameter update and buffer retransmission mechanisms. The first one helps to bypass slow-start phase for a generic handover between two interfaces with mSCTP. Its principle is to adapt proportionally congestion control parameters considering the available bandwidth ratio of the two paths. The second one is used to solve packet reordering problem for handover in heterogeneous access networks environment. The simulations results show that the proposed solution has a better performance in comparison with the original mSCTP in terms of throughput and achievement of seamless handover.

In future works, we extend our simulation with the wireless interfaces such as 3G and Wi-Fi in order to verify our algorithm in a more realistic context. An implementation of our algorithm in a real test-bed with an Openmoko terminal [12] as well as with laptops equiped with two interfaces, Wifi and cellular (GPRS or 3G), is in progress and will be subject to future publications.

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## REFERENCES

[1] R. Stewart, *Stream Control Transmission Protocol*. IETF RFC 4960, September 2007.

[2] L. Ong and J. Yoakum, *An Introduction to the Stream Control Transmission Protocol (SCTP)*. IETF RFC 3286, May 2002.

[3] M. Riegel, Q. Xie, and M. Tuexen, *Mobile SCTP*. draft-riegeltuexen-mobile-sctp-09.txt, Internet-Draft, November 2007.

[4] R. Stewart,Q. Xie,M. Tuexen, S. Maruyama, and M. Kozuka, *Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration*. IETF RFC 5061, September 2007.

[5] S.J. Koh, M.J. Chang, and M. Lee, *mSCTP for Soft Handover in Transport Layer*. IEEE communications letters,Vol. 8, No. 3, pp. 189-191, March 2004.

[6] S.H. Kwon,T.W. Um, and W. Ryu, *Mobile SCTP with Bicasting for Vertical Handover*. Third International Conference on Convergence and Hybrid Information Technology (ICCIT), Busan, Korea, November 2008.

[7] K.J. Lee, S. S. Nam, and B. I. Mun, *SCTP Efficient Flow Control During Handover*. Wireless Communications and Networking Conference (WCNC), Las Vegas, United States of America, April 2006.

[8] D.P. Kim, S. J. Koh, and V. Leung, *On the Packet Reordering of mSCTP for Vertical Handover in Heterogneous Wireless Networks*. Vehicular Technology Conference (VTC), Calgary, Canada, September 2008.

[9] R. Fracchia, C. Casetti, C.-F. Chiasserini, and M. Meo, *WiSE: Best-path selection in wireless multihoming environments*. IEEE Transactions on Mobile Computing, Vol. 6, No. 10,pp. 1130-1141, October 2007.

[10] K. Lai and M. Baker, *Measuring bandwidth*. Proceedings of the Conference on Computer Communications (IEEE Infocom), Vol.1, pp. 235-245, New York, United States of America, March 1999.

[11] ns-2 network simulator (ver. 2), URL: http://www.isi.edu/nsnam/ns 20.04.2011.

[12] Openmoko terminal , URL: http://wiki.openmoko.org/wiki/Main_Page 20.04.2011.