A Transport Layer Mobility Support Mechanism

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Abstract. Recently, mobile SCTP (mSCTP) has been proposed as a transport layer approach for supporting mobility. mSCTP is based on the 'multi-homing' feature of Stream Control Transmission Protocol (SCTP), and utilize the functions to dynamically add or delete IP addresses of end points to or from the existing connection in order to support mobility. In this paper, we propose a mechanism to determine when to add or delete an IP address, utilizing the link layer radio signal strength information in order to enhance the performance of mSCTP. We also propose a mechanism for a mobile node to initiate the change of data delivery path based on link layer radio signal strength information. The simulation results show that the performance of proposed transport layer mobility support mechanism is competitive compared to the traditional network layer mobility supporting approach. Especially, when the moving speed of mobile node is fast, it shows better performance than the traditional network layer approach.

1 Introduction

For the next-generation Internet, one of the essential requirements of the users is being connected to the network while roaming. Mobile IP is the proposed standard of IETF for supporting mobility based on IP [1]. Various protocols to enhance the performance of Mobile IP have also been proposed [1, 2, 3, 4, 5, 6]. These protocols, including Mobile IP, take a common stance in the sense that they all deal with mobility at the network layer. If mobility is handled at the network layer, transport connections may remain transparent to the user movement. Mobility support at the network layer requires special entities such as HA (Home Agent) and FA (Foreign Agent) to be deployed in the network, and this involves overhead and inefficiency such as tunneling and/or triangle routing [1, 2, 3, 4, 5, 6].

Recently, mobility support at the transport layer protocol has been discussed in the specification of some of the newly emerging transport protocols such as Stream Control Transmission Protocol (SCTP) or Datagram Congestion Control Protocol (DCCP) [7, 8]. Especially with the SCTP, an extension named mobile SCTP (mSCTP), which facilitates mobility has been drafted in [9].

SCTP is a new IETF standard track general purpose transport protocol for the Internet. Similar to TCP, SCTP provides a connection oriented reliable service, and a connection between two SCTP endpoints is called as an association.

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One of the major features that SCTP provides is multi-homing. Multi-homing allows an endpoint of an SCTP association to be mapped to multiple IP-addresses. Among those addresses, one is chosen as the 'primary path' and is used as the destination for normal transmission. The other addresses are used for retransmissions only. A sender may change the primary path if the number of successive retransmissions in the current primary path is over a certain threshold. New primary path is randomly selected among the available active IP addresses mapped to the receiving end of SCTP association.

Multi-homing feature of SCTP provides a basis for mobility support since it allows a mobile node (MN) to add a new IP address, while holding the old IP address already assigned to itself. On top of SCTP multi-homing feature, mSCTP utilizes ADDIP and DELETEIP functions which enables dynamically adding and deleting an IP addresses to and from the list of association end points in the middle of association [10]. If an MN obtains a new IP address when it moves into a new subnet, the mSCTP at MN sends out ADDIP message to inform the mSCTP at correspondent node (CN) of the new IP address to be added to the list of end point addresses for the association. mSCTP at MN also informs the mSCTP at CN to delete the IP address of previous subnet from the address list by sending out DELETEIP message. The SCTP association, therefore, can continue data transmission to a moved new location without aid from the network layer.

In the current specification of mSCTP is, though, at a very primitive stage, and it mearly illustrates the basic requirements and suggestions to utilize ADDIP and DELETEIP to support session mobility. Some essential issues, such as when and by which criteria the primary path to be changed or the addition and deletion of the IP addresses mapped to the SCTP association should occur in order to deal with handover seamlessly, are yet left for future elaboration. Without these issues being defined, the current mSCTP cannot practically handle mobility. For example, without appropriate mechanism to determine when to change and how to select the primary path, a serious oscillation problem, which may degrade the performance to the minimum, could occur during handover. In this paper, we identify these loosely defined or missing aspects of the current mSCTP definition and propose a transport layer mobility supporting scheme which addresses all of those aspects. Through extensive simulations, the proposed transport layer mobility supporting scheme is tested and the performance is compared with the traditional TCP over Mobile IP.

The rest of this paper is organized in the following way. Section 2 gives a detailed explanation on the operation of proposed scheme. Simulations and its numerical results are presented in section 3. Finally, section 4 concludes the paper.

2 An mSCTP Enhancement Scheme

When MN moves into a new subnet, layer 2 (L2) handover and new IP address acquisition should happen. The proposed scheme assumes that L2 handover and the acquisition of a new IP address is achieved in the same as they are done with Mobile IP. For IPv4, it is assumed that the new IP address is obtained by DHCP (Dynamic Host Configuration Protocol) or CCoA (Co-located Care-Of Address) is deployed; for IPv6, the new IP address is assumed to be obtained by Stateless Address Auto configuration [11]. Typically, IP address acquisition starts after L2 handover in the new subnet is completed. In [11, 12], it is proposed to proceed IP address acquisition and L2 handover simultaneously in order to reduce the handover latency. The proposed scheme can work with either of these two cases.

When handover happens, mSCTP at MN should perform ADDIP for the new IP address and DELETEIP for the old one. In the proposed scheme, mSCTP at MN performs ADDIP as soon as the signal strength of the new access router exceeds the signal strength threshold value that enables communications (hereinafter, it is called L2 handover threshold). Once an IP address is added, DELETEIP for that address is not triggered until the signal strength from the corresponding access router becomes lower than the L2 handover threshold. With these policies, an SCTP association of the proposed scheme maintains the MN's IP addresses corresponding to all of the accessible subnets, and furthermore an accessible IP address is added to the SCTP association as early as possible. The main purpose of these policies regarding adding or deleting end point IP addresses is to maximize the chance that an end point IP address is ready when it is needed for handover.

When handover happens, primary path also needs to be changed. The current mSCTP does not specifically mention about how to change the primary path for handovers. If the way that SCTP uses to change the primary path is adopted in mSCTP, CN should experiences multiple data packet losses for each handover before it finally determines to change the primary path. In order to prevent these losses, the proposed scheme makes the mSCTP at MN to trigger primary path change toward the mSCTP at CN when handover happens. Furthermore, mSCTP at MN triggers this request before DELETEIP for the current primary path occurs in order to avoid a time interval during which no primary path exists for data transmission. Similar to issuing an ADDIP or a DELETEIP, mSCTP at MN uses L2 radio signal strength information for primary path changes. If the radio signal strength of the primary path becomes lower than a certain threshold (hereinafter it is called primary change threshold), primary path is replaced. The threshold value for this purpose is set slightly higher than L2 handover triggering threshold in order to have the primary path change occur before DELETEIP of the primary path. While satisfying this condition, the primary change threshold should be as low as possible in order to reduce primary path changes. In addition, the proposed scheme let mSCTP at MN determine a new primary path utilizing the L2 radio signal strength information of the wireless subnet, and inform it to mSCTP at CN. Among the accessible subnet, the one providing strongest radio signal is selected as the new primary path in order to minimize the possible oscillation.

The functions of the proposed scheme as described above are implemented in a logical block named AMM (Address Management Module). Fig.1 presents

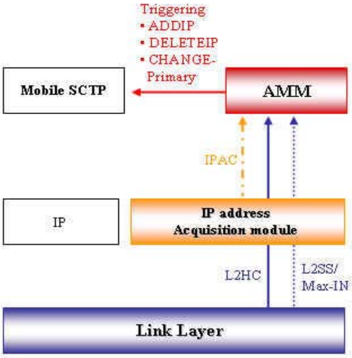


Fig. 1. Signaling in proposed scheme

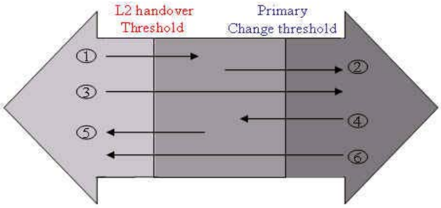


Fig. 2. L2 Signal strength change

the interaction between AMM and the rest of mSCTP, IP address acquisition module, and link layer respectively. Receiving signals from the link layer and the IP address acquisition module, AMM determines when to trigger ADDIP, DELETEIP, and primary path change and informs it to mSCTP. mSCTP at MN then interact with peer mSCTP at CN to change the end point mapping or the primary path for the SCTP association.

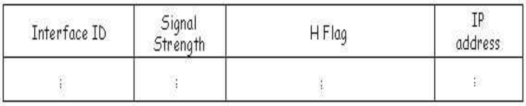
Link layer sends out following three types of signals to AMM whenever a corresponding event happens:

1. L2HC (L2 Handover Completion): the L2 handover is completed for the interface specified in the signal.
2. MaxIN (Interface with Maximum signal strength): the interface providing maximum signal strength has been changed to the one specified in the signal.
3. L2SS (L2 Signal Strength): one of the L2 signal strength changes shown in Fig. 2 has occurred for a certain interface; the signal specifies the interface and the types of signal strength change (S) whose value is determined according to Table 1.

IP address acquisition module sends out IPAC (IP address Acquisition Completion) signal when an IP address acquisition for an interface is completed. The IPAC signal indicates the interface ID as well as the acquired IP address.

Table 1. S field value of L2SS

Signal Strength Change	S field of L2SS
1	1
2, 3	2
4	3
5	4
6	5



Interface ID	Signal Strength	H Flag	IP address
⋮	⋮	⋮	⋮

Fig. 3. Address Table in AMM

In order to store the information collected from the signals from the link layer and the IP address acquisition module, AMM maintains an Address Table as shown in Fig. 3. The SS (Signal Strength) field of the Address Table indicates the current signal strength of the interface, and the meaning of the value of this field is shown in Table 2. This field is updated from the S value of L2SS signal. As shown in Fig. 2 and Table 1, S value of L2SS can be used to induce in which state the signal strength of the given interface belongs to. The H flag in the Address Table indicates whether the L2 handover is completed for the corresponding interface. Receiving L2HC signal for a certain interface, H flag of corresponding entry in the Address Table can be set. The IP address field of the Address Table is filled when IPAC signal for the corresponding entry comes in from the IP address acquisition module. In addition to Address Table, AMM also maintains information such as the interface corresponding to the current primary path and the interface with maximum signal strength.

mSCTP at MN starts ADDIP for a certain IP address when both the L2 handover and the IP address acquisition of the corresponding interface are completed. That is, for a certain entry of the Address Table, AMM triggers mSCTP to start ADDIP for the corresponding interface when both the IP address field and the H flag are set upon receiving L2HC or IPAC signals.

When the received L2SS is for the current primary path interface and its S field is 3 or 5, AMM should trigger mSCTP to start primary path change. Before this triggering, AMM checks whether there is an alternative interface ready to be used as the new primary path. If one is found, it immediately triggers mSCTP to start the replacing primary path with that interface. In order for an interface to be a primary path interface, it should satisfy the following three conditions:

1. It is the interface with maximum signal strength and the signal strength is greater than the 'primary change threshold'. Note that there could be a case that even the interface with maximum signal strength may not provide the signal strength higher than the primary change threshold.

Table 2. The vaule of SS field in the Address Table

SS	Signal Strength ρ
0	$\rho <$ L2 handover threshold
1	L2 handover threshold $< \rho <$ Primary change threshold
2	Primary change threshold $< \rho$

2. Link layer handover is completed.
3. IP address acquisition is completed.

If there is no such interface, AMM just updates the SS field of the Address Table to be 0 or 1 depending on the value of S field in L2SS, and postpones triggering the primary change. Afterwards, as L2SS, L3HC, or IPAC signals are received at AMM, an interface satisfying all three of the above conditions could show up. When SS=0 or 1 for the primary path interface, AMM triggers mSCTP to start the primary path change as soon as an interface satisfying all three conditions of the primary path interface shows up.

If AMM receives an L2SS signal with S=4 or 5 for a certain interface, AMM triggers mSCTP to start DELETEIP for that interface. Before this triggering, AMM checks whether the interface corresponds to the current primary path. If it is, an alternative interface to serve as the primary path should be searched. If there is no interface ready to replace the primary path, DELETEIP triggering should be postponed. In this case, whenever primary path change can be triggered afterwards, DELETEIP for the current primary path interface should be triggered together.

The primary path change and DELETEIP are triggered together if primary path change happens after the MN completely moves out of the cell overlapping area. In this case, the acknowledgements for the outstanding packets that are transmitted through the previous primary path may not come back to CN, resulting in the disruption of steady arrival of acknowledgements. If the arrival of acknowledgements is disrupted, not only that the fast retransmit cannot be applied but also the opening of the receiving window is not informed to the sending side. Furthermore both flow and error control may erroneously trigger timeouts as well as window reduction. In order to avoid the performance degradation cause by these, we make the mSCTP at MN to inform this to situation the mSCTP at CN by setting one of the flags in the SCTP ASCONF chunk which encapsulates the primary path change and DELETEIP requests [10]. Receiving the ASCONF chunk with this particular flag set, the mSCTP at CN transmits a probe packet to MN. According to the SACK for the probe packet, mSCTP at CN immediately starts the retransmission of gaps without waiting for further acknowledgements. When CN starts transmitting data to the new primary path, the data transmission window is controlled by slow start in all cases.

3 Simulation

In this section, we present the simulation model and compare the performance of proposed scheme and TCP over Mobile IP (hereafter, TOM) through the numerical results of the simulation. For the performance comparison purpose, TOM is specifically chosen since it is the representative data transmission framework based on network layer mobility support. The comparison of proposed scheme to the original mSCTP is not performed since plain mSCTP cannot cope with the mobility on its own due to the reasons explained in the introduction.

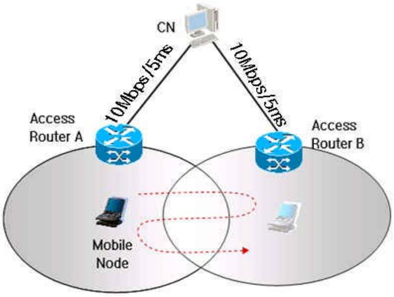


Fig. 4. Simulation Network Model

3.1 Simulation Model

The simulation was implemented using ns-2 simulator proposed by U.C. Berkeley. For the proposed scheme, the ns-2 SCTP node module implemented in [13] is patched. The simulation was run on RedHat Linux 7.3 with the v2.4.18 kernel.

Fig. 4 shows the network model used in our simulations. The wireless channel is assumed to be 802.11b WLAN with 2Mbps capacity and negligible propagation delay. All of the wired links are assumed to have 10Mbps link capacity with 5ms of propagation delay. The coverage radius of each wireless cell is assumed to be 300 meters, and the distance between two neighboring cells is 520 meters. Therefore, the longest distance across the overlapping area is 80 meters. In order to take account for the impact of handover to the performance, we made MN move between two access routers in turn at constant moving speed during the whole simulation time.

As for the performance metric, the elapsed time for MN to download the 140Mbytes of file form the CN is measured, and it is denoted as file transfer time. Handover latency, which is defined as the length of time interval between the instance receiving the last packet from the old path and the instance receiving the first packet from the new path when handover happens, is also measured. The performance of proposed scheme and TOM are measured with these two performance metrics for various moving speed of MN and the path acquisition time. The path acquisition time is defined as the time to complete both the L2 handover and the IP address acquisition for a wireless subnet.

3.2 Simulation Results

Fig. 5 and 6 show the file transfer time and the handover latency respectively for changing path acquisition time. The moving speed of mobile node is set to 30m/sec for this experiment. If the path acquisition time is very short (when it is 1 second in our experiment), the performance of TOM is better than the proposed scheme.

In this case, both TOM and mSCTP can start transmitting data to the new path while MN is transiting the cell overlapping area, and the chance for MN

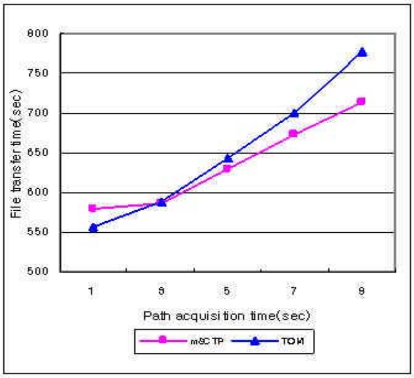


Fig. 5. Signaling in proposed scheme

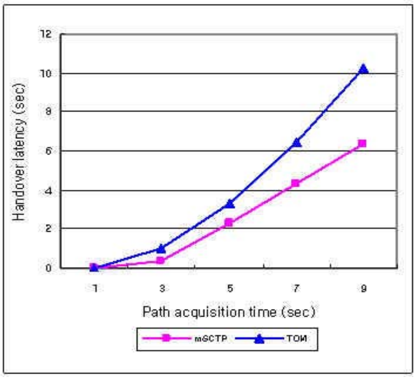


Fig. 6. L2 Signal strength change

to successfully receive all the data transmitted through the old path before it leaves the overlapping area is very high. That is, the impact of handover is minimal in this case. Under these circumstances, the performance of proposed scheme is worse than TOM due to SCTP's higher header overhead as well as the impact of slow start used in mSCTP. Note TCP in TOM is not aware of the handover, and maintains the congestion window size of the previous path, which is higher than the initial window size of the slow start in most of the cases, when it starts transmitting on the new path. On the other hand, mSCTP always starts transmitting to the new path with the initial window size of the slow start. As the path acquisition time becomes longer, the time to start transmitting data through new path is delayed and as a result the amount of data, which are transmitted through the old path and not being able to be delivered to MN while it is transiting the overlapping area, increases. That is, amount of losses caused by handover increases. Moreover, changing the data delivery path may not even happen while MN is transiting the overlapping area if the path acquisition time becomes larger than the MN's overlapping area transiting time. The amount of losses caused by handover grows even larger in this case. Since TCP in TOM is not aware of handover, it reduces the transmission window if handover causes packet losses. Furthermore, if timeout occurs due to the losses during handover, transmission through the new path may not start even after handover is completed due to the retransmission timeout interval. On the other hand, the proposed mSCTP enhancement schemes makes mSCTP to start transmitting data to the new path as soon the handover is completed. Therefore, the proposed mSCTP enhancement scheme always shows smaller handover latency as presented in Fig. 6. Mainly due to the impact of handover latency, it also shows shorter file transfer time than TOM when path acquisition time is larger than 3 seconds as presented in Fig. 5.

Fig. 7 and 8 show the handover latency and the file transfer time respectively for different moving speed of MN. For this experiment, both the parallel and the sequential approaches, in terms of processing the L2 handover and the IP

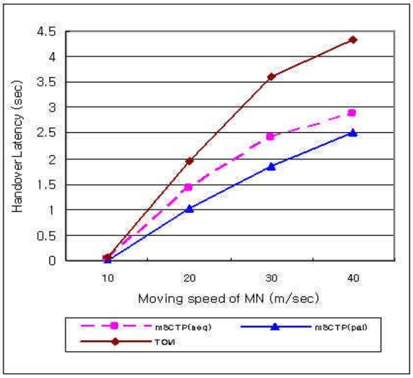


Fig. 7. Signaling in proposed scheme

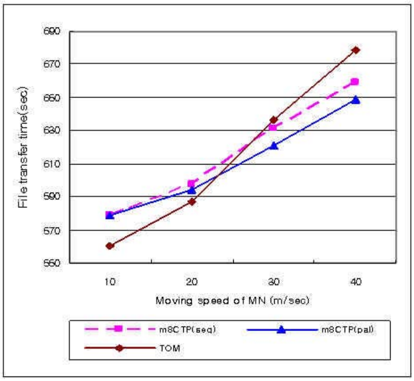


Fig. 8. L2 Signal strength change

address acquisition, are applied for the proposed scheme in order to investigate the impact of path acquisition time to the performance of the proposed scheme. These two different cases are specified as mSCTP(seq) and mSCTP(pal) in the figures.

As the moving speed of MN becomes faster, handover latency increases in both the proposed scheme and TOM. If two MNs with different moving speed start transiting the cell overlapping area at the same time, the faster MN should escape from the overlapping area earlier, i.e., the faster MN stops receiving packets from the previous path earlier. Since the path acquisition time is not affected by the moving speed of MN, the time to start receiving packets through the new path is almost the same regardless of the moving speed. Therefore, handover latency, which is defined as the length of time interval between the instance receiving a packet from the old path for the last time and the instance receiving a packet from the new path for the first time, becomes larger as the moving speed becomes faster. Due to the reason explained for Fig. 6, the proposed scheme always has shorter handover latency than TOM for all moving speeds.

In Fig. 8, it is shown that the proposed scheme outperforms TOM when the moving speed of MN is over 20m/sec. As clearly illustrated in Fig. 5, the relative performance gain of proposed scheme compared to TOM, with respect to the file transfer time, becomes greater as the ratio of path acquisition time to cell overlapping area transiting time becomes larger. Since the cell overlapping area transiting time becomes smaller as the moving speed becomes faster, the proposed scheme shows better performance than TOM when the moving speed of MN is relatively faster.

With respect to both the handover latency and the file transfer time, the proposed scheme performs relatively better when the L2 handover and the IP address acquisition proceed in parallel. This result is symmetric to the performance comparison between TOM and fast handover [11].

4 Conclusion

Recently, mSCTP has been proposed as a transport layer approach to support mobility. We propose an enhancement scheme of mSCTP, which utilizes the link layer radio signal strength information and specifically addresses the following aspects:

- Adding or deleting IP addresses for handover
- Initiating the change of data delivery path from MN in case of handovers
- Selecting a new primary path by MN
- Reducing handover latency by explicit signaling and probing at the transport layer

The simulation results show that the proposed scheme is very competitive compared to the traditional network layer mobility support mechanism. Expecially, when the moving speed of mobile node is fast, it shows better performance.

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