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An Adaptive Primary Path Switching Scheme for Seamless mSCTP Handover

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| ***Abstract*:** In this paper, a primary path switching scheme is proposed to provide a seamless handover for dual-homed mobile terminals. This scheme is proposed as an enhancement to the mSCTP protocol. With this scheme, a mobile terminal performs primary path switching before it becomes unavailable due to its primary path drop. The improvement achieved by the scheme is that it considers the temporal velocity of the mobile terminal with relative RTT variances of all available paths when it performs the handover process in the overlapped area between two different networks. Our simulation results show that the proposed scheme achieves a better overall performance than other schemes, and anticipatory switching is more important for faster moving terminals. |

***Keywords*:** mSCTP, Primary Path Switching, RTT-based, Speed-based

# 1. Introduction

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s various networks (e.g., LAN, WLAN, and 3GPP) are currently deployed, and the next generation network is converging into an all-IP-based, unified network, many mobile terminals are configured for multi-homed environments by simply installing two or more network interfaces. In this environment, the *mobile stream control transmission protocol* (mSCTP) [1] has been considered as a proper transport layer protocol. mSCTP provides connection-oriented, reliable transmission over the IP core network via *selective ACK* (SACK) flow control, congestion control and avoidance, as well as failure detection and recovery.

Among its many functionalities, the multi-homing feature of mSCTP can maximize the utilization of the multi-homed environment and increase network availability. The multi-homing feature enables a mobile terminal (MT) to use more than one IP address in order to support more than one communication path, namely a primary path together with several alternative paths in a single SCTP session. The primary path is used to transport the data packets, and MT will change its primary path to an alternative path when its current primary path has failed. A link failure can easily occur, especially when an MT performs a handover between different network domains.

In this condition, the MT is in an overlapping state between different networks and both paths are available. This issue has led to numerous proposals [2–7] to determine the appropriate network conditions for primary path switching. Unfortunately, the existing schemes have not properly considered the switching conditions.



**Figure 1. An example of mSCTP handover between different networks**

We propose a new primary path switching scheme, which considers the network conditions including round trip times (RTTs) of all available paths and the MT velocity. In other words, an MT takes into account the historical and relative difference among the evaluated *round trip times* (RTTs) of multiple paths against its estimated movement speed when it is located in the overlapped area between two different networks. Based upon these measurable characteristics, MT adaptively determines when it needs to change its primary path. The contribution of proposed scheme can be summarized as follows.

* It improves performance in terms of transmission delay by reducing the probability of data packet loss at MT;
* It increases the overall throughput of MT since the reduced number of retransmission requests from MT allows the *correspondent terminal* (CT) to maintain its current congestion window size;
* The case-adaptive feature of the proposed scheme guarantees network availability for MT.

The rest of this paper is organized as follows. The next section describes related works. In the proposed scheme section, we propose a new primary path switching scheme taking into account the network conditions and movement speed of MT. The performance evaluation section includes performance evaluations and discussion of the effect of the proposed scheme. Finally, we conclude this paper in the last section.

# 2. Related Work

The multi-homing feature of SCTP allows target applications to glue together more bandwidth from heterogeneous wireless networks. This bandwidth availability can ensure fault tolerance for the corresponding network applications. An example is introduced in [8]. As this great advantage can be only maintained with an efficient primary path switching scheme, we investigate the existing primary path switching schemes that have been proposed as an extension to the legacy mSCTP. These schemes essentially differ in the strategies they use for determining which conditions should be satisfied for performing path switching.

Other proposals [3, 4] considered bandwidth for both paths as a decision metric. Based upon the narrowest end-to-end bandwidth and required minimum bandwidth by application, the scheme classified four different cases and suggested different switching conditions in terms of bandwidth gaps for two paths. However, the scheme did not consider the end-to-end delay for both paths, which significantly affects the retransmission strategy of mSCTP.

# 3. The Proposed Scheme

In order to determine the primary path switching criteria for each MT, we take into account two metrics, including the historical relative difference of RTT against the estimated movement speed of MT. Both metrics are calculated only when MT is in dual-homing mode as it is located in the overlapping state among different networks, as is shown in Figure 1. In order to simplify our description, we assume that each MT has only one alternative path, since the proposed scheme can be applied in a straight forward manner to the multi-alternative paths environment.

## 3.1 RTT-Based Scheme

mSCTP achieves reliable transmission by defining SACK packets sent by the receivers. With the mSCTP protocol, MT can check the connectivity of the current primary path with the SACK packets for the delivered SCTP data packets. MT can also check the connectivity of the alternative path via interaction with periodical HEARTBEAT and HEARTBEAT-ACK packets. These packet exchanges allow the MTs to measure their RTTs for both paths in a timely manner.

In order to determine the primary path switching criteria, the proposed scheme first calculates the difference between the RTTs of both paths. This can be expressed as Equation (1). Note that MTs start to measure the RTTs of both paths when the alternative path is activated at time *TS*. On the other hand, they terminate the measurement process when one of the paths is deactivated at time *TE*. Once we assume that MT has measured the RTTs *n* times during (*TE* – *TS*) time period, the size of measurement interval ∆*T* is equal to (*TE* – *TS*)/*n* and the absolute difference of RTTs between two paths at the *i*-th measurement step can be expressed as *D*(*i*) such that

*D*(*i*)= RTT<*P*>*i* – RTT<*A*>*i* , (1 ≤ *i* ≤ *n* ) (1)

where RTT<*P*>*i* and RTT<*A*>*i* are respectively the RTT for the primary path and the alternative path at the *i*-th measurement step.

Note that *D*(*i*) is considered only when RTT<*P*>*i* is larger than RTT<*A*>*i*, that is, when *D*(*i*) is positive. In addition, a weighted average of the measured *D*(*i*) values can be expressed as *Di* such that

*Di* = , (2)

whereis the weight of the *j*-th measurement step.

As we have more interest in the recent deviation of the difference, our weighted average puts more weight on *D*(*i*) than on *D*(*i*–1). Here, we define *DT* as configured threshold time (*DT* > 0) that is used to determine the relative network condition directly affected by the data size, the RTTs of the current primary path can be overestimated compared to the RTTs of the alternative path, which may have been estimated based upon a small data size. Second, they provide an acceptable compromise between the RTTs and congestion window (*cnwd*) size. If we simply allow an MT to switch its primary path to the alternative path when the alternative path shows a shorter RTT at a current measurement step, then MT will experience performance degradation because this switching requires significant overhead, since the switched MT is required to re-start its congestion control at the slow start phase.

## 3.2 Speed-Based Scheme

The above proposed RTT-based scheme shows partial success in terms of throughput. However, using this as the sole RTT measure alone does not effectively determine the primary path switching criteria because it does not adequately reflect the velocity of the MTs. Even though an MT has a much shorter RTT in its alternative path than that of its current primary path and our weighted average value *D* is larger than *α*∙*DT*, we cannot obviously conclude that the velocity of MT is high because RTT is likely to fluctuate from chunk to chunk, depending upon the level of congestion in the routers, and upon the varying load on the MT’s. One example of this would be the fast moving MT experiences an even larger RTT for the alternative path that will be used in its new network when the new *access router* (AR) is suffering from congestion. According to our Linux test-bed experiments, we found the velocity of MT’s should be considered as an important factor in determining the primary path switching, especially for the fast moving MT’s. The usual primary path switching procedure performs the following sequence of actions.

1. MT detects a link-up of a new path and configures a new IP address at the network layer.
2. MT sends an “Add-IP” message to the correspondent terminal (CT).
3. MT sends a “Primary-Switching” message to CT if some conditions have been satisfied.
4. MT sends a “Delete-IP” message to CT.
5. MT detects link-down of its previous primary path.

**Table 1. Experiment Parameters**

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| Parameters | Values |
| Minimum network condition coefficient: *α* | 2 |
| Minimum switching coefficient: *β* | 5 |
| Minimum speed coefficient: *γ* | 6 |
| Minimum frequency coefficient: *δ* | 5 |
| Historical RTT threshold: *DT* (ms) | *β*RTT<A> |
| Historical Speed threshold: *ST* (km/h) | 10 |
| Data packet size (byte) | 1440 |
| Control packet size (byte) | 288 |
| RTT measurement interval: ∆*T* (sec) | 1 |
| Standard moving distance (meter) | 400 |
| Standard moving distance in overapping area (meter) | 200 |

Note that the alternative path is used for a correspondent terminal to a mobile terminal (CT-to-MT) data packet after event 3, while the primary path is still used for MT-to-CT data packet before processing event 4. That is, for the receiving data packets, MT immediately uses its alternative path as a primary path as soon as it explicitly requests the primary path switching. On the other hand, for sending data packets, MT does not use the alternative path until it explicitly deletes its current primary path.

We estimate the moving speed of MT’s based upon the elapsed moving time and the moving distance from the previous network to the current network. We define time *T*(*k*) as a time when MT sends the *ADD-IP* message to CT in its previous network *k*. As MT records these times whenever it moves to a different networks, it keeps a series of *T*(*k*) such that 1 ≤ *k* ≤ *K–*1 by assuming it has visited *K* networks. Therefore, the elapsed moving time Δ*T*(*k*) of MT between two successive networks *k*–1 and *k* can be obtained by

Δ*T*(*k*) = *T*(*k*) – *T*(*k*–1). (3)

The estimated speed of MT at a given network domain can now be obtained by dividing the moving distance that MT has traversed in the current network by the elapsed moving time Δ*T*. Also, Δ*T* tends to be frequently changed from network to network, and thus the proposed scheme only considers a limited number of recent historical speeds rather than a full history. Therefore, the expected speed *E*(*S*)*k*+1 of MT in its next network *k*+1 considers the recent *k* histories, and this will fulfill the following equation.

*E*(*S*)*k*+1 =, (4)

where *dj* is the average moving distance of MTs in network *j*, and is the weight value at network *j*. As MT tends to keep its current speed, the proposed scheme maximizes the size of *j* and puts much more weight, say 0.875, on the most recent speed of MT.

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| **Join** SCTP session  **Begin** loop  **Switch** (**event**)  **event:**(*E*(*S*)≥ *γ*∙*ST*)  **If** [(*D* ≥ *DT*) || (RTT<*P*>*i* ≥ RTT<*A*>*i*)]  Sends “Primary-Switching”  **Else**  Stay on the current primary path  **event:**(*ST* ≤ *E*(*S*) < *γ*∙*ST*)  **If** (*D* ≥ *α*∙*DT*)  Sends “Primary-Switching”  **Else**  Stay on the current primary path  **event:**(*E*(*S*) < *ST*)  **If** [(*D* ≥ *α*∙*DT*) && (RTT<*P*>*i* ≥ *β*∙RTT<*A*>*i*)]  Sends “Primary-Switching”  **Else**  Stay on the current primary path  **End switch**  **End** loop  **Leave** SCTP session |

**Figure 2. Primary path switching algorithm**

In order to differentiate among MT’s in terms of velocity, we also define *ST* as a preconfigured threshold time (*ST* > 0) that is used to determine the relative speed of MTs and *γ* as a fast speed coefficient (*γ* ≥ 1). Each MT can now be classified into three different categories including 1) fast moving MTs with a large *S* value such that *E*(*S*) ≥ *γ*∙*ST*; 2) slow moving MTs with a small *E*(*S*) value such that *ST* ≤ *E*(*S*) < *γ*∙*ST*; and 3) slow moving MTs having a ping pong movement pattern with extra-small *E*(*S*) values such that *E*(*S*) < *ST*. Based upon these observations, each MT determines whether or not it performs primary path switching. The overall actions are described in more detail in Figure 2.

# 4. Performance Evaluation

In order to evaluate the performance improvement achieved by the proposed scheme, we consider a small test

**Figure 3. RTTs variations of MT with 30km/h moving speed**

**Figure 4. RTTs variations of MT with 60km/h moving speed**

topology considered in [9], where mSCTP MT has two different NICs, which use IEEE 802.11b as a wireless link, while mSCTP CT has one NIC, which uses Ethernet as a wired link. We also consider that these two mSCTP hosts are interconnected through a 100Mbps IP core network, having an average of 10 network hops. Under this topology, the whole simulation was conducted in an ns-2 environment. We have generated SCTP segments with an FTP application and observed the variations of RTTs between the two hosts. These experiments have been performed with MT having different movement speeds ranging from 10km/h to 150km/h.

Figures 3 shows the evaluated RTTs for the MTs with 30km/h and 60km/h moving speeds, respectively. At first, we can observe the slow speed MT and fast speed MT have dual-home status about 41 seconds and 8 seconds in the overlapped area, respectively. We recognize that the duration of dual-home status of MT is not always proportion to the moving speed of MT, because it really depends on the movement patterns of MT as well as the speed. We now compare the proposed scheme to the RTT-only scheme [2], which has most recently been proposed but considered only the RTT difference at a given time. Under our scheme, MT switches its primary path as long as the condition of RTT<*P*> ≥ *β*∙RTT<*A*> is satisfied. We do not show the performance of the MTs having irregular movement patterns. Due to the conservative approach, both schemes will not allow MTs to switch their primary path as long as their movement patterns are not significantly changed.

For the slow moving MTs in Figure 3, as we set the minimum switching coefficient *β* to 5, the RTT-based scheme will allow MT to switch its primary path at 51 seconds because 1.84 ≥ 5∙0.33(=1.65). However, this aggressive switching requires CT to reset its *cwnd*. Unfortunately, the switched primary path experiences a sudden RTT peak at 56 seconds, which indicates the overall throughput is limited using the RTT-only scheme. On the other hand, our proposed scheme delays this path switching to 60 seconds when the historical RTT condition is satisfied for recent *δ* (=5) consecutive measurement steps. We can also observe that the alternative path shows steady RTT after the primary path has explicitly failed at 66 seconds. More importantly, this delayed switching affects the throughput since it allows both CT and MT to continuously increase or maintain their *cwnd* rather than restarting at the slow-start phase. In our experiment, we put the different weight  at the measurement step *j* by obeying the following rule where the weight of most recent RTT  is equal to 0.875.

For performance comparison among the three different schemes, we have counted the number of packets arriving at MT with their delay. For 30km/h moving speed, owing to their predicted switching, both our proposed scheme and RTT-only scheme show better throughput and shorter overall delay than the legacy-SCTP scheme. Also, both schemes show almost the same level of throughput and delay. However, we need to mention that our delayed switching, based on the historical RTT difference between the two paths, allows MT to switch its primary path with certainty for handoff. For 60km/h moving speed, MT with other previous schemes experiences network unavailability when it performs a handoff. We set the new NIC activation delay to 2 seconds. Owing to our fast primary path switching, our proposed scheme will not suffer from this delay. As shown in Figure 4, it shows better throughput than the other schemes. Also, the average delay per packet of the proposed scheme is shorter than those of the other schemes indicating an improved QoS. This throughput difference from other schemes is more prominent with longer NIC activation delay and a faster moving speed for MT.

# 5. Conclusion

In this paper, we have proposed a new scheme for switching the primary path and an alternative path within the SCTP protocol for MTs that are moving at various speeds between networks. The proposed scheme achieves a better overall performance than other existing schemes as shown by performance simulation. This is due to the fact that the proposed scheme utilizes the performance trade-off relationship between RTT and *cwnd* and performs switches between the current primary path and the alternative path according to RTT, as well as the velocity of movement of MT.

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