# Performance Evaluation of Layered Mobility Management Schemes for Wireless Mobile Internet

Yong-Jin Lee*, Gab-Sang Ryu**
Korea National University of Education*, Dongshin University**

ABSTRACT

The aim of this study is to present the handover procedures and the performance comparisons of layered mobility management schemes for wireless mobile Internet. To investigate efficient mobility management schemes providing seamless information services in a mobile environment, this paper provided the detailed discussions of existing network layered mobility management scheme, including Mobile IPv4, Mobile IPv6, and new transport layer mobility management scheme, stream control transmission protocol (SCTP) based mobility architecture (SMA). Network simulator-2 (ns-2) was used to compare the performance between Mobile IPv6 and SMA in the wireless mobile Internet environment. Simulation results show that for typical network configuration and parameters, SMA has a lower handover latency, lower packet loss rate, and higher throughput than Mobile IPv6.

Keywords : Wireless Mobile Internet, Mobility Management Scheme, Mobile IP, SCTP

# 무선 이동 인터넷에서 계층 이동성 관리기법의 성능평가

이용진*, 류갑상**
한국교원대학교 기술교육과*, 동신대학교 컴퓨터학과**

요 약

본 연구는 무선 이동 인터넷에서 사용가능한 계층별 이동성 관리 기법의 핸드오버 절차와 성능을 비교한 것이다. 이동 환경에서 무결정성의 정보 서비스를 제공하기 위한 효율적인 이동성 관리 기법을 조사하기 위해 먼저 기존의 네트워크 계층에서의 이동성 지원 기법인 모바일 IPv4와 모바일 IPv6에 대한 핸드오버 절차를 설명하고, 이어서 트랜스포트 계층에서의 이동성 지원 기법인 SCTP에 기반한 모바일 구조(SMA)의 핸드오버 절차를 비교한다. NS-2를 이용하여 무선 이동 환경에서 모바일 IPv6와 SMA의 성능을 비교한 시뮬레이션 결과는 SMA가 핸드오버 지연시간, 패킷 손실률 그리고 처리율에서 Mobile IPv6보다 우수함을 보였다.

키워드 : 무선 모바일 인터넷, 이동성 관리 기법, 핸드오버, 모바일 IP, SCTP

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## 1. Introduction

The explosive growth and availability of small portable hosts in the form of personal digital assistance (PDA), portable multimedia displayer (PMP), smart phone, tablets and laptop computer has made many information services such as e-learning, web surfing, content delivery, and online game to be performed in mobile environment. These mobile devices also allow mobile Internet access anytime and anywhere (including at home) for information services[8].

Most of these information services using mobile devices have multimedia characteristic that have bounded delay in order to meet certain quality of service (QoS) guarantees. However, if seamless (low packet loss and delay) information service is not provided for a user, the effect using mobile devices is not particularly good. These features of multimedia services have created an increased demand for efficient mobility management scheme in wireless mobile Internet[1].

Additionally, it is expected that the core of next generation mobile network will become all IP-based networks. Consequently, mobile technology based on the current wired IP infrastructure will be required for providing the cost effective service.

As a mobility management scheme in the current Internet, Mobile IPv4/v6 (MIPv4/MIPv6) [2] and SCTP based mobility architecture [3] have been proposed to handle mobility of Internet hosts at the network layer and transport layer, respectively. Link layers currently do not provide mobility management they carry out movement detection to inform the upper layer of a mobile host.

To handle mobility of Internet hosts at the network layer, MIPv4 has been designed. It allows a transport layer connection to remain alive when a mobile host (MH) moves between points of attachments. MIPv4, when used in a mobile computing environment, suffers from several drawbacks; the most important ones identified to date are high handover latency, high packet loss rate, and requirement for infrastructure change.

To reduce the inefficiency of MIPv4, MIPv6 removes the concept of foreign agent in Mobile IPv4. Route optimization is built in as an integral part of MIPv6 to reduce triangular routing encountered in MIPv4. Fast handovers for Mobile IPv6 aims to reduce the handover latency [4] by configuring a new IP address before entering the new subnet. This results in reduced time to prepare for new data transmission; packet loss rate is thus expected to decrease. Like hierarchical IP in MIPv4, hierarchical MIPv6 mobility management also introduces a hierarchy of mobile agents to reduce the registration latency and the possibility of an outdated new IP address. However, MIPv6 still experiences high delay and packet loss rate. Furthermore, MIPv6 is known to be unsuitable or real time application due to the limited lifetime of newly obtained IP address.

Until late 2000, transmission control protocol (TCP) was the only available standard transport layer protocols for reliable data transfer. To overcome the limitations of TCP, a new transport protocol, stream control transmission protocol (SCTP) [5] over IP network, has been proposed by IETF. SCTP incorporated several new features that are not available in TCP. These features include robustness to DOS attacks, multi-streaming to alleviate the head-of-line blocking effect, and multi-homing which allows two endpoints to set up an association with multiple IP addresses for each endpoint. Especially, the recent extension of SCTP multi-homing feature, called dynamic IP address reconfiguration [9] can support transport layer mobility. Through dynamic address reconfiguration, an SCTP endpoint can add and delete IP addresses during handovers. SMA exploits the dynamic IP address reconfiguration feature to carry out seamless handovers without requiring any modification to the IP infrastructure.

The main contribution of this paper is a detailed discussion and comparison of network layer and transport layered mobility management schemes to provide seamless information services in wireless mobile Internet. The rest of this paper is structured as follows: First, Section 2 describes an overview and discussion of network layered mobile technology, including MIPv4 and MIPv6. Section 3 describes the discussion of transport layered mobile technology- SMA. We provide a brief performance comparison of MIPv6 and SMA in Section 4. Finally, concluding remarks are presented in Section 5.

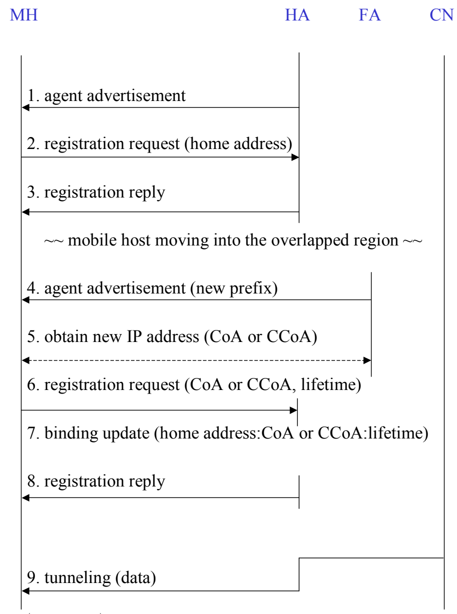
## 2. Network Layered Mobility Management

### 2.1 Mobile IPv4

Mobile IPv4 (MIPv4) was designed by IETF to support host mobility. MIPv4 uses two IP addresses: the permanent home address and the CoA (Care-of-Address) that identifies the current location of mobile host (MH). The timeline of MIPv4 handover is represented in Figure 1.

Initially, MH hears agent advertisement from home agent (HA) in its home network (1, Figure 1). MH sends the registration request for its home address to HA (2, Figure 1). HA sends registration reply to MH after binding home address on its own database (3, Figure 1). Of course, the above registration request/reply procedure can be omitted if HA already knows the home address of MH intrinsically.

When MH, while communicating with the CN (correspondent node), moves into the new IP network, it hears agent advertisement from foreign agent (FA) attached to the new IP network. MN detects its movement into new IP network by investigating the new IP prefix included in the agent advertisement (4, Figure 1).



(Fig. 1) Timeline of MIPv4 handover

MH obtains a CoA directly from its associated FA's advertisement or CCoA (collocated CoA) by contacting dynamic host configuration protocol (DHCP) server (5, Figure 1). MH sends the registration request containing its new CoA to the HA via its associated FA or sends the registration request containing its new CCoA (or CoA) and lifetime to the HA directly (or via FA) (6, Figure 1). HA performs the binding update to associate each new CCoA (or CoA) to the MH's home address (7, Figure 1). Lifetime means duration that the CoA (or CCoA) persists on HA. Then, HA sends registration reply to MH (8, Figure 1).

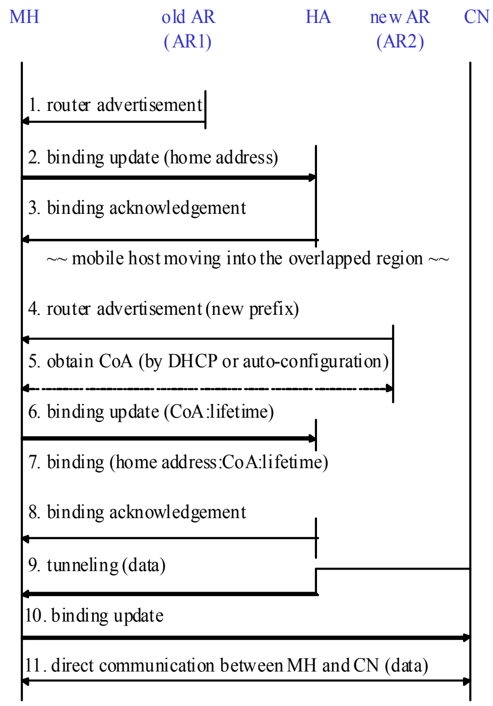
CN does not know the movement of MH and continues to transfer data to previous home address. HA intercepts data from CN and forwards data to MH by using tunneling process. In tunneling process, HA encapsulates the packets by using an IP-within-IP approach. If CoA is used, HA adds the MH's CoA to data packet from CN and forwards it to the FA. FA eliminates the CoA and delivers the rest packet to MH. If CCoA is used, HA adds the MH's CCoA and forwards it to MH directly. In this case, MH eliminates CCoA (9, Figure 1).

### 2.2 Mobile IPv6

Mobile IPv6 (MIPv6) is similar to MIPv4 except that MIPv6 does not have the concept of an FA. MIPv6 also uses IPv6, which provides the stateless auto-configuration of IP address. Since FA is not used in MIPv6, CoA concept in MIPv4 is useless. Instead, CoA in MIPv6 represents MH's new IP address obtained in the foreign network (same concept as CCoA in MIPv4).

Figure 2 shows the timeline of MIPv6 handovers. Initially, MH hears router advertisement from old access router (AR1) in its home network (1, Figure 2). MH sends the binding update message to register its home address to HA (2, Figure 2). HA sends the binding acknowledgement message to MH after binding home address on its own database (3, Figure 2).

When MH, while communicating with the CN, moves into the foreign IP network, it hears router advertisement from new access router (AR2) in the foreign IP network. MH detects its movement into the foreign IP network by investigating the new IP prefix included in the router advertisement (4, Figure 2). MH obtains a CoA by using stateless auto-configuration function of IPv6 directly or by contacting DHCPv6 server (5, Figure 2).




(Fig. 2) Timeline of MIPv6 handover

MH sends a binding update message containing its new CoA and lifetime to the HA directly (6, Figure 2). HA performs the binding update procedure to associate new CoA and lifetime to the MH's home address (7, Figure 2). Then, HA sends binding acknowledgement message to MH (8, Figure 2).

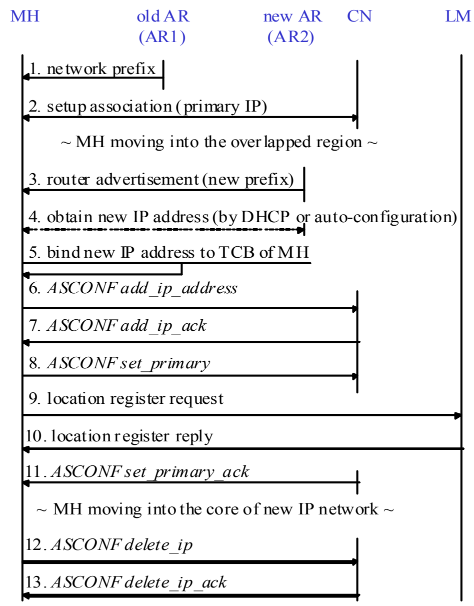
Since CN knows only MH's home address at this time, it continues to transfer data to previous home address. The datagram from CN is intercepted by the HA and is tunneled to the CoA of MH like MIPv4 (9, Figure 2). However, MH in MIPv6 can send the binding update to CN without any assistance from the HA directly unlike MIPv4 (10, Figure 2). When CN knows the MH's CoA, the CN sends the datagram to the MN directly using IPv6 header (11, Figure 2). This is called optimized routing, which is the option in MPv4, but the integrated function in MIPv6. Therefore, MIPv6 can improve the performance by avoiding the triangle routing problem arises in MIPv4.

## 3. Transport Layered Mobility Management

Most of the current applications in the Internet are end-to-end; a transport layer-based mobility solution would be a natural candidate for an alternative approach to MIPv4/MIPv6. Figure 3 represents the time line of SMA, the transport layer mobility management scheme.

Initially, mobile host (MH) hears router advertisement from old access router (AR1) in network 1, and finds the network prefix included in router advertisement (1, Figure 3). MH acquires its own IP address by using stateless auto-configuration of IPv6 based on the network prefix (when using IPv6) or inquiring to dynamic host configuration protocol (DHCPv4/v6) server (when using IPv4/IPv6). MH and CN establish the association by exchanging each own IP address. At this time, each end point specifies the primary IP address on which data is sent (2, Figure 3). Information related to the association is recorded in each transmission control block (TCB) of MH and CN, followed by exchange of data.

The mobile host, while communicating with the CN, moves from the coverage of old AR to the overlapping region, which is covered by both old AR (AR1) and new AR (AR2). MH hears new router prefix from AR2 in network 2 (3, Figure 3), and detects its movement into new network by comparing its current network prefix (1, Figure 3) with new network prefix (3, Figure 3). If MH uses IPv6, it can itself configure new IP address using stateless auto-configuration based on the network prefix. Otherwise, it can acquire a new IP address from the DHCPv4/v6 server (4, Figure 3), which increases the required signaling time. Anyway, newly obtained IP address is bound on the local transport address list in the TCB of mobile host (5, Figure 3).



(Fig. 3) Timeline of SMA

After binding the new IP address on TCB, mobile host informs the CN that it will use the new IP address by sending ASCONF add_ip_address(6, Figure 3). CN modifies its own TCB by adding the received new IP address of MH and replies to the MH by an ASCONF add_ip_ack(7, Figure 3). At this time, MH becomes multi-homed, and is thus reachable by two different networks. It can receive data on both old and new IP addresses. Consequently, if there is a physical problem with the path related to the primary address, the new IP address could be used as an alternate address.

As MH leaves the overlapped region and enters the coverage of new AR, it experiences more packet loss on the primary path. If the amount of received packets on new IP address is greater than on the primary IP address, MH sends out the ASCONF set_primary chuck to CN. This makes the CN to use the new IP address as primary address for data communications (8, Figure 3).

Location manager (LM) maintains a database of the correspondence between MH's identity and MH's current primary IP address. MH can use any unique information as its identity, such as home address (like MIPv4/v6), or domain name, or a public key defined in public key infrastructure (PKI). Once MH decides to handover, it should update the location manager's relevant entry with the new IP address. To perform location update, MH sends location register request to LM (9, Figure 3). LM replies to location register reply to MH after updating MH's current IP address (10, Figure 3). The purpose of this procedure is to ensure that after MH moves from network1 into network2, subsequent new association setup requests can be routed to MH's new IP address. Note that this update has no impact on the existing active associations.

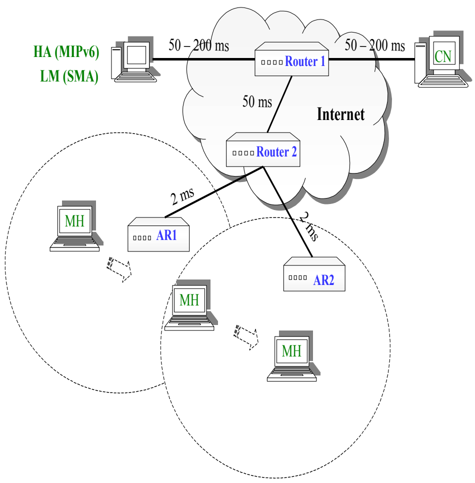
We can observe an important difference between transport layered mobility management scheme (SMA) and network layered mobility scheme (MIPv4/v6): the location management and data traffic forwarding functions are coupled together in MIPv4/v6, while in SMA, they are decoupled to speedup handover and make the deployment more flexible. Meanwhile, CN replies to the ASCONF set_primary_ack chunk to MH (11, Figure 3). This procedure is performed regardless of location update procedure (9 and10, Figure 3).

As the MH continues to move into the core coverage of new AR, the previous primary IP address becomes obsolete. MH sends out the ASCONF delete_IP chuck to CN, which eliminates the previous primary IP address (12, Figure 3). The reason to delete the obsolete IP address is as follows: We assume that the newly set primary path is broken in the coverage of new AR. If we did not delete the previous primary IP address in the binding list, it might become an alternate path. Thus, data from CN may be redirected to the alternate path. However, the previous primary IP address cannot receive any data in the coverage of new AR. As a result, there exists the unnecessary traffic in the network. Handover is completed by the CN when responding by ASCONF delete_ip_ack to MH (13, Figure 3).

## 4. Performance Evaluation of Mobility Managem -ent Schemes

In this section, we provide the brief summary of performance comparison between MIPv6 and SMA. We first describe the simulation topology and configurations that have been used to compare the performance of SMA and MIPv6, the two best schemes for layered mobility management schemes. Next, we will show performance comparison between MIPv6 and SMA in terms of handover latency, packet loss rate, and throughput. We have used ns-2 simulator that supports SCTP as the transport protocol, and incorporated MIPv6 implementations [6] and MIPv6 route optimization [7]. We have also implemented SMA on ns-2. Figure 4 depicts the network topology used in our simulations for MIPv6 and SMA. Figures on the link such as 50-200 ms represent the link delays. We assumed that each link bandwidth is 2 Mbps.

We define handover latency as the time interval between the last data segment received by the MH through the old path and the first data segment received through the new path. Packet loss rate is defined as the number of packets lost due to handover divided by the total number of packets sent by the CN. We define throughput as the total number of useful bits that can be delivered to MH's upper layer application divided by the simulation time. This provides an estimate of the average transmission speed that can be achieved by an SCTP association.




(Fig. 4) Simulation topology

In order to see the impact of moving speed, we first vary the speed of MH from 1.0 m/s up to 15.0 m/s, while fixing link delays between HA (LM) and Router1, and CN and Router1 to 20 ms, 5 ms, respectively. Next, to investigate the impact of the link delay between HA (LM) and Router1 (which affects the time taken by MH to update HA or LM), we vary the delay from 50 ms up to 200 ms, while keeping the MH's moving speed, and CN-Router1 link delay at 5 m/s and 5 ms, respectively. And then, to see the impact of the link delay between CN and Router1, we vary the delay from 50 ms up to 200 ms, while fixing MH's moving speed, and HA (LM)-Router1 link delay at 5 m/s and 20 ms, respectively.

Table 1 shows performance comparison on the handover latency, packet loss rate, and throughput according to above three impact parameters- moving speed, link delay between HA (LM) and router 1, and link delay between CN and router 1. Mobile IPv6 and SMA in Table 1 represent the mean of results over various values of impact factors.

As shown in Table 1, results indicate that for typical network configuration and parameters, SMA has a lower handover latency, lower packet loss rate, and higher throughput than MIPv6. However, because performance in wireless mobile Internet can be affected by local network condition, further research on performance comparison of network layered mobility management scheme and transport layered mobility management scheme in various situations is required.

(Table 1) Comparison of MIPv6 and SMA

| erformance Measure | Factors | Mobile IPv6 (Mean) | SMA (Mean) |
|---|---|---|---|
| Handover latency (seconds) | moving speed (m/s): 1, 5, 10, 15 | 1.68 | 0.22 |
| | HA-Router 1 link delay (ms): 50, 100, 150, 200 | 1.00 | 0.05 |
| | CN-Router 1 link delay (ms): 50, 100, 150, 200 | 1.20 | 0.10 |
| Packet loss (packets) | moving speed (m/s): 1, 5, 10, 15 | 0.007 | 0.006 |
| | HA-Router 1 link delay (ms): 50, 100, 150, 200 | 0.004 | 0.001 |
| | CN-Router 1 link delay (ms): 50, 100, 150, 200 | 0.007 | 0.006 |
| Throughput (packets) | moving speed (m/s): 1, 5, 10, 15 | $4.1 \times 10^5$ | $6.5 \times 10^5$ |
| | HA-Router 1 link delay (ms): 50, 100, 150, 200 | $3.8 \times 10^5$ | $6.5 \times 10^5$ |
| | CN-Router 1 link delay (ms): 50, 100, 150, 200 | $1.8 \times 10^5$ | $4.0 \times 10^5$ |

## 5. Conclusions

In this paper, we have outlined the importance of seamless data transfer for providing mobile information services. We have discussed Mobile IPv4 and Mobile IPv6, the basic technologies to support network layer mobility. However, both Mobile IPv4 and Mobile IPv6 experience performance degradations in terms of handover latency, packet loss rate, and throughput. As alternatives to Mobile IPv4/v6, we have introduced the transport layered mobility management scheme, SMA, and provided performance comparison with Mobile IPv6. Future work consists of investigating more efficient mobility management schemes to provide seamless information service in the future wireless Internet.

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## Author


Yong Jin Lee

1995. Ph. D. Department of Computer Science and Engineering, Korea University

1995 – 2005. Professor Department of Computer Science, Woosong University

2005 – Present Professor Technology Education Department, Korea National University of Education.

Area of Interest : wireless mobile Internet, ICT education.

e-mail : lyj@knue.ac.kr

Gab Sang Ryu

1983. B.S. Department of Computer Science, Chonnam University

1985. M.S. Department of Computer Science, Chonnam University

2006. Ph. D. Department of Computer Science and Engineering, Korea University

1995 – 2005. Research Engineer, Korea Institude of Machine and Metal

1996 – Present Professor Department of Computer Science, Dongshin University

Area of Interest : wireless mobile Internet, ICT education. CAD/CAM

e-mail : gsryu@dsu.ac.kr