A Scheme for Supporting Fast Handover in Hierarchical Mobile IPv6 Networks

HeeYoung Jung, EunAh Kim, JongWha Yi, and HyeongHo Lee

ABSTRACT—This Letter proposes a scheme that supports a fast handover effectively in hierarchical mobile IPv6 networks (F-HMIPv6) by optimizing the associated data and control flows during the handover. By NS-2 simulation, we show that the proposed scheme can give better handover performance than a simple combination of existing schemes.

Keywords—Mobility, mobile IPv6, fast handover, hierarchical mobile IPv6, F-HMIPv6.

I. Introduction

For improving the handover performance of mobile IPv6 (MIPv6) [1], two typical extensional schemes, hierarchical MIPv6 (HMIPv6) [2] and fast handover for MIPv6 (FMIPv6) [3], are being standardized in the Internet Engineering Task Force. Both FMIPv6 and HMIPv6 have so far been designed in their own ways so as to enhance MIPv6 in the signaling and handover aspects. HMIPv6 facilitates to reduce the signaling overhead and delay concerned with the binding update using a hierarchical architecture, and a new entity, a mobility anchor point (MAP), is introduced for it. On the other hand, FMIPv6 exploits various L2 triggers to prepare for a new care-of-address (CoA) at the new router in advance, and a bi-directional tunnel is established between access routers to minimize any service disruption during the handover.

It is noted that HMIPv6 does not touch the fast handover support described in FMIPv6. This means that we still need a certain fast handover scheme in HMIPv6-based networks. At a glance, a scheme that simply integrating the FMIPv6 with HMIPv6 (S-FHMIPv6) may look straightforward. However, S-FHMIPv6 may induce unnecessary processing overhead for re-tunneling at the previous access router (AR), as well as inefficient usage of network bandwidth if we don't assume a direct secure link between them. The main reason for this is that the data transport of HMIPv6 is based on the tunneling from the MAP to mobile nodes (MNs), not ARs, while FMIPv6 uses the tunneling between the previous AR (PAR) and new AR (NAR) for fast handover.

We have proposed F-HMIPv6 [4] to overcome such ineffectiveness of the simple combination of FMIPv6 and HMIPv6. This letter briefly describes the operation of F-HMIPv6 and analyzes its handover performance using NS-2 simulation.

II. F-HMIPv6 Operation

In fast handover HMIPv6 (F-HMIPv6), the tunnel for a handover is established between the MAP and NAR, rather than between PAR and NAR. For this purpose, the MN exchanges the signaling messages for the handover with MAP, not PAR. F-HMIPv6 utilizes the FMIPv6 messages for handover support without further defining any new messages.

The procedure of F-HMIPv6 is illustrated in Fig. 1. In the figure, it is assumed that an MN is trying to move from PAR to NAR in the MAP region, and the MAP already has the information on the link-layer address (or identifier) and network prefix of each AR in the region. Also, it is assumed that the layer 2 triggers indicating events on layer 2 are informed to the MN. Note also in the figure that F-HMIPv6 defines no additional messages to the existing FMIPv6 messages, except for changing the source and/or destination IP addresses of the messages.

When the MN knows its movement toward NAR by using

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HeeYoung Jung (phone: +82-42-860-4928, email: hyjung@etri.re.kr), EunAh Kim (email: eakim@etri.re.kr), JongWha YI (email: jhyiee@etri.re.kr), and HyeongHo LEE (email: holee@etri.re.kr) are with Basic Research Laboratory, ETRI, Daejeon, Korea.

the layer 2 pre-handover trigger that includes the link layer address of NAR, it sends a router solicitation for proxy to request the information of NAR and a new on-link care-of address (LCoA). On receiving this request, the MAP replies with a proxy router advertisement that contains the network prefix of NAR.

The MN configures the new CoA by using the prefix information. Then, the MN requests a fast binding update (F-BU) to the MAP with the new LCoA. On reception of the F-BU, the MAP starts the fast handover procedure by sending a handover initiate (HI) message to NAR. This HI message includes the request for verification of the new LCoA and for an establishment of a bi-directional tunnel between the MAP and NAR. In response to the HI, the NAR performs the duplicated address detection process and then responds with a handover acknowledgement (HACK) to the MAP. After receiving the HACK, the MAP sends the result to the MN by using a fast binding update acknowledgement.

When the MN gets the connection to NAR, it sends a router solicitation message including a fast neighbor advertisement option in order to inform its presence. Then, the NAR will deliver the packets to the MN.

As described earlier, F-HMIPv6 does not need a new message except the messages already defined in HMIPv6 and HMIPv6. However, the following extensions of existing messages are needed.

- A new flag is defined in the HMIPv6 MAP option so as to indicate whether or not the MAP supports the F-HMIPv6 within the HMIPv6 domain.
- Some of the FMIPv6 messages have a different IP source and destination addresses in the respective IP fields. In particular, the MAP address is used instead of the PAR address.

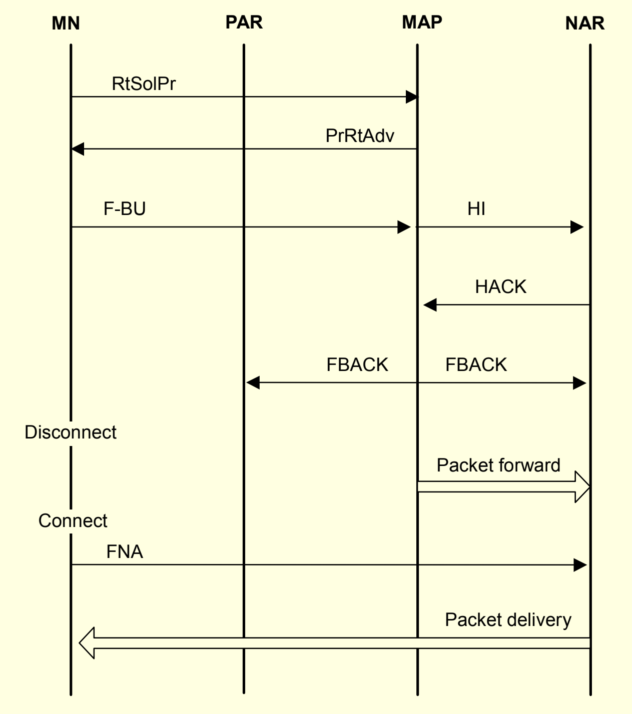


Fig. 1. The F-HMIPv6 procedure.

III. Performance Analysis

Each simulation using NS-2 has been performed over a Linux platform. Figure 2 shows the test network topology used for simulation. As shown in the figure, the network consists of two MAPs (MAP1 and MAP2) and several access routers (ARs). The HA is connected to MAP1 via a link of 5 Mbps bandwidth and 300 ms transmission delay. The CN is connected to MAP2 via a link of 5 Mbps and 300 ms delay. On the other hand, MAP1 is connected to MAP2 by the 5 Mbps and 100 ms link, and each AR is connected to the MAPs by a 5 Mbps and 40 ms link. The cell size of each node is assumed as 250 m, and each cell has a 50 m overlap region. It is assumed that the layer 2 trigger for FMIPv6 operation occurs at 249.5 m and the link down at 250 m. The link up timing is assumed at 20 ms after link down.

In the simulation, the MN starts to move from the location of (100, 100) at time 10 s, and then moves toward node 9 at a speed of 50m/sec. Our simulation focused on evaluating the handover performance of the MN in the area spanning nodes 5 to 9. For each test simulation, the CN generates user datagram protocol (UDP) and TCP traffic. The UDP traffic assumes constant bit rate (CBR) traffic with a 0.015 s time interval. The packet size is 50 bytes. TCP traffic is given as FTP traffic (NewReno).

Table 1 shows a comparison of the average handover latency for the S-FHMIPv6 and F-HMIPv6 schemes. These values are

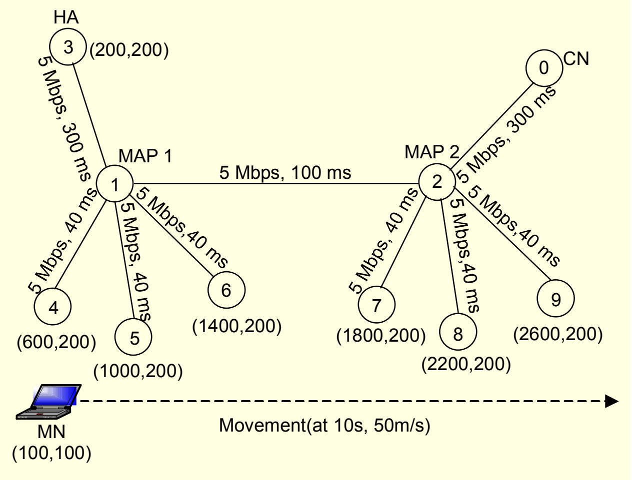


Fig. 2. Network topology for simulation.

Table 1. Comparison of the average handover latency.

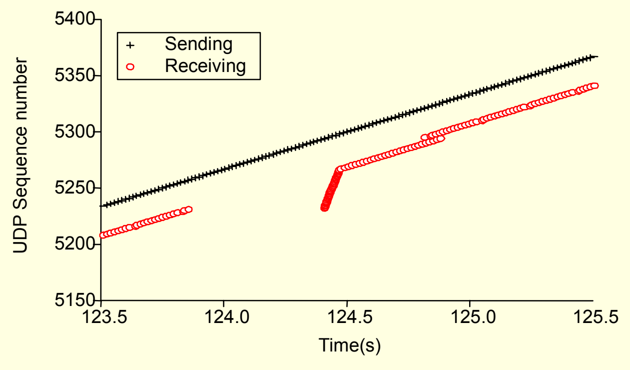
Schemes	Handover latency (ms)				
	4 to 5	5 to 6	6 to7[1]	8 to 9	9 to 10
S-FHMIPv6	289	280.3	404.1	268.7	274
F-HMIPv6	89.8	89.8	237.3	90.2	93.8

1) Movement between MAPs

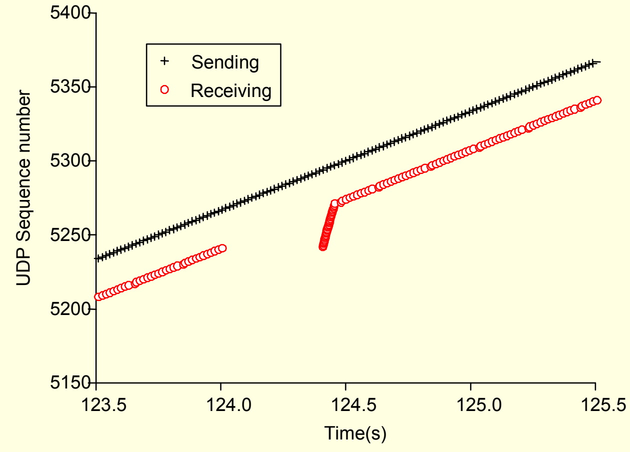
obtained by averaging ten simulation results to eliminate the irrelevant effects due to the inherent characteristic of NS-2. For each scheme, we measured the handover latency as the interval between the last packet in the previous access router and the first packet in the next access router.

As shown in the table, F-HMIPv6 shows lower handover latency than the simple combination schemes by about 200 ms, even in the case of movement between MAPs. This is mainly caused by the effective data forwarding and signaling path of F-HMIPv6. That is, the path is established directly between a MAP and an AR in the proposed scheme. On the other hand, S-FHMIPv6 uses an indirect path via a MAP.

Note that F-HMIPv6 has another merit regarding being out of sequence due to the change of forwarding path during the handover. The sequence numbers of sending/receiving packets for two schemes are plotted in Fig. 3. In this graph, S-FHMIPv6 has some out of sequence region. This is because some packets that were forwarded directly from the MAP arrive earlier than the packets that were forwarded from PAR arrive at the NAR. These out of sequence packets might cause serious performance degradation if TCP application is used. However, as shown in Fig. 3 (b), the F-HMIPv6 shows no out of sequence region because it provides effective data forwarding and a signaling path with the MAP rather than with PAR. The optimized path of F-HMIPv6 brings a quicker change of the forward path so as to reduce considerably the probability of an out of sequence state in the received packet at NAR.



(a) S-FHMIPv6



(b) F-HMIPv6

Fig. 3. Sending/receiving sequence numbers in each case.

The negative effect by the out of sequence state could be disclosed through TCP traffic simulation. The simulation results for FTP traffic are shown in Fig. 4. It is shown that the out of sequence problem, which was described in Fig. 3, decreases the window size in S-FHMIPv6. However F-HMIPv6 does not show any decrease because it does not have the out of sequence problem.

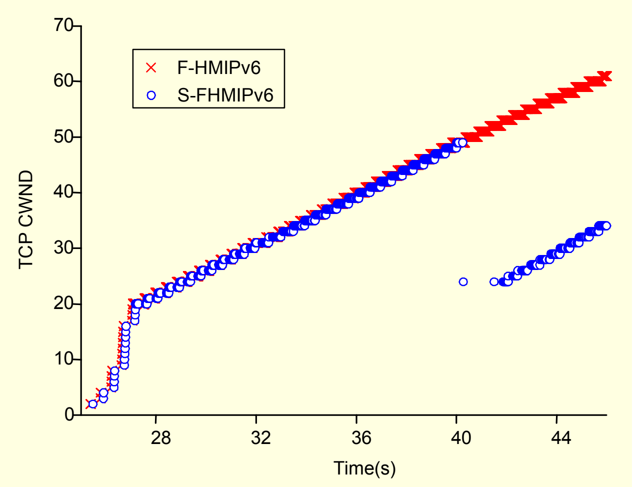


Fig. 4. Window size variation in each case.

IV. Conclusions

This letter has described a new scheme, named F-HMIPv6, for supporting a fast handover effectively in HMIPv6. All messages used in F-HMIPv6 are just extensions of existing messages already defined in FMIPv6 and HMIPv6. Therefore, F-HMIPv6 could be easily introduced in existing systems.

For analysis, F-HMIPv6 is compared to the simple combination of FMIPv6 and HMIPv6 in terms of handover latency and variation of TCP window size. From the analytical results, F-HMIPv6 can further reduce the handover latency of a simple combination. Also, note that F-HMIP6 additionally can reduce the potential out of sequence possibility of the existing or combined schemes so that it can obtain better TCP traffic performance.

The current F-HMIPv6 was designed to deal with the MN movement within a MAP. The effective operation between MAP is left for further study.

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