# HMIPv6 Applying User's Mobility Pattern in IP-Based Cellular Networks*

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**Abstract.** Hierarchical Mobile IPv6 (HMIPv6) was proposed by the Internet Engineering Task Force (IETF) for efficient mobility management of Mobile IPv6 nodes. In HMIPv6, when a mobile node moves access router in the different MAP domain, such a movement is called macro mobility handover. In this situation, the mobile node creates new RCoA and LCoA and performs registrations with the new MAP and HA. Especially, until the address registrations with an MAP and HA are completed, the mobile node cannot receive IP packet and it is hard to actualize seamless services. Therefore, we need to execute the macro mobility handover in advance to reduce the handover latency and packet loss. We propose a scheme that is able to improve the macro mobility handover efficiently in HMIPv6. To do this we will adjust the user's mobility patterns to edge access routers between different MAP domains in the handover situation. In this paper, we compare cost of the macro mobility handover of the proposed scheme with that of the original HMIPv6. As a result, we can obtain the improved macro mobility handover in HMIPv6.

## 1 Introduction

Mobility management is an essential technology because mobile service has to find out user's current location and deliver data correctly [1]. In this situation, the Mobile IP working group within Internet Engineering Task Force (IETF) proposed a mobile IPv6 (MIPv6) [2] protocol to support mobility management in IPv6 network. MIPv6 allows a mobile node (MN) to move while maintaining connections between the MN and correspondent nodes (CNs). To do this the MN sends Binding Update (BU) messages to its home agent (HA) and all CNs. But, handover involves the time of the new prefix discovery on the new subnet, the time for generating a new care-of address (CoA) and the time for registering the new address with the HA and the CNs. These are called the handover latency and can disrupt the real-time multimedia application service. Therefore, the extensions of MIPv6 have been proposed by IETF to offer

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seamless service in MIPv6 and a hierarchical MIPv6 (HMIPv6) [3] protocol manages the movement of the MN by using mobility anchor point (MAP).

In HMIPv6, macro handover is that a MN moves between access routers in the different MAP domain. In this situation, the MN creates new regional CoA (RCoA) and local CoA (LCoA) and performs registration with the new MAP and HA. Especially, the MN cannot receive IP packet and it is hard to actualize seamless services, until the address registration with an MAP and HA is completed. Therefore, we need to execute the macro mobility handover in advance to reduce the handover latency and packet loss. We propose a scheme that is able to improve the macro mobility handover efficiently in HMIPv6. To do this we will adjust the user's mobility patterns to edge access routers between different MAP domains during handover. We also use fast handover technique [4], [5]. In this paper, we compare cost of the macro mobility handover of the proposed scheme with that of the original HMIPv6. Therefore, we can improve macro mobility handover in HMIPv6.

## 2 Related Works

### 2.1 Hierarchical Mobile IPv6 (HMIPv6)

In HMIPv6, the MAP can be located at any level in a hierarchical network of routers and is intended to limit the amount of MIPv6 signaling outside the local domain. In HMIPv6, an MN can perform two types of handover. Firstly if the MN moves between access routers belonging to the same MAP domain, it is called a micro mobility handover. Secondly when the MN moves between access routers belonging to the different MAP domains, it is called a macro mobility handover and we have to analyze this situation.

When an MN enters into a new MAP domain, it receives a router advertisement (RA) message from a new access router. The MN generates a new LCoA and RCoA based on the access router's prefix contained in the RA message and the prefix of the MAP contained in the MAP option, respectively. After generation of the new addresses, the MN sends a local binding update (LBU) message to the MAP. The LBU includes new RCoA and LCoA. The MAP performs the duplicate address detection (DAD) process to verify that the MN's new RCoA is unique in the MAP domain. Then, the MAP stores the RCoA and LCoA of the MN in its binding cache. After that, the MAP intercepts the packets transmitted to the RCoA of the MN through a proxy neighbor advertisement message. The MAP sends the packets to the MN's LCoA by tunneling. If the new addresses of the MN are stored in MAP, the MN sends a binding update (BU) message to its HA to inform its new RCoA as CoA. After the registration with the HA, the MN can perform the registration with the CN.

If the MN performs macro mobility handover, it cannot receive IP packet until the address registrations with the MAP and the HA are completed. Namely, macro handover is hard to actualize seamless real-time services.

# 3 Proposed Scheme

## 3.1 User's Mobility Pattern and Proposed Scheme

In spite of development of transport systems, people spend a lot of time in limited zone such as home, school and one's place of work and have similar life pattern. Also, they always come and go between their routine places and the movement paths of each people are scarcely changed. According to this fact we can analyze mobility patterns of people and anticipate future movement spot. Especially, if Mobile IPv6 nodes use this technique, MN can know next access router in advance. As a result, when handover happens, Mobile IPv6 nodes reduce latency and protect packet loss considerably.

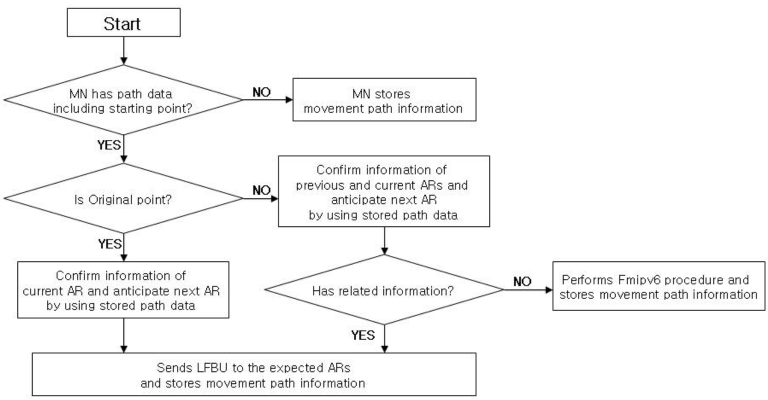


**Fig. 1.** Access router prediction algorithm based on user pattern

## 3.2 Access Router Prediction Algorithm Based on User Pattern

In this paper, we propose access router prediction algorithm based on user pattern and we assume that people register original points such as home and school or one's place of work to their mobile equipment and MNs store their path between source address and destination address every movement. By stored data, an MN keeps various user mobile paths and pattern. When an MN accesses some router, it checks whether the MN had current router information or the router is an original point. If the router is an original point and the MN has the router information, the MN gets the next router through the router link information. Although the router is not original router, if the MN has the router information, then, the MN expects the next router by comparison of previous router and current router information. Else the MN stores the movement paths and performs the basic FMIPv6 procedure. Stored data must not be duplicated. Fig. 1 shows access router prediction algorithm based on user pattern.

## 3.3 Procedure of the Proposed Scheme

In procedure of the proposed scheme, we assume that mobile users already came back from their own routine mobility paths. While MNs move access routers, each MN stores mobility path data such as access router and map information. The procedure of proposed scheme is divided by two steps of LCoA and RCoA establishment, as shown in Fig. 2. When the handover will happen, the MN operates access router prediction algorithm based on user pattern and anticipate the next router. If an MN gets next router information, the MN generates an RCoA and an LCoA based on the prefixes of the MAP2 domain and the AR3. At this time, the MN sends an LCoA FBU message including the new LCoA to the AR2. The AR2 sends an LCoA HI message to the AR3 that is in the MAP2 domain for establishing new LCoA of the mobile node. The AR3 performs the DAD to verify the uniqueness of the MN's new LCoA in the AR3 subnet. If the AR3 completes the DAD about the address, it sends an LCoA HACK message to the AR2 in the MAP1 domain. By an LCoA FBACK message the MN gets information that the new LCoA of the MN is available and the first step of the fast macro mobility handover is ready.

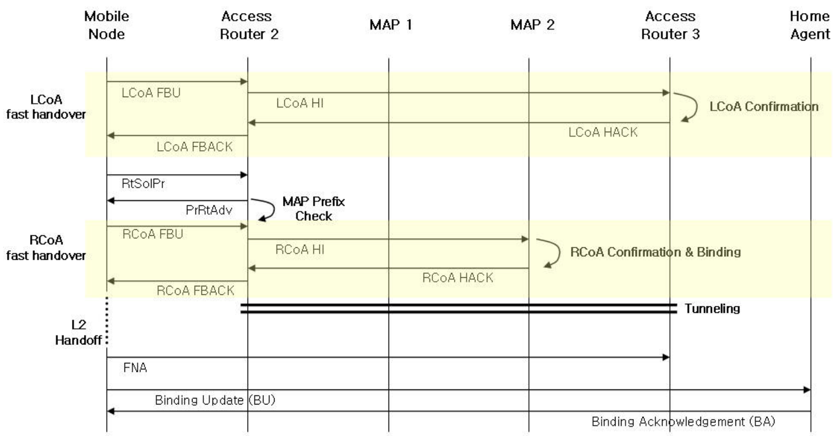


**Fig. 2.** The procedure of proposed method (LCoA fast handover and RCoA fast handover)

By AP signal strength, the MN will recognize that it is close to another AR and MAP domain and exchange an RtsolPr and a PrRtAdv messages. The MN compares prefix of new RCoA with MAP prefix information of PrRtAdv message and confirms the next MAP and access route. And then, the MN performs the second step of fast macro mobility handover process. The MN sends an RCoA FBU message including the new RCoA to the AR2. The AR2 sends an RCoA HI message to the MAP2 for both establishing new RCoA of the mobile node and binding RCoA and LCoA. The MAP2 performs the DAD to verify that the mobile node's new RCoA is unique. If the MAP2 completes the DAD about the address and binding, it sends an RCoA HACK message to the AR2 in the MAP1 domain and the AR2 transfers an RCoA FBACK message to the MN. Especially, in order to reduce processing load of MAP, after an MN makes certain its real movement to the MAP2, the MN operates handover with new RCoA of MAP2. During the L2 handover, all packets sent by the CN are stored by the AR3 through the tunnel along the MAP1 and MAP2 and AR3. The AR3 buffers the packets until the L2 handover of the mobile node ends. After the MN completes the L2 handoff, it sends a FNA message to the AR3 to announce that the mobile node is on-link in AR3 subnet. The AR3 received the FNA message stops the proxy function for the mobile node's LCoA and transmits all buffered packets to the mobile node. Therefore, the mobile node can receive all packets transferred during the macro mobility handover. After this handover procedure, the mobile nodes can perform the location update with its HA and CN, too. But, if stored data and current and previous router information has not same value, an MN stores movement paths and operates basic HMIPv6 and FMIPvc6 process.

# 4 Performance Evaluation

## 4.1 System Modeling

We use the evaluation model in [6], [7] to evaluate performance of the proposed scheme. Fig. 3 shows the distance of entities and values. We define the variables for this paper in Table 1 and assume that message treatment cost is identical at each hop.

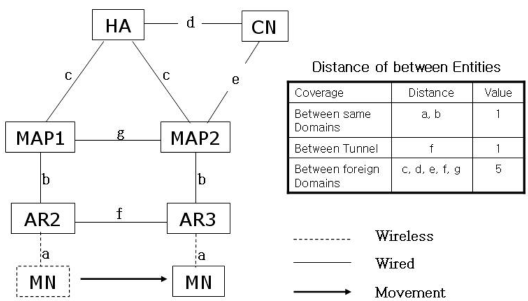


**Fig. 3.** System method for performance analysis

**Table 1.** Defined variables for computation of performance evaluation Reference

| | |
|---|---|
| $\lambda$ | the rate that correspond node (CN) transmits data packets to a mobile node (MN) |
| $\mu$ | the rate that MN moves from one subnet to another |
| $p$ | packet to Mobility Ratio (PMR) : the mean number of packets that a MN received from a CN |
| $l_c$ | the average control packet length (=200byte) |
| $l_d$ | the average data packet length (=1024byte) |
| $l$ | $l = l_d / l_c$ |
| $r$ | cost of processing control packets (all hosts) |

## 4.2 Cost Analysis

In this paper, in order to analyze the performance of mobile networks, we consider the total cost that consists of signaling cost and packet delivery cost.

$$C_{total} = C_{signal} + C_{packet} \quad (1)$$

### 4.2.1 Signaling Cost

Contrary to the basic HMIPv6, the proposed scheme reduces packet loss by using fast macro handover. But, we should consider the additional signaling costs such as detection of DB and accomplishment of two pre-handover works. In the proposed scheme, the signaling cost for macro handover can be expressed as follows:

$$C_{signal} = C_{fast-l} + C_{fast-r} + C_{HA} \quad (2)$$

Signaling cost consists of the cost of LCoA Fast Handover ($C_{fast-l}$), RCoA Fast Handover ($C_{fast-r}$), and registration with HA ($C_{HA}$). Each signaling costs are as defined in the following expressions.

$$C_{fast-l} = 2(a + 2b + g) + 9r \quad (3)$$

$$C_{fast-r} = 5a + 2(b + g) + 16r \quad (4)$$

$$C_{HA} = 2(a + b + c) + 13r \quad (5)$$

In this paper we assume that the processing cost is $r$ per message treatment, registration or confirmation and distance is directly proportional to process time. Each processing cost is increased or decreased in accordance with message process method.

## 4.3 Packet Transmission Cost

Packet transmission cost is $C_{packet}$ that consists of packet forwarding cost ($C_{fwd}$) and the packet loss cost ($C_{loss}$).

$$C_{packet} = C_{fwd} + C_{loss} = (\lambda \times t_{delay} \times C_{dt}) + C_{loss} \quad (6)$$

where $t_{delay}$ is waiting time that MN can't receive any message and it includes L2 handoff latency ($t_{L2}$), the movement time of hops ($t_x$), and packet processing time on host ($t_r$). $C_{dt}$ is a single data packet cost delivered from CN to MN and it is calculated as $C_{dt} = l \times (g + f + h + d) + 3r$ . Since the packet transmission cost is greater than the signaling cost, reducing the delay of packet transmission cost decreases the total cost. Therefore, a main focus of the proposed method is a reduction of a packet forwarding latency. $t_{delay}$ can be calculated as follows:

$$t_{delay} = 2t_a + 2t_r + t_{L2} \quad (7)$$

The proposed method decreases configuration latency because it performs DAD and binding procedure in advance. In basic HMIPv6, $t_{delay}$ is obtained from the following equation.

$$t_{delay-hmip} = 2(2t_a + t_b) + 8t_r + t_{L2} + 2t_{DAD} , \quad (8)$$

where $t_{DAD}$ is DAD time which spends 10 times as large as $t_r$. The proposed method reduces the delay regardless of predictive or reactive mode. Especially, the suggested method in reactive mode gets high performance improvement in comparison with other methods. Packet loss cost is delay cost of real-time service caused by latency. In this paper, we define packet loss cost as a partial packet transmission cost from completion of fast handover process to home registration. It is because buffered packets are not seamless real-time service.

$$C_{loss} = \eta \times (\lambda \times (t_{delay} - t_{delay-fast}) \times C_{dt}) \tag{9}$$

In Eq. (9), $\eta$ is weight of a packet loss cost. We assume that $\eta$ is 1 , because real-time service does not re-transmit packets.

### 4.4 Numerical Results

We verify the improvement by using the rate of cost. When a mobile node moves to the new domain, the rate shows below. The rate is the total cost of proposed method about the total cost of the comparison method. In this paper, we assume that the total cost includes loss cost because the service data for the waiting time is not retransmitted in real-time service. We refer to the method in [7] and use Eq. (10) and Eq. (11).

$$t_{RT-wire}(h,k) = 3.63k + 3.21(h-1) \text{ (msec)} \tag{10}$$

$$t_{RT-wireless}(k) = 17.1k \text{ (msec)} \tag{11}$$

The k is packet length (kbyte) and h is the number of hops. In [8], [9], it provides the latency ( $t_{L2}$ =84 msec and $t_r$ =0.5 msec) for wireless section. And we use $\lambda = p \times \mu$ in Eq. (12) to apply mobility. Eq. (12) is the rate in predictive mode of Fast Handover.

$$\lim_{p\to\infty} \frac{C_{total}}{C_{total-hmip}} = \lim_{p\to\infty} \frac{C_{fast-l} + C_{fast-r} + C_{HA} + (\lambda \times t_{delay} \times C_{dt}) + C_{loss}}{C_{signal-hmip} + C_{HA} + (\lambda \times t_{delay-hmip} \times C_{dt}) + C_{loss}} \tag{12}$$

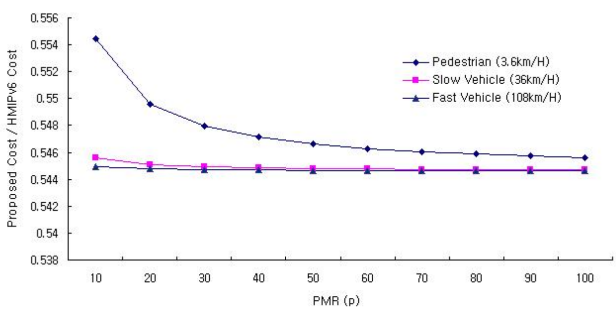


**Fig. 4.** The variation of the cost ratio of the proposed method per the basic HMIPv6 PMR

Through Eq. (12), we can get the results illustrated in Fig. 4. In the figure, the abscissa and ordinate show PMR value and the rate of cost decrease. The result rate converges at a spot rather than 100 point of PMR. The rate of Eq. (12) converges to 0.546 in pedestrian and vehicle (3.6km/H: $\mu = 0.01$ ~ 108km/H: $\mu = 0.5$(m/msec)).

The proposed method gets approximately 45% cost profit in comparison with the basic HMIPv6. By this result we know that the proposed method reduces handover latency and supports real-time services.

## 5 Conclusions

During macro mobility handover, the MN creates new RCoA and LCoA and performs registration with the new MAP and HA. Especially, until the address registration with an MAP and HA completed, the MN cannot receive IP packet and it is hard to actualize seamless services. In order to solve handover latency problem, we need to analyze user mobile patterns. People spend a lot of time in limited zone such as home, school and one's place of work and have similar life pattern. Also, they always come and go between their routine places and the movement paths of each people are scarcely changed. According to this fact we can analyze mobility patterns of people and anticipate future movement spot. If Mobile IPv6 nodes use this technique, an MN can know next access router in advance. As a result, when handover happens, Mobile IPv6 nodes reduce latency and protect packet loss considerably. By performance evaluation, we compare cost of the macro mobility handover of the proposed scheme with the original HMIPv6 and obtain the improved macro mobility handover in HMIPv6.

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