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A FAST HANDOVER MECHANISM FOR HIERARCHICAL MOBILE IPV6 USING NEIGHBORING MAP INFORMATION

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Abstract. *This paper proposes a fast handover mechanism of hierarchical mobile IPv6 (HMIPv6) with assistance of a base station (BS) for wireless networks. To implement the proposed mechanism, a couple of messages used in link-layer (L2) and network-layer (L3) are defined and they are exchanged between mobile node (MN) and BS. The L2 message is defined by adding specific information to the available field of existing message. The L3 message for MAP table request/reply is defined in order that the MN gets neighboring mobility anchor point (MAP) information. The proposed mechanism does not require the neighboring MAP discovery and the IEEE 802.21 media independent handover (MIH) function/server, which are required for existing mechanisms. The proposed mechanism is compared with existing mechanisms for handover latency and handover preparation time. From comparative analysis results, the proposed mechanism is shown to be comparable to or better than existing mechanisms although there is no additional network entity.*
Keywords: Hierarchical mobile IPv6, Fast handover, Handover preparation, Handover latency

1. **Introduction.** The mobile IPv6 (MIPv6) [1, 2] was extended to hierarchical MIPv6 (HMIPv6) to reduce handover latency suffered by mobile nodes (MNs) and signaling overhead incurred due to movement of MNs within the micro mobility region [3, 4, 5, 6, 7]. However, HMIPv6 has an inevitable network-layer (L3) handover latency caused by several latencies. This L3 handover latency could be appreciable for real-time applications and throughput sensitive applications. Thus, fast handover mechanisms have been developed to improve handover latency and handover preparation time of HMIPv6 for horizontal handover [8, 9, 10] as well as vertical handover [11, 12].

However, the horizontal fast handover mechanism in [8, 9, 10] requires the neighboring MAP discovery phase of [3] and thus can have long handover preparation time. This can decrease the probability of predictive behavior for the fast handover mechanism and thus increase handover latency. The vertical fast handover mechanism in [11, 12] requires additional function and network entity such as the IEEE 802.21 media independent handover (MIH) function and the media independent information service (MIIS) server of [13, 14], although the adverse impacts of long handover preparation time are resolved.

Therefore, this paper proposes an alternative fast handover mechanism of HMIPv6 for wireless networks. This paper considers the wireless network environment where there are several mobility anchor points (MAPs) connected by base stations (BSs) of WiFi, WiMAX, 4G LTE, etc. These BSs assist to provide the fast handover of the MN. Two kinds of messages used in link-layer (L2) and L3 are defined and they are exchanged between MN and BS. The L2 message is defined by adding specific information to the available field of existing message. The L3 message for MAP table request/reply is defined in order that the MN gets neighboring MAP information. The proposed mechanism does not require the neighboring MAP discovery and the IEEE 802.21 MIH function/server, which are required for existing mechanisms. The proposed mechanism is compared with existing mechanisms [8, 9, 10, 11, 12] for handover latency, handover preparation time, additional function and network entity. Comparison results show that the proposed mechanism can be comparable to or better than existing mechanisms although there is no additional network entity.

The paper is organized as follows. In Section 2, L2 and L3 messages exchanged between MN and BS are defined. In Section 3, the operation procedure of the proposed mechanism is described. In Section 4, the proposed mechanism is compared with existing mechanisms. Finally, conclusions are made in Section 5.

2. Definition of Messages Exchanged between MN and BS. As shown in Figure 1, this paper considers the wireless network environment where there are several MAPs connected by BSs of WiFi, WiMAX, 4G LTE, etc. These BSs assist to provide the fast handover of the MN. It is assumed that all BSs caches the MAP table as shown in Table 1. In this section, a couple of messages used in L2 and L3 are defined and they are exchanged between MN and BS.

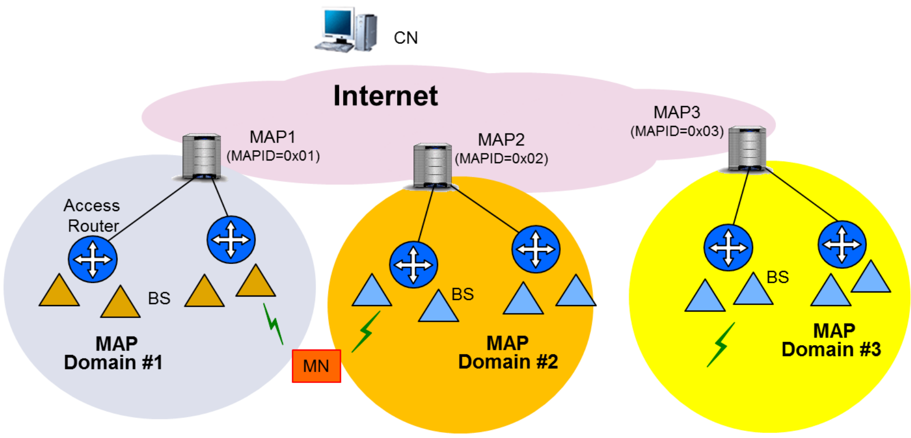

FIGURE 1. Handover scenario for wireless networks with several MAP domains

TABLE 1. Example of MAP table

MAP	MAPID	Prefix
MAP Domain #1	0x01	2001:db8:1:1::/64
MAP Domain #2	0x02	2001:db8:1:2::/64
MAP Domain #3	0x03	2001:db8:1:3::/64

2.1. **L2 message for MAP identifier.** The L2 message is defined newly by adding specific information to the available field of existing message. In general, it can be assumed that this L2 message is given by BS to MN, such as the beacon message of IEEE 802.11 WLAN. The available field of existing L2 message is modified by adding specific information "MAPID". MAPID means the identifier of MAP that the MN is connected currently or is going to be connected soon. Since this field uses the existing reserved field, other fields are not affected. For example, the beacon message of IEEE 802.11 WLAN contains information such as timestamp, beacon interval, capability information, and SSID. The capability information field can be modified by adding MAPID as shown in Figure 2. Receiving the newly defined L2 message including MAPID from the BS, the MN continues

Figure 2. Example of L2 message: IEEE 802.11 WLAN beacon message

real-time communication in the serving MAP (sMAP) domain if MAPID is not changed and quickly prepares the L3 handover for the target MAP (tMAP) domain if MAPID is changed. That is, the proposed mechanism can quickly detect any L3 movement and perform handover preparation as shown in [11, 12].

2.2. **L3 message for MAP table.** Secondly, L3 messages for MAP table request/reply are defined newly. Using these messages at the initial booting time, the MN gets the MAP table from the serving BS(sBS) that the MN is connected currently. Thus, the MN can get neighboring MAP information such as MAP prefix. This could resolve the neighboring MAP discovery issue in [8, 9, 10] since the MAP table is delivered to the MN through this L3 message much before the actual handover. In addition, it is assumed that the MN stores and maintains the obtained MAP table for all handovers. Then, using the L3 information of corresponding neighboring MAPs, the MN knows the tMAP domain prefix and formulates target on-link care-of address (tLCoA) and target regional care-of address (tRCoA) prior to handover. Thus, during the handover procedure, the configuration procedure time for tLCoA and tRCoA, which is related with the neighboring MAP discovery, can be decreased. Since several signalling messages such as Router Solicitation for Proxy (RtSolPr) and Proxy Router Advertisement (PrRtAdv) are reduced during the handover preparation, the overall handover preparation time can be reduced. Therefore, the adverse impacts of the long handover preparation time in [8, 9, 10] can be resolved since the neighboring MAP discovery phase is eliminated as shown in [11, 12].

3. **Operation Procedure.** When the MN is booting, it sends a MAP table request message to a BS in the sMAP domain that MN is connected currently. Then corresponding BS caches the MAP table, answers a MAP table reply message to the MN and then the MN stores and maintains the obtained MAP table for all handovers. Note that this MAP table request/reply is performed once only at the booting time and thus is not performed in real-time communication. Assume that the MN communicates with the corresponding node (CN) as shown Figure 1.

In real-time communication, when the MN moves, the "L2 trigger" may arrive from specific L2 events that might determine the need for handover. In this paper, this trigger itself is not specified in detail. Since this trigger is based on the L2 message given by BS, the MN can know the MAPID from the L2 trigger. Then, the MN checks this MAPID using the MAP table stored previously, in order to determine whether the MN moves to BS in sMAP domain or tMAP domain. If the MN moves to BS in sMAP domain, MAPID is not changed. In this case, MN continues real-time communication via the sMAP. If the MN moves to BS in tMAP domain, MAPID is changed. In this case, the MN finds the tMAP corresponding to MAPID from the MAP table, and formulates tLCoA and tRCoA using the tMAP prefix. Then, the MN sends a fast binding update (FBU) message to the sMAP. After receiving FBU, the sMAP sends a handover initiation (HI) message to the tMAP to establish tunnel between two MAP domains and determine whether tRCoA and tLCoA are acceptable to the tMAP. In response to the HI message, the tMAP determines whether tRCoA and tLCoA supplied in the HI message are valid for use. After the tMAP considers tRCoA and tLCoA acceptable for use, it sends a handover acknowledgement (Hack) message to the sMAP. Then, the sMAP sends a fast binding acknowledgement (FBack) message to the MN. The result of the FBU and FBack processing is that the

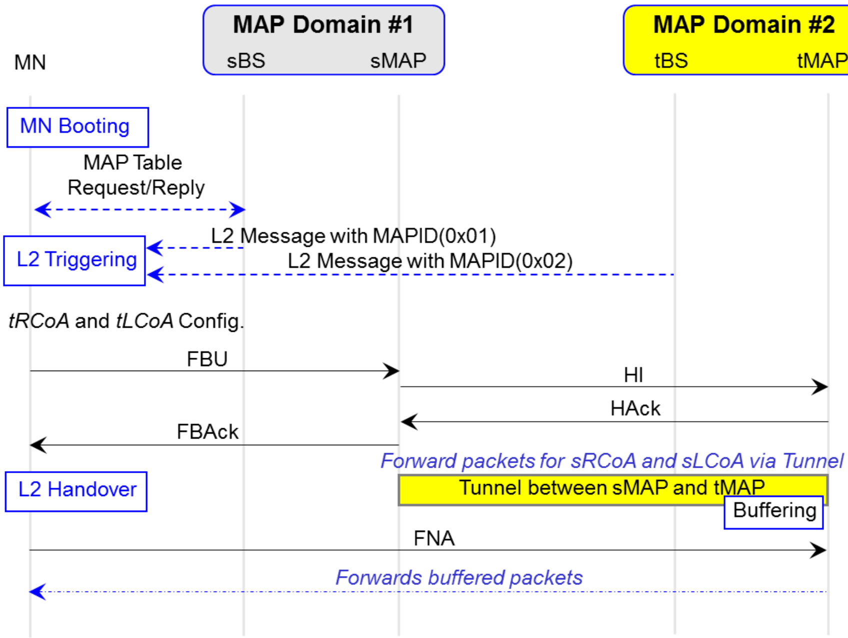

FIGURE 3. Operation procedure of proposed mechanism

sMAP begins tunneling the MN's packets for sRCoA and sLCoA to tRCoA and tLCoA, and the tMAP begins buffering copies of incoming packets from the sMAP. Such a tunnel remains active until the MN completes the binding update with the home agent (HA) and CNs. Then, the MN sends immediately the fast neighbor advertisement (FNA) message to the tMAP and thus the tMAP forwards arriving and buffered packets to the MN right away.

4. **Comparative Analysis.** In this section, the proposed mechanism is compared with existing mechanisms [8, 9, 10, 11, 12] for handover latency, handover preparation time, additional function and network entity.

4.1. **Analytical evaluation.** To present analytical results for estimating handover latency and handover preparation time, following parameters are defined.

- T_{L2D}: Time from L2 triggering to L2 handover start, which is hard to estimate because it might be highly variable according to MN's moving speed, a sudden degradation of L2 quality, an L2 handover decision rule, etc.
- T_{L2H}: Time required for L2 handover.
- T_{CoA}: Time required for CoA configuration.
- T_{FNA}: Time required for FNA to reach tMAP.
- $T_{RtSolPr-PrRtAdv}$: Time required for exchange of RtSolPr and PrRtAdv messages for heterogeneous neighboring MAP discovery between MN and sMAP.
- $T_{FBU-FBAck}$: Time required for exchange of FBU and FBack messages between MN and tMAP.
- $T_{HI-HAck}$: Time required for exchange of HI and HAck messages between sMAP and tMAP.
- $T_{FNA(R)}$: Time required for FNA including FBU to reach tMAP (only for reactive behavior).
- $T_{FBU-FBAck(R)}$: Time required for exchange of FBU and FBack messages between sMAP and tMAP (only for reactive behavior).

Analytical results of handover latency and handover preparation time are shown in Table 2 and Table 3. Table 2 shows that the handover latency of all mechanisms is the same. However, as shown in Table 3, the handover preparation time of the existing mechanism [11, 12] and the proposed mechanism is shorter than the existing mechanisms [8, 9, 10] since the neighboring MAP discovery phase is eliminated. Actually, the time from L2 triggering to L2 handover start, defined by T_{L2D}, is hard to be estimated because it might be highly variable according to MN's moving speed, a sudden degradation of L2 quality, an L2 handover decision rule, etc. If the handover preparation time is longer than T_{L2D}, the MN loses its connectivity to the sMAP and thus the "reactive" behavior is operated. Thus, the probability of "predictive" behavior decreases as the handover preparation time increases, which causes the handover latency to increase as shown in Table 2. Therefore, the probability of predictive behavior of the existing mechanisms [11, 12] and the proposed mechanism can be higher than the existing mechanisms [8, 9, 10].

Table 2. Handover latency for both existing and proposed mechanisms

Predictive behavior	Reactive behavior
$T_{L2H} + T_{FNA}$	$T_{L2H} + T_{FNA(R)} + T_{FBU-FBAck(R)}$

Table 3. Handover preparation time

Mechanisms	Handover preparation time
Existing [8, 9, 10]	$T_{RtSolPr-PrRtAdv} + T_{CoA} + T_{FBU-FBAck} + T_{HI-HAck}$
Existing [11, 12] and Proposed	$T_{CoA} + T_{FBU-FBAck} + T_{HI-HAck}$

Table 4. Additional function and network entity

Mechanisms	Additional function	Additional network entity
Existing [8, 9, 10]	–	–
Existing [11, 12]	MIH	MIIS server
Proposed	BS-Assistance	–

4.2. **Additional function and network entity.** The proposed mechanism and existing mechanisms are compared in terms of additional function and network entity for overall handover procedure as shown in Table 4. Basically, both proposed mechanism and existing mechanisms require FMIPv6 functionality of [15]. The existing mechanisms [8, 9, 10] do not require additional functionality. However, the existing mechanisms [11, 12] require IEEE 802.21 MIH functionality and the proposed mechanism requires BS-assistance functionality. Basically, for both proposed mechanism and existing mechanisms, MN, tMAP, sMAP, BSs in sMAP and tMAP domains are involved for overall handover procedure. The existing mechanism [8, 9, 10] and the proposed mechanism do not require additional network entity. However, the existing mechanism [11, 12] requires the MIIS server for IEEE 802.21 MIH functional operations. Although the existing mechanisms [8, 9, 10] do not require any additional functionality and network entity, their handover preparation time is much larger than the existing mechanisms [11, 12] as well as the proposed mechanism. In addition, the proposed mechanism can be comparable to the existing mechanisms [11, 12] although there is no additional network entity.

5. **Concluding Remarks.** In this paper, an alternative fast handover mechanism of HMIPv6 has been proposed for wireless networks. This paper has considered the wireless network environment where there are several MAPs connected by BSs of diverse wireless networks. These BSs assist to provide the fast handover of the MN. A couple of messages used in L2 and L3 have been defined and they are exchanged between MN and BS.

The L2 message has been defined by adding specific information to the available field of existing messages. The L3 message for MAP table request/reply has been defined in order that the MN gets neighboring MAP information. The proposed mechanism does not require the neighboring MAP discovery and the IEEE 802.21 MIH function/server, which are required for existing mechanisms. The proposed mechanism has been compared with existing mechanisms for handover latency, handover preparation time, additional function and network entity. Comparative analysis results have shown that the proposed mechanism is comparable to or better than existing mechanisms although there is no additional network entity.

Actually, when the number of MNs increases, the size of MAP table also increases. Thus, a scalability problem in this case should be considered for future research.

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