Fast IP Mobility Management for Mobile Computing Service with Multiple Pre-Registration and Late Tunneling

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요약

In order to provide a low latency IP handover for real-time mobile and/or pervasive computing service, the IETF has specified FMIPv6 protocol. However, in FMIPv6, if a prediction about a mobile node movement is erroneous, both large handover latency and packet loss result. This is because the handover is performed in reactive mode, when the prediction is found to be incorrect. In this paper, we have proposed an intelligent mobile IPv6 handover scheme, called IMIPv6, which can remedy the above limitations of the FMIPv6. In the IMIPv6, multiple pre-registrations of CoAs, intelligent movement detection and late tunneling are employed to reduce handover latency and to eliminate packet loss. The simulation results show that the IMIPv6 can drastically reduce the handover latency, while eliminating packet loss.

1. Introduction

Recent proliferation of IP-based real-time mobile computing services is requiring seamless fast mobile IPv6 handover over heterogeneous wireless networks. In order to provide session continuity during a handover, the IETF has proposed several standards, which include Mobile IPv4 (MIPv4) [1], Mobile IPv6 (MIPv6) [2], and Fast Handover for Mobile IPv6 (FMIPv6) [3]. Although MIPv4 had been introduced quite a long time ago, it has not been widely deployed due to its complexity in implementation, triangular routing problem, and security problems caused by ingress filtering. While MIPv6 eliminates the problems of MIPv4, its handover latency is, however, known to be unacceptable for real-time multimedia services. The reason is that it takes at least a few seconds to detect mobile node movement and to allocate a new care-of-address (CoA).

The FMIPv6 has recently been proposed to reduce IP handover latency by predicting mobile node movement and preparing a new care-of-address in advance. The handover latency resulting from FMIPv6, however, is still unacceptable for real-time services [4] because prediction of mobile node movement could be incorrect. This is because FMIPv6 constructs a tunnel between access routers right after handover initiation, and it executes the handover without ensuring that the mobile node moves into the predicted domain. If the mobile node moves into an unpredicted domain, large packet loss, as well as large handover latency, may occur since the handover operation of FMIPv6 may be executed in reactive mode. Such a situation may often arise due to the diverse fading and shadowing effects of radio propagation in large metropolitan areas.

In order to improve performance in handover latency and packet loss, lots of re-searches have been conducted [5-7]. Most of this research was concerned with the reduction of handover latency, either by incorporating movement detection function at access routers, or by access points. Situations whereby a mobile node initiates the handover and the prediction of the movement is wrong were not considered. The objective of this research is to design a fast IP handover scheme which can eliminate packet loss and delay problems, when the mobility patterns of mobile nodes are un-predictable. These situations often occur in large metropolitan area where the radio propagation behavior is mostly unpredictable due to large building and other obstacles.

The simultaneous binding mechanism [7] tries to solve incorrect movement prediction by using n-casting. However, although new CoAs are made at multiple locations in [7], the tunnels are immediately constructed to n-casted routers as in FMIPv6. Therefore, packet loss and delays may occur when mobile nodes stop or move very slowly or very fast as described in [3]. There is also a security problem in [7] since the traffic may arrive at unexpected sites.

In order to solve these problems, we propose an intelligent mobile IPv6 handover scheme (IMIPv6), using multiple pre-registrations and late tunneling. The idea of IMIPv6 is to prepare in advance multiple CoAs, but tunneling is performed late in time when the layer 2 handover condition is satisfied. The intelligent movement detection function provides the proper timing information for tunnel construction and L2 handover execution. Therefore, a tunnel between access routers is constructed late in time at a moment when the layer 2 handover condition is satisfied. These multiple pre-registrations combined with the late tunneling mechanism can effectively eliminate both packet loss and large handover latency of FMIPv6, when the movement prediction is
incorrect.

We have designed the intelligent movement detection using the IEEE 802.21 Media Independent Handover (MIH) functions [8]. IEEE 802.21 MIH standard defines the standard interfaces for L2 movement detection and handover execution in con-verged heterogeneous wireless networks. In order to show the efficiency of the proposed IMIPv6, we have compared the performance of the proposed IMIPv6 with that of the existing IETF’s FMIPv6. The simulation results show that the proposed scheme outperforms in both delay and packet loss.

In Section 3, we briefly describe the background, and the handover latency and packet loss problems of FMIPv6. In Section 3, we present the algorithm of IMIPv6 in detail. The signaling flow of IMIPv6 is outlined. In Section 4, simulation results are described and concluding remarks follow in Section 5.

2. Limitation of FMIPv6

The IETF MIPSHOP WG has proposed MIPv6 [2] for supporting the mobility of a mobile node (MN) in the IPv6 network. As mentioned previously, MIPv6, however, is not suitable for supporting real-time multimedia service because it requires at least a few seconds to conduct a handover [9-10]. Fast Handovers for Mobile IPv6 (FMIPv6) [3] is proposed in order to solve the aforementioned large handover latency problem of MIPv6. It reduces CoA acquisition latency by configuring a new care-of-address (NCoA) of a mobile node in advance, before a Layer 2 handover takes place, with the aid of link layer triggering information. The FMIPv6 protocol has two operational modes; one is the predictive mode, and the other is the reactive mode. The two modes are different in terms of the handover execution procedure and timing. In the predictive mode, the MN completes the handover operations before Layer 2 handover begins, and in the reactive mode, the MN may initiate the handover operations after the Layer 2 handover, when the predictive mode fails.

The performance of FMIPv6 is strongly dependent on the timing of the Layer 2 triggering, and the integrity of the information of next access routers and their associated link layer addresses information. For example, suppose that the Layer 2 (L2) triggering for IP handover could be performed at time in far advance before the actual handover occurs. In this case, since the time interval between L2 triggering and hand-over may be too long, so the information of next access point and router may be out of date. So, the IP handover may not be successful. In other case, suppose that after initiating a handover, the signal strengths of neighboring access points (APs) have drastically changed, possibly due to shadowing effect, and a handover directed to the apparently best AP from the previous L2 triggering information may fail, or the mobile node may select a new AP that is entirely missing from the previous L2 triggering information. This may be caused by incorrect timing of L2 triggering operation. Both cases would limit the ability of the MN to choose the correct next access router in the predictive mode of FMIPv6 operation. In summary, since the FMIPv6 had been designed on the assumption that an MN can accurately predict the next visited network according to the mobility information generated by a layer 2 trigger, both large packet loss and handover latency may result in, if an MN can not accurately predict the next visited network.

3. Algorithm and Signaling Flow Diagram of IMIPv6

In this section, we describe an intelligent mobile IPv6 handover (IMIPv6) scheme, which can be achieved by multiple pre-registrations of CoAs, intelligent movement detection and late tunneling mechanisms.

3.1 Intelligent Mobile IPv6 Handover Algorithm

Fig. 1 shows a scenario of multiple pre-registrations and late tunneling in IMIPv6 in wireless LAN environment for simplicity. The scenario can however be extended to heterogeneous wireless environment without difficulty. The signaling messages have been designed according to the IMIPv6 algorithm which is described subsequently. Here, we define the CAP as the Current Access Point, to which a mobile node is currently attached, and NAP as the Next Access Point, to which the mobile node will attach after movement. CAR is the Current Access Router which is currently accessed by a mobile node, and NAR is the Next Access Router which will be accessed by the mobile node after its movement. The Candidate_NAR_Group is a set of candidates of next access routers.

In IMIPv6, a mobile node builds the CoA by using the network prefix of CAR, and then it performs duplicate address detection (DAD). If the CoA is proven to be valid via the DAD procedure, the mobile node sends the pre-registration request to the candidate of next access router, and it is registered in the Candidate_NAR_Group. This operation prohibits other mobile nodes from using the same CoA again. The Candidate_NAR_Group is usually stored and maintained in the mobile node. In Fig. 1, the mobile node sends the (1a) Pre-Registration request to the CAR in order to register a new CoA in the candidate access router NAR1. The CAR includes the new CoA in the Pre-Registration request, and sends it to NAR1, and NAR1 performs the DAD procedure. If the new CoA is not duplicated, the NAR1 registers it into its Neighbor Cache Entry. Thus, even if the mobile node is not in the accessible region of NAR1, it can check the duplication of an IP address. NAR1 registers the new CoA at its Neighbor Cache Entry, it sends the response message (1b) Pre-Registration ACK, notifying that the new CoA has been successfully registered.

As the mobile node receives the (1b) Pre-Registration ACK from the NAR1 via CAR, it registers NAR1 into its Candidate_NAR_Group, and tests conditions for executing the L2 handover by accessing MIH server. If the conditions are not satisfied, it searches another wireless access subnet,
by accessing NAP2 and NAR2. The same pre-registration operations are repeated, i.e., (2a) and (2b) as shown in Fig. 1. If the L2 handover condition is satisfied, the mobile node selects an NAP whose radio signal strength is the strongest, and also determines the corresponding NAR in Candidate_NAR_Group. Then it sends the binding message to the NAR via CAR, constructs a tunnel between the CAR and NAR, and executes handover to the NAP and NAR, which are indicated by 2-4 signaling messages in Fig. 1.

In the algorithm Intelligent-Mobile-IPv6-Handover below, we describe the detailed steps of IMIPv6.

![Algorithm Intelligent-Mobile-IPv6-Handover](image)

**Algorithm Intelligent-Mobile-IPv6-Handover**

**Begin**

**Step 1:** Generate the Candidate_NAR_Group.

**Step 2:** As the MIH L2 triggering event occurs, ask members of Candidate_NAR_Group to prepare new CoAs by performing duplicate address detection.

**Step 3:** As a mobile node moves, test whether the MIH L2 handover execution condition is satisfactory for access points, which are associated with Candidate_NAR_Group.

**Step 4:** If the test is acceptable, select the optimal NAP and its corresponding NAR, and construct a tunnel between CAR and NAR, and execute the MIH L2 handover execution operation.

**Step 5:** If the L2 handover is completed successfully, the reserved CoAs in non-selected NARs are removed, and go back to Step 1. Otherwise, select one of the APs for non-selected NARs in Candidate_NAR_Group, and perform L2 handover execution until the handover is completed successfully.

**End**

As a mobile node moves into a new domain, it generates a set of feasible candidates of next access routers to which a move node will be connected. As the MIH L2 triggering message arrives, the mobile node registers CoAs at multiple locations. It, however, does not construct a tunnel immediately, but waits, and performs tunneling late as the L2 handover condition is satisfied. In contrast to immediate tunneling construction in FMIPv6, the handover is prepared in multiple possible locations in advance, and the actual handover operation is executed opportunistically, i.e., delayed until the optimal condition is satisfied [11]. This is the reason that the proposed hand-over mechanism is called intelligent. In this way, the proposed IMIPv6 protocol can reduce handover latency even if the original prediction is found to be wrong. It is noted that in FMIPv6, the handover operation may be executed in a reactive mode when the prediction mode is unsuccessful, so that large handover latency and packet loss could occur.

### 3.2 Singaling Flow Diagram of IMIPv6

Fig. 2 shows the signaling time sequence diagram of the IMIPv6 using multiple pre-registration. In Fig. 2, a mobile node first detects the movement from the L2 triggering message. It performs the pre-registration operation. If the L2 handover execution conditions are met, it proceeds to execute the L2 handover execution, by switching the point of attachments (PoAs). Otherwise, it repeats the pre-registration and testing operation to NAR2 and NAR3, as described in Fig. 2.

In Fig. 2, NAR 1, NAR 2, and NAR 3 are the NAR candidates. If the L2 handover execution conditions are met, the mobile node selects the NAR (NAR 1 in Fig. 2) with the strongest radio signal strength indicator (RSSI) from the NAR candidates, constructs a tunnel between the CAR and NAR1, and switches the point of attachment to NAP1. After the tunnel is built, the data are transmitted to NAR1. The mobile node transmits binding update message to the home agent and the correspondent node. In this way,
the mobile node can connect to the correspondent node without packet loss. In Fig. 2, the signaling messages are also included to cancel all existing relevant re-registrations, and the handover is prepared for through re-initialization.

Fig. 2. A signaling sequence diagram of multiple pre-registrations.

4. Performance Evaluation

We have evaluated the performance of the proposed multiple pre-registrations by using Network Simulator Version 2 (NS-2). In order to evaluating the performance of IMIPv6, we have compared the handover latency and packet loss of IMIPv6 with those of FMIPv6 from the IETF. The simulation was performed for handover situation, where a mobile node moves to an unpredicted NAR, and the CAP is disconnected for a long time after the MN received FBack message.

In the first simulation, we set up domains which consist of three access routers, CAR, NAR1, and NAR2. Each AR is assumed to contain only one AP. Simulations perform for 30 seconds. The simulation starts at 0 seconds, and the CN starts to transmit CBR data to the MN at 5 seconds. At 10 seconds, the MN moves to the NAP1 directly, and starts to handover to the NAP1 at 15 seconds. As soon as the MN starts the handover, the MN turns to the NAP2. At 15.1 seconds, the MN disconnects with the NAP1, and starts to execute Layer 2 handover to the NAP1. The MN stops transmitting CBR data at 25 seconds. Finally, the second simulation ends at 30 seconds. Table 1 shows the average handover delay of FMIPv6 and the proposed IMIPv6. We have measured the average handover latency by conducting 10 times. As shown in Table 1, FMIPv6 takes 592ms during a handover when a MN suddenly changes its direction of movement. IMIPv6, however, requires 182ms during a handover. When a MN stops moving during handover procedures, FMIPv6 needs 5354ms. IMIPv6, however, requires 180ms. As shown in Table 1, if the MN moves to an unpredicted domain or stops movement during a handover, it can drastically reduce handover latency in comparison with FMIPv6.

Table 1. A comparison of handover latency

<table>
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<tr>
<th></th>
<th>FMIPv6</th>
<th>IMIPv6</th>
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<tbody>
<tr>
<td>Stop movement</td>
<td>5354ms</td>
<td>180ms</td>
</tr>
<tr>
<td>Change direction</td>
<td>592ms</td>
<td>182ms</td>
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</table>

Fig. 3 shows the packet delivery characteristics at the MN. We have measured packet loss and handover latency by analyzing the time stamp and the ID of the packets, which are delivered from the CN to the MN. Fig. 3(a) shows the results of packet delivery monitoring using FMIPv6 at the MN during the entire simulation period. The MN begins a handover at 14.8s, and is disconnected from the CAR at 15s. At this time, the CAR forwards packets to the NAR1. The MN, however, does not move to NAR1,
but to NAR2. Therefore, the packets forwarded to the NAR1 will be lost. Then, the MN receives data again from the CN at 15.51s.

Fig. 3 Packet delivery characteristics at the mobile node

(a) Delivered packets at the mobile node for FMIPv6

(b) Delivered packets at the mobile node for IMIPv6

(a) Packet delivery monitoring at the mobile node for FMIPv6
Fig. 3(b) shows the results of packet delivery monitoring using IMIPv6 at the MN, during the entire simulation period. The MN begins pre-registration at 14.8s, and is disconnected from the CAR at 15s. The MN receives data again from the CN at 15.21s. The data transmitted from the CN during disconnected period, are buffered by the CAR. After the MN is connected to the NAR2, it receives buffered data from CAR. Therefore, as shown in Figure 3(b), the MN does not lose packets during a handover. And after handover completion, burst data, which are buffered by the PAR, are delivered to the MN immediately.

Fig. 4 shows the packet delivery characteristics when the MN stops moving. In Fig. 4(a), buffer size of the NAR1 is limited, so all packets forwarded from the CAR can not be stored at the NAR1 buffer. Therefore, packets, which are forwarded after the buffer has overflowed, should be dropped. As shown in Fig. 4(a), although FMIPv6 is used, packet loss is drastically increased in this case. In Fig. 4(b), although the MN performs pre-registration at 14.8s, the packets from the CN can be transmitted to the MN until the MN sends the tunneling request message. As shown in Fig. 4(b), the MN does not lose any packets during a handover, and after the handover is completed, burst data, which are buffered by the PAR, can be delivered to the MN immediately.

5. Conclusion

In this article, we have presented an intelligent fast IPv6 handover mechanism for real-time mobile multimedia services such as mobile VoIP, mobile multi-party video conferencing and mobile IPTV. The simulation results show that the proposed intelligent handover mechanism outperforms FIMIPv6 in most cases. Further research area includes signaling and security issues.

6. Reference