Seamless Handover Scheme for Proxy Mobile IPv6 Using Smart Buffering

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ABSTRACT
PMIPv6 is proposed as a new network-based mobility protocol and it does not require MN's involving in mobility signaling. PMIPv6 can handover relatively faster than MIPv6 because of using link layer attachment information and micro mobility characteristic. However, current PMIPv6 cannot prevent packet loss in disruption period. We proposed in this paper, Smart Buffering scheme for supporting seamless handover in PMIPv6. Smart Buffering scheme prevents packet loss totally by buffering lost candidate packets in a current serving MAG and forwarding it to a new MAG, after an MN successfully connected. Smart Buffering also performs redundant packet removing in a previous MAG and packet reordering in a new MAG to maximize performance of seamless handover. All these procedures between a previous MAG and a new MAG are processed using simple message exchanges without requiring any involving of an MN.

We verified the effectiveness of the Smart Buffering by simulation with various parameters. Simulation results prove that proposed scheme prevent packet loss in the handover and handle buffered packets very efficiently. As a result, we conclude that Smart Buffering is very useful for supporting seamless handover in PMIPv6.

Categories and Subject Descriptors
C.2.1 [Computer-Communication Networks]: Network architecture and Design – Wireless communication

General Terms
Performance

Keywords
Mobility support, Proxy Mobile IPv6, PMIPv6, Mobile IPv6, Reactive Handover

1. INTRODUCTION
The main purpose of the mobility management protocols, such as Mobile IPv6 (MIPv6)[1] is providing continuous service to an MN without breaking the connection when an MN changes its Point of Attachment (PoA). However, disruption of communication is inevitable in the circumstance that MN usually has single wireless interface and the link layer lost connection until it attaches to a new PoA during handover.

In the most handover protocols, the handover procedure is initiated after an MN being attached to a PoA, and this kind of handover method is called reactive handover. The handover provided in reactive ways cannot prevent connection disruption and packet losses during handover. So, it is very important to reduce or remove this disruption period for providing improved overall handover performance.

Proactive handover approach utilizes predictive information about a prospective PoA to setup data forwarding path between current and prospective access routers. The proactive handover schemes generally outperform the reactive handover in handover delay and packet loss. However, the proactive approach also has several restrictions, such as erroneous movement and signaling overhead[2]. Meanwhile, reactive approach is simple and robust because it does not need to know previous PoA at all and reactive approach can be used even in the circumstance that proactive handover is failed.

Most mobility management protocol operates in reactive handover and proactive handover is supported additionally for performance. For example, well-known mobility management protocol, MIPv6, supports only the reactive handover and Fast Handover for Mobile IPv6 (FMIPv6)[3] provides both methods, but major advantage of FMIPv6 comes from its proactive characteristic.

Recently, Proxy Mobile IPv6 (PMIPv6)[4] has been proposed by NETLMM WG[5] as a network-based mobility protocol. PMIPv6 does not require MNs to be involved in mobility signaling, which is initiated and processed by MNs in MIPv6.
Current PMIPv6 only supports reactive handover but it can perform relatively faster handover than MIPv6 by using the link layer attachment information. In spite of faster handover signaling, however, it still has packet loss during disruption period that caused from the reactive mechanism.

In this paper, we propose Smart Buffering scheme for seamless handover in PMIPv6. In Smart Buffering, previous access router performs buffering without any information about new PoA and forwards buffered packets after the MN is attached to new PoA. The Smart Buffering also deals with redundant packet removing in a previous router and adjusting packet ordering in a new access router.

The rest of this paper is organized as follows. In the next section, we introduce new network based mobility management mechanism, PMIPv6, and mention about its limitation. In Section 3, we introduce the proposed seamless handover scheme and show the result of performance evaluation in Section 4. Finally, we conclude this paper in Section 5.

2. RELATIVE WORKS

PMIPv6 is one of the micro-mobility mechanisms and the main purpose of supporting micro-mobility is shortening the signaling time to minimize the period of data disruption[4][6].

PMIPv6 performs mobility management similar to micro-mobility scale by updating bindings with the localized entity, Local Mobility Anchor (LMA) and by shortening the movement detection time using the mobile node attachment event at the Mobile Access Gateway (MAG).

Figure 1 shows the signal flows of PMIPv6. When an MN is attached or handovers to access network, an MAG has responsible to identify and handle it. An MAG obtains a profile related to an MN containing a home network prefix, an MN-HNP of MN and an address and LMA Address (LMAA). An MAG sends a Proxy Binding Update (PBU) to the LMA in order to update a current location of MN. Upon accepting PBU in the LMA, it replies a Proxy Binding Acknowledgement (PBA) to an MAG which includes an MN-HNP. The LMA also creates a Binding Cache Entry (BCE) and establishes a bi-directional tunnel to an MAG. After receiving PBA, the MAG gateway sets up a bi-directional tunnel to the LMA and a routing table entries for MN. At this point, the MAG sends a Router Advertisement (Rtr_Adv) which includes an MN-HNP actively or waits until receiving a Router Solicitation (Rtr_Sol) from an MN. After the MN receives Rtr_Adv, it can configure IPv6 address by itself.

When a LMA receives packets from any correspondent node (CN) to an MN, it forwards the packets to an MAG using the bi-directional tunnel established when the MAG registered the MN. The tunneled packets are encapsulated in IP-in-IP. When an MAG receives tunneled packets, it decapsulates and forwards the packets to an MN. All packets from the MN are reverse tunneled to the LMA from an MAG.

While PMIPv6 shortens signaling update time and reduces disruption period, it is not good enough to prevent data loss in handover. Because any handover in PMIPv6 requires L2 handover which needs tens of milliseconds to complete, and the data sent this handover period are lost regardless of how shortened signaling time. In addition, a new MAG needs little update time to register new location of an MN to a LMA, if a new MAG has to contact an AAA to retrieve the MN's profile. For supporting various requirements of applications, especially in real time application, we need to enhance seamlessness of handover in PMIPv6.

Recently, several improved handover methods have been introduced to support fast handover in PMIPv6[7][8]. These approaches adopt FMIPv6 to PMIPv6. FMIPv6 includes buffering on the fly to reduce packet loss in an Access Router (AR) and can operate independently with a process of PMIPv6. The main difficulty of applying FMIPv6 to PMIPv6 is how an MAG knows beginning of MN's handover and target AR information. In the original FMIPv6, an MN notifies a handover decision to an AR using a FBU message, and the FBU message includes the target AR information.

In [7], "L2 HO signaling" is used to detect MN's decision about handover. The "L2 HO signaling" contains information of an MN identifier and a new AP identifier. In case of IEEE 802.16e, the MOB HO IND message may acts as "L2 HO signaling." However, if L2 layer does not provide such a message in IEEE 802.11, this procedure will not work. In [8], the dependency of L2 technology is avoided by using Context Transfer Protocol[9]. In this protocol, an MN sends a REPORT message which includes MN ID and new AP ID to a serving MAG, and the serving MAG starts fast handover procedure with receiving of this message; the REPORT message actually used as a FBU message in FMIPv6. The problem of this approach is that an MN must support new Context Transfer Protocol.

These approaches hide interaction between the MN and AR by using Layer 2 handover signaling or Context Transfer Protocol, and a mobility functionality related to FMIPv6 seems to be removed in an MN. But, unfortunately, these interactions conflict with main principle of PMIPv6, which is proposed to avoid any involvement of the MN for mobility support.

3. THE PROPOSED SCHEME

In FMIPv6, handover related functionalities are located at an MN. The MN decides which AP is going to be attached and when it is going to start the handover procedure. In the previous proposed methods[7][8], the handover functionalities are still located at the MN even if these functionalities, choosing a new AP and
handover decision point, are moved to an another layer or an another protocol. However, the principle of PMIPv6 excludes an involvement of an MN from any mobility support.

The main benefits of using FMIPv6 with MIPv6 are fast handover and minimizing packet loss using tunneling and buffering. In FMIPv6, a fast handover is not by fast handover signaling but by minimizing packet disruption time. Although PMIPv6 reduces handover time by lessening signaling overhead by using host-based micro-mobility concepts, reducing packet disruption time is not concerned. To achieve the minimal packet disruption time to prevent packet loss, we need a new method to apply the key FMIPv6 functionalities to PMIPv6 without MN's involvement as well as any violation of PMIPv6 specification.

The information about where packets are forwarded to and when a serving AR starts forwarding must be known to a serving MAG without MN's help. In PMIPv6, a serving MAG can predict a movement when receiving signal strength from the MN is going down below certain threshold. The time for an MAG to detect a movement without MN's help is only after the MN attached to new MAG. When a new MAG detects the MN attachment, a data disruption has been already occurred at least link layer handover period. To avoid packet loss during this period, packets should be kept in a serving MAG. And a serving MAG must be notified where the buffered packets should be forwarded to a new MAG.

We introduce Smart Buffering in MAGs to support seamless handover in PMIPv6. Smart Buffering consists of three functional parts: packet buffering in a serving MAG, a discovery of serving MAG, and packet reordering in a new MAG. Buffering is performed to keep packets in a serving MAG, based on the receiving signal strength (RSS) for the packets from the MN. While RSS becomes lower than certain threshold, which means an MN is expected to do handover soon, the serving MAG starts buffering until it receives a forwarding request from a new MAG. In the Smart Buffering state, a serving MAG duplicates packets towards an MN and stacks duplicated packets to a buffer while original packets are transferred to an MN.

With buffering in a serving MAG, two methods of removing redundant packets which an MN may receive successfully before it moves to a new MAG are performed to prevent excessive buffering. One is that a serving MAG buffers packets only arrived during an expected disconnection period and the other is that a serving MAG tries to remove redundant packets among buffered packets with an assistance of the layer 2 retransmission information. All packets older than an expected disconnection time are discarded from the forwarding buffer. The expected disconnection period varies from link layer technologies such as IEEE 802.11 or IEEE 802.16e and from vendors of wireless network interface. Therefore, we should use an average or worst time of link layer handover latency for assuring that an MAG keeps all packets during link layer handover. Even though we limit the maximum buffering time, there must be some redundant packets in buffer because we cannot know the exact disconnection period of an MN, if wireless technology that we use does not provide such information. We can remove these duplicated packets which are considered that an MN may receive successfully, using layer 2 information. For example, IEEE 802.11 has MAC retransmission scheme, which retries several times before it gives up retransmission. Once we get a first event of giving up retransmission after starting Smart Buffering, we can guess that a link is disconnected very soon and all packets are about to be dropped. It also means that all buffered packet before this event are delivered successfully to an MN, and those packets must be removed from the buffer.

To fetch the buffered packets in a serving MAG after an MN attached to a new MAG, the new MAG must know about a serving MAG. Despite an MN knows a serving MAG it cannot provide that information to a new MAG under PMIPv6. So, we need another method to obtain serving MAG information. There are two ways how a new MAG can know a serving MAG. One is a proactive notification by a serving MAG and the other is a reactive discovery by a new MAG. The former sends information of a serving MAG to neighbor MAGs when MN's RSS becomes lower than threshold, and the latter discovers a serving MAG using a discovery mechanism as soon as an MN attaches to a new MAG.

In the proactive notification, a serving MAG sends a notification of handover with serving MAG information to neighbor MAGs, when an MN is likely to move to another MAG. Neighbor MAGs that received the notification keep the information for certain period. When an MN attached one of these MAGs, a new MAG sends a forwarding request to a serving MAG based on the pre-notified information. In the reactive discovery, a new MAG multicasts a discovery message to its neighbor MAGs, when an MN is attached to a new MAG. When the serving MAG receives this recovery message, it replies an acknowledge message to a new MAG, which includes information for packet forwarding to an MN, and flushes packets in the buffer.

Both of schemes allows a serving MAG to obtain target MAG information without from an MN. However, in proactive method neighbor MAGs have to maintain information for serving MAGs and MNs, in soft-state. On the other hand, extra delay for discovering a serving MAG in reactive mechanism can be ignored in the condition that a serving MAG is already buffering all the MN’s packets. The proposed Smart Buffering is designed with the reactive method. It is notable that buffering in FMIPv6 is actually done by a new AR rather than a previous AR, and the proactive method is more suitable to FMIPv6.

As soon as a serving MAG and a new MAG recognize each other, buffered packets in the serving MAG must be delivered to an MN. We use IP-in-IP forwarding tunnel between MAGs. It may use link layer forwarding tunnel if neighbor MAG is one-hop relation. Each MAG can establish a tunnel with neighboring MAGs when it is booted. Soon, we assume that neighboring relationship between MAGs is predefined based on physical deployment of MAGs. Because the forwarding tunnel is pre-established, forwarding buffered packets does not take any extra time for establishing tunnel, and forwarding packets takes place immediately when it is needed.

If we consider the buffer of a new MAG which maintains receiving packets from a serving MAG, a new MAG must delay packets from a LMA until all packets from a serving MAG is forwarded to an MN to guarantee packet ordering. A serving MAG and a new MAG is in neighbor, so the difference of packet traveling time from a LMA to a serving MAG and from a LMA to a new MAG may be very small. The last packet sent to a serving MAG has to travel from a serving MAG to a new MAG, but it is expected that forwarding time will be very short. Therefore, the
last packet sent to a serving MAG will be arrived at a new MAG at almost the same time with the first packet sent to a new MAG from a LMA. So, the buffering time for packets directly sent to a new MAG will be minimal. Even if the buffering time is minimal, buffering itself is needed for keeping packet order, and it is desirable to serve delayed packets as soon as finishing processing of packets from a serving MAG.

Figure 2 shows a sequence diagram of proposed scheme when an MN hands over from an MAG1 to an MAG2 while communicating with a CN. MAG1 starts buffering when MN's signal strength is below certain threshold which is high enough to start buffering before an MN is disconnected. During buffering state, incoming packets to an MN is duplicated and buffered. When an MN makes association with an MAG2, an MAG2 should advertise an MN's ID to its neighboring MAGs to identify which MN's buffer need to be flushed. We introduce a new message, Flush Request/Reply Message (FRM) for buffered packets management. If an MAG1 receives a FRM request message, it replies a FRM reply message with buffering information such as buffered packets count and average or maximum inter-packet arrival time to calculate maximum time to reordering.

After an MAG2 received a FRM reply message, it starts packet reordering within certain time calculated based on the information piggybacked with a FRM reply. In the reordering state, flushed packets from an MAG1 are forwarded to an MN without delay and packets arrived directly from a LMA to an MAG2 are buffered. When the calculated flushing time is over, buffered packets an MAG2 are also flushed, and reordering process is completed. The buffering time for reordering in Figure 2 is depicted as long. But in actual environment exchanging FRM and PBU/PBA occurs in simultaneous, this buffering time is relatively very short compared with buffering in a serving MAG.

4. EXPERIMENTS

4.1 Simulation Setup
We performed simulation using ns-2 network simulator in IEEE 802.11 environment. The current ns-2 itself does not have full functionality for IEEE 802.11 MAC. So we used NIST-modified-ns-2.29[10] for our experiments. The simulation network topology is shown by Figure 3.

The CN is directly attached to the LMA with link rate of 100 Mbps and delay of 100ms. The LMA manages two MAGs and the MN moves from the MAG1 to the MAG2 while communicating with the CN. The link delays for all links are 10 ms and the link capacity is 100 Mbps for wired the link and 11 Mbps for the wireless link. The CN communicates with the MN through CBR over UDP with rates, 300 Kbps, 500 Kbps, 1 Mbps, and 2 Mbps.

The MAG1 and the MAG2 have the implementation of proposed Smart Buffering scheme. We simulated four different scenarios to compare original PMIPv6 with the proposed scheme and to show effectiveness of Smart Buffering.

Table 1. Simulation Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Buffering in a serving MAG</th>
<th>Removing-redundant</th>
<th>Reordering in a new MAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>O</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

As shown in Table 1, Scenario 1 performs original PMIPv6 only. Scenario 2 through 4 supports Smart Buffering with three combinations of removing successfully delivered packets from the queue and reordering between flushed packets from old MAG and newly arrived packets through a new path.

We performed each scenario for one hundred times and analyzed the simulation results.
4.2 Simulation Results
Table 2 shows average dropped packets from an MN verifying how Smart Buffering protects packets from dropping. Because Scenario 1 does not use buffering scheme, it shows relatively many dropped packets. On the other hand, from Scenarios 2 to 4, we cannot notice any packet drops.

<table>
<thead>
<tr>
<th>Rate</th>
<th>Scenario 1</th>
<th>Scenarios 2, 3 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 Kbps</td>
<td>16.33</td>
<td>0</td>
</tr>
<tr>
<td>500 Kbps</td>
<td>28.53</td>
<td>0</td>
</tr>
<tr>
<td>1 Mbps</td>
<td>56.80</td>
<td>0</td>
</tr>
<tr>
<td>2 Mbps</td>
<td>114.87</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4 shows total buffered packets of Scenarios 2 and 3. In our experiment, we find out that buffered packets consist of timed out, removed, and flushed packets. The timed out packets are the packets which are exceeded maximum lifetime among buffered packets, and the removed packets are redundant packets which are considered as successfully delivered to an MN while an MN is attached to an MAG1. The flushed packets are real transmitted packets to an MAG2 from an MAG1. The buffered packet lifetime for all simulations is set to 0.5 second, and it assumes that an MN will complete handover with a new attachment point within 0.5 second at worst.

Scenario 2 never used the information of layer 2 MAC retransmission failure. It means that at the time of flushing, we cannot distinguish packets between redundant packets successfully delivered to an MAG and possibly lost packet without buffering. These packets are considered as redundant and removed in Scenario 3, so we can see the removed packets in Scenario 3.

Scenario 4 has no out-of-ordered packets, and in contrast, Scenario 2 shows relatively many out-of-ordered packets compared to Scenarios 3 and 4, because Scenario 2 does not perform redundant removing in an old MAG neither reordering in a new MAG. Despite Scenario 3 performs reordering, it still has out-of-ordered packets because redundant packets are included in flushed packets. In the result of Scenario 4, there are no out-of-ordered packets at all, because it has removed the redundant packets in old an MAG and also performed reordering in a new MAG.
Figure 6 shows a sequence diagram in Scenario 2 at 300 Kbps test. We can see the handover period from 5.02 seconds to 5.42 seconds. Left part of figure represents the packets successfully received while the MN is attached to the MAG1. The steep part on the right shows flushed packets from the MAG1 and the gentle part is the packets received directly from the LMA via the MAG2. In Figure 6, packets in the lower circle are duplicated because the MN already received on left part. On the other hand, packets the upper circle are new valid packets for the MN although they are out-of-ordered because they are arrived after first packet received through a new path. With Smart Buffering which utilizes redundant removing in the MAG1 and reordering in the MAG2, we can remove both out-of-ordered packets.

We can see the effectiveness of Smart Buffering clearly in Figure 7. By removing redundant packets from buffer, the MN does not receive duplicated packets from the beginning of flush. And reordering delays the packets from a new path not to be mixed with the flushed packets. In Figure 7, first packet from a new path is buffered because it arrived to the MAG1 while flushing. And after all flushed packets are delivered to the MN, the MAG1 start to forward packet from a new path including buffered packets.

Figure 8 shows the time of first valid packet arrived at MN, after the MN has been attached to the new MAG. This time is very important factor in total handover latency. We measured the first valid packet arrived time after the attachment time of MN to the new MAG to exclude link layer handover time, which depends on vendors of hardware.

Determining the first valid packet also varies to the scenarios. In Scenario 1, there is only one path, from the LMA to the MN, and no buffered packets. So, there is no other option considering the first arrived packet through this path as the first valid packet. As we have noticed in Table 2, however, there exist packet losses in Scenario 1 and the first valid packet arriving time itself does not make much sense over other scenarios.

In Scenarios 2 to 4, receiving packets are consist of the packets which are flushed from old MAG and the packets which are arrived directly to the MN from the LMA via new MAG. Packets from the latter path are all valid, so first valid packet is the first packet. On the other hands, the validity of packets from flushed path depend on scenarios. In Scenario 2, some of leading packets are may duplicated and it is not guaranteed that the first flushed packet is valid one. In Scenarios 3 and 4, first packet is valid by removing duplicated packets.

If we consider the first valid packet in Scenario 4, the flushed packets always comes first by result of reordering. But in case of Scenarios 2 and 3, packets of two paths are mixed and we cannot easily determine which packets of each path come first for the valid packet.

In results of Figure 8, as the CBR rate increases, the arrival time for the first valid packet decreases from smaller inter-packet delay in higher rate. The results of Scenarios 2 to 4, which are adopting buffering method, show improved performance in the arrival time of first valid packet over Scenario 1, while the difference is more noticeable at the lower rate. The result means that a buffered packet is arrived first and it decreases the handover time. We can notice the effectiveness of removing redundant packets from the improvement between the result of Scenario 2 and 3. Scenario 4, which utilizes Smart Buffering, shows the lowest result among scenarios. From these results, Smart Buffering makes an MAG supporting exact handover timing for an MN even though the MAG starts buffering earlier and ensures packet ordering during the handover.

5. CONCLUSION
PMIPv6 is a network-based mobility support protocol and it does not require MNs to be involved in the mobility support signaling. PMIPv6 only supports reactive handover method, and it causes data disruption during handover period, even though PMIPv6 can handover relatively faster than MIPv6 because of using link layer attachment information and micro mobility characteristic.

In this paper, we proposed Smart Buffering scheme for supporting seamless handover in PMIPv6. Proposed Smart Buffering scheme buffers packets in a previous MAG without knowing target PoA and the time of detachment of an MN. Smart Buffering also
utilizes redundant packet removing in a previous MAG and packet reordering in a new MAG to maximize performance of seamless handover. All buffering and forwarding processes between a previous MAG and a new MAG are based on additional simple message exchanges, and do not require any assistance of MN. So, it well confirms the principle of PMIPv6 in contrast to the using FMIPv6 in PMIPv6.

We performed simulations to verify the effectiveness of the Smart Buffering in various conditions. Simulation results show that proposed scheme can prevent packet loss in the handover and presents very efficient performance in handling buffered packet. With Smart Buffering, PMIPv6 can handover seamlessly without packet disruption periods.

For future studies, we can adjust Smart Buffering scheme to other mobility protocols. The design of Smart Buffering has very small dependency on other protocols, and it is possible to apply other mobility protocols besides PMIPv6.

6. REFERENCES