:: GENERAL INFORMATION ::

This is the 25th of the International Conference on Information Networking (ICOIN), which was started under the name of Joint Workshop on Computer Communications in 1986. At that time, it was a technical meeting for researchers and engineers on the Internet technologies in East Asian countries, where several technical issues were discussed, especially “how to connect each other.” In 1993, the meeting was reorganized as an international conference known as ICOIN.

Recent past editions were held in Busan, Korea (2010), Chiang Mai, Thailand (2009), Busan, Korea (2008), Estoril, Portugal (2007), and Sendai, Japan (2006).

The ICOIN 2011 conference looks for significant contributions to the computer communications and wireless networks, in the theoretical and practical aspects. Original papers are invited on wired/wireless network architecture, design, protocol, service, analysis, implementation, measurement and simulation.
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Fast Handover using Multicast Handover Agents in PMIPv6-based Wireless Networks

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Abstract—This paper addresses the multicast handover in the wireless networks based on the Proxy Mobile IPv6 (PMIPv6). The existing PMIPv6 multicast schemes tend to induce severe packet losses, large handover delays and unnecessary data transmissions during handover. To overcome these problems, we propose the use of Multicast Handover Agent (MHA) for fast handover. In the proposed scheme, called PMIP-MHA, each mobile access gateway (MAG) has a MHA, which maintains a cache to keep the list of active mobile nodes per multicast group. The MHA is used to stop unnecessary data transmissions when the last mobile node for the group leaves the network. The MHA also performs the fast join with its neighboring MHA during handover. From numerical analysis, it is shown that the proposed scheme can give better performance than the existing PMIPv6-based multicast handover schemes in terms of handover latency and packet loss.

Keywords; PMIP, MHA, Multicast Handover, Wireless network

I. INTRODUCTION

The recent advancement in wireless communication and the popularity of the Internet, there is a compelling need to support real time multimedia services [1, 2]. These services are based on the group communication and IP multicasting. IP multicast provides packet delivery for mobile nodes belonging to multicast group. IP Multicast consists of group membership protocol and multicast routing protocol [3]. The group membership protocol, such as Multicast Listener Discovery (MLD) [4, 5], and Internet Group Management Protocol (IGMP) [6, 7] collects the local membership information and then this information is employed to build up a multicast tree by using the multicast routing protocols such as DVMRP [8], CBT [9], MOSPF [10], PIM-SM [11], etc.

To support the seamless mobility for multicasting services, we may consider Mobile IP (MIP) [12] and Fast MIP (FMIP) [13], which are the host-based mobility solutions, while the Proxy MIP (PMIP) [14] is the network-based mobility solution and provides the local mobility management to a mobile node without any modification in the same PMIPv6 domain. These management functions are performed by Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG).

In this paper we propose the PMIPv6-based multicast handover scheme, which is based on the use of the Multicast Handover Agent (MHA) and named the PMIP-MHA. The proposed scheme can be used to reduce the handover latency and packet losses and also unnecessary transmission of data during handover.

The rest of this paper is organized as follows. Section II reviews the existing works on the PMIPv6-based mobile multicasting schemes. Section III describes the proposed PMIP-MHA scheme for fast multicast handover in details. Section IV and V compare and discuss the performance of the proposed and existing schemes. Section VI concludes this paper.

II. RELATED WORKS

Some schemes have been proposed for the PMIPv6 multicasting in [14], in which the multicast router function is separated from LMA of PMIPv6. This is purported to solve the problem of the so-called tunnel convergence and also to solve the problem of handover latency caused by MLD query/report. When a Mobile Node (MN) moves into a new network region, the previous MAG (PMAG) will forward a context transfer message to the new MAG (NMAG), which includes MN-ID, current MAG’s IP address, and multicast IP address. Then NMAG will check whether there is a receiving node that has joined the same group in the subnet domain. If this is not the case, the NMAG joins the group by sending an MLD report to the attached multicast router.

The work in [15] describes the two types of LMAs in the PMIPv6 domain: some LMAs are dedicated for unicast traffic, and the other LMAs are dedicated for multicast traffic. When MN wants to receive the unicast data, the PMIPv6 tunnel is established between LMA and MAG for unicast data after triggering the router solicitation message from MN. Unicast data will then flow between MN and MAG. For multicast traffic, a multicast tunnel is established dynamically when the first MN appears at MAG or pre-configured between MAG and LMA. The MN sends a MLD report message in response to the MLD query message from MAG. The MAG is acting as a MLD proxy. Therefore, the MAG will send the aggregated message to LMA. The multicast data will then flow between MN and MAG. When MN moves to another network region...
and is attached to the NMAG, the NMAG sends a MLD query to MN. The MN sends a MLD report on the response of MLD query from NMAG. The NMAG then sends the aggregated message (i.e., for more than one MNs) to LMA. The multicast data will then flow between NMAG and MN.

Another work was done to improve the PMIPv6-based mobile multicasting scheme for fast handover [16]. This scheme can reduce the handover latency and packet loss by specifying the bi-directional tunneling between PMAG and NMAG, in which NMAG requires the multicast context information so as to set up the bi-directional tunnel to deliver multicast data to MN continuously. This context information contains the MN_ID.

In this paper, we will focus on the works in [17] and [18], because these two schemes use the PMIP tunnel between the MAGs and LMA, and also they uses the MLD support in the PMIP domain. In these two schemes, the MAG acts as the MLD proxy functionality. Our proposed scheme will also use these functionalities.

In [17], which will be called the PMIP-MLD in this paper, whenever MN moves into another network region, and the link comes up between NMAG and MN, as shown in Fig 1, the MN sends a router solicitation message to NMAG and receives a router advertisement message from NMAG. The PMIP binding update operations are performed after the MAG determines the corresponding LMA. Then the new MAG forwards the MLD query for group membership to MN, and MN sends a MLD report message as the response of MLD query from NMAG. The MAG is acting as the MLD Proxy, and the NMAG will forwards the aggregated membership report to LMA. The multicast traffic will then start between MN and NMAG.

In [18], which is called the PMIPv6 extension for multicast in [18], the MAG operates as an MLD proxy. Whenever MN is attached to NMAG as shown in Fig 2, the NMAG requests the context transfer information to PMAG. The PMAG can use a context transfer protocol so as to deliver the MN profile to NMAG and multicast context information. The NMAG subscribes the multicast channel on behalf of MN by sending PBU-M (Proxy Binding Update for Multicasting) to LMA. LMA replies to NMAG with a Proxy Binding ACK (PBA). If the PBA message has the status field of ‘0’, it means that the PBU is accepted and then NMAG will establish a multicast tunnel between LMA and NMAG for forwarding of multicast data packets. After that, to receive the new multicast data packets, MN will exchange the messages of MLD query and report with NMAG, and further NMAG will exchange the MLD report message with LMA.

In this PMIP-MM scheme, there is the same problem of packet loss and larger handover latency, and unnecessary data transmission from PMAG, when the last MN leaves the multicast group by handover.

In the PMIPv6 extension for multicast in [18], which is called the PMIP-MM in this paper, the MAG operates as an MLD proxy. Whenever MN is attached to NMAG as shown in Fig 2, the NMAG requests the context transfer information to PMAG. The PMAG can use a context transfer protocol so as to deliver the MN profile to NMAG and multicast context information. The NMAG subscribes the multicast channel on behalf of MN by sending PBU-M (Proxy Binding Update for Multicasting) to LMA. LMA replies to NMAG with a Proxy Binding ACK (PBA). If the PBA message has the status field of ‘0’, it means that the PBU is accepted and then NMAG will establish a multicast tunnel between LMA and NMAG for forwarding of multicast data packets. After that, to receive the new multicast data packets, MN will exchange the messages of MLD query and report with NMAG, and further NMAG will exchange the MLD report message with LMA.

In this PMIP-MM scheme, there is the same problem of packet loss and larger handover latency, and unnecessary data transmission from PMAG, when the last MN leaves the multicast group by handover.

III. PROPOSED SCHEME

In this paper, we proposed a multicast handover agent (MHA) that is used for fast handover, in which each MHA maintains a cache that contains the list of active MNs per group. The MHA will be used to reduce the unnecessary data transmissions, when the last MN leaves the group by handover. This cache is also used to support the fast join during handover. The list of active MNs may be maintained with a suitable timer.

To support handover, we consider the following L2 triggers: Link-Detected (LD) and Link-Up (LU) of the new link, as per the IEEE 802.21 [19]. It is noted that these L2 triggers can contain the topology information of neighboring
MAGs or LMAs (e.g., IP address of LMA or identifier of MAG) in the network domain.

Figure 3 shows the proposed PMIP-MHA handover operations. When LD trigger is detected, MN sends a proxy MLD report message to PMAG for pre-registration before L2 handoff, and then MHA of PMAG updates its cache.

![Figure 3. Proposed PMIP-MHA operations](image)

At the same time, the MHA of PMAG initiates the fast join with MHA of NMAG, in which we assume that the LD trigger contains the information of NMAG with the help of IEEE 802.21 [19].

Now, the MHA of PMAG sends a context transfer request message to MHA of NMAG. The NMAG sends the context transfer acknowledgement to PMAG as the response of context transfer request. The context transfer request message contains information of MN and group address, by which the MHA of NMAG sends a report to LMA. With LU event, a new link connection is established, there is no need of router discovery messages because the context transfer message contains the information of MN and thus the MN can receive multicast data from NMAG after the PMIP binding update.

IV. PERFORMANCE ANALYSIS

In order to evaluate the performance of proposed scheme, we study the handover latency and packet loss costs during handover. We consider a network environment with a single domain with 2 subnets. The whole domain is served by a single LMA and each subnet is served by a single MAG as shown in Fig 4.

![Figure 4. Network Model](image)

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Now, the MHA of PMAG sends a context transfer request message to MHA of NMAG. The NMAG sends the context transfer acknowledgement to PMAG as the response of context transfer request. The context transfer request message contains information of MN and group address, by which the MHA of NMAG sends a report to LMA. With LU event, a new link connection is established, there is no need of router discovery messages because the context transfer message contains the information of MN and thus the MN can receive multicast data from NMAG after the PMIP binding update.

In the figure, the link between MN and MAG are wireless links and the link between MAG and LMA are wired links.

For analysis, we define the following notations:

- $S_c$ and $S_d$: sizes of control and data packets;
- $B_w$ and $B_{wl}$: bandwidths of wired and wireless links;
- $L_w$ and $L_{wl}$: link delays for wired and wireless links;
- $d_{MN-MAG}$: hop count between MN and MAG;
- $d_{MAG-LMA}$: hop count between MAG and LMA.

Let $t(s, d_{x-y})$ denote the transmission delay of a message of size $s$ sent from ‘x’ to ‘y’ via the ‘wireless’ link. Then, $t(s, d_{x-y})$ can be expressed as follows:

For control packets: $t(s, d_{x-y}) = d_{x-y} \times \left(\frac{S_c}{B_{wl}} + L_{wl}\right)$
For data packets: $t(s, d_{x-y}) = d_{x-y} \times \left(\frac{S_d}{B_{wl}} + L_{wl}\right)$

Let $t(s, d_{x-y})$ denote the transmission delay of a message of size $s$ sent from ‘x’ to ‘y’ via ‘wired’ link. Then, $t(s, d_{x-y})$ can be expressed as follows:

For control packets: $t(s, d_{x-y}) = d_{x-y} \times \left(\frac{S_c}{B_w} + L_w\right)$
For data packets: $t(s, d_{x-y}) = d_{x-y} \times \left(\frac{S_d}{B_w} + L_w\right)$

A. Multicast Handover Latency

The handover latency is defined as the time interval from the time that MN loses L2 connection with PMAG until the time that MN receives the first packet from NMAG.

The handover latency of the PMIP-MLD can be composed of link switching delay ($T_{l2}$), router discovery time ($T_{RD}$), Proxy binding update/ack time (2T_{PBUPBA}(S_c)), delay of MLD query and MLD report between MN and NMAG (2T_{MLD}(S_c)), delay of MLD report (T_{MLD}(S_c)) between NMAG and LMA, delay of data between the LMA and NMAG ($T_{LMA-NMAG}(S_d)$), and delay of data between the NMAG and MN ($T_{NMAG-MN}(S_d)$). Then, we can derive the equation of the handover latency of the PMIP-MLD as follows:

$$HL_{PMIP-MLD} = T_{l2} + T_{RD} + 2T_{PBUPBA}(S_c) + 2T_{MLD}(S_c) + T_{MLD}(S_c) + T_{LMA-NMAG}(S_d) + T_{NMAG-MN}(S_d)$$ (1)
The handover latency of the PMIP-MM can be composed of link switching delay ($T_{l2}$), Router discovery time ($T_{RD}$), context request and transfer time ($2T_{CReq/CXTP}(S_c)$), Proxy binding update/ack time ($2TPBU/PBA(S_c)$), delay of data between the LMA and NMAG ($T_{LMA-NMAG}(S_d)$), and delay of data between the NMAG and MN ($T_{NMAG-MN}(S_d)$). We can derive the equation of the handover latency of the PMIP-MM as follows:

$$HL_{PMIP-MM} = T_{l2} + T_{RD} + 2T_{CReq/CXTP}(S_c) + 2TPBU/PBA(S_c) + T_{LMA-NMAG}(S_d) + T_{NMAG-MN}(S_d)$$ (2)

The handover latency of the PMIP-MHA can be composed of link switching delay ($T_{l2}$), Proxy binding update/ack time ($2TPBU/PBA(S_c)$), delay of data between the LMA and NMAG ($T_{LMA-NMAG}(S_d)$) time, and delay of data between the NMAG and MN ($T_{NMAG-MN}(S_d)$). We can derive the equation of the handover latency of the PMIP-MHA as follows:

$$HL_{PMIP-MHA} = T_{l2} + 2TPBU/PBA(S_c) + T_{LMA-NMAG}(S_d) + T_{NMAG-MN}(S_d)$$ (3)

### B. Packet Loss Cost

In this paper, the packet loss cost which is denoted by $C_{loss}$. Let us define $\lambda_p$ as the packet arrival rate in the number of packets per unit time.

The packet loss cost of PMIP-MLD is computed as follows:

$$C_{loss}(PMIP-MLD) = \lambda_p \times [T_{l2} + T_{RD} + 2TPBU/PBA(S_c) + 2T_{MLD}(S_c) + T_{MLD}(S_c)]$$ (4)

The packet loss cost of PMIP-MM is computed as follows:

$$C_{loss}(PMIP-MM) = \lambda_p \times [T_{l2} + T_{RD} + 2T_{CReq/CXTP}(S_c) + 2TPBU/PBA(S_c)]$$ (5)

The packet loss cost of PMIP-MHA is computed as follows:

$$C_{loss}(PMIP-MHA) = \lambda_p \times [T_{l2} + 2TPBU/PBA(S_c)]$$ (6)

### V. NUMERICAL RESULTS

Based on the analytical equations for the handover latency and packet loss cost given so far, we compare the performance of the existing and proposed schemes. For the numerical analysis, we configure the default parameter values as those described in Table 1, by referring to [20].

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<th>Parameters</th>
<th>Symbols</th>
<th>Values</th>
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<td>Router Discovery Delay</td>
<td>$T_{RD}$</td>
<td>100 ms</td>
</tr>
<tr>
<td>L2 Handoff Delay</td>
<td>$T_{l2}$</td>
<td>50 ms</td>
</tr>
<tr>
<td>Wired link bandwidth</td>
<td>$B_w$</td>
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</tr>
<tr>
<td>Wireless Link Bandwidth</td>
<td>$B_{wl}$</td>
<td>11 Mbps</td>
</tr>
<tr>
<td>Wired Link Delay</td>
<td>$L_w$</td>
<td>2 ms</td>
</tr>
<tr>
<td>Wireless Link Delay</td>
<td>$L_{wl}$</td>
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</tr>
<tr>
<td>Control Packet Size</td>
<td>$S_c$</td>
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</tr>
<tr>
<td>Data packet Size</td>
<td>$S_d$</td>
<td>200 bytes</td>
</tr>
<tr>
<td>Packet Arrival Rate</td>
<td>$\lambda_p$</td>
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</tr>
<tr>
<td>hops between MAG and LMA</td>
<td>$d_{MAG-LMA}$</td>
<td>2</td>
</tr>
<tr>
<td>hops between MN and MAG</td>
<td>$d_{MN-MAG}$</td>
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The handover latency is depicted in Figure 5 as a function of the link switching delay. We observe that the handover latency increases proportionally to the link switching delay for all the schemes. It is noted that the proposed scheme (PMIP-MHA) outperforms existing schemes (PMIP-MLD and PMIP-MM), and they are more efficient when the link switching delay increases. The gap of handover latency among proposed scheme and existing schemes gets larger, as augmentation of link switching delay.

![Figure 5. Impact of Link Switching Delay on handover latency](image)

In Figure 6, we can see that the handover latency increases proportionally with the wireless link delay. We observe that the existing schemes (PMIP-MLD and PMIP-MM) have worse results, while the proposed scheme (PMIP-MHA) performs better than the existing schemes.
Figure 6 shows the impacts of router discovery delay on the handover latency. The proposed scheme (PMIP-MHA) is not affected by router discovery delay, because of the context transfer mechanisms is done before the link-up, whereas the handover latency of existing schemes gets larger, as router discovery delay increases. We can also see that the proposed PMIP-MHA scheme provides lower handover latency than the existing schemes.

Figure 8 illustrates the packet loss cost as a function of packet arrival rate ($\lambda_p$). We can see that the packet loss cost increases proportionally to $\lambda_p$ for all the schemes. The proposed scheme outperform existing schemes (PMIP-MLD and PMIP-MM). The proposed scheme are more efficient when $\lambda_p$ increases. This means that the proposed scheme is well suited to real time applications in which periodic packets are sent at a high rate.

Figure 9 shows that the proposed scheme provides better performance for packet loss cost than the existing schemes, as the link switching delay increases. The packet loss will be also lesser for proposed scheme than the existing schemes as the link switching delay increases.

Figure 10 shows the impacts of the wireless link delay on the packet loss cost. From the figure, we can see that the PMIP-MLD scheme depends on the wireless link delay very much, whereas PMIP-MM and PMIP-MHA are not affected by wireless link delay. On the other hand, we can see the proposed PMIP-MHA scheme give smaller packet loss cost than the PMIP-MM scheme.
VI. CONCLUSION
This paper proposed the multicast handover agent (MHA) to support fast handover in the PMIPv6 based wireless networks. To reduce the packet losses and handover latency and unwanted data transmissions of the existing schemes during handover, we proposed the multicast handover agent scheme for seamless multicast handover in PMIP-based networks. The performance has been evaluated in the terms of handover latency and packet loss cost. The analyzed result shows that our scheme can reduce the handover latency and packet loss cost, compared to the existing schemes.

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