Localized Management for Proxy Mobile IPv6

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Abstract— **Proxy Mobile IPv6 is a promising protocol for supporting mobility. Unlike Mobile IPv6, which is based on host-mobility, the Proxy Mobile IPv6 is based on network-based mobility so that it can remove additional implementations on a Mobile Node (MN). Due to this feature, Proxy Mobile IPv6 has been considered as a better protocol than Mobile IPv6 in supporting mobility. However, PMIPv6 still has a limitation, called localized management. All the messages from a MN should go through a Local Mobility Anchor or LMA, which causes the selection of non-optimal path for message exchanging as well as the bottleneck problem. Some previous works applies route optimization mechanisms; however, they are concerned about the data packet only. A little attention has been given to route optimization of both binding message and the data packet. In this paper, to provide safety for the bottleneck problem and shortest path for both binding message and the data packet, we propose the Localized Management support PMIPv6 (LM-PMIPv6) that support localized handover and route optimization using the reactive fast handover mechanism and hierarchical architecture. It enables handover without LMA's participation and has smaller handover delay and packet delivery cost compared with PMIPv6.**

I. Introduction

The Proxy Mobile IPv6 (PMIPv6) [1] is a kind of a IP protocol that support network mobility. Due to this feature, PMIPv6 is considered as a promising IP protocol for the Internet. PMIPv6 is a collection of several mobile nodes (MN), mobile access gateways (MAG) and local mobility anchor (LMA).. An MN is a client equipment and MAG is an access point (AP) for the MNs. The LMA manages the MN's connections and acts as anchor point for external network.

According to Table 1 [2], PMIPv6 is a suitable mobility support IP protocol for the Internet because of its features. PMIPv6 has small air interface traffic overhead, tunneling overhead and handover delay. And PMIPv6 does not require an additional implementation on a MN.

Nevertheless these merits, PMIPv6 still has some demerits. In PMIPv6, all the messages should go through an LMA even though the destination entity is located at the same PMIPv6 domain. To solve this problem, route optimization mechanisms are proposed. But almost all of these mechanisms focus on the path for the data packet only. More explicitly, they consider route optimization for the data packet between an MN and the correspond node (CN) when the CN is in the same PMIPv6 domain. However, they do not consider the binding message route optimization. In other words, the route optimization mechanism should consider both binding message and data packets.

TABLE 1 Comparison of mobility support IP protocol

Features	MIPv6[3]	FMIPv6[4]	PMIPv6
Air interface traffic overhead	High	High	Low
Terminal modifications	Yes	Yes	No
Tunnelling overhead at MN	High	High	Low
Handover delay	High	High	Low

In this paper, we propose localized management for Proxy Mobile IPv6 (LM-PMIPv6) which enables localized management in PMIPv6 domain. We design LM-PMIPv6 using reactive fast handover mechanism and the hierarchical architecture. LM-PMIPv6 enables localized management that it has small handover delay than PMIPv6.

The remainder of the paper is organized as follows. Section II discusses the related works. Section III describes the motivation and Section IV presents the proposed LM-PMIPv6 scheme. Section V describes the performance evaluation of the proposed LM-PMIPv6. Finally, Section VI concludes our works.

II. Related Works

Jun Lei and Xiaoming Fu [5] proposed F-MIPv6 that combines PMIPv6 with FMIPv6 and MIH-PMIPv6 that combines PMIPv6 with 802.21 MIHF. FMIPv6, HMIPv6, F-HMIPv6, PMIPv6 and these proposed protocols are compared considering the handover delay and handover signalling overhead. They conclude that handover delay of PMIPv6 increases when delay between the LMA and AR rises. It means that a localized mobility management is required to

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decrease the delay between an LMA and an AR, especially for PMIPv6 where all binding messages pass through the LMA. To improve handover delay and handover signalling overhead simultaneously, the PMIPv6 should be designed by a hierarchical architecture.

Byung-Jin Han et. al. [6] proposed route optimization mechanism using the routing table at the MAG. This proposal reduces the packet delivery cost by decreasing signalling cost. However, the authors did not consider other factors like binding message costs and localized mobility.

Huu-Nghia Nguyen et. al. [7] proposes a cluster based PMIPv6 with two prefixes: one global and another is for site-scope. Using these prefixes, their scheme forms a cluster-based architecture. However, it also needs an LMA for maintaining connections to the external network.

There are some other proposals for supporting route optimization [8]. However, most of the suggestions are not concerned about the multi-hop environment between the MAG and LMA, and they usually change the signal message flow toward the LMA in order to get benefits from the traditional protocols.

III. Motivation

A. Bottleneck problem

In PMIPv6, an LMA should maintain binding cache entry (BCE) to keep binding information for each MN. So, MN and LMA exchange PBU (Proxy Binding Update) and PBA (Proxy Binding Acknowledgement) for updating the BCE when an MAG detects an MN movement.

When an MN enters into the PMIPv6 for the first time, the LMA adds the MN's identifier, proxy-CoA (Care of Address) and HoA (Home Address) in its BCE. The LMA assigns HoA to MN and makes bi-directional tunnel between the LMA and MAG. When the MN is moving and changes the serving MAG, only the proxy-CoA at the BCE is modified to denote the new MAG's proxy-CoA. So HoA is not changed during the handover phase in a PMIPv6 domain. To avoid the bottleneck problem, we need to re-design PMIPv6 that exchange signal message locally and maintain proxy-CoA and MN table in each MAG.

B. Handover Delay

Another problem is the huge handover delay. According to [9][10], handover delay is related with number of hops and it is especially affected by the network-layer handover delay. Fig. 1 shows the relationship between handover delay and number of hops. Network-layer delay increases with number of hops. Unlike network-layer delay, link-layer delay is almost fixed regardless of hop count. So, Fig. 1 shows that signal message for binding should go through shortest path to minimize handover delay.

When handover event occurs in PMIPv6, the previous MAG (pMAG) and the LMA exchange PBU /PBA messages for deregistration. After that, LMA waits for the PBU message for registration. During this term, LMA runs a *MinDelayBeforeBCEDelete* timer to maintain the session of the MN. When the MN is attached again later, LMA considers the MN as not a new joining but handover, and the LMA maintains old HoA of MN. During this process, MN's Proxy-CoA is changed and MN's HoA remains unchanged. If the timer is finished and the MN is attached to the PMIPv6 domain, LMA considers the MN as new joining and MN's Proxy-CoA and HoA are changed together.

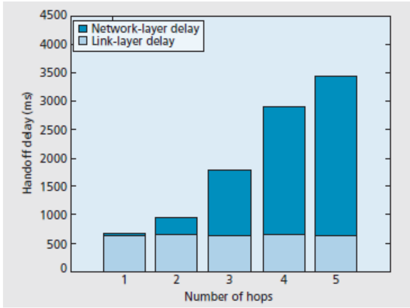

Fig. 1 The relationship between handover delay and number of hops

If all the handover signal messages go through the LMA, a large number of hops will be required because the path to a neighbourhood MAG is shorter than the path to LMA. To decrease handover delay, we should re-design PMIPv6 to establish handover locally.

C. Route Optimization

Route optimization is discussed to make the shortest path between MN and CN. Traditional PMIPv6 supports communication between the MN and CN through LMA even though the CN is located at the same PMIPv6 domain. As all the data packets from the MN or CN have to pass through the tunnel interface, the tunnel header sets the source address to LMAA or Proxy-CoA, and the destination address to LMAA or Proxy-CoA. To establish route optimization between MN and CN, PMIPv6 domain has to check whether data packet's destination address is exist in identical domain or not and route changing mechanism to build shortest path. We use LBCE (Local Binding Cache Entry) for check CN's existence in same PMIPv6 domain and send the data packet to CN through shorter path than PMIPv6.

IV. The Proposed Scheme of LM-PMIPv6

In this section, we explain the detailed operation of LM-PMIPv6. We re-design the PMIPv6 using reactive fast handover mechanism and hierarchical architecture to accomplish the localized management.

A. Comparison about handover procedure between PMIPv6 and LM-PMIPv6

LM-PMIPv6 has hierarchical handover procedure that changes signal message locally. Fig. 2 and Fig. 3 show the handover procedure of PMIPv6 and that of LM-PMIPv6, respectively.

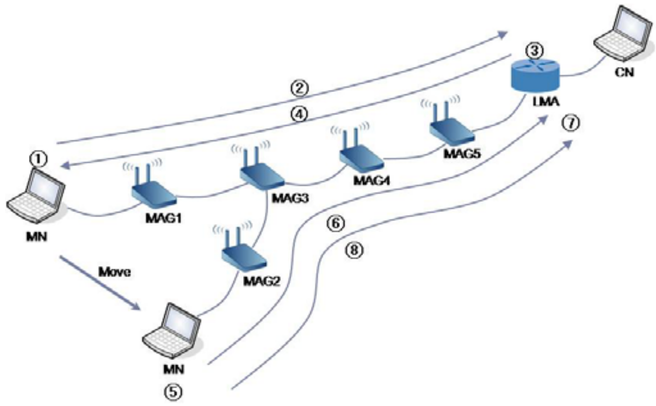

Fig. 2 The handover procedure of PMIPv6

If MN moves, MN is detached from the pMAG (MAG1) first (①). And serving MAG sends PBU to LMA through pMAG (②). After that LMA enables MinDelayBeforeBCEDelete timer for deregistration (③). And LMA sends PBA to MN for notifying that MN is removed successfully from PMIPv6 domain (④). Then, MN is attached to an nMAG (new MAG, MAG2) (⑤). nMAG sends PBU for LMA to notifying that MN is now attached with nMAG (⑥). LMA updates BCE for new connection (⑦) and sends back PBA to MAG2 to notify that MN is successfully added to PMIPv6 domain (⑧).

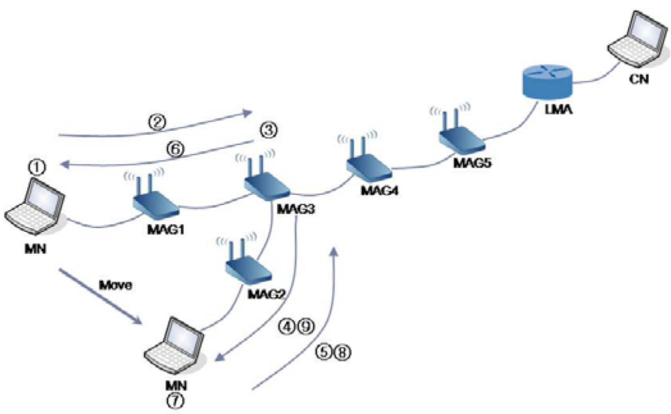

Fig. 3 The handover procedure of LM-PMIPv6

On the other hand, in LM-PMIPv6, before an MN moves, it gets nMAG's Proxy CoA using LGD (Link Going Down) [11] for reactive fast handover, and then it detaches (①). The serving MAG (MAG2) sends the LH-PBU message including nMAG's (MAG2) proxy-CoA to the parent MAG (②). Each parent MAG checks whether new MAG's Proxy CoA is maintained on LBCE or not. In Fig. 3, common parent MAG (MAG3)'s LBCE maintains nMAG (MAG2)'s information (③). Then the common parent MAG (MAG3) sends PBU toward nMAG (MAG2) and all the MAGs which is located at path toward nMAG (MAG2) update it's LBCE that MN is attached nMAG (MAG2) except the common parent MAG's (MAG3) LBCE (④). Then, PBU send back to common parent MAG (MAG3) for acknowledgement (⑤). This message is sent back to the pMAG (MAG1) for notifying that PMIPv6 domain is ready to handover (⑥). As soon as receiving this message, the MN attaches to MAG2 (⑦).The pMAG (MAG2) sends PBU for registration (⑧). Because all the MAGs which located at path toward a common parent MAG (MAG3) are updated already, handover is done only after common parent MAG's (MAG3) LBCE is updated. After that, the common parent MAG (MAG3) sends PBA message for acknowledgement (⑨).

B. Comparison about binding architecture between PMIPv6 and LM-PMIPv6

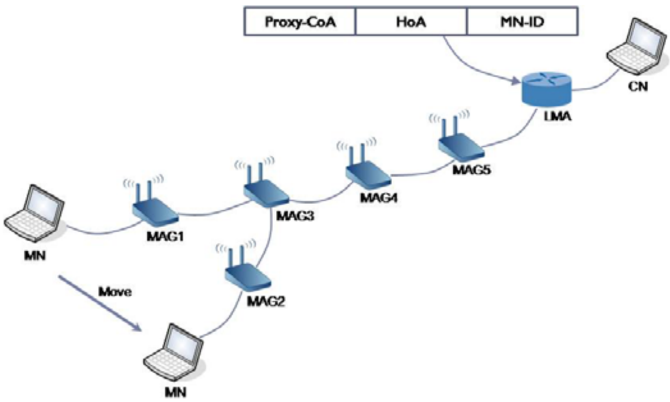

Fig. 4 The binding architecture of PMIPv6

Fig. 4 shows the binding architecture of current PMIPv6 protocol. In this case, BCE is required only for supporting MN's movement. That is why all the signal messages set focus on LMA that may cause the bottleneck problem.

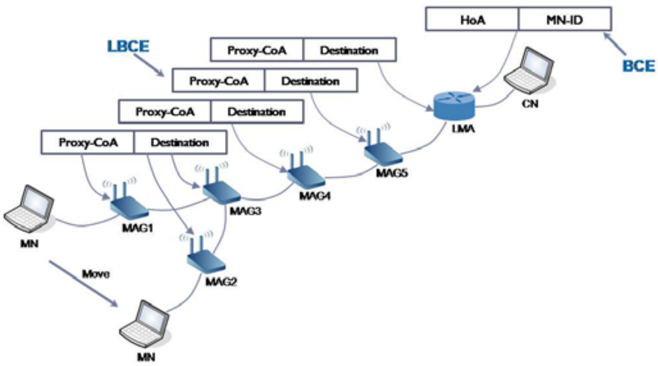

Fig. 5 The binding architecture of LM-PMIPv6

However, as shown in Fig. 5, all MAGs and LMA maintain LBCE for localized handover to support handover locally in LM-PMIPv6. The LBCE points to the leaf MAG by comparing the destination address. So, when MN moves to nMAG (MAG2) area, all the signal messages for handover are processed at the common parent MAG (MAG3) and its branch MAG. In Fig. 5, MAG5's LBCE is recorded as [MAG4:MN,MAG1,MAG3,MAG4] and MAG3's LBCE is recorded as [MAG1:MN,MAG1], [MAG2:MAG2] if MAG1 is the serving MAG of the MN.

C. PBU (Proxy Binding Update) and PBA (Proxy Binding Acknowledgement)

MN and LMA have to change PBU/PBA for binding update. Traditional PMIPv6 uses Proxy-CoA and LMAA for source address and destination address of PBU. However, in LM-PMIPv6, to send binding message directly, it uses Proxy-CoA of pMAG and Proxy-CoA of nMAG for source address and destination address of PBU and PBA, respectively. Proxy-CoA can be obtained using the MIH function, named LGD primitive to support reactive fast handover mechanism. If there is no matched binding information in the LBCE of a MAG, the MAG relays the PBU message to the parent MAG until it reaches the LMA. If the LMA does not maintain binding information of the nMAG also, then it considers that the movement event requires a global handover and such a case is out of the scope of this paper.

D. Route Optimization

In PMIPv6, the format of the tunnelled packet from LMA to MAG is shown Fig. 6. To accomplish communication between MN and CN, tunnel header maintains source address as LMAA and destination address as Proxy-CoA in PMIPv6.

IPv6 header (src= LMAA, dst=Proxy CoA)	/* Tunnel Header */
ESP Header in tunnel mode	/* ESP Header */
IPv6 header (src= MN-HoA, dst= CN)	/* Packet Header */
Upper layer protocols	/* Packet Content */

Fig. 6 The format of the PMIPv6 tunnelled packet

To communicate successfully between MN and CN located at external network, the tunnel header of LM-PMIPv6 should be modified. LMA's BCE does not maintain serving MAG's Proxy-CoA anymore. Instead, only 1-depth leaf MAG's Proxy-CoA is maintained in LMA's LBCE. So, tunnel header is required to be modified. Fig. 7 shows the format of the modified tunnelled packet for LM-PMIPv6.

IPv6 header (src= Proxy-CoA(Serving MAG's proxy CoA or LMAA), dst= Proxy-CoA (1-depth leaf MAG's proxy-CoA))	/* Tunnel Header */
ESP Header in tunnel mode	/* ESP Header */
IPv6 header (src= MN-HoA, dst= CN)	/* Packet Header */
Upper layer protocols	/* Packet Content */

Fig. 7 The format of the tunnelled packet of LM-PMIPv6

In case of the tunnelled downlink packets from the CN at external network, the source address of the tunnelled header is LMAA, which is similar to PMIPv6. However, when the downlink packet from CN at the internal network and the uplink packet from CN at the internal network are maintain its source address of tunnel header as serving MAG's proxy CoA.

The packet is relayed toward the parent MAG. If current MAG does not maintain the destination address information, MAG considers that CN is not located at its branch MAG and relays the packet to its parent MAG. This procedure is performed recursively until LMA is reached. If LMA's LBCE does not maintain the destination address information, LMA considers that the packet is for an external network.

E. PBRU (Proxy Binding Remove Request) and PBRA (Proxy Binding Remove Acknowledgement)

In PMIPv6, BCE uses *timeout* parameter for maintaining the mobility session of an MN. *Timeout* starts counting after MN is detached and wait for handover event from same MN with Proxy-CoA. If MN is attached again before time breaks, then handover procedure is performed. If MN is attached later than time breaks, is termed as *new joining* and BCE registers MN again. When timeout occurs, binding entry for MN is deleted.

In LM-PMIPv6, *timeout* is managed by MN's serving MAG. So we need a new binding message for deleting MN's binding entry which is maintained by LMA's BCE.

PBRU is occurred by MAG to delete MN's binding cache. It is maintained by MAG and LMA which is located along the path toward LMA. PBRA is an acknowledgement message of PBRU that return its result.

V. Performance Evaluation

LM-PMIPv6 is a better Protocol than PMIPv6 considering the bottleneck problem, handover delay and route optimization.

In multi-hop-based environment, all the signal messages for binding are centralized to LMA which incurs network overhead at LMA by enormous signalling messages. However through LM-PMIPv6, handover signalling message can be exchanged among neighbour MAG and its common parent MAG. So LM-PMIPv6 has less probability in suffering the bottleneck problem than PMIPv6.

Handover delay is proportional to the number of hops. Strictly speaking, not link-layer delay but network-layer delay has relationship with number of hops. When MN moves to PMIPv6 domain, it exchanges PBU / PBA with LMA which has a large number of hops. However, in case of LM-PMIPv6, it supports binding message exchange through shorter path than PMIPv6 by localized management. Consequently, handover delay is decreased by number of hops between serving MAG and common parent MAG.

Considering other route optimization mechanisms which connect pMAG and nMAG directly, LM-PMIPv6 has a bit higher packet delivery cost than that mechanism because of the route establishment for the data packet by common parent

MAG. However, LM-PMIPv6 has a lower packet delivery cost than PMIPv6 and the gap becomes larger in large-scale PMIPv6 domain. Table 2 shows performance comparison between PMIPv6, RO-PMIPv6(Route optimization support PMIPv6), and LM-PMIPv6. In Table 2, we consider that RO-PMIPv6 is derived from M. Liebsch et al. scheme proposed in [8] which uses RO signalling message for route optimization.

TABLE 2 PERFORMANCE COMPARISON OF MOBILITY SUPPORT IP PROTOCOL

Features	PMIPv6	RO-PMIPv6	LM-PMIPv6
Probability of the bottleneck problem	High	High	Low
Handover delay	High	High	Low
Packet delivery cost	High	Very low	Low

VI. CONCLUSION

PMIPv6 is considered as a promising mobility support IP Protocol for Internet and it will be deployed in the near future. Even though PMIPv6 shows better performance than other IP Protocols, it still has problems like high bottleneck probability and higher handover delay for multi-hop based environment and non-optimal packet delivery. To solve these problems, we re-design PMIPv6 using reactive fast handover mechanism and hierarchical architecture. In other words, we proposed LBCE, PBRU and PBRA in different way and change BCE, PBU, PBA and tunnel header for supporting localized management. LM-PMIPv6 can communicate with CN which is located at both internal and external network through shorter path than PMIPv6 and supports localized mobility that decreases bottleneck probability and handover delay.

Although PMIPv6 is considered as a promising protocol for Internet, PMIPv6 has no specific concerns on global mobility management and so on. We need more research about LM-PMIPv6, related with the problems of PMIPv6's and require numerical analysis and real test-bed for verification as a future work.

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