Design and Implementation of PMIPv6 Based Multihoming for Make-Before-Break Handover

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Abstract

Unlike the various existing protocols for IP mobility management such as Mobile IPv6 (MIPv6), Proxy Mobile IPv6 (PMIPv6), which is a network-based approach, has salient features that expedite IP mobility management deployment. However, moving from one access network to another gives rise to a Break-Before-Make handover process that incurs packet losses and service disruption for the Mobile Node (MN) in the basic PMIPv6.

Mobility support combined with multihoming is the missing piece in basic PMIPv6. This motivated us to design and analyze the PMIPv6 multihoming based Make-Before-Break handover mechanism and implement it in a real network test-bed.

From the experimental results, we show that our approach completely mitigates the consequences of handover latency and packet losses when applied to the basic PMIPv6 protocol.

Keywords: Handover, PMIPv6 , Multihoming.

1 Introduction

In wireless/mobile networks, Mobile Node (MN) can change their attachment points when communicating with a Correspondent Node (CN). Hence, mobility management is essential in tracking the MN's current location so that its data can be delivered correctly.

Unlike the various existing host-based protocols for IP mobility management such as Mobile IPv6 (MIPv6) [1], Proxy Mobile IPv6 (PMIPv6) which is a network-based approach [2], has salient features that expedite IP mobility management deployment [3][4].

The serving network controls mobility management on behalf of the MN, which is not required to participate in any mobility-related signaling.

Recently, a number of mobile devices supporting multiple network interfaces have hit the market. Multihoming is the capability of these devices to connect to multiple networks, yielding the following benefits [5-7]:

- Fault-Tolerance/Redundancy
- Load-Sharing
- Policy-Routing
- Cost based control
- Make-Before-Break handover

Multihoming can supplement the current mobility solutions such as MIPv6. However, mobility support combined with multihoming is the missing piece in the basic PMIPv6 protocol. In this paper, we design and implement PMIPv6 based multihoming for Make-Before-Break handover, where the MN contains multiple interfaces.

In the following sections, we firstly present the basic PMIPv6 protocol together with its multihoming extension. We then present the implementation design for PMIPv6 and its multihoming extension after a simple comparison of the handover performance. At last, we set up a test-bed, conduct some experiments and present conclusions.

2 Related Work

2.1 PMIPv6

PMIPv6 is intended to provide network-based IP mobility management support to the MN, without requiring its participation in any IP mobility related signaling. The mobility entities in the network will track the MN's movement, initiate mobility signaling and setup the required routing state. The core functional entities in the PMIPv6 infrastructure are the Local Mobility Anchor (LMA) and the Mobile Access Gateway (MAG). The LMA is responsible for maintaining the MN's reachability state and is the topological anchor point of the MN's Home Network Prefix (HNP). The MAG is the entity that performs mobility management on behalf of the MN by residing in the access link where the MN is anchored. The MAG is responsible for detecting the MN's movement to and from the access link and for initiating binding registration to the MN's

LMA. Figure 1 shows the signaling call flow for the basic PMIPv6.

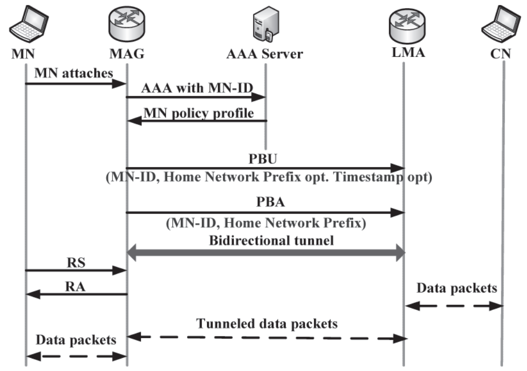

Figure 1 Signaling Call Flow of Basic PMIPv6

Once an IPv6-enabled MN attaches to a MAG and after access authentication, the MAG can obtain the MN's configuration associated profile based on MN's identifier (MN-ID) from the policy store, such as an AAA server.

For updating the LMA about the current location of the MN, the MAG sends a Proxy Binding Update (PBU) message to the MN's LMA. Upon accepting this PBU message, the LMA sends back a Proxy Binding Acknowledgement (PBA) message including the MN's HNP. It also creates a binding cache entry and establishes a bidirectional tunnel to the MAG. The MAG on receiving the PBA message sets up a bi-directional tunnel to the LMA and establishes the data path for the MN's traffic. At this point, the MAG has all the required information for emulating the MN's home link. When MN typically sends a Router Solicitation (RS) message, MAG sends Router Advertisement (RA) messages to the MN on the access link to advertise the MN's HNP as the hosted on-link-prefix. Since the MN always detects the same home network prefix on the access link, it can continue to use its Home Address (MN-HoA). Such an operation exactly matches the purpose of location privacy since it is now quite difficult for attackers to obtain the current MN location.

After the bidirectional tunnel between LMA and MAG is successfully set up, all traffic sent from the MN gets routed to its LMA through the tunnel. The LMA receives any data packets sent to the MN and forwards them to the MAG through the tunnel. After receiving the packets, the MAG on the other end of the tunnel removes the outer header and forwards the packets to the MN.

If the MN changes its point of attachment after obtaining the initial address configuration in the PMIPv6 domain, the previous MAG (pMAG) on the previous link will detect the MN's detachment from the link and will signal the LMA to remove the binding and routing state for that MN. The new MAG (nMAG) on the new access link upon detecting the MN on its access link will signal the LMA for updating the binding state. Once that signaling is completed, the MN will continue to receive the RAs containing its HNP, making it believe it is still on the same link and it will use the same address configuration on the new access link.

2.2 Multihoming Extension of PMIPv6

Make-Before-Break handovers with multiple interfaces can be introduced to any mobility management protocol as long as the identity of the MN is independent of the interface it uses. Thus, any mobility management protocol which operates on network layer or above can take advantage of multihoming to execute Make-Before-Break handover.

The MN installed with multiple interfaces may attach to different MAGs in a PMIPv6 domain simultaneously. The LMA will receive multiple PBUs from the MAGs to which the MN is attached via its multiple interfaces [8][9]. To manage the multiple bindings for the same MN, the PBU and PBA messages are extended. The Interface Identifier Option [11] is used to identify the specific MN interface. The Handoff Indicator Option [11] is used to notify the types of connections. Figure 2 shows the signaling call flow for the multi-interface MN's handover from pMAG to nMAG. The interface 1 (If1) and interface 2 (If2) are two interfaces of MN and connected to the pMAG and nMAG separately.

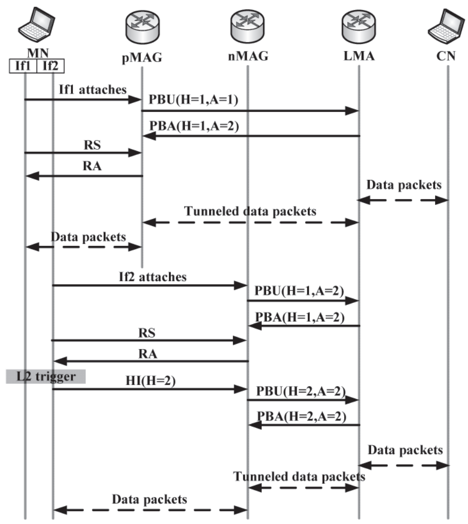

Figure 2 Signaling Call Flow of Multihoming PMIPv6

When MN enters the PMIPv6 domain and attaches to an access link with If1, pMAG on that access link will detect the MN's attachment. For updating the LMA about the MN's current location, the pMAG sends a PBU message to the MN's LMA with the handover indicator set to "1" which means that it is an attachment over a new interface to this MAG. The interface indication is set to "1" which means that the MN uses the interface indicated by "1" to attach to pMAG. Upon accepting this PBU message, the LMA sends back a PBA message including the MN's HNP. It also creates a binding cache entry and establishes a bidirectional tunnel to the pMAG. The pMAG on receiving the PBA message sets up a bi-directional tunnel to the LMA and sets up the data path for the MN's traffic. Because the LMA recognizes that it is the first binding to that MN, LMA transmits packets through this newly constructed tunnel.

When the MN attaches to an access link with If2, the nMAG on that access link sends a PBU message to the MN's LMA with the handover indicator set to "1" which means that it is an attachment over a new interface to this nMAG. The interface indication is set to "2" which means that the MN uses the interface indicated by "2" to attach to nMAG. Upon accepting this PBU message, the LMA sends back a PBA message including the MN's HNP. It also creates another binding cache entry and establishes a bidirectional tunnel to the nMAG. The nMAG on receiving the PBA message sets up a bi-directional tunnel to the LMA and sets up the data path for the MN's traffic. Because the LMA recognizes that a binding for that MN already exists and this PBU does not command the handover, it dose not change the transmission path but only maintains the newly constructed tunnel.

When the MN gets an L2 (Link layer) trigger such as a fading signal quality, it sends out a handover command to the nMAG using a Handover Indication (HI) message which will be explained later. After receiving the HI message and recognizing that the MN will execute a handover, the target nMAG will send out a PBU message again with the handover indicator set to "2" which means it is a handover between interfaces. The LMA who recognizes that a binding to this MN interface exists will change the route to the corresponding nMAG to continue the packet transmission for the MN.

3 Implementation Designing

According to the presentation in the previous section, we describe the implementation design for basic PMIPv6 and its multihoming extension in this section. Our implementation of PMIPv6 and its multihoming are based on the MIPL2.0 [10] and comply with the PMIPv6 protocol [11]. The current implementation covers the basic part of the RFC 5213, and some optional parts are under development as the future work.

3.1 Implementation of the Basic PMIPv6 Protocol

We extend the implementation modules proposed in paper [12] as shown in Figure 3. The implementation architecture for the basic PMIPv6 protocol can be divided into four parts: the LMA part, the MAG part, the AAA part and the MN part.

The LMA part supports the full Home Agent (HA) function in MIPv6 but extends its binding cache entry, and the PBU/PBA process module is used to maintain the routing state and binding cache. The MAG part implements the MN detection module on the basis of the Layer 2 equipment such as AP (Access Point) or BS (Base Station) which is used to detect the connection state of MN. The PBU/PBA process module generates the PBU message and processes the PBA message to maintain the routing state and binding update list. The Route Advertisement module emulates the home link of MN after MAG receives the PBA message from LMA.

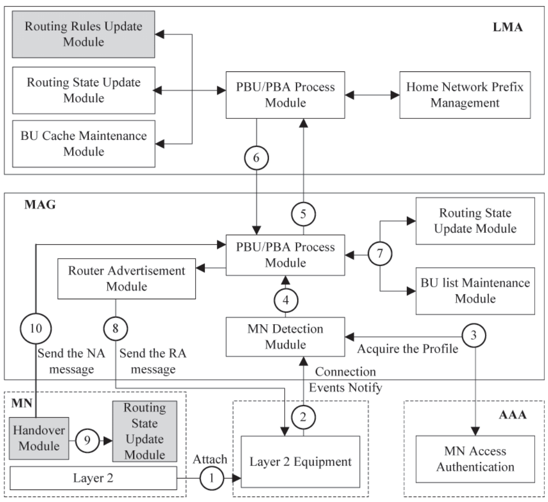

Figure 3 Implementation Modules of PMIPv6 and Its Multihoming Extension

When the MN attaches to an access network, the Layer 2 equipment detects the MN's attachment and will notify the attachment event to the corresponding MAG through the MN detection module. The MAG gets the Layer 2 address of the MN from the notification message and acquires the MN-ID and policy profile from the policy server, which may be a remote AAA server or a local policy store deployed in MAG. In our implementation, the profile is managed in the local policy store for simplicity. The authenticated MN's information containing MN-ID and LMAA (LMA Address) information is transmitted from the MN detection module to PBU/PBA process module which generates and sends the PBU message to the LMA. The LMA uses the PBU/PBA process module to establish binding cache and update the routing state.