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Use of Proxy Mobile IPv6 for Distributed Mobility Control
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Abstract

This document discusses how to use the Proxy Mobile IPv6 (PMIP) protocol for distributed mobility control. Specifically, we describe the two schemes of distributed mobility control: Signal-driven PMIP (S-PMIP) and Signal-driven Distributed PMIP (SD-PMIP).

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1. Introduction

Most of the existing protocols for Internet mobility support are based on the centralized approach, as shown in the Mobile IPv6 (MIP) and Proxy Mobile IPv6 (PMIP), in which all control and data traffic will be processed by a centralized mobility anchor, such as Home Agent (HA) of MIP or Local Mobility Anchor (LMA) of PMIP. The centralized mobility anchor allows a mobile host to be reachable, when it is not connected to its home domain, by ensuring the forwarding of packets destined to or sent from the mobile device. However, such a centralized mobility scheme is vulnerable to some problems. First, the centralized anchor may induce unwanted traffic into the core network, which tends to give a big burden to mobile network operators in terms of operational costs. In addition, a single point of failure of the central anchor may affect overall data transmission and degradation of performance, which will increase the cost of network dimensioning and engineering.

To overcome the limitations of centralized mobility management, the IETF has recently discussed the distributed mobility management. The distributed mobility management can be classified into the partially distributed approach, in which only the data plane is distributed, and the fully distributed approach where both data plane and control plane are distributed. In the centralized management, the routing path through a centralized anchor tends to be longer, which results in non-optimal routes and performance degradation, whereas the route optimization will be intrinsically supported in the distributed management. Moreover, the distributed mobility management can reduce unnecessary traffics, if the two end hosts communicate directly each other, not relying on a centralized anchor. This will also be helpful to reduce the handover delay. Moreover, the centralized approach is vulnerable to a single point of failure, whereas the distributed approach will mitigate such problem to a local network.

In the partially distributed approach, the control plane is separated from the data plane, and only data plane will be distributed for route optimization. First, a mobile node (MN) is connected to a mobility agent (MA). Then, the MA binds the location of MN with the control function. If a correspondent node (CN) sends a data packet toward MN, the MA will find the location of MN by contacting with the control function, in which location query and query acknowledgement messages can be exchanged. Based on the obtained location information, the MA of CN can deliver the data packets directly to the MA of MN. Now, the data packet is forwarded to MN.

In the fully distributed architecture, both control plane and data plane are distributed and it can be further classified into the data-driven multicast/broadcast scheme and the peer-to-peer search scheme. However, the data-driven multicast/broadcast scheme seems to be not effective, since unnecessary data packets may be excessively generated in the domain, since the data packets will be delivered by multicast to all the MAs in the domain. On the other hand, in the peer-to-peer search scheme, just before transmission of data packets, a searching process will be activated among MAs in the domain to find the location of MN. After network attachment, CN transmits a data packet to its MA. The MA of CN will find the location of MN by using an appropriate searching mechanism, such as the distributed hash table (DHT). Then, the MA of MN will respond to the MN of CN. Now, the MA of CN delivers the data packet to the MA of MN. The data packet will be forwarded to MN.

In this document, we discuss how to implement the distributed mobility control in the PMIP-based mobile networks. Based on the PMIP, we describe the two schemes of distributed mobility control: Signal-driven PMIP (S-PMIP) and Signal-driven Distributed PMIP (SD-PMIP). S-PMIP can be regarded as a partially distributed approach, whereas SD-PMIP corresponds to the fully distributed schemes.

In this document, we will only focus the distributed mobility control for 'intra-domain' movement of MN, since there are various possible scenarios for 'inter-domain' movement.

2. Conventions used in this document

In examples, "C:" and "S:" indicate lines sent by the client and server respectively.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

3. Operations

3.1. Overview

Table 1 summarizes the main features of the existing PMIP scheme and the proposed distributed mobility control schemes, S-PMIP and SD-PMIP.

Table 1. Comparison of PMIP and Distributed Mobility Control Schemes

Scheme	Agents	Mobility Architecture	Binding Update	Data Delivery	Binding Query
PMIP	MAG LMA	Centralized	Used	Data driven	Not Used
S-PMIP	MAG LMA	Partially Distributed	Used	Signal driven	Used (unicast)
SD-PMIP	MAG	Fully Distributed	Not Used	Signal driven	Used (multicast)

The existing PMIPv6 can be regarded as a centralized architecture, in which Mobile Access Gateway (MAG) performs the Proxy Binding Update (PBU) operation with LMA, and the data packets are first delivered to LMA and then forwarded to MN. Therefore, all control and data traffics concentrate on the LMA.

S-PMIPv6 is a partially distributed architecture in which the control plane is separated from the data plane. The PBU operation will be performed between MAG and LMA, as done in PMIP. In the packet delivery operation, however, the MAG of CN first finds the CoA of MN, just before data delivery, by contacting with LMA. To do this, the MAG of CN will transmit a newly defined Proxy Binding Query (PBQ) message to LMA, and the LMA will respond with a newly defined Proxy Query ACK (PQA) message to the MAG. These newly defined PBQ and PQA messages will be specified in the next section. In this sense, this scheme is named 'signal-driven' scheme. After that, the MAG of CN will deliver the data packet directly to the MAG of MN, and further to MN.

SD-PMIPv6 is also a fully distributed architecture, which is similar to the peer-to-peer search scheme. No PBU operation is performed. In the data packet delivery, on the other hand, MAG of CN will find the MAG of MN by using sending a PBQ message to all of the MAGs in the PMIP domain by multicast. The MAG of MN will respond with a PBA message. After that, the MAG of CN will deliver the data packet directly to the MAG of MN, further to MN.

3.2. Signal-driven PMIP(S-PMIP)

3.2.1. Procedures

```
                                  +-----+
                       2.PBU      |     |     5.PBQ
                  +--------------->| LMA |<---------------+
                  |               |     |               |
                  |               +-----+               |
                  |                |   |                |
                  |                |   |                |
               +-----+    3.PBA    |   |    6.PQA    +-----+
               |     |<------------+   +------------>|     |
        8.Data | MAG |            7.Data             | MAG |  4.Data
          ++===|     |<==============================|     |<==++
          ||   +-----+                               +-----+   ||
          ||     ^                                             ||
          ||     |                                             ||
          ||     | 1. Connection setup                         ||
          \/     |   (HoA Acquisition)                         ||
        +----+   |                                           +----+
        | MN |---+                                           | CN |
        +----+                                               +----+
```

Figure 1. S-PMIP Operations

Figure 1 shows the operation of S-PMIP. First, MN setups a PMIP connection with MAG and obtains its HoA (step 1). The MAG sends a PBU message to LMA to bind HoA and CoA of MN (step 2). On receiving the PBU request, LMA will create the associated binding cache entry, and send a PBA message to the MAG (step 3). Now, CN sends a data packet to MN (step 4). Then, the MAG of CN sends a PBQ message to LMA to find the CoA (i. e., IP address of MAG) of MN (step 5). On the reception of PBQ, the LMA responds with a PQA message including the CoA of MN to MAG of CN, after lookup of its binding cache (step 6). During this process, MAG of CN may buffer the data packets received from CN to prevent the packet losses. After establish the tunnel, the MAG of CN sends its buffered data packets first. After that, the MAG of CN sends the data packet to MAG of MN (step 7). Finally, the data packet is forwarded to MN (step 8).

3.2.2. LMA Operations

For distributed mobility control of S-PMIP, the LMA must support the functional capability described in this section.

On receiving a PBQ message from MAG, the LMA must perform the following operations.

1. Check if the PBQ message contains the Q flag set to 1.

2. Find the CoA of MN by looking up the binding cache of LMA.

3. If the corresponding HoA-CoA entry is found in the binding cache, LMA will respond to MAG of CN with a PQA message containing a success indication. Otherwise, if not found, LMA will respond with the PQA containing a failure indication.

The responding PQA message from LMA to MAG of CN is constructed as follows.

1. Source address field in the IP header must be set to IP address of LMA

2. Destination address filed in the IP header must be set to IP address of the MAG of CN

3. The PBA message MUST include the CoA of MN.

3.2.3. MAG Operations

For distributed mobility control of S-PMIP, each MAG in the domain must support the functional capability described in this section.

When a data packet arrives at CN, the MAG of CN must send a PBQ message to LMA so as to find the CoA of MN. During this query process, MAG of CN may buffer the data packets received from CN to prevent the packet losses. The detailed issue of how to buffer the data packets from CN is for further study.

The PBQ message from MAG to LMA must be constructed, as specified below.

1. Source address field in the IP header must contain the IP address of MAG.

2. Destination address filed in the IP header must contain the IP address of LMA.

3. The PBQ message must include the HoA of MN.

On receiving a PQA message from LMA, the MAG of CN must perform the following operations.

1. Check if the PQA message contains the Q flag set to 1.

2. If the PQA message contains any failure, the associated information may be forwarded to CN, which is for further study. Otherwise, if it contains a success indication, the MAG of CN must establish a tunnel with the MAG of MN for data delivery. Then, the MAG of CN will first forward the data packets buffered, if any. The subsequent data packets will be delivered directly from MAG of CN to MAG of MN.

3.3. Signal-driven Distributed PMIP(SD-PMIP)

3.3.1. Procedures

Figure 2 shows the operation of SD-PMIP. The MN setups a PMIP connection with the MAG (step 1). When CN sends a data packet to MN (step 2), the MAG of CN sends a PBQ message all the MAGs in the domain by multicast (step 3). For multicast transmission, it is assumed that all the MAGs in the domain have already been subscribed to a specific multicast address in the initialization process. Note that all the MAGs in the domain are under the control of the same network administrator, and that the multicast transmissions will be allowed only within the local PMIP domain. In the multicast transmission, the MAG of CN will encapsulate the original data packet by adding an outer IP header for multicasting, in which the destination address is set to a multicast address and the source address is set to IP address of MAG of CN.

```
                                  +-----+
                                  |     |     3.PBQ
                  +-------------->| MAG |<--------------+
                  |               |     |               |
                  |               +-----+               |
               +-----+             3.PBQ             +-----+
               |     |<------------------------------|     |
        6.Data |     |             4.PQA             |     |  2.Data
          ++===| MAG |------------------------------>| MAG |<==++
          ||   |     |             5.Data            |     |   ||
          ||   |     |<==============================|     |   ||
          ||   +-----+            +-----+            +-----+   ||
          ||     ^                |     |     3. PBQ    |      ||
          ||     |                | MAG |<--------------+      ||
          ||     |                |     |                      ||
          ||     |                +-----+                      ||
          ||     |                                             ||
          ||     | 1. Connection setup                         ||
          \/     |   (HoA Acquisition)                         ||
        +-----+  |                                           +-----+
        | MN |---+                                           | CN |
        +-----+                                              +-----+
                       Figure 2. SD-PMIP Operations
```

For the PBQ message transmitted by multicast, only the MAG of MN will respond with a PQA message to MAG of CN (step 4). All the other MAGs in the domain must ignore and drop the PBQ packet. Note that the responding PQA message ensures that the further subsequent data packets of CN can be delivered directly from MAG of CN to MAG of MN by unicast. Now, the data packet will be delivered to MAG of MN (step 5), and further to MN (step 6).

3.3.2. MAG Operations

For distributed mobility control of SD-PMIP, each MAG in the PMIP domain must support the functional capability described in this section. In this section, we will describe the control operations of PBQ and PQA. Note that the data delivery operations of SD-PMIP are the same with those of S-PMIP.

When a data packet arrives at CN, the MAG of CN must send a PBQ message to MAG by multicast so as to find the CoA of MN. During this query process, MAG of CN may buffer the data packets received from CN to prevent the packet losses. The detailed issue of how to buffer the data packets from CN is for further study.

The PBQ message from MAG to all the other MAGs must be encapsulated by IP-in-IP tunneling, with the following outer header.

1. Source address field of outer header must contain the IP address of MAG.

2. Destination address filed of outer header must contain a pre-specified multicast address.

3. The PBQ message must include the HoA of MN.

On receiving a PBQ message from MAG of CN, the MAG of MN must respond with a PQA message, as specified below.

1. Check if the PBQ message contains the Q flag set to 1.

2. Find the CoA of MN by looking up the binding cache of MAG.

3. If the corresponding HoA-CoA entry is found in the binding cache, the MAG of MN will respond to the MAG of CN with a success indication. Otherwise, if not found, it may not respond or may respond with a failure indication.

The responding PQA message of MAG of MN to MAG of CN is constructed as follows.

1. Source address field in the IP header must be set to the IP address of MAG of MN.

2. Destination address filed in the IP header must be set to the IP address of MAG of CN.

4. New Messages

In the S-PMIP and SD-PMIP schemes, the following two messages are newly defined. The PBQ message is an extension of the PBU message, whereas the PQA message is an extension of the PBA message.

4.1. Proxy Binding Query(PBQ)

The PBQ message is made by adding a new flag (Q) to the PBU message of PMIP. The rest of the PBU message remains unchanged.

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |            Sequence #         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |A|H|L|K|M|R|P|Q|    Reserved   |            Lifetime           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    .                                                               .
    .                        Mobility Options                       .
    .                                                               .

    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Query Flag (Q)

A new flag (Q) must be set, if the PBU message is used to find the CoA of MN in S-PMIP and SD-PMIP. In the normal PMIP operation, the flag must be set to 0.

4.2. Proxy Query ACK(PQA)

The PQA message is made by adding a new flag (Q) to the PBA message of PMIP. The rest of the PBA message remains unchanged.

```
     0                   1                   2                   3
     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |     Status    |K|R|P|Q|Reserve|
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |          Sequence #           |            Lifetime           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    .                                                               .
    .                        Mobility Options                       .
    .                                                               .

    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Query Flag (Q)

A new flag (Q) must be set, if the PBA message is used as a response to the PBQ in S-PMIP and SD-PMIP. In the normal PMIP operation, the flag must be set to 0.

5. Security Considerations

TBD

6. IANA Considerations

TBD

7. References

7.1. Normative References

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