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Routes Optimization for Multicast Sender in Proxy Mobile IPv6 Domain
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Abstract

To support IP multicasting in PMIPv6 domain, MULTIMOB WG has issued several proposals including the base solution, dedicated schemes and direct routing which requires all communications to go through the local mobility anchor(LMA), the dedicated server and the native multicasting infrastructure, respectively. As this can be suboptimal, this document describes multicast routes optimazition mechanisms for multicast sender. Multicast sender attached to the same or different mobile access gateways(MAG) with multicast listener sends multicast data via the tunnel between the gateways without any dedicated devices or dependence of the native multicasting infrastructure. The MAG and the LMA are the mobility entities defined in the PMIPv6 protocol and act as PIM-SM routers.

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1. Introduction

Proxy Mobile IPv6 (PMIPv6) [RFC5213] enables network-based mobility for IPv6 mobile nodes (MNs) that do not implement any mobility protocols. The Local Mobility Anchor (LMA) is the topological anchor point to manages the mobile node's binding state. The Mobile Access Gateway (MAG) is an access router or gateway that manages the mobility- related signaling for an MN. An MN is attached to the Proxy Mobile IPv6 Domain (PMIPv6-Domain) that includes LMA and MAG(s), and is able to receive data coming from outside of the PMIPv6-Domain through LMA and MAG.

Network-based mobility support for unicast is addressed in [RFC5213], while multicast support in PMIPv6 is not discussed in it. In order to deploy the multicast service in the PMIPv6 domain, many schemes have been proposed:

The base solution described in [RFC6224] provides options for deploying multicast listener functions in PMIPv6-Domains without modifying mobility and multicast protocol standards. However, in this specification, MAG MUST act as an MLD proxy [RFC4605] and hence MUST dedicate a tunnel link between LMA and MAG to an upstream interface for all multicast traffic. It requires all the LMA to forward multicast packets to MAG via PMIPv6 tunnel which can be suboptimal.

[draft-ietf-multimob-pmipv6-ropt-00]uses a multicast tree mobility anchor(MTMA) as the topological anchor point for multicast traffic, as well as a direct routing option where the MAG can provide access to multicast content in the local network. All the multicast traffic has to go through the MAG-MTMA tunnel which result in suboptimal multicast routing path like the base solution. And the direct routing solution needs native multicasting infrastructure as a requirement.

[draft-ietf-multimob-pmipv6-source-00]describes the support of multicast senders in Proxy Mobile IPv6 domains. MLD proxy functions are deployed at the MAG. Multicast traffic MUST be tunneled up to the LMA of the multicast sender, transferred to the LMA of the multicast listener and then tunneled downwards to the MAG of the multicast listener. The problem is especially manifested when multicast listener and sender attach to the same MAG but different LMAs, the traffic has to go up to one LMA, cross over to the other LMA, and then be tunneled back to the same MAG, causing non-optimal multicast routes and redundant flows at the MAG.In the direct routing scenario, multicast traffic MUST be tunneled up to the common multicast router(MR) and then tunneled downwards to the MAG. In both scenarios, multicast traffic has to always go through the LMA-MAG or

MR-MAG bi-directional tunnel which can be suboptimal.

This document describes multicast routes optimazition mechanisms for multicast sender. Figure 1 shows the Architecture of Multicast Deployment with listener and sender in the same PMIPv6 domain.

```
                          Internet
                              :
                              |
                              |
                           +-----+
                           | LMA |   Multicast Anchor
                           +-----+
                              ||
                             //\\
                            //  \\
                           //    \\
                          //      \\
                         //        \\
                        //          \\
                       ||            ||
                     +----+        +----+
                     |MAG1|        |MAG2|
                     +----+        +----+
                       |              |
                       |              |
                    +----+          +----+
                    | MN1|          | MN2|
                    +----+          +----+
          Multicast Listener(s)     Multicast Sender(s)
```

Figure1 Architecture of Multicast Deployment with listener and source in the same PMIPv6 domain

The proposed protocol assumes that both LMA and MAG enable the Protocol- Independent Multicast - Sparse Mode (PIM-SM) multicast routing protocol [RFC4601], and further MAG MUST operate as an "SSM-aware" router [RFC4604]. The proposed protocol supports seamless handover. In this document, because routes optimazition for multicast sender is mainly focused on, the detail specification of source mobility is not described.

2. Terminology

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].

The following terms used in this document are to be interpreted as defined in [RFC5213]; Home Address(HoA), Mobile Access Gateway (MAG), Local Mobility Anchor (LMA), Mobile Node (MN), Proxy Mobile IPv6 Domain (PMIPv6-Domain), LMA Address (LMAA), Proxy Care-of Address (Proxy-CoA), Proxy Binding Update (PBU), and Proxy Binding Acknowledgement (PBA).

Terms DR(Designated Router), MRIB(Multicast Routing Information Base), RPF(Reverse Path Forwarding), RPF Neighbor, SPT(shortest-path tree), PIM Join, Pim Prune, iif(incoming interface),oiflist(outgoing interface list), Source-Specific Multicast(SSM) are to be interpreted as defined in[RFC4601]

3. Overview

In the SSM scenario, the multicast Listeners actively send the (S,G) subscribe message, S is the multicast sender’s Home Address (HoA) .

```
                          Internet
                              :
                              |
                              |
                           +-----+
                           | LMA |      Unicast Anchor
                           +-----+
                              ||
                            //  \\
                          //      \\
                        //          \\  Unicast Tunnel
                      //              \\
                    //                  \\
                  //                      \\
                 ||                        ||
               +----+                    +----+
               |MAG1|=O=O=O=O=O=O=O=O=O=O|MAG2|
               +----+                    +----+
                 |     Multicast Tunnel     |
                 |                          |
              +----+                      +----+
              | MN1|                      | MN2|
              +----+                      +----+
       Multicast Listener(s)         Multicast Sender(s)
```

Figure2 Architecture of Optimized Multicast Routing

As shown in Figure 2, MN1(the multicast Listener) and MN2(the multicast sender) are both mobile nodes in the same PMIPv6 domain, they both have binding cache entry in the LMA. MN1 sends (S,G) subscribe message(MLD Report messages) to the access link to establish the SPT, MN1 has to operate as an "SSM-aware" host [RFC4604]. On receiving the (S,G) subscribe message from MN1, the attached MAG1 sends a PBU-Q message to LMA to query the CoA (i. e., IP address of MAG2) of MN2. On the reception of PBU-Q, the LMA responds with a PBA-Q message including the CoA of MN2 to MAG1. After acquiring the CoA of MN2, MAG1 establishes bi-directional tunnel with MAG2, and sends PIM Join message to MAG2 through this tunnel, MAG1 and MAG2 establish the ralated muticast state. So the MAG-based SPT is established successfully and the subsequent multicast data flow will be transmitted through the MAG-based SPT which is represented by "=O" in Figure 2. Unicast data flow will be transmitted through base PMIPv6 tunnel which is represented by "||" in Figure 2.

The tunnel between MAG1 and MAG2 is used for multicast packets(including signaling and data flow) transmission only.

As described in [RFC4601], on receipt of data from S to G on interface iif (incoming interface of the packet), the DR will firstly check whether the source is directly connected and the iif is identical to the Reverse Path Forwarding (RPF) interface. As shown in Figure 2, MAG2 is the DR of MN2, MAG1 is the DR of MN1. After tunnel establishment between MAG1 and MAG2, MAG1 add the tunnel route to the MRIB, the RPF check will be successful.

This draft assumes that every MN supporting multicast service is previously registered in the PMIPv6 unicast domain to get a unicast IP address(HoA).

4. Protocol Operation

4.1. Add Route to MRIB

In PIM-SM, the MRIB is used to decide where to send Join/Prune messages. on receiving the MLD Report message from MN,the MAG of MN has to choose a RPF Neighbor that the MRIB indicates should be used to forward packets to, and then send the Join/Prune message to the RPF Neighbor.

After tunnel establishment between MAG1 and MAG2, MAG1 add the tunnel route to the MRIB, so that the RPF Neighbor of MAG1 is MAG2, MAG1 send PIM Join/Prune message through this tunnel.

4.2. Optimized Multicast Route Establishment

This section provides the multicast routes optimization procedure.The procedures are described as follows and illustrated in Figure 3.

```
     MN1             MAG1                LMA      MN2        MAG2
      |       1.       |                   |        |           |
      |--MLD Report->|                   |        |           |
      |  (S,G) join    |         2.        |        |           |
      |                |------PBU-Q------->|        |           |
      |                |         3.        |        |           |
      |                |<------PBA-Q-------|        |           |
      |                |Acquire CoA of MN2 |        |           |
      |                |                   |        |           |
      |                |                   |        |           |
      |                |                   4.       |           |
      |                |<==================================>|
      |                |   Establish multicast Bi-dir tunnel    |
      |                |                   |        |           |
      |               5.                   |        |           |
      |       Add route to MRIB            |        |           |
      |                |                   |        |           |
      |                |                   |        |           |
      |               6.                   |        |           |
      |       Update (S,G) state           |        |           |
      |            Set iif                 |        |           |
      |                |                   |        |           |
      |                |                   7.       |           |
      |                |             PIM (S,G) join |           |
      |                |=============Bi-dir tunnel============>|
      |                |                   |        |           |
      |                |                   |        |          8.
      |                |                   |        |Update (S,G) state
      |                |                   |        |   Set oiflist
      |                |                   |        |           |
      |                |                   |      Multicast data
      |                |                   9.       |--------->|
      |                |             Multicast data |           |
      |Multicast data|<============Bi-dir tunnel=============|
      |<-------------|                   |        |           |
```

Figure3 Procedure of establishing multicast Route

1.MN1 sends (S,G) subscribe message to the access link, S is the HoA of MN2.

2.On receiving the (S,G) subscribe message from MN1, the attached MAG1 sends a PBU-Q message to LMA to query the CoA (i. e., IP address of MAG2) of MN2.

3.On the reception of PBU-Q, the LMA responds with a PBA-Q message including the CoA of MN2.

4.After acquire the CoA of MN2, MAG1 establish bi-directional tunnel with MAG2. Refer to [RFC5213] for the detailed tunnel negotiation mechanism.

5.After tunnel establishment, MAG1 add the tunnel route to the MRIB, so that the RPF Neighbor of MAG1 is MAG2.

6.If there are multicast channels the MN1 has subscribed but MAG1 has not yet subscribed, MAG1 establishes multicast state for the channel, and sets the iif of the multicast state as MAG1-MAG2 tunnel interface. if MAG1 already subscribed the channel, MAG1 updates the iif of the multicast state as MAG1-MAG2 tunnel interface.

7.MAG1 joins the corresponding multicast channels by sending the PIM Join message to the RPF Neighbor MAG2 through the MAG1-MAG2 tunnel.

8.On the reception of PIM Join message from MAG1, If MAG2 has not yet subscribed the multicast channel, MAG2 establishes multicast state for the channel, and adds the MAG2-MAG1 tunnel interface to the oiflist of the multicast state. if MAG2 already subscribed the channel, MAG2 updates the oiflist of the multicast state by adding the MAG2-MAG1 tunnel interface to the oiflist.

9.The subsequent multicast data flow will be transmitted through the optimized multicast route(MAG1-MAG2 bi-directional tunnel).

4.3. Multicast Route Deletion

```
        MN1            MAG1                                    MAG2
         |     1.       |                                       |
         |--MLD Report->|                                       |
         | leave (S,G)  |                                       |
         |              |                                       |
         |              2.                                      |
         |With regard to MN2,MN1 is the                         |
         |last multicast listener on MAG1                       |
         |              |                                       |
         |              |                                       |
         |              3.                                      |
         | delete all the (S,G) state                           |
         |  ralating to MN2 on MAG1                             |
         |              |                                       |
         |              |                                       |
         |              |                                       |
         |              |                  4.                   |
         |              |             PIM (S,G) prune           |
         |              |=============Bi-dir tunnel============>|
         |              |                                       |
         |              |                                       |
         |              |                                       5.
         |              |                             update (S,G) state
         |              |                             update oiflist
         |              |                 6.                    |
         |              |     Remove multicast Bi-dir tunnel    |
         |              |<======================================|
         |              |                                       |
```

Figure4 Procedure of deleting multicast Route

1.MN1 sends (S,G) leave message(MLD Report messages) to the access link, S is the HoA of MN2.

2.On receiving the (S,G) leave message from the MN1, if MAG1 figures that MN1 is the last multicast listener subscribed to the MN2, MAG1 perform the following steps, otherwise, MAG1 simply delete the multicast state of MN1 as normal, which is removing MAG1-MN1 interface from the oiflist of the multicast state.

3.MAG1 delete all the multicast state related to MN2.

4.MAG1 remove the tunnel route from the MRIB and leave the corresponding multicast channels by sending the PIM Prune message to the RPF Neighbor MAG2 through the MAG1-MAG2 tunnel.

5.On the reception of PIM Prune message from MAG1, MAG2 updates the oiflist of the multicast state by removing the MAG2-MAG1 tunnel interface from the oiflist.

6.Remove bi-directional tunnel between MAG1 and MAG2. Refer to [RFC5213] for the detailed tunnel negotiation mechanism.

5. Local Mobility Anchor Operation

On receiving a PBU-Q message from MAG1, the LMA must perform the following operations.

1.Check if the PBU-Q message contains the Q flag set to 1.

2.Query the CoA of MN2 by looking up the binding cache of LMA.

3.If the corresponding HoA-CoA entry is found in the binding cache, LMA will respond PBA-Q message containing a success indication. Otherwise, if not found, LMA will respond PBA-Q message containing a failure indication.

The responding PBA-Q message from LMA to MAG1 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 MAG1.

3.The PBA-Q message MUST include the CoA of MN2.

6. Mobile Access Gateway Operation

The MAG MUST operate as an "SSM-aware" router. [RFC4604] provide the behavior of an "SSM-aware" router.

6.1. MN1 and MN2 attach to the same MAG

On receiving the (S,G) subscribe message from the MN1, MAG1 could decide whether MN2 attaches to itself according to MN2’s HoA which is included in the (S,G) subscribe message. If MAG1 figures that MN1 and MN2 both attach to it. MAG1 operates as below:

If there are multicast channels the MN1 has subscribed but MAG1 has not yet subscribed, MAG1 establishes multicast state for the channel,and adds the MAG1-MN1 interface to the oiflist of the multicast state.

If MAG1 already subscribed the channel, MAG1 updates the oiflist of the multicast state by adding the MAG1-MN1 interface to the oiflist.

MAG1 will send the multicast data flow from MN2 to MN1 locally.

6.2. MN1 and MN2 attach to different MAG

The PBU-Q message from MAG1 to LMA MUST be constructed, as specified below.

1.Source address field in the IP header must contain the IP address of MAG1.

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

3.The PBU-Q message must include the HoA of MN2.

On receiving a PBA-Q message from LMA, MAG1 MUST perform the following operations.

1.Check if the PBA-Q message contains the Q flag set to 1.

2.MAG1 MUST establish a tunnel with MAG2 for muticast data delivery.

3.MAG1 MUST add route to Multicast Routing Information Base (MRIB) and send PIM Join/Prune messages through MAG1-MAG2 tunnel interface.

4.MAG1 MUST create/update multicast state for the channel, the iif of the multicast state MUST be set to MAG1-MAG2 tunnel interface.

On receiving a PIM Join/Prune messages from MAG2-MAG1 tunnel interface, MAG2 MUST create/update multicast state for the channel.

1.Add MAG2-MAG1 tunnel interface to the oiflist of the multicast state on receiving a PIM Join message from MAG2-MAG1 tunnel interface.

2.Delete MAG2-MAG1 tunnel interface from the oiflist of the multicast state on receiving a PIM Prune message from MAG2-MAG1 tunnel interface.

7. Mobile Node Operation

The MN MUST operate as an "SSM-aware" host . [RFC4604] provide the behavior of an "SSM-aware" host.

8. Message Format Extension

8.1. Proxy Binding Update with Source Address Query Extension

```
      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                       .
     .                                                               .

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

Figure5 Proxy Binding Update with Source Address Query Extension

A Binding Update message that is sent by MAG to LMA is referred to as the "Proxy Binding Source Address Query" message. A new flag (Q) is included in the Proxy Binding Update message with Source Address Query extension (PBU-Q). The rest of the Binding Update message format remains the same as defined in[RFC3775] and with the additional (R), (M), and (P) flags, as specified in [RFC3963], [RFC4140], and [RFC5213], respectively.

Source Address Query Flag

A new flag (Q) is included in the Binding Update message to indicate to LMA that the Binding Update message is a Source Address Query message. In the normal PMIP operation, the flag must be set to 0.

The PBU-Q message is transfered for quering the MN2’s CoA. The rest of the PBU message remains unchanged.

8.2. Proxy Binding Acknowledgement Message with Source Address Query Extension

```
      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                       .
     .                                                               .

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

Figure6 Proxy Binding Update with Source Address Query Extension

A "Proxy Binding Acknowledgement" message is sent from LMA to MAG in response to a Proxy Binding Update message. A new flag (Q) is included in the Proxy Binding Acknowledgement message with Source Address Query extension (PBA-Q). The rest of the Binding Acknowledgement message format remains the same as defined in [RFC3775] and with the additional (R) flag, as specified in [RFC3963] and [RFC5213], respectively.

Source Address Query Flag

A new flag (Q) is included in the Binding Acknowledgement message to indicate to MAG that the Binding Acknowledgement message is a Source Address Query message. In the normal PMIP operation, the flag must be set to 0.

When (Q) flag is specified in PBA-Q message, the mobility options field includes "MN2’s CoA"(Section 8.3).

8.3. Care-of Address Option

```
     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
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |   Type = TBD  |  Length = 16  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +                                                               +
    |                                                               |
    +                       Care-of Address                         +
    |                                                               |
    +                                                               +
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure7 Care-of Address Option

The Care-of Address field contains the care-of address of MN2.

This option is valid only in PBA-Q message. On the reception of PBU-Q, the LMA responds with a PBA-Q message including the Care-of Address Option.

9. Security Considerations

TBD

10. IANA Considerations

11. Normative References

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