PMIPv6 Extensions for Multicast
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Abstract

This document describes Proxy Mobile IPv6 (PMIPv6) extensions and solutions to support IP multicast. The Mobile Access Gateway (MAG) and the Local Mobility Anchor (LMA) are the mobility entities defined in the PMIPv6 protocol and establish a bi-directional tunnel to manage mobility for mobile nodes within the Proxy Mobile IPv6 domain. This document defines the roles of LMA and MAG to support IP multicast for the mobile nodes.

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1. Introduction

Proxy Mobile IPv6 (PMIPv6) [2] 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 manage the mobile node’s binding state. The Mobile Access Gateway (MAG) is an access router or gateway that manages the mobility-related signaling for a mobile node. 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 [2], while multicast support in PMIPv6 is not discussed in it. This document describes PMIPv6 extensions and solutions to support IP multicast communication for mobile nodes in PMIPv6-Domain. The problem statements and the requirements for multicast communication in a network-based mobility protocol have been documented in [12]. In this document, multicast listener mobility is considered, while multicast source mobility will be discussed in another draft.

Functions required on LMA and MAG for multicast communication are described in this document. LMA and MAG set up the bi-directional tunnel and set up the forwarding for the mobile node’s traffic. LMA must be capable of forwarding multicast packets through MAG toward the corresponding mobile nodes. This condition requires LMA to attach multicast networks by supporting multicast routing protocols such as Protocol-Independent Multicast - Sparse Mode (PIM-SM) [3] or other methods, and make traffic and QoS control if needed. On the other hand, MAG must maintain multicast membership status for the attached mobile nodes at the edge and forwards the multicast data from LMA to the member nodes. This condition requires MAG to support MLD [4]. Since each mobile node connects MAG with a point-to-point access link, scalable operations and extensions for MAG must be considered.

Seamless and fast handover must also be considered. When a host receiving multicast data moves from an access link to another access link, the host continuously receives the multicast data through newly attached MAG. The handover procedure should guarantee multicast session continuity and avoid extra packet loss and session disruption. Context transfer will be the required function to support seamless handover, while its effective procedure should be taken into account interaction with multicast communication protocols.

The PMIPv6 extension proposed in this document does not require to change unicast communication methods or protocols defined in [2], and
therefore both unicast and multicast communications for mobile nodes in PMIPv6-Domain are enabled after all.
2. Conventions and Terminology

2.1. Conventions Used in This Document

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 [1].

2.2. Terminology

The following terms used in this document are to be interpreted as defined in the Proxy Mobile IPv6 specification [2]; 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), Mobile Node’s Home Network Prefix (MN-HNP), Mobile Node Identifier (MN-Identifier), Proxy Binding Update (PBU), and Proxy Binding Acknowledgement (PBA).

As defined in [8], "upstream interface" or "host interface" is an MLD proxy device’s interface in the direction of the root of the tree. Each of an MLD proxy device’s interfaces that is not in the direction of the root of the tree is called "downstream interface" or "router interface".

The Context Transfer Protocol (CXTP) specification [13] describes the mechanism that allows better support for minimizes service disruption during handover. In this document, CXTP is adopted for the multicast context transfer protocol in PMIPv6, and "Multicast-Context Transfer Data (M-CTD)" is defined as the new terminology for transferring MLD state from previously attached MAG (p-MAG) to newly attached MAG (n-MAG).

Mobile Node’s Policy Profile includes "multicast channel information", whose contents are the same one M-CTD contains, and the mandatory fields of the policy profile specified in [2]. MN’s Policy Profile is provided by "policy store" whose definition is the same as of [2], or by CXTP.
3. Overview

3.1. Multicast Communication in PMIPv6


The architecture of a Proxy Mobile IPv6 domain is shown in Figure 1. LMA and MAG are the core functional entities in PMIPv6-Domain. The entire PMIPv6-Domain appears as a single link from the perspective of each mobile node.
When a mobile node wants to subscribe/unsubscribe a multicast channel, the node sends MLD Report messages with specifying interesting/uninteresting sender and multicast addresses to the access link. The attached MAG detects this membership information and transfers the information to the corresponding LMA over a bi-directional tunnel when needed, or transfers the information to the adjacent multicast router.

When an LMA receives the membership information with MLD Report messages or with PIM Join/Prune messages, it coordinates the corresponding multicast routing tree if necessary. This operation requires multicast routing protocols or proxy functions for LMA.

When a MAG detects mobile node’s handover, it can proceed the seamless handover procedures. Since both PMIPv6 and multicast protocols (i.e., MLD and PIM-SM) do not have the functions for handover in the original protocol specifications, external functions or protocols such as CXTP [13] can be additionally used with PMIPv6 Proxy Binding Update (PBU).

3.2. Protocol Sequence for Joining and Leaving Multicast Channels

Upon multicast data reception, a mobile node sends MLD Report messages including source and multicast addresses. Although MLDv2 specification [4] permits to use the unspecified address (::) for a host whose interface has not acquired a valid link-local address yet, MLDv2 Report messages MUST be sent with a valid IPv6 link-local source address in PMIPv6 as defined in [10]. As well, MLDv2 Report messages MAY be sent with an IP destination address of FF02:0:0:0:0:0:0:16, to which all MLDv2-capable multicast routers listen, but the IP unicast address of the attached MAG SHALL be used in many cases as explained in [10].

An MLD proxy [8] can simplify the implementation of multicast data forwarding. By not supporting complicated multicast routing protocols, it reduces the implementation cost and the operational overhead. Reducing the operational overhead will also contribute to faster routing convergence. Another advantage is that an MLD proxy can be independent of the multicast routing protocol used by the core network routers.

When a MAG operates as an MLD proxy and receives MLD Report messages from attached mobile nodes, it sends MLD messages on behalf of the mobile nodes. MLD messages are always transferred over pre-configured bi-directional tunnels as seen in Figure 2. MAG operating as an MLD proxy always registers "downstream interface (or router interface)" upon MLD message reception, but does not send MLD Report when the received source and multicast addresses have been already
When a MAG operates as a PIM-SM router and receives MLD report messages from attached mobile nodes, it joins the multicast delivery tree by sending PIM join messages. At the same time, the MAG sends MLD report messages with the Hold extension [10] with the corresponding multicast channel information to the LMA (Figure 3). When receiving the MLD Hold, the LMA joins the multicast delivery tree but does not forward multicast data to the MAG; the idea is to make the LMA ready to forward data while a new MAG completes the handover routing update (detailed in Section 8).
Figure 3: MLD Report Messages Transmission when MAG acts as a router

Whether a MAG works as an MLD proxy or a PIM-SM router, it MAY store multicast channel information reported by attached mobile nodes in the MN’s policy profile (as defined in [2]). This information may be used by the new MAG during the handover process (see Section 8).
4. Local Mobility Anchor Operation

4.1. LMA Operating As PIM-SM Router

An LMA is responsible for maintaining the mobile node’s reachability state and is the topological anchor point for the mobile node’s home network prefix(es). When an LMA acts as a PIM-SM [3] multicast router, it serves MAGs as listener nodes. Each MAG is connected through a bi-directional tunnel, and each tunnel end-point address is a Proxy-CoA.

An LMA sets up the multicast state and joins the group. Multicast packets are tunneled to a MAG that requested to receive the corresponding multicast session after being received by the LMA. The MAG forwards these packets to the MN according to the multicast listener state in the MAG.

[TODO: What is the required function for an LMA as a multicast router? There is a case that a number of mobile nodes, let us say more than 1,000 nodes, attach MAG and they are listening multicast sessions. In addition, these mobile nodes connect to MAG with point-to-point links with different prefixes. This condition will require some protocol modification?]

4.2. LMA Operating As MLD Proxy

An LMA may act as an MLD proxy [8]. When LMA acts as an MLD proxy, multicast data is forwarded from outside to mobile nodes through a bi-directional tunnel to MAG.

When LMA acts as an MLD proxy, the attached MAGs must also act as an MLD proxy.

4.3. LMA Operating As AMT Relay

It is possible for an LMA to support the AMT [9]. In this case, LMA acts as an AMT Relay and the attached MAGs must act as AMT Gateways. When LMA acts as an AMT Relay, it MUST also work as a PIM-SM router.
5. Mobile Access Gateway Operation

The mobile access gateway (MAG) is the entity that performs the mobility management on behalf of a mobile node. MAG is responsible for detecting the mobile node's movements to and from the access link.

5.1. MAG Operating As MLD Proxy

[2] supports only point-to-point access link types for MAG and MN connection; hence an MN and a MAG are the only two nodes on an access link, where the link is assumed to be multicast capable. Since a MAG will deal with mobile nodes' membership states reported by a large number of the downstream mobile nodes with MLD Report messages, the protocol scalability must be taken into account.

A MAG acting as an MLD proxy sends MLD Query messages to all or some of attached mobile nodes as described in [10]. After MAG receives MLD Report messages from the mobile nodes, it forwards the MLD Report messages on behalf of these mobile nodes to LMA. Mobile nodes send MLD messages with their link-local address to MAG, and MAG forwards the MLD messages through the bi-directional tunnel to LMA with the MAG’s link-local address.

An MLD proxy requires that the upstream and downstream interfaces must be statistically configured. As well, MAG MUST configure an upstream interface that is the interface MLD Report messages are sent to LMA and downstream interfaces that are the interfaces MLD Report messages are received from mobile nodes.

5.2. MAG Operating As PIM-SM Router

The optimal multicast routing path does not always include LMA, especially in local routing described in [12]. The local routing option is designed to support node-to-node communication within PMIPv6-Domain where a local content source exists.

When LMA is not on a multicast delivery tree, MAG runs multicast routing protocols to attach the optimal multicast routing path. This document assume use of PIM-SM [3] as the supported multicast routing protocol.

Because of its implementation or operational costs, operators may not want to support PIM-SM on MAG. However, an MLD proxy requires to statically configure its upstream interface, which is a bi-directional tunnel as specified in Section 5.1, to receive all multicast data, because there is no method to dynamically change the upstream interface. Therefore, if operators need to take into
account the case that an upstream interface for the optimized multicast path is NOT a bi-directional tunnel to LMA but other interface, and want MAG to "select" optimized routing path, MAG must act as a PIM-SM router.

5.3. MAG Operating As AMT Gateway

It is possible for MN and MAG to perform with AMT [9]. In this case, MAG acts as an AMT Gateway. MAG then summarizes all downstream membership states. Since AMT data message that is a UDP packet encapsulating IP multicast data is transmitted as a regular unicast packet, the AMT data is not transmitted through a bi-directional tunnel between MAG and LMA but forwarded toward the LMA by hop-by-hop manner.

When MAG acts as an AMT Gateway, it SHOULD also work as an MLD proxy as specified in [9].
6. Mobile Node Operation

Mobile nodes attached to MAG can behave as the regular receiver hosts. A mobile node sends MLD messages to MAG when it wants to subscribe and unsubscribe IP multicast channels. And mobile nodes do not change their behaviors whether MAG is acting as an MLD proxy or an AMT Gateway. All MLD related considerations are described in [10], which will give some advantage for its resource saving and seamless handover for PMIPv6 multicast.

[2] allows a mobile node is a router. However, if MN is a multicast router, it requires to make MAG act as a multicast router. To avoid the complexity, in this document, MN may behave as an MLD proxy [8] but should not work as a PIM-SM router, when MN needs to forward multicast data to its downstream nodes.

[TODO: What is the other function for MN needed? Any specific requirement?]
7. Dual-Mode Implementation

Operators may want to make LMA or MAG act as both an MLD proxy and a PIM-SM multicast router to support different customers. This document proposes a "dual-mode" implementation that enables LMA or MAG to support both an MLD proxy function and a multicast routing function simultaneously.

To simplify mobile node’s handover procedure among dual-mode MAGs, p-MAG and n-MAG should not change the behaviors for the same mobile node. For instance, in dual-mode, if p-MAG that a mobile node attaches is working as an MLD proxy, n-MAG that the mobile node will attach must also work as an MLD proxy. It is same as of PIM-SM.
8. Handover Process

MAG is responsible for detecting the mobile node’s movements to and from the access link and for initiating binding registrations to the mobile node’s LMA. MAG tracks the mobile node’s movements to and from the access link and for signaling the mobile node’s LMA. In PMIPv6, it SHOULD NOT require for mobile nodes to initiate to re-subscribe multicast channels, and MAG SHOULD keep multicast channel subscription status for mobile nodes even if they attach a different MAG in PMIPv6-Domain. In this section, mobility handover procedures are described.

8.1. MAG Operating As MLD Proxy

When MAG operates as an MLD proxy, there are two possible ways to proceed MLD listener handover; MLD listener handover with CXTP and MLD listener handover with MN’s Policy Profile. A Proxy Binding Update with multicast extension (PBU-M) (defined in Section 8.4) is always used to request the LMA to forward multicast data.

The MLD listener handover with CXTP shown in Figure 4 is defined as follows;

1. Whenever MN attaches to n-MAG, the n-MAG requests multicast context transfer to p-MAG.

2. p-MAG provides the multicast states corresponding to the moving MN-Identifier to n-MAG. p-MAG utilizes a context transfer protocol to deliver MN’s profile to n-MAG, and sends Multicast Context Transfer Data (M-CTD) (defined in Section 8.3) to n-MAG.

3. n-MAG records MN’s profile including multicast channel information.

4. n-MAG subscribes multicast channel on behalf of MN. PBU-M is transmitted to LMA to establish a bi-directional tunnel for forwarding corresponding multicast data.
After MN attaches to n-MAG, the multicast data will be delivered to the MN immediately. MN’s multicast membership state is maintained with MLD Query and Report messages exchanged by MN and n-MAG.

Mobile node’s multicast state is kept in MN’s profile. If MN’s policy profile is stored in a policy store [2], it is not necessary to use a context transfer protocol between p-MAG and n-MAG. In such a case, n-MAG obtains MN’s multicast state by the same mechanism used to acquire MN-ID and profile during MN’s attachment process [2].

The procedure for MLD listener handover with MN’s Policy Profile (Figure 5) is shown as follows;
1. n-MAG obtains the MN-Identifier and learns multicast channel information described in Mobile Node’s Policy Profile associated to this MN-Identifier.

2. n-MAG prepares the PBU-M that includes multicast channel information the MN has subscribed.

3. n-MAG transmits PBU-M to LMA to establish a bi-directional tunnel for forwarding corresponding multicast data.

4. LMA forwards requested multicast data through a bi-directional tunnel between the LMA and n-MAG.

Figure 5: MLD listener handover with MN’s Policy Profile
8.2. MAG Operating As Multicast Router

MAG operating PIM-SM multicast routing protocol joins the multicast delivery tree when an attached mobile node subscribes a multicast channel. In order to reduce handover latency, LMA forwards multicast data to n-MAG until n-MAG has joined the multicast delivery tree. A Proxy Binding Update with multicast extension (PBU-M) is always used to request the LMA to forward multicast data.

When MAG operates PIM-SM routing protocol, leveraging CXTP is the possible handover scenario as in the following procedure;

1. Whenever MN attaches to n-MAG, the n-MAG requests multicast context transfer to p-MAG.

2. p-MAG provides the multicast states corresponding to the moving MN-Identifier to n-MAG. p-MAG utilizes a context transfer protocol to deliver MN’s profile to n-MAG, and sends M-CTD to n-MAG.

3. n-MAG initiates the process to subscribe the multicast channels.

4. n-MAG requests LMA to forward multicast data in the meantime. n-MAG prepares the PBU-M that includes multicast channel information the MN has subscribed and has not yet received at n-MAG.

5. LMA forwards requested multicast data through a bi-directional tunnel between the LMA and n-MAG.

6. Whenever n-MAG joins the multicast delivery tree, it notifies the LMA to stop forwarding the data and switches to the optimal multicast routing path.
The following procedure is for PIM-SM handover using MN’s Policy Profile:

1. When n-MAG detects a moving mobile node, it obtains the MN-Identifier and learns multicast channel information described in Mobile Node’s Policy Profile associated to this MN-Identifier.
2. n-MAG prepares the PBU-M that includes multicast channel information the MN has subscribed and has not yet received at n-MAG.

3. n-MAG transmits PBU-M to LMA to establish a bi-directional tunnel for forwarding corresponding multicast data.

4. LMA subscribes requested multicast channels and forwards the data through a bi-directional tunnel between the LMA and n-MAG.

5. Whenever n-MAG joins the multicast delivery tree, it notifies the LMA to stop forwarding the data and switches to the optimal multicast routing path.
### 8.3. Multicast Context Transfer Data Format

The following information is necessary to keep mobile node’s membership status, and hence M-CTD includes the information;

1. **Receiver address** - indicates an address of a receiver host sending the Current-State Report.

---

Figure 7: PIM-SM handover with MN’s Policy Profile
2. Last membership report - indicates the time that the router receives the last Current-State Report.

3. Filter mode - indicates either INCLUDE or EXCLUDE as defined in [4].

4. Source addresses and multicast address - indicates the address pair that the receiver has joined.

8.4. Proxy Binding Update with Multicast Extension

```
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|C|   Reserved    |            Lifetime           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8: Proxy Binding Update Message with Multicast Extension

A Binding Update message that is sent by MAG to LMA is referred to as the "Proxy Binding Update" message. A new flag (C) is included in the Binding Update message with multicast extension. The rest of the Binding Update message format remains the same as defined in [11] and with the additional (R), (M), and (P) flags, as specified in [14], [15], and [2], respectively.

Multicast Channel Subscription Flag

A new flag (C) is included in the Binding Update message to indicate to LMA that the Binding Update message is a multicast channel subscription.

When (C) flag is specified in PBU-M message, the mobility options field includes the same information of MLDv2 Report message [4]:
Each Multicast Address Record has the following internal format:
Figure 10

All the above fields contain data with the same definitions in [4].
9.  IPv4-Only and Dual-Stack Node Support

The mobile node may be an IPv4-only node, IPv6-only node, or a dual-stack (IPv4/v6) node. Although this document mainly describes IPv6 address/prefix mobility with the transport network being IPv6, it proposes the tunneling method by which IPv4-only mobile node or a dual-stack mobile node that wants to subscribe IPv4 multicast channels. As with the discussion in the MBONE working group, AMT [9] is the possible candidate to fulfill the requirement. AMT provides the multicast connectivity to the unicast-only inter-network. To do this, multicast packets being sent to or from a site are encapsulated in unicast packets.

When MAG behaves as an AMT Gateway, it sends an MLD report message via its AMT Pseudo-Interface that encapsulates the message to a particular AMT Relay (i.e., LMA).

While MLD messages or multicast packets are always encapsulated with both IPv4 and IPv6 headers, AMT messages, which are the regular IPv6 unicast packets, are not transmitted over a bi-directional tunnel.
10. IANA Considerations

This document creates a new registry for the flags in the Binding Update message called the "Binding Update Flags".

The following flags are reserved:

- (A) 0x8000 [RFC3775]
- (H) 0x4000 [RFC3775]
- (L) 0x2000 [RFC3775]
- (K) 0x1000 [RFC3775]
- (M) 0x0800 [RFC4140]
- (R) 0x0400 [RFC3963]
- (P) 0x0200 [RFC5213]

This document reserves a new flag (C) for "Proxy Binding Update with Multicast Extension" as described in Section 8.4 as follows:

- (C) 0x0100

The rest of the values in the 16-bit field are reserved. New values can be assigned by Standards Action or IESG approval.
11. Security Considerations

TBD.
12. Acknowledgements

Many of the specifications described in this document are discussed and provided by the PMIPv6 multicast support design team members.
13. References

13.1. Normative References


13.2. Informative References


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