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Proxy Mobile IPv6 Extensions to Support Flow Mobility

Abstract

Proxy Mobile IPv6 (PMIPv6) allows a mobile node to connect to the same PMIPv6 domain through different interfaces. This document describes extensions to the PMIPv6 protocol that are required to support network-based flow mobility over multiple physical interfaces.

This document updates RFC 5213. The extensions described in this document consist of the operations performed by the local mobility anchor and the mobile access gateway to manage the prefixes assigned to the different interfaces of the mobile node, as well as how the forwarding policies are handled by the network to ensure consistent flow mobility management.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc7864.

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1. Introduction

Proxy Mobile IPv6 (PMIPv6), specified in [RFC5213], provides network-based mobility management to hosts connecting to a PMIPv6 domain. PMIPv6 introduces two new functional entities, the Local Mobility Anchor (LMA) and the Mobile Access Gateway (MAG). The MAG is the entity detecting the Mobile Node's (MN's) attachment and providing IP connectivity. The LMA is the entity assigning one or more Home Network Prefixes (HNPs) to the MN and is the topological anchor for all traffic belonging to the MN.

PMIPv6 allows an MN to connect to the same PMIPv6 domain through different interfaces. This document specifies protocol extensions to Proxy Mobile IPv6 between the LMA and MAGs to enable "flow mobility" and, hence, distribute specific traffic flows on different physical interfaces. It is assumed that the MN IP-layer interface can simultaneously and/or sequentially attach to multiple MAGs, possibly over multiple media. One form to achieve this multiple attachment is described in [RFC7847], which allows the MN supporting traffic flows on different physical interfaces, regardless of the assigned prefixes on those physical interfaces. Another alternative is to configure the IP stack of the MN to behave according to the Weak ES Model (commonly referred to as the weak host model) [RFC1122].

In particular, this document specifies how to enable "flow mobility" in the PMIPv6 network (i.e., LMAs and MAGs). In order to do so, two main operations are required: i) proper prefix management by the PMIPv6 network and ii) consistent flow forwarding policies. This memo analyzes different potential use case scenarios, involving different prefix assignment requirements and, therefore, different PMIPv6 network extensions to enable "flow mobility".

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 defined in the Proxy Mobile IPv6 [RFC5213]:

o Local Mobility Anchor (LMA)

o Mobile Access Gateway (MAG)

o Proxy Mobile IPv6 Domain (PMIPv6-Domain)

- o LMA Address (LMAA)
- o Proxy Care-of Address (Proxy-CoA)
- o Home Network Prefix (HNP)

The following terms used in this document are defined in the Multiple Care-of Addresses Registration [RFC5648] and Flow Bindings in Mobile IPv6 and Network Mobility (NEMO) Basic Support [RFC6089]:

- o Binding Identification (BID) Number
- o Flow Identifier (FID)
- o Traffic Selector (TS)

The following terms are defined and used in this document:

- o Flow Mobility Initiate (FMI): Message sent by the LMA to the MAG conveying the information required to enable flow mobility in a PMIPv6-Domain.
- o Flow Mobility Acknowledgement (FMA): Message sent by the MAG in reply to an FMI message.
- o Flow Mobility Cache (FMC): Conceptual data structure to support the flow mobility management operations described in this document.

3. Overview of the PMIPv6 Flow Mobility Extensions

3.1. Use Case Scenarios

In contrast to a typical handover where connectivity to a physical medium is relinquished and then re-established, flow mobility assumes that an MN can have simultaneous access to more than one network. In this specification, it is assumed that the LMA is aware of the MN’s ability to have simultaneous access to both access networks and the ability to handle the same or a different set of prefixes on each access. How this is done is outside the scope of this specification.

There are different flow mobility scenarios. In some of them, the MN might share a common set of prefixes among all its physical interfaces; in others, the MN might have a different subset of prefixes configured on each of the physical interfaces. The different scenarios are the following:

1. At the time of a new network attachment, the MN obtains the same prefix or the same set of prefixes as already assigned to an existing session. This is not the default behavior with basic PMIPv6 [RFC5213], and the LMA needs to be able to provide the same assignment even for the simultaneous attachment (as opposed to the handover scenario only).

2. At the time of a new network attachment, the MN obtains a new prefix or a new set of prefixes for the new session. This is the default behavior with basic PMIPv6 [RFC5213].

A combination of the two above-mentioned scenarios is also possible. At the time of a new network attachment, the MN obtains a combination of prefix(es) in use and new prefix(es). This is a hybrid of the two scenarios described before. The local policy determines whether the new prefix is exclusive to the new attachment or can be assigned to an existing attachment as well.

The operational description of how to enable flow mobility in each of these scenarios is provided in Sections 3.2.1 and 3.2.2.

The extensions described in this document support all the aforementioned scenarios.

3.2. Basic Operation

This section describes how the PMIPv6 extensions described in this document enable flow mobility support.

Both the MN and the LMA MUST have local policies in place to ensure that packets are forwarded coherently for unidirectional and bidirectional communications. The details about how this consistency is ensured are out of the scope of this document. Either the MN or the LMA can initiate IP flow mobility. If the MN makes the flow mobility decision, then the LMA follows that decision and updates its forwarding state accordingly. The network can also trigger mobility on the MN side via out-of-band mechanisms (e.g., 3GPP / Access Network Discovery and Selection Function (ANDSF) sends updated routing policies to the MN). In a given scenario and MN, the decision on IP flow mobility MUST be taken either by the MN or the LMA, but it MUST NOT be taken by both.

3.2.1. MN Sharing a Common Set of Prefixes on All MAGs

This scenario corresponds to the first use case scenario described in Section 3.1. Extensions to basic PMIPv6 [RFC5213] signaling at the time of a new attachment are needed to ensure that the same prefix (or set of prefixes) is assigned to all the interfaces of the same MN that are simultaneously attached. Subsequently, no further signaling is necessary between the local mobility anchor and the MAG, and flows are forwarded according to policy rules on the LMA and the MN.

If the LMA assigns a common prefix (or set of prefixes) to the different physical interfaces attached to the domain, then every MAG already has all the routing knowledge required to forward uplink or downlink packets after the Proxy Binding Update / Proxy Binding Acknowledgement (PBU/PBA) registration for each MAG, and the LMA does not need to send any kind of signaling in order to move flows across the different physical interfaces (because moving flows is a local decision of the LMA). Optionally, signaling MAY be exchanged in case the MAG needs to know about flow-level information (e.g., to link flows with proper QoS paths and/or inform the MN [RFC7222]).

The LMA needs to know when to assign the same set of prefixes to all the different physical interfaces of the MN. This can be achieved by different means, such as policy configuration, default policies, etc. In this document, a new Handoff Indicator (HI) ("Attachment over a new interface sharing prefixes" (6) value) is defined that allows the MAG to indicate to the LMA that the same set of prefixes MUST be assigned to the MN. The considerations of Section 5.4.1 of [RFC5213] are updated by this specification as follows:

- o If there is at least one Home Network Prefix Option present in the request with a NON_ZERO prefix value, there exists a Binding Cache Entry (BCE) (with all HNPs in the BCE matching the prefix values of all Home Network Prefix Options of the received Proxy Binding Update message), and the entry matches the MN identifier in the Mobile Node Identifier Option of the received Proxy Binding Update message, and the value of the HI of the received Proxy Binding Update is equal to "Attachment over a new interface sharing prefixes".

  1. If there is a Mobile Node Link-layer Identifier Option present in the request, and the BCE matches the Access Technology Type (ATT) and the MN-LL-Identifier, then the request MUST be considered as a request for updating that BCE.

2. If there is a Mobile Node Link-layer Identifier Option present in the request, and the BCE does not match the Access Technology Type (ATT) and the MN-LL-Identifier, then the request MUST be considered as a request for creating a new mobility session sharing the same set of HNPs assigned to the existing BCE found.

3. If there is not a Mobile Node Link-layer Identifier Option present in the request, then the request MUST be considered as a request for creating a new mobility session sharing the same set of HNPs assigned to the existing BCE found.

```
                              LMA Binding Cache
           +----+       ========================
           |LMA|         MN1, ATT1, pref1, MAG1
           +----+         MN1, ATT2, pref1, MAG2
            //\\
 +---------//--\\-------------+
(         //    \\             ) PMIPv6 domain
(        //      \\            )
 +------//--------\\----------+
       //          \\
      //            \\
   +-----+         +-----+
   |MAG1|          |MAG2|
   +-----+         +-----+
     |                 |
     |   +-------+     |
     |   |  I P  |     |
     |   +---+---+     |
     |---|if1|if2|----|
         +---+---+
            MN1
```

Figure 1: Shared Prefix Across Physical Interfaces Scenario

Next, an example of how flow mobility works in this case is shown. In Figure 1, a mobile node (MN1) has two different physical interfaces (if1 of access technology type ATT1, and if2 of access technology type ATT2). Each physical interface is attached to a different MAG, both of them controlled by the same LMA. Both physical interfaces are assigned the same prefix (pref1) upon attachment to the MAGs. If the IP layer at the MN shows one single logical interface (e.g., as described in [RFC7847]), then the mobile node has one single IPv6 address configured at the IP layer: pref1::mn1. Otherwise, per interface IPv6 addresses (e.g., pref1::if1 and pref1::if2) would be configured; each address MUST be valid on every interface. We assume the first case in the following example (and in the rest of this document). Initially, flow X goes through MAG1 and flow Y through MAG2. At a certain point, flow Y can be moved to also go through MAG1. Figure 2 shows the scenario in which no flow-level information needs to be exchanged, so there is no signaling between the LMA and the MAGs.

Note that if different IPv6 addresses are configured at the IP layer, IP-session continuity is still possible (for each of the configured IP addresses). This is achieved by the network delivering packets destined to a particular IP address of the MN to the right of MN’s physical interface where the flow is selected to be moved, and the MN also selecting the same interface when sending traffic back uplink.

```
                 +-----+         +------+        +------+      +-----+
   Internet      | LMA |         | MAG1 |        | MAG2 |      | MN1 |
                 +-----+         +------+        +------+      +-----+
      |             |               |               |             |
      |  flow X to  |   flow X to   |           flow X to         |
      |  pref1::mn1 |   pref1::mn1  |           pref1::mn1        |
      |<----------->|<------------->|<-------------------------->if1
      |  flow Y to  |           flow Y to           |  flow Y to  |
      |  pref1::mn1 |           pref1::mn1          |  pref1::mn1 |
      |<----------->|<----------------------------->|<---------->if2
      |             |               |               |             |
      |       ============          |               |       ============
      |       ||  flow  ||          |               |       ||  flow  ||
      |       || policy ||          |               |       || policy ||
      |       || update ||          |               |       || update ||
      |       ============          |               |       ============
      |             |               |               |             |
      |  flow Y to  |   flow Y to   |          flow Y to          |
      |  pref1::mn1 |   pref1::mn1  |          pref1::mn1         |
      |<----------->|<------------->|<-------------------------->if1
      |             |               |               |             |
```

Figure 2: Flow Mobility Message Sequence with a Common Set of Prefixes

Figure 3 shows the state of the different network entities after moving flow Y in the previous example. This document reuses some of the terminology and mechanisms of the flow bindings and multiple care-of address registration specifications. Note that, in this case the BIDs shown in the figure are assigned locally by the LMA, since there is no signaling required in this scenario. In any case, alternative implementations of flow routing at the LMA MAY be used, as it does not impact the operation of the solution in this case.

```
                            LMA Binding Cache        LMA flowmob state
                       (BID, MN-ID, ATT, HNP, PCoA)       (BID, TS)
                  +---+ ===========================  ===================
                  |LMA|  1, MN1, ATT1, pref1, MAG1       1, flow X
                  +---+  2, MN1, ATT2, pref1, MAG2       1, flow Y
                   //\\
        +---------//--\\-------------+
       (         //    \\             ) PMIPv6 domain
       (        //      \\            )
        +------//--------\\----------+
              //          \\
             //            \\       MAG1 routing state
          +----+          +----+  ================================
          |MAG1|          |MAG2|     (dest)        (next hop)
          +----+          +----+   pref1::/64   p2p-iface-with-MN1
            |                |        ::/0            LMA
            |                |
            |                |     MAG2 routing state
            |   +-------+    |    ================================
            |   |  I P  |    |       (dest)        (next hop)
            |   +---+---+    |     pref1::/64   p2p-iface-with-MN1
            |---|if1|if2|----|        ::/0            LMA
                +---+---+
                   MN1
```

Figure 3: Data Structures with a Common Set of Prefixes

3.2.2. MN with Different Sets of Prefixes on Each MAG

A different flow mobility scenario happens when the LMA assigns different sets of prefixes to physical interfaces of the same mobile node. This covers the second case, or a combination of scenarios, described in Section 3.1. In this case, additional signaling is required between the LMA and the MAG to enable relocating flows between the different attachments, so the MAGs are aware of the prefixes for which the MN is going to receive traffic, and local routing entries are configured accordingly.

In this case, signaling is required when a flow is to be moved from its original interface to a new one. Since the LMA cannot send a PBA message that has not been triggered in response to a received PBU message, the solution defined in this specification makes use of two mobility messages: FMI and FMA, which actually use the format of the Update Notifications for PMIPv6 defined in [RFC7077]. The trigger for the flow movement can be on the MN (e.g., by using layer-2 signaling with the MAG), or on the network (e.g., based on congestion and measurements), which then notifies the MN for the final IP flow mobility decision (as stated in Section 3.1). Policy management functions (e.g., 3GPP/ANDSF) can be used for that purpose; however, how the network notifies the MN is out of the scope of this document.

If the flow is being moved from its default path (which is determined by the destination prefix) to a different one, the LMA constructs a FMI message. This message includes a Home Network Prefix Option for each of the prefixes that are requested to be provided with flow mobility support on the new MAG (note that these prefixes are not anchored by the target MAG, and therefore the MAG MUST NOT advertise them on the MAG-MN link), with the off-link bit (L) set to one. This message MUST be sent to the new target MAG, i.e., the one selected to be used in the forwarding of the flow. The MAG replies with an FMA. The message sequence is shown in Figure 4.

```
                 +-----+         +------+        +------+      +-----+
   Internet      | LMA |         | MAG1 |        | MAG2 |      | MN1 |
                 +-----+         +------+        +------+      +-----+
      |             |               |               |             |
      |  flow X to  |   flow X to   |           flow X to         |
      |  pref1::mn1 |   pref1::mn1  |           pref1::mn1        |
      |<----------->|<------------->|<---------------------------->if1
      |  flow Y to  |           flow Y to           |  flow Y to  |
      |  pref2::mn1 |           pref2::mn1          |  pref2::mn1 |
      |<----------->|<----------------------------->|<----------->if2
      |             |               |               |             |
      |       ============          |               |       ============
      |       ||  flow  ||          |               |       ||  flow  ||
      |       || policy ||          |               |       || policy ||
      |       || update ||          |               |       || update ||
      |       ============          |               |       ============
      |             |               |               |             |
      |             | FMI[MN1-ID, HNPs]             |             |
      |             |-------------->|               |             |
      |             |          FMA  |               |             |
      |             |<--------------|               |             |
      |  flow Y to  |   flow Y to   |          flow Y to          |
      |  pref2::mn1 |   pref2::mn1  |          pref2::mn1         |
      |<----------->|<------------->|<---------------------------->if1
      |             |               |               |             |
```

Figure 4: Flow Mobility Message Sequence When the LMA Assigns Different Sets of Prefixes per Physical Interface

The state in the network after moving a flow, in the case where the LMA assigns a different set of prefixes is shown in Figure 5.

```
                      LMA Binding Cache          LMA flowmob state
                 (BID, MN-ID, ATT, HNP, PCoA)        (BID, TS)
            +---+ ============================  ===================
            |LMA|  1, MN1, ATT1, pref1,               1, flow X
            +---+                  pref2,  MAG1       1, flow Y
             //\\  2, MN1, ATT2, pref2,  MAG2
  +---------//--\\-------------+
 (         //    \\             ) PMIPv6 domain
 (        //      \\            )
  +------//--------\\----------+
        //          \\
       //            \\       MAG1 routing state
    +----+          +----+  ================================
    |MAG1|          |MAG2|    (dest)        (next hop)
    +----+          +----+   pref1::/64   p2p-iface-with-MN1
      |               |      pref2::/64   p2p-iface-with-MN1
      |               |         ::/0            LMA
      |               |
      |   +-------+   |      MAG2 routing state
      |   |  I P  |   |     ================================
      |   +---+---+   |       (dest)        (next hop)
      |---|if1|if2|----|      pref2::/64   p2p-iface-with-MN1
          +---+---+             ::/0            LMA
             MN1
```

Figure 5: Data Structures When the LMA Assigns a Different Set of Prefixes

3.3. Use of PBU/PBA Signaling

This specification introduces the FMI/FMA signaling, which allows the LMA to exchange required information with the MAG to enable flow mobility without waiting to receive a PBU. However, there are scenarios in which the trigger for flow mobility might be related to a new MN’s interface attachment. In this case, the PBA sent in response to the PBU received from the new MAG can convey the same signaling that the FMI does. In this case, the LMA MUST include a Home Network Prefix Option in the PBA for each of the prefixes that are requested to be provided with flow mobility support on the new MAG with the off-link bit (L) set to one.

3.4. Use of Flow-Level Information

This specification does not mandate flow-level information to be exchanged between the LMA and the MAG to provide flow mobility support. It only requires that the LMA keeps a flow-level state (Section 5.2). However, there are scenarios in which the MAG might need to know which flow(s) is/are coming within a prefix that has been moved, to link it/them to the proper QoS path(s) and optionally, inform the MN about it. This section describes the extensions used to include flow-level information in the signaling defined between the LMA and the MAG.

This specification reuses some of the mobility extensions and message formats defined in [RFC5648] and [RFC6089], namely the Flow Identification Mobility Option and the Flow Mobility Sub-Options.

If the LMA wants to convey flow-level information to the MAG, it MUST include in the FMI (or the PBA) a Flow Identification Mobility Option for all the flows that the MAG needs to be aware of with flow granularity. Each Flow Identification Mobility Option MUST include a Traffic Selector Sub-Option including such flow-level information.

To remove a flow-binding state at the MAG, the LMA simply sends an FMI (or a PBA, if it is in response to a PBU) message that includes flow identification options for all the flows that need to be refreshed, modified, or added, and simply omits those that need to be removed.

Note that even if a common set of prefixes is used, providing the MAG with flow-level information requires signaling to be exchanged, in this case between the LMA and the MAG. This is done by sending an FMI message (or a PBA, if it is sent in response to a PBU).

4. Message Formats

This section defines modifications to the PMIPv6 [RFC5213] protocol messages.

This specification requires implementation of Update Notification (UPN) [RFC7077] and Update Notification Ack (UPA) [RFC7077] messages with the specific Notification Reason and Status Code values as defined by this document. This document does not require implementation of any other aspects of [RFC7077].

4.1. Home Network Prefix

A new flag (L) is included in the Home Network Prefix Option to indicate to the MAG whether the conveyed prefix has to be hosted on-link or not on the point-to-point interface with the MN. A prefix is hosted off-link for the flow mobility purposes defined in this document. The rest of the Home Network Prefix Option format remains the same as defined in [RFC5213].

```
 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     |   Length      |L|  Reserved   | Prefix Length |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+                   Home Network Prefix                         +
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Off-link Home Network Prefix Flag (L):

The Off-link Home Network Prefix Flag is set to indicate to the MAG that the HNP conveyed in the option is not to be hosted on-link, but has to be considered for flow mobility purposes, and therefore added to the MAG routing table. If the flag is set to 0, the MAG assumes that the HNP has to be hosted on-link.

4.2. Flow Mobility Initiate (FMI)

The FMI message used in this specification is the UPN message specified in [RFC7077]. The message format, transport, and security considerations are as specified in [RFC7077]. The format of the message is specified in Section 4.1 of [RFC7077]. This specification does not modify the UPN message; however, it defines the following new notification reason value for use in this specification:

Notification Reason:

FLOW-MOBILITY (8). Request to add/refresh the prefix(es) conveyed in the Home Network Prefix Options included in the message to the set of prefixes for which flow mobility is provided.

The Mobility Options field of an FMI MUST contain the MN-ID, followed by one or more Home Network Prefix Options. Prefixes for which flow mobility was provided that are not present in the message MUST be removed from the set of flow mobility-enabled prefixes.

4.3. Flow Mobility Acknowledgement (FMA)

The FMA message used in this specification is the UPA message specified in Section 4.2 of [RFC7077]. The message format, transport, and security considerations are as specified in [RFC7077]. The format of the message is specified in Section 4.2 of [RFC7077]. This specification does not modify the UPA message, however, it defines the following new status code values for use in this specification:

Status Code:

0: Success

131: Reason unspecified

132: MN not attached

When the Status code is 0, the Mobility Options field of an FMA MUST contain the MN-ID, followed by one or more Home Network Prefix Options.

5. Conceptual Data Structures

This section summarizes the extensions to PMIPv6 that are necessary to manage flow mobility.

5.1. Multiple Proxy Care-of Address Registration

The binding cache structure of the LMA is extended to allow multiple proxy care-of address (Proxy-CoA) registrations, and support the mobile node using the same address (prefix) beyond a single interface and MAG. The LMA maintains multiple BCEs for an MN. The number of BCEs for an MN is equal to the number of the MN’s interfaces attached to any MAGs.

This specification reuses the extensions defined in [RFC5648] to manage multiple registrations, but in the context of PMIPv6. The binding cache is therefore extended to include more than one proxy care-of address and to associate each of them with a BID. Note that the BID is a local identifier, assigned and used by the local mobility anchor to identify which entry of the FMC is used to decide how to route a given flow.

BID-PRI	BID	MN-ID	ATT	HNP(s)	Proxy-CoA
20	1	MN1	WiFi	HNP1,HNP2	IP1 (MAG1)
30	2	MN1	3GPP	HNP1,HNP3	IP2 (MAG2)

Figure 6: Extended Binding Cache

Figure 6 shows an example of an extended binding cache, containing two BCEs of a mobile node MN1 attached to the network using two different access technologies. Both of the attachments share the same prefix (HNP1), but they are bound to two different Proxy-CoAs (two MAGs).

5.2. Flow Mobility Cache (FMC)

Each LMA MUST maintain an FMC as shown in Figure 7. The FMC is a conceptual list of entries that is separate from the binding cache. This conceptual list contains an entry for each of the registered flows. This specification reuses the format of the flow-binding list defined in [RFC6089]. Each entry includes the following fields:

- o Flow Identifier Priority (FID-PRI)
- o Flow Identifier (FID)
- o Traffic Selector (TS)
- o Binding Identification (BID)
- o Action
- o Active/Inactive

FID-PRI	FID	TS	BIDs	Action	A/I
10	2	TCP	1	Forward	Active
20	4	UDP	1,2	Forward	Inactive

Figure 7: Flow Mobility Cache

The BID field contains the identifier of the BCE to which the packets matching the flow information described in the TS field will be forwarded. When it is decided that a flow is to be moved, the affected BID(s) of the table are updated.

Similar to the flow binding described in [RFC6089], each entry of the FMC points to a specific BID. When a flow is moved, the LMA simply updates the pointer of the flow-binding entry with the BID of the interface to which the flow will be moved. The TS in the flow-binding table is defined in [RFC6088]. TS is used to classify the packets of flows based on specific parameters such as service type, source, and destination address, etc. The packets matching with the same TS will be applied the same forwarding policy. FID-PRI is the order of precedence to take action on the traffic. The action may be to forward or drop. If a binding entry becomes "Inactive", it does not affect data traffic. An entry becomes "Inactive" only if all of the BIDs are de-registered.

The MAG MAY also maintain a similar data structure. In case no full flow mobility state is required at the MAG, the Binding Update List (BUL) data structure is enough: no extra conceptual data entries are needed. If full per-flow state is required at the MAG, it SHOULD also maintain an FMC structure.

6. Mobile Node Considerations

This specification assumes that the mobile node IP-layer interface can simultaneously and/or sequentially attach to multiple MAGs, possibly over multiple media. The MN MUST be able to enforce uplink policies to select the right outgoing interface. One alternative to achieve this multiple attachment is described in [RFC7847], which allows the MN supporting traffic flows on different physical interfaces, regardless of the assigned prefixes on those physical interfaces. Another alternative is configuring the IP stack of the MN to behave according to the weak host model [RFC1122].

7. IANA Considerations

This specification establishes new assignments to the IANA mobility parameters registry:

- o Handoff Indicator Option type: "Attachment over a new interface sharing prefixes" has been assigned the value 6 from the "Handoff Indicator Option type values" registry defined in <http://www.iana.org/assignments/mobility-parameters>.

- o Update Notification Reason: "FLOW-MOBILITY" has been assigned the value 8 from the "Update Notification Reasons Registry" defined in <http://www.iana.org/assignments/mobility-parameters>.

- o Update Notification Acknowledgement Status: "Reason unspecified" has been assigned the value 131 and "MN not attached" has been assigned the value 132 from the "Update Notification Acknowledgement Status Registry".

8. Security Considerations

The protocol-signaling extensions defined in this document share the same security concerns of Proxy Mobile IPv6 [RFC5213] and do not pose any additional security threats to those already identified in [RFC5213] and [RFC7077].

The MAG and the LMA MUST use the IPsec security mechanism mandated by Proxy Mobile IPv6 [RFC5213] to secure the signaling described in this document.

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

[RFC5213] Gundavelli, S., Ed., Leung, K., Devarapalli, V., Chowdhury, K., and B. Patil, "Proxy Mobile IPv6", RFC 5213, DOI 10.17487/RFC5213, August 2008, <http://www.rfc-editor.org/info/rfc5213>.

[RFC5648] Wakikawa, R., Ed., Devarapalli, V., Tsirtsis, G., Ernst, T., and K. Nagami, "Multiple Care-of Addresses Registration", RFC 5648, DOI 10.17487/RFC5648, October 2009, <http://www.rfc-editor.org/info/rfc5648>.

[RFC6088] Tsirtsis, G., Giarreta, G., Soliman, H., and N. Montavont, "Traffic Selectors for Flow Bindings", RFC 6088, DOI 10.17487/RFC6088, January 2011, <http://www.rfc-editor.org/info/rfc6088>.

[RFC6089] Tsirtsis, G., Soliman, H., Montavont, N., Giaretta, G., and K. Kuladinithi, "Flow Bindings in Mobile IPv6 and Network Mobility (NEMO) Basic Support", RFC 6089, DOI 10.17487/RFC6089, January 2011, <http://www.rfc-editor.org/info/rfc6089>.

[RFC7077] Krishnan, S., Gundavelli, S., Liebsch, M., Yokota, H., and J. Korhonen, "Update Notifications for Proxy Mobile IPv6", RFC 7077, DOI 10.17487/RFC7077, November 2013, <http://www.rfc-editor.org/info/rfc7077>.

9.2. Informative References

[RFC1122] Braden, R., Ed., "Requirements for Internet Hosts - Communication Layers", STD 3, RFC 1122, DOI 10.17487/RFC1122, October 1989, <http://www.rfc-editor.org/info/rfc1122>.

[RFC7222] Liebsch, M., Seite, P., Yokota, H., Korhonen, J., and S. Gundavelli, "Quality-of-Service Option for Proxy Mobile IPv6", RFC 7222, DOI 10.17487/RFC7222, May 2014, <http://www.rfc-editor.org/info/rfc7222>.

[RFC7847] Melia, T., Ed. and S. Gundavelli, Ed., "Logical-Interface Support for IP Hosts with Multi-Access Support", RFC 7847, DOI 10.17487/RFC7847, May 2016, <http://www.rfc-editor.org/info/rfc7847>.

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