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Interactions between PMIPv6 and MIPv6: scenarios and related issues
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Status of this Memo

Abstract

The scenarios where Proxy Mobile IPv6 (PMIPv6) and Mobile IPv6 (MIPv6) protocols are both deployed in a network require some analysis and considerations. This document describes all identified possible scenarios, which require an interaction between PMIPv6 and MIPv6 and discusses all issues related to these scenarios. Solutions and reccomendations to enable these scenarios are also described.

Requirements Language

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].

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1. Introduction

Proxy Mobile IPv6 [RFC5213] is a network based IP mobility protocol standardized by IETF. In some deployment scenarios this protocol will be deployed together with MIPv6 [RFC3775], for example with PMIPv6 as local mobility protocol and MIPv6 as global mobility protocol. While the usage of a local mobility protocol should not have implications of how global mobility is managed, since PMIPv6 is partially based on MIPv6 signaling and data structure, some considerations are needed to understand how the protocols interact and how the different scenarios can be enabled.

Some SDOs are also investigating more complex scenarios where the mobility of some nodes are handled using Proxy Mobile IPv6, while other nodes use Mobile IPv6; or the mobility of a node is managed in turn by a host-based and a network-based mechanism. This needs also to be analyzed as a possible deployment scenario.

This document provides a taxonomy of all scenarios that require direct interaction between MIPv6 and PMIPv6. Moreover, this document presents and identifies all issues pertained to these scenarios and discusses possible means and mechanisms that are recommended to enable them.

2. Terminology

General mobility terminology can be found in [RFC3753]. The following acronyms are used in this document:

MN-HoA: the home address of a mobile node in a Proxy Mobile IPv6 domain.

MN-HNP: the IPv6 prefix that is always present in the Router Advertisements that the mobile node receives when it is attached to any of the access links in that Proxy Mobile IPv6 domain. MN-HoA always belongs to this prefix.

MIPv6-HoA: the Home Address the MN includes in MIPv6 binding

update messages.

MIPv6-CoA: the Care-of Address the MN includes in MIPv6 binding update messages.

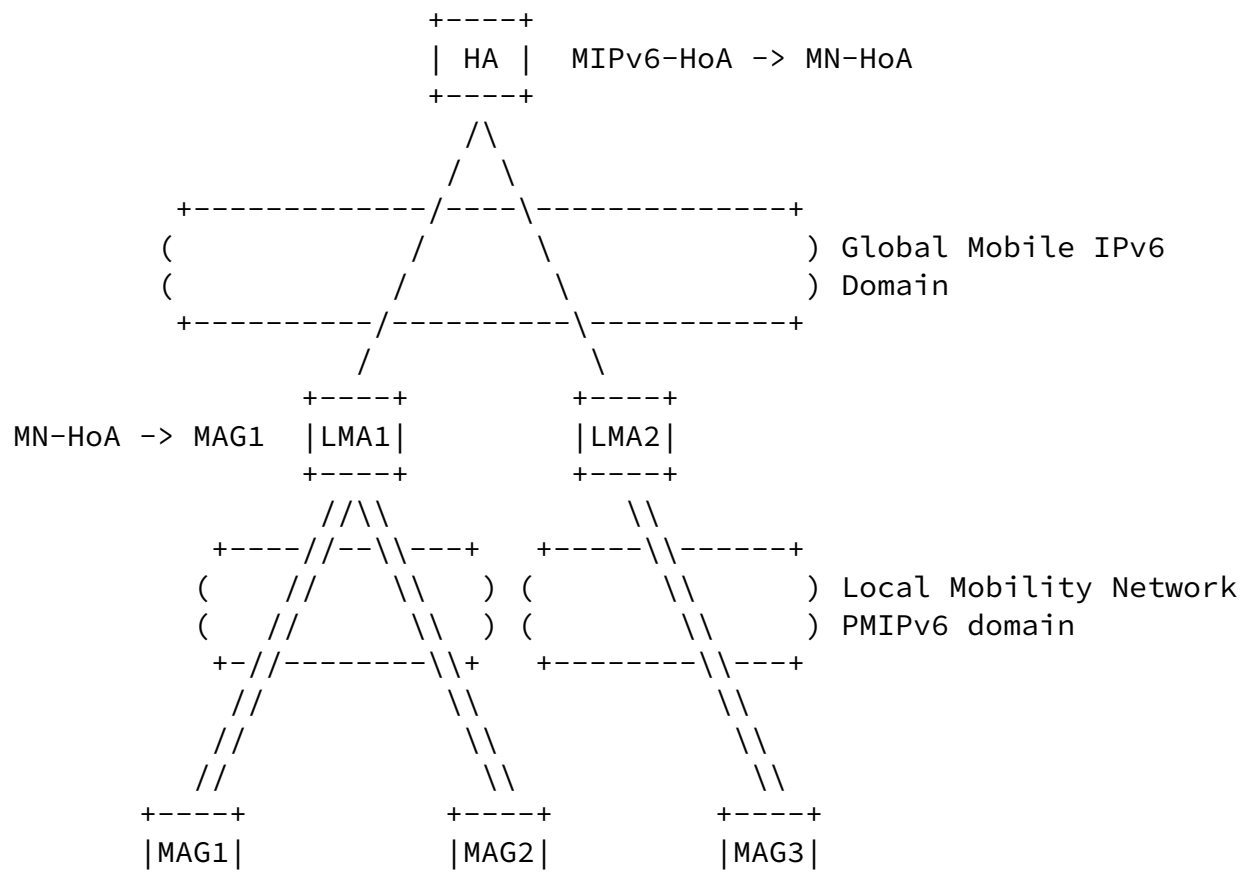
3. Overview of the scenarios and related issues

Several scenarios can be identified where Mobile IPv6 and Proxy Mobile IPv6 are deployed in the same network. This document does not only focus on scenarios where the two protocols are used by the same mobile node to manage local and global mobility, but it investigates also more complex scenarios where the protocols are more tightly integrated or where there is a co-existence of nodes which do or do not implement Mobile IPv6.

The following scenarios are identified:

- Scenario A - in this scenario Proxy Mobile IPv6 is used as a network based local mobility management protocol whereas Mobile IPv6 is used as a global mobility management protocol. This interaction is very similar to the HMIPv6-MIPv6 interaction; Mobile IPv6 is used to manage mobility among different access networks, while the mobility within the access network is handled by Proxy Mobile IPv6. The address managed by PMIPv6 (i.e. the MN-HoA) is registered as Care-of Address by the MN at the HA. This means that the HA has a binding cache entry for MIPv6-HoA that points to the MN-HoA.

The following figure illustrates this scenario.



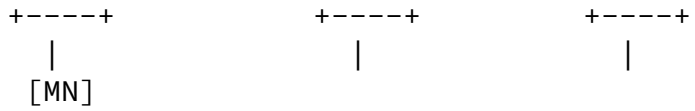


Figure 1 - Scenario A

o Scenario B - in this scenario some mobile nodes use Mobile IPv6 to manage their movements while others rely on a network-based mobility solution provided by the network as they don't support Mobile IPv6. There may be a common mobility anchor that acts as Mobile IPv6 Home Agent and Proxy Mobile IPv6 LMA, depending on the type of the node as depicted in the figure. However, the LMA and HA can be also separated and this has no impacts to the mobility of the nodes.

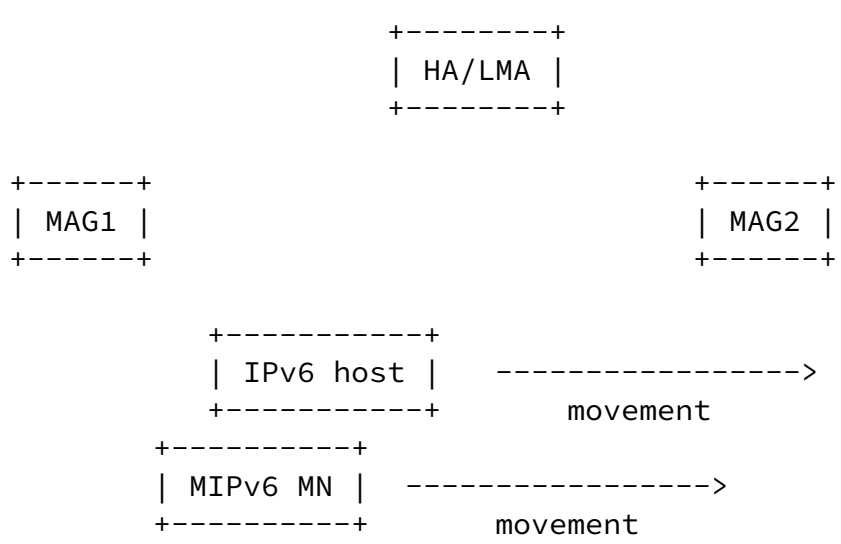
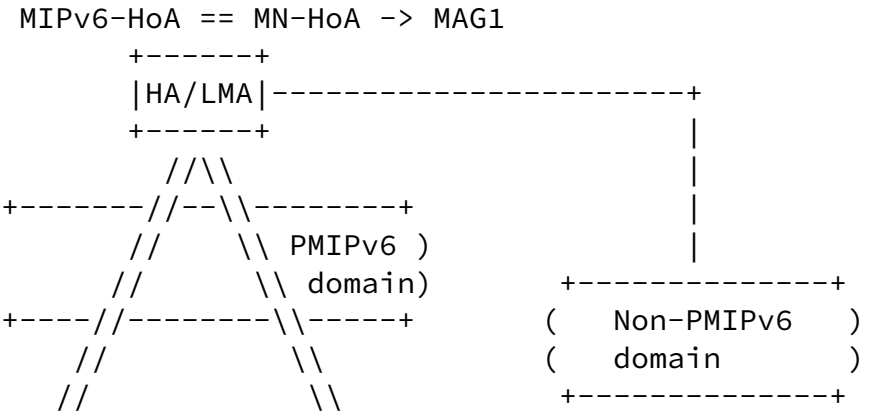


Figure 2 - Scenario B

- Scenario C - in this scenario the mobile node is moving across different access networks, some of them supporting Proxy Mobile IPv6 and some others not supporting it. Therefore the mobile node is roaming from an access network where the mobility is managed through a network-based solution to an access network where a host-based management (i.e. Mobile IPv6) is needed. This scenario may have different sub-scenarios depending on the relations between the Mobile IPv6 home network and the Proxy Mobile IPv6 domain. The following figure illustrates an example of this scenario, where the MN is moving from an access network where PMIPv6 is supported (i.e. MAG functionality is supported) to a network where PMIPv6 is not supported (i.e. MAG functionality is not supported by the AR). This implies that the home link of the MN is actually a PMIPv6 domain. In this case the MIPv6-HoA is equal to the MN-HoA (i.e. the address managed by PMIPv6).



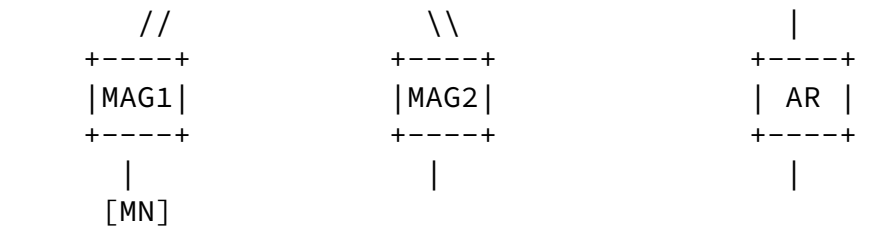
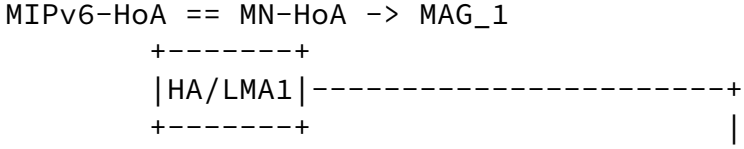
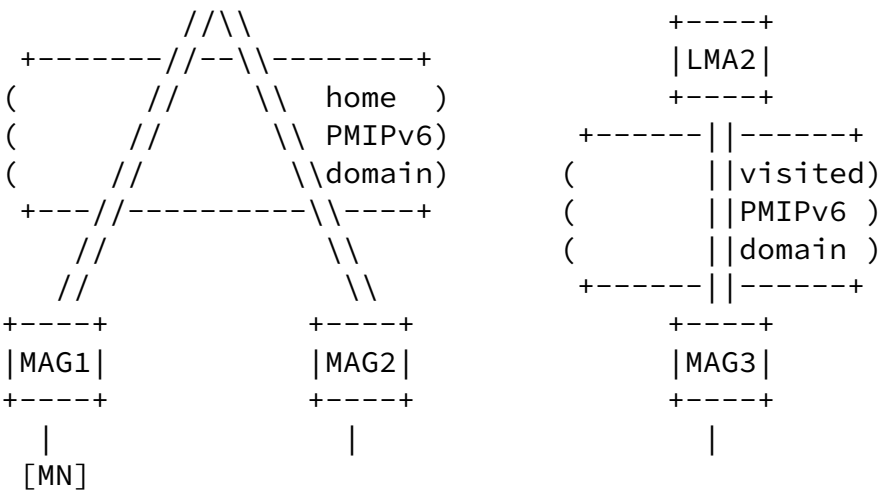


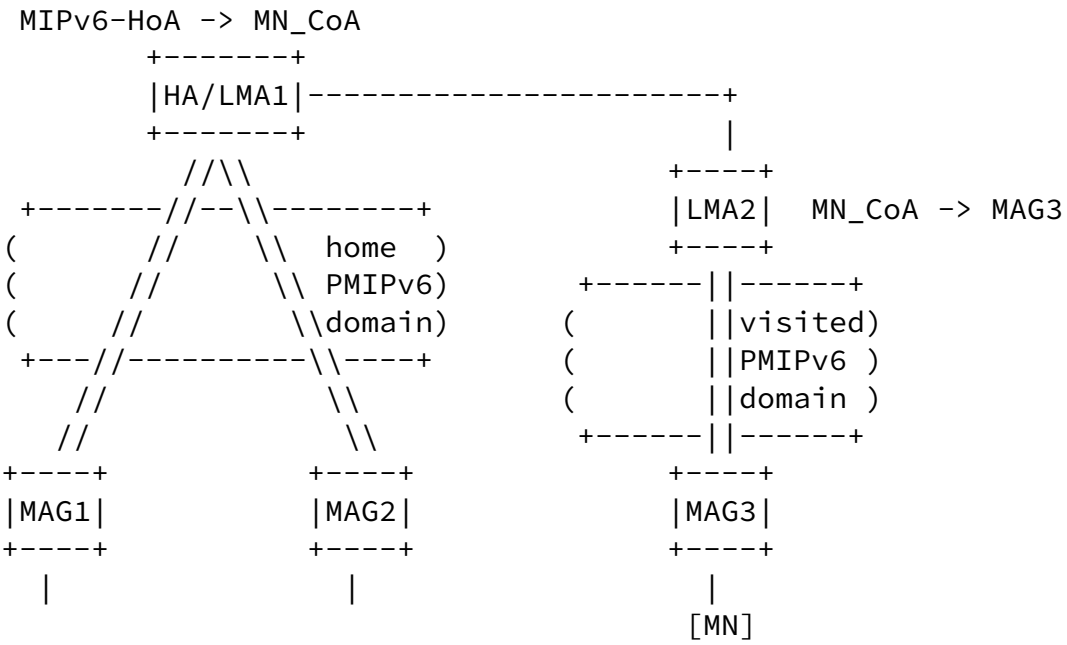
Figure 3 - Scenario C

In the above figure the non-PMIPv6 domain can actually be also a different PMIPv6 domain that handles a different MN_HoA. The following figure illustrates this sub-case: the MIPv6-HoA is equal to the MN_HoA; however when the MN hands over to MAG3 it gets a different IP address (managed by LMA2 using PMIPv6) and registers it as a MIPv6 CoA.





(a)



(b)

Figure 4 - Scenario C with visited PMIPv6 domain

Note that some of the scenarios can be combined. For instance, scenario B can be combined with scenario A or scenario C.

The following sections describe some possible issues for each

scenario. Respective recommendations are described in Section 4.3. The specifications considered as a baseline for the analysis are the following: [RFC3775], [RFC4877] and [RFC5213].

3.1. Issues related to scenario A

This scenarios is very similar to other hierarchical mobility schemes, including a HMIPv6-MIPv6 scheme. This is the scenario referenced in [RFC4830]. No issues have been identified in this scenario. Note that a race condition where the MN registers the CoA at the HA before the CoA is actually bound to the MAG at the LMA is not possible. The reason is that per PMIPv6 specification the MAG does not forward any packets sent by the MN until the PMIPv6 tunnel is up, regardless the mechanism used for address allocation.

Section 4.1 describes one message flow in case PMIPv6 is used as a local mobility protocol and MIPv6 is used as a global mobility protocol.

3.2. Issues related to scenario B

In this scenario there are two types of nodes in the access network: some nodes support Mobile IPv6 while some others do not. The rationale behind such a scenario is that the nodes implementing Mobile IPv6 manage their own mobility to achieve better performance, e.g. for inter-technology handovers. Obviously, nodes that do not implement MIPv6 must rely on the network to manage their mobility: therefore Proxy MIPv6 is used for those nodes.

Based on the current PMIPv6 solution described in [RFC5213], in any link of the PMIPv6 domain the MAG emulates the mobile node's home link, advertising the home link prefix to the MN in a unicast Router Advertisement message. This ensures that the IP address of the MN is still considered valid by the MN itself. The home network prefix (and any other information needed to emulate the home link) is included in the mobile node's profile that is obtained by the MAG via context transfer or via a policy store.

However, in case there are nodes that implement Mobile IPv6 and want to use this protocol, the network must offer MIPv6 service to them. In such case the MAG should not emulate the home link. Instead of advertising the HNP, the MAG should advertise the topologically correct local IP prefix, i.e. the prefix belonging to the MAG, so that the MN detects an IP movement, configures a new CoA and sends a MIPv6 Binding Update based on [RFC3775].

3.3. Issues related to scenario C

This section highlights some considerations that are applicable to scenario C where the LMA and HA are logically collocated and need to be evaluated when selecting the technical approach to be chosen.

1. HoA management and lookup key in the binding cache

   * in MIPv6 [RFC3775] the lookup key in the Binding Cache is the Home Address of the MN. In particular, based on the base specification [RFC3775], the MN does not include any identifier, such as the MN-ID [RFC4283], in the Binding Update message other than its Home Address. As described in [RFC4877], the identifier of the MN is known by the Home Agent after the IKEv2 exchange, but this is not used in the MIPv6 signaling, nor as a lookup key for the binding cache. On the other hand, as specified in [RFC5213], a Proxy Binding Update contains the Home Prefix of the MN, the MN-ID and does not include the Home Address of the MN (since it may not be known by the MAG and consequently by the HA/LMA). The lookup key in the binding cache of the LMA is either the home prefix or the MN-ID. This implies that lookup keys for MIPv6 and PMIPv6 registrations are different. Because of that, when the MN moves from its home network (i.e. from the PMIPv6 domain) to the foreign link, the Binding Update sent by the MN is not identified by the HA as an update of the Proxy Binding Cache Entry containing the home prefix of the MN, but a new binding cache entry is created. Therefore PMIPv6 and MIPv6 will always create two different binding cache entries in the HA/LMA which implies that the HA and LMA are logically separated. How to handle the presence of the two binding cache entries for the same MN is described in Section 4.3.

2. MIPv6 de-registration Binding Update deletes PMIPv6 binding cache entry

   * When the mobile node moves from a MIPv6 foreign network to the PMIPv6 home domain, the MAG registers the mobile node at the LMA by sending a Proxy Binding Update. Subsequently, the LMA updates the mobile node's binding cache entry with the MAG

address and the MAG emulates the mobile node's home link. Upon detection of the home link, the mobile node will send a de-registration Binding Update to its home agent. It is necessary to make sure that the de-registration of the MIPv6 BU does not change the PMIPv6 BCE just created by the MAG.

3. Race condition between Binding Update and Proxy Binding Update messages (Sequence Numbers and Timestamps)

   * MIPv6 and PMIPv6 use different mechanisms for handling re-ordering of registration messages and they are sent by different entities. Whereas Binding Update messages are ordered by a sequence numbers and sent by the mobile node, Proxy Binding Update messages are ordered by a timestamp option and sent by MAGs.

4. Use of wrong home agent or LMA after handover

   * This issues can arise if multiple LMAs are deployed in the PMIP home domain. If the mobile node moves from a MIPv6 foreign network to the PMIPv6 home domain, the MAG must send the Proxy Binding Update to the particular LMA that is co-located with the home agent which maintains the active binding cache entry of the mobile node. If a different LMA is assigned to the MAG, the MN will not be on the home link but will still have MIPv6 active and this may be not desirable in some deployments.

   * Similarly, if the mobile node moves from the PMIPv6 home domain to a MIPv6 foreign network, the mobile node must send the Binding Update to the particular home agent that is co-located with the LMA which maintains the active proxy binding cache entry of the mobile node. If the mobile node selects a different home agent, packets addressed to the mobile node's home address do not reach the mobile node.

5. Threat of compromised MAG

   * In MIPv6 base specification [RFC3775] there is a strong

binding between the Home Address registered by the MN and the Security Association used to modify the corresponding binding cache entry.

* In PMIPv6 specification, the MAG sends proxy binding updates on behalf of a mobile node to update the binding cache entry that corresponds to the mobile node's home address. Since the MAG sends the binding updates, PMIPv6 requires security associations between each MAG and the LMA.

* As described in [RFC4832], in PMIPv6 the MAG compromise or impersonation is an issue. RFC4832, section 2.2, describes how a compromised MAG can harm the functionality of LMA, e.g. manipulating LMA's routing table (or binging cache).

* In this mixed scenario, both host-based and network-based security associations are used to update the same binding cache entry at the HA/LMA (but see the first bullet of this list, as the entry may not be the same). Based on this consideration, the threat described in [RFC4832] is worse as it affects also hosts that are using the LMA/HA as MIPv6 HA and are not using PMIPv6.

4. Analysis of possible solutions

4.1. Solutions related to scenario A

As mentioned in Section 3.1, there are no significant issues in this scenario.

Figures 5 and 6 show a scenario where a MN is moving from one PMIPv6 domain to another, based on the scenario of Figure 1. In Figure 5, the MN moves from an old MAG to MAG2 in the same PMIPv6 domain: this movement triggers a PBU to LMA1 and the updating of the binding cache at the LMA1; there is no MIPv6 signaling as the CoA_1 registered at the HA is the Home Address for the PMIPv6 session. In Figure 6, the MN moves from MAG2 in the LMA1 PMIPv6 domain to MAG3 in a different PMIPv6 domain: this triggers the PMIPv6 signaling and the creation of a binding at the LMA2. On the other hand, the local address of the MN is changed, as the LMA hss changed, and therefore the MN sends a

MIPv6 Binding Update to the HA with the new CoA_2.

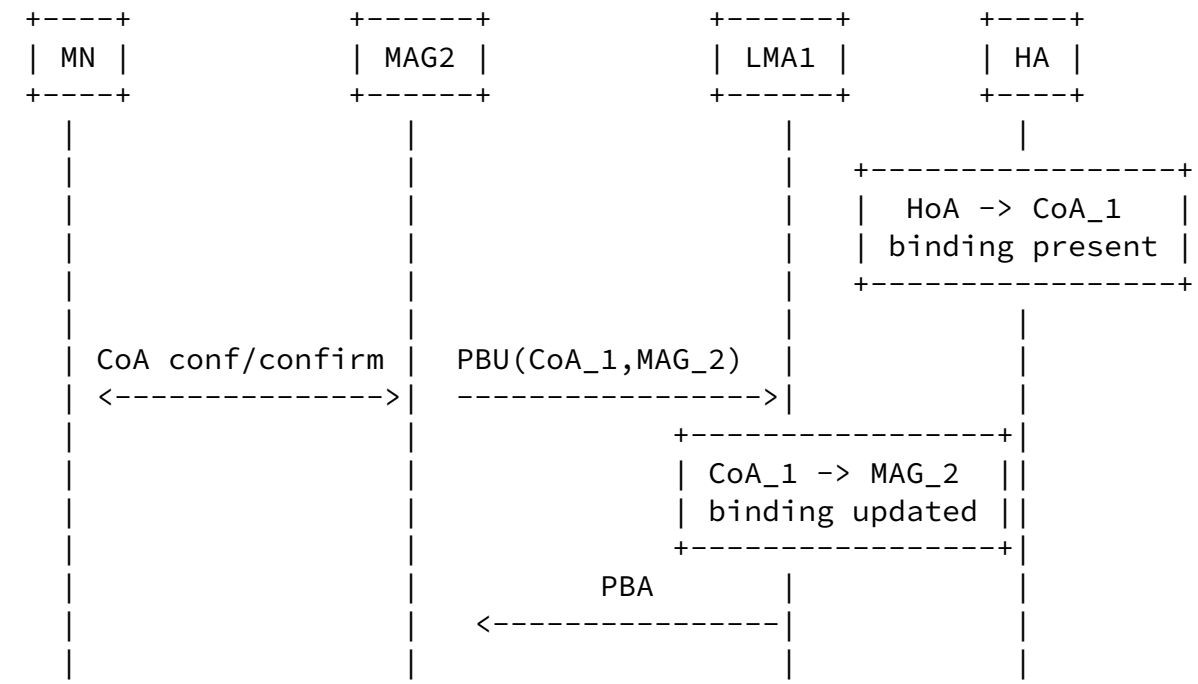


Figure 5 - Local Mobility Message Flow

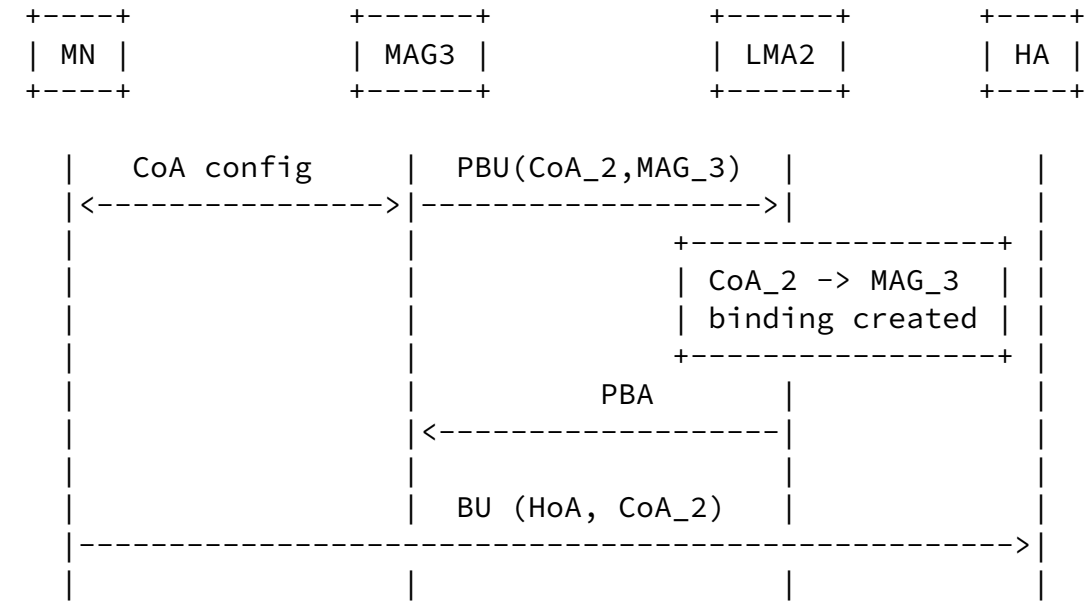


Figure 6 - Global Mobility Message Flow

4.2. Solutions related to scenario B

The solution for this scenario may depend on the access network being able to determine that a particular mobile node wants to use Mobile IPv6. This requires a solution at the system level for the access network and is out of scope of this document. Solutions that do not depend on the access network are out of the scope of this document.

4.3. Solutions related to scenario C

As described in Section 3.3, in this scenario the mobile node relies on Proxy Mobile IPv6 as long as it is in the Proxy Mobile IPv6 domain. The mobile node then uses Mobile IPv6 whenever it moves out of the PMIPv6 domain which basically implies that the MIPv6 home link is a PMIPv6 domain.

Analyzing the issues described in Section 3.3, it is clear that most of them are applicable only to the case where there is a common BCE for the PMIPv6 registration and the MIPv6 registration. The issue 1

on how the two protocols identify the BCE is valid only in case we assume that a PMIPv6 message has any value for a MIPv6 BCE. Also the issues 2 and 3 are not applicable in case different logical BCEs are used by the LMA and the HA. For this reason, it is recommended that when the MIPv6 home link is implemented as a PMIPv6 domain, the HA/ LMA implementation treats the two protocol as independent.

More in details the following principles should be followed by the HA/LMA implementation:

- PMIPv6 signaling does not overwrite any MIPv6 BCE. In particular, when a PMIPv6 binding cache entry is created for a MN which has

previously created a MIPv6 BCE, the MIPv6 BCE of the UE is not overwritten and a new PMIPv6 BCE is created.

- The downlink packets in the case where both the MIPv6 BCE and PMIPv6 BCE exist are processed as follows:

  1. The MIPv6 BCE is processed first. If the destination address of the received downlink packet matches the the BCE of the HA, the packet is forwarded by encapsulating it with the care-of-address contained in the BCE.

  2. If the destination address does not match the MIPv6 BCE, the BCE created by PMIPv6 is applied and the packet are encapsualted to the registered MAG.

The following subsections provide a description of the procedures which will be followed by the MN and HA/LMA based on the above principles. The analysis is performed in two different subsections, depending if the MN moves from a PMIPv6 domain to a non-PMIPv6 domain or vice versa.

4.3.1. Mobility from a PMIPv6 domain to a non-PMIPv6 domain

Let's assume the MN is attached to a PMIPv6 domain and there is a valid Proxy Binding Cache entry at the LMA. Then the MN moves to a different access network and starts using MIPv6 (e.g. because PMIPv6 is not supported). The MN needs to bootstrap MIPv6 parameters and send a MIPv6 Binding Update in order to have service continuity. Therefore the following steps must be performed by the UE:

- HA/LMA address discovery: the MN needs to discover the IP address of the LMA which has a valid binding cache entry for its home network prefix. This is described in Section 3.3 as issue 4.

- Security Association establishment: the MN needs to establish an IPsec Security Association with the HA/LMA as described in [RFC4877]

- HoA or home network prefix assignment: as part of the MIPv6 bootstrapping procedure the HA assigns a MIPv6 HoA to the MN. This address must be the same the MN was using in the PMIPv6

domain.

Since all these steps must be performed by the MN before sending the Binding Update, they have an impact on the handover latency experienced by the MN. For this reason it is recommended that the MN establishes the IPsec security association (and consequently is provided by the HA/LMA with a MIPv6-HoA) when it is still attached to the PMIPv6 domain. This implies that the mobile node has Mobile IPv6 stack active while in the PMIPv6 domain, but as long as it is attached to the same Proxy Mobile IPv6 domain, it will appear to the mobile node as if it is attached to the home link.

In order to establish the security association with the HA/LMA, the MN needs to discover the IP address of the LMA/HA while in the PMIPv6 domain. This can be done either based on DNS or based on DHCPv6, as described in [RFC5026] and [boot-integrated]. The network should be configured so that the MN discovers or gets assigned the same HA/LMA that was serving as the LMA in the PMIPv6 domain. Details of the exact procedure are out of scope of this document.

When the MN establishes the security association, it acquires a home address based on [RFC5026]. However, based on PMIPv6 operations, the LMA knows only the Home Network Prefix used by the MN and does not know the MN-HoA.For this reason, the MN must be configured to propose MN-HoA as the home address in the IKEv2 INTERNAL_IP6_ADDRESS attribute during the IKEv2 exchange with the HA/LMA. Alternatively the HA/LMA can be configured to provide the entire Home Network Prefix via the MIP6_HOME_LINK attribute to the MN as specified in [RFC5026]; based on this Home Network Prefix the MN can configure a home address. Note that the security association must be bound to the MN-HoA used in the PMIPv6 domain as per [RFC4877]. Note that the home network prefix is shared between the LMA and HA and this implies that there is an interaction between the LMA and the HA in order to assign a common home netowrk prefix when triggered by PMIPv6 and MIPv6 signaling

When the MN hands over to an access network which does not support Proxy Mobile IPv6, it sends a Binding Update to the HA. The MN may set the R bit defined in NEMO specification (implicit mode) in order to indicate that the entire HNP is moved to the new CoA. A MIPv6 BCE is created irrespective of the existing PMIPv6 BCE. Packets matching

the MIPv6 BCE are sent to the CoA present in the MIPv6 BCE. The PMIPv6 BCE will expire in case the MAG does not send a refresh PBU.

4.3.2. Mobility from a non-PMIPv6 domain to a PMIPv6 domain

In this section it is assumed that the MN is in a non-PMIPv6 access network and it has bootstrapped MIPv6 operations based on [RFC5026]; therefore there is valid binding cache for its MIPv6-HoA (or HNP in case of NEMO) at the HA. Then the MN moves to a PMIPv6 domain which is configured to be the home link for the MIPv6-HoA the MN has been assigned.

In order to provide session continuity, the MAG needs to send a PBU to the HA/LMA that was serving the MN. The MAG needs to discover the HA/LMA; however the current version of [RFC5213] assumes that the LMA is assigned to the MAG or discovered by the MAG when the MN attaches to the MAG. the exact mechanism is not specified in [RFC5213]. A detailed description of the necessary procedure is out of the scope of this document. Note that the MAG may also rely on static configuration or lower layer information provided by the MN in order to select the correct HA/LMA.

The PBU sent by the MAG creates a PMIPv6 BCE for the MN which is independent of the MIPv6 BCE. Traffic destined to the MIPv6-HoA (or to the HNP in case the MN had set the flag R in the last BU) is still forwarded to the CoA present in the MIPv6 BCE. When the MN wants to use the HoA directly from the home link, it sends a de-registration message and at that point only the PMIPv6 BCE is present.

5. Security Considerations

Scenarios A and B described in Section 3 do not introduce any security considerations in addition to those described in [pmipv6-draft] or [RFC3775].

This document requires that the a home agent that also implements the PMIPv6 LMA functionality should allow both the mobile node and the authorized MAGs to modify the binding cache entries for the mobile node. Note that the compromised MAG threat described in [RFC4832] applies also here.

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