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Interactions between PMIPv6 and MIPv6: Route Optimization Issues
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Abstract

The interactions scenarios between Proxy Mobile IPv6 (PMIPv6) and Mobile IPv6 (MIPv6) protocols are described in [[ID-MIP-PMIP](#)]. This document analyzes these scenarios when route optimization is used. The analysis results in the identification of possible issues that should be considered in the design of extensions for Route Optimization in PMIPv6.

Internet-Draft

PMIPv6-MIPv6 R0 Issues

February 2008

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

The NETLMM WG is standardizing Proxy Mobile IPv6 (PMIPv6) as the protocol for network-based localized mobility management. The MIPv6-PMIPv6 interactions document [[ID-MIP-PMIP](#)] captures the issues with the inter-working between host-based (MIPv6) and network-based (PMIPv6) mobility and identifies three main scenarios. However, the document does not consider the cases when a route optimized path is set up.

In PMIPv6 the mobile access gateway (MAG) manages the mobility-related registrations with the local mobility agent (LMA) on behalf of the mobile nodes (MNs) attached to it. According to the base PMIPv6 specification [[ID-PMIPv6](#)] all data packets are bi-directionally tunneled between MAG and LMA. In some scenarios, e.g. if the communicating end nodes are located in the same PMIPv6 domain, it is advantageous to route the packets directly between the MAGs to which the nodes are attached. The PMIPv6 base spec does not support route optimization (RO) between different MAGs, however, there are individual proposals (see [Section 3.2](#)) for establishing such a route optimized path. In these proposals the MNs are unaware about the proxy RO set up in PMIPv6 domain between the MAGs. On the other hand, in MIPv6 the MN itself performs the route optimization with a CN.

This document provides an analysis of the scenarios and possible issues when the PMIPv6 and MIPv6 route optimization procedures interact.

2. Terminology

General mobility terminology can be found in [[RFC3753](#)]. Further, PMIPv6-related terminology used in this document is defined in [[ID-PMIPv6](#)]

[3.](#) Overview of route optimization

This section provides an overview of the route optimization procedures specified for MIPv6 and the general characteristics of a potential to-be-standardized route optimization procedure for PMIPv6.

[3.1.](#) Route optimization in MIPv6

MIPv6 protocol comes with a route optimization scheme that enables a direct communication between MN and CN, i.e. the data packets are bypassing the Home Agent. Route optimization requires the mobile

node to register its current binding of home address (HoA) to care-of-address (CoA) at the correspondent node. The CN establishes a binding cache entry and packets from the CN can be routed directly to the CoA of the MN.

MPv6 specification [[RFC3775](#)] defines the return routability (RR) procedure that authorizes the BU sent by the MN by the use of a cryptographic token exchange (keygen tokens). The binding update is signed by binding management key (Kbm) that is generated based on the keygen tokens obtained from CN separately for the home address and care-of-address. The detailed RR and R0 procedures are described in sections [5.2](#), [6.1](#), [9.4](#) and [9.5](#) in [[RFC3775](#)].

[3.2.](#) Route optimization in PMIPv6

Route optimization in PMIPv6 (proxy R0) is not in the charter of the NetLMM working group and is not specified in the PMIPv6 base specification [[ID-PMIPv6](#)]. However, [[ID-PMIPv6](#)] describes one case where the local routing at the MAG is possible. The local routing is applied when the two communicating mobile nodes are attached to the same MAG and the MAG's policy in coordination with LMA allows such routing. In all other attachment constellations the PMIPv6 protocol mandates reverse tunneling of data packets to the LMA.

However, interest in the area of PMIPv6 R0 (henceforth called proxy R0) exists from various working group members and individual solutions are already available. In the following, the general characteristics of possible PMIPv6 R0 mechanisms are analyzed. Subsequently, some individual submissions are briefly presented as

example solutions.

In general, the proxy R0 can be categorized in the following cases:

1. Between the MN and the CN's MAG. In this case the R0 is initiated by the MN and the MAG is the endpoint of the route optimized path. For instance, if MIPv6 R0 is used, CN's MAG performs the role of MIPv6 CN with respect to R0.
2. Between the MN's MAG and the CN. In this case the MN's MAG initiates the R0 with CN on behalf of the MN and the endpoint of the route optimized path is MN's MAG instead of MN. For instance, if MIPv6 R0 is used the MAG performs the role of MIPv6 MN with respect to R0.
3. Between MAGs. In this case the MAG, to which the MN is attached, initiates R0 with the CN's MAG and a route optimized path between both MAGs is established. For instance, if MIPv6 R0 is used, the MN's MAG performs the role of MIPv6 MN with respect to R0 and the

MAG, to which the CN is attached, performs the role of MIPv6 CN.

Each of the above cases is analyzed in different MIPv6-PMIPv6 interaction scenarios in [Section 4](#).

The document [[PMIPv6-R0-RR](#)] describes the applicability of Enhanced Route Optimization for Mobile IPv6 specified in [[RFC4866](#)] for PMIPv6, i.e. how cryptographically generated addresses (CGA) and the corresponding optimized R0 signalling (compared to [[RFC3775](#)]) are used. The authors describe a proxy Return Routability (RR) procedure performed by the MAG on behalf of the MN. The document addresses cases 2 and 3 from above.

Another individual approach for R0 in PMIPv6 is described in [[PMIPv6-R0-ROA](#)]. In this approach, the exchange of R0 setup messages (similar to binding updates messages) between the MAGs is performed either a) via the LMAs, to which the MAGs are attached, or b) directly between the MAGs. In the latter case, a route optimization association (ROA) between the MAGs is needed. The document addresses the case 3 (i.e. MAG-MAG R0) from above.

A further individual solution is described in [[PMIPv6-R0-IPv4](#)] that

presents a more general approach and considers a combination of both individual solutions presented in the previous paragraphs: either performing a proxy RR between MAGs or having a Security Association between MAGs for direct exchange of binding updates.

In general, if a mobile node attached to a MAG in PMIPv6 domain moves to a new MAG, the old MAG, the new MAG and the LMA should manage the transition of the R0-related state from the old to the new MAG. Further the new MAG shall update the BCE in the correspondent node. These procedures are outside of the scope of this document because it is not specific to MIPv6-PMIPv6 interactions and should be defined in a potential to-be-standardized PMIPv6 R0 procedure.

[4.](#) Analysis of the scenarios and possible issues

The categorization of the MIPv6-PMIPv6 interactions with respect to R0 is based on scenarios A, B and C described in [[ID-MIP-PMIP](#)] in order to achieve compliance between both documents. For each of the scenarios the cases from [Section 3.2](#) are applied and the resulting issues are identified.

[4.1.](#) Proxy R0 in scenario A

In scenario A, PMIPv6 is used as a network-based local mobility management protocol within one access network, whereas MIPv6 is used

as a global mobility management protocol. Furthermore, HA and LMA are not co-located.

In this scenario the MN uses MIPv6 and registers the IP address obtained in the PMIPv6 domain as CoA at the HA. A bi-directional tunnel is set up between the MN and HA. An additional PMIPv6 tunnel is in use between MAG1 and LMA1. Figure 1 illustrates the hierarchical application of MIPv6 and PMIPv6 protocols in scenario A. The CN relies on the PMIPv6 for mobility management, it is attached to MAG2 and anchored at LMA1, where the MN is anchored too.

```
+-----+
|  HA  |
+-----+
//\
```

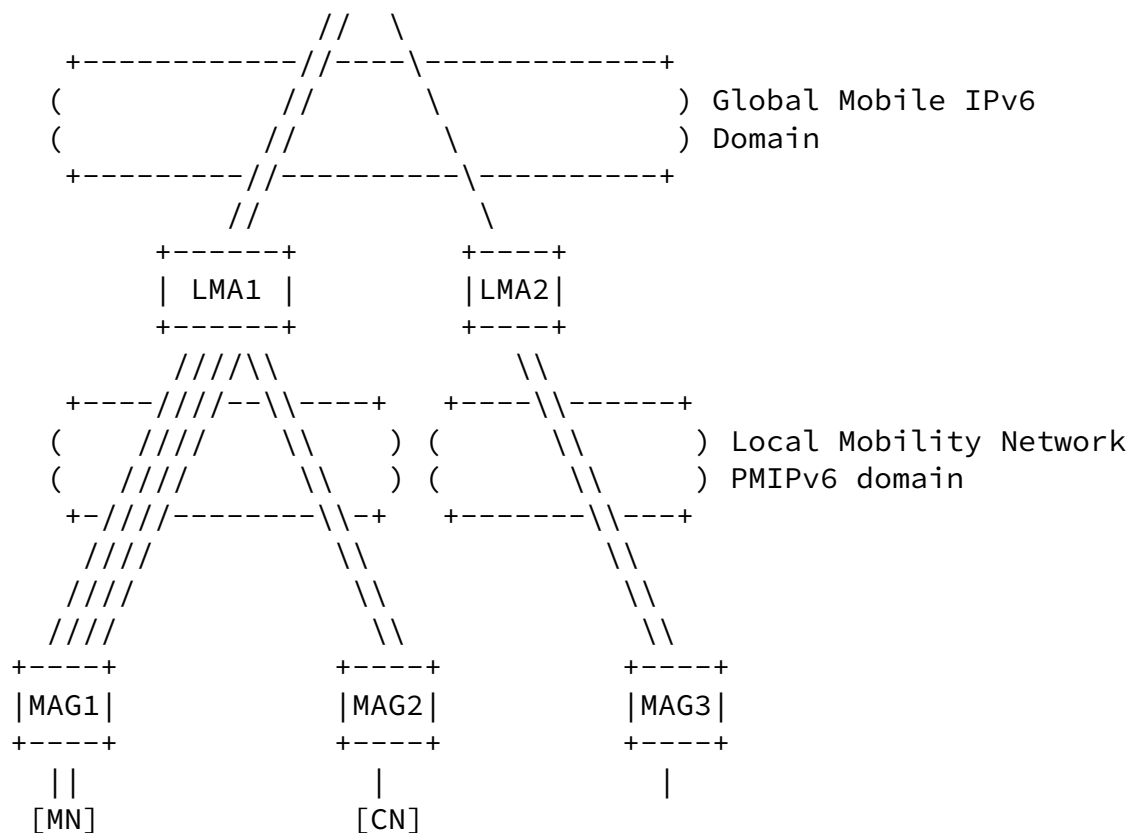


Figure 1 - Scenario A

As MIPv6 bidirectional tunnel is set up between MN and HA, the PMIPv6 entities (MAG1 and LMA1) cannot learn the address of the CN, and thus, cannot perform any actions with respect to proxy R0. Even if the CN is attached to the same or neighbour MAG, to which MN is attached, PMIPv6 entities are unable to discover such a situation assuming that there is no explicit information between MN's HA and LMA. Therefore, proxy R0 initiated by MN's MAG to the CN, i.e. case

2 from [Section 3.2](#), is not possible. The MAG would rather see the HA as CN and establish an optimized route to the HA, which is of course not desired. Proxy R0 between MAG1 and MAG2 (case 3) has the same problem as case 2: since a MIPv6 tunnel is set up between MN and HA, MAG1 cannot discover CN's address and initiate proxy R0.

In contrary to cases 2 and 3, proxy R0 tunnel between MN and MAG2 (case 1) is possible. MN initiates a MIPv6 R0 with the CN and the

MAG2 is configured to act as proxy CN on behalf CN. The resulting path in both directions (i.e. MN->CN and CN->MN) would be MN-MAG1-LMA1-MAG2-CN. Such a situation is comparable to usual PMIPv6 routing, although MIPv6 R0 IP header options are present in the data packets (Routing Header Type 2 and Home Address destination option). This situation reveals CN address to MAG1 and hence gives opportunity for a proxy R0 tunnel set up between MAG1 and MAG2. A potential to-be-standardized PMIPv6 R0 procedure shall consider the handling of such a situation, where already MIPv6 R0 is running between MN and CN (or CN's MAG, i.e. MAG2). In summary, proxy PMIPv6 R0 from MAG1 to CN or from MAG1 to MAG2 in scenario A cannot be initiated unless MN performs MIPv6 R0 with CN (unless there are other means of informing MAG1 of the CN address).

Another proxy R0 constellation is possible, in which the MAG2 initiates proxy R0 with the MN on behalf of the CN. After such a route optimized path is set up, the data packets would continue to flow via the HA, i.e. the path would be the same as before the proxy R0. The MAG2 however cannot recognize such a constellation. Therefore it is advantageous if MAG2 does not initiate proxy R0 with MN.

Figure 1 shows a case where the CN is using only a PMIPv6 service. However, a situation is possible, in which the CN (analogically to MN) is also using PMIPv6 for local mobility and MIPv6 for global mobility. In such a situation both end nodes (MN and CN) must perform MIPv6 procedure in order to utilize a proxy R0 tunnel between the MAGs. The proxy R0 tunnel between the MAGs can be set up before the MIPv6 R0 procedures are completed, however, the MAGs must know the care-of-address of the corresponding node and the respective MAG they are attached to. After the PMIPv6 R0 is completed, the MAGs create a routing state pointing the CoA of the correspondent node to its respective MAG. The MAGs start to forward packets over the proxy R0 tunnel as soon as the end nodes start to use the CoA of the correspondent node.

[4.2.](#) Proxy R0 in scenario B

In scenario B some MNs use MIPv6 to manage their movements while others rely on a PMIPv6 protocol provided by the network. The configuration of the MAG for supporting such scenario is described in

anchor for MIPv6 and PMIPv6 is the same entity implementing the functions of both HA and LMA (below denoted as HA/LMA). For a MN, to which PMIPv6 service is offered, the HA/LMA is acting as LMA and for a MN, to which MIPv6 service is offered, the HA/LMA is acting as HA.

Figure 2 illustrates scenario B where a MN uses MIPv6 and a CN relies on PMIPv6 for mobility management. The MN utilizes MIPv6 tunnel to the HA/LMA via AR whereas a PMIPv6 tunnel is set up for CN between MAG2 and HA/LMA.

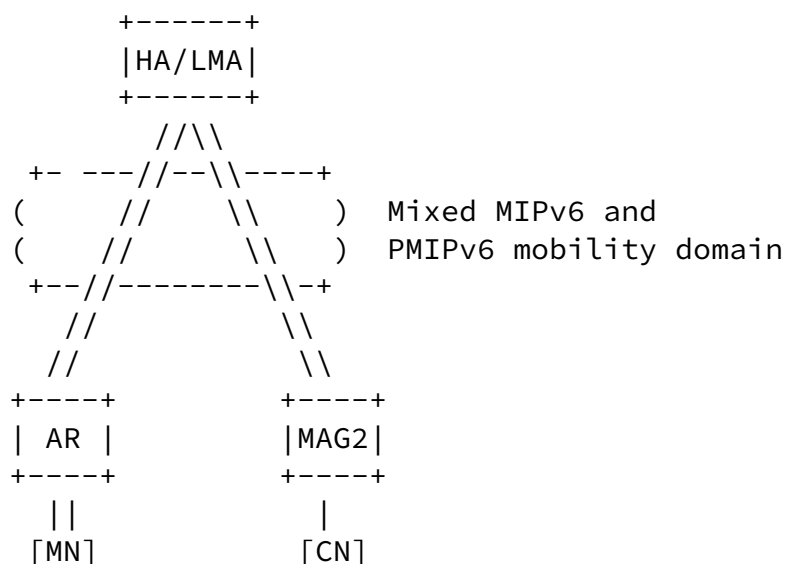


Figure 2 - Scenario B with colocated HA and LMA

An additional case is possible in scenario B, where MN's HA and CN's LMA are not colocated, however, they are in the same PMIPv6 mobility domain. Such a case is depicted on Figure 3.

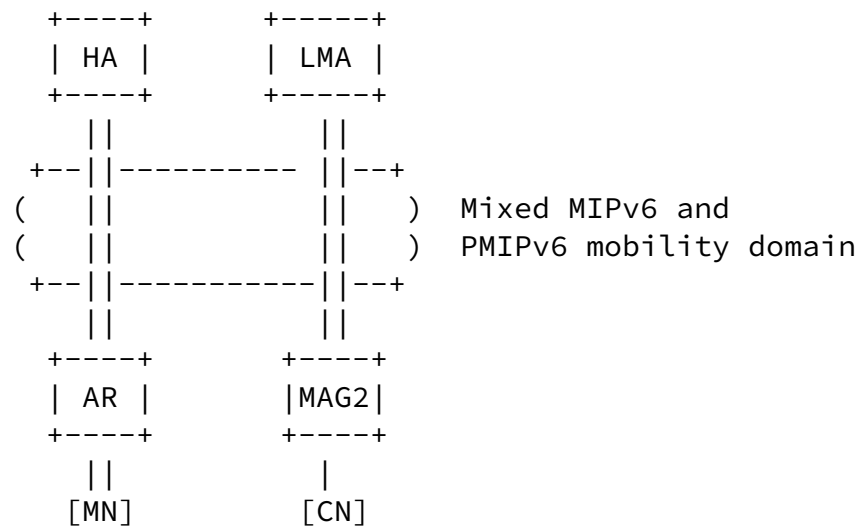


Figure 3 - Scenario B with separated HA and LMA

First, the analyses focuses on the proxy RO from MN side. For the constellations in Figure 2 and Figure 3, proxy RO is possible only between MN and MAG2 (case 1). The proxy RO cases 2 and 3 from [Section 3.2](#) are not possible because MN is attached to an AR. If the MN initiates a MIPv6 RO with CN, MAG2 may respond as proxy on behalf of the CN, which results in case 1. The RO path is set up between MN and MAG2, which is the optimal route from MN to CN. Additionally, MAG2 may initiate proxy RO with the MN in order to achieve route optimized path in direction from CN to MN. If the RO is performed in both directions, no further optimizations are needed.

Second, the analyses focuses on the proxy RO from CN side. This is the case if MAG2 initiates proxy RO with MN. In Figure 2, the resulting route optimized path would be via the MN's HA/LMA, because MAG2 does not know MN's CoA. The proxy RO in such a case does not lead to any path optimization and hence it is beneficial if MAG1 does not initiate proxy RO with MN. In Figure 3, the resulting route optimized path would be from MAG2 directly to MN's HA. In such a case the proxy RO would have a small benefit, as the data path doesn't run over LMA.

In summary, to achieve the optimal RO path in scenario B between MN using MIPv6 and CN relying on PMIPv6 service in the same network domain, the MN should initiate MIPv6 RO and additionally a proxy RO between MN and MAG should be performed. The network can assist the MN to initiate MIPv6 RO, as the network entities (most probably LMA) can discover such constellation.

4.3. Proxy R0 in scenario C

In scenario C a MIPv6-capable MN moves between access networks using different mobility management schemes, i.e. some access networks support PMIPv6 and others do not. This results in transition between PMIPv6 and MIPv6 mobility management for the particular MN and requires that LMA and HA functions are located in the same physical entity. Scenario C is depicted in Figure 4.

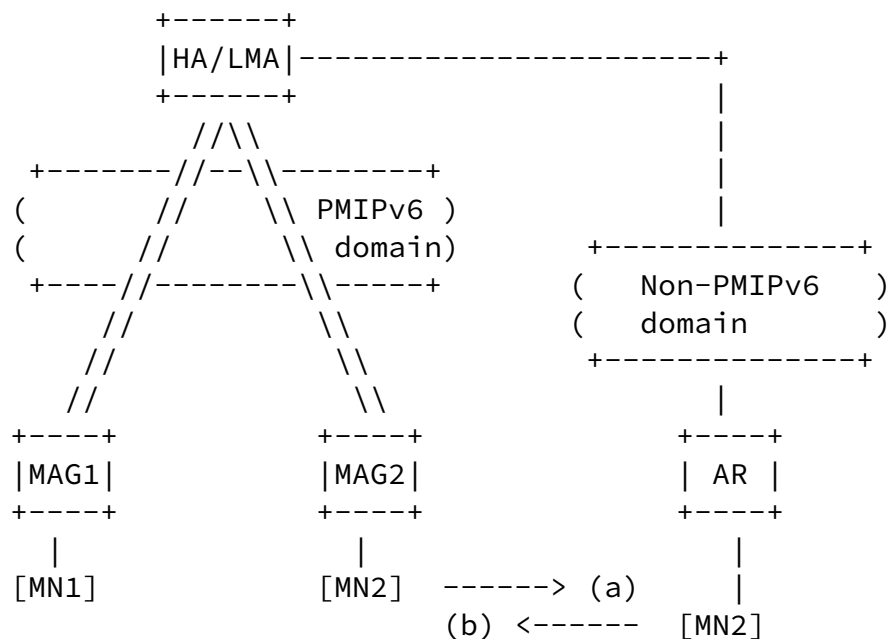


Figure 4 - Scenario C

4.3.1. MN2 performs MN role

In order to analyze the issues with R0 in scenario C, first it is assumed that MN2 has the role of MN and MN1 has the role of CN. Further two transition scenarios are investigated denoted by the arrows (a) and (b) in Figure 4. In transition (a) the MN2 moves from MAG2 of PMIPv6 domain to an AR of non-PMIPv6 domain, whereas in transition (b) the MN2 moves from AR to MAG2. At first, transition

(a) is analyzed. If a MN2 is attached to MAG2 and MN1 is attached to MAG1, a proxy R0 path can be set up according to cases 2 (MAG2->MN1) and case 3 (MAG2->MAG1) from [Section 3.2](#). Cases 1 (MN2->MAG1) is not possible because the assumption is that MN2 is at the home link supporting PMIPv6 service, i.e. the MN2 does not have a CoA to register with the CN. In the following analysis, cases 2 and 3 are investigated together because the only difference is which entity (MN1 or MAG1) performs the CN role regarding R0 functionality. Therefore, below CN is indicated as MN1/MAG1.

If the MN2 moves outside the PMIP domain to an AR of a MIPv6 domain, the MN2 performs MIPv6 registration with the HA/LMA. Since the MN2 is not aware about the proxy R0 before the handover, it does not necessarily initiate registration of its CoA to MN1/MAG1. It depends on the MN2's MIPv6 implementation whether MIPv6 R0 is performed. Furthermore, there would be some delay till the MIPv6 R0 path is setup after the handover. The steps performed by the MAG2, after detection of MN2 detachment, depend on a potential PMIPv6 R0 specification. If the MAG2 does not deregister the MN2 with the MN1/MAG1, MN1/MAG1 continues to send packets to MAG2 and this could lead to packet loss. Therefore a potential PMIPv6 R0 protocol shall take care of this situation. On the other hand, if a mechanism is available in MAG2 to deregister MN2 with MN1/MAG1, then the proxy R0 path is terminated and data packets are routed via HA/LMA. The change of route optimized to non-optimized path would result in increased end-to-end delay and possibly to data packets lost due to transport layer time out. To avoid this situation, a future protocol mechanism should allow to keep the R0 path between the MN2 and MN1 after the MN2 moves out of the PMIPv6 domain.

The transition (b) from Figure 4 is observed hereby, where the MN2 is first attached to a MIPv6 domain and later moves to the home link that supports PMIPv6 service (home PMIPv6 domain). Case 1 (MN2->MAG1) from [Section 3.2](#) is the only possible way of performing proxy R0 before the handover. While attached to the MIPv6 domain, a proxy R0 path between MN2 and MAG1 is set up, i.e. MN2 creates BCE in MAG1. When the MN2 moves to the home PMIPv6 domain, it performs the returning home procedure described in [[RFC3775](#)], i.e. sends deregistration BU messages to HA and all CNs, to which a MIPv6 R0 has been set up. Thus, the MN2 deletes the BCE in MAG1 and MAG1 sends data packets to MN2's HoA, i.e. to HA/LMA. Such a scenario does not result in data packet loss, however, the MN-CN path after the

handover is not optimized.

In conclusion, the MN2's transition between PMIPv6 and MIPv6 mobility schemes results in issues that should be considered by a future protocol mechanisms. The transition from PMIPv6 to non-PMIPv6 domain may result in packet loss or affect the transport layer application due to increased end-to-end delay.

4.3.2. MN2 performs CN role

The MIPv6 R0 procedure [[RFC3775](#)] specifies the functionality of a CN, however, it does not consider mobile CN. In the following a mobile CN performing PMIPv6-MIPv6 transition in scenario C is analyzed in order to identify possible issues. In scenarios A and B the mobile CN does not change the mobility management scheme and therefore such an analysis is not needed. With respect to Figure 4, the assumption

now is that the MN's role is implemented in MN1 (respectively MAG1) and CN's role - in MN2 (respectively MAG2). In transition (a) the MN2 hands over from MAG2 to the AR. Before the handover, a proxy R0 tunnel exists between MAG1 and MAG2. MN2 sends data packets to MN1's HoA, but the MAG2 tunnels the packets to MAG1. After the handover, the MN2 performs MIPv6 registration with HA and continues to send the data packets to MN1's HoA. The LMA forwards the data packets to the MAG1 and they are delivered to MN1. However, in the opposite direction (MN1->MN2) MAG1 would continue to keep the proxy R0 path with MAG2, although MN2 is no longer attached to MAG2, which would result in packet loss. Such a situation should be considered by the potential to-be-standardized proxy R0 specification.

In transition (b), the MN2 hands over from AR to MAG2. Before the handover, MN2 uses MIPv6 bi-directional tunneling to the home network and a proxy R0 tunnel has been set up between MAG1 and MN2. MN2 performs the role of CN, i.e. the proxy BCE in MN2 is created by MAG1. Since in Figure 4 the MN2's HA is co-located with MN1's LMA, the proxy R0 tunnel does not bring any benefit for the data path. The proxy R0 tunnel would be beneficial in case that LMA and HA are not co-located (similar to Figure 3). After the handover to MAG2, the MN2 keeps the proxy BCE, and thus, sends the packets to MN1's CoA (e.g. MAG1's IP address). The packets are encapsulated by MAG2 in a PMIPv6 tunnel to LMA, and thus, the MN1-MN2 path results in an usual non-optimized PMIP path. However, in the direction MN1->MN2 the

proxy R0 state state in MAG1 is still active. MAG1 continues to update the MN2's BCE because MAG1 does not learn about the MN2 movement. Such a situation is undesired and shall be handled by a to-be-standardized proxy R0 procedure.

To sum up the issues with mobile CN in scenario C, transition (a) may lead to a situation in which the entity performing the MN's role (MAG1) continues to perform proxy R0 with the MAG2, although MN2 is no longer attached to MAG2. Transition (b) results in the non-optimal situation of tunneling data packets between MAG2 and LMA although a BCE exists in MN2 for optimal route to MN1.

5. Summary of the issues

The analyses of the different scenarios of MIPv6-PMIPv6 interactions with respect to R0 shows a couple of issues that should be considered during the design of to-be-standardized proxy R0 procedure. This section summarizes the main points of the above analyses:

- o In scenarios where both end nodes are located in the same PMIP domain and at least one of the end nodes uses MIPv6 for global mobility (scenario A and B), MIPv6 R0 procedure should be

performed in order to utilize a PMIPv6 R0 tunnel. In some constellations (scenario B, proxy R0 tunnel MN-MAG2), the set up of proxy R0 tunnel does not lead to any improvement in the data path unless the end node that uses MIPv6 does not perform MIPv6 R0.

- o In scenarios where transition between MIPv6 and PMIPv6 occurs (Scenario C), depending on the constellation, PMIP R0 states must be transferred (from MAG to MN or from MN to MAG) or updated when the transition occurs.
- o In some constellations (in scenario A) it may be advantageous for MAGs to know the CoA of the corresponding end nodes in order to set up a proxy R0 tunnel in advance before the MIPv6 R0 procedure is completed.

6. Security Considerations

The current document analyzes scenarios and describes issues; it does not present new protocol design. Therefore this document does not introduce any security issues in addition to those described in [ID-PMIPv6] or [RFC3775].

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