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M. Liebsch
NEC
S. Jeong
ETRI
Q. Wu
Huawei
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PMIPv6 Localized Routing Problem Statement
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Abstract

Proxy Mobile IPv6 is the IETF standard for network-based localized mobility management. In Proxy Mobile IPv6, mobile nodes are topologically anchored at a Local Mobility Anchor, which forwards all data for registered mobile nodes. The set up and maintenance of localized routing, which allows forwarding of data packets between mobile nodes and correspondent nodes directly without involvement of the Local Mobility Anchor in forwarding, is not considered. This document describes the problem space of localized routing in Proxy Mobile IPv6.

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1. Introduction

The IETF has specified Proxy Mobile IPv6 (PMIPv6) [[RFC5213](#)] as the base protocol for network-based localized mobility management (NetLMM), which takes basic operation for registration, de-registration and handover into account. In scope of the base protocol is the set up and maintenance of a forwarding tunnel between an MN's Mobility Access Gateway (MAG) and its selected Local Mobility Anchor (LMA). Data packets will always traverse the MN's MAG and its LMA, irrespective of the location of the MN's remote communication endpoint. Even though two communicating MNs might be attached to the same MAG or to different MAGs of the same local mobility domain, packets will traverse the MNs' LMA(s).

Objectives of designing a solution for localized routing in PMIPv6 are to specify protocol messages and enable associated protocol operation between PMIPv6 components to support the set up of a direct routing path for data packets between the MNs' MAGs without forwarding these packets through the MNs' LMA(s) and to maintain localized routing in case one or both MNs handover to a different MAG. Relevant protocol interfaces may include the interface between associated MAGs, between a MAG and an LMA as well as between LMAs.

This document analyzes and discusses the problem space of using always the default route through two communicating mobile nodes' local mobility anchors. Furthermore, the problem space of enabling localized routing in PMIPv6 is analyzed and described, while different communication and mobility scenarios are taken into account.

2. Conventions and 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 [[RFC2119](#)].

This document uses the terminology of [[RFC5213](#)]. The following terms are used in the context of this problem statement:

- o Mobile Node (MN): Mobile Node without IP mobility support, which is attached to a Mobility Access Gateway (MAG) and registered with a Local Mobility Anchor (LMA) according to the PMIPv6 specification [[RFC5213](#)].
- o Correspondent Node (CN): Correspondent Node with or without IP mobility support. The CN represents the communication peer of an MN, which is attached to a MAG and registered with an LMA according to the PMIPv6 specification.
- o Localized Routing: Result of signaling to set up routing states on relevant network entities to allow forwarding of data packets between an MN and a CN within a single PMIPv6 domain without intervention of the MN's LMA and the CN's LMA in data forwarding.
- o Localized Routing States: Information for localized routing on relevant forwarding entities on the direct data path between an MN and a CN. Such information includes route entries and may include further information about the MN and the CN, such as IDs.

3. Problem Statement for Localized Routing in PMIPv6

The Mobile IPv6 (MIPv6) protocol [[RFC3775](#)] has built-in mechanisms for direct communication between a MN and a CN. Mechanisms for route optimization in MIPv6 cannot be directly applied in PMIPv6, as MNs do not take part in mobility management and associated signaling. Following the architecture of PMIPv6, rather entities of the network infrastructure are dedicated to perform signaling to set up a more direct route between an MN and a CN. In case of communication between two nodes, which are attached to the PMIPv6 network infrastructure and each node is registered with an LMA, data packets between these two nodes will always traverse the responsible LMA(s). At least some deployment would benefit from having such communication localized, rather than traverse the core network to the LMA(s). In the context of this document, such localized communication comprises offloading traffic from LMAs and establish a direct forwarding path between the two communication endpoints.

Localized routing is understood in [[RFC5213](#)] as optimization of traffic between a MN and a CN under the same access router, whereas the MN connects to the MAG function of this access router and is registered with an LMA, but the CN is a regular IPv6 node without getting PMIPv6 service. In such case, the MAG forwards traffic directly between the MN and the CN, assuming the MAG is enabled to support this feature (setting of the EnableMAGLocalRouting flag on the MAG) and the MN's LMA enforces this optimization. [[RFC5213](#)] does not specify how an LMA can enforce optimization for such local communication. Maintaining local forwarding between the MN and the regular IPv6 CN gets more complex in case the MN performs a handover to a different MAG. Such use case is not considered in the specification and out of scope of this problem statement. This document focuses on use cases, where both nodes, the MN and the CN, are each registered with an LMA and both obtain PMIPv6 mobility service.

Localized routing is crucial at least for the following two reasons: First, by limiting the communication to the access nodes, the data traffic traversing the MAG - LMA path (network) can be reduced. This is significant considering that the transport network between the access and the core is often the bottleneck in terms of costs and performance. And there are performance benefits in terms of delay and packet loss, especially when the MNs are attached to the same MAG and the LMA is topologically far away from that MAG. Even when the MNs are attached to different MAGs, there could be benefit in limiting the communication to the access network only, rather than traversing the transport network to the LMA. Hence, providing the necessary protocol specification to enable localized routing in PMIPv6 is necessary.

Several tasks need to be performed by the network infrastructure components before relevant information for such direct communication is discovered and associated states for localized routing can be set up. The following list summarizes some key functions, which need to be performed by the PMIPv6 enabled network infrastructure to substitute mobile nodes in setting up a direct route.

- o Detection of the possibility to perform localized routing. This function includes looking at data packets' source and destination address.
- o Initiation of a procedure, which sets up a localized routing path.
- o Discovery of stateful entities (i.e. the LMA(s) and/or the MAG(s)), which maintain and can provide relevant information needed to set up a localized routing path. Such information may include the routable address of an LMA or MAG, where one or both mobile nodes are connected to and registered with.
- o Control in setting up and maintaining (e.g. during handover) the localized routing path. Control is also needed to terminate the use of a localized routing path and to delete associated states, whereas a trigger for the termination may come from a non-PMIPv6 related component.

This problem statement focuses on local communication between PMIPv6 managed nodes within a single PMIPv6 domain. The following list analyzes different use cases, which are limited to the communication within a single PMIPv6 domain, but they consider the existence of multiple LMAs. Figure 1 depicts the network of a PMIPv6 domain with two mobility anchors.

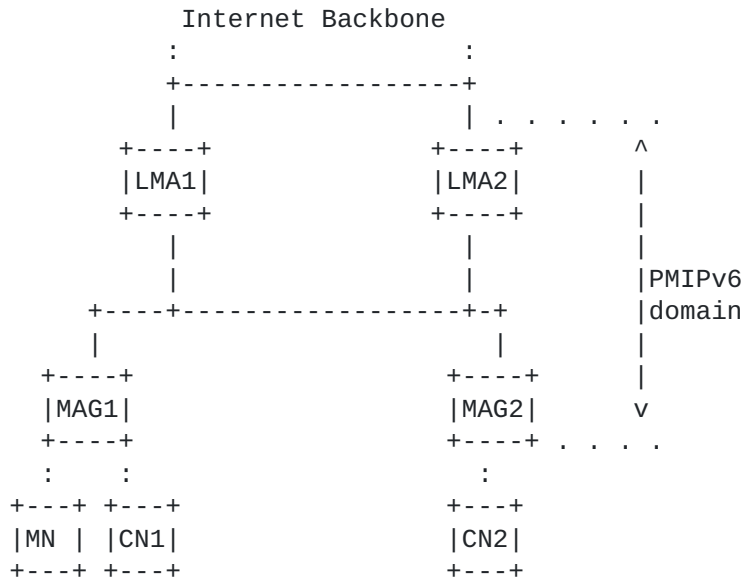


Figure 1: Reference architecture for localized routing in PMIPv6

All use cases A assume that both the MN and the CN are registered with an LMA according to the PMIPv6 protocol. Whereas MAG1 is always considered as the MN's current pCoA, the CN can be either connected to the same or a different MAG or LMA as the MN. Accordingly, these topological difference are denoted as follows:

A[number of MAGs][number of LMAs]

A11: MN and CN (CN1) connect to the same MAG (MAG1) and are registered with the same LMA (LMA). The common MAG may forward data packets between the MN and the CN directly without forwarding any packet to the LMA.

A12: MN and CN (CN1) connect to the same MAG (MAG1) and are registered with different LMAs (LMA1 and LMA2) of the same PMIPv6 domain. The common MAG may forward data packets between the MN and the CN directly without forwarding any packet to the LMAs. Following the policy of [\[RFC5213\]](#) and enforcement of the set up of a localized forwarding path, potential problems exist in case LMA1 and LMA2 differ in their policy to control the MAG.

A21: The CN (CN2) connects to a different MAG (MAG2) as the MN (MAG1), but MN and CN are registered with the same LMA (LMA1). The result of localized routing should be the existence of routing information at MAG1 and MAG2, which allows direct forwarding of packets between the MN's MAG1 and the CN's MAG2. As LMA1 is the

common anchor for MN and CN and maintains location information for both nodes, no major race condition and instability in updating the states for localized routing is expected.

A22: The CN (CN2) connects to a different MAG (MAG2) and a different LMA (LMA2) as the MN (MAG1, LMA1) in the same PMIPv6 domain. The result of localized routing should be the existence of routing information at MAG1 and MAG2, which allows direct forwarding of packets between the MN's MAG1 and the CN's MAG2. As the location information of the CN and the MN is maintained at different LMAs, both LMAs need to be involved in the procedure to set up localized routing. In case of a handover of MNs to a different MAG, not synchronized control of updating the states for localized routing may result in race conditions, superfluous signaling and packet loss.

The following list summarizes general problems with setting up and maintaining localized routing between an MN and a CN within a PMIPv6 domain. In the context of this problem statement, the MN and the CN are always assumed to be registered at an LMA according to the PMIPv6 protocol [[RFC5213](#)].

- o MNs do not participate in mobility management, hence cannot perform binding registration at a CN on their own. Rather entities in the network infrastructure must take over the role of MNs to set up and maintain a direct route. Accordingly, a solution for localized routing in PMIPv6 must specify protocol operation between relevant network components, such as between a MAG and an LMA, to enable localized routing for data traffic without traversing the MNs' LMA(s)
- o In case the MN and the CN are both registered with different LMAs according to the PMIPv6 protocol, relevant information for the set up of a localized routing path, such as the current MAGs of the MN and the CN, is distributed between these LMAs. This may complicate the set up and stable maintenance of states enabling localized routing.
- o In case localized routing between an MN and a CN has been successfully set up and both nodes move and attach to a new access router simultaneously, signaling the new location and maintenance of states for localized routing at relevant routers may run into a race condition situation. This can happen in case coordination of signaling for localized routing and provisioning of relevant state information is distributed between different network entities, e.g. different LMAs.

4. IPv4 Considerations

According to [[I-D.ietf-netlmm-pmip6-ipv4-support](#)], the basic configuration requirements for supporting IPv4 in PMIPv6 are that LMAs and MAGs are both IPv4 and IPv6 enabled. Also, LMAs and MAGs must have a globally unique IPv6 address configured, irrespective of enabled support for IPv6 routing between these components. This requirement should also apply to configuration requirements of localized routing.

4.1. Localized Routing between IPv4 Home Addresses

In case an LMA and a MAG hold a registration to support IPv4 Home Address mobility for an MN, the MAG and the LMA must support appropriate encapsulation of IPv4 packets. To enable localized routing, the MN's MAG must encapsulate and forward routing path optimized packets to the CN's MAG and needs to ensure, that the chosen encapsulation mode is supported by the correspondent MAG. Incompatibility in a selected encapsulation mode causes failure in setting up a localized route. Probably a capability exchange with encapsulation mode selection or negotiation scheme between MAGs must be supported to counteract such failure. Selection of an encapsulation mode is not needed in case both nodes attach to the same MAG, but needs to be performed each time a node hands over to a different MAG.

MAGs must maintain a routing state for each MN-CN-pair and take routing decisions for uplink traffic based on the packets' complete IPv4 source and destination address. Hence, conceptual data structures to handle states for localized routes need to comprise this address tuple for unique identification.

4.2. IPv4 Transport Network Considerations

As stated in the beginning of [Section 4](#), LMA and MAG are both IPv4 and IPv6 enabled when IPv4 is supported in PMIPv6. However, when using IPv4 transport, it is not necessary to enable IPv6 routing between LMA and MAG. Thus, the MN's MAG and the CN's MAG may use different IP versions for the transport of PMIPv6 signaling messages to the LMA. For example, it is possible that the MN's MAG supports IPv4 home address mobility and IPv6 transport, whereas the CN's MAG supports IPv4 home address mobility and IPv4 transport. In that case, it is necessary that the MN's and CN's MAGs negotiate the IP version for localized routing signaling and data forwarding.

When the MN hands over to a new MAG, the MAG may use a different IP version for PMIPv6 signaling as the MN's previous MAG. In that case, the new MAG may need to re-negotiate the IP version of the data

forwarding tunnel for localized routing and signaling or to restart the localized routing procedure.

4.3. NAT Presence Issues

In [[I-D.ietf-netlmm-pmip6-ipv4-support](#)], packets originated from or sent to a MN are routed by default through a bidirectional tunnel between MAG and LMA and the presence of a NAT between MAG and LMA is considered. Even though there may not be any NAT between the MAG and the LMA, there may exist a NAT on the direct routing path between MN's MAG and the CN's MAG or between the MN and CN's LMAs. Therefore, NAT detection and traversal mechanisms should be utilized during initializing localized routing procedures for IPv4 support.

4.4. IPv4 Address Space Overlapping Issues

As described in [[I-D.ietf-netlmm-grekey-option](#)], GRE keys being encapsulated within tunneled packets can be used to distinguish each MN's flow between the MAG and the LMA, even though two MNs may have assigned the same HoA from an overlapping IPv4 address space managed by each MN's operator. However, special care may be taken of a use case where a packet from the CN is sent to two MNs which are assigned the same IPv4 HoA and attach to the same MAG. If the packet does not traverse the tunnel between the MN's MAG and its LMA but is forwarded directly from the CN's MAG to the MN's MAG due to localized routing, the MN's MAG may not be able to identify the MN to which the packet must be delivered. Therefore, in this context there may be the need to utilize some service differential mechanism to identify flows being forwarded directly between MAGs.

5. Security Considerations

Since network entities rather than MNs and CNs perform signaling to set up localized routing, the MIPv6 return routability test [[RFC3775](#)] is not suitable to authenticate associated signaling messages in PMIPv6. Solutions for localized routing in PMIPv6 need to mitigate or to provide sufficient defense against possible security threats. When PMIPv6 participants are administered within the same domain, infrastructure-based authorization mechanisms, such as IPsec, may be usable to protect signaling for localized routing.

Existing security associations according to [[RFC5213](#)] can be re-used to protect signaling for localized routing on the interface between a MAG and an LMA. In case a protocol solution for localized routing in PMIPv6 relies on protocol operation between MAGs, means for protection of signaling between these MAGs must be provided. The same applies for signaling on a possible protocol interface between two LMAs of the same domain.

6. Acknowledgments

Many aspects of the problem space for route optimization in PMIPv6 have been discussed in the context of a PMIPv6 Route Optimization Design Goals document, which has been submitted to the NetLMM WG in November 2007. This group of contributors includes Sangjin Jeong, Christian Vogt, Ryuji Wakikawa, Behcet Sarikaya, Shinta Sugimoto, Long Le, Alice Qinxia and Jaehoon Lee. Many thanks also to Rajeev Koodli for his comments about the structure and scope of this problem statement.

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Appendix A. Change Notes

Changes in version 01

- o Added a note about [[RFC5213](#)]'s understanding of localized routing and the difference to the use cases discussed in this problem statement
- o Added the need for the solution to support also termination of localized routing
- o Some editorial revision
- o Added chapter about IPv4 support according to the discussed and relevant issues

Authors' Addresses

Marco Liebsch
NEC Laboratories Europe
NEC Europe Ltd.
Kurfuersten-Anlage 36
69115 Heidelberg,
Germany

Phone: +49 6221 4342146
Email: liebsch@nw.neclab.eu

Sangjin Jeong
ETRI
138 Gajeongno, Yuseong
Daejeon, 305-700
Korea

Phone: +82 42 860 1877
Email: sjeong@etri.re.kr

Qin Wu
Huawei Technologies, Co., Ltd
12F, Huihong Mansion, No.91, Baixia Rd.,
Nanjing, 210001
China

Phone: +86 21 84565892
Email: sunseawq@huawei.com