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T C. Schmidt
HAW Hamburg
M. Waehlisch
link-lab & FU Berlin
S. Krishnan
Ericsson

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A Minimal Deployment Option for Multicast Listeners in PMIPv6 Domains
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Abstract

This document describes deployment options for activating multicast listener functions in Proxy Mobile IPv6 domains without modifying mobility and multicast protocol standards. Similar to Home Agents in Mobile IPv6, PMIPv6 Local Mobility Anchors serve as multicast subscription anchor points, while Mobile Access Gateways provide MLD proxy functions. In this scenario, Mobile Nodes remain agnostic of multicast mobility operations.

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 (PMIPv6) [RFC5213] extends Mobile IPv6 [RFC3775] by network-based management functions that enable IP mobility for a host without requiring its participation in any mobility-related signaling. Additional network entities, i.e., the Local Mobility Anchor (LMA), and Mobile Access Gateways (MAGs), are responsible for managing IP mobility on behalf of the mobile node (MN).

With these routing entities in place, the mobile node looses transparent end-to-end connectivity to the static Internet, and in the particular case of multicast communication, group membership management as signaled by the Multicast Listener Discovery protocol [RFC3810], [RFC2710] requires a dedicated treatment at the network side, see [I-D.deng-multimob-pmip6-requirement].

Multicast routing functions need a careful placement within the PMIPv6 domain to augment unicast transmission with group communication services. [RFC5213] does not explicitly address multicast communication, whereas bi-directional home tunneling, the minimal multicast support arranged by MIPv6, cannot be applied in network-based management scenarios: A mobility-unaware node will experience no reason to initiate a tunnel with an entity of mobility support.

This document describes options for deploying multicast listener functions in Proxy Mobile IPv6 domains without modifying mobility and multicast protocol standards. Similar to Home Agents in Mobile IPv6, PMIPv6 Local Mobility Anchors serve as multicast subscription anchor points, while Mobile Access Gateways provide MLD proxy functions. Mobile Nodes in this scenario remain agnostic of multicast mobility operations. Accrediting the problem space of multicast mobility [I-D.irtf-mobopts-mmcastv6-ps], this document does not address specific optimizations and efficiency improvements of multicast routing in network-centered mobility beyond base potentials, as such solutions would require changes to the base specification of [RFC5213].

2. Terminology

This document uses the terminology as defined for the mobility protocols [RFC3775] and [RFC5213], as well as the multicast edge related protocols [RFC3810] and [RFC4605].

3. Overview

The reference scenario for multicast deployment in Proxy Mobile IPv6 domains is illustrated in Figure 1.

```
                       +--------------+
                       | Content      |
                       | Source       |
                       +--------------+
                              |
                     ***  ***  ***  ***
                    *   **   **   **   *
                   *                    *
                    *  Fixed Internet  *
                   *                    *
                    *   **   **   **   *
                     ***  ***  ***  ***
                      /            \
                  +-----+        +-----+
                  |LMA1|         |LMA2|                 Multicast Anchor
                  +-----+        +-----+
             LMAA1  |              |  LMAA2
                    |              |
```

```
                    \\           //\\
                     \\         //  \\
                      \\       //    \\                  Unicast Tunnel
                       \\     //      \\
                        \\   //        \\
                         \\ //          \\
               Proxy-CoA1 ||            ||  Proxy-CoA2
                       +-----+         +-----+
                       |MAG1|          |MAG2|            MLD Proxy
                       +-----+         +-----+
                        |  |              |
                MN-HNP1 |  | MN-HNP2      | MN-HNP3
                       MN1 MN2          MN3
```

      Figure 1: Reference Network for Multicast Deployment in PMIPv6

An MN in a PMIPv6 domain will decide on multicast group membership management completely independent of its current mobility conditions. It will submit MLD Report and Done messages following application desires, thereby using its link-local source address and multicast destination addresses according to [RFC3810], or [RFC2710]. These link-local signaling messages will arrive at the currently active MAG via one of its downstream local (wireless) links. A multicast unaware MAG would simply discard these MLD messages.

To facilitate multicast in a PMIPv6 domain, an MLD proxy function

[RFC4605] needs to be deployed on the MAG that selects the tunnel interface corresponding to the MN's LMA for its upstream interface (cf., section 6 of [RFC5213]). Thereby, each LMA-to-MAG tunnel interface defines an MLD proxy domain at the MAG, containing all downstream links to MNs that share this LMA. According to standard proxy operations, MLD Report messages will be forwarded under aggregation up the tunnel interface to its corresponding LMA.

Serving as the designated multicast router or an additional MLD proxy, the LMA will transpose any MLD message from a MAG into the multicast routing infrastructure. Correspondingly, the LMA will implement appropriate multicast forwarding states at its tunnel interface. Traffic arriving for groups under subscription will arrive at the LMA, which it will forward according to all its group/ source states. In addition, the LMA will naturally act as an MLD querier, seeing its downstream tunnel interfaces as multicast enabled links.

At the MAG, MLD queries and multicast data will arrive on the (tunnel) interface that is assigned to a group of access links as identified by its Binding Update List (cf., section 6 of [RFC5213]). As specified for MLD proxies, the MAG will forward multicast traffic and initiate related signaling down the appropriate access links to the MNs. In proceeding this way, all multicast-related signaling and the data traffic will transparently flow from the LMA to the MN on an LMA-specific tree, which is shared among the multicast sources.

In case of a mobility handover, the MN (unaware of IP mobility) will refrain from submitting unsolicited MLD reports. Instead, the MAG is required to maintain group memberships in the following way. On observing a new MN on a downstream link, the MAG sends a General MLD Query. Based on its outcome and the multicast group states previously maintained at the MAG, a corresponding Report will be sent to the LMA aggregating group membership states according to the proxy function. Additional Reports can be omitted, whenever multicast forwarding states previously established at the new MAG already cover the subscriptions of the MN.

In summary, the following steps are executed on handover:

1. The MAG-MN link comes up and the MAG discovers the new MN.

2. Unicast address configuration and PMIPv6 binding are performed, the MAG can determine the corresponding LMA.

3. Following IPv6 address configuration, the MAG SHOULD send an (early) MLD General Query to the new downstream link as part of its standard multicast-enabled router operations.

4. The MAG SHOULD determine whether the MN is admissible to multicast services, and stop here otherwise.

5. The MAG adds the new downstream link to the MLD proxy instance with up-link to the corresponding LMA.

6. The corresponding Proxy instance triggers an MLD General Query on the new downstream link.

7. The MN Membership Reports arrive at the MAG, either in response to the early Query or to that of the Proxy instance.

8. The Proxy processes the MLD Report, updates states and reports upstream if necessary.

After Re-Binding, the LMA is not required to issue a General MLD Query on the tunnel link to refresh forwarding states. Multicast state updates SHOULD be triggered by the MAG, which aggregates subscriptions of all its MNs (see the call flow in Figure 2).


```
   MN1              MAG1              MN2              MAG2              LMA
```

```
   |                |                |               |                |
   |    Join(G)     |                |               |                |
   +--------------->|                |               |                |
   |                |     Join(G)    |               |                |
   |                |<---------------+               |                |
   |                |                |               |                |
   |                |     Aggregated Join(G)         |                |
   |                +=================================================>|
   |                |                |               |                |
   |                |   Mcast Data   |               |                |
   |                |<================================================+
   |                |                |               |                |
   |  Mcast Data    | Mcast Data     |               |                |
   |<---------------+--------------->|               |                |
   |                |                |               |                |
   |                |      < Movement to MAG2 & PMIP Binding Update > |
   |                |                |               |                |
   |                |                |--- Rtr Sol -->|                |
   |                |                |               |                |
   |                |                |   MLD Query   |                |
   |                |                |<--------------+                |
   |                |                |               |                |
   |                |                |   Join(G)     |                |
   |                |                +-------------->|                |
   |                |                |               Aggregated Join(G)
   |                |                |               +===============>|
   |                |                |               |                |
   |                |   Mcast Data   |               |                |
   |                |<================================================+
   |                |                |               |   Mcast Data   |
   |                |                |               |<===============+
   |  Mcast Data    |                |               |                |
   |<---------------+                |  Mcast Data   |                |
   |                |                |<--------------+                |
   |                |                |               |                |
```

Figure 2: Call Flow of Multicast-enabled PMIP

These multicast deployment considerations likewise apply for mobile nodes that operate with its IPv4 stack enabled in a PMIPv6 domain. PMIPv6 can provide an IPv4 home address mobility support [I-D.ietf-netlmm-pmip6-ipv4-support]. Such mobile node will use IGMP [RFC2236],[RFC3376] signaling for multicast, which is handled by an IGMP proxy function at the MAG in an analogous way.

Following these deployment steps, multicast management transparently inter-operates with PMIPv6. It is worth noting that multicast streams can possibly be distributed on redundant paths that lead to duplicate traffic arriving from different LMAs at one MAG, and can cause multiple data transmissions from an MAG over one wireless domain to different MNs (see Appendix C for further considerations).

4. Deployment Details

Multicast activation in a PMIPv6 domain requires to deploy general multicast functions at PMIPv6 routers and to define its interaction with the PMIPv6 protocol in the following way:

4.1. Operations of the Mobile Node

A Mobile Node willing to manage multicast traffic will join, maintain and leave groups as if located in the fixed Internet. No specific mobility actions nor implementations are required at the MN.

4.2. Operations of the Mobile Access Gateway

A Mobility Access Gateway is required to assist in MLD signaling and data forwarding between the MNs which it serves, and the corresponding LMAs associated to each MN. It therefore needs to implement an instance of the MLD proxy function [RFC4605] for each upstream tunnel interface that has been established with an LMA. The MAG decides on the mapping of downstream links to a proxy instance (and hence an upstream link to an LMA) based on the regular Binding Update List as maintained by PMIPv6 standard operations (cf., section 6.1 of [RFC5213]). As links connecting MNs and MAGs change under mobility, MLD proxies at MAGs MUST be able to dynamically add and remove downstream interfaces in its configuration.

On the reception of MLD reports from an MN, the MAG MUST identify the corresponding proxy instance from the incoming interface and perform regular MLD proxy operations: it will insert/update/remove a multicast forwarding state on the incoming interface, and state updates will be merged into the MLD proxy membership database. An aggregated Report will be sent to the upstream tunnel of the MAG when the membership database (cf., section 4.1 of [RFC4605]) changes. Conversely, on the reception of MLD Queries, the MAG proxy instance will answer the Queries on behalf of all active downstream receivers maintained in its membership database. Queries sent by the LMA do not force the MAG to trigger corresponding messages immediately towards MNs. Multicast traffic arriving at the MAG on an upstream interface will be forwarded according to the group/source-specific forwarding states as acquired for each downstream interface within the MLD proxy instance. At this stage, it is important to stress that IGMP/MLD proxy implementations capable of multiple instances are

expected to closely follow the specifications of section 4.2 in [RFC4605], i.e., treat proxy instances in isolation of each other while forwarding.

In case of a mobility handover, the MAG will continue to manage upstream tunnels and downstream interfaces as foreseen in the PMIPv6 specification. It MUST dynamically associate new access links to proxy instances that for a MN provide up-link to its corresponding LMA. In addition, it MUST assure consistency of its up- and downstream interfaces that change under mobility with MLD proxy instances and its multicast forwarding states. The MAG will detect the arrival of a new MN by receiving a router solicitation message and by an upcoming link. To learn about multicast groups subscribed by a newly attaching MN, the MAG sends a General Query to the MN's link. Querying an upcoming interface is a standard operation of MLD queriers (see Appendix A) and performed immediately after address configuration. In addition, an MLD query SHOULD be initiated by the proxy instance, as soon as a new interface has been configured for downstream. In case, the access link between MN and MAG goes down, interface-specific multicast states change. Both cases may alter the composition of the membership database, which then will trigger corresponding Reports towards the LMA. Note that the actual observable state depends on the access link model in use.

An MN may be unable to answer MAG multicast membership queries due to handover procedures, or its report may arrive before the MAG has configured its link as proxy downstream interface. Such occurrences are equivalent to a General Query loss. To prevent erroneous query timeouts at the MAG, MLD parameters SHOULD be carefully adjusted to the mobility regime. In particular, MLD timers and the Robustness Variable (see section 9 of [RFC3810]) MUST be chosen to be compliant with the time scale of handover operations and proxy configurations in the PMIPv6 domain.

In proceeding this way, the MAG is entitled to aggregate multicast subscriptions for each of its MLD proxy instances. However, this deployment approach does not prevent multiple identical streams arriving from different LMA upstream interfaces. Furthermore, a per group forwarding into the wireless domain is restricted to the link model in use.

4.3. Operations of the Local Mobility Anchor

For any MN, the Local Mobility Anchor acts as the persistent Home Agent and at the same time as the default multicast querier for the corresponding MAG. It implements the function of the designated multicast router or a further MLD proxy. According to MLD reports received from a MAG (on behalf of the MNs), it establishes/maintains/

removes group/source-specific multicast forwarding states at its corresponding downstream tunnel interfaces. At the same time, it procures for aggregated multicast membership maintenance at its upstream interface. Based on the multicast-transparent operations of the MAGs, the LMA experiences its tunnel interfaces as multicast enabled downstream links, serving zero to many listening nodes. Multicast traffic arriving at the LMA is transparently forwarded according to its multicast forwarding information base.

On the occurrence of a mobility handover, the LMA will receive Binding Lifetime De-Registrations and Binding Lifetime Extensions that will cause a re-mapping of home network prefixes to Proxy-CoAs in its Binding Cache (see section 5.3 of [RFC5213]). The multicast forwarding states require updating, as well, if the MN within an MLD proxy domain is the only receiver of a multicast group. Two cases need distinction:

1. The mobile node is the only receiver of a group behind the interface at which a De-Registration was received: The membership database of the MAG changes, which will trigger a Report/Done sent via the MAG-to-LMA interface to remove this group. The LMA thus terminates multicast forwarding.

2. The mobile node is the only receiver of a group behind the interface at which a Lifetime Extension was received: The membership database of the MAG changes, which will trigger a Report sent via the MAG-to-LMA interface to add this group. The LMA thus starts multicast distribution.

In proceeding this way, each LMA will provide transparent multicast support for the group of MNs it serves. It will perform traffic aggregation at the MN-group level and will assure that multicast data streams are uniquely forwarded per individual LMA-to-MAG tunnel.

4.4. IPv4 Support

An MN in a PMIPv6 domain may use an IPv4 address transparently for communication as specified in [I-D.ietf-netlmm-pmip6-ipv4-support]. For this purpose, LMAs can register IPv4-Proxy-CoAs in its Binding Caches and MAGs can provide IPv4 support in access networks. Correspondingly, multicast membership management will be performed by the MN using IGMP. For multicast support on the network side, an IGMP proxy function needs to be deployed at MAGs in exactly the same way as for IPv6. [RFC4605] defines IGMP proxy behaviour in full agreement with IPv6/MLD. Thus IPv4 support can be transparently provided following the obvious deployment analogy.

For a dual-stack IPv4/IPv6 access network, the MAG proxy instances

SHOULD choose multicast signaling according to address configurations on the link, but MAY submit IGMP and MLD queries in parallel, if needed. It should further be noted that the infrastructure cannot identify two data streams as identical when distributed via an IPv4 and IPv6 multicast group. Thus duplicate data may be forwarded on a heterogeneous network layer.

4.5. Multicast Availability throughout the Access Network

There may be deployment scenarios, where multicast services are available throughout the access network independent of the PMIPv6 infrastructure. Direct multicast access at MAGs may be supported through native multicast routing, within a flat access network that includes a multicast router, via dedicated (tunnel or VPN) links between MAGs and designated multicast routers, or by deploying AMT [I-D.ietf-mboned-auto-multicast].

Multicast deployment can be simplified in these scenarios. A single proxy instance at MAGs with up-link into the multicast cloud, for instance, could serve group communication purposes. MAGs could operate as general multicast routers or AMT gateways, as well.

These solutions have in common that mobility management is covered by the dynamics of multicast routing, as initially foreseen in the Remote Subscription approach sketched in [RFC3775]. Care must be taken to avoid service disruptions due to tardy multicast routing operations [I-D.irtf-mobopts-mmcastv6-ps], and the different possible approaches should be carefully investigated. Such work is beyond the scope of this document.

4.6. A Note on Explicit Tracking

IGMPv3/MLDv2 [RFC3376], [RFC3810] may operate in combination with explicit tracking, which allows routers to monitor each multicast receiver. This mechanism is not standardized yet, but widely implemented by vendors as it supports faster leave latencies and reduced signaling.

Enabling explicit tracking on downstream interfaces of the LMA and MAG would track a single MAG and MN respectively per interface. It may be used to preserve bandwidth on the MAG-MN link.

5. Message Source and Destination Address

This section describes source and destination addresses of MLD messages. The interface identifier A-B denotes an interface on node A, which is connected to node B. This includes tunnel interfaces.

5.1. Query

Interface	Source Address	Destination Address	Header
LMA-MAG	LMAA	Proxy-CoA	outer
	LMA-link-local	[RFC2710], [RFC3810]	inner
MAG-MN	MAG-link-local	[RFC2710], [RFC3810]	--

5.2. Report/Done

Interface	Source Address	Destination Address	Header
MN-MAG	MN-link-local	[RFC2710], [RFC3810]	--
	Proxy-CoA	LMAA	outer

```
+ MAG-LMA   +---------------+---------------------+----------+
|           | MAG-link-local | [RFC2710], [RFC3810] | inner    |
+-----------+---------------+---------------------+----------+
```

6. IANA Considerations

This document makes no request of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

7. Security Considerations

This draft does neither introduce additional messages nor novel protocol operations. Consequently, no new threats arrive from procedures described in this document in excess to [RFC3810], [RFC4605] and [RFC5213] security concerns.

8. Acknowledgements

This memo is the outcome of extensive previous discussions and a follow-up of several initial drafts on the subject. The authors would like to thank (in alphabetical order) Luis Contreras, Gorry Fairhurst, Seil Jeon, Jouni Korhonen, Sebastian Meiling, Liu Hui, Imed Romdhani, Behcet Sarikaya, Stig Venaas, and Juan Carlos Zuniga for advice, help and reviews of the document. Funding by the German Federal Ministry of Education and Research within the G-LAB

Initiative is gratefully acknowledged.

9. References

9.1. Normative References

[I-D.ietf-netlmm-pmip6-ipv4-support]
Wakikawa, R. and S. Gundavelli, "IPv4 Support for Proxy Mobile IPv6", draft-ietf-netlmm-pmip6-ipv4-support-17 (work in progress), September 2009.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2236] Fenner, W., "Internet Group Management Protocol, Version 2", RFC 2236, November 1997.

[RFC2710] Deering, S., Fenner, W., and B. Haberman, "Multicast Listener Discovery (MLD) for IPv6", RFC 2710, October 1999.

[RFC3376] Cain, B., Deering, S., Kouvelas, I., Fenner, B., and A. Thyagarajan, "Internet Group Management Protocol, Version 3", RFC 3376, October 2002.

[RFC3775] Johnson, D., Perkins, C., and J. Arkko, "Mobility Support in IPv6", RFC 3775, June 2004.

[RFC3810] Vida, R. and L. Costa, "Multicast Listener Discovery Version 2 (MLDv2) for IPv6", RFC 3810, June 2004.

[RFC4605] Fenner, B., He, H., Haberman, B., and H. Sandick, "Internet Group Management Protocol (IGMP) / Multicast Listener Discovery (MLD)-Based Multicast Forwarding ("IGMP/MLD Proxying")", RFC 4605, August 2006.

[RFC5213] Gundavelli, S., Leung, K., Devarapalli, V., Chowdhury, K., and B. Patil, "Proxy Mobile IPv6", RFC 5213, August 2008.

9.2. Informative References

[I-D.deng-multimob-pmip6-requirement]
Deng, H., Chen, G., Schmidt, T., Seite, P., and P. Yang, "Multicast Support Requirements for Proxy Mobile IPv6", draft-deng-multimob-pmip6-requirement-02 (work in progress), July 2009.

[I-D.ietf-mboned-auto-multicast]
Thaler, D., Talwar, M., Aggarwal, A., Vicisano, L., and T. Pusateri, "Automatic IP Multicast Without Explicit Tunnels (AMT)", draft-ietf-mboned-auto-multicast-09 (work in

progress), June 2008.

[I-D.irtf-mobopts-mmcastv6-ps]
Fairhurst, G., Schmidt, T., and M. Waehlisch, "Multicast Mobility in MIPv6: Problem Statement and Brief Survey", draft-irtf-mobopts-mmcastv6-ps-09 (work in progress), October 2009.

[I-D.zuniga-multimob-smspmip]
Zuniga, J., Lu, G., and A. Rahman, "Support Multicast Services Using Proxy Mobile IPv6", draft-zuniga-multimob-smspmip-01 (work in progress), January 2010.

Appendix A. Initial MLD Queries on Upcoming Links

According to [RFC3810] and [RFC2710] when an IGMP/MLD-enabled multicast router starts operating on a subnet, by default it considers itself as Querier and sends several General Queries. Such initial query should be sent by the router immediately, but could be delayed by a (tunable) Startup Query Interval (see Sections 7.6.2. and 9.6. of [RFC3810]).

Experimental tests on Linux and Cisco systems have revealed immediate IGMP Queries following a link trigger event (within a fraction of 1 ms), while MLD Queries immediately followed the autoconfiguration of IPv6 link-local addresses at the corresponding interface.

Appendix B. State of IGMP/MLD Proxy Implementations

The deployment scenario defined in this document requires certain proxy functionalities at the MAGs that implementations of [RFC4605] need to contribute. In particular, a simultaneous support of IGMP and MLD is needed, as well as a configurable list of downstream interfaces that may be altered during runtime, and the deployment of multiple proxy instances at a single router that can operate independently on separated interfaces.

A brief experimental trial undertaken in February 2010 revealed the following divergent status of selected IGMP/MLD proxy implementations.

Cisco Edge Router Software-based commodity edge routers (test device from the 26xx-Series) implement IGMPv2/v3 proxy functions only in combination with PIM-SM. There is no support of MLD Proxy. Interfaces are dynamically configurable at runtime via the CLI, but multiple proxy instances are not supported.

Linux igmpproxy IGMPv2 Proxy implementation that permits a static configuration of downstream interfaces (simple bug fix required). Multiple instances are prevented by a lock (corresponding code re-used from a previous DVMRP implementation). IPv6/MLD is unsupported. Project page: http://sourceforge.net/projects/igmpproxy/.

Linux gproxy IGMPv3 Proxy implementation that permits configuration of the upstream interface, only. Downstream interfaces are collected at startup without dynamic extension of this list. No support of multiple instances or MLD. Project page: http://potiron.loria.fr/projects/madynes/internals/perso/lahmadi/igmpv3proxy/.

Linux ecmh MLDv1/2 Proxy implementation without IGMP support that inspects IPv4 tunnels and detects entcapsulated MLD messages. Allows for dynamic addition of interfaces at runtime and multiple instances. However, downstream interfaces cannot be configured. Project page: http://sourceforge.net/projects/ecmh/

Appendix C. Comparative Evaluation of Different Approaches

In this section, we briefly evaluate two basic PMIP concepts for multicast traffic organization at LMAs: In scenario A, multicast is provided by combined unicast/multicast LMAs as described in this document. Scenario B directs traffic via a dedicated multicast LMA as proposed in [I-D.zuniga-multimob-smspmip], for example.

Both approaches do not establish native multicast distribution between the LMA and MAG, but use tunneling mechanisms. In scenario A, a MAG is connected to different multicast-enabled LMAs, and can receive the same multicast stream via multiple paths depending on the group subscriptions of MNs and their associated LMAs. This problem, a.k.a. tunnel convergence problem, may lead to redundant traffic at the MAGs. Scenario B in contrast configures MAGs to establish a tunnel to a single, dedicated multicast LMA for all attached MNs and relocates overhead costs to the multicast anchor. This eliminates redundant traffic, but may result in an avalanche problem at the LMA.

We quantify the costs of both approaches based on two metrics: The amount of redundant traffic at MAGs and the number of simultaneous

streams at LMAs. Realistic values depend on the topology and the group subscription model. To explore scalability in a large PMIP domain of 1,000,000 MNs, we consider the following two extremal multicast settings.

1. All MNs participate in distinct multicast groups.

2. All MNs join the same multicast groups.

A typical PMIP deployment approximately allows for 5,000 MNs attached to one MAG, while 50 MAGs can be served by one LMA. Hence 1,000,000 MNs require approx. 200 MAGs backed by 4 LMAs for unicast transmission. In scenario A, these LMAs also forward multicast streams, while in scenario B one additional dedicated LMA (LMA-M) serves multicast. In the following, we calculate the metrics described above.

Setting 1:

PMIP multicast scheme	# of redundant streams at MAG	# of sim. streams at LMA / LMA-M
Combined Unicast/ Multicast LMA	0	250,000
Dedicated Multicast LMA	0	1,000,000

1,000,000 MNs are subscribed to distinct multicast groups

Setting 2:

PMIP multicast scheme	# of redundant streams at MAG	# of sim. streams at LMA / LMA-M
Combined Unicast/ Multicast LMA	4	50
Dedicated	0	200

```
      | Multicast LMA     |                |                  |
      +-------------------+----------------+------------------+

      1,000,000 MNs are subscribed to the same multicast group
```

These considerations of extremal settings show that tunnel convergence, i.e., duplicate data arriving at a MAG, does cause much smaller problems in scalability than the stream replication at LMAs.

For scenario A it should be also noted that the high stream replication requirements at LMAs in setting 1 can be attenuated by deploying additional LMAs in a PMIP domain, while scenario B does not allow for distributing the LMA-M, as no handover management is available at LMA-M.

Appendix D. Change Log

The following changes have been made from draft-schmidt-multimob-pmipv6-mcast-deployment-03.

1. Detailed outline of multicast reconfiguration steps on handovers added in protocol overview (section 3).

2. Clarified the details of proxy operations at the MAG along with the expected features of IGMP/MLD Proxy implementations (section 4.2).

3. Clarified querying in dual-stack scenarios (section 4.4).

4. Subsection added on the special case, where multicast is available throughout the access network (section 4.5).

5. Appendix on IGMP/MLD behaviour added with test reports on current Proxy implementations.

The following changes have been made from draft-schmidt-multimob-pmipv6-mcast-deployment-02.

1. Many editorial improvements, in particular as response to draft reviews.

2. Section on IPv4 support added.

3. Added clarifications on initial IGMP/MLD Queries and supplementary information in appendix.

4. Appendix added an comparative performance evaluation regarding mixed/dedicated deployment of multicast at LMAs.

Authors' Addresses

Thomas C. Schmidt
HAW Hamburg
Berliner Tor 7
Hamburg 20099
Germany

Email: schmidt@informatik.haw-hamburg.de
URI: http://inet.cpt.haw-hamburg.de/members/schmidt

Matthias Waehlisch
link-lab & FU Berlin
Hoenower Str. 35
Berlin 10318
Germany

Email: mw@link-lab.net

Suresh Krishnan
Ericsson
8400 Decarie Blvd.
Town of Mount Royal, QC
Canada

Email: suresh.krishnan@ericsson.com