MULTIMOB Working Group Luis M. Contreras
INTERNET-DRAFT Telefonica I+D
Intended Status: Proposed Standard Carlos J. Bernardos
Expires: April 18, 2013 Universidad Carlos III de Madrid
Juan Carlos Zuniga
InterDigital
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Extension of the MLD proxy functionality to support multiple upstream interfaces
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Abstract

This document presents different scenarios of applicability for an MLD proxy running more than one upstream interface. Since those scenarios impose different requirements on the MLD proxy with multiple upstream interfaces, it is important to ensure that the proxy functionality addresses all of them for compatibility.

The purpose of this document is to define the requirements in an MLD proxy with multiple interfaces covering a variety of applicability scenarios, and to specify the proxy functionality to satisfy all of them.

Status of this Memo

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1 Introduction

The aim of this document is to define the functionality that an MLD proxy with multiple upstream interfaces should have in order to support different scenarios of applicability in both fixed and mobile networks. This compatibility is needed in order to simplify node functionality and to ensure an easier deployment of multicast capabilities in all the use cases described in this document.

2. Terminology

This document uses the terminology defined in [3]. Specifically, the definition of Upstream and Downstream interfaces, which are reproduced here for completeness.

Upstream interface:
A proxy device’s interface in the direction of the root of the tree. Also called the "Host interface".

Downstream interface:
Each of a proxy device’s interfaces that is not in the direction of the root of the tree. Also called the "Router interfaces".

3. Problem statement

The concept of MLD proxy with several upstream interfaces has emerged as a way of optimizing (and in some cases enabling) service delivery scenarios where separate multicast service providers are reachable through the same access network infrastructure. Figure 1 presents the conceptual model under consideration.

```
                   downstream        upstream
                   interface      interface A
                        |                |
                        |                |      _______________
                        |   +-------+    v     /               \
                        |   |       O-------( Multicast Set 1 )
         +----------+   v   |  MLD  |          \_______________/
         | Listener |------|       |           _______________
         +----------+       | Proxy |          /               \
                            |       O-------( Multicast Set 2 )
                            +-------+    ^     \_______________/
                                         |
                                         |
                                      upstream
                                    interface B
```

Figure 1. Concept of MLD proxy with multiple upstream interfaces

For illustrative purposes, two applications for fixed and mobile networks are here introduced. They will be elaborated later on the document.

In the case of fixed networks, multicast wholesale services in a competitive residential market require an efficient distribution of multicast traffic from different operators, i.e. the incumbent operator and a number of alternative ones, on the network infrastructure of the former. Existing proposals are based on the use of PIM routing from the metro network, and multicast traffic aggregation on the same tree. A different approach could be achieved with the use of an MLD proxy with multiple upstream interfaces, each of them pointing to a distinct multicast router in the metro border which is part of separated multicast trees deep in the network. Figure 2 graphically describes this scenario.

In the case of mobile networks, IP mobility services guarantee the continuity of the IP session while a Mobile Node (MN) changes its point of attachment. Proxy Mobile IPv6 (PMIPv6) [1] standardized a protocol that allows the network to manage the MN mobility without requiring specific support from the mobile terminal. The traffic to the MN is tunneled from the Home Network making use of two entities, one acting as mobility anchor, and the other as Mobility Access Gateway (MAG). Multicast support in PMIPv6 [2] implies the delivery of all the multicast traffic from the Home Network, via the mobility anchor. However, multicast routing optimization [4] could take advantage of an MLD proxy with multiple upstream interfaces by supporting the decision of subscribing a multicast content from the Home Network or from the local PMIPv6 domain if it is locally available. Figure 3 presents this scenario.

Informational text is provided in Appendix A summarizing how the basic solution for deploying multicast listener mobility with Proxy Mobile IPv6 works.

```
                 downstream       upstream
                 interface       interface A
                     |                 |
                     |                 |     _______________
                     |   +--------+   v    /               \
                     |   |        O-------( Multicast Set 1 )
                     |   |  Aggr. |        \_______________/
           +----+   v   | Switch |     (e.g. from the Incumbent
           | AN |-------|        |             Operator)
           +----+        |  (MLD  |          _______________
           (e.g.         | Proxy) |        /               \
           DSLAM)        |        O-------( Multicast Set 2 )
                         +--------+   ^    \_______________/
                                      | (e.g. from an Alternative
                                      |         Operator)
                                      |
                                  upstream
                                 interface B
```

Figure 2. Example of usage of an MLD proxy with multiple upstream interfaces in a fixed network scenario

```
                 downstream       upstream
                 interface       interface A
                     |                 |
                     |                 |     _______________
                     |   +--------+   v    /               \
                     |   |        O-------( Multicast Set 1 )
                     |   |        |        \_______________/
           +----+   v   |   MAG  |    e.g. from the Home Network
           | MN |-------|        |     via the mobility anchor)
           +----+        |  (MLD  |          _______________
                         | Proxy) |        /               \
                         |        O-------( Multicast Set 2 )
                         +--------+   ^    \_______________/
                                      | (e.g. from the local PMIPv6
                                      |  domain via direct routing)
                                      |
                                  upstream
                                 interface B
```

Figure 3. Example of usage of an MLD proxy with multiple upstream interfaces in a mobile network scenario

Since those scenarios can motivate distinct needs in terms of MLD proxy functionality, it is necessary to consider a comprehensive approach, looking at the possible scenarios, and establishing a minimum set of requirements which can allow the operation of a versatile MLD proxy with multiple upstream interfaces as a common entity to all of them (i.e., no different kinds of proxies depending on the scenario, but a common proxy applicable to all the potential scenarios).

4. Scenarios of applicability

This section describes in detail a number of scenarios of applicability of an MLD proxy with multiple upstream interfaces in place. A number of requirements for the MLD proxy functionality are identified from those scenarios.

4.1 Fixed network scenarios

Residential broadband users get access to multiple IP services through fixed network infrastructures. End user’s equipment is connected to an access node, and the traffic of a number of access nodes is collected in aggregation switches.

For the multicast service, the use of an MLD proxy with multiple upstream interfaces in those switches can provide service flexibility in a lightweight and simpler manner if compared with PIM-routing based alternatives.

4.1.1 Multicast wholesale offer for residential services

This scenario has been already introduced in the previous section, and can be seen in Figure 2. There are two different operators, the one operating the fixed network where the end user is connected (e.g., typically an incumbent operator), and the one providing the Internet service to the end user (e.g., an alternative Internet service provider). Both can offer multicast streams that can be subscribed by the end user, independently of which provider contributes with the content.

Note that it is assumed that both providers offer distinct multicast groups. However, more than one subscription to multicast channels of different providers could take place simultaneously.

4.1.1.1 Requirements

- The MLD proxy should be able to deliver multicast control messages sent by the end user to the corresponding provider’s multicast router.

- The MLD proxy should be able to deliver multicast control messages sent by each of the providers to the corresponding end user.

4.1.2 Multicast resiliency

In current PIM-based solutions, the resiliency of the multicast distribution relays on the routing capabilities provided by protocols like PIM and VRRP. A simpler scheme could be achieved by implementing different upstream interfaces on MLD proxies, providing path diversity through the connection to distinct leaves of a given multicast tree.

It is assumed that only one of the upstream interfaces is active in receiving the multicast content, while the other is up and in standby for fast switching.

4.1.2.1 Requirements

- The MLD proxy should be able to deliver multicast control messages sent by the end user to the corresponding active upstream interface.

- The MLD proxy should be able to deliver multicast control messages received in the active upstream to the end users, while ignoring the control messages of the standby upstream interface.

- The MLD proxy should be able of rapidly switching from the active to the standby upstream interface in case of network failure, transparently to the end user.

4.1.3 Load balancing for multicast traffic in the metro segment

A single upstream interface in existing MLD proxy functionality typically forces the distribution of all the channels on the same path in the last segment of the network. Multiple upstream interfaces could naturally split the demand, alleviating the bandwidth requirements in the metro segment.

4.1.3.1 Requirements

- The MLD proxy should be able to deliver multicast control messages sent by the end user to the corresponding multicast router which provides the channel of interest.

- The MLD proxy should be able to deliver multicast control messages sent by each of the multicast routers to the corresponding end user.

- The MLD proxy should be able to decide which upstream interface is selected for any new channel request according to defined criteria (e.g., load balancing).

4.1.4 Summary of the requirements needed for mobile network scenarios

Following the analysis above, a number of different requirements can be identified by the MLD proxy to support multiple upstream interfaces in fixed network scenarios. The following table summarizes these requirements.

Functionality	Fixed Network Scenarios: Multicast Wholesale	Multicast Resiliency	Load Balancing
Upstream Control Delivery	X	X	X
Downstr. Control Delivery	X	X	X
Active / Standby Upstream		X	
Upstr i/f selection per group			X
Upstr i/f selection all group		X	

Table I. Functionality needed on MLD proxy with multiple upstream interfaces per application scenario in fixed networks

4.2 Mobile network scenarios

The mobile networks considered in this document are supposed to run PMIPv6 protocol for IP mobility management. A brief description of multicast provision in PMIPv6-based networks can be found in Appendix A.

The use of an MLD proxy supporting multiple upstream interfaces can improve the performance and the scalability of multicast-capable PMIPv6 domains.

4.2.1 Applicability to multicast listener mobility

Three sub-cases can be identified for the multicast listener mobility.

4.2.1.1 Single MLD proxy instance on MAG

The base solution for multicast service in PMIPv6 [2] assumes that any MN subscribed to multicast services receive the multicast traffic through the associated LMA, as in the unicast case. As standard MLD proxy functionality only supports one upstream interface, the MAG should implement several separated MLD proxy instances, one per LMA, in order to serve the multicast traffic to the MNs, according to any particular LMA-MN association.

A way of avoiding the multiplicity of MLD proxy instance in a MAG is to deploy a unique MLD proxy instance with multiple upstream interfaces, one per LMA, without any change in the multicast traffic distribution.

4.2.1.1.1 Requirements

- The MLD proxy should be able of delivering the multicast control messages sent by the MNs to the associated LMA.

- The MLD proxy should be able of delivering the multicast control messages sent by each of the connected LMAs to the corresponding MN.

- The MLD proxy should be able of routing the multicast data coming from different LMAs to the corresponding MNs according to the MN to LMA association.

- The MLD proxy should be able of maintaining a 1:1 association between an MN and LMA (or downstream to upstream).

4.2.1.2 Remote and local multicast subscription

This scenario has been already introduced in the previous section, and can be seen in Figure 3. Standard MLD proxy definition, with a unique upstream interface per proxy, does not allow the reception of multicast traffic from distinct upstream multicast routers. In other words, all the multicast traffic being sent to the MLD proxy in downstream traverses a concrete, unique router before reaching the MAG. There are, however, situations where different multicast content could reach the MLD proxy through distinct next-hop routers.

For instance, the solution adopted to avoid the tunnel convergence problem in basic multicast PMIPv6 deployments [4] considers the possibility of subscription to a multicast source local to the PMIPv6 domain. In that situation, some multicast content will be accesses remotely, through the home network via the multicast tree mobility anchor, while some other multicast content will reach the proxy directly, via a local router in the domain.

4.2.1.2.1 Requirements

- The MLD proxy should be able of delivering the multicast control messages sent by the MNs to the associated upstream interface based on the location of the source, remote or local, for a certain multicast group.

- The MLD proxy should be able of delivering the multicast control messages sent either local or remotely to the corresponding MNs.

- The MLD proxy should be able of routing the multicast data coming from different upstream interfaces to a certain MN according to the MN subscription, either local or remote. Note that it is assumed that a multicast group can be subscribed either locally or remotely, but not simultaneously. However more than one subscription could happen, being local or remote independently.

- The MLD proxy should be able of maintaining a 1:N association between an MN and the remote and local multicast router (or downstream to upstream).

- The MLD proxy should be able of switching between local or remote subscription for per multicast group according to specific configuration parameters (out of the scope of this document).

4.2.1.3 Dual subscription to multicast groups during handover

In the event of an MN handover, once an MN moves from a previous MAG (pMAG) to a new MAG (nMAG), the nMAG needs to set up the multicast status for the incoming MN, and subscribe the multicast channels it was receiving before the handover event. The MN will then experience a certain delay until it receives again the subscribed content.

A generic solution is being defined in [5] to speed up the knowledge of the ongoing subscription by the nMAG. However, for the particular case that the underlying radio access technology supports layer-2 triggers (thus requiring extra capabilities on the mobile node), there could be inter-MAG cooperation for handover support if pMAG and nMAG are known in advance.

This could be the case, for instance for those contents not already arriving to the nMAG, where the nMAG temporally subscribes the multicast groups of the ongoing MN's subscription via the pMAG, while the multicast delivery tree among the nMAG and the mobility anchor is being established.

A similar approach is followed in [6] despite the solution proposed there differs from this approach (i.e., there is no consideration of an MLD proxy with multiple interfaces).

4.2.1.3.1 Requirements

- The MLD proxy should be able of delivering the multicast control messages sent by the MNs to the associated upstream interface based on the handover specific moment, for a certain multicast group.

- The MLD proxy should be able of delivering the multicast control messages sent either from pMAG or the multicast anchor to the corresponding MNs, based on the handover specific moment.

- The MLD proxy should be able of handle the incoming packet flows from the two simultaneous upstream interfaces, in order to not duplicate traffic delivered on the point-to-point link to the MN.

- The MLD proxy should be able of maintaining a 1:N association between an MN and both the remote multicast router and the pMAG (or downstream to upstream).

- The MLD proxy should be able of switching between local or remote subscription for all the multicast groups (from pMAG to multicast anchor) according to specific configuration parameters (out of the scope of this document).

4.2.2 Applicability to multicast source mobility

A couple of sub-cases can be identified for the multicast source mobility.

4.2.2.1 Support of remote and direct subscription in basic source mobility

In the basic case of source mobility, the multicast source is connected to one of the downstream interfaces of an MLD proxy. According to the standard specification [3] every packet sent by the multicast source will be forwarded towards the root of the multicast tree.

However, linked to the mobility listener problem, there could be the case of simultaneous remote subscribers, subscribing to the multicast content through the home network, and local subscribers, requesting the contents directly via a multicast router residing on the same PMIPv6 domain where the source is attached to.

Then, in order to provide the co-existence of both types of subscribers, an MLD proxy with two upstream interfaces could simultaneously serve all kind of multicast subscribers.

Basic source mobility is being defined in [7] but the solution proposed there does not allow simultaneous co-existence of remote and local subscribers (i.e., the content sent by the source is either distributed locally to a multicast router in the PMIPv6 domain, or remotely by using the bi-directional tunnel towards the mobility anchor, but not both simultaneously).

4.2.2.1.1 Requirements

- The MLD proxy should be able of forwarding (replicating) the multicast content to both upstream interfaces, in case of simultaneous remote and local distribution.

- The MLD proxy should be able of handling control information incoming through any of the two upstream interfaces, providing the expected behavior for each of the multicast trees.

- The MLD proxy should be able of routing the multicast data towards different upstream interfaces for both remote and local subscriptions that could happen simultaneously.

- The MLD proxy should be able of maintaining a 1:N association between an MN and both the remote and local multicast router (or downstream to upstream).

4.2.2.2 Direct communication between source and listener associated with distinct LMAs but on the same MAG

In a certain PMIPv6 domain can be MNs associated to distinct LMAs using the same MAG to get access to their corresponding home networks. For multicast communication, according to the base solution [2], each MN <-> LMA association implies a distinct MLD proxy instance to be invoked in the MAG.

In these conditions, when a mobile source is serving multicast content to a mobile listener, both attached to the same MAG but each of them associated to different LMAs, the multicast flow must traverse the PMIPv6 domain from the MAG to the LMA where the source maintains an association, then from that LMA to the LMA where the listener is associated to, and finally come back to the same MAG from where the flow departed. This routing is extremely inefficient.

An MLD proxy with multiple upstream interfaces avoids this behavior since it allows to invoke a unique MLD proxy instance in the MAG. In this case, the multicast source can directly communicate with the multicast listener, without need for delivering the multicast traffic to the LMAs.

4.2.2.3.1 Requirements

- The MLD proxy should be able of forwarding (replicating) the multicast content to different upstream or downstream interfaces where subscribers are present.

- The MLD proxy should be able of handling control information incoming through any of the upstream or downstream interfaces requesting a multicast flow being injected in another downstream interface.

- The MLD proxy should be able of maintaining a 1:N association between an MN and any of the upstream or downstream interfaces demanding the multicast content.

4.2.2.3 Route optimization support in source mobility for remote subscribers

Even in a scenario of remote subscription, there could be the case where both the source and the listener are attached to the same PMIPv6-Domain (for instance, no possibility of direct routing within the PMIPv6, or source and listener pertaining to distinct home networks). In this situation there is a possibility of route optimization if inter-MAG communication is enabled, in such a way that the listeners in the PMIPv6 domain are served through the tunnels between MAGs, while the rest of remote listeners are served through the mobility anchor.

A multi-upstream MLD proxy would allow the simultaneous delivery of traffic to such kind of remote listeners.

A similar route optimization approach is proposed in [8].

4.2.2.3.1 Requirements

- The MLD proxy should be able of forwarding (replicating) the multicast content to both kinds of upstream interfaces, inter-MAG tunnel interfaces and MAG to mobility anchor tunnel interface.

- The MLD proxy should be able of handling control information incoming through any of the two types of upstream interfaces, providing the expected behavior for each of the multicast trees (e.g., no forwarding traffic on one inter-MAG link once there are not more listeners requesting the content).

- The MLD proxy should be able of routing the multicast data towards different upstream interfaces for both remote and route optimized subscriptions that could happen simultaneously.

- The MLD proxy should be able of maintaining a 1:N association between an MN and both the remote and local MAGs (or downstream to upstream).

4.2.3 Summary of the requirements needed for mobile network scenarios

After the previous analysis, a number of different requirements can be identified by the MLD proxy to support multiple upstream interfaces in mobile network scenarios. The following table summarizes these requirements.

	Mobile Network Scenarios					
	Mulicast Listener			Mulicast Source		
Functio-nality	Single MLD Proxy	Remote & local subscr.	Dual subscr. in HO	Direct & remote subscr.	Listener & source on MAG	Route optimi.
Upstream Control Delivery	X	X	X	X	X	X
Downstr. Control Delivery	X	X	X		X	
Upstream Data Delivery				X		X
Downstr. Data Delivery	X	X	X		X	
1:1 MN to upstream assoc.	X					
1:N MN to upstream assoc.		X	X	X	X	X
Upstr i/f selection per group		X				
Upstr i/f selection all group			X			
Upstream traffic replicat.				X		X

Table II. Functionality needed on MLD proxy with multiple upstream interfaces per application scenario in mobile networks

5 Functional specification of an MLD proxy with multiple interfaces

<To be completed>.

6 Security Considerations

<To be completed>.

7 IANA Considerations

<IANA considerations text>.

8 Conclusions

<To be completed>.

9 Acknowledgements

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10 References

10.1 Normative References

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Appendix A. Basic support for multicast listener with PMIPv6

This section briefly summarizes the operation of Proxy Mobile IPv6 [1] and how multicast listener support works with PMIPv6 as specified in [2].

Proxy Mobile IPv6 (PMIPv6) [1] is a network-based mobility management protocol which enables the network to provide mobility support to standard IP terminals residing in the network. These terminals enjoy this mobility service without being required to implement any mobility-specific IP operations. Namely, PMIPv6 is one of the mechanisms adopted by the 3GPP to support the mobility management of non-3GPP terminals in future Evolved Packet System (EPS) networks.

PMIPv6 allows a Media Access Gateway (MAG) to establish a distinct bi-directional tunnel with different Local Mobility Anchors (LMAs), being each tunnel shared by the attached Mobile Nodes (MNs). Each mobile node is associated with a corresponding LMA, which keeps track of its current location, that is, the MAG where the mobile node is attached. IP-in-IP encapsulation is used within the tunnel to forward traffic between the LMA and the MAG. Figure 4 (taken from [1]) shows the architecture of a PMIPv6 domain.

```
              +----+                +----+
              |LMA1|                |LMA2|
              +----+                +----+
       LMAA1 -> |                      | <-- LMAA2
                |                      |
                \\                    //\\
                 \\                  //  \\
                  \\                //    \\
               +---\\------------- //------\\----+
              (     \\  IPv4/IPv6 //        \\    )
              (      \\  Network //          \\   )
               +------\\--------//------------\\-+
                       \\      //              \\
                        \\    //              \\
                         \\  //              \\
             Proxy-CoA1--> |                      | <-- Proxy-CoA2
                        +----+                 +----+
                        |MAG1|-----{MN2}       |MAG2|
                        +----+    |            +----+
                          |       |               |
             MN-HNP1 -->  |     MN-HNP2           | <-- MN-HNP3, MN-HNP4
                        {MN1}                   {MN3}
```

Figure 4. Proxy Mobile IPv6 Domain

The basic solution for the distribution of multicast traffic within a PMIPv6 domain [2] makes use of the bi-directional LMA-MAG tunnels. The base solution follows the so-called remote subscription model, in which the subscribed multicast content is delivered from the Home Network. By doing so, an individual copy of every multicast flow is delivered through the tunnel connecting the mobility anchor to any of the access gateways in the domain. In many cases, these individual copies traverse the same routers in the path towards the access gateways, incurring in an inefficient distribution, equivalent to the unicast distribution of the multicast content in the domain.

The reference scenario for multicast deployment in Proxy Mobile IPv6 domains is illustrated in Figure 5 (taken from [2]).

This fact leads to distribution inefficiencies and higher per-bit delivery costs, incurred by the PMIPv6 domain operator offering transport capabilities to the Home Network operator for serving their MNs when attached to the PMIPv6 domain. As long as the remotely subscribed multicast service is not affected, it seems worthy to explore more optimal ways of distributing such content within the PIMPv6 domain.

```
                       +-------------+
                       | 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 5. Reference Network for Multicast Deployment in PMIPv6

Authors' Addresses

Luis M. Contreras
Telefonica I+D
EMail: lmcm@tid.es

Carlos J. Bernardos
Universidad Carlos III de Madrid
EMail: cjbc@it.uc3m.es

Juan Carlos Zuniga
InterDigital Communications, LLC
EMail: JuanCarlos.Zuniga@InterDigital.com