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IP Mobile Multicast: Problems and Solutions

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Abstract

IP multicast is a technique for one-to-many and many-to-many communication over an IP infrastructure in a network. It provides an efficient and cost effective way to accommodate requirements of various applications like Internet TV, Video on Demand, etc. Many protocols support efficient multicast by using a multicast delivery tree. The main drawback of these protocols is that they are designed to support the multicast parties whose members are stationary. The movement of multicast member causes in reality many problems to multicast service. The Internet Engineering Task Force (IETF) proposed the Mobile IPv6 (MIPv6) protocol, the Proxy Mobile IPv6 (PMIPv6) protocol and many solutions that are based on these protocols to solve these problems. In this document, we would like to generally introduce the problems and solutions to deploy multicast service with to 2 approaches: centralized mobility approach and distributed mobility approach.

Keywords: IP Multicast, IP mobile multicast, PMIPv6, DMM, Source mobility, Receiver mobility

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Introduction

Recently, the deployment of IP multicast has accelerated. Multicast plays a particularly important role and owns a lot of distinct advantages in mobile environments where operating frequency bands are shared between users and bandwidth is constrained. It enables a scalable and global many-to-many broadcast function for multimedia applications by eliminating the need for equivalent increase in bandwidth usage [5].

However, multicast mobility has coped with some issues derived from IP multicast problems and IP mobility problems. The Internet Engineering Task Force (IETF) has proposed the Mobile IPv6 (MIPv6) protocol [1], the Proxy Mobile IPv6 (PMIPv6) protocol [3] and many solutions to solve these problems. These solutions are based on 2 approaches: centralized mobility approach and distributed mobility approach. In the first approach, there is an (or several) mobility anchor (s) point in the network that allows a mobile device to be reachable when it is not connected to its home domain and ensures forwarding of packets destined to or sent from the mobile device, e.g., HA in MIPv6, LMA in PMIPv6. So, both MN context and traffic encapsulation need to be maintained at the mobility anchor. However, when hundreds of thousands of MNs are communicating in a given cellular network, a centralized mobility anchoring point causes well-known bottlenecks and single point of failure issues [21]. The second approach introduces a deployment scenario of IP mobility mechanisms in flat mobile architectures: distribution of mobility function. It is called DMM (Distributed Mobility Management).

1. Abbreviations

3GPP	3rd Generation Partnership Project
ASM	Any Source Multicast
BCE	Binding Cache Entry
CBT	Core Based Trees
CDMA	Code Division Multiple Access
CoA	Care of Address
CXTP	Context Transfer Protocol
D-LMA	Destination LMA
DMM	Distributed Mobility Management
DVMRP	Distance Vector Multicast Routing Protocol
HA	Home Agent
HAck	Handover Acknowledgement

HI	Handover Initiate
H-LMA	Home LMA
HO	Handover
HoA	Home Address
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
LM	Location Management
LMA	Local Mobility Anchor
MAG	Mobile Access Gateway
MAR	Mobility capable Access Router
MIPv6	Mobile IPv6
MLD	Multicast Listener Discovery
M-LMA	Dedicated Multicast LMA
MLQ	Multicast Listener Query
MLR	Multicast Listener Report
MN	Mobile Node
MOSPF	Multicast Open Shortest Path First
MR	Mobility Routing
M-Tunnel	Dedicated Multicast Tunnel
n-MAG	New MAG
O-LMA	Originating LMA
PBA	Proxy Binding Acknowledgement
PBU	Proxy Binding Update
PBU-M	PBU with Multicast Extension
PIM-DM	Protocol Independent Multicast - Dense Mode
PIM-SM	Protocol Independent Multicast - Spare Mode
p-MAG	Previous MAG
PMIPv6	Proxy Mobile IPv6
RPF	Reverse Path Forwarding
RP	Rendezvous Point
RPT	Rendezvous Point Tree
SAE	System Architecture Evolution
SPT	Shortest Path Tree
SSM	Source Specific Multicast
U-LMA	Dedicated Unicast LMA
UMTS	Universal Mobile Telecommunications System
V-LMA	Visited LMA

2. Terminologies

We define the followings concepts for the rest of the document. Some definitions are based on [3] [23]:

Local Mobility Anchor (LMA) is responsible for maintaining the mobile node's reachability state and is the topological anchor point for the mobile node's home network prefix (es).

Mobile Access Gateway (MAG) is an access router or gateway that performs the mobility-related signaling on behalf of the MNs attached to its access links. It is responsible for tracking the MN's movements in PMIPv6 domain.

Home local mobility anchor (H-LMA) to a mobile node is the full set of logical functions of a local mobility anchor to the mobile node: home address allocation, location management, and mobility routing.

Visited local mobility anchor (V-LMA) to a mobile node is a subset of the full logical functions of a local mobility anchor towards the mobile node. It intercepts packets to/from the mobile node and forwards packets using the location management information it acquires from the home local mobility anchor of the mobile node.

Originating local mobility anchor (O-LMA) is the first local mobility anchor that intercepts a packet destined to a mobile node.

Destination local mobility anchor (D-LMA) of a mobile node is the local mobility anchor to which the mobile node is currently anchored.

Mobility capable Access Router (MAR) is an access router which provides mobility management functions. It has both mobility anchoring and location update functional capabilities.

Multicast Querier: If there is more than one router on the LAN performing IP multicasting, one of the routers is elected "Querier" and assumes the responsibility of querying the LAN for group members. Only the Querier router sends queries. On multi-access networks, an IGMP Querier router is elected based on the lowest IP address.

Reverse Path Forwarding (RPF) check is the mechanism that is used by routers to forwards multicast packets. The router accepts a packet from source S through the interface I only if I is the interface which router would use in order to reach S.

3. Background

3.1. IP Multicast

Multicasting aims to deliver data to a set of selected receivers in an effective way. In multicast, the sender only needs to send every packet one time and the network (router) duplicates the packet as required until a copy of the packet reaches each one of the intended receivers. So the router has to employ a multicast protocol to build distribution trees to deliver multicast data.

There are 2 IP multicast models: the Any Source Multicast (ASM) and the Source Specific Multicast (SSM). The pair (S, G) identifies a SSM channel while the notion (*, G) is used for ASM in which S is the multicast source address, and G is the multicast group address.

There are 2 groups of protocols for multicast: multicast group membership protocols and multicast routing protocols. Multicast group membership protocols are used by hosts and adjacent multicast routers to establish multicast group memberships such as IGMP (for IPv4) and MLD (for IPv6). The current version of IGMP (IGMPv3) [24] [26] and MLD (MLDv2) [25] [26] have similar functionalities and have 2 parts: host part and router part that are performed by multicast listener and multicast router respectively.

The IGMP/MLD messages are used to communicate between multicast receivers and multicast routers to manage multicast group membership. For example, the MLDv2 specifies 2 types of messages: multicast listener query (MLQ) and multicast listener report (MLR). The MLQ is used by multicast router to query an attached link for listening host to build and refresh the multicast state of routers on attached links. The General Query is used to query the multicast listeners of all multicast address while the Source-and-Group Specific Query is used to query the multicast listener of a specific multicast address. The MLR is used by multicast listener to report interest in receiving multicast traffic from a given multicast address or to response to a MLQ. Based on the membership information, multicast routers join to the multicast delivery tree of the specified multicast group by using the appropriate multicast routing protocol.

To avoid deploying multicast routers and multicast routing protocols inside a given network, IGMP/MLD Forwarding Proxy entities are used. This proxy performs membership management and acts as a multicast Querier for its subnet and as a host for an upstream proxy or multicast router [4].

Multicast routing protocols enable a collection of multicast routers to build distribution trees when a host on a directly attached subnet wants to receive traffic from a certain multicast group. There are five multicast routing protocols: DVMRP [37], MOSPF [38], PIM-DM [39], PIM-SM [27] and CBT [40]. Each of the multicast routing protocols uses its multicast routing algorithms to build multicast delivery tree. In multicast, we are interested in 2 types of multicast delivery tree: Shortest Path Tree (SPT) or Source-based Tree and Shared Distribution Tree or Rendezvous-Point Tree (RPT).

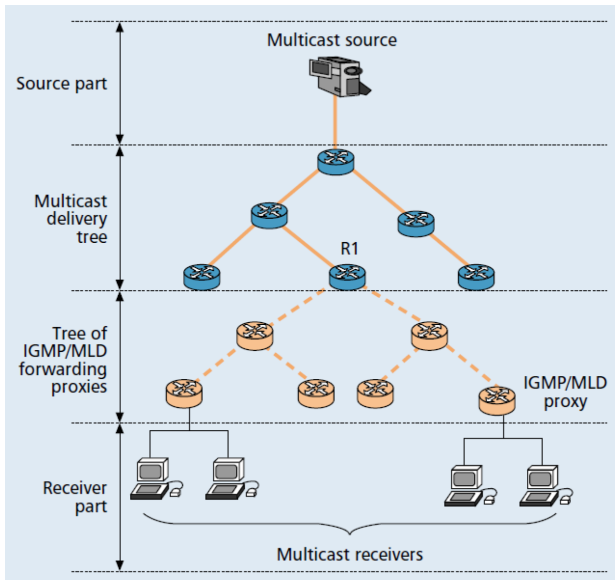

Figure 1. IGMP/MLD proxy [4]

3.2. Proxy Mobile IPv6 (PMIPv6)

PMIPv6 enables network-based mobility for IPv6 mobile nodes (MNs) without implementing any mobility protocols. PMIPv6 introduces 2 network entities called the Local Mobility Anchor (LMA) and the Mobile Access Gateway (MAG). The LMA is responsible for maintaining the MN's reachability state and is the topological anchor point for the mobile node's home network prefix (es). The MAG is an access router or gateway that performs the mobility-related signaling on behalf of the MNs attached to its access links. It is responsible for tracking the MN's movements in PMIPv6 domain [3].

When a Mobile Node enters a PMIPv6 domain, it attaches to an access link provided by a MAG. If the MAG determines that the MN is authorized for network-based mobility service, it will perform mobility related signaling on behalf of the MN. The MAG sends a Proxy Binding Update (PBU) message to the MN's LMA that includes the identity of the MN. Upon accepting this message, the LMA sends a Proxy Binding Acknowledgement (PBA) message including the prefix (es) allocated to the MN. It also creates the Binding Cache entry (BCE) and sets up its endpoint of the bi-directional tunnel to the MAG. The MAG on receiving the PBA message sets up its endpoint of the bi-directional tunnel to the LMA and sends Router Advertisement messages to the MN including the MN's prefix (es). So the MN can configure its interfaces using either stateful or stateless address configuration modes [3] [6].

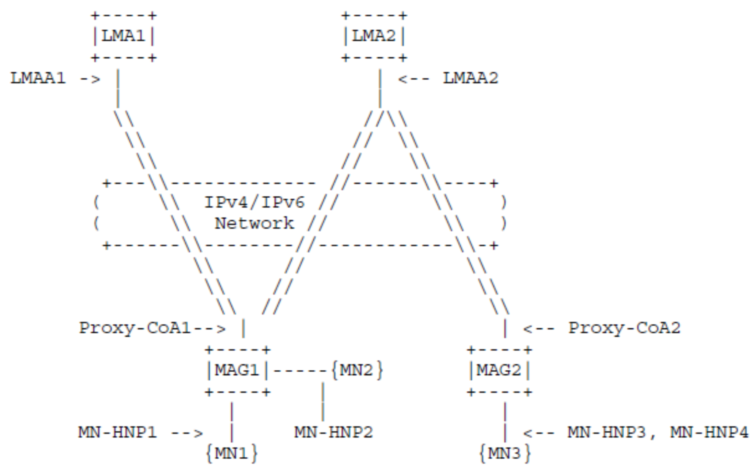

Figure 2. PMIPv6 domain [3]

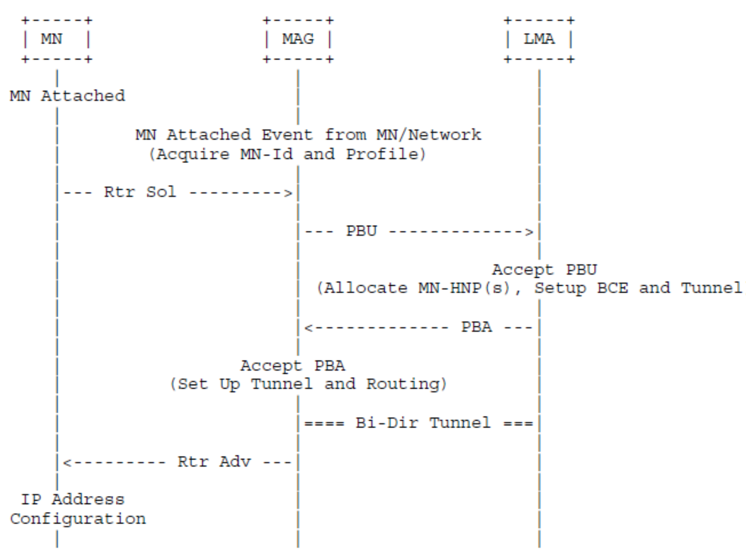

Figure 3. Mobile node attachment [3]

The LMA, being the topological anchor point for the MN's home network prefix (es), receives any packets that are sent to the MN (except in the case of local routing). It forwards these packets to the MAG through the bi-directional tunnel. The MAG removes the outer header and forwards the packet on the access link to the MN [3]. Uplink packets originating from the MN are sent to the LMA from the MAG through the tunnel, and then are forwarded to the destination by the LMA (except in the case of local routing) [3] [6].

Whenever the MN moves, the new MAG, upon detecting the mobile node on its access link, will signal the LMA to update the MN's location and send the Router Advertisement containing the same prefix (es) to the MN, thereby making the IP mobility transparent to the MN [3].

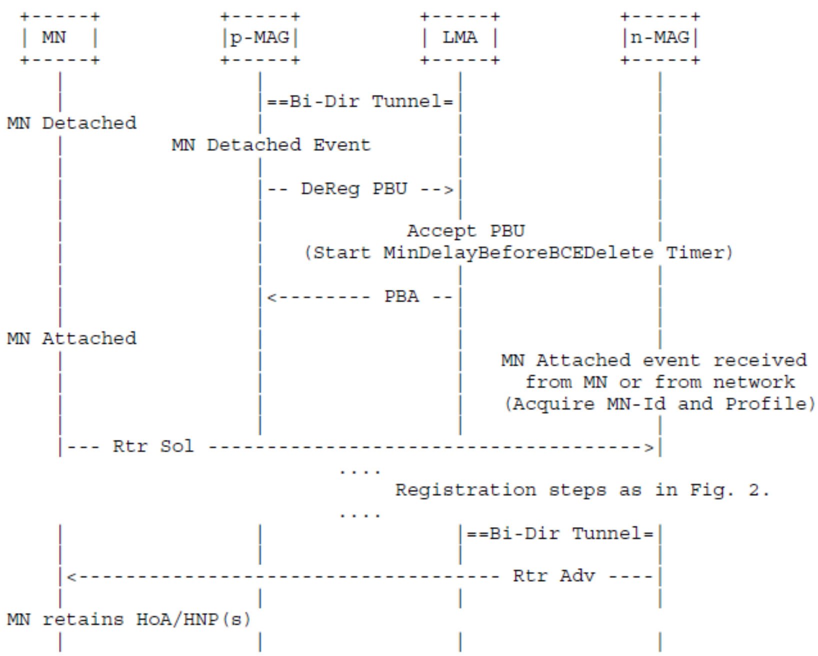

Figure 4. MN Handoff [3]

3.3. Distributed Mobility Management (DMM)

The IETF proposed Mobile IPv6 protocol (MIPv6) [1] [2] and Proxy Mobile IPv6 protocol (PMIPv6) [3] to solve the IP mobility problems. Both of them leverage on centralized mobility approach. The presence of the centralized mobility anchor allows a mobile device to be reachable when it is not connected to its home domain. Examples of such centralized mobility anchors are the HA (in MIPv6 domain) and the LMA (in PMIPv6 domain). Current mobile networks such as UMTS network, CDMA network, and 3GPP SAE network also use centralized mobility management. But a centralized mobility anchor has to manage the traffic of millions of mobile subscribers. So there exists some limitations of this approach compared with distributed and dynamic mobility management: non-optimal routes, network architecture evolution (overload the centralized data anchor), centralized route and mobility context maintenance (difficult with a large number of hosts), need versus no need for mobility support (distinguish whether there is real need for mobility support), numerous variants and extensions of MIP, excessive signaling overhead (can reduce in case of point-to-point communication), single point of failure and attack (centralized mobility anchor) [19] [21] [22] [32].

Current mobility support (MIPv6, PMIPv6) has been designed to be "always on" and to maintain the context for each mobile subscriber whereas the mobile node remains motionless. But, IP mobility management support is not required for applications that launch and complete while connected to the same point of attachment and for some intelligent applications [19] [21]. So, mobility should be provided dynamically and provide handover capability only when it is really needed. One of solutions is the distributed mobility management (DMM).

DMM introduces a deployment scenario of IP mobility mechanisms in flat mobile architectures: distribution of mobility function including distribution of mobility anchor and distributed mobility management.

4. Mobile Multicast challenges

Current infrastructure (architecture, protocols) is not prepared to deal with the problem of mobile multicast. Despite the fact that the IEFT has proposed many solutions based on MIPv6 and PMIPv6, there still exists many problems like tunnel convergence, service performance optimization (low delay, no loss), conversation of network resources, local routing, source mobility, support of multiple flows, etc. In details, we can classify the main problems into 2 categories: mobile receiver problems and mobile source problems.

Mobile receiver problems

- Multicast latency: When a receiver mobile, it will experience additional delay in receiving multicast packets due to handover, multicast membership protocol, multicast tree computation, propagation to the new location.
- Packet loss: During handover, the MN needs to continue receiving multicast packets. So, forwarding mechanism is required to support seamless handover. The IETF also proposed some solutions for handover such as using CXTP, HI/HAck message (see section 5.2).
- Packet duplication: Causing by a handoff event, a MAG can receive the same multicast stream coming from more than one LMA. It is called tunnel convergence problem.

Mobile source problems

- Transparency: It is a major issue for mobile multicast source. When a mobile source moves from one subnet to other subnet, it receives a new IP address (CoA). So it requires some mechanisms to make sure that multicast traffic has to continue delivering to the receivers.
- Reverse Path Forwarding (RPF): When source IP address (CoA) changes, the RPF check will be fail when SPT-based tree is used. The multicast router will drop multicast packets due to RPF failure. So, the multicast routing states should be modified to reflect the new IP address. But the RPT-based scheme can easily resolve this problem by using home LMA as source address (Rendezvous Point) (see section 5.4).

Moreover, there are some multicast routing and multicast deployment issues such as network inactivity, multicast encapsulation/decapsulation, routing state maintenance, etc. But, in this report, we do not cover these issues.

5. Mobile multicast solutions in PMIPv6

To solve these problems above, the IETF has proposed many solutions. Such solution addresses one or several problems. In general, we can classify the solutions into 3 categories: no protocol changes solutions, solutions that change PMIPv6 and solutions that change multicast protocols. The first class of solutions provides the solutions that deploy multicast services in PMIPv6 without changing PMIPv6. The second category proposes some PMIPv6 extensions in order to optimize multicast traffic such as: localized routing for multicast traffic, reduction of handover delays, etc. The last category describes how to change or extend multicast protocols to reduce the conversation of network resources, reduce multicast service latency and increase MN's life time, etc. Section 5.1 and 5.2 describe some solutions for multicast receiver mobility while solution proposed in section 5.4 addresses the multicast source mobility problems.

5.1. No change protocols solutions

In this section, we introduce 2 principal solutions for deploying multicast function in PMIPv6 domains without modifying mobility and multicast protocol standards: bi-directional tunneling solution [7] and direct routing solution [8] [41]. In the first solution, the LMA acts as multicast subscription anchor point, while the MAG provides MLD proxy functions. This solution does not support mobile multicast source**.** In the second solution, the MAG acts as a multicast router. So, multicast traffic is routed directly from designated multicast router to the MAG.

Bi-directional tunneling solution [7]

In the first solution, the MN may join multicast groups via a bi-directional tunnel between its LMA and its MAG. In this case, the MAG will act as a MLD proxy to receive MLD Report/Done messages from the MNs which it serves [25]. 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 [27]. To reduce the number of join messages from MAG to LMA, the aggregated join is used.

In handover, after MN attaches to the new MAG (n-MAG), the n-MAG obtains the MN's multicast information by using MLD query. In this case, the previous MAG (p-MAG) does not forward multicast traffic to n-MAG. So some packets will be lost during the handover. In this solution, there is another problem in which the MAG may receive same multicast packets from several LMAs. It is called "tunnel convergence" problem.

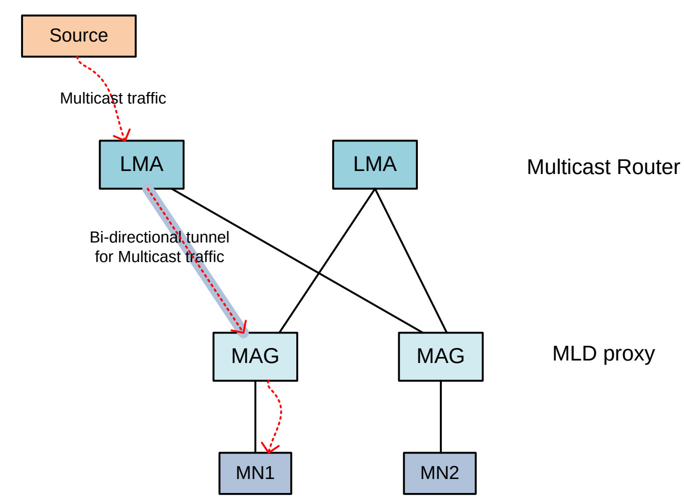

Figure 5. Bi-directional tunneling solution (LMA acts as Multicast Router, MAG as MLD proxy)

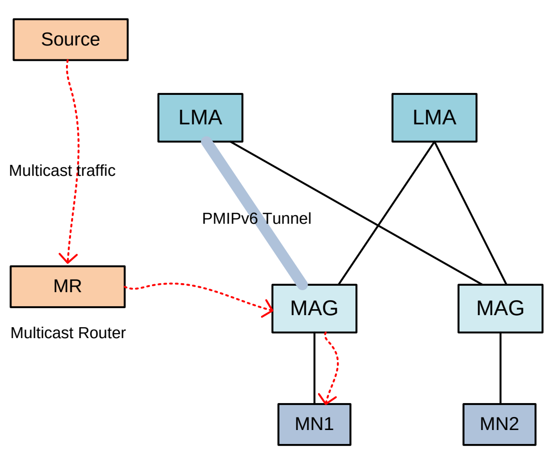

Figure 6. Direct routing solution (MAG acts as Multicast Router)

Direct routing solution [8] [41]

In this solution, the MAG acts as a multicast router [8], from point of view of the MN and as a multicast client from point of view of upstream multicast router. In addition, the MAG can act as a MLD proxy [41]. Multicast traffic, in this solution, is routed directly from the designated multicast router to the MAG. In handover process, the n-MAG utilizes MLD Queries to get MN's multicast group information. This solution helps to avoid the tunnel convergence problem and reduce the complexity in LMA.

5.2. Solutions that change PMIPv6

The solution in [7] has some problems such as local routing, no source mobility support, no provision of any seamless handover mechanism with a context transfer function, network resources wastages, etc. Therefore, this section introduces some PMIPv6 extensions to resolve these problems.

PMIPv6 Extensions for Multicast [9]

In draft [9], the establishment of a dedicated multicast tunnel (M-Tunnel) is proposed which may be dynamically created and released or be pre-configured in a static manner. The M-Tunnel aggregates the same MLD and multicast packets and can transmit different multicast channel data. It is per MAG basis and shared with all mobile nodes attached to MAG.

Both of two mobility entities MAG and LMA may be operated as MLD proxy or multicast router. So there are various scenarios to deployment. Seamless handover is also considered in this solution. So context transfer will be provided.

There are 2 principal scenarios. In the first scenario, MAG acts as a MLD proxy while LMA acts as a PIM-SM router (multicast router). The second scenario, both entities MAG and LMA act as PIM-SM router. In both cases of them, during handover, the multicast group states will be transfer from p-MAG to n-MAG via CXTP [36] or n-MAG obtains this information from the policy store. It is worth noting that with handover using CXTP, MAG must enable explicit membership tracking function [14]. Furthermore, we must extend PBU with multicast extension (PBU-M) to indicate that the PBU message is a multicast channel subscription.

In the second scenario, the MAG also sends MLD report with Hold extension with the corresponding multicast channel information to the LMA. On receiving MLD hold, the LMA join multicast delivery tree but does not forward multicast traffic to the MAG. The idea is to make the

LMA ready to forward multicast data. In handover, the LMA will forward data to n-MAG until it receives the native multicast traffic (after join multicast delivery tree) (see figure 9).

Moreover, both MAG and LMA can act as MLD proxy. In this case, the LMA will send aggregated MLD message to upstream multicast router. Listeners will be receiving multicast traffic from the LMA via M-Tunnel between LMA and MAG.

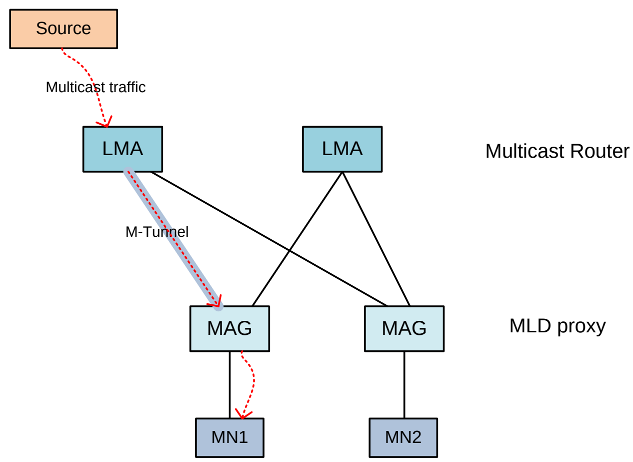

Figure 7. Scenario 1, MAG acts as MLD proxy, LMA acts as multicast router

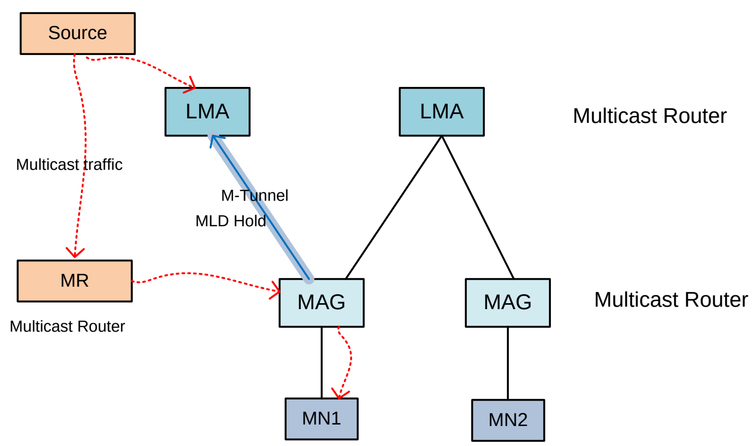

Figure 8. Scenario 2, LMA and MAG act as multicast router

Multicast Services Using Proxy Mobile IPv6 [10]

In base solution [7], the MAG may receive same multicast packets from several LMAs (tunnel convergence problem). To reduce this problem, in [10], a Dedicated Multicast LMA is introduced as topological anchor point for multicast traffic. Furthermore, this solution have many advantages to reduce the protocol complexity such as reducing total resource and states at LMAs, simplifying the multicast tree topology and allowing different PMIPv6 deployment scenarios.

This solution is based on “U-LMA: M-LMA” ratio in a PMIPv6 domain:

- Several unicast PMIPv6 domains served by one M-LMA (relationship N: 1): this deployment is suitable for initial scenario. In this scenario, it reduces multicast tree size and adapts to low multicast-MN customer base [28].
- One unicast PMIPv6 domain served by several Multicast LMAs (relationship 1: N): this deployment is suitable for service differentiation (distinct content providers, transport technology, content type), load balance, redundancy. It is suitable for high multicast-MN customer base [28].

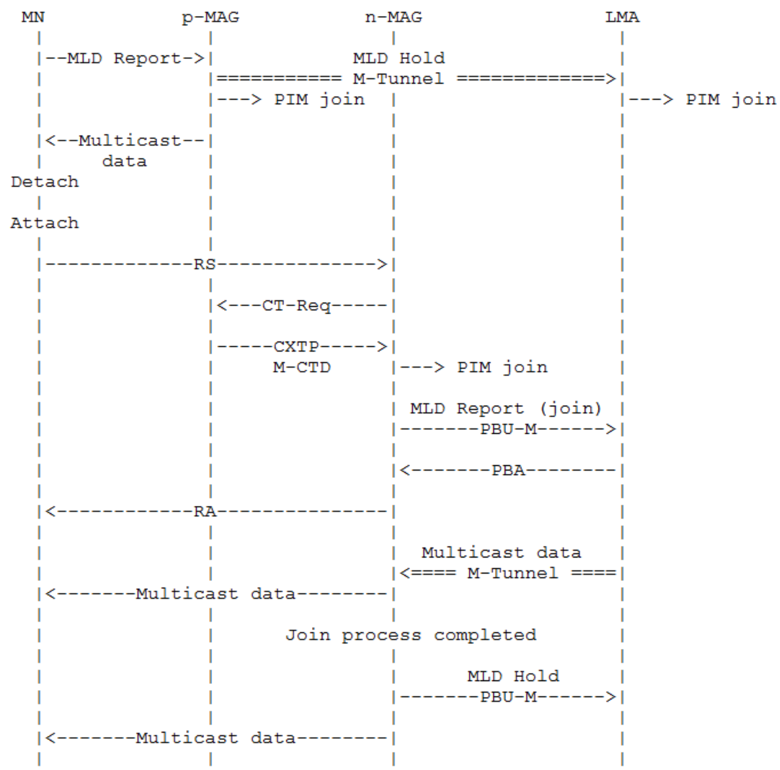

Figure 9. (LMA, MAG as PIM-SM Multicast router) handover with CXTP [7]

Solutions for Handover

MAG entity in base solution [7] relays on standard MLD procedures to get knowledge of MN multicast subscription after handover. In addition, there is not M-tunnel for multicast traffic during handover between p-MAG and n-MAG. Consequently, latency and packet loss which are caused by handover will affect the quality of multicast service. There are some solutions that intend to reduce the handover latency and packet loss problem.

Document [11] introduces a solution for PFMIPv6 (and FMIPv6) in which n-MAG obtains multicast group states from p-MAG via HI/HAck (HO Initiate and HO Acknowledgement) message

(Predictive Handover) or from MN by using MLD Query (Reactive Handover). Another document, [12] provides a solution to reduce latency and packet loss during handover (fast handover) by using 2 messages HI and HAck to transfer multicast group states from p-MAG to n-MAG. During handover, MN's multicast group states are transferred from p-MAG to n-MAG via HI message. In both 2 solutions, p-MAG forwards multicast traffic to n-MAG via an M-tunnel during handover.

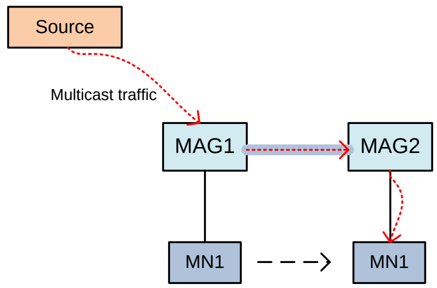

Figure 10. Multicast traffic during handover

The solution proposed in [13] accelerates the MAG's knowledge of the MN's multicast subscription after handover. The n-MAG obtains MN's multicast group states from the LMA via extended PBA message. There are 2 modes of handover: Predictive Handover and Reactive Handover. In the Predictive Handover, the LMA receives MN de-registration from p-MAG before MN registration from n-MAG. So the LMA caches MN's multicast information that is included in the extended de-registration PBU in Binding Cache. In the Reactive Handover, the LMA receives MN registration from n-MAG before MN de-registration from p-MAG. So in this case, the LMA must utilize Subscription Info Query/Response to get MN's multicast group information from p-MAG.

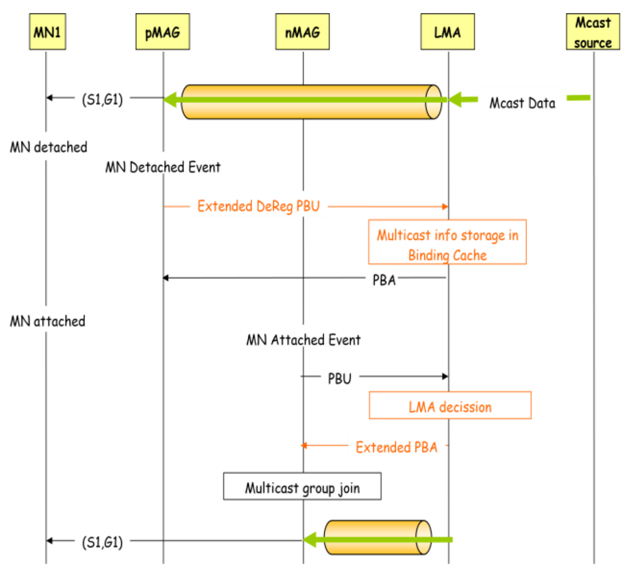

Figure 11. Rapid acquisition of the MN multicast subscription after handover - Predictive mode [29]

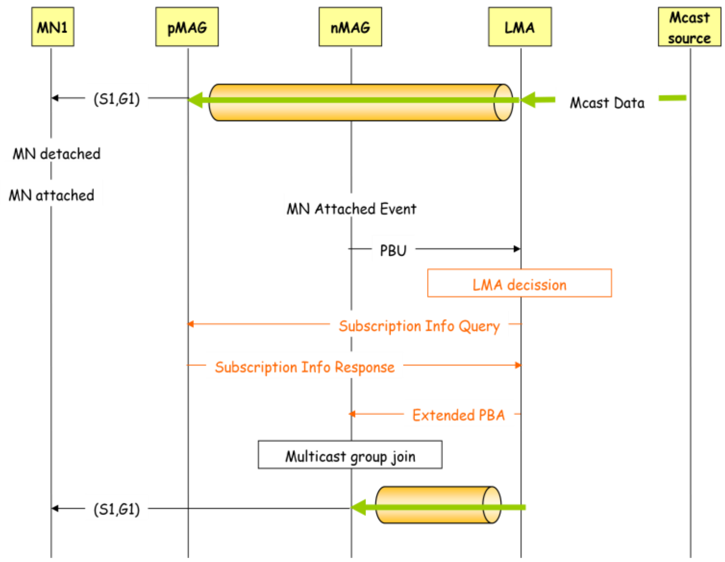

Figure 12. Rapid acquisition of the MN multicast subscription after handover - Reactive mode [29]

5.3. Solutions that change multicast protocols

The IGMP for IPv4 [24] [26] and MLD for IPv6 [25] [26] are the standard protocols used by listener hosts and multicast routers. Multicast routers are able to periodically maintain the multicast membership state of downstream hosts attached on the same link by getting Unsolicited Report messages and synchronize the actual membership state. However, this approach does not guarantee that the membership state is always perfectly synchronized [14]. In addition, MAG entity relays on standard MLD procedures to get knowledge of MN multicast subscription after handover. Consequently, there exists the problem in a burst of IGMP/MLD message transmission and problem in delays caused by MLD Query processing. So, tuning IGMP/MLD protocol behavior can provide solutions to reduce handover delays (join/leave latency), reduce bandwidth wastage, etc.

IGMP/MLD-Based Explicit Membership Tracking Function for Multicast Routers [14]

Document [14] describes the explicit tracking function that is used by routers to keep track of the downstream multicast membership states. The explicit tracking function works for:

- Per-host accounting
- Reducing the number of transmitted Query and Report messages
- Shortening leave latencies
- Maintaining multicast channel characteristics

When a router enables the explicit tracking function, the membership state information is stored in 2 ways: the complete state information (S, G, number of receivers, (receiver records)) or the minimum state information (S, G, number of receivers). In this case, a receiver record is IGMP/MLD source address. Normally, whenever a router receives the State-Change Report from a MN, routers must use Group-Specific or Group-and-Source Specific Query messages to confirm whether the Report sender is the last member of multicast group or not. In addition, MNs have to response to General Query from Router with a Current-State Report. So there are many MLD message transmissions in network. A router enabling the explicit tracking function can resolve this problem because it works with the expectation that the sender's State-Change Report is the last remaining member of the channel. So, it does not need to always ask Current-State-Report message transmission to the member host whenever it receives the State-Change-Report. It also reduces leave latency by tuning timers and values related.

IGMP and MLD Protocol Extension for Mobility [15]

According to a smooth handover scenario, a mobile host wants to accelerate multicast service termination in the previous network before handoff and immediately rejoin the session after the movement. Draft [15] describes a "Notification operation" and "Hold and Release protocol extensions" for the IGMP/MLD protocols for the mobile hosts and routers. In details, MN explicitly notifies Current-State Report without solicitation. So, the IGMP/MLD Notification operation reduces the number of IGMP/MLD General Query messages.

The LMA/Designated Multicast router can keep MN's membership state for fast packet forwarding by receiving an IGMP/MLD Hold message from MAG and releases it after handover after receiving IGMP/MLD Release message.

Proposal for Tuning IGMPv3/MLDv2 Protocol Behavior in Wireless and Mobile Network [16]

With the wide deployment of different wireless networks, multicast communication over wireless network comes to attract more and more interests from content and service providers, but still faces great challenges. On the other hand, unlike wired network, some of wireless networks often offer limited reliability, consume more power and cost more transmission overhead, thus in worse case are more prone to loss and congestion.

As IGMP and MLD are designed for fixed users using wired link, they does not work perfectly for wireless link types. They should be enhanced or tuned to adapt to wireless and mobile environment to meet the reliability and efficiency requirement of multicast services.

Existing multicast support for fixed user can be extended to mobile users in wireless environments. However, applying such support to wireless multicast is of great difficulty due to some following reasons: limited bandwidth, large packets loss, frequent membership change, prone to performance degradation, increased leave latency.

These issues can be addressed by tuning these parameters (timer values and counter values) and tuning of protocol behavior to improve the performance of wireless and mobile multicast network. According to this document, IGMPv3/MLD v2 or LW-IGMPv3/MLDv2 [30] is recommended to be used as the basis for optimization of IGMP/MLD to adapt to wireless mobile networks. The behavior of these protocols can be tuned by using the following optimizations approaches [16]:

- Using Explicit tracking function without Group-specific and Group-and-Source Specific Query
- Report suppression for the hosts and Query suppression for the routers
- Minimizing Query frequency by increasing interval each time
- Switching between Unicast Query and Multicast Query
- Triggering reports and queries quickly during handover
- Etc.

Tuning the Behavior of IGMP/MLD for Mobile Host and Routers [17]

As the protocols IGMP and MLD are designed for fixed users using wired link, they does not work perfectly for wireless link types. They should be tuned to adapt to wireless and mobile environment to meet the reliability and efficiency requirement of multicast services. The tuning the IGMPv3/MLDv2 protocol behavior for mobility includes a query and other timers tuning. Draft [17] proposes a combination appropriate of using explicit tracking function and other mechanisms like unicast/multicast general query, tuning the parameters (timers, counters). It aims to become a guideline for query and other timers tuning.

5.4. Multicast source mobility

In order to deploy the multicast service in the PMIPv6 network, many schemes have been proposed ([2] [7] [10] [11] [12] [13]). However, all of these schemes aim to support the multicast service for the mobile receiver and how to support the multicast source mobility in the PMIPv6 network is not yet discussed. In [8] [9] [41], multicast source mobility can be enabled in PMIPv6-domain, when MAG acts as a multicast router. But these documents do not cover the detail description of source mobility.

The multicast source mobility is also a very important issue for the deployment of the multicast service. RFC 5757 [2] introduces 2 solutions for multicast source mobility issues in MIPv6 network which are based on RPT-based scheme and SPT-based scheme. The above 2 schemes can also be used in the PMIPv6 network.

In draft [18], the two schemes are proposed: the LMA-based scheme and the MAG-based scheme. Both of them are used in two scenarios: the ASM and the SSM. In the LMA-based scheme, the multicast traffic from the source are directed to the LMA first and then transmitted to the receivers according to the multicast routing protocols. While in the MAG-based scheme, the multicast traffic can be directly transmitted from the MAG to the receivers.

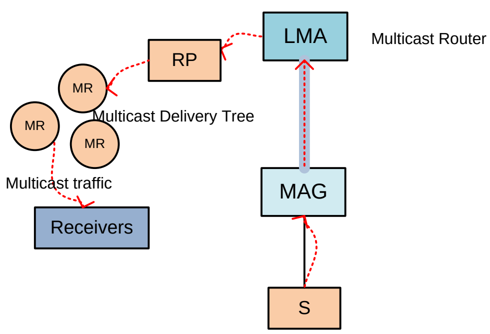

Figure 13. the LMA-based RPT scheme (ASM)

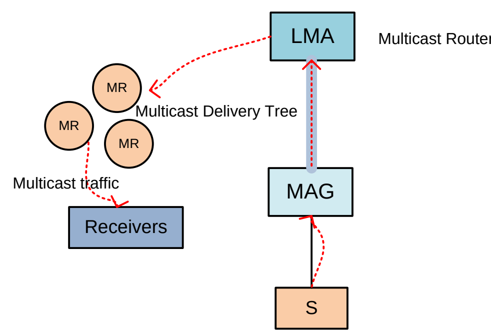

Figure 14. the LMA-based SPT scheme (ASM/SSM)

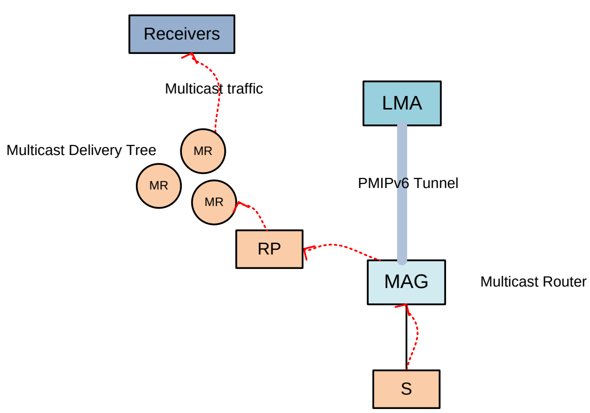

Figure 15. The MAG-based RPT scheme (ASM)

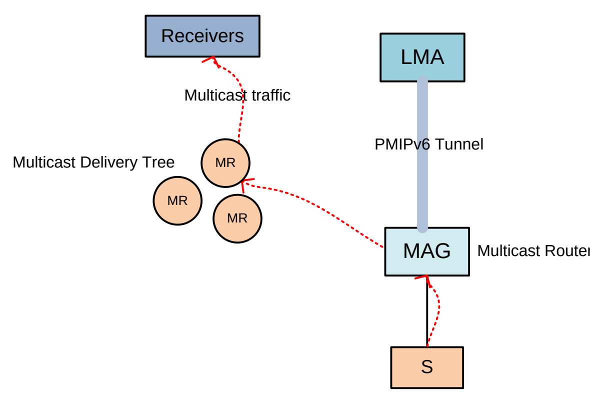

Figure 16. The MAG-based SPT scheme (ASM/SSM)

In the LMA-based scheme, the multicast traffic is always routed via LMA. Consequently, in the case of SPT, the path is not the topological shortest path tree due to the existence of PMIPv6 tunnel between LMA and MAG. Meanwhile in the MAG-based SPT scheme, all multicast listeners are forced to know the address of the MAG corresponding to the multicast service. Therefore, it requires some extra mechanisms to inform the multicast listeners of MAG address. So, it is suggested that the MAG-based SPT scheme should not be considered.

In general, the LMA-based scheme is easy to implement since the extra extensions of the PMIPv6 protocol and the multicast routing protocol are unnecessary. Moreover, the MAG-based RPT scheme is also a good choice for multicast service.

The detailed comparison of the two schemes is described in figure below.

			PMIPv6 Extension	PIM-SM Extension	handover delay	handover overhead	Path
ASM	LMA-based	RPT	/	/	low	low	worst
		SPT	/	/	low	low	medium
	MAG-based	RPT	MAG	/	low	low	better than LMA-based RPT
		SPT	MAG/LMA	multicast router & receiver DR	high	high	best
SSM	LMA-based		/	/	low	low	medium
	MAG-based		MAG/LMA	multicast router & receiver DR	high	high	best

Figure 17. Comparison of the LMA-based scheme and the MAG-based scheme

In order to support multicast source mobility, the basic PMIPv6 signalings (PBU/PBA) are required to extend. A one bit "S" is used to indicate that the MN is multicast source while a one bit "J" is added to indicate whether the MAG has the ability to adopt the MAG-based scheme.

5.5. Solution proposal for both of multicast source mobility and multicast receiver mobility

As mentioned in section 5.1, 5.2 and 5.3, the LMA-based scheme (SPT or RPT) is suitable for both of multicast source mobility and multicast receiver mobility thanks to its simple implementation/deployment. In this scheme, LMA and MAG act as multicast router. In addition, in RPT scheme the LMA can play a role of RP. We can switch between SPT scheme and RPT scheme [MAG or LMA will determine to switch]. The MAG-based PRT scheme also can be used as a solution for multicast source and receiver mobility. However, the behavior of MAG (multicast router) has to tune to route multicast traffic directly to MR.

Furthermore, there are some cases in which traffic sends back to the previous MR [see figure 18, 19]. If necessary, we could envision some modifications of PIM-SM, and/or MLD-proxy behavior to solve this problem. Based on this modification, we can determine switch between SPT and RPT to achieve the route optimal.

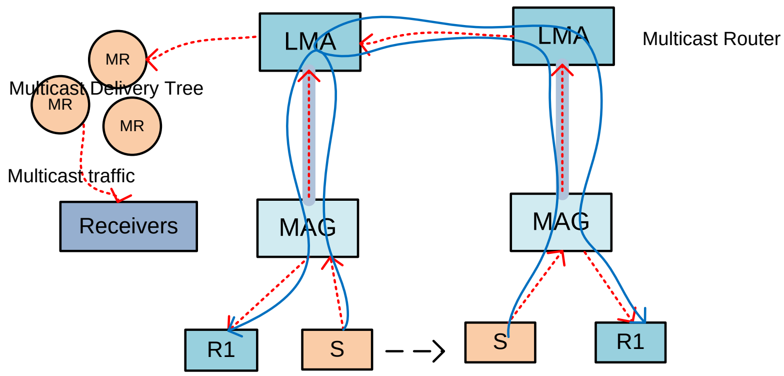

Figure 18. Traffic sends back to the LMA/MAG (1)

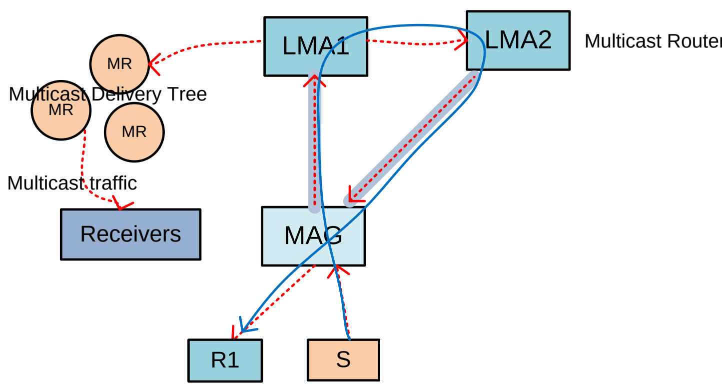

Figure 19. Traffic sends back to the LMA/MAG (2): S is served by (MAG, LMA1) while R1 is served by (MAG, LMA2)

A problem associated with PMIPv6 is that all traffic flows through the centralized mobility anchor (LMAs) which causes well-known bottlenecks and single point of failure issues, especially for demanding services such as HD video. Such issue will be explored in proposals within the next section [see section 6].

6. Multicast in DMM

One of the trends in the evolution of mobile networks is to go on flat architecture with the distribution of network functions including mobility functions. As we mentioned above, DMM introduces a deployment scenario of IP mobility mechanisms in flat mobile architectures: distribution of mobility. In this section, we introduce some DMM aspects that deploy a dynamic distributed mobility management architecture where anchors are deployed towards the network edge and are dynamically available to MNs when really needed.

The DMM can be applied at different parts of the mobile network: mobile core network (Core-level and AR-level), access network (Access-level) and host-level [20] [33].

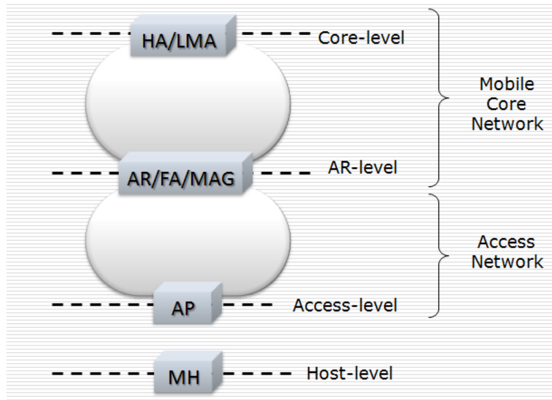

Figure 20. Multiple level of distribution [33]

There are also 2 approaches for DDM: partially distributed approach and fully distributed approach. In the partially distributed approach, control and data plane are separated. Control plane is centralized while data plane is distributed. In the fully distributed approach, both of control and data plan is distributed. In this case, there is a problem with selection of the appreciate mobility anchor. In order to resolve this problem, two solutions are proposed. One called "Search and delivery" approach which searches for the correct mobility anchor before delivering packets. But the search time cannot be ignored when the number of mobility anchors increases. Another approach, called "Multiple delivery" (or Broadcast/multicast type of network). In this approach, packets are delivered to all or multiple mobility anchors and only the corresponding mobility anchor delivers the packets to the mobile host. This approach does not require the search mechanism, the signaling between MAGs, but does not use network resource efficient. So it is good for limited scope of network such as local area network or metropolitan area network [20].

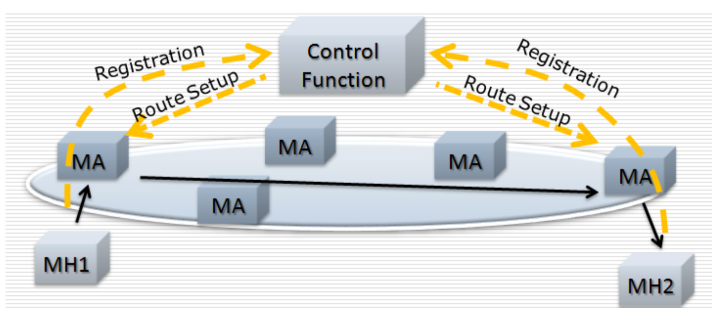

Figure 21. Partially distributed approach [33]

In both of 2 approaches, partially distributed approach and fully distributed approach, network provides what it called dynamic mobility management only to the hosts who really need it.

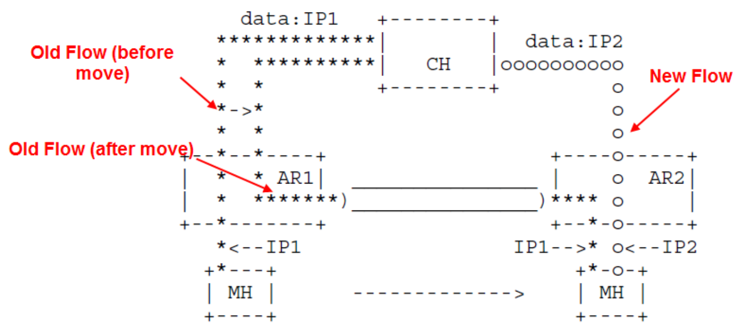

Figure 22. Dynamic mobility management [20]

Distributed Local Mobility Anchors [23]

The problem of triangle routing in PMIPv6 when a mobile node is far from its home agent is one of the main issues of deployment multicast in PMIPv6. This problem can be resolve by having multiple home agents in different geography location [34] [23]. But the synchronization of all the home agents is a challenge. To avoid the problem of synchronization, draft [21] [23] proposes to decouple the logical functions of a local mobility anchor into 3 logical functions: home address allocation, location management (LM), and mobility routing (MR). The home address allocation function and the LM function are may be kept only at the home network while the MR function is copied in different networks. So this is a deployment scenario of PMIPv6 in a flat architecture.

Figure 23. A deployment scenario of PMIPv6 in a flat architecture [35]

To understand this deployment scenario, three cases of packet flow are considered in [23]: (1) sending packets to a mobile node (MN) from a non-mobile correspondent node (CN), (2) sending packets from a mobile node to a non-mobile correspondent node, (3) sending packet from a mobile node to a mobile correspondent node.

(1) Sending packets to a mobile node from a non-mobile correspondent node (CN)

Normally, CN attempts to communicate with MN using MN's HoA. So, the packets are routed from the originating LMA (O-LMA) via the home LMA (H-LMA) to the destination LMA (D-LMA). It causes the triangle routing problem. But this problem exists for only first few packets. Because the H-LMA also informs the O-LMA the current MN's location information (D-LMA), the O-LMA caches this information in its cache. So, the O-LMA may forward subsequent packets directly to the D-LMA.

Figure 24. Receiving packets- first few packets [35]

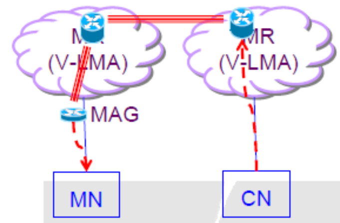

Figure 25. Receiving packets- subsequent packets [35]

```
+---+   +---+-----+   +-----+-----+   +-----+---+   +---+---+   +---+
|HoA|-->|HoA| HoA |   | HoA | HoA |   | HoA |HoA|   |HoA|HoA|-->|HoA|
|   |   |   |-----|   |-----|-----|   |-----|---|   |---|   |   |   |
|   |   |   |H-LMA|-->|H-LMA|V-LMA|-->|V-LMA|CoA|-->|CoA|   |   |   |
+---+   +---+-----+   +-----+-----+   +-----+---+   +---+---+   +---+

 CN         O-LMA         H-LMA          V-LMA          MAG        MN
```

Figure 26. Network layer in the protocol stack of first few packets [23]

```
+---+       +---+-----+       +-----+---+       +---+---+       +---+
|HoA|  -->  |HoA| HoA |       | HoA |HoA|       |HoA|HoA|  -->  |HoA|
|   |       |   |-----|       |-----|---|       |---|   |       |   |
|   |       |   |D-LMA|  -->  |D-LMA|CoA|  -->  |CoA|   |       |   |
+---+       +---+-----+       +-----+---+       +---+---+       +---+

 CN            O-LMA             D-LMA             MAG           MN
```

Figure 27. Network layer in the protocol stack of the subsequent packets [23]

It is possible for the D-LMA (or H-LMA) to inform O-LMA the MN's proxy-CoA. So the O-LMA may tunnel packets directly to the MAG. It is called bypassing D-LMA.

A MN can change its MAG or its LMA when it has an ongoing multicast session. In the case of changing MAG (and proxy-CoA) while anchoring to the same D-LMA, packets forwarded from the O-LMA to the D-LMA are unaffected. Moreover, if bypassing D-LMA is indicated, the p-MAG will need to tunnel the packets to the n-MAG (for first few packets). Meanwhile the p-MAG will inform the O-LMA to tunnel future packets directly to the n-MAG. In the case of changing LMA during an ongoing session, the H-LMA will be notified to ensure to have the correct MN's location information. But some LMAs may have cached the old location information. They may be continuing to tunnel packets to the previous D-LMA. In this case, forwarding mechanism is required from previous D-LMA to new D-LMA (for some packets). If in the case bypassing D-LMA

(O-LMA directly tunnels packets to the MAG), p-MAG will need to forward the packets to n-MAG (for some packets).

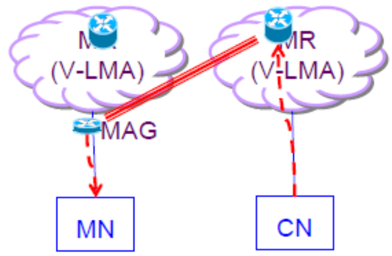

Figure 28. Bypassing D-LMA [35]

(2) Sending packets form a mobile node to a non-mobile correspondent node

When a mobile node want to send the packets to a non-mobile correspondent node (fixed node), the packets may go through the LMA to preserve location privacy.

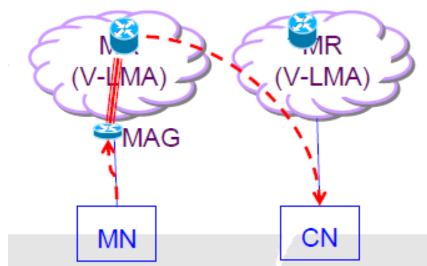

Figure 29. Sending packets from MN to a fixed CN [35]

```
+---+     +---+---+     +---+---+     +---+
|HoA| --> |HoA|HoA|     |HoA|HoA| --> |HoA|
|   |     |   |---|     |---|   |     |   |
|   |     |   |CoA| --> |CoA|   |     |   |
+---+     +---+---+     +---+---+     +---+

 MN          MAG          O-LMA        CN
```

Figure 30. Network layer showing the source IP address as a packet traverses from MN to CN [23]

(3) Sending packets form a mobile node to a mobile correspondent node

In this case, the mobile node MN1 sends the packets to the other mobile node MN2. The packets from MN1 will first be tunneled from MAG to O-LMA. The route from O-LMA to MN2 will be the same as the case send from a correspondent node to a mobile node [see figure 18]. The route for the first few packets will be: [MN1 -> MAG1 -> O-LMA -> H-LMA (of MN2) -> D-LMA -> MAG2 -> MN2] and for the subsequent packets will be: [MN1 -> MAG1 -> O-LMA -> D-LMA -> MAG2 -> MN2].

To reduce the latency, bypassing the tunneling role of the LMA is proposed by removing the need for the LMA to de-capsulate the tunneling header of an incoming packet and to encapsulate the packet again (for outgoing tunnel). But bypassing the tunneling may affect to the location privacy. Therefore, the network needs to know whether bypassing the LMA or not. In general, tunneling a packet once between 2 network nodes may be sufficient to protect the location privacy of a mobile node. So in some cases, we can use this solution like the scenario described in the figure below [Figure 26].

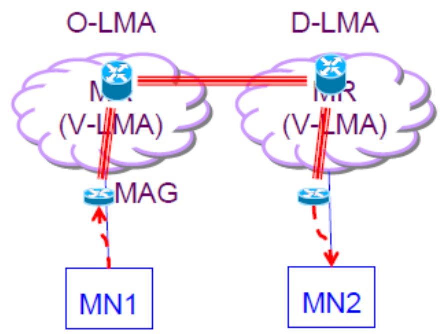

Figure 31**. Sending packets form MN to another MN [35]**

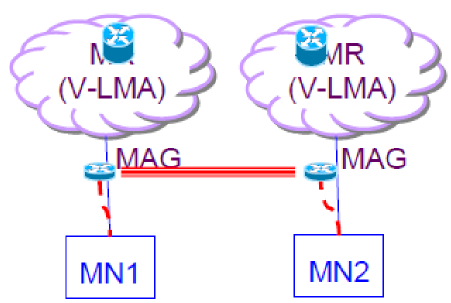

Figure 32. Bypassing the tunneling role of the LMA [35]

Many DMM's aspects are also considered in some IETF drafts such as [21] [22]. Draft [21] proposes 3 solutions to deploy mobility mechanism in a flat architecture: client-based solutions, network-based solutions and splitting the routing and the location management function. In the client-based solutions, the HA functionalities is implemented in Access Routers (AR) while in the network-based solutions, ARs support both HA and MAG functionalities. The third solution has the same idea with [23] in which the logical functions of LMA are split in to the routing and the location management function.

The goal of [22] is to dynamically adapt the mobility support of the MN's need by applying traffic redirection only to MN's flows when an IP handover occurs. So, this solution is slightly different in comparison with solution in [23]. The idea of the solution proposed in [22] is that regular IPv6 routing applies when an IP communication is initiated. In this case, the mobility anchoring for the same mobile node depends on where the flow is initially created. When a mobile node moves across several MARs (Mobility capable Access Router), the tunnel is established between the initial MAR and current attached MAR for only the flows that are initiated initial MAR. This solution is also applied in the context of multiple-interface terminals (Multi-homing) and IP flow mobility.

Conclusions

This report aims to bring the overview of IP mobile multicast: the problems and the solutions. It mainly leverages on the IETF documents which support multicast mobility in PMIPv6 and in DMM.

Despite having many solutions proposed, multicast mobility is still difficult to deploy especially in the case of mobile source and mobile listener at the same time. In our future work, we will try to combine different solutions or propose new solution to give an optimal solution for IP mobile multicast.

References

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

[2] Schmidt, T., Waehlisch, M., Fairhurst, G., “Multicast Mobility in Mobile IP Version 6 (MIPv6): Problem Statement and Brief Survey”, RFC 5757, February 2010

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

[4] Romdhani, I., Kellil, M., Lach, H. Y., Bouabdallah, A., and Bettahar, H., “IP Mobile Multicast: Challenges and Solutions”, *IEEE Communications Surveys & Tutorials*, 2004

[5] Kurup, G., Sekercioglu, Y. A, “Source Specific Multicast (SSM) for MIPv6: A Survey of Current State of Standardisation and Research”, Available: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.5.757

[6] Soto, I., Bernardos, C., Calderon, M., Melia, T., “PMIPv6: A Network-Based Localized Mobility Management Solution”, The Internet Protocol Journal, Volume 13, No.3, September 2010

[7] Schmidt, T., Waehlisch, M., Krishnan, S., “Base Deployment for Multicast Listener Support in PMIPv6 Domains”, draft-ietf-multimob-pmipv6-base-solution-07.txt (work in progress), December 2010

[8] Jeon. S, Kim, Y., “Mobile Multicasting Support in Proxy Mobile IPv6”, draft-sijeon-multimob-mms-pmip6-02.txt (expired), March, 2010

[9] Asaeda, H., Seite, P., Xia, J.,” PMIPv6 Extensions for Multicast”, draft-asaeda-multimob-pmip6-extension-05.txt (work in progress), February 2011

[10] Zuniga, J., Rahman, A., Contreras, M., Bernardos, C., Soto, I., “Support Multicast Services Using Proxy Mobile IPv6”, draft-zuniga-multimob-smspmip-05.txt (work in progress), March 2011

[11] Schmidt, T., Waehlisch, M., Koodli, R., Fairhurst, R., “Multicast Listener Extensions for MIPv6 and PMIPv6 Fast Handovers”, draft-schmidt-multimob-fmipv6-pfmipv6-multicast-03.txt (work in progress), November 2010

[12] Hui, M., Chen, G., Deng, H., “Fast Handover for Multicast in Proxy Mobile IPv6”, draft-hui-multimob-fast-handover-02.txt (expired), July 2010

[13] Contreras, L., Bernardos, C., Soto, I., “Rapid Acquisition of the MN multicast subscription after handover”, draft-contreras-multimob-rams-00.txt (expired), June 2010

[14] Asaeda, H., Uchida, Y., “IGMP/MLD-Based Explicit Membership Tracking Function for Multicast Routers”, draft-asaeda-mboned-explicit-tracking-01(work in progress), October 2010

[15] Asaeda, H., Schmidt, C., “IGMP and MLD Protocol Extensions for Mobility”, draft-asaeda-multimob-igmp-mld-mobility-extensions-04.txt (expired), March 2010

[16] Wu, Q., Liu, H., “Proposal for Tuning IGMPv3/MLDv2 Protocol Behavior in Wireless and Mobile networks”, draft-wu-multimob-igmp-mld-tuning-03.txt (work in progress), October 2010

[17] Asaeda, H., Uchida, Y., Wu, Q., Liu, H., “Tuning the Behavior of IGMP and MLD for Mobile Hosts and Routers”, draft-asaeda-multimob-igmp-mld-optimization-05 (work in progress), February 2011

[18] Zhang, H.,Yan, Z. H., Gao, S., Wang, L. L., Wu, Q., Li, H. W., “Multicast Source Mobility Support in PMIPv6 Network”, draft-zhang-multimob-msm-02.txt (work in progress), March 2011

[19] Chan, H., Ed., “Problem statement for distributed and dynamic mobility management”, draft-chan-distributed-mobility-ps-00.txt (work in progress), October, 2010

[20] Yokota, H., Seite, P., Demaria, E., Cao, Z., “Use case scenarios for Distributed Mobility Management”, draft-yokota-dmm-scenario-00.txt (work in progress), October 2010

[21] Liu, D., Cao, Z., Seite, P., Chan, H., “Distributed mobility management”, draft-liu-distributed-mobility-02.txt (expired), July, 2010,

[22] Seite, P., Ed. and P. Bertin, "Dynamic Mobility Anchoring", draft-seite-netext-dma-00.txt (expired), March 2010.

[23] Chan, H., Xia, F., Xiang, J., and H. Ahmed, "Distributed Local Mobility Anchors", draft-chan-netext-distributed-lma-03.txt (expired), March 2010

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

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

[26] 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

[27] Estrin, D., Farinacci, D., Helmy, A., Thaler, D., Deering, S., Handley, M., Jacobson, V., Liu, C., Sharma, P., Wei, L., “Protocol Independent Multicast-Spare Mode (PIM-SM): Protocol Specification”, RFC 2362, June 2008

[28] Zuniga, J., Rahman, A., Contreras, M., Bernardos, C., Soto, I., “Dedicated Multicast LMA”, IETF 79, November 2010

[29] Contreras, L., Bernardos, C., Soto, I., “Rapid Acquisition of the MN multicast subscription after handover”, IETF 79, Multimob WG, November 2010

[30] Liu, H., Cao, W., Asaeda, H., “Lightweight Internet Group Management Protocol Version 3 (IGMPv3) and Multicast Listener Query Version 2(MLDv2) Protocols”, RFC 5790, February 2010

[31] Zhang, H.,Yan, Z. H., Gao, S., Wang, L. L., Wu, Q., Li, H. W., “Multicast Source Mobility Support in PMIPv6 Network”, IETF 79, Multimob WG, November 2010

[32] Laganier, J., “Distributed and Dynamic Mobility Management with Mobile IPv6”, IETF 79, MEXT WG, November 2010

[33] Yokota, H., Seite, P., Demaria, E., Cao, Z., Liu, D., Chan, H.A., Perkins, C., Meria, T., Deng, H., Haddad, W, “Use case scenarios for Distributed Mobility Management”, IETF 79, MEXT WG, November 2010

[34] Thubert, P., Wakikawa, R., and V. Devarapalli, “Global HA to HA protocol”, draft-thubert-mext-global-haha-01 (work in progress), July 2009

[35] Chan, H. A., “Distributed LMA”, IETF 77, NETEXT WG, March 2010

[36] Loughney, J., Nakhjiri, M., Perkins, C., Koodli, R., “Context Transfer Protocol (CXTP)”, RFC 4067, July 2005

[37] Waitzman, D., Partridge, C., Deering, S.,"Distance Vector Multicast Routing Protocol", RFC 1075, November 1988

[38] Moy, J., “Multicast Extensions to OSPF”, RFC 1584, March 1994

[39] Adams, A., Nicholas, J., Siadak, W., "Protocol Independent Multicast - Dense Mode (PIM-DM): Protocol Specification (Revised)", RFC 3973, January 2005

[40] Ballardie, A., "Core Based Trees (CBT version 2) Multicast Routing", RFC 2189, September 1997

[41] Jeon, S., Kim, Y., “PMIPv6 Multicasting Support using Native Infrastructure”, draft-sijeon-multimob-direct-routing-pmip6-00.txt (work in progress), March 2011