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MOBILITY SUPPORT IN IP MULTICAST: PROPOSALS REVIEW AND EVALUATION

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Multicast is one-to-many or many-to-many delivery of packets. Multicast data delivery increases network efficiency and decreases the bandwidth demand by eliminating the need for redundant packets when more than one client wishes to access a data stream. With this in mind, the importance of multicast routing becomes evident. However, the main drawback of the current multicast routing protocols is that they are developed without mobility in mind. It is anticipated that many users are likely to become mobile in the near future, thus mechanisms are needed to support multicast for the groups whose members are both mobile and static. The main aim of this paper is to study and evaluate the current approaches for mobility support in multicast. It presents the main concepts of multicast. It also performs a study and evaluation to the Internet Engineering Force Task (IEFT) approaches to handle the mobility of the multicast users. Then the discussion is extended to include different protocols that are introduced to overcome the limitations of IEFT proposals highlighting their advantages and limitations.

Key words: Multicast, Mobility Support
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1 Introduction

Traditionally data communications has been one-to-one (Unicast), which creates a single steam of data to every user. However, with the advent of new technologies such as Video over DSL, distance learning, video conferencing, Streaming Media and others, IP-Multicast is becoming a core part of new emerging networks. IP multicast routing provides efficient communication services for applications that send the same data to multiple recipients, without incurring network overloads. It allows servers to send single copies of data streams which are then replicated and routed to recipients. Hence, at each router, only one copy of an incoming multicast packet is sent per link, rather than sending one copy of the packet per number of receivers accessed via that link. IP Multicast groups are identified by a certain multicast address (class D address in case of IPv4) [1]. These groups are open i. e. Data from any sender can be forwarded to open groups, dynamic i. e. the member of the group can change during a communication, and heterogeneous i. e. members are having different capabilities [2]. The multicast groups are also known as transient group since they exists only when the group has members. Unlike anonymous group, multicast groups are aware of the identity of the other members in the group. In IP multicast, the group members are associated with a certain registration mechanism. The registration is required only for receivers. Thus, a source does not need to register as a member to send packets to a multicast group. Members can join and leave during the life of a multicast session. The Internet Group Management Protocol (IGMP) [RFC 2236] for IPv4, or Multicast Listener Discovery (MLD) [RFC 2710] for IPv6, is used to advertise and join specific multicast groups. A local multicast router periodically sends Membership Query Messages. A receiver joins a multicast group by sending a Membership Report Message to the local multicast-enable router, which specifies the group that it wishes to join. The router then forwards all multicast traffic for the specified group to the recipient's subnet. A host can be a member of several multicast group at any given time, and is able to join and leave any group (by sending the appropriate Membership Report Messages) independently.

It is anticipated that many users are likely to become mobile in the near future. To provide reachability during movement, IEFT has proposed Mobile IPv4 [3] and the Mobile IPv6 [4] protocols. However, Mobile IPv4/IPv6 handles multicast in a rough way i.e. through Remote Subscription (RS) and Bidirectional Tunnelling (BT). Both techniques suffer from several drawbacks that make them inefficient especially during frequent user's movement. On the other hand, multicast routing protocols are not developed with mobility in mind. Hence, there are several proposals to provide more support to the mobile users in IP multicast environment. These proposals are, essentially, aiming to overcome IETF techniques limitations. The main aim of this paper is to study and evaluate these current proposals. To achieve that, these proposals are classified into two categories. The first category is Home Agent base (HA), where the mobile users subscribe to the multicast session through the Home Agent. The other category is Remote subscription base (RS), where the mobile nodes join the multicast group via a local multicast router on the foreign link being visited.

This paper is organized as follows: Section two discusses IETF main proposals to support mobile users in IP multicast. Section three presents other proposals that have been introduced to overcome the limitations of IETF proposals. It highlights the main features of the protocols under study. Last section presents a conclusion followed by a table of abbreviations.

2 IETF Proposals to support mobile users

2.1 Bidirectional Tunnelling

In Bi-directional Tunnelling approach (BT), a mobile node subscribes to a multicast group through its home network. It tunnels all its MLD messages to the home agent, which will then forward the packets down the tunnel to the mobile receiver. A mobile multicast source will directly send its multicast packets towards its home network through the MIPv6 bi-directional tunnel, always using its home address as source address of its packets.

This approach requires the home agent to be a multicast enabled, figure 1. The main advantages of the bi-directional tunnelling approach are:

- It hides multicast sender/receiver mobility.
- It does not require any re-construction of the multicast tree.

However, the main limitations of this approach are:

- It introduces a non-optimal routing of the multicast traffic due the triangular forwarding of the packets through the home agent.
- The home agent represents a single point of failure and introduces scalability issues.

- It may introduce tunnel convergence. In case of many mobile receivers, subscribing to the same group, are located in the same foreign network, the home agent duplicates the multicast packets for each mobile receiver. Hence, resulting in non-optimal bandwidth and resources usage which violates the multicast nature.

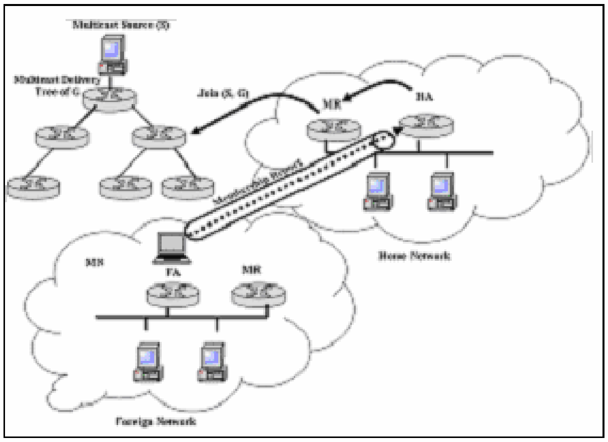

Figure 1 Bidirectional tunneling.

2.2 Remote Subscription

In Remote Subscription approach (RS), figure 2, the mobile node joins the multicast group via a local multicast router (LMR) on the foreign link being visited. It sends MLD Report Messages to the local multicast routers using an IPv6 link local source address. The multicast delivery tree will be reconstructed according to the current location of the mobile node, hence results in optimal routing. The mobile node must use its care-of address if it wants to send data to the group (if the mobile node is also a source) in order to avoid possible problems with ingress filtering. All packets are sent directly on the foreign link.

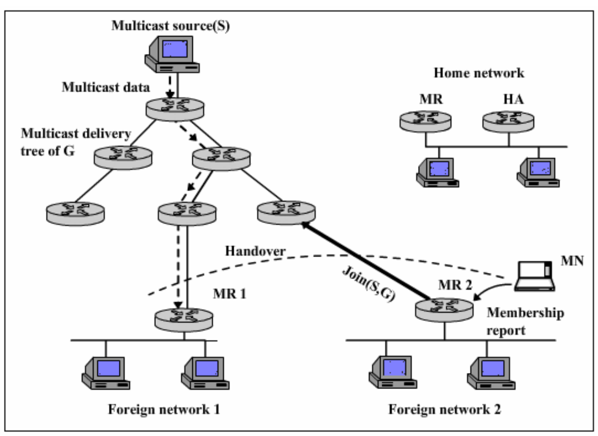

Figure 2 Remote subscription.

The advantages of RS are:

- Optimal routing, since the multicast data follows a shortest path route between the mobile node and the root of the multicast delivery tree in the foreign link.
- Network resource consumption, because it doesn't require duplication of packets.
- Scalable

However, the main limitations of this approach are:

- Reconstruction of (a branch of) the multicast tree at each movement of the mobile node may introduce long interruptions of the multicast session. This interruptions may be very sever especially if a mobile node is the source of a source-rooted tree
- It requires native multicast support at the visited network

3. Evaluation of Mobility Support in Multicast Proposals

3.1 Mobile multicast Protocol (MoM)

MoM [5] has been proposed to solve the tunnel convergence problem of bi-directional tunnelling. This problem occurs because several HAs may have their receivers with the same FA. This protocol aims to avoid multiple tunnels resulting from different HAs through the same Foreign Agent (FA), figure 3. It proposes a new entity called Designated Multicast Service Providers (DMSPs) to improve the scalability of mobile multicast. In this approach, the FA need not join groups on behalf of mobile hosts that are visiting its network. Instead, the FA selects one HA as the designated multicast service provider for a given multicast group. The DMSP forwards only one multicast datagram to the FA which delivers the data in native multicast over its local link. HAs that are not the DMSP for a given multicast group can suppress delivery down the Mobile IP tunnel.

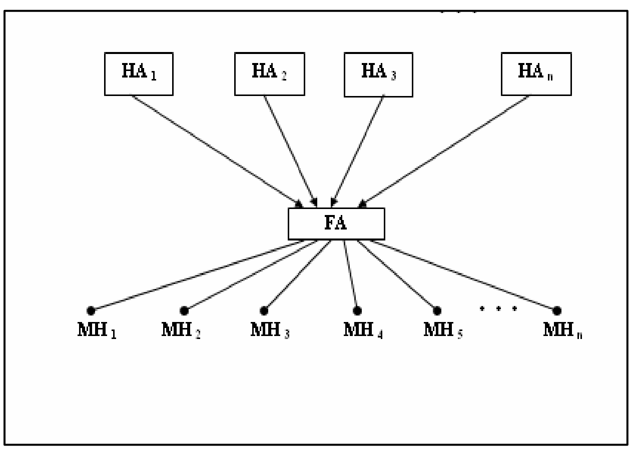

Figure 3 Tunnel convergence problem

The main advantages of this protocol are:

- It reduces the packet duplication problem.
- It is based on Bidirectional Tunnelling; hence minimal changes are required to extend Mobile IP to support MOM.

However, this protocol suffers from the following:

- Non- optimal routing problem due the fact that packets have to be routed through the HA and FA.
- The complexity involved in the mechanism of DMSP selection.
- When a mobile host moves from a foreign network to another network (home or foreign), there is a possibility for a temporary disruption of multicast delivery for other mobile hosts on the (previous) foreign network, this lead to packet loss. This problem is addressed by selecting more than one DMSP at a given time, but this might result in packet duplication.
- As the number of handoff of mobile hosts is increased, this approach requires frequent DMSP's handoff, i.e. FA has to reselect the DMSP.

Lastly, this protocol has been considered for use with IPv4 and, because it makes use of a foreign agent, it cannot be directly extended to IPv6.

3.2 *Range-Based Mobile Multicast (RBMoM)*

RBMoM [6] is another Home-Agent based protocol that intends to trade off between the shortest delivery path and the frequency of the multicast tree reconfiguration. It introduces a router, called Multicast Home Agent (MHA), which is responsible for tunneling multicast data to the foreign agent to which the Mobile Host (MH) is currently attached. RBMoM uses the service range and MHA to restrict the tunnel length to reduce the cost of tunnelling. The initial MHA of a mobile host is set to be it's HA. The *range* of a MHA means the service range to its MHs. That is, a MHA can only serve the mobile hosts which are roaming around the foreign networks which are within its service range, or the network to which the MHA is attached. In figure (4) for example, the service range is set to be one hop. Therefore MHA_a can only forwards multicast packets to its MH in the foreign networks 2, 3, 6 or its current network, while MHA_b can only serve its MHs in the networks 8, 12 or its current network. If a mobile host moves to a new foreign network and becomes out of its MHA service range, then the MHA handoff will occur. The current FA then joins the multicast group and becomes the new MHA. Data structures have to be maintained in the HAs to keep track of the MHs locations and the current MHA of each MH. FAs also have to maintain Visitor Table to keep track of its visitors, their MHA and when these binding expire. Lastly, there are three lists maintained by the MHA which include the member list, the FA list and the DMSP list.

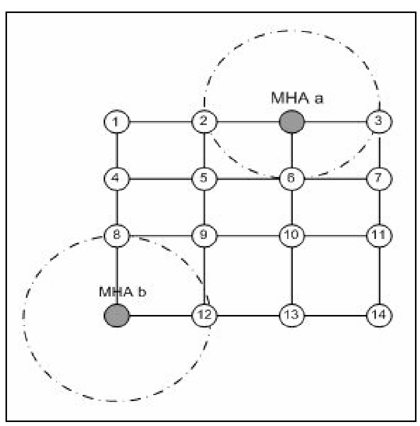

Figure 4 Service range of each MHA

The main advantages of this protocol are:

- By implementing the service range concept, RBMoM restricts the tunnel length.
- It also reduces the multicast tree update compared to remote subscription.

However, the main drawbacks of this approach are:

- It does not define a certain criterion for determining an optimal service range.
- Another problem of the RBMoM is the service disruption time that occurs when a mobile host moves away out of the present service range and moves to another foreign network. In this case if the foreign network is not a member of the present multicast group, the service disruption time corresponding to the amount of time required to join the present multicast group occurs.
- The complexity involved maintaining and updating the data structure in HAs, FAs and MHAs,

Lastly this protocol uses MIPv4 infrastructure, which makes it difficult to be extended to MIPv6.

3.3 Multicast by Multicast Agent (MMA)

As a RS-based protocol, Multicast by Multicast Agent (MMA) [7] introduces a Multicast Agent (MA) and a Multicast Forwarder (MF). MA provides multicast service to mobile hosts; each MA has one MF per multicast group. The MF of a MA is the MA that forwards multicast packets to it, the MF of an MA may be the MA itself when its local network is included in the multicast tree, or the MF can be an MA in another network that belongs to the multicast group. A MF is responsible for forwarding multicast packets to the MA of the foreign network (which forwards it in native multicast on its local link). Unlike RBMoM, in MMA the range of the MF is unlimited.

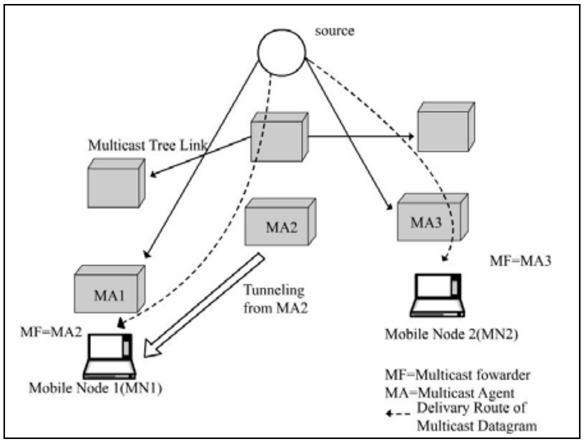

Figure 5 Operation of MMA protocol

The basic operation of MMA is shown in figure (5); MA2 and MA3 are multicast tree nodes, while MA1 is not. MF of MA3 is MA3 itself, MH2 that is located in the same network as MA3 receives multicast datagram directly from multicast tree through MA3. Since MA1 is not a multicast tree node, it receive a datagram through the tunnel from MA2 (which is the MF of MA1) to it itself, and then transmit the datagram to MH1. The main advantages of this protocol are:

- It reduces the number of duplicated packets and total amount of tunnelling since multicast packets can be forwarded directly from the multicast router in the current network.
- It also reduces the disruption of the multicast service during handover.
- It offers better (sub-optimal) delivery route than HA-based protocols since the MF is generally located in an adjacent network that is included in the multicast delivery tree.

However the drawbacks of this protocol are:

- It introduces complex data structure on the mobile node which has to update its MF value and change its membership report message.
- The complexity involved in MA discovery.

Lastly this protocol was designed for IPv4 environment.

3.4 *Mobicast*

Another RS-based protocol is Mobicast [8]. This protocol is suitable for mobile hosts roaming between small wireless cells. It adopts the Domain Foreign Agent (DFA) concept to shield all mobility with in the foreign domain from the multicast delivery tree. In figure (6), the DFA is responsible for all foreign mobile hosts within the campus. At the subnet level, agent advertisement messages containing the IP address of the DFA are broadcast periodically. When a mobile node hears a beacon and decides to attach to the wired network, it registers with the DFA and sends the IP address of the DFA to its care-off address, so subsequent multicast subscriptions or sending of packets to a multicast group by the MH are done through the DFA. When the MH moves from one cell to another it changes the serving BS, this change is shielded from the rest of the multicast group.

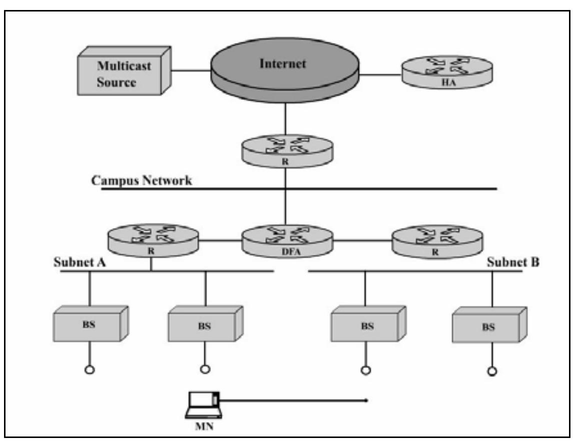

Figure 6 Hierarchical mobility architecture approach using domain foreign agent

The main advantages of this protocol are:

- It solves the tunnelling convergence problem and triangular routing.

- It also hides the mobility of the MH from the Multicast Delivery Tree.
- Lastly, using buffering techniques and since the neighbouring base stations subscribe to the same multicast group prior to the actual movement of the MH, this minimize the packet loss and provides fast hand off.

However, the main limitations of this protocol are:

- The overhead on the network which is arising due to the buffering of recent multicast packets by the neighbouring base stations other than the serving base station causes an increase in bandwidth consumption and network traffic.
- This protocol works only for mobile IPv4 environment and it necessitates certain modifications in the FA.

3.5 Timer-based mobile multicast (TBMOM)

Timer-based mobile multicast (TBMOM) aims to provide the shortest delivery path for low-speed mobile hosts and low tree reconstruction and fast data delivery for high-speed mobile hosts [9]. It takes advantages of both HA-based and FA-based approach from the perspective of MHs' speed. It uses two timers, the 'JOIN' timer and 'GROUP' timer. Each mobile host keeps the JOIN timer, and each FA keeps the GROUP timer. When a MH starts, it sets its JOIN timer value with a predetermined value. The JOIN timer decreases with time and keeps turning around throughout the multicast session duration time. When the MH hands off, the MH registers its remaining JOIN timer value to the FA. The FA sets its GROUP timer to the value. If multiple MHs exist, the GROUP timer sets to the minimum remaining value among those of multiple visiting MHs. The GROUP timer always decreases synchronously with the minimum value JOIN timer. When the GROUP timer expires, the FA joins the required multicast tree and makes itself the Foreign Multicast Agent (FMA) for the multicast group. Figure 6 shows the operation of FA when the Group-timer expires.

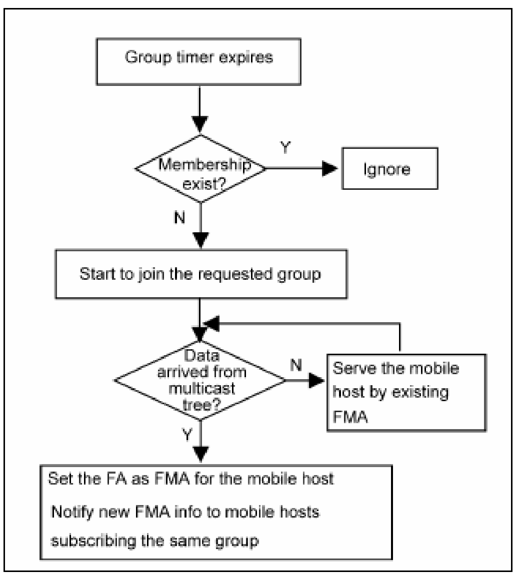

Figure 6 Operation of FA when the Group-timer expires

The main advantages of this protocol are that:

- It provides the shortest delivery path for low-speed mobile hosts and low tree reconstruction and fast data delivery for high-speed mobile hosts.
- It reduces multicast packet loss and tree reconfiguration overhead.
- Similar to MoM, TBMOM solves the tunnel convergence problem.

However, the drawbacks of this protocol are:

- It introduces complex data structures

It depends on the speed of the mobile members. This speed parameter may vary from one network to another.

4.6 Mobile Multicast Routing Protocol using perdition of Dwelling time of a mobile host

Mobile Multicast Routing Protocol using perdition of Dwelling time of a mobile host [10] is an extension to Timer Based Mobile Multicast (TBMOM). It aims to reduce the tunnel length from a foreign agent connected to a multicast tree to a mobile host. In this protocol, a foreign agent predicts the expiration time of a timer in a mobile host during hand-off and decides whether it joins the multicast tree. A mobile host that stays in a foreign network receives multicast datagrams from a Foreign Multicast Agent (FMA) through tunnelling. When a mobile host hands off, the foreign agent in the foreign network where it moves calculates the expected dwelling time for which the mobile host will stay in the foreign network. The foreign agent decides whether it will be included in the multicast tree using the expected dwelling time during hand-off. Figure 7 shows that when the mobile host moves from ($i-1$)-th network to i-th network, the foreign agent in i-th network predicts the expiration of the timer of the mobile host. The foreign agent requests a tree join if expiration of the timer is predicted.

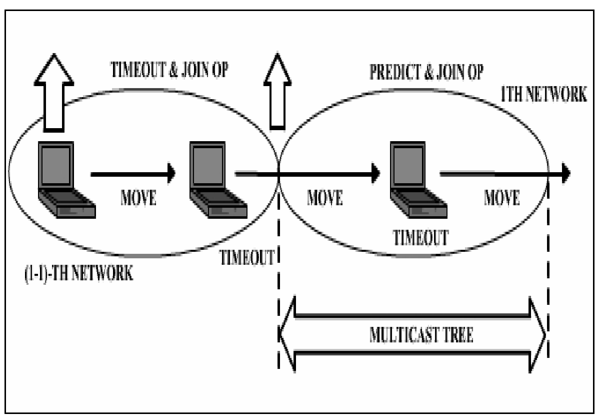

Figure 7 Operation of Mobile Multicast Routing Protocol using perdition of Dwelling time of a mobile host

The main advantages of this protocol are:

- It reduces the tunnel length from FMA to the foreign network by predicting the expiration of the timer of a mobile host.
- It also reduce the tree reconfiguration overhead

However the main disadvantages of this approach are:

- Similar to TBMOM, it introduces complex data structure.

- The overhead involved in calculating the dwelling time of each mobile node visiting the foreign network

Table 1, summaries a qualitative comparison of the above mentioned protocols.

Table 1: Qualitative comparison between Mobile Multicast Protocols

Protocol	Multicast subscription	Mobility Protocol	Network identity	Main characteristics
BT [3], [4] Section 2.1	Home Subscription	MIPv4/ MIPv6	HA, FA (MIPv4)	o It hides multicast sender/receiver mobility and does not require any re-construction of the multicast tree o It does not require multicast support it he visited network. o It introduces tunnelling convergence and wastes network resources o Produces high processing overhead at the home agent.
RS [3], [4] Section 2.2	Remote Subscription	MIPv4/ MIPv6	HA, FA (IPv4), LMR	o Optimal routing o Scalable o A foreign agent must support multicast. o High overhead due to tree reconstruction
MoM [5] Section 3.1	Home Subscription	IPv4	HA, FA, DMSP	o It reduces the packet duplication problem. o Non- optimal routing. o The complexity involved in the mechanism of DMSP selection.
RBMoM [6] Section 3.2	Home Subscription	MIPv4	HA, FA, DMSP, MHA	o It restricts the tunnel length. o It reduces the multicast tree update compared to remote subscription. o The complexity involved maintaining and updating the data structure in HAs, FAs and MHAs.
MMA [7] Section 3.3	Remote Subscription	MIPv4	HA, FA, MA, MF	o It reduces the number of duplicated packets. o It also reduces the disruption of the multicast service during handover. And offers better (sub-optimal) delivery route. o It introduces complex data structure on the mobile node which has to update its MF value and change its membership report message. o The complexity involved in MA discovery.
Mobicast [8] Section 3.4	Remote Subscription	MIPv4	HA, FA, DFA	o Using buffering techniques minimize the packet loss. o It solves the tunnelling convergence problem and triangular routing. It also hides the mobility of the MH from the Multicast Delivery Tree. o The overhead on the network due to the buffering of recent multicast packets by the neighbouring base stations.

TBMOM [9] Section 3.5	Both Remote/home Subscription	MIPv4	HA, FA, FMA	o It provides the shortest delivery path for low-speed mobile hosts and low tree reconstruction and fast data delivery for high-speed mobile hosts. o It reduces multicast packet loss and tree reconfiguration overhead. o It introduces complex data structures and depends on the speed of the mobile members.
TPMOM* [10] Section 3.6	Both Remote/home Subscription	MIPv4	HA, FA, FMA	o It reduces the tunnel length from FMA to the foreign network by predicting the expiration of the timer of a mobile host. o It reduces the tree reconfiguration overhead o It introduces complex data structure and overhead involved in calculating the dwelling time of each mobile node visiting the foreign network.

4. Conclusion

This paper has presented the fundamental concepts of IP multicast. It has then extended the discussion to the support of mobile users in IP multicast, presenting IETF proposal, their advantages and limitations. Lastly it has presented the other current proposals to support mobile users in IP multicast, highlighting their advantages and drawbacks.

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Appendix 1: Abbreviations

Table 2. Abbreviations

BT	Bidirectional Tunnel
DFA	Domain Foreign Agent
DMSD	Designated Multicast Service Provider
DSL	Digital Subscriber Line
FA	Foreign Agent
FMA	Foreign Multicast Agent
HA	Home Agent
ICMP	Internet Control Message Protocols
IGMP	Internet Group Management Protocol
LMR	Local Multicast Router
MA	Multicast Agent
MF	Multicast Forwarder
MH	Mobile Host
MHA	Multicast Home Agent
MLD	Multicast Listener Discovery
MMA	Multicast by Multicast Agent
MN	Mobile Node
MoM	Mobile Multicast Protocol
RBMoM	Range Base Mobile Multicast
RS	Remote Subscription