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Multicast for Mobile Hosts in IP Networks

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Abstract In today's Internet, the need for multimedia communication leads to rapid progress in multicast technology. Using multicast can efficiently deliver packets to a group of receivers. Compared with unicast, multicast can significantly reduce the bandwidth demand in networks. In the meantime, with the wide use of mobile devices and the introduction of Mobile IP, people can contact with the Internet at anytime and anywhere. It is a very meaningful work to support multicast in Mobile IP. In this paper, we will analyse and evaluate several mobile multicast protocols and provide a new one which is based on Mobile IPv6.
Keywords Mobile IP, Multicast, Internet

1. Introduction

Mobile computing gives people the convenience to connect with the Internet at anywhere and anytime without disruption of the communication with other nodes. To support the mobility of mobile hosts, Mobile IPv4 was introduced as an extension of IPv4 and the standard is specified in RFC3220. Mobile IPv6 is in working and the latest draft is version 18. In Mobile IP protocol two approaches were given to support multicast, which are called remote subscription and home subscription.

Using multicast in Internet can greatly reduce the bandwidth demand, which is very important for some new emerging applications such as distance learning, video conference and IP TV. The current multicast protocols on the Internet, PIM[9], CBT[10], DVMRP[11], and MOSPF[12], implicitly assume static hosts when constructing multicast delivery tree. They do not consider the dynamic member location and cannot work efficiently in mobile environment. With the rapid increase of mobile hosts in Internet, providing multicast support in mobile environment is a challenging and promising work. Some algorithms have been proposed for mobile multicast,

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such as MoM[3], RBMoM[4], MA[5], and MMA[6].

The rest of this paper is organized as follows. In section 2, we provide several aspects in evaluating a mobile multicast protocol. In section 3, we analyse some important mobile multicast protocols and discuss their merit and shortcoming respectively. In section 4, we propose a new mobile multicast protocol call FMSR (First Multicast region agent Second Remote subscription). Section 5 is the conclusions and perspectives.

2. Evaluating criteria

Mobile multicast protocol should consider not only the dynamic membership but also the dynamic member location. Changes of the mobile host's location can cause the transmission path of multicast packets to change and will degrade the Quality of Service. Different from what we consider when hosts are static, in mobile environment we mainly consider the following aspects in evaluating the performance of a mobile multicast protocol.

- Service Disruption Time: when a mobile host changes its location, it disconnects with its current link, so it will not get the multicast packets temporarily. Mobile host will not receive multicast packets until it connects with a new link and finishes corresponding operation, this interval is called Service Disruption Time (SDT). SDT can be divided into two parts, one is the time from attachment of the mobile host on a new a link to the moment when the mobile host gets its Care of Address; the second part is from the time that mobile host requests to get multicast packets again to the time that mobile host receives multicast packets. For different mobile multicast protocols, the former interval will not different from each other very much, what making sense is the later interval. So we use the later one to measure the duration of SDT.
- Rebuilding of Multicast Delivery Tree: mobile host's movement may lead to rebuilding of the multicast delivery tree, which will increase the protocol overload and degrade the quality of service. The multicast delivery tree rebuilding scale and frequency are very important parameters in evaluating mobile multicast protocols.
- Leave Delay: because the mobile host cannot notify the network when it leaves current link, if this mobile host is the last one on the link, even though there is no receiver on this link, the network will continue to receive multicast packets and forward them on it until timer expires. That will waste bandwidth resource on the link. The interval from when the mobile host leaves its current network to the time that network stops receiving and forwarding packets on it is called Leave Delay.
- Transmission Path (or Transmission Delay): the path from multicast source to receiver. This path includes the path on the multicast delivery tree and the path in tunnel. Usually we use the transmission hops to measure the path length. This parameter is used to indicate whether the transmission path is optimization, also it can be used to estimate the transmission delay of the multicast packets.
- System Load: when multicast packets travel in networks, they will occupy bandwidth of the networks and processing power of routers. For simplicity we consider the sum of links or nodes when a multicast packet travels from source to all receivers.
- Modification of Existed Protocol: in order to minimize the cost, when support multicast in mobile environment, we expect not to modify existed network entities and protocols too much.
- Support to Multicast Source Mobility: when multicast source is moving, the cost to rebuild the delivery tree may be very great. So we expect the cost to reconstruct multicast delivery tree to be as low as possible.

3. Existing protocols

In RFC3220 and the Mobile IPv6 draft, two basic approaches to support mobile multicast are proposed, they are remote subscription and home subscription. Now we will introduce and analyse these two algorithms and some new proposed ones.

3.1 RS (Remote Subscription)

In remote subscription, when mobile host moves to a new network, it sends a JOIN request messages to the multicast router on the new network and joins multicast group directly via it. Mobile host exchanges membership messages with the multicast router in the new network and receives multicast packets from it.

Because mobile host joins multicast group directly via the router in foreign network and receives multicast packet from it, the transmission path is optimization, the networks system load is minimum and little modification of existed protocols is needed. But this algorithm requires every foreign network has a multicast router on it. In remote subscription whenever the mobile host moves to a new network it will rejoin the multicast group, which will cause the multicast delivery tree to rebuild frequently and the Service Disruption Time is quite long. When mobile host leaves its current network, the router on it will not notice it's leaving until timer expires, so the Leave Delay is very long too. What's more, RS cannot support source mobility very well, the delivery tree will be considerably rebuilt when the multicast source moves to a new network. Specially, the delivery tree will be rebuilt completely when "source rooted tree" is used.

3.2 HS (Home Subscription)

In HS, when mobile host moves to a new network, a bi-directional tunnel will be constructed between the mobile host and its home agent. The mobile host's home agent intercepts all multicast packets destined to the mobile host and tunnels those packets to the mobile host. Group membership messages are also transmitted in tunnel. If the mobile host acts as a multicast sender, it sends packets to its home agent by tunnel and the home agent forwards these packets on the multicast delivery tree.

There is a problem called "*Tunnel Convergence Problem*" in HS algorithm. When several group members that have different home agents move to the same foreign network, each mobile host's home agent will forward a copy of the same packet to that foreign network, so a lot of bandwidth will be wasted.

HS hides the mobility of mobile host. The multicast delivery tree will not be rebuilt when the mobile host moves to a new network. This algorithm can support source mobility very well. The implement of HS involves only home agent and mobile host (in Mobile IPv4 is the foreign agent). But we can see that the transmission path is not optimal, the Service Disruption Time includes the time registering to home agent and the time that packets flow in tunnel, the leave delay is from mobile host leaving its current network to the time it re-registers to home agent, all these are related to the path length from home agent to the mobile host (or foreign agent in Mobile IPv4).

3.3 MoM (Mobile Multicast Protocol)

MoM is based on Mobile IPv4's HS algorithm. To solve the tunnel convergence problem, MoM introduces the conception of DMSP (Designated Multicast Service Provider). When several group members that have different home agents move to the same foreign network, MoM protocol selects a "good" home agent to forward multicast packets to the foreign network and other home agents will not forward packets. If foreign network can support link layer multicast, it can make use of this mechanism to save bandwidth.

The use of DMSP has the advantage that the system load is greatly reduced, but it brings the problem of DMSP handoff that will increase the frequency and duration of service disruption. Other aspects of performance are similar to HS algorithm.

3.4 RBMoM (Range-Based Mobile Multicast)

In RBMoM there is a new entity called MHA (Multicast Home Agent) and it brings up the conception of "service range". Each mobile host has a MHA, MHA is a multicast router and the mobile host's MHA information is stored in its home agent. In initial moment a mobile host's MHA is its home agent. MHA joins in the multicast delivery tree on behalf of the mobile host and forwards multicast packets to it by tunnel. A MHA has a certain service range R that is measured by the distance from MHA to home agent and the MHA can only provide multicast service to mobile hosts within its service range. To limit MHA's service range can avoid forming long tunnel between MHA and home agent. When mobile host arrives at a new network, it registers with the foreign agent, then the foreign agent communicates with mobile host's home agent and gets information of its MHA. After that, the foreign agent measures the distance between the MHA and the foreign agent. If that distance exceeds MHA's service range, MHA handoff will occur, a new MHA will be selected. For simplicity, the new MHA can be the foreign agent. After the new MHA is selected, mobile host's home agent will be notified to refresh its MHA record. If the mobile host is still within its MHA's service range, the foreign agent just notifies the MHA to forward a copy of packets received from the multicast delivery tree to it. If mobile host is in its MHA's service range, but the foreign agent has joined in the multicast delivery tree, then the foreign agent will be selected as the new MHA. In the situation that several mobile hosts having different MHAs move to the same foreign network, the tunnel convergence will occur too. To solve this problem, RBMoM selects a "good " MHA as DMSP that is similar to the approach used in MoM.

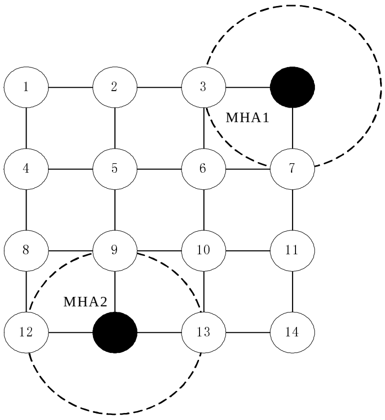

Figure 1: Service range of MHA

Remote subscription and home subscription can be seeing as two extremes of RBMoM. When the service range R is 0, the foreign agent will act as MHA, then RBMoM equals to RS; when R is ∞, mobile host's home agent will be its MHA, then RBMoM equals to HS.

RBMoM is very flexible, by defining different value of service range R, it can tradeoff between packet transmission delay, system load, and service disruption time. The less the service range R, the shorter the transmission delay, the lower the system load, but the more frequent to rebuild the multicast delivery tree, also the more frequent service disruption will occur. Mobile hosts' mobility may bring MHA handoff that will increase the number of service disruption occurs. Even though, the average service disruption time is shorter than RS. RBMoM protocol introduces MHA, the protocol needs to modify home agent, foreign agent, and mobile host. It dose not consider the mobility of multicast source too.

3.5 MA (Multicast Agent)

Multicast Agent protocol is based on Mobile IPv4, it introduces an entity called Multicast Agent. MA is a multicast router, which serves a certain number of networks, those networks forms the MA's service range. For multicasting to mobile hosts, this protocol uses a three-layer architecture which is MA->foreign agent->mobile host. MA joins the multicast delivery tree on behalf of all mobile hosts within its service range and forwards multicast packets to mobile host's foreign agent by tunnel.

When a mobile host moves into a new network, it reports its arrival to the foreign agent. If the foreign network supports multicast, standard IGMP messages can be used to report mobile host's group membership. Foreign agent maintains a list that records all groups having members in the foreign network. In order to update the group list, the foreign agent sends query messages periodically to all the groups, the group members response with a membership report message. If the foreign network cannot support multicast, the foreign agent must maintain not only the group list but also maintain a member list for each group.

If the foreign agent detects any changes in the group list, it notifies the MA to join or leave a multicast delivery tree. MA maintains a list that records groups having members in its service range, for each group there is a list recording the foreign agents that have mobile host to receive multicast packets. MA forwards what it receives from the delivery tree to all foreign agents in the corresponding group's foreign agent list by tunnel and foreign agents then forwards packets to the mobile hosts.

The multicast delivery tree will not be rebuilt when mobile host moves around within the same MA's service range. The time from the mobile host's arrival on a new network to the time foreign agent receives multicast packets is the service disruption time. If the foreign agent is receiving packets from MA, the mobile host can directly receive packets from it, so the service disruption time is very short. If MA has not joined the group mobile host belongs, the multicast delivery tree will be modified, and then the mobile host will experience a long period of service disruption. The foreign network will not notice mobile host's leaving until its timer expires, so the leave delay is quite long. By limiting the service range of MA to a small region, mobile host can be located very close to the multicast delivery tree so the tunnel between the MA and foreign agent will be very short, that means the transmission path and system load are very optimal. MA protocol has no special requirement of the network infrastructure, it can work no matter the foreign agent supports multicast or not. It needs a little modification of the router works as MA. The protocol does not refer source mobility, but it can provide a certain degree of supporting to source mobility, for if the multicast source moves around within the same MA's service range and uses tunnel to forward packets to MA and the MA forwards them on the delivery tree, the delivery tree will not be rebuilt while source is moving.

3.6 MMA (Mobile Multicast Agent)

In MMA protocol two entities are introduced, they are called Multicast Forwarder and Multicast Agent. MF is a node on the multicast delivery tree and forward packets to MA, MA needs not always be a node on the tree and it forwards what receives to mobile hosts attach on it. Every MA has only one MF. In the initial time, the mobile host requests to join the multicast group via the MA on its current network, if the MA has not already been a group member, it starts the join procedure, after the MA joins the multicast delivery tree, it uses itself as its MF. When mobile host moves to a new network it registers its former MF to the MA on the new network. If the MA has already been in the multicast delivery tree, MA will use itself as its MF; if MA is not in the multicast delivery tree and MA has no information of other MFs that has been in the delivery tree, then the MA uses mobile host's former MF as its MF; if MA is not in the multicast delivery tree and MA has information of other MFs, then the MA selects a "good" one among all these MFs as its MF, usually MA selects the one closest to itself. In order to receive multicast packets more efficiently, at the same time MA receives packets from its MF it starts the join procedure. After MA joins the multicast delivery tree, it will use itself as its MF and notify its former MF stop forwarding packets to it.

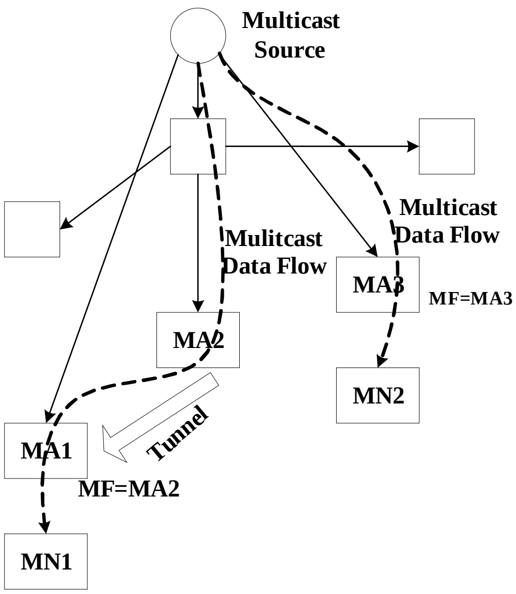

Figure 2: The operations in MMA

In MMA protocol, because MFs are always in the delivery tree, the service disruption time is very short, but MA and MF will not notice mobile host's leaving until their timers expire, so the leave delay is quite long. The tunnel between MA and its MF will bring some addition burden to the network system, but it will be quite slight because the tunnel will not be very long and will exist just a very short time. If MA starts the join procedure while it receives packets from MF (this MF is not the MA itself), the packet transmission path and system load are close to optimization. MMA protocol has some shortcoming, it needs every subnet has a MA and needs to do some modification to existed protocols because of the operation between MA and MF. MMA protocol does not support source mobility too.

4. A new mobile multicast protocol

The new mobile multicast protocol is called FMSR (First MRA Second RS) according to the operation process described below.

4.1 The architecture

We propose a new mobile multicast protocol on the base of mobile IPv6. In our protocol, we use a hierarchical architecture to limit the delivery tree rebuilding frequency and introduce two entities call MRA (Multicast Region Agent) and MSA (Multicast Subnet Agent). The MSA can be the access router or other machine on the subnet. MSA can support multicast or not, if the MSA is not a multicast capable machine it must implement the function of MLD-proxy[7]. As shown in Figure 3, a region can contain several subnets and there is only one MRA in each region. MRA is a multicast router that takes part in multicast routing and it is the access point that mobile hosts connect to the multicast backbone.

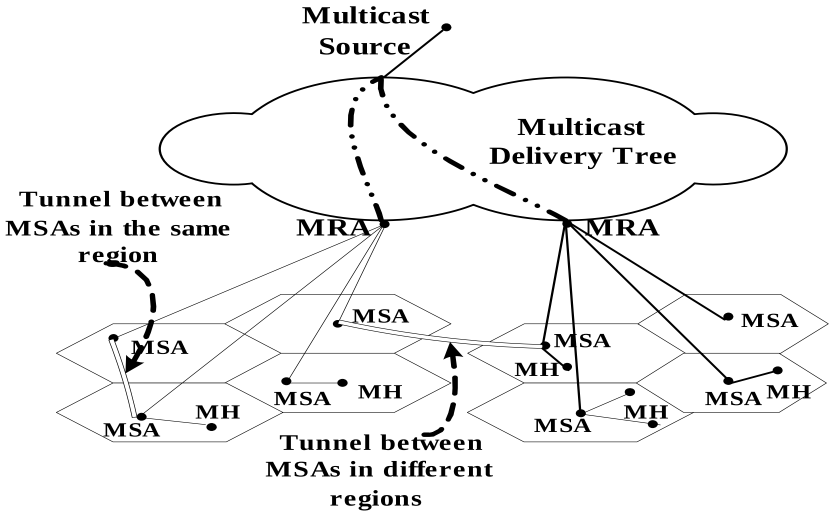

Figure 3: Architecture of the new protocol

4.2 Operations

In this new mobile multicast protocol, MRA provides multicast service to all mobile hosts within its service range. The service range of a MRA consists of a group of subnets. MRA receives multicast packets on behalf of all the mobile hosts in its service range and forwards packets to MSA, then MSA forwards packets to mobile host. Because MRA is the access point to multicast backbone, the MSA can be a multicast capable machine or not. When mobile host moves to a new subnet which has not received multicast packets yet, it will build a tunnel between its current MSA and it's former MSA, whose length is much shorter than the tunnel between mobile host and its home agent in Jelgar's algorithm[7], so the mobile host can receive packets from it's former MSA almost immediately and at the same time it will send a JOIN request to the new MSA, this MSA will determine whether it should send a JOIN request to MRA or not. More details are presented in the following paragraph.

When a mobile host moves to a new foreign network, it sends a MLD group membership report message to the MSA on that foreign network and requests to rejoin the multicast group. If there are hosts on that foreign network that have already joined the multicast group, that means the MSA is receiving multicast packets from the MRA. So the mobile host can receive packets from MSA on that foreign network and it dose not need to build a tunnel to the previous MSA and the new MSA needs not to send membership report message to the MRA. If the mobile host is the first group member in the new foreign network, the MSA on that network can build a tunnel to the previous MSA (we use pMSA to represent it) and get packets from it. In the same time, MSA on the new foreign network sends a group membership report message to the MRA. If MRA has joined that group, it should only record the MSA sending that message and forward packets to the MSA, or else the MRA must start the procedure to join that multicast group. Before MRA joins the multicast group, mobile host can receive packets from its pMSA. When MRA had attached the multicast delivery tree and MSA could receive packets from the MRA, the tunnel between current MSA and pMSA should be destroyed. After all those are done, multicast packets arrive at the mobile host following the MRA->current MSA->mobile host path, so the delivery path is close to optimal.

4.3 Advantages

In the new protocol, mobile host can receive packets from the tunnel to previous MSA. Because the mobile host's movement is continuous, the tunnel built between the MSA on the current foreign network and the MSA on the previous network is very short, which makes the multicast service disruption time very short. In Jelger's algorithm[7], before the mobile host can receive multicast packets from the foreign network, it gets packets from the home agent. If the mobile host is far away from it home network, the time used in building tunnel between the mobile host and its home agent is quite long, which will make the mobile host cannot receive packets for a long time. In the new protocol, the tunnel between the current MSA and the pMSA is just one hop in most case, so the mobile host can continue to get multicast packets very quickly after it moves to a new foreign network.

Second, by limiting the distance from MSA to MRA, the packet transmission path can be close to optimization.

Third, because MRA will serve all subnets within the region, when mobile host moves into a new region, the multicast delivery tree will be rebuilt one times at most. The multicast delivery tree will not be rebuilt when the mobile host moves around all subnets within the same MRA's region.

Finally, FMSR can partly support source mobility. Multicast source sends packets to the MSA on its current subnet and the MSA forwards them to MRA, then MRA forwards those packets on the multicast delivery tree. If multicast source moves around within a MRA's service range, the multicast delivery tree starting from the MRA will not change, that can greatly reduce the tree rebuilding cost. If the source moves into a new MRA's service range, the cost of rebuilding the delivery tree will be very considerable.

Table 1: Comparision of algorithms

criterion / algorithm	Delivery rebuilding	Service disruption time	Leaving delay	Transmission path	System load	Source mobility	Note
RS	The most frequent	Long	Long	shortest	Lightest	Poorly supports	Based on IPv4&IPv6
HS	No	Depends on the tunnel length	Depends on the tunnel length	Long	More heavy than MoM	Well supports	Based on IPv4&IPv6
MoM	Frequent	Long when DMSP handoff occurs	Depends on the tunnel length	Long	Heavy	Not supports	Based on IPv4
RBMoM	Not very frequent	Long when MHA handoff occurs	Short	Depends on service region	Light	Not supports	Based on IPv4
MA	Not frequent	Short when MA is in group, otherwise long	Long	Short than HS	Light	Partly supports	Based on IPv4
MMA	Frequent	Short	Long	Short than HS	Light	Not supports	Based on IPv4
FMSR	Not frequent	Very Short	Long	Close to shortest	Light	Partly supports	Based on IPv6

5. Conclusion and Perspectives

The main issue in mobile multicast is how to efficiently manage the multicast delivery tree and optimize the transmission path in the condition hosts are in mobility. Many protocols have been proposed to integrate Mobile IP and multicast technologies, among them, remote subscription has the most optimum transmission path, and home subscription has no cost in rebuilding multicast delivery tree. Other protocols are tradeoffs between packets transmission path and cost of rebuilding delivery tree.

Although much research has been done in this field, we should notice that there are still many problems.

First, little attention has been paid to the situation that the multicast source is in mobility. Second, there is no group management protocol specialized in mobile environment while IGMP and MLD are not very suitable for it. Third, people are not very clear that whether the mobility support should be integrated in the existing Internet with its current multicast features, or the multicast capabilities should be added in existing or future wireless mobile networks. Finally, in order to offer different types of multicast and mobility support for different networking environments, an adaptive mechanism should be proposed, but this is poorly studied. All these need us to do future work to solve these problems.

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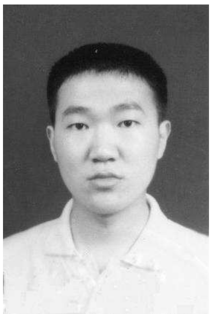

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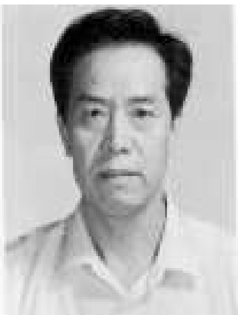

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