An Efficient Multicast Protocol in Mobile IPv6 Networks

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***Abstract*—Mobile IPv6 provides two basic schemes called remote subscription and home subscription to provide multicast service for mobile hosts. Those two algorithms have complementary advantages. In this paper, we propose a new scheme called previous network subscription, which can provide low handover delay for real time multicast applications. We also propose a new multicast routing protocol called RHMoM (Region based Hierarchical Mobile Multicast) by combining the previous network subscription and the home subscription. RHMoM uses two kinds of agent and employs the region based hierarchical architecture to limit the reconstruction frequency of the multicast tree and optimize the delivery path. The simulation results show that RHMoM has better performance than other mobile multicast solutions in mobile IPv6 network.**

Keywords-multicast; mobile IPv6

I. INTRODUCTION

Mobile IP is the standard for IP mobility support. Two basic mechanisms have been proposed in Mobile IP for multicast service, which are the remote subscription (RS) and the home subscription (HS). They have been described in [2] for IPv4 and [1] for IPv6. In home subscription, mobile host sends and receives multicast packets by a unicast bi-directional tunnel from its home agent. This approach hides host mobility from all other members of the group. The multicast delivery tree will not be reconstructed because of the member location change. The shortcomings of HS is that the multicast routing path may be far from optimal, and the home agent may be heavily loaded as it must replicate and deliver the tunneled multicast packets to all of its mobile hosts respectively.

In remote subscription, each mobile host always sends group report messages to rejoin its desired multicast group when it enters a new foreign network. The local multicast router on the network must be attached to the multicast delivery tree, so the mobile host can receive and send packets directly from the foreign network by the shortest path. However, the reconstruction frequency of the multicast delivery tree depends on how often the handover occurs. RS also implicitly assumes that there is a multicast router on each foreign network.

In this paper, we propose a new scheme of multicast service called previous network subscription (PS). By integrating PS and RS, we propose a new multicast routing protocol for mobile host to reduce the interruption time of the multicast service and optimize the delivery path. The protocol uses the region based hierarchical architecture in order to limit the reconstruction frequency of multicast tree.

The rest of this paper is organized as follows. Section 2 presents the previous works about mobile multicast protocols. Section 3 discusses the previous network subscription and the RHMoM protocol in detail. Section 4 gives out the simulation results and compares them with other protocols. Finally, we conclude this paper in Section 5.

II. RELATED WORKS

Mobile Multicast protocol (MoM)[3] is proposed to solve Tunnel Convergence Problem in HS. It selects one agent among several home agents as the designated multicast service provider (DMSP) and only the DMSP forwards packets. Range Based Mobile Multicast protocol (RBMoM)[4] intends to trade off between the shortest delivery path and the minimal reconstruction frequency of the multicast tree by controlling the service range of the multicast home agent (MHA). RBMoM can be regarded as the generalization of RS and HS.

Some multicast-agent based approaches were presented. Multicast Agent (MA)[5] protocol uses the MA->foreign agent->mobile host hierarchical architecture to reduce reconstruction frequency of the multicast delivery tree. MA is a multicast router which serves for a certain number of subnets. Mobile host can be located very close to the multicast delivery tree by limiting the service range of a MA. Mobile Multicast Agent protocol (MMA)[6] introduces a multicast agent (MA) and a multicast forwarder (MF). MF is a node on the multicast delivery tree that is in charge of forwarding multicast packets to MA. The MF of a MA may be the MA itself when the MA is on the multicast tree or another MF on the near network, in which the MF can be a MA that belongs to the multicast group. The delay between MA and its MF is short. MA needs to continually find MF and have different MF for different group.

All these protocols above are based on Mobile IPv4 and they have the operations of the foreign agent. As there is no foreign agent in Mobile IPv6, they cannot be directly extended to Mobile IPv6. RS and HS can be statically combined to achieve better multicast support, such as a mobile host can use a unidirectional tunnel to send multicast packets to its home agent and receive from the foreign network. The possible

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combinations are detailed and evaluated in reference [7], but the study in [7] only focuses on PIM-DM.

Reference [8] provides an optimized mechanism (we called it as First Home subscription Second Remote subscription, FHSR) for multicast reception. FHSR improves the performance in terms of latency and routing by dynamic combining two basic multicast approaches of mobile IP. FHSR assumes the delay for mobile host to get packets from the home agent is relatively shorter than the time required to rejoin the multicast group from the foreign network. When a mobile host moves to a new foreign network, it should build a bi-directional tunnel with its home agent to receive multicast packets. In the meantime, the mobile host starts the rejoin procedure of the desired group on the foreign network. The mobile host informs its home agent to stop forwarding packets when local subscription completes. FHSR implicitly requires that mobile host's home agent must maintain as a member of the appropriate groups even not forwarding multicast packets. That can reduce the interruption time of the multicast service because of handover, but some bandwidth may be wasted and the home agent is easy to be overloaded.

HMIPv6[9] uses the hierarchical mobility management architecture. Binding is handled by the MAP (Mobility Anchor Point) when mobile host moves within a region. The introduction of the MAP concept can minimize the latency due to handovers between the access routers. Inspired by the principle of HMIPv6, we propose the region based hierarchical mobile multicast protocol that integrates PS and RS.

III. PROPOSED PROTOCOL

A. *Integration of PS and RS*

The multicast delivery path is the shortest in RS while in HS the multicast delivery tree will not be reconstructed when host moves. We introduce a third basic scheme and call it as previous network subscription. Previous network is the one that the mobile host just visited before it is handover to the current network. In PS, when a mobile host moves to a new foreign network, it will build a bi-directional tunnel with the previous network, so mobile host can continue to receive multicast packets soon after handover without reconstructing the multicast delivery tree. As the current network and the previous network are always neighbored, the tunnel built is usually much shorter than the tunnel between mobile host and its home agent. Reference [8] mentioned that because the tunnels may have different delay (length) in HS, MLD pseudo-synchronization would be almost impossible to achieve. This problem does not exist in PS because of the short tunnel. Mobile host can not receive packets before the multicast router on current network rejoins multicast group in RS, the service interruption time may be considerable. Compared with RS, the interruption time is shortened in PS as the mobile host can get packets through the short tunnel.

RHMoM protocol integrates PS and RS. When a mobile host moves to a new foreign network, it first uses PS, as step (1) in Fig.1, a tunnel between the mobile host and the access router (AR) on the previous network will be built, and so multicast packets arriving at the previous network can be forwarded to the mobile host. In step (2), while mobile host is receiving multicast packets by the tunnel, it sends a group report message to the AR on the current network to start the rejoin procedure according to RS. Step (3), after mobile host can receive multicast packets directly from current AR, the tunnel started from the previous network will be removed.

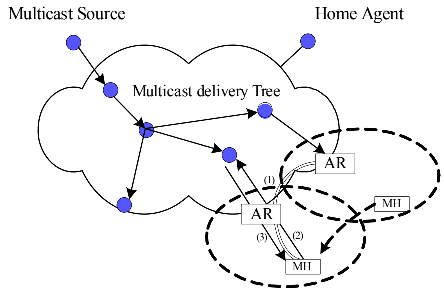

Figure 1. Operations of combining PS and RS

The integration of PS and RS has several advantages. First, the waiting time for joining the multicast group after mobile host's handover is avoided. Second, the load of home agent is lightened, as the home agent does not need to forward multicast packets to all of its mobile hosts. Third, the delivery path is optimized as mobile host will rejoin the multicast group on the new foreign network and get packets from the local multicast router.

B. *Hierarchical Architecture*

When mobile host changes it location, the transmission path will be quite inefficient and the mobile host even can't get any multicast packet if the multicast delivery tree remains unchanged. In remote subscription, rejoining multicast group on the foreign network after a handover occurs may lead to frequently reconstruct multicast tree, which increases the protocol overhead and the interruption times of multicast service. To resolve those problems, RHMoM protocol employs the region based hierarchical routing architecture.

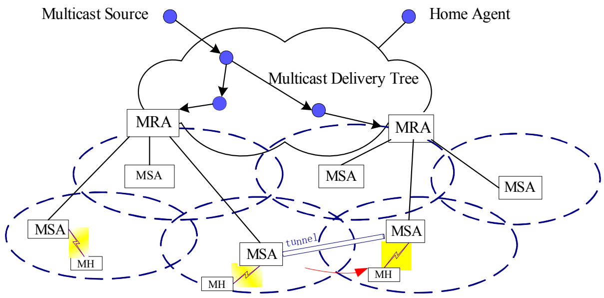

Figure 2. Multicast packets delivery path

As shown in Fig.2, in RHMoM protocol, there is only one Multicast Subnet Agent (MSA) in each subnet that provides multicast service to all the mobile hosts in that subnet. Several subnets form a service region in which there is only one Multicast Region Agent (MRA). MRA is a multicast router that is on the multicast delivery tree. It acts as the access point for mobile host in its service region to connect to the multicast backbone. MSA can be a multicast router or not. This avoids the requirement of a multicast router in each subnet. The MRA forwards multicast packets to the MSA by tunnels or by multicasting.

When a mobile host moves to a new foreign subnet, it sends a MLD report message to the MSA in the new foreign subnet immediately and request to rejoin the desired multicast group. If there are hosts in the subnet that have already been in the group, mobile host can get multicast packets from the MSA without any additional operations and it is not needed to build a tunnel between the current MSA and the MSA on that mobile host's previous subnet (denoted by pMSA). If the mobile host is the first member of desired multicast group in the new subnet, the current MSA should build a tunnel to mobile host's pMSA and get multicast packets from pMSA. At the same time, the current MSA sends a MLD report message to its MRA. MRA should only record the MSA information and forward multicast packets to the MSA if it has already joined that group, or else the MRA should start to join the desired multicast group. After the current MSA receives multicast packets from its MRA, the tunnel between current MSA and the pMSA should be removed.

Our algorithm has the following advantages. First, as RHMoM integrates PS and RS, mobile host can receive multicast packets by tunnel from its pMSA, which makes the multicast service interruption time very short because the tunnel is much shorter than that between the mobile host and its home agent, especially when the mobile host is far away from its home network. Second, as subnets are clustered into different regions in RHMoM, the multicast delivery tree will be reconstructed at most one times when mobile host moves into a new region, and when mobile host moves around all subnets within the same MRA's region, the multicast delivery tree will not be reconstructed. Third, by limiting the distance from MSA to MRA, the delivery path of multicast packets can be close to optimization.

C. Group Management

When mobile host moves into a new foreign network, it registers its new care-of address to its home agent and also sends a group membership report message to current MSA.

If MSA supports local multicast, it can use standard MLD protocol to manage the active groups in its subnet and update the group list by sending MLD query messages periodically. When a mobile host enters a foreign network, it should send report messages and responds to MSA's query messages. The tunnel between two MSAs indicates one MSA is a group member of the other, so the query and report messages should also be exchanged between them. MSA should forward multicast packets to all mobile members in its subnet and other MSAs who want to get the packets through the tunnels. When the last mobile member leaves one subnet, as the MSA of that subnet can not know mobile host's leaving, it may still receive and forward multicast packets on local subnet, which wastes some network bandwidth. When a MSA does not receive any report message from one tunnel for a certain time, it cancels the multicast branch on that tunnel.

If MSA does not support local multicast, it should implement the function of MLD-proxy. In this case, MSA should maintain a list of active multicast groups in its subnet, and a list of all mobile members for each group. MSA periodically sends unicasting query message to every mobile member respectively to update the active group list and the group member lists according to the reply messages.

When a MSA detects any changes in the active group list, it should notify its MRA that it want to join or leave a multicast group. The MRA maintains and updates a list of multicast groups in its region and a list of MSAs that have members in its subnet for each group by sending out MLD query messages periodically. The MRA joins every multicast group on behalf of the mobile hosts in its region and takes part in the multicast routing, and it should forward multicast packets to all MSAs in the member list of corresponding group.

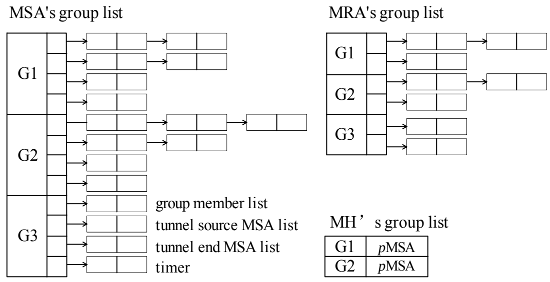

Figure 3. Data structures for RHMoM

We consider the situation that MSA does not support local multicast and the MRA communicates with MSA by tunnel. The data structures needed to implement for the RHMoM protocol are illustrated in Fig.3. The "tunnel end MSA list" entry in MSA's group list is a unicast IP address that indicates which MSAs the current MSA should forward packets to the "tunnel source MSA list" entry indicates which MSA the current MSA should get packets from, the "group member list" records all roaming mobile hosts of that group in the subnet. The "Timer" entry indicates the interval between sending two group query messages.

D. Multicast Source Mobility

In the above we focus on the situation that the multicast source is static. While the multicast source is a mobile host, it should send unicast packets to the MRA by way of its current MSA and the MRA forwards packets on the multicast delivery tree. To a receiver outside of the MRA's service region, the MRA seems like the multicast source. When mobile host roams around within the same MRA's service region, the multicast delivery tree does not need to be reconstructed. If receivers and multicast source are in the same region, the MRA will act as the core for multicast delivery and forward packets to all those receivers. MRA has a somewhat similar functionality to the RP (rendezvous point) in the PIM-SM protocol. However, the RP is relatively static and it does not depend on the location of the source. When mobile sender comes into new MRA region, a new multicast tree is rebuilt again.

IV. PERFORMANCE EVALUATION

We compare the performance of RHMoM with RS, HS, and FHSR by simulation in terms of the reconstruction cost of multicast delivery tree, the delivery delay, and the delivery cost.

A. Simulation Model

We use a 12×12 mesh network in our simulation, in which each vertex is regarded as a subnet. Each subnet has a home agent and a MSA on it. The service range of the MRA is a N×N region (the default value of N is 4) . MRA is located in (or near) the center of the square and communicates with the MSAs in its region by tunnel. There is only one multicast source, which is a static host and located in the center of the mesh network. The multicast delivery tree in our simulation is source-rooted tree. The initial locations of all the group members are randomly distributed in the mesh network. All group members are mobile hosts and their group memberships are static in one simulation. In any time unit, each mobile host can stay in its current subnet or move into one of the neighboring subnets with equal probability. The amount of group members varies from 22 to 210, resulting in group densities from 0.028 to 7.1.

B. Analysis of the Results

The movement of mobile host may lead to graft and prune some branches in the multicast delivery tree, and those operations increases the delivery tree maintenance overhead. In RS, mobile host has to rejoin the multicast group every time it moves, which results in more JOIN and LEAVE operations. There is no reconstruction cost because of host mobility in HS. We compute the average number of branches grafted and pruned when a mobile host moves once. Fig.4 shows the results in RS, FHSR, and RHMoM. We can see that the modification of multicast delivery tree in RHMoM is the least because of the region based hierarchical architecture it uses.

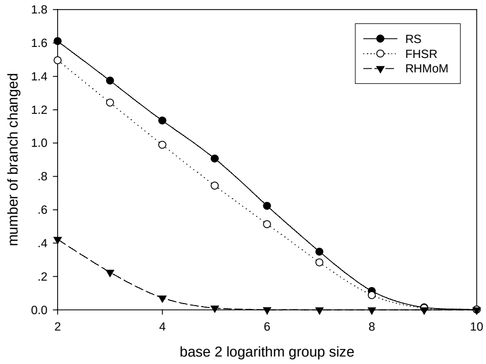

Figure 4. number of branch changed per mobility

The interruption time of multicast service is the interval from the time when mobile host cannot receive packets from the previous subnet to the time it can receive packets again from the current subnet when a handover occurs. This interval consists of two parts, one is the time used to obtain care-of address (denoted by t1) and the other is from the time when mobile host gets its care-of address to the time when mobile host gets multicast services again (denoted by t2). Because t1 is always the same in different protocols, we just consider t2 and call it as join delay. In Fig.5, we can see that RHMoM has the least join delay because of the short tunnel between two MSAs. The join delay of HS is the longest because tunnel between mobile host and its home agent may be long. As mobile host can receive multicast packets from its home agent before rejoin the group, the join delay of FHSR is between that of RS and RHMoM.

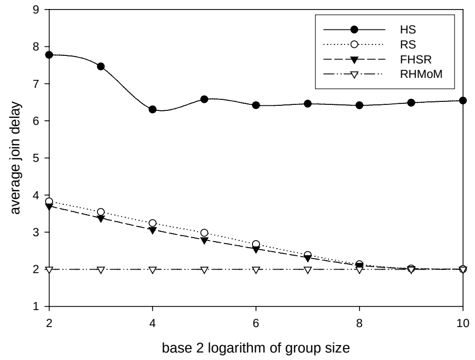

Figure 5. Average join delay per multicast packet

The delay of delivering a multicast packet to a group member can be calculated by the length of the path from the source node to the group member, which includes the path on the multicast delivery tree and the path in the tunnel (if exists). Fig.6 and Fig.7 show the results. In HS, there may be a long tunnel between mobile host and its home agent, so the delivery path is far from optimal. As the delivery path only includes the path in the delivery tree from multicast source to the group member, the delivery path in RS is optimal. Because MRA communicates with MSAs by tunnels and multicast packets follows the path of MRA→ MSA→ mobile host, the average delay of RHMoM is a little longer than that of FHSR. The maximum delivery delay in FHSR and HS are almost the same, as in FHSR mobile host may get multicast packets from its home agent.

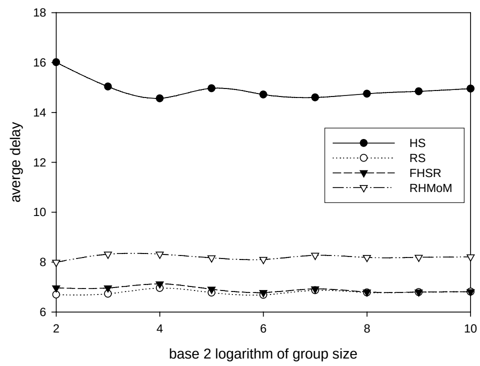

Figure 6. Average delivery delay per multicast packet

The delivery cost of a multicast packet can be measured by the total number of links that the multicast packet travels from the source to all members of the group. This includes the number of links in the multicast tree and in all the tunnels which are used to delivery the multicast packet. As shown in Fig.8, the delivery cost in HS is the highest, as home agent tunnels multicast packets to all of its roaming mobile hosts of that group. The delivery cost in RS is the lowest because of RS's optimal path. The delivery cost in RHMoM is a little higher than that in RS and FHSR because MRA communicates with MSA by tunnel.

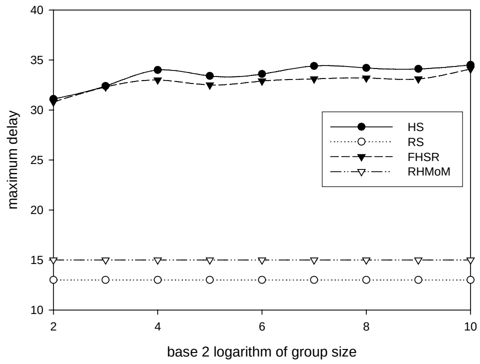

Figure 7. Maximum delivery delay per multicast packet

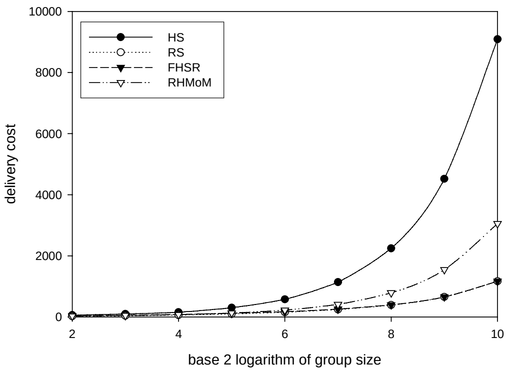

Figure 8. Average delivery cost per multicast packet

The performance of RHMoM is affected by the size of MRA's service range. The larger the MRA's service range, the longer the tunnel between MRA and MSA, the larger the delivery delay and the delivery cost, but the modification of delivery tree will be less. The simulation results for different sizes of MRA's service range are not given out here because of page limit.

V. CONCLUSION

In this paper, we propose a new basic multicast scheme for mobile IPv6, previous network subscription, as a supplement to remote subscription and home subscription. In PS, mobile host builds a tunnel from previous network other than home network when a handover occurs. By integrating previous network subscription and remote subscription, we propose the RHMoM protocol which uses region based hierarchical architecture. In this protocol, a tunnel is built between previous MSA and current MSA which does not receive packets yet. While the current MSA is receiving packet from previous MSA, it will request multicast service from its MRA. Compared with existing protocols, RHMoM can much reduce the interruption time of multicast service and the delivery tree maintenance overhead, and it can be close to the optimal remote subscription scheme in terms of the delivery path and the delivery cost when the service range of MRA is limited. The simulation results show that RHMoM protocol gets improved performance over those existing protocols and is an efficient multicast routing protocol in mobile IPv6 networks.

On the base of RHMoM, we have designed a new reliable mobile multicast protocol called RRHMoM (Reliable RHMoM)[11]. The MRA and MSA act as recovery nodes in RRHMoM. MRA is responsible for retransmitting lost packets to all MSAs in its service region. MSA is the recovery node that retransmits lost packets to mobile hosts in the subnet. MRA and MSA form a tree like hierarchical recovery system.

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