A Reliable Region based Hierarchical Mobile Multicast Protocol for IPv6 Network*

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Abstract: We propose a basic mobile multicast scheme in Mobile IPv6 called *previous network subscription* (*PS*). In *PS*, when a mobile host moves to a new foreign network, it will build a bi-directional tunnel with its previous network, so mobile host can continue to receive multicast packets soon after handover. We also propose a new reliable mobile multicast protocol called RRHMoM (Reliable Region based Hierarchical Mobile Multicast). It combines *PS* and remote subscription (RS). Hierarchical architecture is adopted in RRHMoM. The acknowledge mechanism combines NAK and ACK. Simulation results show that RRHMoM has better performance than existing reliable mobile multicast protocols.

Key Words: reliable multicast, mobile multicast, mobile IPv6, reliable mobile multicast protocol, RRHMoM.

1. INTRODUCTION

Many new applications in Internet, such as news dissemination, weather forecasting, and software distribution, require reliable data transmission from one transmitter to multiple receivers. Reliable IP multicast support is desired in Internet and many reliable multicast protocols have been designed.

In wireless networks using mobile IP, multicast packet is more inclined to lose because wireless medium is easier to be interfered. Another important fact is that mobile host continues to be handover between different subnets, which causes the multicast transmission path to change frequently and lots of packets may be lost during handover. Providing reliable multicast service to mobile host is a more challenging work.

The rest of this paper is organized as follows. In section 2, related works on reliable and mobile multicast is given out. Details of our protocol are presented in section 3. Simulation results and related analyses are given out in section 3. Section 4 is the conclusion.

2. RELATED WORKS

Mobile IPv6 [1] provides two basic multicast schemes that are called remote subscription and home subscription. In remote subscription, there should be a local multicast router in each foreign network and mobile host sends request messages to rejoin group by the multicast router in its current network after each handover. The local multicast router must be attached to the multicast delivery tree. Mobile host can receive and send packets directly from the foreign network by the shortest path. But the multicast delivery tree may be rebuilt frequently because of handover. In home subscription, mobile host sends and receives multicast packets by the unicast bi-directional tunnels between the mobile host and the home agents. The multicast delivery tree will not be reconstructed because of member location change. But the routing path for multicast delivery may be far from optimal.

Several mobile multicast protocols have already been proposed such as MoM (Mobile Multicast protocol)[2], RBMoM (Range-Based Mobile Multicast) [3], MA (Multicast Agent) [4], but there are less works done on reliable mobile multicast protocol.

RMMP (Reliable Mobile Multicast Protocol)[5] is based on remote subscription. The mobile agent in RMMP is not only the mobile manager but also the reliable multicast agent. After mobile host is handover to a new subnet, it reports the receiving state to the mobile agent on the previous subnet. If that mobile agent finds out that the mobile host has lost some packets, the mobile agent checks its cache to find out those packets and forwards them to mobile host by tunnel. RRBMoM (Reliable Range Based Mobile Multicast)[6] is extension of RBMoM (Range Based Mobile Multicast). The acknowledgement used in RRBMoM is periodical positive ACK. The sender and local servers act as recovery nodes. Mobile host sends ACK messages to its MAH (Multicast Home Agent). Then MHA fuses ACK messages from all receivers in its service region and sends the fused ACK message to upstream node. Error recovery packets are unicasted to corresponding receiver by MHA.

In this paper, we introduce a new basic mobile multicast scheme called *previous network subscription*. Previous network is the one that mobile host visited before it is handover to the current subnet. In *previous network subscription*, when a mobile host moves to a new foreign network, it builds a bi-directional tunnel with the mobile agent on previous network rather than that on home network as home subscription. Mobile host can continue to

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receive multicast packets soon after handover without the multicast delivery tree being reconstructed.

3. THE RRHMoM PROTOCOL

In this section, the details of RRHMoM are presented. We describe the system architecture, the error recovery, and the acknowledgement mechanism respectively.

3.1 Region Based Hierarchical Architecture

The RRHMoM protocol combines previous network subscription and remote subscription. The system architecture is a hierarchical one, as shown in Fig.1. There is only one Multicast Subnet Agent (MSA) in each subnet that provides reliable multicast service to all 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 being attached to the multicast delivery tree. It acts as the access point for mobile host in its service region for connecting to the multicast backbone.

The MRA and MSA also act as recovery nodes. 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.

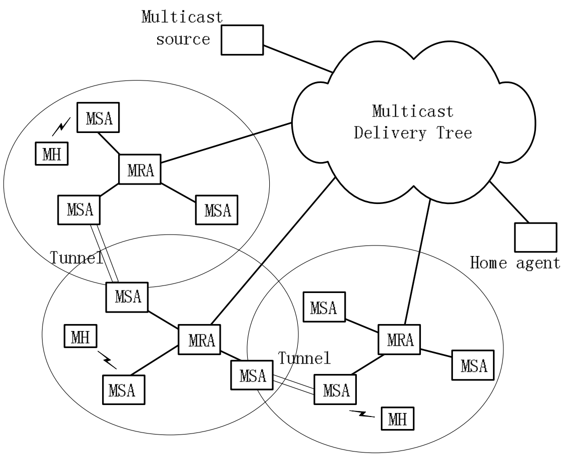

Fig.1 The hierarchical architecture adopted in RRHMoM

3.2 Error Recovery by Retransmission and Handover

There are two main methods to retransmit error recovery packet, unicast and multicast. In unicast retransmission, recovery node sends recovery packets to receivers that have lost packets by unicast. This kind of retransmission is suitable for that only a few receivers lose packets. In multicast retransmission, recovery node sends lost packets to receivers by multicast. It is efficient when there are lots of receivers having lost packets. These two methods can be adopted simultaneously. If the number of receivers requesting for a lost packet exceeds a threshold in a certain period of time, the recovery node retransmits that packet by multicast, or else, unicast retransmission is used.

Multicast retransmission can be classified into two groups according to the scope of multicast—global multicast and local multicast. Retransmission packets are sent to all group members in global multicast. That will waste network bandwidth and nodes' processing power, but the system is more robust. Local multicast retransmission just sends recovery packets to the region that packet losing has happened. Local multicast has the advantage of reducing network resource demand.

Because of the characteristic of wireless medium, mobile hosts in the same subnet are inclined to be interfered at the same time and lose packets. To deal with this situation in RRHMoM, MSA retransmits recovery packets to mobile receivers in its subnet by multicast. The usual connection between MRA and MSA is high quality wired lines that packet lose rarely occurs, so MRA retransmits recovery packets to MSA by unicast.

Handover usually causes multicast packet lose in RRHMoM protocol. After moving to a new foreign subnet, while the mobile host is registering its current care-of address to its home agent and correspondent nodes, it sends a MLD report message to the MSA in the new subnet to rejoin the desired multicast group. The mobile host also reports the max packet sequence number it has received to the MSA on the current subnet. If there are group members in the current subnet and current MSA caches the lost packets, mobile host can get lost packets and new packets from the MSA in the current subnet without any additional operations. If current MSA is receiving multicast packets of that group but has not the lost packets, it builds a tunnel to the MSA on mobile host previous visiting subnet (denoted as *p*MSA). Lost packets can be transmitted from *p*MSA to the current MSA and then to mobile host. If the mobile host is the first member of desired multicast group in the new subnet, the current MSA builds a tunnel to mobile host's *p*MSA and also sends a MLD report message to its MRA. MRA need only to forward multicast packets to the MSA if it has already joined that group, or else, the MRA should start to join the multicast group. After the current MSA receives multicast packets from its MRA and gets all lost packets from the *p*MSA, the tunnel between current MSA and the *p*MSA should be removed.

As the current subnet and the previous subnet are neighbored, the tunnel between them is usually much shorter than the tunnel between mobile host and its home agent. Because tunnels may have different delay (length) in home subscription, MLD pseudo-synchronization would be almost impossible to achieve [7]. This problem does not exist in previous network subscription because of short tunnel. Mobile host can not receive packets before the multicast router on current network rejoins multicast group in remote subscription, the service interruption time may be considerable. That interruption time is shortened in previous network subscription as mobile host can get packets through the short tunnel.

3.3 Acknowledgement in RRHMoM

Positive acknowledge (ACK) and negative acknowledge (NAK) are two main acknowledgement mechanisms in reliable multicast. In positive acknowledge, the sender need to maintain receiving states for all receivers. If sender sends out a packet and doesn't receive one receiver's ACK message after a certain time's waiting, sender should retransmits that packet. In negative acknowledgement, a receiver sends out a message to some recovery node to request the lost packet when it finds out that one packet has been lost. Positive acknowledge (ACK) mechanism can ensure that all receivers will miss no multicast packet, but be very poor in scalability. For negative acknowledge (NAK), the scalability to large number of receivers is not a problem, but the sender can not guarantee that all receivers can receive all packets if the sender has only finite cache memories.

In RRHMoM protocol, ACK and NAK combined acknowledgement mechanism is adopted. Because the typical connection between MSA and MRA is high quality wired lines, MSAs only send periodical ACK messages to their MRA in RRHMoM. As a MRA service for a limited number of MSAs, the ACK explosion is not a big problem. NAK mechanism is used in subnet so that mobile host can send out retransmission request messages to the MSA on the current subnet immediately after the mobile host discovers a packet losing, which can help to recover locally. To avoid NAK messages explosion, NAK suppression is used to prevent multiple mobile hosts in the same subnet to send out the same retransmission request messages.

If only periodical ACK acknowledgement is used, mobile host may move to another subnet before MSA finds out that some multicast packets is missed by the mobile host. That increases the retransmission delay and the retransmission cost. If NAK acknowledgement is used, the mobile host can send out retransmission request message to MSA immediately after mobile host detects a lost packet and the MSA can retransmit the lost packet promptly, so the retransmission delay and retransmission cost is reduced.

Compared with existing reliable mobile multicast protocols, RRHMoM protocol has the following advantages. First, because mobile host sends NAK messages immediately after it finds out a packet losing, the MSA on its current subnet can retransmit requested multicast packets in most case. The NAK mechanism and previous network subscription help to reduce both the retransmission delay and retransmission cost. Second, because of the region based hierarchical architecture and local recovery, the RRHMoM protocol is scalable and can be used in large network. Third, because of the open and shared property of wireless medium, multiple mobile hosts can be interfered at the same time. Multicast retransmission and NAK suppression in subnet are very useful for wireless bandwidth efficiency.

4. SIMULATIONS

We evaluate RRHMoM protocol by simulation, in which we focus on the packet losing during handoff and analysis the performance of RRHMoM in terms of retransmission cost, retransmission delay, and signaling cost.

4.1 Simulation model

The network used in simulation is a 12*12 mesh network. There are one MSA on each subnet. A MRA's service region is 4*4 square (the service of the MHA in RRBMoM is also set to 4*4). MRA is in the center of its service region. Multicast source is located in the center of the mesh network system. In the initial state, all group members are distributed randomly. During simulation, mobile hosts' group membership is unchanged. The interval between two ACK messages is 10 time units. A mobile host stays time in the same subnet for an average of 4 time units. The connection between MRA and MSA is high quality wired line and no packets will be lost on wired connections. Mobile host links to MSA by wireless medium. All wireless connections' packet losing rate is the same. When a mobile host is handover to a different subnet, one packet will be lost.

4.2 Simulation Results and Analyses

We compare the performance of RRHMoM with RRBMoM and RMMP. The packet losing rate of wireless medium is 10%, and the number of mobile member ranges from 2^0 to 2^{10}.

The change of average retransmission cost with the change of mobile member number is shown in Fig.2. Because NAK is not used in RMMP and RRBMoM protocols, the transmission path of recovery packets may be quite long. In RRBMoM, the mobile agents are not recovery nodes and all recovery packets are sent out by MHA. From Fig.2 we can see that the retransmission cost of RRHMoM protocol is the lightest and RRBMoM's retransmission cost is the heaviest.

The simulation result of average retransmission delay is shown in Fig.3. Because NAK messages are used in RRHMoM, the retransmission delay is the shortest and goes to 2 as the number of mobile host increases. RMMP and RRBMoM don't use NAK messages, so the retransmission delays are longer.

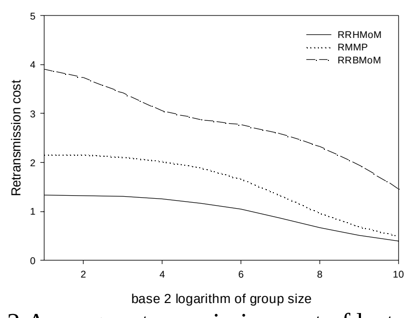

Fig. 2 Average retransmission cost of lost packet

We use the number of ACK and NAK messages to denote the signaling overload. The average signaling overload is shown in Fig.4. Because the mobile agent in RRBMoM does not cache multicast packets, and also because the retransmission request messages must go to MHA or even multicast source if MHA has not required packet, RRBMoM's signaling overload is the heaviest. RMMP does not use NAK messages too, but the retransmission request messages goes to the mobile agent on the previous subnet in the worst case, so its signaling overload is the lightest. Besides the periodically sent out ACK messages, NAK messages are also used in RRHMoM, but the average signaling overload is just slightly heavier than RMMP because of the NAK acknowledgement messages are suppressed.

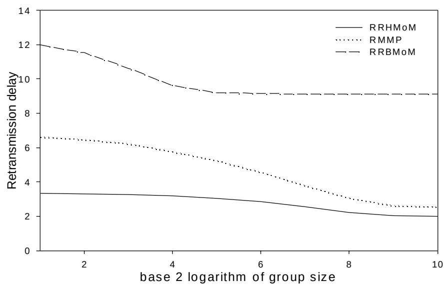

Fig. 3 Average retransmission delay of lost packet

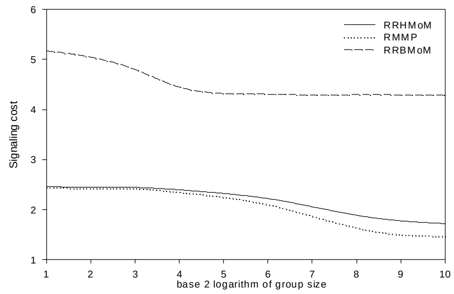

Fig. 4 Average signaling cost of lost packet

The multicast service disruption time caused by handoff is the duration from the time when mobile host stops receiving packet from the current subnet to the time when mobile host begins receiving packet from the next subnet. The multicast service disruption time can be denoted by join delay, which is the interval from mobile host's arrival to the new subnet to the time when mobile host can receive multicast packet again. The simulation result of average join delay is shown in Fig.5.

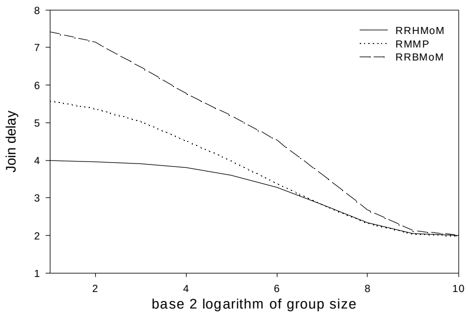

Fig. 5 Average join delay

When handover occurs in RRHMoM, if the current MSA is receiving packets of corresponding group, the join delay is 2 time units, or else the join delay is 4 time units because the packets comes from *p*MSA. The join delay declines and runs to 2 as the number of mobile host in the mesh network increases. Because mobile host needs to request to the MHA for multicast packets in RRBMoM, join delay in RRBMoM is larger than that in RMMP and RRHMoM.

5. CONCLUSION

In this paper, a reliable mobile multicast protocol called RRBMoM is proposed. The main features of RRBMoM can be summarized as region based hierarchical architecture, combining previous network subscription and remote subscription, retransmitting by multicast in a same subnet, combining ACK and NAK acknowledgement, and NAK suppression. Simulation result shows that RRHMoM exceeds existing reliable mobile multicast protocols in retransmission delay, retransmission cost, signaling overload, and multicast service disruption time.

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