IPv4 Based Reliable Mobile Multicast Technology

Zhong Qiu, Chen Xiaohua, Liu Danpu
(Beijing University of Posts and Telecommunications, Beijing 100876, P. R. China)

Abstract:
The mobile multicast technology has been a research hotspot in the wireless Internet field in recent years. Quite a large part of its applications requires the reliability in a mobile environment to be equivalent to that provided by wireline links. However, the inherent features of a mobile environment, that is, high error rate of links and dynamically changing multicast members' locations, are great difficulties for mobile multicast, let alone reliable mobile multicast. The IPv4-based reliable mobile multicast algorithms come with two different design philosophies. A part of the algorithms is to be improved for better reliability by solving existing algorithm-related problems; while other algorithms are to implement reliable mobile multicast with new function entities introduced to guarantee reliability.

There are two most important protocols of multicast technology for the fixed network. One is the multicast routing protocol and the other is member group management protocol. With the combination of mobility and multicast, the multicast manages the members in the dynamic multicast group, establishes and maintains the multicast tree, and also solves problems rising from dynamic location changes of members. The Internet Engineering Task Force (IETF) proposes the Bidirectional Tunneling and Remote Subscription protocols to deliver multicast in a mobile network environment. The protocols come with serious drawbacks though. Researchers have worked out many improved protocols on their basis, including Mobile Multicast (MoM) protocol, Range-Based Mobile Multicast (RBMoM) protocol and Mobile Multicast with Routing Optimization (MMROP)[1]. The performance of these protocols will be discussed in the following parts.

To provide reliable multicast is a feature of mobile IP multicast that is important to applications such as software distribution and community whiteboard. Problems to be solved by reliable mobile multicast include: Loss, error, repetition, and out-of-sequence of multicast packet. This article will focus on the new problems faced by reliable multicast in a mobile environment, and also some typical protocols of reliable mobile multicast.

1 Current Mobile Multicast Protocols

With the bidirectional tunneling algorithm, a bidirectional tunnel is to be set up between the Mobile Node (MN) and Home Agent (HA) with the help of Foreign Agent (FA). What is noteworthy is that HA is a router whose one port connects with the MN's home link, while the FA is a router on the MN's foreign link. HA joins the multicast group on behalf of MN, and MN receives and sends out multicast data from HA by way of the tunnel. The essence of such algorithm is to hide the mobility of MN, so that the mobility is transparent for the multicast protocol and the multicast tree does not need be reconstructed to suit the location change of MN. However, the bidirectional tunneling algorithm has the following serious drawbacks:

(1) It has triangle routing and high link overhead. When MN joins a local multicast group on the foreign link far away from its home network, long delay and high overhead are generated.

(2) It has the tunnel convergence problem, as shown in Figure 1 (where MN_{1-1} and MN_{1-2} belong to HA_1; MN_{2-1} belongs to HA_2; MN_{3-1} and MN_{3-2} belong to HA_3). When there are several MNs belonging to the same multicast group on a foreign link, while these MNs come from different home network, HA of every MN sets up a bidirectional tunnel with a foreign link and sends the same multicast packet through these tunnels, hence wasting of network resource.

Another mobile multicast algorithm proposed by the IETF is Remote Subscription. When an MN leaves the FA, it obtains a transfer address and joins the original multicast group again with this transfer address to accept service of this group again. This algorithm is simple to implement as the current multicast protocol can be used directly without the need to set up any tunnel. That is, there will be no tunnel convergence problem or triangle routing (the multicast packet's transfer route will be optimal). However, this algorithm has the following drawbacks:

(1) Every time when an MN moves onto a new link, it has to apply again to join the multicast group, which results in the reconstruction of the multicast tree. If the MN moves frequently, enormous reconstruction overhead of the multicast tree will be generated.

(2) Even if the handover is done very quickly, the delays of receiving multicast packet by different subnets are different because the networks are dynamic, resulting in the out-of-sync problem of the mobile environment.

Most current mobile multicast protocols are improved ones on the basis of bidirectional tunneling and remote

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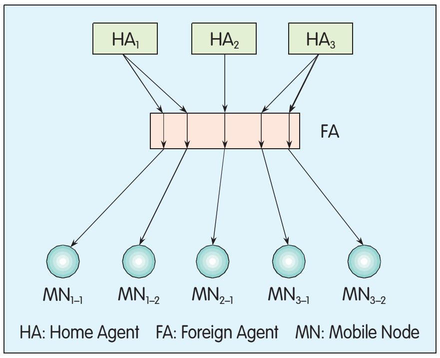


▲Figure 1. Tunnel convergence problem.

subscription, including algorithms of MoM, RBMoM and MMROP.

The MoM algorithm is one improved from the bidirectional tunneling algorithm. The core of this algorithm is that it introduces the Designated Multicast Service Provider (DMSP). Every FA has one, and only one, DMSP to set up a tunnel for it to transfer data, so that it will not receive several copies of the same data. The MoM algorithm solves the problem of tunnel convergence but not the inherent problem of bidirectional tunneling, that is, triangle routing. Also the algorithm is yet to come up with a good solution to the problem of DMSP switchover caused by the fact that the MN moves among different foreign links[2].

The RBMoM scheme is one improved from the MoM algorithm. Its main technical feature is that it introduces the range-based multicast. The RBMoM selects one Multicast Home Agent (MHA) for every MN and the MHA transfers the multicast packet to the FA where the MN is located[3]. The MHA only transfers data for the MN located within its service range. The essence of RBMoM is combination of bidirectional tunneling and remote subscription and the scheme features optimal multicast packet transfer route and low multicast tree update overhead. Generally speaking, the RBMoM is an innovative algorithm but it does not clarify how to define the service range. Consequently, research on the way to adaptively determine the service range of MHA according to network environment is worth attention. Also with the RBMoM scheme, if several MNs of one FA are serviced by different MHAs, a problem similar to tunnel convergence of bidirectional tunneling will be resulted in. RBMoM selects one DMSP from MHA to solve this problem, just leading to new problems of DSMP selection and switchover: How a DMSP can be selected and what if the service is interrupted during the process of DMSP switchover.

The MMROP protocol is based on remote subscription and it solves the out-of-sync problem caused by the MN moving to a new foreign link. This part of lost packet will be provided by the old FA to the new FA through the tunnel. The MMROP retains the feature of remote subscription, that is, the optimal transfer route, and at the same time solves the problem of packet loss. However, it fails to put an end to the problem faced by remote subscription, that is, frequent multicast tree updates.

2 Reliable Mobile Multicast

The reliable multicast can be defined as: Every receiver is able to receive all multicast packets correctly, and in most cases, the multicast packets arrive in sequence without loss or repetition. The multicast employs unreliable connectionless mode and to meet the reliability requirement, the reliable multicast protocol is introduced where the Automatic Repeat request (ARQ) and Forward Error Correction (FEC) mechanisms are used. ARQ has a long delay as it needs to make error feedback. FEC comes with increased network traffic as it needs to use redundant information, and it cannot guarantee the correctness after all. Reliable multicast usually has the FEC and ARQ combined for use.

Typical reliable multicast protocols are: Scalable Reliable Multicast (SRM), Reliable Multicast Transport Protocol (RMTP), and Reliable Multicast Protocol (RMP). These protocols have their own different application ranges. For example, RMTP is for tree-based topological structure, while RMP is for ring-based topological structure. All of them have good performance in fixed networks.

It needs to be pointed out that the characteristics of mobile network pose greater challenges for reliable multicast. Firstly, the wireless links are with limited bandwidth, and the error rate of data transmission is quite high. Besides, dynamic location changes of moving nodes lead to loss of switchover packets and out-of-sync problems. While a node moves from an old link to a new one, it has to register the transfer address and join the multicast group again and as a result, the multicast service might be interrupted for a while. Furthermore, original reliable multicast protocols do not take into consideration the frequent reconstruction of multicast tree resulted from the frequent move of hosts[4]. A lot of reliable multicast protocols are therefore put forward to address issues coming from the mobile environment. The protocols include the following:

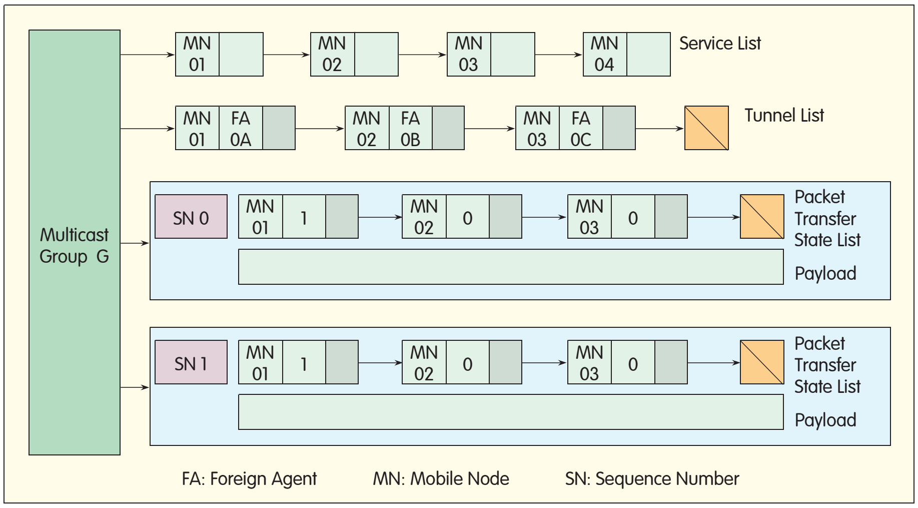
2.1 Host View Membership Protocol

The Host View Membership Protocol (HVMP)[5] employs Mobile Support Stations (MSSs) to provide reliable multicast for mobile nodes. The MMS caches all multicast groups so that just when a mobile node moves to a new link, the node can acquire from the MSS the packets possibly lost during the switchover. However, the protocol needs a high cache of MSS, and the load will be too high for the MSS especially when a large amount of data is to be transmitted. In a word, the HVMP protocol is not very practical.

2.2 Reliable Mobile Multicast Protocol

The Reliable Mobile Multicast Protocol (RMMP)[6] has the reliability improved on the basis of MMROP. The MMROP protocol is based on remote subscription and it features optimal transfer route and at the same time solves the problem of packet loss produced in the switchover process. The RMMP retains these features and at the same time adopts the packet acknowledgement mechanism. With the RMMP, the mobile agents (HA and FA included) provide not only mobility management functions but also support of reliable multicast.

The principle of RMMP is to introduce the tunneling mechanism to the remote subscription algorithm. When a mobile node switches over, the old agent supplements the multicast packets lost during the switchover to the new agent so that the problem of out-of-sync is solved. Meanwhile, the mobile agents join the multicast group on behalf of the mobile node of the subnet and also



▲Figure 2. Data structure of tables for mobile agent.

collect the ACK of the mobile node of the subnet and then transfer the ACK to the reliable multicast agent.

As shown in Figure 2, every mobile agent maintains a table that consists of three parts: Service list, which keeps a record of the mobile nodes of the subnet that join the multicast group; tunnel list, which keeps a record of the mobile nodes that once registered in the subnet but has now left and required the mobile agent to restore the lost multicast packet; Packet Delivery State List (PDSL), which keeps a record of reception state feedback of every managed mobile node for receiving every multicast packet.

When receiving a multicast packet with the sequence number of n, the mobile agent adds a PDSL record to the cache and all hosts are added to the service list. The packet will not be deleted from the cache until all hosts in PDSL acknowledge that they have received the multicast packet with the sequence number of n. To solve the out-of-sync problem, when a mobile node moves to a new link, it needs to send the Internet Group Management Protocol (IGMP) message to the new FA requiring joining the multicast group, and then the FA joins the multicast G on behalf of the mobile node. At the same time, the mobile node need check the sequence number difference of multicast packets between old and new links. Once any packet loss is found, it sends to the old FA the leave message with some offset, so that the old FA make corresponding supplement of packet through the tunnel.

2.3 Reliable Range Based Mobile Multicast

The Reliable Range Based Mobile Multicast (RRBMoM)[7] protocol is one proposed on the basis of RBMoM. It makes a compromise between the two features of RBMoM, that is, shortest transfer route and frequent multicast tree update. By defining a service range, the MHA serves only the mobile nodes on the mobile link within the service range. As for the reliability, it provides ACK-based reliability and the error recovery mechanism for which the sender is responsible. To prevent ACK explosion, it uses a tree-based hierarchical acknowledgement structure and, as different from the way that every multicast receiver sends out the ACK message, the MHA works as the agent of all mobile nodes within the service range and sends the ACK message to the multicast sender.

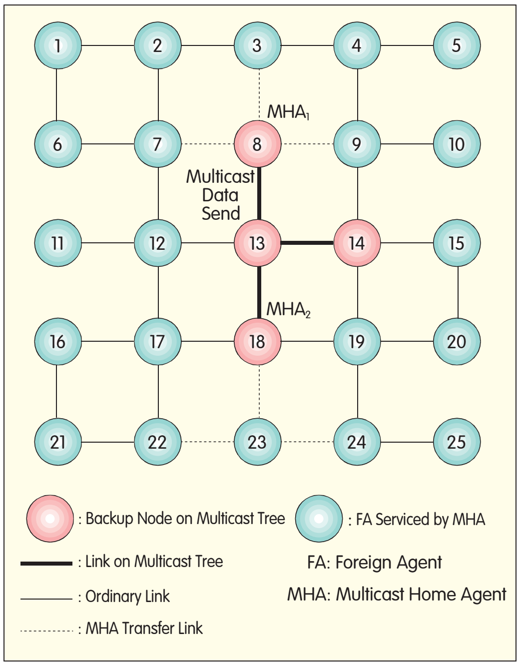
Figure 3 shows the concept of service range. MHA_1 and MHA_2 are two multicast routers on the multicast tree. The bold line in the figure refers to the multicast tree. Suppose that the service range is one hop. After MHA_1 joins the multicast tree and receives data from the multicast source, it transfers the multicast packets to FA_3, FA_7 and FA_9 within the service range. Likewise, MHA_2 transfers packets to FA_{17}, FA_{19} and FA_{23}.

The protocol needs to define which nodes should backup the multicast packet for recovery purposes. Since the MHA collects the ACK messages of FA within the service range and resends the lost packets to the multicast receiver, it is reasonable that the protocol selects to have the packet backed up in the MHA.

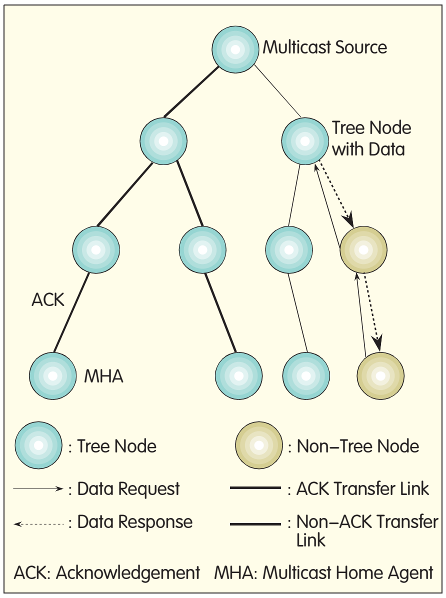
When the mobile node reaches a new foreign network, it registers to the FA and at the same time reports the sequence number of the packet. If any host on the FA has already joined the multicast group, the FA will transfer the information to the MHA. Next, the MHA will transfer the information to the root of the multicast tree. To lessen the load of senders, other nodes on the tree can process and resend the information.

The RRBMoM protocol uses the tree-based hierarchical structure to handle the ACK explosion. As shown in Figure 4, the MHA sends ACK messages to the father node. After nodes on the tree have collected the ACK messages of all downstream nodes, they send their own state information to the father node, hence the hierarchical tree-shaped structure. Please note that in the state information, one received packet indicates that all downstream nodes have received the packet correctly.

The RRBMoM, as compared to the



▲Figure 3. Concept of service range.



▲Figure 4. ACK tree and data recovery.

remote subscription algorithm, has a lowered update frequency of the multicast transfer tree. Also its multicast transfer route is close to optimal and it introduces the hierarchical ACK mechanism for improved reliability.

Yet still, the RRBMoM fails to define the network state-based service range and because the MHA is responsible for data recovery of all hosts within the service range, heavy load on the MHA (in case of a large service range) will obviously result in lowered efficiency.

2.4 Reliable Range Based Mobile Multicast

The Reliable Range Based Protocol of Mobile Multicast (RRBMM)[8] protocol is one with improved reliability on the basis of RBMoM. When a node moves, the packet is supplemented through tunnels set up among the mobile agents. This is in fact a method adopted by MMROP.

Similar to the MHA of RBMoM, RRBMM uses MFA to transfer the multicast packet to the FA of MH. When a node moves to a new foreign link, if there already is the MFA record of the multicast group in the new FA, the MFA information will be used directly to update the MFA information in the MH. However, if there is no MFA record of the multicast group in the new FA, the original MFA will be obtained from the MH and the distance between FA and MFA will be computed accordingly. If the distance is greater than the service range, a new MFA will have to be selected. A simple way is to designate a new FA as the new MFA. The new MFA needs join the multicast group and the multicast transfer tree should be updated consequently.

For less loss of multicast packet in the process of switchover, MH needs to check the sequence number difference of multicast packets between new and old links. If that of the old link is greater than that of the new link, MH sends to the old FA the leave message and indicates the sequence number offset is 0; otherwise, MH sends the leave message and indicates the multicast packet's offset value. Next the old FA makes supplements for this part of multicast packets to new FA by way of the tunnel.

The MFA is different from the MHA in terms of concept. The MHA information is stored in the HA, and every node on a foreign link may have a different MHA. Only the MHA as the DMSP can transfer packets to the FA. However, the MFA information is stored in the MH and all nodes on a foreign link have the same MFA, that is, a unique MFA transfers packets to the FA and there is no such problem as tunnel convergence.

Figure 5 depicts the data structure of RRBMM.

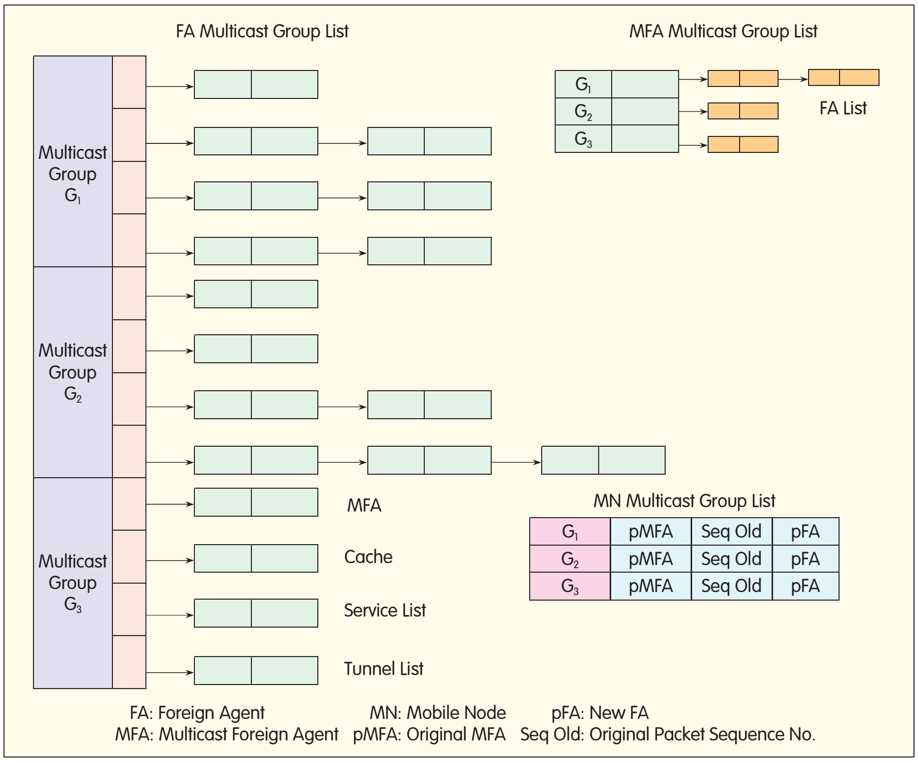
This algorithm solves the DMSP problem of RBMoM and improves the out-of-sync problem through the tunnel. Besides, as compared to MMROP, it maintains the reliability and keeps a balance, through change of service range, between the optimal transfer route and frequency of multicast tree reconstruction.

A defect of the algorithm is that it fails to solve the problem of packet loss caused by the wireless link. It does not propose how to select the service range on the basis of network state, either.

2.5 Multi-Level Reliable Mobile Multicast Supporting SRM

With the Scalable Reliable Multicast (SRM), all members enjoy the same statue. The SRM applies to a wide range of group scale and dynamic topology, but not mobility. The Multi-Level Reliable Mobile Multicast (MRMoM) supporting SRM[9] supports both mobile multicast and multi-level reliability.

To support mobile multicast, the MRMoM adopts the mobile IP region registration technology to isolate the mobility of mobile nodes from the main multicast tree. This way, the probability of



▲Figure 5. Data structure used in algorithm.

▼Table 1. Contrast of reliable mobile multicast protocols

Mobile Multicast Protocols	Route Optimization	Reliability	Support Moving Source or Not	Delay of Join and Graft	Protocol Overhead	Tunnel Convergence Problem
HVMP	No	Support, Requiring Enormous Cache	No	Short	Very low	No
RMMP	Optimal	Support, Requiring Large Cache	No	Long	High	A little
RRBMoM	Close to Optimal	Support, Supporting ACK Tree Structure	No	Short	Low	A little
RRBMM	Close to Optimal	Support	No	Short	High	A little
MRMoM	Close to Optimal	Support Multi-Level Reliability	Yes	Very Short	High	Little

HVMP: Host View Membership Protocol
MRMoM: Multi-Level Reliable Mobile Multicast
RMMP: Reliable Mobile Multicast Protocol
RRBMM: Reliable Range Based Protocol of Mobile Multicast
RRBMoM: Reliable Range Based Mobile Multicast

multicast tree reconstruction caused by moving hosts can be minimized. With the MRMoM, the mobile nodes are separated into different regions and every region is available with a Gateway Foreign Agent (GFA) responsible for registration in the region. The GFA also works as a multicast agent.

MRMoM provides end-to-end reliability when mobile nodes work as receivers.

(1) From multicast source to GFA: Use SRM.

(2) From GFA to FA: GFA transfers to FA the received packets of multicast source through end-to-end transmission, whose reliability is guaranteed with the Negative Acknowledgement (NACK)-based feedback mechanism.

(3) From FA to mobile node: Use the NACK-based retransmission mechanism. When FA transfers data to the group members, every mobile node checks the sequence number of the multicast packet. If any packet loss is found, the mobile node sends NACK to FA, and FA will perform retransmission.

MRMoM is a reliable mobile multicast algorithm whose performance is relatively good, with high data transmission efficiency and short end-to-end delay. It is applicable when the multicast source moves.

2.6 Contrast of Protocols

Table 1 lists the abovementioned protocols and their features.

3 Future Research Possibilities

The research of reliable mobile multicast has begun not long before, and so far no algorithm is able to balance the performances to apply to various reliable multicast scenarios.

Many researchers are now working on protocols on the basis of existing mobile multicast protocols. The MRMoM protocol makes use of some technologies of reliable multicast for fixed network and shows good performance in certain applications. More research work is also necessary for applications, for example, for video stream and software distribution QoS, how to differentiate these services so that different strategies can be adopted accordingly. The research of reliable mobile multicast should also take the differences brought about by IPv6 and MIPv6 into considerations[10-13], since the concept of FA has been removed from MIPv6 and the multicast group management protocols are also different.

4 Conclusion

The reliable mobile multicast is an important part and also a hotspot of mobile multicast research. This article analyzes the challenges the reliable multicast faces in the mobile environment and several typical mobile multicast protocols, and predicts future research trend of reliable mobile multicast.

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Biographies

Zhong Qiu

Zhong Qiu is a master candidate at School of Telecommunications Engineering, Beijing University of Posts and Telecommunications (BUPT). His research interests include mobile IP and mobile multicast technology.

Chen Xiaohua

Chen Xiaohua is a master candidate at School of Telecommunications Engineering, BUPT. His research interests include mobile IP and mobile multicast technology.

Liu Danpu

Liu Danpu is a professor at BUPT. Her research interests include broadband wireless communications technologies, MIMO/OFDM, physical-layer and MAC technologies for ultra-wideband wireless communications systems. She has published more than 30 technical papers.