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Design and implementation of light-weight mobile multicast for fast MIPv6

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ABSTRACT

Mobile multicast is a research hotspot and can provide many applications. Some mobile multicast schemes have been proposed, but most of them introduce new entities and study construction algorithms of the dynamic multicast delivery structure which is heavyweight for wireless devices. In this paper, we propose a light-weight mobile multicast (LMM) scheme for Fast Mobile IPv6 which reduces the redundant operational overhead by simplifying multicast listener discovery (MLD) proxying. The LMM scheme implements simplified MLD proxying function on home agent to reduce the complicated multicast routing protocol and modifies MLD host part function on mobile node to reduce the multicast membership messages interaction. In order to solve the tunnel convergence problem, LMM also introduces a multicast tunnel combination and reconstruction algorithm. We set up a test-bed to evaluate the performance of LMM, and compare it with other mobile multicast schemes. The experimental results show that LMM reduces the multicast disruption time at handover. Based on the experimental results, we analyze the cost of LMM, and the results show that it has lower protocol cost than other schemes.

1. Introduction

Multicast has developed from the fixed platform to the wireless and mobile platform with the development of mobile and wireless communication technologies. To provide the mobile multicast services, mobile multicast has to manage the dynamic group membership and the mobility of mobile subscribers. Multicast listener discovery (MLD) [1], which consists of the MLD router part function and the MLD host part (listener part) function, is an asymmetric protocol and is used to manage the dynamic membership for Internet Protocol version 6 (IPv6) to enable each IPv6 router to discover the presence of multicast listeners. However, it cannot maintain the multicast states for the mobile multicast listeners. To solve this problem, the mobile multicast needs the support of both the link layer handover specifications such as IEEE 802.11 and the network layer handover specifications such as Mobile IPv6 (MIPv6) [2] and NEtwork MObility (NEMO). However, we cannot simply combine them to provide the effective mobile multicast services.

Mobile IPv4 [4] describes two basic mobile multicast methods, bi-directional tunneling (BT) and remote subscription (RS). BT forwards the multicast packets from the home agent (HA) through the unicast tunnel set up by Mobile IP. As a result, BT has lower join latency and does not require the multicast support in foreign networks, but when multiple mobile nodes that join the same multicast group move into the same foreign network, there will be multiple unicast tunnels to transmit the same multicast data which is known as the tunnel convergence problem. As a result, it may cause the large delivery overheads. As for the RS method, it transmits the multicast packets from the current access router which is more scalable and has optimal routing, but it has longer join latency and needs multicast support in the foreign networks. Based on the BT and the RS methods, several improved schemes such as mobile multicast protocol (MoM) [5], range-based mobile multicast (RBMoM) [6] and multicast by multicast agent protocol (MMA) [7] have been proposed. While these schemes try to make the tradeoffs between BT and RS using different multicast agent selection algorithms, the management and maintenance overheads of various multicast agents introduced by these schemes increases the operational complexity which is heavyweight for mobile devices.

With the development of MIPv6, several extensions of MIPv6 such as Fast MIPv6 (FMIPv6) [8] and Hierarchical MIPv6 (HMIPv6) [9] have been proposed. MIPv6 takes about 2–3 s to complete the handover procedure, which is too long to be used for the real-time applications. FMIPv6 configures the new care-of-address (CoA) based on the link layer information in advance to shorten the handover delay, and creates the tunnel between previous access router (PAR) and new access router (NAR) to minimize the packet loss. HMIPv6 introduces a new entity called mobility anchor point which acts as a local HA to eliminate the overhead of global

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handover signaling. Some mobile multicast schemes based on the FMIPv6 and HMIPv6 were proposed in the past few years, but most of them introduce additional operation overheads.

Previous studies on mobile multicast mainly focus on the construction algorithms of the dynamic multicast tree, while little considers the power consumption problem which is very important for the mobile devices. In this paper, we propose a lightweight mobile multicast (LMM) scheme which is based on the MLD proxying [18] and FMIPv6 to reduce the signaling messages and multicast disruption time. We also introduce the tunnel combination and reconstruction (TCR) algorithm which detects the tunnel convergence and reconstructs the tunnels to solve the multicast tunnel convergence problem. To evaluate its performance, we set up a test-bed and compare the multicast disruption time and protocol cost with other mobile multicast schemes.

The rest of the paper is organized as follows. Section 2 introduces the related work of mobile multicast in IPv6. Section 3 describes the LMM scheme in detail. Section 4 analyses the multicast disruption time and the protocol cost of LMM, and compares it with other mobile multicast schemes. Finally, Section 5 gives the conclusions.

2. Related work

Multicast consists of multicast routing protocols and group member management protocols. In order to provide the mobile multicast services, we can extend the group membership management protocols or the mobility support specifications.

2.1. Extensions of the group membership management protocols

Based on the MLD protocol, Jelger and Noel [10] propose a mobile multicast scheme which combines the BT and the RS methods by using the MLD-proxy-capable HA. This scheme introduces a new type of MLD message called multicast listener hold to notify the HA to stop forwarding the multicast packets but hold multicast states for the MN. When the MN moves among the foreign networks, it uses the BT method to transmit the multicast packets at first, and then it changes to the RS method. Once the MN gets the native multicast packets from the current access router (AR), the MN will send the multicast listener hold message to the HA to keep the multicast states but stop forwarding the encapsulated multicast packets. However, this scheme has the out-of-synch problem [11] which means the multicast will be disordered during the handover.

Romdhani et al. [12] propose an adaptive multicast membership management scheme for mobile multicast receivers. The HA implements the MLD Replay function which does not maintain multicast states but only transmits MLD messages between a multicast router and a mobile listener. This scheme modifies the query message interval and stops forwarding general queries when MN gets the multicast packets to reduce the energy consumption caused by periodic MLD query messages.

2.2. Extensions of the mobility support specifications

Based on the FMIPv6, Xia and Sarikaya [13] propose a Multicast fast handover (MFH) scheme, which introduces the multicast group information option in the fast binding update (FBU) message and the handover initiate (HI) message. In order to reduce the join delay, PAR transmits multicast group information to NAR through the FBU and the HI messages to join the multicast group in advance. However, the MFH scheme suffers from the long join delay. Afterwards, Leoleis et al. [14] propose the FMIPv6 extensions for multicast handover support with flow tunneling and buffering scheme, which uses the conditional tunneling to solve the tunnel convergence problem. More recently, Kwon et al. [15] propose an efficient multicast scheme for FMIPv6 which introduces new multicast options in the mobility header and the Internet Control Message Protocol (ICMP) header to record the multicast group information. This scheme also establishes a multicast tunnel between PAR and NAR to eliminate the tunnel convergence problem.

Based on the HMIPv6, Schmidt and Waehlisch [16] propose a seamless multicast handoff in HMIPv6, which transmits all multicast packets through the mobility anchor point. Subsequently, Zhang et al. [17] propose a dynamic multicast agent scheme, which dynamically selects the multicast agent to reduce the handoff frequency.

The mobile multicast schemes described above mostly based on the assumption that the HA or the AR has an IP multicast function which not only increases the processing overhead on the HA or the AR but also increases the energy consumption on mobile device. MIPv6 suggests that the HA should have a full IPv6 multicast function or proxy MLD function coupled with kernel multicast forwarding. However, the full multicast function is complicated and may introduce the inter-domain multicast problem. As for the proxy MLD function, it has to periodically transmit the MLD message between HA and MN which increases the operational overhead on the HA especially when multiple mobile nodes are away from home network [12].

To provide the effective mobile multicast services for mobile devices, we propose the LMM scheme for FMIPv6. In the LMM scheme, the HA implements the simplified MLD proxying function which collects and forwards the MLD messages to reduce the operational overhead, and the MN modifies the MLD host part function which sends the unsolicited MLD report message once its CoA changed to reduce the multicast join delay. In order to solve the tunnel convergence problem, LMM also introduces a tunnel combination and reconstruction algorithm.

3. The LMM Scheme for FMIPv6

3.1. Function implementation of LMM

3.1.1. The simplified MLD proxying function on HA

The HA implements the simplified MLD proxying function based on the MLD proxying [18] which forwards the MLD messages and the multicast packets between a multicast router and a multicast listener. MLD proxying learns and maintains the group information on behalf of the multicast subscribers, and it can be configured manually into a spanning tree whose root is a multicast router. MLD proxying configures the upstream interfaces attached to multicast routers to perform MLD host part function and the downstream interfaces attached to multicast subscribers to perform MLD router part function. MLD proxying records all the subscriptions information on the downstream interfaces. When the HA uses MLD proxying to forward the multicast packets, the mobile multicast scheme will be independent of the multicast routing protocols used in the fixed networks. However, due to the periodic MLD query messages, MN cannot use the dormancy mode when it leaves the multicast groups. So, in the LMM scheme, we simplify the MLD proxying to reduce the operational overheads.

The simplified MLD proxying only deals with the join and leave messages. When the HA implements the simplified MLD proxying, it configures the interface attached to the multicast router as the upstream to transmit the MLD messages and configures the bi-directional tunnels as the downstream interfaces to transmit the multicast packets. To maintain the multicast states for the mobile nodes, the HA uses the binding cache lifetime as the default time. Once a MN leaves the group, it sends the MLD done message through the tunnel. During the handover, HA and MN does not introduce additional operations except the MIPv6 signaling messages. When the MN moves into another subnet, HA still can maintain the multicast states for the MNs and forward the multicast packets.

Fig. 1 shows the functional modules of simplified MLD proxying. To deploy the simplified MLD proxying function, HA needs to create and maintain three information lists. The first is the MN list which records the mobile nodes information based on the binding caches, the home address and CoA of MN, the address of the current AR and lifetime which is set to be the binding lifetime of the MN. To get the current AR address, LMM introduces an AR address suboption in the mobility option and transmits the address to the HA through the binding update (BU) message. Fig. 2 shows the extension of the BU message which introduces the T flag to notify the current address of AR when it is set, and this address will be filled in the extended mobility option. The extension is used to solve the tunnel convergence problem, and the detailed description is in Section 3.3. The second list is the group membership list which records the group member information for mobile nodes including the multicast address, multicast mode and multicast scope, etc. The third list is the forward list which records the forwarding interfaces for every multicast group.

3.1.2. The modified MLD host part on MN

When a MN moves away from the home network, it needs to reconstruct the multicast delivery tree or update the tunnel. To shorten the multicast disruption time, the LMM scheme modifies the MLD host part function by introducing the address detection mechanism as the trigger. Once the MN changes its address, it will send the unsolicited MLD report message to update the multicast states.

3.2. The operation of the LMM scheme

Suppose that a MN joins a multicast group in the home network and moves into PAR and NAR. The PAR and the NAR send the router advertisement (RA) messages at specific intervals to advertise its own subnet network prefix. Fig. 3 shows the detailed operation flow of the LMM scheme.

3.2.1. MN at the home network

The MN sends an unsolicited MLD report message to join a multicast group and gets the multicast packets. In this phase, the MN joins and leaves the group like a fixed node (Step 1).

3.2.2. MN Moves into the PAR

When the MN moves into the PAR, it performs the MIPv6 handover and uses the BU message and binding acknowledge (BA) message to set up the bi-directional tunnel. After that the HA gets the MN information from the binding cache and maintains the group membership on behalf of the MN. Multicast traffic will be disrupted during the handover. In this phase, MN sends the unsolicited MLD report message through the tunnel to update the multicast membership information (Steps 2–5).

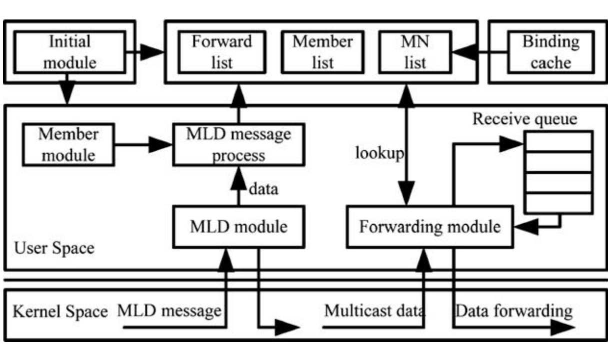

Fig. 1. Simplified MLD proxying function.

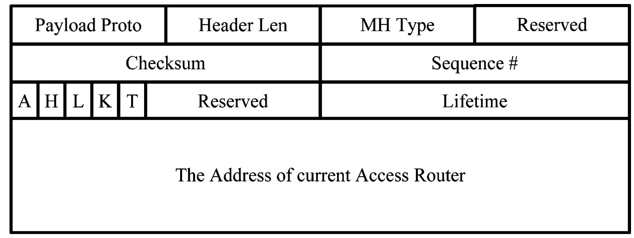

Fig. 2. The extension of mobility header.

3.2.3. MN moves from the PAR to the NAR

The MN performs the FMIPv6 handover during the movement. First, it scans available access points (APs) nearby before L2 handover, creates router solicitation for proxy advertisement (RtSolPr) message and sends the message to the PAR for resolving subnet routing information. The PAR will reply with a proxy router advertisement (PrRtAdv) message with the [AP-ID, AP-Info] tuples. Multicast traffic will be disrupted during the scanning procedure. The MN sends the FBU message including the new CoA to the PAR. After receiving the FBU message, the PAR and the NAR set up a tunnel during the handover. After that the PAR sends the fast binding acknowledge (FBack) message to the MN and the NAR, and begins to buffer and forward the multicast packets to the NAR. Once the MN attaches to the NAR and sends the fast neighbor advertisement (FNA) message, the MN will get the buffered multicast packets from the NAR (Steps 6–13).

3.2.4. MN attaches to the NAR

After the HA gets the new BU message, it modifies the tunnel end-point and stops forwarding multicast packets to the PAR. As a result, the HA transmits the multicast packets to the MN through the NAR (Steps 14–17).

3.3. Tunnel combination and reconstruction (TCR) algorithm

The reason of multicast tunnel convergence problem is that the mobility support specifications do not support the mobile multicast services especially the MIPv6. Compared with MIPv4, MIPv6 sets up the tunnel between HA and MN which benefits the unicast traffic but increases the difficulty of multicast services. When the BT-based methods are used, they treat the multicast as a special case of the unicast. As a result, as the number of mobile nodes in the same group attaching to the same foreign network increases, multiple tunnels will be set up to transmit the same multicast packets. Fig. 4 shows two kinds of tunnel convergence in MIPv6. Fig. 4(a) shows that multiple HAs in different networks have MNs in the same multicast group attaching to the same foreign network, and multiple multicast packets are transmitted through the link between foreign AR and the MNs. While Fig. 4(b) shows the case when one HA have multiple MNs in the same multicast group accessing the same foreign network.

For the first kind of tunnel convergence problem, we can use the designated multicast service provider (DMSP) [5] to select one HA as the DMSP, so that the case shown in Fig. 4(a) can convert into the second kind. In our scheme, HA records the DMSP state in the forward list and sets the default value to 1 which means the HA performs the DMSP service.

Fig. 5 shows the detailed process of the tunnel combination and reconstruction algorithm which consists of tunnel convergence detection and tunnel reconstruction.