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이동 IP 망에서의 효율적인 멀티캐스트 전달 방안

(An Efficient Multicast Delivery Scheme for Mobile IP Network)

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요 약

본 논문에서는 이동 멀티캐스트 프로토콜에서 단말기 핸드오프로 인하여 발생하는 패킷 손실을 최소화하기 위하여 두 가지 새로운 멀티캐스트 전달 방안을 제안한다. 제안된 방식에서는 주 designated multicast service provider (DMSP)와 여분의 백업 DMSP를 사용한다. 모의실험을 통하여 본 논문에서 제안된 방식은 망의 트래픽 증가와 백업 DMSP 수행과 관련된 프로토콜 비용 증가를 통하여 패킷 손실을 크게 줄일 수 있음을 알 수 있다.

Abstract

Two multicast delivery schemes are proposed to minimize the packet loss that occurs in the mobile multicast (MoM) protocol due to the handoff and relocation. The proposed schemes use a primary designated multicast service provider (DMSP) and a redundant or non-redundant backup DMSP. The simulation results verify that the proposed schemes greatly reduce the packet loss rate at the expense of the increased network traffic or the extra protocol overhead related to the operation of the non-redundant backup DMSP.

Keywords : mobile IP, multicast, home agent, foreign agent, packet loss

I. Introduction

Providing multicast support for mobile nodes in an IP internetwork is a challenging problem. The addi-tion of mobility to the host group model implies that the multicast routing algorithm must deal not only with dynamic group membership, but also with dyna-mic group member location. Most multicast routing protocols, such as DVMRP[1], CBT[2], and MOSPF[3], implicitly assume that hosts are static when setting up a multicast delivery tree. Reconstructing the multi-cast delivery tree every time a mobile host (MH) moves is expensive due to the overhead incurred, but leaving the multicast tree unchanged may result in inefficiency or even failure in multicast packet de-livery.

The IETF has proposed two approaches to provide multicast over Mobile IP[4], i.e., remote subscription and bi-directional tunneling.

In remote subscription, the MH resubscribes to the multicast group each time it moves to a new foreign network. It is the simplest way of providing multicast through Mobile IP. There is no special encapsulation needed, and it works well with basic Mobile IP. How-ever, this approach is not suitable for highly mobile users since frequent resubscription in each foreign network may lead to lost packets. Moreover, frequent reconfiguration of the multicast delivery tree may result in substantial control overhead.

In bi-directional tunneling, the MH sends and rece-ives multicast packets by way of its home agent

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(HA) using the unicast Mobile IP tunnels. This app -roach hides host mobility from all other members of the group. Since packets are forwarded from the HA, there is no need of updating the multicast delivery tree due to the MH movement. The main drawback of this approach is the routing path for multicast packet delivery that can be far from optimal. In addi -tion, the HA must replicate and deliver tunneled mul -ticast packet to all its MHs, regardless of at which foreign networks they reside. When many MHs, be -longing to different HAs, move to the same foreign agent (FA), each of the respective HAs creates a separate tunnel to the FA so that multicast packets to their respective MHs can be forwarded. If these MHs were subscribed to the same group, all of the tunnels from different HAs to the FA would carry the same multicast packet, resulting in packet duplica -tion. This is called the tunnel convergence problem.

MoM[5] addressed the tunnel convergence problem by selecting only one HA among the given set of HAs. The selected HA among the given set of HAs is called designated multicast service provider (DM SP). However, this scheme may result in packet loss if the MH belonging to the currently serving DMSP moves out. The FA comes to know about the move -ment of the MH only after its lifetime expires, while the HA comes to know about the movement of the MH as soon as it receives a register message from a new foreign network. As a result, the HA stops sending packets to the old FA, thinking that the MH is no longer in the previous foreign network. So, within the handoff duration and the MH's lifetime, the FA will not receive any packets for that group; hence, there could be packet loss. MMROP[6] is remo -te subscription based approach to provide recipient mobility. MobiCast[7] is designed for an internetwork environment with small wireless cells. It adopts a hierarchical mobility management approach to isolate the mobility of the mobile hosts from the main multi -cast delivery tree.

In this paper, two multicast delivery schemes are proposed to minimize the packet loss that occurs in the MoM protocol with single DMSP during DMSP handoff and relocation. The proposed schemes use a primary DMSP and a redundant or non-redundant backup DMSP. These schemes greatly reduce the pac -ket loss rate at the expense of the increased net -work traffic or the extra protocol overhead related to the operation of the backup DMSP.

The remainder of this paper is divided as follows. A brief description of the MoM protocol with single DMSP is presented in Section Ⅱ. The proposed two schemes to minimize the packet loss during DMSP handoff and relocation are presented in Section Ⅲ. The discrete-event simulation model to evaluate the performance of the proposed schemes is presented in Section Ⅳ. The comparative simulation results and discussions are presented in Section Ⅴ. Finally, Sec -tion Ⅵ presents the conclusions.

Ⅱ. MoM Protocol with Single DMSP

This section provides a description of the MoM protocol with single DMSP. Further details are given in [5].

Each HA maintains an away list to keep track of which of its own MHs are away, where they are (i.e., which FA), and when their bindings expire. Similarly, each FA maintains a visitor list to keep track of which MHs are currently at its network, where these MHs came from (i.e., which HA), and when these bindings expire.

Each HA also keeps track of three lists for each multicast group: a list of away MHs that are mem -bers of the group, a list of the FAs at which the away group members reside, and a list of the FAs for which the HA has DMSP responsibilities. Similar -ly, each FA keeps track of three lists on a per group basis: a list of visiting MHs that are members of the multicast group, a list of HAs to which these visiting group members belong, and a list of the HAs that are currently serving as DMSPs for this group.

When a MH arrives at a foreign network, this event updates the visitor list at the FA and the away list at the HA, and updates three group lists at both agents so that the DMSP status determined by the

FA is known by the HA. Note that each FA makes the DMSP decision independently for each multicast group.

When a MH arrives at its home network, this event updates the away list and three group lists only at the HA. Similar updates of the visitor list and three group lists at the former FA are handled by timer expiration. The expiration of a timer at a foreign network may result in a DMSP handoff for some multicast groups.

When a MH moves from a foreign network to another network (home or foreign), there is a possibility for a temporary disruption of multicast packet delivery for other mobile hosts on the previous foreign network. This temporary multicast service outage stems from the fact that in Mobile IP there is no explicit deregistration with the FA when a host moves out. The MH's HA learns of the movement when the MH reregisters at the new network, but the FA at the old foreign network learns about the movement only through a timeout. In the case that the moving host's HA was the DMSP for a group at the previous foreign network, a DMSP handoff will be required to a different HA to forward multicast packets for the remaining multicast group members at the foreign network. Until this DMSP handoff completes, multicast packet delivery for group mem-bers at the foreign network may be disrupted.

III. MoM Protocol with Backup DMSP

This section provides a description of the modified MoM protocol to minimize the packet loss that occurs in basic MoM protocol with single DMSP during DMSP handoff and relocation. In modified MoM protocol, each FA selects a primary DMSP and a backup DMSP whenever the number of visiting MHs at the FA changes. A backup DMSP can not be selected at a FA if all the visiting MHs at the FA are from one home network.

There are two schemes according to the operation of the HA which is designated as a backup DMSP. In the first scheme, both the primary and the backup DMSPs send multicast packets to the corresponding FA. This is redundant backup DMSP scheme. If one of these DMSPs stops forwarding packets, the FA can rely on the other for multicast packet delivery, thereby greatly reducing any packet loss for the MHs. This redundant backup DMSP scheme provides trade-off between the packet loss rate and the network traffic generated by multicast packet delivery. By using the redundant backup DMSP, the packet loss rate can be greatly reduced, but the network traffic is increased at most twice as much as the single DMSP case.

In the second scheme, only the primary DMSP sends multicast packets to the corresponding FA and the backup DMSP is in the standby mode. While the backup DMSP in standby mode receives multicast packets from the multicast source, it does not send them to the corresponding FA. This is non-redundant backup DMSP scheme. The primary DMSP keeps on sending multicast packets to the corresponding FA until its last MH at the FA moves elsewhere. At this point in time, the primary DMSP informs the FA that it is no longer willing to provide the multicast service for the FA. Then the FA changes the backup DMSP as a primary DMSP and selects a new backup DMSP, if available. Since the backup DMSP was receiving the multicast packets from the multicast source, it can simply forward these packets to the corresponding FA with minimal added delay. Thus, the packet loss rate for the non-redundant backup DMSP scheme becomes almost zero. Also, the network traffic for the non-redundant backup DMSP scheme is relatively low. It is a little bit higher than the network traffic of the MoM protocol with single DMSP. The only cost we should pay in this non-redundant backup DMSP scheme is to maintain the backup DMSP in standby mode and a little protocol overhead related to the processing of DMSP status.

IV. Simulation Model

This section provides a description of the discrete-event simulation model to evaluate the performance

표 1. 네트워크 모의실험 파라메타
Table 1. Network and Workload Parameter.

Parameter	Description	Value
N	Number of LANs	5
H	Host per LAN	10
TO	Registration timeout value (in time units)	30, 60, 90
M	Number of multicast groups	1
g	Multicast group size	5..50
λ	Multicast message generation rate (msgs/time unit)	0.1

of the MoM protocol with backup DMSP, relative to the previous approaches. It is assumed that there are N local area networks (LANs), each with H mobile hosts. Each LAN has an associated HA and FA. In the simulation model, MHs can be in one of two states: at the home network or at a foreign network. Foreign networks to visit are chosen equiprobably at random, while the homing probability after each visit to a foreign network is 0.5. The residency time for each visit to a network (home or foreign) is drawn from an exponential distribution with a mean of 60 time units, and the travel time for going between net-works (regardless of distance) is exponentially distri-buted with a mean of 15 time units. The network topology between the LANs is not explicitly modeled in this simulation. Thus, hosts spend 20% of their time in transit, and 80% of their time connected to a LAN (53.3% at foreign networks, and 26.7% at home network).

It is assumed that there are M multicast groups. For each multicast group, group members are chosen equiprobably at random and there is a single multi-cast source. Also, it is assumed that each MH has a static membership of multicast groups during a simu-lation. Multicast messages are generated in a Pois-son fashion with message arrival rate .

Table 1 summarizes the main network and worklo-ad parameters used in the simulation experiments. In the simulation, the multicast group size was varied from 5 to 50 and the HA entry that has been in the HA list the longest time is chosen as the DMSP by the FA.

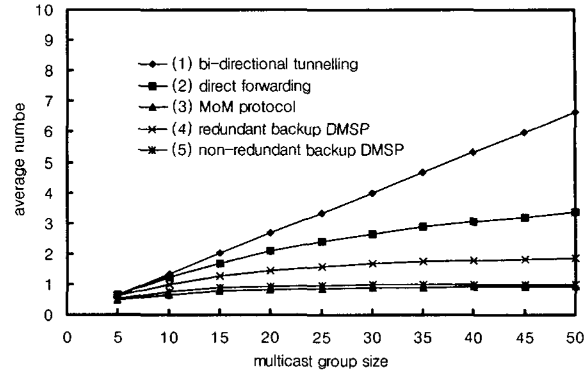

그림 1. 이동 멀티캐스트 프로토콜의 스케일 특성 (TO = 60 time units)
Fig. 1. Scaling characteristics of mobile multicast proto-cols (TO = 60 time units).

V. Simulation Results

The first simulation experiment compares the performance of the MoM protocol with backup DMSP to the previous approaches in terms of the network traffic generated by multicast packet delivery. Figure 1 shows how various aspects of the mobile routing environment scale as the multicast group size is in-creased. In this simulation, the oldest-HA DMSP selection policy[5] was used. Thus, the HA entry that has been in the HA list the longest time is chosen as the DMSP by a FA.

The five lines in Fig. 1 are: (1) the average num-ber of a HA's mobile hosts that are multicast group members who are away from the home network; (2) the average number of foreign networks (i.e., FAs) at which these mobile multicast group members reside; (3) the average number of foreign networks for which the HA is the DMSP for the MoM protocol with single DMSP; (4) the average number of foreign networks for which the HA is the DMSP(primary or backup) for the redundant backup DMSP scheme; and (5) the average number of foreign networks for whi-ch the HA is the primary DMSP for the non-redundant backup DMSP scheme.

The network traffic generated by multicast packet delivery is greatly affected by the way in which the multicast packets are forwarded to the mobile hosts served by a HA. The most efficient method is the remote subscription approach. This simulation experiment does not include the remote subscription method.

Bi-directional tunneling requires that each HA forwards all multicast packets from groups to which its MHs are subscribed, to each MH individually. The number of packets transmitted in this approach corresponds to the average number of MHs away from home (line 1).

The number of packets delivered using direct forwarding by each HA scales with the number of FAs visited (line 2). This is because each HA will forward multicast packets to each FA where its MHs are visiting.

DMSP forwarding (lines 3-5) improves upon this by restricting the number of forwarding HAs for each foreign network to some small constant number. MoM protocol with single DMSP (line 3) shows the best performance results in terms of the network traffic generated by multicast packet delivery. Note that the average number of FAs for which a HA has DMSP responsibilities is less than 1. This is because each FA assigns only one DMSP.

For the redundant backup DMSP scheme (line 4), the average number of FAs for which a HA has DMSP responsibilities is increased approximately twice as much as the single DMSP case. This is because each FA assigns a primary and a backup DMSPs, if available, and both DMSPs transmit multicast packets redundantly. However, by using this redundant back-up DMSP scheme, the packet loss rate can be greatly reduced as shown in Fig. 2. Thus, the redundant backup DMSP scheme provides trade-off between the packet loss rate and the network traffic.

For the non-redundant backup DMSP scheme, the average number of FAs for which a HA has the primary DMSP responsibilities is a little bit higher than that of the single DMSP case (line 5). This is because, in the non-redundant backup DMSP scheme, the backup DMSP becomes the primary DMSP as soon as the FA is informed that the former primary DMSP stops its role due to the MH movement. Note that the network traffic of the non-redundant backup

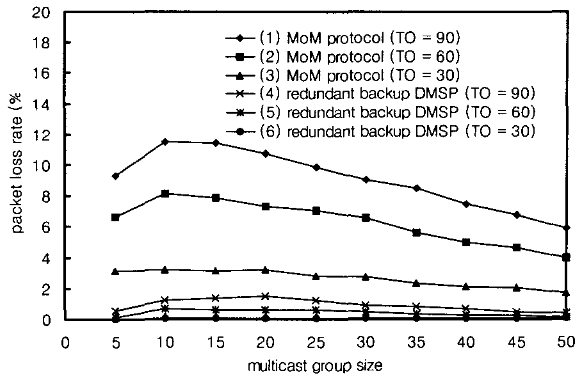

그림 2. MoM 프로토콜과 여분의 백업 DMSP 방식의 패킷 손실률

Fig. 2. Packet loss rates of the MoM protocol and the redundant backup DMSP scheme.

DMSP scheme is equal to that of the single DMSP case with timeout value of zero.

The second simulation experiment was conducted to study the degree of packet losses due to DMSP handoff, varying the timeout value and the multicast group size. Figure 2 shows the packet loss rates of both the single DMSP and the redundant backup DMSP schemes with various timeout values. The packet loss rate is defined as the ratio of the number of packets lost due to DMSP handoff to the number of packets that is to be delivered to the multicast group members.

From the simulation results, it is shown that the packet loss rate increases as the timeout value at the FA increases for both schemes. This is because the larger the timeout value, it takes more time for the FA to recognize the departure of the visiting MH and perform DMSP handoff in the case that the moving host's HA was the DMSP. Until this handoff completes, multicast packet delivery for group members at the foreign network may be disrupted. By using small timeout value at the FA, the packet loss rate can be reduced. However, the processing overhead to check the existence of a MH at every timeout interval increases. Thus, there is a trade-off between the packet loss rate and the processing overhead at the FA.

For the single DMSP scheme operating at the time-out value of 60 time units and multicast group size of 50, the packet loss rate is about 4%. For the redundant backup DMSP scheme operating at the same parameters, the packet loss rate is reduced to 0.14%. In Fig. 2, it is shown that the packet loss rates of the redundant backup DMSP scheme opera-ting at the timeout value of 60 time units are under 0.67% for all group sizes. By using the redundant backup DMSP scheme, the packet loss rate can be greatly reduced at the expense of the increased net-work traffic as shown in Fig. 1.

Finally, the non-redundant backup DMSP scheme has no packet loss that occurs due to the DMSP han-doff, and it shows almost the same network traffic as the single DMSP scheme. However, this scheme requires extra protocol overhead related to the opera-tion of the standby mode for the backup DMSP.

VI. Conclusions

In this paper, two multicast delivery schemes were proposed to minimize the packet loss that occurs in the MoM protocol with single DMSP during handoff and relocation. The first scheme uses a redundant backup DMSP and reduces the packet loss rate at the expense of the increased network traffic. The second scheme uses a non-redundant backup DMSP and ex-hibits many desirable features such as the almost -zero packet loss rate and the low network traffic at the expense of the extra protocol overhead related to the processing of non-redundant backup DMSP.

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