Multicast Routing Protocol in Mobile Networks

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Abstract - **Providing multicast service to mobile hosts is difficult due to frequent changes of mobile host location and group membership. To overcome the difficulty, several multicast protocols for mobile hosts have been proposed. But they include glitches such as a non-optimal delivery route, duplicated datagrams, and overheads caused by the frequent reconstruction of a multicast tree. In this paper, we summarize these problems and propose an efficient multicast protocol. The proposed protocol reduces data delivery path length and decreases not only the amount of duplicated data but also multicast traffic load. The performance of the proposed protocol was evaluated by simulation and we got an improved performance.**

I. INTRODUCTION

Rapid progress in hardware technology has made computers compact, powerful, and low-cost. Furthermore, the recent advance in data communication technology has spawned an increasing demand for various services over networks irrespective of users' location. As a result, we have witnessed an explosive growth of research and development efforts in the field of wireless mobile networks [4,10].

Recently, providing multicast services to hosts becomes popular and many multicast protocols have been proposed. However, Many of existing multicast proposals were designed assuming static hosts, which do not work well in mobile environments. Upon designing a multicast protocol for mobile users, we should consider the characteristics of wireless mobile networks – limited bandwidth, error-prone links, frequent handoff, limited battery life, etc. Several existing protocols designed for mobile hosts also have problems such as non-optimal delivery path, datagram duplication, etc.

In this paper, we propose an efficient multicast protocol using a multicast agent, where a mobile host receives a tunneled multicast datagram from a multicast agent located in a network close to it or directly from the multicast router in the current network. The proposed protocol reduces network traffic load by decreasing the number of duplicated datagrams and reduces multicast data delivery path length since datagrams are forwarded to mobile hosts by multicast agents close to the current network. We studied the performance of the proposed protocol by simulation and we got an improved performance over existing protocols.

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II. BACKGROUND AND RELATED WORK

The current IETF Mobile-IP specification briefly proposes two approaches for supporting multicast to mobile hosts [12-14]: foreign agent-based multicast (referred to as remote-subscription), and home agent-based multicast (referred to as bi-directional tunneling) [5,8].

In foreign agent-based multicast, a mobile host has to subscribe to multicast groups whenever it moves to a foreign network. It is very simple scheme and does not require any encapsulations. This scheme has the advantages of offering an optimal routing path and nonexistence of duplicated packets. However, when the mobile host is highly mobile, its multicast service may be very expensive because of the difficulty in managing the multicast tree. Furthermore, the extra delay incurred from rebuilding a multicast tree can create the possibility of a disruption in multicast data delivery.

In home agent-based multicast, data delivery is achieved by unicast Mobile IP tunneling via the home agent: when the home agent receives a multicast datagram destined for a mobile host, it encapsulates the datagram twice (with the mobile host address and the care-of-address of the mobile host) and then transmits the datagram to the mobile host as a unicast packet. Consequently, if multiple mobile hosts that belong to the same home network visit the same foreign network, duplicated copies of multicast packets will arrive at that foreign network as shown in Figure 1.

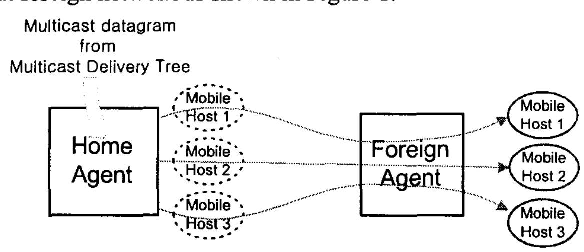

Fig. 1. Multicast data duplication problem in home agent-based multicast

In [8], Harrison et. al., proposed a home agent based protocol called MoM (Mobile Multicast), where a home agent is responsible for tunneling multicast datagrams to the mobile host. However, the home agent forwards only one copy of the multicast packet to each foreign network that contains its mobile hosts. Upon receiving the multicast packet, a foreign agent delivers it to mobile hosts using link-level multicasting. But there still exists a problem, referred to as the tunnel convergence problem [5,8] (see Figure 2), resulting from the

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fact that multiple tunnels from different home agents can terminate at one foreign agent. To solve this problem, the foreign agent appoints one home agent as the DMSP (Designated Multicast Service Provider) for the given multicast group. The DMSP forwards only one datagram into the tunnel, while other home agents that are not the DMSP do not forward the datagram.

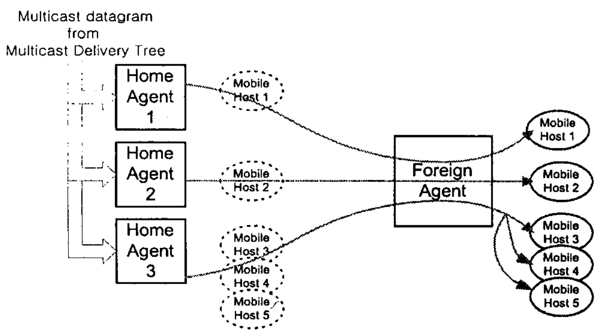

Fig. 2. Tunnel convergence problem

The MoM protocol reduces multicast traffic by decreasing the number of duplicated datagrams. However, multicast datagrams from both the DMSP and a multicast router can cause a duplication since it is possible that local static hosts in the foreign network are members of the same group as the visiting mobile hosts (see Figure 3). Moreover, this approach uses a non-optimal delivery route since a home agent (DMSP) forwards the multicast datagram to tunnels leading to each foreign agent (see Figure 4).

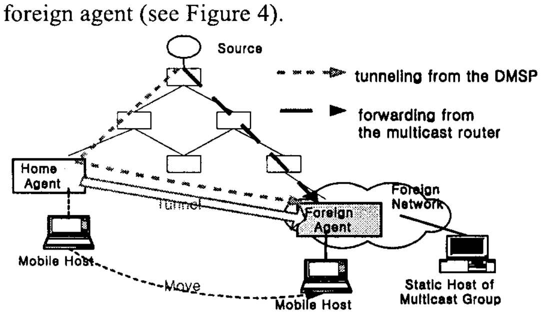

Fig. 3. Multicast data duplication problem

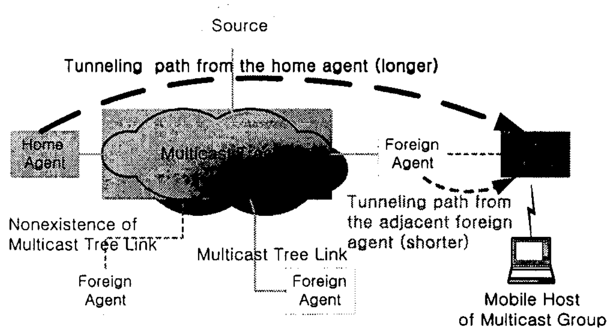

Fig. 4. Inefficient tunneling problem

III. PROPOSED MMA PROTOCOL

A. *Protocol Overview*

The proposed MMA (Multicast by Multicast Agent) protocol introduces Multicast Agent (MA) and Multicast Forwarder (MF). MAs provide multicast service to mobile hosts. Each MA has one MF per multicast group and the MF of an MA is the MA that forwards multicast datagrams to it. The MF of an MA may be the MA itself when its local network is included in the multicast tree, or the MF can be an MA in another network that belongs to the multicast group when its local network is not covered by the multicast tree.

When a mobile host moves from a network (e.g., N1) to another network (e.g., N2), different events occur according to the states of N2 and the mobile host. First, the mobile host sends its MF information to the MA in N2 during registration, which is used by the MA for selecting the new MF. If N2 belongs to the multicast delivery tree, the MA itself becomes the MF. The MA and the mobile host update the MF information with the MA. If the MA in N2 does not belong to the multicast delivery tree, the MF value that the mobile host had in N1 is used as the MF in N2. Optionally, the MA in N2 selects one that is closer to it, between the MF information that the MA has and the MF that the mobile host had in N1. The MA and the mobile host update the MF value with the selected MA. A mechanism of multicast tree join processing may also be required by visiting mobile hosts according to the optional function of mobile hosts. This multicast tree join processing is similar to that in the foreign agent-based multicast mechanism. It is very efficient when the mobility of a mobile host is low. While setting up a connection to the multicast tree, a mobile host receives forwarded data from its MF, and thus there is no service disruption period. Figure 5 shows the basic operation of the MMA protocol.

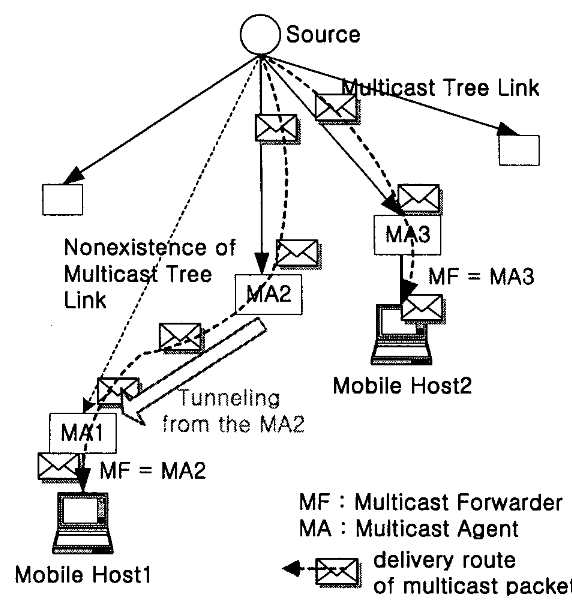

Fig. 5. Operation of the MMA protocol

B. Data Structure

Figures 6 and 7 illustrate the group information table for a mobile host and an MA, respectively. Each mobile host has information of group ID, current MF, and join_option. The join_option is used when mobile hosts want multicast tree join processing. Each MA maintains the information of group ID, current MF, the number of static hosts of the multicast group, a list of visiting mobile hosts that are members of the multicast group, and a list of the foreign agents that receive multicast datagrams through tunneling from the MA. The group membership is certified by checking the N_SH, MHs List, and FAs List.

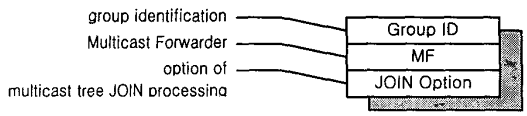

Fig. 6. Group Information Table for a mobile host

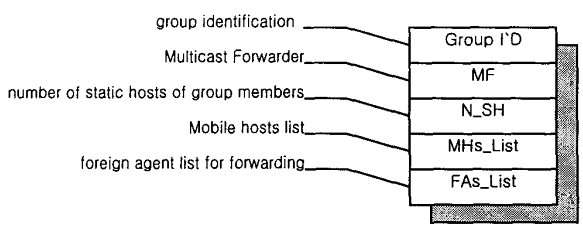

Fig. 7. Group Information Table for an MA

When a host moves into a new network and registers with a new MA, this group information for the mobile host may be sent to the MA using a previous foreign agent notification format that is included in the registration request message extension [12,13]. The information on the forwarding mechanism including forwarding REQUEST/STOP messages can be exchanged among MAs using the binding update message. This processing is based on the unicast routing of standard Mobile IP and can be implemented by the route optimization or other methods of Mobile IP implementations.

C. Algorithmic Description

The operation of a mobile host is similar to that in Mobile IP. A difference is that message extension is needed for the processing of registration with an MA. A mobile host is responsible for managing and submitting the group information table to a new network.

The operation of an MA depends on various events, such as host arrival, host departure, multicast data arrival, and control message arrival. The operation of an MA can be summarized using the event driven algorithms as follows:

a) When a mobile host (MH) that is a member of a multicast group arrives:

```
IF (Registration Request Message is received from a MH) {
    Take the information (Group ID, MF, JOIN Option) ;
    IF (Group ID is already registered in Group Information Table) {
        Add MH to MHs List;
        Select new optimal MF;
        IF (New MF equals to the MF of MA) {
            Notify new MF to MH;
        } ELSE {
            Notify new MF to all mobile hosts except MH;
            Update MF of MA with new MF;
            Send Forwarding REQUEST message to new MF;
            Send Forwarding STOP message to old MF;
        }
    } ELSE {
        Make new group entry;
        Add MH to MHs List;
        Set up MF of MA with MF of MH;
        Send Forwarding REQUEST message to new MF;
        Send Forwarding STOP message to old MF;
    }
    IF (Multicast router exists && Host requests tree JOIN process)
        Send join message for connection to multicast delivery tree;
}
```

b) When a multicast datagram arrives:

```
IF (Group entry exists in Group Information Table) {
    Transmit multicast data to all MHs in MHs_List;
    Transmit multicast data to all agents in FAs_List through tunnels;
}
```

c) When a mobile host (MH) that is a member of a multicast group leaves the current network (according to soft-state, MA detects the movement of a mobile host by time-out):

```
IF (Time-out occurs for MH) {
    Delete MH from MHs_List in all group entries joined by MH;
    IF (Group member doesn't exist in group entry anymore) {
        IF (MF equals to itself) {
            /* The network belongs to multicast delivery tree */
            Send PRUNE message;
        } ELSE {
            /* The multicast data is forwarded from MF */
            Send Forwarding STOP message to MF;
        }
        Delete group entry from Group Information Table;
    }
}
```

d) When a control packet from another MA arrives:

```
IF (Forwarding STOP message is received) {
    Delete the agent from FAs_List in group entry;
    IF (Group member doesn't exist in group entry anymore)
        Send PRUNE message;
} ELSE IF (Forwarding REQUEST message is received)
    Add the agent to FAs_List in group entry;
```

e) When a connection to the multicast tree is completed:

```
IF (Group entry exists in Group Information Table) {
        Send Forwarding STOP message to MF in the group entry;
} ELSE
        Make new group entry;
Set up MF of MA with it;
Send Registration Reply Extension message including the MF information
to all MHs in MHs_List;
```

The proposed MMA protocol offers better (sub-optimal) delivery route than home agent-based protocols since the forwarding pointer (i.e., MF) is generally located in an adjacent network that is included in the multicast delivery tree. In addition, the MMA protocol reduces the number of duplicated datagrams and total amount of tunneling since multicast datagrams can be forwarded directly from the multicast router in the current network.

IV. PERFORMANCE EVALUATION

We have evaluated performance of the proposed protocol using a discrete-event simulation. We assumed that 400 LANs are located on the x-y coordinate system, with the x and y coordinates are chosen uniformly at random for each LAN. This set of LAN locations is fixed for each simulation time. In a randomly selected network model, the initial multicast tree is established for a randomly selected set of LANs and the initial tree has two modes: sparse and dense. In the sparse mode, group members are distributed sparsely across the overall network, while group members are centralized in the dense mode. Mobile hosts show diverse mobility rates ranging from 1 (low) to 5 (high).

We evaluated performance of the MMA protocol with various numbers of mobile hosts, various sizes of the initial multicast tree, and various rates of host mobility, in both the initial multicast delivery tree modes. The shortest path length between two LANs is measured by the Shortest-Path Euclidean Distance, and we used generic time units. We assumed that there is a single source and it is selected randomly and is fixed during the simulation time. Table 1 summarizes the parameters used in our simulation study.

[Table 1] Simulation Parameters

Parameter	Description	Values
N	number of LANs	400
T	number of initial tree nodes	10-90
H	number of mobile hosts per LAN	1-29
MR	host mobility rate	1-5
α	service time	5 units
β	join delay	1 unit
Time	total simulation time	100-1000 units

We compared the performance of the proposed MMA protocol with the MoM protocol and the home agent-based multicast protocol. The main features considered are the amount of multicast data traffic per unit time and average delivery path length per mobile host. In addition, we observed a scaling characteristic of the protocols with multicast group size and a comparison of DMSP handoff with MF handoff. The results are illustrated in Figures 8-11.

Total network traffic generated by a multicast delivery is the sum of the traffic occurred on the multicast tree and the traffic occurred by tunneling from the forwarding pointer to the mobile host. Thus we can compare the additional traffic by tunneling in the protocols. The number of tunneling is proportional to the number of mobile hosts in the home agent based multicast protocol, the number of foreign networks which has mobile hosts having multicast membership in the MoM protocol, and the number of MAs which receive data forwarded by an MF. Figure 8 compares these in sparse mode as a function of H when T=50 and MR=3. As shown, the proposed MMA protocol shows better performance in the network traffic generated by a multicast delivery.

Figure 9 shows the average delivery path length (relative to optimal) in MoM and MMA protocols as a function of tree size, when the optimal path length (in foreign agent-based protocol) is 1, MR=3, and the range of H is 1-29. As shown, MMA shows an improved performance and the difference becomes larger for large tree sizes.

We divided the delivery path into a tree path and a tunnel path and compared them in detail. In Figure 10, the top plot shows the difference in tree path length of MMA and MoM protocols (that is, tree path length of MMA - tree path length of MoM), the bottom plot shows the difference in tunnel path length of MMA and MoM protocols (that is, tunnel path length of MMA - tree path length of MoM), and the middle plot shows difference in total path length of MMA and MoM protocols (that is, total path length of MMA - total path length of MoM). The middle plot is just the sum of the top and bottom plots. As shown in the figure, MoM shows shorter tree path length than MMA, but MoM shows much more tunnel path length than MMA. As a result, MMA shows less total path length than MoM.

Figure 11 compares the number of MF handoffs in MMA protocol with the number of DMSP handoffs in MoM. As shown, MF handoff frequency in MMA is much less than DMSP handoff frequency in MoM. Frequent handoffs of MF or DMSP cause much traffic in networks, which increases network overhead, and causes performance degradation due to the out-of-service period during a handoff.

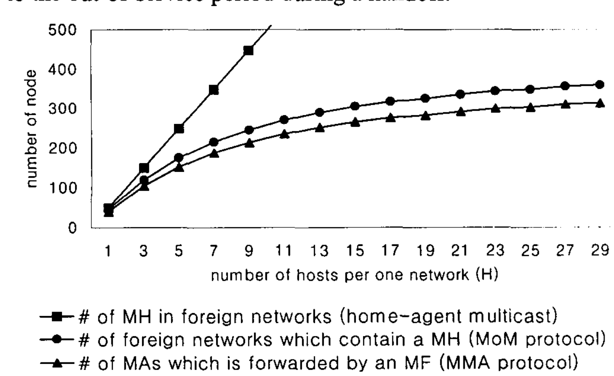

Fig. 8. Comparisons of network traffic (sparse mode)

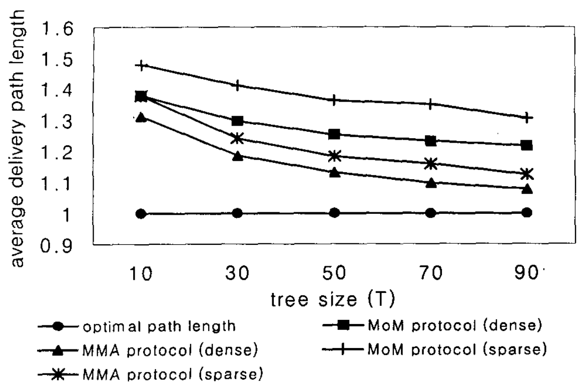

Fig. 9. Comparisons of multicast data delivery path length T=(10-90), MR=3, H=(1-29)

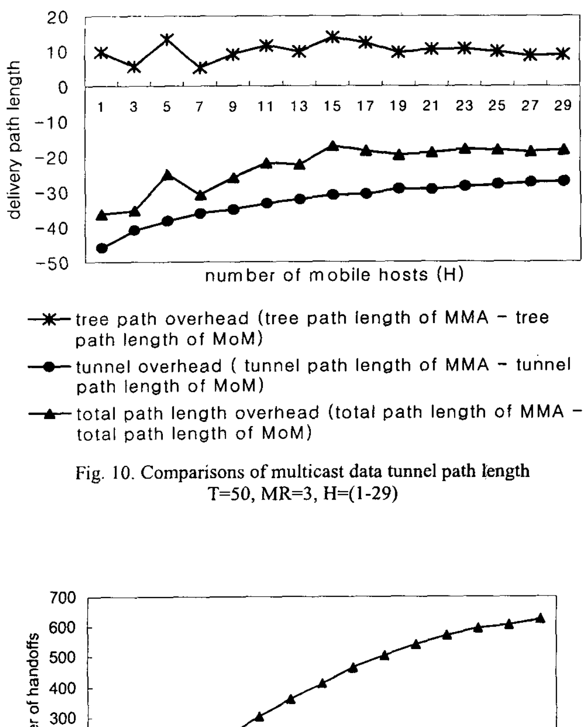

Fig. 10. Comparisons of multicast data tunnel path length T=50, MR=3, H=(1-29)

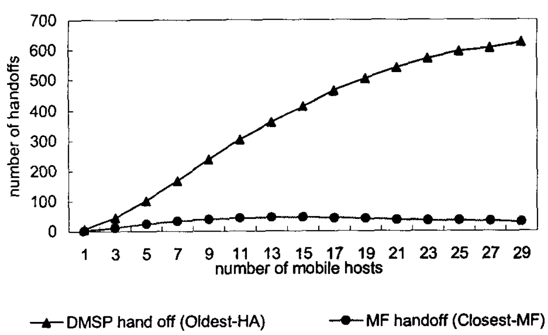

Fig. 11. Comparisons of handoff rate (sparse mode) T=50, MR=3, H=(1-29)

V. CONCLUSION

In this paper, we propose an efficient multicast protocol supporting host mobility. The proposed MMA protocol uses multicast agents, where a mobile host receives multicast datagrams through a tunnel from a selected multicast agent, called multicast forwarder, located a network close to the current network or directly from the multicast router in the current network. The protocol reduces network traffic by decreasing the number of duplicated datagrams and reduces multicast data delivery path length since datagrams are forwarded to mobile hosts by multicast agents close to the current network or directly from the multicast router in the current network.

We examined and compared the performance of the proposed protocol and existing protocols by simulation under various environments and we got improved performance over the existing solutions.

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