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Mobile Multicast Support using Old Foreign Agent (MMOFA)

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Abstract**—**IP multicasting is a key technology for many existing and emerging applications on the Internet. Furthermore, with increasing popularity of wireless devices and mobile equipment, it is necessary to determine the best way to provide this service in a wireless environment. IETF Mobile IP, that provides mobility for hosts in IP networks, proposes two approaches for mobile multicasting, namely, remote subscription (MIP-RS) and bi-directional tunneling (MIP-BT). In MIP-RS, a mobile host re-subscribes to the multicast groups each time it moves to a new foreign network. MIP-RS suffers from serious packet losses while mobile host handoff occurs. In MIP-BT, mobile hosts send and receive multicast packets by way of their home agents (HAs), using Mobile IP tunnels. Therefore, it suffers from inefficient routing and wastage of system resources. In this paper, we propose a protocol called Mobile Multicast support using Old Foreign Agent (MMOFA) for Mobile Hosts. MMOFA is derived from MIP-RS and with the assistance of Mobile host's Old foreign agent, routes the missing datagrams due to handoff in adjacent network via tunneling. Also, we studied the performance of the proposed protocol by simulation under ns-2.27. The results demonstrate that MMOFA has optimal routing efficiency and low delivery cost, as compared to other approaches.

Keywords**—**Mobile Multicast, Mobile IP, MMOFA, NS-2. 27.

I. INTRODUCTION

RECENTLY, Mobile Hosts (MHs) such as laptop computers spread explosively and mobile communications is developing. In order to continue seamless Internet Protocol (IP) communication, Mobile IP [1] is widely studied. In Mobile IP, Home Agent (HA) and Foreign Agent (FA) are introduced. When a MH leaves its home network and enters a foreign network, MH should acquire a care of address (CoA) from FA, and HA registers CoA with own table to notify the current location of MH. HA intercepts IP packets destined to MH from corresponding host (CH) and forwards them to MH using IP tunneling. CH can continue seamless communication with a MH in Mobile IP environment.

IP Multicasting is a key technology for many existing and emerging applications on the Internet. The concept of multicasting was introduced by Steve Deering [2] in the late ’80s. Adding multicast to the Internet does not alter the basic model of the network. Any host can send multicast data, but with a new type of address called a host group address. IPv4 has reserved class D addresses to support multicasting. A user can dynamically subscribe to the group to receive multicast traffic by informing a local router that it is interested in a particular multicast group. However, it is not necessary to belong to a group to send multicast. The delivery of multicast traffic in the Internet is accomplished by creating a multicast tree, with all its leaf nodes as recipients.

Providing multicast support for mobile hosts in an IP inter-network is a challenging problem, for several reasons. First, the addition of mobility to the host group model [3] implies that multicast routing algorithms must now deal not only with dynamic group membership, but also with dynamic member location. Second, the current multicast protocols on the Internet, DVMRP [4], MOSPF [5], and PIM [6], implicitly assume static hosts when building a multicast delivery tree. They do not consider the dynamic member location. Reconstructing the delivery tree every time a member moves will involve the overhead; yet leaving the tree unchanged can result in inefficient, incorrect, or even failure of multicast datagram delivery. Thus they are not suitable for the mobile environment.

The current version of Mobile IP proposes two approaches to support mobile multicast, i.e., bidirectional tunneling and remote subscription. In the MIP-BT, the mobile host receives multicast datagrams by way of its home agent using the unicast Mobile IP tunnels. This approach handles source mobility and recipient mobility, and in fact hides host mobility from all other members of the group. Therefore, the multicast delivery tree will not be updated because of member location change. The main drawback of the approach is the routing path for multicast delivery which can be far from optimal. In addition, the HA must replicate and deliver tunneled multicast datagram to all its MHs, regardless of at which foreign networks they reside. Therefore, the network resource will be wasted.

In MIP-RS, each MH always resubscribes to its desired multicast group when it enters a foreign network. Therefore its local multicast router must be added to the multicast tree. The update frequency of the multicast tree will depend on how often the mobile handoff occurs. Obviously, remote subscription has better performance if mobile hosts spend a

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longer time within a network, compared with the join and graft latencies [7]. The main advantage of this approach is that the multicast datagrams are always delivered on the shortest paths. However, the overhead is the cost of reconstructing the delivery tree while a handoff occurs. Also the source mobility is not handled.

In this paper, we propose a protocol called Mobile Multicast support using Old Foreign Agent (MMOFA) for Mobile Hosts. MMOFA is derived from MIP-RS and with the assistance of Mobile host's Old foreign agent, routes the missing datagrams due to handoff in adjacent network via tunneling. Also, we studied the performance of the proposed protocol by simulation under ns-2.27 [8] and we got an improved performance over existing protocols.

The rest of the paper is organized as follows. Section II presents the background and previous works. Section III presents our MMOFA protocol. Section IV evaluates the performance and compares MMOFA with the other protocols. Finally, paper conclusion is presented.

II. Background and Related Works

The MIP-BT solution for multicast over Mobile IP creates an interesting situation when many MHs, belonging to different HAs, move to the same foreign agent (FA). According to MIP-BT, 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 (Fig. 1), resulting in packet duplication. This is called the **Tunnel convergence** problem. MoM [9]-[11] based on MIP-BT uses the DMSP (Designated Multicast Service Provider) to avoid duplicate datagram being tunneled to the common FA. In this protocol, the FA performs a selection to appoint one HA as the DMSP. Only DMSP forwards the multicast datagram to the foreign agent. Thus, the FA can only receive one copy of each multicast datagram. For example, in figure 1, one of home agents HAa, HAb, and HAc is selected as the DMSP. Only one copy (rather than three) of the datagrams will be received by FA. We can find that this protocol has better performance particularly as the number of mobile group members increases. Although this approach addresses the problem of packet duplication, it may result in temporary disruption of service if the MH belonging to the DMSP moves out of the FA and it is the only MH belonging to the DMSP in the FA. According to Mobile IP specifications, the FA may know about this event only if the registration time expires and till a new DMSP is selected, there may be disruption of service to the MH. Although MoM suggests selecting more than one DMSP at a given time, it results in packet duplication.

RBMoM [12], [13] that is an enhancement of MoM intends to trade off between the shortest delivery path and the frequency of the multicast tree reconfiguration. It selects a router, called a multicast HA (MHA), which is responsible for tunneling multicast packets to the FA to which the MH is currently subscribed. The MHA can only serve MHs that are roaming around foreign networks and are within its service range. If an MH is out of service range, MHA handoff will occur. Initially, the MHA of a MH set to its HA. Every MH can have only one MHA, which changes dynamically with the location of the MH, whereas the HA of an MH never changes. This protocol requires that each MHA be a multicast group member.

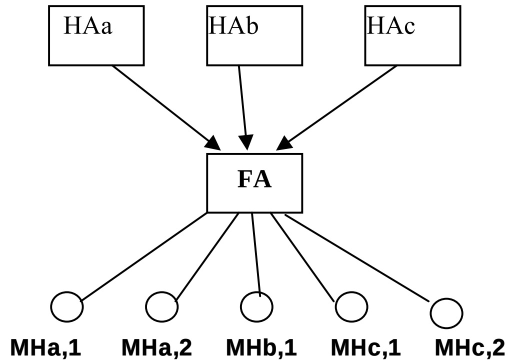

Fig. 1 Tunnel convergence problem

A framework to handle multicast source movement over Mobile IP is proposed in [14]. In case an MH is serving as both source and recipient of a multicast group, during the movement to a new FA it creates a bidirectional tunnel from its new FA if needed. In the meantime, the FA initiates a multicast tree join in case it is not presently subscribed to the multicast group. Once it starts receiving multicast packets through the tree, it disassociates its reverse tunnel to the HA and only keeps the forward tunnel to send multicast packets.

MMP [15] is used to address micro level mobility for multicasting over Mobile IP. MMP provide fast and efficient handoffs for MHs in foreign networks and enable location-independent addressing. It combines Mobile IP and CBT where the former controls communication up to the foreign network and the latter manages movement of hosts inside them.

MobiCast [16] is designed for an internetwork environment with small wireless cells. In MobiCast many cells grouped together and served by domain FAs (DFAs). DFAs are multicast FAs and are meant to isolate the mobility of the MH from the main multicast delivery tree. This hierarchical mobility management approach isolates the mobility of the MHs from the main multicast delivery tree.

AMRM [17] is a local recovery based reliable multicast routing protocol. It still has the advantage of quick recovery, but the amount of buffer required in AMRM to store recovery data is reduced greatly. In AMRM, each base station adaptively adjusts the amount of packets stored in its buffer according to the ratio of unsuccessful handoff it observed in its subnet. If this ratio is larger than a designate threshold, base station increases the amount of packets it keeps in the buffer; on the contrary, if this ratio is lower than another

TABLE I
A COMPARISON OF IP-BASED WIRELESS MULTICAST ROUTING PROTOCOL

	MOM	MIP-BT	MIP-RS	MMROP	RM2	RMMP	MobiCast	MMP	AMRM
Optimal routing	NO	NO	Yes	Yes	Yes	Yes	Yes	No	Yes
Multicast Protocol Dependency	No	No	No	No	No	No	No	CBT	No
Join & Graft delays	NO	NO	Yes	Yes	Yes	Yes	Yes	No	Yes
Packet Redundancy	Minimal	Yes	No	Minimal	NO	Yes	Minimal	Minimal	Minimal
Reliability	No	No	No	Yes	Yes	Yes	No	No	Yes

designate threshold, base station can decrease the amount of packets kept in its buffer. In this way, only necessary packets are kept and the corresponding buffer size is small. The unsuccessful handoff is the cost that AMRM pays for. But the number of unsuccessful handoff can be restricted to a small value. Compared to other factors, such as blackout in wireless channel, out of power of mobile host, the unreliable transmission due to unsuccessful handoff is ignorable.

RM2 [18] is a reliable multicast protocol that can be used for both wired and wireless environments. Furthermore, RM2 guarantees sequential packet delivery with no packet loss to all its multicast members. RM2 relies on the Internet Group Management Protocol (IGMP) [19] to manage group membership, and on the IETF's Mobile IP to support host mobility.

MMROP [20] is MIP-RS based approach that employs a modified join and leave mechanism and extend mobility agent in Mobile IP to assist multicasting for mobile hosts. RMMP [21], [22] and RMDP [23] are **reliable multicast routing protocols** running over mobile IP. Table I compares various wireless multicast routing protocols.

III. Proposed Protocol

A. Assumptions and Design Goals

The following assumptions have been made in the design of our protocol:

- The service to be provided is the **unreliable, best effort, connectionless delivery of multicast datagrams**, i.e., datagrams may be lost, duplicated, delayed or delivered out of order. Higher level protocols are responsible for handling such conditions.
- Multicast support must conform to the host group model.
- A mobile host that wishes to receive multicast datagrams is capable of receiving them on its home network using existing (static) multicast techniques.
- The home agents and foreign agents are static (not mobile) hosts.
- IETF Mobile IP used for mobility management.
- In the proposed protocol, mobility agents in Mobile IP (HA & FA) extended to assist multicasting for mobile hosts.

Our design goals include:

Scalability: The protocol should work well even when the number of mobile hosts in the internetwork is large (which it soon will be). Clearly, the protocol should work for both small and large multicast groups.

Robustness: The disruption of multicast service due to movement of a host from one network to another must be minimal.

Simplicity: We would like the scheme to be as simple as possible, in the sense that it be able to interoperate with existing Internet protocols and mechanisms, with as few changes as possible.

Optimal routing: Multicast datagrams are always delivered to mobile hosts on the shortest paths.

B. Protocol Overview

As mentioned earlier, MMOFA is derived from MIP-RS and is an extension of the work proposed in [14]. MMOFA enjoys the advantage of high routing efficiency as in MIP-RS. The system components and the operation of Mobile IP in unicast delivery remain unchanged. The mobility agent, in addition to mobility management, also serves as a proxy of multicast services for mobiles. From the perspective of a multicast router, the agent is just like a group participant, and from mobile hosts, the agent enables multicast service. Thus, the mobility agent must join the multicast group of interest on behalf of the mobiles in its affiliated subnet.

The table maintained by the mobility agent is extended to address group information, including a member list and a tunneling list, on a per-group basis. The member list maintains the registered mobile hosts participating in group G in the network. The tunneling list records the mobile hosts previously registered with this agent but are currently roaming to adjacent networks and requesting multicast datagrams of group G from tunnel. The mobility agent encapsulates the datagrams requested by the mobiles in the tunneling list, in unicast packets to the corresponding foreign agents in the adjacent networks, where the tunneled packets are de-capsulated, and forwarded to the affiliated networks.

C. Operation of MMOFA

When a mobile host (MH) roams to a foreign network, it first registers with the new foreign agent (nFA), as in Mobile

IP unicast. If the MH would like to join a multicast group, say group G, it sends a join message for group G to nFA. nFA adds MH to the member list of group G, then sends an IGMP-join message for the multicast group G to the immediately neighboring multicast router if there is no other mobile host participating in group G in its network. In this case, because of join and graft latencies, MH may lose some packets, therefore to reduce number of lost packets in MH, nFA sends a **Handoff** message to MH's old foreign agent (oFA) and requests to forward multicast packets of group G for MH via tunneling. If there is other mobile host participating in nFA's network for group G, MH can receive multicast packets of group G with no delay and therefore nFA sends a **Leave** message to MH's oFA.

Upon receiving **Handoff** message by oFA, oFA removes the MH from the member list to the tunneling list in the entry of group G, then creates a tunnel toward nFA and forwards multicast datagram of group G, using this tunnel to nFA. On receipt of a tunneled packet from oFA, if the encapsulated packet is detected as a multicast datagram of group G, nFA will forward the datagram to its affiliated subnet. Existence of this tunnel is temporary and it is kept till the nFA starts receiving packets from its tree-joining request. Once the nFA starts receiving packets from its new branch on multicast tree, it sends an **Exit** message to oFA and requests to discontinue forwarding packets of group G. In this way, MMOFA can reduce the number of lost packet encountered by roaming hosts.

On receipt of a **Leave** message for group G from a mobile host, oFA deletes the mobile host from the member list of group G and on receipt of an **Exit** message for group G, oFA deletes the mobile host from the tunneling list of group G. Once both the member list and the tunneling list are empty, oFA sends an IGMP-leave message to the multicast router for leaving the group.

D. Multicast Handoff

We use a smooth handoff technique to reduce the service disruption for the multicast session during the handoff. The service disruption period due to handoff is mainly contributed by three main entities:

1) Duration at which MH has no network connectivity
2) MH registration period in Foreign Domain
3) Multicast Tree Join in the Foreign Domain.

In a given handoff, depending on the group membership in the foreign domain and signal strength, any or all of the above entities may contribute to multicast service disruption.

In our protocol, we assume a MH initiated handoff. Based on the beacon strength received by the MH, it decides if it needs to handoff to the new FA. If it is true, before MH handoff from oFA to nFA, it sends a **greet** message to the nFA. The **greet** message consists of registration information as well as information relating to the multicast group that the MH is presently subscribed to. In this case, MH can receive multicast packets from oFA until its registration in nFA completed. Therefore, impact of MH registration period in nFA, on multicast service disruption period decreases. Consequently packet loss due to handoff in MH reduces.

IV. Performance Evaluation

A. Simulation Setup

This section describes the simulation setup for our protocol to compare it with MIP-RS, MIP-BT, and protocol proposed in [14] that calling **MMHA** in this paper. The performance of the MMOFA was evaluated through a simulation model built on the Network Simulator tools (NS2) version 2.lb7a. We consider a network topology of a 4-by- 4 mesh with each node connected to four neighboring node as shown in Fig. 2. Each node consists of a mobility agent (HA & FA) associated with a multicast router and is connected to a subnet. Also, each node acts as a base station. For simplicity, there is only one multicast group in which only one source is assumed. Also, we assume all the group participants to be mobile hosts and the group size and the mean sojourn time that a mobile host stays in each subnet change randomly. The multicast source selected randomly from fixed nodes in the 4 x 4 mesh.

The amount of the mobile hosts (the number of the mobile group members) varies from 5 to 15. Initially, a mobile host randomly placed in one of the subnets. In our simulation, the mobility pattern of a mobile is described as (D, T), where D is the direction to move, and T, the mean sojourn time to stay in the newly visited network. A mobile can move to one of the four directions of east, west, south, and north with an equal probability of 1/4. T is selected randomly from 2 to 5 time unit.

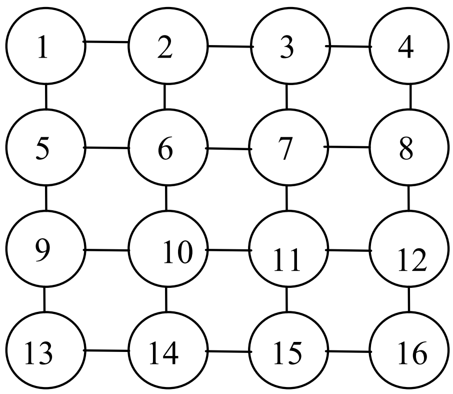

Fig. 2 Network Topology used in simulation

B. Simulation Results

1) Packet loss

The first experiment is to study the degree of packet losses due to roaming for both MIP-RS and MMOFA, upon varying the group size. Fig. 3 shows the loss percentage, defined as the number of the packets lost due to roaming to the total number of packets sent by the source, for MIP-RS and MMOFA. Results shows that MMOFA is robust and has lower packet losses due to roaming in all cases considered, because, MMOFA use MH's old foreign agent in roaming and smooth handoff technique. MIP-RS, on the other hand, suffers from the out-of-synch problem and serious packet losses, especially when the mean sojourn time is short and group size is small.

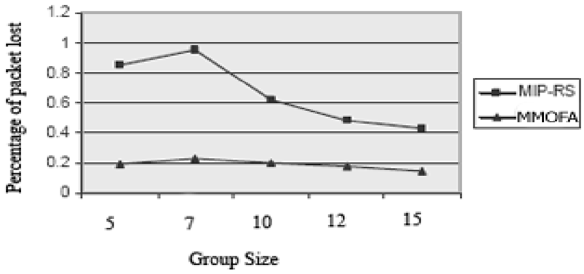

Fig. 3 Packet Loss percentage versus group size

2) Delivery efficiency

This experiment is to investigate the delivery efficiency (path length) of the four approaches in terms of the average number of hops each multicast datagram travels from the source to the mobile hosts, upon varying the group size. Fig. 4 shows that MMOFA nearly has the same efficient delivery as MIP-RS. MIP-BT Suffering from the triangular routing problem, thus the number of hops traveled by multicast datagrams when using MIP-BT is very greater than other approaches. In MMHA, because of using MH's home agent for delivery of lost packets, path length is greater than MMOFA that using MH's old foreign agent.

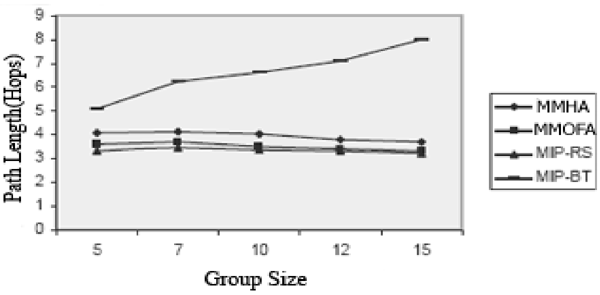

Fig. 4 Path length versus group size

3) Network load

This experiment is to study the network load of the four approaches in terms of the average number of packets that each mobility agent receives, upon varying the group size.

Fig. 5 shows that MMOFA nearly has the same network load as MIP-RS. MIP-BT delivers all packets through MH's home agent, thus the network load when using MIP-BT is very high. In MMHA, because of using MH's home agent for delivery of lost packets, network load is greater than MMOFA and MIP-RS but it is lower than MIP-BT.

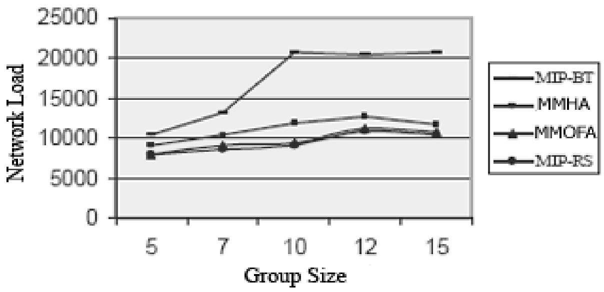

Fig. 5 Network load versus group size

V. CONCLUSION

In this paper, we have proposed a new protocol called Mobile multicast support using old foreign agent (MMOFA) with the characteristics of optimal routing efficiency, scalability and simplicity to be a mobile multicast mechanism. With MMOFA, the mobility agent in Mobile IP, in addition to mobility management, is extended to assist multicasting for mobiles. MMOFA is derived from MIP-RS, and with the assistance of mobility agents, routes the missing datagrams due to handoff problem in adjacent subnets via tunneling to ensure optimal routing efficiency and reduced packet losses from roaming.

We also compared the performance of the proposed protocol with existing protocols by simulation under NS-2.27 simulator. The results demonstrate that MMOFA has optimal routing efficiency, low packet loss and high robustness, as compared to other approaches.

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