Multicast Routing by Mobility Prediction for Mobile Hosts

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Abstract-**In this paper, we propose an efficient multicast routing protocol based on mobile IP standard in wireless mobile networks. A mobile host that is located in a foreign network receives a tunneled multicast datagram from a multicast agent, which is located in a remote network or local network. While receiving a tunneled multicast datagram from a remote multicast agent, the local multicast agent starts a multicast tree join operation if the mobile host is expected to remain the network relatively long period of time, while it does not start multicast tree join operation if the mobile host is expected to remain the network relatively short period of time. The proposed protocol tries to minimize the number of unnecessary multicast tree join operations. We examined performance of the proposed protocol by simulation under various environments and we got good performance results.**

I. INTRODUCTION

Rapid progress 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 [6,14]. While existing computing systems assume static devices and wired networks, a wireless mobile system allows users with portable devices to access a shared communication network independent of their physical location [11].

In wireless mobile networking environments, users still require particular network applications, such as the dissemination of textual information, multipoint communications, and distributed systems functions, for which a multicast mechanism is more efficient. Many multicast protocols, such as DVMRP [21], MOSPF [17], CBT [3], and PIM [10], have been proposed to support the multicast service. However, the proposals were designed assuming static hosts, and thus they do not work well in mobile networking environments. In wireless mobile networks, the bandwidth is limited, wireless links are error-prone, mobile hosts frequently handoff, and battery lifetime of a mobile device is limited. Thus, when we design a multicast routing protocol for wireless mobile networks, the characteristics mentioned above should be carefully considered. Several multicast routing protocols for wireless mobile networks have been proposed [7,12,19,22]. Although the protocols solve several problems inherent in multicast routing proposals for static hosts, they still have problems such as non-optimal delivery path, datagram duplication, etc.

The current IETF mobile-IP specification also briefly proposes two approaches for supporting multicast service to mobile hosts [18,19,22]: foreign agent-based multicast (referred to as remote-subscription) and home agent-based multicast (referred to as bi-directional tunneling) [7,12]. 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 the shortest routing path and nonexistence of duplicate copies of datagrams. However, when a 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 home agent. When a home agent receives a multicast datagram destined for a mobile host, it encapsulates the datagram twice (with the mobile host address and its care-of address) and then transmits the datagram to the mobile host as a unicast datagram. This scheme takes advantage of its interoperability with existing networks and its transparency to foreign networks that a mobile host visits. However, the multiple encapsulation increases the packet size, and a datagram delivery path is non-optimal since each delivery route must pass through a home agent. Furthermore, if multiple mobile hosts that belong to the same home network visit the same foreign network, duplicate copies of multicast datagrams will arrive at the foreign network.

In [12], Harrison et al. proposed a home agent-based multicast protocol called MoM (Mobile Multicast), where a home agent is responsible for tunneling multicast datagrams to the mobile host. In home agent-based multicast schemes, a home agent forwards a separate copy of multicast datagram for each mobile host even if all mobile hosts that wish to receive the multicast datagram are in the same foreign network. However, by MoM protocol, the home agent forwards only one copy of the multicast datagram to each foreign network that contains its mobile hosts. Upon receiving the multicast datagram, a foreign agent delivers it to mobile hosts using link-level multicasting. This scheme reduces the number of duplicate multicast datagrams and the additional load on low-bandwidth wireless links. But there still exists a problem, referred to as the tunnel convergence problem [7,12], resulting from the fact that multiple tunnels from different home agents can terminate at one foreign agent. Thus, when multiple home agents have mobile hosts on the same foreign network, one copy of every multicast datagram is forwarded to the same foreign agent by each home agent. Therefore, the foreign agent suffers from the convergence of tunnels set up by each home 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. MoM protocol

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reduces multicast traffic by decreasing the number of duplicate copies of 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. Moreover, this approach uses a non-optimal delivery route since a home agent (DMSP) forwards multicast datagrams to tunnels leading to each foreign agent.

In [20], Suh et al. proposed a multicast routing protocol called MMA, where a mobile host receives a multicast datagram from a multicast forwarding agent in a network located near the mobile host's current foreign network. As an option, the mobile host's local multicast agent may start multicast join process, while receiving a tunneled multicast datagram from a remote multicast agent. However, joining and pruning a multicast tree each time a mobile host changes locations result in a large network overhead. Furthermore, if the speed of a mobile host is very high, a local multicast router joins a multicast tree unnecessarily since the mobile host may move to another network before the multicast router finishes joining the multicast tree.

In this paper, we propose an efficient multicast routing protocol based on MMA protocol [20]. A mobile host that is located in a foreign network receives a tunneled multicast datagram from a multicast agent, which is located in a remote network. While receiving a tunneled multicast datagram from a remote multicast agent, the local multicast agent starts a multicast tree join operation only when the currently visiting mobile host is expected to remain in the network relatively long period of time. If the expected time for a visiting mobile host to remain in the network is not long enough, the local multicast agent does not start a multicast tree join operation. In this case, the mobile host receives tunneled multicast datagrams from a remote multicast agent located in a network close to the local network.

The proposed protocol reduces the number of duplicate copies of datagrams and the multicast data delivery path length since datagrams are forwarded to mobile hosts by multicast agents which are located close to the current location of mobile hosts or located in the current network. The proposed protocol also tries to reduce network traffic overhead by reducing the number of unnecessary multicast tree join operations.

II. PROPOSED PROTOCOL

A. Protocol Overview

The main problems of bi-directional tunneling are non-optimal datagram delivery path length and duplicate copies of multicast datagrams. On the other hand, the high overhead of frequent multicast tree reconstruction is a problem of remote-subscription. The main goal of the proposed protocol is to minimize the multicast tree reconstruction overhead while keeping datagram delivery path length sub-optimal. Multicast tree reconstruction overhead can be reduced if we minimize the number of unnecessary multicast tree join operations.

If a mobile host entering into a network moves to another network before the local multicast router finishes joining the multicast tree, then the join process becomes unnecessary. Furthermore, the multicast router has to perform a prune operation since the host requested multicast service has left the network. Thus, both the unnecessary join and prune operations increase the network load. Even if the mobile host remains at the network after the completion of the join operation, it may be unnecessary if the mobile host leaves the network in very short time after finishing tree join process.

In the proposed protocol, a mobile host manages a timer which records the staying time of the mobile host at the previous network. This can be done by recording the time difference between the time a mobile host arrives at a network and the time it leaves the network. The point is that, although not exact, the speed of a mobile host at a network is highly dependent on the speed of the mobile host at the previous network. That is, the probability that a mobile host moves slow (or fast) at the current network is high if the host moves slow (or fast) at the previous network.

In the proposed protocol, a mobile host that is located at a foreign network receives a tunneled multicast datagram from a multicast agent, which is located at a remote network. While receiving a tunneled multicast datagram from a remote multicast agent, the local multicast agent starts a multicast tree join operation only when the currently visiting mobile host is expected to remain the network relatively long period of time. The expected time for a mobile host to stay at the current network is calculated from the measured staying time of the mobile host at the previous network. If the expected time for a visiting mobile host to remain the network is not long enough, the local multicast agent does not start a multicast tree join operation. In this case, the mobile host receives tunneled multicast datagrams from a remote multicast agent located in a network close to the local network.

B. Protocol Details

There are two important entities in the proposed protocol: multicast agent (MA) and multicast forwarder (MF). MAs provide multicast services to mobile hosts. Each MA has the information of a single MF per multicast group. MF of a MA (e.g., MA1) is the MA selected among MAs which are located near MA1 and must be multicast tree nodes of a given multicast group. A MF is responsible for forwarding multicast datagrams to MA1. If MA in the visiting network of a mobile host belongs to a multicast tree, the mobile host directly receives multicast data from the local multicast router (e.g., MA) in the network. In this case, the MA itself becomes the MF. If the visiting network does not belong to a multicast tree, multicast data are delivered to a mobile host through tunneling from a MA that is included in the multicast tree of a given multicast group and located in a network close to the mobile host's visiting network. In this case, a MA in a remote network becomes the MF.

Initially, when a mobile host wants to subscribe a multicast group in a network, subscription is done through MA in the network, which must be a tree node of the multicast group. If not, the MA starts tree joining process. This MA configures the MF value of the multicast group with the MA itself, and delivers multicast datagrams to the mobile host in the network.

When a mobile host moves from a network (e.g., N1) to another (e.g., N2), the mobile host sends its MF information to MA2 in N2 during registration, which is used by MA2 for selecting new MF. If N2 belongs to the multicast delivery tree, MA2 itself becomes the MF. MA2 and the mobile host update the MF information with MA2. If MA2 does not belong to the multicast delivery tree and MA2 has no MF information on the multicast group, the MF value that the mobile host had in N1 is used as the MF in N2. If MA2 does not belong to the multicast delivery tree but MA2 has MF information on the multicast group, the MF value that the mobile host had in N1 is used as the MF in N2 (oldest MF selection). Alternatively, MA2 selects one that is closer to it, between the MF information that MA2 currently has and the MF that the mobile host had in N1 (closest MF selection). At any case, MA2 and the mobile host update the MF value with the selected MF. Now, MA2 sends a forwarding request message to the selected MF. Then, the MF starts forwarding multicast datagrams to MA2, and MA2 delivers the datagrams to MA2.

Completing the registration procedure, a mobile host checks its timer value (staying-time at the previous network). If the timer value is over a threshold value (low mobility), the mobile host requests MA2 to start multicast tree join operation. While MA2 is joining to the multicast tree, the mobile host receives forwarded data from its MF, and thus there is no service disruption period. When the join process finishes, multicast datagrams are delivered directly to the mobile host, just as in foreign agent based multicasting. Since MA2 is now a multicast tree node, it sets its MF value as itself and advertises the newly updated MF value to the currently subscribing mobile hosts. If the timer value is below a threshold value (high mobility), the mobile host keeps silent. Alternatively, the mobile host also sends its timer value to MA2 at its registration time. Then, MA2 decides whether it should start tree join operation or not, by referring its local threshold data and the staying time information received from the mobile host.

Fig. 1 shows the basic operation of the proposed protocol. In the figure MA1 and MA2 are multicast tree nodes, while MA3 and MA4 are not. A mobile node MH moves from network N1 to N2, N3, and N4, in that order. Since MA1 is a multicast tree node, MH receives multicast datagrams from MA1 (that is, MA1 is the MF of MH). When MH enters into N2 it sends its MF information (e.g., MA1) to MA2 during registration. Since MA2 is a multicast tree node, MA2 itself becomes a new MF at N2. After some period of time, when MH moves to N3, it sends its MF information (e.g., MA2) to MA3 during registration. In this case, MA3 is not a multicast tree node, and thus MA3 sends a forwarding request message to the MF (e.g., MA2). Then, MF (MA2) starts forwarding multicast datagrams to MA3, and MA3 delivers the datagrams to MA2. In the meantime, MH checks its timer value. If we assume that the timer value is below a threshold value, MH does not request multicast tree join operation to MA3. Now, MH enters into N4, and it sends its MF information (MA2) to MA4 during registration, and then it checks its timer value. If we assume that the timer value is over a threshold value, then MH requests MA4 to start multicast tree join operation. While MA4 is joining to the multicast tree by way of MR1 and MR2, the mobile host receives forwarded data from its MF (MA2).

C. Host Mobility Prediction and Tree Joining Decision

In the proposed protocol, determining a mobile host's speed is very important. The best approach determining a mobile host's speed is using the information received from Global Positioning System (GPS). A mobile host requests a tree join process when the mobile host's speed received by GPS is above a given threshold value. But, if GPS information is not available, an alternative approach is measuring the period of time that a mobile host stays at the previous network. If the staying time at the previous network does not give a good information on the host mobility, another approach is using several staying time values at several previously visited networks. A mobile host records its staying time at each of *n* networks it recently stayed before it enters into the current network. The point is that, although not exact, the speed of a mobile host in the current network is highly dependent on the speed of the mobile host at the networks the mobile host recently stayed before it enters into the current network.

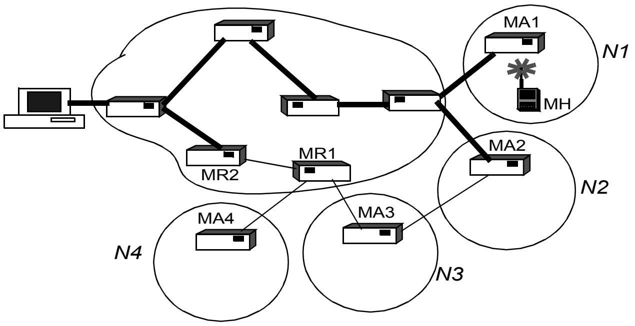


Figure 1. Example of the proposed protocol

In the proposed protocol, the choice of *n* is important parameter and must be reasonably chosen. In addition, the expected time for a mobile host to stay at the current network is also important. In this paper, we calculate the expected staying time value (T_E) as follows:

$$T_E = \beta \times \frac{1}{n-1} \times \sum_{i=1}^{n-1} T_i + (1-\beta) \times T_n .$$

where $0 \le \beta \le 1$, T_i $(1 \le i \le n-1)$ is the measured staying time at previous *n*-1 networks (excluding the most recently visited network), and *Tn* is the measured staying time at the previous network (the most recently visited network). β is a weight factor, and if $\beta = 0$, the expected staying time of a mobile host at the current network is determined by the staying time at the previous network only.

Now, T_E is found, and a mobile host requests a tree join operation according to the following rule:

If $T_E > T_{th}$
MH sends a join request to its current MA
Otherwise,
MH does not send a join request

where T_{th} is the threshold value for join.

The decision rule defined above is very simple: when the predicted staying time at a network is above a certain threshold value, a mobile host requests tree join operation. Upon receiving the request, MA at the network performs join operation if it is not a multicast tree node. T_{th} is a critical value for the performance of the proposed protocol. The value should be determined according to several network parameters.

III. PERFORMANCE EVALUATION

We have evaluated performance of the proposed protocol using a discrete-event simulation. We assumed that 20x20 LANs are located on the x-y coordinate system as shown in Fig. 2, 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. We assume that there is one MA at each LAN. The shaded area in Fig. 2 denotes the wireless transmission range of a LAN. In a randomly selected network model, the initial multicast tree is established for a randomly selected set of LANs.

The random way point model [5] is used in this simulation. In this model, each mobile host selects its destination in random fashion, and starts its journey to the destination with randomly chosen movement speed. When a mobile host reaches its destination, it remains stationary for a certain period of time, which is called pause time. After a pause time, the mobile host moves again in the same way stated above. We set the pause time to be 0 in the simulation study since we want to evaluate the performance in worst

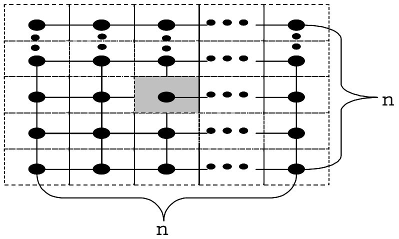


Figure 2. Network model used in simulation

condition (high mobility). We assume that each mobile node moves with a speed ranging from 0 to 5.0 cell/unit time. Since a unit time is a virtual tick in the simulation model, we used it as a relative speed of node movements.

We evaluated performance of the proposed protocol with various numbers of mobile hosts, various sizes of the initial multicast tree. The number of mobile hosts used in this paper denotes the number of mobile hosts per LAN in a randomly selected initial multicast tree. Thus, for example, when the initial tree size is 50 and the number of mobile hosts per LAN in the initial tree is 10, then there are 500 mobile hosts in total in the simulation network. In the simulation, the maximum number of mobile hosts per LAN in the initial multicast tree is limited to 20. When the number of mobile hosts per LAN in the initial multicast tree is greater than 20, since there are too many mobile hosts in the simulation network, it is highly probable that each mobile host makes MAs in a foreign network to join the multicast tree, and thus all LANs join to the multicast tree as soon as simulation starts. The shortest path length between two LANs is measured by the Shortest-Path Euclidean Distance. We assumed that there is a single source which is selected randomly and it 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	50
H	average number of mobile hosts per initial tree node	1-20
MR	host mobility rate	[0 - 5] cell/unit time
P	pause time	0 unit
T_{JD}	join delay	1 unit
β	weight factor	0
T_{th}	threshold value for join	3, 5, 7 units
Time	total simulation time	500 units

Our simulation study compares the performance of the proposed protocol, MMA protocol with join option [20] and MoM protocol [12]. The main features considered are the number of join operations performed by the proposed protocol and MMA protocol in various situations. In addition, we observed the multicast data traffic per unit time and average delivery path length of multicast data per mobile host for protocols listed above. The results are illustrated in Figures 3- 6.

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 in which mobile hosts subscribing a given multicast group are visiting (in MoM protocol), and the number of MAs which receive data forwarded by a MF (in MMA protocol and the proposed protocol). Fig. 3 compares these as a function of H, when T_{th}=3, 5, 7 and T = 50 (see Table 1 for definition of the parameters). As shown in the figure, the network traffic generated by the proposed protocol is very comparable to (but a little bit more than) that of MMA protocol with join option. It is due to the fact that when the mobility prediction is used, there are certain cases that join operations are not performed since the expected time for a mobile host to remain the network is below the threshold value. Network traffic generated by MMA protocol with join option is the optimum value since the protocol performs tree join operation at every network (just as foreign agent-based multicast routing protocol).

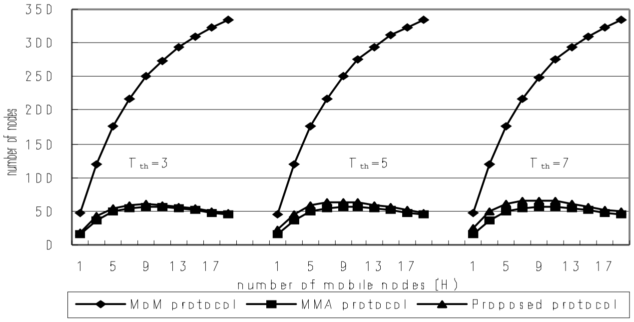


Figure 3. Comparison of network traffic

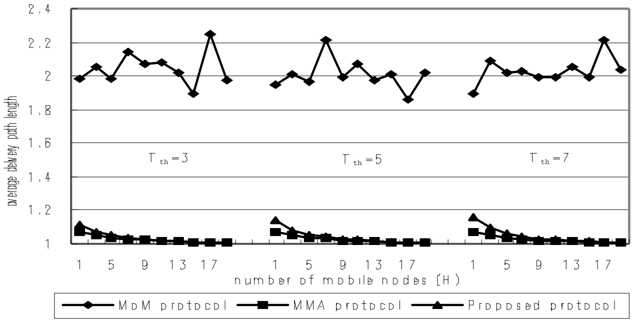


Figure 4. Comparison of average multicast delivery

Fig. 4 shows the average delivery path length of the proposed protocol, MoM, and MMA, relative to optimal path length, as a function of H, when the optimal path length (in foreign agent-based protocol) is 1 and T_{th}=3, 5, 7. As shown in the figure, the average delivery path length of the proposed protocol is comparable to, but a little bit longer than that of MMA with join option. It is also due to the fact that the proposed protocol performs smaller number of join operations than MMA with join option. There are several cases that join operations are not performed in the proposed protocol. In such cases, the datagrams to a mobile host are forwarded from the forwarder in the proposed protocol. On the other hand, in MMA protocol with join option, every MA eventually joins to the multicast tree, which reduces the delivery path length.

Fig. 5 compares the number of joins performed in the proposed protocol and MMA protocol with join option as a function of H when T_{th}=3, 5, 7, and T=50. As shown in the figure, the number of joins in the proposed protocol is less than that of MMA protocol with join option. The difference becomes larger as T_{th} increases. Although frequent tree join operations reduce the network traffic occurred by tunneling and average packet delivery path length as shown in Figures 4 and 5, they increases the overhead of reconstructing the multicast tree. So, tradeoffs are required between the number of tree join opera-

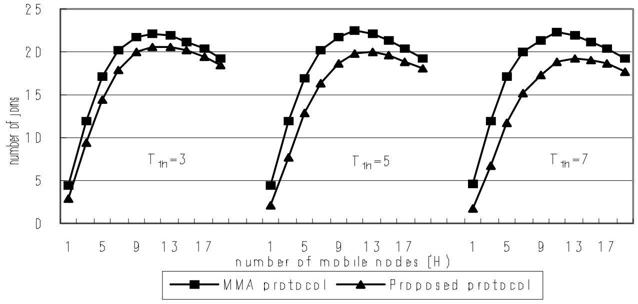
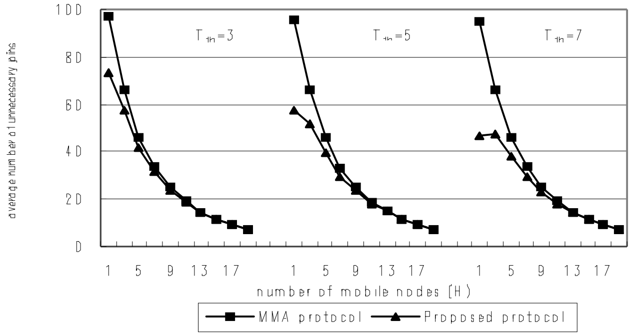
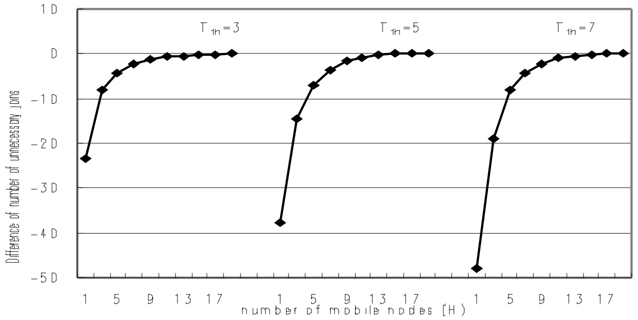


Figure 5. Comparison of number of joins



(a) Comparison of average number of unnecessary joins



(b) Difference of number of unnecessary joins

Figure 6. Comparison of number of unnecessary joins

tions and packet delivery path length. The motivation of the proposed protocol is to allow necessary join operations to reduce packet delivery packet length, while minimizing the number of unnecessary join operations. As stated earlier, when mobile hosts move fast, there are some MAs that perform unnecessary join operations. The number of unnecessary join operations can be expressed as the number of MAs that currently have no visiting mobile hosts subscribing multicast groups that MAs join for the mobile hosts. We counted the average number of such MAs per unit time. Fig. 6(a) compares the number of unnecessary join operations in the proposed protocol and MMA protocol and Fig. 6(b) shows the differences in the number of unnecessary join operations (i.e., the number of unnecessary joins in the proposed protocol - the number of unnecessary joins in MMA protocol with join option) as a function of H with T_{th}=3,5,9. From the figures, we can see that the proposed protocol reduces the number of unnecessary join operations significantly, and the differences are getting larger as T_{th} is increased. It is very important feature. Reducing the number of unnecessary joins in turn reduces the unnecessary overhead for reconstructing the multicast tree.

From our simulation study, we can see that the proposed protocol reduces the number of join operations significantly by reducing unnecessary joins, while its multicast delivery path length is very comparable to that of MMA protocol with join.

IV. CONCLUSION

In this paper, we proposed an efficient multicast routing protocol supporting host mobility. A mobile host that is located in a foreign network receives a tunneled multicast datagram from a multicast agent, which is located in a remote network. While receiving a tunneled multicast datagram from a remote multicast agent, the local multicast agent starts a multicast tree join operation only when the currently visiting mobile host is expected to remain the network relatively long period of time. If the expected time for a visiting mobile host to remain the network is not long enough, the local multicast agent does not start a multicast tree join operation. In this case, the mobile host receives tunneled multicast datagrams from a remote multicast agent located in a network close to the local network.

While maintaining the multicast data delivery path length comparable to foreign agent-based protocols, the proposed protocol reduces the number of unnecessary join operations. We compared the performance of the proposed protocol with existing protocols by simulation under various wireless mobile networking environments, and we got very positive results. We are currently performing more detailed performance evaluation study in diverse networking environments.

REFERENCES

[1] A. Acharya and B. Badrinath "A Framework for Delivering Multicast Message in Networks with Mobile Hosts," *Mobile Networks and Applications*, pp. 199-219, 1996.

[2] A. Acharya, A. Bakre, and B. Badrinath "IP Multicast Extensions for Mobile Internetworking," *Proc. of IEEE INFOCOM*, 1996.

[3] A. Ballardie, P. Francis and J. Crowcroft, "Core Based Trees (CBT): An Architecture for Scalable Inter-domain Multicast Routing," *Proc. of ACM SIGCOMM*, pp. 85-95, September 1993.

[4] A. Bartoli "Group-based Multicast and Dynamic Membership in Wireless Networks with Incomplete Spatial Coverage," *Mobile Networks and Applications*, pp. 175-188, 1998.

[5] J. Broch, D. Maltz, D. Johnson, Y.-C. Hu and J. Jetcheva, “A performance Comparison of Multi-hop Wireless Ad Hoc Network Routing Protocols,” Mobicom’98, October 1998

[6] D. C. Cox "Wireless Personal Communications: What is it?," *IEEE Personal Communications*, pp. 20-35, April 1995.

[7] V. Chikarmane and C. L. Williamson "Multicast Support for Mobile Host using Mobile IP: Design Issues and Proposed Architecture," *Mobile Networks and Applications,* pp. 365-379, 1998.

[8] V. Chikarmane and C. Williamson "Performance Evaluation of the MoM Mobile Multicast Protocol," *Mobile Networks and Applications*, pp. 189-201, 1998.

[9] S. Deering "Multicast Routing in Datagram Internetworks and Extended LANs," *ACM Trans. on Computer Systems*, Vol.8, No.2, pp. 85-110, 1990.

[10] S. Deering, D. Estrin, D. Farinacci and V. Jacobson, An Architecture for Wide-area Multicast Routing," *Proc. of ACM SIGCOMM*, pp. 126-135, 1994.

[11] H. Forman, J. Zahorjan, "The Challenges of Mobile Computing," *IEEE Computer*, 27 (4), pp. 38-47, April 1994.

[12] T. Harrison, C. Williamson, W. Mackrell, and R. Bunt, "Mobile Multicast (MoM) Protocol: Multicast Support for Mobile Hosts," *Proc. of ACM MOBICOM*, pp. 151-160, 1997.

[13] J. Ioannidis, D. Dduchamp, and G. Maguire "IP-based Protocols for Mobile Internetworking," *Proc. of ACM SIGCOMM*, pp. 235-245, 1991.

[14] B. Jabbari and G. Colombo "Network Issues for Wireless Communications," *IEEE Communications Magazine*, pp. 88-98, January 1995.

[15] E. D. Kaplan, editors, Understanding the GPS: Principles and Applications. Boston: Artech House, February 1996.

[16] C. K. Miller, Multicast Networking and Applications, Addison Wesley.

[17] J. Moy, "Multicast Routing Extension for OSPF," *Communications of ACM*, Vol.37, No.8, pp. 61-66, August 1994.

[18] C. Perkins, IP Mobility Support, RFC 2002.

[19] C. Perkins, Mobile IP Design Principles and Practices, Addison Wesley.

[20] Y.-J. Suh, H.-S. Shin, and D.-H. Kwon, "An Efficient Multicast Routing Protocol in Wireless Mobile Networks," ACM Wireless Networks, vol.7, no.5, pp.443-453, Sep. 2001.

[21] D. Waitzman, C. Partridge and S. Deering, "Distance Vector Multicast Routing Protocol," RFC 1075, November 1998.

[22] G. Xylonmenos and G. Polyzos, "IP Multicast for Mobile Hosts," IEEE Communications Magazine, pp. 54-58, January 1997.