Multicast Service for Hierarchical Regional Registration Mobile IP Networks*

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ABSTRACT

In this paper, we consider the problem of providing multicast service for Hierarchical Regional Registration Mobile-IP (HRRMIP) networks. Using existing multicast protocols in a mobile environment is inefficient especially when dealing with frequent membership or location changes. This paper describes a new protocol for supporting IP multicast for mobile nodes using IETF Mobile IP in the case of hierarchical networks. The basic unicast routing capability of HRRMIP is used to found a new efficient multicast service for mobile nodes. The proposed protocol is transparent to upper layers, simple and the simulation results show that it is robust, scalable and efficient.

Keywords: *Mobile IP, multicast, regional registration, hierarchical networks.*

1. INTRODUCTION

Computers capable of attaching to the Internet from many places are growing in popularity so fast that many protocols are studied to provide mobility. IETF proposed its Mobile IP [1] to provide unicast delivery of datagrams for mobile nodes (MN) in a TCP/IP internetwork. Mobile IP has been extended to provide the same service on Hierarchical Regional Registration Mobile IP networks (HRRMIP)in which the registration of the mobile node with its home is reduced and decreased the load on its home agent [2].

Multicast is a mechanism for efficient one-to-many communication in which the source transmits a single datagram, and the network performs the task of delivering that datagram to the multiple destinations with as minimum datagram duplication as possible.

Multicast operation on the Internet is now supported for fixed nodes through IP multicast using the host group model [3]. Examples of multicast routing protocols for fixed nodes are MOSPF, DVMRP, CBT and PIM [4], [5], [6] and [7]. Group management protocols are used to inform the multicast routers that a new host wants to join or leave a multicast group. IGMP is an example of such protocol [8].

IETF proposed two solutions for providing multicasting to MN using *remote subscription* or *bi-directional tunneling* [1]. Remote subscription does provide the most efficient delivery of multicast datagrams. However, this service may come at a high price for the network involved. The multicast routers will reconstruct the multicast delivery tree on each movement of the MN. MNs suffer from join and graft latencies [9]. Bi-directional tunneling suffers from some drawbacks. If multiple MNs on the same foreign network belong to the same multicast group then duplicate copies of the multicast packets will arrive at the foreign network.

In bi-directional tunneling, packets travelling the reverse route from the MN to the HA are multicast packets encapsulated with a unicast header with the MN's home address as the source address [10]. This multiple encapsulation increases the packet size substantially and can cause fragmentation.

Williamson et al. [11] pointed out some problems that should be taken into account when designing a multicast protocol for a mobile environment. These problems are the tunnel convergence problem, the duplication problem, the scoping problem, and the disruption of the multicast service. Some solutions to these problems are suggested also.

In this paper, we consider the problem of multicast to groups in a TCP/IP internetwork with mobile nodes in case of HRRMIP networks. Our approach uses IETP M - bile IP protocol so that it can handle multicast forwarding with adequate scalability.

The rest of the paper is organized as follows. In Section 2, we present the new protocol. In Section 3, the simulation model and the workload model are presented. Simulation results are given in Section 4. The conclusion is given in Section 5.

2. MULTICAST PROTOCOL FOR HRRMIP

In our approach to provide multicast service for MNs we use the data provided already through HRRMIP. We add only data structures to store the group membership information.

2.1 Protocol Overview

To send multicast datagrams while being visiting a foreign network, the MN reverse tunnels them to its multicast home agent (HA) which will forward them for it. Any recipients on the same foreign network receive the datagrams through the multicast tree rather than directly

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via link-level multicast by the MN. The IGMP is modified on the MN to check whether it is at home or at a foreign network. In the latter case, the MN should send the IGMP membership report to the foreign agent (FA) instead of broadcasting it on the LAN as usual. The foreign agent (FA) propagates the request through the hierarchy till reaching the gateway foreign agent (GFA) who will send the request to the HA.

The GFA chooses a DMSP from the HAs of the MNs subscribing in the group *G* and informs it with this. The HA adds itself to the multicast distribution tree and it receives all the multicast traffic of group *G*. It encapsulates and forwards it to the GFA for which it is a DMSP.

When a gateway foreign agent or a regional foreign agent (RFA) at each level of the hierarchy receives an encapsulated multicast datagram, it decapsulates it and retunnels it through the next lower-level RFA or FA in the hierarchy whose address exist in its visitor list. When the FA receives the multicast datagram, it forwards it through the link-layer multicast.

The GFA should be a multicast router, which enables it to be aware whether it has a fixed host in its network member of the group *G* (the duplication problem). In this case, the GFA may be itself the DMSP.

When the MN makes a regional registration, a deregi - tration from the old FA will happen either through smooth handoff or through a zero-lifetime Binding Update message from the GFA or the first RFA recognizing the MN. Whereas when the MN moves to another network under another GFA, the HA receives explicit information about the movement, and it will deregisters from the old GFA if the MN is not using smooth handoff [12]. The tunnel to the old GFA is discarded if the MN was the last one from the same home network of the DMSP, and the GFA should designate other DMSPs for the relevant groups if needed.

To eliminate this disruption in the multicast delivery, another redundant DMSP is designated for each group if possible with one of them as the primary. The GFA r - ceives the multicast datagram from them, caches them and forwards those of the primary DMSP to the network. When receiving multicast datagrams from the secondary DMSP only for a certain time, the GFA should forward the buffered datagrams and it should switch to another primary. The caches must be small (probably fewer than 10 packets) to conserve resources at the GFA, and to minimize the delay introduced through storing the packets in the cache.

2.2 Needed Data structures

From Mobile IP and its extension for HRRMIP, each HA maintains an Away Table containing information about its away MNs; their mobility bindings. Every mobility agent in a foreign network (GFA, RFA, or FA) maintains in their Visitor Lists the mobility bindings of the its visiting MNs. The GFA and RFAs maintain the next level mobility agent through which it can reach the MNs.

Our protocol requires that the different mobility agents know the group membership information. Besides, Each GFA has a HA List for each multicast group *G*. Each HA List contains the HAs of the member MN's to keep track of the candidate DMSPs. The GFA has a DMSP List for each group to know who are the DMSPs for it.

Each HA has a GFA List containing the GFAs with which the group member MNs have registered. Each HA saves the information of its DMSP responsibilities in a DMSP List.

Due to space limitation, we refer the reader to [13] for a complete and algorithmic description of all the events handling routines of the protocol.

3. MULTICAST SIMULATION MODEL

We have evaluated our approach to mobile multicast for HRRMIP using a discrete-event simulation tool constructed for this purpose. The simulator helped evaluating the performance of the protocol relative to IETF Bidirectional tunneling and to Direct forwarding of a single copy of multicast datagrams to every GFA at which there is member MNs, as workload parameters are varied.

3.1 Network model

We assume that there are 2N local area networks; N home networks and N foreign networks. Each of the home networks has H hosts. A fraction p of the H hosts constitutes the MNs. In the simulation, we used p = 1.0, i.e. all of hosts in the home networks are mobile since no extra insight is gained by simulating stationary hosts. The MNs are not necessarily away from home; they travel in the internetwork from network to network then return home then re-travel and so on. We haven't modeled the topology of the home networks. Each home network has a HA. The HA is assumed to be a multicast router.

The foreign networks which are hierarchical, are a - sumed to have a complete tree topology, with FA as the leaves of the tree, the RFA as its inner nodes, and the GFA as the root of the tree. We take a complete tree model with degree 2 and height 4. The GFA is a multicast-capable router to solve the duplication problem.

Fig. 1 illustrates the assumed MN mobility model if there exist only two foreign networks: *i* & *j*. A MN can either be at home, at a FA from foreign network *i*, or at a FA from foreign network *j*. MNs begin the simulation at their home network, and they are allowed to roam about in the network at random. Foreign networks to visit are chosen equiprobably. FAs within a foreign domain are also chosen randomly.

When the MN leaves a FA, it may return home with a homing probability $h = 0.4$ or may stay away. It may roam regionally with roaming probability $r = 0.7$ or visit another foreign domain. The number of foreign networks visited on each trip away from home is thus geometrically distributed with mean $1/h = 2.5$.

The residence time in any network is assumed to be an exponential distribution with Mean Residence Time = 90 time units. The travel time for going between network is also assumed to be exponentially distributed with Mean Travel Time = 6 time units. MNs thus spend 6.25% of their time in transit, and 93.75% of their time connected to a LAN. The average cycle time for a MN in our simulation model is 90+2.5*90+(1+2.5)*6 = 336 time units.

Multicast group communication is also simulated, for M groups. For each multicast group, group members are chosen randomly, with the group size as a workload parameter. For each group, there is a single point source for all multicast datagrams located in the internetwork and physically disjoint from all simulated LANs.

The experiments in this paper all assume static membership of multicast groups, although the group members themselves may move freely in the internetwork.

The network and workload parameters are not empirically validated. They are chosen to "exercise" the protocol.

4. SIMULATION RESULTS

This section presents the results from our mobility multicast simulation study. Here, we study the scalability of the system when any of the multicast group size, number of LANs, or number of multicast groups varies. Besides, we study the overhead of the protocol and its fairness and the adopted DMSP selection policies.

4.1 Scalability with group size

The first simulation experiment compares the performance of our approach to both bi-directional tunneling and direct forwarding of a single copy of multicast datagrams to every GFA at which there exist group member MNs. Fig. 2 illustrates how various aspect of the mobile routing environment scale as the multicast group size increases. The plotted values are averages calculated on a per-HA basis.

In bi-directional tunneling each HA forwards all multicast datagrams from groups to which its MNs are subscribing to each MN individually. Whereas direct forwarding only forwards a single copy of multicast datagrams to every GFA at which there is member MNs scales with the number of visited foreign networks.

The simulation results show that direct forwarding has better performance than bi-directional tunneling which can also be noticed because the HA sends at most one copy of the multicast datagrams to a foreign network, depending on whether or not there exist MNs members of the multicast group.

Our approach shows a better performance from bi-directional tunneling and from direct forwarding since there is a restriction to which GFAs the HA will forward the multicast datagrams. The number of multicast datagrams forwarded by any HA corresponds to DMSP responsibilities per HA.

4.2 Scalability with number of LANs

Fig. 3 shows the scaling characteristics when we change the number of LANs in the system. Our protocol still behaves better than both bi-directional tunneling and direct forwarding. When the number of LANs increases, the performance of bi-directional tunneling tends to be close to the performance of direct forwarding. This can be interpreted as with greater number of LANs, each away group member is at a different network. However the number of DMSP responsibilities still remains low.

4.3 Scalability with number of multicast groups

Since each multicast group is handled independently, the overhead of the protocol scales linearly with the number of multicast groups in the system. Fig. 4 shows the average number of DMSP responsibility per HA, as a function of multicast group size, for four different numbers of multicast groups in the network (M = 1, 2, 4, 8). Each group is assumed to have the same number of members. As shown in the Fig. 4, the DMSP responsibilities per HA increase in an additive manner with the number of multicast groups present in the network.

4.4 Protocol overhead

Our protocol involves some messaging overhead when a GFA wants to inform a HA about its designation to provide the multicast service for the MNs of a certain group and when group membership information are to be notified to the foreign mobility agents.

Messages to inform the mobility agents about the group membership information of a MN can be piggybacked on the registration messages as they always occur after a home or regional registration.

Messages informing HAs that they will be DMSPs of a certain group can occur either synchronously or asynchronously with a registration message. Overhead messages can be piggybacked onto the Registration Request messages from a MN to its HA in the case of synchronous DMSP handoff. Fig. 5 shows the DMSP handoff rate. We observed that for small multicast groups of sizes not more than 50 MNs, the synchronous handoff form more than 50% of the overall DMSP handoffs. When the multicast group is of size 100, synchronous handoffs form about 43% of the overall handoffs. Thus the DMSP messaging overhead does increase a bit with the increase of the multicast group size since the synchronous DMSP handoffs will then decrease.

4.5 DMSP selection policy

The DMSP is a HA selected from the HA List to be designated to provide the multicast service. It can be selected with by many ways. We adopted four policies to select the DMSP:

- *Most Kids:* The DMSP is selected from the HA List of the GFA such that it currently has the most member visitors at this GFA.
- *Random:* The DMSP is chosen at random from the HA List.
- *Oldest HA:* The HA that has been in the HA List of the GFA for the longest time is the DMSP.
- *Newest MN:* Whenever a new MN visits the foreign domain, its HA is the DMSP.

The different policies of selecting the DMSP do not affect the transmission of the multicast data traffic. They just affect the rate at which the DMSP is changed, i.e., the overall DMSP handoff rate. Fig. 6 shows the overall DMSP handoff rate for the four selection policies. *Newest MN* and *Random* have linear scaling characteristics. Whereas *Most Kids* and *Oldest HA* have sub-linear scaling characteristics. In fact, *Newest MN* behaves worse than *Random*. A GFA that receives a MN arrival from a newly seen HA will always hand off, while *Random* scales only part of the time. *Oldest HA* clearly outperforms *Newest MN* as it postpones the DMSP handoff decisions for the longest possible period. In fact, this policy has the minimum handoff rates at all. The *Most Kids* selection policy falls in between the *Oldest HA* and the *Newest MN* policies.

4.6 Protocol fairness

Our protocol designates some of the HAs to provide the multicast service for the group member MNs that are vi - iting a foreign domains. Fig. 7 illustrates the load distribution of the DMSP responsibilities among the HAs. We can see that the forwarding task is distributed evenly amongst the HAs in the internetwork regardless of the DMSP selection policy adopted.

5. CONCLUSION

In this paper, we introduce a new protocol for providing multicast service for Hierarchical Regional Registration Mobile IP networks (HRRMIP). This protocol is robust and provides no disruption of the multicast service. It is scalable with respect to the multicast group size, the number of LANs, and the number of multicast groups. Moreover, it is fair in its load distribution.
[14]

We believe that this solution is possible and offers important advantages over IETF multicast solutions for Mobile IP. There is no join and graft delay incurred as in remote subscription and it is superior to bi-directional tunneling in terms of performance. Besides, it is independent of the underlying multicast routing scheme.

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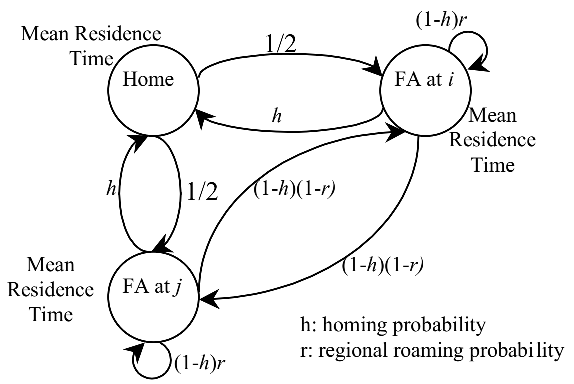

Fig. 1 MN's Mobility model when we have only two foreign networks (*i* and *j*)

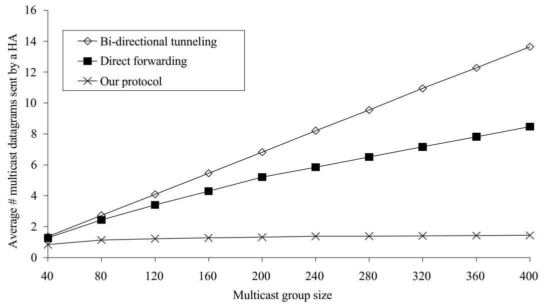

Fig. 2 Effect of changing the multicast group size on the proposed protocol. M = 1, N = 20, H = 20, Oldest

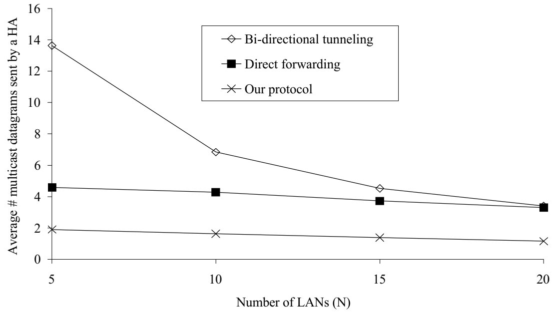

Fig. 3 Effect of changing the number of LANs on the proposed protocol. *M* = 1, *g* = 100, *H* = 20, Oldest HA

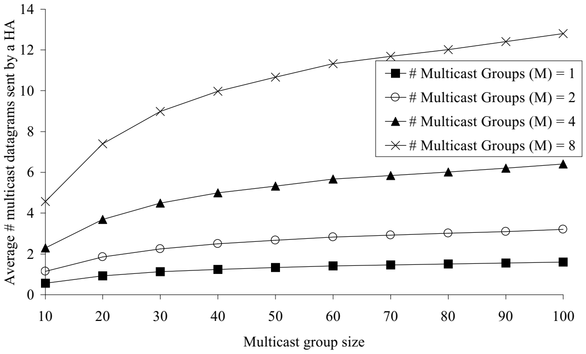

Fig. 4 Effect of changing the number of multicast groups on the proposed protocol. N = 10, H = 10, Oldest HA

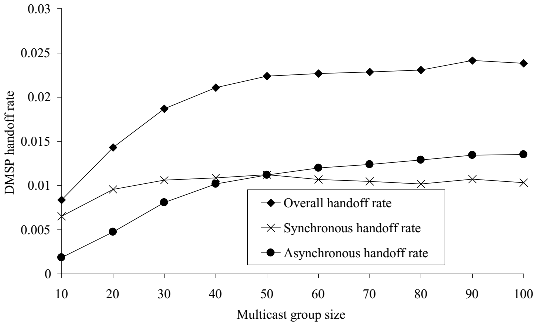

Fig. 5 DMSP handoff rate. M = 1, N = 10, H = 10, Oldest HA

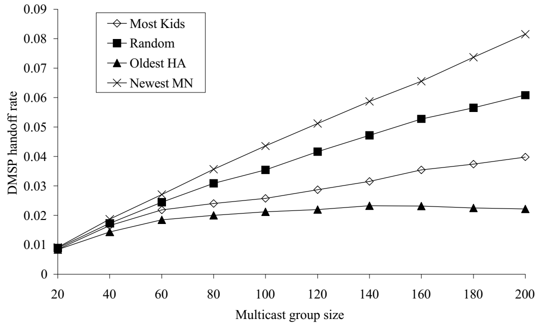

Fig. 6 DMSP handoff rates. M = 1, N = 10, H = 20

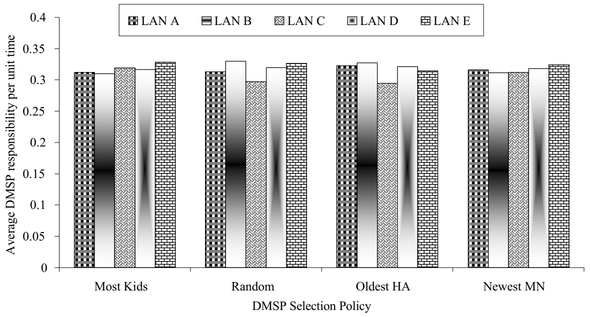

Fig. 7 Load distribution of DMSP responsibilities among HAs. *M* = 1, *g* = 25, *N* = 5, *H* = 5