An Enhancement of Mobile IP by Home Agent Handover

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Abstract- In this paper, we propose an enhancement of Mobile IP called MIP with HA Handover (HH-MIP) to enjoy most of the advantages of Route Optimization MIP (ROMIP) but with only a small increase of signaling overhead. In HH-MIP, the concept of Temporary HA (THA) is proposed and the mobile host registers the new CoA with its THA rather than its original HA. Moreover, HH-MIP adopts an aggressive approach in selecting the THA for an MH, i.e. whenever an MH is moving away from HA or previous THA, the MH triggers the handover of THA. Simulation results demonstrate that HH-MIP enjoys small handoff latency as well as routing efficiency and the number of control packets generated in HH-MIP is significantly less than that in ROMIP.

Keywords: Mobile IP, Route Optimization

I. INTRODUCTION

Mobility management in IP layer [1] is an essential component in wireless mobile networking. *Mobile IP* (*MIP*) [2, 3] was proposed to support global Internet mobility through the introduction of location directories and address translation agents. In MIP, a *mobile host* (*MH*) uses two IP addresses: a fixed *home address* and a *care-of-address* (*CoA*) that changes at each new point of attachment (subnet). A router called *Home Agent* (*HA*) on an MH's home network is responsible for maintaining the mapping (binding) of the home address to the CoA. When an MH moves to a foreign network, the MH obtains a CoA from the *Foreign Agent* (*FA*) and registers the CoA with its HA. In this way, whenever an MH is not attached to its home network, the HA gets all packets destined for the MH and arranges to deliver to the MH's current point of attachment by *tunneling* the packets to the MH's CoA. Some inefficiencies were identified in MIP: (1) Triangular routing from the sender (called *correspondent node*, *CN*) to the HA then to the mobile host leads to unnecessarily large end-to-end packet delay, (2) HA is inevitably overloaded due to tunneling operations, and (3) When an MH is far away from its home network, the long signaling path for CoA registration leads to a long handoff latency resulting in a high packet loss.

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To remedy the problem of triangular routing and reduce the packet loss during handoff, *Route Optimization MIP* (*ROMIP*) [4, 5] was proposed. ROMIP allows every CN to cache and use binding copies. The original binding for an MH is kept in its HA, but ROMIP supports that a binding copy can be propagated to the requiring nodes. Local bindings in a CN enable most packets in a traffic session to be delivered by direct routing. Moreover, an MH also informs its previous FA about the new CoA, so that the packets tunneled to the old location (due to an out-of-date binding copy) can be forwarded to the current location. This forwarding mechanism in ROMIP reduces the handoff latency and thus reduces the packet loss during handoff. However, the improvement of ROMIP over MIP in terms of routing efficiency and smaller handoff latency is at the cost of significantly larger signaling overhead. One question arises: "Is it possible to enjoy most of the advantages of ROMIP but with only a small increase of signaling overhead. The answer to the question led to the research of this paper.

An interesting point of view about the reason of the disadvantages of MIP in routing and handoff latency is because the MH has the potential to move away from its home network and HA. If somehow we can dynamically make the HA closer to the current location of the MH, both routing and handoff efficiency can be achieved. Since the MH's home address is permanent, MH's HA should not move. Therefore, the idea of *Temporary HA* (*THA*) emerges and the extension of MIP adopting THA called *HA Handover MIP* (*HH-MIP*) is proposed in the paper. As will be shown in the simulation study, HH-MIP enjoys small handoff latency as well as routing efficiency and the number of control packets generated in HH-MIP is significantly less than that in ROMIP.

The rest of the paper is organized as follows. The proposed scheme of MIP with HA handover is presented in section II. Some of the related work is briefly surveyed in section III. Simulation study for performance evaluation and comparison is presented in section IV. Finally, section V concludes this paper.

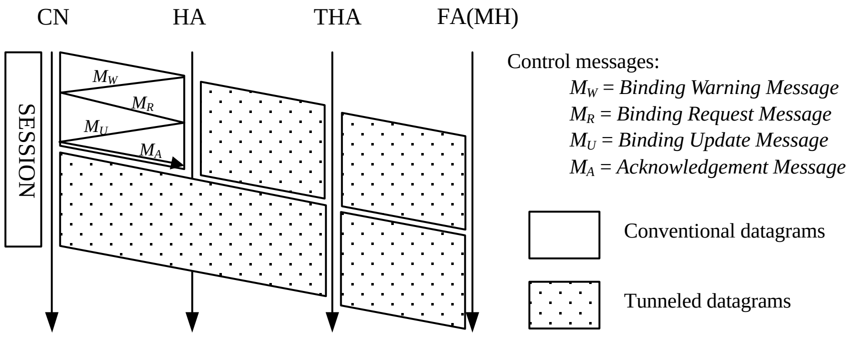
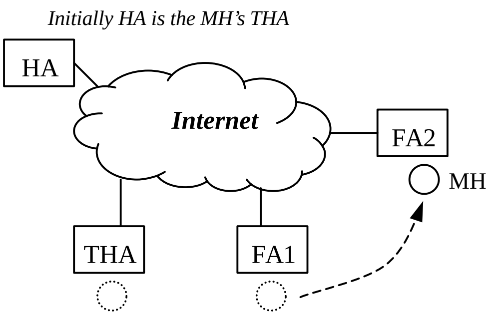


Figure 1. Flow diagram for data delivery in HH-MIP



If *Distance* (FA2, HA) < *Distance* (FA2, THA) then
/*** MH is moving closer to its HA ***/
HA is selected as the new THA

Else if *Distance* (FA2, THA) > *Distance* (FA1, THA)
/*** MH is moving away from its previous THA ***/
FA2 is selected as its new THA

Else
MH's THA remains the same

Figure 2. Selection of THA in HH-MIP

II. HH-MIP: MIP WITH HA HANDOVER

A. *Basic idea & Data Delivery*

As mentioned in section I, HH-MIP introduces the concept of Temporary HA (THA) and as in ROMIP each CN is required to maintain two addresses for an MH: the *home address* of the MH and the *THA address* of the MH. The HA of an MH maintains the binding of the THA address for the MH. Handover of the THA requires the MH to update the binding cache in its HA. The handoff of an MH to a new FA only triggers registration of the new CoA to the THA (instead of the HA) when the THA of the MH remains unchanged. Since the THA of an MH is selected to be close to the current location of the MH, HH-MIP reduces the handoff latency and shortens the signaling path of registration as well.

Data delivery in HH-MIP is similar to that in ROMIP as explained in the following. Initially the CN sends packets to the home address of the destined MH, the HA intercepts and sends the packets to the THA by tunneling, and the THA tunnels the packets to the current location (FA) of the MH. Meanwhile, a binding copy of MH's THA is sent by HA to the CN so that later packets can be directly delivered to the THA, and THA tunnels the packets to the current location (FA) of the MH. Therefore, regular data delivery in HH-MIP requires the packets sent by the CN to be tunneled twice before they reach the destined MH.

Four messages are used for binding update of THA as in ROMIP: (1) *Binding Warning Message* (M_W), (2) *Binding Request Message* (M_R), (3) *Binding Update Message* (M_U), and (4) *Acknowledgement Message* (M_A). The HA just after having tunnels the first packet sends an M_W back to the CN informing that the MH is not in the home network. In response to the received M_W, the CN sends an M_R to the HA asking for binding update. The HA replies with an M_U containing the requested CoA (i.e. THA's address). Finally, CN sends an M_A to the HA acknowledging the successful binding update. Figure 1 illustrates the process of data delivery in HH-MIP.

B. *THA Handover*

Initially, an MH selects its HA as the THA. HH-MIP adopts an aggressive approach in selecting the THA for an MH: whenever an MH is moving away from the HA or the previous THA, the MH triggers the handover of THA. As illustrated in Figure 2, if the distance (hop count) from FA2 (MH's current location) to THA is longer than the distance from FA1 to THA implying that the MH is moving away from THA, FA2 is selected as the new THA, and the MH notifies its HA of the new THA. On the other hand, if HA is closer to FA2 than THA implying that the MH is moving back to HA, HA should be selected as the new THA.

Once a new FA is selected as the new THA by an MH, the MH sends the *Binding Update Message* (M_U) to its HA as well as the previous THA. Before the CN gets the address of the

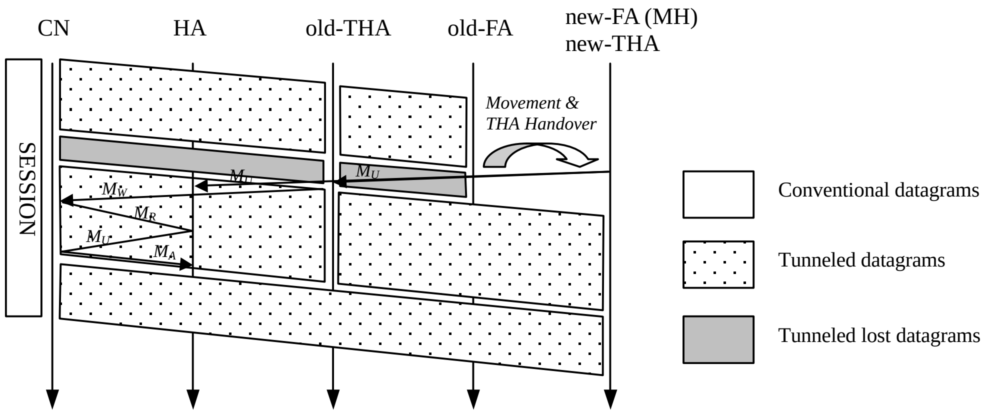


Figure 3. Flow diagram for THA handover

new THA (according to the M_U sent by the HA), packets are still tunneled to the previous THA, and the previous THA tunnels (forwards) the packets to the current FA (i.e. the new THA) which is similar to the forwarding mechanism in ROMIP. When the binding update of the new THA is complete in the CN, packets are sent to the new THA as mentioned in section II-A. Flow diagram for the handover of THA is illustrated in Figure 3.

C. *Discussion*

In order to support HH-MIP, each FA or HA must be equipped with the functions of THA. The functions of the THA include: (1) maintaining a *Temporary Children List* (*TCL*) and dealing with the registration of the new CoA for every MH in the TCL, and (2) a previous THA for an MH is responsible for forwarding packets to the new THA after the MH performs THA handover. Moreover, a probe packet is defined in HH-MIP to measure the distance from an MH to other nodes (FA, THA, or HA).

III. RELATED WORK

User mobility in wireless networks that support IP mobility can be broadly classified into *macro-mobility* and *micro-mobility*. The macro-mobility is for the case when an MH roams across different administrative domains. The macro-mobility occurs less frequently and usually involves longer timescales. MIP was proposed to support global Internet mobility which falls in the category of macro-mobility. IP micro-mobility protocols are designed for environments where mobile hosts change their point of attachment to the network so frequently that the base MIP mechanism introduces significant network overhead in terms of increased delay, packet loss, and signaling.

Most of the related work attempt to improve the MIP micro-mobility handling capability [6], such as *Cellular IP* [7, 8], *Hierarchical MIP* (*HMIP*) [9], *Mobile IP Regional Registration* (*MIP-RR*) [10], and the *Handoff-Aware Wireless Access Internet Infrastructure* (*HAWAII*) [11], etc. Integration of Mobile IP and Cellular IP has been addressed in [12] and [13]. The basic idea of the integration is using the two protocols at the same time but in different levels. Although the proposed HH-MIP adopts the similar idea of localizing registration as in most of the micro-mobility protocols, HH-MIP is basically an enhancement of MIP and also falls in the category of macro-mobility. Therefore, HH-MIP can also be integrated with micro-mobility protocols, such as HMIP or CIP. Integration of HH-MIP with micro-mobility protocols is beyond the scope of the paper.

Some MIP enhancement schemes based on "*pointer forwarding*" technique are proposed in [14] and [15]. In these schemes, pointers are setup when MHs move to new subnets. The pointer chain length is critical to the performance of the pointer forwarding scheme. However, the impact of the chain length was not considered in [14]. *Dynamic Hierarchical MIP* (*DHMIP*) was proposed in [15] in which the location update messages to the HAs can be reduced by setting up a hierarchy of FAs, where the level number of the hierarchy is dynamically adjusted based on each mobile host's up-to-date mobility and traffic load condition. Since the idea of route optimization was not included in DHMIP, it suffers the performance problem of longer transmission paths. Moreover, DHMIP requires more processing in handling the bi-directional pointers between FAs in the hierarchy for data delivery and binding update of the new CoA.

IV. PERFORMANCE EVALUATION

A. *Simulation environment and performance criteria*

The network topology for the simulation is an 8 x 8 mesh. Each node in the mesh represents an FA. There are 1000 mobile hosts in the network. The location of the HA and the CN for an MH is randomly selected from the nodes. Initially, each MH is in its home network. In order to model the mobility of mobile hosts, time is slotted and a parameter called *MoveProb* (*Movement Probability*) is used in the simulation. *MoveProb* represents the probability that a mobile host leaves its current FA in the next time slot. Thus, we could model a high mobility by assigning a large value of *MovProb*. When a mobile node decides to leave its current FA in the next time slot, its next FA is randomly selected from the neighboring FAs. Total run time in the simulation for each scheme is 500 time slots. We compare MIP, ROMIP, DHMIP, and the proposed HH-MIP in the simulation in terms of the following performance criteria:

(1) *Signaling cost*: the signaling cost for each scheme is measured in terms of the average number of control packets generated in the wired network (Internet). The control packets generated in HH-MIP include (1) Four control messages (M_W, M_R, M_U, M_A) for binding update, (2) Two control messages (one M_U to the previous THA, one M_U to the HA) for THA handover.

    Note that the probe packet for distance measuring is not included in the signaling cost since the FA directly replies the probe packet to the MH by querying its routing table. From the implementation viewpoint, the probing message can be piggybacked in the packets transmitted between the MH and FA.

(2) *Average handoff latency*: The handoff latency is measured as the length (in hop counts) of the path for binding update. A longer handoff latency results in the increase of in flight packet loss.

(3) *Average end-to-end path length*: The average path length (in hop counts) for end-to-end data delivery is used to evaluate routing efficiency of each scheme.

B. Simulation results

Figure 4 displays the average handoff latency (in hop counts) and the average length of end-to-end path (in hop counts) for MIP, ROMIP, HH-MIP, and DHMIP respectively. MIP suffers from the longest handoff latency since it requires the MH to register to its HA whenever the MH handoff to a new FA. ROMIP enjoys the shortest handoff latency (one hop) since it adopts the forwarding mechanism in which the MH notifies its previous FA with the new CoA when the MH handoff to a new FA and the previous FA forwards packets to the new FA. Localized registration in both HH-MIP and DHMIP results in shorter handoff latency than MIP. However, due to the limitation of the level number in FA hierarchy, the MH in DHMIP sometimes has to register back to the HA resulting in the increase of the average handoff latency in comparing with HH-MIP.

On the other hand, as shown on the right side in Figure 4, ROMIP enjoys the shortest end-to-end path length since the CN maintains the binding cache for the MH and sends packets directly to the MH. Route optimization is not adopted in MIP and DH-MIP, so both they suffer from the long transmission path. The average end-to-end path of DHMIP is even slightly longer than that of MIP, because the packets tunneled from the HA have to go through the forwarding hierarchy of FAs. The average length of end-to-end delay of the proposed HH-MIP is relatively moderate since HH-MIP makes use of both localized registration as well as route optimization.

The end-to-end path in each scheme includes different components. For example, in HH-MIP, the packets are first tunneled from the CN to the THA, and THA tunnels the packets to the MH's current FA. For more insights, we displays the average length of different components in the end-to-end path for each scheme in Figure 5.

The signaling cost for each scheme is shown in Figure 6 for different mobility levels. The signaling cost (i.e. the average number of control packets) generated in HH-MIP is significantly less than that in ROMIP and moderately more than that in MIP and DHMIP (note that the curves of MIP and DHMIP in Figure 6 are almost overlapping).

In summary, the triangular routing problem is reduced in HH-MIP, since the THA is close to MH's current location. Moreover, a close THA also shorten the signaling path and thus reduce the handoff latency.

V. Conclusion

Mobile IP (MIP) was proposed to support global Internet mobility through the introduction of location directories and address translation agents. To remedy the problem of triangular routing and reduce the packet loss during long handoff latency in the original MIP scheme, Route Optimization MIP (ROMIP) was proposed. However, the improvement of ROMIP over MIP in terms of routing efficiency and smaller handoff latency is at the cost of significantly larger signaling overhead. In this paper, we propose an enhancement of MIP called MIP with HA Handover (HH-MIP) to enjoy most of the advantages of ROMIP but with only a small increase of signaling overhead. In HH-MIP, the concept of Temporary HA (THA) is proposed and the mobile host registers the new CoA with its THA rather than its original HA. Moreover, HH-MIP adopts an aggressive approach in selecting the THA for an MH, i.e. whenever an MH is moving away from HA or previous THA, the MH triggers the handover of THA. Simulation results demonstrate that HH-MIP enjoys small handoff latency as well as routing efficiency and the number of control packets generated in HH-MIP is significantly less than that in ROMIP.

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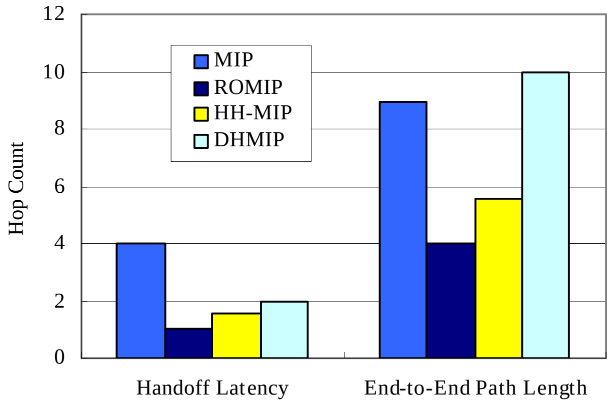

Figure 4. Handoff latency & end-to-end delay

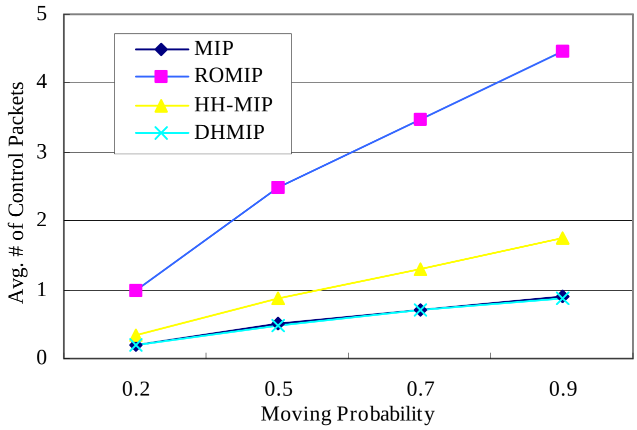

Figure 6. Signaling cost

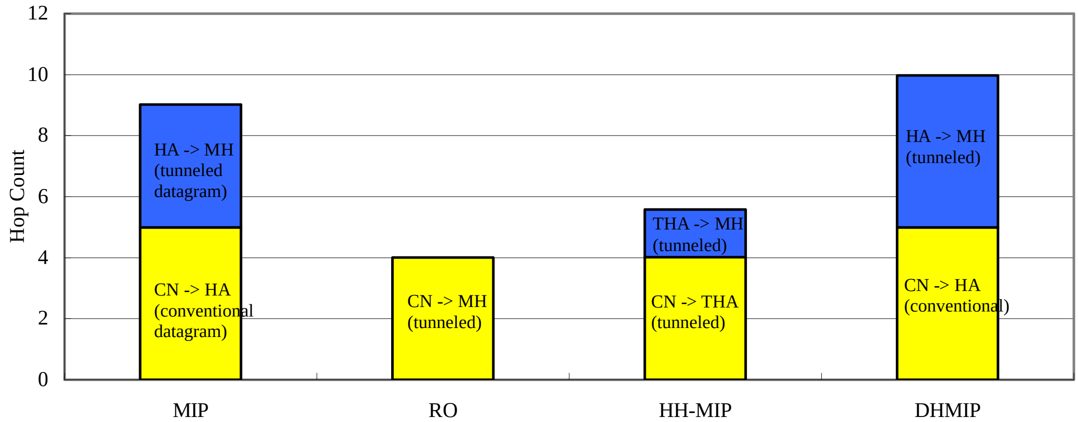

Figure 5. Components in the end-to-end path