Mobility Issues in Hierarchical Mobile IP

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Abstract: Mobile IP is a powerful protocol that supports Internet mobility. Micro-mobility approach was introduced because Mobile IP suffers in case of frequent movement, i.e. intra-domain mobility. Micro-mobility protocols aim to handle local movement of Mobile Nodes (MNs) without interaction with the Home Agent (HA) through the Internet. This has the benefit of reducing delay and packet loss during handoff and eliminating registration between MN and possibly distant Home Agents (HA) when MN remain inside their local coverage areas. The Hierarchical Mobile IP (HMIP) protocol handles Mobile IP registration locally using a hierarchy of foreign agents. In HMIP, registration messages are sent by the MNs to update their respective location information. This registration messages will establish tunnels between neighboring foreign agents along the path from the mobile node to a gateway foreign agent (GFA). This will form a network of tunnels where packets addressed to the MN will travel. The aim of this research is to study and evaluate HMIP protocol. The paper presents mobility issues in HMIP. The performance analysis of the protocol is carried out using NS-2 simulator. Some recommendation was suggested to improve mobile communication in HMIP.
Key words: Hierarchical, Mobile IP, Micro-mobility, Performance Analysis.

1 Introduction

Mobile IP is an Internet standards protocol, which enhances the existing Internet Protocol (IP) to accommodate mobility. Over the Internet, when a Mobile Node (MN) moves and attaches itself to another domain, it needs a new IP address. With this all the existing connections with the home network will be terminated. Mobile IP was introduced to overcome this problem. But later on, Mobile IP itself experiences its own other discrepancies. This is when micro-mobility protocols were proposed and implemented. One of the protocols is HMIP.

For HMIP protocol a hierarchy of foreign agent is employed to locally manage registration. Hierarchical schemes reduce handoff latency by employing a hierarchical network structure in minimizing the location update signalling with external network. The hierarchical structure separates mobility into micro-mobility (within one domain) and macro-mobility (between domains).

1.1 Mobile IP

When a MN that is not in its home network received packets, the packets will be routed through its Home Agent (HA). Conversely, the packets from the MN to the Correspondent Nodes (CN) will be routed directly without the need of the its HA. This process is called triangle routing. Figure 1 illustrates triangular routing.

Nonetheless, Mobile IP encounters some problems. For instance, in triangular routing, if the CN and the MN are in the same domain but not in the home network of the MN, they will experience unnecessary delay as they have to be first routed to the HA that resides in the home network. One way to improve this is Route Optimization. Route Optimization (Debalina 2002) is an extension proposed to the basic Mobile IP protocol. In this case, packets from the CN are routed directly to the MN's CoA without having to go through the HA.

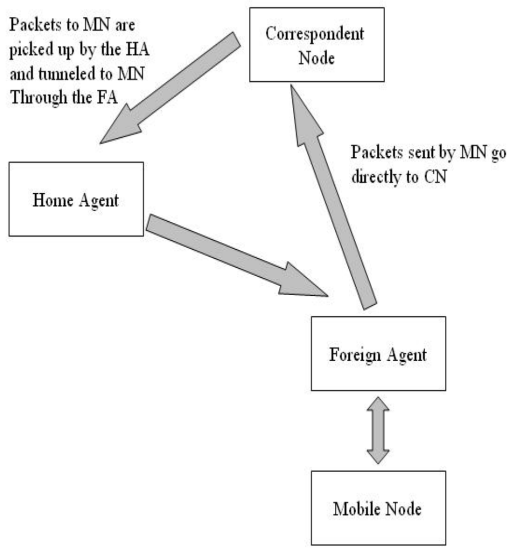


Figure 1. *Triangular Routing*

Due to frequent change of MN's point-of-attachment, a few disadvantages occurred. The disadvantages are delay in handoff, packet loss and signaling load. Therefore HMIP protocol is proposed.

1.2 Hierarchical Mobile IP

A hierarchical solution is more appropriate to the Internet as it differentiates local mobility from global mobility. The Hierarchical Mobile IP protocol employs a hierarchy of FAs to locally handle Mobile IP registration. Typically one level of hierarchy is considered where all foreign agents are connected to the gateway foreign agent (GFA). Figure 2 explains the architecture of Hierarchical Mobile IP.

In this case, direct tunnels connect the gateway foreign agent to foreign agents that are located at access points. Paging extensions (Haverinen & al 2000) for Hierarchical Mobile IP are presented in allowing idle mobile nodes to operate in a power saving mode while located within a paging area. The location of mobile hosts is known by home agents and is represented by paging areas. After receiving a packet addressed to a mobile host located in a foreign network, the home agent tunnels the packet to the paging foreign agent, which then pages the mobile host to re-establish a path toward the current point of attachment. The paging system uses specific communication time-slots in a paging area. This is similar to the paging channel found concept found in second-generation cellular systems.

In Hierarchical Mobile IP, the mobile host sends mobile IP registration messages with appropriate message extensions to update its location information. These registration messages are used by the protocol to establish tunnels between neighboring foreign agents that are on the path from the mobile host to the gateway foreign agent. A packet that is addressed to the mobile host travels in this network of tunnels. This network of tunnels can be considered as a routing network sitting on top of IP. Tunnels connect the gateway foreign agent to other foreign agents at the network access points (Chew 2002).

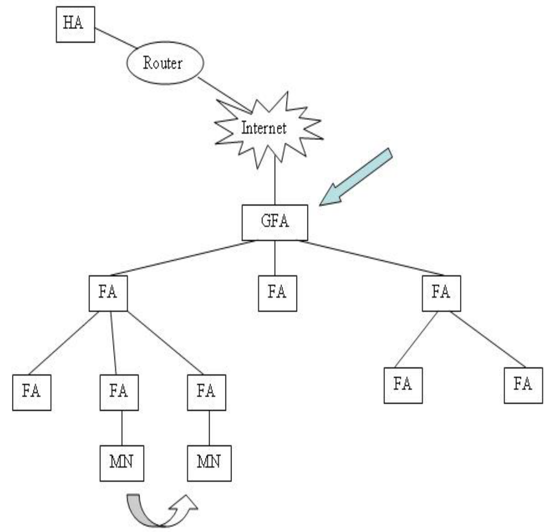


Figure 2. *Hierarchical Mobile IP*

Hierarchical Mobile IP used the hierarchical tunneling approach in which the foreign agents in the network maintain the location information in a distributed fashion. The protocol updates the routing only when registration messages arrive at the gateway foreign agent. When the mobile moves to a new access point, it sends a control message that propagates toward the gateway foreign agent and downlink routing information along the new path is generated. Since Hierarchical Mobile IP employs a single level routing point hierarchy to reduce the number of mobility managing nodes in the network, a higher handoff delay compared with other mobility protocols using the mobile-specific routing approach is introduced (Chew 2002).

1.3 Paging

The paging extensions for Mobile IP (P-MIP) (Zhang & al 2000) developed by Columbia University, Fujitsu and Broadcom is designed to reduce signaling load in the core Internet and power consumption of MN. In Mobile IP, MN registers with a new FA when it changes its point of attachment. On the other hand, an idle MN does not register when it moves in a same paging area. It is only forced to register when it moves to a new paging area.

In Mobile IP data packets that are received by the HA destined to the MN are forwarded to the registered FA. Then the FA checks if it has the MN information on record. If there is a record, then it checks whether the MN supports paging or not. If the MN supports paging, then the registered FA checks the state of the MN. If the MN is in active state, then the FA decapsulates and forward the data packets to the MN, as in Mobile IP. But, if the MN is in the idle state, the registered FA sends a paging request message to other FA in the same paging area as well as transmitting the message on its own network.

The MN registers through the current FA to its HA when it receives the paging request. After the MN has received the registration request, it will then send a paging reply to its registered FA through its current FA. This is done to inform the registered FA of the MN current location. When the registered FA receives a paging reply, it forwards any buffered packets to the MN.

For the comparison between HMIP and Mobile IP, the standard Network Simulator, ns, with the distribution version ns-allinone 2.1b6 was patched with a freely available ns wireless extension module. The wireless extension meant is Columbia IP Micromobility Software (CIMS).

2. Related Works

In (Andrew & al 2003), it is mentioned that the primary role of micromobility protocols is to ensure that packets arriving from the Internet and addressed to mobile nodes are forwarded to the appropriate wireless access point in an efficient manner. It is also mentioned that to do this, micromobility protocols maintain a location database that maps mobile node identifiers to location information. In this paper they stated that by using hierarchical protocol, it could reduce the disadvantages of Mobile IP protocol such as delay, packet loss and signaling load. However the authors are more focused on comparing only Cellular IP and HAWAII.

Work in (Haverinen & al 2000) focuses on paging which is one of the main characteristics of Hierarchical Mobile IP. The paging extension that is used in HMIP allows idle mobile nodes to operate in a power saving mode while located within a paging area. The location of mobile nodes is known by Home Agents (HA) and is represented by paging areas. After receiving a packet addressed to a mobile node located in a foreign network, the HA tunnels the packet to the paging FA, which then pages the mobile node to reestablish a path toward the current point-of-attachment. The paging system uses specific communication time slots in a paging area.

In (Debalina 2002) the author compares between the inter-domain mobility management and the intra-domain mobility management. The advantages stated by the author are first; the mobility of a node within a domain is fully transparent to its correspondent nodes. The second advantage stated is that when inter-domain and intra-domain are differentiated, an architecture, which is hierarchical, scalable flexible and customize is provided. The paper proved that the mobility management signaling load is reduced by 69% compared to Mobile IP using a hierarchical mobility management scheme. However full comparison between Hierarchical Mobile IP and standard and Mobile IP is not given.

3 Simulation Scenario

3.1 Packet Loss

The following simulation scenarios are conducted using NS-2 simulator. The packet loss is obtained by using the formula:

Number of Packet Loss =

Number of Send Packet – Number of Received Packet

In MIP, referring to Figure 3, starting at t = 10sec, there is already packet loss. This packet loss is due to the signaling overhead at the Internet, the registration process (Binding Update) between the MN and the HA and registration due to time out when the MN is in the foreign network. Furthermore, in the simulation done, there are bandwidth limitations of 5Mbps and the queue limit is only up to 200 bytes. When the queue reached its limit, congestion occurs; this will lead to more packet loss.

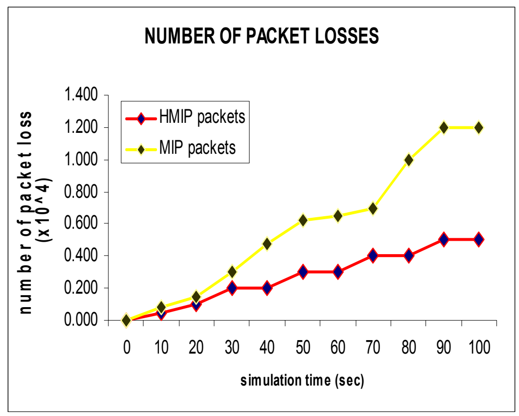


Figure 3. *Comparison of Packet Losses*

In HMIP, at t = 5sec, it starts to loss packets because of the registration request and reply between MN, GFA and HA. Then the packets loss increases gradually because of the regional tunneling in the GF Network. The process of encapsulation and decapsulation of packets by the FAs also increases the loss. This shows that in micromobility, HMIP is better than MIP in terms of packet loss.

3.2 Delay

From the graph, for MIP the delay starts at 4ms and it increases and decreases inconsistently. The delay is caused by the congestion of traffic and the queue size limitation that is set. The packets will be buffered before being forwarded. The delay increases and decreases inconsistently because of the registration to the HA through the Internet frequently.

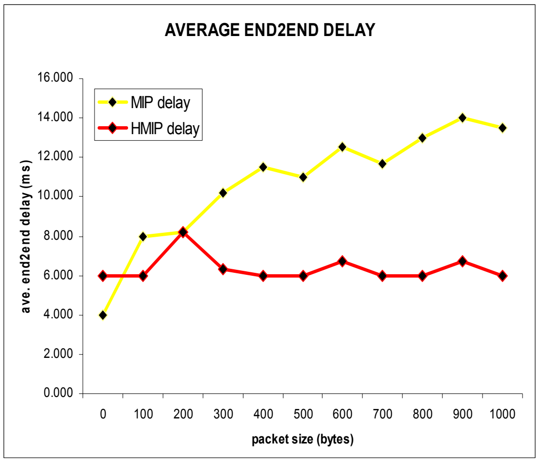


Figure 4. *Comparison of End2End Delay*

From the graph, for MIP the delay starts at 4ms and it increases and decreases inconsistently. The delay is caused by the congestion of traffic and the queue size limitation that is set. The packets will be buffered before being forwarded. The delay increases and decreases inconsistently because of the registration to the HA through the Internet frequently. A conclusion can also be made that as the number of packets increase, so will the delay. It can also be concluded that packets size and delay are relatively proportional in MIP.

In HMIP, the delay starts at 6ms because of the links delay (propagation delay) in the topology. At 100 bytes the delay starts to increase, this is because, at this time the MN will have to register to it's HA and it has to wait for the registration reply from the HA (inter-domain communication). When HA knows the CoA of MN (equals to the GFA CoA), only then the MN can starts to receive and send packets. In HMIP there is slight increment and decrement in delay. This happens because of the registration process to the GFA as the MN changes its point of attachment within the domain (intra-domain communication).

3.3 Signaling Load

In MIP, when a MN moves to a foreign network, it will have to go through a registration process. At first, it will send a registration request to HA. Then the HA will send the registration reply to the MN. As shown in Figure 5 (a).

This means that the HA knows the CoA of the MN. The discrepancy here is that every registration process will have to go through the Internet (because MIP is macromobility). This will result in signaling overhead at the Internet and it will cause delay, packet loss and also handoff latency during transmission. The next time MN changes its point of attachment, the same process will be repeated as shown in Figure 5 (b).

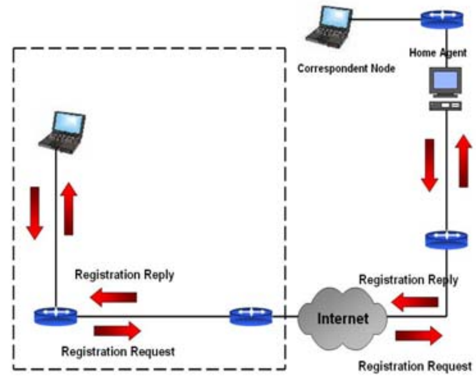


Figure 5 (a). *Signaling Load in MIP*

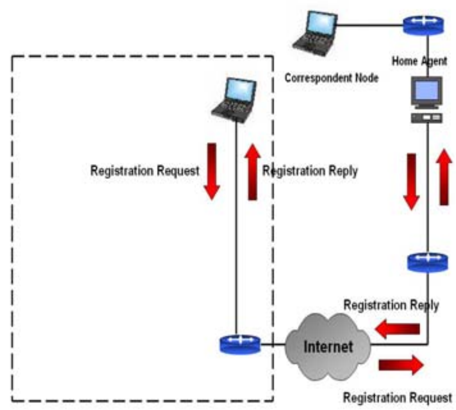


Figure 5 (b). *Signaling Load in MIP after MN changes its Point-of-Attachment*

For HMIP, when the MN moves to a foreign network for the first time, it will have to send a registration request to the HA. Then it will have to wait for a registration reply from the HA. Here, the CoA of the MN will be the same as its GFA. This is illustrated in Figure 6 (a)

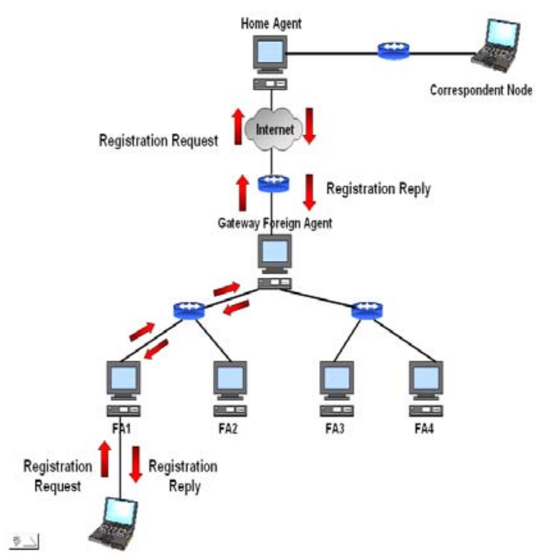


Figure 6 (a). *Signaling Load in HMIP (first registration to the HA and GFA)*

After that, if the MN moves within the GF network, it will only have to inform and send Binding Updates to its GFA as shown in Figure 6 (b). This will reduce the signaling overhead at the Internet. Using HMIP, the signaling overhead will be within the GFA (micromobility).

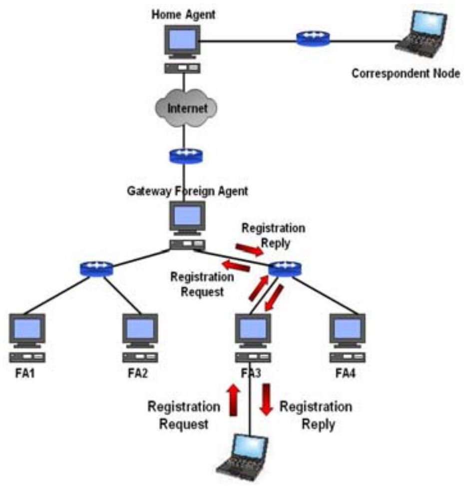


Figure 6 (b). *Signaling Load in HMIP within the GF network*

4. Recommendation

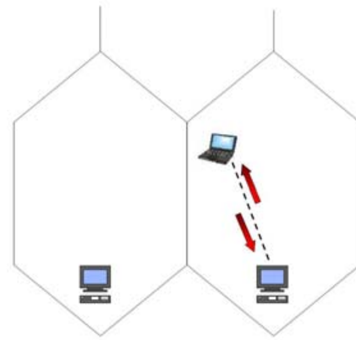
4.1 Handoff Latency

The MN does not send a BU (Binding Update) to the CN since it does not maintain a BU list while the MN is at home when performing a handoff between the home network and the foreign network. The first packet received from a CN to a MN after a HA–FA handoff will produce latency proportional to the round-trip time necessary by a BU to arrive from the foreign network to the home network. The FA–FA handoff case differs in that the latency is proportional to the minimum time required by a BU to arrive either at the agent on previous access router, HA or the CN.

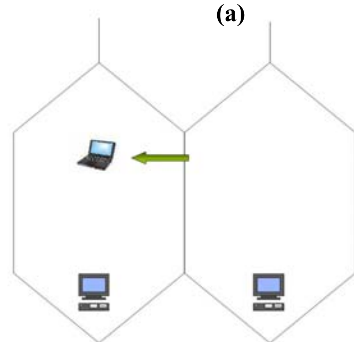
The HA–FA handoff will always result in a higher or similar latency value compared to the FA–FA case. This is because in the case of a HA–FA handoff the mobile node will only send a BU to the HA and not to the CN. This will result in a higher latency time than in the case of FA–FA because from MN's perspective at the foreign AR.

MIP is a standard protocol that is good for an inter-domain communication. However, as explained it is not a preferable protocol to be utilized in an intra-domain communication that is why micromobility protocols are proposed. Instead HMIP is better for intra-domain communication but not for an inter-domain communication.

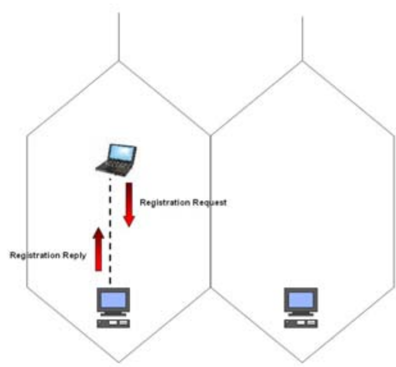
HMIP implements the handoff schemes that are shown in Figure 7 (a) for an inter-domain communication. In Figure 7 (b) it shows that in this handoff, if the MN wants to change its point of attachment, it will not be able to receive packet. This is because, once it started to move to a new point of attachment, the old point (old FA) would not be able to detect the MN. Therefore, the MN will have to make registration request to the new FA and wait for the reply as in Figure 7 (c). Within this period of time, it will not be able to send or receive any packets (handoff latency). After a registration reply send through the new FA, then only the MN can start to send and receive messages again.



(a)



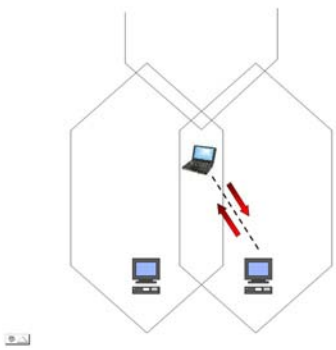
(b)



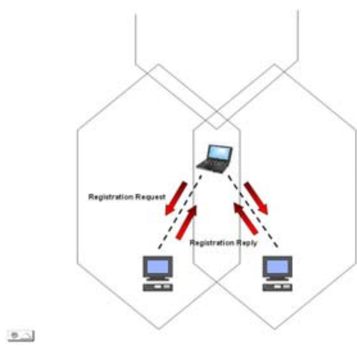
(c)

Figure 7. *Handoff Operation in HMIP*

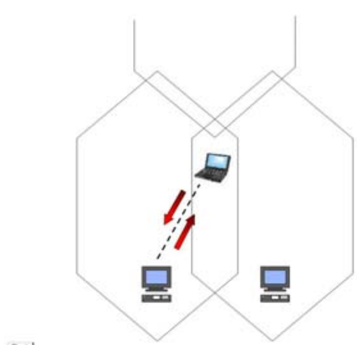
To reduce the delay, packet losses and signaling load in HMIP, it is recommended that the MN is placed at the overlapping area of handoff as shown in Figure 8. Figure 8 (a) shows the normal packets handoff between the MN and the FA. In Figure 8 (b) the MN wants to change its point of attachment, therefore it will sent a registration request through a new point of attachment (new FA) to the GFA but it will still receive messages from its old point of attachment. This process took place while MN is in the overlapping area of handoff. After receiving registration reply from the new FA, it will start to send and receive packets through the new FA as shown in Figure 8 (c).



(a)



(b)



(c)

Figure 8. *Recommended Handoff Operation in HMIP*

Conclusion

In this paper, we briefly explained Hierarchical Mobile IP overview and how it operates. HMIP is considered as an appropriate protocol for micromobility because it differentiates between local mobility management scheme and global mobility management scheme. To demonstrate the performance we use a set of simulation developed under CIMS ns-2 extension that supports programming models for HMIP. Simulation was performed for typical Mobile IP and Hierarchical Mobile IP and the scenario was observed and analyzed. Our main focus was to determine packet losses, end-to-end delay, handoff latency and signaling load for both MIP and HMIP.

HMIP uses different level of hierarchies according to the mobility pattern. This occurs when a mobile node is moving quickly and communicating with a host that is far from its location. However, a hierarchical scheme is not suitable for slow moving node and global communication. From the calculation and observation made using ns-2 simulator and trace graph, we conclude that HMIP packet transmission within a domain reduces latency and signaling load. However, HMIP suffers from some delay for global communication. Hence, some recommendation was suggested to overcome the problem.

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