Hierarchical Mobile IPv6 (HiMIPv6) Supporting Seamless Handoff

Chung-Chun Huang, Cheng-Wei Lee, Fan Liu, and Professor Yeali S. Sun

Information Management Department, National Taiwan University

1. Introduction

As the growing development and deployment of Wireless networks (such as IEEE 802.11b/a/g WLAN and 3G mobile communications), mobile Internet and real-time IP applications, such as Voice over IP (VoIP) and videoconferencing, are synergic to boost their usability. As a result, there has been much inter est in developing efficient and effective IP-based mobility management to support seamless handoff while crossing IP subnet boundary.

The current specification of Mobile IP (RFC2002) suffers from several drawbacks such as long update latency, high signaling overhead, and lack of paging support. Over the past several years, several IP-based micro mobility managements have been proposed, designed and implemented to complement the Mobile IP. In order to reduce the signaling overhead caused by the global mobility management, micro mobility management uses the route modification approach to support the location update management. Specifically, hierarchical mobility management architecture is employed to localize the signaling messages within a network domain so to reduce the number of binding updates. The proposed Hierarchical Mobile IPv6 (HiMIPv6) scheme is aimed to minimize the latency and packet loss to support seamless handoff

2. Development Concept

We consider a foreign network domain comprised by a number of routers interconnected into a hierarchy as shown in Fig. 1. Each router is equipped with an extended Foreign Agent referred to as the Foreign Mobility Agent (FMA) that supports Hierarchical Mobility Management. There are three types of FMAs responsible for slightly different functions: root-FMA, interior-FMA and leaf-FMA.

When a Mobile Node (MN) first moves to a foreign network, according to the IETF mobile IP framework, it will send a registration message (i.e. binding update) to its Home Agent (HA) and all the Correspondent Nodes (CN) that the MN is communicating to update them its new location. Subsequently, as MN may roam across different subnets within the domain, the binding updates sent by the MN will be identified and intercepted by the switching-FMAs to update the "visitor lists" without forwarding the binding updates to the HA and CNs. Under this hierarchical mobile IP architecture, MN's Care-of Address (CoA) known to the HA and CNs is the address of the root-FMA. In addition, the MN will obtain a new local CoA as it roams from one subnet to another.

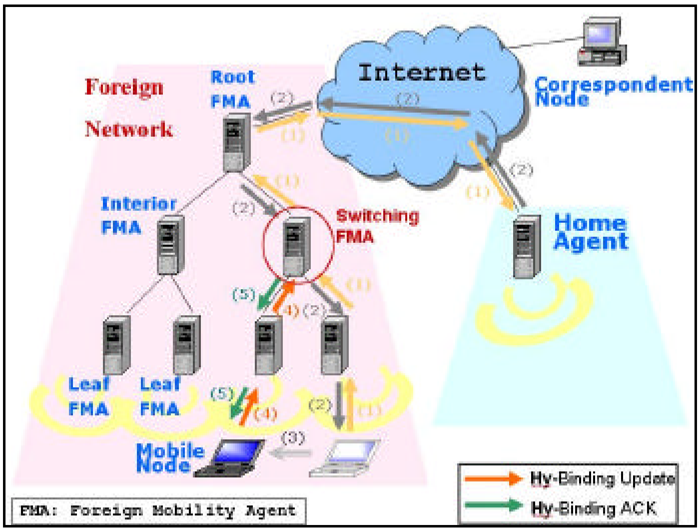

Fig. 1. Hierarchical Mobile IPv6 network with FMAs.

3. System Features: Foreign Mobility Agents

To achieve the goals, three types of FMA are implemented on IPv6 router to maintain appropriate visiting MNs' information and to assure packet to a roaming MN is correctly routed. We use an unused field in the original Mobile IPv6 registration message to indicate the support of the Hierarchical Mobile IPv6 Management.

Many routers do not accept or forward packets that have a source address which appears topologically incorrect or packets with un-authorized source address (e.g., the CoA of a MN). In our implementation, a visiting MN uses its CoA as the source address in the outgoing packets, which will be intercepted by the root-FMA. Root-FMA changes the source address of the packet to its own IPv6 address. In addition, we define a new IPv6 Destination option Header Extension type (Receiver Home Address Option) to record the home address of the MN, which is included in the packet delivered to MN.

The functions of the FMAs are listed as follows:

- Intercept HiMIPv6 messages including HiMIPv6 Binding Update (Hy-BU), Mobile IPv6 Binding Acknowledgement (BA) and Binding Request (BR).
- Root-FMA modifies the source address of outgoing

packets from visiting MNs from MN's local CoA to root-FMA address.

- Root-FMA modifies the destination address of incoming packets delivered to visiting MNs from root-FMA's address to corresponding visiting MN's current CoA (The identification of MN is based on the home address recorded in the Receiver Home Address Option).
- Maintain the Visitor List for each pending or current registration. Each entry includes MN home address, the address of each node received a binding update from the MN, current local CoA, MN's registration state, lifetime, etc.
- Generate HiMIPv6 Binding Inform (Hy-BI) for each suppressed Hy-BU message. When a MN moves to a new leaf FMA within the same foreign HiMIPv6 domain, the crossing point, called *switching FMA*, of the old and current registration paths will stop the forwarding of the binding update and send a BA to the MN as if it were the HA. At the same time, the switching FMA also
sends a Hy-BI to inform all the FMAs in the old registration path that the MN has already left their coverage (as shown in Fig. 2).
- Generate HiMIPv6 Router Advertisement.

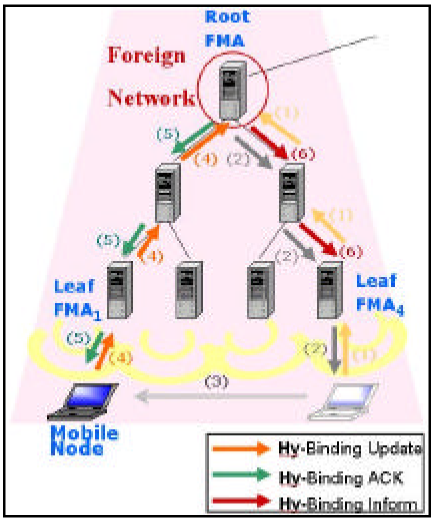

Fig. 2. MN roams to another subnet under the same foreign domain with Hy-Binding Inform

4. Detailed Implementation Designs

A. Visitor List

The visitor list is an important data structure used by the FMAs to process HiMIPv6 messages and route packets from/to visiting mobile nodes within the domain. The lookup performance of the visitor list table is therefore critical to the performance of the routers. In our implementation, we use MN's Home Address and the destination address of the HiMIPv6 messages as the hash keys to search the table. The State field is used to record the stage of the binding update procedure, i.e. BU, BA or BR.

B. Hierarchical Router Advertisement (Hy-RA)

We define a new flag field referred as the Hierarchy (Hy) field, in the Router Advertisement packet as shown in Fig. 3. The "Hy" bit is set to one if the router implements leaf-FMA.

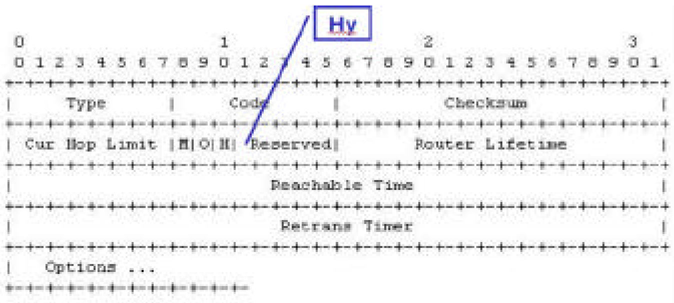

Fig. 3. The Router Advertisement with the "Hy" bit.

C. Hierarchical Binding Update (Hy-BU)

A "Hy"-bit flag is also defined and set in the Binding Update message sent by MN to indicate the node supports HiMIPv6.

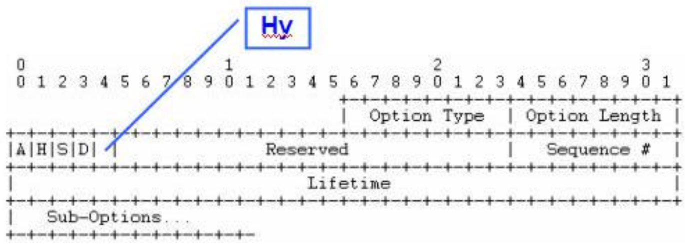

Fig. 4. The Binding Update message with the "Hy" bit.

D. Receiver Home Address Option

The Receiver Home Address Option with Option Type 205 (0xCD) is included in each packet sent by HA or CN in HiMIPv6. The goal is to inform the FMAs of the Home Address of the packet's true receiver. Under the HiMIPv6, the source address of the packets received by HA and CNs has been changed by the root-FMA to its own address when going out of the FMA Hierarchy. If HA/CN regards the source address of the received packet as MN's care-of address, the root-FMA would need to know the true receiver so to perform address translation and packet forwarding. By including the Receiver Home Address option in the packets, FMAs would know the true receiver and perform accordingly. The option format is shown as follows in Fig. 5.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                |  Option Type  | Option Length |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+                     Receiver Home Address                     +
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Sub-Options...
+-+-+-+-+-+-+-+-+-+-+-+-
```

Fig. 5. The Receiver Home Address Destination Option Header Extension.

E. Hy-Binding Inform (Hy-BI)

We define that Hierarchical Binding Inform is Binding Acknowledgement with the status field “200”.

```
 0                   1                   2                   3
 0 1 2 [200] 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                                +-+-+-+-+-+-+-+-+
                                                |  Option Type  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Option Length |    Status     |        Sequence Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Lifetime                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Refresh                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Sub-Options...
+-+-+-+-+-+-+-+-+-+-+-+-
```

Fig. 6. The Hierarchical Binding Inform message

5. The Implementation Environment and Testbed

Our implementation is on Linux Kernel 2.4.7 (Red Hat 7.2), based on the Mobile IP code developed by the HUT Telecommunications and Multimedia Lab. We extend and modify the code to support Hierarchical Mobile IPv6 as described above. Specifically we focus on the alleviation of high control overhead due to frequent notifications to the HA and CN, and high latency and disruption during handoff as MN roams within an administrative domain of a wireless access network. The Fig. 6 shows our experimental environment.

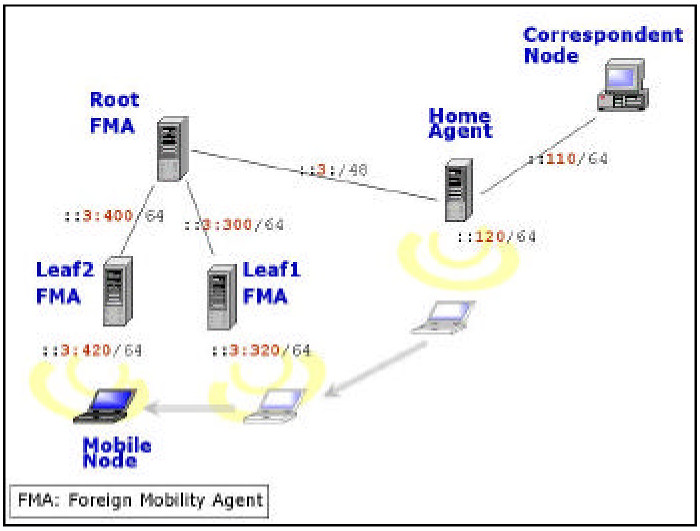

Fig. 6. Experimental Environment

The system operation requirements are as follows:

- RedHat 7.2 (Linux Kernel v2.4.7)
- MIPL package (mipv6-0.9-v2.4.7.tar.gz) implementing draft-ietf-mobileip-ipv6-13.
- RADVD(radvd-0.7.1.tar.gz)
- Usagi (usagi-linux24-s20020930.tar.bz2)
- Wireless tool (wireless_tools.25.tar.gz)

The installation detail of the HiMIPv6 system is described in the installation guide uploaded to the contest FTP site.

We have designed and done 2 major tests to assure the correctness of our implementation. We use Ethereal to capture the packets transmitted over the links. The test results are also described in the PowerPoint files uploaded to the contest FTP site.

Besides, we have considered the network management issue while our HiMIPv6 system is operating. Therefore, we implement a SNMP Monitoring Tool to monitor the current statistics of the HiMIPv6 control messages and the visitor lists of FMAs. The detailed description of SNMP Monitoring tool is described in the installation guide.

6. Conclusion

In this work, we have implemented the Hierarchical Mobile IPv6 systems including software components for Foreign Mobility Agents on routers, IPv6 Home Agent, IPv6 Corresponding Node and IPv6 Mobile Node. This system has the following advantages over traditional Mobile IPv6.

1. **Reduction of the signaling overhead in the Internet**

   When a mobile node moves between FMAs under the same FMA hierarchy in HiMIPv6, the re-registration by the mobile node only occurs within the hierarchy. The re-registration packet will not go to the Home Agent or the corresponding node.

2. **Reduction of handoff latency for Mobile Node**

   As re-registration only occurs within FMA hierarchy, the handoff can be performed promptly. This is very important for the increasing demand of the real-time traffics.

3. **Ease the load of HA and CN**

   All operations are transparent for HA and CN.

4. **Minimal modification on Mobile IPv6**

   The modifications on MN, HA, and CN are minimal. Most of the operations are done by the FMAs. Our implementation is loaded as a Kernel module. Therefore, the impact on Mobile IPv6 is very limited.