

An Implementation of Multiple Home Agents Mechanism in Mobile IPv6

† Hongbo Shi and ‡ Shigeki Goto

† Department of Health Information, Tokyo Health Care University
3-11-3 Setagaya, Setagaya-ku, Tokyo, 154-8568 JAPAN
Email: h-shi@thcu.ac.jp

‡ Department of Information and Computer Science, Waseda University
3-4-1 Ohkubo Shijuku-ku, Tokyo, 169-8555 JAPAN
Email: goto@goto.info.waseda.ac.jp

Abstract—This paper proposes a new mechanism of multiple home agents to realize a stable connection in Mobile IPv6. The new mechanism has multiple home agents instead of only one home agent in the existing specification of Mobile IPv6.

In the existing Mobile IPv6 protocol, it takes time to find a new home agent and make it work. A mobile node cannot find that the home agent is down until the mobile node needs to register or update the binding information at the home agent. When a home agent is down and a mobile node is away from home and on a foreign link, the mobile node cannot receive any packets from a newly joining correspondent node.

The new mechanism provides multiple home agents with a new Binding Update Message and a new ICMP Home Agent Unreachable Error Message. The new binding update procedure realizes a fast home agent recovery. This paper describes the result of an experiment which shows how a mobile node works with multiple home agents. We also compare the fast home agent recovery process with existing methods.

I. INTRODUCTION

Mobile IP is a protocol that realizes the mobility in the network (IP) layer. In Mobile IP, a mobile node (MN) has a home IP address as the primary identifier, regardless of the current location in the Internet. When a mobile node is away from home, the mobile node has a care-of IP address, which shows the current location of the mobile node. There is a protocol standard in Mobile IPv6 [1] which has been modified significantly from the original idea of Mobile IPv4 [3].

In Mobile IPv6, the concept of *foreign agent* (FA) in Mobile IPv4 does not exist any more. A mobile node can operate in any location without any help from the foreign agent. However, each mobile node needs the help from a home agent. The home agent forwards the packets sent by the correspondent nodes (CNs) if CNs do not have the *binding information* of the mobile node.

Each mobile node needs to register the home IP address on the home link. The home address is the identifier of the current location in the Internet. When a mobile node moves to a foreign link, a new IP address called a *Care-of Address* (CoA) is assigned. The care-of address shows the current location of the mobile node. It is necessary to register or update the care-of address to the home agent of the mobile node. This registration is performed by *Binding Registration* (BA). When the lifetime of a binding is expired, the mobile

node has to update the information. This process is called *Binding Update* (BU). The information of *binding* consist of the current care-of address, the home address of the mobile node and the remaining lifetime. If a correspondent node has the valid binding of a mobile node, the correspondent node can send any packet to the care-of address of the mobile node directly. Otherwise, the packet will be sent to the home address of the mobile node. It is forwarded to the current care-of address of the mobile node by the home agent.

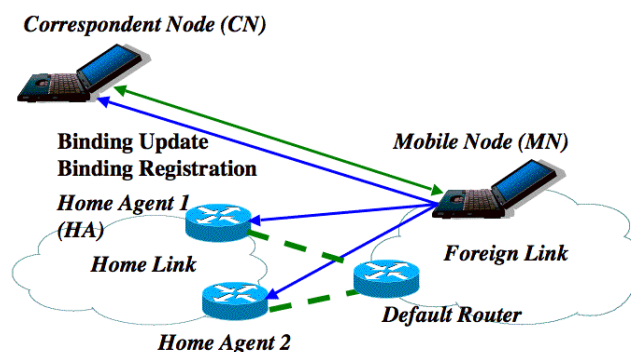


Fig. 1. Multiple Home Agent

This paper proposes a new mechanism of multiple home agents (Fig. 1) to realize a stable connection in Mobile IPv6. In order to support the new multiple home agents mechanism, new Binding Update Message format and ICMP Home Agent Unreachable Error Message format are proposed in this paper. The new mechanism achieves a fast home agent recovery.

Section II explains the features and issues in the existing home agent mechanism. In Section III, this paper proposes the new solution of *Multiple Home Agents*. Section V shows our working implementation and the testbed of Multiple Home Agents Mechanism. Section VI concludes this paper.

II. ISSUES OF HOME AGENT MECHANISM

A home agent plays an important role in Mobile IPv6. It is not safe to have only one home agent. There is a problem in the home agent backup procedure in the existing Mobile IPv6 standard. When a home agent is out of order by some

reason, no correspondent node can start communicating with the mobile node until a new home agent is found. A mobile node does not know if the home agent is dead or alive in a short time, when a mobile node is located at a foreign link. The mobile node can find that the home agent is down only when it tries to update the binding information at the home agent or when it moves to a new link and tries to send a new binding information.

The relationship between home agents and mobile nodes is one-to-many in the existing Mobile IPv6. One home agent can handle the binding information from many mobile nodes. If a mobile node can have multiple home agents, the relationship between home agents and mobile nodes becomes many-to-many. In the many-to-many relationship between home agents and mobile nodes, each home agent has other home agents. As a result, the relationship among multiple home agents is many-to-many.

In 2006, a new Internet Draft of *Home Agent Reliability Protocol* [4] is proposed at IETF. This Home Agent Reliability Protocol suggests a mechanism to provide multiple home agents and home links as a backup mechanism in Mobile IPv6. The new mechanism makes the mirroring of the binding information which is shared among the multiple home agents (Fig. 2).

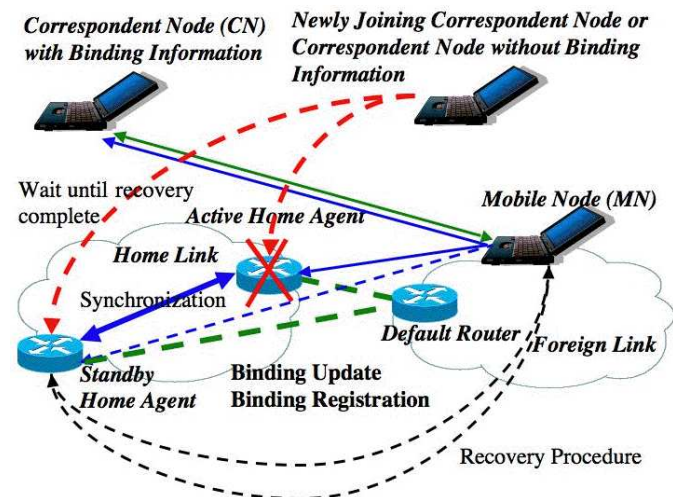


Fig. 2. Home Agent Reliability Protocol

In the proposed Home Agent Reliability Protocol, a mobile node sends the binding information to a home agent called *Active Home Agent*. Since the relationship among multiple home agents is many-to-many, the active home agent should synchronize the binding information with the standby home agents. This synchronization causes some traffic on the home link (Fig. 3).

Though the suggestion has not been implemented yet, there is a problem in the specification. The binding information on the correspondent standby home agents is not always correct. It may be an old information. A similar mirroring problem is already found between the primary and secondary servers in Domain Name System (DNS). If necessary, the standby home agents should ask the related mobile nodes for the new

binding information. There is another issue in the Home Agent Reliability Protocol. A standby home agent cannot forward the packets for a mobile node without the recovery procedure called *home agent switch*. The recovery procedure takes some time and it may cause some packets loss between a mobile node and the correspondent node.

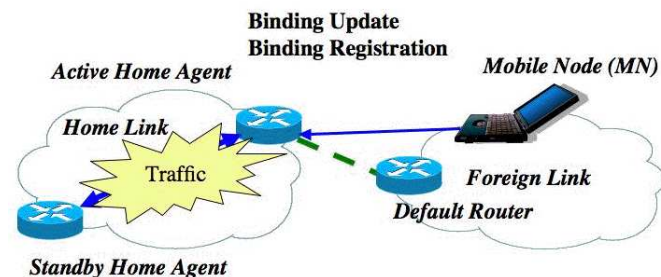


Fig. 3. Traffic on Home Link

III. NEW MULTIPLE HOME AGENTS MECHANISM

This paper proposes a new mechanism of Multiple Home Agents (Fig. 1). The existing specification of Mobile IPv6 is described in RFC, *Mobility Support in IPv6* [1]. RFC3775 does not deal with the issue that nobody can start communicating with a mobile node when the home agent is down until the mobile node find a new home agent. According to the specification of Mobile IPv6 RFC, a mobile node does not know if the home agent is dead or alive in a short time while the mobile node is on a foreign link. A mobile node finds the home agent is down only when it tries to update the binding information at the home agent or when the mobile node moves to a new link and make a binding update.

This paper proposes a structure where a mobile node can have more than one home agents when a mobile node is out of home. If a home agent is down, other working home agents can forward the packets to the mobile node (Fig. 4).

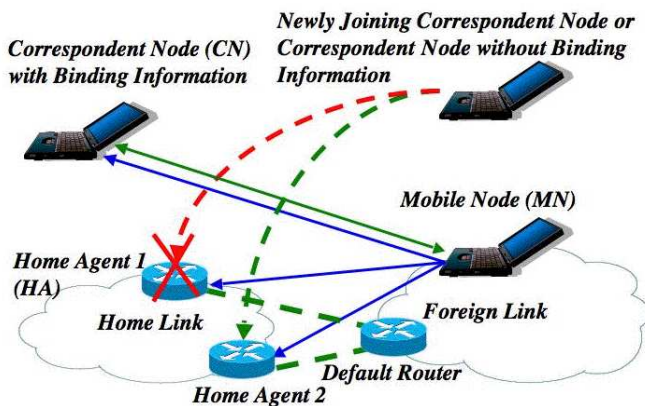


Fig. 4. Route to another Home Agent

In order to detect that other home agents are dead or alive, an improved Neighbor Unreachability Detection[5] called ICMP Home Agent Unreachability Detection is used. If a

home agent finds that another home agent which serves the same mobile node is unreachable through the routing, the home agent puts the IP address of the unreachable home agent into the ICMP Unreachability Message and informs the mobile node. When a mobile node receives the ICMP unreachability message, it starts finding a new home agent on the home link (Fig. 5). Thus, a mobile node can utilize multiple home agents.

A. Binding Update Procedure

In the new method, a mobile node should update the binding information at all the home agents simultaneously. This introduces extra traffic on the network (Fig. 6). It can be compared with the traffic caused by periodical mirroring of the binding information between the primary home agent and backup agents (Fig. 3). It shows extra traffic as well.

The new method solved the problem in the Home Agent Reliability Protocol [4]. Each home agent always has the correct binding information.

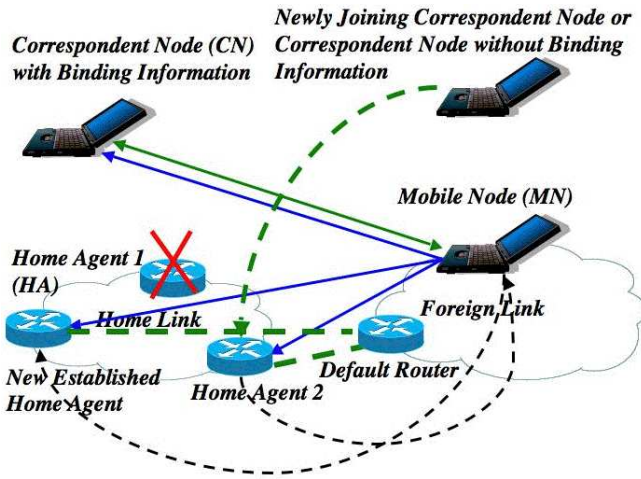


Fig. 5. Establish a new Home Agent



Fig. 6. Extra traffic

B. State Transition

A mobile node utilizes multiple home agents when it is away from the home link. When the mobile node is back to the home link, it needs only one home agent. Let us describe the mechanism in detail.

- **Initial State:** Mobile Node is at the home link

- **Move 1:** Mobile Node moves from the home link to a foreign link
- **Move 2:** Mobile Node moves between foreign links
- **Move 3:** Mobile Node moves back to the home link

The new method assumes that a mobile node can detect the movement by itself. There is a *Movement Detection* mechanism in the current Mobile IPv6 protocol. It consists of IPv6 Neighbor Discovery, Router Discovery and Neighbor Unreachability Detection. Through the subnet prefix of the assigned care-of IP address, a mobile node can find the changes of the location.

A mobile node needs to find more than two home agents and send them Binding Registration Messages when it is in **Move 1**. All of the home agents can be found by Dynamic Home Agent Address Discovery. A mobile node sends ICMP Home Agent Address Discovery Request Message to the Mobile IPv6 home agents *anycast address* using the home IP subnet prefix. When a home agent receives this message, then it should reply a Home Agent Address Reply Message to the mobile node. The message includes the *Home Agents List*. The mobile node should choose more than one home agents from the list in the Multiple Home Agents structure. Then the mobile node sends Binding Registration Messages to the multiple home agents and waits for the Binding Acknowledgement from the home agents.

In Mobile IPv6, a mobile node needs to maintain *Binding Update List* which is sent as the binding information to home agents. When a mobile node uses Multiple Home Agents Mechanism, the mobile node should add new entries to the Bind Update List.

When a mobile node has the multiple home agents, it should send Binding Update Message with the Multiple Home Agents Option to them (Fig. 8).

When a mobile node is in **Move 2**, the mobile node has a new care-of IP address assigned from the new foreign link. Then it should send Binding Update Messages to home agents and correspondent nodes based on the Binding Update List. If a correspondent node does not support Mobile IPv6, the packets sent to or received by the mobile nodes will be forwarded by the multiple home agents.

When a mobile node is in **Move 3**, the mobile node has only one home agent. When a mobile node is at home, packets addressed to the home address are routed to the home link, using conventional Internet routing mechanisms. We do not need to keep Multiple Home Agents Mechanism. All the binding information should be discarded either by the mobile node or by other nodes including home agents.

C. Modified Binding Update Message

Binding Update Message is modified in this paper to inform that Multiple Home Agent Mechanism is used. In Fig. 7, a new M bit is added in the Binding Update Message.

When M bit is set, it means the current mobile node is using Multiple Home Agent Mechanism. When M bit is set, a new Option including list of home agents addresses, Multiple Home Agents (Fig. 8), is used in the new method. The list of home agents addresses included in the Binding Update

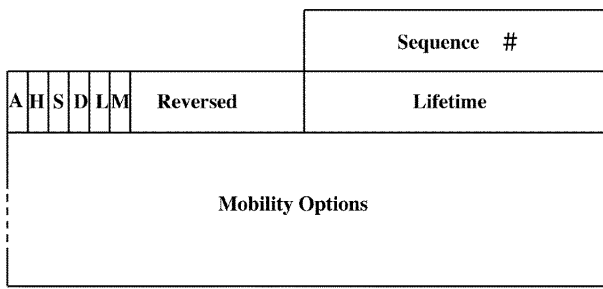


Fig. 7. Modified Binding Update Message

Message is kept by the multiple home agents. According to the list, the home agents can recognize which are other home agents related to the same mobile nodes. When a home agent is down, the proper home agent sends the ICMP Home Agent Unreadable Error Message (Sec. III-D) to the correspondent mobile node based on the list of home agents address.

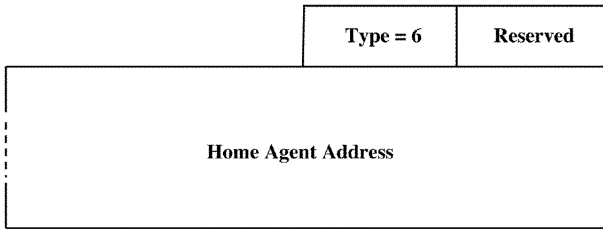


Fig. 8. Multiple Home Agents Option

D. New ICMP Home Agent Unreachable Error Message

In the current Mobile IPv6 protocol, there are 4 new ICMP messages. They are Home Agent Address Discovery Request, Home Agent Address Discovery Reply, Mobile Prefix Solicitation and Mobile Prefix Advertisement. In this paper, a new ICMP message in Fig. 9 is used.

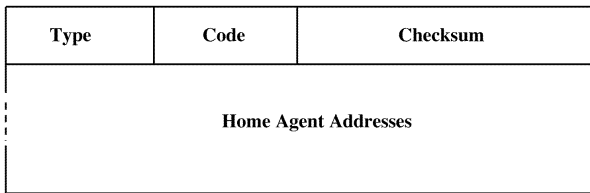


Fig. 9. ICMP Home Agent Unreachable Error Message

In Fig. 9, Home Agent Address Field is used to include those IP addresses of unreachable home agents. Type value is set to 154 temporarily in this paper.¹

IV. DISCUSSION

The original method of a home agent recovery in Mobile IPv6 is shown as follows.

- **Initial State:** Home agent is down. GOTO Step 1.

¹The value should be set by ICANN

- **Step 1:** In order to update the binding information, a mobile node contacts the home agent and finds that the home agent is down. GOTO Step 2.
- **Step 2:** The Mobile Node starts DHAAD to find a new home agent. GOTO Step 3.
- **Step 3:** The Mobile Node sends binding registration to the new home agent. GOTO Step 4.
- **Step 4:** Re-routing is performed. The new home agent starts to forward packets for mobile node. END.

It is assumed that **Step 1** takes *Time A*, **Step 2** takes *Time B*, **Step 3** takes *Time C* and **Step 4** takes *Time D*. The total time of the home agent recovery is the sum of the time intervals of those 4 steps. The formula of the recovery time is

$$Recovery\ Time = Time\ A + Time\ B + Time\ C + Time\ D.$$

The process of home agent recovery in Home Agent Reliability [4] is described as follows.

- **Initial State:** Active home agent is down. If a standby home agent finds the failure of the active home agent earlier than the mobile node, then GOTO Step 1, else GOTO Step 2.
- **Step 1:** The standby home agent finds that the active home agent is down and sends message to the mobile node to inform the failure of active home agent. GOTO Step 3.
- **Step 2:** In order to update the binding information, the mobile node contacts the home agent and finds the home agent is down. GOTO Step 3.
- **Step 3:** The mobile node and the standby home agent change home agent switch messages each other. If the binding information on the standby home agent is valid then GOTO Step 5, else GOTO Step 4.
- **Step 4:** The mobile node sends binding registration to the new home agent. GOTO Step 5.
- **Step 5:** Re-routing is performed. The new home agent starts to forward packets for mobile node. END.

It is assumed that **Step 1** takes *Time E*, **Step 2** takes *Time F*, **Step 3** takes *Time G*, **Step 4** takes *Time H* and **Step 5** takes *Time I*.

The formula of the best recovery time is

$$Best\ Recovery\ Time = Time\ E + Time\ G + Time\ I.$$

The worst time of the recovery is

$$Worst\ Recovery\ Time = Time\ F + Time\ G + Time\ H + Time\ I.$$

The **Step 1** in Mobile IPv6 recovery process is the same as the **Step 2** in Home Agent Reliability. $Time\ A = Time\ F$. The **Step 3** in Mobile IPv6 recovery process is the same as the **Step 4** in Home Agent Reliability. $Time\ C = Time\ H$. The **Step 4** in Mobile IPv6 recovery process is same as the **Step 5** in Home Agent Reliability. $Time\ D = Time\ I$.

The formula of the best recovery time of Home Agent Reliability is $Best\ Recovery\ Time = Time\ E + Time\ G + Time\ D$. The formula of the worst recovery time of Home Agent Reliability is $Worst\ Recovery\ Time = Time\ A + Time\ G + Time\ C + Time\ D$. It is true that Home Agent Reliability [4] provides a faster home agent recovery mechanism than Mobile IPv6.

In the new proposed Multiple Home Agents mechanism, there is no special process in the home agent recovery. Some

of the recovery steps, like binding registration and update are included in the normal operation regardless of the status of home agents. When the home agent is down, the route to the mobile node is re-routed to another working home agent based on the normal routing algorithm. Multiple home agent mechanism only need to perform the last re-routing step. Thus, the recovery time of our proposal is simply $Recovery\ Time = TimeD$.

Table I shows the comparison. The original Mobile IPv6 does not use multiple home agents which run concurrently. A mobile node sends binding information to the single home agent. When the home agent is out of order, a mobile node cannot recognize the emergency problem until the lifetime of the binding information is expired. The *binding lifetime* is set to 420 seconds (7 minutes) in RFC3775 standard [1]. The binding lifetime could be short, but it increases the traffic on the network. And it also increases the loads at the home agent and the mobile node. As the worst case, a mobile node does not realize the home agent is down in 7 minutes. Comparing with the original mechanism of the Mobile IPv6, Home Agent Reliability [4] provides a mechanism for multiple home agents. However, home agents are listed in the priority order. The binding information is only sent to the high priority home agent, which is an active home agent. Active home agent synchronizes the binding information with the secondary home agent, which is the standby home agent, periodically. The synchronization causes some traffic on the home link. There is a problem. The binding information on a standby home agent is not always correct. The home agent recovery procedure takes some time.

We propose a new mechanism of Multiple Home Agents in this paper. It allows a mobile node to have multiple home agents simultaneously. A mobile nodes updates the binding information at all the home agents to keep the valid binding information. This method realized a quick home agent recovery process within a limited traffic.

TABLE I
FUNCTION COMPARISON

	Multiple HAs	Traffic	HA Recovery Time
Mobile IPv6	<i>not used</i>	<i>low</i>	<i>long</i>
HA Reliability	<i>backup only</i>	<i>fair</i>	<i>medium</i>
Multiple HAs	<i>fully used</i>	<i>fair</i>	<i>short</i>

V. IMPLEMENTATION AND EXPERIMENT

New functions of the multiple home agent are implemented to the KAME software [9]. KAME is based on the RFC3775: Mobility Support in IPv6 [1].

A. Testbed

We have a testbed shown in Fig. 10. There are two home agents on the home link 2001:200:1:2::/64 and two foreign links, one is 2001:200:1:3::/64 and the other is 2001:200:1:1::/64. A dynamic routing algorithm, RIPng[10], is used in the testbed. A mobile node moves between the home link and the foreign link. Some log files of the experiment are

reported in the following sections. The results of the experiment show that finding multiple home agents and sending Binding Update and Registration Messages to the multiple home agents are working properly.

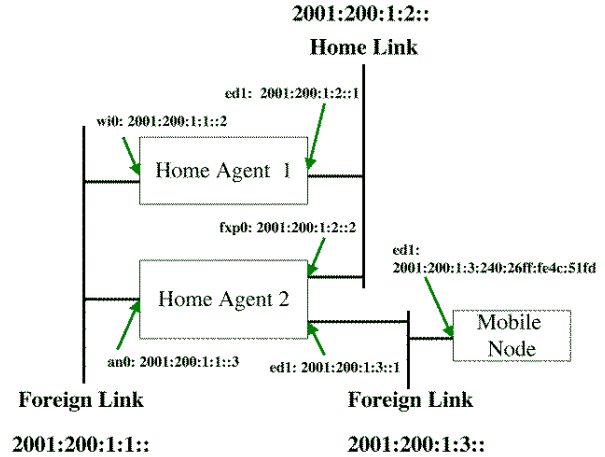


Fig. 10. Multiple Home Agents Testbed

B. Binding Registration Cache on Home Agent 1

Fig. 11 shows the binding registration cache on the first home agent, Home Agent 1 whose IPv6 address is 2001:200:1:2::1. The binding information was sent by the mobile node with a home address of 2001:200:1:2:240:26ff:fe4c:51fd and a care-of address of 2001:200:1:3:240:26ff:fe4c:51fd.

```

phaddr 2001:200:1:2:240:26ff:fe4c:51fd
pcoa   2001:200:1:3:240:26ff:fe4c:51fd
addr   2001:200:1:2::1
flags  AHS-L-
seqno  34285
lifetim 420
ltxp   372
state  ---

phaddr  fe80::240:26ff:fe4c:51fd%ed1
pcoa   2001:200:1:3:240:26ff:fe4c:51fd
addr   2001:200:1:2::1
flags  AHS-Lc
seqno  34285
lifetim 420
ltxp   372
state  ---

```

Fig. 11. Home Agent 1: Binding Registration Cache

C. Binding Update Cache on Home Agent 1

Fig. 12 shows the binding update cache on the first home agent, Home Agent 1. The sequence number in this cache is 1 bigger than the sequence number used in Binding Registration Cache on Home Agent 1 (in Sec. V-B). This means that the binding information here is followed by the binding registration information.

```

phaddr 2001:200:1:2:240:26ff:fe4c:51fd
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::1
flags AHS-L-
seqno 34286
lifetim 420
ltxp 334
state ---

phaddr fe80::240:26ff:fe4c:51fd%ed1
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::1
flags AHS-Lc
seqno 34286
lifetim 420
ltxp 334
state ---

```

Fig. 12. Home Agent 1: Binding Update Cache

```

phaddr 2001:200:1:2:240:26ff:fe4c:51fd
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::2
flags AHS-L-
seqno 10804
lifetim 420
ltxp 369
state ---

phaddr fe80::240:26ff:fe4c:51fd%fxp0
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::2
flags AHS-L-
seqno 10804
lifetim 420
ltxp 369
state ---

```

Fig. 14. Home Agent 2: Binding Update Cache

D. Binding Registration Cache on Home Agent 2

Fig. 13 shows the binding registration cache on the second home agent, Home Agent 2 whose IPv6 address is 2001:200:1:2::2. The binding information was sent by the mobile node with a home address of 2001:200:1:2:240:26ff:fe4c:51fd and a care-of address of 2001:200:1:3:240:26ff:fe4c:51fd.

```

phaddr 2001:200:1:2:240:26ff:fe4c:51fd
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::2
flags AHS-L-
seqno 10803
lifetim 420
ltxp 393
state ---

phaddr fe80::240:26ff:fe4c:51fd%fxp0
pcoa 2001:200:1:3:240:26ff:fe4c:51fd
addr 2001:200:1:2::2
flags AHS-L-
seqno 10803
lifetim 420
ltxp 393
state ---

```

Fig. 13. Home Agent 2: Binding Registration Cache

E. Binding Update Cache on Home Agent 2

Fig. 14 shows the binding update cache on the second home agent, Home Agent 2. The sequence number in this cache is 1 bigger than the sequence number used in Binding Registration Cache on Home Agent 2 (in Sec. V-D). This means that the binding information here is followed by the binding registration information.

F. Binding Registration on Mobile Node

Fig. 15 shows the log of binding registration messages sent by the mobile node. There are 2 sequence number, one is 10803 and the other is 34285. The binding registration message with sequence number 10803 can be found in Bind

Registration on Home Agent 2 (in Sec. V-D). As the same, the binding update message with sequence number 34285 refers to Binding Update on Home Agent 1 (in Sec. V-B).

```

paddr 2001:200:1:2::2
haddr 2001:200:1:2:240:26ff:fe4c:51fd
coa 2001:200:1:3:240:26ff:fe4c:51fd
lifetim 420
ltxp 355
refresh 208
retexp 143
seqno 10803
flags AHS-L-
pfsm BOUND
sfsm START
state --

paddr 2001:200:1:2::1
haddr 2001:200:1:2:240:26ff:fe4c:51fd
coa 2001:200:1:3:240:26ff:fe4c:51fd
lifetim 420
ltxp 355
refresh 208
retexp 143
seqno 34285
flags AHS-L-
pfsm BOUND
sfsm START
state --

```

Fig. 15. Mobile Node: Binding Registration

G. Binding Update on Mobile Node

Fig. 16 the logs of binding update messages sent by the mobile node. There are 2 sequence number, one is 10804 and the other is 34286. The binding update message with sequence number 10804 can be found in Bind Update on Home Agent 2 (in Sec. V-E). As the same, the binding update message with sequence number 34286 refers to Binding Update on Home Agent 1 (in Sec. V-C). Moreover, the binding update messages were sent after sending registration messages.

```

paddr      2001:200:1:2::2
haddr      2001:200:1:2:240:26ff:fe4c:51fd
coa        2001:200:1:3:240:26ff:fe4c:51fd
lifetim    420
ltxp       394
refresh    208
retexp     182
seqno      10804
flags      AHS-L-
pfsm       BOUND
sfsm       START
state      --

paddr      2001:200:1:2::1
haddr      2001:200:1:2:240:26ff:fe4c:51fd
coa        2001:200:1:3:240:26ff:fe4c:51fd
lifetim    420
ltxp       394
refresh    208
retexp     182
seqno      34286
flags      AHS-L-
pfsm       BOUND
sfsm       START
state      --

```

Fig. 16. Mobile Node: Binding Update

Our new implementation enables a mobile node to select two home agent when a mobile node is away from home. The mobile node can send Binding *Registration* Messages to the multiple home agents successfully. Moreover the mobile node can send Binding *Update* Messages to the multiple home agents as well as to the correspondent nodes.

VI. CONCLUSION AND FUTURE PLAN

The current specification of Mobile IPv6 is described in RFC, Mobility Support in IPv6. If there is a trouble with a home agent, then newly joining correspondent nodes cannot communicate with the mobile nodes which the home agent supports. There is a mechanism called DHAAD (Dynamic Home Agent Addresses Detection) in Mobile IPv6. However, it is not useful until a mobile node finds the home agent is down. According to the specification of the Mobile IPv6 RFC, a mobile node will find the home agent is down only when the mobile node needs to send Binding Registration or Update Messages to the home agent. Because the route optimization is used in Mobile IPv6, a mobile node contacts the home agent less frequently. Then, a mobile node cannot know that the home agent is down in a short time.

This paper proposes a new mechanism for a mobile node to have multiple home agents simultaneously when it is away from the home link. Since a mobile node has multiple home agents, if there is anything wrong with one of them, other working home agents can keep on forwarding packets to the mobile node. Multiple home agents mechanism provides a faster home agent recovery than Home Agent Reliability proposal.

If a home agent is down, through using Neighbor Unreachability Detection among home agents, other working home agents can detect the problem in a short time. Then, other

home agents inform the mobile node by using ICMP Home Agent Unreachable Error Message. After receiving the error message, the mobile node starts finding a new home agent instead of the dead one. The new method make mobile nodes keep the connections more smoothly than using a single home agent in the current Mobile IPv6 protocol. The new method decreases the packet loss when the home agent is down or unreachable.

We implement the functions of the new method, including finding multiple home agents, sending Binding Update and Registration Messages to multiple home agents. The experiment shows that the mechanism works properly.

We have a plan to implement the remaining function, ICMP Home Agent Unreachable Detection, to KAME implementation to realize the total system of the new mechanism.

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APPENDIX

Following are the logs at the mobile node in a debug mode.

A. Start to Work as a Mobile Node

```

Feb 18 20:11:39 mobile-mn /kernel:
.../netinet6/mip6_subnet.c:200:
subnet timer started.
Feb 18 20:11:39 mobile-mn /kernel:
.../netinet6/mip6.c:1459:
Authdata protection disabled
Feb 18 20:11:39 mobile-mn /kernel:
.../netinet6/mip6.c:1389:
MN function enabled
Feb 18 20:11:39 mobile-mn /kernel:
.../netinet6/mip6.c:1003: CoA has changed to
2001:0200:0001:0002:0240:26ff:fe4c:51fd

```

B. Mobile Node is on Home Link

```
Feb 18 20:11:39 mobile-mn /kernel: location = 1
Feb 18 20:16:06 mobile-mn /kernel:
../netinet6/mip6.c:373:
prefix 2001:0200:0001:0002::0002
from fe80:0008::0203:47ff:fe88:6ebd
Feb 18 20:16:06 mobile-mn /kernel:
../netinet6/mip6.c:461:
found a new router
fe80:0008::0203:47ff:fe88:6ebd
(2001:0200:0001:0002::0002)
Feb 18 20:18:56 mobile-mn /kernel:
../netinet6/mip6.c:373:
prefix 2001:0200:0001:0002::0001
from fe80:0008::0200:f4ff:fe4d:547a
Feb 18 20:18:56 mobile-mn /kernel:
../netinet6/mip6.c:461:
found a new router
fe80:0008::0200:f4ff:fe4d:547a
(2001:0200:0001:0002::0001)
```

C. Mobile Node is on Foreign Link

```
Feb 18 20:27:29 mobile-mn /kernel:
../netinet6/mip6.c:373:
prefix 2001:0200:0001:0003::
from fe80:0008::0240:26ff:fe94:eb2c
Feb 18 20:27:30 mobile-mn /kernel:
../netinet6/mip6.c:427:
receive a new prefix 2001:0200:0001:0003::
Feb 18 20:27:30 mobile-mn /kernel:
../netinet6/mip6.c:461:
finds a new router
fe80:0008::0240:26ff:fe94:eb2c
(2001:0200:0001:0003::)
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6.c:1003: CoA has changed to
2001:0200:0001:0003:0240:26ff:fe4c:51fd
Feb 18 20:27:33 mobile-mn /kernel: location = 2
```

D. Mobile Node finds Home Agent 1

```
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:444:
mip6_bu_create for (0)th.
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:953:
BU timer started.
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:468:
bu_list_insert for (0)th.
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:472:
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd,
paddr: 2001:0200:0001:0002::0001
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:27:33 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:27:33 mobile-mn /kernel:
```

```
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

E. Mobile Node finds Home Agent 2

```
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:444:
mip6_bu_create for (1)th.
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:468:
bu_list_insert for (1)th.
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:472:
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd,
paddr: 2001:0200:0001:0002::0002
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:27:33 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:27:33 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:27:33 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

F. Mobile Node sends Binding Registration to Home Agent 1

```
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:27:36 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:27:36 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

G. Mobile Node sends Binding Registration to Home Agent 2

```
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:27:36 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:27:36 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

H. Mobile Node received the Binding Acknowledgement from Home Agent 1

```
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:895:
Mobility options: 10<REFRESH>
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1005:
IN CHECK MOBILITY OPTIONS
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1015:
ip6m_binding_ack: ip6ma_seqno:
34285 of peer 2001:0200:0001:0002::0001
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_fsm.c:552:
MIP6_BU_PRI_FSM_STATE_WAITA
```

I. Mobile Node received the Binding Acknowledgement from Home Agent 2

```
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:895:
Mobility options: 10<REFRESH>
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1005:
IN CHECK MOBILITY OPTIONS
Feb 18 20:27:36 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1015:
ip6m_binding_ack: ip6ma_seqno:
10803 of peer 2001:0200:0001:0002::0002
```

Mobile Node started to update the binding cache on its multiple home agents.

J. Mobile Node sends Binding Update Message to Home Agent 1

```
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_fsm.c:1217:
MIP6_BU_PRI_FSM_STATE_BOUND
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:31:05 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:31:05 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0001,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

K. Mobile Node receives the Binding Acknowledgement Message from Home Agent 1

```
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:895:
Mobility options: 10<REFRESH>
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1005:
IN CHECK MOBILITY OPTIONS
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1015:
```

```
ip6m_binding_ack: ip6ma_seqno:
34286 of peer 2001:0200:0001:0002::0001
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_fsm.c:756:
MIP6_BU_PRI_FSM_STATE_WAITAR
```

L. Mobile Node sends Binding Update Message to Home Agent 2

```
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_fsm.c:1217:
MIP6_BU_PRI_FSM_STATE_BOUND
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_binding.c:870:
create an ipv6 header to send a binding update
Feb 18 20:31:05 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_binding.c:904:
send a binding update.
Feb 18 20:31:05 mobile-mn /kernel:
paddr: 2001:0200:0001:0002::0002,
haddr: 2001:0200:0001:0002:0240:26ff:fe4c:51fd
```

M. Mobile Node receives the Binding Acknowledgement Message from Home Agent 2

```
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:895:
Mobility options: 10<REFRESH>
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1005:
IN CHECK MOBILITY OPTIONS
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_pktproc.c:1015:
ip6m_binding_ack: ip6ma_seqno:
10804 of peer 2001:0200:0001:0002::0002
Feb 18 20:31:05 mobile-mn /kernel:
../netinet6/mip6_fsm.c:756:
MIP6_BU_PRI_FSM_STATE_WAITAR
```