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Ryuji Wakikawa
Keio University/WIDE
Vijay Devarapalli
Nokia
Pascal Thubert
Cisco Systems

Inter Home Agents Protocol (HAHA)

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Status of This Memo

Abstract

This document describes an inter Home Agents (HAHA) protocol to provide multiple Home Agents support for both Mobile IPv6 and the Nemo Basic Support protocol. The HAHA protocol provides Home Agent redundancy and load-balancing for both protocols. The HAHA protocol allows multiple Home Agents to be placed at different links. It also allows a Mobile Node/Router to utilize multiple Home Agents simultaneously. The protocol consists of 3 mechanisms, Home Agent List management, Binding Synchronization, and Home Agent Switching. A Mobile Node/Router picks one Home Agent as its primary Home Agent and registers with it. The primary Home Agent synchronizes the binding cache information with other Home Agents. Any of Home Agents can intercept a packet meant for the Mobile Node/Router and tunnel the packet directly to its current Care-of address. Alternatively, the Home Agent can tunnel the packet to the primary Home Agent.

Contents

1. Introduction

In Mobile IPv6 [1], a Mobile Node could be tunneling and receiving all its traffic through a bi-directional tunnel with its Home Agent, unless it uses Route Optimization with its Correspondent Nodes. In Nemo Basic Support protocol [6], the default mode of operation is to tunnel all traffic meant for the Mobile Network through the Home Agent serving the Mobile Router. Consequently, Home Agents could become a considerable bottleneck in the performance of Mobile IPv6 and Nemo protocols. This becomes more significant when the Home Agent serves thousands of Mobile Node and Mobile Routers. Sometimes the Mobile Network could be closer to the Correspondent Node than the Home Agent. If the Mobile Router could pick another Home Agent closer to its current location, the tunneling overhead on every packet could be reduced to a much shorter path in the Internet.

This draft specifies the inter Home Agents protocol (HAHA protocol) to provide redundancy and load balancing of Home Agents. For the HAHA protocol, the definition of Home Agent is extended to place multiple Home Agents at different links. Multiple Home Agents could be located on different links and still serve the same home prefix. Mobile IPv6 uses a IPv6 Neighbor Discovery based mechanism for maintaining the list of Home Agents serving the same prefix, at each Home Agent. If the Home Agents are not present on the same physical link, Neighbor Discovery based mechanisms don't work. The HAHA protocol defines a mechanism for Home Agents List management using new ICMP messages for Home Agents located on different links.

The HAHA protocol makes it possible to have two new scenarios which would not have possible with Mobile IPv6 and the Nemo Basic Support Protocol. These scenarios are Solo Home Agent Activation and Multiple Home Agent Activation and are explained in the following paragraphs.

In the scenario of Solo Home Agent activation, a Mobile Router always selects the best Home Agent to register its binding depending on Mobile Router's current location or Home Agent status. For example, when a Mobile Router registers its binding to the nearest Home Agent, the path between the Mobile Router and the Home Agent can be the shortest possible path. This is particularly useful for a Mobile Router which moves over geographically wide areas such as a Mobile Router on an airplane.

In the scenario of Multiple Home Agent activation, a Mobile Node/Router registers its binding to multiple Home Agents at the same time. The Mobile Router sends a binding update to its primary home agent. After the home registration, the primary Home Agent exchanges the binding information with the other Home Agents. Thereafter, the Mobile Node/Router can use any of these Home Agents which have the

binding. The Mobile Router can accept packets which are tunneled by any of the Home Agents. Alternatively, a Home Agent who intercepts packets can tunnel packets to the primary Home Agent. In this case, the Mobile Router receives packets through the primary Home Agent. If many Home Agents are scattered on the Internet, the Home Agent nearest to the correspondent node intercepts packets meant for the Mobile Node or the Mobile Network and tunnels them to the Mobile Node/Router. The route path between the correspondent node and the Home Agent can be kept short.

2. Terminology

There is a separate Nemo terminology document [2], which defines the

terms related to Network Mobility used in the document.

The keywords ``MUST'', ``MUST NOT'', ``REQUIRED'', ``SHALL'', ``SHALL NOT'', ``SHOULD'', ``SHOULD NOT'', ``RECOMMENDED'', ``MAY'', and ``OPTIONAL'' in this document are to be interpreted as described in RFC 2119.

Home Agent

A Home Agent is originally defined in [1]. Traditional Home Agents, if they all serve the same home prefix are configured on a single link. This document extends the definition of Home Agents such that the Home Agents need not be on the same link. There could be multiple Home Agents attached to different links serving the same home prefix.

Primary Home Agent

A Home Agent who receives Binding Update from a Mobile Router. The Mobile Router is always associated with a primary Home Agent to register its binding.

3. Overview of Inter Home Agents Protocol

When multiple Home Agents are configured at different links, each home agent is expected to know the other Home Agents beforehand and establishes Security Association with them for a secure path towards the other home agent.

Each Home Agent manages information of all Home Agents in its Home Agent list. But each Home Agent can not listen Router Advertisements sent by the other Home Agents configured at different link, because Router Advertisements can not be sent over the link-local scope. Therefore, each Home Agents periodically unicasts a Home Agent Advertisement message instead of Router Advertisement to the other Home Agents configured at different links. The Home Agent Advertisement message MUST be sent with the ICMP Prefix Information Option and the ICMP Home Agent Information Option defined in [1]. Whenever a Home Agent receives a Home Agent Advertisement message, it updates its home agent list according to the received message. The Home Agent proceeds the Home Agent Advertisement as same as when it receives Router Advertisements with the H bit flag. The Home Agent

manages the home agent list as same as the Mobile IPv6 specification. If the lifetime of an entry is expired in the home agent list, the Home Agent should solicit a Home Agent Advertisement message by unicasting a Home Agent Solicitation message.

Binding synchronization of a particular Mobile Node/Router can activate multiple Home Agents simultaneously. When a primary Home Agent receives a Binding Update and creates a binding, it notifies the binding to the other Home Agents by unicasting Binding Information Reply messages. Home Agents receiving the Binding Information Reply message records binding information and the address of the primary home agent into their binding cache. A Home Agent sends a Binding Information Request message to solicit a Binding Information Reply message to the primary Home Agent if needed.

When a Home Agent wants a Mobile Router to change the primary Home Agent, it sends a Home Agent Switch Request message to trigger the Dynamic Home Agent Address Discovery to a Mobile Node/Router. After receiving an ICMP Home Agent Address Discovery Request, the Home Agent should reply an ICMP Home Agent Address Discovery Reply with addresses of appropriate Home Agent addresses. If the Home Agent has already had the desired new primary Home Agent, it contains the address of the new Home Agent in the Home Agent Switch Request message. The Mobile Router switches its primary Home Agent to the new Home Agent. When the Mobile Node/Router changes the primary Home Agent proactively, it selects a new Home Agent from its home agent list. After determination of the new Home Agent, it simply registers its binding to the new Home Agent. The Mobile Node/Router should

de-register its binding from the old Home Agent before the home registration to the new Home Agent.

The scenarios for the HAHA protocol are described in Section 8. In the solo Home Agent activation scenario, only a primary Home Agent manages a binding for a Mobile Node/Router and takes responsibility for tunneling packets from and to a Mobile Node/Router. The Mobile Node/Router can switch its primary Home Agent to a Home Agent located in different link by the HAHA protocol.

In the Multiple Home Agents activation scenario, a primary Home Agent shares the registered binding for a Mobile Node/Router with all other Home Agents. Each Home Agent intercepts packets and take responsibility for delivering intercepted packets to either the

Mobile Node/Router or the primary Home Agent. The Mobile Node/Router accepts tunneled packets directly from the Home Agent. Otherwise, when the primary Home Agent receives tunneled packets from other Home Agents, it delivers packets to the Mobile Node/Router. The Mobile Node/Router always tunnels outgoing packets to the primary Home Agent. The Mobile Node/Router can switch its primary Home Agent to a Home Agent located in different link by the HAHA protocol.

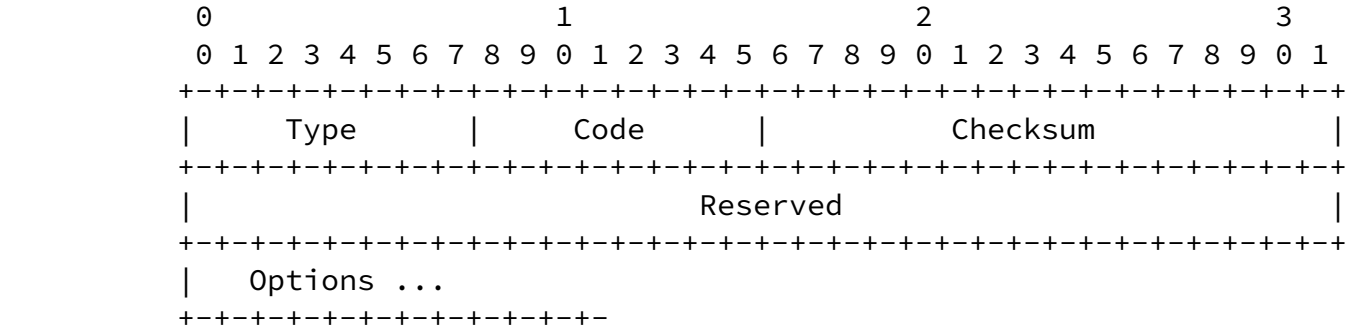
4. Message Formats

4.1. New ICMP Messages

4.1.1. Home Agent Solicitation Message

The Home Agents Solicitation message is only used if a particular entry is expiring in the Home Agents list and there has been no unsolicited Home Agent Advertisement message from the Home Agent whose entry is expiring.

The Home Agent Solicitation message has similar format of Route Solicitation message [8]. The Home Agent Solicitation message MUST be unicasted to invoke Home Agent Advertisement messages to other Home Agents. The Home Agent Solicitation message MUST NOT be multicasted and MUST NOT be used for Home Agents located at the local link.



The Source Address filed of the IPv6 header MUST be set to a originator (Home Agent) address. The Destination Address field of the IPv6 header MUST be set to an IPv6 global unicast address of other Home Agents. Both a non-global scope address and non unicast address MUST NOT be used in a Home Agent Solicitation message. The

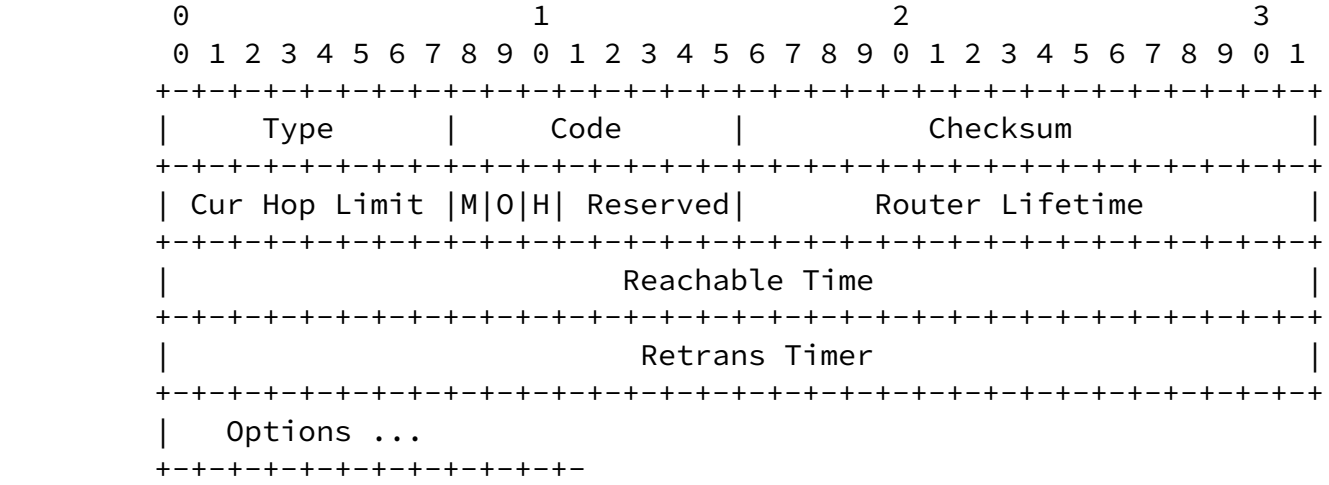
Hop Limit field of the IPv6 header MUST be set to an initial hop limit value, similarly to any other unicast packet.

The fields of a Home Agent Solicitation message are same as a Router Solicitation message except for the Type field. The type field MUST be set to 155 (To Be Assigned by IANA).

Home Agent Solicitation message MUST be authenticated and encrypted by the use of IPsec ESP.

4.1.2. Home Agent Advertisement Message

The Home Agent Advertisement messages are sent between Home Agents to maintain the Home Agents List at each Home Agent.



The Source Address filed of the IPv6 header MUST be set to a originator (Home Agent) address. The Destination Address field of the IPv6 header MUST be set to the global unicast address of another Home Agent. Non-global scope or non-unicast addresses MUST NOT be used in a Home Agent Advertisement message. The Hop Limit field of the IPv6 header MUST be set to an initial hop limit value, similarly to any other unicast packet.

The fields of a Home Agent Advertisement message are same as a Router Advertisement message except for the Type field. The type field MUST be set to 156 (To Be Assigned by IANA).

A Prefix Information Option and a Home Agent Information Option MUST be included in a Home Agent Advertisement message. The treatment of

options is same as options defined in Mobile IPv6 [1].

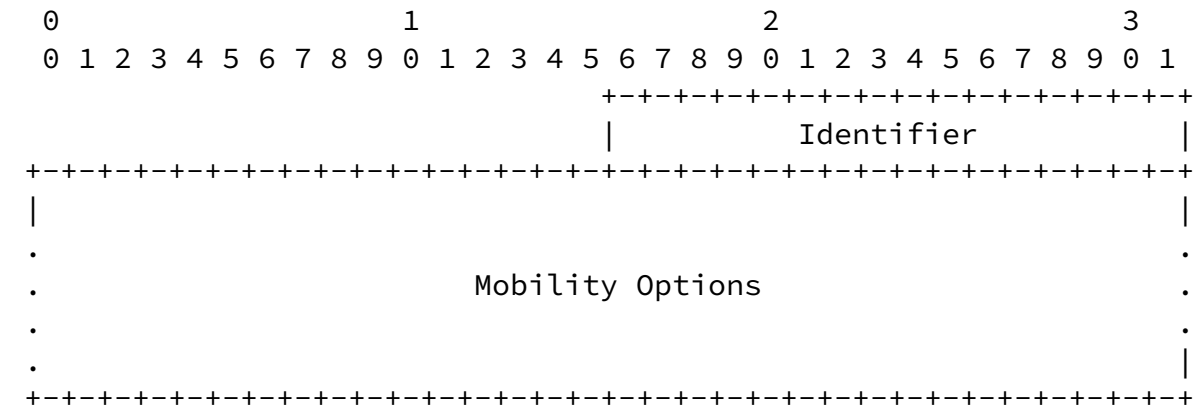
Home Agent Advertisement message MUST be authenticated and encrypted by IPsec ESP.

4.2. New Mobility Header Messages

The Mobility Header format is defined in section 6 of [1]. This document defines three new mobility messages for Binding Cache information exchange and for switching primary Home Agents.

4.2.1. Binding Information Request Message

The Binding Information Request Message is used to request Binding Cache Information corresponding to a particular Mobile Node/Router. It is sent only between Home Agents. The format of the is as follows:



Identifier

The 16-bit identifier to aid in matching Home Agent Information Reply message. The identifier should never be set to 0. It should always be more than 1.

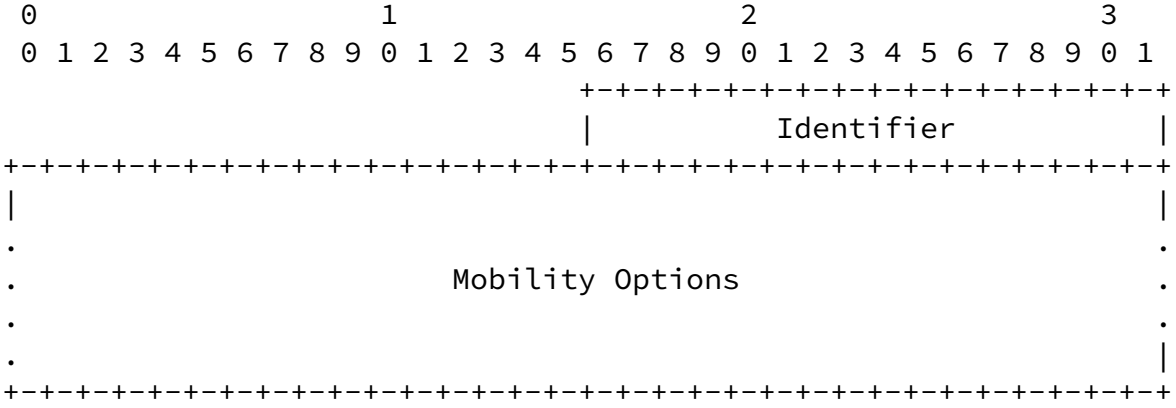
This message MUST include either the Home Address mobility option 4.3.1 or the Mobile Network Prefix Option 4.3.2. If a Home Agents want the Binding Cache Information for a particular Mobile Node/Router it includes a Home Address mobility option. If a Home Agent wants to know the forwarding state setting up for a particular Mobile Network Prefix, it includes the Mobile Network Prefix Option.

This message is optional if Home Agents send out unsolicited Binding Information Reply messages.

Binding Information Request message MUST be authenticated and encrypted by IPsec ESP.

4.2.2. Binding Information Reply Message

The Binding Information Reply message is used by the Home Agents to exchange Binding Cache Information. The message format is as follows:



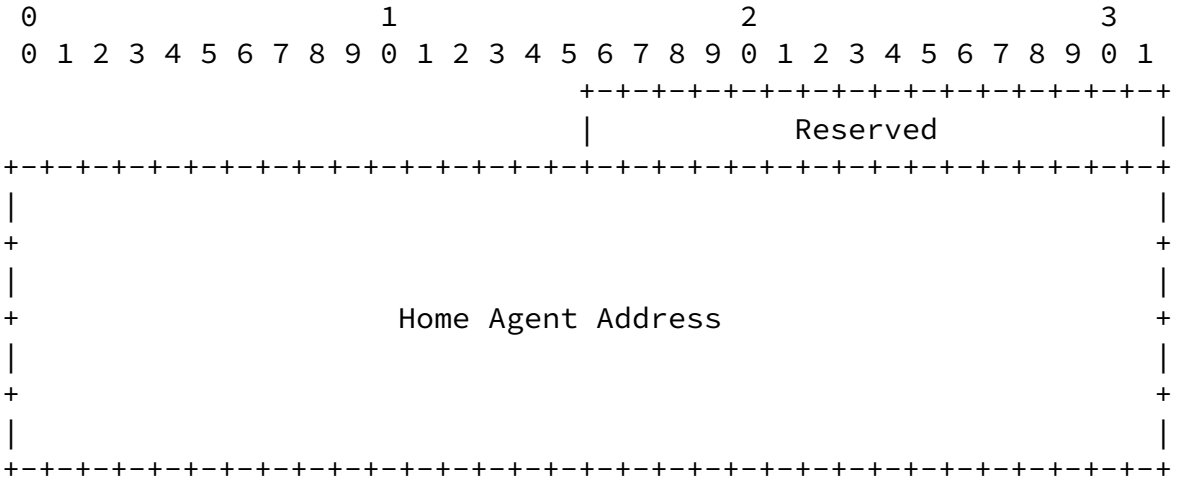
Identifier

The identifier should be set 0 for unsolicited Binding Information Reply messages. Otherwise, the identifier should be set to the identifier in a Binding Information Request message if this is a solicited Binding Information Reply message.

Binding Information Reply message MUST be authenticated and encrypted by IPsec ESP.

4.2.3. Home Agent Switch Request Message

This message is sent by a Home Agent to a Mobile Node/Router to trigger Dynamic Home Agent Discovery. The message format is as follows:



Reserved

16-bit field reserved for future use. The value SHOULD be initialized to zero by the sender, and MUST be ignored by the receiver.

Home Agent Address

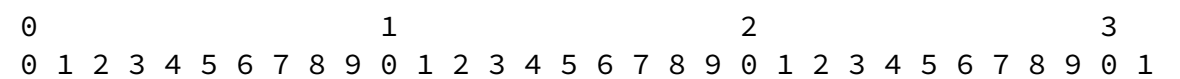
A 16 byte field contains the new primary Home Agent Address. The Home Agent address MUST be recorded in the Home Agent list of the Mobile Router. If this field does not contain the valid global IPv6 address or the unknown Home Agent address, the Mobile Router sends dynamic Home Agent address discovery request message. Otherwise, the Mobile Router switches to this Home Agent immediately as its primary Home Agent.

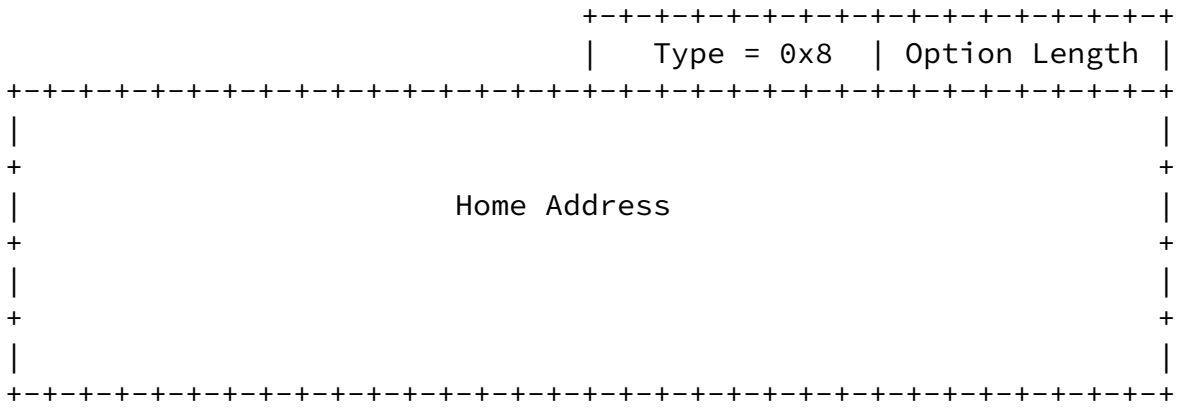
Home Agent Switch Request message MUST be authenticated and encrypted by the use of IPsec ESP mode.

4.3. New Mobility Options

4.3.1. Home Address

The Home Address option has an alignment requirement of 8n+6. Its format is as follows:





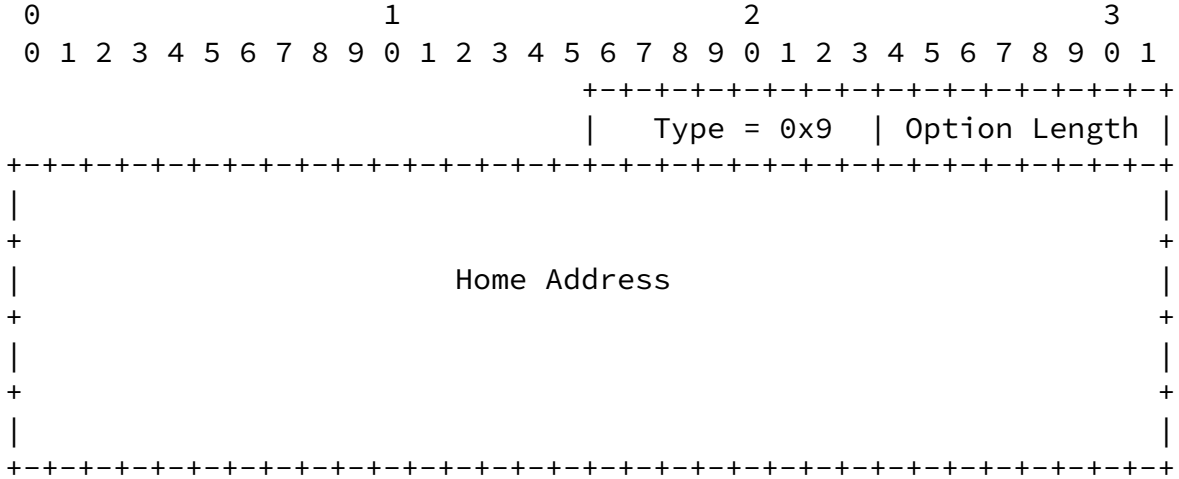
This option is used when the Home Agent needs to figure out the Binding Cache information for a particular Mobile Node or Mobile Router. not useful when each Home Agent sends an unsolicited binding cache information for each BU it receives.

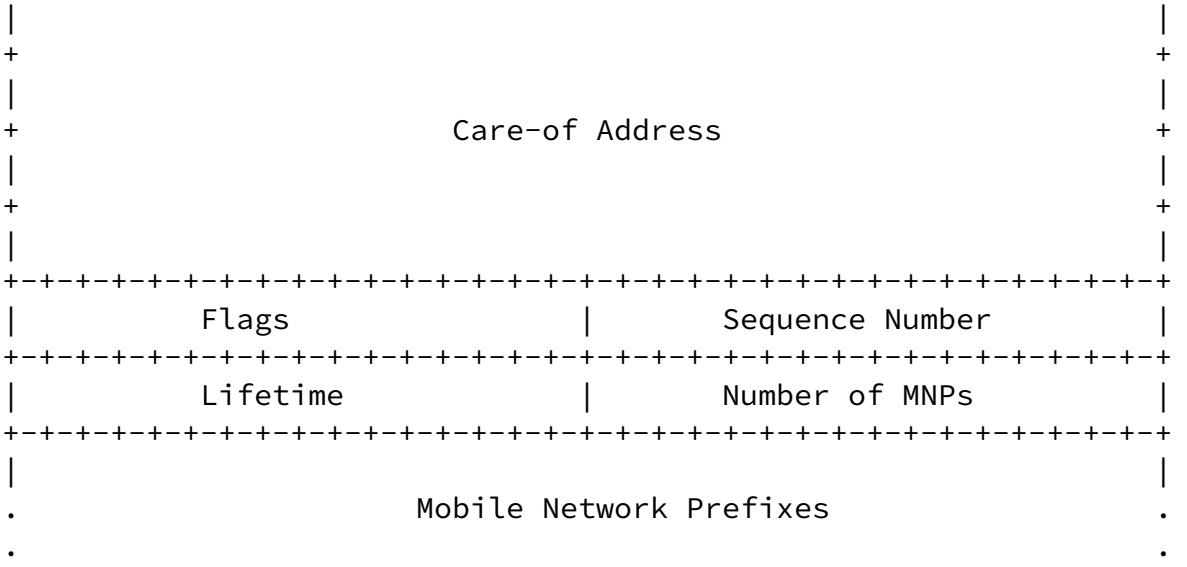
4.3.2. Mobile Network Prefix Option

This option is already defined in the Nemo basic support [6]. This option is included in the Binding Information Request message only if a Home Agent is requesting information regarding a particular Mobile Network Prefix.

4.3.3. Binding Cache Entry Information Option

The Binding Cache Entry Information option has an alignment requirement of 8n+2. Its format is as follows:





Binding Cache Entry Information option is valid in the Binding Information Reply.

The fields of Home Address, Care-of Address, Flags, Sequence Number, and Lifetime are copied from the registered binding of a particular Mobile Node or Mobile Router.

The field ``Number of MNPs'' tells the receiving Home Agent which Mobile Network Prefixes are owned by a Mobile Router. The receiving Home Agent can then setup forwarding for each Mobile Network Prefix. for Mobile IPv6, the ``Number of MNPs'' field is set to 0.

5. Home Agent Lists Management

Mobile IPv6 uses Router Advertisement messages to manage Home Agent lists on each Home Agents. When home agents are placed at different links, Router Solicitation and Advertisement messages can not be used due to link-local limitation. Therefore, we defined new ICMP messages to exchange similar information of Router Solicitation and Advertisement among Home Agents over the home link.

A Home Agent MUST know other Home Agents which configured in different links beforehand. This is manually configured on each Home Agent. This mechanism MUST be used only between Home Agents on different links serving the same home prefix. It SHOULD not be used between Home Agents on the same link.

If a Home Agent Solicitation message or a Home Agent Advertisement message is received from unknown Home Agent, the message MUST be silently dropped.

5.1. Requesting Home Agent Information

A Home Agent sends a Home Agent Solicitation message when the home agent wants to update information of a particular Home Agent. This is useful a Home Agent boots up and starts acting as a home agent or when the lifetime of a Home Agent list entry is about to expire.

A sender Home Agent MUST construct the Home Agent Solicitation in the same manner as a Router Solicitation message [8] and MUST unicast it to the target Home Agent.

The receiver MUST verify the Source address field of the IPv6 header. If the source address is not among the known Home Agents, the message MUST be discarded. If the Home Agent Solicitation message is processed successfully, the receiver sends a Home Agent Advertisement message to the Home Agent which solicits the information.

5.2. Notifying Home Agent Information

A Home Agent MUST send a Home Agent advertisement message when it receives a valid Home Agent Solicitation message. The Home Agent SHOULD also send a Home Agent Advertisement when its local information such as preference, lifetime, and registration status, etc. changes.

A Home Agent Advertisement MUST be constructed as same manner as a Router Advertisement message described in section 7 of [1] and MUST be sent by a unicast to the destination (other Home Agents).

The receiver of a Home Agent Advertisement MUST verify the Source

address field of the IPv6 header. If the source address is not in the list of know Home Agents, the message MUST be silently dropped. Otherwise, the receiver processes the Home Agent Advertisement message to update its Home Agent list.

The receiver MUST NOT treat the Home Agent Advertisement as a Router Advertisement for the address autoconfiguration or the default router list management. The Home Agent Advertisement MUST be used only for the Home Agent list management. Therefore, the Home Agent Advertisement MUST have Home Agent (H) bit and MUST have a Modified Prefix Information Option and a Home Agent Information Option. If these are not included in the Home Agent Advertisement message, the receiver MUST ignore the message.

Any Home Agent Advertisement message satisfying all of these tests MUST be processed to update its Home Agent list according to the processing rules described in section 10.5.1 of [1].

6. Binding Synchronization among Home Agents

A binding for a particular Mobile Node/Router is shared among Home Agents. Therefore, each Home Agents can always know the binding for a particular Mobile Router and the primary Home Agent which is currently serving the Mobile Router. This makes it possible for Mobile Routers to utilize multiple Home Agents simultaneously.

6.1. Requesting Binding

When a Home Agent wants a binding for a particular Mobile Node/Router, it can solicit Binding Information Reply message. The Home Agent sends a Binding Information Request message to the primary home agent of the Mobile Node/Router. The Home Agent MUST set a random value to the Identifier field in the Binding Information Request message and MUST include either a Home Address mobility option or a Mobile Network Prefix mobility option.

6.2. Notifying Binding

The primary Home Agent sends Binding Information Reply messages when it is solicited by Binding Information Request message or when it creates or updates binding for a particular Mobile Node/Router.

When the primary Home Agent receives a Binding Information Request message, it MUST verifies the Source address field of the IPv6

header. If the source address is not among the know Home Agents, the message MUST be silently discarded.

If a Home Agent who receives a Binding Information Request message is not the primary Home Agent for the requested Mobile Node/Router, it MUST ignore the message. Otherwise, it SHOULD reply to the Binding Information Request message.

The binding information of the requested Mobile Node/Router are stored in the Binding Information Reply message. The primary Home Agent MUST copy the binding information of the requested Mobile Node/Router to each fields of a Binding Cache Entry Information option. If the Binding Information Reply message is sent in response to the Binding Information Request message, the primary Home Agent MUST copy the Identifier field of the Request message to the same filed in the Reply message. Otherwise, it MUST set zero to the Identifier field.

When a Home Agent receives a Binding Information Reply message, it MUST verify the Source address field of the IPv6 header. If the source address is not among the know Home Agents, the message MUST be silently discarded. If the Binding Information Reply message is sent from the primary Home Agent, the Home Agent SHOULD record the binding information and the primary Home Agent address into its Binding Cache.

Both a Binding Information Reply message and a Binding Information Request message MUST be authenticated and encrypted by IPsec ESP. If a message does not have IPsec ESP header, the message MUST be ignored.

7. Primary Home Agent Switching

A Mobile Router always associates with the best Home Agent from home agents configured for the Mobile Router. The Mobile Router initiates dynamic Home Agent discovery to get the most appropriate home agents. The Mobile Router can ensure the best Home Agent by issuing a dynamic Home Agent address discovery request message at each visiting foreign links. Alternatively, Home Agent can send Home Agent Switch Request message as a trigger of a dynamic Home Agent address discovery request message to the Mobile Router.

The Home Agent initiated switching is useful for load-sharing of each Home Agents. A Home Agent can control the load average by moving some of Mobile Routers to other Home Agents compulsory.

The Mobile Router initiated switching guarantees a Mobile Router to register its binding to the best Home Agent all the time. For example, the best Home Agent is the nearest one.

7.1. Home Agent initiated Switching

A Mobile Router can change its primary Home Agent when it is requested by a Home Agent. When a Mobile Router receives a Home Agent Switch Request, it checks the Home Address field in the request. If the address in the Home Address field is global scope address and is already recorded in the Home Agent list of the Mobile Router, the Mobile Router immediately switches to the requested Home Agent by the Home Agent Switch Request. On the other hand, the Mobile Router MUST send a Dynamic Home Agent Discovery Request message to the Mobile IPv6 Home-Agents anycast address. After receiving a Dynamic Home Agent Discovery Reply, the Mobile Router selects the most appropriate home agent and changes its primary Home Agent to the selected Home Agent.

The primary Home Agent switching is completed when the Mobile Router registers its binding to the new Home Agent.

7.2. Mobile Router initiated Switching

When a Mobile Router decides to change its primary Home Agent, it selects the new Home Agent from its Home Agent list. The Mobile Router can start Dynamic Home Agent Address Discovery to update Home Agents information such as a preference value of each Home Agents.

After selection of a new Home Agent, it registers its binding to the new Home Agent.

8. Scenarios

8.1. Solo Home Agent Activation

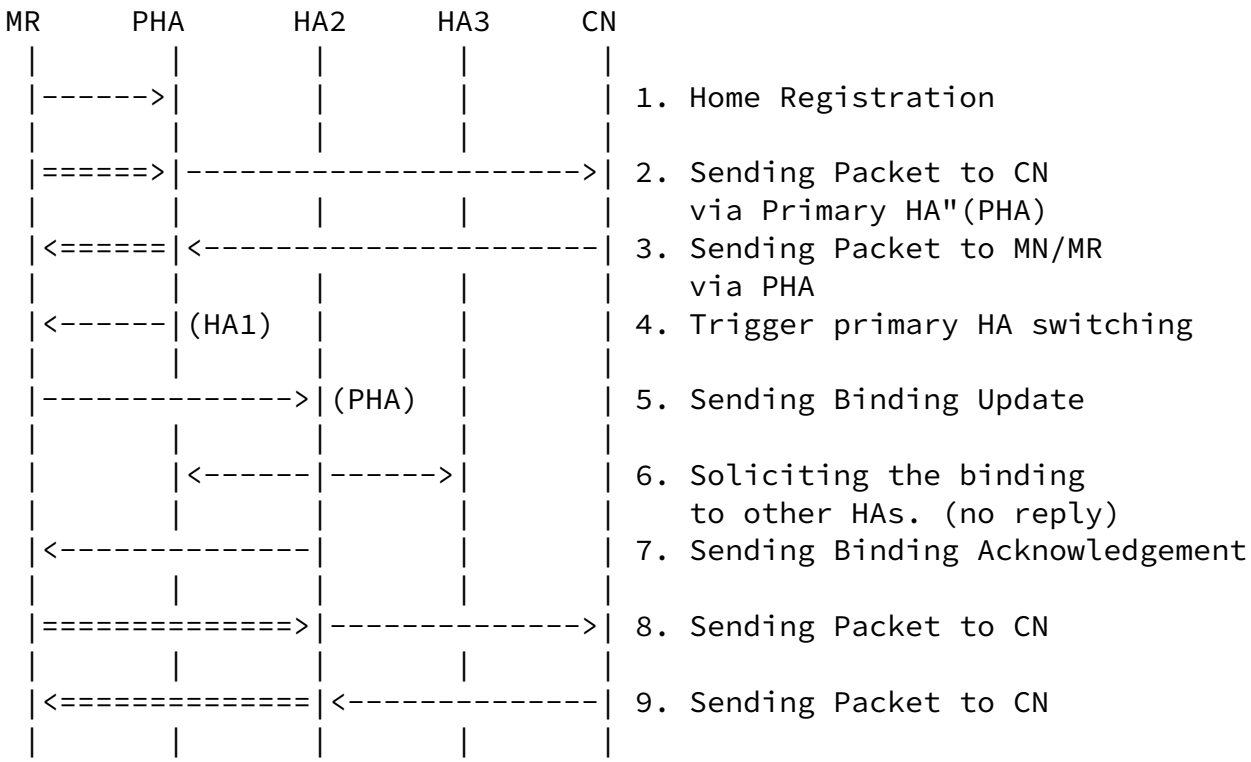


Figure 1: Solo Home Agent with single bi-directional tunnel

This scenario is only valid for the Nemo basic support. Only the primary Home Agent advertises a home prefix and mobile network prefixes (might be aggregated in terms of extended/aggregated home prefix [7]) to the Internet in Fig 1. When a Home Agent receives a Binding Update from a Mobile Router and processes the Binding Update successfully, it enables route distribution for the mobile network prefixes. On the other hand, if the Home Agent receives a Binding Update requesting to delete the binding (de-registration), it stops distributing routes for the mobile network prefixes. The Home Agent should not stop route distribution when the binding is expired due to lifetime expiration. The Home Agent needs explicit de-registration (i.e. Binding Updates for de-registration) to stop the routes distribution.

All packets meant for the mobile network are routed to the primary Home Agent and are intercepted by the primary Home Agent as well as the Nemo basic support. Then, the primary Home Agent tunnels packets to the Mobile Router according to the forwarding states established by a Binding Update (Seq2 and Seq3).

When the Mobile Router switches its primary Home Agent, it sends a Binding Update to the new primary Home Agent (Seq5). The new primary Home Agent receiving the Binding Update verifies whether the other Home Agents still hold the binding for the Mobile Router. It sends Binding Information Request messages to all the other Home Agents (Seq6). If it receives any Binding Information Reply message in response to the Binding Information Request messages, it sends a Binding Acknowledge to the Mobile Router with the status value set to 144 (another Home Agent is still active). Otherwise, the Home Agent accepts the Binding Update and becomes the primary Home Agent for the Mobile Router (Seq7).

If the Mobile Router receives the Binding Acknowledge with a negative status code, it de-registers its binding from the old primary home agent and retries to send a Binding Update to the new primary home agent. Before trying home registration to the new Home Agent, the Mobile Router should de-register its binding from the current primary Home Agent.

When the Mobile Router receives a Home Agent Switch Request from the current primary Home Agent, it MUST switch its primary Home Agent to the new Home Agent specified in the Home Agent Switch Request. The Mobile Router can also switch the primary Home Agent proactively without the Home Agent Switch Request.

8.2. Multiple Home Agent Activation

This scenario can be applied to both Mobile IPv6 and the Nemo basic support protocol. Each Home Agent advertises the same home prefix to the Internet. In the Nemo case, all the Home Agents having a binding for a Mobile Router MUST distribute routes for mobile network prefixes as well as the home prefix. The home prefix and the mobile network prefixes could be aggregated in terms of extended/aggregated home prefix described in [7].

Each Home Agent synchronizes a binding for a particular Mobile Node/Router by the HAHA protocol. If all the Home Agents who have the binding for the Mobile Router can setup forwarding for the Home Address and the mobile network prefixes owned by the Mobile Router, it tunnels intercepted packets directly to the Mobile Node/Router (Fig 3). On the other hand, if the Home Agent does not enable forwarding for the Home Address and the mobile network prefixes, it tunnels intercepted packets to the primary Home Agent (Fig 2) first. Then the primary Home Agent re-tunnels packets to the Mobile

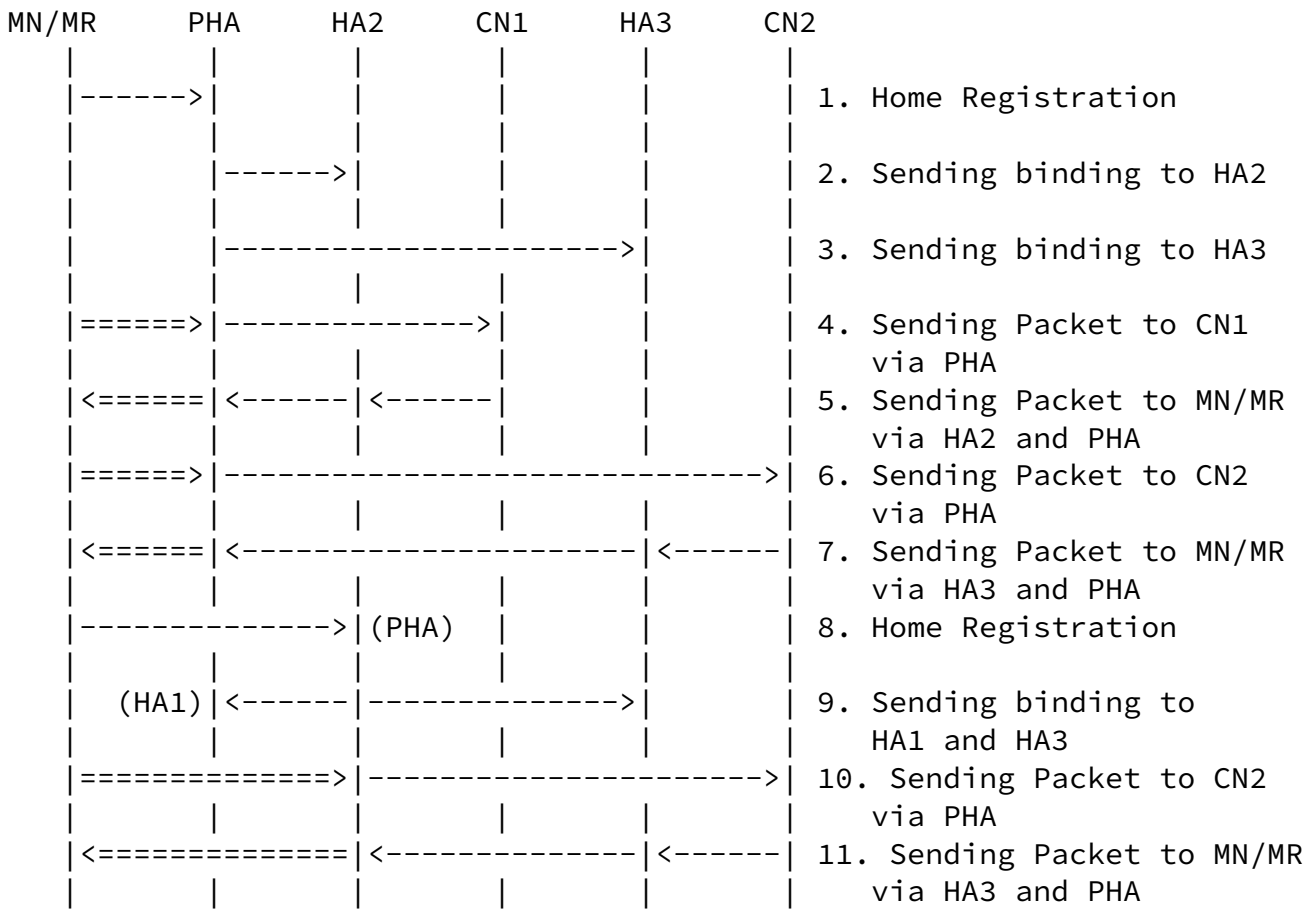


Figure 2: Multiple Home Agents with single bi-directional tunnel

Node/Router. It is a matter of operations whether forwarding setting is enable on all the Home Agent or not.

In the figure 2, a Mobile Node/Router first registers its binding to the primary Home Agent (Seq1). Once the primary Home Agent creates a binding for the home address of the Mobile Node/Router and sets up forwarding for the mobile network prefixes, it sends Binding Information Reply messages to other Home Agents to synchronize the binding information (Seq2 and Seq3). When a Home Agent receives the Binding Information Reply message, it records the binding and the primary Home Agent address (which can be retrieved from the source address of the Binding Information Reply messages) in the binding cache entry.

After the completion of the binding synchronization, all Home Agents start to distribute the network routes for the mobile network prefixes to the Internet. Therefore, when the mobile network node communicates with a correspondent node, outgoing packets from the mobile network are tunneled to the closer primary Home Agent (Seq4)

and incoming packets to the mobile network are intercepted by the Home Agent which is close to the correspondent node (Seq5). Then, the intercepted packets are forwarded/tunneled to the primary Home Agent. The primary Home Agent delivers the packets to the Mobile Router through the bi-directional tunnel (Seq5).

If the Mobile Router decides to switch its primary Home Agent due to its movement, it sends a Binding Update to the new primary home agent. Then, the new primary Home Agent starts to synchronize the binding information with other Home Agents (Seq9). All Home Agent updates the binding and the primary Home Agent address according to the received Binding Information Reply message.

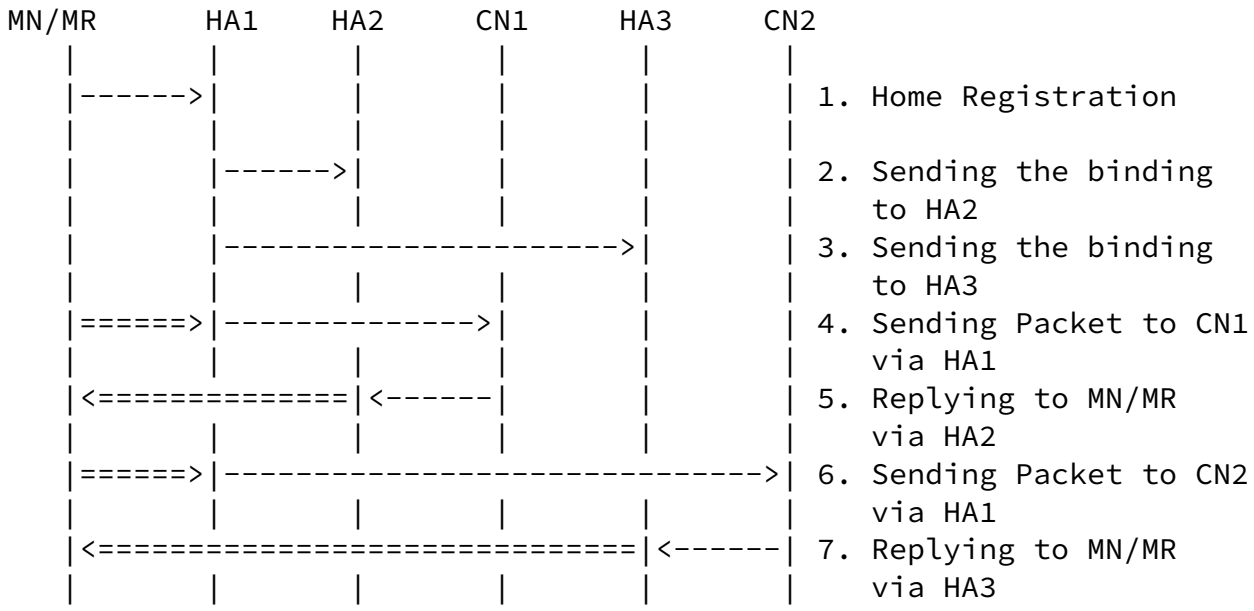


Figure 3: Multiple Home Agents with multiple bi-directional tunnels

In the figure 3, a Mobile Node/Router first sends a Binding Update

to its primary Home Agent (Seq1). The primary Home Agent also notifies the binding information to other Home Agents by using Binding Information Reply messages (Seq2 and Seq3). When a Home Agent receives the Binding Information Reply message, it records the binding and the primary home agent address as a binding cache entry for the Mobile Node/Router and sets up forwarding for mobile network prefixes if any.

After creating the binding cache entry and setting up forwarding, each Home Agent starts to distribute network routes for the mobile network prefixes to the Internet. When the Mobile Network Node communicates with a Correspondent Node, outgoing packets from

the mobile network are tunneled to the primary Home Agent (Seq4). Incoming packets to the mobile network are intercepted by the Home Agent which is close to the Correspondent Node (Seq5). Then, the intercepted packets are tunneled directly to the current Care-of Address according to binding and forwarding (Seq5).

The procedure of primary Home Agent switching is same as the procedure described in Fig 2.

9. Modifications to Mobile IPv6 and the Nemo Basic Support Protocol

The HAHA protocol modifies the below items of Mobile IPv6 [1] and the Nemo Basic Support protocol [6].

- The new status values for the Binding Acknowledgment.

  When a Mobile Node/Router receives this status for its home registration, it MUST de-register its binding from the old primary Home Agent and SHOULD re-try home registration. A Home Agent SHOULD use this status value only in the solo Home Agent activation scenario. The primary Home Agent can not be duplicated in the scenario and can only have a binding for a particular Mobile Node/Router all the time.

  Status

  144 Another primary Home Agent is still active.

- Binding Cache Registration
  The conceptual fields of each Binding Cache entry are defined in [1]. The HAHA protocol introduces an additional field to record the primary Home Agent address for a Mobile Node/Router.

  When a Home Agent receives a Binding Information Reply message, it creates or updates the binding cache entry. The Home Agent MUST record the primary Home Agent address in the binding cache entry. The address can be derived from the Source address field of IPv6 header in the Binding Information Reply message.

  When a primary Home Agent receives a Binding Update from a Mobile Node/Router, it MUST records its own address as the primary Home Agent address in the binding cache entry.

- Tunneling packets to Mobile Node/Router from Home Agents
  Home Agents who registers a binding by the HAHA protocol can tunnel packets meant for the Mobile Node/Network to the current Care-of Address as well as the primary Home Agent. The Mobile

  Node/Router can accept the tunneled packets. The Mobile Node/Router MUST know all the Home Agents who has its binding in the home agent list so as to verify the Source address of outer IPv6 header.

- Tunneling packets to primary Home Agent from Home Agents
  When one of Home Agents who has a binding intercepts packets meant for a particular Mobile Node/Router, the Home Agent can tunnel packets to the primary Home Agent recorded in the binding cache. The primary Home Agent tunnels packets to the current Care-of Address of the Mobile Node/Router.

10. IANA Considerations

This document defines two new ICMP options

- Home Agent Solicitation Message

- Home Agent Advertisement Message

This document defines three new Mobility Header messages

- Binding Information Request Message

- Binding Information Reply Message

- Home Agent Switch Request Message

This document defines two new Mobility Options.

- Home Address

- Binding Cache Entry Information

11. Security Considerations

Multiple Home Agents advertise routes for either same Home Prefix and possibly Mobile Network Prefix in the HAHA protocol, these routes MUST be correctly advertised. System Administrators MUST prevent malicious (blackhole) routes for these prefixes.

A Home Agent MUST know the other Home Agent serving a same Mobile Node/Router and MUST establish a secure association with each Home Agent. All signaling messages between the Mobile Router and the Home Agent MUST be authenticated and encrypted by IPsec ESP [4].

The Mobile Node/Router MUST verify that packets are tunneled through the known Home Agent. In Multiple Home Agent activation scenario, the Mobile Node/Router may receives packets tunneled by multiple Home Agents. The Mobile Node/Router MUST know all Home Agents who has its binding by the HAHA protocol in its Home Agent List by using Home Agent Address Discovery. It is necessary for a Mobile Node/Router to know all other Home Agents in order to protect attacks launched by malicious Home Agents.

Please refer to the Mobile IPv6 specification [1] and the Nemo Basic Support protocol specification [6] for security considerations.

References

[1] D. Johnson, C. Perkins and J. Arkko. Mobility Support in IPv6 (work in progress). Internet Draft, IETF. draft-ietf-mobileip-ipv6-22.txt. May 2003.

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[3] J. Arkko, V. Devarapalli and F. Dupont. Using IPsec to Protect Mobile IPv6 Signaling between Mobile Nodes and Home Agents (work in progress). Internet Draft, IETF. draft-ietf-mobileip-mipv6-ha-ipsec-05.txt May 2003

[4] S. Kent and R. Atkinson. IP Encapsulating Security Payload (ESP). RFC 2402, IETF. November 1998.

[5] A. Conta and S. Deering. Generic Packet Tunneling in IPv6 Specification. RFC 2473, IETF. December 1998.

[6] V. Devarapalli and R. Wakikawa and A. Petrescu and P. Thubert. Nemo Basic Support Protocol (work in progress). Internet Draft, IETF. draft-ietf-nemo-basic-support-01.txt September 2003

[7] P. Thubert and R. Wakikawa and V. Devarapalli. Examples of basic Nemo usage (work in progress). Internet Draft, IETF. draft-ietf-nemo-basic-usage-00.txt October 14 2003.

[8] T. Narten and E. Nordmark and W. Simpson. Neighbor Discovery for IP Version 6 (IPv6). RFC 2461, IETF. December 1998.

A. Predictive HA discovery

There are at least 3 approaches in order to locate the Home Agent that has a registration for a given Mobile Node, Router or Mobile Network:

- reactive: This method is also referred to as 'on-demand'. In case of a binding cache miss, a Home Agent floods a request to all the other Home Agents with the (destination of the packet) home address that is sought for. Every Home Agent that has a registration for that home address or for a Mobile Network

that encompasses that home address responds. This approach is traditionally used in fast changing configurations, for instance if Mobile Nodes register and de-register very often.

- proactive: an information is pushed to all Home Agents with the home address and the Mobile Network Prefixes each time a primary binding entry is created for a new registration. This approach is preferred for stable configurations, for instance if Mobile IP is used as a tool to simplify the configuration and reconfiguration of mostly stable networks.

- predictive: Ranges of Home Addresses and prefixes are assigned to the Home Agents, following a rule that is commonly computed by all Home Agents. Dynamic Home Agent Address Discovery (DHAAD) returns only the address of one Home Agent, the one that is pre-allocated for that Mobile Node. When the wrong Home Agent intercepts packets, it can compute which is the right Home Agent and forward packets to it at L2 if they are directly connected, or via a HAHA tunnel which is established between Home Agents. This is what we call 'Z' routing.

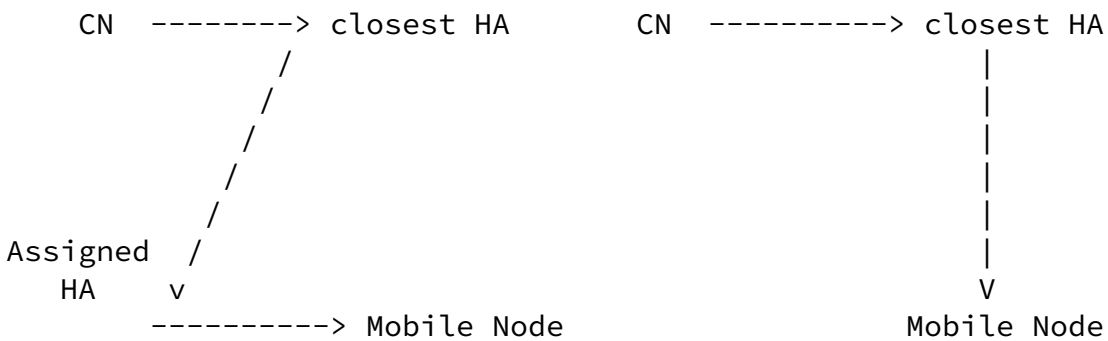


Figure 4: Z routing vs dogleg

The Predictive Mode minimizes the control traffic, which may be required for a large configuration. Some additional controls would be necessary for the HAHA protocol to allow the negotiation and the distribution of the shares of Home to be attributed to each Home Agent.

One specific advantage of not relying on a Home Link for HAHA communication is that for a large configuration, the Home Agents can

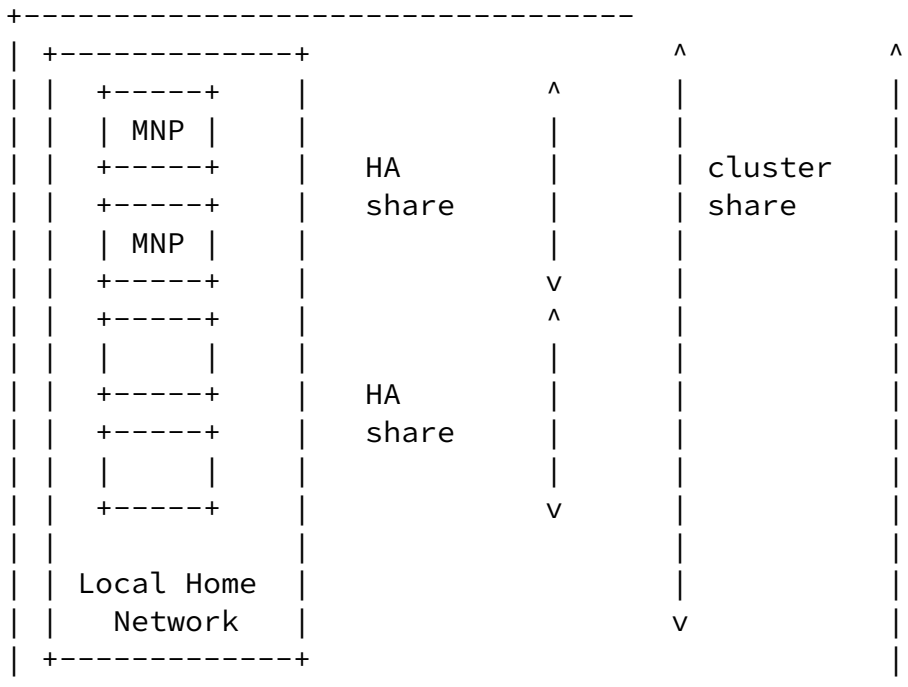
be organized hierarchically and distributed geographically, as a set of local clusters linked together to form a global Home Network.

For instance, it is possible for a large ISP to partition the Home Network for a given worldwide service, and assign a partition to a cluster of Home Agents in each of the geographies. In predictive mode, each Home Agent in the world would be able to compute the best suited Home Agent in its local cluster (call this a Acting Home Agent) and the best suited Home Agent worldwide (call this the Assigned Home Agent) for each and any Home Address.

Any Home Agent processing a anycast DHAAD can predict the Assigned HA and local Acting Home Agents for a Home Address if that information is added to the DHAAD request. In the case of Mobile Routers, the service must be arranged in such ways that, for a given registration, all the Mobile Networks are assigned to a same Home Agent.

Possible flows:

In order to register, a Mobile Router uses DHAAD which returns one Home Agent in the closest cluster. This can be a Acting HA if the Mobile Node is roaming far from Home, but hopefully it is in general the Assigned Home Agent for that Mobile Node. When this is a Acting HA, it needs to register to the Assigned HA as proxy binding.



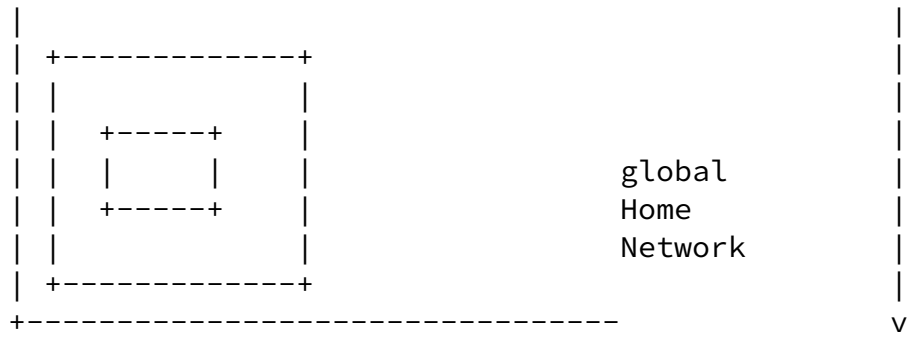


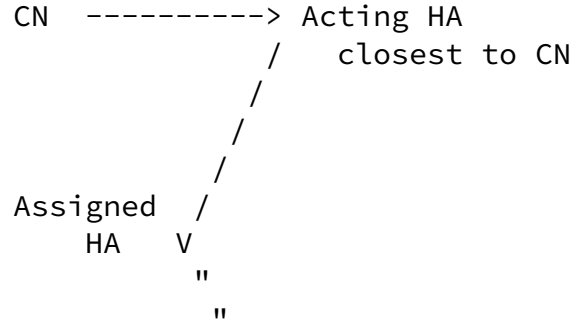
Figure 5: Distributed Hierarchical Home Network

When a packet destined to a given Home Address arrives at a Home Agent from a Correspondent Node:

If the Home Agent is Assigned for that Home Address and it has a direct registration (it is primary), the Home Agent forwards the packet over its bi-directional tunnel established with the Mobile Node/Router (the MRHA tunnel). If it has a proxy registration (it is secondary), it forwards the packet to the primary Acting HA - or directly to the Mobile Node/Router if that is practical for tunnel setup and security reasons. Else it drops the packet.

Else If the Home Agent is Acting HA for that Home Address and it has a direct registration (it is primary), the Home Agent forwards the packet over its MRHA tunnel. If it has a proxy registration (it is secondary), it forwards the packet to the primary Acting HA - or

directly to the Mobile Node if that is practical for tunnel setup and security reasons. Else, it forwards the packet to the Assigned HA.



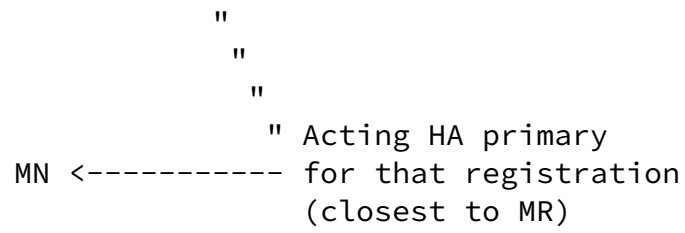


Figure 6: Acting HA to Acting HA without Route Optimization

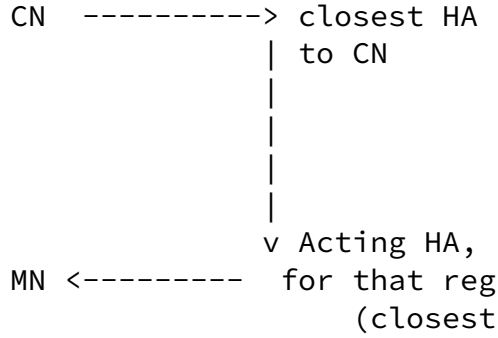


Figure 7: Acting HA to Acting HA Route Optimization

Else (if the HA is the 'wrong Home Agent') the Home Agent tunnels the packet to the best suited of the local Home Agents, be it the Assigned Home Agent, or a local Acting Home Agent.

In the worst case, the packet may bounce from the receiving Home Agent to the local Acting HA, then to the Assigned HA, and finally to the Acting HA that has the registration. It is up to the Assigned Home Agent to forward the proxy binding states to the Acting Home

Agent on the receiving side in order to allow Acting HA to Acting HA 'Z' routing.

If the Home Agents are distributed geographically, it is expected that, in general, the angles of the Z (the Home Agents) are close to the Mobile Router and Correspondent Node respectively, relatively to the distance between the Home Agents, which makes the cost of the bouncing acceptable in terms of distance and hops.

When a packet from a registered Mobile Node arrives over the MRHA tunnel to a Home Agent (one that it is registered to), the Home Agent forwards the packet directly to the Correspondent Node. That Home Agent is supposed to be close to the Mobile Node, making the MR-HA-CN triangle as flat as possible and limiting the cost of the dogleg.

Authors Addresses

Ryuji Wakikawa
Keio University and WIDE
5322 Endo Fujisawa Kanagawa
252-8520
Japan
Email: ryuji@sfc.wide.ad.jp

Vijay Devarapalli
Nokia Research Center
313 Fairchild Drive
Mountain View, CA 94043
USA
Email: vijay.devarapalli@nokia.com

Pascal Thubert
Cisco Systems Technology Center
Village d'Entreprises Green Side
400, Avenue Roumanille
Biot - Sophia Antipolis 06410
France
Email: pthubert@cisco.com

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