MEXT Working Group R. Wakikawa
Internet-Draft R. Kuntz
Intended status: Experimental Toyota ITC
Expires: March 5, 2012 Z. Zhu
L. Zhang
UCLA
September 2, 2011

Global HA to HA Protocol Specification
draft-wakikawa-mext-global-haha-spec-02

Abstract

This document presents a revised version of the global HAHA protocol specification. Global HAHA allows the deployment of Home Agents over the Internet for reliability, scalability and performance purposes. This version clarifies several issues that were vague in the original specification. Global HAHA makes use of the signaling defined by the Home Agent Reliability protocol (HARP) although it is not designed to operate in conjunction with HARP.

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction 4

2. Terminology 6

3. Overview 8
   3.1. Initial Binding Registration 9
   3.2. Primary Home Agent Switch 9
   3.3. Routing Packets 10
   3.4. Differences between global HAHA and HARP 11

4. Home Agent Configurations 12
   4.1. Home Agent and Subnet Distributions 12
   4.2. Anycast Routing Consideration 13

5. Global HAHA Protocol 14
   5.1. Home Agents Bootstrap 14
   5.2. Management of global Home Agent set 14
      5.2.1. Home Agent List for the global HAHA 15
      5.2.2. Modified HARP Message 15
      5.2.3. Sending Home Agent Hello Messages 16
      5.2.4. Receiving Hello Message 16
   5.3. Primary Home Agent Receiving Binding Update 17
   5.4. Global Binding Management 18
      5.4.1. Global Binding 18
      5.4.2. Modified State Synchronization Message and Mobility Option 19
      5.4.3. Global Binding Registration 19
   5.5. Primary Home Agent Switch 21
   5.6. Packet Interception and Delivery 22
   5.7. Home Agents Discovery 23

6. IANA considerations 24

7. Security Considerations 25

8. Acknowledgements 26

9. References 26
   9.1. Normative References 26

9.2. Informative References 26

Authors' Addresses 28

1. Introduction

The global HAHA protocol aims at leveraging the global deployment of Home Agents over the Internet, by proposing reliability, scalability and better performances to Mobile IPv6 [RFC6275] deployments.

The original global HAHA protocol [I-D.thubert-mext-global-haha] has been discussed for several years in MIP6, NEMO and now MEXT working groups. Several documents [I-D.thubert-mext-global-haha] [I-D.wakikawa-mip6-nemo-haha-spec] [I-D.wakikawa-mext-haha-interop2008] have been published and presented in past IETF meetings, and received valuable feedback. This document presents a revised version of the global HAHA protocol specification. This version clarified several issues that were vague in the original specification [I-D.thubert-mext-global-haha].

Global HAHA makes use of the signaling defined by the Home Agent Reliability protocol (HARP) [I-D.ietf-mip6-hareliability] which is being standardized in the MEXT working group. On one hand, HARP provides a redundancy mechanism for the Home Agents located on the same layer-2 link (or in different layer-2 links provided that proper routing updates are performed between links upon failure). On the other hand, global HAHA builds on anycast routing to not only provide redundancy but also achieve a better distributed mobility management for Mobile IPv6. More specifically, global HAHA provides the following advantages:

- It eliminates the single point of failure and bottleneck in Mobile IPv6 and NEMO protocols. By distributing multiple Home Agents over wide areas, scalability and robustness of the mobility infrastructure can be improved.

- It provides very flexible deployment schemes. When home agents are placed at Internet Exchange Points, they can improve the performances of mobility over long distances (such as depicted in aeronautics scenarios [RFC5522]) by minimizing triangle routing as compared to the path utilizing a single home agent (so called dog-leg routing). Alternatively, when home agents are placed closer to the edge of the network, a more flat design can be achieved. Offloading near the edge of the network becomes possible, to the benefit of the core network load [I-D.kuntz-dmm-summary].

- It makes use of existing protocols (HARP signaling [I-D.ietf-mip6-hareliability], Home Agent Switch messages [RFC5142]) while confining the required changed to the home agent only.

Global HAHA also provides reliability in case of a home agent failure. Whether it would be useful to be able to combine HARP with global HAHA for local reliability of a home agent is open for future discussion. Such combination can bring better performances in cases that may be unlikely to happen often, at the cost of an increased complexity. Furthermore, whether Global HAHA should be independent from HARP and define its own signaling protocol is also open for further discussion.

The global HAHA concept has been evaluated through prototype implementations in several places [PAPER-CONEXT] and the results show that the design is simple and effective in reducing triangle routing. Several industry sectors such as aviation [RFC5522] and automobile [I-D.ietf-mext-nemo-ro-automotive-req] have shown their interests in using global HAHA to meet the need for their mobility managements.

As every coin has two sides, the global HAHA protocol is not an exception. It achieves the above goals through utilizing anycast routing, which has raised a concern on routing scalability, and it introduces additional overheads due to the need to synchronize the mobility state among distributed home agents. By presenting a complete design together with the design justifications, we hope that this document will help move the discussion towards a converged understanding on the pros and cons of the global HAHA protocol.

2. Terminology

This document uses terms defined in [RFC3753], [RFC6275], [RFC3963] and and [I-D.ietf-mip6-hareliability]. A few new terms are also introduced in this document:

Home subnet prefix

It is assigned to a home subnet, and the home agent unicast address (defined below) of a mobile node is assigned out of this prefix block. In this global HAHA specification, the home subnet prefix is assumed to be a provider independent prefix.

Home agent unicast address

A unicast IP address created from the home subnet prefix and assigned to a home agent. This is the address used by Mobile nodes when sending Binding Updates to their Home Agent.

Home agent locator address

A unicast IP address assigned to a home agent by the ISP who provides the Internet connectivity for the home agent. This address is used to exchange mobility messages between globally distributed home agents.

Home agent anycast address

The anycast address defined as per [RFC2526] and used by mobile nodes for Dynamic Home Agent Address Discovery purposes.

Global home agent set

The set of home agents serving the same home subnet prefix. The home agents are located in topologically and/or geographically different locations. A global home agent set is identified with a 8-bit group ID.

HAHA link

All the home agents in the same global home agent set share the same home subnet prefix although they may be located in different parts on Internet. In order for each of them to reach all the others directly as required by IP subnet definition, logical connectivity links are created between each pair of home agents. These logical links, called HAHA links, can be realized using IP tunnel technologies such as IP tunnel, IPsec tunnel, L2TP, PPTP, and so on. Data packets and Binding Updates that need to be forwarded between home agents are sent over these HAHA links.

Primary Home Agent

The home agent which a mobile node is currently registered with. Among all the available home agents in the same set, this primary home agent should be topologically closest to the mobile node. At any given time each mobile node has one primary home agent.

Global Binding

When a mobile node registers with a primary home agent, the home agent notifies this binding, called the global binding, to all the other home agents in the same global home agent set. The receiver of this global binging information learns the mapping between the mobile node and its current primary home agent, and creates a route entry for the mobile node with the next hop pointing to the primary home agent locator address. This route entry has a lifetime which can be different from the lifetime carried in the original binding message. When the lifetime expires, the route is deleted.

3. Overview

Global HAHA relies on IP anycast routing between geographically and topologically different home agent locations. The home subnet prefix is announced by all the home agents in a deployed global HAHA system, so that packets from and to mobile nodes are always routed towards the closest home agents in a way that is completely transparent to the mobile and correspondent nodes.

Global HAHA does not require any modification to mobile nodes and mobile routers (i.e. end mobile entity). Supporting Mobile IPv6 [RFC6275] and Home Agent Switch message [RFC5142] is sufficient to run mobile nodes with globally distributed home agents.

Figure 1 shows the protocol sequence of the global HAHA. As an assumption, each home agent in the same global home agent set MUST establish HAHA links for interconnecting other home agents. The detail of HAHA link establishment is described in Section 5.1.

```
     MN        HA1       HA2       CN
      |         |         |         |
      |----> (Primary)    |         |   1. Binding Update
      |<--------|         |         |   2. Binding Acknowledgment
      |         |-------->|         |   3. State Synchronization
      |<========|<========|<--------|   4. From CN to MN
      |========>|------------------>|   5. From MN to CN
      |         |         |         |
      :         :         :         :      MN MOVEMENT
      |         |         |         |
      |-----------------+|         |   6. Binding Update
      |         |<=======+|         |
      |<--------|         |         |   7. Binding Acknowledgment
      |<--------|         |         |   8. Home Agent Switch
      |--------------> (Primary)    |   9. Binding Re-registration
      |         |<--------|         |  10. State Synchronization
      |<==================|<--------|  11. From CN to MN
      |==================>|-------->|  12. From MN to CN
      |         |         |         |

     ==== for tunneling
     ---- for direct packets
```

Figure 1: Overview of global HAHA

3.1. Initial Binding Registration

Global HAHA home agents can be reached by the mobile node through both the home agent anycast address (e.g. obtained with Dynamic Home Agent Address Discovery [RFC6275]) and the Home agent unicast address (e.g. obtained from the DNS) created from the home agent home subnet prefix (see Section 5.7). Note that the home agent locator address is not known by the mobile nodes and is only used between global home agents to exchange mobility messages among them.

When the mobile node attempts the binding registration to a home agent using the HA anycast address (operation 1 in Figure 1), the binding update is routed to the topologically closest home agent of the mobile node via IP anycast routing. The closest home agent which the mobile node registers its binding with is called a primary home agent for the mobile node. This specification assumes that the route of home subnet prefix is advertised from each of different locations where an HAHA home agent resides.

After sending a binding Acknowledgment to the mobile node (operation 2 in Figure 1) and registering a binding cache for the mobile node, the primary home agent (HA1) sends State Synchronization messages to all the other home agent (i.e. HA2) in the same global home agent set (operation 3 in Figure 1). Then, HA2 creates a global binding for the mobile node and creates the mobile node's route entry with the next hop set to the locator address of the primary home agent (HA1). The global binding needs to be updated when a mobile node changes its primary home agent. It must also be refreshed before its lifetime expiration.

When HA2 receives packets from a correspondent node destined to the mobile node, it forwards them to the primary home agent (HA1) over the HAHA link according to the global binding (operation 4 in Figure 1). When a mobile node sends data to the correspondent node, the traffic is tunneled to the primary home agent, which then routes directly to the destination (operation 5 in Figure 1).

If the mobile node obtained the home agent unicast address through the DNS, and that address does not correspond to the topologically closest home agent, a home agent switch will be performed as described in the next section.

3.2. Primary Home Agent Switch

In this example, from the routing perspective, the closest home agent of the mobile node is now changed from HA1 to HA2 after a mobile node's movement. Thus, the primary home agent of the mobile node needs to be updated from HA1 to HA2. This case can also happen if the home agent unicast address obtained from the DNS (during the bootstrapping phase of the mobile node) is set to HA1 whereas the mobile node is initially closer to HA2.

The Primary Home Agent switch operation consists of two binding updates exchange. The first binding update is used to detect the closer home agent by the current primary home agent. The second binding update is to let the mobile node change its primary home agent.

When a mobile node changes its point of attachment, it simply sends the first Binding Update to its current primary home agent (i.e. HA1 in Figure 1) in order to renew its binding as per [RFC6275]. However, since HA2 also advertises the same home subnet prefix, the Binding Update is first routed to the HA2 by IP anycast routing. HA2 knows that HA1 belongs to the same global Home Agent set, and thus forwards the Binding Update to its destination (HA1) over the HAHA link (operation 6 in Figure 1).

Due to fact that the binding update is forwarded from one of other home agents in the same global home agent set, the HA1 now detects that the primary home agent is changed to the HA2. The HA1 first processes the Binding Update and returns a Binding Acknowledgment to the mobile node (operation 7 in Figure 1). In parallel, it triggers a Home Agent Switch message [RFC5142] to the mobile node (operation 8 in Figure 1). In the Home Agent switch message, the home agent unicast address of HA2 is stored in the Home Agent Address field so that the mobile node can associate with the closest home agent.

When the mobile node receives the Home Agent Switch message from the HA1, it switches its home agent to the HA2 according to [RFC5142]. The mobile node sends another Binding Update to the HA2 (operation 9 in Figure 1). After receiving the Binding Update, the HA2 creates the binding cache and sends a State Synchronization message to the other Home Agents (i.e. HA1) in the global home agent set (operation 10 in Figure 1). The HA1 removes the binding cache entry of the mobile node and creates a global binding as well as the route for the mobile node with the next hop set to the locator address of HA2 over the HAHA link.

3.3. Routing Packets

The packets originated by the mobile node are always routed through the primary home agent as shown in operations 5 and 12 in Figure 1. They are tunneled to the primary home agent and, then, routed directly to the CN.

On the other hand, the packets originated by the correspondent node are routed to the closest home agent by IP anycast routing as shown in operations 4 and 11 in Figure 1. If the home agent is not the primary home agent of the mobile node (destination), the home agent looks up the global binding and routes them to the primary home agent of the mobile node over the HAHA link. Then, the primary home agent routes the packets to the mobile node over the Mobile IPv6's bi-directional tunnel.

In some scenario, the path between a mobile node and a correspondent node becomes asymmetric. In the global HAHA, the primary home agent does not have any specific information of the correspondent nodes and does not forward the packets to the closest home agent of the correspondent node.

3.4. Differences between global HAHA and HARP

The global HAHA protocol makes use of the signaling defined by the Home Agent Reliability protocol (HARP) [I-D.ietf-mip6-hareliability] which is being standardized in the MEXT working group. However, global HAHA is not designed to be operated in conjunction with HARP. HARP extends Mobile IPv6 [RFC6275] to provide reliability to home agents. Its concept is similar to the router's redundancy protocols such as VRRP and HSRP. When one home agent fails, another standby home agent located in the same home link or in a different network can immediately take over the function of the failed one, so that ongoing sessions of mobile nodes will not be interrupted by any single home agent failures.

Global HAHA can also achieve reliability by relying on IP anycast routing. The home subnet prefix being announced by all the home agents, packets from and to mobile nodes can be forwarded to remaining functional home agents in a transparent manner. In addition, global HAHA can achieve better scalability and provide optimized paths between a mobile node and its correspondents, by always associating the nearest home agent to the mobile node.

4. Home Agent Configurations

4.1. Home Agent and Subnet Distributions

Figure 2 shows the subnet and home agent distribution in a global HAHA system. Home agents are connected to a number of subnets located in various places on Internet, they are all assigned the same Provider-Independent (PI) prefix as their home subnet prefix. Each home subnet is connected to the global Internet through an ISP who also assigns a prefix out of its own address block to the home subnet. We call this ISP assigned prefix "Locator Prefix" (LP). Each home agent has two unicast IP addresses: one from its PI home subnet prefix (the "home agent unicast address") and another from its provider (the "home agent locator address"). Each ISP that hosts a HAHA subnet also agrees to announce the HAHA's PI Home subnet prefix to the global Internet, so that packets destined to any IP address that belongs to the home subnet prefix are delivered to the topologically closest home agent.

```
        Home Link1 (2001:db8:0:1::/64)
            HA1
             |
           --+--
             |     /|\ LP-1 Prefix
        +--------+  |
        |  ISP1  |
        +--------+         LP-2 Prefix
             |              -->
        +--------+  +--------+    |
        |Backbone|--|  ISP2  |----+- HA2     Home Link2
        +--------+  +--------+    |      (2001:db8:0:1::/64)
             |
        +--------+
        |  ISP3  |
        +--------+  |  LP-3 Prefix
             |     \|/
           --+--
             |
            HA3
        Home Link3 (2001:db8:0:1::/64)

           HA unicast address (PI)     HA locator address (LP)
    - HA1     2001:db8:0:1::1             LP-1Prefix::1
    - HA2     2001:db8:0:1::2             LP-2Prefix::2
    - HA3     2001:db8:0:1::3             LP-3Prefix::3
```

Figure 2: Home Subnets and Agents Distribution

4.2. Anycast Routing Consideration

IP anycast routing has been widely used in recent years. As documented in [RFC4786], anycast has become increasingly popular for adding redundancy to DNS servers to complement the redundancy that the DNS architecture itself already provides. Several root DNS server operators have distributed their servers widely around the Internet, and DNS queries are directed to the nearest functioning servers. Another popular anycast usage is by web service providers, where two or more web farms share the same IP prefix, so that when all the sites are up, HTTP requests are forwarded to the web servers closest to the browsers; when a site is down, requests are automatically routed to next nearest web farm. Anycast routing provides a simple and effective means to provide robust services.

A concept related to anycast is MOAS (Multi-Origin AS) prefixes, they are prefixes advertised by more than one origin AS. A MOAS prefix represents an anycast prefix, although the inverse is not necessarily true, i.e. an anycast prefix may not be a MOAS prefix if the prefix is announced to the routing system by one origin AS out of the AS's multiple locations. Our measurement using BGP data collected by RouteViews and RIPE observed about 2000 or so MOAS prefixes in today's global routing system, which is a very small percentage of the current routing table entries of about 300K entries.

One basic cost from providing anycast services is an additional entry in the global routing table for each anycast prefix. When the number of anycast applications is small, the impact on the global routing system scalability is small. The use of anycast for important infrastructure services, such as DNS root servers, is well justified. Using anycast to bootstrap other important services may also be justified, if the services are globally scoped are commonly used, and the number of anycast prefixes needed is small. However anycast is clearly not for everyone or for all applications usage. It is a worthwhile investigation to consider where best to draw the line.

5. Global HAHA Protocol

5.1. Home Agents Bootstrap

For the global HAHA protocol, each home agent SHOULD be configured with the following information:

- An own home subnet prefix (Provider Independent prefix, PI)

- An own home agent unicast address (created from the PI)

- An own home agent locator address (created from the Locator Prefix, LP)

- A home agent anycast address for Dynamic Home Agent Address discovery mechanism (created as per [RFC2526])

- A Group ID of own global home agent set

- Home Agent locator addresses of all the other home agents in the same global home agent set.

A home agent first establishes HAHA links with all the other home agents. How to establish a HAHA link is out of scope in this document. For instance, IP tunnel is established between two home agent's locator addresses. This HAHA link is used to exchange data packets destined to the mobile node and binding updates coming from the mobile node. Although all the Binding Updates are already securely exchanged, it is recommended to secure every packets tunneled over this HAHA link. Note that Home Agent HELLO message and State Synchronization message do not need to be tunneled over the HAHA link as they can be sent directly using the Home Agent locator addresses as source and destination addresses.

As soon as HAHA links are fully ready, the home agent now provides its home agent service to a mobile node. Without HAHA links, a home agent SHOULD NOT configure with its home subnet prefix and act as a home agent of the home subnet prefix. The home agent now starts sending its Home Agent HELLO message as described in Section 5.2 and soliciting global bindings of all the other home agents as discussed in Section 5.4.3.

5.2. Management of global Home Agent set

A home agent exchanges its availability with other home agents of the same global home agent set. The status exchange is done with a Home Agent HELLO message defined in the Home Agent Reliability protocol [I-D.ietf-mip6-hareliability].

5.2.1. Home Agent List for the global HAHA

[RFC6275] and [I-D.ietf-mip6-hareliability] specify and extend the data structure named the Home Agent List. This list is used to manage home agent information at a same home link. The following two fields introduced in [RFC6275] are not used in this specification:

- The link-local IP address of a home agent

- The preference for this home agent

5.2.2. Modified HARP Message

This specification defines a new flag for the HARP HA-HELLO message (Type 4):

```
 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
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                |     Type      |   Group ID    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Sequence #           |A|R|V|M|G| Rsvd|   Status      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Home Agent Preference    |      Home Agent Lifetime      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Hello Interval         |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
|                                                               |
.                        Mobility Options                       .
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: HARP Message

Home Agent Preference

In this specification, a same preference value is used among home agents in a global home agent set. A home agent is selected by a mobile node according to routing topology (i.e. anycast routing), but not by these preference values. This value SHOULD be set to 0. The receiver SHOULD ignore this value.

Group Identifier

This value is used to identify a particular global home agent set.

Global (G) flag

Global HA flag. If this flag is set, the home agent sending this HA-HELLO message is operated with this specification.

5.2.3. Sending Home Agent Hello Messages

Each home agent periodically sends HA-HELLO to the other home agents in the same global home agent set. Each home agent MUST also generate HA-HELLO in the following cases:

- o when a home agent receives a HA-HELLO with the G (Global HA) and R (Request) flag set

- o When a new home agent boots up, it SHOULD solicit HA-HELLO messages by sending a HA-HELLO with the G and R-flag set in parallel with sending its own HA-HELLO message.

When a home agent sends HA-HELLO, the following rule MUST be applied in addition to the Section 4.3.2.1 of [I-D.ietf-mip6-hareliability].

- o It MUST set G flag in HA-HELLO.

- o It MUST specify its global home agent set's ID to the Group ID field in HA-HELLO.

- o The source and destination IPv6 addresses of the IPv6 header of the HA-HELLO MUST be the source and destination home agent locator addresses. They MUST belong to the same global home agent set.

- o It MUST protect HA-HELLO by IPsec ESP.

5.2.4. Receiving Hello Message

When a home agent receives HA-HELLO, it follows the verification described in Section 4.3.2.2 of [I-D.ietf-mip6-hareliability]. In addition to this, it MUST process HA-HELLO which G flag is set as follows:

- o If the HA-HELLO is not protected by IPsec ESP, it MUST be discarded.

- o If the source IPv6 address of HA-HELLO does not belong to one of the home agents in the redundant home agent set, the HA-HELLO MUST be ignored.

- If the Group ID field of the received HA-HELLO and the receiver's Group ID are different, HA-HELLO MUST be discarded. HA-HELLO MUST NOT be sent to home agents whose Group ID is different from the sender.

- HA-HELLO satisfying all of above tests MUST be processed by receiver. The receiver copies home agent information in HA-HELLO to the corresponding home agent list entry. The home agent locator address of the sender is retrieved from the source address field of the IPv6 header of the HA-HELLO.

5.3. Primary Home Agent Receiving Binding Update

The binding update sent by a mobile node is routed to the one of home agents in the global home agent set according to the anycast routing. If the receiver does not have any binding cache entry nor global binding for this mobile node, it processes the binding update according to [RFC6275] and stores a binding cache entry for the mobile node. After successful binding registration, the home agent becomes a primary home agent for the mobile node. The primary home agent has the following functional requirements:

- Delivering IP packets destined to the mobile node over the bi-directional tunnel

- Updating the binding according to the mobile node's binding refreshment

- Notifying the mobile node binding to the other home agents in the same global home agent set

- Sending a Home Agent Switch message if another home agent is more preferable to be the primary home agent. Usually, this is trigerred by the reception of a valid Binding Update via another home agent of the global home agent set

- Providing state synchronization information to other home agents of the global home agent set when a binding is created, updated, removed or upon request.

The binding registration and management are the same as specified in [RFC6275]. The global HAHA requires to register global bindings of the mobile node by sending the state synchronization message to all the other home agents as described in the next section.

5.4. Global Binding Management

5.4.1. Global Binding

A global binding has the following information. Any mobile node's specific information can be potentially stored in the global binding. The aim of this global binding is to forward the data packets of a mobile node received at non-primary home agent to the primary home agent of the mobile node. It is not used to deliver a packet directly to a mobile node from the non-primary home agents. Therefore, the mobile node's care-of address is not necessary in the global binding, more than likely the primary home agent of the mobile node is important in the global binding.

- The primary home agent locator address
- The mobile node's home address
- The mobile router's mobile network prefix(es)
- The binding sequence number of a binding update
- The flags of a binding update
- The lifetime of the global binding
- The mobile node's care-of address (optional)

The modified State Synchronization message [I-D.ietf-mip6-hareliability] described in the next section is used to exchange the global bindings among the home agents.

When a global binding is created, the home agent MAY use proxy Neighbor Discovery or IP routing to intercept the packets addressed to the mobile node's home address.

When a global binding is created, the home agent MUST create a mobile node's route entry which next hop is set to the locator address of the primary home agent. If a mobile node is a mobile router [RFC3963], the following mobile node's routes are created: one for the home address and one per mobile network prefix. If the mobile router's home address is derived from its mobile network prefix [RFC3963] (i.e. the operation of aggregated home network [RFC4887]), only a single route for the mobile network prefix is sufficient.

5.4.2. Modified State Synchronization Message and Mobility Option

Figure 4 shows the modified version of the state synchronization (SS) message defined in [I-D.ietf-mip6-hareliability]. A new G flag is introduced to explicitly indicate the global binding registration.

```
     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
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |     Type      |A|G| Reserved  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |         Identifier            |                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               .
    .                                                               .
    .                        Mobility Options                       .
    .                                                               .
    .                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: State Synchronization Message

Global (G) flag

When State Synchronization messages are exchanged for global binding registration, the Global flag MUST be set.

Mobility Options

The Binding Cache Information Option as defined in [I-D.ietf-mip6-hareliability] is mandatory for the State Synchronization Request (SS-REQ) message (Type 0) as well as State Synchronization Reply (SS-REP) message (Type 1).

Others options (e.g. AAA Information option, Vendor Specific Mobility option, as well as the others referenced in [I-D.ietf-mip6-hareliability]) can be used too.

The SS Status Option as defined in [I-D.ietf-mip6-hareliability] MUST be used in the State Synchronization Reply-Ack (SS-ACK) message (Type 2).

5.4.3. Global Binding Registration

If a primary home agent sends a SS-REP message for every binding registration from a mobile node, it causes certain overhead to exchange messages. Unless the binding information is changed (except for sequence number and lifetime), the state synchronization reply message is not necessarily sent per mobile nodes' binding refreshment. A SS-REP message MUST be sent by a primary home agent to register a global binding at the following timing:

- When a primary home agent registers a binding for a mobile node for the first time. The primary home agent MUST register a global binding to the global home agent set.

- When a global binding is expired. The primary home agent MUST refresh the global binding.

When a primary home agent receives a binding update from a mobile node and registers a binding for it, it sends a State Synchronization Reply message. SS-REP is sent to all the other home agents in the global home agent set with the following rules:

- The A (Ack) and G (Global) flags MUST be set in SS-REP.

- At least, one Binding Cache Information Option MUST be stored in the mobility option field. Multiple options can be stored in a SS-REP.

- Other optional mobility options listed in Section 5.4.2 MAY be stored in the mobility option field.

- IPsec ESP MUST be applied.

- The source and destination addresses of the SS-REP MUST be the source and destination home agent locator addresses.

- The source and destination addresses MUST belong to the same global home agent set.

When a home agent receives the SS-REP, the following rules must be applied to the received SS-REP:

- If the SS-REP is not protected by IPsec ESP, it MUST be discarded.

- If no options are carried in SS-REP, the receiver MUST ignore the SS-REP and MUST send SS-ACK with the Status Synchronization Status option which status value is set to the newly defined value [131: No Mobility Option].

- If the sender of SS-REP is not in the same global home agent set, the receiver MUST reject the SS-REP and MUST send SS-ACK with the Status Synchronization Status option which status value is set to [130: Not in same global home agent set].

- o If the G flag is not set in RR-REP, the receiver MUST ignore the SS-REP and MUST send SS-ACK with the Status Synchronization Status option which status value is set to [129: Malformed SS-REP].

- o If no errors are found in SS-REP, the receiver MUST register or update the global binding per Binding Cache Information Option. If the supplemental mobility options are specified for a mobile node, the information MUST be stored in the global binding.

- o After the successful global binding registration, it MUST create a mobile node's route entry which next hop is set to the primary home agent locator address (i.e. the sender of SS-REP). If a mobile node is a mobile router [RFC3963], the following mobile node's routes are created: one for the home address and one per mobile network prefix. If the mobile router's home address is derived from its mobile network prefix [RFC3963] (i.e. the operation of aggregated home network [RFC4887], only a single route for the mobile network prefix is sufficient.

- o The receiver of SS-REP then sends SS-ACK with state synchronization status mobility options for all the mobile nodes registering its global binding.

When a home agent needs to solicit SS-REP, it can send SS-REQ to a home agent. The rules to construct SS-REQ is described in Section 4.4.3 of [I-D.ietf-mip6-hareliability]. In addition, the following rules MUST be applied:

- o IPsec ESP MUST be applied.

- o The source and destination addresses of the SS-REQ MUST be the source and destination home agent locator addresses.

- o The source and destination addresses MUST belong to the same global home agent set.

5.5. Primary Home Agent Switch

Primary Home Agent switch operation consists of two binding update exchanges. The first binding update is basically used by a primary home agent to detect the better home agent in the same global home agent set and to trigger sending a home agent switch message to mobile nodes. The second one is to complete primary home agent switch by registering the binding to the new primary home agent.

When a mobile node moves, it sends a binding update to its primary home agent currently registering the binding. If the binding update is directly routed to the destination (i.e. home agent), there is no need to start the primary home agent switch. On the other hand, if the binding update is first routed to one of non-primary home agents, the receiver of the binding update SHOULD become the primary home agent of the mobile node from the routing perspective. The receiver does not operate any inspection of the binding update and simply forwards it to the destination address of the binding update over the HAHA link.

Once the primary home agent receives the binding update forwarded by one of home agents in the same global home agent set, it processes the binding update as described in Section 5.3. In addition, it starts sending a home agent switch message [RFC5142] for the primary home agent switch operation. How to send the home agent switch message is described in [RFC5142] and Section 4.5 of [I-D.ietf-mip6-hareliability].

The mobile node receiving the home agent switch message simply updates its home agent address and re-registers its binding to the new primary home agent. The new primary home agent sends SS-REP to all the other home agents to update its global binding. After receiving SS-REP, the previous primary home agent SHOULD delete its original binding and create a global binding for the mobile node. According to [RFC5142], upon receipt of a Home Agent Switch message, the mobile node must delete its home binding by sending a Binding Update deregistration message. However, the mobile node SHOULD NOT send this de-registration in this specification, since the previous active home agent knows the primary home agent switch by receiving the SS-REP. Although this represents a slight modification of the mobile node side, this helps achieving minimum latency of the primary home agent switch by eliminating the binding de-registration process.

5.6. Packet Interception and Delivery

When a home agent receives a packet destined to a mobile node, it first check the binding cache. If it finds an original binding, it tunnels the packet to the mobile node over the bi-directional tunnel. Otherwise, it checks the global binding of the mobile node. If it finds the global binding, it then routes the packet to the primary home agent recorded in the global binding over the HAHA link. The packet is delivered to the primary home agent by IP encapsulation. In the outer IP header, the home agent source and destination locator addresses should be used. If neither a binding nor a global binding is found, the packet MUST be simply discarded. The home agent SHOULD return an ICMP Destination Unreachable (Code 3) message to the packet's source address (unless this source address is a multicast address).

5.7. Home Agents Discovery

When a mobile node boots up and needs to discover a home agent, it can either use Dynamic Home Agent Address Discovery (DHAAD) or perform a DNS lookup by home agent name or service name as specified in [RFC5026].

In the DHAAD case, the mobile node simply sends a DHAAD request message to the home agent anycast address. In that case, the DHAAD request message is routed to the closest home agent via IP anycast routing. The closest home agent SHOULD return its own unicast address with the highest priority in the DHAAD reply message so that the mobile node can use the closest home agent for its binding registration.

In the DNS case, the lookup by home agent name or service name may return either the home agent anycast address or a home agent unicast address. In both cases, the binding update sent by the mobile node will reach the closest home agent thanks to IP anycast routing. However, in the second case, the binding update may be forwarded by that home agent towards the owner of the home agent unicast address used in the binding update. In that case, a primary home agent switch may be initiated right after the registration of the mobile node. In order to avoid this case, the DNS may be configured to return only the home agent anycast address, or have the necessary mechanisms to return the unicast address of the closest home agent for the mobile node.

6. IANA considerations

This document does not contain any actions for the IANA

7. Security Considerations

TBA: Section 7 of [I-D.ietf-mip6-hareliability] gives useful information.

8. Acknowledgements

We would like to thank to Pascal Thubert and Vijay Devarapalli for the original discussion of the global HAHA. We also thank to Arnaud Ebalard for his review and valuable comments.

9. References

9.1. Normative References

[I-D.ietf-mip6-hareliability]
Wakikawa, R., "Home Agent Reliability Protocol (HARP)", draft-ietf-mip6-hareliability-09 (work in progress), May 2011.

[RFC3963] Devarapalli, V., Wakikawa, R., Petrescu, A., and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol", RFC 3963, January 2005.

[RFC5142] Haley, B., Devarapalli, V., Deng, H., and J. Kempf, "Mobility Header Home Agent Switch Message", RFC 5142, January 2008.

[RFC6275] Perkins, C., Johnson, D., and J. Arkko, "Mobility Support in IPv6", RFC 6275, July 2011.

9.2. Informative References

[I-D.ietf-mext-nemo-ro-automotive-req]
Baldessari, R., Ernst, T., Festag, A., and M. Lenardi, "Automotive Industry Requirements for NEMO Route Optimization", draft-ietf-mext-nemo-ro-automotive-req-02 (work in progress), January 2009.

[I-D.kuntz-dmm-summary]
Kuntz, R., Sudhakar, D., Wakikawa, R., and L. Zhang, "A Summary of Distributed Mobility Management", draft-kuntz-dmm-summary-01 (work in progress), August 2011.

[I-D.thubert-mext-global-haha]
Thubert, P., Wakikawa, R., and V. Devarapalli, "Global HA to HA protocol", draft-thubert-mext-global-haha-01 (work in progress), July 2009.

[I-D.wakikawa-mext-haha-interop2008]
Wakikawa, R., Shima, K., and N. Shigechika, "The Global

HAHA Operation at the Interop Tokyo 2008", draft-wakikawa-mext-haha-interop2008-00 (work in progress), July 2008.

[I-D.wakikawa-mip6-nemo-haha-spec]
Wakikawa, R., "Inter Home Agents Protocol Specification", draft-wakikawa-mip6-nemo-haha-spec-01 (work in progress), March 2006.

[PAPER-CONEXT]
Wakikawa, R., Valadon, G., and J. Murai, "Migrating Home Agents towards Internet-Scale Mobility Deployments", CoNEXT 2006 Conference on Future Networking Technologies, December 2006.

[RFC2526] Johnson, D. and S. Deering, "Reserved IPv6 Subnet Anycast Addresses", RFC 2526, March 1999.

[RFC2991] Thaler, D. and C. Hopps, "Multipath Issues in Unicast and Multicast Next-Hop Selection", RFC 2991, November 2000.

[RFC3753] Manner, J. and M. Kojo, "Mobility Related Terminology", RFC 3753, June 2004.

[RFC4786] Abley, J. and K. Lindqvist, "Operation of Anycast Services", BCP 126, RFC 4786, December 2006.

[RFC4885] Ernst, T. and H-Y. Lach, "Network Mobility Support Terminology", RFC 4885, July 2007.

[RFC4887] Thubert, P., Wakikawa, R., and V. Devarapalli, "Network Mobility Home Network Models", RFC 4887, July 2007.

[RFC4888] Ng, C., Thubert, P., Watari, M., and F. Zhao, "Network Mobility Route Optimization Problem Statement", RFC 4888, July 2007.

[RFC4889] Ng, C., Zhao, F., Watari, M., and P. Thubert, "Network Mobility Route Optimization Solution Space Analysis", RFC 4889, July 2007.

[RFC5026] Giaretta, G., Kempf, J., and V. Devarapalli, "Mobile IPv6 Bootstrapping in Split Scenario", RFC 5026, October 2007.

[RFC5522] Eddy, W., Ivancic, W., and T. Davis, "Network Mobility Route Optimization Requirements for Operational Use in Aeronautics and Space Exploration Mobile Networks", RFC 5522, October 2009.

Authors' Addresses

Ryuji Wakikawa
Toyota InfoTechnology Center USA, Inc.
465 Bernardo Ave
Mountain View, California 94045
USA

Email: ryuji@us.toyota-itc.com

Romain Kuntz
Toyota InfoTechnology Center USA, Inc.
465 Bernardo Ave
Mountain View, California 94045
USA

Email: rkuntz@us.toyota-itc.com

Zhenkai Zhu
UCLA
420 Westwood Plaza
Los Angeles, California 90095
USA

Email: zhenkai@cs.ucla.edu

Lixia Zhang
UCLA
3713 Boelter Hall
Los Angeles, California 90095-1596
USA

Email: lixia@cs.ucla.edu