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Global HA to HA Protocol Specification
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Abstract

This document presents a revised version of the global HAHA protocol specification. This version clarified several issues that were vague in the original specification. All the protocol specifications for the global HAHA are now added on top of the Home Agent Reliability protocol.

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1. Introduction

The Global HAHA protocol [ID-HAHA] has been discussed for a few years in MIP6, NEMO and now MEXT working group. We have published several documents [ID-HAHA] [ID-HAHAPROTO] [ID-HAHAINTEROP] and presented several times 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 [ID-HAHA]. All the protocol specifications for the global HAHA are now added on top of the Home Agent Reliability protocol [ID-HARELIABILITY] which has been standardized at the MEXT working group.

The global HAHA concept has been evaluated through prototype implementations in several places and the results show that the design is simple and effective in reducing triangle routing. Several industry sectors such as aviation and automobile have shown their interests in using global HAHA to meet the need for their mobility managements. The main advantages of the global HAHA can be summarized as follows:

- It can provide a more optimized route compared to the non-direct path via a single home agent so called dog-leg routing;

- It eliminates the single point of failure and bottleneck in Mobile IPv6 and NEMO protocols.

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 concerns by various people, and it introduces new 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 [RFC-3753], [RFC-3775], [RFC-3963] and [ID-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 address 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 Address

An address created from the home subnet prefix and assigned to a home agent.

Home Agent Locator Address

An 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.

Global Home Agent Set

The set of home agents serving the same home subnet prefix. The home agents can be located in topologically or geographically different locations. A global home agent set is identified with a 16-bit group ID.

HAHA link

Because all the home agents in the same global home agent set share the same home subnet prefix, yet they may be lcoated 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.

Primary Home Agent

The home agent which a mobile node is currently registered with. Among all the available home agent in the same set, this primary home agent should be topologically closest to the mobile node. 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 receivers of this global binding informaiton learns the pair of a 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. 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

This protocol is defined as an extension to the Home Agent Reliability protocol. The Home Agent Reliability protocol extends Mobile IPv6 [RFC-3775] to provide reliability to home agents at the local home link. Its concept is similar to the router's redundancy protocols such as VRRP and HSRP. When one home agent fails, another standby home agent can immediately take over the function of the failed one, so that ongoing session of mobile nodes will not be interrupted by any single home agent failures.

Similar to the Home Agent Reliability protocol, the global HAHA protocol requires no modification to mobile nodes and mobile routers (i.e. end mobile entity). Supporting Mobile IPv6 [RFC-3775] and Home Agent Switch message [RFC-5142] is sufficient to run mobile nodes with globally distributed home agents. However different from the Home Agent Reliability protocol, the global HAHA places multiple home agents at geographically and topologically different locations and can provide uninterrupted services in the face of multiple Home Agent failures. This robustness feature is achieved through the use of IP anycast routing, where all the Home Agents in a deployed global HAHA system share one anycast address, so that packets from mobile nodes can be forwarded to remaining functional home agent in a way that is completely transparent to the mobile nodes.

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 Registration
      |         |-------->|         |   2. State Synchronization
      |<========|<========|<--------|   3. From CN to MN
      |========>|------------------>|   4. From MN to CN
      |         |         |         |
      :         :         :         :      MN MOVEMENT
      |         |         |         |
      |------------------+|         |   5. Binding Registration
      |         |<=======+|         |
      |<--------|         |         |   6. Home Agent Switch
      |--------------> (Primary)    |   7. Binding Re-registration
      |         |<--------|         |   8. Binding Notification
      |<==================|<--------|   9. From CN to MN
      |==================>|-------->|  10. From MN to CN
      |         |         |         |

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

Figure 1: Overview of Global HAHA

3.1. **Initial Binding Registration**

When the mobile node attempts the binding registration to a home agent (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. Each HAHA home agent can be reached through both the HAHA anycast address and the unicast IP address assigned by the local service provider.

After registering 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 2 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 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 destined to the mobile node, it forwards them to the primary home agent (HA1) over the HAHA link according to

the global binding (operation 3 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 4 in Figure 1).

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 mobile node's movement. Thus, the primary home agent of the mobile node needs to be updated from HA1 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 a first Binding Update to the current primary home agent (i.e. HA1 in Figure 1) in order to renew its binding as [RFC-3775]. However, HA2 also advertises the home subnet prefix which is the same prefix of the binding update's destination address (HA1's home agent address), the Binding Update is first routed to the HA2 by IP anycast routing and then forwarded to its destination (HA1) over the HAHA link by HA2 (operation 5 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. In parallel, it triggers a Home Agent Switch message [RFC-5142] to the mobile node. In the Home Agent switch message, the address of the HA2 is stored in the Home Agent Address field so that the mobile node can associate with the closest home agent (operation 6 in Figure 1).

When the mobile node receives the Home Agent Switch message from the HA1, it switches its home agent to the HA2 according to [RFC-5142] . The mobile node sends another Binding Update to the HA2. 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. The HA1 removes the binding cache entry of the mobile node and creates the route for the mobile node with the next hop set to the 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 3, 4, 9, 10 in

Figure 1. They are tunneled to the primary home agent to which the mobile node is currently registering 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. 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.

4. Home Agent Configurations

4.1. Home Agent and Subnet Distributions

Figure 2 shows the home agents located on the same home link as introduced in [RFC-3775] and [ID-HARELIABILITY]. Multiple home agents are placed on the same home subnet (2001:db8:0:1::/64) and standby home agents are prepared for home agent reliability [ID-HARELIABILITY]. The home agents are assigned with different IP address as an individual home agent address. The standby home agent for HAa, HAa', shares the same IP address with HAa.

```
          +--------+
          |Internet|
          +--------+
              |
        --+---+---+--Home Link (2001:db8:0:1::/64)
          |   |   |
         HAa HAb (HAa')

            HA Address
    - HAa  2001:db8:0:1::1
    - HAb  2001:db8:0:1::2
    - HAa' 2001:db8:0:1::1 (Standby)
```

Figure 2: Home Agents Distribtuion

Figure 3 shows the combination of home agents and subnets 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 of out its own address block to the home subnet. We call this ISP assigned prefix "locator prefix". Each home agent has two IP addresses: one from its PI home subnet prefix and another from its provider. 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 destinated to any of the home agent's IP addresses are delivered to the topologically closest home agent.

```
        Home Link1 (2001:db8:0:1::/64)
      HA1a HA1b (HA1a')
         |   |   |
         ----+----
             |     /|\ PA-1 Prefix
        +--------+  |
        |  ISP1  |
        +--------+         PA-2 Prefix
             |              -->   +- HA2a
        +--------+  +--------+    |
        |Backbone|--|  ISP2  |----+        Home Link2
        +--------+  +--------+    |        (2001:db8:0:1::/64)
             |                    +- (HA2a')
        +--------+
        |  ISP3  |
        +--------+  |  PA-3 Prefix
             |     \|/
        +----+----+
        |         |
     HA3a       (HA3a')
        Home Link3 (2001:db8:0:1::/64)

             HA address (PI)        HA Locator address (PA)
    - HA1a  2001:db8:0:1::1a       PA-1Prefix::1a
    - HA1b  2001:db8:0:1::1b       PA-1Prefix::1b
    - HA1a' 2001:db8:0:1::1a       PA-1Prefix::1a (Standby)

    - HA2a  2001:db8:0:1::2a       PA-2Prefix::2a
    - HA2a' 2001:db8:0:1::2a       PA-2Prefix::2a (Standby)

    - HA3a  2001:db8:0:1::3a       PA-3Prefix::3a
    - HA3a' 2001:db8:0:1::3a       PA-3Prefix::3a (Standby)
```

Figure 3: Home Subnets and Agents Distribtuion

4.2. Anycast Routing Consideration

IP anycast routing has been widely used in recent years. As documented in RFC4786 [RFC-4786], 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.

- o An own home subnet prefix
- o An own home agent address
- o An own home agent locator address
- o A home agent anycast address for Dynamic Home Agent Address discovery mechanism
- o A Group ID of own global home agent set
- o Home Agent locator addresses of all the other home agents in the same global home agent set.

A home agent first establishes a HAHA link 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 Home Agent HELLO message, State Synchronization message and data packets destined to a mobile node. Although all the signal packets are securely exchanged, it is recommended to secure every packets exchanged over this HAHA link.

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. These status exchange is done with a Home Agent HELLO message defined in the Home Agent Reliability protocol [ID-HARELIABILITY]. Unlike the Home Agent Reliability protocol, geographically separated home agents are operated more carefully and their availability should be always confirmed (ex. by the Home Agent Reliability protocol). Therefore, it MAY use longer interval value for the hello message exchange, because these messages

are exchanged over the network (i.e. not on the same link).

5.2.1. Home Agent List for the global HAHA

[RFC-3775] specifies the data structure named the Home Agent List. This list is used to manage home agent information at a same home link. In this specification, the home agent list is extended to manage geographically distributed home agents. The following information MUST be stored for globally distributed home agents in the home agent list.

o home agent address(es)

o home agent locator address(es)

o The remaining lifetime of this Home Agents List entry

o Group ID of global home agent set

The following two fields introduced in [RFC-3775] are not used in this specification.

o The link-local IP address of a home agent

o The preference for this home agent

5.2.2. Modified Home Agent Hello Message

```
        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
                                       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
+
                                       |          Sequence #
|
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
+
       |      Home Agent Preference    |      Home Agent Lifetime
|
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
+
       |        Hello Interval         |   Group ID    |A|R|G|Reserved
|
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
+
       |
|
       .                                                               .
       .                        Mobility
Options                       .
       .                                                               .
       .
```

```
|
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
+
```

Figure 4: Home Agent Hello Message

Home Agent Preference

In this specification, the equal 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.

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 and R-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 7.3.2 of [ID-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 home agent locator address.

o It SHOULD protect HA-HELLO by IPsec ESP transport mode. Only if HAHA-link is secured enough (ex. dedicated leased line), IPsec can be eliminated.

5.2.4. Receiving Hello Message

When a home agent receives HA-HELLO, it follows the verification described in Section 7.3.3 of [ID-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 SHOULD be discarded.
- o If the source IPv6 address of HA-HELLO is not belong to one of the home agents in the redundant home agent set, the HA-HELLO MUST be ignored.
- o If the Group ID field of the received HA-HELLO and the receiver's Group ID is different, HA-HELLO MUST be discarded. HA-HELLO MUST NOT be sent to home agents whose Group ID is different from the sender.
- o 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 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. The receiver of the home agent processes the binding update according to [RFC-3775] and stores a binding 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 following functional requirements:

- o Delivering IP packets destined to the mobile node over the bi-directional tunnel
- o Updating the binding according to the mobile node's binding refreshment
- o Notifying the mobile node binding to the other home agents in the same global home agent set.
- o 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

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

The binding registration and management are same as [RFC-3775]. 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.

o The primary home agent locator address

o The mobile node's home address

o The mobile router's mobile network prefix(es)

o The binding sequence number of a binding update

o The flags of a binding update

o The lifetime of the global binding

o The mobile node's care-of address (optional)

The modified State Synchronization message [ID-HARELIABILITY] is used to exchange the global binding among the home agents.

When a global binding is created, the home agent MAY use proxy Neighbor Discovery to intercept the packets addressed to the mobile node's home address. If there is only single home agent at a home link, it simply skip the proxy neighbor discovery and intercepts the packet according to IP routing.

When a global binding is created, the home agent MUST create a mobile node's route entry which next hop is set to the primary home agent (i.e. the primary home agent locator address). If a mobile node is a mobile router [RFC-3963], 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 [RFC-3963] (i.e. the operation of aggregated home network [RFC-4887]), only a single route for the mobile network prefix is sufficient.

5.4.2. Modified State Synchronization Message and Mobility Option

Figure 5 shows the modified version of the state synchronization message defined in [ID-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 5: State Synchronization Message

Global (G) flag

When State Synchronization message are exchanged between geographically distributed home agents, the global flag MUST be set.

Mobility Options

The same options introduced in [ID-HAREALIBILITY] can be used in SS-REQ.

The following options can be used in SS-REP:

* Binding Cache Information Option (mandatory)

* AAA Information Option (optional)

* Vendor Specific Mobility Option (optional)

The following options can be used in SS-ACK:

* SS Status Option (mandatory)

Figure 6 is a new mobility option of State Synchronization message. In the global HAHA, SS-ACK is mandatory for receivers of SS-REP to notify the global binding registration status

```
        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 = TBD  |   Length      |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |  Status       |                  Reserved                     |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                                                               |
       +                                                               +
       |                        Home Address                           |
       +                                                               +
       |                                                               |
       +                                                               +
       |                                                               |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: State Synchronization Status Option

Type

8-bit Type value. The value is TBD.

Length

8-bit length value.

Status

8 bit Status value of global binding registration.

* 0: Success

* 128: Reason unspecified

* 129: Malformed SS-REP

* 130: Not in same global home agent set

* 131: No Mobility Option

Reserved

24 bit Reserved fields

Home Address

Corresponding home address of the status code.

5.4.3. Global Binding Registration

A State Synchronization Reply message MUST be sent by a primary home agent to register a global binding at the following timing. If a primary home agent notifies its State Synchronization Request message for every binding registration from a mobile node, it causes certain overhead to exchange messages. Unless the binding information except for sequence number and lifetime is changed, the state synchronization message isn't necessarily sent per mobile nodes' binding refreshment.

o when a primary home agent registers a binding for a mobile node at the first time. The primary home agent MUST register a global binding to the global home agent set.

o 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.

o The A and G flags MUST be set in SS-REP.

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

o Other optional mobility options listed in Figure 5 MAY be stored in the mobility option field.

o IPsec ESP transport mode SHOULD be applied. Only if HAHA-link is secured enough (ex. dedicated leased line), IPsec can be eliminated.

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

o The source and destination address 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.

o If the SS-REP is not protected by IPsec, it SHOULD be discarded.

o 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 [131: No Mobility Option].

o 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 (i.e. the sender of SS-REP). If a mobile node is a mobile router [RFC-3963], 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 [RFC-3963] (i.e. the operation of aggregated home network [RFC-4887]), 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 7.4.1 of [ID-HARELIABILITY]. In addition, the following rules MUST be applied:

- IPsec ESP transport mode SHOULD be applied. Only if HAHA-link is secured enough (ex. dedicated leased line), IPsec can be eliminated.

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

- The source and destination address 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 exchange. 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 not 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 [RFC-5142] for the primary home agent switch operation. How to send the home agent switch message is described in [RFC-5142] and Section 9 of [ID-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.

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 locator address 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 simply sends a dynamic home agent address discovery message to the home agent's anycast address. In that case, the dynamic home agent address discovery message is routed to the closest home agent. The closest home agent SHOULD return its own address with the highest priority in the dynamic home agent address reply message so that the mobile node can use the closet home agent for its binding registration.

Alternatively, it discovers a home agent from DNS server.

6. IANA considerations

TBA

7. Security Considerations

TBA: Section 10 of [ID-HARELIABILITY] gives useful information.

8. Acknowledgements

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Appendix A. References

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