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Global HA to HA protocol
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Abstract

This HAHA protocol extends MIPv6 (Johnson, D., Perkins, C., and J. Arkko, “Mobility Support in IPv6,” June 2004.) [RFC3775] and NEMO (Devarapalli, V., Wakikawa, R., Petrescu, A., and P. Thubert, “Network Mobility (NEMO) Basic Support Protocol,” January 2005.) [RFC3963] to remove their link layer dependencies on the Home Link and distribute the HAs at IP layer. Global HAHA considers the distribution at the scale of the Internet, and introduces the MIP proxy for Local Mobility Management and Route Optimization in the Infrastructure.

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1. Introduction

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The reader of this document is expected to be familiar with both the Mobile IPv6 (Johnson, D., Perkins, C., and J. Arkko, “Mobility Support in IPv6,” June 2004.) [RFC3775] and NEMO Basic Support (Devarapalli, V., Wakikawa, R., Petrescu, A., and P. Thubert, “Network Mobility (NEMO) Basic Support Protocol,” January 2005.) [RFC3963] documents. As such, the reader is expected to understand the concept of a Home Link and the Neighbor Discovery related operations that take place over that link.

Home Agent global distribution is useful when a Mobile Router moves geographically large area such as airplane, vehicle, etc... The overhead of the basic NEMO protocol is redundant route caused by the bi-directional tunnel between a Home Agent and a Mobile Router. If a Mobile Router moves far away from a Home Agent, the overhead can not be ignored.

Thus, it is reasonable to consider that a Mobile Router dynamically switches to the topologically closest Home Agent (Home Link). This distribution is also effective for load-balancing. The Home Agent is expected to serve thousands of Mobile Routers on its Home Link and tunnels all packets for the Mobile Routers by itself.

But with NEMO basic support and MIPv6, Home is locally anchored to the Home Link at Layer 2, so Home can not be distributed geographically. In particular for NEMO, what's needed is a route to a mobile prefix via a tunnel end point that is the CareOf address of the Mobile Router. The Home Address is but a practical artifact that is mostly needed as a correlator for the registration.

This draft proposes a model that enables the HA to HA communication at Layer 3, allowing to get rid of the Home Link in configurations where it's not needed.

This draft also introduces the concept of proxy Home Agent, enabling a Mobile Router to binding locally as it is roaming far from any of its own Home Agents.

Finally, the draft presents how the Home Agents and the proxy Home Agents can use the concept of route projection to improve the data path between Mobile Routers.

2. Motivations

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2.1. Requirements

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This draft addresses two generic requirements expressed in the Nemo requirements (Ernst, T., “Network Mobility Support Goals and Requirements,” July 2007.) [RFC4886]:

> **Local Mobility and Global Mobility:** Multihoming is mentioned as desirable. The global mobility type is not expected to be limited for any consideration other than administrative and security policies.
>
> **Scalability:** NEMO support signaling and processing is expected to scale to a potentially large number of mobile networks. Thus draft extends the scalality of the NEMO basic protocol.

There is a requirement from airplane companies which want to be at Home in the various airports that their planes visit. In fact, this is expressed in an abstract fashion by the case (1,n,1) of the NEMO multihoming issues (Ng, C., Ernst, T., Paik, E., and M. Bagnulo, “Analysis of Multihoming in Network Mobility Support,” October 2007.) [RFC4980] draft: "Single MR, Multiple HAs, Single NEMO-Prefix". There is also a general direction that indicates that NEMO could be extended as a solution for VPN. To get there, we must ensure that NEMO is upscaled to the classical capabilities of VPN, including the global distribution of Points Of Presence. It is a classical feature for VPNs to allow the roaming users to connect to the closest point of presence into their company VPN. The same feature can not be provided with MIPv6 or NEMO, because the Home depends on a link that has a unique physical location.

2.2. Layer 3 operations

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Mobile IPv6 (Johnson, D., Perkins, C., and J. Arkko, “Mobility Support in IPv6,” June 2004.) [RFC3775] standarizes an interface between a Mobile Node and its Home Agent and its correspondents, as well as an interface between Home Agents. One angle of the MIPv6 operation is that the protocols hides the MN mobility by making as if the Mobile Node was always connected to a Home Link. The connectivity is maintained by Home Agents that are permanently and physically attached to that Home Link. So the model for MIPv6 is Home Link centric and it is no surprise that it extends IPv6 Neighbor Discovery (Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)," September 2007.) [RFC4861] for its operations, in particular for HAs to discover each others, and to discover when one of them has a binding for a Mobile Node, and which one. An immediate consequence of being Link centric is that Home can not be distributed at Layer 3, locally within a site or over the Internet.

the NEMO Basic Support (Devarapalli, V., Wakikawa, R., Petrescu, A., and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol," January 2005.) [RFC3963] inherits the concept of Home Link and MIPv6 operations on that link, making NEMO partially a link layer operation. On the other hand, the NEMO Basic Support also operates as a routing protocol at L3, for example when it injects routes in the explicit prefix mode. So NEMO operations are somewhat half L2 and half L3.

What we are getting at with the HAHA protocol is placing NEMO fully at L3. This mostly means the replacement of all ND based exchanges by some equivalent, but at Layer 3, over the Internet Protocol. This also means the abstraction of the concept of Home Address into a globally unique router ID, as opposed to an address from a Home Link.

So even if this paper trivially applies to Mobile IPv6, we place our descriptions in the context of NEMO, and use MRs where MIPv6 MNs could fit as well.

2.3. Route Optimization

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MIPv6 comes with a Route Optimization scheme that enables a direct MR-CN conversation, bypassing the Home Agent. With the basic support, NEMO does not have such a support yet. In any case, RO comes at an additional cost in terms of protocol, which varies with the degree of expected trust.

Without Route optimization, all the packets MR-CN flow via the Home Agent; this increases both the cost and the latency. The resulting path can be illustrated like this:

```
        CN1  <--------------------- -- -- ----------------+   +---> CN2
       (NYC)                                               |   |    (NICE)
                                                           |   |
                                                           |   |
                                                           |   |
                                                           |   |
                            MRHA tunnel                    |   |
              ===================== == == ================
        MR   <--------------------- -- -- -----------------  HA (BRITTANY)
       (NJ)   ===================== == == ================
                                                             |
                                                             |
                                                           -----
                                                           /////
                                                         Home Link
```

Figure 1: Current model with a Home Link

The routing overhead becomes costly when:

> The distance ||MR, CN|| is much smaller then the sum of the distances ||MR, HA|| + ||HA, CN||.
>
> AND
>
> ||MR, HA||+||HA, CN|| is costly. If the 3 points are very close, the overhead is relatively important, but small in absolute terms.

In the picture above, say that a European phone (MR) is roaming in New Jersey but Homed in Brittany. And say that the phone owner places a call in New York city to CN1. Without RO, the voice packets flow back and forth over the peering lines between Brittany and the US, and the routing overhead causes an additional latency that decreases the perceived quality of the phone call.
On the other hand, calling CN2 would result in a small, acceptable overhead, considering that the distance ||HA, CN2|| is very small with regards to ||MR, HA|| or ||MR, CN2||. Now, when the MR moves back to Brittany and places a new call to CN2, going via the HA might double the distance, but the whole thing being local, it is negligible.
The geographical distribution of Home generalizes this latter situation. If we can get rid of the concept of a Home Link that anchors the HA in a single location, then we can distribute HAs geographically, and, hopefully, one is close to our MR when it's roaming.
So if a MR can locate and bind with a closeby HA, then ||MR, HA|| is contained and the overhead is globally limited. In a same fashion, when a CN sends a packet to the MR, it finds a HA closeby and the overhead ||HA, CN|| is contained as well.

```
   CN1  <-----+                                         +-----> CN2
  (NYC)       |                                         |      (NICE)
              |                                         |
              |                                         |
              |                                         |
              |               long distance             |
              |               HAHA tunnel               |
                   =========== == == =================
             HA'  ------------ -- -- ------------------ HA (BRITTANY)
            (DC)   =========== == == =================
           || | ||       (under the Atlantic :)
           || | ||
           || | || short distance
           || | || MRHA Tunnel
           || | ||
              v
            MR (NJ)
```

Figure 2: Globally Distributed HA for World Wide service

In our previous example, we see that a HA' deployed in the East Coast saves the round trip over the Atlantic. There is a new overhead for the call to Europe, though, since an additional path is involved between MR and HA'. Then again, if both ||MR, HA'|| and ||CN2, HA|| are relatively small compared to ||HA, HA'|| then the overhead is acceptable; unless all 3 points are located closeby, in which case, again, the additional cost is acceptable.

```
                                                          CN2 (NICE)
                                                             ^
                                                             |
  HA'(DC)  ------------------------------------------------- HA
    |                                                    (BRITTANY)
    v
  MR (NJ)


  <------------------------------------------------------------->
             Diagonal (direct path) cost

  <--------------------------------------------------------------->
             Via HAs
```

Figure 3: Illustrating that the overhead can be relatively small

2.4. Single point of failure

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The Home Link is a single point of failure for MIPv6/NEMO operations. Should the Home Link fail, the whole set of MNs / MRs is disconnected from the rest of the world. One could decide to use a virtual link for Home, but then:
MIPv6 provides a support for multiple HAs, with the DHAAD mechanism. This mechanism helps scaling up the Home by adding HAs dynamically, and eventually load balancing the bindings between them. But this all relies on HAHA communication over the PHYSICAL Home Link; so making that link virtual implies a single Home Agent.
In turn this makes the HA a single point of failure, and disables the scalability that the DHAAD mechanism provides to MIPv6.

3. Rationale for the proposed solution

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For the time being, the precise flows are not elaborated. One idea is that a protocol such as IS-IS or OSPFv3 could help a lot, mostly in the registration phase. Another is that HAs should be proactively preassigned to receive a given set of registration, in order to allow a certain degree of aggregation within sites and in between site.
Finally, the concept of proxy is introduced to limit the number of primary sites (to 1?) and as a key element for an upcoming NEMO route optimization scheme, where routes can be echanged in a trusted fashion between proxies.

4. A proxy for Mobile IP

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The draft references extensively a MIP proxy HA function. The word proxy, here, is taken in a classical sense, like, for instance, a web proxy: a MIP proxy Home Agent acts as a HA for the MN and as a MN for the HA, the CN, and other proxies. In particular, the MIP proxy terminates the MR-HA tunnel and the associated encryption, extracts the packets, and reencapsulates them to the destination.
This differs from a proxy-MIP function, which performs the Mobile Node operation on behalf of a non MIP-enabled node, in order to manage its mobility transparently.

```
                      +-------+         +-------+
                      |       |         |       |
                      | HA 1  |         | HA 2  |
                      |       |         |       |
                      +-------+         +-------+
                    primary ^         primary ^
                    binding |         binding |
  +-------+           +-------+         +-------+
  |       | --------->|       |---------->|       |
  | MN/MR |  proxy    |proxy 1| secondary |proxy 2|
  |     1 |  binding  |       | binding   |       |
  +-------+           +-------+         +-------+
                       RO    |          proxy   ^
                    binding v         binding |
                      +-------+         +-------+
                      |       |         |       |
                      |  CN   |         | MN/MR |
                      |       |         |     2 |
                      +-------+         +-------+
```

Figure 4: MIP proxy Home Agent

Distributing widely the MIP proxies presents a number of advantages:

Route Optimization: a proxy-to-proxy path between to MNs/MRs could be much shorter then the path via the HAs.

Local Mobility Management: when the MN moves around a given proxy, but keeps binding to that same proxy, the proxy does not need to inform the primary HA.

Nested NEMO: when Mobile Routers attach to one another and form a nested NEMO, the corresponding MRHA tunnel are nested as well. If they all bind to a same proxy, the proxy will decapsulate all the levels of tunneling, and retunnel only once towards the Internet

5. Overview

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This description covers the specific case of a Partitioned Home Network. Home is subnetted and the subnets are attributed to the distributed sites. As a result, in a given location, HAs will be operating both as primary HA taking the registrations for the local partition and proxy HA for registrations that belong to other sites. Additional satellite sites might be deployed around some of the main sites.

```
                 ##                                         ##
       ##        ##                                         ##
       ##\       ||                                         ||proxy/parent
         \\      ||                                         || tunnel
          \\  ---||----            ...... ...           ----||---
           \\|         |       ....   ....  ...        |         |
            \   @---@  |    ....              .....    |  @---@  |
      ## -----  | X |  ---------------------------------   \ /   ------##
      ## -----  @---@    ....  HAHA tunnel        ....      @    ------##
             |         ---------------------------------         |
              ------\ \ ...                        .... / /-||---
                     \ \...                         .../ /  ||
                      \.\.                            /./   ||
                      .\.\       internet            /./.   ||
                       .\.\     ...........         / /...  ##
                      ...\ \                       / / ..   ##
                       .. \ \                     / /  ...
                        ...\ \                   / / ...
                          ..\ \   ......        / /...
                             \.\ .    ...... .././
       @  primary HA          \ \          .. / /
                               \ \ --------- / /
       ## proxy HA or           \ \  @   @  / /
       ## satellite site         \    \ /    /
                                  \    @    /-----##
       --                         |   / \   ------##
      |  | primary site           |  @   @  |
       --                          ---------
```

Figure 5: Overview

It is out of the scope of this document to discuss how the subnetting was decided and configured. It is also out of the scope of this document to describe the operations within a site where more than one HA is deployed. It is expected that in each primary site, HAs discover each other, mesh using tunnels, and form an area that owns the partition of Home that was assigned to that site.

5.1. Initial routing

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5.1.1. External routing

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Sites are expected to be connected locally to the internet, via the network of one or more service provider. Each site has a default route to the internet via that connection.

```
                         . ..   /
 ---------          ........ ..;.           ---------
|         |       ..          / .....      |         |
|     ::/0 ->  ....          ;      ...  <- ::/0     |
|         ============HAHA=TUNNEL===========         |
|         | ....           ;          .... |         |
|         | .<- Home::/16 /  Home::/16 ->..|         |
 --------- ...           ;             ...  ---------
             .....      /               ..
                    .  ;....      ......
                      /  ..........
```

In return, each site advertises a Home aggregation to the internet. The Home aggregation has a very short prefix which should be partitioned amongst a number of Service Providers and subnetted to serve as Distributed Home Networks for their customers. One could visualize this aggregation as a subway for Mobile Nodes.

```
                         ......
 ---------           ....... .../           ---------
|         |      .....         ;  ....     |         |
|         ----------------------------------         |
|     <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<     |
|    v    ------------HAHA-tunnel-----------   ^     |
|    v    |                /              .|   ^     |
|    \  ==MRHA==          /            ... |   ^     |
|  HA >---------- MR     ;              .. |   ^     |
|    /  =tunnel=        /                 .|   ^     |
|    v    |            ;                   |   ^     |
|     >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> CN >>>>>> HA   |
|         | .        ;                ...  |         |
 ---------   .      /                ...    ---------
              ...  ;....      ......
                  /    ..........
```

Thus, a site attracts the DHAAD requests from any MR that happens to be roaming close to the site, regardless of the MR primary site. So MRs bind to the closest site from their physical location. In a same fashion, CNs send all packets to LFNs via the closest Home site. But packets back flow directly from the site where the MR is bound.

5.1.2. Internal routing

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In each site, border HAs are elected to mesh with peers in other sites. Sites are interconnected over a mesh tunnels and private links. Routing between sites obeys the traditional rules of the Internet, using for instance an Exterior Gateway Protocol (like BGP) between different service providers, and an IGP within a Distributed Home Network. Between sites of a given Distributed Home Network, it might be preferable to form a fully meshed backbone, in order to limit the cost of routing and optimize the paths.

```
                                      ......
              ---------           ....... .../           ---------
             | site1   |      .....         ;  ....     |    Site2|
             |         ---------------------------------          |
             |  Home:Site2::/48 ->            <- Home:Site1::/48  |
             |         ------------HAHA-tunnel----------          |
             |  @ @ @  |                /              .|   @   @ |
             |   @ @   | <- Home::/16  ;   Home::/16 -> |  @ @ @  |
              ---------   .           /            ...   ---------
                           ...   ....;     ......
                                    /.........
```

It can be expected that, in order to scale, satellite sites would be deployed to take the proxy bindings but would not participate to the HAHA protocol that happens between the primary sites - at least when a proactive version of HAHA is being used.

```
                                      ......
              ---------           ....... .../.          ---------
             | Sat1    |      .....         ;   ....    |   Site1 |
             |         ---------------------------------          |
             |  Home::/16 ->               <- Home:Site1:Sat1:/64 |
             |         ----proxyHAHA-tunnel-------------          |
             |  ####   |                /              .|  @ @ @  |
             |  ####   | <-  Home::/16 ;   Home::/16 -> |   @ @   |
              ---------   .           /            ...   ---------
                           ...   ....;     ......
                                    /.........
```

In a satellite site, HAs are only proxy, never primary. Each proxy HA has at least one assigned parent HA, which belongs to a primary site. A tunnel is established between the proxy HA and the parent HA. The parent advertises the Home Aggregation to the proxy over that tunnel, as it does over the internet. In return, the proxy advertises its own prefixes, and redistributes the Home Aggregation over the internet. Finally, the parent redistributes the route to the proxy's network into its area, via itself, as an external route.

5.2. Binding

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At that point, the primary sites are ready to accept bindings, either directly from Mobile Routers or via proxy HAs. This is the runtime phase for HAHA.
A MR that is located close to its primary site will register there for its primary binding. In that case, the binding is direct. Otherwise, the MR will use a proxy in order to bind locally, and the proxy will perform the primary binding on behalf of the MR. If the proxy is parented at the primary site, the binding is local; otherwise, it is called a foreign binding.

5.2.1. Direct primary binding

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When the primary HA accepts a direct binding from a MR, then it must let the other primaries know that it owns the binding for that Home Address, in a fashion that is discussed in Section 10.2 (Locating the HA that owns the binding for a HoA).

```
                     ......
             ......../.    ...    --------------------------
         ...         ;       ..  |                    Site1 |
         ..         / Home::/16 ->.|   @--@--@               |
        ...        ;           .. |  /                      |
       ....       /    MR ==MRHA==== @ <- Home:site1:MNP::/64  |
        ....     ;     |        .. |  \                      |
       ...      /    ------   ...  |   @--@                  |
        ...    ;      MNP          |                        |
          ... / ..          ...    --------------------------
                ..........
```

Figure 6: Primary HA injects necessary MR routes in area

The primary HA installs all (implicit and explicit) routes to the MR MNPs over the MRHA tunnel. It must also inject any required route, such as explicit prefix routes, into the primary area, as external routes via itself. All these routes are summarized at the area border and the other areas are not affected by the routing change.

5.2.2. local proxy binding

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When a MR binds to a satellite site, a HA acts as a proxy and binds in turn with a primary site, on behalf of that MR, to create the primary binding. The proxy binding can only succeed if the primary binding does. If the primary accepts the binding, then it returns a positive Binding Ack, with the list of the prefixes that are routed via the Mobile Router.

```
                         .. ........
              ---------     ..   .       ...    -----------------
             | Sat1    |  ..               /.  |           Site1 |
             |         | <- Home::/16     ;  . |                 |
             |         | ..             /  .. |                 |
             |  ---> ========================== @ <- Home:site1  |
             | |       |.             /    .. |        :MNP::/64 |
             |  --  # ======= MR      ;   ...  |                 |
             |         | .    |      /         |                 |
              ---------   . -----   ;   ...     -----------------
                            MNP.../..
```

Then the proxy HA installs the routes that it got from the the positive Binding Acknowledgement over the proxy MRHA tunnel, and Acknowledges the proxy BU. Once a primary binding has succeeded, the proxy might establish secondary bindings with other sites.

5.2.3. Foreign proxy binding

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When a MR binds to a foreign site, whether the site is primary or satellite, a HA from the site acts as a proxy as if the site was a satellite from the primary.

```
 -----------------    .. ..       ...    -----------------
| Foreign site    | ..     ..   |     .  | MR primary Site |
|                 ------------------------                 |
|        +-------------------------------------- primary   |
|        | +----------proxyHAHA----------------            |
|        | |      ------------------------       ^         |
|        | |      |             .        |       ^         |
 -------|| ||-----  ..          |     ..  -----------------
        || ||    - . - . - . - . -     .
 -------|| ||-----              |      .
|        | |      |.      |MNP  .     ..
|      proxy --MRHA--- MR-|     |   ...
|         HA ---------    |     |     ...
|                 | ..          .      .
|Foreign satellite|<- Home::/16 |      .
 -----------------     ...  ..      ...
```

5.3. Route Optimizations

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When the MR binds in a foreign location, the transport between an arbitrary correspondent and the MR within the HAHA network might be far from optimized.
As a result of the primary binding, a proxyHAHA tunnel is established between the proxy and the primary HA. That tunnel is itself encapsulated in the HAHA tunnels when packets flow over the internet.

```
                         .. ..  |...
 -----------------    ..        .  ...    -----------------
| Foreign site    | ..          |     .  | MR primary Site |
|                 ------------------------                 |
|        +-------------------------------------- primary   |
|        |v<<<<<<<<<<<home:site:mnp::/64<<<<<<<< HA        |
|        |v+----------proxyHAHA-----------------           |
|        |v|      ------------------------        ^        |
|        |v|      |             .        |        ^        |
 -------||v||-----  ..          |     ..  ------| ^ |------
        ||v||    - . - . - . - . - . - . -      | ^ |
 -------||v||-----              |      .  ------| ^ |------
|        |v|      |.            .     .. |        ^        |
|            --MRHA---     |MNP |   ...  |      home:      |
|   proxyHA  >>>>>>>>>> MR-|    .     .. |      site::     |
|            ---------     |    |     ...|       /48       |
|                 |             .      ..|        ^        |
|Foreign satellite|<- Home::/16 |      . |Foreign ^ site   |
 -----------------              .      .. ------| ^ |------
             - . - . - . - .- . - . - . -       | ^ |
                 ...                  ..  ------| ^ |------
                    ..                ...|        ^        |
                  ...         CN >>>>Home::/16>>>>>        |
                   ...                 ..|                 |
                    ..                 ..|                 |
                     .....   Home::/16 ->|                 |
                        .....    ....... |Foreign satellite|
                            ..........    -----------------
```

Figure 7: The path from CN to MR is not optimized

Also, packets from an arbitrary correspondent reach the site that is closest to the correspondent, then forwarded to the primary site for the destination. Within the primary site, they are encapsulated towards the proxy and sent across the HAHA network again. Finally they reach the proxy that decapsulates the packets and encapsulates them back. In order to improve this, various possibilities are offered:

5.3.1. Leaking MNP routes in the HAHA network

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The proxy can establish a secondary binding with its parent. In return, the parent redistributes an external route to the MNP via itself, and leaks that route inside the whole HAHA network.

```
                                .. ..  |...
        -----------------    ..        .  ..
       | Foreign site    | ..          |     .
       |                 ----------------------------------+
       |     parentHA <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< |
       |                 ------------------------------+ ^ |
       |        |v|      |             .               | ^ |
        -------||v||-----  ..          |     ..        | ^ |
               ||v||    - . - . - . - . - . - . -      | ^ |
        -------||v||-----              |      .  ------| ^ |------
       |        |v|      |.            .     .. |      home:      |
       |           --MRHA---     |MNP |   ...  |      site:      |
       |   proxyHA  >>>>>>>>>> MR-|    .     .. |      mnp::      |
       |           ---------     |    |     ...|       /64       |
       |                 |             .      ..|        ^        |
       | egress satellite|<- Home::/16 |      . |Foreign ^ site   |
        -----------------              .      .. ------| ^ |------
                    - . - . - . - .- . - . - . -       | ^ |
                        ...                  ..  ------| ^ |------
                           ..                ...|        ^        |
                         ...         CN >>>>Home::/16>>>>>        |
                          ...                 ..|                 |
                           ..                 ..|                 |
                            .....   Home::/16 ->|                 |
                               .....    ....... |ingress satellite|
                                   ..........    -----------------
```

Figure 8: The path from CN to MR bypasses the primary HA

This bypasses the primary home agent for packet forwarding. Note that the packets still flow within the HAHA network between the ingress site close to the correspondent and the egress (satellite) site.
Note also that when the proxy HA binds to either its parent or the primary HA, it uses an address from within the HAHA network (its HAHA Address), as CareOf.

5.3.2. On-demand proxy routes

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The proxy can establish a secondary binding with the correspondent's proxy provided there's such a node. It might be envisioned to adapt NHRP (Fox, B. and B. Petri, “NHRP Support for Virtual Private Networks,” December 1999.) [RFC2735] for IPv6 in order to discover the remote tunnel end point.

```
 -----------------            ....
|                  |  ....             ..
| egress satellite|<- Home::/16 |    . ..
|                  |  ..                  .
|             --MRHA---      |MNP1         ..
|   proxyHA  >>>>>>>>>> MR1-|              ..
|             ---------      |              ...
|        ^        |                       ..
 ------| ^ |------                          ..
  .... | ^ |                                .
 ..    | ^ | proxy-to-proxy             ...
 ...   | ^ | on demand tunnel             ...
  ..   | ^ |                                ..
  - . -| ^ |. - . - . - .- . - . - . - . -
 ------| ^ |------                        ..
|        ^        |                     .....
|        ^   --MRHA---      |MNP2         .....
|   proxyHA  <<<<<<<<<< MR2-|              ....
|             ---------      |              ...
|                  |.                      ..
|ingress satellite|<- Home::/16       ...
|                  |  ...             ....
 -----------------         ...........
```

Figure 9: The path is now direct between the proxies

An example of application is when two proxies from a same Home establish a cross binding. In fact, the Mobile Routers are unaware of the Route Optimization that takes place. This feature might be desirable when the privacy of the location is an issue for the service provider.

As part of the secondary binding to the ingress proxy, the egress proxy passes all the MNPs for the MR. This can be done using HAHA signalling, as explicit prefix routes. It is expected that the proxies belong to a chain of trust that links the primary and the satellite sites together. This, the ingress proxy trusts the egress proxy both for the binding and for the explicit prefixes.

The routes are literally projected from a proxy to the other while unseen by node in between; this is why this model is called Route Projection, by opposition with the traditional model of route injection which impacts the nodes on the way and is problematic with mobility. Note that in that case, the binding uses the proxy's external address as careof. The packets are thus routed straight between the proxies, outside of the HAHA network.

6. Terminology and concepts

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Most of the mobility related terms used in this document are defined in the Mobility Related Terminology document (Manner, J. and M. Kojo, “Mobility Related Terminology,” June 2004.) [RFC3753] and in the Mobile IPv6 specification (Johnson, D., Perkins, C., and J. Arkko, “Mobility Support in IPv6,” June 2004.) [RFC3775].
Additionally, some terms were created or extended for NEMO. These specific terms are defined in the NEMO Terminology document (Ernst, T. and H-Y. Lach, “Network Mobility Support Terminology,” July 2007.) [RFC4885].
This draft introduces the following definitions:

Distributed Home Network: In distributed home network, a global Home is advertised by several sites that are geographically distributed and meshed using tunnels in a VPN fashion. Mobile Nodes locate the closest site using DHAAD and bind there. More in Section 7 (Distributed Home Network)...

Partitioned Home Network: A Partitioned Home is a specific deployment of a Distributed Home Network where each location owns a subnet of Home. The local Home Agents accept registration for the local partition. The local HAs also act as NEMO proxy HAs for the rest of Home.

Primary Home Agent: A Home Agent that can serve a Binding Update from a Mobile Router. The Mobile Router is always associated with a (set of) primary Home Agent (s) to register its binding.

Proxy Home Agent: This is a form of proxy, for the NEMO protocol. A proxy HA acts as a HA for MRs to register, but needs to register to a primary HA in order to accept the binding.

Primary site: A site is primary for a MR if at least one local HA on that site can accept a registration for that MR. When Home is not partitioned and sites overlap, primary HAs for a same subnet have to be aware of each other in order to find if a binding already exists in one of the sites and in which Home Agent.

satellite site: A site that is not primary for any binding. It is dependent on a parent primary site for HAHA operations. satellite sites are deployed around central primary sites, and one final goal for HAHA is to dynamically draw routes between satellite sites in order to shortcut the backbone of primary HAs.

Secondary site: A site is secondary for a MR if it is primary for other MRs but not that one. HAs in a secondary site can act as proxies for that MR, and the site is its own parent.

Primary Binding: A Binding is primary if it happens with a primary Home Agent, whether the client is a MR or a proxy HA.

Secondary Binding: A Binding is secondary if it happens between a proxy and a non primary Home Agent. It is used to improve the path between sites towards the HA where a MR is registered.

Proxy Binding: A Binding is proxy if it happens between a MR and a proxy HA, whether the proxy is a pure proxy HA or a secondary HA acting as proxy for that MR. The proxy HA relays the proxy binding to a primary HA in a primary binding. It may maintain a set of secondary bindings, depending on the deployment.

Direct Binding: A Binding that does not pass via a proxy, straight between the MR and its Home Agent.

7. Distributed Home Network

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This section describes a detailed example how multiple Home Agents are configured in different routing domains. You are encouraged to read the nemo basic Home Network Models (Thubert, P., Wakikawa, R., and V. Devarapalli, “Network Mobility Home Network Models,” July 2007.) [RFC4887] draft before going through this section.

```
            HA                                    HA
            |                  ______             |
 --+-----+--+- . -+- . -+--    TUNNEL    --+-----+--+- . -+- .. -+--
   |     |        |     |      ______      |     |        |      |
  MR1   MR2      MRi   MRN                MR1   MR2      MRi    MRN
------  ------  ------ ------            ------  ------  ---- - ----
 /64        A:B:1:i::/64                  /64         A:B:n:i::/64


                   Distributed Home Network /48
<------------------------------------------------------------------>

    extended HN             Aggregated HN              Virtual HN
<----------------------><---------------------->...<--------------->

 Home    Mob       Mob    Mob    Mob       Mob       Mob       Mob
<-----><----->...<-----><-----><----->...<----->...<----->...<----->
```

In distributed home network, a global Home is advertised by several sites that are geographically distributed and meshed using tunnels in a VPN fashion. Mobile Nodes locate the closest site using DHAAD against the global Home Network and bind there. Some form of inter-site synchronization (e.g. a routing protocol), which Mobile IPv6 and Nemo Basic Support do not provide, must take place in order to allow packets to be routed between the incoming site to the Mobile Node. The HAHA (Home Agent to Home Agent) protocol is being designed for that purpose.
In one model, called the Partitioned Home Network each site is responsible for a subnet of Home. When a Mobile Node roams far from its natural (primary) site, it registers to a Home Agent on a remote site, that takes the registration and notifies at least the natural site of the foreign registration.
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.

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8. Message Formats

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A traditional IGP coul be used over the HAHA tunnel. But in order to integrate HAHA smoothly with the rest of the MIP operation, this drafts suggest to use the messages and formats detailed in the HAHA specification (Wakikawa, R., “Inter Home Agents Protocol Specification,” March 2006.) [I-D.wakikawa-mip6-nemo-haha-spec].

9. Mobile Router Operation

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9.1. Locating Home

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10. Home Agent Operation

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10.1. Locating the other HAs that serve the same Home

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10.2. Locating the HA that owns the binding for a HoA

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At the time of processing a binding update, a Home Agent (be it primary or simply proxy for the binding Home Address) needs to discover if the binding already exists with a primary Home Agent. There are at least 3 approaches that might be deployed for that purpose:

> **Reactive:** This method is also referred to as 'on-demand'. In case of a binding cache miss, a primary Home Agent floods a Binding Information Request message to all the other primary Home Agents for the home address that is sought for. The reactive approach can be used between a satellite site and its parent site even when the primary HAs use an other method in the backbone.
>
> **Proactive:** The binding information is shared proactively between the primary Home Agents for the existing bindings. All primary HAs know at any point of time which Home Addresses are bound and with which primary Home Agent. This approach is preferred for

stable configurations, for instance if NEMO is used as a tool to simplify the configuration and reconfiguration of mostly stable networks.

Predictive: Ranges of Home Addresses and prefixes are preassigned to the Home Agents, following a rule that is shared or commonly computed by all HAs. A partitioned Home Network is an example of that, but this is mostly useful within a site between local Home Agents.

11. Acknowledgements

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The authors wish to thank:

12. IANA considerations

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This document does not require any IANA action.

13. Security Considerations

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This document explores how t use the haha protocol but does not standardize any new operation that would be harmful.

14. References

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14.1. informative reference

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