

Network Mobility
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NEMO Home Network models
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Abstract

This paper documents some usage patterns and the associated issues when deploying a Home Network for Nemo enabled Mobile Routers, conforming the NEMO Basic Support draft [7].

The aim here is specifically to provide some examples of organization of the Home Network, as they were discussed in the NEMO and NEMO Design mailing lists.

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1. Introduction

This document assumes that the reader is familiar with Mobile IPv6 as defined in [6], and with the concept of Mobile Router defined in the NEMO terminology document [9].

Four different organizations of the Home Network including a hierachical construction are documented:

Extended Home Network: In this disposition, the Home Network is but one subnet of a larger aggregation that encompasses the Mobile Networks, called extended Home Network. When at Home, a Mobile Router performs normal routing between the Home Link and the Mobile Networks.

Aggregated Home Network: In this disposition, the Home Network actually overlaps with the Mobile Networks. When at Home, a Mobile Router acts as a bridge between the Home Link and the Mobile Networks.

Virtual Home Network: In this disposition, there is no physical Home Link at all for the Mobile Routers to come back Home to.

Mobile Home Network: In this disposition, there is a bitwise hierarchy of Home Networks. A global Home Network is advertised to the infrastructure by a head Home Agent and further subnetted into Mobile Networks. Each subnet is owned by a Mobile Router that registers it in a NEMO fashion while acting as a Home Agent for that network.

In all cases, the Home Agents collectively advertise only the aggregation of the Mobile Networks. The dichotomy is kept within the Home Agents and the Mobile Routers, as opposed to advertised by means of routing protocols to other parties.

Also, it is valid for a Mobile Router to register using an address from one of its own NEMO-Prefixes in all three cases.

The examples provided here aim at illustrating the NEMO Basic Support draft [7] but are by no mean at limiting its scope of application.

[2](#). Terminology and concepts

The key words MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD, SHOULD NOT, RECOMMENDED, MAY, and OPTIONAL in this document are to be interpreted as described in [RFC2119](#) [5].

The following terms used in this document are defined in the IPv6 Addressing Architecture document [4]:

link-local unicast address

link-local scope multicast address

The following terms used in this document are defined in the mobile IPv6 specification [6]:

home agent (HA)

The following terms used in this document are defined in the mobile network terminology document [9]:

mobile router (MR)

mobile network

mobile host (MH)

This draft uses the following additional or modified terminology:

Home Link: The link attached to the interface at the Home Agent on which the Home Prefix is configured. The interface can be a virtual interface, in which case the Home Link is a virtual Home Link.

Home Network: The Network formed by the application of the Home Prefix on the Home Link. With NEMO, the concept of Home Network is extended as explained below.

Home Address: With Mobile IPv6, a Home Address is derived from the Home Network prefix. This is generalized in NEMO, with some limitations: A Home Address can be either derived from the Home Network or from one of the Mobile Router's NEMO-prefixes.

MRHA Tunnel: The bi-directional tunnel between a Mobile Router and its Home Agent

Mobile Aggregated Prefix: An aggregation of NEMO-Prefixes.

Aggregated Home Network: The Home Network associated with a Mobile Aggregated Prefix. This Aggregation is advertised as a subnet on the Home Link, and thus used as Home Network for NEMO purposes.

Extended Home Network: The network associated with the aggregation of one or more Home Network(s) and Mobile Network(s). As opposed to the Mobile IPv6 Home Network that is a subnet, the extended Home Network is an aggregation and is further subnetted.

Virtual Home Network: The Home Network associated with a Virtual Network. The Extended Home Network and the Aggregated Home Network can be configured as Virtual Home Network.

Mobile Home Network: A Mobile Network that is also a Home Network. The MR that own the NEMO-Prefix acts as a Home Agent for it.

[3.](#) General Expectations

With Mobile IPv6, the Home Network is generally a physical network interconnecting the Home Agents, and the Mobile Nodes that are at Home. NEMO extends the concept of Home so that it is not only a flat subnet composed of Home Addresses but an aggregation that is itself subnetted in mobile and Home Networks. This aggregation is still referred to as Home.

As an example, say that the aggregation has a global routing prefix of $m = 48$ bits ($A:B:C::/48$), with subnet ID size of $n = 16$ bits ($n + m = 64$).

Say that a Mobile Router, MR1, owns the NEMO-Prefix $A:B:C:1::/64$:

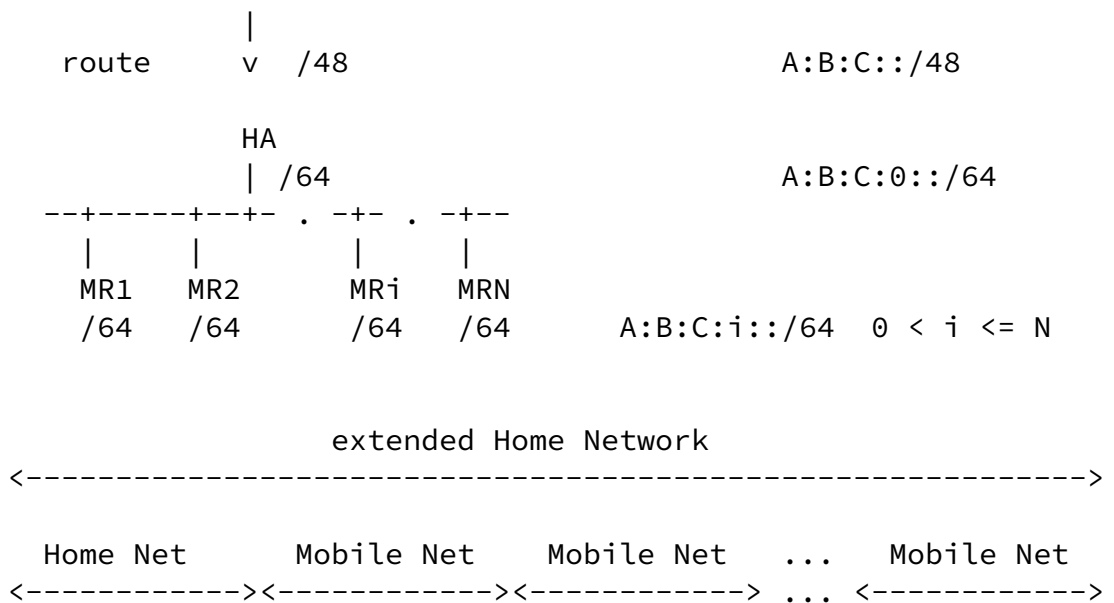
With basic NEMO, and depending on the deployment, MR1 may register using a Home Address from the Home network, A:B:C:0::1, say, or a Home Address, A:B:C:1::1, say, from one of its NEMO-Prefixes.

In a given deployment, one subnet may be reserved for the Home Link (say A:B:C:0::/64) while the others are attributed to Mobile Routers as Mobile Networks (as A:B:C:1::/64 for MR1). Another approach could be to configure the Aggregation of Mobile Networks as the subnet on the Home Link, and let the Mobile Routers manage the overlapping networks. Finally, the aggregation could be configured on a virtual network, with no physical Home Link at all, in which case Home means topologically and administratively close to the Home Agent that owns the virtual network.

The following sections provide additional information on these forms of Home Network:

[4.](#) Extended Home Network

One simple approach can be to reserve one or several subnets from an aggregation for the Home Link, and to use the other subnets as NEMO-Prefixes. In that case, the Home Network and the Mobile Networks do not overlap. The aggregation is called an extended Home Network.



In that configuration:

- o There is one physical Home Network and multiple Mobile Networks
- o The Home and the NEMO-prefixes are tailored to allow for IPv6 Stateless Address Autoconfiguration with typical interface identifier length for the type of interface (can be for example /64).
- o The prefix length of the extended Home Network is shorter than that of the Home Network and the NEMO-prefixes, since it is an aggregation (can be for example /48).
- o The Mobile Routers are assigned individually a Home Address from the Home Network and use it to register their NEMO-Prefix(es). In that case, the Home Agent performs DAD in the Home Network as prescribed by Mobile IPv6 for the Home Addresses.
- o Alternatively, a Mobile Router could also form a Home Address from one of its prefixes and use it to register, performing its own DAD on its ingress network.

[4.1](#) Returning Home

In the extended Home Network model, the Home Network is configured on a physical interface of the Home Agent, the Home Link.

A Mobile Router returns Home by connecting directly to the Home Link, and dropping the MRHA tunnel.

If the Home Address of the Mobile Router is derived from one of its Mobile Networks, then the MR may connect to the Home Link using an egress interface and autoconfigure an address on the Home Link. The MR recognizes the prefix of its Home Agent in order to decide that it is Home. Note that in that case the Home Address does not match the Home Prefix.

When at Home, the Mobile Router ensures the connectivity of the Mobile Network using standard router operations.

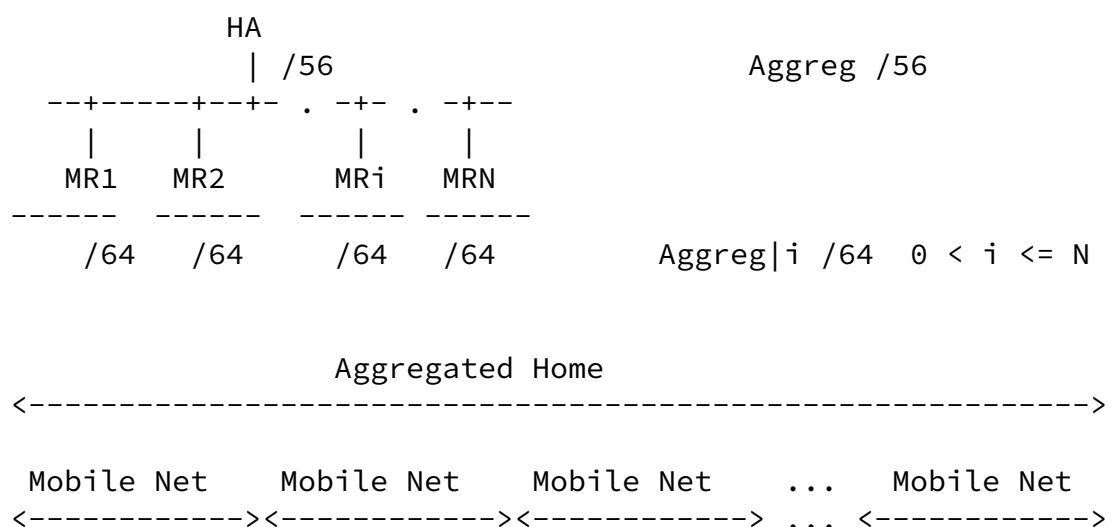
In particular, if the HA has the necessary information to continue routing to the NEMO-Prefixes in the absence of registration, for instance if the Home Address of the Mobile Router is derived from the Home Network, and if the HA uses a static route to the NEMO-Prefix(es) via that address, then the participation of the MR to the Home IGP is not required.

But in the general case, when the MR is at Home, it resumes IGP operations on the Home Link in order to advertise its Mobile Networks.

Alternate procedures for ensuring the connectivity of the Mobile Networks when at Home are described in [Section 6](#). In Particular, it is

5. Aggregated Home

One other approach is to consider that the Aggregation of all the NEMO-prefixes is used plainly as the Home Network, referred to as the Aggregated Home Network. This means that the Mobile Aggregated Prefix is configured on the Home Link and advertised by the Home Agent as a subnet.



Note: a Mobile Router coming Home sees overlapping prefixes between the ingress and the egress interface and some specific support may be needed.

A node on the Home Link will compute that the Aggregated Home Network is actually a subnet on the Home Link and may use it for autoconfiguration purposes. Such a node may also install a connected route to the Aggregated Home Network over the Home Link.

As a result, unless the node has a better (longest match) route to a given NEMO-Prefix, it will lookup all MNNs using Neighbor Discovery over the Home Link.

Thus, the Home Agent MUST intercept all the packets to the MNNs on the registered prefixes. In order to do so, the Home Agent MAY perform ND proxying for all addresses in all registered Mobile Network Prefixes, and protect the NEMO-Prefix space from autoconfiguration by uncontrolled visitors on the Home Link.

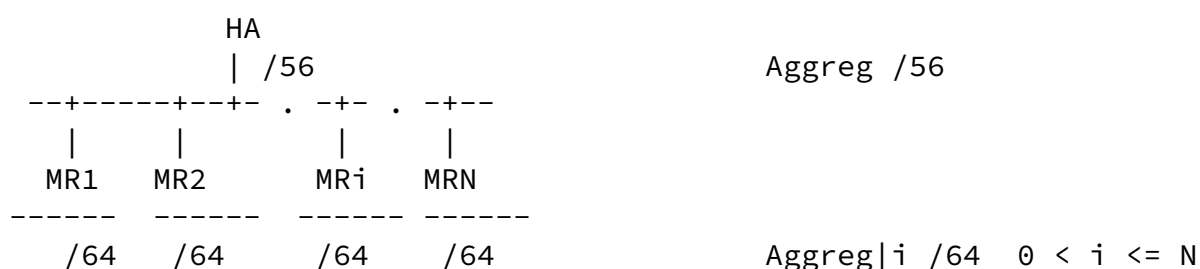
Alternatives based on a routing protocol or ICMP redirect may apply in some cases.

5.1 Returning Home

The Aggregated Home Prefix is configured on a physical interface of the Home Agent, the Home Link. As a consequence, the Home Agent has a connected route to the Aggregated Home Network over the Home Link.

A Mobile Router returns Home by connecting directly to the Home Link, and dropping the MRHA tunnel. The Mobile Router recognizes its Home Link by a prefix match with its Home Agent. Note that it must expect a shorter prefix than that of its Mobile Networks, even if its Home Address is formed out of one of its NEMO-Prefixes, but that the Home Address matches the Home Network Prefix.

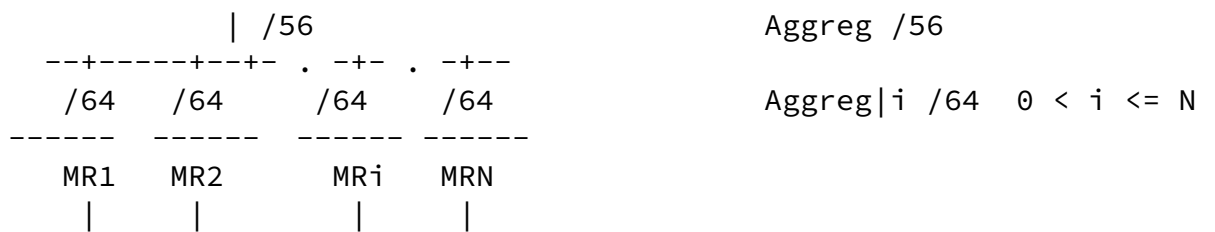
When a Mobile Router connects to the Home Link using its egress interface, it MAY set up a bridge between its ingress interface(s) and the Home Link. Alternatively, the Mobile Router MAY perform ND proxying for all addresses in its NEMO-Prefixes, between the egress and the related ingress interface. Since the prefixes on the egress and ingress interfaces are overlapping, routing is disallowed.



Bridging between egress and ingress

Alternatively, if the MR has a single ingress Interface, the Mobile Router may use the Mobile Link to connect to the Home Link, merging the two links in a single consistent network.

HA

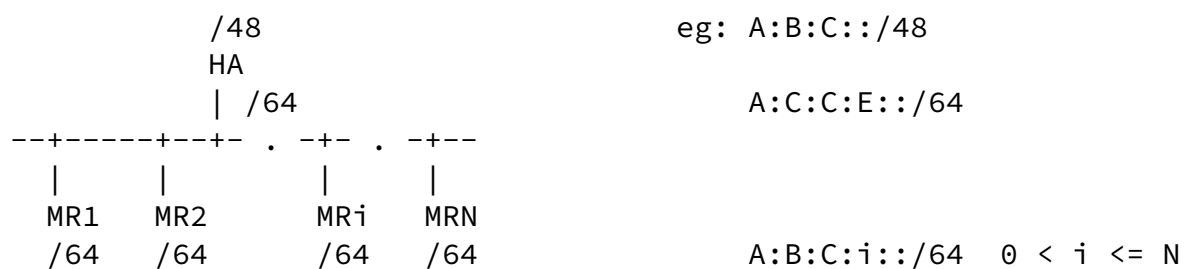


Merging the Home and the Mobile Networks

This fits the connected route model, since the Aggregated Home is truly located on that network.

6. Virtual Home Network

The Home Link can be configured on the Home Agent on a virtual link, in which case there's no physical Home Link for Mobile Routers to return Home or for Home Agents to discover each others and perform the ND level interactions as described in Mobile IPv6. [6]



Virtual Home Network

The Extended Home network and the Aggregated Home network models can be adapted for virtual links. There is no change in the way Home Addresses are allocated. As in the case of a physical link, the Home Address of a Mobile router is constructed based on the Home Prefix or one of the prefixes of its Mobile Network(s).

There are certain advantages to making the Home Link a virtual link:

A virtual link may not experience any disruption related to physical maintenance or to hardware problems, so it is more available than a physical link. The high availability of the Home Link is critical for the mobility service.

The Home Agent does not have to defend the Mobile Router's Home Address through Proxy Neighbor Discovery. The Home Agent does not also have to perform Duplicate Address Detection (DAD) for the Mobile Router's Home Address when it receives a Binding Update from the Mobile Router.

The Mobile Router does not have to implement the Returning Home procedure ([section 11.5.4](#) of Mobile IPv6. [6]).

In order for a Mobile Router to emulate returning Home, it can connect to one or more access link(s) configured for that purpose on the Home Agent. The Mobile Router, after connecting to the access link, SHOULD not send any routing protocol updates on the egress interface because the routing information from the Mobile Router

might adversely affect IPv6 route aggregation on the Home Network. However, the Mobile Router must register its binding as if it was accessing a foreign link.

There are also some drawbacks to the virtual Home Link approach:

There can be only one Home Agent since Mobile IPv6 relies on Neighbor Discovery on the Home Link for other HA discovery and for Duplicate Address Detection.

The Home Agent must maintain a Binding Cache entry for a Mobile Router and forwarding state for its Mobile Network even when the Mobile Router is directly connected to it. All traffic to and from the Mobile Network is sent through the bi-directional tunnel regardless of the Mobile Router location. This results in a tunneling overhead even though the Mobile Router is connected to the Home Network.

Some solutions can be proposed in order to perform an equivalent of returning Home on a virtual Home Network. One such approach is sketched in appendix as an illustration.

[7.](#) Mobile Home

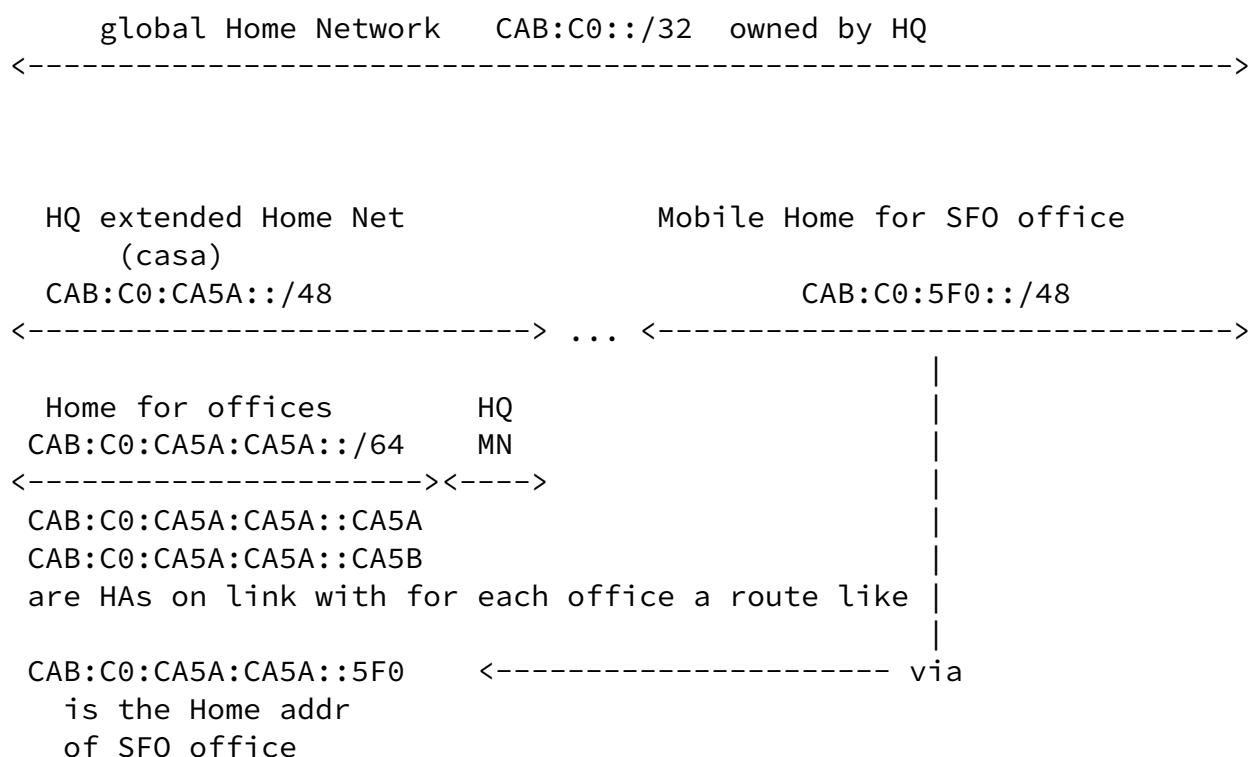
In this disposition, there is a bitwise hierarchy of Home Networks. A global Home Network is advertised to the infrastructure by a head Home Agent(s) and further subnetted into Mobile Networks. As a result, only the Home Agent(s) responsible for the most global (shortest prefix) aggregation receive all the packets for all the NEMO-prefixes, which are leaves in the hierarchy tree.

Each subnet is owned by a Mobile Router that registers it in a NEMO fashion while acting as a Home Agent for that network. This Mobile Router is at Home at the upper level of hierarchy. This configuration is referred to as Mobile Home.

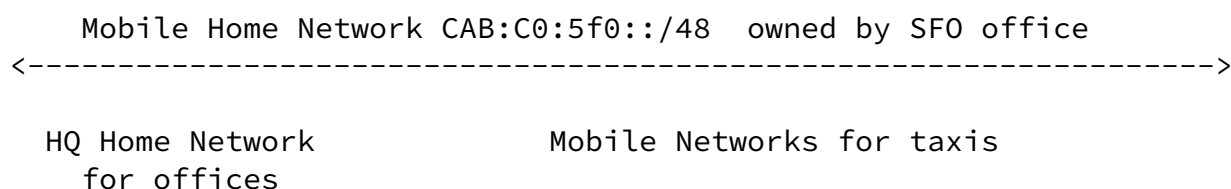
An example of that is the Cab Co configuration. Say a Taxi Company

owns a /32 prefix. This prefix is advertised at a fixed point, the Headquarters say. Regional offices are deployed around the world. Even though these regional offices are relatively stable in terms of location and prefix requirement -say this changes every few years- making them mobile allows a simpler management when a move has to take place, or should the ISP service change. Finally, each regional office owns a number of taxis, each one equipped with a mobile router and an associated /64 prefix.

To illustrate this, here is a possible addressing scheme:



and recursively for each Office, say San Francisco (SF0) as example:



```

CAB:C0:5F0:5F0::/64  CAB:C0:5F0:CAB1::/64      CAB:C0:5F0:.....:/6
<-----><-----> ... <----->
CAB:C0:5F0:5F0::5F0      |
is HA on link with for    |
each taxi a route like    |
                           |
CAB:C0:5F0:5F0::CAB1 <----- via
    is the Home addrSsync
    of CAB 1

```

Note that the hierarchy occurs at a configuration level and may not be reflected in the actual connection between nodes. For instance in the Cab Co case, cabs are roaming within the city, each one attaching to a different hot spot, while the regional office is connected to the infrastructure using some ISP connection.

But it is also possible to reflect the organizational hierarchy in a moving cloud of Mobile Router. If a Mobile Home Agent acts as root-MR for a nested configuration of its own MRs, then the communication between MRs is confined within the nested structure.

This can be illustrated in the case of a fleet at sea. Say that now SF0 is a communication ship of a fleet, using a satellite link to join the infrastructure, and that the cabs are Mobile Routers installed on smaller ships, equipped with low range radios.

If SF0 is also the root-MR of a nested structure of cabs, the communication between cabs is relayed by SF0 and does not require the satellite link. SF0 recursively terminates the nested tunnels to the cabs and reencapsulates all the packets between the nested cloud and correspondents in the infrastructure in a single tunnel to CA5A, this providing for nested NEMO Route Optimization.

Added Mobile Home Section

9. Acknowledgements

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[Appendix A](#). Returning Home emulation in the virtual case

When a Home Link is virtual, all traffic to and from the Mobile Network is sent through the bi-directional tunnel even at the Home Link. This section describes one possible mechanism that extends basic NEMO to eliminate this tunneling overhead.

Although the Home Link is virtual, the Home Agent has at least one physical link to communicate with the external world. One or several of such links, called the virtual Home Access Links, are conceptually associated with the virtual Home Link and considered as part of Home.

When accessing one of its virtual Home Access Links, a Mobile Router autoconfigures a Care-of Address from a Router Advertisement as it would do on any visited link, in order to perform the next binding flow.

If the Mobile Router is configured to recognize the virtual Home Access Links as part of Home, it deregisters by sending a Binding update with null lifetime sourced at the CareOf. Alternatively, the Home Agent may indicate that the MR has moved to the virtual Home Access Links as a status code in the binding acknowledgement. The status code implies that Home Agent successfully de-register the binding at the virtual Home Access Link. Detection of the virtual Home Access Links is achieved by a prefix comparison(s) between the care-of address and the prefix(es) on the virtual Home Access Link(s).

With both approaches, the result of the binding flow is a deregistration. Consequently, both the Mobile Router and the Home Agent disable the bi-directional tunnel. At that point, the Home Agent configures its forwarding in order to reach the Mobile Router

and its mobile networks at Home. For instance, this may take the form of a route to the Mobile Network prefixes via the MR Home Address, and a connected host route to the MR Home Address via the virtual Home Access link.

After successful binding de-registration, the Mobile Router MUST receive packets meant to the Mobile Router's Home Address at the Virtual Home Link. How to intercept packets addressed to the Home Address depends on implementations of the Mobile Router. If the Home Address is not configured at the egress interface, the Mobile Router MUST use proxy Neighbor Discovery to intercept all packets addressed to the Home Address on the virtual Home Link. Otherwise, the Mobile Router does not have to perform any special operation at the virtual Home Link.

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