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Vijay Devarapalli
Nokia
Ryuji Wakikawa
Keio University
Alexandru Petrescu
Motorola
Pascal Thubert
Cisco Systems
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Nemo Basic Support Protocol
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Status of This Memo

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Abstract

This document describes the Nemo Basic Support protocol to support network mobility as the mobile network attaches to different points in the Internet. The protocol is based on extensions to Mobile IPv6 and allows for session continuity for every node in the mobile network as the network moves. It also allows every node in the mobile network to be reachable while moving around. The Mobile Router, which connects the network to the Internet, runs the NEMO Basic Support protocol with its Home Agent. The protocol is designed in such a way that network mobility is transparent to the nodes inside the mobile network.

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[1](#). Introduction

This document describes protocol extensions to Mobile IPv6 (MIPv6) [[1](#)] to enable support for network mobility. The extensions provide backward compatibility with Mobile IPv6, and in particular, a Nemo compliant Home Agent can operate as a MIPv6 Home Agent as well.

The Nemo Basic Support works in such a way that session continuity is ensured for all the nodes in the mobile network even as the Mobile Router changes its point of attachment to the Internet. It also provides connectivity and reachability for all nodes in the mobile network as the network moves. The solution supports both Local Fixed Nodes [[8](#)] and Mobile Nodes in the Mobile Network.

Within the context of this document, the definition of a Mobile Router extends that of a Mobile IPv6 [[1](#)] Mobile Node, by adding the capability of routing between its point of attachment (Care-of Address) and a subnet which moves with the Mobile Router.

The solution described in this document requires setting up a bi-directional tunnel between the Mobile Router and its Home Agent. This tunnel is set up when the Mobile Router sends a successful Binding Update to its Home Agent, informing the Home Agent of its

current point of attachment.

All traffic between the nodes in the Mobile Network and Correspondent Nodes passes through the Home Agent. This document does not describe how to route optimize this traffic.

The terminology document [8] describes Nested Mobility as a scenario where a Mobile Router allows another Mobile Router to attach to its mobile network. There could be arbitrary levels of nested mobility. The operation of each Mobile Router remains the same whether the Mobile Router attaches to another Mobile Router or to a fixed Access Router on the Internet. The solution described here does not place any restriction on the number of levels for nested mobility. But it should be noted that this might introduce significant overhead on the data packets as each level of nestedness introduces another IPv6 header encapsulation.

[2](#). Terminology

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [2].

There is a separate NEMO terminology document [8], which defines the terms related to Network Mobility used in the document.

Prefix Table

It is a list of a Mobile Network Prefixes indexed by the Home Address of a Mobile Router. The prefix table is managed by the Home Agent and is used by the Home Agent to determine which Mobile Network Prefixes are owned

a particular Mobile Router. This is an optional data structure.

[3.](#) Overview of the Nemo Protocol

A Mobile Network is a network segment or subnet which can move and attach to arbitrary points in the Internet. A Mobile Network does not allow any transit traffic and can only be accessed via specific gateways called Mobile Routers that manage its movement. A Mobile Router does not distribute the Mobile Network routes to

the infrastructure at its point of attachment (i.e. in the visited network). Instead, it maintains a bidirectional tunnel to a Home Agent that advertises an aggregation of Mobile Networks to the infrastructure. The Mobile Router is also the default gateway for the Mobile Network.

A Mobile Network can also consist of multiple and nested subnets. A router with no support for mobility may be permanently attached to a Mobile Network for local distribution. Also, Mobile Routers may be attached to Mobile Networks owned by different Mobile Routers and form a graph. In particular, with Basic Nemo Support, each Mobile Router is attached to another Mobile Network by a single interface, and if loops are avoided, the graph is a tree.

A Mobile Router has an unique Home Address through which it is always reachable. The Home Address is configured from a prefix that is aggregated and advertised by its Home Agent. The prefix could either be the prefix advertised on the home link or the prefix delegated to the Mobile Router. The Mobile Router can have more than one Home Address if there are multiple prefixes in the home link. The Mobile Router also advertises one or more prefixes in the mobile network attached to it. The actual mechanism for allocating these Mobile Network Prefixes is outside the scope of this specification.

When the Mobile Router moves away from the home link and attaches to a new access router, it acquires a Care-of Address from the visited link. The Mobile Router at any time can appear and behave as a Mobile Host or a Mobile Router. If the Mobile Router wants connectivity, reachability and session continuity for nodes in the Mobile Network, it acts as a Mobile Router. In either case, as soon as the Mobile Router acquires a Care-of Address, it immediately sends a Binding Update to its Home Agent as described in [\[1\]](#). When the Home Agent receives this Binding Update it creates a binding cache entry binding the Mobile Router's Home Address to its Care-of address at the current point of attachment.

If the Mobile Router wishes to act as a Mobile Router and provide connectivity to nodes in the Mobile Network, it indicates this to the Home Agent by setting a flag 'R' in the Binding Update. It MAY also include information about the Mobile Network Prefix in the Binding Update using one of the modes described in [section 5.2](#), so that the Home Agent can forward packets meant for nodes in the mobile

network to the Mobile Router. Two new Mobility Header Options are described in this document to carry prefix information. These new options are described in [section 4.3](#) and [section 4.4](#). If the Mobile Network has more than one IPv6 prefix and wants the Home Agent to setup forwarding for all these prefixes, it includes multiple prefix information options in a single Binding Update. The Home Agent sets up forwarding for each of these prefixes to the Mobile Router's Care-of Address. In some scenarios the Home Agent already knows which prefixes are owned by a Mobile Router. In these scenarios, the Mobile Router does not include any prefix information in the Binding Update. The Home Agent sets up forwarding for all prefixes owned by the Mobile Router, when it receives a Binding Update from the mobile router with the router flag 'R' set.

The Home Agent acknowledges the Binding Update by sending a Binding Acknowledgement to the Mobile Router. A positive acknowledgement means that the HA has set up forwarding for the Mobile Network. Once the binding process completes, a bi-directional tunnel is established between the Home Agent and the Mobile Router. The tunnel end points are Mobile Router's Care-of Address and the Home Agent's address. If a packet with a source address belonging to the Mobile Network Prefix is received from the Mobile Network, the Mobile Router reverse-tunnels the packet to the Home Agent through this tunnel. This reverse-tunneling is done by using IP-in-IP encapsulation [3]. The Home Agent decapsulates this packet and forwards it to the Correspondent Node. The Mobile Router is however free to use route optimization as described in [1] for packet originated by the Mobile Router itself.

When a data packet is sent by a Correspondent Node to a node in the Mobile Network, it gets routed to the Home Agent which currently has the binding for the Mobile Router. It is expected that the Mobile Router's network prefix would be aggregated at the Home Agent, which advertises the resulting aggregation. Alternatively, the Home Agent may receive the data packets meant for the Mobile Network by advertising routes to the Mobile Network prefix. The actual mechanism by which these routes are advertised is outside the scope of this document. When the Home Agent receives a data packet meant for a node in the mobile network, it tunnels the packet to Mobile Router's current Care-of address. The Mobile Router decapsulates the packet and forwards it onto the interface where the Mobile Network is connected. The Mobile Router before decapsulating the tunneled packet, has to check if the Source address on the outer IPv6 header is the Home Agent's address. It also has to make sure the destination address on the inner IPv6 header belongs to one of its Mobile Network Prefixes before forwarding the packet to the Mobile Network.

The Mobile Network could consist of nodes which are Local Fixed Nodes, Local Mobile Nodes and Visiting Mobile Nodes [8]. The protocol described here ensures complete transparency of network mobility to the Local Fixed Nodes. Visiting Mobile Nodes are those nodes which are Mobile Nodes as described in Mobile IPv6. Visiting Mobile Nodes treat the Mobile Network as just a normal IPv6 access network and run the Mobile IPv6 protocol.

It is also possible for the Mobile Router and the Home Agent to run a routing protocol through the bi-directional tunnel. In that case, the Mobile Router need not include prefix information in the Binding Update. Instead the Home Agent uses the routing protocol updates to setup forwarding for the Mobile Network. When running the routing protocol it is required that the bi-directional tunnel be treated as a tunnel interface. The tunnel interface is included as the list of interfaces on which routing protocol is active. The Mobile Router should be configured not to run the routing protocol on its egress interface when it is away from the home link.

Finally, the Home Agent may be configured with static routes to the Mobile Network Prefix via the Mobile Router's Home Address. In that case, the routes are set independently of the binding flows and the returning Home of a Mobile Router. The benefit is that such movement does not induce any additional signalling in the form of routing updates in the Home Network. The drawback of that model is that the routes are present even if the related Mobile Routers that are not reachable (at Home or bound) at a given point of time.

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Mobility Options

Variable length field which can include zero or more mobility options. This document defines two new mobility options in addition to what is defined in [1]. The receiver MUST skip and ignore any options which it does not understand.

[4.2.](#) Binding Acknowledgement

There is no change in the Binding Acknowledgement format from what is used in Mobile IPv6 [1]. However, this document introduces the following new status values for the binding acknowledgement.

Status

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- | | |
|-----|---------------------------------------|
| 2 | Mobile Router Binding Update accepted |
| 140 | Mobile Router Operation not permitted |
| 141 | Invalid Prefix |
| 142 | Not Authorized for Prefix |
| 143 | Forwarding Setup failed |

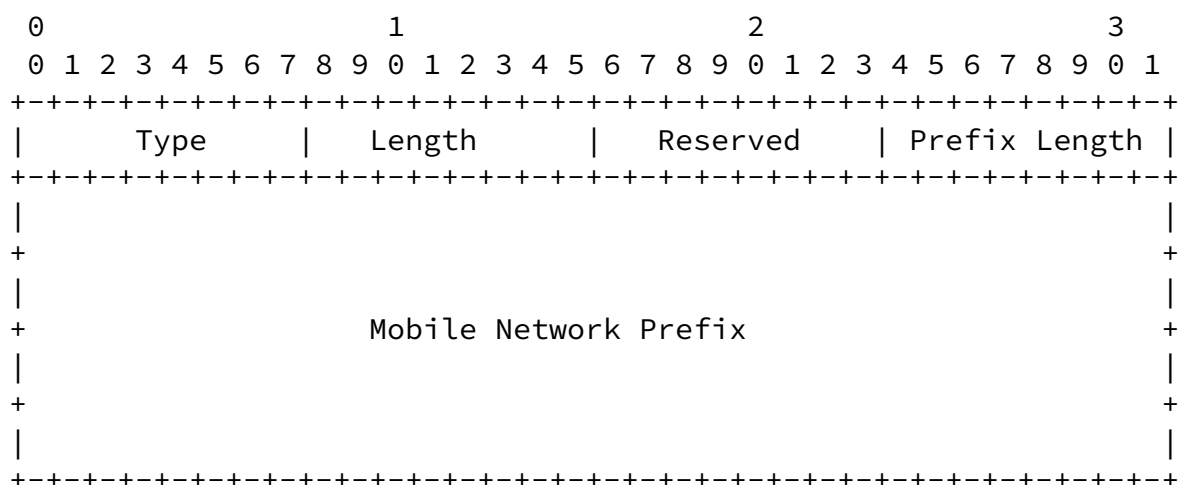
Status values less than 128 indicate that the Binding Update was processed successfully by the receiving nodes. Values greater than 128 indicate that the Binding Update was rejected by the receiving node.

[4.3.](#) Mobile Network Prefix Option

The Mobile Network Prefix Option is included in the Binding Update to indicate to the Home Agent the prefix information for the mobile network. There could be multiple Mobile Network Prefix Options if the Mobile Router has more than one IPv6 prefix in the Mobile Network and wants the Home Agent to forward packets for each of these prefixes to the Mobile Router's current location.

The Mobile Network Prefix Option has an alignment requirement of

$8n+4$. Its format is as follows.



Type

TBA

Length

8 bit unsigned integer indicating the length in octets of the option excluding the type and length fields. Set to 18.

Reserved

This field is unused for now. The value **MUST** be initialized to zero by the sender, and **MUST** be ignored by the receiver.

Prefix Length

8 bit unsigned integer indicating the prefix length of the IPv6 prefix contained in the option.

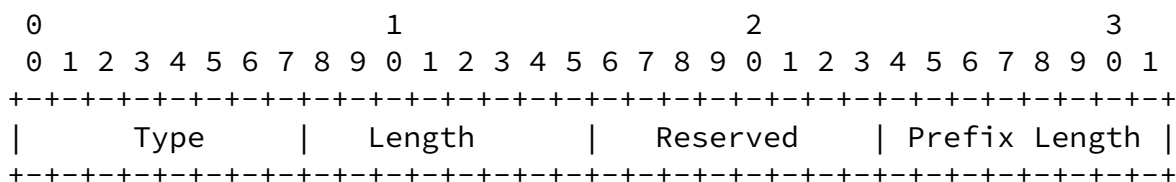
Mobile Network Prefix

A 16 byte field contains the Mobile Network Prefix.

4.4. Mobile Network Prefix Length Option

The Mobile Network Prefix Length Option can be used by the Mobile Router if the Mobile Network Prefix can be deduced from the Home Address of the Mobile Router. If there is only one Mobile Network Prefix owned by the Mobile Router, using this option helps in saving 16 bytes in the Binding Update by not including the prefix information.

There can only be one instance of this option in a Binding Update. The Mobile Network Prefix Option cannot be present in the Binding Update if this option is present.



Type

TBA

Length

8 bit unsigned integer indicating the length in octets of the option excluding the type and length field. Set to 2.

Reserved

This field is unused for now. The value MUST be initialized to zero by the sender, and MUST be ignored by the receiver.

Prefix Length

8 bit unsigned integer indicating the prefix length of the IPv6 prefix from which the Home Address included in the Binding Update was configured.

Mobile Router operation is derived largely from the combined behaviors of a Host, of a Router [6], and of a Mobile Node [1] (also please see definition of a Mobile Host in [8]).

A Mobile Node can act in two different ways: (1) as a Mobile Host (in which case the Mobile IPv6 Home Agent doesn't maintain any prefix information related to the Mobile Host's Home Address, but does maintain a binding cache entry related to the Mobile Host's Home Address) and (2) as a Mobile Router (in which case, in addition to maintaining the binding cache entry corresponding to the Mobile Router Home Address, the Mobile IPv6 Home Agent also maintains forwarding information related to prefixes assigned to the mobile network). The distinction between the two modes is represented by the value of the Mobile Router flag 'R'.

[5.1.](#) Data Structures

Like a Mobile Host, a Mobile Router also maintains a Binding Update List, described in [section 11.1](#) of Mobile IPv6 specification[1]. The Binding Update list is a conceptual data structure which records information that is sent in the Binding Updates. There is one entry per each destination that the Mobile Router is currently sending Binding Updates to.

This document introduces a new Prefix Information field in the Binding Update list structure. This field is used to store any prefix information that the Mobile Router includes in the Binding Update. If the Mobile Router sets the Mobile Router flag 'R' in the Binding Update, but does not include any prefix information in it (implicit mode), this field is set to null.

Similar to a Mobile Host, a Mobile Router stores the information regarding status of flags of the Binding Update, in the corresponding Binding Update List entry. This document introduces a new mobile router flag 'R' for this entry. The status of this flag is stored in the Binding Update list whenever a Binding Update is sent.

A Mobile Router also maintains a Home Agent list populated according to the same procedure as a Mobile Host.

[5.2.](#) Sending Binding Updates

A Mobile Router sends Binding Updates to its Home Agent according to the same procedures that a Mobile Host uses. The Mobile Router uses one of the following modes to instruct the Home Agent to determine

the prefixes owned by the Mobile Router. In all three modes, the Mobile Router sets the Mobile Router flag 'R'.

Implicit:

In this mode, the Mobile Router does not include either a Mobile Network Prefix Option or a Mobile Network Prefix Length Option in the Binding Update (but it does include the Home Address Option in the Destination Options header, as all Mobile Hosts do). The Home Agent can use any mechanism (not defined in this document) to determine the Mobile Network Prefix(es) owned by the Mobile Router and setup forwarding for the Mobile Network. One example would be manual configuration at the Home Agent mapping the Mobile Router's Home Address to the information required for setting up forwarding for the Mobile Network.

Explicit Network:

In this mode, the Mobile Router includes one or more Mobile Network Prefix Options in the Binding Update. These options contain information about the Mobile Network Prefix(es) configured on the mobile network.

Explicit Prefix Length:

In this mode, the Mobile Router instructs the Home Agent to derive the Mobile Network Prefix by using: (1) the Home Address in the Home Address Option carried in the Destination Options header of the same packet that carries the Mobility Header containing this Binding Update and (2) the prefix length carried in the Mobile Network Prefix Length Option. In this case, Mobile Router includes one and only one Mobile Network Prefix Length Option. It MUST NOT include a Mobile Network Prefix Option if this method is used.

If the Mobile Router flag is set, Home Registration flag 'H' MUST be set.

[5.3. Receiving Binding Acknowledgements](#)

The Mobile Router receives Binding Acknowledgements from the Home Agent, corresponding to the Binding Updates it sent. If the Binding Acknowledgement status is set to '2' (Mobile Router Binding Update accepted), the Mobile Router assumes that the Home Agent has

successfully processed the Binding Update and has set up forwarding for the Mobile Network. The Mobile Router can then start using the

bi-directional tunnel for reverse tunneling traffic from the mobile network.

[5.4.](#) Error Processing

If the Binding Acknowledgement status is set to a value between 128 and 140, the Mobile Router takes necessary actions as described in the Mobile IPv6 specification [[1](#)].

If the Binding Acknowledgement status is set to '0' (Binding Update accepted), the Mobile Router concludes that the Home Agent which processed the Binding Update is a MIPv6 Home Agent that has not implemented support for Mobile Routers. It should send a similar Binding Update to another Home Agent on the link. If no Home Agent replies positively then the Mobile Router **MUST** refrain from sending any Binding Update with the Mobile Router flag set to any home agent on the home link and log the information.

If the Mobile Router sent a Binding Update to the Home Agent in implicit mode (i.e. the prefix field in the Binding Update list entry is null) then the Mobile Router interprets only the error status '140' (Mobile Router Operation not permitted) and '143' (Forwarding Setup failed) For this Binding Update, the Mobile Router **MUST** discard Binding Acknowledgements with codes '141' and '142'.

For the same Binding Update, if the status is '140', then the Mobile Router should send a similar Binding Update (implicit mode) to another Home Agent on the same home link. If no Home Agent replies positively then the Mobile Router **MUST** refrain from sending any Binding Update with the Mobile Router flag set to any Home Agent on the home link, and log the information.

For the same Binding Update, if the status is '143', then the Mobile Router should send a similar Binding Update (implicit mode) to another Home Agent on the same home link. If no Home Agent replies positively then Mobile Router **SHOULD** refrain from sending this Binding Update to any Home Agent on the home link, and **MAY** send

Binding Updates in another mode (e.g. explicitly include a prefix) to a Home Agent on the same home link.

If the Mobile Router sent a Binding Update to Home Agent in any other mode than implicit mode (i.e. the prefix field in the Binding Update list entry is not null) then the Mobile Router interprets only the error status '141' (Invalid Prefix) and '142' (Not Authorized for Prefix). For this Binding Update, the Mobile Router MUST discard Binding Acknowledgements with codes '140' and '143'.

For the same Binding Update, if the status is set to '141', then the Mobile Router should send a similar Binding Update (same explicit prefix(es) or prefix lengths) to another Home Agent on the same home link. If no Home Agent replies positively then Mobile Router SHOULD refrain from sending this Binding Updates to any Home Agent on the home link. At this point, Mobile Router MAY try to obtain and own a prefix by the same means that it initially got attributed the Invalid Prefix in question. Alternatively, Mobile Router MAY send Binding Updates in another mode (e.g. implicit mode) to a Home Agent on the same home link.

For the same Binding Update, if the status is set to '142', then the Mobile Router should send a similar Binding Update (same explicit prefix(es) or prefix lens) to another Home Agent on the same home link. If no Home Agent replies positively then Mobile Router SHOULD refrain from sending this Binding Updates to any Home Agent on the home link. Additionally, the Home Agent MUST stop advertising the respective prefix(es) in the mobile network with associated Router Advertisements, and modify its own forwarding information accordingly. Following this, the Mobile Router MAY send Binding Updates in another mode (e.g. implicit) to a Home Agent on the same home link.

If at the end of this Error Processing procedure the Mobile Router has tried every available modes of sending Binding Updates and still has not received a positive Binding Acknowledgement (status value between 0 and 127) for this Home Address from any Home Agent on its home link, then the Mobile Router MUST stop sending Binding Updates with the Mobile Router flag set for this Home Address and log the information.

In all the above cases, the Mobile Router MUST conclude that the Home Agent did not create a binding cache entry for the Mobile Router's Home Address.

[5.5.](#) Establishment of Bi-directional Tunnel

When a successful Binding Acknowledgement with status set to '2' (Mobile Router Binding Update accepted) is received, the Mobile Router set up its endpoint of the bi-directional tunnel.

The bi-directional tunnel between Mobile Router and Home Agent allows packets to flow in both directions between these entities, while the Mobile Router is connected to a Visited Link. The bi-directional tunnel involves two virtual links [\[3\]](#): one virtual link has the address of the tunnel entry point as the Care-of Address of the Mobile Router and the tunnel exit point as the address of the Home Agent; the other virtual link has as tunnel entry point the

Home Agent address and as tunnel exit point the Care-of Address of the Mobile Router. Both addresses are unicast addresses. All IPv6 traffic to and from the Mobile Network is sent through this bi-directional tunnel.

A Mobile Router MAY limit the number of mobile routers that attach to its mobile network (the number of levels in the nested aggregation) by means of setting the Tunnel Encapsulation Limit field of the Tunnel Encapsulation option.

A Mobile Router uses the Tunnel Hop Limit that is normally assigned to routers (not to hosts). See [\[3\]](#).

[5.6.](#) Neighbour Discovery for Mobile Router

A Mobile Router MAY be configured to send Router Advertisements and reply to Router Solicitations on the interface attached to the home link. The value of the Router Lifetime field MUST be set to zero to prevent other nodes from configuring the Mobile Router as the default router.

A Mobile Router SHOULD NOT send unsolicited Router Advertisements and SHOULD NOT reply to Router Solicitations on any egress interface when that interface is attached to a visited link. However, the Mobile Router SHOULD reply with Neighbor Advertisements to Neighbor Solicitations received on the egress interface, for topologically correct addresses.

A Mobile Router MUST NOT ignore Router Advertisements received on the egress interface. The received Router Advertisements MAY be used for address configuration, default router selection or movement detection.

[5.7](#). Multicast Groups for Mobile Router

When at home, the Mobile Router joins the multicast group All Routers Address with scopes '1' interface-local (on the home-advertising interface) and '2' link-local on any of its egress interfaces. When in a visited network, the Mobile Router MUST NOT join the above multicast groups on the corresponding interface.

[6](#). Home Agent Operation

In order for a Mobile Router to operate correctly, the Home Agent MUST satisfy all the requirements listed in section 8.4 of [[1](#)]. The Home Agent MUST implement all the modes described in [Section 5.2](#).

[6.1](#). Data Structures

[6.1.1](#). Binding Cache

The Home Agent maintains Binding Cache Entries for each Mobile Router that is currently registered with the Home Agent. The Binding Cache is a conceptual data structure described in detail in [[1](#)].

The Home Agent might need to store the Mobile Network Prefixes associated with a Mobile Router in the corresponding Binding Cache Entry. This is required if the Binding Update (that created the Binding Cache Entry) contained explicit prefix information. This information can be used later to cleanup routes installed in explicit mode, when the Binding Cache Entry is removed, and to maintain the routing table, for instance should the routes be manually removed.

The Home Agent also stores the status of the Mobile Router Flag 'R' in the Binding Cache entry.

[6.1.2](#). Prefix Table

In some deployment scenarios it may be necessary for the Home Agent to prevent a misbehaving Mobile Router from claiming mobile network prefixes belonging to another Mobile Router. The Home Agent can prevent such attacks if it maintains a Prefix Table and verifies the Prefix Information provided by the Mobile Router against the entries in the Prefix Table. However, this verification is done only if the Binding Update contained explicit prefix information in the form of either the Mobile Network Prefix Option or the Mobile Network Prefix Length Option.

Each entry in the Prefix Table conceptually contains the following fields:

- The Home Address of the Mobile Router. This field is used as the key for searching the pre-configured prefix table.
- The Mobile Network Prefix of the Mobile Router associated with the Home Address.

[6.2](#). Mobile Network Prefix Registration

The Home Agent processes the Binding Update as described in [section 10.3.1](#) of the Mobile IPv6 specification [1]. This section describes the processing of the Binding Update if the Mobile Router (R) flag is set. The Home Agent performs the following check in addition.

- The Home Registration (H) flag MUST be set. If not, the Home Agent MUST reject the Binding Update and send a Binding Acknowledgement with status set to 140. Note: The basic support does not allow sending Binding Update for a Mobile Network Prefix to correspondent nodes (for route optimization).
- If the Mobile Network Prefix Length option is present in the Binding Update, then there MUST be only one instance of this option in the Binding Update. Also the Mobile Network Prefix Option MUST NOT be present in the same Binding Update. Otherwise, the Home Agent MUST discard the Binding Update and send an ICMP Parameter Problem, Code 0, message to the Mobile Router.

If the Home Agent does not reject the Binding Update as described above, then it retrieves the Mobile Network Prefix information as described below.

- If a Mobile Network Prefix Length Option is present in the Binding Update, the Home Address in the Home Address destination option MUST be an Home Address. In that case, the Mobile Network Prefix is obtained from that Home Address and the prefix length in the Mobile Network Prefix Length Option.

If the Home Agent verifies the prefix information with the Prefix Table and the check fails, the Home Agent MUST discard the Binding Update and send a Binding Acknowledgement with status set to 142 (Not Authorized for Prefix).

- If a Mobile Network Prefix Option is present in the Binding Update, the prefix information for the mobile network prefix is retrieved from the Mobile Network Prefix field and the Prefix Length field of the option. If the Binding Update contains more than one option, the Home Agent MUST set up forwarding for all of the Mobile Network Prefixes. If the Home Agent fails to setup forwarding to all the prefixes listed in the Binding Update, then it MUST NOT forward traffic to any of the prefixes, reject the Binding Update and send a Binding Acknowledgement with status set to 141 (Invalid Prefix).

If the Home Agent verifies the prefix information with the Prefix Table and the check fails, the Home Agent MUST discard the

Binding Update and send a Binding Acknowledgement with status set to 142 (Not Authorized for Prefix).

- If there are no options in the Binding Update, the Home Agent uses manual pre-configured information to determine the prefixes assigned to the Mobile Router and for setting up forwarding for the Mobile Network. If there is no information that the Home Agent can use, it MUST reject the Binding Update and send a Binding Acknowledgement with status set to 143 (Forwarding Setup failed).

If the Lifetime specified in the Binding Update is zero or the specified Care-of address matches the Home Address in the Binding Update, then this is a request to delete the cached binding for the home address and specified Mobile Network Prefixes. The Binding Update is processed according to the procedure described in [section 6.7](#).

If all checks are passed, the Home Agent creates a binding cache entry for Mobile Router's Home Address, or updates the binding cache entry if it already exists. Otherwise, the Home Agent MUST NOT register the binding of the Mobile Router's Home Address.

The Home Agent defends the Mobile Router's Home Address through Proxy Neighbor Discovery by multicasting onto the home link a Neighbor Advertisement message on behalf of the mobile router. All fields in each such Neighbor Advertisement message SHOULD be set in the same way they would be set by the mobile router itself if sending this Neighbor Advertisement while at home, as described in [7], with the exception that the Router (R) bit in the Advertisement MUST be set if the Mobile Router (R) flag has been set in the Binding Update.

The Home Agent also creates a bi-directional tunnel to the mobile router for the requested Mobile Network Prefix, or update an existing bi-directional tunnel as described in [section 6.4](#).

[6.3](#). Advertising Mobile Network Reachability

In order to be able to receive packets meant for the mobile network, the Home Agent advertises reachability to the mobile network. If the Home Link is configured with a prefix that is an aggregation and if the Mobile Network Prefix is aggregated under that prefix, then the routing updates advertising reachability to the mobile network are sent only on the Home Link. If the Home Agent is the only default router on the Home Link, routes to the Mobile Network Prefix get aggregated naturally under the Home Agent and the Home Agent does not have to do anything special.

If the Home Agent receives routing updates through a dynamic routing protocol from the Mobile Router, those routes are propagated by the routing protocol running on the Home Agent on the relevant interfaces.

[6.4.](#) Establishment of Bi-directional Tunnel

The establishment and operation of the bi-directional tunnel is implementation specific. However, all implementations MUST be capable of the following operations.

- The Home Agent can tunnel packets meant for the mobile network prefix to the Mobile Router's current location, the Care-of Address of the Mobile Router.
- The Home Agent can accept packets tunneled by the Mobile Router with source address of the outer IPv6 header set to the Care-of Address of the Mobile Router.

[6.5.](#) Forwarding Packets

When the Home Agent receives a data packet destined for the mobile network, it forwards the packet to the Mobile Router through the bi-directional tunnel. The Home Agent either uses only the routing table, only the Binding Cache or a combination of routing table and Binding Cache to route packets to the mobile network. This is implementation specific. Two examples are shown below.

1. The Home Agent maintains a route to the Mobile Network Prefix with the next hop set to the Mobile Router's Home Address. When the Home Agent tries to forward the packet to the next hop, it finds a binding cache entry for the home address. Then the Home Agent extracts the Mobile Router's Care-of address and tunnels the packet to the Care-of address.
2. The Home Agent maintains a route to the Mobile Network Prefix with the outgoing interface set to the bi-directional tunnel interface between the Home Agent and the Mobile Router. For this purpose, the Home Agent MUST treat this tunnel as a tunnel

interface. When the packets are forwarded through the tunnel interface, they get encapsulated automatically with the source address and destination address in the outer IPv6 header set to the Home Agent's address and the Mobile Router's Care-of address, respectively.

[6.6](#). Sending Binding Acknowledgements

A Home Agent serving a Mobile Router sends Binding Acknowledgements according to the same rules it uses for sending Binding Acknowledgements to Mobile Hosts, with the following enhancements.

The Home Agent sets the status code in the Binding Acknowledgement to '2' (Mobile Router Binding Update accepted) in order to indicate to the Mobile Router that it accepted the Binding Update, set up the tunnel endpoint and the necessary forwarding information.

If the Home Agent is configured not to support mobile routers, it sets the status code in the Binding Acknowledgement to '140' (Mobile Router Operation not permitted).

If one or more prefixes received in the Binding Update are invalid and the Home Agent cannot setup forwarding for the prefixes, the Home Agent sets the status code in the Binding Acknowledgement to '141' (Invalid Prefix) in order to indicate this to the Mobile Router.

If the Mobile Router is not authorized to use this Home Address to forward packets for one or more prefixes that are present in the Binding Update, the Home Agent sets the status code in the Binding Acknowledgement to '142' (Not Authorized for Prefix) in order to indicate this.

The Home Agent sets the status code to 143 (Forwarding Setup failed) if it is unable to determine the information needed to setup forwarding for the Mobile Network. This is used in the Implicit mode where the Mobile Router does not include any prefix information in the Binding Update.

[6.7.](#) Mobile Network Prefix De-Registration

The Mobile Router de-registers with the Home Agent by sending a Binding Update with the lifetime set to zero. When the Home Agent successfully processes the de-registration BU, it deletes the Binding Cache Entry for the Mobile Router's Home Address and stops proxying the Home Address. This is described in detail in the Mobile IPv6 specification [[1](#)].

In addition, the Home Agent also removes the bi-directional tunnel and stops forwarding packets to the mobile network. The HA should keep all necessary information to clean up whichever routes it installed, whether they come from implicit or explicit source.

[7.](#) Support for Dynamic Routing Protocols

In the solution described so far, forwarding to the Mobile Network at the Home Agent is set up when the Home Agent receives a Binding Update from the Mobile Router. An alternative to this is for the Home Agent and the Mobile Router to run an intra-domain routing protocol like RIPng [[10](#)] and OSPF [[11](#)] through the bi-directional tunnel. The Mobile Router can continue running the same routing protocol that it was running when it was attached to the home link.

This feature is very useful when the Mobile Network is large with multiple subnets containing different IPv6 prefixes. Routing changes in the Mobile Network are propagated to the Home Agent quickly. Routing changes in the home link are also propagated to the Mobile Router very quickly.

When the Mobile Router is attached to the home link, it runs a routing protocol by sending routing updates through its egress interface. When the mobile router moves and attaches to a visited network, it MUST stop sending routing updates on the interface with which it attaches to the visited link. This is very important so that IPv6 prefixes specific to the Mobile Network do not leak into the visited network. The Mobile Router then starts sending routing protocol messages through the bi-directional tunnel towards the Home Agent. Most routing protocols use link local addresses as source

addresses for the routing information messages. The Mobile Router is allowed to use link local addresses for the inner IPv6 header of an encapsulated packet. But these messages after decapsulation MUST NOT be forwarded to another link by either the Mobile Router or the Home Agent.

When the Home Agent receives the encapsulated routing protocol message, it processes the inner packets and updates its routing table accordingly. The next hop information in these routing entries is filled with the Mobile Router's link local address with the outgoing interface set to the bi-directional tunnel.

Similary, the Home Agent also sends routing updates through the bi-directional tunnel to the Mobile Router. The Mobile Router processes these routing protocol messages and updates its routing table. For all routes advertised by the Home Agent, the Mobile Router sets the outgoing interface to the bi-directional tunnel to the Home Agent.

When the Mobile Router and the Home Agent exchange routes through a dynamic routing protocol, the Mobile Router should be careful in including the same mobile network prefixes in the Binding Update to the HA and in the routing protocol updates. The HA depending on its configuration might not add routes based on the prefix information in

the Binding Updates at all, and might use only the routing protocol updates. Moreover, including the same prefix information in both the Binding Update and the routing protocol update is redundant.

The tunneled routing messages MUST be authenticated and encrypted by using IPsec ESP [\[4\]](#) in tunnel mode.

[8](#). Security Considerations

All signaling messages between the Mobile Router and the Home Agent MUST be authenticated by IPsec [\[5\]](#). The use of IPsec to protect Mobile IPv6 signaling messages is described in detail in the HA-MN IPsec specification [\[2\]](#). The signaling messages described in this document just extend Mobile IPv6 messages and do not require any changes to what is described in the HA-MN IPsec specification.

The Home Agent has to verify that packets received through the bi-directional tunnel belong to the Mobile Network. This check is necessary in order to prevent nodes from using the Home Agent to launch attacks that would have otherwise been prevented by ingress filtering. The source address of the outer IPv6 header MUST be set the Mobile Router's current Care-of address. The source address of the inner IPv6 header MUST belong to the Mobile Network Prefix owned by the Mobile Router.

When the Mobile Router is running a dynamic routing protocol as described in [section 7](#), it injects routing update messages into the Home Link. The Home Agent MUST verify that the Mobile Router is allowed to send routing updates before processing the messages and propagating the routing information.

Please refer to the Mobile IPv6 specification [\[1\]](#) for security considerations when the Mobile Router operates as a Mobile Host.

[9](#). IANA Considerations

This document defines two new Mobility Header Options.

- Mobile Network Prefix Option.
- Mobile Network Prefix Length Option.

These options are described in [section 4.3](#) and [section 4.4](#). The type values for these options need to assigned from the same space used by the mobility options defined in [\[1\]](#)

[10](#). Contributors

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[11](#). Acknowledgements

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Tim Leinmueller for many insightful remarks and implementation aspects.

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Normative References

- [1] D. Johnson, C. Perkins and J. Arkko. Mobility Support in IPv6. Internet Draft, IETF. [draft-ietf-mobileip-ipv6-24.txt](#) (work in progress). June 2003.
- [2] J. Arkko, V. Devarapalli and F. Dupont. Using IPsec to Protect Mobile IPv6 Signaling between Mobile Nodes and Home Agents. Internet Draft, IETF. [draft-ietf-mobileip-mipv6-ha-ipsec-06.txt](#) (work in progress). June 2003.
- [3] A. Conta and S. Deering. Generic Packet Tunneling in IPv6 Specification. [RFC 2473](#), IETF. December 1998.
- [4] S. Kent and R. Atkinson. IP Encapsulating Security Payload (ESP). [RFC 2402](#), IETF. November 1998.
- [5] S. Kent and R. Atkinson. Security Architecture for the Internet Protocol. [RFC 2401](#), IETF. November 1998.
- [6] S. Deering and R. Hinden. Internet Protocol, Version 6 (IPv6) Specification. [RFC 2460](#), IETF. December 1998.
- [7] T. Narten, E. Nordmark and W. Simpson. Neighbour Discovery for IP Version 6 (IPv6). [RFC 2461](#), IETF. December 1998.

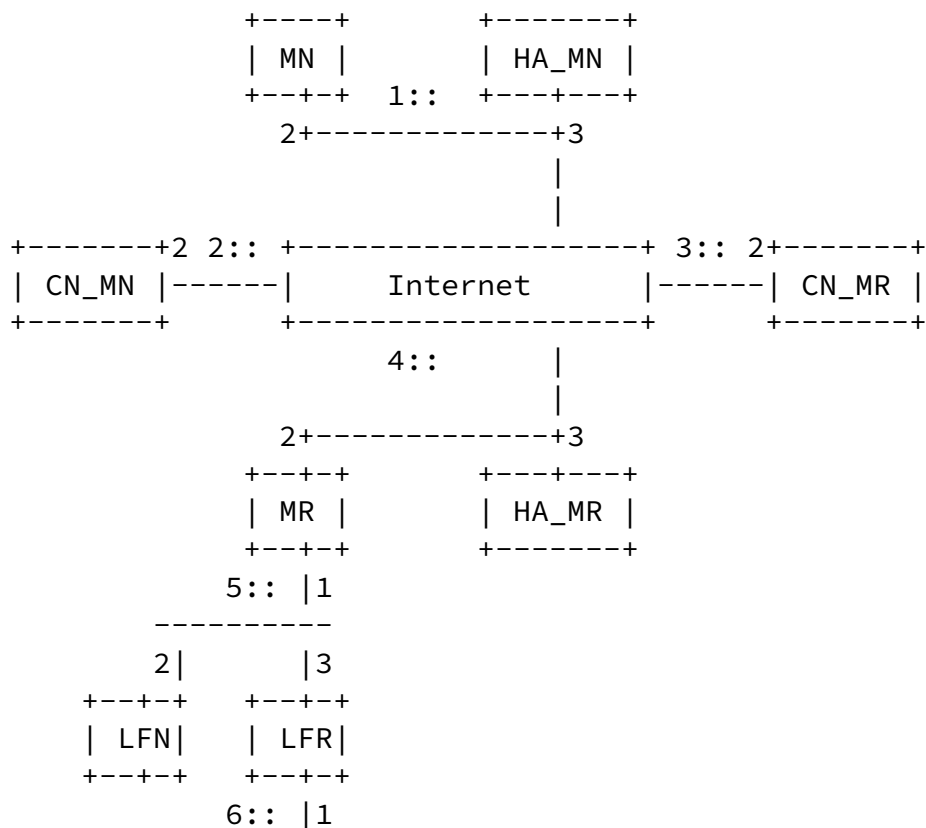
Informative References

- [8] T. Ernst and H.-Y. Lach. Network Mobility Support Terminology. Internet Draft, IETF. [draft-ietf-nemo-terminology-00.txt](#) (work in progress). May 2003.
- [9] T. Ernst. Network Mobility Support Goals and Requirements. Internet Draft, IETF. [draft-ietf-nemo-requirements-01.txt](#) (work in progress). May 2003.
- [10] G. Malkin and R. Minnear. RIPng for IPv6. [RFC 2080](#), IETF. January 1997.
- [11] R. Coltun, D. Ferguson and J. Moy. OSPF for IPv6. [RFC 2470](#), IETF. December 1999.

A. Examples of Operation

This section tries to illustrate the NEMO protocol using a Mobile Router and a Mobile Node belonging to different administrative domains. The Mobile Router's mobile network consists of a Local Fixed Node (LFN) and a Local Fixed Router (LFR) [8]. The LFR has an access link to which other Mobile Nodes or Mobile Routers could attach to.

Figure 1 depicts the scenario where both the Mobile Router and the Mobile Node are at home.



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```

+-----+ +-----+
| MN | | HA_MN |
+---+---+ 1:: +---+---+
2+-----+3
|
|
+-----+2 2:: +-----+ 3:: 2+-----+
| CN_MN |-----| Internet |-----| CN_MR |
+---+---+ +---+---+ +---+---+
| 7:: 4:: | 4::2->7::2
| |
2+ +3
+---+---+ +---+---+
| MR | | HA_MR | 4::2->7::2
+---+---+ +---+---+ 5::/prefixlen -> forward
5:: |1 to MR
-----
2| |3
+---+---+ +---+---+
6::/prefixlen -> forward
to MR

```

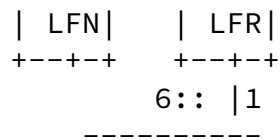
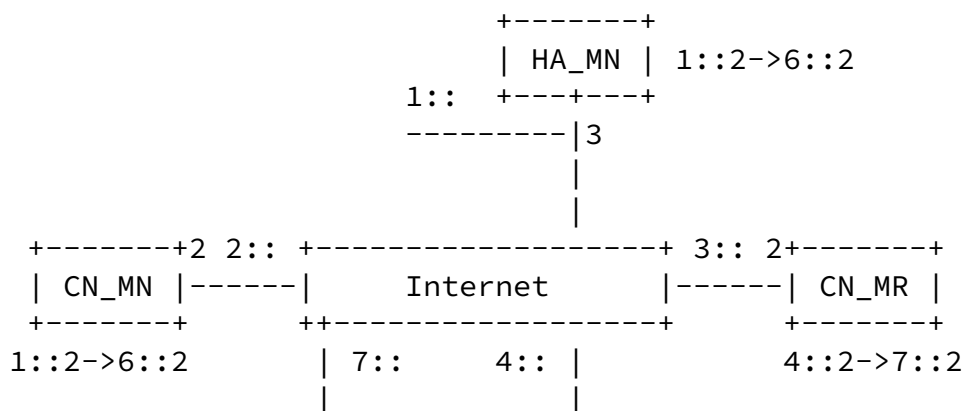


Figure 2: Mobile Router on a Visited Link.

Figure 3 shows the Mobile Node moving away from its home link and attaching to the Mobile Router. The Mobile Node configures a Care-of Address from the prefix advertised on the mobile network and sends a Binding Update to its Home Agent (HA_MN) and its Correspondent Node (CN_MN). Both HA_MN and CN_MN create binding cache entries for the Mobile Node's Home Address.



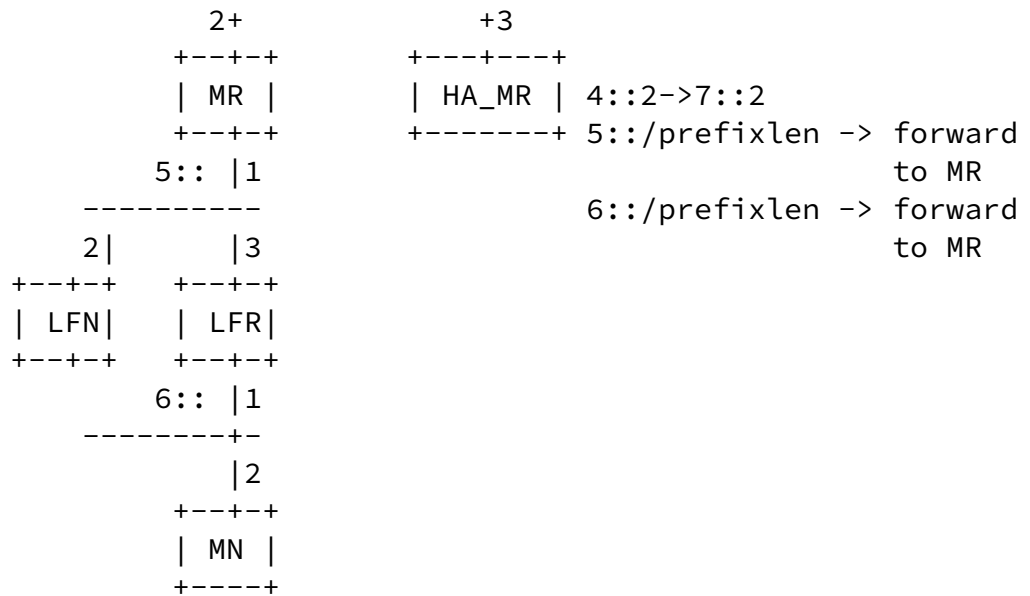


Figure 3: Mobile Node attached to Mobile Router on a Visited Link

B. Changes from Previous Version

The following changes have been made to this document from version 00

- Clarified that Router flag must be set in the Proxy Neighbor Advertisement sent for a Mobile Router by the Home Agent. (Issue 1).
- Clarified that if the Router flag in the Binding Update is set, then the HA should assume that the Mobile Router wants to be treated as a mobile node. (Issue 3).

- Added text to make it clear that the Home Agent must perform ingress filtering on all packets reverse tunneled by the Mobile Router. (Issue 3).
- Extended Home Network concept has been removed from this document. (Issue 5).
- Added text to clarify differences between Implicit mode and running a dynamic routing protocol. (Issue 6).
- Clarified that Prefix Table is used only in explicit mode. In Implicit mode the Prefix Table is not used. (Issue 7 and 12).
- Added text to specify the Home Agent must support all modes. The Mobile Router needs to support only one mode. (Issue 11).
- Added text to support interoperability between a Mobile Router and a legacy MIPv6 Home Agent. (Issue 15).

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

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

Alexandru Petrescu
Motorola Labs
Parc les Algorithmes Saint Aubin
Gif-sur-Yvette 91193
France
Email: Alexandru.Petrescu@motorola.com

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

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