IETF Mobile IP Working Group
INTERNET-DRAFT

David B. Johnson
Rice University
Charles Perkins
Nokia
17 November 2000

Mobility Support in IPv6

<draft-ietf-mobileip-ipv6-13.txt>

Status of This Memo

Abstract

This document specifies the operation of mobile computers using IPv6. Each mobile node is always identified by its home address, regardless of its current point of attachment to the Internet. While situated away from its home, a mobile node is also associated with a care-of address, which provides information about the mobile node's current location. IPv6 packets addressed to a mobile node's home address are transparently routed to its care-of address. The protocol enables IPv6 nodes to cache the binding of a mobile node's home address with its care-of address, and to then send any packets destined for the mobile node directly to it at this care-of address. To support this operation, Mobile IPv6 defines four new IPv6 destination options, including one that MUST be supported in packets received by any node, whether mobile or stationary.

Contents

1. Introduction

This document specifies the operation of mobile computers using Internet Protocol Version 6 (IPv6) [6]. Without specific support for mobility in IPv6, packets destined to a mobile node (host or router) would not be able to reach it while the mobile node is away from its home link (the link on which its home IPv6 subnet prefix is in use), since routing is based on the subnet prefix in a packet's destination IP address. In order to continue communication in spite of its movement, a mobile node could change its IP address each time it moves to a new link, but the mobile node would then not be able to maintain transport and higher-layer connections when it changes location. Mobility support in IPv6 is particularly important, as mobile computers are likely to account for a majority or at least a substantial fraction of the population of the Internet during the lifetime of IPv6.

The protocol operation defined here, known as Mobile IPv6, allows a mobile node to move from one link to another without changing the mobile node's IP address. A mobile node is always addressable by its "home address", an IP address assigned to the mobile node within its home subnet prefix on its home link. Packets may be routed to the mobile node using this address regardless of the mobile node's current point of attachment to the Internet, and the mobile node may continue to communicate with other nodes (stationary or mobile) after moving to a new link. The movement of a mobile node away from its home link is thus transparent to transport and higher-layer protocols and applications.

The Mobile IPv6 protocol is just as suitable for mobility across homogeneous media as for mobility across heterogeneous media. For example, Mobile IPv6 facilitates node movement from one Ethernet segment to another as well as it facilitates node movement from an Ethernet segment to a wireless LAN cell, with the mobile node's IP address remaining unchanged in spite of such movement.

One can think of the Mobile IPv6 protocol as solving the network-layer mobility management problem. Some mobility management applications -- for example, handoff among wireless transceivers, each of which covers only a very small geographic area -- have been solved using link-layer techniques. For example, in many current wireless LAN products, link-layer mobility mechanisms allow a "handoff" of a mobile node from one cell to another, reestablishing link-layer connectivity to the node in each new location. Within the natural limitations imposed by link-management solutions, and as long as such handoff occurs only within cells of the mobile node's home link, such link-layer mobility mechanisms MAY offer faster convergence and lower overhead than Mobile IPv6. Extensions to the

Mobile IPv6 protocol have been proposed to support a more local, hierarchical form of mobility management, but such extensions are beyond the scope of this document.

The protocol specified in this document solves the problem of transparently routing packets to and from mobile nodes while away from home. However, it does not attempt to solve all general problems related to the use of mobile computers or wireless networks. In particular, this protocol does not attempt to solve:

- Handling links with partial reachability, such as typical wireless networks. Some aspects of this problem are addressed by the movement detection procedure described in Section 10.4, but no attempt has been made to fully solve this problem in its general form. Most aspects of this problem can be solved by the workaround of restricting such networks to only one router per link, although there are still possible hidden terminal problems when two nodes on the same link (on opposite sides of the router) attempt to communicate directly.

- Access control on a link being visited by a mobile node. This is a general problem any time an untrusted node is allowed to connect to any link layer. It is independent of whether the connecting node uses Mobile IP, DHCP [2], or just "borrows" an IP address on the link.

2. Comparison with Mobile IP for IPv4

The design of Mobile IP support in IPv6 (Mobile IPv6) represents a natural combination of the experiences gained from the development of Mobile IP support in IPv4 (Mobile IPv4) [19, 18, 20], together with the opportunities provided by the design and deployment of a new version of IP itself (IPv6) and the new protocol features offered by IPv6. Mobile IPv6 thus shares many features with Mobile IPv4, but the protocol is now fully integrated into IP and provides many improvements over Mobile IPv4. This section summarizes the major differences between Mobile IPv4 and Mobile IPv6:

- Support for what is known in Mobile IPv4 as "Route Optimization" [21] is now built in as a fundamental part of the protocol, rather than being added on as an optional set of extensions that may not be supported by all nodes as in Mobile IPv4. This integration of Route Optimization functionality allows direct routing from any correspondent node to any mobile node, without needing to pass through the mobile node's home network and be forwarded by its home agent, and thus eliminates the problem of "triangle routing" present in the base Mobile IPv4 protocol [19]. The Mobile IPv4 "registration" functionality and the Mobile IPv4 Route Optimization functionality are performed by a single protocol rather than two separate (and different) protocols.

- Support is also integrated into Mobile IPv6 -- and into IPv6 itself -- for allowing mobile nodes and Mobile IP to coexist efficiently with routers that perform "ingress filtering" [7]. A mobile node now uses its care-of address as the Source Address in the IP header of packets it sends, allowing the packets to pass normally through ingress filtering routers. The home address of the mobile node is carried in the packet in a Home Address destination option, allowing the use of the care-of address in the packet to be transparent above the IP layer. The ability to correctly process a Home Address option in a received packet is required in all IPv6 nodes, whether mobile nor stationary, whether host or router.

- The use of the care-of address as the Source Address in each packet's IP header also simplifies routing of multicast packets sent by a mobile node. With Mobile IPv4, the mobile node had to tunnel multicast packets to its home agent in order to transparently use its home address as the source of the multicast packets. With Mobile IPv6, the use of the Home Address option allows the home address to be used but still be compatible with multicast routing that is based in part on the packet's Source Address.

- There is no longer any need to deploy special routers as "foreign agents" as are used in Mobile IPv4. In Mobile IPv6,

mobile nodes make use of IPv6 features, such as Neighbor Discovery [17] and Address Autoconfiguration [27], to operate in any location away from home without any special support required from its local router.

- Unlike Mobile IPv4, Mobile IPv6 utilizes IP Security (IPsec) [11, 12, 13] for all security requirements (sender authentication, data integrity protection, and replay protection) for Binding Updates (which serve the role of both registration and Route Optimization in Mobile IPv4). Mobile IPv4 relies on its own security mechanisms for these functions, based on statically configured "mobility security associations".

- The movement detection mechanism in Mobile IPv6 provides bidirectional confirmation of a mobile node's ability to communicate with its default router in its current location (packets that the router sends are reaching the mobile node, and packets that the mobile node sends are reaching the router). This confirmation provides a detection of the "black hole" situation that may exist in some wireless environments where the link to the router does not work equally well in both directions, such as when the mobile node has moved out of good wireless transmission range from the router. The mobile node may then attempt to find a new router and begin using a new care-of address if its link to its current router is not working well. In contrast, in Mobile IPv4, only the forward direction (packets from the router are reaching the mobile node) is confirmed, allowing the black hole condition to persist.

- Most packets sent to a mobile node while away from home in Mobile IPv6 are sent using an IPv6 Routing header rather than IP encapsulation, whereas Mobile IPv4 must use encapsulation for all packets. The use of a Routing header requires less additional header bytes to be added to the packet, reducing the overhead of Mobile IP packet delivery. To avoid modifying the packet in flight, however, packets intercepted and tunneled by a mobile node's home agent in Mobile IPv6 must still use encapsulation for delivery to the mobile node.

- While a mobile node is away from home, its home agent intercepts any packets for the mobile node that arrive at the home network, using IPv6 Neighbor Discovery [17] rather than ARP [23] as is used in Mobile IPv4. The use of Neighbor Discovery improves the robustness of the protocol (e.g., due to the Neighbor Advertisement "override" bit) and simplifies implementation of Mobile IP due to the ability to not be concerned with any particular link layer as is required in ARP.

- The use of IPv6 encapsulation (and the Routing header) removes the need in Mobile IPv6 to manage "tunnel soft state", which was required in Mobile IPv4 due to limitations in ICMP for IPv4. Due

to the definition of ICMP for IPv6, the use of tunnel soft state is no longer required in IPv6 for correctly relaying ICMP error messages from within the tunnel back to the original sender of the packet.

- The dynamic home agent address discovery mechanism in Mobile IPv6 uses IPv6 anycast [10] and returns a single reply to the mobile node, rather than the corresponding Mobile IPv4 mechanism that used IPv4 directed broadcast and returned a separate reply from each home agent on the mobile node's home link. The Mobile IPv6 mechanism is more efficient and more reliable, since only one packet need be sent back to the mobile node. The mobile node is less likely to lose one of the replies because no "implosion" of replies is required by the protocol.

- Mobile IPv6 defines an Advertisement Interval option on Router Advertisements (equivalent to Agent Advertisements in Mobile IPv4), allowing a mobile node to decide for itself how many Router Advertisements (Agent Advertisements) it is willing to miss before declaring its current router unreachable.

- The use of IPv6 destination options allows all Mobile IPv6 control traffic to be piggybacked on any existing IPv6 packets, whereas in Mobile IPv4 and its Route Optimization extensions, separate UDP packets were required for each control message.

3. Terminology

3.1. General Terms

IP

Internet Protocol Version 6 (IPv6).

node

A device that implements IP.

router

A node that forwards IP packets not explicitly addressed to itself.

host

Any node that is not a router.

link

A communication facility or medium over which nodes can communicate at the link layer, such as an Ethernet (simple or bridged). A link is the layer immediately below IP.

interface

A node's attachment to a link.

subnet prefix

A bit string that consists of some number of initial bits of an IP address.

interface identifier

A number used to identify a node's interface on a link. The interface identifier is the remaining low-order bits in the node's IP address after the subnet prefix.

link-layer address

A link-layer identifier for an interface, such as IEEE 802 addresses on Ethernet links.

packet

An IP header plus payload.

3.2. Mobile IPv6 Terms

home address

An IP address assigned to a mobile node within its home link.

home subnet prefix

The IP subnet prefix corresponding to a mobile node's home address.

home link

The link on which a mobile node's home subnet prefix is defined. Standard IP routing mechanisms will deliver packets destined for a mobile node's home address to its home link.

mobile node

A node that can change its point of attachment from one link to another, while still being reachable via its home address.

movement

A change in a mobile node's point of attachment to the Internet such that it is no longer connected to the same link as it was previously. If a mobile node is not currently attached to its home link, the mobile node is said to be "away from home".

correspondent node

A peer node with which a mobile node is communicating. The correspondent node may be either mobile or stationary.

foreign subnet prefix

Any IP subnet prefix other than the mobile node's home subnet prefix.

foreign link

Any link other than the mobile node's home link.

home agent

A router on a mobile node's home link with which the mobile node has registered its current care-of address. While the mobile node is away from home, the home agent intercepts packets on the home link destined to the mobile node's home

address, encapsulates them, and tunnels them to the mobile node's registered care-of address.

care-of address

An IP address associated with a mobile node while visiting a foreign link; the subnet prefix of this IP address is a foreign subnet prefix. Among the multiple care-of addresses that a mobile node may have at a time (e.g., with different subnet prefixes), the one registered with the mobile node's home agent is called its "primary" care-of address.

binding

The association of the home address of a mobile node with a care-of address for that mobile node, along with the remaining lifetime of that association.

3.3. Specification Language

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 [3].

4. Overview of Mobile IPv6

4.1. Basic Operation

A mobile node is always addressable by its home address, whether it is currently attached to its home link or is away from home. While a mobile node is at home, packets addressed to its home address are routed to it using conventional Internet routing mechanisms in the same way as if the node were never mobile. Since the subnet prefix of a mobile node's home address is the subnet prefix (or one of the subnet prefixes) on the mobile node's home link (it is the mobile node's home subnet prefix), packets addressed to it will be routed to its home link.

While a mobile node is attached to some foreign link away from home, it is also addressable by one or more care-of addresses, in addition to its home address. A care-of address is an IP address associated with a mobile node while visiting a particular foreign link. The subnet prefix of a mobile node's care-of address is the subnet prefix (or one of the subnet prefixes) on the foreign link being visited by the mobile node; if the mobile node is connected to this foreign link while using that care-of address, packets addressed to this care-of address will be routed to the mobile node in its location away from home.

The association between a mobile node's home address and care-of address is known as a "binding" for the mobile node. A mobile node typically acquires its care-of address through stateless [27] or stateful (e.g., DHCPv6 [2]) Address Autoconfiguration, according to the methods of IPv6 Neighbor Discovery [17]. Other methods of acquiring a care-of address are also possible, such as static pre-assignment by the owner or manager of a particular foreign link, but details of such other methods are beyond the scope of this document.

While away from home, a mobile node registers one of its care-of addresses with a router on its home link, requesting this router to function as the "home agent" for the mobile node. This binding registration is done by the mobile node sending to the home agent a packet containing a "Binding Update" destination option; the home agent then replies to the mobile node by returning a packet containing a "Binding Acknowledgement" destination option. The care-of address in this binding registered with its home agent is known as the mobile node's "primary care-of address". The mobile node's home agent thereafter uses proxy Neighbor Discovery to intercept any IPv6 packets addressed to the mobile node's home address (or home addresses) on the home link, and tunnels each intercepted packet to the mobile node's primary care-of address.

To tunnel each intercepted packet, the home agent encapsulates the packet using IPv6 encapsulation [4], with the outer IPv6 header addressed to the mobile node's primary care-of address.

When a mobile node moves from one care-of address to a new care-of address on a new link, it is desirable for packets arriving at the previous care-of address to be tunneled to the mobile node's care-of address. Since the purpose of a Binding Update is to establish exactly this kind of tunneling, it is specified to be used (at least temporarily) for tunnels originating at the mobile node's previous care-of address, in exactly the same way that it is used for establishing tunnels from the mobile node's home address to the mobile node's current care-of address. Section 10.9 describes the use of the Binding Update for this purpose.

Section 10.18 discusses the reasons why it may be desirable for a mobile node to use more than one care-of address at the same time. However, a mobile node's primary care-of address is distinct among these in that the home agent maintains only a single care-of address registered for each mobile node, and always tunnels a mobile node's packets intercepted from its home link to this mobile node's registered primary care-of address. The home agent thus need not implement any policy to determine which of possibly many care-of addresses to which to tunnel each intercepted packet. The mobile node alone controls the policy by which it selects the care-of addresses to register with its home agent.

It is possible that while a mobile node is away from home, some nodes on its home link may be reconfigured, such that the router that was operating as the mobile node's home agent is replaced by a different router serving this role. In this case, the mobile node may not know the IP address of its own home agent. Mobile IPv6 provides a mechanism, known as "dynamic home agent address discovery", that allows a mobile node to dynamically discover the IP address of a home agent on its home link with which it may register its care-of address while away from home. The mobile node sends an ICMP "Home Agent Address Discovery Request" message to the "Mobile IPv6 Home-Agents" anycast address for its own home subnet prefix [10] and thus reaches one of the (possibly many) routers on its home link currently operating as a home agent. This home agent then returns an ICMP "Home Agent Address Discovery Reply" message to the mobile node, including a list of home agents on the home link. This list of home agents is maintained by each home agent on the home link through use of the Home Agent (H) bit in each home agent's periodic unsolicited multicast Router Advertisements.

The Binding Update and Binding Acknowledgement destination options, together with a "Binding Request" destination option, are also used to allow IPv6 nodes communicating with a mobile node, to dynamically learn and cache the mobile node's binding. When sending a packet to any IPv6 destination, a node checks its cached bindings for an entry for the packet's destination address. If a cached binding for

this destination address is found, the node uses an IPv6 Routing header [6] (instead of IPv6 encapsulation) to route the packet to the mobile node by way of the care-of address indicated in this

binding. If, instead, the sending node has no cached binding for this destination address, the node sends the packet normally (with no Routing header), and the packet is subsequently intercepted and tunneled by the mobile node's home agent as described above. Any node communicating with a mobile node is referred to in this document as a "correspondent node" of the mobile node, and may itself be either a stationary node or a mobile node.

Since a Binding Update, Binding Acknowledgement, and Binding Request are each represented in a packet as an IPv6 destination option [6], they may be included in any IPv6 packet. Any of these options can be sent in either of two ways:

- the messages can be included within any IPv6 packet carrying any payload such as TCP [25] or UDP [24].

- the messages can be sent as a separate IPv6 packet containing no payload. In this case, the Next Header field in the last extension header in the packet is set to the value 59, to indicate "No Next Header" [6].

Mobile IPv6 also defines one additional IPv6 destination option. When a mobile node sends a packet while away from home, it will generally set the Source Address in the packet's IPv6 header to one of its current care-of addresses, and will also include a "Home Address" destination option in the packet, giving the mobile node's home address. Many routers implement security policies such as "ingress filtering" [7] that do not allow forwarding of packets that have a Source Address which appears topologically incorrect. By using the care-of address as the IPv6 header Source Address, the packet will be able to pass normally through such routers, yet ingress filtering rules will still be able to locate the true topological source of the packet in the same way as packets from non-mobile nodes. By also including the Home Address option in each packet, the sending mobile node can communicate its home address to the correspondent node receiving this packet, allowing the use of the care-of address to be transparent above the Mobile IPv6 support level (e.g., at the transport layer). The inclusion of a Home Address option in a packet affects only the correspondent node's receipt of this single packet; no state is created or modified in the correspondent node as a result of receiving a Home Address option in a packet.

4.2. New IPv6 Destination Options

As mentioned in Section 4.1, the following four new IPv6 destination options are defined for Mobile IPv6:

Binding Update

A Binding Update option is used by a mobile node to notify a correspondent node or the mobile node's home agent of its current binding. The Binding Update sent to the mobile node's home agent to register its primary care-of address is marked as a "home registration". Any packet that includes a Binding Update option MUST be protected by IPsec [13], as defined in Section 4.4, to guard against malicious Binding Updates. The Binding Update option and its specific IPsec requirements are described in detail in Section 5.1.

Binding Acknowledgement

A Binding Acknowledgement option is used to acknowledge receipt of a Binding Update, if an acknowledgement was requested in the Binding Update. Any packet that includes a Binding Acknowledgement option MUST be protected by IPsec [13], as defined in Section 4.4, to guard against malicious Binding Acknowledgements. The Binding Acknowledgement option and its specific IPsec requirements are described in detail in Section 5.2.

Binding Request

A Binding Request option is used to request a mobile node to send to the requesting node a Binding Update containing the mobile node's current binding. This option is typically used by a correspondent node to refresh a cached binding for a mobile node, when the cached binding is in active use but the binding's lifetime is close to expiration. No authentication is required for the Binding Request option. The Binding Request option is described in detail in Section 5.3.

Home Address

A Home Address option is used in a packet sent by a mobile node to inform the recipient of that packet of the mobile node's home address. For packets sent by a mobile node while away from home, the mobile node generally uses one of its care-of addresses as the Source Address in the packet's IPv6 header. By including a Home Address option in the packet, the correspondent node receiving the packet is able to substitute the mobile node's home address for this care-of address when processing the packet, thus making the use of the care-of address transparent to the correspondent node. If the IP header of a packet carrying a Home Address option is covered by authentication, then the Home Address option MUST also be

covered by this authentication, but no other authentication is required for the Home Address option. See sections 10.2 and 5.4 for additional details about requirements for the

calculation and verification of the authentication data. The Home Address option is described in detail in Section 5.4.

Mobile IPv6 also defines a number of "sub-options" for use within these destination options; if included, any sub-options MUST appear after the fixed portion of the option data specified in this document. The presence of such sub-options will be indicated by the Option Length field within the option. When the Option Length is greater than the length required for the option specified here, the remaining octets are interpreted as sub-options. The encoding and format of defined sub-options are described in Section 5.5.

4.3. Alignment Requirements for New Destination Options

IPv6 requires that options appearing in a Hop-by-Hop Options header or Destination Options header be aligned in a packet so that multi-octet values within the Option Data field of each option fall on natural boundaries (i.e., fields of width n octets are placed at an integer multiple of n octets from the start of the header, for n = 1, 2, 4, or 8) [6]. Mobile IPv6 sub-options have similar alignment requirements, so that multi-octet values within the Sub-Option Data field of each sub-option fall on natural boundaries. The alignment requirement of an option or sub-option is specified in this document using the standard notation used elsewhere for IPv6 alignment requirements [6]. Specifically, the notation xn+y means that the Option Type or Sub-Option Type field must fall at an integer multiple of x octets from the start of the header, plus y octets. For example:

2n means any 2-octet offset from the start of the header.

8n+2 means any 8-octet offset from the start of the header, plus 2 octets.

4.4. IPsec Requirements for New Destination Options

Any packet that includes a Binding Update or Binding Acknowledgement option MUST be protected by IPsec [13] to guard against malicious Binding Updates or Acknowledgements. Specifically, any packet that includes a Binding Update or Binding Acknowledgement option MUST utilize IPsec sender authentication, data integrity protection, and replay protection.

Mobile IPv6 requires that this protection covering a Binding Update or Binding Acknowledgement MUST be provided by use of AH [11]. If another Security Association applied to the packet for other reasons requires use of ESP [12], for example to encrypt the transport layer

data carried in the packet, this use of ESP is not sufficient to satisfy the authentication requirements of Mobile IPv6; instead,

the packet MUST use both AH and ESP. Use of ESP for protecting the Binding Update or Binding Acknowledgement is not currently defined in this document, since ESP does not protect the portion of the packet above the ESP header itself [12].

4.5. New IPv6 ICMP Messages

Mobile IPv6 also introduces two new ICMP message types, for use in the dynamic home agent address discovery mechanism. As discussed in general in Section 4.1, the following two new ICMP message types are used:

Home Agent Address Discovery Request

The ICMP Home Agent Address Discovery Request message is used by a mobile node to initiate the dynamic home agent address discovery mechanism. When attempting a home registration, the mobile node may use this mechanism to discover the address of one or more routers currently operating as home agents on its home link, with which it may register while away from home. The Home Agent Address Discovery Request message is described in detail in Section 5.6.

Home Agent Address Discovery Reply

The ICMP Home Agent Address Discovery Reply message is used by a home agent to respond to a mobile node using the dynamic home agent address discovery mechanism. When a home agent receives a Home Agent Address Discovery Request message, it replies with a Home Agent Address Discovery Reply message, giving a list of the routers on the mobile node's home link serving as home agents. The Home Agent Address Discovery Reply message is described in detail in Section 5.7.

4.6. Conceptual Data Structures

This document describes the Mobile IPv6 protocol in terms of the following three conceptual data structures:

Binding Cache

A cache, maintained by each IPv6 node, of bindings for other nodes. A separate Binding Cache SHOULD be maintained by each IPv6 node for each of its IPv6 addresses. The Binding Cache MAY be implemented in any manner consistent with the external behavior described in this document, for example by being combined with the node's Destination Cache as maintained by

Neighbor Discovery [17]. When sending a packet, the Binding Cache is searched before the Neighbor Discovery conceptual

Destination Cache [17] (i.e., any Binding Cache entry for this destination SHOULD take precedence over any Destination Cache entry for the same destination). Each Binding Cache entry conceptually contains the following fields:

- The home address of the mobile node for which this is the Binding Cache entry. This field is used as the key for searching the Binding Cache for the destination address of a packet being sent. If the destination address of the packet matches the home address in the Binding Cache entry, this entry SHOULD be used in routing that packet.

- The care-of address for the mobile node indicated by the home address field in this Binding Cache entry. If the destination address of a packet being routed by a node matches the home address in this entry, the packet SHOULD be routed to this care-of address, as described in Section 8.9, for packets originated by this node, or in Section 9.6, if this node is the mobile node's home agent and the packet was intercepted by it on the home link.

- A lifetime value, indicating the remaining lifetime for this Binding Cache entry. The lifetime value is initialized from the Lifetime field in the Binding Update that created or last modified this Binding Cache entry. Once the lifetime on this entry expires, the entry MUST be deleted from the Binding Cache.

- A flag indicating whether or not this Binding Cache entry is a "home registration" entry.

- A flag indicating whether or not this Binding Cache entry represents a mobile node that should be advertised as a router in proxy Neighbor Advertisements sent by this node on its behalf. This flag is only valid if the Binding Cache entry indicates that this is a "home registration" entry.

- The value of the Prefix Length field received in the Binding Update that created or last modified this Binding Cache entry. This field is only valid if the "home registration" flag is set on this Binding Cache entry.

- The maximum value of the Sequence Number field received in previous Binding Updates for this mobile node home address. The Sequence Number field is 16 bits long, and all comparisons between Sequence Number values MUST be performed modulo 2**16. For example, using an

implementation in the C programming language, a Sequence Number value A is greater than another Sequence Number

value B if ((short)((a) - (b)) > 0), if a "short" data type is a 16-bit signed integer.

- Recent usage information for this Binding Cache entry, as needed to implement the cache replacement policy in use in the Binding Cache and to assist in determining whether a Binding Request should be sent when the lifetime on this entry nears expiration.

- The time at which a Binding Request was last sent for this entry, as needed to implement the rate limiting restriction for sending Binding Requests.

An entry in a node's Binding Cache for which the node is serving as a home agent is marked as a "home registration" entry and SHOULD NOT be deleted by the home agent until the expiration of its binding lifetime. Other Binding Cache entries MAY be replaced at any time by any reasonable local cache replacement policy but SHOULD NOT be unnecessarily deleted. The Binding Cache for any one of a node's IPv6 addresses may contain at most one entry for each mobile node home address. The contents of a node's Binding Cache MUST NOT be changed in response to a Home Address option in a received packet. The contents of all of a node's Binding Cache entries, for each of its IPv6 addresses, must be cleared when the node reboots.

Binding Update List

A list, maintained by each mobile node, recording information for each Binding Update sent by this mobile node, for which the Lifetime sent in that Binding Update has not yet expired. The Binding Update List includes all bindings sent by the mobile node: those to correspondent nodes, those to the mobile node's home agent, and those to a home agent on the link on which the mobile node's previous care-of address is located. However, for multiple Binding Updates sent to the same destination address, the Binding Update List contains only the most recent Binding Update (i.e., with the greatest Sequence Number value) sent to that destination. The Binding Update List MAY be implemented in any manner consistent with the external behavior described in this document. Each Binding Update List entry conceptually contains the following fields:

- The IP address of the node to which a Binding Update was sent. This node might still have a Binding Cache entry created or updated from this Binding Update, if the Binding Update was successfully received by that node (e.g., not

lost by the network) and if that node has not deleted the entry before its expiration (e.g., to reclaim space in its Binding Cache for other entries).

- The home address for which that Binding Update was sent. This will be one of the following:

  * the mobile node's home addresses for typical Binding Updates (Sections 10.6 and 10.8), or

  * the mobile node's previous care-of address for Binding Updates sent to establish forwarding from the mobile node's previous care-of address by a home agent from this previous care-of address (Section 10.9).

- The care-of address sent in that Binding Update. This value is necessary for the mobile node to determine if it has sent a Binding Update giving its new care-of address to this destination after changing its care-of address.

- The initial value of the Lifetime field sent in that Binding Update.

- The remaining lifetime of that binding. This lifetime is initialized from the Lifetime value sent in the Binding Update and is decremented until it reaches zero, at which time this entry MUST be deleted from the Binding Update List.

- The maximum value of the Sequence Number field sent in previous Binding Updates to this destination. The Sequence Number field is 16 bits long, and all comparisons between Sequence Number values MUST be performed modulo 2**16. For example, using an implementation in the C programming language, a Sequence Number value A is greater than another Sequence Number value B if ((short)((a) - (b)) > 0), if a "short" data type is a 16-bit signed integer.

- The time at which a Binding Update was last sent to this destination, as needed to implement the rate limiting restriction for sending Binding Updates.

- The state of any retransmissions needed for this Binding Update, if the Acknowledge (A) bit was set in this Binding Update. This state includes the time remaining until the next retransmission attempt for the Binding Update, and the current state of the exponential back-off mechanism for retransmissions.

- A flag that, when set, indicates that future Binding Updates should not be sent to this destination. The mobile node sets this flag in the Binding Update List entry when it receives an ICMP Parameter Problem, Code 2,

error message in response to a Binding Update sent to that destination, as described in Section 10.14.

Home Agents List

A list, maintained by each home agent and each mobile node, recording information about each home agent from which this node has received a Router Advertisement in which the Home Agent (H) bit is set, for which the remaining lifetime for this list entry (defined below) has not yet expired. The home agents list is thus similar to the Default Router List conceptual data structure maintained by each host for Neighbor Discovery [17], although the Home Agents List MAY be implemented in any manner consistent with the external behavior described in this document.

Each home agent maintains a separate Home Agents List for each link on which it is serving as a home agent; this list is used by a home agent in the dynamic home agent address discovery mechanism. Each mobile node, while away from home, also maintains a Home Agents List, to enable it to notify a home agent on its previous link when it moves to a new link; a mobile node MAY maintain a separate Home Agents List for each link to which it is (or has recently) connected, or it MAY maintain a single list for all links. Each Home Agents List entry conceptually contains the following fields:

- The link-local IP address of a router on the link, that this node currently believes is operating as a home agent for that link. A new entry is created or an existing entry is updated in the Home Agents List in response to receipt of a valid Router Advertisement in which the Home Agent (H) bit is set. The link-local address of the home agent is learned through the Source Address of the Router Advertisements received from it [17].

- One or more global IP addresses for this home agent, learned through Prefix Information options with the Router Address (R) bit set, received in Router Advertisements from this link-local address. Global addresses for the router in a Home Agents List entry MUST be deleted once the prefix associated with that address is no longer valid [17].

- The remaining lifetime of this Home Agents List entry. If a Home Agent Information Option is present in a Router Advertisement received from a home agent, the lifetime of the Home Agents List entry representing that home agent is initialized from the Home Agent Lifetime field in the option; otherwise, the lifetime is initialized from the Router Lifetime field in the received Router Advertisement.

The Home Agents List entry lifetime is decremented until it reaches zero, at which time this entry MUST be deleted from the Home Agents List.

- The preference for this home agent; higher values indicate a more preferable home agent. The preference value is taken from the Home Agent Preference field (a signed, twos-complement integer) in the received Router Advertisement, if the Router Advertisement contains a Home Agent Information Option, and is otherwise set to the default value of 0. A home agent uses this preference in ordering the Home Agents List returned in an ICMP Home Agent Address Discovery message in response to a mobile node's initiation of dynamic home agent address discovery. A mobile node uses this preference in determining which of the home agents on its previous link to notify when it moves to a new link.

4.7. Binding Management

When a mobile node configures a new care-of address and decides to use this new address as its primary care-of address, the mobile node registers this new binding with its home agent by sending the home agent a Binding Update. The mobile node indicates that an acknowledgement is needed for this Binding Update and continues to periodically retransmit it until acknowledged. The home agent acknowledges the Binding Update by returning a Binding Acknowledgement to the mobile node.

When a mobile node receives a packet tunneled to it from its home agent, the mobile node assumes that the original sending correspondent node has no Binding Cache entry for the mobile node, since the correspondent node would otherwise have sent the packet directly to the mobile node using a Routing header. The mobile node thus returns a Binding Update to the correspondent node, allowing it to cache the mobile node's binding for routing future packets to it. Although the mobile node may request an acknowledgement for this Binding Update, it need not, since subsequent packets from the correspondent node will continue to be intercepted and tunneled by the mobile node's home agent, effectively causing any needed Binding Update retransmission.

A correspondent node with a Binding Cache entry for a mobile node may refresh this binding, for example if the binding's lifetime is near expiration, by sending a Binding Request to the mobile node. Normally, a correspondent node will only refresh a Binding Cache entry in this way if it is actively communicating with the mobile node and has indications, such as an open TCP connection to the mobile node, that it will continue this communication in the future. When a mobile node receives a Binding Request, it replies by returning a Binding Update to the node sending the Binding Request.

A mobile node may use more than one care-of address at the same time, although only one care-of address may be registered for it at

its home agent as its primary care-of address. The mobile node's home agent will tunnel all intercepted packets for the mobile node to its (single) registered primary care-of address, but the mobile node will accept packets that it receives at any of its current care-of addresses. Use of more than one care-of address by a mobile node may be useful, for example, to improve smooth handoff when the mobile node moves from one wireless link to another. If each of these wireless links is connected to the Internet through a separate base station, such that the wireless transmission range from the two base stations overlap, the mobile node may be able to remain connected to both links while in the area of overlap. In this case, the mobile node could acquire a new care-of address on the new link before moving out of transmission range and disconnecting from the old link. The mobile node may thus still accept packets at its old care-of address while it works to update its home agent and correspondent nodes, notifying them of its new care-of address on the new link.

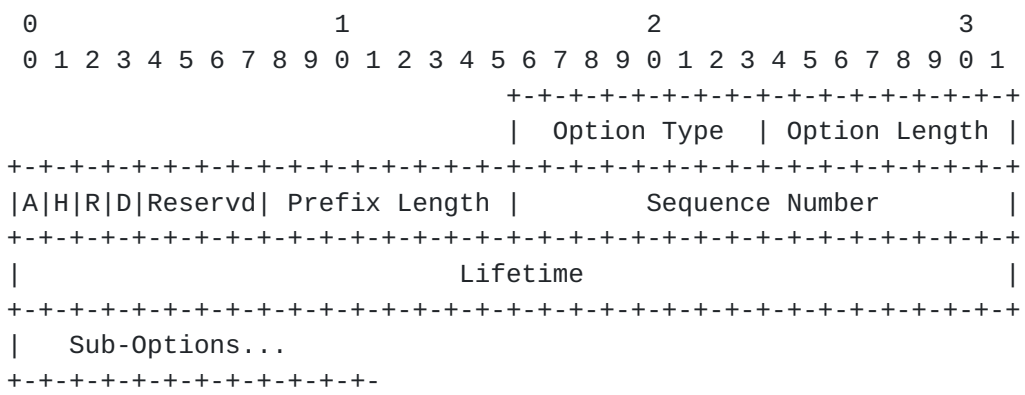
Since correspondent nodes cache bindings, it is expected that correspondent nodes usually will route packets directly to the mobile node's care-of address, so that the home agent is rarely involved with packet transmission to the mobile node. This is essential for scalability and reliability, and for minimizing overall network load. By caching the care-of address of a mobile node, optimal routing of packets can be achieved from the correspondent node to the mobile node. Routing packets directly to the mobile node's care-of address also eliminates congestion at the mobile node's home agent and home link. In addition, the impact of any possible failure of the home agent, the home link, or intervening networks leading to or from the home link is reduced, since these nodes and links are not involved in the delivery of most packets to the mobile node.

5. New IPv6 Destination Options and Message Types

5.1. Binding Update Option

The Binding Update destination option is used by a mobile node to notify other nodes of a new care-of address for itself. As a destination option, it MAY be included in any existing packet being sent to this same destination or MAY be sent in a packet by itself; a packet containing a Binding Update is sent in the same way as any packet sent by a mobile node (Section 10.1).

The Binding Update option is encoded in type-length-value (TLV) format as follows:



Option Type

198 = 0xC6

Option Length

8-bit unsigned integer. Length of the option, in octets, excluding the Option Type and Option Length fields. This field MUST be set to 8 plus the total length of all sub-options present, including their Sub-Option Type and Sub-Option Len fields.

Acknowledge (A)

The Acknowledge (A) bit is set by the sending mobile node to request a Binding Acknowledgement (Section 5.2) be returned upon receipt of the Binding Update.

Home Registration (H)

The Home Registration (H) bit is set by the sending mobile node to request the receiving node to act as this node's home agent. The destination of the packet carrying this option MUST be that

of a router sharing the same subnet prefix as the home address

of the mobile node in the binding (given by the Home Address field in the Home Address option in the packet).

Router (R)

The Router (R) bit, when set, indicates that the sending mobile node is a router. This bit is only valid when the Home Registration (H) bit is also set, and MUST NOT be set otherwise. This bit is saved in the home agent's "home registration" Binding Cache entry for the mobile node, and is copied into the corresponding bit in all proxy Neighbor Advertisement messages sent on behalf of this mobile node by the home agent using this Binding Cache entry.

Duplicate Address Detection (D)

The Duplicate Address Detection (D) bit is set by the sending mobile node to request the receiving node (the mobile node's home agent) to perform Duplicate Address Detection [27] on the mobile node's home link for the home address in this binding. This bit is only valid when the Home Registration (H) and Acknowledge (A) bits are also set, and MUST NOT be set otherwise. If the Duplicate Address Detection performed by the home agent fails, the Status field in the returned Binding Acknowledgement will be set to 138 (Duplicate Address Detection failed).

Reservd

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

Prefix Length

The Prefix Length field is valid only for a "home registration" Binding Update; this field MUST be zero if the Home Registration (H) bit is not set in the Binding Update. The Prefix Length field is set by the sending mobile node to the (nonzero) length of its subnet prefix in its home address (given in the Home Address option in the packet) to request its home agent to use the interface identifier in the mobile node's home address (the remaining low-order bits after the indicated subnet prefix) to form all other home addresses for the mobile node on the home link. The home agent becomes the home agent not only for the individual home address given in this binding, but also for all other home addresses for this mobile node formed from this interface identifier. That is, for each on-link prefix on the home link, the home agent uses the interface identifier to form other valid addresses for

the mobile node on the home link, and acts as a home agent also for those addresses. In addition, the home agent forms

the link-local address and site-local address corresponding to this interface identifier, and defends each for purposes of Duplicate Address Detection. The home agent also performs Duplicate Address Detection on at least one such address as part of the home registration processing (before returning the Binding Acknowledgement), if the Duplicate Address Detection (D) bit is set in the Binding Update; it is not necessary to perform Duplicate Address Detection individually on each of these addresses, since address uniqueness here is determined solely by the interface identifier [27]. Details of this operation are described in Section 9.3.

Sequence Number

Used by the receiving node to sequence Binding Updates and by the sending node to match a returned Binding Acknowledgement with this Binding Update. Each Binding Update sent by a mobile node MUST use a Sequence Number greater than the Sequence Number value sent in the previous Binding Update (if any) to the same destination address (modulo 2**16, as defined in Section 4.6). There is no requirement, however, that the Sequence Number value strictly increase by 1 with each new Binding Update sent or received.

Lifetime

32-bit unsigned integer. The number of seconds remaining before the binding MUST be considered expired. A value of all one bits (0xffffffff) indicates infinity. A value is zero indicates that the Binding Cache entry for the mobile node MUST be deleted.

Sub-Options

Additional information, associated with this Binding Update option, that need not be present in all Binding Updates sent. This use of sub-options also allows for future extensions to the format of the Binding Update option to be defined. The encoding and format of defined sub-options are described in Section 5.5. The following sub-options are valid in a Binding Update option:

- Unique Identifier Sub-Option

- Alternate Care-of Address Sub-Option

The alignment requirement [6] for the Binding Update option is 4n+2.

Any packet that includes a Binding Update option MUST also include

a Home Address option. The home address of the mobile node in the binding given in the Binding Update option is that which was received

as the value of the Home Address field in the Home Address option in the packet.

The care-of address for the binding given in the Binding Update option is normally that which was received as the value in the Source Address field in the IPv6 header of the packet carrying the Binding Update option. However, a care-of address different from the Source Address MAY be specified by including an Alternate Care-of Address sub-option in the Binding Update option.

Any packet that includes a Binding Update option MUST be protected by IPsec [13] to guard against malicious Binding Updates. The specific requirements for this protection are defined in Section 4.4.

If the care-of address for the binding (specified either in an Alternate Care-of Address sub-option in the Binding Update option, if present, or in the Source Address field in the packet's IPv6 header) is equal to the home address of the mobile node, the Binding Update option indicates that any existing binding for the mobile node MUST be deleted. Likewise, if the Lifetime field in the Binding Update option is equal to 0, the Binding Update option indicates that any existing binding for the mobile node MUST be deleted. In each of these cases, a Binding Cache entry for the mobile node MUST NOT be created in response to receiving the Binding Update.

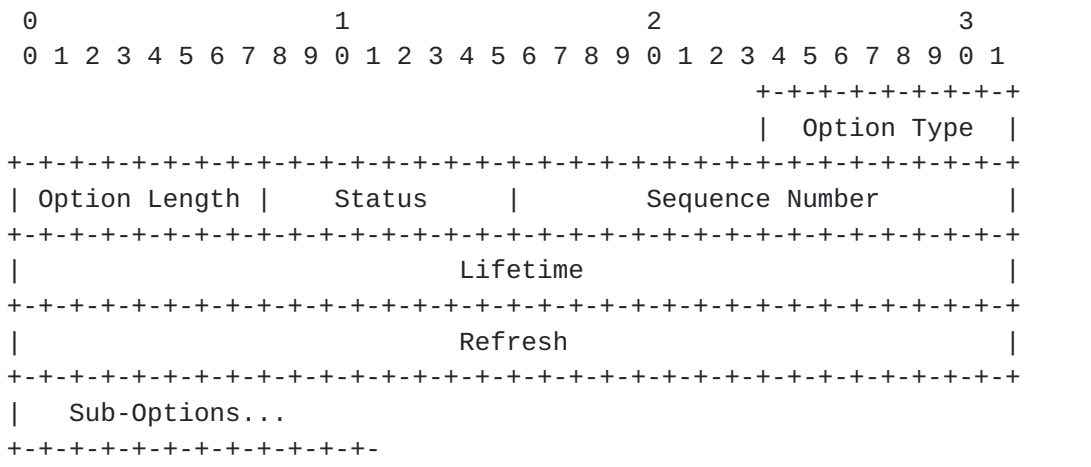
The last Sequence Number value sent to a destination in a Binding Update is stored by the mobile node in its Binding Update List entry for that destination; the last Sequence Number value received from a mobile node in a Binding Update is stored by a correspondent node in its Binding Cache entry for that mobile node. Thus, the mobile node's and the correspondent node's knowledge of the last sequence number expire at the same time. If the sending mobile node has no Binding Update List entry, the Sequence Number may start at any value; if the receiving correspondent node has no Binding Cache entry for the sending mobile node, it MUST accept any Sequence Number value in a received Binding Update from this mobile node.

The three highest-order bits of the Option Type are encoded to indicate specific processing of the option [6]. For the Binding Update option, these three bits are set to 110, indicating that any IPv6 node processing this option that does not recognize the Option Type must discard the packet and, only if the packet's Destination Address was not a multicast address, return an ICMP Parameter Problem, Code 2, message to the packet's Source Address; and that the data within the option cannot change en-route to the packet's final destination.

5.2. Binding Acknowledgement Option

The Binding Acknowledgement destination option is used to acknowledge receipt of a Binding Update option (Section 5.1). When a node receives a packet containing a Binding Update option, with this node being the destination of the packet (only the destination node processes the option since it is a destination option), this node MUST return a Binding Acknowledgement to the source of the packet, if the Acknowledge (A) bit is set in the Binding Update. As a destination option, this node MAY include the Binding Acknowledgement in any existing packet being sent to the mobile node or MAY send it in a packet by itself. A packet containing a Binding Acknowledgement is sent in the same way as any packet to a mobile node, using a Routing header to route the packet to the mobile node by way of the care-of address in the binding (Section 8.9).

The Binding Acknowledgement option is encoded in type-length-value (TLV) format as follows:



Option Type

7

Option Length

8-bit unsigned integer. Length of the option, in octets, excluding the Option Type and Option Length fields. This field MUST be set to 11 plus the total length of all sub-options present, including their Sub-Option Type and Sub-Option Len fields.

Status

8-bit unsigned integer indicating the disposition of the Binding Update. Values of the Status field less than 128

indicate that the Binding Update was accepted by the receiving node. The following such Status values are currently defined:

0 Binding Update accepted

Values of the Status field greater than or equal to 128 indicate that the Binding Update was rejected by the receiving node. The following such Status values are currently defined:

128 Reason unspecified
130 Administratively prohibited
131 Insufficient resources
132 Home registration not supported
133 Not home subnet
136 Incorrect interface identifier length
137 Not home agent for this mobile node
138 Duplicate Address Detection failed

Up-to-date values of the Status field are to be specified in the most recent "Assigned Numbers" [26].

Sequence Number

The Sequence Number in the Binding Acknowledgement is copied from the Sequence Number field in the Binding Update being acknowledged, for use by the mobile node in matching this Acknowledgement with an outstanding Binding Update.

Lifetime

The granted lifetime, in seconds, for which this node will attempt to retain the entry for this mobile node in its Binding Cache. If the node sending the Binding Acknowledgement is serving as the mobile node's home agent, the Lifetime period also indicates the period for which this node will continue this service; if the mobile node requires home agent service from this node beyond this period, the mobile node MUST send a new Binding Update to it before the expiration of this period (even if it is not changing its primary care-of address), in order to extend the lifetime. The value of this field is undefined if the Status field indicates that the Binding Update was rejected.

Refresh

The recommended interval, in seconds, at which the mobile node SHOULD send a new Binding Update to this node in order to "refresh" the mobile node's binding in this node's Binding Cache. This refreshing of the binding is useful in case the node fails and loses its cache state. The Refresh period is determined by the node sending the Binding Acknowledgement (the node caching the binding). If this node is serving as

the mobile node's home agent, the Refresh value may be set, for example, based on whether the node stores its Binding

Cache in volatile storage or in nonvolatile storage. If the node sending the Binding Acknowledgement is not serving as the mobile node's home agent, the Refresh period SHOULD be set equal to the Lifetime period in the Binding Acknowledgement; even if this node loses this cache entry due to a failure of the node, packets from it can still reach the mobile node through the mobile node's home agent, causing a new Binding Update to this node to allow it to recreate this cache entry. The value of this field is undefined if the Status field indicates that the Binding Update was rejected.

Sub-Options

Additional information, associated with this Binding Acknowledgement option, that need not be present in all Binding Acknowledgements sent. This use of sub-options also allows for future extensions to the format of the Binding Acknowledgement option to be defined. The encoding and format of defined sub-options are described in Section 5.5. Currently, no valid sub-options are defined for a Binding Acknowledgement option.

The alignment requirement [6] for the Binding Acknowledgement option is 4n+3.

Any packet that includes a Binding Acknowledgement option MUST be protected by IPsec [13] to guard against malicious Binding Acknowledgements. The specific requirements for this protection are defined in Section 4.4.

If the node returning the Binding Acknowledgement accepted the Binding Update for which the Acknowledgement is being returned (the value of the Status field in the Acknowledgement is less than 128), this node will have an entry for the mobile node in its Binding Cache and MUST use this entry (which includes the care-of address received in the Binding Update) in sending the packet containing the Binding Acknowledgement to the mobile node. The details of sending this packet to the mobile node are the same as for sending any packet to a mobile node using a binding, as are described in Section 8.9. The packet is sent using a Routing header, routing the packet to the mobile node by way of its care-of address recorded in the Binding Cache entry.

If the node returning the Binding Acknowledgement instead rejected the Binding Update (the value of the Status field in the Acknowledgement is greater than or equal to 128), this node MUST similarly use a Routing header in sending the packet containing the Binding Acknowledgement, as described in Section 8.9, but MUST NOT use its Binding Cache in forming the IP header or Routing header

in this packet. Rather, the care-of address used by this node in sending the packet containing the Binding Acknowledgement MUST be copied from the care-of address received in the rejected Binding

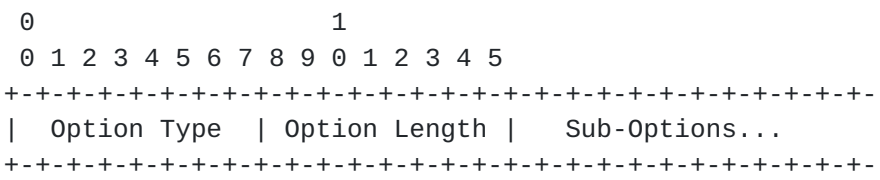
Update; this node MUST NOT modify its Binding Cache in response to receiving this rejected Binding Update and MUST ignore its Binding Cache in sending the packet in which it returns this Binding Acknowledgement. The packet is sent using a Routing header, routing the packet to the home address of the rejected Binding Update by way of the care-of address indicated in the packet containing the Binding Update. When sending a Binding Acknowledgement to reject a Binding Update, the Binding Acknowledgement MUST be sent in an IPv6 packet containing no payload (with the Next Header field in the last extension header in the packet set to indicate "No Next Header" [6]).

The three highest-order bits of the Option Type are encoded to indicate specific processing of the option [6]. For the Binding Acknowledgement option, these three bits are set to 000, indicating that any IPv6 node processing this option that does not recognize the Option Type must skip over this option and continue processing the header, and that the data within the option cannot change en-route to the packet's final destination.

5.3. Binding Request Option

The Binding Request destination option is used to request a mobile node's binding from the mobile node. As a destination option, it MAY be included in any existing packet being sent to the mobile node or MAY be sent in a packet by itself; a packet containing a Binding Request option is sent in the same way as any packet to a mobile node (Section 8.9). When a mobile node receives a packet containing a Binding Request option, it SHOULD return a Binding Update (Section 5.1) to the source of the Binding Request.

The Binding Request option is encoded in type-length-value (TLV) format as follows:



Option Type

8

Option Length

8-bit unsigned integer. Length of the option, in octets, excluding the Option Type and Option Length fields. This field MUST be set to 0 plus the total length of all sub-options present, including their Sub-Option Type and Sub-Option Len fields.

Sub-Options

Additional information, associated with this Binding Request option, that need not be present in all Binding Requests sent. This use of sub-options also allows for future extensions to the format of the Binding Request option to be defined. The encoding and format of defined sub-options are described in Section 5.5. The following sub-options are valid in a Binding Request option:

- Unique Identifier Sub-Option

There is no requirement for alignment [6] of the Binding Request option.

The three highest-order bits of the Option Type are encoded to indicate specific processing of the option [6]. For the Binding

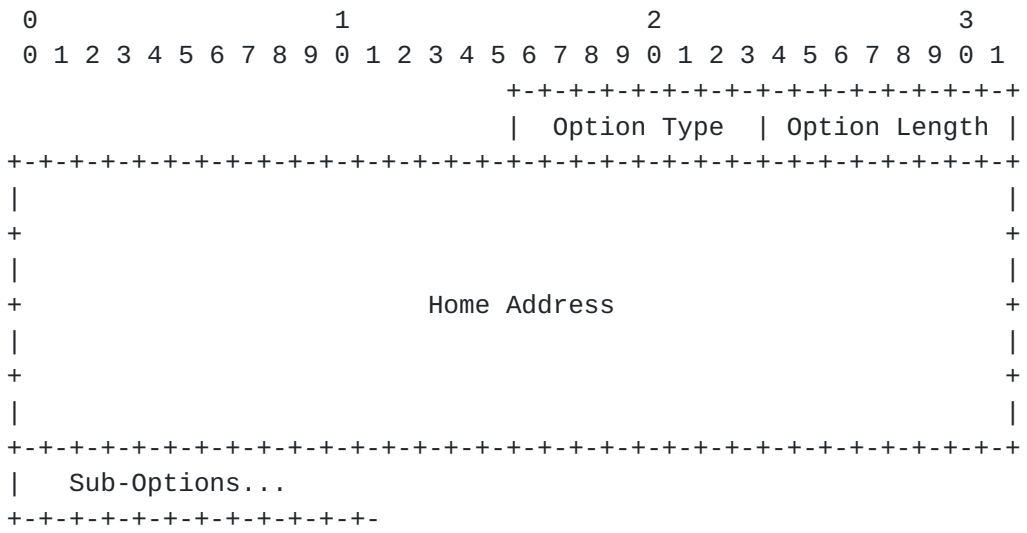
Request option, these three bits are set to 000, indicating that any IPv6 node processing this option that does not recognize the Option

Type must skip over this option and continue processing the header, and that the data within the option cannot change en-route to the packet's final destination.

5.4. Home Address Option

The Home Address destination option is used in a packet sent by a mobile node while away from home, to inform the recipient of that packet of the mobile node's home address. For packets sent by a mobile node while away from home, the mobile node generally uses one of its care-of addresses as the Source Address in the packet's IPv6 header. By including a Home Address option in the packet, the correspondent node receiving the packet is able to substitute the mobile node's home address for this care-of address when processing the packet, thus making the use of the care-of address transparent to the correspondent node.

The Home Address option is encoded in type-length-value (TLV) format as follows:



Option Type

201 = 0xC9

Option Length

8-bit unsigned integer. Length of the option, in octets, excluding the Option Type and Option Length fields. This field MUST be set to 16 plus the total length of all sub-options present, including their Sub-Option Type and Sub-Option Len fields.

Home Address

The home address of the mobile node sending the packet.

Sub-Options

Additional information, associated with this Home Address option, that need not be present in all Home Address options sent. This use of sub-options also allows for future extensions to the format of the Home Address option to be defined. The encoding and format of defined sub-options are described in Section 5.5. Currently, no valid sub-options are defined for use in a Home Address option.

The alignment requirement [6] for the Home Address option is 8n+6.

The inclusion of a Home Address option in a packet affects the receiving node's processing of only this single packet; no state is created or modified in the receiving node as a result of receiving a Home Address option in a packet. In particular, the presence of a Home Address option in a received packet MUST NOT alter the contents of the receiver's Binding Cache and MUST NOT cause any changes in the routing of subsequent packets sent by this receiving node.

The Home Address option MUST be placed as follows:

- After the Routing Header, if that header is present
- Before the Fragment Header, if that header is present
- Before the AH Header or ESP Header, if either one of those headers is present

No authentication of the Home Address option is required, except that if the IPv6 header of a packet is covered by authentication, then that authentication MUST also cover the Home Address option; this coverage is achieved automatically by the definition of the Option Type code for the Home Address option, since it indicates that the data within the option cannot change en-route to the packet's final destination, and thus the option is included in the authentication computation. By requiring that any authentication of the IPv6 header also cover the Home Address option, the security of the Source Address field in the IPv6 header is not compromised by the presence of a Home Address option. Security issues related to the Home Address option are discussed further in Section 13. When attempting to verify authentication data in a packet that contains a Home Address option, the receiving node MUST make the calculation as if the care-of address were present in the Home Address option, and the home address were present in the source IPv6 address field of the IPv6 header. This conforms with the calculation specified in section 10.2.

A packet MUST NOT contain more than one Home Address option, except

that an encapsulated packet [4] MAY contain a separate Home Address option associated with each encapsulating IP header.

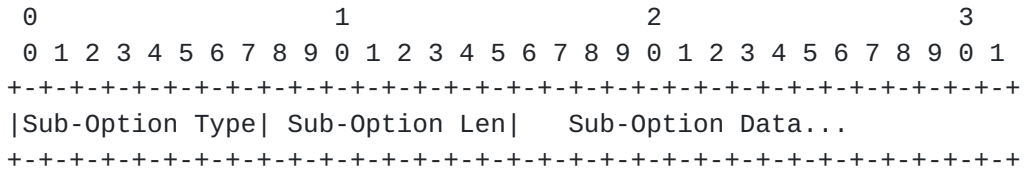
The three highest-order bits of the Option Type are encoded to indicate specific processing of the option [6]. For the Home Address option, these three bits are set to 110, indicating that any IPv6 node processing this option that does not recognize the Option Type must discard the packet and, only if the packet's Destination Address was not a multicast address, return an ICMP Parameter Problem, Code 2, message to the packet's Source Address; and that the data within the option cannot change en-route to the packet's final destination.

5.5. Mobile IPv6 Destination Option Sub-Options

In order to allow optional fields that may not be needed in every use of any given Mobile IPv6 destination option, and to allow future extensions to the format of these destination options to be defined, any of the Mobile IPv6 destination options defined in this document MAY include one or more sub-options.

Such sub-options are included in the data portion of the destination option itself, after the fixed portion of the option data specified for that particular destination option (Sections 5.1 through 5.4). The presence of such sub-options will be indicated by the Option Length field. When the Option Length is greater than the standard length defined for that destination option, the remaining octets are interpreted as sub-options.

These sub-options are encoded within the remaining space of the option data for that option, using a type-length-value (TLV) format as follows:



Sub-Option Type

8-bit identifier of the type of sub-option. When processing a Mobile IPv6 destination option containing a sub-option for which the Sub-Option Type value is not recognized by the receiver, the receiver SHOULD quietly ignore and skip over the sub-option, correctly handling any remaining sub-options in the option.

Sub-Option Length

8-bit unsigned integer. Length of the Sub-Option Data field of this sub-option, in octets. The Sub-Option Len does not include the length of the Sub-Option Type and Sub-Option Len fields.

Sub-Option Data

Variable-length field. Sub-Option-Type-specific data.

As with IPv6 options appearing in a Hop-by-Hop Options header or Destination Options header [6], individual sub-options within a Mobile IPv6 destination option may have specific alignment

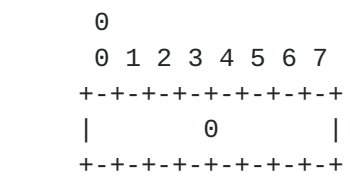
requirements, to ensure that multi-octet values within Sub-Option Data fields fall on natural boundaries. The alignment requirement

of each sub-option is specified as part of the definition of each sub-option below.

Each section above defining the Mobile IPv6 destination options specifies which of the defined sub-options is valid for that destination option. In addition, there are two padding sub-options, Pad1 and PadN (defined below), which are used when necessary to align subsequent sub-options. The Pad1 and PadN sub-options are valid for all Mobile IPv6 destination options. Unlike the padding options used in Hop-by-Hop Options header or Destination Options header [6], there is no requirement for padding the total size of any Mobile IPv6 destination option to a multiple of 8 octets in length, and the Pad1 and PadN sub-options SHOULD NOT be used for this purpose. All Mobile IPv6 sub-options defined in this document MUST be recognized by all Mobile IPv6 implementations.

Currently, the following sub-option types are defined for use in Mobile IPv6 destination options:

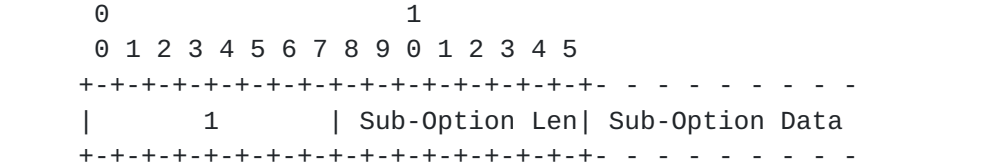
Pad1 Sub-Option (alignment requirement: none)



NOTE! the format of the Pad1 sub-option is a special case -- it does not have Sub-Option Len and Sub-Option Data fields.

The Pad1 sub-option is used to insert one octet of padding into the Sub-Options area of a Mobile IPv6 option. If more than one octet of padding is required, the PadN sub-option, described next, should be used, rather than multiple Pad1 sub-options.

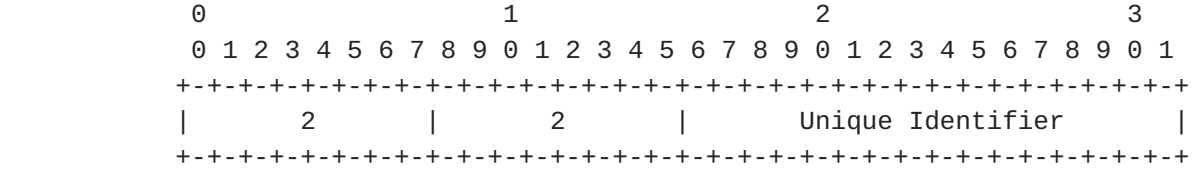
PadN Sub-Option (alignment requirement: none)



The PadN sub-option is used to insert two or more octets of padding into the Sub-Options area of a Mobile IPv6 option. For N octets of padding, the Sub-Option Len field contains the value N-2, and the Sub-Option Data consists of N-2

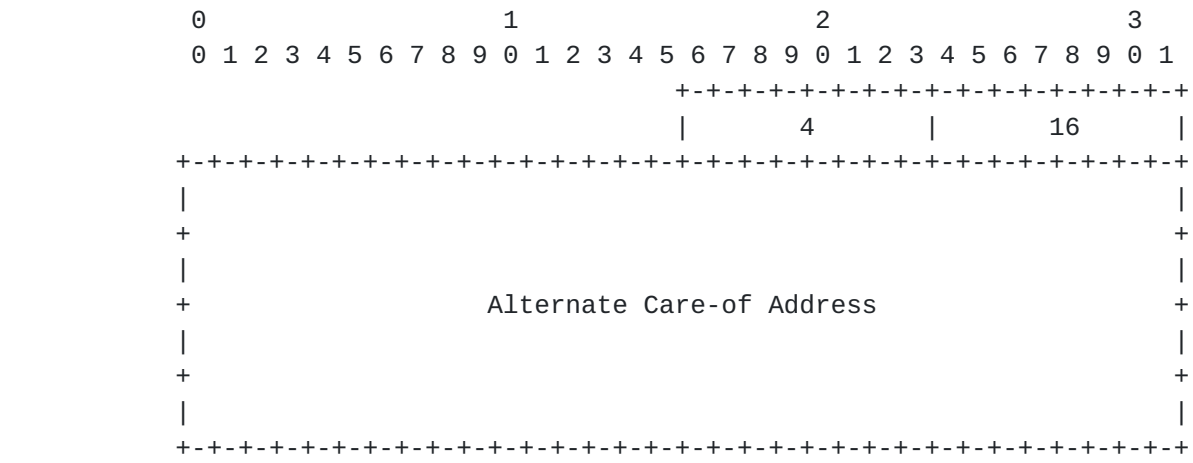
zero-valued octets.

Unique Identifier Sub-Option (alignment requirement: 2n)



The Unique Identifier sub-option is valid only in Binding Request and Binding Update destination options. The Unique Identifier field contains a 16-bit value that serves to uniquely identify a Binding Request among those sent by this Source Address, and to allow the Binding Update to identify the specific Binding Request to which it responds. This matching of Binding Updates to Binding Requests is required in the procedure for renumbering the home subnet while a mobile node is away from home (Section 9.8).

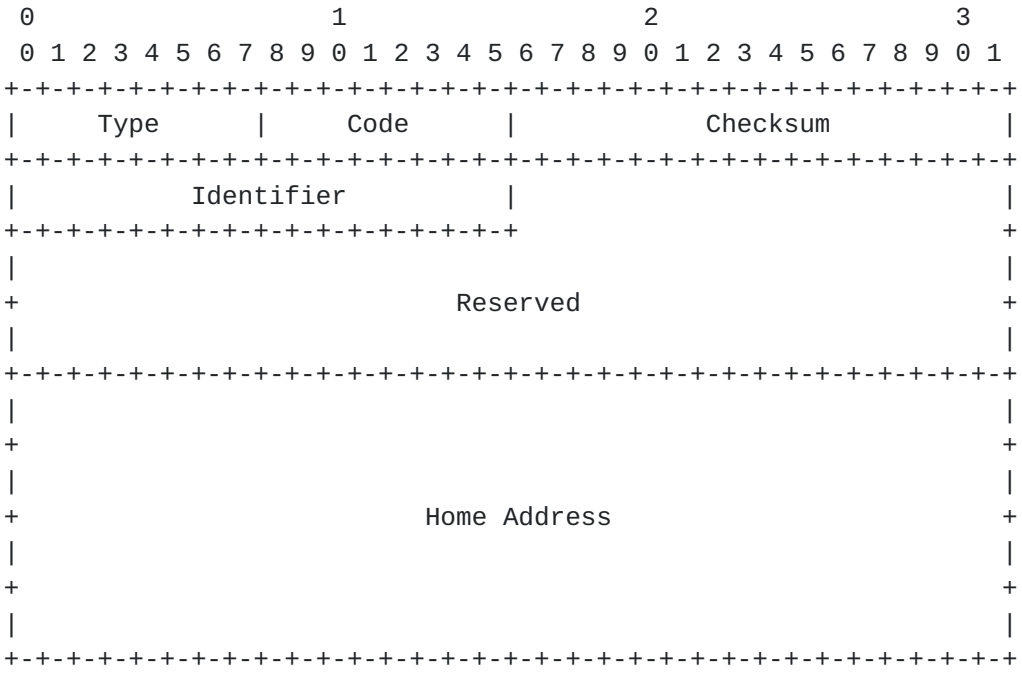
Alternate Care-of Address Sub-Option (alignment requirement: 8n+6)



The Alternate Care-of Address sub-option is valid only in Binding Update destination options. The Alternate Care-of Address field contains an address to use as the care-of address for the binding, rather than using the Source Address of the packet as the care-of address.

5.6. ICMP Home Agent Address Discovery Request Message

The ICMP Home Agent Address Discovery Request message is used by a mobile node to initiate the dynamic home agent address discovery mechanism, as described in Sections 9.2 and 10.7. The mobile node sends a Home Agent Address Discovery Request message to the "Mobile IPv6 Home-Agents" anycast address for its own home subnet prefix [10], and one of the home agents there responds to the mobile node with a Home Agent Address Discovery Reply message giving a list of the routers on the mobile node's home link serving as home agents.



Type

<To Be Assigned by IANA>

Code

0

Checksum

The ICMP checksum [5].

Identifier

An identifier to aid in matching Home Agent Address Discovery Reply messages to this Home Agent Address Discovery Request message.

Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

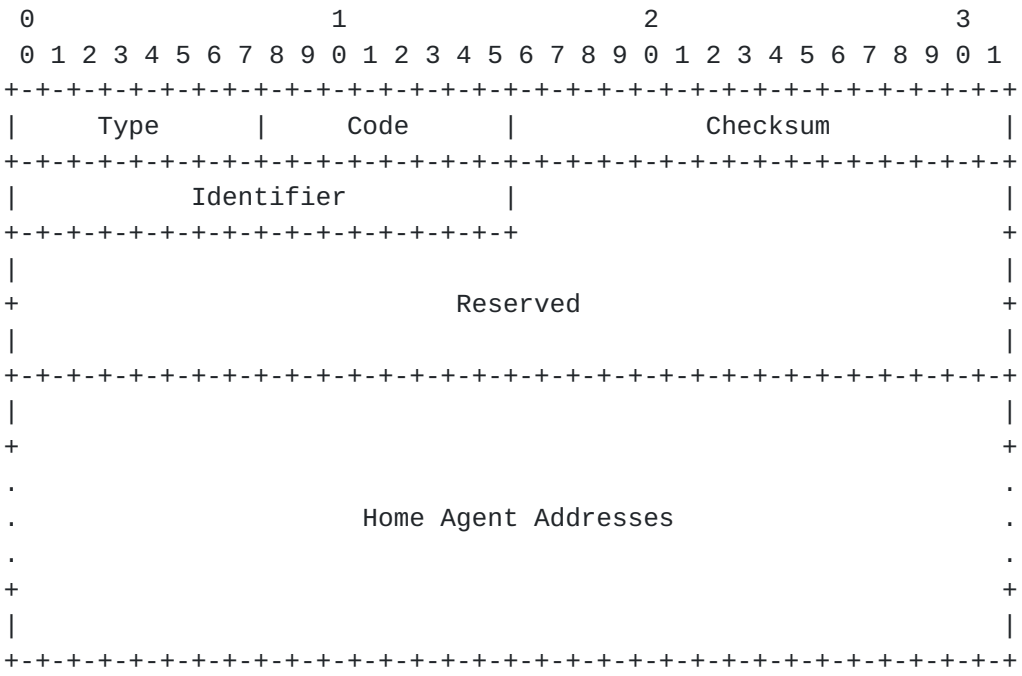
Home Address

The home address of the mobile node sending the Home Agent Address Discovery Request message.

The Source Address of the Home Agent Address Discovery Request message packet MUST be one of the mobile node's current care-of addresses, and the mobile node MUST NOT include a Home Address option in this packet; the home agent then MUST return the Home Agent Address Discovery Reply message directly to this care-of address. These restrictions are necessary, since at the time of performing this dynamic home agent address discovery, the mobile node is generally not registered with its home agent; using the mobile node's care-of address simplifies the return of the Reply message to the mobile node.

5.7. ICMP Home Agent Address Discovery Reply Message

The ICMP Home Agent Address Discovery Reply message is used by a home agent to respond to a mobile node using the dynamic home agent address discovery mechanism, as described in Sections 9.2 and 10.7. The mobile node sends a Home Agent Address Discovery Request message to the "Mobile IPv6 Home-Agents" anycast address for its own home subnet prefix [10], and one of the home agents there responds to the mobile node with a Home Agent Address Discovery Reply message giving a list of the routers on the mobile node's home link serving as home agents.



Type

<To Be Assigned by IANA>

Code

0

Checksum

The ICMP checksum [5].

Identifier

The identifier from the invoking Home Agent Address Discovery Request message.

Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

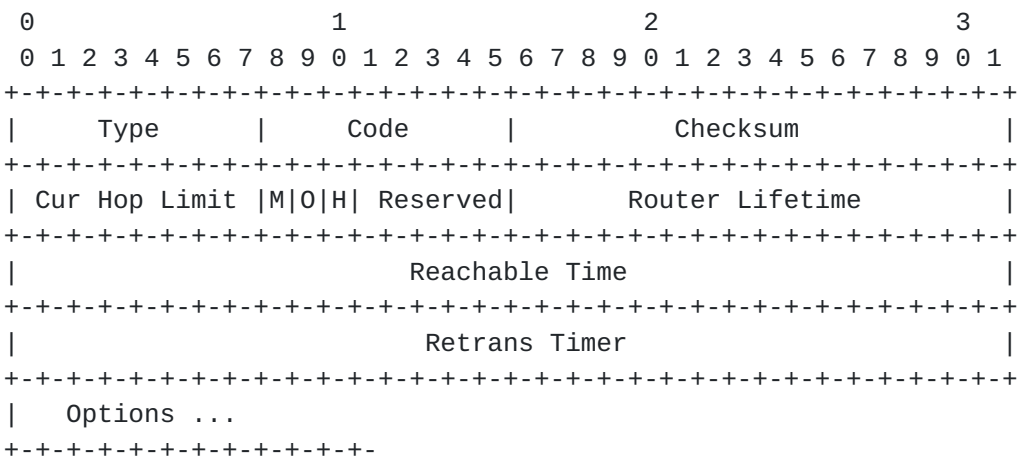
Home Agent Addresses

A list of addresses of home agents on the home link for the mobile node. The number of addresses present in the list is indicated by the remaining length of the IPv6 packet carrying the Home Agent Address Discovery Reply message.

6. Modifications to IPv6 Neighbor Discovery

6.1. Modified Router Advertisement Message Format

Mobile IPv6 modifies the format of the Router Advertisement message [17] by the addition of a single flag bit to indicate that the router sending the Advertisement message is serving as a home agent on this link. The format of the Router Advertisement message is as follows:



This format represents the following changes over that originally specified for Neighbor Discovery [17]:

Home Agent (H)

The Home Agent (H) bit is set in a Router Advertisement to indicate that the router sending this Router Advertisement is also functioning as a Mobile IP home agent on this link.

Reserved

Reduced from a 6-bit field to a 5-bit field to account for the addition of the Home Agent (H) bit.

6.2. Modified Prefix Information Option Format

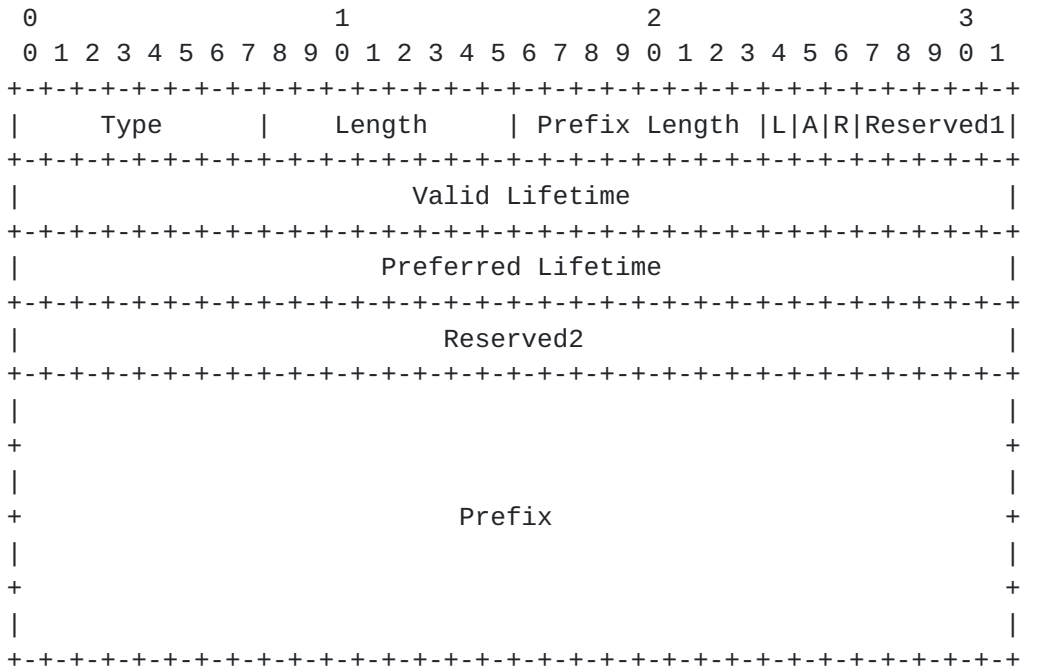
Mobile IPv6 requires knowledge of a router's global address for two reasons:

- To allow a home agent (a router) to learn the address of all other home agents on the link for which it is providing home agent service, for use in building its Home Agents List as part of the dynamic home agent address discovery mechanism (Sections 9.2 and 10.7).

- To allow a mobile node to send a Binding Update to a router on the link on which its previous care-of address is located, for purposes of establishing forwarding from this previous care-of address to its new care-of address (Section 10.9).

However, Neighbor Discovery [17] only advertises a router's link-local address, by requiring this address to be used as the IP Source Address of each Router Advertisement.

Mobile IPv6 extends Neighbor Discovery to allow a router to easily and efficiently advertise its global address, by the addition of a single flag bit in the format of a Prefix Information option for use in Router Advertisement messages. The format of the Prefix Information option is as follows:



This format represents the following changes over that originally specified for Neighbor Discovery [17]:

Router Address (R)

1-bit router address flag. When set, indicates that the Prefix field, in addition to advertising the indicated prefix, contains a complete IP address assigned to the sending router. This router IP address has the same scope and conforms to the same lifetime values as the advertised prefix. This use of the Prefix field is compatible with its use in advertising the prefix itself, since prefix advertisement uses only the leading number Prefix bits specified by the Prefix Length field. Interpretation of this flag bit is thus independent of the processing required for the On-Link (L) and Autonomous Address-Configuration (A) flag bits.

Reserved1

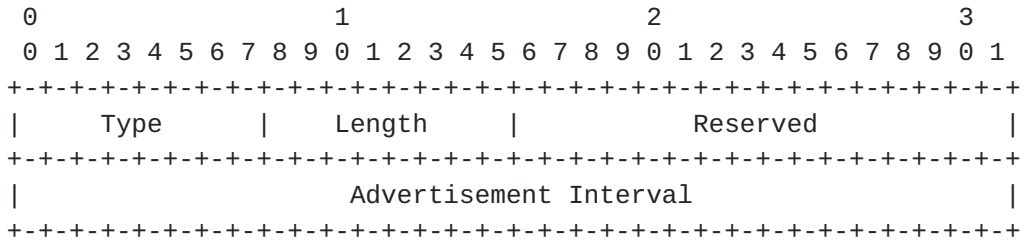
Reduced from a 6-bit field to a 5-bit field to account for the addition of the Router Address (R) bit.

In a solicited Router Advertisement, a router MUST include at least one Prefix Information option with the Router Address (R) bit set. Neighbor Discovery specifies that, if including all options in a Router Advertisement causes the size of the Advertisement to exceed the link MTU, multiple Advertisements can be sent, each containing a subset of the options [17]. In this case, at least one of these multiple Advertisements being sent instead of a single larger solicited Advertisement, MUST include a Prefix Information option with the Router Address (R) bit set.

All routers SHOULD include at least one Prefix Information option with the Router Address (R) bit set, in each unsolicited multicast Router Advertisement that they send. If multiple Advertisements are being sent instead of a single larger unsolicited multicast Advertisement, at least one of these multiple Advertisements SHOULD include a Prefix Information option with the Router Address (R) bit set.

6.3. New Advertisement Interval Option Format

Mobile IPv6 defines a new Advertisement Interval option, used in Router Advertisement messages to advertise the interval at which the sending router sends unsolicited multicast Router Advertisements. The format of the Advertisement Interval option is as follows:



Type

7

Length

8-bit unsigned integer. The length of the option (including the type and length fields) in units of 8 octets. The value of this field MUST be 1.

Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

Advertisement Interval

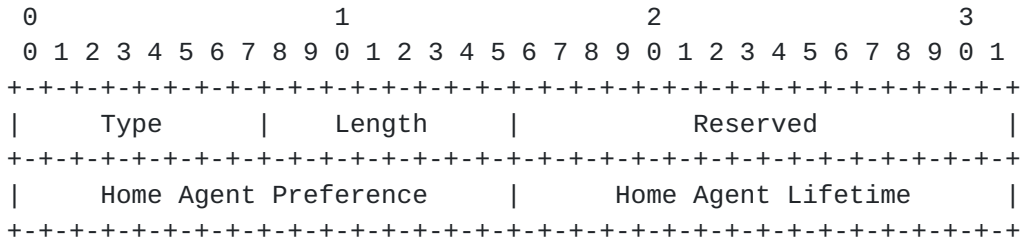
32-bit unsigned integer. The maximum time, in milliseconds, between successive unsolicited router Router Advertisement messages sent by this router on this network interface. Using the conceptual router configuration variables defined by Neighbor Discovery [17], this field MUST be equal to the value MaxRtrAdvInterval, expressed in milliseconds.

Routers MAY include this option in their Router Advertisements. A mobile node receiving a Router Advertisement containing this option SHOULD utilize the specified Advertisement Interval for that router in its movement detection algorithm, as described in Section 10.4.

This option MUST be silently ignored for other Neighbor Discovery messages.

6.4. New Home Agent Information Option Format

Mobile IPv6 defines a new Home Agent Information option, used in Router Advertisement messages sent by a home agent to advertise information specific to this router's functionality as a home agent. The format of the Home Agent Information option is as follows:



Type

8

Length

8-bit unsigned integer. The length of the option (including the type and length fields) in units of 8 octets. The value of this field MUST be 1.

Reserved

This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

Home Agent Preference

16-bit signed, twos-complement integer. The preference for the home agent sending this Router Advertisement, for use in ordering the addresses returned to a mobile node in the Home Agent Addresses field of a Home Agent Address Discovery Reply message. Higher values mean more preferable. If this option is not included in a Router Advertisement in which the Home Agent (H) bit is set, the preference value for this home agent SHOULD be considered to be 0. Values greater than 0 indicate a home agent more preferable than this default value, and values less than 0 indicate a less preferable home agent.

The manual configuration of the Home Agent Preference value is described in Section 7.3. In addition, the sending home agent MAY dynamically set the Home Agent Preference value, for example basing it on the number of mobile nodes it is currently serving or on its remaining resources for serving additional mobile nodes; such dynamic settings are beyond the scope of

this document. Any such dynamic setting of the Home Agent Preference, however, MUST set the preference appropriately,

relative to the default Home Agent Preference value of 0 that may be in use by some home agents on this link (i.e., a home agent not including a Home Agent Information option in its Router Advertisements will be considered to have a Home Agent Preference value of 0).

Home Agent Lifetime

16-bit unsigned integer. The lifetime associated with the home agent in units of seconds. The maximum value corresponds to 18.2 hours. A value of 0 MUST NOT be used. The Home Agent Lifetime applies only to this router's usefulness as a home agent; it does not apply to information contained in other message fields or options. If this option is not included in a Router Advertisement in which the Home Agent (H) bit is set, the lifetime for this home agent MUST be considered to be the same as the Router Lifetime specified in the main body of the Router Advertisement message.

Home agents MAY include this option in their Router Advertisements. This option MUST NOT be included in a Router Advertisement in which the Home Agent (H) bit (see Section 6.1) is not set.

This option MUST be silently ignored for other Neighbor Discovery messages.

If both the Home Agent Preference and Home Agent Lifetime are set to their default values specified above, this option SHOULD NOT be included in the Router Advertisement messages sent by this home agent.

6.5. Changes to Sending Router Advertisements

The Neighbor Discovery protocol specification [17] limits routers to a minimum interval of 3 seconds between sending unsolicited multicast Router Advertisement messages from any given network interface (limited by MinRtrAdvInterval and MaxRtrAdvInterval), stating that:

> "Routers generate Router Advertisements frequently enough that hosts will learn of their presence within a few minutes, but not frequently enough to rely on an absence of advertisements to detect router failure; a separate Neighbor Unreachability Detection algorithm provides failure detection."

This limitation, however, is not suitable to providing timely movement detection for mobile nodes. Mobile nodes detect their own movement by learning the presence of new routers as the mobile node moves into wireless transmission range of them (or physically connects to a new wired network), and by learning that previous routers are no longer reachable. Mobile nodes MUST be able to quickly detect when they move to a link served by a new router, so that they can acquire a new care-of address and send Binding Updates to register this care-of address with their home agent and to notify correspondent nodes as needed.

Thus, to provide good support for mobile nodes, Mobile IPv6 relaxes this limit such that routers MAY send unsolicited multicast Router Advertisements more frequently. In particular, on network interfaces where the router is expecting to provide service to visiting mobile nodes (e.g., wireless network interfaces), or on which it is serving as a home agent to one or more mobile nodes (who may return home and need to hear its Advertisements), the router SHOULD be configured with a smaller MinRtrAdvInterval value and MaxRtrAdvInterval value, to allow sending of unsolicited multicast Router Advertisements more often. Recommended values for these limits are:

- MinRtrAdvInterval 0.5 seconds

- MaxRtrAdvInterval 1.5 seconds

Use of these modified limits MUST be configurable, and specific knowledge of the type of network interface in use SHOULD be taken into account in configuring these limits for each network interface.

When sending unsolicited multicast Router Advertisements more frequently than the standard limit on unsolicited multicast Advertisement frequency, the sending router need not include all options in each of these Advertisements, but it SHOULD include at least one Prefix Information option with the Router Address (R) bit

set (Section 6.2) in each.

6.6. Changes to Sending Router Solicitations

In addition to the limit on routers sending unsolicited multicast Router Advertisement messages (Section 6.5), Neighbor Discovery defines limits on nodes sending Router Solicitation messages, such that a node SHOULD send no more than 3 Router Solicitations, and that these 3 transmissions SHOULD be spaced at least 4 seconds apart. However, these limits prevent a mobile node from finding a new default router (and thus a new care-of address) quickly as it moves about.

Mobile IPv6 relaxes this limit such that, while a mobile node is away from home, it MAY send Router Solicitations more frequently. The following limits for sending Router Solicitations are recommended for mobile nodes while away from home:

- A mobile node that is not configured with any current care-of address (e.g., the mobile node has moved since its previous care-of address was configured), MAY send more than the defined Neighbor Discovery limit of MAX_RTR_SOLICITATIONS Router Solicitations.

- The rate at which a mobile node sends Router Solicitations MUST be limited, although a mobile node MAY send Router Solicitations more frequently than the defined Neighbor Discovery limit of RTR_SOLICITATION_INTERVAL seconds. The minimum interval MUST be configurable, and specific knowledge of the type of network interface in use SHOULD be taken into account in configuring this limit for each network interface. A recommended minimum interval is 1 second.

- After sending at most MAX_RTR_SOLICITATIONS Router Solicitations, a mobile node MUST reduce the rate at which it sends subsequent Router Solicitations. Subsequent Router Solicitations SHOULD be sent using a binary exponential backoff mechanism, doubling the interval between consecutive Router Solicitations, up to a maximum interval. The maximum interval MUST be configurable and SHOULD be chosen appropriately based on the characteristics of the type of network interface in use.

- While still searching for a new default router and care-of address, a mobile node MUST NOT increase the rate at which it sends Router Solicitations unless it has received a positive indication (such as from lower network layers) that it has moved to a new link. After successfully acquiring a new care-of address, the mobile node SHOULD also increase the rate at which it will send Router Solicitations when it next begins searching for a new default router and care-of address.

- A mobile node that is currently configured with a care-of address SHOULD NOT send Router Solicitations to the default router

on it current link, until its movement detection algorithm (Section 10.4) determines that it has moved and that its current care-of address might no longer be valid.

7. Requirements for Types of IPv6 Nodes

Mobile IPv6 places some special requirements on the functions provided by different types of IPv6 nodes. This section summarizes those requirements, identifying the functionality each requirement is intended to support. Further details on this functionality is provided in the following sections.

7.1. Requirements for All IPv6 Hosts and Routers

Since any IPv6 node may at any time be a correspondent node of a mobile node, either sending a packet to a mobile node or receiving a packet from a mobile node, the following requirements apply to ALL IPv6 nodes (whether host or router, whether mobile or stationary):

- Every IPv6 node MUST be able to process a Home Address option received in any IPv6 packet.

- Every IPv6 node SHOULD be able to process a Binding Update option received in a packet, and to return a Binding Acknowledgement option if the Acknowledge (A) bit is set in the received Binding Update.

- Every IPv6 node SHOULD be able to maintain a Binding Cache of the bindings received in accepted Binding Updates.

7.2. Requirements for All IPv6 Routers

The following requirements apply to all IPv6 routers, even those not serving as a home agent for Mobile IPv6:

- Every IPv6 router SHOULD be able to send an Advertisement Interval option in its Router Advertisements, to aid movement detection by mobile nodes. The use of this option in Router Advertisements MUST be configurable.

- Every IPv6 router SHOULD be able to support sending unsolicited multicast Router Advertisements at the faster rate described in Section 6.5. The use of this faster rate MUST be configurable.

7.3. Requirements for IPv6 Home Agents

In order for a mobile node to operate correctly while away from home, at least one IPv6 router on the mobile node's home link must function as a home agent for the mobile node. The following additional requirements apply to all IPv6 routers capable of serving as a home

agent:

- Every home agent MUST be able to maintain an entry in its Binding Cache for each mobile node for which it is serving as the home agent. Each such Binding Cache entry records the mobile node's binding with its primary care-of address and is marked as a "home registration".

- Every home agent MUST be able to intercept packets (using proxy Neighbor Discovery) addressed to a mobile node for which it is currently serving as the home agent, on that mobile node's home link, while the mobile node is away from home.

- Every home agent MUST be able to encapsulate such intercepted packets in order to tunnel them to the primary care-of address for the mobile node indicated in its binding in the home agent's Binding Cache.

- Every home agent MUST be able to return a Binding Acknowledgement option in response to a Binding Update option received with the Acknowledge (A) bit set.

- Every home agent MUST maintain a separate Home Agents List for each link on which it is serving as a home agent, as described in Section 4.6.

- Every home agent MUST be able to accept packets addressed to the "Mobile IPv6 Home-Agents" anycast address for the subnet on which it is serving as a home agent [10], and MUST be able to participate in dynamic home agent address discovery (Section 9.2).

- Every home agent SHOULD support a configuration mechanism to allow a system administrator to manually set the value to be sent by this home agent in the Home Agent Preference field of the Home Agent Information Option in Router Advertisements that it sends.

7.4. Requirements for IPv6 Mobile Nodes

Finally, the following requirements apply to all IPv6 nodes capable of functioning as mobile nodes:

- Every IPv6 mobile node MUST be able to perform IPv6 decapsulation [4].

- Every IPv6 mobile node MUST support sending Binding Update options, as specified in Sections 10.6, 10.8, and 10.9; and MUST be able to receive and process Binding Acknowledgement options, as specified in Section 10.12.

- Every IPv6 mobile node MUST support use of the dynamic home agent address discovery mechanism, as described in Section 10.7.

- Every IPv6 mobile node MUST maintain a Binding Update List in which it records the IP address of each other node to which it has sent a Binding Update, for which the Lifetime sent in that binding has not yet expired.

- Every IPv6 mobile node MUST support receiving a Binding Request option, by responding with a Binding Update option.

- Every IPv6 mobile node MUST support sending packets containing a Home Address option; this option MUST be included in all packets sent while away from home, if the packet would otherwise have been sent with the mobile node's home address as the IP Source Address.

- Every IPv6 mobile node MUST maintain a Home Agents List, as described in Section 4.6.

8. Correspondent Node Operation

A correspondent node is any node communicating with a mobile node. The correspondent node, itself, may be stationary or mobile, and may possibly also be functioning as a home agent for Mobile IPv6. The procedures in this section thus apply to all IPv6 nodes.

8.1. Receiving Packets from a Mobile Node

Packets sent by a mobile node while away from home generally include a Home Address option. When any node receives a packet containing a Home Address option, it MUST process the option in a manner consistent with exchanging the Home Address field from the Home Address option into the IPv6 header, replacing the original value of the Source Address field there. However, any actual modifications to the Source Address field in the packet's IPv6 header MUST not be performed until after all processing of other options contained in the same Destination Options extension header is completed. Currently, no other such options are defined.

Further processing of such a packet after all IPv6 options processing (e.g., at the transport layer) thus does not need to know that the original Source Address was a care-of address, or that the Home Address option was used in the packet. Since the sending mobile node uses its home address at the transport layer when sending such a packet, the use of the care-of address and Home Address option is transparent to both the mobile node and the correspondent node above the level of the Home Address option generation and processing.

8.2. Receiving Binding Updates

Upon receiving a Binding Update option in some packet, the receiving node MUST validate the Binding Update according to the following tests:

- The packet meets the specific IPsec requirements for Binding Updates, defined in Section 4.4.

- The packet MUST contain a Home Address option.

- The Option Length field in the Binding Update option is greater than or equal to the length specified in Section 5.1.

- The Sequence Number field in the Binding Update option is greater than the Sequence Number received in the previous Binding Update for this home address, if any. As noted in Section 4.6, this Sequence Number comparison MUST be performed modulo 2**16.

Any Binding Update not satisfying all of these tests MUST be silently ignored, and the packet carrying the Binding Update MUST be discarded.

In this section, the care-of address refers to the IPv6 address, which was originally located in the IPv6 header when the packet was transmitted by the mobile node.

If the Binding Update is valid according to the tests above, then the Binding Update is processed further as follows:

- If the Lifetime specified in the Binding Update is nonzero and the specified Care-of Address is not equal to the home address for the binding, then this is a request to cache a binding for the mobile node. If the Home Registration (H) bit is set in the Binding Update, the Binding Update is processed according to the procedure specified in Section 9.3; otherwise, it is processed according to the procedure specified in Section 8.3.

- If the Lifetime specified in the Binding Update is zero or the specified Care-of Address matches the home address for the binding, then this is a request to delete the mobile node's cached binding. If the Home Registration (H) bit is set in the Binding Update, the Binding Update is processed according to the procedure specified in Section 9.4; otherwise, it is processed according to the procedure specified in Section 8.4.

8.3. Requests to Cache a Binding

When a node receives a Binding Update, it MUST validate it and determine the type of Binding Update according to the steps described in Section 8.2. This section describes the processing of a valid Binding Update that requests a node to cache a mobile node's binding, for which the Home Registration (H) bit is not set in the Binding Update.

In this case, the receiving node SHOULD create a new entry in its Binding Cache for this mobile node (or update its existing Binding Cache entry for this mobile node, if such an entry already exists). The new Binding Cache entry records the association between this home address and the care-of address for the binding. The lifetime for the Binding Cache entry is initialized from the Lifetime field specified in the Binding Update, although this lifetime MAY be reduced by the node caching the binding; the lifetime for the Binding Cache entry MUST NOT be greater than the Lifetime value specified in the Binding Update. Any Binding Cache entry MUST be deleted after the expiration of this lifetime in the Binding Cache entry.

8.4. Requests to Delete a Binding

When a node receives a Binding Update, it MUST validate it and determine the type of Binding Update according to the steps described in Section 8.2. This section describes the processing of a valid Binding Update that requests a node to delete a mobile node's binding from its Binding Cache, for which the Home Registration (H) bit is not set in the Binding Update. In this case, the receiving node MUST delete any existing entry in its Binding Cache for this mobile node.

8.5. Sending Binding Acknowledgements

When any node receives a packet containing a Binding Update option in which the Acknowledge (A) bit is set, it MUST return a Binding Acknowledgement option acknowledging receipt of the Binding Update. If the node accepts the Binding Update and creates or updates an entry in its Binding Cache for this binding, and the `A' bit was set in the Binding Update, the Status field in the Binding Acknowledgement MUST be set to a value less than 128; if, on the other hand the Binding Update is accepted and the `A' bit is not set, the node SHOULD NOT send a Binding Acknowledgement. If the node rejects the Binding Update and does not create or update an entry for this binding, a Binding Acknowledgement MUST be sent even if the `A' bit was not sent, and the Status field in the Binding Acknowledgement MUST be set to a value greater than or equal to 128. Specific values for the Status field are described in Section 5.2 and in the most recent "Assigned Numbers" [26].

The packet in which the Binding Acknowledgement is returned MUST meet the specific IPsec requirements for Binding Acknowledgements, defined in Section 4.4; and the packet MUST be sent using a Routing header in the same way as any other packet sent to a mobile node using a care-of address (even if the binding was rejected), as described in Section 8.9.

8.6. Sending Binding Requests

Entries in a node's Binding Cache MUST be deleted when their lifetime expires. If such an entry is still in active use in sending packets to a mobile node, the next packet sent to the mobile node will be routed normally to the mobile node's home link, where it will be intercepted and tunneled to the mobile node. The mobile node will then return a Binding Update to the sender, allowing it to create a new Binding Cache entry for sending future packets to the mobile node. Communication with the mobile node continues uninterrupted, but the forwarding of this packet through the mobile node's home agent creates additional overhead and latency in delivering packets

to the mobile node.

If the sender knows that the Binding Cache entry is still in active use, it MAY send a Binding Request option to the mobile node in an attempt to avoid this overhead and latency due to deleting and recreating the Binding Cache entry. Since a Binding Request is a destination option, it may, for example, be included in any packet already being sent to the mobile node, such as a packet that is part of ongoing TCP communication with the mobile node. When the mobile node receives a packet from some sender containing a Binding Request option, it returns a Binding Update option to that sender, giving its current binding and a new lifetime.

8.7. Cache Replacement Policy

Any entry in a node's Binding Cache MUST be deleted after the expiration of the Lifetime specified in the Binding Update from which the entry was created or last updated. Conceptually, a node maintains a separate timer for each entry in its Binding Cache. When creating or updating a Binding Cache entry in response to a received and accepted Binding Update, the node sets the timer for this entry to the specified Lifetime period. When a Binding Cache entry's timer expires, the node deletes the entry.

Each node's Binding Cache will, by necessity, have a finite size. A node MAY use any reasonable local policy for managing the space within its Binding Cache, except that any entry marked as a "home registration" (Section 9.3) MUST NOT be deleted from the cache until the expiration of its lifetime period. When attempting to add a new "home registration" entry in response to a Binding Update with the Home Registration (H) bit set, if insufficient space exists (and sufficient space cannot be reclaimed) in the node's Binding Cache, the node MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the sending mobile node, in which the Status field is set to 131 (insufficient resources). When otherwise attempting to add a new entry to its Binding Cache, a node MAY, if needed, choose to drop any entry already in its Binding Cache, other than a "home registration" entry, in order to make space for the new entry. For example, a "least-recently used" (LRU) strategy for cache entry replacement among entries not marked as a "home registration" is likely to work well.

Any binding dropped from a node's Binding Cache due to lack of cache space will be rediscovered and a new cache entry created, if the binding is still in active use by the node for sending packets. If the node sends a packet to a destination for which it has dropped the entry from its Binding Cache, the packet will be routed normally, leading to the mobile node's home link. There, the packet will be intercepted by the mobile node's home agent and tunneled to the

mobile node's current primary care-of address. As when a Binding Cache entry is initially created, this indirect routing to the mobile node through its home agent will result in the mobile node sending

a Binding Update to this sending node when it receives the tunneled packet, allowing it to add an entry again for this destination mobile node to its Binding Cache.

8.8. Receiving ICMP Error Messages

When a correspondent node sends a packet to a mobile node, if the correspondent node has a Binding Cache entry for the destination address of the packet, then the correspondent node uses a Routing header to deliver the packet to the mobile node through the care-of address in the binding recorded in the Binding Cache entry. Any ICMP error message caused by the packet on its way to the mobile node will be returned normally to the correspondent node.

On the other hand, if the correspondent node has no Binding Cache entry for the mobile node, the packet will be routed to the mobile node's home link. There, it will be intercepted by the mobile node's home agent, encapsulated, and tunneled to the mobile node's primary care-of address. Any ICMP error message caused by the packet on its way to the mobile node while in the tunnel, will be transmitted to the mobile node's home agent (the source of the tunnel). By the definition of IPv6 encapsulation [4], this encapsulating node MUST relay certain ICMP error messages back to the original sender of the packet, which in this case is the correspondent node.

Likewise, if a packet for a mobile node arrives at the mobile node's previous link and is intercepted there by a home agent for the mobile node's previous care-of address as described in Section 10.9 (e.g., the mobile node moved after the packet was sent), that home agent will encapsulate and tunnel the packet to the mobile node's new care-of address. As above, any ICMP error message caused by the packet while in this tunnel will be returned to that home agent (the source of the tunnel), which MUST relay certain ICMP error messages back to the correspondent node [4].

Thus, in all cases, any meaningful ICMP error messages caused by packets from a correspondent node to a mobile node will be returned to the correspondent node. If the correspondent node receives persistent ICMP Destination Unreachable messages after sending packets to a mobile node based on an entry in its Binding Cache, the correspondent node SHOULD delete this Binding Cache entry. If the correspondent node subsequently transmits another packet to the mobile node, the packet will be routed to the mobile node's home link, intercepted by the mobile node's home agent, and tunneled to the mobile node's primary care-of address using IPv6 encapsulation. The mobile node will then return a Binding Update to the correspondent node, allowing it to recreate a (correct) Binding

Cache entry for the mobile node.

8.9. Sending Packets to a Mobile Node

Before sending any packet, the sending node SHOULD examine its Binding Cache for an entry for the destination address to which the packet is being sent. If the sending node has a Binding Cache entry for this address, the sending node SHOULD use a Routing header to route the packet to this mobile node (the destination node) by way of the care-of address in the binding recorded in that Binding Cache entry. For example, assuming use of a Type 0 Routing header [6], if no other use of a Routing header is involved in the routing of this packet, the mobile node sets the fields in the packet's IPv6 header and Routing header as follows:

- The Destination Address in the packet's IPv6 header is set to the mobile node's care-of address copied from the Binding Cache entry.

- The Routing header is initialized to contain a single route segment, with an Address of the mobile node's home address (the original destination address to which the packet was being sent).

Following the definition of a Type 0 Routing header [6], this packet will be routed to the mobile node's care-of address, where it will be delivered to the mobile node (the mobile node has associated the care-of address with its network interface). Normal processing of the Routing header by the mobile node will then proceed as follows:

- The mobile node swaps the Destination Address in the packet's IPv6 header and the Address specified in the Routing header. This results in the packet's IP Destination Address being set to the mobile node's home address.

- The mobile node then resubmits the packet to its IPv6 module for further processing, "looping back" the packet inside the mobile node. Since the mobile node recognizes its own home address as one of its current IP addresses, the packet is processed further within the mobile node, in the same way then as if the mobile node was at home.

If, instead, the sending node has no Binding Cache entry for the destination address to which the packet is being sent, the sending node simply sends the packet normally, with no Routing header. If the destination node is not a mobile node (or is a mobile node that is currently at home), the packet will be delivered directly to this node and processed normally by it. If, however, the destination node is a mobile node that is currently away from home, the packet will be intercepted by the mobile node's home agent and tunneled (using IPv6 encapsulation [4]) to the mobile node's current primary care-of

address, as described in Section 9.6. The mobile node will then send a Binding Update to the sending node, as described in Section 10.8,

allowing the sending node to create a Binding Cache entry for its use in sending subsequent packets to this mobile node.

9. Home Agent Operation

9.1. Receiving Router Advertisement Messages

For each link on which a router provides service as a home agent, the router maintains a Home Agents List recording information about all other home agents on that link. This list is used in the dynamic home agent address discovery mechanism, described in Section 9.2. The information for the list is learned through receipt of the periodic unsolicited multicast Router Advertisements from each other home agent on the link, in which the Home Agent (H) bit is set, in a manner similar to the Default Router List conceptual data structure maintained by each host for Neighbor Discovery [17].

On receipt of a valid Router Advertisement, as defined in the processing algorithm specified for Neighbor Discovery [17], the home agent performs the following steps, in addition to any steps already required of it by Neighbor Discovery:

- If the Home Agent (H) bit in the Router Advertisement is not set, skip all of the following steps. There are no special processing steps required by Mobile IP for this Router Advertisement, since the Advertisement was not sent by a home agent.

- Otherwise, extract the Source Address from the IP header of the Router Advertisement. This is the link-local IP address on this link of the home agent sending this Advertisement [17].

- Determine from the Router Advertisement the preference for this home agent. If the Router Advertisement contains a Home Agent Information Option, then the preference is taken from the Home Agent Preference field in the option; otherwise, the default preference of 0 MUST be used.

- Determine from the Router Advertisement the lifetime for this home agent. If the Router Advertisement contains a Home Agent Information Option, then the lifetime is taken from the Home Agent Lifetime field in the option; otherwise, the lifetime specified by the Router Lifetime field in the Router Advertisement SHOULD be used.

- If the link-local address of the home agent sending this Advertisement is already present in this home agent's Home Agents List and the received home agent lifetime value is zero, immediately delete this entry in the Home Agents List.

- Otherwise, if the link-local address of the home agent sending this Advertisement is already present in the receiving home agent's Home Agents List, reset its lifetime and preference to

the values determined above.

- If the link-local address of the home agent sending this Advertisement, as determined above, is not already present in the Home Agents List maintained by the receiving home agent, and the lifetime for the sending home agent, as determined above, is non-zero, create a new entry in the list, and initialize its lifetime and preference to the values determined above.

- If the Home Agents List entry for the link-local address of the home agent sending this Advertisement was not deleted as described above, determine any global address(es) of the home agent based on each Prefix Information option received in this Advertisement in which the Router Address (R) bit is set (Section 6.2). For each such global address determined from this Advertisement, add this global address to the list of global addresses for this home agent in this Home Agents List entry.

A home agent SHOULD maintain an entry in its Home Agents List for each such valid home agent address until that entry's lifetime expires, after which time the entry MUST be deleted.

9.2. Dynamic Home Agent Address Discovery

A mobile node, while away from home, MAY use the dynamic home agent address discovery mechanism to attempt to discover the address of one or more routers serving as home agents on its home link. This discovery may be necessary, for example, if some nodes on its home link have been reconfigured while the mobile node has been away from home, such that the router that was operating as the mobile node's home agent has been replaced by a different router serving this role.

As described in Section 10.7, a mobile node attempts dynamic home agent address discovery by sending an ICMP Home Agent Address Discovery Request message to the "Mobile IPv6 Home-Agents" anycast address [10] for its home IP subnet prefix, using its care-of address as the Source Address of the packet. A home agent receiving such a Home Agent Address Discovery Request message that is serving this subnet (the home agent is configured with this anycast address on one of its network interfaces) SHOULD return an ICMP Home Agent Address Discovery Reply message to the mobile node (at its care-of address that was used as the Source Address of the Request message), with the Source Address of the Reply packet set to one of the global unicast addresses of the home agent. The Home Agent Addresses field in the Reply message is constructed as follows:

- The Home Agent Addresses field SHOULD contain one global IP address for each home agent currently listed in this home agent's own Home Agents List (Section 4.6). However, if this

home agent's own global IP address would be placed in the list (as described below) as the first entry in the list, then this home agent SHOULD NOT include its own address in the Home Agent

Addresses field in the Reply message. Not placing this home agent's own IP address in the list will cause the receiving mobile node to consider this home agent as the most preferred home agent; otherwise, this home agent will be considered to be preferred in its order given by its place in the list returned.

- The IP addresses in the Home Agent Addresses field SHOULD be listed in order of decreasing preference value, based either on the respective advertised preference from a Home Agent Information option or on the default preference of 0 if no preference is advertised (or on the configured home agent preference for this home agent itself). The home agent with the highest preference SHOULD be listed first in the Home Agent Addresses field, and the home agent with the lowest preference SHOULD be listed last.

- Among home agents with equal preference, their IP addresses in the Home Agent Addresses field SHOULD be listed in an order randomized with respect to other home agents with equal preference, each time a Home Agent Address Discovery Reply message is returned by this home agent.

- For each entry in this home agent's Home Agents List, if more than one global IP address is associated with this list entry, then one of these global IP addresses SHOULD be selected to include in the Home Agent Addresses field in the Reply message. As described in Section 4.6, one Home Agents List entry, identified by the home agent's link-local address, exists for each home agent on the link; associated with that list entry is one or more global IP addresses for this home agent, learned through Prefix Information options with the Router Address (R) bit is set, received in Router Advertisements from this link-local address. The selected global IP address for each home agent to include in forming the Home Agent Addresses field in the Reply message MUST be the global IP address of the respective home agent sharing a prefix with the mobile node's home address as indicated in the Home Address option in the Request message; if no such global IP address is known for some home agent, an entry for that home agent MUST NOT be included in the Home Agent Addresses field in the Reply message.

- In order to avoid the possibility of the Reply message packet being fragmented (or rejected by an intermediate router with an ICMP Packet Too Big message [5]), if the resulting total packet size containing the complete list of home agents in the Home Agent Addresses field would exceed the minimum IPv6 MTU [6], the home agent SHOULD reduce the number of home agent IP addresses returned in the packet to the number of addresses that will fit

without exceeding this limit. The home agent addresses returned in the packet SHOULD be those from the complete list with the highest preference.

9.3. Primary Care-of Address Registration

When a node receives a Binding Update, it MUST validate it and determine the type of Binding Update according to the steps described in Section 8.2. This section describes the processing of a valid Binding Update that requests the receiving node to serve as its home agent, registering its primary care-of address.

To begin processing the Binding Update, the home agent MUST perform the following sequence of tests:

- If the node is not a router that implements home agent functionality, then the node MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to 132 (home registration not supported).

- Else, if the home address for the binding (the Home Address field in the packet's Home Address option) is not an on-link IPv6 address with respect to the home agent's current Prefix List, then the home agent MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to 133 (not home subnet).

- Else, if the Prefix Length field is nonzero in the Binding Update and this length differs from the length of the home agent's own knowledge of the corresponding subnet prefix on the home link, then the home agent MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to 136 (incorrect subnet prefix length).

- Else, if the home agent chooses to reject the Binding Update for any other reason (e.g., insufficient resources to serve another mobile node as a home agent), then the home agent SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to an appropriate value to indicate the reason for the rejection.

- Finally, if the Duplicate Address Detection (D) bit is set in the Binding Update, this home agent MUST perform Duplicate Address Detection [27] on the mobile node's home link for the home address in this binding (before returning the Binding Acknowledgement); if the Prefix Length field is nonzero in the Binding Update, the home agent MAY choose to perform Duplicate Address Detection for only one of the addresses formed from the interface identifier for this binding, and if so, the address used for Duplicate Address Detection SHOULD be the mobile node's link-local address. Normal processing for Duplicate

Address Detection specifies that, in certain cases, the node SHOULD delay sending the initial Neighbor Solication message of Duplicate Address Detection by a random delay between 0 and

MAX_RTR_SOLICITATION_DELAY [17, 27]; however, in this case, the home agent SHOULD NOT perform such a delay. If this Duplicate Address Detection fails, then the home agent MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to 138 (Duplicate Address Detection failed).

If the home agent does not reject the Binding Update as described above, then it becomes the home agent for the mobile node. The new home agent (the receiving node) MUST then create a new entry in its Binding Cache for this mobile node (or update its existing Binding Cache entry for this mobile node, if such an entry already exists) The home address of the mobile node is taken to be the value which, when the packet was originally received, was located in the Home Address field in the packet's Home Address option. The care-of address for this Binding Cache entry is taken to be the value which, when the packet was originally received, was located either in the Alternate Care-of Address sub-option in the Binding Update option, if present, or from the Source Address field in the packet's IPv6 header, otherwise.

The home agent MUST mark this Binding Cache entry as a "home registration" to indicate that the node is serving as a home agent for this binding. Binding Cache entries marked as a "home registration" MUST be excluded from the normal cache replacement policy used for the Binding Cache (Section 8.7) and MUST NOT be removed from the Binding Cache until the expiration of the Lifetime period.

In addition, the home agent MUST copy the Router (R) bit from the Binding Update into the corresponding bit in this Binding Cache entry for this mobile node.

The lifetime for the Binding Cache entry MUST NOT be greater than the remaining valid lifetime for the subnet prefix in the mobile node's home address specified with the Binding Update, and MUST NOT be greater than the Lifetime value specified in the Binding Update. The remaining valid lifetime for this prefix is determined by the home agent based on its own Prefix List entry for this prefix [17]. Furthermore, if the Prefix Length field in the Binding Update is nonzero, then the lifetime for the Binding Cache entry MUST NOT be greater than the minimum remaining valid lifetime for all subnet prefixes on the mobile node's home link. If the value of the Lifetime field specified by the mobile node in its Binding Update is greater than this prefix lifetime, the home agent MUST decrease the binding lifetime to less than or equal to the prefix valid lifetime. The home agent MAY further decrease the specified lifetime for the binding, for example based on a local policy implemented by the home

agent. The resulting lifetime is stored by the home agent in the Binding Cache entry, and this Binding Cache entry MUST be deleted by the home agent after the expiration of this lifetime.

The Prefix Length in the Binding Update MUST also be saved in the Binding Cache entry.

The home agent MUST return a Binding Acknowledgement to the mobile node, constructed as follows:

- The Status field MUST be set to a value indicating success (the value MUST be less than 128). The only currently defined success Status value is 0, indicating simply that the Binding Update was accepted.

- The Sequence Number field MUST be copied from the Sequence Number given in the Binding Update.

- The Lifetime field MUST be set to the remaining lifetime for the binding as set by the home agent in its "home registration" Binding Cache entry for the mobile node. As described above, this lifetime MUST NOT be greater than the remaining valid lifetime for the subnet prefix in the mobile node's home address.

- The Refresh field MUST be set to a value less than or equal to the Lifetime value being returned in the Binding Update. If the home agent stores the Binding Cache entry in nonvolatile storage (that survives the crash or other failure of the home agent), then the Refresh field SHOULD be set to the same value as the Lifetime field; otherwise, the home agent MAY set the Refresh field to a value less than the Lifetime field, to indicate that the mobile node SHOULD attempt to refresh its home registration at the indicated shorter interval (although the home agent will still retain the registration for the Lifetime period, even if the mobile node does not refresh its registration within the Refresh period).

In addition, the home agent MUST follow the procedure defined in Section 9.5 to intercept packets on the mobile node's home link addressed to the mobile node, while the home agent is serving as the home agent for this mobile node.

9.4. Primary Care-of Address De-registration

When a node receives a Binding Update, it MUST validate it and determine the type of Binding Update according to the steps described in Section 8.2. This section describes the processing of a valid Binding Update that requests the receiving node to no longer serve as its home agent, de-registering its primary care-of address.

To begin processing the Binding Update, the home agent MUST perform the following test:

- If the receiving node has no entry in its Binding Cache for this mobile node that is marked as a "home registration", then this node MUST reject the Binding Update and SHOULD return a Binding Acknowledgement to the mobile node, in which the Status field is set to 137 (not home agent for this mobile node).

If the home agent does not reject the Binding Update as described above, then it MUST delete any existing entry in its Binding Cache for this mobile node.

If the Acknowledge (A) bit is set in the Binding Update (it SHOULD be), then the home agent MUST return a Binding Acknowledgement to the mobile node, constructed as follows:

- The Status field MUST be set to a value indicating success (the value MUST be less than 128). The only currently defined success Status value is 0, indicating simply that the Binding Update was accepted.

- The Sequence Number field MUST be copied from the Sequence Number given in the Binding Update.

- The Lifetime field MUST be set to zero.

- The Refresh field MUST be set to zero.

In addition, the home agent MUST stop intercepting packets on the mobile node's home link addressed to the mobile node (Section 9.5).

9.5. Intercepting Packets for a Mobile Node

While a node is serving as the home agent for mobile node (while the node has an entry in its Binding Cache for this mobile node that is marked as a "home registration"), this node MUST attempt to intercept packets on the mobile node's home link addressed to the mobile node, and MUST tunnel each intercepted packet to the mobile node using using IPv6 encapsulation [4].

In order to intercept such packets on the home link, when a node becomes the home agent for some mobile node (it did not already have a Binding Cache entry for this mobile node marked as a "home registration"), then the home agent MUST multicast onto the home link a "gratuitous" Neighbor Advertisement message [17] on behalf of the mobile node. Specifically, the home agent performs the following steps:

- The home agent examines the value of the Prefix Length field in the new "home registration" Binding Cache entry. If this

value is zero, the following step is carried out only for the individual home address specified for this binding. If, instead,

this field is nonzero, then the following step is carried out for each address for the mobile node formed from the interface identifier in the mobile node's home address in this binding (the remaining low-order bits in the address after the indicated subnet prefix), together with each one of the subnet prefixes currently considered by the home agent to be on-link (including both the link-local and site-local prefix).

- For each specific IP address for the mobile node determined in the first step above, the home agent multicasts onto the home link (to the all-nodes multicast address) a Neighbor Advertisement message [17] on behalf of the mobile node, to advertise the home agent's own link-layer address for this IP address.

  All fields in each such Neighbor Advertisement message SHOULD be set in the same way they would be set by the mobile node itself if sending this Neighbor Advertisement while at home [17], with the following exceptions:

  * The Target Address in the Neighbor Advertisement message MUST be set to the specific IP address for the mobile node.

  * The Advertisement MUST include a Target Link-layer Address option specifying the home agent's link-layer address.

  * The Router (R) bit in the Advertisement MUST be copied from the corresponding bit in the home agent's Binding Cache entry for the mobile node.

  * The Solicited Flag (S) in the Advertisement MUST NOT be set, since it was not solicited by any Neighbor Solicitation message.

  * The Override Flag (O) in the Advertisement MUST be set, indicating that the Advertisement SHOULD override any existing Neighbor Cache entry at any node receiving it.

Any node on the home link receiving one of the Neighbor Advertisement messages described above will thus update its Neighbor Cache to associate the mobile node's address with the home agent's link layer address, causing it to transmit any future packets for the mobile node normally destined to this address instead to the mobile node's home agent. Since multicasts on the local link (such as Ethernet) are typically not guaranteed to be reliable, the home agent MAY retransmit this Neighbor Advertisement message up to MAX_ADVERT_REXMIT times to increase its reliability. It is still possible that some nodes on the home link will not receive any of these Neighbor Advertisements, but these nodes will eventually be

able to detect the link-layer address change for the mobile node's home address, through use of Neighbor Unreachability Detection [17].

While a node is serving as a home agent for some mobile node (it still has a "home registration" entry for this mobile node in its Binding Cache), the home agent uses IPv6 Neighbor Discovery [17] to intercept unicast packets on the home link addressed the mobile node's home address. In order to intercept packets in this way, the home agent MUST act as a proxy for this mobile node to reply to any received Neighbor Solicitation messages for it. When a home agent receives a Neighbor Solicitation message, it MUST check if the Target Address specified in the message matches the home address of any mobile node for which it has a Binding Cache entry marked as a "home registration". This check MUST include all possible home addresses for the mobile node, based on the subnet prefixes currently considered to be on-link by the home agent (including the corresponding link-local address and site-local address), if the Prefix Length in the Binding Cache entry for this mobile node (from the Binding Update that created this Cache entry) is nonzero.

If such an entry exists in the home agent's Binding Cache, the home agent MUST reply to the Neighbor Solicitation message with a Neighbor Advertisement message, giving the home agent's own link-layer address as the link-layer address for the specified Target Address. In addition, the Router (R) bit in the Advertisement MUST be copied from the corresponding bit in the home agent's Binding Cache entry for the mobile node. Acting as a proxy in this way allows other nodes on the mobile node's home link to resolve the mobile node's IPv6 home address, and allows the home agent to defend these addresses on the home link for Duplicate Address Detection [17].

9.6. Tunneling Intercepted Packets to a Mobile Node

For any packet sent to a mobile node from the mobile node's home agent (for which the home agent is the original sender of the packet), the home agent is operating as a correspondent node of the mobile node for this packet and the procedures described in Section 8.9 apply. The home agent (as a correspondent node) uses a Routing header to route the packet to the mobile node by way of the care-of address in the home agent's Binding Cache (the mobile node's primary care-of address, in this case).

While the mobile node is away from home and this node is acting as the mobile node's home agent, the home agent intercepts any packets on the home link addressed to the mobile node's home address (including addresses formed from other on-link prefixes, if the Prefix Length field was nonzero in the Binding Update), as described in Section 9.5. The home agent cannot use a Routing header to forward these intercepted packets to the mobile node, since it cannot modify the packet in flight without invalidating any existing IPv6

AH [11] or ESP [12] header present in the packet.

For forwarding each intercepted packet to the mobile node, the home agent MUST tunnel the packet to the mobile node using IPv6 encapsulation [4]; the tunnel entry point node is the home agent, and the tunnel exit point node is the primary care-of address as registered with the home agent (which is an address of the mobile node itself). When a home agent encapsulates an intercepted packet for forwarding to the mobile node, the home agent sets the Source Address in the prepended tunnel IP header to the home agent's own IP address, and sets the Destination Address in the tunnel IP header to the mobile node's primary care-of address. When received by the mobile node (using its primary care-of address), normal processing of the tunnel header [4] will result in decapsulation and processing of the original packet by the mobile node.

However, packets addressed to the mobile node's link-local address MUST NOT be tunneled to the mobile node. Instead, such a packet MUST be discarded, and the home agent SHOULD return an ICMP Destination Unreachable, Code 3, message to the packet's Source Address (unless this Source Address is a multicast address). Packets addressed to the mobile node's site-local address SHOULD be tunneled to the mobile node by default, but this behavior MUST be configurable to disable it; currently, the exact definition and semantics of a "site" and a site-local address are undefined in IPv6, and this default behavior might change at some point in the future.

Tunneling of multicast packets to a mobile node follows similar limitations to those defined above for unicast packets addressed to the mobile node's link-local and site-local addresses. Multicast packets addressed to a multicast address with link-local scope [9], to which the mobile node is subscribed, MUST NOT be tunneled to the mobile node; such packets SHOULD be silently discarded (after delivering to other local multicast recipients). Multicast packets addressed to a multicast address with scope larger than link-local but smaller than global (e.g., site-local and organization-local) [9], to which the mobile node is subscribed, SHOULD be tunneled to the mobile node by default, but this behavior MUST be configurable to disable it; this default behavior might change at some point in the future as the definition of these scopes become better defined in IPv6.

9.7. Handling Reverse Tunneled Packets from a Mobile Node

A home agent MUST support decapsulating reverse tunneled packets sent to it from a mobile node. Such reverse tunneled packets MAY be discarded unless accompanied by a valid AH. This support for reverse tunneling allows mobile nodes to defeat certain kinds of traffic analysis. Requiring AH on reverse tunneled packets allows the home

agent to protect the home network against unwarranted intrusions by malicious nodes masquerading as a mobile node with a home address on the network served by the home agent.

9.8. Renumbering the Home Subnet

IPv6 provides mechanisms through Neighbor Discovery [17] and Address Autoconfiguration [27] to aid in renumbering a subnet, such as when a site switches to a new network service provider. In renumbering, new prefixes and addresses can be introduced for the subnet and old ones can be deprecated and removed. These mechanisms are defined to work while all nodes using the old prefixes are at home, connected to the link using these prefixes. Mobile IPv6 extends these mechanisms for the case in which one or more mobile nodes using the old prefixes are away from home while the renumbering takes place.

The IPv6 renumbering mechanisms are based on nodes on the link receiving Prefix Information options in Router Advertisement messages giving the valid lifetime and preferred lifetime for different prefixes on the link [17]. Mobile IPv6 arranges to tunnel certain Router Advertisements giving "important" Prefix Information options to mobile nodes while away from home. To avoid the need to tunnel all Router Advertisements from the home link to a mobile node away from home, those Router Advertisements that are tunneled to the mobile node are retransmitted until acknowledged. To avoid possible security attacks from forged Router Advertisements tunneled to the mobile node, all such tunneled Router Advertisements must be authenticated to the mobile node by its home agent using IPsec [13, 11, 12].

9.8.1. Building Aggregate List of Home Network Prefixes

A mobile node on a remote network SHOULD autoconfigure the same set of home addresses it would autoconfigure if it were attached to the home network. To support this, the home agent monitors prefixes advertised by other routers on the home subnet and passes the aggregate list of home subnet prefixes on to the mobile node in Router Advertisements.

The home agent SHOULD construct the aggregate list of home subnet prefixes as follows:

- Copy prefix information defined in the home agent's AdvPrefixList on the home subnet's interfaces to the aggregate list. Also apply any changes made to the AdvPrefixList on the home agent to the aggregate list.

- Check valid prefixes received in Router Advertisements from the home network for consistency with the home agent's AdvPrefixList, as specified in section 6.2.7 of RFC 2461 (Neighbor Discovery [17]). Do not update the aggregate list with any information from received prefixes that fail this check.

- Add valid prefixes received in Router Advertisements from the home network that are not yet in the aggregate list to the aggregate list along with the value of their L and A flags. Clear the R flag and zero the interface-id portion of the prefix field to prevent mobile nodes from treating another router's interface address as belonging to the home agent. Treat the lifetimes of these prefixes as "deprecating".

- Do not perform consistency checks on valid prefixes received in Router Advertisements on the home network that do not exist in the home agent's AdvPrefixList. Instead, if the prefixes already exist in the aggregate list, update the prefix lifetime fields in the aggregate list according to the rules specified for hosts in section 6.3.4 of RFC 2461 (Neighbor Discovery [17]) and section 5.5.3 of RFC 2462 (Stateless Address Autoconfiguration [27]).

- If the L or A flag is set on valid prefixes received in a Router Advertisement, and that prefix already exists in the aggregate list, set the corresponding flag in the aggregate list. Ignore the received L or A flag if it is clear.

- Ignore the R flag and interface id portion of any prefix received in a Router Advertisement.

- Delete prefixes from the aggregate list when their valid lifetimes expire.

The home agent uses the information in the aggregate list to construct Router Advertisements, possibly including Binding Acknowledgement or Binding Request destination options, for delivery to a mobile node for which it is maintaining a current binding.

9.8.2. Sending Changed Prefix Information to the Mobile Node

A home agent serving some mobile node MUST schedule the delivery of new prefix information to the mobile node when any of the following conditions occur:

- A valid or preferred lifetime of a prefix in the aggregate list of prefixes changes.

- The state of the flags for a prefix in the aggregate list changes.

- A new prefix is introduced on the home link.

- The mobile node requests the information with a Router Solicitation (see section 10.16).

The home agent determines these conditions based on its own configuration as a router and based on the Router Advertisements that it receives on the home link.

The home agent uses the following algorithm to determine when to send prefix information to the mobile node.

- If a mobile node sends a solicitation, answer with everything.

- If a prefix changes state in a way that causes a mobile node's address to go deprecated, send an advertisement right away.

- For any existing previx, if the mobile node's binding expires before the advertised Preferred Lifetime, do not schedule the advertisement. The mobile node will get the revised information in its next Binding Acknowledgement.

- If a prefix is added, or if it changes in any way that does not cause the mobile node's address to go deprecated, ensure that a transmission is scheduled at time RAND_ADV_DELAY in the future.

- If a prefix advertisement is scheduled, and a Binding Update arrives, perform that advertisement and include the information in a Router Advertisement that has the Binding Acknowledgement as a Destination Option. Remove the future scheduled advertisement.

The home agent uses the following algorithm to compute RAND_ADV_DELAY, the offset from the current time for the scheduled transmission.

If there is a transmission already scheduled, then

   if the current RAND_ADV_DELAY would cause another transmission BEFORE the Preferred Lifetime of the mobile node's home address derived from the prefix whose advertisement information has changed, then

      add the new information to be transmitted to the existing scheduled transmission -- return.

   otherwise,

      continue with the following computation, and add the data from the existing scheduled transmission to the newly scheduled transmission, deleting the previously scheduled transmission event.

If the mobile node's binding expires after the Preferred Lifetime, then compute

```
   MAX_SCHEDULE_DELAY ==
   min (MAX_PFX_ADV_DELAY, Preferred Lifetime)
```

for the newly advertised Preferred Lifetime.
Then compute RAND_ADV_DELAY =
MinRtrAdvInt + rand()*(MAX_SCHEDULE_DELAY - MinRtrAdvInt)

9.8.3. Tunneling Router Advertisements to the Mobile Node

When tunneling a Router Advertisement to the mobile node, the home agent MUST construct the packet as follows:

- The Source Address in the packet's IPv6 header MUST be set to the home agent's IP address to which the mobile node addressed its current home registration.

- The packet MUST be protected by IPsec [13, 11, 12] to guard against malicious Router Advertisements. The IPsec protection MUST provide sender authentication, data integrity protection, and replay protection, covering the Router Advertisement.

- The packet MUST include a Binding Request destination option.

- The Binding Request destination option MUST include a Unique Identifier Sub-Option (Section 5.5), with the unique identifier in the sub-option data set to a value different than that in any other Binding Request sent recently by this node. The word "recently" here means within the maximum likely lifetime of a packet, including transit time from source to destination and time spent awaiting reassembly with other fragments of the same packet, if fragmented. However, it is not required that a source node know the maximum packet lifetime. Rather, it is assumed that the requirement can be met by maintaining a simple 16-bit "wrap-around" counter to generate unique identifiers for Binding Requests that contain a Unique Identifier Sub-Option, incremented each time a Binding Request containing a Unique Identifier Sub-Option is sent.

- The packet MUST be tunneled to the mobile node's primary care-of address using a Routing header, in the same way as any packet sent to the mobile node originated by the home agent (rather than using IPv6 encapsulation, as would be used by the home agent for intercepted packets).

The home agent SHOULD periodically continue to retransmit this tunneled packet to the mobile node, until it is acknowledged by the receipt from the mobile node of a Binding Update matching the Binding Request in the packet (i.e., with matching Sequence

Number). A Binding Update matches a Binding Request if it specifies a binding for the mobile node to which the Binding Request was sent

and contains a Unique Identifier Sub-Option matching the unique identifier sent in the Unique Identifier Sub-Option in the Binding Request.

If while the home agent is still retransmitting a Router Advertisement to the mobile node, another condition as described above occurs on the home link causing another Router Advertisement to be tunneled to the mobile node, the home agent SHOULD combine any Prefix Information options in the unacknowledged Router Advertisement into the new Router Advertisement and then begin retransmitting the new Router Advertisement rather than the old one. When tunneling a new Router Advertisement, even if it contains Prefix Information options sent previously in an unacknowledged tunneled Router Advertisement, the home agent MUST generate a new unique identifer for use in the Unique Identifier Sub-Option in the Binding Request tunneled with the new Router Advertisement.

Whenever a mobile node has a valid binding on a network other than its home network, the home agent MUST tunnel a router advertisement with all prefixes in the aggregate list to the mobile node at least once per HomeRtrAdvInterval seconds, and upon receipt of a valid Router Solicitation from the mobile node.

9.8.4. Lifetimes for Changed Prefixes

In addition, as described in Section 9.3, the lifetime returned by a mobile node's home agent in its Binding Acknowledgement in response to registration of a new primary care-of address by the mobile node MUST be no greater than the remaining valid lifetime for the subnet prefix in the mobile node's home address. Furthermore, as described in Section 10.8, Binding Updates sent by the mobile node to other nodes MUST use a lifetime no greater than the remaining lifetime of its home registration of its primary care-of address. These limits on the binding lifetime serve to prohibit use of a mobile node's home address after it becomes invalid. The mobile node SHOULD further limit the lifetimes that it sends on any Binding Updates to be within the remaining preferred lifetime for the prefix in its home address.

10. Mobile Node Operation

10.1. Sending Packets While Away from Home

While a mobile node is away from home, it continues to use its home address as well as also using one or more care-of addresses. When sending a packet while away from home, a mobile node MAY choose among these in selecting the address that it will use as the source of the packet, as follows:

- From the point of view of protocol layers and applications above Mobile IP (e.g., transport protocols), the mobile node will generally use its home address as the source of the packet for most packets, even while away from home, since Mobile IP is designed to make mobility transparent to such software. Doing so also makes the node's mobility---and the fact that it is currently away from home---transparent to the correspondent nodes with which it communicates. For packets sent that are part of transport-level connections established while the mobile node was at home, the mobile node MUST use its home address in this way. Likewise, for packets sent that are part of transport-level connections that the mobile node may still be using after moving to a new location, the mobile node SHOULD use its home address in this way. When sending such packets, Mobile IP will modify the packet to move the home address into a Home Address option and will set the IPv6 header's Source Address field to one of the mobile node's care-of addresses; these modifications to the packet are then reversed in the node receiving the packet, restoring the mobile node's home address to be the packet's Source Address before processing by higher protocol layers and applications.

- For short-term communication, particularly for communication that may easily be retried if it fails, the mobile node MAY choose to directly use one of its care-of addresses as the source of the packet, thus not requiring the use of a Home Address option in the packet. An example of this type of communication might be DNS queries sent by the mobile node [15, 16]. Using the mobile node's care-of address as the source for such queries will generally have a lower overhead than using the mobile node's home address, since no extra options need be used in either the query or its reply, and all packets can be routed normally, directly between their source and destination without relying on Mobile IP. If the mobile node has no particular knowledge that the communication being sent fits within this general type of communication, however, the mobile node SHOULD NOT use its care-of address as the source of the packet in this way.

For packets sent by a mobile node while it is at home, no special Mobile IP processing is required for sending this packet. Likewise, if the mobile node uses any address other than its home address as

the source of a packet sent while away from home (from the point of view of higher protocol layers or applications, as described above), no special Mobile IP processing is required for sending that packet. In each case, the packet is simply addressed and transmitted in the same way as any normal IPv6 packet.

For each other packet sent by the mobile node (i.e., packets sent while away from home, using the mobile node's home address as the source, from the point of view of higher protocol layers and applications), special Mobile IP processing of the packet is required for the insertion of the Home Address option. Specifically:

- Construct the packet using the mobile node's home address as the packet's Source Address, in the same way as if the mobile node were at home. This preserves the transparency of Mobile IP to higher protocol layers (e.g., to TCP).

- Insert a Home Address option into the packet, with the Home Address field copied from the original value of the Source Address field in the packet.

- Change the Source Address field in the packet's IPv6 header to one of the mobile node's care-of addresses. This will typically be the mobile node's current primary care-of address, but MUST be a care-of address with a subnet prefix that is on-link on the network interface on which the mobile node will transmit the packet.

By using the care-of address as the Source Address in the IPv6 header, with the mobile node's home address instead in the Home Address option, the packet will be able to safely pass through any router implementing ingress filtering [7].

10.2. Interaction with Outbound IPsec Processing

This section sketches the interaction between outbound Mobile IP processing and outbound IP Security (IPsec) processing for packets sent by a mobile node while away from home. Any specific implementation MAY use algorithms and data structures other than those suggested here, but its processing MUST be consistent with the effect of the operation described here and with the relevant IPsec specifications. In the steps described below, it is assumed that IPsec is being used in transport mode [13] and that the mobile node is using its home address as the source for the packet (from the point of view of higher protocol layers or applications, as described in Section 10.1):

- The packet is created by higher layer protocols and applications

(e.g., by TCP) as if the mobile node were at home and Mobile IP

were not being used. Mobile IP is transparent to such higher layers.

- As part of outbound packet processing in IP, the packet is compared against the IPsec Security Policy Database (SPD) to determine what processing is required for the packet [13].

- As a special case for Mobile IP, if a Binding Update or Binding Acknowledgement is being included in the packet, IPsec authentication, integrity protection, and replay protection MUST be applied to the packet [13, 11, 12], as defined in Section 4.4. If the SPD check above has already indicated that authentication and replay protection are required, this processing is sufficient for the Mobile IP requirement that all packets containing Binding Updates or Binding Acknowledgements be authenticated and covered by replay protection. Otherwise, an implementation can force the required IPsec processing on this individual packet by, for example, creating a temporary SPD entry for the handling of this packet.

- If IPsec processing is required, the packet is either mapped to an existing Security Association (or SA bundle), or a new SA (or SA bundle) is created for the packet, according to the procedures defined for IPsec.

- Since the mobile node is away from home, the mobile node inserts a Home Address option into the packet, replacing the Source Address in the packet's IP header with a care-of address suitable for the link on which the packet is being sent, as described in Section 10.1. The Destination Options header in which the Home Address option is inserted MUST appear in the packet before the AH [11] (or ESP [12]) header, so that the Home Address option is processed by the destination node (and, possibly, intermediate routing nodes) before the AH or ESP header is processed.

- If a Binding Update is being included in the packet, it is also added to a Destination Options header in the packet. The Destination Options header in which the Binding Update option is inserted MUST appear after the AH or ESP header.

- Finally, once the packet is fully assembled, the necessary IPsec authentication (and encryption, if required) processing is performed on the packet, initializing the Authentication Data in the AH or ESP header. The authentication data MUST be calculated as if the following were true:

  * the IPv6 source address in the IPv6 header contains the mobile node's home address,

* the Home Address field of the Home Address destination option (section 5.4) contains the new care-of address.

This allows, but does not require, the receiver of the packet containing the Binding Update to exchange the two fields of the incoming packet, simplifying processing for all subsequent packet headers. The mechanics of implementation do not absolutely require such an exchange to occur; other implementation strategies may be more appropriate, as long as the result of the authentication calculation remain the same.

In addition, when using any automated key management protocol [13] (such as IKE [8]) to create any new SA (or SA bundle) while away from home (whether due to the inclusion of a Binding Update or Binding Acknowledgement in an outgoing packet, or otherwise), a mobile node MUST take special care in its processing of the key management protocol. Otherwise, other nodes with which the mobile node must communicate as part of the automated key management protocol processing may be unable to correctly deliver packets to the mobile node if they and/or the mobile node's home agent do not then have a current Binding Cache entry for the mobile node. For the default case of using IKE as the automated key management protocol [8, 13], such problems can be avoided by the following requirements on the use of IKE by a mobile node while away from home:

- The mobile node MUST use its care-of address as the Source Address of all packets it sends as part of the key management protocol (without use of Mobile IP for these packets, as suggested in Section 10.1).

- In addition, for all security associations bound to the mobile node's home address, the mobile node MUST include an ISAKMP Identification Payload [14] in the IKE exchange, giving the mobile node's home address as the initiator of the Security Association [22].

10.3. Receiving Packets While Away from Home

While away from home, a mobile node will receive packets addressed to its home address, by one of three methods:

- Packets sent by a correspondent node that does not have a Binding Cache entry for the mobile node, will be sent by the correspondent node in the same way as any normal IP packet. Such packets will then be intercepted by the mobile node's home agent, encapsulated using IPv6 encapsulation [4], and tunneled to the mobile node's primary care-of address.

- Packets sent by a correspondent node that has a Binding Cache entry for the mobile node that contains the mobile node's current care-of address, will be sent by the correspondent node using

a Routing header. The packet will be addressed to the mobile node's care-of address, with the final hop in the Routing header

directing the packet to the mobile node's home address; the processing of this last hop of the Routing header is entirely internal to the mobile node, since the care-of address and home address are both addresses within the mobile node.

- Packets sent by a correspondent node that has a Binding Cache entry for the mobile node that contains an out-of-date care-of address for the mobile node, will be sent by the correspondent node using a Routing header, as described above. If the mobile node sent a Binding Update to a home agent on the link on which its previous care-of address is located (Section 10.9), and if this home agent is still serving as a home agent for the mobile node's previous care-of address, then such a packet will be intercepted by this home agent, encapsulated using IPv6 encapsulation [4], and tunneled to the mobile node's new care-of address (registered with this home agent).

For packets received by either the first or last of these three methods, the mobile node SHOULD send a Binding Update to the original sender of the packet, as described in Section 10.8, subject to the rate limiting defined in Section 10.11. The mobile node SHOULD also process the received packet in the manner defined for IPv6 encapsulation [4], which will result in the encapsulated (inner) packet being processed normally by upper-layer protocols within the mobile node, as if it had been addressed (only) to the mobile node's home address.

For packets received by the second method above (using a Routing header), the mobile node SHOULD process the received packet in the manner defined for the type of IPv6 Routing header used [6], which will result in the packet being processed normally by upper-layer protocols within the mobile node, as if it had been addressed (only) to the mobile node's home address.

In addition, the general procedures defined by IPv6 for Routing headers suggest that a received Routing header MAY be automatically "reversed" to construct a Routing header for use in any response packets sent by upper-layer protocols, if the received packet is authenticated [6]. If this is done for upper-layer protocol response packets sent by a mobile node while away from home, the mobile node SHOULD NOT include its own care-of address, which appears in the Routing header of the received packet, in the reversed route for the response packet. If the received Routing header contained no additional hops (other than the mobile node's home address and care-of address), then any upper-layer protocol response packet SHOULD NOT include a Routing header.

10.4. Movement Detection

A mobile node MAY use any combination of mechanisms available to it to detect when it has moved from one link to another. The primary movement detection mechanism for Mobile IPv6 defined here uses the facilities of IPv6 Neighbor Discovery, including Router Discovery and Neighbor Unreachability Detection, although the mobile node MAY supplement this mechanism with other information available to the mobile node (e.g., from lower protocol layers). The description here is based on the conceptual model of the organization and data structures defined by Neighbor Discovery [17].

Mobile nodes SHOULD use Router Discovery to discover new routers and on-link subnet prefixes; a mobile node MAY send Router Solicitation messages, or MAY wait for unsolicited (periodic) multicast Router Advertisement messages, as specified for Router Discovery [17]. Based on received Router Advertisement messages, a mobile node (in the same way as any other node) maintains an entry in its Default Router List for each router, and an entry in its Prefix List for each subnet prefix, that it currently considers to be on-link. Each entry in these lists has an associated invalidation timer value (extracted from the Router Advertisement and Prefix Information options) used to expire the entry when it becomes invalid.

While away from home, a mobile node SHOULD select one router from its Default Router List to use as its default router, and one subnet prefix advertised by that router from its Prefix List to use as the subnet prefix in its primary care-of address. A mobile node MAY also have associated additional care-of addresses, using other subnet prefixes from its Prefix List. The method by which a mobile node selects and forms a care-of address from the available subnet prefixes is described in Section 10.5. The mobile node registers its primary care-of address with its home agent, as described in Section 10.6.

While a mobile node is away from home and using some router as its default router, it is important for the mobile node to be able to quickly detect when that router becomes unreachable, so that it can switch to a new default router and to a new primary care-of address. Since some links (notably wireless) do not necessarily work equally well in both directions, it is likewise important for the mobile node to detect when it becomes unreachable for packets sent from its default router, so that the mobile node can take steps to ensure that any correspondent nodes attempting to communicate with it can still reach it through some other route.

To detect when its default router becomes unreachable, a mobile node SHOULD use Neighbor Unreachability Detection. As specified in

Neighbor Discovery [17], while the mobile node is actively sending packets to (or through) its default router, the mobile node can detect that the router (as its neighbor) is still reachable either

through indications from upper layer protocols on the mobile node that a connection is making "forward progress" (e.g., receipt of TCP acknowledgements for new data transmitted), or through receipt of a Neighbor Advertisement message from its default router in response to an explicit Neighbor Solicitation messages to it. Note that although this mechanism detects that the mobile node's default router has become unreachable to the mobile node only while the mobile node is actively sending packets to it, this is the only time that this direction of reachability confirmation is needed. Confirmation that the mobile node is still reachable from the router is handled separately, as described below.

For a mobile node to detect when it has become unreachable from its default router, the mobile node cannot efficiently rely on Neighbor Unreachability Detection alone, since the network overhead would be prohibitively high in many cases for a mobile node to continually probe its default router with Neighbor Solicitation messages even when it is not otherwise actively sending packets to it. Instead, a mobile node SHOULD consider receipt of any IPv6 packets from its current default router as an indication that it is still reachable from the router. Both packets from the router's IP address and (IPv6) packets from its link-layer address (e.g., those forwarded but not originated by the router) SHOULD be considered.

Since the router SHOULD be sending periodic unsolicited multicast Router Advertisement messages, the mobile node will have frequent opportunity to check if it is still reachable from its default router, even in the absence of other packets to it from the router. If Router Advertisements that the mobile node receives include an Advertisement Interval option, the mobile node MAY use its Advertisement Interval field as an indication of the frequency with which it SHOULD expect to continue to receive future Advertisements from that router. This field specifies the minimum rate (the maximum amount of time between successive Advertisements) that the mobile node SHOULD expect. If this amount of time elapses without the mobile node receiving any Advertisement from this router, the mobile node can be sure that at least one Advertisement sent by the router has been lost. It is thus possible for the mobile node to implement its own policy for determining the number of Advertisements from its current default router it is willing to tolerate losing before deciding to switch to a different router from which it may currently be correctly receiving Advertisements.

On some types of network interfaces, the mobile node MAY also supplement this monitoring of Router Advertisements, by setting its network interface into "promiscuous" receive mode, so that it is able to receive all packets on the link, including those not link-level addressed to it (i.e., disabling link-level address filtering). The

mobile node will then be able to detect any packets sent by the router, in order to detect reachability from the router. This use of

promiscuous mode may be useful on very low bandwidth (e.g., wireless) links, but its use MUST be configurable on the mobile node.

If the above means do not provide indication that the mobile node is still reachable from its current default router (i.e., the mobile node receives no packets from the router for a period of time), then the mobile node SHOULD attempt to actively probe the router with Neighbor Solicitation messages, even if it is not otherwise actively sending packets to the router. If it receives a solicited Neighbor Advertisement message in response from the router, then the mobile node can deduce that it is still reachable. It is expected that the mobile node will in most cases be able to determine its reachability from the router by listening for packets from the router as described above, and thus, such extra Neighbor Solicitation probes should rarely be necessary.

With some types of networks, it is possible that additional indications about link-layer mobility can be obtained from lower-layer protocol or device driver software within the mobile node. However, a mobile node MUST NOT assume that all link-layer mobility indications from lower layers indicate a movement of the mobile node to a new link, such that the mobile node would need to switch to a new default router and primary care-of address. For example, movement of a mobile node from one cell to another in many wireless LANs can be made transparent to the IP level through use of a link-layer "roaming" protocol, as long as the different wireless LAN cells all operate as part of the same IP link with the same subnet prefix. Upon lower-layer indication of link-layer mobility, the mobile node MAY send Router Solicitation messages to determine if new routers (and new on-link subnet prefixes) are present on its new link.

Such lower-layer information might also be useful to a mobile node in deciding to switch its primary care-of address to one of the other care-of addresses it has formed from the on-link subnet prefixes currently available through different routers from which the mobile node is reachable. For example, a mobile node MAY use signal strength or signal quality information (with suitable hysteresis) for its link with the available routers to decide when to switch to a new primary care-of address using that router rather than its current default router (and current primary care-of address). Even though the mobile node's current default router may still be reachable in terms of Neighbor Unreachability Detection, the mobile node MAY use such lower-layer information to determine that switching to a new default router would provide a better connection.

10.5. Forming New Care-of Addresses

After detecting that it has moved from one link to another (i.e., its current default router has become unreachable and it has discovered

a new default router), a mobile node SHOULD form a new primary care-of address using one of the on-link subnet prefixes advertised by the new router. A mobile node MAY form a new primary care-of address at any time, except that it MUST NOT do so too frequently. Specifically, a mobile node MUST NOT send a Binding Update about a new care-of address to its home agent (which is required to register the new address as its primary care-of address) more often than once per MAX_UPDATE_RATE seconds.

In addition, after discovering a new on-link subnet prefix, a mobile node MAY form a new (non-primary) care-of address using that subnet prefix, even when it has not switched to a new default router. A mobile node can have only one primary care-of address at a time (which is registered with its home agent), but it MAY have an additional care-of address for any or all of the prefixes on its current link. Furthermore, since a wireless network interface may actually allow a mobile node to be reachable on more than one link at a time (i.e., within wireless transmitter range of routers on more than one separate link), a mobile node MAY have care-of addresses on more than one link at a time. The use of more than one care-of address at a time is described in Section 10.18.

As described in Section 4, in order to form a new care-of address, a mobile node MAY use either stateless [27] or stateful (e.g., DHCPv6 [2]) Address Autoconfiguration. If a mobile node needs to send packets as part of the method of address autoconfiguration, it MUST use an IPv6 link-local address rather than its own IPv6 home address as the Source Address in the IPv6 header of each such autoconfiguration packet.

In some cases, a mobile node may already know a (constant) IPv6 address that has been assigned to it for its use only while visiting a specific foreign link. For example, a mobile node may be statically configured with an IPv6 address assigned by the system administrator of some foreign link, for its use while visiting that link. If so, rather than using Address Autoconfiguration to form a new care-of address using this subnet prefix, the mobile node MAY use its own pre-assigned address as its care-of address on this link.

After forming a new care-of address, a mobile node MAY perform Duplicate Address Detection [27] on that new address to confirm its uniqueness. However, doing so represents a tradeoff between safety (ensuring that the new address is not used if it is a duplicate address) and overhead (performing Duplicate Address Detection requires the sending of one or more additional packets over what may be, for example, a slow wireless link through which the mobile node is connected). Performing Duplicate Address Detection also in general would cause a delay before the mobile node could use the

new care-of address, possibly causing the mobile node to be unable to continue communication with correspondent nodes for some period of time. For these reasons, a mobile node, after forming a new

care-of address, MAY begin using the new care-of address without performing Duplicate Address Detection. Furthermore, the mobile node MAY continue using the address without performing Duplicate Address Detection, although it SHOULD in most cases (e.g., unless network bandwidth or battery consumption for communication is of primary concern) begin Duplicate Address Detection asynchronously when it begins use of the address, allowing the Duplicate Address Detection procedure to complete in parallel with normal communication using the address.

In addition, normal processing for Duplicate Address Detection specifies that, in certain cases, the node SHOULD delay sending the initial Neighbor Solication message of Duplicate Address Detection by a random delay between 0 and MAX_RTR_SOLICITATION_DELAY [17, 27]; however, in this case, the mobile node SHOULD NOT perform such a delay in its use of Duplicate Address Detection, unless the mobile node is intializing after rebooting.

10.6. Sending Binding Updates to the Home Agent

After deciding to change its primary care-of address as described in Sections 10.4 and 10.5, a mobile node MUST register this care-of address with its home agent in order to make this its primary care-of address. To do so, the mobile node sends a packet to its home agent containing a Binding Update option, with the packet constructed as follows:

- The Home Registration (H) bit MUST be set in the Binding Update.
- The Acknowledge (A) bit MUST be set in the Binding Update.
- The packet MUST contain a Home Address option, giving the mobile node's home address for the binding.
- The care-of address for the binding MUST be used as the Source Address in the packet's IPv6 header, unless an Alternate Care-of Address sub-option is included in the Binding Update option.
- The Prefix Length field SHOULD be set to the length of the mobile node's subnet prefix in its home address, to request the mobile node's home agent to serve as a home agent for all home addresses for the mobile node based on all on-link subnet prefixes on the home link. Otherwise, this field MUST be set to zero.
- The value specified in the Lifetime field SHOULD be less than or equal to the remaining lifetime of the home address and the care-of address specified for the binding.

The Acknowledge (A) bit in the Binding Update requests the home agent to return a Binding Acknowledgement in response to this

Binding Update. As described in Section 5.2, the mobile node SHOULD retransmit this Binding Update to its home agent until it receives a matching Binding Acknowledgement. Once reaching a retransmission timeout period of MAX_BINDACK_TIMEOUT, the mobile node SHOULD continue to periodically retransmit the Binding Update at this rate until acknowledged (or until it begins attempting to register a different primary care-of address).

The Prefix Length field in the Binding Update allows the mobile node to request its home agent to serve all home addresses for the mobile node, as indicated by the interface identifier in the mobile node's home address (the remaining low-order bits after the indicated subnet prefix), together with each on-link subnet prefix on the home link. Until the lifetime of this registration expires, the home agent considers itself the home agent for each such home address of the mobile node. As the set of on-link subnet prefixes on the home link changes over time, the home agent changes the set of home addresses for this mobile node for which it is serving as the home agent.

When sending a Binding Update to its home agent, the mobile node MUST also create or update the corresponding Binding Update List entry, as specified in Section 10.8.

If the mobile node has additional home addresses using a different interface identifier, then the mobile node SHOULD send an additional packet containing a Binding Update to its home agent to register the care-of address for each such other home address (or set of home addresses sharing an interface identifier). These additional Binding Updates MUST each be sent as a separate packet, since each MUST be protected by IPsec [13, 11, 12] to authenticate the Binding Update as coming from the home address being bound, as defined in Section 4.4.

While the mobile node is away from home, it relies on the home agent to participate in Duplicate Address Detection (DAD) to defend its home address against stateless autoconfiguration performed by another node. Therefore, the mobile node SHOULD set the Duplicate Address Detection (D) bit based on any requirements for DAD Detection that would apply to the mobile node if it were at home [17, 27].

The home agent will only perform DAD for the mobile node's home address when the mobile node has supplied a valid binding between its home address and a care-of address. If some time elapses during which the mobile node has no binding at the home agent, it might be possible for another node to autoconfigure the mobile node's home address. Therefore, the mobile node MUST treat creation of a new binding with the home agent using an existing home address the same as creation of a new home address. In the unlikely event that the mobile node's home address is autoconfigured as the IPv6 address

of another network node on the home network, the home agent will reply to the mobile node's subsequent Binding Update with a Binding Acknowledgement showing Status 138, Duplicate Address Detection

failed. See section 10.10 for information about retransmitting Binding Updates.

10.7. Dynamic Home Agent Address Discovery

It is possible that when the mobile node needs to send a Binding Update to its home agent to register its new primary care-of address, as described in Section 10.6, the mobile node may not know the address of any router on its home link that can serve as a home agent for it. For example, some nodes on its home link may have been reconfigured while the mobile node has been away from home, such that the router that was operating as the mobile node's home agent has been replaced by a different router serving this role.

In this case, the mobile node MAY use the dynamic home agent address discovery mechanism to find the address of a suitable home agent on its home link. To do so, the mobile node sends an ICMP Home Agent Address Discovery Request message to the "Mobile IPv6 Home-Agents" anycast address [10] for its home subnet prefix. This packet MUST NOT contain a Home Address option and must be sent using the mobile node's care-of address as the Source Address in the packet's IP header (the packet is sent from the care-of address, not using Mobile IP). As described in Section 9.2, the home agent on its home link that receives this Request message will return an ICMP Home Agent Address Discovery Reply message, giving this home agent's own global unicast IP address along with a list of the global unicast IP address of each other home agent operating on the home link.

The mobile node, upon receiving this Home Agent Address Discovery Reply message, MAY then send its home registration Binding Update to the home agent address given as the IP Source Address of the packet carrying the Reply message or to any of the unicast IP addresses listed in the Home Agent Addresses field in the Reply. For example, if necessary, the mobile node MAY attempt its home registration with each of these home agents, in turn, by sending each a Binding Update and waiting for the matching Binding Acknowledgement, until its registration is accepted by one of these home agents. In trying each of the returned home agent addresses, the mobile node SHOULD try each in the order listed in the Home Agent Addresses field in the received Home Agent Address Discovery Reply message. If the home agent identified by the Source Address field in the IP header of the packet carrying the Home Agent Address Discovery Reply message is not listed in the Home Agent Addresses field in the Reply, it SHOULD be tried before the first address given in the list; otherwise, it SHOULD be tried in its listed order.

If the mobile node has a current registration with some home agent

on its home link (the Lifetime for that registration has not yet expired), then the mobile node MUST attempt any new registration first with that home agent. If that registration attempt fails

(e.g., times out or is rejected), the mobile node SHOULD then reattempt this registration with another home agent on its home link. If the mobile node knows of no other suitable home agent, then it MAY attempt the dynamic home agent address discovery mechanism described above.

10.8. Sending Binding Updates to Correspondent Nodes

A mobile node MAY send a Binding Update to any correspondent node at any time to allow the correspondent node to cache the mobile node's current care-of address (subject to the rate limiting defined in Section 10.11). In any Binding Update sent by a mobile node, the care-of address (either the Source Address in the packet's IPv6 header or the Care-of Address field in the Binding Update) MUST be set to one of the care-of addresses currently in use by the mobile node or to the mobile node's home address.

If set to one of the mobile node's current care-of addresses (the care-of address given MAY differ from the mobile node's primary care-of address), the Binding Update requests the correspondent node to create or update an entry for the mobile node in the correspondent node's Binding Cache to record this care-of address for use in sending future packets to the mobile node. In this case, the value specified in the Lifetime field sent in the Binding Update SHOULD be less than or equal to the remaining lifetime of the home address and the care-of address specified for the binding.

If, instead, the care-of address is set to the mobile node's home address, the Binding Update requests the correspondent node to delete any existing Binding Cache entry that it has for the mobile node. A mobile node MAY set the care-of address differently for sending Binding Updates to different correspondent nodes.

When sending any Binding Update, the mobile node MUST record in its Binding Update List the following fields from the Binding Update:

- The IP address of the node to which the Binding Update was sent.
- The home address for which the Binding Update was sent (the value in the Home Address option in the packet carrying the Binding Update).
- The initial lifetime of the binding, initialized from the Lifetime field sent in the Binding Update.
- The remaining lifetime of the binding, also initialized from the Lifetime field sent in the Binding Update. This remaining lifetime value counts down and may also be reduced when the

matching Binding Acknowledgement is received, based on the
Lifetime value specified in that Binding Acknowledgement, as

described in Section 10.12. When the remaining lifetime reaches zero, the Binding Update List entry MUST be deleted.

The mobile node MUST retain in its Binding Update List information about all Binding Updates sent, for which the lifetime of the binding has not yet expired. However, when sending a Binding Update, if an entry already exists in the mobile node's Binding Update List for an earlier Binding Update sent to that same destination node, the existing Binding Update List entry is updated to reflect the new Binding Update rather than creating a new Binding Update List entry.

In general, when a mobile node sends a Binding Update to its home agent to register a new primary care-of address (as described in Section 10.6), the mobile node will also send a Binding Update to each other node for which an entry exists in the mobile node's Binding Update List. Thus, other relevant nodes are generally kept updated about the mobile node's binding and can send packets directly to the mobile node using the mobile node's current care-of address.

The mobile node, however, need not send these Binding Updates immediately after configuring a new care-of address. For example, since the Binding Update is a destination option and can be included in any packet sent by a mobile node, the mobile node MAY delay sending a new Binding Update to any correspondent node for a short period of time, in hopes that the needed Binding Update can be included in some packet that the mobile node sends to that correspondent node for some other reason (for example, as part of some TCP connection in use). In this case, when sending a packet to some correspondent node, the mobile node SHOULD check in its Binding Update List to determine if a new Binding Update to this correspondent node is needed, and SHOULD include the new Binding Update in this packet as necessary.

In addition, when a mobile node receives a packet for which the mobile node can deduce that the original sender of the packet has no Binding Cache entry for the mobile node, or for which the mobile node can deduce that the original sender of the packet has an out-of-date care-of address for the mobile node in its Binding Cache, the mobile node SHOULD return a Binding Update to the sender giving its current care-of address (subject to the rate limiting defined in Section 10.11). In particular, the mobile node SHOULD return a Binding Update in response to receiving a packet that meets all of the following tests:

- The packet was tunneled using IPv6 encapsulation.

- The Destination Address in the tunnel (outer) IPv6 header is equal to any of the mobile node's care-of addresses.

- The Destination Address in the original (inner) IPv6 header is equal to one of the mobile node's home addresses; or this

Destination Address is equal to one of the mobile node's previous care-of addresses for which the mobile node has an entry in its Binding Update List, representing an unexpired Binding Update sent to a home agent on the link on which its previous care-of address is located (Section 10.9).

- The Source Address in the tunnel (outer) IPv6 header differs from the Source Address in the original (inner) IPv6 header.

The destination address to which the Binding Update should be sent in response to receiving a packet meeting all of the above tests is the Source Address in the original (inner) IPv6 header of the packet. The home address for which this Binding Update is sent should be the Destination Address of the original (inner) packet.

Binding Updates sent to correspondent nodes are not generally required to be acknowledged. However, if the mobile node wants to be sure that its new care-of address has been entered into a correspondent node's Binding Cache, the mobile node MAY request an acknowledgement by setting the Acknowledge (A) bit in the Binding Update. In this case, however, the mobile node SHOULD NOT continue to retransmit the Binding Update once the retransmission timeout period has reached MAX_BINDACK_TIMEOUT.

A mobile node MAY choose to keep its location private from certain correspondent nodes, and thus need not send new Binding Updates to those correspondents. A mobile node MAY also send a Binding Update to such a correspondent node to instruct it to delete any existing binding for the mobile node from its Binding Cache, as described in Section 5.1. No other IPv6 nodes are authorized to send Binding Updates on behalf of a mobile node.

10.9. Establishing Forwarding from a Previous Care-of Address

When a mobile node connects to a new link and forms a new care-of address, it MAY establish forwarding of packets from a previous care-of address to this new care-of address. To do so, the mobile node sends a Binding Update to any home agent on the link on which the previous care-of address is located, indicating this previous care-of address as the home address for the binding, and giving its new care-of address as the binding's care-of address. Such packet forwarding allows packets destined to the mobile node from nodes that have not yet learned the mobile node's new care-of address, to be forwarded to the mobile node rather than being lost once the mobile node is no longer reachable at this previous care-of address.

In constructing this Binding Update, the mobile node utilizes the following specific steps:

- The Home Address field in the Home Address option in the packet carrying the Binding Update MUST be set to the previous care-of address for which packet forwarding is being established.

- The care-of address for the new binding MUST be set to the new care-of address to which packets destined to the previous care-of address are to be forwarded. Normally, this care-of address for the binding is specified by setting the Source Address of the packet carrying the Binding Update, to this address. However, the mobile node MAY instead include an Alternate Care-of Address sub-option in the Binding Update option, with its Alternate Care-of Address field set to the care-of address for the binding.

- The Home Registration (H) bit MUST also be set in this Binding Update, to request this home agent to temporarily act as a home agent for this previous care-of address.

This home agent will thus tunnel packets for the mobile node (packets destined to its specified previous care-of address) to its new care-of address. All of the procedures defined for home agent operation MUST be followed by this home agent for this registration. Note that this home agent does not necessarily know (and need not know) the mobile node's (permanent) home address as part of this registration.

The packet carrying the Binding Update MUST be addressed to this home agent's global unicast address. Normally, this global unicast address is learned by the mobile node based on the Router Advertisements received by the mobile node (Section 6.2) while attached to the link on which this previous care-of address and this home agent are located; the mobile node obtains this home agent address from its Home Agents List (Section 4.6). Alternatively, the mobile node MAY use dynamic home agent address discovery (Section 10.7) to discover the global unicast address of a home agent on this previous link, but it SHOULD use an address from its Home Agents List if available for the prefix it used to form this previous care-of address.

As with any packet containing a Binding Update (see section 5.1), the Binding Update packet to this home agent MUST meet the IPsec requirements for Binding Updates, defined in Section 4.4.

10.10. Retransmitting Binding Updates

When the mobile node sends a Binding Update, it has to determine a value for the initial retransmission timer. If the mobile node is changing or updating an existing binding at the home agent, it should use the specified value of INITIAL_BINDACK_TIMEOUT for this

initial retransmission timer. If on the other hand the mobile node does not have an existing binding at the home agent, it SHOULD use a

value for the initial retransmission timer that is at least 1.5 times longer than (RetransTimer * DupAddrDetectTransmits). This value is likely to be substantially longer than the otherwise specified value of INITIAL_BINDACK_TIMEOUT that would be used by the mobile node. This longer retransmission interval will allow the the home agent to complete the DAD procedure which is mandated in this case, as detailed in section 10.6.

If, after sending a Binding Update in which the care-of address has changed and the Acknowledge (A) bit is set, a mobile node fails to receive a valid, matching Binding Acknowledgement within the selected initial retransmission interval, the mobile node SHOULD retransmit the Binding Update, until a Binding Acknowledgement is received. Such a retransmitted Binding Update MUST use a Sequence Number value greater than that used for the previous transmission of this Binding Update. The retransmissions by the mobile node MUST use an exponential back-off process, in which the timeout period is doubled upon each retransmission until either the node receives a Binding Acknowledgement or the timeout period reaches the value MAX_BINDACK_TIMEOUT.

10.11. Rate Limiting for Sending Binding Updates

A mobile node MUST NOT send Binding Updates about the same binding to any individual node more often than once per MAX_UPDATE_RATE seconds. After sending MAX_FAST_UPDATES consecutive Binding Updates to a particular node with the same care-of address, the mobile node SHOULD reduce its rate of sending Binding Updates to that node, to the rate of SLOW_UPDATE_RATE per second. The mobile node MAY continue to send Binding Updates at this slower rate indefinitely, in hopes that the node will eventually be able to process a Binding Update and begin to route its packets directly to the mobile node at its new care-of address.

10.12. Receiving Binding Acknowledgements

Upon receiving a packet carrying a Binding Acknowledgement, a mobile node MUST validate the packet according to the following tests:

- The packet meets the specific IPsec requirements for Binding Acknowledgements, defined in Section 4.4.

- The Option Length field in the Binding Acknowledgement option is greater than or equal to the length specified in Section 5.2.

- The Sequence Number field matches the Sequence Number sent by the mobile node to this destination address in an outstanding Binding

Update.

Any Binding Acknowledgement not satisfying all of these tests MUST be silently ignored, although the remainder of the packet (i.e., other options, extension headers, or payload) SHOULD be processed normally according to any procedure defined for that part of the packet.

When a mobile node receives a packet carrying a valid Binding Acknowledgement, the mobile node MUST examine the Status field as follows:

- If the Status field indicates that the Binding Update was accepted (the Status field is less than 128), then the mobile node MUST update the corresponding entry in its Binding Update List to indicate that the Binding Update has been acknowledged; the mobile node MUST then stop retransmitting the Binding Update. In addition, if the value specified in the Lifetime field in the Binding Acknowledgement is less than the Lifetime value sent in the Binding Update being acknowledged, then the mobile node MUST subtract the difference between these two Lifetime values from the remaining lifetime for the binding as maintained in the corresponding Binding Update List entry (with a minimum value for the Binding Update List entry lifetime of 0). That is, if the Lifetime value sent in the Binding Update was L_update, the Lifetime value received in the Binding Acknowledgement was L_ack, and the current remaining lifetime of the Binding Update List entry is L_remain, then the new value for the remaining lifetime of the Binding Update List entry should be

  max((L_remain - (L_update - L_ack)), 0)

  where max(X, Y) is the maximum of X and Y. The effect of this step is to correctly manage the mobile node's view of the binding's remaining lifetime (as maintained in the corresponding Binding Update List entry) so that it correctly counts down from the Lifetime value given in the Binding Acknowledgement, but with the timer countdown beginning at the time that the Binding Update was sent.

- If the Status field indicates that the Binding Update was rejected (the Status field is greater than or equal to 128), then the mobile node MUST delete the corresponding Binding Update List entry, and it MUST also stop retransmitting the Binding Update. Optionally, the mobile node MAY then take steps to correct the cause of the error and retransmit the Binding Update (with a new Sequence Number value), subject to the rate limiting restriction specified in Section 10.11.

10.13. Receiving Binding Requests

When a mobile node receives a packet containing a Binding Request, it SHOULD return to the sender a packet containing a Binding Update.

The Lifetime field in this Binding Update SHOULD be set to a new lifetime, extending any current lifetime remaining from a previous Binding Update sent to this node (as indicated in any existing Binding Update List entry for this node), except that this lifetime MUST NOT exceed the remaining lifetime for the mobile node's primary care-of address registration at its home agent. When sending this Binding Update, the mobile node MUST update its Binding Update List in the same way as for any other Binding Update sent by the mobile node.

Note, however, that the mobile node MAY choose to keep its current binding private from the sender of the Binding Request. In this case, the mobile node instead SHOULD return a Binding Update to the sender, in which the Lifetime field is set to zero and the care-of address is set to the mobile node's home address.

If the Binding Request for which the Binding Update is being returned contains a Unique Identifer Sub-Option, the Binding Update MUST also include a Unique Identifier Sub-Option. The unique identifier in the Sub-Option Data field of the Unique Identifier Sub-Option MUST be copied from the unique identifier carried in the Binding Request.

10.14. Receiving ICMP Error Messages

The Option Type value for a Binding Update option specifies that any node receiving this option that does not recognize the Option Type SHOULD return an ICMP Parameter Problem, Code 2, message to the sender of the packet containing the Binding Update option. If a node sending a Binding Update receives such an ICMP error message in response, it SHOULD record in its Binding Update List that future Binding Updates SHOULD NOT be sent to this destination.

Likewise, although ALL IPv6 nodes (whether host or router, whether mobile or stationary) MUST implement the ability to correctly process received packets containing a Home Address option, all Option Type values in IPv6 include a specification of the behavior that a node receiving a packet containing this option performs if it does not implement receipt of that type of option. For the Home Address option, the Option Type value specifies that any node receiving this option that does not recognize the Option Type SHOULD return an ICMP Parameter Problem, Code 2, message to the sender of the packet containing the Home Address option. If a mobile node receives such an ICMP error message from some node indicating that it does not recognize the mobile node's Home Address option, the mobile node SHOULD log the error and then discard the ICMP message; this error message indicates that the node to which the original packet was addressed (the node returning the ICMP error message) does not

correctly implement this required part of the IPv6 protocol.

10.15. Receiving Local Router Advertisement Messages

Each mobile node maintains a Home Agents List recording information about all home agents from which it receives a Router Advertisement, for which the home agent lifetime indicated in that Router Advertisement has not yet expired. This list is used by the mobile node to enable it to send a Binding Update to the global unicast address of a home agent on its previous link when it moves to a new link, as described in Section 10.9. On receipt of a valid Router Advertisement, as defined in the processing algorithm specified for Neighbor Discovery [17], the mobile node performs the following steps, in addition to any steps already required of it by Neighbor Discovery and by other procedures described in this document:

- If the Home Agent (H) bit in the Router Advertisement is not set, skip all of the following steps. There are no special processing steps required by this aspect of Mobile IP for this Router Advertisement, since the Advertisement was not sent by a home agent.

- Otherwise, extract the Source Address from the IP header of the Router Advertisement. This is the link-local IP address on this link of the home agent sending this Advertisement [17].

- Determine from the Router Advertisement the preference for this home agent. If the Router Advertisement contains a Home Agent Information Option, then the preference is taken from the Home Agent Preference field in the option; otherwise, the default preference of 0 MUST be used.

- Determine from the Router Advertisement the lifetime for this home agent. If the Router Advertisement contains a Home Agent Information Option, then the lifetime is taken from the Home Agent Lifetime field in the option; otherwise, the lifetime specified by the Router Lifetime field in the Router Advertisement SHOULD be used.

- If the link-local address of the home agent sending this Advertisement is already present in this mobile node's Home Agents List and the received home agent lifetime value is zero, immediately delete this entry in the Home Agents List.

- Otherwise, if the link-local address of the home agent sending this Advertisement is already present in the receiving mobile node's Home Agents List, reset its lifetime and preference to the values determined above.

- If the link-local address of the home agent sending this Advertisement, as determined above, is not already present in the

Home Agents List maintained by the receiving mobile node, and
the lifetime for the sending home agent, as determined above,

is non-zero, create a new entry in the list, and initialize its lifetime and preference to the values determined above.

- If the Home Agents List entry for the link-local address of the home agent sending this Advertisement was not deleted as described above, determine any global address(es) of the home agent based on each Prefix Information option received in this Advertisement in which the Router Address (R) bit is set (Section 6.2). For each such global address determined from this Advertisement, add this global address to the list of global addresses for this home agent in this Home Agents List entry.

A mobile node SHOULD maintain an entry in its Home Agents List for each such valid home agent address until that entry's lifetime expires, after which time the entry MUST be deleted.

10.16. Sending Tunneled Router Solicitations

When a mobile node has a home address that is about to become invalid, it tunnels a Router Solicitation to its home agent in an attempt to acquire fresh routing prefix information. The new information enables the mobile node to participate in renumbering operations affecting the home network, as described in section 9.8.

The mobile node SHOULD tunnel a Router Solicitation to the home agent when its home address will become invalid within MaxRtrAdvInterval seconds, where this value is acquired in a previous Router Advertisement from the home agent. If no such value is known, the value MAX_PFX_ADV_DELAY seconds is used instead.

The mobile node tunnels (using IPv6 encapsulation [4]) the solicitation, including the following IPv6 header fields:

```
Outer src = care-of address
Outer dst = Home Agent's global address
Inner src = home address
Inner dst = Home Agent's global address
```

If the mobile node does not have a valid home address available for use as the Inner src address, it MAY use the unspecified IPv6 address (0:0:0:0:0:0:0:0).

This solicitation follows the same retransmission rules as already specified for Router Solicitations [17], except that the initial retransmission interval is specified to be INITIAL_SOLICIT_TIMER.

10.17. Receiving Tunneled Router Advertisements

Section 9.8 describes the operation of a home agent to support renumbering a mobile node's home subnet while the mobile node is away from home. The home agent tunnels certain Router Advertisement messages to the mobile node while away from home, giving "important" Prefix Information options that describe changes in the prefixes in use on the mobile node's home link.

When a mobile node receives a tunneled Router Advertisement, it MUST validate it according to the following tests:

- The Source Address of the IP packet carrying the Router Advertisement is the same as the home agent address to which the mobile node last sent an accepted "home registration" Binding Update to register its primary care-of address.

- The packet MUST be protected by IPsec [13, 11, 12] to guard against malicious Router Advertisements. The IPsec protection MUST provide sender authentication, data integrity protection, and replay protection, covering the Router Advertisement.

- The packet contains a Binding Request destination option.

- The Binding Request option contains a Unique Identifier Sub-Option.

Any received tunneled Router Advertisement not meeting all of these tests MUST be silently discarded.

If a received tunneled Router Advertisement is not discarded according to the tests listed above, the mobile node MUST process the Router Advertisement as if it were connected to its home link [17]. Such processing may result in the mobile node configuring a new home address, although due to separation between preferred lifetime and valid lifetime, such changes should not affect most communication by the mobile node, in the same way as for nodes that are at home.

In processing the packet containing this Router Advertisement, the mobile node SHOULD return to the home agent a Binding Update in response to the Binding Request carried in the packet. The correct formation of this Binding Update by the mobile node and processing of it by the home agent will be viewed by the home agent as an acknowledgement of this Router Advertisement, confirming to it that this Router Advertisement was received by the mobile node.

In addition, if processing of this Router Advertisement resulted in the mobile node configuring a new home address, and if the method used for this new home address configuration would require the mobile

node to perform Duplicate Address Detection [27] for the new address if the mobile node were located at home, then the mobile node MUST

set the Duplicate Address Detection (D) bit in this Binding Update to its home agent, to request the home agent to perform this Duplicate Address Detection on behalf of the mobile node.

10.18. Using Multiple Care-of Addresses

As described in Section 10.5, a mobile node MAY use more than one care-of address at a time. Particularly in the case of many wireless networks, a mobile node effectively might be reachable through multiple links at the same time (e.g., with overlapping wireless cells), on which different on-link subnet prefixes may exist. A mobile node SHOULD select a primary care-of address from among those care-of addresses it has formed using any of these subnet prefixes, based on the movement detection mechanism in use, as described in Section 10.4. When the mobile node selects a new primary care-of address, it MUST register it with its home agent by sending it a Binding Update with the Home Registration (H) and Acknowledge (A) bits set, as described in Section 10.6.

To assist with smooth handoffs, a mobile node SHOULD retain its previous primary care-of address as a (non-primary) care-of address, and SHOULD still accept packets at this address, even after registering its new primary care-of address with its home agent. This is reasonable, since the mobile node could only receive packets at its previous primary care-of address if it were indeed still connected to that link. If the previous primary care-of address was allocated using stateful Address Autoconfiguration [2], the mobile node may not wish to release the address immediately upon switching to a new primary care-of address.

10.19. Routing Multicast Packets

A mobile node that is connected to its home link functions in the same way as any other (stationary) node. Thus, when it is at home, a mobile node functions identically to other multicast senders and receivers. This section therefore describes the behavior of a mobile node that is not on its home link.

In order to receive packets sent to some multicast group, a mobile node must join that multicast group. One method by which a mobile node MAY join the group is via a (local) multicast router on the foreign link being visited. The mobile node SHOULD use one of its care-of addresses that shares a subnet prefix with the multicast router, as the source IPv6 address of its multicast group membership control messages. The mobile node MUST insert a Home Address destination option in such outgoing multicast packets, so that any multicast applications that depend on the address of the sending node

will correctly use the mobile node's home address for that value.

Alternatively, a mobile node MAY join multicast groups via a bi-directional tunnel to its home agent. The mobile node tunnels its multicast group membership control packets to its home agent, and the home agent forwards multicast packets down the tunnel to the mobile node.

A mobile node that wishes to send packets to a multicast group also has two options: (1) send directly on the foreign link being visited; or (2) send via a tunnel to its home agent. Because multicast routing in general depends upon the Source Address used in the IPv6 header of the multicast packet, a mobile node that tunnels a multicast packet to its home agent MUST use its home address as the IPv6 Source Address of the inner multicast packet.

10.20. Returning Home

A mobile node detects that it has returned to its home link through the movement detection algorithm in use (Section 10.4), when the mobile node detects that its home subnet prefix is again on-link. The mobile node SHOULD then send a Binding Update to its home agent, to instruct its home agent to no longer intercept or tunnel packets for it. In this Binding Update, the mobile node MUST set the care-of address for the binding (the Source Address field in the packet's IPv6 header) to the mobile node's own home address. As with other Binding Updates sent to register with its home agent, the mobile node MUST set the Acknowledge (A) and Home Registration (H) bits, and SHOULD retransmit the Binding Update until a matching Binding Acknowledgement is received.

When sending this Binding Update to its home agent, the mobile node must be careful in how it uses Neighbor Solicitation [17] (if needed) to learn the home agent's link-layer address, since the home agent will be currently configured to defend the mobile node's home address for Duplicate Address Detection. In particular, a Neighbor Solicitation from the mobile node using its home address as the Source Address would be detected by the home agent as a duplicate address. In many cases, Neighbor Solicitation by the mobile node for the home agent's address will not be necessary, since the mobile node may have already learned the home agent's link-layer address, for example from a Source Link-Layer Address option in the Router Advertisement from which it learned that its home address was on-link and that the mobile node had thus returned home. If the mobile node does Neighbor Solicitation to learn the home agent's link-layer address, in this special case of the mobile node returning home, the mobile node MUST unicast the packet, and in addition set the Source Address of this Neighbor Solicitation to the unspecified address (0:0:0:0:0:0:0:0). Since the solicitation is unicast, the home agent

will be able to distinguish from a similar packet that would only be used for DAD.

The mobile node then sends its Binding Update using the home agent's link-layer address, instructing its home agent to no longer serve as a home agent for it. By processing this Binding Update, the home agent will cease defending the mobile node's home address for Duplicate Address Detection and will no longer respond to Neighbor Solicitations for the mobile node's home address. The mobile node is then the only node on the link using the mobile node's home address. In addition, when returning home prior to the expiration of a current binding for its home address, and configuring its home address on its network interface on its home link, the mobile node MUST NOT perform Duplicate Address Detection on its own home address, in order to avoid confusion or conflict with its home agent's use of the same address. If the mobile node returns home after the bindings for all of its care-of addresses have expired, then it SHOULD perform DAD.

After receiving the Binding Acknowledgement for its Binding Update to its home agent, the mobile node MUST multicast onto the home link (to the all-nodes multicast address) a Neighbor Advertisement message [17], to advertise the mobile node's own link-layer address for its own home address. The Target Address in this Neighbor Advertisement message MUST be set to the mobile node's home address, and the Advertisement MUST include a Target Link-layer Address option specifying the mobile node's link-layer address. The mobile node MUST multicast such a Neighbor Advertisement message for each of its home addresses, as defined by the current on-link prefixes, including its link-local address and site-local address. The Solicited Flag (S) in these Advertisements MUST NOT be set, since they were not solicited by any Neighbor Solicitation message. The Override Flag (O) in these Advertisements MUST be set, indicating that the Advertisements SHOULD override any existing Neighbor Cache entries at any node receiving them.

Since multicasts on the local link (such as Ethernet) are typically not guaranteed to be reliable, the mobile node MAY retransmit these Neighbor Advertisement messages up to MAX_ADVERT_REXMIT times to increase their reliability. It is still possible that some nodes on the home link will not receive any of these Neighbor Advertisements, but these nodes will eventually be able to recover through use of Neighbor Unreachability Detection [17].

11. Protocol Constants

INITIAL_BINDACK_TIMEOUT	1 second
INITIAL_SOLICIT_TIMER	2 seconds
MAX_BINDACK_TIMEOUT	256 seconds
MAX_UPDATE_RATE	once per second
SLOW_UPDATE_RATE	once per 10 seconds
MAX_FAST_UPDATES	5 transmissions
MAX_ADVERT_REXMIT	3 transmissions
MAX_PFX_ADV_DELAY	1,000 seconds
HomeRtrAdvInterval	1,000 seconds

12. IANA Considerations

This document defines four new types of IPv6 destination options, each of which must be assigned an Option Type value:

- The Binding Update option, described in Section 5.1;
- The Binding Acknowledgement option, described in Section 5.2;
- The Binding Request option, described in Section 5.3; and
- The Home Address option, described in Section 5.4.

In addition, this document defines two ICMP message types, used as part of the dynamic home agent address discovery mechanism:

- The Home Agent Address Discovery Request message, described in Section 5.6; and
- The Home Agent Address Discovery Reply message, described in Section 5.7.

This document also defines two new Neighbor Discovery [17] options, which must be assigned Option Type values within the option numbering space for Neighbor Discovery messages:

- The Advertisement Interval option, described in Section 6.3; and
- The Home Agent Information option, described in Section 6.4.

Finally, this document defines a new type of anycast address, which must be assigned a reserved value for use with any subnet prefix to define this anycast address on each subnet:

- The "Mobile IPv6 Home-Agents" anycast address [10], used in the dynamic home agent address discovery mechanism described in Sections 9.2 and 10.7.

13. Security Considerations

13.1. Binding Updates, Acknowledgements, and Requests

The Binding Update option described in this document will result in packets addressed to a mobile node being delivered instead to its care-of address. This ability to change the routing of these packets could be a significant vulnerability if any packet containing a Binding Update option was not authenticated. Such use of "remote redirection", for instance as performed by the Binding Update option, is widely understood to be a security problem in the current Internet if not authenticated [1].

The Binding Acknowledgement option also requires authentication, since, for example, an attacker could otherwise trick a mobile node into believing a different outcome from a registration attempt with its home agent.

No authentication is required for the Binding Request option, since the use of this option does not modify or create any state in either the sender or the receiver. The Binding Request option does open some issues with binding privacy, but those issues can be dealt with either through existing IPsec encryption mechanisms or through use of firewalls.

The existing IPsec replay protection mechanisms allow a "replay protection window" to support receiving packets out of order. Although appropriate for many forms of communication, Binding Updates MUST be applied only in the order sent. The Binding Update option thus includes a Sequence Number field to provide this necessary sequencing. The use of this Sequence Number together with IPsec replay protection is similar in many ways, for example, to the the sequence number in TCP. IPsec provides strong replay protection but no ordering, and the sequence number provides ordering but need not protect against replays such as may occur when the sequence number wraps around.

13.2. Security for the Home Address Option

No special authentication of the Home Address option is required, except that if the IPv6 header of a packet is covered by authentication, then that authentication MUST also cover the Home Address option; this coverage is achieved automatically by the definition of the Option Type code for the Home Address option (Section 5.4), since it indicates that the option is included in the authentication computation. Thus, even when authentication is used in the IPv6 header, the security of the Source Address field in the IPv6 header is not compromised by the presence of a Home Address

option. Without authentication of the packet, then any field in the IPv6 header, including the Source Address field, and any other parts

of the packet, including the Home Address option, can be forged or modified in transit. In this case, the contents of the Home Address option is no more suspect than any other part of the packet.

The use of the Home Address option allows packets sent by a mobile node to pass normally through routers implementing ingress filtering [7]. Since the care-of address used in the Source Address field of the packet's IPv6 header is topologically correct for the sending location of the mobile node, ingress filtering can trace the location of the mobile node in the same way as can be done with any sender when ingress filtering is in use. A node receiving a packet that includes a Home Address option MAY implement the processing of this option by physically exchanging the Home Address option field with the source IPv6 address in the IPv6 header.

13.3. General Mobile Computing Issues

The mobile computing environment is potentially very different from the ordinary computing environment. In many cases, mobile computers will be connected to the network via wireless links. Such links are particularly vulnerable to passive eavesdropping, active replay attacks, and other active attacks. Furthermore, mobile computers are more susceptible to loss or theft than stationary computers. Any secrets such as authentication or encryption keys stored on the mobile computer are thus subject to compromise in ways generally not common in the non-mobile environment.

Users who have sensitive data that they do not wish others to have access to SHOULD use additional mechanisms (such as encryption) to provide privacy protection, but such mechanisms are beyond the scope of this document. Users concerned about traffic analysis SHOULD consider appropriate use of link encryption. If stronger location privacy is desired, the mobile node can create a tunnel to its home agent. Then, packets destined for correspondent nodes will appear to emanate from the home subnet, and it may be more difficult to pinpoint the location of the mobile node. Such mechanisms are all beyond the scope of this document.

Whether or not the mobile node is away from home is likely to influence the choice of security policy from the SPD. For instance, if a mobile node is connected to its home network and it communicates with a correspondent node on its home network, no security may be needed. If, on the other hand, the mobile node is attached to foreign network and has sent a Binding Update to its home agent, then the mobile node may need to make use of security features in order to communicate with that same correspondent node.

Changes from Previous Version of the Draft

This appendix briefly lists some of the major changes in this draft relative to the previous version of this same draft, draft-ietf-mobileip-ipv6-12.txt:

- Specified that the Home Address destination option MUST be inserted between Routing Header and Fragment Header
- Specified that the Binding Update MUST be located after the IPsec header(s).
- Specified that the AH is to be calculated as if the home address were in the IPv6 header, and the care-of address were in the Home Address destination option.
- Changed SHOULD to MUST for treating unspecified home agent preferences as 0.
- Introduced the notion of scheduling Router Advertisements to be sent to the mobile node whenever a prefix advertisement or internal reconfiguration causes a mobile node's home address to be in danger of becoming deprecated.
- Specified that the mobile node MUST set the `D' bit whenever it sends a Binding Update that is new, instead of simply updating an existing binding to a new care-of address or binding lifetime.
- Added new section on mobile node tunneling Router Solicitations
- Added appendix about remote autoconfiguration for home addresses.
- Added specification about picking a longer initial retransmission interval for initial Binding Updates sent to the home agent, because the home agent will take longer since it has to perform DAD.
- Added the following protocol constants:

  INITIAL_SOLICIT_TIMER: 2 seconds

  MAX_PFX_ADV_DELAY: 1,000 seconds

  HomeRtrAdvInterval: 1,000 seconds

Acknowledgements

We would like to thank the members of the Mobile IP and IPng Working Groups for their comments and suggestions on this work. We would particularly like to thank (in alphabetical order) Fred Baker (Cisco), Josh Broch (Carnegie Mellon University), Robert Chalmers (University of California at Santa Barbara), Rich Draves (Microsoft Research), Francis Dupont (ENST Bretagne), Thomas Eklund (SwithCore), Jun-Ichiro Itojun Hagino (IIJ Research Laboratory), Aime Lerouzic (Bull S.A.), Thomas Narten (IBM), Erik Nordmark (Sun Microsystems), Simon Nybroe (Ericsson Telebit), David Oran (Cisco), Basavaraj Patil (Nokia), Ken Powell (Compaq), Phil Roberts (Motorola), Patrice Romand (Bull S.A.), Tom Soderlund (Nokia Research), Hesham Soliman (Ericsson), Jim Solomon (RedBack Networks), Tapio Suihko (Technical Research Center of Finland), Benny Van Houdt (University of Antwerp), Jon-Olov Vatn (KTH), and Xinhua Zhao (Stanford University) for their detailed reviews of earlier versions of this document. Their suggestions have helped to improve both the design and presentation of the protocol.

We would also like to thank the participants in the Mobile IPv6 testing event held at Nancy, France, September 15-17, 1999, for their valuable feedback as a result of interoperability testing of four Mobile IPv6 implementations coming from four different organizations: Bull (AIX), Ericsson Telebit (FreeBSD), NEC (FreeBSD), and INRIA (FreeBSD). Further, we would like to thank the feedback from the implementors who participated in the Mobile IPv6 interoperability testing at Connectathon 2000 in San Jose, California, March 6-9, 2000. Finally, we would like to thank the participants at the ETSI interoperability testing at ETSI, in Sophia Antipolis, France, during October 2-6, 2000, including teams from Compaq, Ericsson, INRIA, Nokia, and Technical University of Helsinki.

References

[1] S. M. Bellovin. Security Problems in the TCP/IP Protocol Suite. ACM Computer Communications Review, 19(2), March 1989.

[2] Jim Bound and Charles Perkins. Dynamic Host Configuration Protocol for IPv6 (DHCPv6), February 1999. Work in progress.

[3] Scott Bradner. Key words for use in RFCs to Indicate Requirement Levels. RFC 2119, March 1997.

[4] Alex Conta and Stephen Deering. Generic Packet Tunneling in IPv6 Specification. RFC 2473, December 1998.

[5] Alex Conta and Stephen Deering. Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification. RFC 2463, December 1998.

[6] Stephen E. Deering and Robert M. Hinden. Internet Protocol Version 6 (IPv6) Specification. RFC 2460, December 1998.

[7] Paul Ferguson and Daniel Senie. Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing. RFC 2267, January 1998.

[8] Dan Harkins and Dave Carrel. The Internet Key Exchange (IKE). RFC 2409, November 1998.

[9] Robert M. Hinden and Stephen E. Deering. IP Version 6 Addressing Architecture. RFC 2373, July 1998.

[10] David B. Johnson and Stephen E. Deering. Reserved IPv6 Subnet Anycast Addresses. RFC 2526, March 1999.

[11] Stephen Kent and Randall Atkinson. IP Authentication Header. RFC 2402, November 1998.

[12] Stephen Kent and Randall Atkinson. IP Encapsulating Security Payload (ESP). RFC 2406, November 1998.

[13] Stephen Kent and Randall Atkinson. Security Architecture for the Internet Protocol. RFC 2401, November 1998.

[14] Douglas Maughan, Mark Schneider, Mark Schertler, and Jeff Turner. Internet Security Association and Key Management Protocol (ISAKMP). RFC 2408, November 1998.

[15] P. Mockapetris. Domain Names -- Concepts and Facilities. RFC 1034, November 1987.

[16] P. Mockapetris. Domain Names -- Implementation and Specification. RFC 1035, November 1987.

[17] Thomas Narten, Erik Nordmark, and William Allen Simpson. Neighbor Discovery for IP Version 6 (IPv6). RFC 2461, December 1998.

[18] Charles Perkins. IP Encapsulation within IP. RFC 2003, October 1996.

[19] Charles Perkins, editor. IP Mobility Support. RFC 2002, October 1996.

[20] Charles Perkins. Minimal Encapsulation within IP. RFC 2004, October 1996.

[21] Charles Perkins and David B. Johnson. Route Optimization in Mobile IP, February 1999. Work in progress.

[22] Derrell Piper. The Internet IP Security Domain of Interpretation for ISAKMP. RFC 2407, November 1998.

[23] David C. Plummer. An Ethernet Address Resolution Protocol: Or Converting Network Protocol Addresses to 48.bit Ethernet Addresses for Transmission on Ethernet Hardware. RFC 826, November 1982.

[24] J. B. Postel. User Datagram Protocol. RFC 768, August 1980.

[25] J. B. Postel, editor. Transmission Control Protocol. RFC 793, September 1981.

[26] Joyce K. Reynolds and Jon Postel. Assigned Numbers. RFC 1700, October 1994. See also http://www.iana.org/numbers.html.

[27] Susan Thomson and Thomas Narten. IPv6 Stateless Address Autoconfiguration. RFC 2462, December 1998.

A. Remote Home Address Configuration

The method for initializing a mobile node's home addresses on power-up or after an extended period of being disconnected from the network is beyond the scope of this specification. Whatever procedure is used should result in the mobile node having the same stateless or stateful (e.g., DHCPv6) home address autoconfiguration information it would have if it were attached to the home network. Due to the possibility that the home network could be renumbered while the mobile node is disconnected, a robust mobile node would not rely solely on storing these addresses locally.

A mobile node MAY generate a temporary home address using the following information:

- the subnet prefix from the home network's mobile agent anycast address, and

- the globally unique interface identifier that would have been used to generate the link local address if the mobile node were attached directly to the home network.

Such a temporary address could be used to establish a binding with a home agent in the absence of any other known home addresses. It could be created with short valid lifetime and a preferred lifetime of zero to ensure a quick transition to other addresses generated when stateless or stateful (DHCPv6) address autoconfiguration runs.

Such a mobile node could initialize by using the following procedure:

1. Generate a care-of address using stateless or stateful autoconfiguration.

2. Query DNS for the home network's mobile agent anycast address.

3. Send a Home Agent Address Discovery Request message to the home network.

4. Receive Home Agent Address Discovery Reply message.

5. Select the most preferred home agent address and use it to generate a temporary home address for the mobile node using the rules defined above.

6. Send a binding update option with a Router Solicitation to the home agent. This registers the mobile node's temporary home address and requests a router advertisement to initiate stateless address autoconfiguration at the same time.

7. Receive binding acknowledgement and binding request options with a router advertisement from the home agent.

8. Parse the Router Advertisement and configure all prefixes and addresses according to the method stated there. If the M or O flags are set in the router advertisement, follow the stateful (DHCPv6) configuration procedures. These procedures could make the temporary home address permanent by increasing its valid and preferred lifetimes.

9. Send binding update option(s) to update the binding for the temporary home address and to establish bindings for any new home addresses.

Chair's Address

The Working Group can be contacted via its current chairs:

Phil Roberts
Motorola
1501 West Shure Drive
Arlington Heights, IL 60004

Phone: +1 847 632-3148
E-mail: qa3445@email.mot.com

Basavaraj Patil
Nokia
6000 Connection Drive
M/S M8-540
Irving, TX 75039
USA

Phone: +1 972 894-6709
Fax: +1 972 894-5349
E-mail: raj.patil@nokia.com

Authors' Addresses

Questions about this document can also be directed to the authors:

David B. Johnson
Rice University
Department of Computer Science, MS 132
6100 Main Street
Houston, TX 77005-1892
USA

Phone: +1 713 348-3063
Fax: +1 713 348-5930
E-mail: dbj@cs.rice.edu

Charles Perkins
Nokia
313 Fairchild Drive
Mountain View, CA 94043
USA

Phone: +1 650 625-2986
Fax: +1 650 625-2502
E-mail: charliep@iprg.nokia.com