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IPv4 Support for Proxy Mobile IPv6
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Abstract

This document specifies extensions to Proxy Mobile IPv6 protocol for adding IPv4 protocol support. The scope of IPv4 protocol support is two-fold: 1) enable IPv4 home address mobility support to the mobile node. 2) allowing the mobility entities in the Proxy Mobile IPv6 domain to exchange signaling messages over an IPv4 transport network.

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1. Overview

The transition from IPv4 to IPv6 is a long process and during this period of transition, both the protocols will be enabled over the same network infrastructure. Thus, it is reasonable to assume that a mobile node in a Proxy Mobile IPv6 domain may operate in an IPv4-only IPv6-only or in dual-stack mode and additionally the network between the mobile access gateway and a local mobility anchor may be an IPv4 or an IPv6 network. It is also reasonable to expect the same mobility infrastructure in the Proxy Mobile IPv6 domain to provide mobility to the mobile nodes operating in IPv4, IPv6 or in dual mode and whether the transport network is IPv4 or IPv6 network. The motivation and scope of IPv4 support in Mobile IPv6 is summarized in [RFC-4977] and all those requirements apply to Proxy Mobile IPv6 protocol as well.

The Proxy Mobile IPv6 protocol [RFC-5213] specifies a mechanism for providing IPv6 home address mobility support to a mobile node in a Proxy Mobile IPv6 domain. The protocol requires IPv6 transport network between the mobility entities. The extensions defined in this document extends IPv4 support to the Proxy Mobile IPv6 protocol [RFC-5213].

The scope of IPv4 support in Proxy Mobile IPv6 includes the support for the following two features:

- IPv4 Home Address Mobility Support: A mobile node that has an IPv4 stack enabled will be able to obtain an IPv4 address and be able to use that address from any of the access networks in that Proxy Mobile IPv6 domain. The mobile node is not required to be allocated or assigned an IPv6 address to enable IPv4 home address support.

- IPv4 Transport Network Support: The mobility entities in the Proxy Mobile IPv6 domain will be able to exchange Proxy Mobile IPv6 signaling messages over an IPv4 transport and furthermore the mobile access gateway may be using an IPv4 private address and with NAT [RFC-3022] translation devices on the path to the local mobility anchor.

These two features, the IPv4 Home Address Mobility support and the IPv4 transport support features, are independent of each other and deployments may choose to enable any one or both of these features as required.

Figure-1 shows a typical Proxy Mobile IPv6 domain with IPv4 transport network and with IPv4 enabled mobile nodes. The terms used in this illustration are explained in the Terminology section.

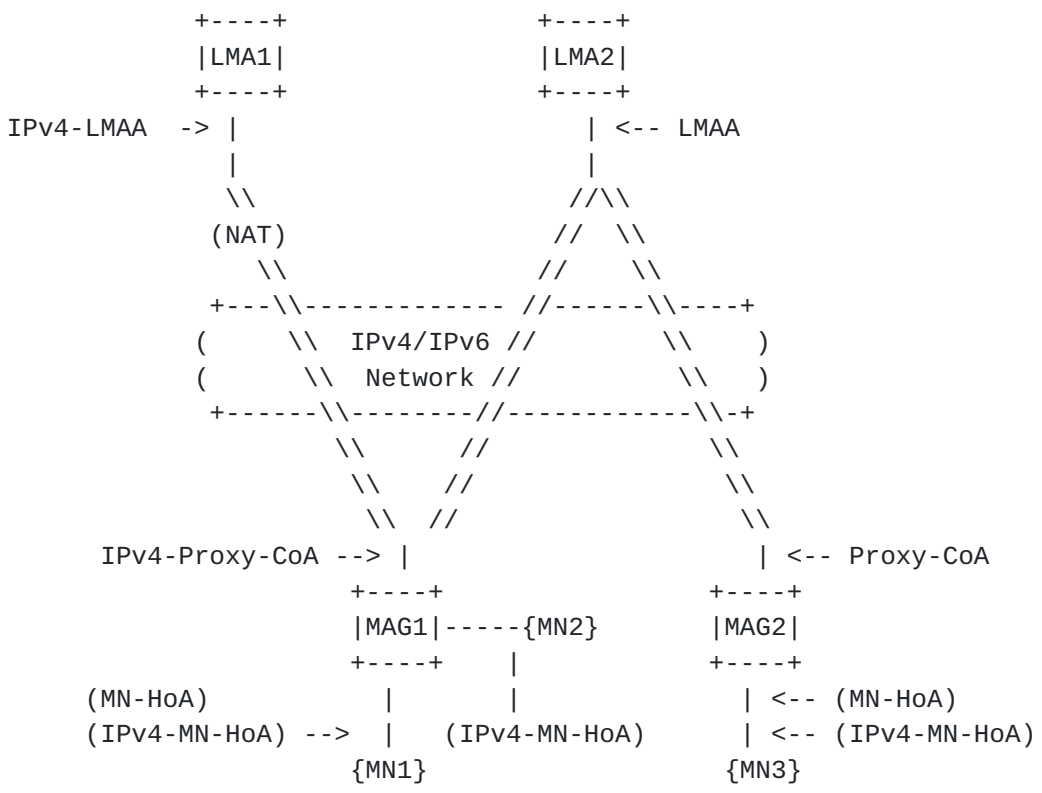


Figure 1: IPv4 support for Proxy Mobile IPv6

1.1. Stated Assumptions

The following are the system and configuration requirements from the mobility entities in the Proxy Mobile IPv6 domain for supporting the extensions defined in this document.

- Both the mobility entities, the local mobility anchor and the mobile access gateway are dual stack (IPv4/IPv6) enabled. Irrespective of the type of transport network (IPv4 or IPv6) separating these two entities, the mobility signaling is always based on Proxy Mobile IPv6 [RFC-5213].

- The local mobility anchor and the mobile access gateway MUST be configured with IPv6 globally unique addresses, even when they are in IPv4-only network. These addresses can be of the type Unique Local IPv6 Unicast Address [RFC-4193], IPv6 Global Unicast Address [RFC-3587] or IPv4-mapped IPv6 address [RFC-4291]. When using IPv4 transport, it is not required that there is IPv6 routing enabled between the local mobility anchor and the mobile access gateway. However, they must be able to receive any IPv6 packets sent to the configured IPv6 addresses, after removing the outer

IPv4 encapsulation header.

- The mobile node can be operating in IPv4-only, IPv6-only or in dual mode. Based on what is enabled for a mobile node, it should be able to obtain IPv4-only, IPv6-only or both IPv4 and IPv6 address(es) for its interface and furthermore achieve mobility support for those addresses.

- For enabling IPv4 home address mobility support to a mobile node, it is not required that the IPv6 home address mobility support needs to enabled. However, the respective protocol(s) support, such as IPv4 or IPv6 packet forwarding, must be enabled on the access link between the mobile node and the mobile access gateway.

- The mobile node can obtain an IPv4 address for its attached interface. Based on the type of link, it may be able to acquire its IPv4 address configuration using standard IPv4 address configuration mechanisms such as DHCP [RFC-2131], IPCP [RFC-1332], IKEv2 [RFC-4306] or static address configuration.

- The mobile node's IPv4 home subnet is typically a shared address space. It is not for the exclusive use of any one mobile node. There can be multiple mobile nodes that are assigned IPv4 addresses from the same subnet.

- The mobile access gateway is the IPv4 default router for the mobile node on its access link. It will be in the forwarding path for the mobile node's data traffic. Additionally, as specified in section 6.9.3 of [RFC-5213], all the mobile access gateways in the Proxy Mobile IPv6 domain MUST use the same link-layer address on any of the access links wherever the mobile node attaches.

1.2. Relevance to Dual-Stack Mobile IPv6

IPv4 support for Mobile IPv6 is specified in Dual-Stack Mobile IPv6 specification [RFC-5555]. This document to most part leverages the approaches, messaging options and processing logic defined in that document for extending IPv4 support to Proxy Mobile IPv6, except with deviation in some aspects for obvious reasons of supporting a network-based mobility model. Following are some of the related considerations.

- The messaging options, IPv4 Home Address, IPv4 Address Acknowledgement, IPv4 Care-of Address option defined in [RFC-5555] for use in Binding Update and Binding Acknowledgement messages are used by this specification to be carried in Proxy Binding Update and Proxy Binding Acknowledgement messages.

- The extensions needed to the conceptual data structures, Binding Cache entry and Binding Update List entry, for storing the state related to the IPv4 support defined in [RFC-5555], will all be needed and relevant for this document.

- The NAT traversal logic specified in [RFC-5555] for detecting the on-path NAT devices is valid for this specification as well.

- The tunneling considerations specified in [RFC-5555] for supporting IPv4 transport is relevant for this document as well.

If a given home agent [RFC-3775] implementation has support for both Dual-stack Mobile IPv6 [RFC-5555] and local mobility anchor function [RFC-5213], when extending IPv4 support as specified in this document the above common functions and the related considerations have to be reused for Proxy Mobile IPv6 signaling flows.

2. Conventions & Terminology

2.1. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC-2119].

2.2. Terminology

All the mobility related terms used in this document are to be interpreted as defined in the Mobile IPv6 specification [RFC-3775] and Proxy Mobile IPv6 specification [RFC-5213]. In addition this document introduces the following terms.

IPv4 Proxy Care-of Address (IPv4-Proxy-CoA)

The IPv4 address that is configured on the egress-interface of the mobile access gateway. When using IPv4 transport, this address will be the registered care-of address in the mobile node's Binding Cache entry and will also be the transport-endpoint of the tunnel between the local mobility anchor and a mobile access gateway. However, if the configured address is a private IPv4 address and with a NAT device in the path to the local mobility anchor, the care-of address as seen by the local mobility anchor will be the address allocated by the NAT device for that flow.

IPv4 Local Mobility Anchor Address (IPv4-LMAA)

The IPv4 address that is configured on the egress-interface of the local mobility anchor. When using IPv4 transport, the mobile access gateway sends the Proxy Binding Update messages to this address and will be the transport-endpoint of the tunnel between the local mobility anchor and the mobile access gateway.

Mobile Node's IPv4 Home Address (IPv4-MN-HoA)

The IPv4 home address assigned to the mobile node's attached interface. This address is topologically anchored at the local mobility anchor. The mobile node configures this address on its attached interface. If the mobile node connects to the Proxy Mobile IPv6 domain via multiple interfaces each of the interfaces are assigned a unique IPv4 address. All the IPv6 home network prefixes and the IPv4 home address assigned to a given interface of a mobile node will be managed under one mobility session.

Selective De-registration

A procedure for partial de-registration of all the addresses that belong to one address family, i.e., de-registration of either IPv4 home address, or all of the IPv6 home network prefixes.

Encapsulation Modes

This document uses the following terms when referring to the different encapsulation modes.

IPv4-or-IPv6-over-IPv6

IPv4 or IPv6 packet carried as a payload of an IPv6 packet

IPv4-or-IPv6-over-IPv4

IPv4 or IPv6 packet carried as a payload of an IPv4 packet

IPv4-or-IPv6-over-IPv4-UDP

IPv4 or IPv6 packet carried as a payload in an IPv4 packet with a UDP header

IPv4-or-IPv6-over-IPv4-UDP-TLV

IPv4 packet carried as a payload in an IPv4 packet with UDP and TLV headers

3. IPv4 Home Address Mobility Support

The IPv4 home address mobility support essentially enables a mobile node in a Proxy Mobile IPv6 domain to obtain IPv4 home address configuration for its attached interface and be able to retain that address configuration even after changing its point of attachment in that Proxy Mobile IPv6 domain. This section describes the protocol operation and the required extensions to Proxy Mobile IPv6 protocol for extending IPv4 home address mobility support.

When an IPv4-enabled or a dual-stack enabled mobile node attaches to the Proxy Mobile IPv6 domain, the mobile access gateway on the access link where the mobile node is attached will identify the mobile node and will initiate the Proxy Mobile IPv6 signaling with the mobile node's local mobility anchor. The mobile access gateway will follow the signaling considerations specified in Section 3.2 for requesting IPv4 home address mobility support. Upon the completion of the signaling, the local mobility anchor and the mobile access gateway will establish the required routing states for allowing the mobile node to use its IPv4 home address from its current point of attachment.

The mobile node on the access link using any of the standard IPv4 address configuration mechanisms supported on that access link, such as IPCP [RFC-1332], IKEv2 [RFC-4306] or DHCP [RFC-2131], will be able to obtain an IPv4 home address (IPv4-MN-HoA) for its attached interface. Although the address configuration mechanisms for delivering the address configuration to the mobile node is independent of the Proxy Mobile IPv6 protocol operation, however there needs to be some interactions between these two protocol flows. Section 3.4 identifies these interactions for supporting DHCP based address configuration.

The support for IPv4 home address mobility is not dependent on the IPv6 home address mobility support. It is not required that the IPv6 home address mobility support needs to be enabled for providing IPv4 home address mobility support. A mobile node will be able to obtain IPv4-only, IPv6-only or dual IPv4/IPv6 address configuration for its attached interface. The mobile node's policy profile will determine if the mobile node is entitled for both the protocol versions or a single protocol version. Based on the policy, only those protocols will be enabled on the access link. Furthermore, if the mobile node after obtaining the address configuration on its interface performs an handoff, either by changing its point of attachment over the same interface or to a different interface, the network will ensure the mobile node will be able to use the same IPv4 address configuration after the handoff.

Additionally, If the mobile node connects to the Proxy Mobile IPv6 domain, through multiple interfaces and simultaneously through different access networks, each of the connected interfaces will obtain an IPv4 home address from different subnets. In such scenario, there will be multiple Binding Cache entries for the mobile node on the local mobility anchor. All the address (IPv4/IPv6) assigned to a given interface will be managed as part of one mobility session, as specified in Section 5.4 of [RFC-5213].

3.1. Local Mobility Anchor Considerations

3.1.1. Extensions to Binding Cache Entry

To support this feature, the conceptual Binding Cache entry data structure maintained by the local mobility anchor needs to include the following parameters.

- The IPv4 home address assigned to the mobile node's interface and registered by the mobile access gateway. The IPv4 home address entry also includes the corresponding subnet mask. It is to be noted that this parameter is defined in the [RFC-5555] and is presented here for completeness.

- The IPv4 default router address assigned to the mobile node.

3.1.2. Signaling Considerations

3.1.2.1. Processing Proxy Binding Updates

The processing rules specified in Section 5.3 of [RFC-5213] are applied for processing the received Proxy Binding Update message. However, if the received Proxy Binding Update message has an IPv4 Home Address option [RFC-5555], the following considerations MUST be applied additionally.

- If there is an IPv4 Home Address option [RFC-5555] present in the received Proxy Binding Update message, but if there is no Home Network Prefix option [RFC-5213] present in the request, the local mobility anchor MUST NOT reject the request as specified in Section 5.3.1 of [RFC-5213]. At least one instance of any of these two options, either the IPv4 Home Address option or the Home Network Prefix option, MUST be present. If there is not a single instance of any of these two options present in the request, the local mobility anchor MUST reject the request and send a Proxy Binding Acknowledgement message with Status field set to MISSING_HOME_NETWORK_PREFIX_OPTION (Missing mobile node's home

network prefix option) [RFC-5213].

- If there is at least one instance of Home Network Prefix option [RFC-5213] present in the received Proxy Binding Update message, but either if it is known from the mobile node's policy profile that the mobile node is not authorized for IPv6 service or if IPv6 routing not enabled in the home network, the local mobility anchor MUST reject the request and send a Proxy Binding Acknowledgement message with the Status field set to NOT_AUTHORIZED_FOR_IPV6_HOME_NETWORK_PREFIX (mobile node not authorized for the requesting IPv6 home network prefix).

- If there are more than one instance of the IPv4 Home Address option present in the request, then the local mobility anchor MUST reject the request and send a Proxy Binding Acknowledgement message with the Status field set to MULTIPLE_IPV4_HOME_ADDRESS_ASSIGNMENT_NOT_SUPPORTED (multiple IPv4 home address assignment not supported).

- If the prefix request(P) flag in the IPv4 Home Address option [RFC-5555] is set to a value of (1), then the local mobility anchor MUST reject the request and send a Proxy Binding Acknowledgement message with the Status field set to IPV4_PREFIX_ASSIGNMENT_NOT_SUPPORTED (IPv4 prefix assignment not supported).

- For associating the received Proxy Binding Update message to an existing mobility session, the local mobility anchor MUST perform the Binding Cache entry existence test by applying the following considerations.

  * If there is at least one instance of the Home Network Prefix option [RFC-5213] with a NON_ZERO prefix value, or, if there is an IPv4 Home Address option [RFC-5555] with the IPv4 address in the option set to ALL_ZERO, considerations from Section 5.4.1 of [RFC-5213] MUST be applied.

  * If there is an IPv4 Home Address option [RFC-5555] present in the request with the IPv4 address value in the option set to a NON_ZERO value, considerations from Section 3.1.2.7 MUST be applied.

- If there is no existing Binding Cache entry that can be associated with the request, the local mobility anchor MUST consider this request as an initial binding registration request and considerations from Section 3.1.2.2 MUST be applied. Additionally, if there are one or more Home Network Prefix options [RFC-5213] present in the request, considerations from Section

5.3.2 of [RFC-5213] MUST also be applied.

- If there exists a Binding Cache entry that can be associated with the request, the local mobility anchor MUST apply considerations from Section 5.3.1 of [RFC-5213], (point 13), to determine if the request is re-registration or a de-registration request. If the request is a re-registration request, considerations from Section 3.1.2.3 MUST be applied and if it is a de-registration request, considerations from Section 3.1.2.4 MUST be applied.

- If there exists a Binding Cache entry that can be associated with the request and if it is determined that the request is a re-registration request for extending IPv4 home address mobility support to the existing IPv6-only mobility session, considerations from Section 3.1.2.2 MUST be applied with respect to IPv4 support.

3.1.2.2. Initial Binding Registration (New Mobility Session)

- If there is an IPv4 Home Address option [RFC-5555] present in the Proxy Binding Update message with the IPv4 address value in the option set to ALL_ZERO, the local mobility anchor MUST allocate an IPv4 home address to the mobile node and associate it with the new mobility session created for that mobile node.

- If there is an IPv4 Home Address option [RFC-5555] with the IPv4 address in the option set to a NON_ZERO value, the local mobility anchor before accepting the request MUST ensure the address is topologically anchored on the local mobility anchor and furthermore the mobile node is authorized to use that address. If the mobile node is not authorized for that specific address, the local mobility anchor MUST reject the request and send a Proxy Binding Acknowledgement message with the Status field set to NOT_AUTHORIZED_FOR_IPV4_HOME_ADDRESS (mobile node not authorized for the requesting IPv4 address). It MUST also include the IPv4 Address Acknowledgement option [RFC-5555] in the reply with the status field value in the option set to 129 (Administratively prohibited).

- If the local mobility anchor is unable to allocate an IPv4 address due to lack of resources, it MUST reject the request and send a Proxy Binding Acknowledgement message with Status field set to 130 (Insufficient resources). It MUST also include the IPv4 Address Acknowledgement option [RFC-5555] in the reply with the status field value in the option set to 128 (Failure, reason unspecified).

- Upon accepting the request, the local mobility anchor MUST create a Binding Cache entry for this mobility session. However, if the request also contains one or more Home Network Prefix options [RFC-5555], there should still be only one Binding Cache entry that should be created for this mobility session. The created Binding Cache entry MUST be used for managing both IPv4 and IPv6 home address bindings. The fields in the Binding Cache entry MUST be updated with the accepted values for that session.

- The local mobility anchor MUST establish a bi-directional tunnel to the mobile access gateway and with the encapsulation mode set to the negotiated mode for carrying the IPv4 payload traffic. When using IPv6 transport, the encapsulation mode is IPv4-or-IPv6-over-IPv6 (IPv4 or IPv6 packet carried as a payload of an IPv6 packet). When using IPv4 transport, the encapsulation mode is as specified in Section 4.0.

- The local mobility anchor MUST create an IPv4 host route (or a platform specific equivalent function that sets up the forwarding) for tunneling the packets received for the mobile node's home address associated with this mobility session.

- The local mobility anchor MUST send the Proxy Binding Acknowledgement message with the Status field set to 0 (Proxy Binding Update Accepted). The message MUST be constructed as specified in Section 3.1.2.6.

3.1.2.3. Binding Lifetime Extension (No handoff)

All the considerations from Section 5.3.3 of [RFC-5213] MUST be applied.

3.1.2.4. Binding Lifetime Extension (After handoff)

- If there is no Home Network Prefix option(s) [RFC-5213] present in the request, but if the Binding Cache entry associated with this request has IPv6 home network prefix(es), the local mobility anchor MUST consider this as a request to extend lifetime only for the IPv4 home address and not for the IPv6 home network prefix(es). Hence, the local mobility anchor SHOULD release all the IPv6 home network prefix(es) assigned to that mobile node and for that specific attached interface. Similar considerations apply for the case where there is no IPv4 Home Address option [RFC-5555] present in the request, but if the Binding Cache entry associated with that request has both IPv4 home address and IPv6 home network prefix(es).

- The local mobility anchor MUST remove the previously created IPv4 host route (or the forwarding state) and the dynamically created bi-directional tunnel for carrying the IPv4 payload traffic (if there are no other mobile nodes for which the tunnel is being used). This will remove the routing state towards the mobile access gateway where the mobile node was anchored prior to the handoff.

- The local mobility anchor MUST create a bi-directional tunnel to the mobile access gateway that sent the request (if there is no existing bi-directional tunnel) and with the encapsulation mode set to the negotiated mode for carrying the IPv4 payload traffic. An IPv4 host route for tunneling the packets received for the mobile node's IPv4 home address MUST also be added.

- The required forwarding state identified in Section 5.3.6 of [RFC-5213] is for IPv6 payload traffic. Those considerations apply for IPv4 payload traffic as well. However, if IPv4 transport is in use, considerations from Section 4.0 MUST be applied.

3.1.2.5. Binding De-Registration

All the considerations from Section 5.3.5 of [RFC-5213] MUST be applied. Additionally, for removing the IPv4 state as part of the Binding Cache entry deletion, the IPv4 host route and the dynamically created bi-directional tunnel for carrying the IPv4 payload traffic (if there are no other mobile nodes for which the tunnel is being used) MUST be removed. However, if the request is for a selective de-registration (IPv4 home address only, or all the IPv6 home network prefixes), the Binding Cache entry MUST NOT be deleted, only the respective states with respect to those addresses MUST be deleted.

3.1.2.6. Constructing the Proxy Binding Acknowledgement Message

The local mobility anchor when sending the Proxy Binding Acknowledgement message to the mobile access gateway MUST construct the message as specified in Section 5.3.6 of [RFC-5213]. Additionally, the following considerations MUST be applied.

- Section 5.3.6 of [RFC-5213] requires the local mobility anchor to include at least one instance of Home Network Prefix option [RFC-5213] in the Proxy Binding Acknowledgement message that it sends to the mobile access gateway. However, if the received Proxy Binding Update message has only the IPv4 Home Address option [RFC-5555] and did not contain the Home Network Prefix option(s), then the local mobility anchor MUST NOT include any Home Network Prefix option(s) in the reply. However, there MUST be at least one instance of either the Home Network Prefix option [RFC-5213] or

the IPv4 Address Acknowledgement option [RFC-5555] present in the Proxy Binding Acknowledgement message.

- The IPv4 Address Acknowledgement option [RFC-5555] MUST be present in the Proxy Binding Acknowledgement message.

  1. If the Status field is set to a value greater than or equal to (128), i.e., if the Proxy Binding Update is rejected, then there MUST be an IPv4 Address Acknowledgement option [RFC-5555] corresponding to the IPv4 Home Address option [RFC-5555] present in the request and with the IPv4 address value and the prefix length fields in the option set to the corresponding values in the request. The status field value in the option must be set to the specific error code.

  2. For all other cases, there MUST be an IPv4 Address Acknowledgement option for carrying the IPv4 home address assigned for that mobility session and with the value in the option set to the allocated IPv4 address. The prefix length in the option MUST be set to the prefix length of the allocated address. The status field value in the option must be set to 0 (Success).

- The IPv4 Default-Router Address option MUST be present, if the Status field value in the Proxy Binding Acknowledgement message is set to 0 (Proxy Binding Update Accepted). Otherwise, the option MUST NOT be present. If the option is present, the default router address in the option MUST be set to the mobile node's default router address.

3.1.2.7. Binding Cache Entry Lookup Considerations

The Binding Cache entry lookup considerations specified in section 5.4.1.1 of [RFC-5213] uses the Home Network Prefix option [RFC-5213] as the key parameter for identifying the Binding Cache entry. However, when there are no Home Network Prefix options with a NON_ZERO value present in the request a single Home Network Prefix option with NON_ZERO value present in the request, but if there an IPv4 Home Address option with a NON_ZERO value present in the request, the following considerations MUST be applied.

- The search rules specified in section 5.4.1.1 of [RFC-5213], which primarily uses IPv6 home network prefix set as the search key, are equally valid when using a single IPv4 home address as the key. When applying those considerations, instead of the IPv6 home network prefix(es), the IPv4 home address from the IPv4 Home Address option present in the request MUST be used as the search key.

- These rules specified in section 5.4.1.1 of [RFC-5213], assume the presence of one or more IPv6 home network prefixes in the received request and also in the Binding Cache entry. But, when using the IPv4 home address as the search key, these considerations MUST always assume just one single IPv4 home address, both in the request and also in the Binding Cache entry.

3.1.3. Routing Considerations for the Local Mobility Anchor

Intercepting Packets Sent to the Mobile Node's IPv4 home address:

- When the local mobility anchor is serving a mobile node, it MUST advertise a connected route in to the Routing Infrastructure for the mobile node's IPv4 home address or for its home subnet, in order to receive packets that are sent to the mobile node's IPv4 home address. This essentially enables IPv4 routers in that network to detect the local mobility anchor as the last-hop router for that subnet.

Forwarding Packets to the Mobile Node:

- On receiving a packet from a correspondent node with the destination address matching the mobile node's IPv4 home address, the local mobility anchor MUST forward the packet through the bi-directional tunnel setup for that mobile node.

- The format of the tunneled packet when payload protection is not enabled:

```
IPv6 header (src= LMAA, dst= Proxy-CoA       /* Tunnel Header */
   IPv4 header (src= CN, dst= IPv4-MN-HOA )  /* Packet Header */
      Upper layer protocols                  /* Packet Content*/
```

Figure 2: Tunneled Packets from LMA to MAG

Forwarding Packets Sent by the Mobile Node:

- All the reverse tunneled packets that the local mobility anchor receives from the mobile access gateway, after removing the tunnel header MUST be routed to the destination specified in the inner IPv4 packet header. These routed packets will have the source address field set to the mobile node's IPv4 home address.

3.2. Mobile Access Gateway Considerations

3.2.1. Extensions to Binding Update List Entry

To support the IPv4 home address mobility feature, the conceptual Binding Update List entry data structure needs to be extended with the following additional fields.

- The IPv4 home address assigned to the mobile node's attached interface. This IPv4 home address may have been statically configured in the mobile node's policy profile, or, may have been dynamically allocated by the local mobility anchor. The IPv4 home address entry also includes the corresponding subnet mask.

- The IPv4 default router address of the mobile node. This is acquired from the mobile node's local mobility anchor through the received Proxy Binding Acknowledgment message.

3.2.2. Extensions to Mobile Node's Policy Profile

To support the IPv4 Home Address Mobility Support feature the mobile node's policy profile, specified in Section 6.2 of [RFC-5213] MUST be extended with the following additional fields.

Extensions to the mandatory section of the policy profile:

- This field identifies all the IP protocol versions for which the home address mobility support needs to be extended to the mobile node. The supported modes are IPv4-only, IPv6-only and dual IPv4/IPv6.

Extensions to the optional section of the policy profile:

- The IPv4 home address assigned to the mobile node's attached interface. The specific details on how the network maintains the association between the address and the attached interface is outside the scope of this document. This address field also includes the corresponding subnet mask.

3.2.3. Signaling Considerations

3.2.3.1. Mobile Node Attachment and Initial Binding Registration

After detecting a new mobile node on its access link, the mobile access gateway on the access link MUST determine if IPv4 home address mobility support needs to be enabled for that mobile node. The mobile node's policy profile identifies the supported modes (IPv4-only, IPv6-only or dual IPv4/IPv6) for that mobile node for which the mobile service needs to be enabled. Based on those policy considerations and from other triggers such as from the network, if it is determined that IPv4 home address mobility support needs to be enabled for the mobile node, considerations from section 6.9.1.1 of [RFC-5213] MUST be applied with the following exceptions.

- The IPv4 Home Address option [RFC-5555] MUST be present in the Proxy Binding Update message.
  - If the mobile access gateway learns the mobile node's IPv4 home address either from its policy profile, or from other means, the mobile access gateway MAY ask the local mobility anchor to allocate that specific address by including exactly one instance of the IPv4 Home Address option [RFC-5555] with the IPv4 home address and the prefix length fields in the option set to that specific address and its prefix length. Furthermore, the (P) flag in the option MUST be set to 0.
  - The mobile access gateway MAY also ask the local mobility anchor for dynamic IPv4 home address allocation. It can include exactly one instance of the IPv4 Home Address option with the IPv4 home address and the prefix length fields in the option set to ALL_ZERO value. Furthermore, the (P) flag in the option MUST be set to 0. This essentially serves as a request to the local mobility anchor for the IPv4 home address allocation.
- The Proxy Binding Update message MUST be constructed as specified in Section 6.9.1.5 of [RFC-5213]. However, the Home Network Prefix option(s) [RFC-5213] MUST be present in the Proxy Binding Update only if IPv6 home address mobility support also needs to be enabled for the mobile node. Otherwise, the Home Network Prefix option(s) MUST NOT be present.
- When using IPv4 transport for carrying the signaling messages, the related considerations from section 4.0 MUST be applied additionally.

3.2.3.2. Receiving Proxy Binding Acknowledgement

All the considerations from section 6.9.1.2 of [RFC-5213] MUST be applied with the following exceptions.

- If the received Proxy Binding Acknowledgement message has the Status field value set to NOT_AUTHORIZED_FOR_IPV4_HOME_ADDRESS(The mobile node is not authorized for IPv4 home address), the mobile access gateway SHOULD NOT send a Proxy Binding Update message including the IPv4 Home Address option [RFC-5555] till an administrative action is taken.

- If the received Proxy Binding Acknowledgement message has the Status field value set to NOT_AUTHORIZED_FOR_IPV4_HOME_ADDRESS(The mobile node is not authorized for the requesting IPv4 home address), the mobile access gateway SHOULD NOT request for the same address again, but MAY request the local mobility anchor to do the assignment of address by including exactly one instance of IPv4 Home Address option [RFC-5555] with the IPv4 home address and the prefix length fields in the option set to ALL_ZERO value.

- If there is no IPv4 Address Acknowledgement option [RFC-5555] present in the received Proxy Binding Acknowledgement message, the mobile access gateway MUST NOT enable IPv4 support for the mobile node and the rest of the considerations from this section can be skipped.

- If the received Proxy Binding Acknowledgement message has the Status field value in the IPv4 Address Acknowledgement Option [RFC-5555] set to a value that indicates that the request was rejected by the local mobility anchor, the mobile access gateway MUST NOT enable forwarding for that specific IPv4 home address.

- If the received Proxy Binding Acknowledgement message has the Status field value set to 0 (Proxy Binding Update accepted), the mobile access gateway MUST update a Binding Update List entry for that mobile node. The entry MUST be updated with the assigned IPv4 home address and other accepted registration values.

- If the received Proxy Binding Acknowledgement message has the Status field value set to 0 (Proxy Binding Update accepted) and has the IPv4 Address Acknowledgement Option [RFC-5555] set to a value that indicates that the request was accepted by the local mobility anchor, the mobile access gateway MUST establish a bi-directional tunnel to the local mobility anchor (if there is no existing bi-directional tunnel to that local mobility anchor) and with the encapsulation mode set to IPv4-or-IPv6-over-IPv6 (IPv4 or IPv6 packet carried as a payload of an IPv6 packet).

Considerations from Section 5.6.1 of [RFC-5213] MUST be applied for managing the dynamically created bi-directional tunnel. However, when using IPv4 transport, the encapsulation mode MUST be set to the negotiated encapsulation mode, as specified in Section 4 of this specification.

- The mobile access gateway MUST set up the route for forwarding the IPv4 packets received from the mobile node (using its IPv4 home address) through the bi-directional tunnel set up for that mobile node.

- The default router address MUST be obtained from the IPv4 Default-Router Address option present in the received Proxy Binding Acknowledgement message. The mobile access gateway MAY configure this address on its interface and respond to any ARP requests sent by the mobile node for resolving the hardware address of the default router. It MAY also use this address as the source address for any datagrams sent to the mobile node and originated by the mobile access gateway itself. It MAY also use this address in the DHCP Router option [RFC-2132] in the DHCP messages.

- If there is an IPv4 DHCP Support Mode option present in the received Proxy Binding Acknowledgement message and if the (S) flag in the option is set to a value of (1), then the mobile access gateway MUST function as a DHCP server for the mobile node. If either the (S) flag in the option is set to a value of (0), or if the option is not present in the request, then the mobile access gateway MUST function as a DHCP Relay for the mobile node.

3.2.3.3. Binding Re-Registration and De-Registrations

When sending a Proxy Binding Update either for extending the lifetime of a mobility session or for de-registering the mobility session, the respective considerations from [RFC-5213] MUST be applied. Furthermore, the following additional considerations MUST also be applied.

- If there is an IPv4 home address assigned to the mobility session, then there MUST be exactly one instance of the IPv4 Home Address option [RFC-5555] present in the Proxy Binding Update message. The IPv4 home address and the prefix length fields in the option MUST be set to that specific address and its corresponding subnet-mask length. The (P) flag in the option MUST be set to 0.

- If there was no IPv4 home address requested in the initial Proxy Binding Update message, but if it is determined that the IPv4 home address MUST be requested subsequently, then there MUST be exactly one instance of the IPv4 Home Address option [RFC-5555] present in

the Proxy Binding Update message. The IPv4 home address in the option MUST be set to either ALL_ZERO or to a specific address that is being requested.

- For performing selective de-registration of IPv4 home address but still retaining the mobility session with all the IPv6 home network prefixes, the Proxy Binding Update message with the lifetime value of (0) MUST NOT include any IPv6 Home Network Prefix options(s) [RFC-5213]. It MUST include exactly one instance of the IPv4 Home Address option [RFC-5555] with the IPv4 home address and the prefix length fields in the option set to the IPv4 home address that is being de-registered. Similarly for selective de-registration of all the IPv6 home network prefixes, the Proxy Binding Update message MUST NOT include the IPv4 Home address option, it MUST include a Home Network Prefix option for each of the assigned home network prefixes assigned for that mobility session and with the prefix value in the option set to that respective prefix value.

- The Home Network Prefix option(s) [RFC-5213] MUST NOT be present if the same option(s) was not present in the initial Proxy Binding Update message. Otherwise considerations from [RFC-5213] with respect to this option MUST be applied.

- If at any point the mobile access gateway fails to extend the binding lifetime with the local mobility anchor for the mobile node's IPv4 address, it MUST remove any forwarding state set up for the mobile node's IPv4 home address.

3.2.4. Routing Considerations for the Mobile Access Gateway

- On receiving a packet from the bi-directional tunnel established with the mobile node's local mobility anchor, the mobile access gateway MUST remove the outer header before forwarding the packet to the mobile node.

- Considerations from Section 6.10.3 of [RFC-5213] MUST be applied with respect the local routing and on the use of EnableMAGLocalRouting flag.

- On receiving a packet from a mobile node connected to its access link, the packet MUST be forwarded to the local mobility anchor through the bi-directional tunnel established with the local mobility anchor. The encapsulation considerations specified in section 3.1.3 MUST be applied. However, before forwarding the packet, the mobile access gateway MUST ensure the source address in the received packet is the address allocated for that mobile

node and that there is an active binding on the local mobility anchor for that mobile node.

3.3. Mobility Options and Status Codes

To support the IPv4 home address mobility feature, this specification defines the following new options and Status Codes.

3.3.1. IPv4 Default-Router Address Option

A new option, IPv4 Default-Router Address Option is defined for using it in the Proxy Binding Acknowledgment message [RFC-5213] sent by the local mobility anchor to the mobile access gateway. This option can be used for sending the mobile node's IPv4 default router address.

The IPv4 Default-Router Address option has an alignment requirement of 4n. Its format is as follows:

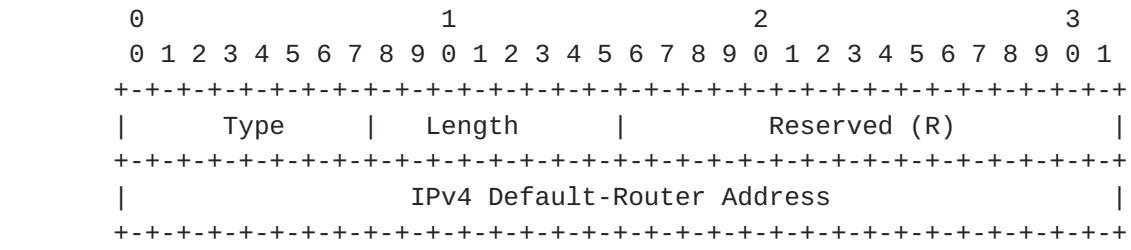


Figure 3: IPv4 Default-Router Address Option

Type

IANA

Length

8-bit unsigned integer indicating the length of the option in octets, excluding the type and length fields. This field MUST be set to (6).

Reserved (R)

This 16-bit field is unused for now. The value MUST be initialized to (0) by the sender and MUST be ignored by the receiver.

IPv4 Default-Router Address

A four-byte field containing the mobile node's default router address.

3.3.2. IPv4 DHCP Support Mode

A new option, IPv4 DHCP Support Mode Option is defined for using it in the Proxy Binding Acknowledgment message [RFC-5213] sent by the local mobility anchor to the mobile access gateway. This option can be used for notifying the mobile access gateway, if it should function as a DHCP Server or a DHCP Relay for the attached mobile node.

The IPv4 DHCP Support Mode option has no alignment requirement. Its format is as follows:

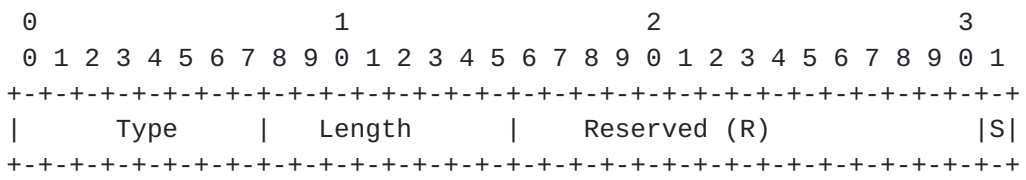


Figure 4: IPv4 DHCP Support Mode Option

Type

IANA

Length

8-bit unsigned integer indicating the length of the option in octets, excluding the type and length fields. This field MUST be set to 2.

Reserved (R)

This 15-bit field is unused for now. The value MUST be initialized to (0) by the sender and MUST be ignored by the receiver.

DHCP Support Mode (S)

A 1-bit field that specifies the DHCP support mode. This flag indicates if the mobile access gateway should function as a DHCP Server or a DHCP Relay for the attached mobile node. The flag value of (0) indicates the mobile access gateway should act as a DHCP Relay and the flag value of (1) indicates it should act as a DHCP Server.

3.3.3. Status Codes

This document defines the following new Status values for use in the Proxy Binding Acknowledgement message [RFC-5213]. These values are to be allocated from the same numbering space, as defined in Section 6.1.8 of [RFC-3775].

NOT_AUTHORIZED_FOR_IPV4_HOME_ADDRESS: IANA

Mobile node not authorized for the requesting IPv4 home address

NOT_AUTHORIZED_FOR_IPV6_HOME_NETWORK_PREFIX: IANA

Mobile node not authorized for the requesting IPv6 home network prefix(es).

MULTIPLE_IPV4_HOME_ADDRESS_ASSIGNMENT_NOT_SUPPORTED

Multiple IPv4 home address assignment not supported

IPV4_PREFIX_ASSIGNMENT_NOT_SUPPORTED

IPv4 prefix assignment not supported

3.4. Supporting DHCP-Based Address Configuration

This section explains how DHCP-based address configuration support can be enabled for a mobile node in a Proxy Mobile IPv6 domain. It explains the protocol operation, supported DHCP server deployment configurations and the protocol interactions between DHCP agents and mobility entities in each of the supported configurations.

This specification supports the following two DHCP deployment configurations.

o DHCP relay agent co-located with the mobile access gateway.

- DHCP server co-located in the mobile access gateway.

The following are the configuration requirements:

- The DHCP server or the DHCP relay agent configured on the mobile access gateway is required to have an IPv4 address for exchanging the DHCP messages with the mobile node. This address is the mobile node's default router address provided by the local mobility anchor. Optionally, all the DHCP servers co-located with the mobile access gateways in the Proxy Mobile IPv6 domain can be configured with a fixed IPv4 address. This fixed address can be potentially an IPv4 private address [RFC-1918] that can be used for the DHCP protocol communication on any of the access links. This address will be used as the server identifier in the DHCP messages.

- A DHCP server identifies a DHCP client from the client identifier, if present, or from the client hardware address (chaddr), as specified in [RFC-2131]. It uses this identity for identifying the client and its interface for which the address is assigned. A mobile node in a Proxy Mobile IPv6 domain, can attach to the network through multiple interfaces and can obtain address configuration for each of its interfaces. Additionally, it may perform handoffs between its interfaces. Following are the related considerations with respect to the identification presented to the DHCP server.

  * If the mobile node attaches to the Proxy Mobile IPv6 domain through multiple interfaces, the DHCP server will uniquely identify each of those interfaces from the client hardware address and will perform address assignment. As the mobile node changes its point of attachment in the network and performs an handoff to a different mobile access gateway, using the same interface, the DHCP server will always be able to identify the binding using the presented client hardware address. The client hardware address and client identifier will remain as the primary keys for each binding, just as how they are unique in a Binding Cache entry.

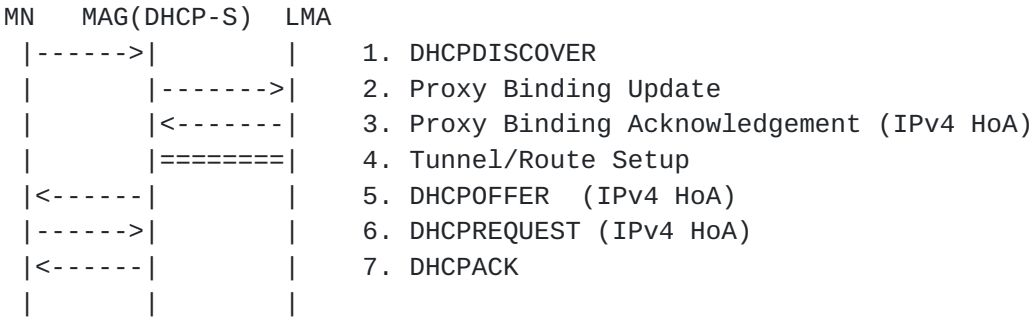
  * However, if the mobile node is capable of performing handoff between interfaces, as per [RFC-5213], the client hardware address in such scenarios needs to be an identifier that is not tied to any of those interfaces. The identifier must be a stable identifier which remains the same through out the mobile node's attachment in that Proxy Mobile IPv6 domain. This identifier must remain fixed for a given binding. This identifier in some implementations can be the identifier

associated to a virtual interface, that is abstracting the physical interfaces.

- All the DHCP servers co-located with the mobile access gateways in a Proxy Mobile IPv6 domain can be configured with the same set of DHCP option values (Ex: DNS Server, SIP Server ..etc.) to ensure the mobile node receives the same configuration values on any of the access links in that Proxy Mobile IPv6 domain.

3.4.1. DHCP Server co-located with the Mobile Access Gateway

This section explains the operational sequence of home address assignment operation when the DHCP server is co-located with the mobile access gateway.



* The DHCP address configuration (starting at Step-1) and the Proxy Mobile IPv6 signaling (starting at Step-2) may start in any order. However, the DHCPOFFER (Step-5) and the immediate steps following it will occur in the specified order and only after the Tunnel/Route Setup (Step-4).

Figure 5: Overview of DHCP Server located at Mobile Access Gateway

Initial IPv4 Home Address Assignment:

- For acquiring the mobile node's IPv4 home address from the local mobility anchor, the mobile access gateway will initiate Proxy Mobile IPv6 signaling with the local mobility anchor.

- After the successful completion of the Proxy Mobile IPv6 signaling and upon acquiring the mobile node's IPv4 home address from the local mobility anchor, the DHCP server on the mobile access gateway will send a DHCPOFFER message [RFC-2131] to the mobile node. The offered address will be the mobile node's IPv4 home address, assigned by the local mobility anchor. The DHCPOFFER message will have the server address field (siaddr) and the

default router option set to the mobile node's default router address. The DHCPOFFER message will be sent to the mobile node just as specified in [RFC-2131].

- If the mobile node sends the DHCPREQUEST message, the DHCP server will send DHCPACK message, as per [RFC-2131].

IPv4 Home Address Renewal with the DHCP server (No Handoff):

- Any time the mobile node goes into the DHCP RENEWING state [RFC-2131], it simply unicasts the DHCPREQUEST message including the assigned IPv4 home address in the 'requested IP address' option. The DHCPREQUEST is sent to the address specified in 'server identifier' field of the previously received DHCPOFFER and DHCPACK messages.

- The DHCP server will send a DHCPACK to the mobile node to acknowledge the assignment of the committed IPv4 address.

IPv4 Home Address Renewal with the DHCP server (After Handoff):

When the mobile node goes into the DHCP RENEWING state [RFC-2131], it directly unicasts the DHCPREQUEST message to the DHCP server that currently provided the DHCP lease. However, if the mobile node changed its point of attachment and is attached to a new mobile access gateway, it is required that the mobile node updates the DHCP server address and uses the address of the DHCP server that is co-located with the new mobile access gateway. The following approach can be adopted to ensure the mobile node uses the DHCP server on the attached link.

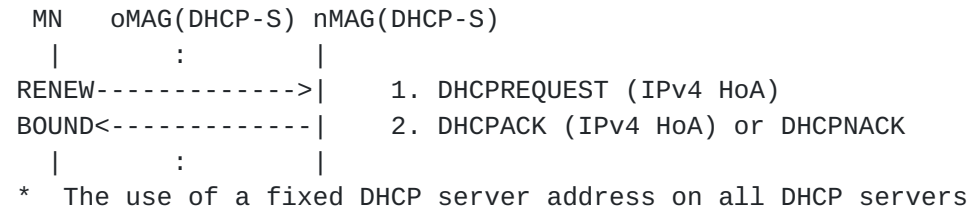


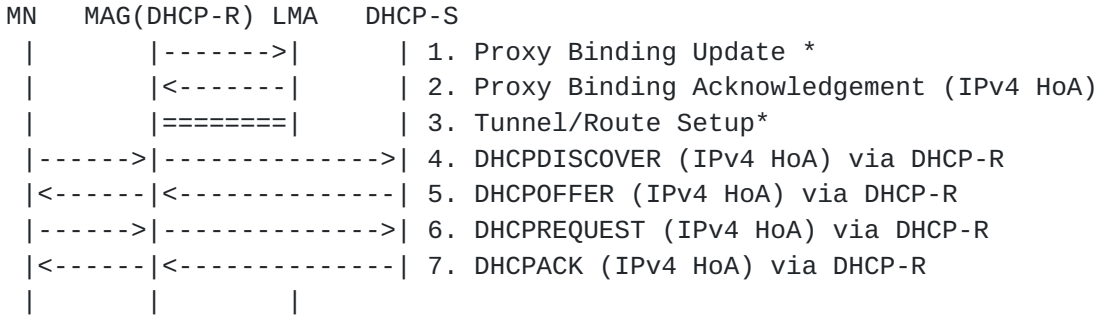
Figure 6: Address renewal with the DHCP server

- If a fixed address such as the IPv4 default router address of the mobile node is used as the DHCP server Id on any of the links in that Proxy Mobile IPv6 domain, the DHCPREQUEST message sent by the mobile node for renewing the address will be received by the new

mobile access gateway on the attached link. The mobile access gateway after completing the Proxy Mobile IPv6 signaling and upon acquiring the IPv4 home address of the mobile node will return the address in the DHCPACK message. However, if the mobile access gateway is unable to complete the Proxy Mobile IPv6 signaling or is unable to acquire the same IPv4 address as requested by the mobile node, it will send a DHCPNACK message [RFC-2131] to the mobile node, as shown in Figure 6-1).

3.4.2. DHCP Relay Agent co-located with the Mobile Access Gateway

A DHCP relay agent is co-located with each mobile access gateway. A DHCP server is located somewhere in the Proxy Mobile IPv6 domain (e.g., is co-located with the local mobility anchor). Figure 7 shows the sequence of IPv4 home address assignment using DHCP Relay.



* The Proxy Mobile IPv6 signaling (starting at Step-1) and the DHCP address configuration (starting at Step-4) may start in any order. However, the DHCPOFFER (Step-5) and the immediate steps following it will occur in the specified order and only after the Tunnel/Route Setup (Step-3).

Figure 7: Overview of the DHCP relay located at mobile access gateway

Initial IPv4 Home Address Assignment:

- For acquiring the mobile node's IPv4 home address from the local mobility anchor, the mobile access gateway will initiate Proxy Mobile IPv6 signaling with the local mobility anchor.

- After the successful completion of the Proxy Mobile IPv6 signaling and upon acquiring the mobile node's IPv4 home address from the local mobility anchor, the mobile access gateway will enable forwarding for all the DHCP messages between the mobile node and the DHCP server.

- The DHCP relay agent on the mobile access gateway will add the DHCP relay agent information option [RFC-3046] to the DHCPDISCOVER message. The assigned IPv4 home address will be included in the Agent Remote ID Sub-option of the DHCP relay agent information option. This sub-option is used as a hint for requesting the DHCP server to allocate that specific IPv4 address.

- On receiving a DHCPOFFER message from the DHCP server, the mobile access gateway will ensure the assigned address is currently assigned by the local mobility anchor to that mobile node. If this address is different from what is assigned to the mobile node, then the mobile access gateway will drop the DHCPOFFER message and an administrative error message will be logged.

- When the DHCP messages are sent over administrative boundaries, the operators needs to ensure these messages are secured. All the DHCP messages relayed by the mobile access gateway can be tunneled to the local mobility anchor if needed. Alternatively, if the network in the Proxy Mobile IPv6 domain is secure enough, the mobile access gateway can just relay the DHCP messages to the server. To achieve this, all the mobile access gateways needs to have a route towards the DHCP server.

IPv4 Home Address Renewal to the same DHCP server: (No Handoff)

- When the DHCP client goes into the DHCP RENEW STATE [RFC-2131], it directly unicasts DHCPREQUEST messages to the DHCP server. The DHCP relay agent may not detect any changes in the DHCP state. For example, if the mobile node releases the IPv4 address, the relay agent would not be aware of it. The following describes additional mechanisms for the mobile access gateway to detect any changes in the DHCP state.

  * The DHCP relay agent can intercept all IPv4 DHCP packets destined to the set of addresses used within the Proxy Mobile IPv6 domain as DHCP addresses. Since the link between a mobile node and a mobile access gateway is the point-to-point link, the mobile access gateway will be in path for all the messages.

  * The DHCP relay agent can use the DHCP Server Identifier Override Sub-option [RFC-5107] to be in path for all the DHCP message flows. The DHCP client uses the DHCP server address which is overridden by the DHCP relay agent address as a destination address of DHCPREQUEST. The DHCP Server Identifier Override Sub-option is recommended only when the fixed DHCP relay address is configured on all the mobile access gateways. Otherwise, the DHCP relay agent address is changed when the

mobile node changes the attached mobile access gateway.

- However, if the DHCP server is co-located with the local mobility anchor, then the DHCP relay agent is not required to intercept the unicast DHCP messages between the mobile node and the DHCP server. This is because the local mobility anchor will ensure that the DHCP state is consistent with the PMIPv6 binding that exists for the IPv4 address.

- Once the mobile access gateway intercepts the DHCP message from the mobile node to the DHCP server, it can verify if the mobile node is negotiating the same IPv4 address that the local mobility anchor allocated for that mobile node. If the address in the DHCPREQUEST message does not match with the IPv4 address allocated for the mobile node, then the mobile access gateway SHOULD silently drop the DHCP message.

- Any time the mobile access gateway detects that the mobile node has released its IPv4 address, it can send a Proxy Binding Update to the local mobility anchor and de-register the IPv4 mobility session.

3.4.3. Common DHCP Considerations

The following DHCP related considerations are common to both the supported configuration modes, specified in Section 3.4.1 and Section 3.4.2.

- When a mobile node sends a DHCPDISCOVER message [RFC-2131], the DHCP server or the relay agent co-located with the mobile access gateway will trigger the mobile access gateway to complete the Proxy Mobile IPv6 signaling. This is the required interaction between these two protocols. The mobile access gateway on receiving this trigger will check if there is already an assigned IPv4 home address for the mobile node, from the local mobility anchor. If there is no assigned IPv4 home address assigned for that mobile node, the mobile access gateway will complete the Proxy Mobile IPv6 signaling with the local mobility anchor by sending a Proxy Binding Update message.

- The mobile node needs to be identified by the MN-Identifier, as specified in Section 6.6 of [RFC-5213]. This identity should be associated to the DHCP messages sent by the mobile node.

- The mobile access gateway will drop all the DHCPDISCOVER messages till it completes the Proxy Mobile IPv6 signaling. If the mobile access gateway is unable to complete the Proxy Mobile IPv6 signaling, or, if the local mobility anchor does not assign an

IPv4 address for the mobile node, the mobile access gateway MUST NOT enable IPv4 home address mobility support for the mobile node on that access link.

- The trigger for initiating Proxy Mobile IPv6 signaling can also be delivered to the mobile access gateway as part of a context transfer from the previous mobile access gateway, or delivered from the other network elements in the radio network, the details of which are outside the scope of this document.

- When the mobile node performs an handoff from one mobile access gateway to another, the mobile access gateway on the new link will initiate the Proxy Mobile IPv6 signaling with the local mobility anchor. On completing the Proxy Mobile IPv6 signaling, the mobile access gateway has the proper IPv4 address state that the local mobility anchor has allocated for the mobile node and which can be used for supporting DHCP based address configuration on that link.

- Any time the mobile node detects a link change event due to handoff, or due to other reasons such as re-establishment of the link-layer, the following are the mobile node's considerations with respect to the DHCP protocol.

  * If the mobile node is DNAv4 [RFC-4436] capable and if it performs DNAv4 procedures after receiving a link change event, it would always detect the same default router on any of the access links in that Proxy Mobile IPv6 domain, as the mobile access gateway configures a fixed link-layer address on all the access links, as per the base Proxy Mobile IPv6 specification [RFC-5213]. The mobile node will not perform any DHCP operation specifically due to this event.

  * If the mobile node is not DNAv4 [RFC-4436] capable, after receiving the link change event it will enter INIT-REBOOT state [RFC-2131] and will send a DHCPREQUEST message as specified in Section 3.7 of [RFC-2131]. The mobile node will obtain the same address configuration as before, as the link change will not be transparent to the mobile node in that Proxy Mobile IPv6 domain.

- The mobile node may release its IPv4 home address at any time by sending the DHCPRELEASE message [RFC-2131]. When the mobile access gateway detects the DHCPRELEASE message sent by the mobile node, it should consider this as a trigger for de-registering the mobile node's IPv4 home address. It will apply the considerations specified in section 3.2.3.3 for performing the de-registration procedure. However, this operation MUST NOT release any IPv6 home network prefix(es) assigned to the mobile node.

4. IPv4 Transport Support

The Proxy Mobile IPv6 specification [RFC-5213] requires the signaling messages exchanged between the local mobility anchor and the mobile access gateway to be over an IPv6 transport. The extensions defined in this section allow the exchange of signaling messages over an IPv4 transport when the local mobility anchor and the mobile access gateway are separated by an IPv4 network and are reachable using only IPv4 addresses.

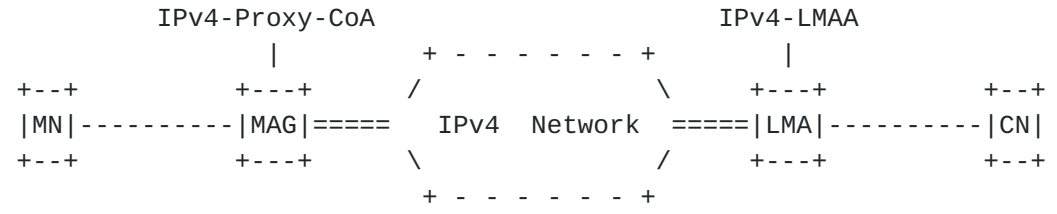


Figure 8: IPv4 Transport Network

When the local mobility anchor and the mobile access gateway are configured and reachable using only IPv4 addresses, the mobile access gateway serving a mobile node can potentially send the signaling messages over IPv4 transport and register its IPv4 address as the care-of address in the mobile node's Binding Cache entry. An IPv4 tunnel (with any of the supported encapsulation modes) can be used for tunneling the mobile node's data traffic. The following are the key aspects of this feature.

- The local mobility anchor and the mobile access gateway are both configured and reachable using an IPv4 address. Additionally, both entities are also IPv6 enabled and have configured IPv6 addresses on their interfaces, as specified in [RFC-5213], but are reachable only over an IPv4 transport network.

- The mobile access gateway can be potentially in a private IPv4 network behind a NAT [RFC-3022] device, with a private IPv4 address configured on its egress interface. But, the local mobility anchor must not be behind a NAT and must be using a globally routable IPv4 address. However, both the local mobility anchor and the mobile access gateway can be in the same private IPv4 routing domain, i.e., when both are configured with private IPv4 addresses and with no need for NAT translation between them.

- The IPv6 address configuration requirement on the mobile access gateway does not imply there needs to be IPv6 routing enabled

between the local mobility anchor and the mobile access gateway. It just requires each of the mobile access gateways and local mobility anchors in a Proxy Mobile IPv6 domain to be configured with a globally unique IPv6 address.

- The Proxy Mobile IPv6 signaling messages exchanged between the local mobility anchor and the mobile access gateway for negotiating the IPv4 transport will be encapsulated and carried as IPv4 packets. However, these signaling messages are fundamentally IPv6 messages using the mobility header and the related semantics as specified in base Proxy Mobile IPv6 specification [RFC-5213], but carried as a payload in an IPv4 packet. The supported encapsulation modes for the signaling messages are either native IPv4 or IPv4 with UDP header.

- The mobile node can be an IPv6, IPv4 or a dual IPv4/IPv6 node and the IPv4 transport support specified in this section is agnostic to the type of address mobility enabled for that mobile node.

- The IPv4 tunnel established between the local mobility anchor and the mobile access gateway (with any of the supported encapsulation modes over IPv4 transport) will be used for carrying the mobile node's IPv4 and IPv6 traffic. The following are the outer headers based on the negotiated encapsulation mode.

  * IPv4 (IPv4 or IPv6 Payload packet carried in an IPv4 packet). If payload protection using IPsec is enabled for the tunneled traffic, the ESP header follows the outer tunnel header.

  * IPv4-UDP (Payload packet carried in an IPv4 packet with UDP header). If payload protection using IPsec is enabled for the tunneled traffic, the ESP header follows the outer tunnel header, as specified in [RFC-3948].

  * IPv4-UDP-TLV (Payload packet carried in an IPv4 packet with UDP and TLV header). Refer to [ID-GREKEY-NEGO]. If payload protection using IPsec is enabled for the tunneled traffic, the ESP header follows the outer tunnel header.

4.1. Local Mobility Anchor Considerations

4.1.1. Extensions to Binding Cache Entry

To support this feature, the conceptual Binding Cache entry data structure maintained by the local mobility anchor [RFC-5213] MUST be extended with the following additional parameters. It is to be noted that all of these parameters are specified in [RFC-5555] and also required here in the present usage context, and are presented here

only for completeness.

- The IPv4 Proxy Care-of Address configured on the mobile access gateway that sent the Proxy Binding Update message. This address can be obtained from the IPv4 Care-of Address option [RFC-5555], present in the received Proxy Binding Update message. However, if the received Proxy Binding Update message is not sent as an IPv4 packet, i.e., when using IPv6 transport, this field in the Binding Cache entry MUST be set to ALL_ZERO value.

- The IPv4 NAT translated address of the mobile access gateway. If the mobile access gateway is not behind a NAT [RFC-3022], this address will be the same as the address configured on the egress interface of the mobile access gateway. This address can be obtained from the IPv4 header of the received Proxy Binding Update message. However, if the received Proxy Binding Update message is not sent as an IPv4 packet, this field in the Binding Cache entry MUST be set to ALL_ZERO value.

- The source UDP port, if the Proxy Binding Update was received in an IPv4 packet with UDP header.

- The destination UDP port, if the Proxy Binding Update was received in an IPv4 packet with UDP header.

4.1.2. Extensions to Mobile Node's Policy Profile

To support the IPv4 Transport Support feature the mobile node's policy profile, specified in Section 6.2 of [RFC-5213] MUST be extended with the following additional fields. These are mandatory fields of the policy profile required for supporting this feature.

- The IPv4 address of the local mobility anchor (IPv4-LMAA).

4.1.3. Signaling Considerations

This section provides the rules for processing the Proxy Mobile IPv6 signaling messages received over IPv4 transport.

4.1.3.1. Processing Proxy Binding Updates

- If the received Proxy Binding Update message was sent encapsulated in an IPv4 or IPv4-UDP packet, the message MUST be authenticated after removing the outer encapsulation (IPv4 or IPv4-UDP) header. Considerations from Section 4 of [RFC-5213] MUST be applied for authenticating and authorizing the request.

- All the considerations from Section 5.3.1 of [RFC-5213] MUST be applied on the encapsulated Proxy Binding Update message, after removing the outer encapsulation (IPv4 or IPv4-UDP) header.

- If there is an IPv4 Care-of Address option [RFC-5555] present in the request and if the outer encapsulation header is IPv4-UDP, then the NAT presence detection procedure specified in Section 4.1.3.3 MUST be used for detecting the NAT in the path.

- Upon accepting the request, the local mobility anchor MUST set up an IPv4 bi-directional tunnel to the mobile access gateway. The tunnel endpoint addresses are IPv4-LMAA and the IPv4-Proxy-CoA. The encapsulation mode MUST be determined by applying the following considerations:

  * If the received Proxy Binding Update message was sent with IPv4 encapsulated header, then the encapsulation mode for the bi-directional tunnel MUST be set to IPv4. Otherwise, the following considerations apply.

  * If NAT is not detected on the path and if the (F) flag in the received Proxy Binding Update message is set to the value of (1), but if the configuration flag, AcceptForcedIPv4UDPEncapsulationRequest, is set to a value of (0), then the local mobility anchor MUST reject the request with the Status field value set to 129 (Administratively prohibited).

  * If the (T) flag [ID-GREKEY-NEGO] in the Proxy Binding Update message is set to value of (1), then the encapsulation mode MUST be set to IPv4-or-IPv6-over-IPv4-UDP-TLV.

  * If NAT is detected on the path, or if the (F) flag in the received Proxy Binding Update message is set to the value of (1), then the encapsulation mode MUST be set to IPv4-or-IPv6-over-IPv4-UDP. Otherwise the encapsulation mode MUST be set to IPv4-or-IPv6-over-IPv4.

- The local mobility anchor MUST send the Proxy Binding Acknowledgement message with the Status field value set to (0) (Proxy Binding Update Accepted). The message MUST be constructed as specified in Section 4.1.3.2.

4.1.3.2. Constructing the Proxy Binding Acknowledgement Message

The local mobility anchor when sending the Proxy Binding Acknowledgement message to the mobile access gateway MUST construct the message as specified in Section 5.3.6 of [RFC-5213]. However, if

the received Proxy Binding Update message was encapsulated in an IPv4 packet or as a payload in the UDP header of an IPv4 packet, the following additional considerations MUST be applied.

- The Proxy Binding Acknowledgement message MUST be encapsulated in an IPv4 packet. However, if the received Proxy Binding Update message was sent encapsulated in an IPv4-UDP packet, then the Proxy Binding Acknowledgement message MUST be encapsulated in the UDP header of an IPv4 packet.

- The source address in the IPv4 header of the message MUST be set to the destination IPv4 address of the received request.

- If the mobile access gateway and the local mobility anchor are using globally routable IPv4 addresses and if there is a security association that is based on IPv4 addresses, then the encapsulated IPv4 packet (containing the IPv6 Proxy Binding Acknowledgement) MUST be protected using IPsec ESP [RFC-4301] mode. There is no need to apply IPsec ESP header to the IPv6 packet. In all other cases, the Proxy Binding Acknowledgement message MUST be protected using IPsec prior to the IPv4 or IPv4-UDP encapsulation.

- The NAT Detection option [RFC-5555] MUST be present only if there is an IPv4 Care-of Address option [RFC-5555] present in the received Proxy Binding Update message and if the NAT detection procedure resulted in detecting a NAT on path. However, if the received Proxy Binding Update message was not sent encapsulated in IPv4 UDP header, then the option MUST NOT be present. Furthermore, in all other cases, the option MUST NOT be present.

- The IPv4 DHCP Support Mode option MAY be present. If this option is not present, the mobile access gateway will enable the default behavior and function as a DHCP Relay for the mobile node.

- Figure 9 shows the format of the Proxy Binding Acknowledgement message encapsulated in an IPv4 packet and protected using IPv6 security association. The UDP header MUST be present only if the received Proxy Binding Update message was sent encapsulated in an IPv4-UDP packet.

```
IPv4 header (src=IPv4-LMAA, dst=pbu_src_address)
  UDP header (sport=DSMIP_PORT, dport= pbu_sport) /*Optional*/
    /* IPv6 PBA Packet protected with ESP header */
```

Figure 9: Proxy Binding Acknowledgment (PBA) Message encapsulated in IPv4 header

4.1.3.3. NAT Presence Detection

When the transport network between the local mobility anchor and the mobile access gateway is an IPv4 network and if the received Proxy Binding Update message was sent encapsulated in IPv4 UDP header, the local mobility anchor performs the NAT Presence Detection as specified below.

On receiving the Proxy Binding Update message encapsulated in an IPv4 UDP packet, the local mobility anchor, if it detects a NAT on the path, will send the Proxy Binding Acknowledgment message with the NAT Detection Option. The presence of this option in the Proxy Binding Acknowledgment is an indication to the mobile access gateway about the presence of NAT in the path. On detecting any NAT in the path, both the local mobility anchor and the mobile access gateway will set the encapsulation mode of the tunnel to IPv4-UDP-based encapsulation. The specific details around the NAT detection and the related logic are described in DSMIPv6 specification [RFC-5555].

However, if the value of the configuration variable, UseIPv4UDPEncapForSignalingMessages, is set to a value of (0), the mobile access gateway will not use IPv4 UDP encapsulation for Proxy Binding Update messages and hence the local mobility anchor will not perform this NAT Presence Detection procedure on these messages that are not sent in IPv4 UDP packet.

4.1.4. Routing Considerations

4.1.4.1. Forwarding Considerations

Forwarding Packets to the Mobile Node:

- On receiving an IPv4 or an IPv6 packet from a correspondent node with the destination address matching any of the mobile node's IPv4 or IPv6 home addresses, the local mobility anchor MUST forward the packet through the bi-directional tunnel set up for that mobile node.

- The format of the tunneled packet is shown below.

```
IPv4 Header (src= IPv4-LMAA, dst= IPv4-Proxy-CoA)] /* Tunnel Header */
  [UDP Header (src port=DSMIPv6, dst port=Z]   /* If UDP encap nego */
    [TLV Header]                               /* If TLV negotiated */
      /* IPv6 or IPv4 Payload Packet */
             IPv6 header (src= CN, dst= MN-HOA)
                        OR
             IPv4 header (src= CN, dst= IPv4 MN-HoA)
```

Figure 10: Tunneled IPv4 Packet from LMA to MAG

- Forwarding Packets Sent by the Mobile Node:
  - All the reverse tunneled packets (IPv4 and IPv6) that the local mobility anchor receives from the mobile access gateway, after removing the tunnel header (i.e., the outer IPv4 header along with the UDP and TLV header, if negotiated) MUST be routed to the destination specified in the inner packet header. These routed packets will have the source address field set to the mobile node's home address.

4.1.4.2. ECN Considerations

The ECN considerations specified in Section 5.6.3 of [RFC-5213] apply for the IPv4 transport tunnels as well. The mobility agents at the tunnel entry and exit points MUST handle ECN information as specified in that document.

4.1.4.3. Bi-Directional Tunnel Management

The Tunnel Management considerations specified in section 5.6.1 of [RFC-5213] apply for the IPv4 transport tunnels as well, with just one difference that the encapsulation mode is different.

4.2. Mobile Access Gateway Considerations

4.2.1. Extensions to Binding Update List Entry

To support the IPv4 Transport Support feature, the conceptual Binding Update List entry data structure maintained by the mobile access gateway [RFC-5213] MUST be extended with the following additional parameters.

- The IPv4 address of the local mobility anchor. This address can be obtained from the mobile node's policy profile.

4.2.2. Signaling Considerations

The mobile access gateway when sending a Proxy Binding Update message to the local mobility anchor MUST construct the message as specified in Section 6.9.1.5 of [RFC-5213]. However, if the mobile access gateway is in an IPv4-only access network, the following additional considerations MUST be applied.

- The Proxy Binding Update message MUST be encapsulated in an IPv4 packet. However, if the value of the configuration variable, UseIPv4UDPEncapForSignalingMessages, is set to 1, then the Proxy Binding Update message MUST be encapsulated in an UDP header of an IPv4 packet.

- The IPv4 Care-of Address option [RFC-5555] MUST be present. The IPv4 address in the option MUST be set to the mobile access gateway's IPv4-Proxy-CoA.

- The packet MUST be constructed as specified in Section 4.2.2.1.

- Just as specified in [RFC-5213], when sending a Proxy Binding message for extending the lifetime of a currently existing mobility session or for de-registering the mobility session, the Proxy Binding Update message MUST be constructed just as the initial request.

Receiving Proxy Binding Acknowledgement

- If the received Proxy Binding Acknowledgement message is encapsulated in IPv4 or IPv4 UDP packet, the message MUST be authenticated after removing the outer IPv4 or IPv4-UDP header. Considerations from Section 4 of [RFC-5213] MUST be applied for authenticating and authorizing the message.

- All the considerations from Section 6.9.1.2 of [RFC-5213] MUST be applied on the encapsulated Proxy Binding Acknowledgement message, after removing the outer IPv4 UDP header.

- If the Status field indicates Success, the mobile access gateway MUST setup a bi-directional tunnel to the local mobility anchor.

- Upon accepting the request, the mobile access gateway MUST set up an IPv4 bi-directional tunnel to the local mobility anchor. The tunnel endpoint addresses are IPv4-Proxy-CoA and the IPv4-LMAA. The encapsulation mode MUST be determined from the below considerations.

- The encapsulation mode for the bi-directional tunnel MUST be set to IPv4. However, if the value of the configuration variable, UseIPv4UDPEncapForSignalingMessages, is set to (1), then the following considerations MUST be applied.

  * If there is a NAT Detection option [RFC-5555] in the received Proxy Binding Acknowledgement message and if the value of the configuration flag, UseIPv4UDPEncapForSignalingMessages, is set to value of (1), then the encapsulation mode for the tunnel MUST be set to IPv4-UDP. Otherwise the encapsulation mode MUST be set to IPv4.

  * If the (T) flag in the Proxy Binding Acknowledgement message is set to value of (1), then the encapsulation mode MUST be set to IPv4-UDP-TLV.

4.2.2.1. Constructing the Proxy Binding Update Message

- The source address in the IPv4 header MUST be set to IPv4-Proxy-CoA of the mobile access gateway and the destination address MUST be set to the local mobility anchor's IPv4-LMAA.

- The IPv4 Care-of Address option [RFC-5555] MUST be present. The address MUST be set to the mobile access gateway's IPv4-Proxy-CoA.

- If the configuration variable ForceIPv4UDPEncapsulationSupport is set to value of (1), then the (F) flag in the Proxy Binding Update message MUST be set to value of (1).

- The Proxy Binding Update message MUST be protected using IPsec ESP [RFC-4301], as specified in [RFC-5213]. The protection MUST be applied on the IPv6 packet of the Proxy Binding Update message, prior to the IPv4 encapsulation.

- The format of the Proxy Binding Update message encapsulated in an IPv4 or IPv4-UDP packet with no IPsec protection:

```
 IPv4 header (src=IPv4-Proxy-CoA, dst=IPv4-LMAA)
    UDP header (sport=ANY, dport= DSMIP_PORT) /*Optional*/
       /* IPv6 PBU Packet protected with ESP header */
```

Figure 11: Proxy Binding Update (PBU) message encapsulated in IPv4 UDP header

4.2.2.2. Forwarding Considerations

Forwarding Packets Sent by the Mobile Node:

- On receiving an IPv4 or an IPv6 packet from the mobile node to any destination, the mobile access gateway MUST tunnel the packet to the local mobility anchor. The format of the tunneled packet is shown below. However, considerations from Section 6.10.3 of [RFC-5213] MUST be applied with respect the local routing and on the use of EnableMAGLocalRouting flag.

```
IPv4 Header (src= IPv4-Proxy-CoA, dst= IPv4-LMAA)] /* Tunnel Header */
   [UDP Header (src port=DSMIPv6, dst port=Z]   /* If UDP encap nego */
       [TLV Header]                             /* If TLV negotiated */
             /* IPv6 or IPv4 Payload Packet */
             IPv6 header (src= CN, dst= MN-HOA)
                         OR
             IPv4 header (src= CN, dst= IPv4 MN-HoA)
```

Figure 12: Tunneled IPv4 Packet from LMA to MAG

- Forwarding Packets received from the bi-directional tunnel:

- On receiving a packet from the bi-directional tunnel established with the mobile node's local mobility anchor, the mobile access gateway MUST remove the outer header before forwarding the packet to the mobile node.

5. Protocol Configuration Variables

5.1. Local Mobility Anchor - Configuration Variables

The local mobility anchor MUST allow the following variables to be configured by the system management. The configured values for these protocol variables MUST survive server reboots and service restarts.

AcceptForcedIPv4UDPEncapsulationRequest

This flag indicates whether or not the local mobility anchor should accept IPv4 UDP encapsulation request for the mobile node's data traffic, even if there is no NAT detected in the path.

The default value for this flag is set to (0), indicating that the local mobility anchor MUST NOT accept IPv4 UDP encapsulation request when NAT is not detected in the path.

When the value for this flag is set to (1), the local mobility anchor MUST accept IPv4 UDP encapsulation request even when NAT is not detected in the path.

5.2. Mobile Access Gateway - Configuration Variables

The mobile access gateway MUST allow the following variables to be configured by the system management. The configured values for these protocol variables MUST survive server reboots and service restarts.

UseIPv4UDPEncapForSignalingMessages

This flag indicates whether or not the mobile access gateway should use IPv4-UDP encapsulation mode for the signaling messages.

The default value for this flag is set to (0), indicating that the mobile access gateway MUST NOT use IPv4-UDP encapsulation mode, but MUST use native IPv4 encapsulation mode for sending the Proxy Mobile IPv6 signaling messages.

When the value for this flag is set to (1), the mobile access gateway MUST use IPv4-UDP encapsulation mode for sending the Proxy Mobile IPv6 signaling messages.

ForceIPv4UDPEncapsulationSupport

This flag indicates whether or not the mobile access gateway should request the mobile node's local mobility anchor for forcing IPv4 UDP encapsulation support for the mobile node's data traffic, even when NAT is not detected in the path.

The default value for this flag is set to (0), indicating that the mobile access gateway MUST NOT request the mobile node's local mobility anchor for forcing IPv4 UDP encapsulation support even when NAT is not detected in path.

When the value for this flag is set to (1), the mobile access gateway MUST force the mobile node's local mobility anchor for IPv4 UDP encapsulation support.

This flag is applicable only when the flag UseIPv4UDPEncapForSignalingMessages is set to a value of (1).

6. IANA Considerations

This document defines two new Mobility Header options, IPv4 Default Router Address option and IPv4 DHCP Support Mode option. These options are described in Section 3.3.1 and Section 3.3.2 respectively. The Type value for these options needs to be assigned from the same number space as allocated for the other mobility options, as defined in [RFC-3775].

The IPv4 DHCP Support Mode Option, described in Section 3.3.2 of this document, introduces a new number space, IPv4 DHCP Support Mode Flags. This document reserves the value 0x1 for the (S) flag. Approval of this flag values are to be made through IANA Expert Review.

This document also defines new status values, used in Proxy Binding Acknowledgement message, as described in Section 3.3.3. These values are to be assigned from the same number space as allocated for other Status codes [RFC-3775]. Each of these allocated values have to be greater than 128.

NOT_AUTHORIZED_FOR_IPV4_HOME_ADDRESS: IANA

Mobile node not authorized for the requesting IPv4 home address

NOT_AUTHORIZED_FOR_IPV6_HOME_NETWORK_PREFIX: IANA

Mobile node not authorized for the requesting IPv6 home network prefix(es).

MULTIPLE_IPV4_HOME_ADDRESS_ASSIGNMENT_NOT_SUPPORTED

Multiple IPv4 home address assignment not supported

IPV4_PREFIX_ASSIGNMENT_NOT_SUPPORTED

IPv4 prefix assignment not supported

7. Security Considerations

All the security considerations from the base Proxy Mobile IPv6 [RFC-5213], Mobile IPv6 [RFC-3775], and Dual-Stack Mobile IPv6 [RFC-5555] apply when using the extensions defined in this document. Additionally, the following security considerations need to be applied.

This document defines new mobility options for supporting the IPv4 Home Address assignment and IPv4 Transport Support features. These options are to be carried in Proxy Binding Update and Proxy Binding Acknowledgement messages. The required security mechanisms specified in the base Proxy Mobile IPv6 protocol for protecting these signaling messages are sufficient when carrying these mobility options.

This specification describes the use of IPv4 transport for exchanging the signaling messages between the local mobility anchor and the mobile access gateway. These signaling messages are fundamentally IPv6 messages, but encapsulated in an IPv4 header and routed as IPv4 packets. The encapsulated inner IPv6 message is still protected using IPsec, using the established security association and this offers the same level of security as when the messages are routed natively as IPv6 packets. The use of outer IPv4 header does not introduce any new security vulnerabilities.

8. Contributors

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