Internet Engineering Task Force (IETF)
Request for Comments: 7629
Category: Experimental
ISSN: 2070-1721

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August 2015

Flow-Binding Support for Mobile IP

Abstract

This specification defines extensions to the Mobile IP protocol for allowing a mobile node with multiple interfaces to register a care-of address for each of its network interfaces and to simultaneously establish multiple IP tunnels with its home agent. This essentially allows the mobile node to utilize all the available network interfaces and build a higher aggregated logical pipe with its home agent for its home address traffic. Furthermore, these extensions also allow the mobile node and the home agent to negotiate IP traffic flow policies for binding individual flows with the registered care-of addresses.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for examination, experimental implementation, and evaluation.

This document defines an Experimental Protocol for the Internet community. This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Not all documents approved by the IESG are a candidate for any level of Internet Standard; see Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc7629.

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1. Introduction

With the ubiquitous availability of wireless networks based on different access technology types, mobile devices are now equipped with multiple wireless interfaces and have the ability to connect to the network using any of those interfaces. For example, most mobile devices are equipped with Wi-Fi and LTE (Long Term Evolution) interfaces. In many deployments, it is desirable for a mobile node to leverage all the available network interfaces and have IP mobility support for its IP flows.

The operation defined in the Mobile IP protocol [RFC5944] allows a mobile node to continue to use its home address as it moves around the Internet. Based on the mode of operation, there will be an IP tunnel that will be established between the home agent and the mobile node or between the home agent and the foreign agent where the mobile node is attached; see [RFC5944]. In both of these modes, there will only be one interface on the mobile node that is receiving the IP traffic from the home agent. This approach of using a single access interface for routing all mobile node's traffic is not efficient and so there is a need to extend Mobile IP to concurrently use multiple access interfaces for routing the mobile node's IP traffic. The goal is for efficient use of all the available access links to obtain higher aggregated bandwidth for the tunneled traffic between the home agent and the mobile node.

This specification defines extensions to Mobile IPv4 protocol for allowing a mobile node with multiple interfaces to register a care-of address for each of its network interfaces and to simultaneously leverage all access links for the mobile node's IP traffic. Furthermore, this specification also defines extensions to allow the mobile node and the home agent to optionally negotiate IP flow policies for binding individual IP flows with the registered care-of addresses.

2. Conventions and 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 [RFC2119].

2.2. Terminology

All the mobility-related terms used in this document are to be interpreted as defined in [RFC5944] and [RFC3753]. In addition, this document uses the following terms.

Binding Identifier (BID)

It is an identifier assigned to a mobile node's binding. A binding defines an association between a mobile node's home address and its registered care-of address. When a mobile node registers multiple bindings with its home agent, each using a different care-of address, then each of those bindings are given a unique identifier. Each of the binding identifiers will have a unique value that will be different from the identifiers assigned to the mobile node's other bindings.

Flow Identifier (FID)

It is an identifier for a given IP flow, uniquely identified by source address, destination address, protocol type, source port, destination port, Security Parameter Index, and other parameters as identified in [RFC6088]. In the context of this document, the IP flows associated with a mobile node are the IP flows using its home address. For a mobile router, the IP flows also include the IP flows using the mobile network prefix [RFC6626].

3. Overview

The illustration below in Figure 1 is an example scenario where a mobile node is connected to WLAN, LTE, and CDMA access networks. The mobile node is configured with a home address, HoA_1, and has obtained the following care-of addresses [RFC5944]: CoA_1, from the WLAN network; CoA_2, from the LTE network; and CoA_3, from the CDMA network.

The mobile node using the extensions specified in this document registers all three care-of addresses with its home agent. The mobile node also establishes an IP tunnel with the home agent using each of its IP addresses, which results in three IP tunnels (Tunnel_1, Tunnel_2, and Tunnel_3) between the mobile node and the home agent. Each of the tunnels represents an overlay routing path between the mobile node and the home agent and can be used for forwarding the mobile node's IP traffic.

Furthermore, using the extensions specified in this document, the mobile node and the home agent can negotiate an IP flow policy. The negotiated flow policy allows the mobile node and the home agent to determine the access network path for each of the mobile node's IP flows.

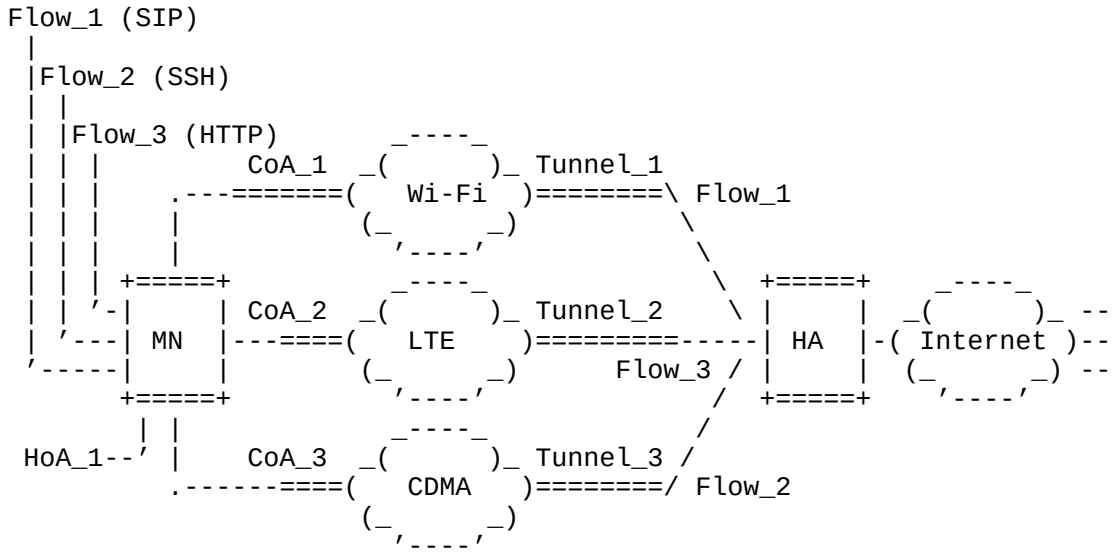

Figure 1: Mobile Node (MN) with Multiple Tunnels to the Home Agent (HA)

The table below is an example of how the individual flows are bound to different care-of addresses registered with the home agent.

Flow ID (FID)	Access Network Preferences	Description
Flow_1	Tunnel_1 / CoA_1 Tunnel_2 / CoA_2 <DROP>	All SIP flows over Wi-Fi (Preferred) If Wi-Fi is not available, use LTE If Wi-Fi and LTE access networks are not available, drop the flow
Flow_3	Tunnel_2 / CoA_2 <DROP>	All HTTP flows over LTE (Preferred) If LTE not available, drop the flow
Flow_2	Tunnel_3 / CoA_3 Tunnel_2 / CoA_2 Tunnel_1 / CoA_1	All SSH flows over CDMA (Preferred) If CDMA not available, use LTE If LTE not available, use Wi-Fi

Figure 2: Example of an IP Traffic Policy

3.1. Example Call Flow

Figure 3 is the call flow for the example scenario where a mobile node is connected to WLAN and LTE access networks.

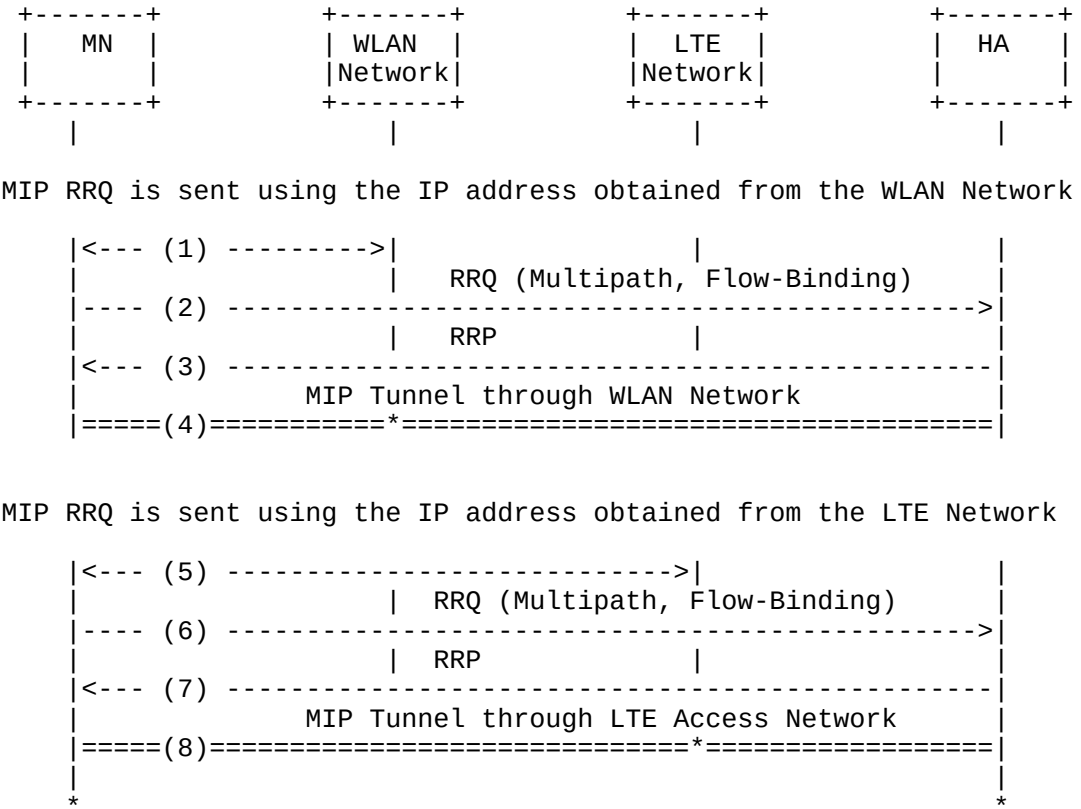

Figure 3: Multipath Negotiation - Example Call Flow

- (1): The mobile node attaches to the WLAN network and obtains the IP address configuration for its WLAN interface.

- (2)-(3): The mobile node sends a Registration Request (RRQ) [RFC5944] to the home agent through the WLAN network. The message includes the Multipath (Section 4.1) and the Flow-Binding (Section 4.2) Extensions. The home agent, upon accepting the request, sends a Registration Reply (RRP) [RFC5944] with a value of (0) in the Code field of the Registration Reply.

- (4): The mobile node and the home agent establish a bidirectional IP tunnel over the WLAN network.

- (5): The mobile node attaches to the LTE network and obtains the IP address configuration from that network.

- (6)-(7): The mobile node sends a Registration Request to the home agent through the LTE network. The message includes the Multipath and the Flow-Binding Extensions. The Flow-Binding Extension indicates that all HTTP flows need to be routed over the WLAN network and if the WLAN access network is not available, they need be routed over other access networks. The negotiated policy also requires all voice-related traffic flows to be routed over the LTE network. The home agent, upon accepting the request, sends a Registration Reply with a value of (0) in the Code field of the Registration Reply.

- (8): The mobile node and the home agent establish a bidirectional IP tunnel over the LTE network. The negotiated traffic flow policy is applied. Both the home agent and the mobile node route all the voice flows over the tunnel established through the LTE access network and the HTTP flows over the WLAN network.

4. Message Extensions

This specification defines the following new extensions to Mobile IP.

4.1. Multipath Extension

This extension is used for requesting multipath support. It indicates that the sender is requesting the home agent to register the current care-of address listed in this Registration Request as one of the many care-of addresses through which the mobile node can be reached. It is also for carrying the information specific to the interface to which the care-of address that is being registered is bound.

This extension is a non-skippable extension and MAY be added by the mobile node to the Registration Request message. There MUST NOT be more than one instance of this extension present in the message. This extension MUST NOT be added by the home agent to the Registration Reply.

This extension should be protected using the Mobile-Home Authentication Extension [RFC5944]. As specified in Sections 3.2 and 3.6.1.3 of [RFC5944], the mobile node MUST place this Extension before the Mobile-Home Authentication Extension in the registration messages so that this extension is integrity protected.

The format of this extension is as shown below. It adheres to the long extension format described in [RFC5944].

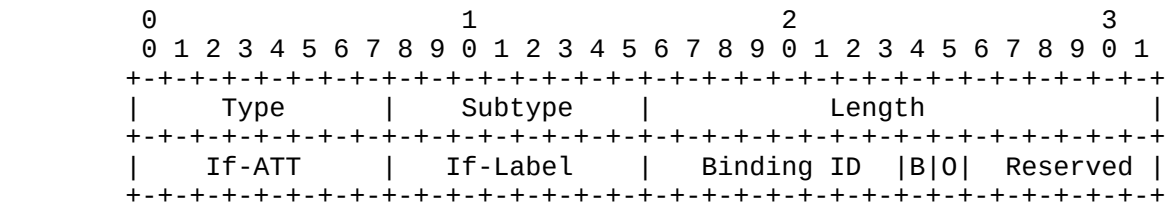

Figure 4: Multipath Extension

Type

Type: Multipath-Extension-Type (154)

Subtype

This field MUST be set to a value of 1 (Multipath Extension).

Length

The length of the extension in octets, excluding Type, Subtype, and Length fields. This field MUST be set to a value of 4.

Interface Access-Technology Type (If-ATT)

This 8-bit field identifies the Access Technology type of the interface through which the mobile node is connected. The permitted values for this are from the Access Technology Type registry defined in [RFC5213].

Interface Label (If-Label)

This 8-bit field represents the interface label represented as an unsigned integer. The mobile node identifies the label for each of the interfaces through which it registers a CoA with the home agent. When using static traffic flow policies on the mobile node and the home agent, the label can be used for indexing forwarding policies. For example, the operator may have a policy that binds an IP flow "F1" to any interface with the label "Blue". When a registration through an interface matching the label "Blue" gets activated, the home agent and the mobile node establish an IP tunnel and the tunnel is marked with that label. Both the home agent and the mobile node generate traffic rules for forwarding IP flow traffic "F1" through the mobile IP tunnel matching the label "Blue". The permitted values for If-Label are 1 through 255.

Binding Identifier (BID)

This 8-bit field is used for carrying the binding identifier. It uniquely identifies a specific binding of the mobile node associated with this Registration Request. Each binding identifier is represented as an unsigned integer. The permitted values are 1 through 254. The BID value of 0 and 255 are reserved.

Bulk Re-registration Flag (B)

The (B) flag, if set to a value of (1), notifies the home agent to update the binding lifetime of all the mobile node's bindings upon accepting this request. The (B) flag MUST NOT be set to a value of (1) if the value of the Registration Overwrite Flag (O) flag is set to a value of (1).

Registration Overwrite (O)

The (O) flag, if set to a value of (1), notifies the home agent that upon accepting this request it should replace all of the mobile node's existing bindings with the new binding that will be created upon accepting this request. The (O) flag MUST NOT be set to a value of (1) if the value of the Bulk Re-registration Flag (B) is set to a value of (1). This flag MUST be set to a value of (0) in De-Registration requests.

Reserved (R)

This 6-bit field is unused for now. The value MUST be initialized to (0) by the sender and MUST be ignored by the receiver.

4.2. Flow-Binding Extension

This extension contains information that can be used by the mobile node and the home agent for binding mobile node's IP flows to a specific multipath registration. There can be more than one instance of this extension present in the message.

This extension is a non-skippable extension and MAY be added to the Registration Request by the mobile node or by the home agent to the Registration Reply.

This extension should be protected by Mobile-Home Authentication Extension [RFC5944]. As specified in Section 3.2 and 3.6.1.3 of [RFC5944], the mobile node MUST place this extension before the Mobile-Home Authentication Extension in the registration messages so that this extension is integrity protected.

The format of this extension is as shown below. It adheres to the long extension format described in [RFC5944].

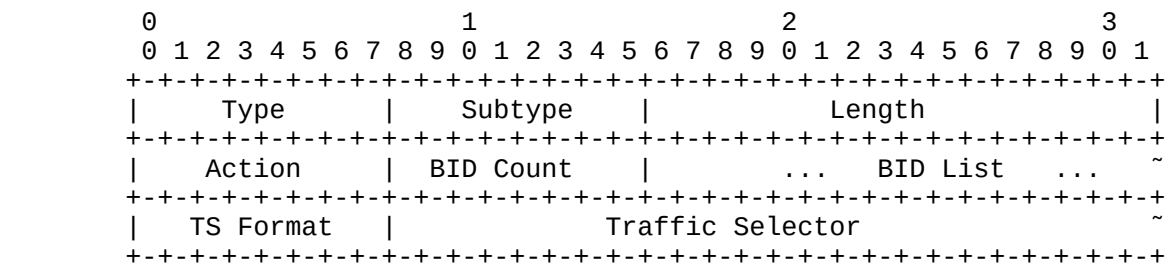

Figure 5: Flow-Binding Extension

Type

Type: Multipath-Extension-Type (154)

Subtype

This field MUST be set to a value of 2 (Flow-Binding Extension).

Length

The length of the extension in octets, excluding Type, Subtype, and Length fields.

Action

The Action field identifies the traffic rule that needs to be enforced. Following are the possible values.

Action	Value	Description
DROP	0	Drop matching packets. A filter rule indicating a drop action MUST include a single BID byte, the value of which MAY be set to 255 by the sender and the value of which SHOULD be ignored by the receiver.
FORWARD	1	Forward matching packets to the first BID in the list of BIDs the filter rule is pointing to. If the first BID becomes invalid (i.e., the corresponding CoA is de-registered), use the next BID in the list.

Figure 6: Action Rules for the Traffic Selector

BID Count

Total number of binding identifiers that follow this field. The permitted values for this field are 1 through 8; each binding identifier is represented as an unsigned integer in a single octet field. There is no delimiter between two binding identifier values; they are spaced consecutively.

TS Format

An 8-bit unsigned integer indicating the Traffic Selector (TS) Format. The value (0) is reserved and MUST NOT be used. When the value of the TS Format field is set to (1), the format that follows is the IPv4 Binary Traffic Selector specified in Section 3.1 of [RFC6088], and when the value of the TS Format field is set to (2), the format that follows is the IPv6 Binary Traffic Selector specified in Section 3.2 of [RFC6088]. The IPv6 traffic selectors are only relevant when the mobile node registers IPv6 prefixes per [RFC5454].

Traffic Selector

A variable-length opaque field for including the traffic specification identified by the TS Format field. It identifies the traffic selectors for matching the IP traffic and binding them to specific binding identifiers.

4.3. New Error Codes for Registration Reply

This document defines the following error code values for use by the home agent in the Code field of the Registration Reply.

MULTIPATH_NOT_ALLOWED (Multipath Support not allowed for this mobile node): 152

INVALID_FB_IDENTIFIER (Invalid Flow-Binding Identifier): 153

5. Protocol Operation

5.1. Mobile Node Considerations

- The mobile node should register a care-of address for each of the connected interfaces that it wishes to register with the home agent. It can do so by sending a Registration Request to the home agent through each of those interfaces.

- Each of the Registration Requests that is sent includes the care-of address of the respective interface. The Registration Request has to be routed through the specific interface for which the registration is sought for. Some of these interfaces may be connected to networks with a configured foreign agent on the link, and in such foreign-agent-based registrations, the care-of address will be the IP address of the foreign agent.

- A Multipath Extension (Section 4.1) reflecting the interface parameters is present in each of the Registration Requests. This serves as an indication to the home agent that the Registration Request is a Multipath registration and the home agent will have to register this care-of address as one of the many care-of addresses through which the mobile node’s home address is reachable.

- If the mobile node is configured to exchange IP flow policy to the home agent, then the Flow-Binding Extension (Section 4.2) reflecting the flow policy can be included in the message. Otherwise, the Flow-Binding Extension will not be included.

- The mobile node, upon receiving a Registration Reply with the Code value set to MULTIPATH_NOT_ALLOWED, MAY choose to register without the Multipath Extension specified in this document. This implies the home agent has not enabled multipath support for this mobile node and hence multipath support MUST be disabled on the mobile node.

- The mobile node, upon receiving a Registration Reply with the Code value set to INVALID_FB_IDENTIFIER, MUST re-register that specific binding with the home agent.

- The mobile node at any time can extend the lifetime of a specific care-of address registration by sending a Registration Request to the home agent with a new lifetime value. The message MUST be sent as the initial multipath registration and must be routed through that specific interface. The message MUST include the Multipath Extension (Section 4.1) with the value in the Binding ID field set to the binding identifier assigned to that binding. Alternatively, the home agent can send a single Registration Request with the Bulk Re-registration Flag (B) set to a value of (1). This serves as a request to the home agent to update the registration lifetime of all the mobile node's registrations.

- The mobile node can, at any time, de-register a specific care-of address by sending a Registration Request to the home agent with a lifetime value of (0). The message must include the Multipath Extension (Section 4.1) with the value in the Binding ID field set to the binding identifier assigned to that binding. Alternatively, the home agent can send a single Registration Request with the Bulk Re-registration Flag (B) set to a value of (1) and a lifetime value of (0). This serves as a request to the home agent to consider this request as a request to de-register all the mobile node's care-of addresses.

- The mobile node can, at any time, update the parameters of a specific registration by sending a Registration Request to the home agent. This includes a change of care-of address associated with a previously registered interface. The message must be sent as the initial multipath registration and must be routed through that specific interface. The message must include the Multipath Extension (Section 4.1) with the value in the Binding ID field set to the binding identifier assigned to that binding, and the Overwrite Flag (O) flag MUST be set to a value of (1).

- The mobile node, upon receiving a Registration Reply with the Code value set to 0 (registration accepted), will establish a Mobile IP tunnel to the home agent using that care-of address. When using a foreign agent care-of address, the tunnel is between the home agent and the foreign agent. The tunnel encapsulation type and any other parameters are based on the registration for that path. If there is also an exchange of flow policy between the mobile node and the home agent, with the use of Flow-Binding Extensions, then the mobile node must set up the forwarding plane that matches the flow policy.

5.2. Home Agent Considerations

The home agent, upon receiving a Registration Request from a mobile node with a Multipath Extension, should check if the mobile node is authorized for multipath support. If multipath support is not enabled, the home agent MUST reject the request with a Registration Reply and with the Code set to MULTIPATH_NOT_ALLOWED.

If the received Registration Request includes a Multipath Extension and additionally has the Bulk Re-registration (B) flag set to a value of (1), then the home agent MUST extend the lifetime of all the bindings associated with that mobile node.

The home agent, upon receipt of a Registration Request with the Flow-Binding Extension, must process the extension and, upon accepting the flow policy, must set up the forwarding plane that matches the flow policy. If the home agent cannot identify any of the binding identifiers, then it MUST reject the request with a Registration Reply and with the Code set to INVALID_FB_IDENTIFIER.

If the received Registration Request includes a Multipath Extension and additionally has the Registration Overwrite (O) flag set to a value of (1), then the home agent MUST consider this as a request to replace all other mobile node’s bindings with just one binding and that is the binding associated with this request.

6. Routing Considerations

When multipath registration is enabled for a mobility node, there will be multiple Mobile IP tunnels established between a mobile node and its home agent. These Mobile IP tunnels appear to the forwarding plane of the mobile node as equal-cost, point-to-point links.

If there is also an exchange of traffic flow policy between the mobile node and the home agent, with the use of Flow-Binding Extensions (Section 4.2), then the mobile node’s IP traffic can be routed by the mobility entities as per the negotiated flow policy. However, if multipath is enabled for a mobility session without the use of any flow policy exchange, then both the mobile node and the home agent are required to have a pre-configured static flow policy. The specific details on the semantics of this static flow policy are outside the scope of this document.

In the absence of any established traffic flow policies, most IP hosts support two alternative traffic load-balancing schemes, per-flow and per-packet load balancing [RFC2991]. These load-balancing schemes allow the forwarding plane to evenly distribute traffic on either a per-packet or per-flow basis, across all the available

equal-cost links through which a destination can be reached. The default forwarding behavior of per-flow load balancing will ensure a given flow always takes the same path and will eliminate any packet re-ordering issues, and that is critical for delay-sensitive traffic, whereas the per-destination load-balancing scheme leverages all the paths much more effectively but with the potential issue of packet re-ordering on the receiver end. This issue will be specially magnified when the access links have very different forwarding characteristics. A host can choose to enable any of these approaches. Therefore, this specification recommends the use of per-flow load balancing.

7. IANA Considerations

Per this document, the following IANA actions have been completed.

- Action 1: This specification defines two new Mobile IP extensions, the Multipath Extension and the Flow-Binding Extension. The format of the Multipath Extension is described in Section 4.1, and the format of the Flow-Binding Extension is described in Section 4.2. Both of these extensions are non-skippable extensions to the Mobile IPv4 header in accordance to the long extension format of [RFC5944]. Both of these extensions use a common Type value, Multipath-Extension (154), but are identified using different Subtype values. The Type value 154 for these extensions has been allocated from the "Extensions to Mobile IP Registration Messages" registry at the URL <http://www.iana.org/assignments/mobileip-numbers>. The field "Permitted for Notification Messages" for this extension MUST be set to "N".

- Action 2: This specification defines a new message subtype space, Multipath Extension subtype. This field is described in Section 4.1. The values for this subtype field are managed by IANA under the "Multipath Extension subtypes (Value 154)" registry. This specification reserves the following Type values. Approvals of new Multipath Extension subtype values are to be made through IANA Expert Review [RFC5226].

0	Reserved
1	Multipath Extension
2	Flow-Binding Extension
3-254	Unassigned
255	Reserved

- Action 3: This document defines new status code values, MULTIPATH_NOT_ALLOWED (152) and INVALID_FB_IDENTIFIER (153), for use by the home agent in the Code field of the Registration Reply, as described in Section 4.3. These values have been assigned from the "Registration denied by the home agent" registry at <http://www.iana.org/assignments/mobileip-numbers>.

8. Security Considerations

This specification allows a mobile node to establish multiple Mobile IP tunnels with its home agent by registering a care-of address for each of its active roaming interfaces. This essentially allows the mobile node's IP traffic to be routed through any of the tunnel paths based on a static or a dynamically negotiated flow policy. This new capability has no impact on the protocol security. Furthermore, this specification defines two new Mobile IP extensions, the Multipath Extension and the Flow-Binding Extension. These extensions are specified to be included in Mobile IP control messages, which are authenticated and integrity protected as described in [RFC5944]. Therefore, this specification does not weaken the security of the Mobile IP protocol and does not introduce any new security vulnerabilities.

9. References

9.1. Normative References

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Acknowledgements

We would like to thank Qin Wu, Shahriar Rahman, Mohana Jeyatharan, Yungui Wang, Hui Deng Behcet Sarikaya, Jouni Korhonen, Michaela Vanderveen, Antti Makela, Charles Perkins, Pierrick Seite, Vijay Gurbani, Barry Leiba, Henrik Levkowetz, Pete McCann, and Brian Haberman for their review and comments on this document.

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