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Flow Binding Support for Mobile IP
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Abstract

This specification defines extensions to 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 an 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 flow policies for binding individual traffic flows with the registered care-of addresses.

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Table of Contents

1.	Introduction	3
2.	Conventions & Terminology	3
2.1.	Conventions	3
2.2.	Terminology	3
3.	Solution Overview	4
3.1.	Example Call Flow	5
4.	Message Extensions	6
4.1.	Multipath Extension	6
4.2.	Flow-Binding Extension	9
4.3.	New Error Codes for Registration Reply	11
5.	Protocol Operation	11
5.1.	Mobile Node Considerations	11
5.2.	Home Agent Considerations	13
6.	Routing Considerations	14
7.	Protocol Configuration Variables	14
8.	IANA Considerations	15
9.	Security Considerations	15
10.	Contributors	16
11.	Acknowledgements	16
12.	References	16
12.1.	Normative References	16
12.2.	Informative References	17

1. Introduction

With the ubiquitous availability of wireless networks supporting different access technologies, mobile devices are now equipped with multiple wireless interfaces and have the ability to connect to the network over any of those interfaces and access the network. In many deployments, it is desirable for a mobile node to leverage all the available network connections and have IP mobility support for its IP sessions.

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 a Mobile 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. In both of these modes, there will only be one interface on the mobile node that is receiving the traffic from the home agent. However, this is not efficient and requires an approach where the mobile node can use more than one interfaces for reaching the home network. The objective being efficient use of all available 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 establish multiple IP tunnels with its home agent. Furthermore, this specification also defines extensions to allow the mobile node and the home agent to optionally negotiate flow policies for binding individual traffic flows with the registered care-of addresses.

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](#) [[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 for a specific binding of a mobile node. A binding defines an association between a mobile node's home address and its registered care-of address. A mobile node, when it registers multiple bindings with its home agent, each using different care-of addresses, then each of those bindings are given a unique identifier. The Binding Identifier is unique within all the bindings for a given mobile node.

Flow Identifier (FID)

It is an identifier for a given IP flow, uniquely identified by source address, destination address, protocol type, source port and destination port. In the context of this document, the IP flows associated with a mobile node are the IP flows using its home address.

3. Solution Overview

The illustration below in Figure-1 is of a mobile node attached to the network over three different access technologies, Wi-Fi, LTE and CDMA. The mobile node is assigned an home address, HoA-1, and has configured the care-of addresses CoA-1 (Wi-Fi), CoA-2 (LTE) and CoA-3 (CDMA). The mobile node has registered the three care-of addresses with the home agent and has established Mobile IP tunnels, Tunnel-1, Tunnel-2 and Tunnel-3 over each of those access networks. The IP traffic using mobile node's home address (HoA-1) can be routed through any of the three tunnel paths. The mobile node's IP flows, Flow-1, Flow-2 and Flow-3 are routed between the home agent and the mobile node over these different Mobile IP tunnels based on the negotiated flow policy.

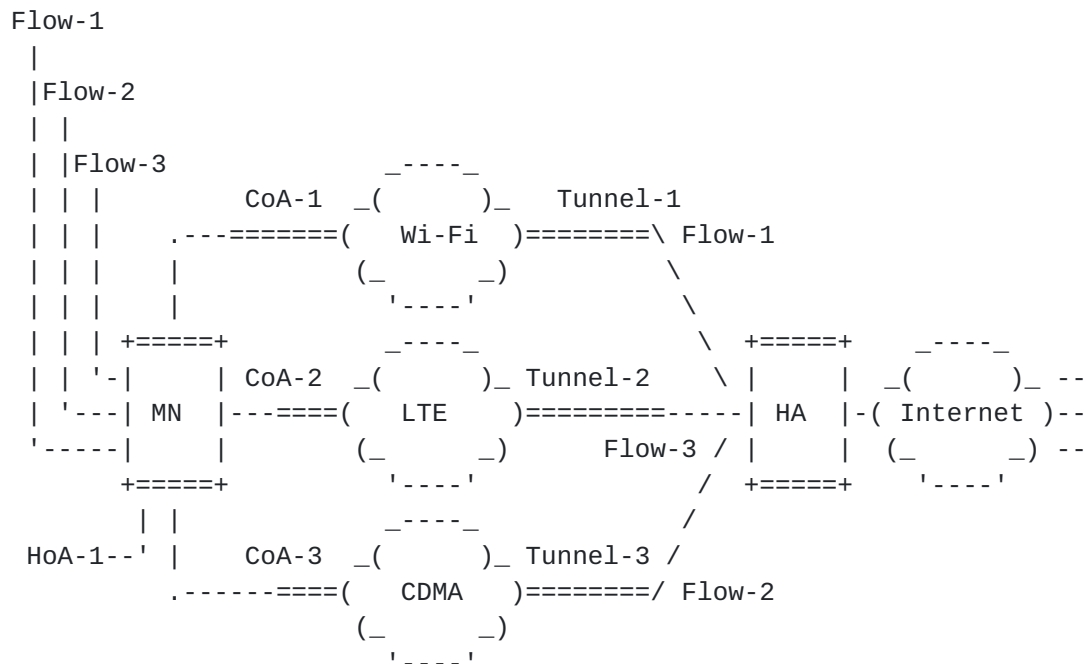


Figure 1: Mobile Node with multiple tunnels to the home agent

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

Flow Id	CoA/Tunnel/BID	Negotiated Flow Policy
1.	CoA-1/Tunnel-1/BID-1	All SIP Flows over WiFi
2.	CoA-2/Tunnel-2/BID-2	All HTTP Flows over LTE
3.	CoA-3/Tunnel-3/BID-3	All SSH Flows over CDMA

Table 1: Example - Flow Binding Table

3.1. Example Call Flow

Figure 2 shows a scenario where a mobile node is attached two WLAN and LTE access networks negotiates multipath support with the home agent. Furthermore, the mobile node and the home agent also negotiate the flow policies which bind specific application traffic to specific access networks.

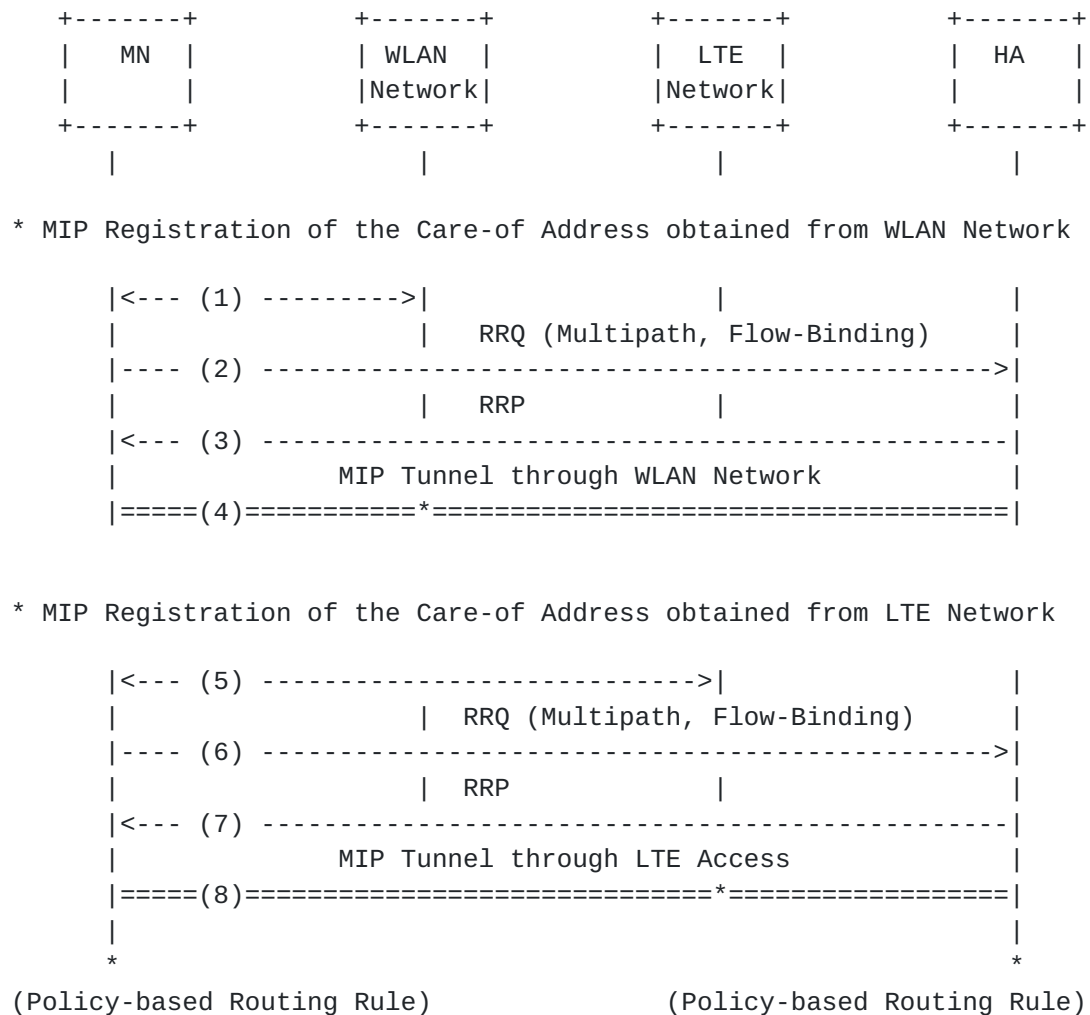


Figure 2: Multipath Negotiation - Call Flow

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-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 addresses that is being registered is bound.

This extension is a non-skippable extension and MAY be added by the

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 generating forwarding policies. For example, the operator may have policy which binds traffic for Application "X" needs to interface with Label "Y". When a registration through an interface matching Label "Y" gets activated, the home agent and the mobile node can dynamically generate a forwarding policy for forwarding traffic for Application "X" through mobile IP tunnel matching Label "Y". Both the home agent and the mobile node can route the Application-X traffic through that interface. 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, to which this request can be associated. 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. The mobile node assigns a unique value for each of its interfaces and includes them in the message.

Bulk Re-registration Flag (B)

This flag, if set to a value of (1), is to notify the home agent to consider this request as a request to update the binding lifetime of all the mobile node's bindings, upon accepting this specific request. This 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)

This 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 this binding. This 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 14-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. There MUST NOT be more than one instance of this extension present in the message. This extension MUST NOT be added by the foreign agent either to the Registration Request or to the Registration Reply.

This extension should be protected by Mobile-Home Authentication extension [RFC5944]. As specified in Section 3.2 and Section 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].

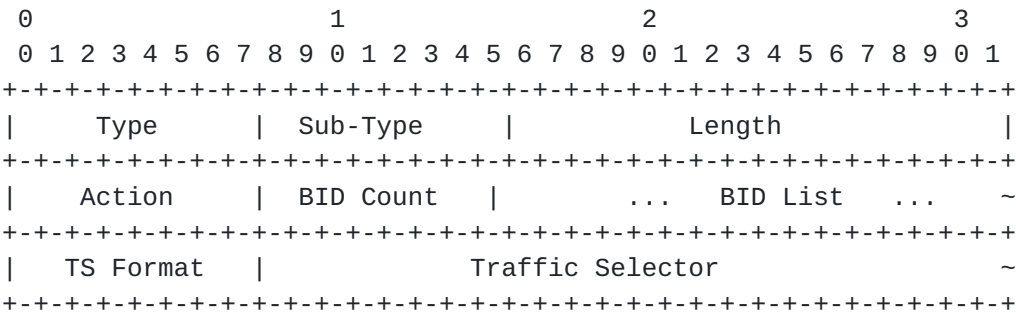


Figure 4: Flow-Binding Extension

Type

Type: <IANA-2>

Sub-Type

This field MUST be set to a value of 1 (Flow-Binding Extension).

Length

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

Action

Action	Value	Comments
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 1st BID in the list of BIDs the filter rule is pointing to. If the 1st BID becomes invalid (i.e., the corresponding CoA is deregistered) use the next BID in the list.

Table 2: Action Rules for the Traffic Selector

BID Count

Total number of binding identifiers that follow this field. Permitted value 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 Format. Value (0) is reserved and MUST NOT be used. When the value of 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 TS Format field is set to (2),

the format that follows is the IPv6 Binary Traffic Selector specified in [section 3.2 of \[RFC6088\]](#).

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 mobility session): <IANA-3>

INVALID_FB_IDENTIFIER (Invalid Flow Binding Identifier): <IANA-4>

5. Protocol Operation

5.1. Mobile Node Considerations

The configuration variable, EnableMultipathSupport, determines if multipath support is enabled or disabled on the mobile node. If multipath support is not enabled, then this specification does not apply. If multipath support is enabled on a mobile node, then the following considerations apply.

- o The mobile node should register a care-of address for each of the active egress 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.
- o Each of the Registration Requests that is sent MUST include 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 MUST be the address of the foreign agent.
- o A Multipath extension [Section 4.1](#) reflecting the interface parameters MUST be 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 MUST register this care-of address as one of the many

care-of addresses through which the mobile node's home address is reachable. The mobile node MUST place this Extension before the Mobile-Home Authentication Extension in the Registration Request message.

- o 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 MUST NOT be present in the message.
- o The mobile node on 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 mobility session and hence multipath support must be disabled on the mobile node.
- o The mobile node on receiving a Registration Reply with the code value set to INVALID_FB_IDENTIFIER, MUST re-register that specific binding for with the home agent.
- o 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 consider this request as a request to update the registration lifetime of all the mobile node's registrations.
- o The mobile node at any time can 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 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) 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.

- o The mobile node at any time can update the parameters of a specific registration by sending a Registration Request to the home agent. This includes 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 set to a value of (1).
- o The mobile node on receiving a Registration Reply with the code value set to 0 (registration accepted), MUST establish a mobile IP tunnel to the home agent using that care-of address. 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 receipt of a Registration Request with the Multipath extension from a mobile node, should check the configuration variable, EnableMultipathSupport. If the value of this variable is set to 0, the home agent MUST reject the request with a registration reply and with the code set to MULTIPATH_NOT_ALLOWED.

The home agent upon receipt of a Registration Request with the Multipath extension and with the Bulk Re-registration (B) flag in the request set to a value of (1), the home agent upon accepting the request MUST extend the lifetime of all the mobile node's bindings.

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.

The home agent upon receipt of a Registration Request with the Multipath extension and if the (O) flag in the request set to a value of 1, the home agent upon accepting the request 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 is enabled for a mobility session, there are potentially multiple mobile IP tunnels established between a mobile node and its home agent. These Mobile IP tunnels appear to the forwarding plane as equal-cost, point-to-point links.

If there is also an exchange of 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 is 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. These load balancing schemes allow the forwarding plane to evenly distribute traffic based on the criteria of either a per-packet or on a 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 affectively, but with the potential issue of packet re-ordering on the receiver end. A host can choose to enable any of these approaches. Therefore, this specification recommends the use of per-flow load balancing.

7. Protocol Configuration Variables

The following protocol configuration variables are required for system management and these variables **MUST** be configurable on all the mobility entities. The configured values for these protocol variables **MUST** survive service restarts.

EnableMultipathSupport

This flag indicates whether or not the mobility entity on which this protocol variable is configured needs to enable Multipath support feature. This protocol variable is applicable to both the home agent and the mobile node.

The default value for this flag is set to value of (1), indicating that the multipath support is enabled.

When the value for this flag is set to value of (0), multipath support is disabled.

8. IANA Considerations

This document requires the following IANA actions.

- o Action-1: This specification defines a new Mobile IP extension, Multipath extension. It is a non-skippable extension to the Mobile IPv4 header in accordance to the short extension format of [RFC5944]. The format of this option is described in [Section 4.1](#). The type value <IANA-1> for this extension needs to be allocated from the registry, "Extensions to Mobile IP Registration Messages", at < <http://www.iana.org/assignments/mobileip-numbers/mobileip-numbers.xhtml>>. RFC Editor: Please replace <IANA-1> in [Section 4.1](#) with the assigned value and update this section accordingly.
- o Action-2: This specification defines a new Mobile IP extension, Flow-Binding extension. It is a non-skippable extension to the Mobile IPv4 header in accordance to the long extension format of [RFC5944]. The format of this option is described in [Section 4.2](#). The type value <IANA-2> for this extension needs to be allocated from the registry, "Extensions to Mobile IP Registration Messages", at < <http://www.iana.org/assignments/mobileip-numbers/mobileip-numbers.xhtml>>. RFC Editor: Please replace <IANA-2> in [Section 4.2](#) with the assigned value and update this section accordingly.
- o Action-3: This document defines new status code value, MULTIPATH_NOT_ALLOWED (<IANA-3>), INVALID_FB_IDENTIFIER (<IANA-4>) for use by the home agent in the Code field of the Registration Reply, as described in [Section 4.3](#). This value needs to be assigned from the "Registration denied by the home agent" registry at <<http://www.iana.org/assignments/mobility-parameters>>. The allocated value has to be greater than 127. RFC Editor: Please replace <IANA-3> in [Section 4.3](#) with the assigned value and update this section accordingly.

9. 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, 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 Mobile IP Protocol, and does not introduce any new security vulnerabilities.

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12. References

12.1. Normative References

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[RFC 3753](#), June 2004.

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