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Generic Notification Message for Mobile IPv4

Abstract

This document specifies protocol enhancements that allow Mobile IPv4 entities to send and receive explicit notification messages using a Mobile IPv4 message type designed for this purpose.

Status of This Memo

This is an Internet Standards Track document.

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). Further information on Internet Standards is available in 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/rfc6098.

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1. Introduction

In some situations, there is a need for Mobile IPv4 entities, such as the home agent (HA), foreign agent (FA) and mobile node (MN) to send and receive asynchronous notification messages during a mobility session. In this context, 'Asynchronous messages' is used to mean messages that are not synchronous with the Registration Request and Registration Reply messages of the base Mobile IP (MIP) specification [RFC5944]. The base Mobile IP specification does not have a provision for this.

In order to rectify that, this document defines a generic notification message and a notification model that can be used by Mobile IPv4 entities to send various notifications. It also defines a corresponding acknowledgement message to make it possible to ensure reliable delivery of notifications. Only the following extensions may be present in these new messages, as defined by this document:

- MN-HA Authentication Extension

- MN-FA Authentication Extension

- FA-HA Authentication Extension

- Message String Extension

The semantics of receiving a generic notification message with a Message String Extension are null; i.e., it has no effect on the state of a mobile node's existing registration. See Section 3.1 for some application examples that motivate the new messages defined in this document.

2. Terminology

It is assumed that the reader is familiar with the terminology used in [RFC4917] and [RFC5944]. In addition, this document frequently uses the following terms:

Notification Message

A message from a mobility agent to a an MN or other mobility agent, or from an MN to a mobility agent, to asynchronously notify it about an event that is relevant to the mobility service it is currently providing.

Generic Notification Message

A Notification Message in the context of Mobile IPv4 with a well-defined envelope format and extensibility, and with certain limitations on how extensions may be defined and used, but otherwise generally available for notification purposes within the Mobile IPv4 protocol. Abbreviated 'GNM' in this document.

Generic Notification Acknowledgement Message

An acknowledgement of a received Generic Notification Message. Abbreviated 'GNAM' in this document.

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].

3. Notification Message - Usage Scenarios

3.1. Notification Message - Examples

The simplest usage scenario for a notification message is one where the notification has no semantic meaning within the protocol; it is only carrying a message that can be displayed to a user or an operator (depending on which is the receiving entity -- see more on this below, in Section 3.2). Examples of such usage are messages from operator to user about billing- or service-related events ("You have used nearly all of your prepaid quota; there are only XX MB left -- please purchase further service if you are going to need it."; or

"You have now used data transfer services for the amount of $XXX since your last bill; this is above the notification threshold for your account.") or messages about service interruptions, and more. These examples are all supported by the use of the Mobile IPv4 Generic Notification Message together with the Message String Extension, as defined in this document.

There are also other examples, which cannot be implemented solely using the messages and extensions defined in this document. Some of these are described briefly below, and covered slightly more extensively in Section 5.

One example of an application of an extended Generic Notification Message is that during handover between CDMA 2000 1x EV-DO and Wireless LAN, the PPP resource on the CDMA side has to be removed on the FA (Packet Data Serving Node) to avoid over-charging subscribers. To address this, the Registration Revocation Message was defined in [RFC3543], but it would have been preferable to have had it defined as a separate message (i.e., the Generic Notification Message) with a Registration Revocation extension.

Other applications are:

- HA switch-over (before the HA decides to go off-line, it would like to notify the MNs to register with another candidate HA),
- Network Mobility (NEMO) prefix changes (an MN is notified by the HA about NEMO prefix changes and service- or billing-related events; this is an operational requirement),
- load balancing (the HA wants to move some of the registered MNs to other HAs),
- service termination (due to end of prepaid time), and
- service interruption (due to system maintenance).

3.2. Notification Message - Topology

There are several scenarios where a mobility agent could initiate notification events. Some of these are described in the following sections.

3.2.1. Notification Message between a Home Agent and a Mobile Node

3.2.1.1. Mobile Registered Using a Foreign Agent Care-of Address

In this case, the HA cannot directly notify the MN, but must send the notification via the FA, and vice versa.

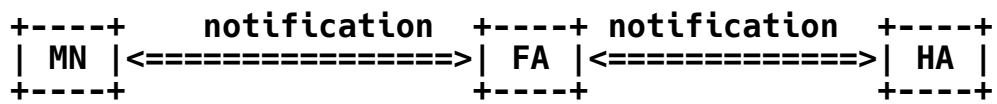


Figure 1: HA notifies MN or MN notifies HA through FA

3.2.1.2. Mobile Registered Using a Co-Located Care-of Address

In this case, the MN has registered with the home agent directly, so the notification message can go directly to the MN.

The notification mechanism as specified here does not support the case of co-located Care-of Address (CoA) mode with registration through an FA (due to the 'R' bit being set in the FA's advertisement messages).

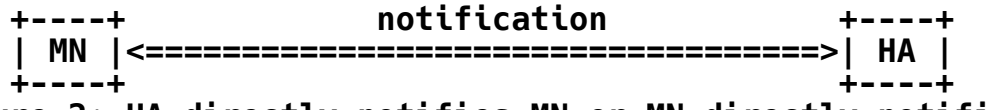


Figure 2: HA directly notifies MN or MN directly notifies HA

3.2.2. Notification Message between a Foreign Agent and a Mobile Node

There are two cases where an FA may send notification messages to an MN -- one where it is relaying a message, the other where the notification is triggered by a message from another network entity, for example, an Authentication, Authorization, and Accounting (AAA) node. (Notification messages between a AAA entity and the FA could be based on RADIUS or Diameter, but this is out of scope for this document.) If the notification is initiated by an FA, the FA may also need to notify the HA about the event.

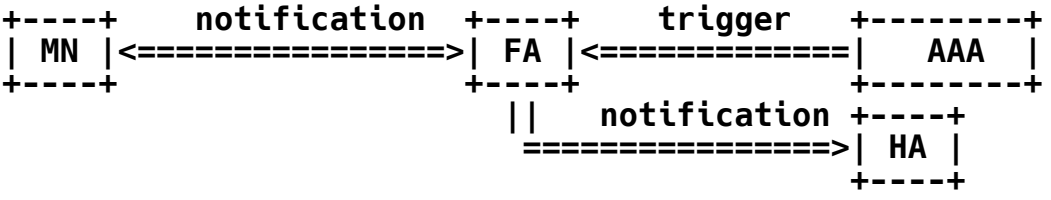


Figure 3: FA notifies MN

3.2.3. Notification Message between a Home Agent and a Foreign Agent

The HA may also need to send a notification to the FA, but not to the MN. The FA may also need to send a notification to the HA, as illustrated below:

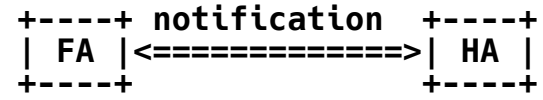


Figure 4: HA notifies FA or FA notifies HA

4. Generic Notification Message and Considerations

This section describes in detail the Generic Notification Message (GNM), Generic Notification Acknowledgement Message (GNAM), and some considerations related to the handling of these messages in the MN, FA, and HA.

The MN and HA MUST maintain the following information:

- the IP source address of the Registration Request/Reply
- the IP destination address of the Registration Request/Reply
- the UDP source port of the Registration Request/Reply
- the UDP destination port of the Registration Request/Reply

The sending node always sends the GNM following the same procedure for sending a Registration Request as in Section 3.3 of [RFC5944], and the receiving node follows the same procedure for Registration Reply as in Section 3.4 of [RFC5944] when sending GNAM.

4.1. Generic Notification Message

A GNM is sent by a mobility agent to inform another mobility agent, or an MN, of MIP-related information in the form of a Message String Extension [RFC4917]. These messages MUST use the same IP and UDP

headers as any previous Registration Request (RRQ) or Reply (RRP) message to the same entity. This would support NAT traversal and ensure the same security association used for GNM/GNAM and RRQ/RRP. The GNM is defined as follows:

IP Fields:

Source Address

Typically, copied from the destination address of the last Registration Reply/ Request message that the agent received from the agent to which it is sending the GNM.

Destination Address

Copied from the source address of the last Registration Reply/Request message that the agent received from the agent to which it is sending the GNM.

UDP Fields:

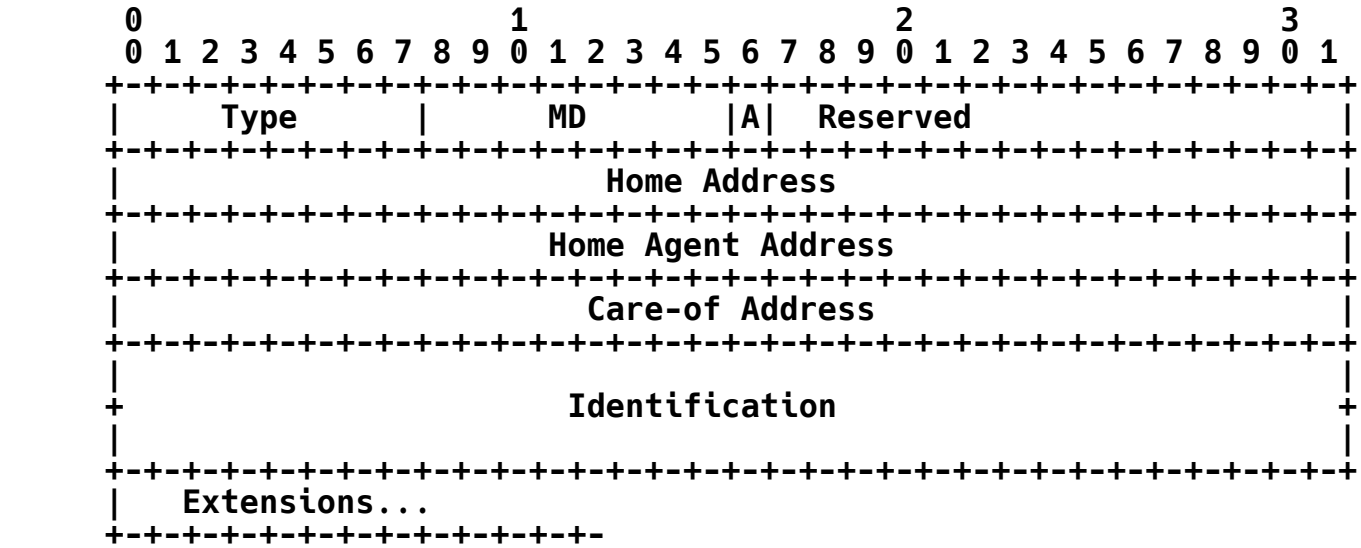
Source Port

Typically, copied from the destination port of the last Registration Reply/Request message that the agent received from the agent to which it is sending the GNM.

Destination Port

Copied from the source port of the last Registration Reply/Request message that the agent received from the agent to which it is sending the GNM.

The UDP header is followed by the Mobile IP fields shown below:



Type 22

MD: Message Direction

This memo defines the semantics of the following MD field value:

0 -- Message sent by the HA to the MN

1 -- Message sent by the HA to the FA

2 -- Message sent by the MN to the HA

3 -- Message sent by the MN to the FA

4 -- Message sent by the FA to the MN

5 -- Message sent by the FA to the HA

A

This bit indicates whether the notification message MUST be acknowledged by the recipient. If the "A" bit has been set during the message, but the sender doesn't receive any acknowledgement message, then the sender will have to re-send the notification message again.

Set to "1" to indicate that acknowledgement is REQUIRED.

Set to "0" to indicate that acknowledgement is OPTIONAL.

Reserved

MUST be sent as 0, and ignored when received.

Home Address

The home address of the mobile node.

Home Agent Address

The IP address of the mobile node's HA.

Care-of Address

The mobile node's care-of address, either the co-located care-of address or the foreign agent care-of address.

Identification

A 64-bit number, constructed by the sender, used for matching GNM with GNAM and for protecting against replay attacks of notification messages. See Sections 7.1.1 and 7.1.2 for more on the use of timestamps and nonces in this field. Support for the use of timestamps is REQUIRED, and support for nonces is OPTIONAL.

Extensions

The fixed portion of the GNM is followed by one or more extensions that may be used with this message, and by one or more authentication extensions as defined in Section 3.5 of [RFC5944].

Apart from the Authentication Extensions mentioned below, only one extension is defined in this document as permitted for use with the GNM: the Message String Extension defined in [RFC4917].

This document requires the MN-HA Authentication Extension (AE) to be used when this message is sent between the MN and the HA; MN-FA AE and FA-HA AE are OPTIONAL. This document also requires the use of the MN-FA AE when this message is sent between the MN and the FA, where the MN-HA AE and FA-HA AE are not needed. This document finally requires the use of the FA-HA AE when this message is sent between the FA and the HA, and the MN-HA AE and MN-FA AE are not needed. This could be determined based on the "MD" value. See Sections 3.6.1.3 and 3.8.3.3 of [RFC5944] for the rules on the order of these extensions as they appear in Mobile IPv4 RRQ and RRP messages. The same rules are applicable to GNM and GNAM.

4.2. Generic Notification Acknowledgement Message

A GNAM is sent by mobility agents or MNs to indicate the successful receipt of a GNM.

IP Fields:

Source Address

Typically, copied from the destination address of the GNM to which the agent is replying.

Destination Address

Copied from the source address of the GNM to which the agent is replying.

UDP Fields:

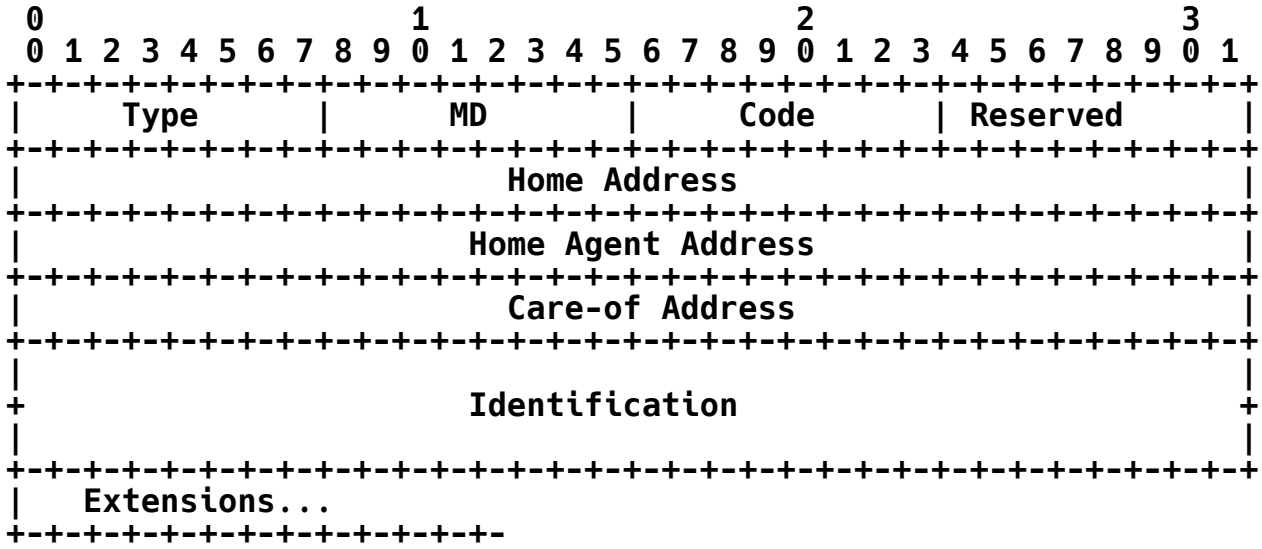
Source Port

Copied from the destination port of the corresponding GNM.

Destination Port

Copied from the source port of the corresponding GNM.

The UDP header is followed by the Mobile IP fields shown below:



Type 23

MD: Message Direction

This memo defines the semantics of the following MD field value:

0 -- Message sent by the HA to the MN

1 -- Message sent by the HA to the FA

2 -- Message sent by the MN to the HA

3 -- Message sent by the MN to the FA

4 -- Message sent by the FA to the MN

5 -- Message sent by the FA to the HA

Code

A value indicating the result of the GNM. See below for a list of currently defined Code values.

Notification successful

0 -- notification accepted

Notification denied by the HA

128 -- reason unspecified

129 -- administratively prohibited

130 -- insufficient resources

131 -- mobile node failed authentication

132 -- foreign agent failed authentication

133 -- notification Identification mismatch

Notification denied by the FA

64 -- reason unspecified

65 -- administratively prohibited

66 -- insufficient resources

67 -- mobile node failed authentication

68 -- home agent failed authentication

69 -- notification Identification mismatch

Notification denied by the mobile node

192 -- reason unspecified

193 -- administratively prohibited

194 -- insufficient resources

195 -- foreign agent failed authentication

196 -- home agent failed authentication

197 -- notification Identification mismatch

Home Address

The home address of the mobile node.

Home Agent Address

The IP address of the sender's home agent.

Care-of Address

The mobile node's care-of address, either the co-located care-of address or the foreign agent care-of address.

Identification

A 64-bit number used for matching the GNM with the GNAM and for protecting against replay attacks of notification messages. See Sections 7.1.1 and 7.1.2 for more on the use of timestamps and nonces in this field. Support for the use of timestamps is REQUIRED, and support for nonces is OPTIONAL. The value is based on the Identification field from the GNM from the sender, and on the style of replay protection used in the security context between the sender and its receiver (defined by the mobility security association between them, and the Security Parameter Index (SPI) value in the authorization-enabling extension).

Extensions

The fixed portion of the GNAM is followed by one or more extensions that may be used with this message, and by one or more authentication extensions as defined in Section 3.5 of [RFC5944].

This document REQUIRES the MN-HA Authentication Extension (AE) to be used when this message is sent between the MN and the HA; MN-FA AE and FA-HA AE are OPTIONAL. This document also requires the use of the MN-FA AE when this message is sent between the MN and the FA, where the MN-HA AE and FA-HA AE are not needed. This document finally requires the use of the FA-HA AE when this message is sent between the FA and the HA, and the MN-HA AE and MN-FA AE are not needed. This could be determined based on the "MD" value. See Sections 3.6.1.3 and 3.8.3.3 of [RFC5944] for the rules on the order of these extensions as they appear in Mobile IPv4 RRQ and RRP messages. The same rules are applicable to GNM and GNAM.

4.3. Notification Retransmission

If the "A" flag has been set during the GNM, but the sender doesn't receive any GNAM within a reasonable time, then the GNM SHOULD be retransmitted. When timestamps are used, a new notification Identification is chosen for each retransmission; thus, it counts as a new GNM. When nonces are used, the unanswered GNM is retransmitted unchanged; thus, the retransmission does not count as a new GNM (Section 7.1). In this way, a retransmission will not require the receiver to re-synchronize with the sender by issuing another nonce in the case in which the original GNM (rather than its GNAM) was lost by the network.

The maximum time until a new GNM is sent SHOULD be no greater than the requested Lifetime of the last GNM. The minimum value SHOULD be large enough to account for the size of the messages, twice the round-trip time for transmission to the receiver, and at least an additional 100 milliseconds to allow for processing the messages before responding. The round-trip time for transmission to the receiver will be at least as large as the time REQUIRED to transmit the messages at the link speed of the sender's current point of attachment. Some circuits add another 200 milliseconds of satellite delay in the total round-trip time to the receiver. The minimum time between GNMs MUST NOT be less than 1 second. Each successive retransmission timeout period SHOULD be at least twice the previous period, as long as that is less than the maximum as specified above.

4.4. General Implementation Considerations

Implementations of this specifications should provide support for management of the various settings related to the notification messages. In particular, it should be possible to do the following:

- List the notification messages supported.
- Show enabled/disabled status for notification message support, overall and in detail.
- Show the value of the maximum and minimum retransmission times.
- Enable and disable notification support entirely.
- Enable and disable the individual notification messages supported.
- Set the values of the maximum and minimum retransmission times described in Section 4.3.

4.5. Mobile Node Considerations

It is possible that the MN MAY receive a GNM from an FA or HA. Both in the case of FA-CoA and co-located CoA, the MN MAY reply with a GNAM based on the "A" flag in the GNM.

4.5.1. Receiving Generic Notification Messages

When the MN is using an FA-CoA and receives a notification message, if the "MD" value is 0, it means that the notification message came from the HA. If the "MD" value is 4, the notification came from the FA. If the MN is using a co-located CoA and receives a notification message, the "MD" value will be 0, indicating that the notification message came from the HA.

The MN MUST check for the presence of an authorization-enabling extension and perform the indicated authentication. Exactly one authorization-enabling extension MUST be present in the GNM.

If this message came from an FA, then an MN-FA AE MUST be present. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, then the MN MUST reject the GNM and MAY send a GNAM to the FA with Code 195, including an Identification field computed in accordance with the rules specified in Section 7.1. The MN MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

If this notification message came from the HA, relayed by the FA, or if the MN is using a co-located CoA, then the MN-HA AE MUST be checked and the MN MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, then the MN MUST reject the GNM and MAY send a GNAM to the initiator with Code 196, including an Identification field computed in accordance with the rules specified in Section 7.1. The MN MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The MN MUST check that the Identification field is correct using the context selected by the SPI within a mandatory authentication extension like the MN-FA AE or MN-HA AE. See Section 7.1 for a description of how this is performed. If incorrect, the MN MUST reject the GNM and MAY send a GNAM to the initiator with Code 197, including an Identification field computed in accordance with the rules specified in Section 7.1. The MN MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The MN MUST also check that the extensions present in the Generic Notification Message are permitted for use with the GNM. If not, the MN MUST silently discard the message. It MUST NOT do any further processing with such a notification, though it SHOULD log the error.

If the MN accepts a GNM, then it will process it according to the specific rules for the extensions. After that, the MN MAY reply to the originator with a GNAM with Code 0 based on the "A" flag in the GNM.

4.5.2. Sending Generic Notification Acknowledgement Messages

Both in the case of a co-located CoA and FA-CoA, the MN MAY reply with a GNAM based on the "A" flag in the GNM as follows:

If the GNM was initiated from the FA to the MN ("MD" value is set to 4), then the MN-FA AE MUST be the last extension in order to protect all other non-authentication extensions as defined in Section 3.5.3 of [RFC5944].

In the case of an FA-CoA, the source address is the MN's address, the destination address is the FA's address.

The Code field of the GNAM is chosen in accordance with the rules specified in Section 4.2. When replying to an accepted notification, an MN SHOULD respond with Code 0.

There are a number of reasons why the MN might reject a notification, such as for example not being permitted to receive notifications, which could be for a number of reasons, causing the return of a GNAM with Code value 193 (administratively prohibited); or being unable to act on or display the notification, or otherwise being resource constrained, causing the use of Code value 194 (insufficient resources); or other reasons for which no other specific Code value is available, which would cause the use of Code value 192 (reason unspecified).

If the GNM was initiated from the HA to the MN ("MD" value is set to 0) and in the case of a co-located CoA, then the MN-HA AE MUST be the last extension in order to protect all other non-authentication extensions as defined in Section 3.5.2 of [RFC5944].

When replying to a GNM from an HA to an MN with an FA-CoA, the source address is the MN's home address and the destination address is the FA's address ("MD" value is set to 2). The ordering of the extension is: any non-authentication Extensions intended for the HA, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944], followed by any non-authentication Extensions intended for the FA, followed by the MN-FA AE defined in Section 3.5.3 of [RFC5944].

4.5.3. Sending Generic Notification Messages

The MN may send a GNM to notify either the FA or HA.

If the message is sent to the FA, then the source address is the MN's address, and the destination address is the FA's address

If the FA is the target of this notification message, then the "MD" value is set to 3, and the MN-FA AE MUST be the last extension in order to protect all other non-authentication extensions. Computing the Authentication Extension Values is done in the same manner as in Section 3.5.1 of [RFC5944].

If the FA is working only as a relay agent, then the "MD" value is set to 2, and the ordering of the extension is: the notification extension, followed by any non-authentication extension expected to be used by HA, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944], followed by any non-authentication Extensions intended for the FA, followed by the MN-FA AE defined in Section 3.5.3 of [RFC5944]. Computing the Authentication Extension Values is done in the same manner as in Section 3.5.1 of [RFC5944].

In the case of a co-located CoA, the MN MAY send a notification message directly to the HA if it needs to be notified. The "MD" value is set to 2, and the ordering of the extension is: the

notification extension, followed by any non-authentication extension expected to be used by HA, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944].

The MN chooses the Identification field in accordance with the style of replay protection it uses with its HA. This is part of the mobility security association the MN shares with its HA. See Section 7.1 for the method by which the MN computes the Identification field.

4.5.4. Receiving Generic Notification Acknowledgement Messages

In the case of an FA-CoA, if the MN receives this message, and the "MD" value is set to 0, it means that the GNAM came from the HA.

If the "MD" value is set to 4, then the MN-FA AE MUST be checked, and the MN MUST check the Authenticator value in the Extension. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, then the MN MUST silently discard the GNAM.

In addition, the low-order 32 bits of the Identification field in the GNAM MUST be compared to the low-order 32 bits of the Identification field in the most recent GNM sent to the replying agent. If they do not match, then the GNAM MUST be silently discarded.

If the "MD" value is set to 0, then the MN-HA AE MUST be checked, and the MN MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, then the MN MUST silently discard the GNAM. If the MN accepted this message, then the MN MAY also process it based on the notification event.

In the case of a co-located CoA, if the MN received this message, then the MN-HA AE MUST be checked, and the MN MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, then the MN MUST silently discard the Notification Acknowledgement message.

4.6. Foreign Agent Consideration

The FA may initiate a GNM to the MN or the HA. Additionally, the FA also relays GNMs and GNAMs between the MN and its HA as long as there is an active binding for the MN at the FA.

4.6.1. Receiving Generic Notification Messages

If the FA receives a GNM, and the "MD" value is set to 0, then it means that the HA is asking the FA to relay the message to the MN. If the "MD" value is set to 1, then it means that the target of the notification is the FA. If the "MD" value is set to 2, then it means that the MN is asking the FA to relay the message to the HA. If the "MD" value is set to 3, then it means that the notification came from the MN to the FA.

If the "MD" value is set to 0, then the FA MAY validate the FA-HA AE if present. If the FA-HA AE is invalid, then all extensions between the HA-MN AE and the HA-FA AE MUST be removed, the FA SHOULD relay the GNM to the MN's home address as specified in the Home Address field of the GNM, and the MN will eventually validate the MN-HA AE to ensure that all information sent to the MN is integrity protected. If the FA-HA AE is valid, the FA MUST relay the GNM to the MN's home address as specified in the Home Address field of the GNM. The FA MUST NOT modify any of the fields beginning with the fixed portion of the GNM through the MN-HA AE or other authentication extension supplied by the HA as an authorization-enabling extension for the MN.

Furthermore, the FA MUST process and remove any extensions following the MN-HA AE. If the FA shares a mobility security association with the MN, the FA MAY append any of its own non-authentication extensions that are relevant to the MN. In this case, the FA MUST append the MN-FA AE after these non-authentication extensions.

If the "MD" value is set to 1, the FA-HA AE MUST be checked, and the FA MUST check the Authenticator value in the Extension. If no FA-HA AE is found, or if more than one FA-HA AE is found, or if the Authenticator is invalid, the FA MUST reject the GNM and MAY send a GNAM to the HA with Code 68, including an Identification field computed in accordance with the rules specified in Section 7.1. The FA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The FA MUST check that the Identification field is correct using the context selected by the SPI within the mandatory FA-HA AE. See Section 7.1 for a description of how this is performed. If incorrect, the FA MUST reject the GNM and MAY send a GNAM to the initiator with Code 69, including an Identification field computed in accordance with the rules specified in Section 7.1. The FA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The FA MUST also check that the extensions present in the Generic Notification Message are permitted for use with the GNM. If not, the FA MUST silently discard the message. It MUST NOT do any further processing with such a notification, though it SHOULD log the error.

If the FA accepts the HA's GNM, it will process it based on the specific rules for the extensions it contains. The FA MAY then reply to the HA with a GNAM with Code 0 based on the "A" flag in the GNM.

In the case of an FA-CoA and if the "MD" value is set to 2, if the FA received this message, and if the MN-FA AE is present, the MN-FA AE MUST be checked, and the FA MUST check the Authenticator value in the Extension. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, the FA MUST silently discard the GNM. If the MN-FA is valid, the FA MUST relay the GNM to the HA's address as specified in the Home Agent Address field of the GNM. The HA will eventually validate the MN-HA AE to ensure that all information sent to the HA is integrity protected. The FA MUST NOT modify any of the fields beginning with the fixed portion of the GNM through the MN-HA AE or other authentication extension supplied by the MN as an authorization-enabling extension for the HA.

Furthermore, the FA MUST process and remove any extensions following the MN-HA AE, and MAY append any of its own non-authentication extensions of relevance to the HA, if applicable. Also, it MUST append the FA-HA AE if the FA shares a mobility security association with the HA.

If the "MD" value is set to 3, the MN-FA AE MUST be checked, and the FA MUST check the Authenticator value in the Extension, as described in Section 3.7.2.1 of [RFC5944]. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, the FA MUST reject the GNM and MAY send a GNAM to the MN with Code 67, including an Identification field computed in accordance with the rules specified in Section 7.1. The FA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The FA MUST check that the Identification field is correct using the context selected by the SPI within mandatory MN-FA AE. See Section 7.1 for a description of how this is performed. If incorrect, the FA MUST reject the GNM and MAY send a GNAM to the initiator with Code 69, including an Identification field computed in accordance with the rules specified in Section 7.1. The FA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

If the FA accepts the MN's GNM, it will process it based on the specific rules for the extensions it contains. The FA MAY then reply to the MN with a GNAM with Code 0 based on the "A" flag in the GNM.

4.6.2. Sending Generic Notification Acknowledgement Messages

The FA may need either to relay a GNAM between the MN and the HA or to send one as a response to a GNM that was sent to it. In both cases, the GNAM is defined as follows.

The source address is the FA address, and the destination address is the HA's or MN's home address.

The Code field of the GNAM is chosen in accordance with the rules specified in Section 4.2. When replying to an accepted notification, an FA SHOULD respond with Code 0.

The FA might reject a notification by returning a GNAM with the Code value 65 (administratively prohibited), which could be for a number of reasons; 64 (reason unspecified); or 66 (insufficient resources).

If the FA is relaying this message to only the HA, the FA MUST NOT modify any of the fields beginning with the fixed portion of the GNAM up through and including the MN-HA AE or other authentication extension supplied by the MN as an authorization-enabling extension for the MN. Furthermore, the foreign agent MUST process and remove any extensions following the MN-HA AE. If the FA shares a mobility security association with the HA, the FA MAY append any of its own non-authentication extensions that are relevant to the HA. In this case, the FA MUST append the FA-HA AE after these non-authentication extensions.

If the notification message is from the HA to the FA, then the "MD" value is set to 5 and the ordering of the extension is: any non-authentication Extensions intended for the FA, followed by the FA-HA AE defined in Section 3.5.4 of [RFC5944].

If the notification message is from the MN to the FA, then the "MD" value is set to 4 and the ordering of the extension is: any non-authentication Extensions intended for the FA, followed by the MN-FA AE defined in Section 3.5.3 of [RFC5944].

4.6.3. Sending Generic Notification Messages

If the FA is initiating a notification to the MN using the GNM, it MAY also notify the HA.

In the message to the MN, the source address is the FA address, the destination address is the MN's address, the "MD" value is set to 4, and the ordering of the extension is: the notification extension, followed by any non-authentication extensions intended for the MN, followed by the MN-FA AE defined in Section 3.5.3 of [RFC5944]. Computing the Authentication Extension Values is done in the same manner as in Section 3.5.1 of [RFC5944] except the payload is the notification rather than the registration.

In the message to the HA, the source address is the FA's address, the destination address is the HA's address (the "MD" value is set to 5), and the ordering of the extension is: notification extension, followed by any non-authentication Extensions intended for the HA, followed by the FA-HA AE defined in Section 3.5.4 of [RFC5944]. Computing the Authentication Extension Value is done in the same manner as described in Section 3.5.1 of [RFC5944], except that the payload is the notification instead of the registration.

4.6.4. Receiving Generic Notification Acknowledgement Messages

In the case of an FA-CoA, if the FA receives this message, and the "MD" value is set to 2, it means that the notification acknowledgement message is from the MN to the HA; if the "MD" value is set to 3, the message is from the MN to the FA; otherwise, it came from the HA.

If the "MD" value is set to 1, the FA-HA AE MUST be checked, and the FA MUST check the Authenticator value in the Extension. If no FA-HA AE is found, or if more than one FA-HA AE is found, or if the Authenticator is invalid, the FA MUST silently discard the Notification Acknowledgement message. If the FA accepted this message, the FA MAY also process it based on the notification event.

If the "MD" value is set to 3, and if the MN-FA AE is present, the AE MUST be checked, and the FA MUST check the Authenticator value in the extension. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, the FA MUST silently discard the GNAM. If the FA accepted this message, the FA MAY also process it based on the notification event.

In the case of an FA-CoA and if the "MD" value is set to 2, if the FA received this message, and if the MN-FA AE is present, the MN-FA AE MUST be checked, and the FA MUST check the Authenticator value in the Extension. If no MN-FA AE is found, or if more than one MN-FA AE is found, or if the Authenticator is invalid, the FA MUST silently discard the GNAM. If the FA accepted the MN's GNAM, it MUST relay this message to the HA. The FA MUST NOT modify any of the fields beginning with the fixed portion of the GNAM up through and including

the MN-HA AE or other authentication extension supplied by the HA as an authorization-enabling extension for the MN. Furthermore, the FA MUST process and remove any extensions following the MN-HA AE and MAY append any of its own non-authentication extensions of relevance to the HA, if applicable. Also, it MUST append the FA-HA AE, if the FA shares a mobility security association with the HA.

4.7. Home Agent Consideration

The HA MAY initiate a GNM to both the mobile node and FA, and it also MAY receive a GNAM from both the FA and MN. The HA also MAY receive a GNM from the FA, but only when there is a binding for an MN. If the HA receives a GNM from an FA and there is no corresponding MN registration, the HA SHOULD drop the GNM.

4.7.1. Sending Generic Notification Messages

In the case of an FA-CoA, the HA may either send a GNM to notify the FA, or have the FA relay the GNM to the MN if the MN needs to be notified.

If the message is from the HA to the FA, the source address is the HA's address, and the destination address is the FA's address

If the FA is working only as a relay agent, the "MD" value is set to 0, and the ordering of the extension is: the notification extension, followed by any non-authentication extension expected to be used by MN, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944], followed by any non-authentication extensions intended for the FA, followed by the FA-HA AE defined in Section 3.5.4 of [RFC5944]. Computing the Authentication Extension Value is done in the same manner as in Section 3.5.1 of [RFC5944].

If the FA is the target of this notification message, then the "MD" value is set to 1, and the ordering of the extension is: the notification extension, followed by any non-authentication Extensions intended for the FA, followed by the FA-HA AE defined in Section 3.5.4 of [RFC5944]. Computing the Authentication Extension Values is done in the same manner as in Section 3.5.1 of [RFC5944].

In the case of a co-located CoA, the HA MAY send a notification message directly to the MN if it needs to be notified. The "MD" value is set to 0, and the ordering of the extension is: the notification extension, followed by any non-authentication extension expected to be used by the MN, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944].

4.7.2. Receiving Generic Notification Acknowledgement Messages

In the case of an FA-CoA, if the HA receives this message, and the "MD" value is set to 2, it means that the GNAM came from the MN.

If the "MD" value is set to 5, and the HA accepted this message, the HA MAY also process it based on the notification event. The FA-HA AE MUST be checked, and the HA MUST check the Authenticator value in the extension. If no FA-HA AE is found, or if more than one FA-HA AE is found, or if the Authenticator is invalid, the HA MUST silently discard the GNAM.

If the "MD" value is set to 2, in the case of an FA-CoA, and if the FA-HA AE is present, the FA-HA AE MUST be checked, and the HA MUST check the Authenticator value in the Extension. If more than one FA-HA AE is found, or if the Authenticator is invalid, the HA MUST silently discard the GNAM. No matter what, the MN-HA AE MUST be checked, and the HA MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, the HA MUST silently discard the GNAM. If the HA accepted this message, the HA MAY also process it based on the notification event.

If the "MD" value is set to 2, in the case of a co-located CoA, the MN-HA AE MUST be checked, and the HA MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, the HA MUST silently discard the GNAM. If the HA accepted this message, the HA MAY also process it based on the notification event.

4.7.3. Receiving Generic Notification Messages

The HA MAY receive a GNM sent from the FA. When the HA receives this message, if the "MD" value is set to 5, this message came from FA. The FA-HA AE MUST be checked, and the HA MUST check the Authenticator value in the extension. If no FA-HA AE is found, or if more than one FA-HA AE is found, or if the Authenticator is invalid, the HA MUST reject the GNM and MAY send a GNAM to the FA with Code 132, including an Identification field computed in accordance with the rules specified in Section 7.1. The HA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception.

The HA MUST check that the Identification field is correct using the context selected by the SPI within a mandatory authentication extension like MN-HA AE or FA-HA AE. See Section 7.1 for a description of how this is performed. If incorrect, the HA MUST reject the GNM and MAY send a GNAM to the initiator with Code 133,

including an Identification field computed in accordance with the rules specified in Section 7.1. The HA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception. If the HA accepts the FA's GNM, it will process it based on the notification extension. Furthermore, the HA MAY reply to the FA with a GNAM with Code 0 based on the "A" flag in the GNM.

If the "MD" value is set to 2, this message comes from the MN. In the case of FA-CoA, if FA-HA AE is present, it MUST be checked, and the HA MUST check the Authenticator value in the Extension. If more than one FA-HA AE Extension is found, or if the Authenticator is invalid, the HA MUST reject the GNM and MAY send a GNAM to the FA with Code 132, including an Identification field computed in accordance with the rules specified in Section 7.1. The HA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception. Also, the MN-HA AE MUST be checked, and the HA MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, the HA MUST reject the GNM and MAY send a GNAM to the MN with Code 131, including an Identification field computed in accordance with the rules specified in Section 7.1. The HA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception. If the HA accepts the MN's GNM, it will process it based on the notification extension. Furthermore, the HA MAY reply to the MN with a GNAM back with Code 0 based on the "A" flag in the GNM.

If the "MD" value is set to 2, in the case of a co-located CoA, the MN-HA AE MUST be checked, and the HA MUST check the Authenticator value in the Extension. If no MN-HA AE is found, or if more than one MN-HA AE is found, or if the Authenticator is invalid, the HA MUST reject the GNM and MAY send a GNAM to the MN with Code 131, including an Identification field computed in accordance with the rules specified in Section 7.1. The HA MUST do no further processing with such a notification, though it SHOULD log the error as a security exception. If the HA accepts the MN's GNM, it will process it based on the notification extension. Furthermore, the HA MAY reply to the MN with a GNAM with Code 0 based on the "A" flag in the GNM.

The HA MUST also check that the extensions present in the Generic Notification Message are permitted for use with the GNM. If not, the HA MUST silently discard the message. It MUST NOT do any further processing with such a notification, though it SHOULD log the error.

4.7.4. Sending Generic Notification Acknowledgement Messages

If the GNM came from the FA only, and if the "A" flag is set in the GNM, then the HA MUST send a GNAM. The message is as follows: The source address is the HA's address, the destination address is the FA's address, and the "MD" value is set to 1. The ordering of the extension is: any non-authentication Extensions intended for the FA, followed by the Foreign-Home Authentication extension defined in Section 3.5.4 of [RFC5944].

The Code field of the GNAM is chosen in accordance with the rules specified in Section 4.2. When replying to an accepted GNM, an MN SHOULD respond with Code 0.

If the GNM came from the MN, and if the "A" flag is set in the GNM, then the HA MUST send a GNAM. The message is as follows: The source address is the HA's address, the destination address is the FA's address, and the "MD" value is set to 0. The ordering of the extension is: any non-authentication extensions intended for the MN, followed by the MN-HA AE defined in Section 3.5.2 of [RFC5944], optionally followed by any non-authentication extensions intended for the FA, optionally followed by the MN-FA AE defined in Section 3.5.3 of [RFC5944].

5. Future Extensibility

This document defines the Generic Notification Message used with the Message String Extension [RFC4917].

However, it is possible to define new notification-related extensions for use with the Generic Notification Message, for cases where the notification is intended to have a semantic content and is intended for the HA, FA, or MN, rather than for the user.

5.1. Examples of Possible Extensions

One example of such usage, which would have been defined in this document if it hadn't already been defined as a separate message, is the Registration Revocation Message [RFC3543]. This is a message sent from the HA to the FA(s) or MN to notify the receiving node that a currently active registration is being revoked. The use case for this is clearly laid out in [RFC3543].

Another example would be managed maintenance switch-over between HA instances, where an HA due to go down for maintenance could direct the MNs registered with it to re-register with another specified HA.

Such a message could also be used for managed load balancing. There is currently no support for such forced switch-over in the Mobile IPv4 protocol.

Yet another example is when the prefix set handled by an MIPv4 NEMO [RFC5177] HA changes; to ensure proper routing, the mobile router needs to be notified about the change so that its internal routing rules may be updated.

One final example is home network changes that require host configuration changes, for instance, a change of address for the DNS server or another network server. Again, this is a case where the HA would want to notify the MN of the change, so that service interruptions can be avoided.

5.2. Extension Specification

In order to avoid making the MIPv4 Generic Notification Message a generic protocol extension mechanism by which new protocol mechanisms could be implemented without appropriate discussion and approval, any new extensions that are to be used with the Generic Notification Message must be registered with IANA, where registration is limited by the 'RFC Required' policy defined in [RFC5226].

If additional extensions are specified for use with the Generic Notification Message, the practice exemplified in [RFC5944] and related specifications should be followed. Generally, it has not been necessary so far to provide versioning support within individual extensions; in a few cases, it has been necessary to define new extensions with new extension numbers where a generalization of a pre-existing extension has been needed. With the current rate of extension number consumption, that seems to be an acceptable approach.

If at some point extensions are specified for use with the Generic Notification Message that overlap with pre-existing notification messages, the authors of the specification should consider providing a method to flag which notification messages are supported, and which notification message usage is requested, in a manner similar to the way tunneling method capabilities and usage requests are flagged in the Mobile IPv4 base specification [RFC5944].

Encoded in the extension number of Mobile IPv4 extensions is the notion of 'skippable' and 'not skippable' extensions; see Section 1.8 of [RFC5944]. This notion is also applicable when extensions are used with the Generic Notification Message: It is not required that a receiver understand a skippable extension, but a non-skippable extension needs to be handled according to Section 1.8 of [RFC5944]

(i.e., the message must be silently discarded if the extension is not recognized). This document does not specify any change from the Mobile IPv4 base specification [RFC5944] in this respect.

6. IANA Considerations

This document defines two new messages, the Generic Notification Message described in Section 4.1, and the Generic Notification Acknowledgement Message described in Section 4.2. The message numbers for these two messages have been allocated from the same number space used by the Registration Request and Registration Reply messages in [RFC5944].

The Generic Notification Message may only carry extensions that are explicitly permitted for use with this message. Section 4.1 of this document defines 4 extensions that are permitted. IANA has added a column to the registry of Mobile IPv4 extensions, which will indicate for each extension if it is permitted for use with the Generic Notification Message. Approval of new extensions that are permitted for use with the Generic Notification Message requires that they be defined in an RFC according to the 'RFC Required' policy described in [RFC5226].

The Generic Notification Acknowledgement Message, specified in Section 4.2, has a Code field. The number space for the Code field values is new and also specified in Section 4.2. The Code number space is structured according to whether the notification was successful, the HA denied the notification, the FA denied the notification, or the MN denied the notification, as follows:

0	Success Code
64-69	Error Codes from the FA
128-133	Error Codes from the HA
192-197	Error Codes from the MN

Approval of new Code values requires expert review.

7. Security Considerations

This specification operates with the security constraints and requirements of [RFC5944]. This means that when this message is transmitted between the MN and the HA, the MN-HA AE is REQUIRED; when this message is transmitted between the MN and the FA, the MN-FA AE is REQUIRED; when this message is transmitted between the FA and the HA, the FA-HA AE is REQUIRED. It extends the operations of the MN, HA, and FA defined in [RFC5944] to notify each other about some events. The GNM defined in this specification could carry

information that modifies the mobility bindings. Therefore, the message MUST be integrity protected. Replay protection MUST also be guaranteed.

RFC 5944 provides replay protection only for Registration Requests sent by the MN. There is no mechanism for replay protection for messages initiated by an FA or HA. The 64-bit Identification field specified in this document (Sections 4.1 and 4.2) for the GNM is used to provide replay protection for the notification messages initiated by the FA or HA.

7.1. Replay Protection for GNMs and GNAMs

The Identification field is used to let the receiving node verify that a GNM has been freshly generated by the sending node, not replayed by an attacker from some previous notification. Two methods are described in this section: timestamps (REQUIRED) and "nonces" (OPTIONAL). All senders and receivers MUST implement timestamp-based replay protection. These nodes MAY also implement nonce-based replay protection

The style of replay protection in effect between any two peer nodes among the MN, FA, and HA is part of the mobile security association. A sending node and its receiving node MUST agree on which method of replay protection will be used. The interpretation of the Identification field depends on the method of replay protection as described in the subsequent subsections.

Whatever method is used, the low-order 32 bits of the Identification field MUST be copied unchanged from the GNM to the GNAM. The receiver uses those bits (and the sender's source address) to match the GNAM with corresponding replies. The receiver MUST verify that the low-order 32 bits of any GNAM Identification field are identical to the bits it sent in the GNM.

The Identification in a new GNM MUST NOT be the same as in an immediately preceding GNM, and SHOULD NOT repeat while the same security context is being used between the MN and the HA.

7.1.1. Replay Protection Using Timestamps

The basic principle of timestamp replay protection is that the node generating a message inserts the current time of day, and the node receiving the message checks that this timestamp is sufficiently close to its own time of day. Unless specified differently in the security association between the nodes, a default value of 7 seconds MAY be used to limit the time difference. This value SHOULD be greater than 3 seconds. Obviously, the two nodes must have

adequately synchronized time-of-day clocks. As with any messages, time synchronization messages may be protected against tampering by an authentication mechanism determined by the security context between the two nodes.

In this document, the timestamps are used, and the sender MUST set the Identification field to a 64-bit value formatted as specified by the Network Time Protocol (NTP) [RFC5905]. The low-order 32 bits of the NTP format represent fractional seconds. Note, however, that when using timestamps, the 64-bit Identification used in a GNM from the sender MUST be greater than that used in any previous GNM, as the receiver uses this field also as a sequence number. Without such a sequence number, it would be possible for a delayed duplicate of an earlier GNM to arrive at the receiver (within the clock synchronization required by the receiver), and thus be applied out of order, mistakenly altering the sender's current status.

Upon receipt of a GNM with an authorization-enabling extension, the receiver MUST check the Identification field for validity. In order to be valid, the timestamp contained in the Identification field MUST be close enough to the receiver's time-of-day clock and the timestamp MUST be greater than all previously accepted timestamps for the requesting sender. Time tolerances and re-synchronization details are specific to a particular mobility security association.

If the timestamp is valid, the receiver copies the entire Identification field into the GNAM, and it returns the GNAM to the sender. If the timestamp is not valid, the receiver copies only the low-order 32 bits into the GNAM, and supplies the high-order 32 bits from its own time of day. In this latter case, the receiver MUST reject the notification by returning Code 69, 133, or 197 (notification Identification mismatch) in the GNAM.

Furthermore, the receiver MUST verify that the low-order 32 bits of the Identification in the GNAM are identical to those in the rejected GNM attempt, before using the high-order bits for clock re-synchronization.

7.1.2. Replay Protection Using Nonces

The basic principle of nonce replay protection is that node A includes a new random number in every message to node B, and checks that node B returns that same number in its next message to node A. Both messages use an authentication code to protect against alteration by an attacker. At the same time, node B can send its own nonces in all messages to node A (to be echoed by node A), so that it too can verify that it is receiving fresh messages.

The receiver may be expected to have resources for computing pseudo-random numbers useful as nonces, according to [RFC4086]. It inserts a new nonce as the high-order 32 bits of the Identification field of every GNAM. The receiver copies the low-order 32 bits of the Identification field from the GNM into the low-order 32 bits of the Identification field in the GNAM. When the sender receives an authenticated GNAM from the receiver, it saves the high-order 32 bits of the Identification field for use as the high-order 32 bits of its next GNM.

The sender is responsible for generating the low-order 32 bits of the Identification field in each GNM. Ideally, it should generate its own random nonces. However, it may use any expedient method, including duplication of the random value sent by the receiver. The method chosen is of concern only to the sender because it is the node that checks for valid values in the GNAM. The high-order and low-order 32 bits of the Identification chosen SHOULD both differ from their previous values. For each notification message, the receiver uses a new high-order value and the sender uses a new low-order value.

If a GNM is rejected because of an invalid nonce, the GNAM always provides the sender with a new nonce to be used in the next message. Thus, the nonce protocol is self-synchronizing.

7.2. Non-Authentication Extensions Handling in the Foreign Agent

When the FA is relaying a GNM between the MN and the HA, and if the FA does not share a mobility security association with the MN or HA, all non-authentication extensions between the MN and FA, or FA and HA, are not protected. In this case, all non-authentication extensions should be silently discarded.

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9. References

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