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Mobile IPv4 Regional Registration

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Abstract

Using Mobile IP, a mobile node registers with its home agent each time it changes care-of address. This document describes a new kind of "regional registrations", i.e., registrations local to the visited domain. The regional registrations are performed via a new network entity called a Gateway Foreign Agent (GFA) and introduce a layer of hierarchy in the visited domain. Regional registrations reduce the number of signaling messages to the home network, and reduce the signaling delay when a mobile node moves from one foreign agent to another within the same visited domain. This document is an optional extension to the Mobile IPv4 protocol.

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1. Introduction

This document is an optional extension to the Mobile IPv4 protocol, and proposes a means for mobile nodes to register locally within a visited domain. By registering locally, the number of signaling messages to the home network are kept to a minimum, and the signaling delay is reduced.

In Mobile IP, as specified in [RFC3344], a mobile node registers with its home agent each time it changes care-of address. If the distance between the visited network and the home network of the mobile node is large, the signaling delay for these registrations may be long. We propose a solution for performing registrations locally in the visited domain: regional registrations. Regional registrations minimize the number of signaling messages to the home network, and reduce the signaling delay when a mobile node moves from one foreign agent to another within the same visited domain. This will both decrease the load on the home network, and speed up the process of handover within the visited domain.

Regional registrations introduce a new network node: the Gateway Foreign Agent (GFA). The address of the GFA is advertised by the foreign agents in a visited domain. When a mobile node first arrives at this visited domain, it performs a home registration -- that is, a registration with its home agent. At this registration, the mobile node registers the address of the GFA as its care-of address with its home agent. When moving between different foreign agents within the same visited domain, the mobile node only needs to make a regional registration to the GFA.

In their simplest form, regional registrations are performed transparently to the home agent. Additionally, regional registrations may also allow dynamic assignment of GFA. The solution for dynamic GFA assignment requires support in the mobile node, the foreign agent, the GFA, and the home agent.

The proposed regional registration protocol supports one level of foreign agent hierarchy beneath the GFA, but the protocol may be utilized to support several levels of hierarchy. Multiple levels of hierarchy are not discussed in this document.

Although this document focuses on regional registrations in visited domains, regional registrations are also possible in the home domain.

Foreign agents that support regional registrations are also required to support registrations according to Mobile IPv4 [RFC3344].

The following section gives an overview of regional registrations.

2. Overview of Regional Registrations

In standard Mobile IP, there are three entities of interest. The Mobile Node (MN), the Foreign Agent (FA), and the Home Agent (HA). The MN communicates with the HA, either through an FA or directly (if it has a co-located care-of address). With Regional Registrations, a new entity is defined: the Gateway Foreign Agent (GFA). The GFA sits between the MN/FA and HA, and to the HA, it appears as if the MN's temporary care-of address is that of the GFA. When a MN moves within a site, it only need interact with the GFA, so that the GFA knows at what temporary address the MN is currently reachable.

Two types of registration messages are used. Regular [RFC3344] Registration Requests/Replies are still used for when the MN exchanges Registration Requests/Replies with the HA, but these messages get forwarded through a GFA, and include new extensions.

In addition, a new pair of registration messages, Regional Registration Requests/Replies, are used between MNs/FAs/GFAs for intra-site signaling. A MN uses these messages to communicate its new addresses to the GFA as it moves around within a site.

There are two models of how the MN uses Regional Registrations. The FA can advertise a GFA to the MN. Alternatively, the FA can indicate that dynamic assignment of GFA is to be used. With dynamic GFA assignment, the MN does not choose the GFA, rather the FA (or GFA) does so after receiving a Registration Request from the MN. However, in this mode the HA must understand (and support) Regional Registrations in order for them to be used. This last form is not transparent because the MN doesn't know in advance what GFA will be used, and cannot include it in a signed message to the HA.

When a MN moves to a new domain (determined by comparing its Network Access Identifier (NAI) [RFC4282] with the FA-NAI included in received Agent Advertisements), it can opt to use Regional Registrations. A site indicates support for Regional Registrations by setting the I-bit of the Mobile IP Agent Advertisement extension. In addition, such advertisements include a list of one or more care-of addresses. If there is only one care-of address, this is the address of the FA itself. In addition, the advertisement may include the address of the GFA. A GFA care-of address of all-ones indicates that dynamic assignment of GFA is supported.

A MN requests initial Regional Registration by sending a normal Registration Request to the FA, but setting the care-of address to that of the GFA (i.e., if it has selected it wishes to use this GFA) or all-zeros (which signals a dynamic GFA assignment request). The FA adds a Hierarchical FA (HFA) extension and relays the request to

the appropriate GFA. The HFA extension contains a single field: the IP address of the FA.

Note: the algorithm for MNs with co-located care-of addresses is similar, except that there is no FA, so the MN behaves as the FA in terms of the messages it sends.

A GFA receives Registration Requests relayed from an FA. If the care-of address in the received Registration Request is zero, the GFA assigns one. A GFA IP Address extension is then added to the Registration Request, and the message is forwarded to the HA. The GFA IP Address extension contains a single field: the IP address of the GFA. (A separate field is needed for this because the Registration Request message between the MN/HA is signed and cannot be modified.)

HAs process received Registration Requests in the same way as before, except in the case of dynamic GFA assignment. In this case, the HA uses the GFA address from the GFA IP Address extension as the MN's current care-of address. In addition, the Registration Reply message must include the GFA IP Address extension.

The regular Registration Requests/Replies are protected as described in [RFC3344], by use of the mobility security association between the MN and the HA. For regional registrations, it is assumed that a mobility security association is established between the MN and GFA during registration with the HA. Regional Registration Requests/ Replies are protected by use of this security association between the MN and the GFA, e.g., by use of a MN-GFA Authentication extension.

HFA extensions, added by an FA to a Registration Request or Regional Registration Request, are protected by an FA-FA Authentication extension. Security associations between FAs and GFAs within a domain are assumed to exist prior to regional registrations.

Dynamic GFA assignment requires means for securely sending Registration Requests from the GFA to the HA, in order to protect the GFA IP Address extension.

3. Terminology

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].

This document uses the following terms:

Critical type
A type value for an extension in the range 0-127, which indicates that the extension MUST either be known to the recipient, or that the message containing the extension MUST be rejected. In other words, an extension with a critical type value is non-skippable.

Domain
A collection of networks sharing a common network administration.

Foreign Agent (FA)
As defined in [RFC3344].

Gateway Foreign Agent (GFA)
A Foreign Agent which has a publicly routable IP address. A GFA may, for instance, be placed in or near a firewall.

Home Agent (HA)
As defined in [RFC3344].

Home domain
The domain where the home network and home agent are located.

Home network
As defined in [RFC3344].

Home Registration
A registration, processed by the home agent and the GFA, using the specification in [RFC3344] possibly with additional extensions defined in this document.

Local Care-of Address
A care-of address that is assigned to either a mobile node or a foreign agent offering local connectivity to a mobile node. A registration message from the mobile node is subsequently sent to a GFA via the local care-of address.

Mobile Node (MN)
As defined in [RFC3344].

Mobility Agent (MA)
As defined in [RFC3344].

Network Access Identifier(NAI)
Some features of this protocol specification rely on use of the Network Access Identifier (NAI) [RFC2794].

Regional Registration
A mobile node performs registration locally at the visited domain, by sending a Regional Registration Request to a GFA, and receiving a Regional Registration Reply in return.

Registration Key
A key used by mobile nodes and mobility agents to secure certain signals and control messages specified by Mobile IP.

Visited domain
The domain where the visited network, the current foreign agent, and the GFA are located.

Visited network
As defined in [RFC3344].

4. Description of the Protocol

This section provides an overview of the regional registration protocol.

4.1. General Assumptions

Our general model of operation is illustrated in Figure 1, showing a visited domain with FA and GFA, and a home network with a HA:

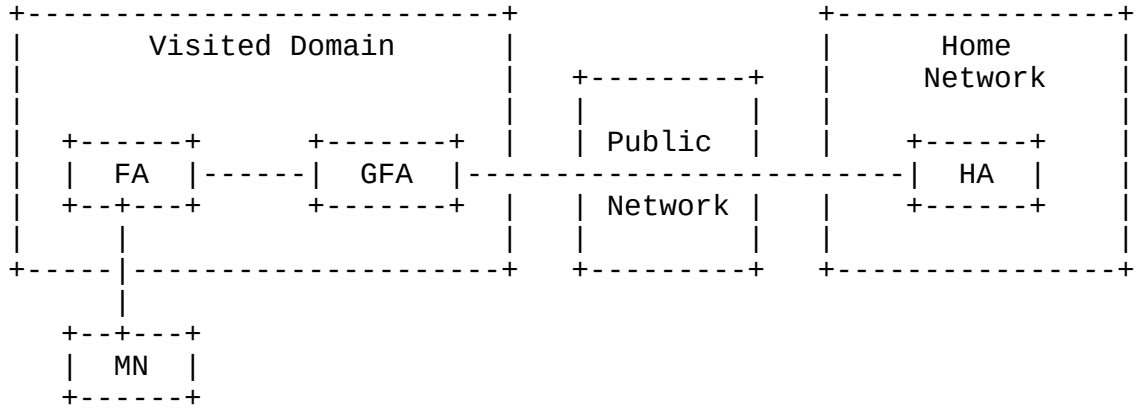


Figure 1: Model of Operation

For MNs that cannot process a NAI, or with mobility agents that are not configured to advertise their NAI, regional registration is still useful, but processing the NAI makes it easier for the mobile node to reliably detect domain changes.

4.1.1. Visited Domain

We assume two hierarchy levels of FAs in the visited domain. At the top level of the hierarchy, there is at least one GFA, which is an FA with additional features. A GFA must have a publicly routable address. Beneath a GFA, there are one or more FAs. We assume that there exist established security associations between a GFA and the FAs beneath it. When designing a domain supporting regional registrations, the FAs and GFAs in this domain must be compatible. That is, they should support the same encapsulation types, compression mechanisms, etc.

When a MN changes care-of address under the same GFA, it MAY perform a regional registration. If the MN changes GFA, within a visited domain or between visited domains, it MUST perform a home registration.

4.1.2. Authentication

With regional registrations, a GFA address is registered at the HA as the care-of address of the MN. If a Mobile-Foreign (MN-FA) Authentication extension is present in a Registration Request message directed to the HA, the GFA will perform the authentication. Similarly, if a Foreign-Home (FA-HA) Authentication extension is present in a Registration Request message, the authentication is performed between the GFA and the HA. To summarize, the GFA takes the role of an FA with regard to security associations in the home registrations.

Regional registration messages also need to be protected with authentication extensions in the same way as registrations with the HA. This means that the MN and the GFA MUST have received the keys needed to construct the authentication extensions before any regional registration is performed. As described above, since the GFA address is the registered care-of address of the MN at its home network, the GFA is the agent within the visited domain that has to have the appropriate security associations with the HA and the MN. The GFA’s security association with the MN is then used to enable proper authentication for regional registrations (see Section 6). How the keys are distributed is outside the scope of this draft. One example is to distribute the keys as part of the home registration, for example according to [RFC4004] and [RFC3957]. Another example is pre-configured keys.

4.2. Protocol Overview

When a MN first arrives at a visited domain, it performs a registration with its home network. During this registration, the HA registers the care-of address of the MN. In case the visited domain supports regional registrations, the care-of address that is registered at the HA is the address of a GFA. The GFA keeps a visitor list of all the MNs currently registered with it.

Since the care-of address registered at the HA is the GFA address, it will not change when the MN changes FA under the same GFA. Thus, the HA does not need to be informed of further MN movements within the visited domain.

Figure 2 illustrates the signaling message flow for home registration. During the home registration, the HA records the GFA address as the care-of address of the MN.

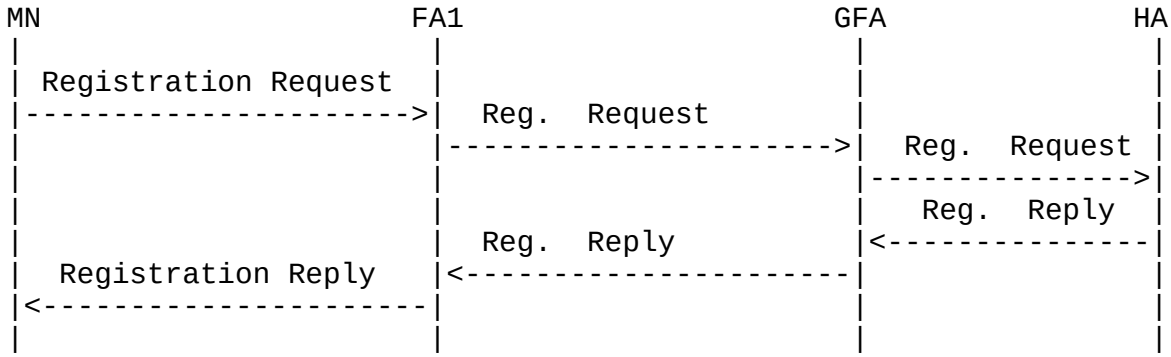


Figure 2: Home Registration

Figure 3 illustrates the signaling message flow for regional registration. Even though the MN's local care-of address changes, the HA continues to use the GFA address as the care-of address of the MN. We introduce two new message types for regional registrations: Regional Registration Request and Regional Registration Reply.

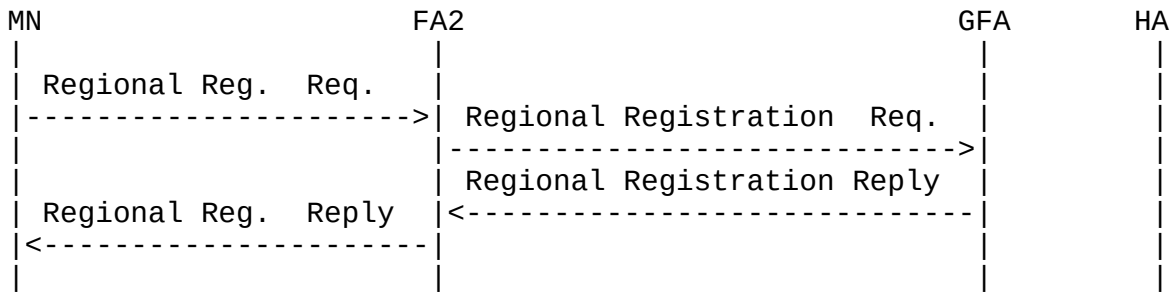


Figure 3: Regional Registration

4.3. Advertising Foreign Agent and GFA

A FA typically announces its presence via an Agent Advertisement message [RFC3344]. If the domain to which an FA belongs supports regional registrations, the following changes apply to the Agent Advertisement.

The 'I' flag (see Section 8.1) MUST be set to indicate that the domain supports regional registrations. If the 'I' flag is set, there MUST be at least one care-of address in the Agent Advertisement. If the 'I' flag is set and there is only one care-of address, it is the address of the FA. If the 'I' flag is set, and there is more than one care-of address, the first care-of address is the local FA, and the last care-of address is the GFA. (Any care-of addresses advertised in addition to these two are out of scope for this document).

The FA-NAI (see Section 8.2) SHOULD also be present in the Agent Advertisement to enable the MN to decide whether or not it has moved to a new domain since its last registration. The decision is based on whether the realm part of the advertised FA-NAI matches the realm of the FA-NAI advertised by the MN's previous FA.

4.4. Backwards Compatibility with RFC 3344

A domain that supports regional registrations should also be backwards compatible.

An FA MUST support registrations according to Mobile IPv4 as defined in [RFC3344]. This allows MNs that don't support regional registrations to register via this FA using standard Mobile IPv4. If the FA advertises both its own care-of address and a GFA care-of address, a MN that supports regional registrations but has a HA that doesn't, will still be able to make use of regional registrations through that GFA care-of address.

The advertised GFA care-of address MAY be set to all-ones, to indicate dynamic GFA assignment. If the MN supports regional registrations, and an all-ones GFA care-of address is advertised, the MN SHOULD use dynamic GFA assignment (see Section 7.1).

5. Home Registration

This section gives a detailed description of home registration, i.e., registration with the HA (on the home network). Home registration is performed when a MN first arrives at a visited domain, when it requests a new HA, or when it changes GFA. Home registration is also performed to renew bindings which would otherwise expire.

5.1. Mobile Node Considerations

Upon receipt of an Agent Advertisement message with the 'I' flag set and an FA-NAI extension, the MN compares the domain part of the FA NAI with the one received in the previous Agent Advertisement, to determine whether it has moved to a new domain since its last registration. If the NAIs do not match, the MN MUST assume it has moved to a new domain.

If the MN determines that it has moved to a new domain, it SHOULD insert the advertised GFA address in the care-of address field in the Registration Request message. For dynamic GFA assignment, see Section 7.1.

A MN with a co-located care-of address might also want to use regional registrations. It then finds out the address of a GFA, either from Agent Advertisements sent by an FA, or by some means not described in this document. The MN MAY then generate a Registration Request message, with the GFA address in the care-of address field, and send it directly to the GFA (not via an FA). In this case, the MN MUST add a Hierarchical Foreign Agent (HFA) extension (see Section 9.2), including its co-located care-of address, to the Registration Request before sending it. The HFA extension MUST be protected by an authentication extension. If the MN has established a mobility security association with the GFA, the HFA extension MUST be placed before the MN-FA Authentication extension, and it SHOULD be placed after the Mobile-Home (MN-HA) Authentication extension. Otherwise, if the MN has no established mobility security association with the GFA, the HFA extension MUST be placed before the MN-HA authentication extension.

If the MN receives an Agent Advertisement with the 'R' bit set, even if it has a co-located care-of address, it still formulates the same Registration Request message with extensions, but it sends the message to the advertising FA instead of to the GFA.

If the home registration is about to expire, the MN performs a new home registration using the same GFA care-of address to refresh the binding [RFC3344]. If the MN has just moved to a new FA and not yet sent a Regional Registration Request when the home registration is due to expire, the MN sends only a Registration Request, as this will update both the GFA and the HA.

If the Registration Reply includes a Replay Protection Style extension, the value in the Initial Identification field is the value to be used for replay protection in the next Regional Registration Request (see Section 6.1).

5.2. Foreign Agent Considerations

When the FA receives a Registration Request message from a MN, it extracts the care-of address field to find the GFA to which the message shall be relayed. All FAs that advertise the 'I' flag MUST also be able to handle Registration Requests with an all-zeros care-of address (used for dynamic GFA assignment).

If the FA receives a Registration Request where the care-of address is set to all-ones (which could happen if a MN that doesn't support Regional Registrations copied an all-ones care-of address from an Agent Advertisement), it MUST reply with the Code field set to "poorly formed request" [RFC3344].

If the Registration Request has the 'T' bit set, the MN is requesting Reverse Tunneling [RFC3024]. In this case, the FA has to tunnel packets from the MN to the GFA for further handling.

If the care-of address in the Registration Request is the address of the FA, the FA relays the message directly to the HA, as described in [RFC3344]. For each pending or current home registration, the FA maintains a visitor list entry as described in [RFC3344]. If reverse tunneling is being used, the visitor list MUST contain the address of the GFA, in addition to the fields required in [RFC3344].

Otherwise, if the care-of address in the Registration Request is the address of a GFA (or all-zeros), the FA adds a Hierarchical Foreign Agent (HFA) extension, including its own address, to the Registration Request, and relays it to the GFA. The HFA extension MUST be appended at the end of all previous extensions that were included in the Registration Request when the FA received it, and it MUST be protected by a Foreign-Foreign (FA-FA) Authentication extension (see Section 11).

5.3. GFA Considerations

For each pending or current home registration, the GFA maintains a visitor list entry as described in [RFC3344]. This visitor list entry is also updated for the regional registrations performed by the MN. In addition to the fields required in [RFC3344], the list entry MUST contain:

- the current care-of address of the MN (i.e., the FA or co-located address) received in the HFA extension
- the remaining Lifetime of the regional registration
- the style of replay protection in use for the regional registration
- the Identification value for the regional registration.

The default replay protection style for regional registrations is timestamp-based replay protection, as defined in Mobile IPv4 [RFC3344]. If the timestamp sent by the MN in the Registration Request is not close enough to the GFA's time-of-day clock, the GFA adds a Replay Protection Style extension (see Section 9.3) to the Registration Reply, with the GFA's time of day in the Identification field to synchronize the MN with the GFA for the regional registrations.

If nonce-based replay protection is used, the GFA adds a Replay Protection Style extension to the Registration Reply, where the high-order 32 bits in the Identification fields is the nonce that should be used by the MN in the following regional registration.

If the Registration Request contains a Replay Protection Style extension (see Section 9.3) requesting a style of replay protection not supported by the GFA, the GFA MUST reject the Registration Request and send a Registration Reply with the value in the Code field set to REPLAY_PROT_UNAVAIL (see Section 9.5).

If the Hierarchical Foreign Agent (HFA) extension comes after the MN-FA Authentication extension, the GFA MUST remove it from the Registration Request. The GFA then sends the Registration Request to the HA. Upon receipt of the Registration Reply, the GFA consults its pending registration record to find the care-of address within its domain that is currently used by the MN, and sends the Registration Reply to that care-of address.

If the Replay Protection Style extension (see Section 9.3) is present in a Registration Request, and follows the MN-HA Authentication extension, the GFA SHOULD remove the Replay Protection Style extension after performing any necessary processing and before sending the Registration Request to the HA.

If the GFA receives a Registration Request from a MN that it already has a mobility binding for, this is an update of a binding that is about to expire. If the address in the Hierarchical Foreign Agent (HFA) extension is the same as the current care-of address in the visitor list for the MN, the entries in the visitor list concerning regional registrations are not changed, except to update the lifetime. If the address in the HFA extension is a new address, the values for the regional registration are updated.

If the Registration Request has the 'T' bit set, the GFA has to decapsulate the packets from the FA and re-encapsulate them for further delivery back to the HA. These actions are required because the HA has to receive such packets from the expected care-of address (i.e., that of the GFA) instead of the local care-of address (i.e., that of the FA).

When receiving a Registration Reply from the HA, the GFA MAY add a Regional Registration Lifetime extension to the message before relaying it to the FA. The extension defines the lifetime that the GFA allows the MN before it has to renew its regional registration. The GFA MUST set the lifetime of the regional registration to be no greater than the remaining lifetime of the MN's registration with its HA. If used, the Regional Registration Lifetime extension MUST be added after any other extensions, and MUST be protected by an MN-FA Authentication extension.

5.4. Home Agent Considerations

The Registration Request is processed by the HA as described in [RFC3344].

6. Regional Registration

This section describes regional registrations. Once the HA has registered the GFA address as the care-of address of the MN, the MN may perform regional registrations. When performing regional registrations, the MN may either register an FA care-of address or a co-located address with the GFA. In the following, we assume that a home registration has already occurred, as described in Section 5, and that the GFA has a mobility security association with the MN.

Suppose the MN moves from one FA to another FA within the same visited domain. It will then receive an Agent Advertisement from the new FA. Suppose further that the Agent Advertisement indicates that the visited domain supports regional registrations, and either that the advertised GFA address is the same as the one the MN has registered as its care-of address during its last home registration, or that the realm part of the newly advertised FA-NAI matches the FA-

NAI advertised by the MN's previous FA. Then, the MN can perform a regional registration with this FA and GFA. The MN issues a Regional Registration Request to the GFA via the new FA. The request is authenticated using the existing mobility security association between the GFA and the MN and the message is authenticated by the MN-GFA Authentication extension (see Section 11). The care-of address should be set to the address of the local FA.

If the Regional Registration Request contains a care-of address field of all-zeros, the FA adds a Hierarchical Foreign Agent (HFA) extension to the message and relays it to the GFA. Based on the information in the HFA extension, the GFA updates the MN's current point of attachment in its visitor list. The GFA then issues a Regional Registration Reply to the MN via the FA.

If the advertised GFA is not the same as the one the MN has registered as its care-of address, and if the MN is still within the same domain as it was when it registered that care-of address, the MN MAY try to perform a regional registration with its registered GFA. If the FA cannot support regional registration to a GFA, other than advertised, the FA denies the Regional Registration Request with code UNKNOWN_GFA (see Section 10.3). In this case, the MN has to do a new home registration via the new GFA.

New message types are introduced for the Regional Registration Request and Reply. The motivation for introducing new message types, rather than using the Registration Request and Reply defined in [RFC3344] is: (1) the MN must be able to distinguish regional registrations from home registrations, since in the former case the timestamps/nonces are synchronized with its GFA and in the latter with its HA; and (2) a home registration MUST be directed to the home network before the lifetime of the GFA care-of address expires.

6.1. Mobile Node Considerations

For each pending or current home registration, the MN maintains the information described in [RFC3344]. The information is also updated for the regional registrations performed by the MN. In addition to the information described in [RFC3344], the MN MUST maintain the following information, if present:

- the GFA address
- the remaining Lifetime of the regional registration
- the style of replay protection in use for the regional registration
- the Identification value for the regional registration.

The replay protection for home registrations and regional registrations is performed as described in [RFC3344]. Since the MN performs regional registrations at the GFA in parallel with home registrations at the HA, the MN MUST be able to keep one replay protection mechanism and sequence for the GFA, and a separate mechanism and sequence for the HA.

For regional registrations, replay protection may also be provided at the FA by the challenge-response mechanism, as described in [RFC4721].

6.2. Foreign Agent Considerations

When the FA receives a Regional Registration Request from a MN, addressed to a GFA, it generally processes the message according to the rules of processing a Registration Request addressed to a HA (see Section 5.2). The only difference is that the GFA IP address field replaces the HA address field. If that address belongs to a known GFA, the FA forwards the request to the indicated GFA. Otherwise, the FA MUST generate a Regional Registration Reply with error code UNKNOWN_GFA.

For each pending or current registration, the FA maintains a visitor list entry as described in [RFC3344]. If reverse tunneling is being used, the visitor list MUST contain the address of the GFA, in addition to the fields required in [RFC3344]. This is required so that the FA can tunnel datagrams, sent by the MN, to the GFA. The GFA then decapsulates the datagrams, re-encapsulates them, and sends them to the HA.

6.3. GFA Considerations

If the GFA accepts a Regional Registration Request, it MUST set the lifetime of the regional registration to be no greater than the remaining lifetime of the MN’s registration with its HA, and put this lifetime into the corresponding Regional Registration Reply. The GFA MUST NOT accept a request for a regional registration if the lifetime of the MN’s registration with its HA has expired. In that case, the GFA sends a Regional Registration Reply with the value in the Code field set to NO_HOME_REG.

If the GFA receives a tunneled packet from an FA in its domain, then after decapsulation the GFA looks to see whether it has an entry in its visitor list for the source IP address of the inner IP header after decapsulation. If so, it checks the visitor list to see whether reverse tunneling has been requested; if it was requested, the GFA re-encapsulates the packet with its own address as the source IP address, and the address of the HA as the destination IP address.

7. Dynamic GFA Assignment

Regional registrations may also allow dynamic assignment of a GFA to a MN. The visited network (i.e., the FA) indicates support for dynamic GFA assignment by advertising an all-ones care-of address in the Agent Advertisement. The MN then sets the care-of address in the Registration Request to all-zeros to request a dynamically assigned GFA. Upon receiving this Registration Request, the FA relays it to the appropriate GFA, and the GFA assigns its address to the MN by means of a GFA IP Address extension added to the Registration Request.

In order for dynamic GFA assignment to work, the MN, GFA, and HA, respectively, MUST support the GFA IP Address extension. Also, the FA MUST be able to advertise an all-ones care-of address and handle a Registration Request with an all-zeros care-of address.

Note also that protection of the GFA IP Address extension, added to the Registration Request, requires either the use of an FA-HA Authentication extension or other means to secure the Registration Request when forwarded from the GFA to the HA.

7.1. Mobile Node Considerations for Dynamic GFA Assignment

If the 'I' flag in the Agent Advertisement sent out by the FA is set, and the care-of address indicating the GFA is set to all-ones, this indicates support for dynamic GFA assignment.

If the MN supports dynamic GFA assignment, and if the advertised GFA address is all-ones, the MN SHOULD set the care-of address field in the Registration Request to all-zeros to request to be assigned a GFA.

When requesting dynamic GFA assignment, the MN MUST check to make sure that it receives a GFA IP Address extension in the Registration Reply.

7.2. Foreign Agent Considerations for Dynamic GFA Assignment

If an FA supports dynamic GFA assignment, and receives a Registration Request with the care-of address field set to all-zeros, the FA assigns a GFA to the MN. A FA can either have a default GFA that it assigns to all MNs or it can assign a GFA by some means not described in this specification.

If an FA that does not support dynamic GFA assignment receives a Registration Request with the care-of address field set to all-zeros, the FA will deny the request as described in [RFC3344], i.e., by

sending a Registration Reply with the Code field set to "invalid care-of address".

7.3. GFA Considerations for Dynamic GFA Assignment

If a GFA supports dynamic GFA assignment, and receives a Registration Request with the care-of address field set to all-zeros, the GFA assigns its own IP address as care-of address for this MN, and adds a GFA IP Address extension with this address to the Registration Request. The GFA MUST NOT insert the GFA IP address directly in the care-of address field in the Registration Request, since that would cause the MN-HA authentication to fail.

The GFA IP Address extension has to be protected so that it cannot be changed by a malicious node when the Registration Request is forwarded to the HA. If the HA and the GFA have a mobility security association, the GFA IP Address extension MUST be protected by the FA-HA authentication extension. Otherwise, the Registration Request MUST be sent to the HA in a secure way, for example via a secure AAA protocol (e.g., [RFC4004], [RFC3957]).

If the GFA does not support dynamic GFA assignment, it will deny the request by sending a Registration Reply with the Code field set to ZERO_COA_NOT_SUPP (see Section 9.5).

7.4. Home Agent Considerations for Dynamic GFA Assignment

If a HA receives a Registration Request with a GFA IP Address extension, and the HA does not allow the use of this extension, the HA MUST return a Registration Reply with the Code value set to DYN_GFA_NOT_SUPP (see Section 9.5).

If a HA receives a Registration Request message with the care-of address set to all-zeros, but no GFA IP Address extension, it MUST deny the request by sending a Registration Reply message with the Code field set to ZERO_CAREOF_ADDRESS (see Section 9.5).

If a HA that does not support dynamic GFA assignment receives a Registration Request with a GFA IP Address extension, the request will be denied by the HA, as described in [RFC3344].

If a HA that supports dynamic GFA assignment receives a Registration Request with the care-of address set to all-zeros and a GFA IP Address extension, it MUST register the IP address of the GFA as the care-of address of the MN in its mobility binding list. If the Registration Request is accepted, the HA MUST include the GFA IP Address extension in the Registration Reply, before the MN-HA Authentication extension.

7.5. Regional Registration

If the MN receives an Agent Advertisement with the care-of address field indicating the GFA set to all-ones, and if the MN determines that it is within the same visited domain as when it did its last home registration, it MAY send a Regional Registration Request to its current GFA. Otherwise, it MUST send a Registration Request to its HA as described in Section 7.1.

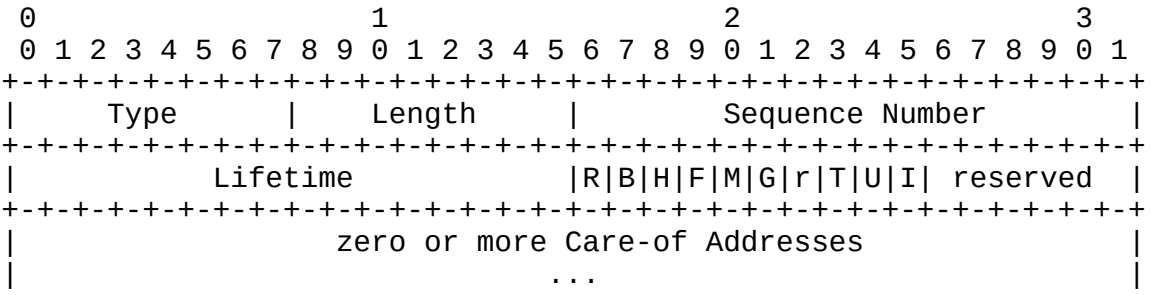
8. Router Discovery Extensions

This section specifies a new flag within the Mobile IP Agent Advertisement, and an optional extension to the ICMP Router Discovery Protocol [RFC1256].

8.1. Regional Registration Flag

The only change to the Mobility Agent Advertisement Extension defined in [RFC3344] is a flag indicating that the domain, to which the FA generating the Agent Advertisement belongs, supports regional registrations. The flag is inserted after the flags defined in [RFC3344], [RFC3024], and [RFC3519].

Regional Registration flag:



The flag is defined as follows:

Type 16 (Mobility Agent Advertisement)

I Regional Registration. This domain supports regional registration as specified in this document.

8.2. Foreign Agent NAI Extension

The FA-NAI extension is defined as subtype 3 of the NAI Carrying Extension [RFC3846].

The FA SHOULD include its NAI in the Agent Advertisement message. If present, the Foreign Agent NAI (FA-NAI) extension MUST appear in the Agent Advertisement message after any of the advertisement extensions defined in [RFC3344].

By comparing the domain part of the FA-NAI with the domain part of the FA-NAI it received in the previous Agent Advertisement, the MN can determine whether it has moved to a new domain since it last registered.

9. Regional Extensions to Mobile IPv4 Registration Messages

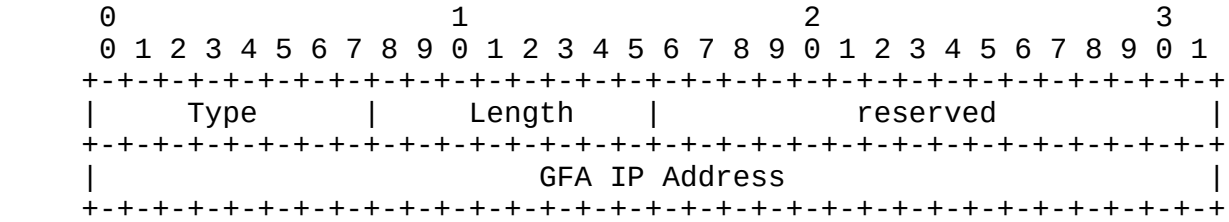
In this section, we specify new Mobile IP registration extensions for the purpose of managing regional registrations.

9.1. GFA IP Address Extension

The GFA IP Address extension is defined for the purpose of supporting dynamic GFA assignment. If the MN requests a dynamically assigned GFA, the GFA adds a GFA IP Address extension to the Registration Request before relaying it to the HA. The MN indicates that it wants a GFA to be assigned by sending a Registration Request with the care-of address field set to all-zeros. The GFA IP Address extension MUST appear in the Registration Request before the FA-HA Authentication extension, if present.

If a HA receives a Registration Request message with the care-of address set to all-zeros, and a GFA IP Address extension, it MUST register the IP address of the GFA as the care-of address of the MN. When generating a Registration Reply message, the HA MUST include the GFA IP Address extension from the Registration Request in the Registration Reply message. The GFA IP Address extension MUST appear in the Registration Reply message before the MN-HA Authentication extension.

The GFA IP Address Extension is defined as follows:



Type
46 (GFA IP Address) (non-skippable)

Length
6

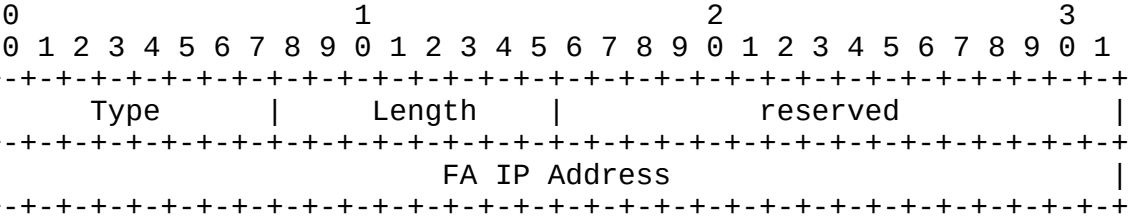
GFA IP Address
The GFA IP Address field contains the Gateway Foreign Agent's (GFA) publicly routable address.

9.2. Hierarchical Foreign Agent Extension

The Hierarchical Foreign Agent (HFA) extension may be present in a Registration Request or Regional Registration Request. When an FA adds this extension to a Registration Request, the receiving mobility agent (GFA) sets up a pending registration record for the MN, using the IP address in the HFA extension as the care-of address for the MN. Furthermore, in this case, the extension MUST be appended at the end of all previous extensions that had been included in the registration message as received by the FA. The HFA extension MUST be protected by an FA-FA Authentication extension. When the receiving mobility agent (GFA) receives the registration message, it MUST remove the HFA extension added by the sending FA.

If a MN with a co-located care-of address adds the HFA extension to a Registration Request, the receiving mobility agent (GFA) sets up a pending registration record for the MN, using the IP address in the HFA extension as the care-of address for the MN. The extension MUST be protected by an authentication extension. If the MN has established a mobility security association with the GFA, the HFA extension MUST be placed before the MN-FA Authentication extension, and it SHOULD be placed after the Mobile-Home (MN-HA) Authentication extension. Otherwise, if the MN has no established mobility security association with the GFA, the HFA extension MUST be placed before the MN-HA authentication extension. If the HFA extension is placed after all other extensions, the receiving mobility agent (GFA) MUST remove the HFA extension added by the MN. Otherwise, when the HA receives the registration message, it ignores the HFA extension.

The Hierarchical Foreign Agent (HFA) Extension is defined as follows:



Type
140 (Hierarchical Foreign Agent) (skippable)

Length
6

FA IP Address
The IP Address of the FA relaying the Registration Request.

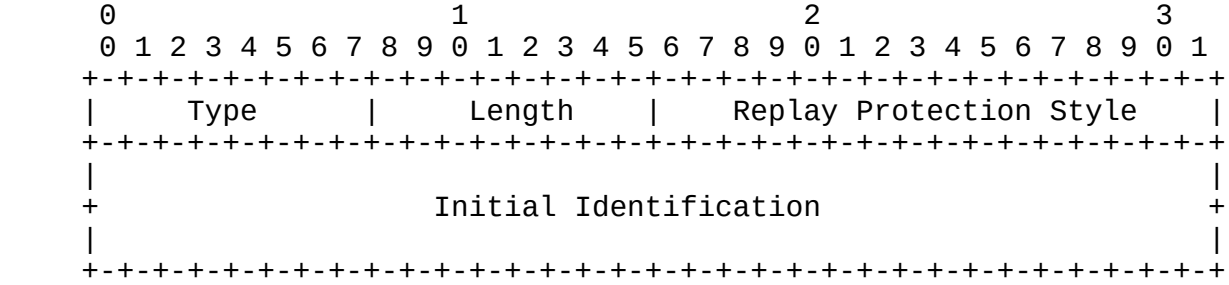
9.3. Replay Protection Style

When a MN uses Mobile IPv4 to register a care-of address with its HA, the style of replay protection used for the registration messages is assumed to be known by way of a mobility security association that is required to exist between the MN and the HA receiving the request. No such pre-existing security association between the MN and the GFA is likely to be available. By default, the MN SHOULD treat replay protection for Regional Registration messages exactly as specified in Mobile IPv4 [RFC3344] for timestamp-based replay protection.

If the MN requires nonce-based replay protection, also as specified in Mobile IPv4, it MAY append a Replay Protection Style extension to a Registration Request. Since Registration Requests are forwarded to the HA by way of the GFA, the GFA will be able to establish the selected replay protection (see Section 5.3).

The GFA also uses this extension by adding a Replay Protection Style extension to a Registration Reply to synchronize the replay protection for Regional Registrations (see Section 5.3).

The format of the Replay Protection Style extension is:



Type
141 (Replay Protection Style) (skippable)

Length
2

Replay Protection Style
An integer specifying the style of replay protection desired by the MN.

Initial Identification
The timestamp or nonce to be used for initial synchronization for the replay mechanism.

Admissible values for the Replay Protection Style are as follows:

Value	Replay Protection Style
0	timestamp [RFC3344]
1	nonce [RFC3344]

The Replay Protection Style extension MUST be protected by an authentication extension. If the MN has an established mobility security association with the GFA, the Replay Protection Style extension MUST be placed before the MN-FA Authentication extension in the Registration Request, and SHOULD be placed after the MN-HA Authentication extension. Otherwise, the Replay Protection Style extension MUST be placed before the MN-HA Authentication extension in the Registration Request.

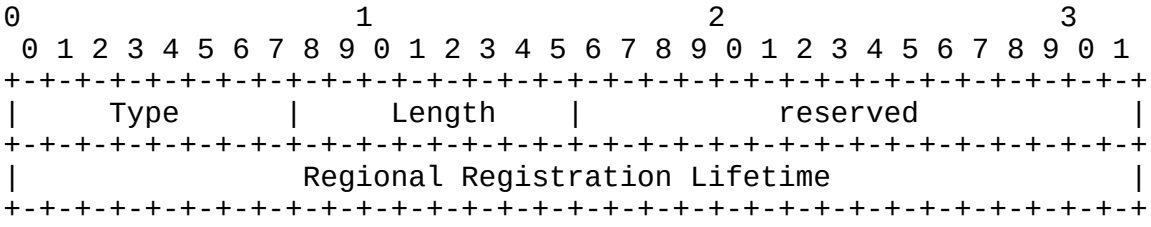
If the GFA adds a Replay Protection Style extension to a Registration Reply, it SHOULD be placed before the MN-FA Authentication extension. The MN-FA Authentication extension should be based on security associations between the MN and GFA established during home registration.

Replay protection MAY also be provided through a challenge-response mechanism, at the FA issuing the Agent Advertisement, as described in [RFC4721].

9.4. Regional Registration Lifetime Extension

The Regional Registration Lifetime extension allows the GFA to set a lifetime for the regional registration with an MN during its home registration. When receiving a Registration Reply from the HA, the GFA MAY add this extension to the Registration Reply before relaying it to the FA. The GFA MUST set the Regional Registration Lifetime to be no greater than the remaining lifetime of the MN’s home registration.

The Regional Registration Lifetime Extension is defined as follows:



Type
142 (Regional Registration Lifetime) (skippable)

Length
6

Regional Registration Lifetime
If the Code field indicates that the registration was accepted, the Regional Registration Lifetime field is set to the number of seconds remaining before the regional registration is considered expired. A value of zero indicates that the MN has been deregistered with the GFA. A value of 0xffff indicates infinity. If the Code field indicates that the home registration was denied, the contents of the Regional Registration Lifetime field are unspecified and MUST be ignored on reception.

If the GFA adds a Regional Registration Lifetime extension to a Registration Reply, it MUST be placed before the MN-FA Authentication extension. The MN-FA Authentication extension should be based on security associations between the MN and GFA established during home registration.

9.5. New Code Values for Registration Reply

The values to use within the Code field of the Registration Reply are defined in [RFC3344]. In addition, the following values are defined:

Registration denied by the GFA:

Error Name	Value	Section of Document
REPLAY_PROT_UNAVAIL	110	Section 5.3
ZERO_COA_NOT_SUPP	111	Section 7.3

Registration denied by the HA (for dynamic GFA assignment):

Error Name	Value	Section of Document
ZERO_CAREOF_ADDRESS	145	Section 7.4
DYN_GFA_NOT_SUPP	146	Section 7.4

10. Regional Registration Message Formats

This section specifies two new registration message types: Regional Registration Request and Regional Registration Reply. These messages are used by the MN instead of the existing Mobile IPv4 Registration Request and Registration Reply, as described in Section 6.

Regional registration messages are protected by required authentication extensions, in the same way as the existing Mobile IPv4 registration messages are protected. The following rules apply to authentication extensions:

- The MN-GFA Authentication extension [RFC3344] MUST be included in all regional registration messages.
- The MN-FA Authentication extension [RFC3344] MAY be included in regional registration messages.
- The FA-HA Authentication extension [RFC3344] MUST NOT be included in any regional registration message.

10.1. Regional Registration Request

The Regional Registration Request is used by a MN to register with its current GFA.

Regional Registration Request:

The Regional Registration Request is defined as the Registration Request in [RFC3344], but with the following changes:

Type
: 18 (Regional Registration Request)

Lifetime
: The number of seconds remaining before the Regional Registration is considered expired. A value of zero indicates a request for deregistration with the GFA. A value of 0xffff indicates infinity.

GFA IP Address
: The IP address of the Gateway Foreign Agent (GFA). (Replaces Home Agent field in Registration Request message in [RFC3344].)

Care-of Address
: Care-of address of local FA; MAY be set to all-ones.

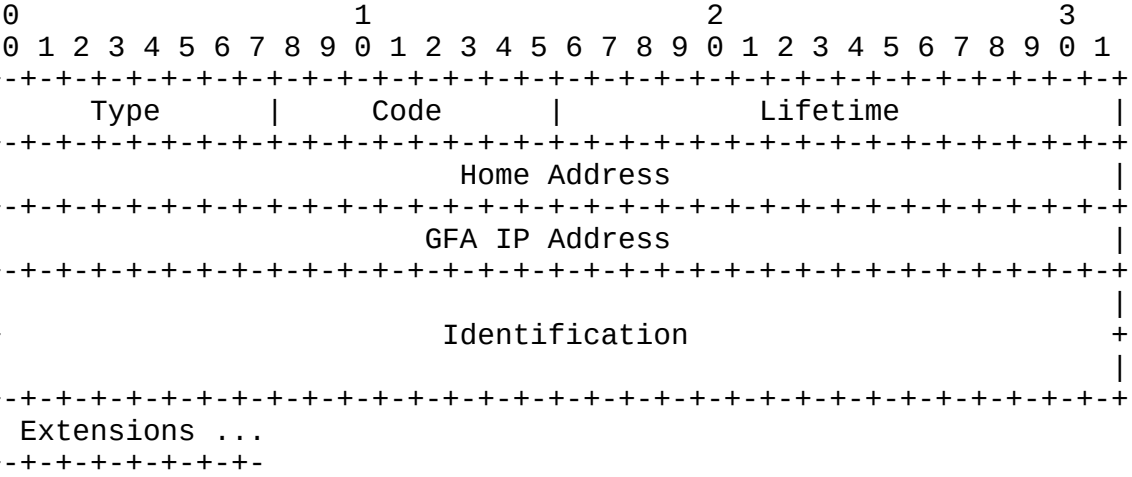
Identification
A 64-bit number, constructed by the MN, used for matching Regional Registration Requests with Regional Registration Replies, and for protecting against replay attacks of regional registration messages.

Extensions
For the Regional Registration Request, the Hierarchical Foreign Agent (HFA) Extension is an allowable extension (in addition to those which are allowable for the Registration Request).

10.2. Regional Registration Reply

The Regional Registration Reply delivers the indication of regional registration acceptance or denial to a MN.

In the Regional Registration Reply, the UDP header is followed by the Mobile IP fields shown below:



This message is defined as the Registration Reply message in [RFC3344], but with the following changes:

Type
19 (Regional Registration Reply)

Code
A value indicating the result of the Regional Registration Request. See [RFC3344] for a list of currently defined Code values.

Lifetime
If the Code field indicates that the regional registration was accepted, the Lifetime field is set to the number of seconds remaining before the regional registration is considered expired. A value of zero indicates that the MN has been deregistered with the GFA. A value of 0xffff indicates infinity. If the Code field indicates that the regional registration was denied, the contents of the Lifetime field are unspecified and MUST be ignored on reception.

GFA IP Address
The IP address of the Gateway Foreign Agent (GFA) generating the Regional Registration Reply. (Replaces Home Agent field specified in Mobile IPv4 [RFC3344].)

Identification
A 64-bit number used for matching Regional Registration Requests with Regional Registration Replies, and for protecting against replay attacks of regional registration messages. The value is based on the Identification field from the Regional Registration Request message from the MN, and on the style of replay protection used in the security context between the MN and its GFA (defined by the mobility security association between them).

10.3. New Regional Registration Reply Code Values

For a Regional Registration Reply, the following additional Code values are defined in addition to those specified in Mobile IPv4 [RFC3344].

Registration denied by the FA:

Error Name	Value	Section of Document
UNKNOWN_GFA	112	Section 6.2
GFA_UNREACHABLE	113	
GFA_HOST_UNREACHABLE	114	
GFA_PORT_UNREACHABLE	115	

Registration denied by the GFA:

Error Name	Value	Section of Document
NO_HOME_REG	193	Section 6.3

The four first Code values are returned to the MN in response to ICMP errors that may be received by the FA.

11. Authentication Extensions

In this section, two new subtypes for the Generalized Authentication Extension [RFC4721] are specified. First, the FA-FA Authentication extension is used by FAs to secure the HFA extension to the Registration Request and Regional Registration Request messages. A new authentication extension is necessary because the HFA extension is typically added after the MN-HA Authentication extension or, e.g., the MN-AAA Authentication extension [RFC4721].

The MN-GFA Authentication extension is used whenever the MN has a co-located address. The MN-GFA Authentication extension is also used to provide authentication for a Regional Registration Request.

The subtype values for these new subtypes are as follows:

Subtype Name	Value
FA-FA authentication	2
MN-GFA authentication	3

The default algorithm for computation of the authenticator is the same as for the MN-AAA Authentication subtype defined in [RFC4721].

12. Security Considerations

This document proposes a method for a MN to register locally in a visited domain. The authentication extensions to be used are those defined in [RFC3344] and [RFC4721]. Key distribution, assumed to take place during home registration, is to be performed, for instance, according to [RFC4004] or [RFC3957]. Alternatively, the keys can be pre-configured.

If the Hierarchical Foreign Agent (HFA) extension is appended to a Registration Request, this extension is to be followed by an FA-FA Authentication extension (see Section 11) to prevent any modification to the data. Security associations between FAs and GFAs within a domain are assumed to exist prior to regional registrations.

If the GFA IP Address extension is added to a registration message, it is to be followed by a authentication extension. In case of the GFA IP Address extension being added to a Registration Request, it should be protected by an FA-HA Authentication extension. If no

security association exists between the GFA and the HA, the Registration Request needs to be protected by other means not defined in this document. When a GFA IP Address extension is added to a Registration Reply, it is protected by the Mobile-Home Authentication extension as defined in [RFC3344].

Replay protection for regional registrations is defined similarly to [RFC3344], with the addition of a Replay Protection Style extension. If this extension is added to a Registration Reply by a GFA, it needs to be protected by a MN-FA Authentication extension.

A co-operating malicious MN-HA pair can trick the GFA into setting up state for an incorrect MN home address. This would result in redirection of data of the node that actually owns that IP address to the malicious MN. Given that the forwarding happens based on the home address at the GFA, such an attack is scoped to the prefix of the HA, not that of the GFA. This type of attack, or its consequences, is not considered in this document.

13. IANA Considerations

This document defines:

- A subtype for the NAI Carrying Extension [RFC3846] is specified in Section 8.2, which needs to have a value assigned from the space of NAI Carrying Extension subtypes.

- Four new extensions to Mobile IP Registration messages: GFA IP Address, Hierarchical Foreign Agent, Replay Protection Style, and Regional Registration Lifetime (see Sections 9.1, 9.2, 9.3, and 9.4). The Type values for the GFA IP Address extension must be within the range 0 through 127, while the other three must be within the range 128 through 255.

- New Code values for Registration Reply messages (see Section 9.5).

- Two new subtypes for the Generalized Authentication Extension [RFC4721]; see Section 11.

- Two new message types for Mobile IP: Regional Registration Request and Regional Registration Reply (see Sections 10.1 and 10.2).

- Code values for Regional Registration Reply messages (see Section 10.3).

14. Acknowledgements

This document is a logical successor to documents written with Pat Calhoun and Gabriel Montenegro; thanks to them and their many efforts to help explore this problem space. Many thanks also to Jari Malinen for his commentary on a rough version of this document.

15. References

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15.2. Informative References

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[RFC4004] Calhoun, P., Johansson, T., Perkins, C., Hiller, T., and P. McCann, "Diameter Mobile IPv4 Application", RFC 4004, August 2005.

Appendix A. Authentication, Authorization, and Accounting (AAA) Interactions

When the mobile node has to obtain authorization by way of Authentication, Authorization, and Accounting (AAA) infrastructure services, the control flow implicit in the main body of this specification is likely to be modified. Typically, the mobile node will supply credentials for authorization by AAA as part of its registration messages. The GFA will parse the credentials supplied by the mobile and forward the appropriate authorization request to a local AAA server (see [RFC3012] and [RFC4004]).

Concretely, this means that:

- The GFA MAY include the Mobile IP Registration Request data inside an authorization request, directed to a local AAA server.

- The GFA MAY receive the Mobile IP Registration Reply data from a message granting authorization, received from the AAA infrastructure.

Appendix B. Anchoring at a GFA

As described earlier in this draft, once a mobile node has registered the address of a GFA as its care-of address with its home agent, it MAY perform regional registrations when changing foreign agent under the same GFA. When detecting that is has changed foreign agent, and if the new foreign agent advertises the 'I' flag, the mobile node MAY address a Regional Registration Request message to its registered GFA, even if the address of that particular GFA is not advertised by the new foreign agent. The foreign agent MAY then relay the request to the GFA in question, or deny the request with error code UNKNOWN_GFA.

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