                 Mobile IPv4 Dynamic Home Agent (HA) Assignment

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Abstract

   Mobile IPv4 (RFC 3344) uses the home agent (HA) to anchor sessions of
   a roaming mobile node (MN). This document proposes a messaging
   mechanism for dynamic home agent assignment and HA redirection. The
   goal is to provide a mechanism to assign an optimal HA for a Mobile
   IP session while allowing any suitable method for HA selection.

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1. Introduction

   This document adds to the Mobile IP protocol [1], by proposing a
   messaging mechanism for dynamic home agent assignment and home agent
   redirection during initial registration. The goal is to assign an
   optimal HA for a Mobile IP session. The mobile node MUST use the
   Network Access Identifier (NAI) extension [2] when requesting a
   dynamically assigned HA.

   The MN requests a dynamically assigned HA by setting the HA field in
   the initial Registration Request to ALL-ZERO-ONE-ADDR (defined in
   Section 2). If the request is accepted, the HA sends a successful
   Registration Reply containing the HA's own address. The requested HA
   can suggest an alternate HA and if so, the Registration Reply is
   rejected with a new error code REDIRECT-HA-REQ and the alternate HA
   address is specified in a new extension (Redirected HA Extension).

   This document also defines a new Requested HA Extension for use in
   Registration Requests when the HA field is set to ALL-ZERO-ONE-ADDR.
   The Requested HA address is a hint to the network about the MN's
   preferred HA.

   The messaging mechanism is defined in this document so that the MN
   can request and receive a dynamic HA address in Mobile IP messages.
   However, the mechanism by which the network selects an HA for
   assignment to the MN is outside the scope of this document. For
   example, the selection may be made by any network node that receives
   the Registration Request (or information about the Registration
   Request), such as a Foreign Agent, AAA server, or home agent. The
   node that selects the HA may select one based on a number of
   criteria, including but not limited to HA load-balancing,
   geographical proximity, administrative policy, etc.

2. Requirements 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 [6].

   The Mobile-IP-related terminology described in RFC 3344 [1] is used
   in this document. In addition, the following terms are used:

   ALL-ZERO-ONE-ADDR: IP address 0.0.0.0 or 255.255.255.255. An
                      address of 255.255.255.255 indicates a preference
                      for an HA in the home domain. An address of
                      0.0.0.0 indicates no preference for home vs.
                      visited domain.

Requested HA: Destination IP address of home agent that the
                     Registration Request is sent to. Must be a
                     unicast IP address. This address can be
                     obtained as described in Section 6.

                     Note that this specification defines a new
                     "Requested HA Extension" in Section 3.4, which
                     is different from the term "Requested HA".

Assigned HA: The HA that accepts an MN's Registration Request
                     and returns a successful Registration Reply.

Redirected HA: If the registration is rejected with error code
                     REDIRECT-HA-REQ, the HA being referred to is
                     specified in a new extension (Redirected HA
                     Extension).

AAA server: Authentication, Authorization, and Accounting
                     Server.

DNS: Domain Name System.

DHCP: Dynamic Host Configuration Protocol.

MN: Mobile node as defined in Mobile IPv4 [1].

HA: Home agent as defined in Mobile IPv4 [1].

FA: Foreign Agent as defined in Mobile IPv4 [1].

CoA: Care-of Address.

CCoA: Co-located Care-of Address.

MN HoA: Mobile node's home address.

NAI: Network Access Identifier [2].

Src IP: Source IP address of the packet.

Dest IP: Destination IP address of the packet.

RRQ: Registration Request.

3. Problem Statement

   The Mobile IPv4 NAI Extension for IPv4 [2] introduced the concept of
   identifying an MN by the NAI and enabling dynamic home address
   assignment. When the home address is dynamically assigned, it is
   desirable to discover the home agent dynamically or inform the MN
   about an optimal HA to use for a multitude of reasons, such as:

   - 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. In such a case, the MN will be anchored
     to its distant home agent, resulting in tunneled traffic traveling
     a long distance between home agent and the mobile node. When a
     Mobile IP session initiates, if the mobile node can be assigned a
     home agent that is close to the mobile node it can drastically
     reduce the latency between the home agent and mobile node.

   - In a large-scale Mobile IP deployment, it is cumbersome to
     provision MNs with multiple HA addresses.

   - It is desirable to achieve some form of load balancing between
     multiple HAs in the network. Dynamic HA assignment and/or HA
     redirection lets the network select the optimal HA from among a set
     of HAs and thus achieve load balancing among a group of HAs.

   - Local administrative policies.

3.1. Scope

   This specification does not address the problem of distributing a
   security association between the MN and HA, and it can either be
   statically preconfigured or dynamically distributed using other
   mechanisms [7].

   The document introduces the terms Requested/Assigned/Redirected HA
   (Section 6). The discovery of candidate HA addresses for insertion
   into the Redirected HA Extension can be accomplished through various
   means that are network and/or deployment specific and hence are
   outside the scope of this specification.

   The MN MAY request dynamic HA assignment when it is not aware of any
   HA address and even when it is aware of at least one HA address.

3.2. Dynamic Home Agent Discovery in Mobile IPv4

   Mobile IPv4 [1] specifies the mechanism for discovering the mobile
   node's home agent using subnet-directed broadcast IP address in the
   home agent field of the Registration Request. This mechanism was

designed for mobile nodes with a static home address and subnet
prefix, anchored on fixed home network. However, using subnet-
directed broadcast as the destination IP address of the Registration
Request, it is unlikely that the Registration Request will reach the
home subnet because routers will drop these packets by default. See
CERT Advisory CA-1998-01 Smurf IP Denial-of-Service Attacks [3].

3.3. NAI Usage and Dynamic HA Assignment

The Mobile IPv4 NAI Extension for IPv4 [2] introduced the concept of
identifying an MN by the NAI and enabling dynamic home address
assignment. This document requires that while using dynamic HA
assignment, MN MUST use the NAI and obtain a home address. MN can
still suggest a static home address in the Registration Request, but
must take the address in the Registration Reply as the home address
for the session. This is compatible with the procedures documented
in the NAI specification [2].

3.4. Dynamic HA Extension

The Dynamic HA Extension, shown in Figure 1, contains the address of
the HA. This is a generic extension and can be used in Registration
Request and Reply messages. It is a skippable extension.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Subtype    |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          HA-Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
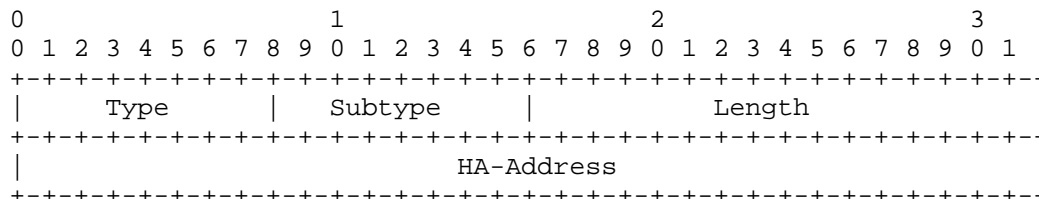
Figure 1: The Dynamic HA Address Extension

   Type   DYNAMIC-HA-ADDRESS (skippable) 139 is the type,
                 which specifies the dynamic HA address.

   Subtype   Defines the use of this extension as:
                 subtype 1 = Requested HA Extension
                         2 = Redirected HA Extension

   Length   Indicates the length of the extension not
                 including the type, subtype, and length fields.
                 Length is always 4 bytes.

   HA-Address   Address of the home agent.

3.4.1. Requested HA Extension

   The Requested HA Extension is a Dynamic HA Extension of subtype 1.

   The MN may include the Requested HA Extension in the Registration
   Request as a hint to the network where it wishes to be anchored.

   This extension contains the address of the HA. A valid unicast IP
   address MUST be used as HA address in this extension.

   In absence of an FA, the Registration Request is forwarded to this
   HA. In presence of an FA, the FA MUST forward the Registration
   Request to the HA address in this extension.

3.4.2. Redirected HA Extension

   The Redirected HA Extension is a Dynamic HA Extension of subtype 2.

   The Redirected HA Extension contains the address of the HA where the
   MN should attempt the next registration. The HA receiving a
   Registration Request can suggest an alternate HA and, if so, the
   Registration Reply is sent with a new error code REDIRECT-HA-REQ and
   the alternate HA address is specified in this extension.

   The Redirected HA Extension MUST be included in Registration Reply
   when the reply code is REDIRECT-HA-REQ.

4. Messaging Mechanism for Dynamic HA Assignment/Redirection

   This specification presents two alternatives for home agent
   assignment:

   (a) Dynamic HA assignment (described in Section 4.1) and
   (b) HA redirection (described in Section 4.2).

4.1. Messaging for Dynamic HA Assignment

   The following sequence of events occurs when the MN requests dynamic
   home agent assignment:

   1. The MN sets the Home Agent address field in the Registration
       Request to ALL-ZERO-ONE-ADDR. If the MN is aware of a desired HA
       address, it can add that address in the Requested HA Extension in
       the Registration Request. If the HA does not support the
       Requested HA Extension, see step 2 below.

   2. This step is applicable, in lieu of step 1, for an MN that is
       aware of the HA address and desires dynamic HA assignment. Also,
       the MN follows this (when aware of a HA address) when it
       discovers a legacy FA in the path or if the known HA does not
       support the Requested HA Extension (see Section 10).

       The MN sets the Home Agent address field in the Registration
       Request to the HA address (instead of setting it to ALL-ZERO-
       ONE-ADDR). The MN also adds the same HA address in the Requested
       HA Extension in the Registration Request.

   3. The MN (if using co-located CoA and registering directly with the
       HA) or the FA (if the MN is registering via the FA) sends the
       Registration Request to the "Requested HA". If the Requested HA
       Extension is present, Requested HA is specified in the "HA
       Address" of this extension.

       Per Section 10, in case of a legacy FA, legacy FA forwards the
       Registration Request to the address in the HA field of the
       request (thus, MN uses step 2 above in case of legacy FA instead
       of step 1).

   4. The "Requested HA" is the home agent that processes the
       Registration Request in accordance with Mobile IPv4 [1] and as
       per the specification in this document. It creates mobility
       binding for a successful Registration Request. It also sends a
       Registration Reply to the MN.

   5. The MN obtains an "Assigned HA" address from the HA field in the
       successful Registration Reply and uses it for the remainder of
       the session. (Note that the "Assigned HA" will be the same as
       the "Requested HA".)

   6. Subsequent Registration Request messages for renewal are sent to
       the Assigned HA.

   Section 5.3.1 describes the Assigned HA in detail. Some ideas on how
   to select the Requested HA are briefly covered in Section 6.

4.1.1. Example with Message Flow Diagram

   Detailed explanation of this alternative is best described with the
   help of a message flow diagram and description.

   Figure 2 shows one specific example of a mobile node using an
   FA-located Care-of Address (FA CoA) and FA understands the Requested
   HA Extension per this specification.

Other scenarios such as when the mobile node uses a co-located care
of address and presence of a legacy HA or FA are not described below,
but the behavior is similar.

```
             MN             FA        Requested/Assigned HA
              |       1      |                |
              |------------->|       2        |
              |              |--------------->|
              |              |                |
              |              |                |
              |              |       3        |
              |       4      |<---------------|
              |<-----------  |                |
              |              |                |
              |              |       5        |
              |----------------------------->|
              |              |                |
```
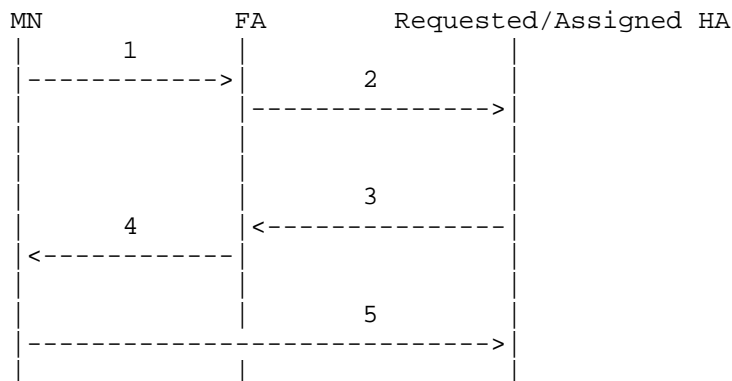
       Figure 2: Example Message Flow for Dynamic HA Assignment

   1. The MN sets the Home Agent address field in the Registration
       Request to ALL-ZERO-ONE-ADDR. Since the MN is using FA CoA in
       this example, it sends the Registration Request to the FA. The
       Registration Request is formatted as follows:

```
       +------------------------------------------------------------+
       | Src IP=| Dest IP = | MN HoA  |    HA Address =   | CoA =   |
       |   MN   |    FA     |         | ALL-ZERO-ONE-ADDR |FA CoA   |
       +------------------------------------------------------------+
```

       If the MN is aware of a desired HA address, it can add that
       address in the Requested HA Extension in Registration Request as
       a hint. That extension is not shown above.

   2. The FA sends the Registration Request to the Requested HA. If
       the Requested HA Extension is present, Requested HA is the HA
       address in this extension. If the Requested HA Extension is not
       present, the FA determines the Requested HA through means outside
       the scope of this specification. The Registration Request is
       formatted as follows:

```
       +------------------------------------------------------------+
       | Src IP=| Dest IP = | MN HoA  |    HA Address =   | CoA =   |
       |   FA   |Requested HA|        | ALL-ZERO-ONE-ADDR |FA CoA   |
       +------------------------------------------------------------+
```

(If MN includes the Requested HA Extension, the FA copies that
extension. The FA then forwards the Registration Request, along
with the Requested HA Extension, to the HA address specified in
Requested HA Extension.)

3. The HA processes the Registration Request in accordance with
    Mobile IPv4 [1] and the messaging defined in this document. The
    HA creates mobility binding for successful request and becomes
    the Assigned HA. The HA then sends a Registration Reply to the
    FA, which is formatted as follows:

```
+----------------------------------------------------------+
| Src IP=| Dest IP =  | MN HoA |    HA Address =   | CoA =  |
|Assigned| Src IP of  |        |     Assigned HA   |FA CoA/ |
|   HA   | the RRQ    |        |                   |        |
+----------------------------------------------------------+
```

4. The FA relays the Registration Reply to the MN, as follows:

```
+----------------------------------------------------------+
| Src IP=| Dest IP =  | MN HoA |    HA Address =   | CoA =  |
|   FA   |    MN      |        |     Assigned HA   |FA CoA/ |
+----------------------------------------------------------+
```

5. The MN obtains the Assigned HA address from the HA field in the
    successful Registration Reply and uses it for the remainder of
    the session. The MN sends subsequent Re-Registration or
    De-Registration Requests for the remainder session directly to
    the Assigned HA. The Home Agent address field in this
    Registration Request is set to ALL-ZERO-ONE-ADDR. Note that the
    Assigned HA is the same as the Requested HA.

4.2. Messaging for HA Redirection

    This section describes the events that occur when the Requested
    HA does not accept the Registration Request and redirects the
    mobile node to another HA (aka Redirected HA) instead. This
    behavior is not exhibited by a legacy HA and so is not referred
    in the description below. In presence of a legacy FA, please
    refer to Section 4.1 for the specific field in the Registration
    Request.

1. The MN sets the Home Agent address field in the Registration
    Request to ALL-ZERO-ONE-ADDR.

2. The MN (if using co-located CoA and registering directly with the
   HA) or FA (if the MN is registering via the FA) sends the
   Registration Request to the "Requested HA". If the MN is aware
   of an HA address, it can add that address in the Requested HA
   Extension in the Registration Request.

3. When the HA receives the Registration Request, if the HA field is
   set to ALL-ZERO-ONE-ADDR, the HA may reject the request with
   Reply code REDIRECT-HA-REQ and suggest an alternate HA.

   The HA may reject the request for a number of reasons, which are
   outside the scope of this specification. If the HA rejects the
   Request, the HA field in the Reply is set to this HA's address.
   The IP address of the HA that is the target of the redirection is
   specified in Redirected HA Extension. The presence of this
   extension is mandatory when the reply code is set to REDIRECT-
   HA-REQ. HA sends the Reply to the FA/MN.

4. FA sends the Reply to the MN.

5. If the error code is set to REDIRECT-HA-REQ, the MN obtains the
   HA address from Redirected HA Extension. The MN then sends a
   Registration Request to Redirected HA. The MN may choose to add
   Requested HA Extension in this new Registration Request. If a
   registration loop occurs (the case when the Redirected HA is an
   HA that had already directed the MN to register elsewhere), then
   the MN stops sending any further Registration Request and
   provides an indication that the loop event was detected. The
   number of consecutive Redirected HAs remembered by the MN for
   loop detection is an implementation parameter.

4.2.1. Example with Message Flow Diagram

   Figure 3 shows one specific example of a mobile node using FA-located
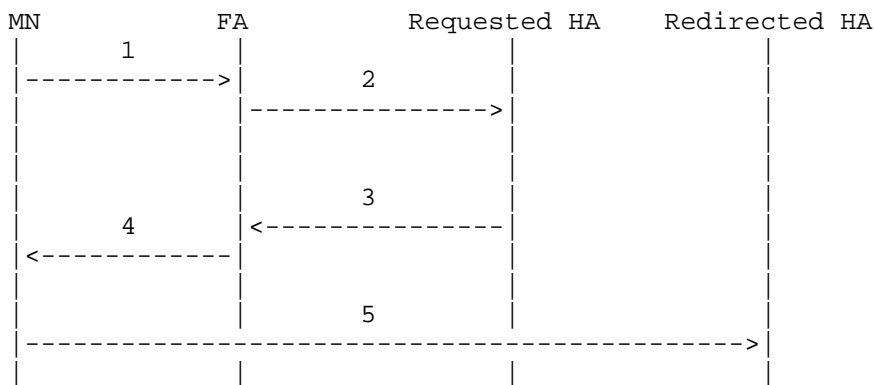   Care-of Address, where the FA is not a legacy FA.

```
    MN              FA          Requested HA    Redirected HA
     |        1       |              |               |
     |--------------->|       2      |               |
     |                |------------->|               |
     |                |              |               |
     |                |              |               |
     |                |       3      |               |
     |        4       |<-------------|               |
     |<---------------|              |               |
     |                |              |               |
     |                |       5      |               |
     |--------------------------------------------->|
     |                |              |               |
```

            Figure 3: Example Message Flow for HA Redirection

   1. The MN sets the Home Agent address field in the Registration
       Request to ALL-ZERO-ONE-ADDR. Since the MN is using FA CoA in
       this example, it sends the Registration Request to the FA. The
       Registration Request is formatted as follows:

```
          +-------------------------------------------------------------+
          | Src IP=| Dest IP =  | MN HoA  |    HA Address =   | CoA =   |
          |  MN    |    FA      |         | ALL-ZERO-ONE-ADDR |FA CoA   |
          +-------------------------------------------------------------+
```

       If the MN is aware of an HA address, it can add that address in
       the Requested HA Extension in the Registration Request as a hint.
       That extension is not shown above.

   2. The FA sends the Registration Request to the Requested HA. If
       Requested HA Extension is present, Requested HA is the HA address
       in this extension. If the Requested HA Extension is not present,
       the FA determines the Requested HA through means outside the
       scope of this specification. The Registration Request is
       formatted as follows:

```
          +-------------------------------------------------------------+
          | Src IP=| Dest IP =  | MN HoA  |    HA Address =   | CoA =   |
          |  FA    |Requested HA|         | ALL-ZERO-ONE-ADDR |FA CoA   |
          +-------------------------------------------------------------+
```

3. The HA processes the Registration Request in accordance with
    Mobile IPv4 [1] and the messaging defined in this specification.
    If the registration is successful, but local
    configuration/administrative policy, etc., directs the HA to
    refer the MN to another HA, the HA rejects the request with error
    code REDIRECT-HA-REQ. The HA fills in the address of the
    Redirected HA in the Redirected HA Extension. The HA then sends
    Registration Reply reject to the FA, which is formatted as
    follows:

```
+-----------------------------------------------------------+
| Src IP=| Dest IP =  | MN HoA  |   HA Address =  | CoA =    |
|        | Src IP of  |         |       HA        |FA CoA    |
|   HA   | the RRQ    |         |                 |          |
+-----------------------------------------------------------+
| Redirected HA Extension ...                               |
+-----------------------------------------------------------+
```

4. The FA relays the Registration Reply to the MN, as follows:

```
+-----------------------------------------------------------+
| Src IP=| Dest IP =  | MN HoA  |   HA Address =  | CoA =    |
|   FA   |    MN      |         |       HA        |FA CoA/   |
+-----------------------------------------------------------+
| Redirected HA Extension ...                               |
+-----------------------------------------------------------+
```

5. If the MN can authenticate the Reply, the MN extracts the HA
    address from the Redirected HA Extension. The MN then sends a
    Registration Request to the Redirected HA, unless it has already
    received a redirection response from that HA while processing the
    Registration Request. The MN may choose to add Requested HA
    Extension in this new Registration Request.

5. Mobility Agent Considerations

   The following sections describe the behavior of each mobility agent
   in detail.

5.1. Mobile Node Considerations

   The mobile node MUST use the NAI extension for home address
   assignment when using the messaging mechanism in this document.
   Since MN uses the NAI extension, the Home Address field is set to
   0.0.0.0.

   While dynamic HA assignment is in progress and the MN has not
   successfully anchored at a home agent, the MN MUST set the Home Agent
   field in the Registration Request to an ALL-ZERO-ONE-ADDR, which is
   either 255.255.255.255 or 0.0.0.0.

   The Registration Request MUST be protected by a valid authenticator
   as specified in Mobile IPv4 [1] or Mobile IPv4 Challenge/Response
   Extensions [5]. Configuring security associations is deployment
   specific and hence outside the scope of this specification. The
   security associations between an MN and an individual HA may also be
   dynamically derived during the dynamic HA assignment, based on a
   shared secret between MN and AAA infrastructure [7].

   The mobile node MUST maintain the remaining Mobile IP session with
   the Assigned HA.

   As mentioned in the Security Considerations (Section 9), there is a
   possibility of more than one HA creating a mobility binding entry for
   a given MN, if a rogue node in the middle captures the Registration
   Request and forwards it to other home agents. The MN can mitigate
   such condition by using a short lifetime (e.g., 5 seconds) in the
   Registration Request with the Home Agent field set to ALL-ZERO-ONE-
   ADDR.

   The following sections describe MN behavior in FA CoA mode and co-
   located CoA mode.

5.1.1. MN Using FA CoA

   When a mobile node initiates a Mobile IP session requesting dynamic
   HA assignment, it MUST set the home agent address field in the
   Registration Request to ALL-ZERO-ONE-ADDR. The destination IP
   address of the Registration Request is the FA. The FA will determine
   the Requested HA and forward the Registration Request to the
   Requested HA. Registration Request processing takes place on the
   Requested HA as per the specification in this document.

The Registration Request MUST be appropriately authenticated for the
HA to validate the Request.

If a successful Registration Reply is received, the MN obtains the
Assigned HA from the HA field of Reply. The Assigned HA address will
be the same as the Requested HA Extension, if it was included in the
Registration Request by the MN.

If a Registration Reply is received with code REDIRECT-HA-REQ, the MN
MUST authenticate the Reply based on HA address in HA field of Reply
and attempt Registration with the HA address specified in the
Redirected HA Extension. The MN MUST put the Redirected HA address
as the Requested HA Extension of the new Registration Request.

In some cases, for the first Registration Request the MN may want to
hint to the network to be anchored at a specific HA. The MN SHOULD
put that address in the HA address of the Requested HA Extension.

5.1.2. MN Using Co-Located CoA

An MN in co-located CoA mode requesting dynamic HA assignment MUST
set the home agent address field in the Registration Request to ALL-
ZERO-ONE-ADDR. The destination IP address of the Registration
Request is the Requested HA. Some ideas on how to select a Requested
HA are briefly covered in Section 6.

If a successful Reply is received, the MN obtains the Assigned HA
address from the successful Registration Reply. The Assigned HA will
be the same as Requested HA to which the Registration Request was
sent. The MN MUST cache the Assigned HA address for the length of
the Mobile IP session. The mobile node then MUST use this previously
cached Assigned HA address as the home agent address in subsequent
Re-Registration and De-Registration Request(s). This will make sure
that for the duration of the Mobile IP session, the mobile node will
always be anchored to the assigned home agent with which it was
initially registered.

If a Registration Reply is received with code REDIRECT-HA-REQ, the MN
MUST authenticate the Reply based on HA address in HA field of Reply
and attempt Registration with the HA address specified in the
Redirected HA Extension. The MN MUST put the Redirected HA in the
Requested HA Extension of the new Registration Request.

In some cases, for the first Registration Request MN may want to hint
to the network to be anchored at a specific HA and the MN SHOULD put
that address in the HA address of the Requested HA Extension.

While requesting dynamic HA assignment and registering directly with
an HA, the Requested HA Extension MUST be included and MUST contain
the address of the HA to which the Registration Request is sent.
When using co-located CoA but registering via a legacy FA, the HA
field in the Registration Request may be set to Requested HA.

If the Registration Request contains the Requested HA Extension, the
HA address in that extension MUST match the destination IP of the
Request.

5.1.3. Refreshing Assigned HA Address on Mobile Node

When the Mobile IP session terminates, the mobile node MAY clear the
Assigned HA address cached as the home agent address. It MAY request
a new HA address for the new Mobile IP session by not including the
Requested HA Extension. The advantage of this approach is that the
mobile node will be always anchored to an optimal home agent from
where it initiated the Mobile IP session.

Alternately, the MN may save the Assigned HA address and use it in
the Requested HA Extension along with ALL-ZERO-ONE-ADDR HA address in
Registration Request for a new Mobile IP session.

5.2. Foreign Agent Considerations

When the mobile node is using an FA CoA, it always registers via the
FA. When the MN is using a co-located CoA, it may register through
an FA or it may register directly with an HA, unless the R bit is set
in the FA's agent advertisement, in which case it always registers
through the FA.

When the FA receives a Registration Request with HA address field set
to ALL-ZERO-ONE-ADDR that doesn't contain the Requested HA Extension,
the FA obtains the Requested HA address to forward the Registration
Request using means outside the scope of this specification. Some
ideas on how to select a Requested HA are briefly covered in Section
6.

If the FA cannot obtain the Requested HA to which to forward a
Registration Request from the MN, it MUST reject request with error
code NONZERO-HA-REQD.

If the MN has included the Requested HA Extension, the FA MUST
forward the Registration Request to the address in this extension.
If the HA address in this extension is not a routable unicast
address, the FA MUST reject the request with error code NONZERO-HA-
REQD.

If the Registration Request contains the Requested HA Extension, the
FA uses that address as the destination for the relayed Registration
Request.

Backward-compatibility issues related to the mobility agents are
addressed in Section 10.

5.3. Home Agent Considerations

A home agent can process an incoming Registration Request in one of
the following two ways:

1. The MN or FA sends the Registration Request to the Requested HA.
    The term Requested HA has meaning in the context of a
    Registration Request message. When the Requested HA successfully
    processes the Registration Request and creates a binding and
    sends a Reply with its address, it becomes the Assigned HA. The
    term Assigned HA is meaningful in the context of a Registration
    Reply message.

2. A home agent receiving a Registration Request with HA field set
    to ALL-ZERO-ONE-ADDR MAY reject the request even if successfully
    authenticated and suggest an alternate HA address in Reply. In
    such a case, the HA puts its own address in HA field of Reply and
    sets the Reply code to REDIRECT-HA-REQ and adds the Redirected HA
    Extension.

If the Registration Request contains the Requested HA Extension, the
HA address in that extension must match the destination IP of the
Request. If it does not match, the Requested HA MUST reject the
Registration Request with error code 136.

5.3.1. Assigned Home Agent Considerations

The HA that processes the incoming Registration Request fully in
accordance with Mobile IPv4 [1] and this specification becomes the
Assigned HA. The Registration Request terminates at the Assigned HA.

The Assigned HA creates one mobility binding per MN and sends the
Registration Reply to the MN by copying its address in the Home Agent
field and as the source IP address of the Reply.

The following table summarizes the behavior of the Assigned HA, based
on the value of the destination IP address and Home Agent field of
the Registration Request.

```
   Dest IP Addr   HA field       Processing at Assigned HA
   ------------   ------------   --------------------------------

   Unicast        non-unicast    Mobile IPv4 [1]: There is no change
                                 in handling for this case from
   (Must be                      Mobile IPv4.  It is mentioned here
   equal to the                  for reference only.
   HA receiving                  HA denies the registration with
   the RRQ)                      error code 136 and sets HA field to
                                 its own IP address in the reply as
                                 per Section 3.8.3.2 in [1].


                  ALL-ZERO-      New Behavior: Accept the RRQ as per
                  ONE-ADDR       this specification.  Authenticate
                                 the RRQ and create mobility binding
                                 if the HA is acting as Assigned HA.
                                 Set HA field to its own IP address
                                 in the Registration Reply.

                                         OR

                                 New Behavior: If authentication is
                                 successful, reject RRQ with a new
                                 error code REDIRECT-HA-REQ.  HA
                                 puts its address in HA address
                                 field of Reject.  HA suggests an
                                 alternate HA to use in the new
                                 Redirected HA Extension.
```

       Table 1: Registration Request Handling at Assigned HA

   As per the messaging proposed here, the mobile node (or the foreign
   agent) sends the Registration Request to the Requested HA address,
   which is a unicast address. Therefore, this document does not
   specify any new behavior for the case where the HA receives a subnet
   directed broadcast Registration Request as specified in Section
   3.8.2.1 of the Mobile IPv4 specification [1]. Although the Home
   Agent field in the Registration Request is not a unicast address, the
   destination IP address is a unicast address. This avoids the problem
   associated with subnet-directed broadcast destination IP address that
   may result in multiple HAs responding. Thus, there is no need to
   deny the registration as stated in Mobile IPv4 [1] Section 3.8.3.2.

   When the destination IP address is a unicast address and the Home
   Agent field is ALL-ZERO-ONE-ADDR, the HA accepts/denies registration
   and sets the HA field to its own IP address in the reply (i.e., the
   registration is not rejected with error code 136).

The HA can reject the request with the error code REDIRECT-HA-REQ and
suggest an alternate HA. This redirection can be used for load
balancing, geographical proximity based on Care-of Address, or other
reasons. The HA puts its own address in the HA field of the
Registration Reply message and puts the address of the redirected HA
in the Redirected HA Extension. If the HA accepts the Request, it
sets the HA field in the Registration Reply to its own address.

The Requested HA always performs standard validity checks on the
Registration Request. If there is any error, the Registration
Request is rejected with error codes specified in Mobile IPv4 [1].

6. Requested Home Agent Selection

When dynamic HA assignment is requested, the MN (or FA in the case of
registration via FA) sends the Registration Request to the Requested
HA. This address MUST be a unicast IP address. If the MN has
included a Requested HA Extension in the Registration Request, the HA
address in this extension is the Requested HA.

Some examples of methods by which the MN or the FA may select the
Requested HA are briefly described below:

DHCP:

   The MN performs DHCP to obtain an IP address on the visited
   network. The Requested HA is learned from the DHCP Mobile IP Home
   Agent Option 68 [4]. The MN sends the Registration Request
   directly to this HA and receives the Assigned HA to be used for
   the remainder of the Mobile IP session.

   AAA:

   MN performs challenge/response [5] with the FA. The FA retrieves
   the Requested HA from the AAA server and forwards the Registration
   Request directly to this HA. The Assigned HA sends a Registration
   Reply to the FA, which relays it to the MN. MN uses the Assigned
   HA for the remainder of the Mobile IP session.

DNS:

   In this case, the hostname of the HA is configured on the MN or
   obtained by some other means, e.g., using a service location
   protocol. The MN performs DNS lookup on the HA hostname. The DNS
   infrastructure provides a resource record with information to
   identify the optimal HA to the MN. The MN sends a Registration
   Request directly to the HA and receives the Assigned HA to be used
   for the remainder of the Mobile IP session.

    Static configuration:

       The HA address is statically configured on the MN. The MN sends
       the Registration Request to the configured address. The Requested
       HA may then redirect the MN to a Redirected HA.

7. Error Values

    Each entry in the following table contains the name and value for the
    error code to be returned in a Registration Reply. It also includes
    the section in which the error code is first mentioned in this
    document.

    Error Name   Value Section Description
    ---------------   ----- ------- -----------------------------
    NONZERO-HA-REQD   90   5.2   Non-zero HA address required
                                         in Registration Request.
    REDIRECT-HA-REQ   143   5.3   Re-register with redirected HA.

8. IANA Considerations

    The code value NONZERO-HA-REQD is a Mobile IP response code [1] taken
    from the range of values associated with rejection by the foreign
    agent (i.e., value in the range 64-127).

    The code value REDIRECT-HA-REQ is a Mobile IP response code [1] taken
    from the range of values associated with rejection by the home agent
    (i.e., value in the range 128-192).

    The Dynamic HA Extension is assigned from the range of values
    associated with skippable extensions at the home agent (i.e., value
    in the range 128-255).

    IANA has recorded the values as defined in Sections 7 and 3.4.

9. Security Considerations

    This specification assumes that a security configuration has been
    preconfigured between the MN and the HA or is configured along with
    the initial Registration Request/Registration Reply as per [7].

    There is a possibility of more than one HA creating a mobility
    binding entry for a given MN, if a man in the middle captures the
    Registration Request with the HA field set to ALL-ZERO-ONE-ADDR and
    forwards it to other HAs. This scenario assumes that the rogue node
    can find out the addresses of the HAs that are able to authenticate
    the Registration Request. It also assumes that the rogue node has
    the capability to store, duplicate, and send packets to the other HAs

within the limited time of the replay window. Otherwise, these HAs
will reject the Registration Requests anyway. In addition, this type
of attack is only possible when the Requested HA Extension is not
included in the registration message. The mobile node can minimize
the duration of this condition by using a short lifetime (e.g., 5
seconds) in the Registration Request.

This specification does not change the security model established in
Mobile IPv4 [1]. Mobile nodes are often connected to the network via
wireless links, which may be more prone to passive eavesdropping or
replay attacks. Such an attack might lead to bogus registrations or
redirection of traffic or denial of service.

As per the messaging in this document, the Assigned Home Agent will
process the incoming Registration Request as per Mobile IPv4 [1].
Hence the Assigned Home Agent will have the same security concerns as
those of the home agent in Mobile IPv4 [1]. They are addressed in
Section 5, "Security Considerations", of Mobile IPv4 [1].

The Registration Request and Registration Reply messages are
protected by a valid authenticator as specified in Mobile IPv4 [1].
Configuring security associations is a deployment-specific issue and
is covered by other Mobile IP specifications. There can be many ways
of configuring security associations, but this specification does not
require any specific way.

An example is where the security association between an MN and an
individual HA (Requested or Assigned) is dynamically derived during
the registration process based on a shared secret between MN and AAA
infrastructure, as defined in [7]. The Registration Request is
protected with MN-AAA Authentication Extension, and Registration
Reply is protected with MN-HA Authentication Extension. Because the
security association is shared between MN and AAA, any dynamically
assigned HA in the local domain can proxy authenticate the MN using
AAA as per [7].

The Assigned Home Agent authenticates each Registration Request from
the mobile node as specified in Mobile IPv4 [1] and/or RFC 3012. The
MN also authenticates the Registration Reply from the Assigned HA;
thus, the existing trust model in Mobile IPv4 [1] is maintained.

10. Backward-Compatibility Considerations

   In this section, we examine concerns that may arise when using this
   specification in a mixed environment where some nodes implement the
   specification and others do not. In each of the examples below, we
   consider the case where one node is a "legacy" node, which does not
   implement the specification in the context of other nodes that do.

Legacy Home Agent:

Legacy home agents may reject the Registration Request with error
code 136 because the Home Agent field is not a unicast address.
However, some legacy HA implementations may coincidentally process
the Registration Request in accordance with this document, when the
HA field in Registration Request is set to ALL-ZERO-ONE-ADDR.

Legacy Foreign Agent:

Legacy foreign agents may forward a Registration Request with home
agent field set to ALL-ZERO-ONE-ADDR by setting the destination IP
address to ALL-ZERO-ONE-ADDR. This will result in the packet being
dropped or incidentally handled by a next-hop HA, adjacent to the FA.
The MN may not be aware of the dropped Registration Request and may
probably retry registration, thereby increasing the delay in
registration.

To reduce the delay in registration, the MN should take the following
steps:

1. The MN should send the Registration Request as specified in this
    specification. In other words, the MN should set the Home Agent
    field in the Registration Request to ALL-ZERO-ONE-ADDR and also
    add the Requested HA Extension.

2. If the MN does not receive a Registration Reply within some time
    and/or after sending a few Registration Requests, it can assume
    that the Registration Request(s) has been dropped, either by a
    legacy FA or an incorrect HA. In addition, if the registration
    is denied with error code 70 (poorly formed Request), the MN can
    assume that the legacy FA cannot process this message. In either
    case, the MN should fall back to a recovery mechanism. The MN
    should quickly send a new Registration Request as mentioned in
    Section 4.1 step 2. This step will ensure that a legacy FA will
    forward the Registration Request to the home agent thereby making
    dynamic HA assignment possible.

Legacy Mobile Node:

An MN that sends a Registration Request to an FA that can do dynamic
HA assignment, but does not set the HA field to ALL-ZERO-ONE-ADDR
will continue to be registered with its statically configured HA,
exactly according to RFC 3344.

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