### Binding Revocation for IPv6 Mobility

Abstract

   This document defines a binding revocation mechanism to terminate a
   mobile node's mobility session and the associated resources.  This
   mechanism can be used both with base Mobile IPv6 and its extensions,
   such as Proxy Mobile IPv6.  The mechanism allows the mobility entity
   which initiates the revocation procedure to request its peer to
   terminate either one, multiple or all specified Binding Cache
   entries.

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## 1.  Introduction

   In the case of Mobile IPv6 and for administrative reasons, sometimes
   it becomes necessary to inform the mobile node that its registration
   has been revoked and the mobile node is no longer able to receive IP
   mobility service for its Home Address.  A similar Mobile IPv4
   registration revocation mechanism [RFC3543] has been specified by the
   IETF for providing a revocation mechanism for sessions that were
   established using Mobile IPv4 registration [RFC3344].

   This document specifies a binding revocation mechanism that can be
   used to revoke a mobile node's mobility session(s).  The same
   mechanism can be used to revoke bindings created using Mobile IPv6
   [RFC3775] or any of its extensions, e.g., Proxy Mobile IPv6
   [RFC5213].  The proposed revocation mechanism uses a new Mobility
   Header (MH) type 16 for revocation signaling that is applicable to
   Mobile IPv6 [RFC3775] and Proxy Mobile IPv6 [RFC5213] and can be used
   by any two IP mobility entities.  As an example, this mechanism
   allows a local mobility anchor (LMA), involved in providing IP
   mobility services to a mobile node, to notify the mobile access
   gateway (MAG) of the termination of that mobile node binding
   registration.  In another example, a mobile access gateway can use
   this mechanism to notify its local mobility anchor peer with a bulk
   termination of all or a subset of proxy mobile IPv6 (PMIPv6) bindings
   that are registered with the local mobility anchor and currently
   being served by the mobile access gateway.  Any mobility entity is
   allowed to revoke only the registration of those mobile node(s)
   mobility sessions that are currently registered with it.

## 2.  Conventions and Terminology

### 2.1.  Conventions Used in This Document

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in [RFC2119].

### 2.2.  Terminology

   All the general mobility related terminology and abbreviations are to
   be interpreted as defined in the Mobile IPv6 [RFC3775], Proxy Mobile
   IPv6 [RFC5213] and IPv4 Support for Proxy Mobile IPv6 [RFC5844]
   specifications.  The following terms are used in this specification.

Initiator

   The mobility node that initiates the binding revocation procedure
   by sending a Binding Revocation Indication message to its peer,
   e.g., home agent, local mobility anchor, or mobile access gateway.

Responder

   The mobility node that receives the Binding Revocation Indication
   message and responds with a Binding Revocation Acknowledgement
   message, e.g., mobile node, mobile access gateway, or local
   mobility anchor.

## 3.  Binding Revocation Protocol and Use Cases Overview

This specification specifies a generic binding revocation mechanism
where a mobility node can communicate to the mobile node or another
mobility node the identity of the mobile node registration binding
that is being terminated.  In the case when this mechanism is used
for bulk termination or multiple bindings, the identities of these
bindings are communicated to the mobile node or mobility node using
the same generic mechanism.  The following subsections present the
protocol overview and applicable use cases.

### 3.1.  Binding Revocation Protocol

In the case of Mobile IPv6, if the home network decides to terminate
the service of the mobile node, the home agent sends a Binding
Revocation Indication (BRI) message to the mobile node.  The home
agent includes the home address (HoA) of the mobile node in the Type
2 routing header as specified in [RFC3775] to indicate the impacted
mobile node binding.  In the case of Dual Stack Mobile IPv6 (DSMIPv6)
[RFC5555], the home agent may include the IPv4 Home Address option
with the home IPv4 address assigned by the mobile node.
Additionally, if the mobile node registered multiple care-of
addresses [RFC5648], the home agent includes the Binding Identifier
(BID) option(s) in the Binding Revocation Indication message to
identify which binding is being revoked.  When the mobile node
receives a Binding Revocation Indication message with its HoA
included in the Type 2 routing header, the mobile node responds by
sending a Binding Revocation Acknowledgement (BRA) message.

Similarly, in the case of Proxy Mobile IPv6 [RFC5213], the revocation
procedure can be initiated by the local mobility anchor by sending a
Binding Revocation Indication message to communicate the termination
of a mobile node registration binding to the mobile access gateway.
In this case, the local mobility anchor includes the mobile node Home
Network Prefix (MN-HNP) option [RFC5213] and the MN-ID option

[RFC4283] to indicate to the mobility access gateway the identity of
the PMIPv6 binding that needs to be terminated.  When the mobile
access gateway receives the Binding Revocation Indication message,
the mobile access gateway responds to the local mobility anchor by
sending a Binding Revocation Acknowledgement message.

On the other hand, the mobile access gateway usually sends a de-
registration message by sending a Proxy Binding Update with a
lifetime of zero to indicate to the local mobility anchor of the
termination of the PMIPv6 mobile node binding registration.  In this
case, the mobile access gateway includes the MN-HNP option, the MN-ID
option, and all other required mobility options as per [RFC5213] in
order for the local mobility anchor to identify the mobile node
PMIPv6 binding.  Additionally, in the case when the mobile access
gateway communicates a bulk termination of PMIPv6 mobility sessions,
the mobile access gateway sends a Binding Revocation Indication
message with the Global (G) bit set and includes the mobile access
gateway identity in the MN-ID option, see Section 9.2 and
Section 8.2.  When the local mobility anchor receives such a Binding
Revocation Indication message, it ensures that the mobile access
gateway is authorized to send such a bulk termination message, see
Section 13, and then processes the Binding Revocation Indication
message accordingly.  If the local mobility anchor processes the
Binding Revocation Indication message successfully, the local
mobility anchor responds to the mobile access gateway by sending
Binding Revocation Acknowledgement message.

In any of the above cases, the initiator of the binding revocation
procedure, e.g., home agent, local mobility anchor, or mobile access
gateway, uses the Revocation Trigger field in the Binding Revocation
Indication message to indicate to the receiving node the reason for
initiating the revocation procedure.

## 3.2.  MIPv6 and DSMIP6 Use Case

The binding revocation mechanism is applicable to Mobile IPv6 and
DSMIPv6 session(s) when the home agent needs to inform the mobile
node that its binding registration has been revoked, e.g., for an
administrative reason.  This mechanism enables the user or the mobile
node to react to the revocation, e.g., reinstate its interrupted
Mobile IPv6 services.

In this case, the home agent sends a Binding Revocation Indication
message to indicate to the mobile node that its current mobile IPv6
(MIPv6) binding has been revoked and it is no longer able to receive
IP mobility service.  The home agent includes the HoA in a Type 2
routing header as used in [RFC3775] and sets the Revocation Trigger
field to a proper value, e.g., Administrative Reason.  In the case of

a DSMIPv6 session, the home agent may additionally include the
mobile-node-assigned IPv4 Home Address in the IPv4 Home Address
option.  When the mobile node receives the Binding Revocation
Indication message, it sends a Binding Revocation Acknowledgement
message to the home agent.  Figure 1 illustrates the message
sequencing when a home agent revokes a mobile node binding
registration.

```
       MN                                             HA
        |                                              |
        |            HoA in Type 2 Routing Hdr         |
        |<<<------------...  +  ...------------------|
        |       BRI [seq.#, Revocation Trigger]        |
        |                                              |
        |                                              |
        | BRA (HoA in Dest. Option)[seq.#, Status]  |
        |--------------------------------------->>>|
        |                                              |
        |                                              |
```
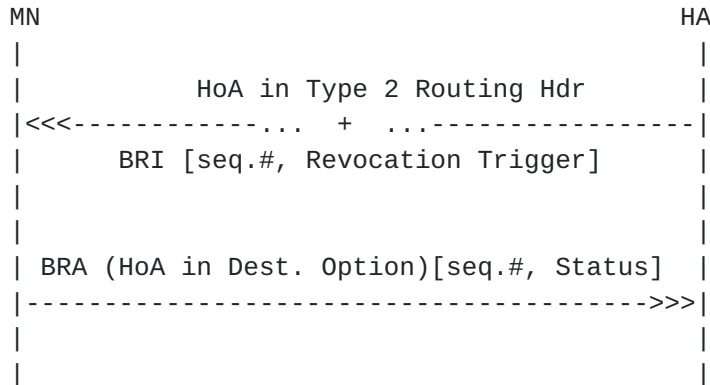
       Figure 1: Home Agent Revokes a Mobile Node Binding Registration

## 3.3.  Multiple Care-of Addresses (MCoA) Use Case

In the case of multiple care-of address registrations [RFC5648], the
home agent maintains a different binding for each care-of address and
home address pair.  These bindings are also indexed and identified
during the mobile node registration using a BID mobility option.  The
HA may revoke one or multiple bindings for the same mobile node home
address.

If the home agent revokes a single binding for a mobile node with
multiple care-of address registrations, the home agent sends a
Binding Revocation Indication message to the mobile node with the
corresponding BID option included.  If more than one of the mobile
node registered care-of addresses needs to be revoked, the home agent
includes all the corresponding BID options in the same Binding
Revocation Indication message.  Figure 2 illustrates the message flow
when the home agent revokes two registered care-of addresses for the
same mobile node in a single Binding Revocation Indication message.

```
                                              HA Binding Cache
                                              ================
                                              MN-BID1 [CoA1+HoA]
   MN                                   HA    MN-BID2 [CoA2+HoA]
    |                                    |    MN-BID3 [CoA3+HoA]
    |                                    |    MN-BID4 [CoA4+HoA]
    |          HoA in Type 2 Routing Hdr |
    |<<<<--------------  +  --------------------|
    |     BRI [seq.#, R. Trigger, BID1, BID4]   |
    |                                    |
    |                                    |
    | BRA (HoA in Dest. Option) [seq.#, Status] |
    |----------------------------------------->>>>|
    |                                    |
    |                                    |
```
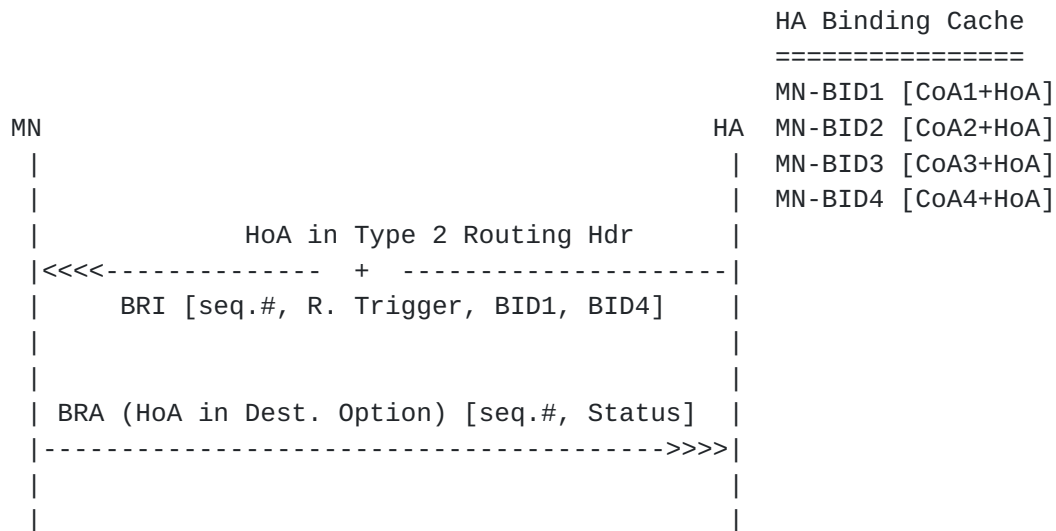
        Figure 2: Home Agent Revokes MN's Specific Care-of Address Bindings

   Additionally, the home agent may revoke all of the mobile node
   registered bindings by sending a BRI message without including any
   BID options while the HoA is included in the Type 2 routing header.
   Figure 1 illustrates the message flow when the home agent revokes all
   registered care-of address bindings for a mobile node in a single
   Binding Revocation Indication message.

## 3.4.  Proxy MIPv6 Use Case

   Since the mobile node does not participate in the mobility mechanism
   in the case of PMIPv6, there are many scenarios where the Binding
   Revocation mechanism is needed to clean resources and make sure that
   the mobility entities, i.e., mobile access gateway and local mobility
   anchor, are always synchronized with respect to the status of the
   existing PMIPv6 bindings.  The binding revocation mechanism is
   generic enough that it can be used for all Proxy Mobile IPv6
   scenarios that follow the [RFC5213] and [RFC5844] specifications.

   When the mobile access gateway receives a Binding Revocation
   Indication message as in Section 9.1, the mobile access gateway sends
   a Binding Revocation Acknowledgement message to the local mobility
   anchor following the rules described in Section 6.1.2.  Similarly, if
   the local mobility anchor receives a Binding Revocation Indication
   message, the local mobility anchor responds to the mobile access
   gateway by sending a Binding Revocation Acknowledgement message.

### 3.4.1.  Local Mobility Anchor Initiates PMIPv6 Revocation

   The local mobility anchor may send a Binding Revocation Indication
   message with the appropriate revocation trigger value to the mobile
   access gateway that hosts a specific PMIPv6 binding to indicate that
   the mobile node binding has been terminated and the mobile access
   gateway can clean up the applicable resources.  When the mobile
   access gateway receives a Binding Revocation Indication message, the
   mobile access gateway identifies the respective binding and it sends
   a Binding Revocation Acknowledgement message to the local mobility
   anchor.  In this case, the mobile access gateway could terminate the
   IPv6 or IPv4 mobility session on the access link and notify the
   mobile node as in Section 9.1.

   As an example, Figure 3, illustrates the message sequence for
   revoking a mobile node binding at the source mobile access gateway
   during the mobile node inter-MAG handover.  During the inter-MAG
   handover, the mobile node moves from the source MAG to the target
   MAG.  The target MAG sends a Proxy Binding Update with the new
   care-of address to the local mobility anchor to update the mobile
   node's point of attachment.  Since the mobile node binding at the
   local mobility anchor points to the source MAG and upon receiving the
   Proxy Binding Update from the target MAG, the local mobility anchor
   updates the MN Binding Cache entry (BCE) and sends a Proxy Binding
   Acknowledgement to the target MAG.  The local mobility anchor can
   send a Binding Revocation Indication message with the appropriate
   revocation trigger value, e.g., inter-MAG handover - different Access
   Types, to the source MAG in order to clean up the applicable
   resources reserved for the specified mobile node binding.  The source
   mobile access gateway acknowledges the Binding Revocation Indication
   message by sending a Binding Revocation Acknowledgement message to
   indicate the success or failure of the termination of the mobile
   node's binding.

   The process identified above can also be used by the local mobility
   anchor in scenarios other than the inter-MAG handover with the proper
   revocation trigger value to indicate to the peer mobile access
   gateway that a specific PMIPv6 binding or bindings have been revoked.

```
        oldMAG          newMAG                          LMA
          |               |                              |
          |               |              PBU             |
          |               |----------------------------->|
          |               |                       PBU triggers
          |               |                      BRI Msg to oldMAG
          |               |                              |
          |               |              PBA             |
          |               |<-----------------------------|
          |               |                              |
          |               |                              |
          |      BRI [seq.#, R. Trigger, P bit, NAI]     |
          |<---------------------------------------------|
          |               |                              |
          |               |                              |
          |               |                              |
          |               |                              |
          |          BRA [seq.#, Status, P bit]          |
          |--------------------------------------------->|
          |               |                              |
          |               |                              |
```
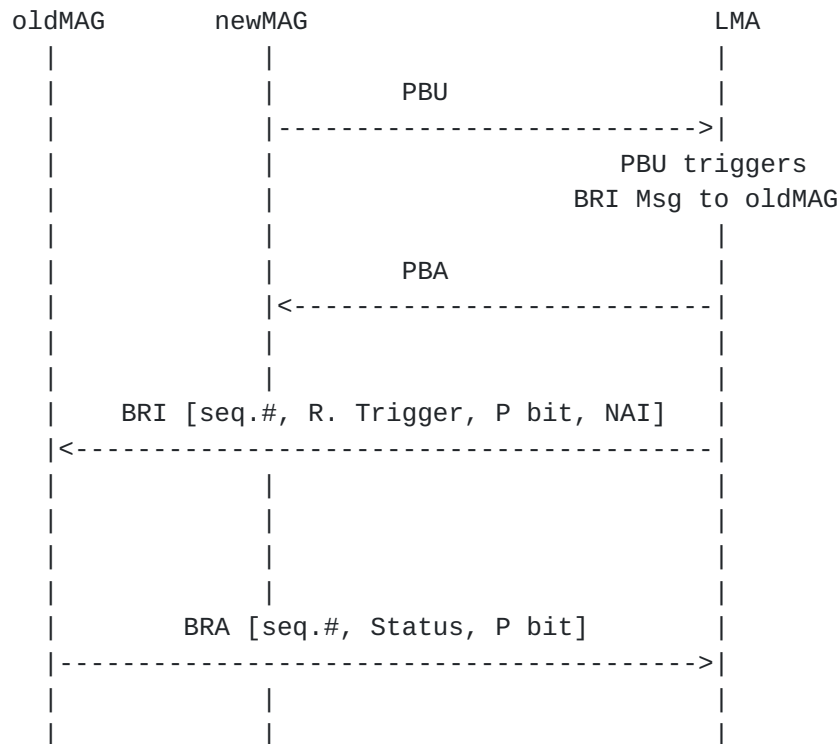
    Figure 3: LMA Revokes an MN Registration During Inter-MAG Handover

    In addition, the local mobility anchor can send a Binding Revocation
    Indication message to indicate that all bindings that are hosted by
    the peer mobile access gateway and registered with the local mobility
    anchor are being revoked by setting the Global (G) bit as described
    in Section 8.1.

## 3.4.2.  Mobile Access Gateway Revokes Bulk PMIPv6 Bindings

    The mobile access gateway sends a BRI message with the Global (G) bit
    set and the Revocation Trigger field set to "Per-Peer Policy" to
    indicate that all mobility bindings that are registered at the local
    mobility anchor and attached to the mobile access gateway are being
    revoked as in Section 9.2.  When the local mobility anchor receives
    this Binding Revocation Indication message from the specified mobile
    access gateway, the local mobility anchor first checks if the mobile
    access gateway is authorized to use global revocations, then it
    responds with the appropriate status code by sending a Binding
    Revocation Acknowledgement message as in Section 6.1.2.

## 4.  Binding Revocation Messages over IPv4 Transport Network

    In some deployments, the network between the mobile access gateway
    and the local mobility anchor may only support IPv4 transport.
    Another case is when a mobile node that supports client mobile IPv6

roams to an access network where only IPv4 addressing and transport
is supported.  In this case, the mobile node is required to register
an IPv4 home address with its home agent using a mobile IPv6 Binding
Update message.

If the Proxy Binding Update and Proxy Binding Acknowledgement
messages or the Binding Update and Binding Acknowledgement messages
are sent using UDP encapsulation [RFC5844] [RFC5555], then the
Binding Revocation Messages are sent using the same UDP
encapsulation.  The same UDP source and destination port numbers and
IPv4 addresses used for exchanging the Proxy Binding Update and Proxy
Binding Acknowledgement or the Binding Update and Binding
Acknowledgement messages MUST be used when transporting Binding
Revocation Messages over IPv4 using UDP encapsulation.  For example,
the source UDP port number, the destination UDP port number, the
source IPv4 address, and the destination IPv4 address of the Binding
Revocation Indication message are set to the destination UDP port
number, the source UDP port number, destination IPv4 address, and
source IPv4 address of the latest received and successfully processed
Proxy Binding Update or Binding Update message, respectively.  For
more details on tunneling Proxy Mobile IPv6 and Mobile IPv6 signaling
messages over IPv4, see [RFC5844] and [RFC5555], respectively.

## 5.  Binding Revocation Message

This section defines the Binding Revocation Message format using an
MH Type 16 as illustrated in Figure 4.  The value in the Binding
Revocation Type field defines whether the Binding Revocation Message
is a Binding Revocation Indication or Binding Revocation
Acknowledgement.  If the Binding Revocation Type field is set to 1,
the Binding Revocation Message is a Binding Revocation Indication as
in Section 5.1.  However, if the value is 2, it is a Binding
Revocation Acknowledgement message as in Section 5.2.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | Payload Proto | Header Len   |   MH Type      |   Reserved   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |           Checksum            |  B.R. Type    |              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+              +
    |                                                             |
    .              Binding Revocation Message Data                .
    |                                                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

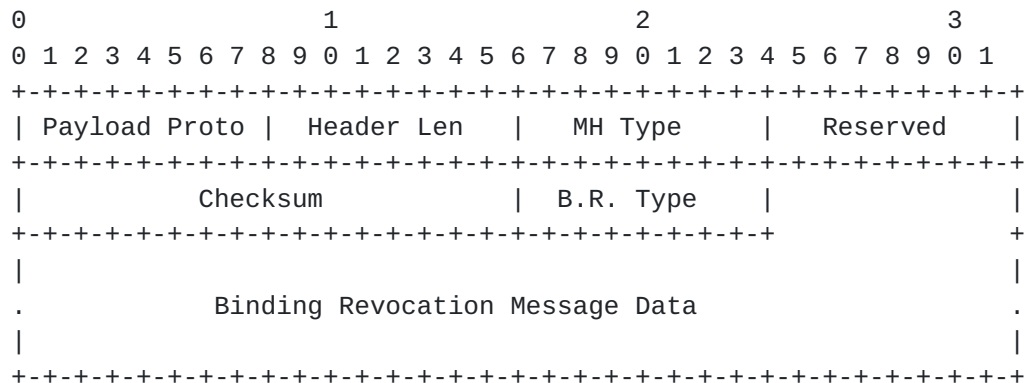                   Figure 4: Binding Revocation Message

Payload Proto

   8-bit selector.  See [RFC3775] for more details.

Header Len

   8-bit unsigned integer.  Representing the length of the Mobility
   Header in units of 8 octets, excluding the first 8 octets.  See
   [RFC3775] for more details.

MH Type

   16, which identifies the mobility message as a Binding Revocation
   Message.

Reserved

   8-bit field reserved for future use.  The value MUST be
   initialized to zero by the sender and MUST be ignored by the
   receiver.

Checksum

   16-bit unsigned integer.  This field contains the checksum of the
   Mobility Header.  The checksum is calculated as described in
   [RFC3775].

Binding Revocation Type

   8-bit unsigned integer.  It defines the type of the Binding
   Revocation Message.  It can be assigned one of the following
   values:

      0  Reserved

      1  Binding Revocation Indication

      2  Binding Revocation Acknowledgement

      All other values are unassigned

Binding Revocation Message Data

   The Binding Revocation Message Data follows the Binding Revocation
   Message format that is defined in this document for the specified
   value in the Binding Revocation Type field.  In this document, it
   is either a Binding Revocation Indication as in Section 5.1 or
   Binding Revocation Acknowledgement as in Section 5.2.

5.1.  **Binding Revocation Indication Message**

   The Binding Revocation Indication (BRI) message is a Binding
   Revocation Message that has an MH type 16 and a Binding Revocation
   Type value of 1.  It is used by the initiator to inform the responder
   of the identity of a specific binding or bindings for which IP
   mobility service are being revoked.  Binding Revocation Indication
   message is sent as described in Sections 7, 8.1, and 9.2.

   When the value 1 is indicated in the Binding Revocation Type field of
   the Binding Revocation Message, the format of the Binding Revocation
   Message Data follows the Binding Revocation Indication message as in
   Figure 5

```
 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
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                | B.R. Type = 1 |  R. Trigger   |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |            Sequence #          |P|V|G|        Reserved        |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 .                                                               .
 .                       Mobility options                        .
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
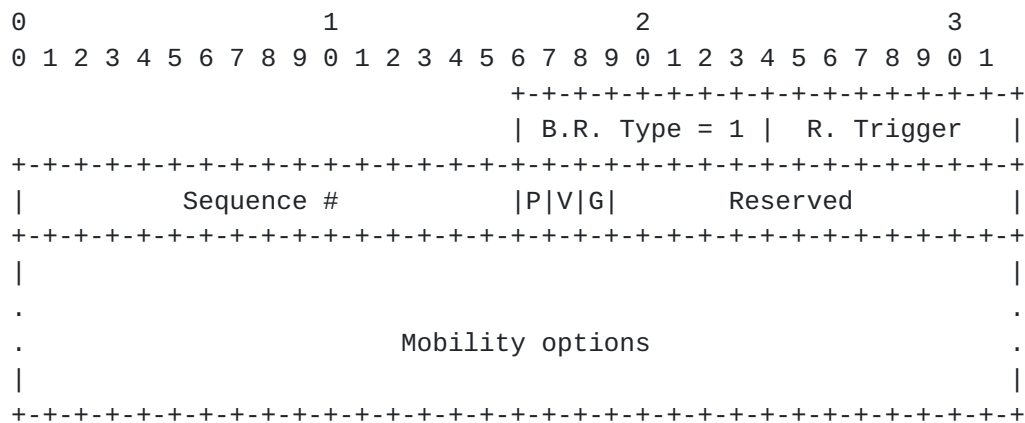
              Figure 5: Binding Revocation Indication Message

   Revocation Trigger

      8-bit unsigned integer indicating the event that triggered the
      initiator to send the BRI message.  The Per-MN Revocation Trigger
      values are less than 128.  The Per-MN Revocation Trigger is used
      when the BRI message intends to revoke one or more bindings for
      the same mobile node.  The Global Revocation Trigger values are
      greater than 128 and less than 250 and used in the BRI message
      when the Global (G) bit is set for global revocation.  The values
      250-255 are reserved for testing purposes only.  The following
      Revocation Trigger values are currently defined:

      Per-MN Revocation Trigger Values:
           0  Unspecified
           1  Administrative Reason
           2  Inter-MAG Handover - same Access Type
           3  Inter-MAG Handover - different Access Type
           4  Inter-MAG Handover - Unknown
           5  User-Initiated Session(s) Termination

          6  Access Network Session(s) Termination
          7  Possible Out-of-Sync BCE State

       Global Revocation Trigger Values:
          128  Per-Peer Policy
          129  Revoking Mobility Node Local Policy

       Reserved Revocation Trigger Values:
          250-255 Reserved For Testing Purposes only
          All other values are Reserved

   Sequence Number

      A 16-bit unsigned integer used by the initiator to match a
      returned Binding Revocation Acknowledgement with this Binding
      Revocation Indication.  This sequence number could be a random
      number.  At any time, implementations MUST ensure there is no
      collision between the sequence numbers of all outstanding Binding
      Revocation Indication Messages.

   Proxy Binding (P)

      The Proxy Binding (P) bit is set by the initiator to indicate that
      the revoked binding(s) is a PMIPv6 binding.

   IPv4 HoA Binding Only (V)

      The IPv4 HoA Binding Only (V) bit is set by the initiator, home
      agent, or local mobility anchor to indicate to the receiving
      mobility entity the termination of the IPv4 Home Address binding
      only as in Sections 7 and 8.1.

   Global (G)

      The Global (G) bit is set by the initiator, LMA or MAG, to
      indicate the termination of all Per-Peer mobility Bindings or
      Multiple Bindings that share a common identifier(s) and are served
      by the initiator and responder as in Sections 8.1 and 9.2.

      Reserved

      These fields are unused.  They MUST be initialized to zero by the
      sender and MUST be ignored by the receiver.

   Mobility Options

      A variable-length field of such length that the complete Mobility
      Header is an integer multiple of 8 octets long.  This field

contains zero or more TLV-encoded mobility options.  This document
does not define any new mobility option.  The receiver MUST ignore
and skip any options that it does not understand.  These mobility
options are used by the responder to identify the specific binding
or bindings that the initiator is requesting be revoked.

The following options are valid in a Binding Revocation Indication:

o  Home Network Prefix option [RFC5213].  This option MAY be used
   only when the (P) bit is set.  This option MUST be present when
   the BRI is used to revoke a single Proxy MIPv6 Binding Cache
   entry.

o  Mobile Node Identifier option [RFC4283].  This option MUST be
   present when the (P) bit is set.  Additionally, if the Global (G)
   bit is set by the mobile access gateway, this option MUST carry
   the MAG identity.  In this specification, only the Mobile Node
   Identifier option with subtype 1 is required and other subtypes
   are currently not supported.

o  Binding Identifier mobility option [RFC5648].  This option MUST be
   present if the initiator requests to terminate one binding of a
   multiple care-of address bindings for the same mobile node.  The
   initiator may include more than one of the BID mobility options.

o  IPv4 Home Address option, which contains the mobile node home IPv4
   address [RFC5555].  This option MUST only be included when the
   IPv4 HoA Binding only (V) bit is set and the (P) bit is cleared.

o  IPv4 Home Address Request option, which contains the mobile node
   proxy home IPv4 address [RFC5844].  This option MUST only be
   included when the IPv4 HoA Binding only (V) and the (P) bits are
   set.

o  Alternate Care-of Address mobility option [RFC3775].  According to
   [RFC5213], the mobile access gateway is allowed to include this
   option in the Proxy Binding Update to indicate the proxy care-of
   address of the mobile node mobility session.  This option MAY be
   included to indicate the proxy care-of address of the mobile
   node's binding that is being revoked.  In the case when the Global
   (G) bit is set, this option identifies all mobility bindings that
   share the same proxy care-of address.

If no mobility options are present in this message, 4 octets of
padding are necessary and the Header Len field of the Binding
Revocation Message will be set to 1.

5.2.  **Binding Revocation Acknowledgement Message**

   The Binding Revocation Acknowledgement (BRA) message is a Binding
   Revocation Message that has an MH type 16 and a Binding Revocation
   Type value of 2.  It is used to acknowledge the receipt of a Binding
   Revocation Indication message described in Section 5.1.  This packet
   is sent as described in Section 6.1.2.

   When the value 2 is indicated in the Binding Revocation Type field of
   the Binding Revocation Message, the format of the Binding Revocation
   Message Data follows the Binding Revocation Acknowledgement message
   as in Figure 6.

```
    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
                                   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                   | B.R. Type = 2 |    Status     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Sequence #          |P|V|G|        Reserved         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                               |
   .                                                               .
   .                        Mobility options                       .
   .                                                               .
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
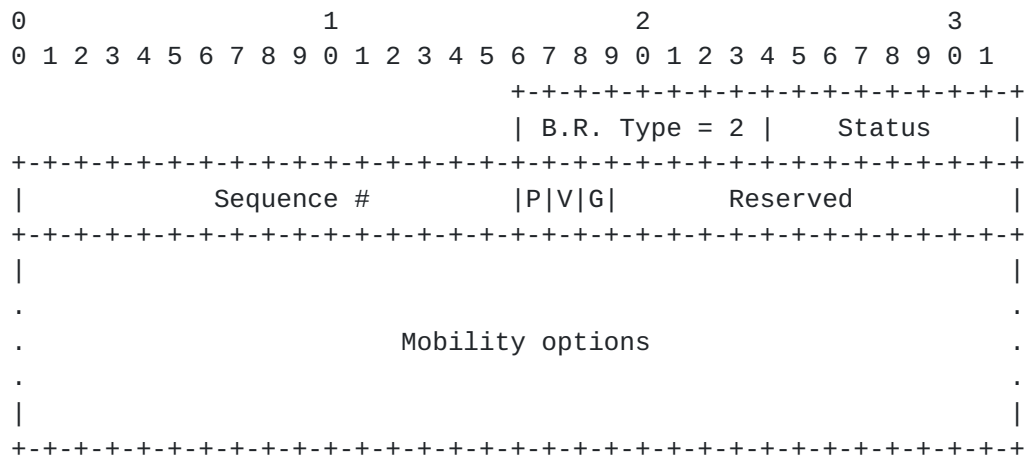
           Figure 6: Binding Revocation Acknowledgement Message

   Status  8-bit unsigned integer indicating the result of processing
      the Binding Revocation Indication message by the responder.
      Values of the Status field less than 128 indicate that the Binding
      Revocation Indication was processed successfully by the responder.
      Values greater than or equal to 128 indicate that the Binding
      Revocation Indication was rejected by the responder.  The
      following Status values are currently defined:

          0  success
          1  partial success
        128  Binding Does NOT Exist
        129  IPv4 Home Address Option Required
        130  Global Revocation NOT Authorized
        131  Revoked Mobile Nodes Identity Required
        132  Revocation Failed - MN is Attached
        133  Revocation Trigger NOT Supported
        134  Revocation Function NOT Supported
        135  Proxy Binding Revocation NOT Supported

Sequence Number

   The sequence number in the Binding Revocation Acknowledgement is
   copied from the Sequence Number field in the Binding Revocation
   Indication.  It is used by the initiator, e.g., HA, LMA, MAG, in
   matching this Binding Revocation Acknowledgement with the
   outstanding Binding Revocation Indication.

Proxy Binding (P)

   The Proxy Binding (P) bit is set if the (P) bit is set in the
   corresponding Binding Revocation Indication message.

IPv4 HoA Binding Only (V)

   The IPv4 HoA Binding Only (V) bit is set if the (V) bit is set in
   the corresponding Binding Revocation Indication message.

Global (G)

   The Global (G) bit is set if the (G) bit is set in the
   corresponding Binding Revocation Indication message.

Reserved

   These fields are unused.  They MUST be initialized to zero by the
   sender and MUST be ignored by the receiver.

Mobility Options

   A variable-length field of such length that the complete Mobility
   Header is an integer multiple of 8 octets long.  This field
   contains zero or more TLV-encoded mobility options.  In the case
   when the Status field is set to success, no mobility option is
   required.  The mobility option(s) is usually used to communicate
   information of the bindings that failed the revocation procedure.

The following mobility options are valid in a Binding Revocation
Acknowledgement:

o  Home Network Prefix option [RFC5213].  This option MAY be included
   only when the (P) bit is set.

o  Mobile Node Identifier Option [RFC4283].  This option MAY be
   included when the (P) bit is set.  This option SHOULD be included
   if the Home Network Prefix option is included.

   o  Binding Identifier mobility option [RFC5648].  The responder MAY
      include this option to indicate the specific BID that failed the
      revocation procedure.

   If no options are present in this message, 4 octets of padding are
   necessary and the Header Len field of the Binding Revocation Message
   will be set to 1.

## 6.  Binding Revocation Process Operation

   The following subsections describe the details of the generic binding
   revocation process as used by the different mobility entities.

### 6.1.  Sending Binding Revocation Message

   When sending a Binding Revocation message, the initiator constructs
   the packet as it would do with any other Mobility Header with the
   exception of setting the MH Type field to 16.

   The Binding Revocation Message MUST be protected using the same
   underlying security association, e.g., IPsec, that is being used
   between the two peers to protect the mobile node's Mobile IPv6 and
   its extensions binding registration signaling.  If IPsec is not used
   as the underlying security mechanism to protect the binding
   registration signaling, the used underlying security mechanism MUST
   provide protection against all identified security threats as
   described under "Security Considerations" in [RFC3775] and [RFC5213].

#### 6.1.1.  Sending Binding Revocation Indication

   The initiator MUST construct the Binding Revocation Message Data
   following the format of the Binding Revocation Indication message as
   described in Section 5.1 and the following:

   o  The initiator MUST set the Sequence Number field to a valid
      sequence number for Binding Revocation.  Since sending a Binding
      Revocation Indication message is not done on a regular basis, a
      16-bit Sequence Number field is large enough to allow the
      initiator to match the Binding Revocation Acknowledgement to the
      associated Binding Revocation Indication using the Sequence Number
      field only.

   o  If the initiator is revoking a binding that was created using
      proxy MIPv6 registration, the initiator MUST set the Proxy Binding
      (P) bit.

o  If the initiator is sending the Binding Revocation Indication
   message to revoke multiple mobility sessions, the initiator MUST
   set the Global (G) bit.  In this case, the initiator MUST set the
   Revocation Trigger field to a valid value from the list of Global
   Revocation Triggers.

o  If the initiator is sending the Binding Revocation Indication
   message with the Global (G) bit cleared, the initiator MUST set
   the Revocation Trigger field to a valid value from the list of
   Per-MN Revocation Triggers.

o  If the initiator is sending the Binding Revocation Indication
   message to indicate the revocation of the mobile node IPv4 HoA
   Binding Only, the initiator MUST set the (V) bit.  In this case,
   the initiator MUST include either the IPv4 Home Address option or
   the IPv4 Home Address Request option in the BRI to identify the
   IPv4 HoA that is being revoked.

## 6.1.2.  Sending Binding Revocation Acknowledgement

The responder MUST send a Binding Revocation Acknowledgement message
to indicate the receipt and the status of processing of the
corresponding Binding Revocation Indication message as follows:

o  Whenever the Binding Revocation Indication is discarded, e.g., as
   described in Section 6.2, a Binding Revocation Acknowledgement
   MUST NOT be sent.  Otherwise, the treatment depends on the
   following rules.

o  If the responder accepts the Binding Revocation Indication
   message, the responder MUST send a successful Binding Revocation
   Acknowledgement with an appropriate status code.

o  If the responder rejects the Binding Revocation Indication
   message, the responder MUST send a Binding Revocation
   Acknowledgement with an appropriate failure status code.

If the Source Address field of the IPv6 header that carried the
Binding Revocation Indication message does not contain a unicast
address, the Binding Revocation Indication packet MUST be silently
discarded.

When the responder acknowledges the received Binding Revocation
Indication message, the responder MUST construct the Binding
Revocation Message Data following the format of the Binding
Revocation Acknowledgement message as described in Section 5.2 and
the following:

o  The responder MUST set the Sequence Number field by copying the
   value from the Sequence Number field of the received Binding
   Revocation Indication.

o  The responder MUST set the Status field to a valid value that
   reflects the status of the processing of the received Binding
   Revocation Indication message.

o  If the (P) bit is set in the received Binding Revocation
   Indication, the responder MUST set the (P) bit in the Binding
   Revocation Acknowledgement.

o  If the Global (G) bit is set in the received Binding Revocation
   Indication, the responder MUST set the Global (G) bit in the
   Binding Revocation Acknowledgement.

o  If the IPv4 HoA Binding Only (V) bit is set in the received
   Binding Revocation Indication, the responder MUST set the (V) bit
   in the Binding Revocation Acknowledgement.

o  The destination IP address of the IPv6 packet of the Binding
   Revocation Acknowledgement is set to the source IP address of the
   received Binding Revocation Indication.

## 6.2. Receiving Binding Revocation Message

When receiving a Binding Revocation Message, the responder MUST
verify the Mobility Header as described in Section 9.2. of [RFC3775].
If the packet is dropped due to failing any of the Mobility Header
test checks, the responder MUST follow the processing rules as in
Section 9.2 of [RFC3775].  If the responder does not support the
Binding Revocation Indication message and does not recognize the MH
type 16, it sends a Binding Error message with the Status field set
to 2 as described in [RFC3775].

Upon receiving a packet carrying a Binding Revocation Message, BRI or
BRA, the receiving mobility entity MUST verify that the packet was
received protected by the security association that is being used to
protect the binding registration and Binding Revocation signaling
between the two peers, e.g., an IPsec Security Association (SA).

## 6.2.1. Receiving Binding Revocation Indication

When the responder receives a packet carrying a Binding Revocation
Indication message that was successfully processed as in Section 6.2,
the responder, in addition, processes the message as follows:

o  The responder MUST validate that the Binding Revocation Indication
   is formatted as in Section 5.1.

o  If the Revocation Trigger field is set to a value that the
   responder does not support, the responder SHOULD reject the
   Binding Revocation Indication message using status code
   "Revocation Trigger NOT Supported".

o  If the Revocation Trigger value is NOT allowed with the Binding
   Revocation Indication message intent, e.g., the Global (G) bit is
   set and the Revocation Trigger field value is Per-MN-specific, the
   responder SHOULD reject the Binding Revocation Indication message
   using status code "Revocation Function NOT Supported".

o  If the responder failed to identify the mobile node(s) bindings as
   identified in the Binding Revocation Indication message, the
   responder MUST reject the BRI using status code "Binding Does NOT
   Exist".

## 6.2.2.  Receiving Binding Revocation Acknowledgement

When the initiator receives a packet carrying a Binding Revocation
Acknowledgement message that was successfully processed as in
Section 6.2, the initiator, in addition, processes the message and
examines the Status field as follows:

o  The initiator MUST validate that the sequence number in the
   Sequence Number field matches the sequence number of an
   outstanding Binding Revocation Indication that was sent by the
   initiator.  If the sequence number does not match a sequence
   number of any of the outstanding Binding Revocation Indication
   messages, the initiator MUST silently discard the message but MAY
   log the event.

o  If the Status field indicates that the Binding Revocation
   Indication was processed successfully, the initiator MUST delete
   the current timer and the mobile node(s) binding(s) and all
   associated resources.

o  If the Status field indicates any value other than success, the
   initiator SHOULD examine any mobility options included in the
   Binding Revocation Acknowledgement.  In this case, it is based on
   the initiator local policy how to handle the mobile node binding.
   The initiator MAY log the appropriate event to reflect the
   received status.

6.3.  Retransmission of Binding Revocation Indication

   If the initiator does not receive a Binding Revocation
   Acknowledgement in response to the outstanding Binding Revocation
   Indication before the InitMINDelayBRIs timer expires, the initiator,
   e.g., LMA, SHOULD retransmit the same BRI message up to the
   BRIMaxRetriesNumber as defined in Section 11.

   The retransmissions by the initiator MUST use an exponential back-off
   process in which the timeout period is doubled upon each
   retransmission, until either the initiator receives a response or the
   timeout period reaches the value MAX_BRACK_TIMEOUT.  The initiator
   MAY continue to send these messages at this slower rate up to the
   BRIMaxRetriesNumber.

   If the initiator does not receive a Binding Revocation
   Acknowledgement message after the BRIMaxRetriesNumber of retransmits
   have been sent, the initiator SHOULD clean up all resources
   associated with this mobile node binding.  The initiator may log the
   event.

7.  Home Agent Operation

   To terminate a mobile node registration and its current binding with
   the home agent, the home agent sends a packet to the mobile node
   containing a Binding Revocation Indication, with the packet
   constructed as follows:

   o  The Revocation Trigger field MUST be set to indicate to the mobile
      node the reason for revoking its IP mobility binding with the home
      agent.  The Revocation Trigger may be used by the mobile node to
      take further steps if necessary.

   o  The Binding Revocation Indication MUST be sent using a Type 2
      routing header that contains the mobile node's registered IPv6
      home address for the binding being revoked.

   o  The care-of address for the binding MUST be used as the
      destination address in the packet's IPv6 header.

   o  If the home agent needs to only revoke the mobile node's IPv4 home
      address binding, the home agent MUST set the IPv4 HoA Binding Only
      (V) bit and MUST include the mobile node's registered IPv4 home
      address that is being revoked in the IPv4 Home Address option.

   When the home agent sends a Binding Revocation Indication to the
   mobile node, the home agent sets a flag in the mobile node BCE to
   indicate that revocation is in progress and starts the

InitMINDelayBRIs timer.  The home agent maintains the mobile node BCE in this state until it receives a Binding Revocation Acknowledgement or retransmits the Binding Revocation Indication message as described in Section 6.3.

In a race condition case, the home agent may receive a Binding Update from the mobile node while the mobile node's BCE has the revocation in progress flag set, the home agent SHOULD handle this case based on the reason for sending the Binding Revocation Indication message and its local policy.  In this case, if the home agent accepts the Binding Update, it needs to update the mobile node BCE accordingly, e.g., removing the revocation in progress flag.

When the home agent needs to revoke one or more of a mobile node bindings that were created using multiple care-of address registrations as in [RFC5648], the home agent MUST include all the related BID mobility options that identify these bindings in the Binding Revocation Indication message.  In the case when the home agent needs to revoke all of the mobile node bindings, the home agent SHOULD NOT include any of the BID mobility options.

When the home agent receives a packet carrying a valid Binding Revocation Acknowledgement message, the home agent follows Section 6.2 in processing this message.

## 8.  Local Mobility Anchor Operation

### 8.1.  Sending Binding Revocation Indication

To terminate a mobile node PMIPv6 registration and its current binding with the local mobility anchor, the local mobility anchor sends a packet to the mobile access gateway containing a Binding Revocation Indication message following the procedure in Section 6.1 and the following rules:

o  The Proxy Binding (P) bit MUST be set to indicate that the binding being revoked is a PMIPv6 binding.

o  The Revocation Trigger field MUST be set to indicate to the mobile access gateway the reason for removing the specified mobile node PMIPv6 binding at the local mobility anchor.  The Revocation Trigger may be used by the mobile access gateway to learn the mobile node's latest movement.

o  The packet MUST contain the Mobile Node Identifier (MN-ID) option, which contains the mobile node's Network Access Identifier (NAI) that was used in the Proxy Binding Update during the mobile node registration.

o  If the Mobile Node Identifier (MN-ID) is registered in more than
   one of the mobile node's BCEs and the local mobility anchor does
   NOT need to revoke all of the mobile node's bindings, the Binding
   Revocation Indication message MUST contain another identifier to
   uniquely identify the mobile node binding(s) that is being
   revoked, e.g., at least one Home Network Prefix option that
   contains the mobile node's registered Home Network Prefix (HNP)
   for the binding being revoked.

o  In the case of revoking all Per-Peer bindings, the local mobility
   anchor MUST set the Global (G) bit and the Revocation Trigger MUST
   contain the value "Per-Peer Policy" to request the mobile access
   gateway to remove all Per-Peer bindings that are registered with
   the local mobility anchor and this mobile access gateway.

o  The proxy care-of address for the binding MUST be used as the
   destination address in the packet's IPv6 header.  However, in the
   case when IPsec is used to protect the Proxy MIPv6 signaling as
   specified in [RFC5213], the destination address MUST be set to the
   mag_address that is being used for keying the IPsec SA.  If the
   mag_address is different than the mobile node proxy care-of
   address, the Alternate Care-of Address option MUST be included and
   MUST contain the mobile node proxy care-of address.

The local mobility anchor MAY delete the mobile node(s) IP tunnel
immediately after sending the initial Binding Revocation Indication
and before receiving the Binding Revocation Acknowledgement message.

When the local mobility anchor sends a Binding Revocation Indication
to the mobile access gateway to remove a specific binding, the local
mobility anchor sets a flag in the mobile node proxy BCE to indicate
that revocation is in progress and starts the InitMINDelayBRIs timer.
The local mobility anchor SHOULD maintain the mobile node proxy BCE
in this state until it receives a Binding Revocation Acknowledgement
or the BRIMaxRetransmitNumber is reached.  In the case when the local
mobility anchor sets the Revocation Trigger field to a value that
indicates inter-MAG handover, the local mobility anchor MAY switch
the mobile node IP tunnel to the target mobile access gateway before
sending the Binding Revocation Indication to the source mobile access
gateway.

In a race condition case, the local mobility anchor may receive a
Proxy Binding Update from the mobile access gateway while the mobile
node's proxy BCE has the revocation in progress flag set.  The local
mobility anchor should handle this case based on the reason for
sending the Binding Revocation Indication message and its local

policy.  In this case, if the local mobility anchor accepts the Proxy
Binding Update, it needs to update the mobile node proxy BCE
accordingly, e.g., removing the revocation in progress flag.

When the local mobility anchor needs to revoke all the mobile node
proxy BCEs that are registered with the local mobility anchor and the
mobile access gateway peer, it MUST set the Global (G) bit and set
the value of the Revocation Trigger field to "Per-Peer Policy".  In
this case, the local mobility anchor MUST NOT include any mobility
options in this Binding Revocation Indication message.

When the local mobility anchor needs to revoke all mobile nodes proxy
BCEs that belong to a specific realm and are registered with the
local mobility anchor and the mobile access gateway peer, the local
mobility anchor MUST set the Global (G) bit and set the value of the
Revocation Trigger field to "Revoking Mobility Node Local Policy".
In this case, the local mobility anchor MUST include a mobility
option in the Binding Revocation Indication that is shared among all
the impacted mobile nodes BCEs, e.g., the mobile node identifier
option, MN-ID option, with a subtype value of 1.  In this case, the
NAI value in the MN-ID MUST follow the format where the content after
the "@" character defines the realm that is shared amongst all of the
impacted mobile nodes proxy BCEs.  As an example: @example.com
identifies all mobile nodes whose MN-ID value contains "example.com"
as the realm, e.g., "1234abdelta@example.com", "axxxyzd@example.com",
and "abcdefg.xyz123@example.com", but not
"1234abdelta@foo.example.com".

When the local mobility anchor needs to revoke a subgroup of the
mobile nodes proxy BCEs that belong to a specific realm and are
registered with the local mobility anchor and the mobile access
gateway, the local mobility anchor MUST set the Global (G) bit and
set the value of the Revocation Trigger field to "Revoking Mobility
Node Local Policy".  In this case, the local mobility anchor MUST
include an additional mobility option to the mobile node identifier
option (MN-ID) option, with a subtype value of 1.  In other words,
the impacted mobile node BCEs are those that have an MN-ID with a
realm as specified above and, e.g., are assigned the same proxy
care-of address as the one included in the Alternate Care-of Address
mobility option.

When the mobile node is registered with multiple Home Network
Prefixes for the same proxy care-of address, the local mobility
anchor SHOULD include an HNP option for each registered HNP in the
Binding Revocation Indication.  Alternatively, it MAY include only
the mobile node identifier (MN-ID) option with the mobile node NAI
included to indicate to the mobile access gateway to remove all
bindings of the specified mobile node NAI in the MN-ID option.

According to the Proxy Mobile IPv6 specification [RFC5213], if the
local mobility anchor receives a Proxy Binding Update message from a
new mobile access gateway for extending the binding lifetime of the
only BCE of this mobile node with the Handoff Indicator value set to
"Handoff state unknown (4)", the local mobility anchor waits a period
of MaxDelayBeforeNewBCEAssign to receive a de-registration message
from the previous mobile access gateway before updating the mobile
node's BCE with the new point of attachment.  If a de-registration
message is not received, the local mobility anchor considers the
received Proxy Binding Update message as a request for a new BCE and
if processed successfully, the local mobility anchor assigns a
different HNP for the new BCE.

This document updates the local mobility anchor's behavior in this
case.  If the local mobility anchor supports the binding revocation
mechanism as described in this document, it SHOULD proactively send a
Binding Revocation Indication message to the previous mobile access
gateway instead of waiting for a de-registration from the previous
mobile access gateway.  In the Binding Revocation Indication message,
the Revocation Trigger MUST be set to "Inter-MAG Handover - Unknown".

If the local mobility anchor sent a Binding Revocation Indication
message with the Revocation Trigger field set to "Inter-MAG Handover
- Unknown" and while waiting for a response, Binding Revocation
Acknowledgement, the following are possible conditions that the local
mobility anchor MUST handle as specified below:

o  If the local mobility anchor receives a successful Binding
   Revocation Acknowledgement message or a de-registration message
   from the previous mobile access gateway, the local mobility anchor
   MUST update the mobile node BCE as if it received a de-
   registration message as described in [RFC5213].

o  If the local mobility anchor receives a Binding Revocation
   Acknowledgement message with the Status field set to "Revocation
   Failed - MN is Attached", the local mobility anchor SHOULD update
   the mobile node BCE as if it did NOT receive a de-registration
   before the MaxDelayBeforeNewBCEAssign timer expired by creating a
   new BCE as described in [RFC5213].

o  If the local mobility anchor did not receive a Binding Revocation
   Acknowledgement message or a de-registration Proxy Binding Update
   from the previous mobile access gateway after it exhausted all of
   the Binding Revocation Indication message retransmissions as
   described in Section 6.3, the local mobility anchor SHOULD update
   the mobile node's BCE as if it did NOT receive a de-registration
   before the MaxDelayBeforeNewBCEAssign timer expired by creating a
   new BCE as described in [RFC5213].  Note that the local mobility

anchor SHOULD use the recommended number of retransmissions for
the Binding Revocation Indication message as described in
Section 11 to avoid delaying the creation of a new Binding Cache
entry for too long, if the mobile node is actually attaching to
the new MAG with a different interface.

When the mobile node is registered with an IPv4 proxy home address in
addition to the Home Network Prefix where both of the IPv4 proxy HoA
(pHoA) and HNP are bound to the same proxy CoA (pCoA), the local
mobility anchor MAY revoke the mobile node IPv4 proxy HoA binding to
the current mobile node proxy CoA while maintaining the mobile node
binding of the HNP to its current pCoA as part of the mobile node
BCE.  In this case, if the local mobility anchor decides to revoke
the mobile node IPv4 proxy HoA only, it MUST send a Binding
Revocation Indication message following the procedure in Section 6.1
and the following rules:

o  The IPv4 HoA Binding Only (V) bit MUST be set in the BRI to
   indicate that only the IPv4 home address binding is being revoked.

o  The IPv4 Home Address Request option MUST be included with the
   mobile node's registered proxy home IPv4 address that is being
   released in addition to the MN-ID option.

o  The mobile node Home Network Prefix option MUST NOT be included.

o  The Revocation Trigger field MUST be set to an appropriate value,
   e.g., "User Initiated Session(s) Termination".

## 8.2.  Receiving Binding Revocation Indication

When the local mobility anchor receives a packet carrying a Binding
Revocation Indication that was successfully processed as in
Section 6.2, the local mobility anchor processes the message as
follows:

o  If the (P) bit is set, the local mobility anchor MUST validate
   that all impacted bindings have the proxy binding flag set.

o  If the Global (G) bit is set and the Revocation Trigger field
   value is "Per-Peer Policy", the LMA MUST validate that the Proxy
   (P) bit is set and the MN-ID option is present with the mobile
   access gateway identity included.  In addition, the local mobility
   anchor MUST verify that the identified mobile access gateway as
   per the value in the MN-ID option is authorized to use the global
   revocation with revocation trigger value "Per-Peer Policy", see
   Section 13.  If the local mobility anchor processes the Global

Binding Revocation Indication message successfully, it MUST accept the Binding Revocation Indication message using the status code "success".

o  If the mobile access gateway is not authorized to use the Per-Peer Global revocation feature or the received Binding Revocation Indication message has the Global (G) bit set and the Revocation Trigger field is set to "Per-Peer Policy", but the MN-ID option is not included, the local mobility anchor MUST reject the Binding Revocation Indication message using status code "Global Revocation NOT Authorized".

o  If the Global (G) bit is set and the Revocation Trigger value is "Per-Peer Policy", and only the mobile node identifier (MN-ID) option is included, the local mobility anchor MUST revoke all mobile node bindings for which the proxy CoA is the one used as the source of the IPv6 packet that carried the Binding Revocation Indication.  However, if the Alternate Care-of Address option is included in addition to the mobile node identifier option, the local mobility anchor MUST revoke all mobile node bindings whose proxy care-of address matches the care-of address in the Alternate Care-of Address option.  After the local mobility anchor successfully processes the Binding Revocation Indication message and identifies all impacted mobile nodes bindings, it MUST accept the Binding Revocation Indication message using the status code "success".

o  If the local mobility anchor accepted the Binding Revocation Indication message but one or more of the bindings identified in the received Binding Revocation Indication message has already been released, the local mobility anchor MUST accept the message and it MAY set the Status field to "partial success" and include the mobile node identifier (MN-ID) or the Home Network Prefix option to identify the binding(s) that failed the revocation procedure.

o  If the Global (G) bit is not set, the local mobility anchor uses the included mobility options to identify the impacted mobile node binding as follows:

   1.  If only the mobile node identifier (MN-ID) option is included, the local mobility anchor MUST accept the message and revoke all bindings for this mobile node that use the specified mobile node NAI including the IPv4 Home Address binding(s) if present.

   2.  If the mobile node identifier (MN-ID) and one Home Network
       Prefix option are included, the local mobility anchor MUST
       accept the message and only remove the specified mobile node
       proxy binding.

   3.  If the mobile node identifier (MN-ID) option and more than one
       Home Network Prefix options are included, the local mobility
       anchor MUST accept the message and remove all bindings that
       are referenced by these Home Network Prefixes for the
       specified mobile node NAI.

   4.  If the IPv4 HoA binding Only (V) bit is set and the mobile
       node identifier (MN-ID) option and the IPv4 Home Address
       Request option are included, the local mobility anchor MUST
       accept the message and remove only the IPv4 HoA address
       binding to the mobile node current proxy care-of address.

   The Revocation Trigger field value in the received Binding Revocation
   Indication could be used by the local mobility anchor to log an event
   or update some local parameters that track the state of the peer
   mobile access gateway.

   After the local mobility anchor accepts or rejects a Binding
   Revocation Indication message, the local mobility anchor MUST follow
   Sections 6.1 and 6.1.2 to send a Binding Revocation Acknowledgement
   message to the mobile access gateway.

## 9.  Mobile Access Gateway Operation

## 9.1.  Receiving Binding Revocation Indication

   When the mobile access gateway receives a packet carrying a Binding
   Revocation Indication that was successfully processed as in
   Section 6.2, the mobile access gateway processes the message as
   follows:

   o  If the Global (G) bit is set and the Revocation Trigger field
      value is "Per-Peer Policy", the mobile access gateway MUST
      validate that the Proxy (P) bit is set and no mobility options are
      included in the message.  If the mobile access gateway processes
      the Global Binding Revocation Indication message successfully, it
      MUST accept the Binding Revocation Indication message using the
      status code "success".

   o  If the Global (G) bit is set and the Revocation Trigger field
      value is "Revoking Mobility Node Local Policy", the mobile access
      gateway MUST validate that the Proxy (P) bit is set and at least
      the MN-ID option with the subtype value of 1 is included in the

Binding Revocation Indication and it is formatted as described is
Section 8.1.  If the mobile access gateway processes this Global
Binding Revocation Indication message successfully, it MUST accept
the message using the status code "success".

o  If the Global (G) bit is set and the Revocation Trigger field
   value is "Revoking Mobility Node Local Policy", and no mobility
   options are included in the Binding Revocation Indication message
   or the mobile access gateway is not able to identify the impacted
   mobile nodes bindings based on the included mobility options, the
   mobile access gateway MUST treat this as an error scenario.  In
   this case, the mobile access gateway MUST reject the Binding
   Revocation Indication message using status code "Revoked Mobile
   Nodes Identity Required".

o  If the Revocation Trigger field value in the received Binding
   Revocation Indication message indicates inter-MAG handover, e.g.,
   Inter-MAG Handover - Unknown, the mobile access gateway uses the
   mobility option(s) included in the Binding Revocation Indication
   message to identify the mobile node binding.  The mobile access
   gateway SHOULD ensure that the mobile node is no longer attached
   to the mobile access gateway before accepting the BRI message
   using status code "success".  However, if the mobile access
   gateway verified that the mobile node is still directly attached,
   the mobile access gateway MUST reject the BRI using status code
   "Revocation failed - MN is Attached".

o  If the IPv4 HoA Binding Only (V) bit is set, the mobile access
   gateway uses the MN-ID option to identify the mobile node binding
   entry in the Binding Update List (BUL).  The mobile access gateway
   MUST verify that the IPv4 address included in the IPv4 Home
   Address Request option in the received Binding Revocation
   Indication is the same as the IPv4 proxy HoA that is assigned to
   the mobile node.  After the mobile access gateway successfully
   validates the received IPv4 home address as the mobile node IPv4
   HoA, it MUST consider this as an indication to ONLY release the
   mobile node IPv4 proxy HoA binding to the mobile node current
   proxy CoA.  Consequently, it MUST continue to maintain the mobile
   node IPv6 proxy HoA or HNP binding to the current mobile node
   proxy CoA as part of the mobile node binding in the BUL entry and
   release all resources associated with the MN IPv4 proxy HoA
   binding to the MN pCoA.  If the mobile access gateway processed
   the BRI successfully, the mobile access gateway MUST accept the
   BRI using status code "success".  On the other hand, if the mobile
   access gateway is able to identify the mobile node binding using
   the MN-ID but failed to identify the received IPv4 proxy HoA, the
   mobile access gateway MUST reject the BRI using status code
   "Binding Does NOT Exist".

   o  If the mobile access gateway accepts the Binding Revocation
      Indication message but one or more of the bindings identified in
      the received Binding Revocation Indication message has already
      been released before processing the Binding Revocation Indication,
      the mobile access gateway MUST accept the Binding Revocation
      Indication message.  In this case, the mobile access gateway MAY
      set the Status field to "partial success" and include the mobile
      node identifier (MN-ID) or the Home Network Prefix option to
      identify the binding(s) that failed to be removed as part of the
      revocation procedure.

   The Revocation Trigger field value in the received Binding Revocation
   Indication could be used by the mobile access gateway to define what
   actions the mobile access gateway could do to inform the mobile node
   that its IP connectivity to the current HNP has been terminated,
   e.g., if the Revocation Trigger field is set to "Administrative
   Reason", the mobile access gateway may terminate the IPv6 or IPv4
   mobility session on the access link and notify the mobile node.  The
   specific details and considerations on how the mobile access gateway
   terminates IPv6 or IPv4 mobility session on the access link and
   notifies the mobile node can be found in [RFC5213] and [RFC5844].

   After the mobile access gateway accepts or rejects a Binding
   Revocation Indication message, the mobile access gateway MUST follow
   Sections 6.1 and 6.1.2 to send a Binding Revocation Acknowledgement
   message to the local mobility anchor.

## 9.2.  Sending Binding Revocation Indication

   The mobile access gateway could send a Binding Revocation Indication
   message to indicate the termination of multiple mobile node bindings,
   e.g., when using the global revocation with the Global (G) bit set.
   In this case, when an event occurs that requires the mobile access
   gateway to inform the local mobility anchor peer to terminate all
   mobile node bindings that are registered at the local mobility anchor
   and the mobile access gateway, the mobile access gateway sends a
   Binding Revocation Indication message following the procedure in
   Section 6.1 and the following:

   o  The Proxy Binding (P) bit MUST be set to indicate that the
      binding(s) being revoked is a PMIPv6 binding.

   o  The Global (G) bit MUST be set and the Revocation Trigger MUST
      contain a value of "Per-Peer Policy" in the Binding Revocation
      Indication to request the local mobility anchor to remove all Per-
      Peer bindings that are registered with the local mobility anchor
      and the mobile access gateway.  In this case, the MN-ID option
      MUST be included in the Binding Revocation Indication and contain

   the mobile access gateway identity.  In addition, the mobile
   access gateway MAY include the Alternate Care-of Address option.
   If included, the Alternate Care-of Address option MUST contain the
   proxy care-of address the bindings that are being impacted by this
   Binding Revocation Indication message.

   o  The mobile access gateway address MAY be used as the source
      address in the packet's IPv6 header.

   As described in Section 6.3, the mobile access gateway SHOULD
   retransmit the Binding Revocation Indication to the local mobility
   anchor until it receives a matching Binding Revocation
   Acknowledgement or the BRIMaxRetransmitNumber is reached.  The mobile
   access gateway MAY delete the mobile node IP tunnels immediately
   after sending the Binding Revocation Indication and before receiving
   a Binding Revocation Acknowledgement message from the LMA.

   In response to a Binding Revocation Indication message, if the mobile
   access gateway receives a packet carrying a Binding Revocation
   Acknowledgement that was successfully processed as in Section 6.2 and
   the Status field indicates "Global Revocation NOT Authorized", the
   mobile access gateway is not authorized to participate in a Per-Peer
   Global Revocation.  The mobile access gateway SHOULD NOT retry
   sending a Binding Revocation Indication with the Global (G) bit set
   and the Revocation Trigger field value set to "Per-Peer Policy" to
   the same local mobility agent.  The mobile access gateway should
   raise an alarm or log an event to indicate this rejection.

10.  Mobile Node Operation

   Upon receiving a packet carrying a Binding Revocation Indication, the
   mobile node MUST validate the packet according to Section 6.2 and the
   following tests:

   o  The mobile node MUST verify that the IP address in the Type 2
      routing header is its Home Address and that its Binding Update
      List contains an entry for that Home Address.  If one of the tests
      fails, the mobile node SHOULD silently discard the received
      Binding Revocation Indication message.

   o  If mobile node Binding Update List contains an entry for the IP
      address in the Type 2 routing header of the received Binding
      Revocation Indication packet, the mobile node MUST accept the BRI
      message using status code "success".

   o  If the IPv4 HoA Binding Only (V) bit is set in the received BRI
      message, the mobile node MUST verify that there is an IPv4 Home
      Address option in the received Binding Revocation Indication and

the IPv4 address included in the IPv4 Home Address option is the
same as its IPv4 HoA that is assigned to the mobile node.  If this
verification is successful, the mobile node MUST consider this
Binding Revocation Indication as an indication to ONLY release the
mobile node IPv4 HoA binding to its current care-of address.
Consequently, the mobile node MUST continue to maintain its IPv6
HoA binding to the current CoA as part of the mobile node binding
in the BUL entry and release all resources associated with the MN
IPv4 HoA binding.  In this case, the mobile node MUST accept the
Binding Revocation Indication message using status code "success".
On the other hand, if the IPv4 Home Address Option was NOT
included in the received BRI with the (V) bit is set, the MN MUST
reject the BRI message with status code "IPv4 Home Address Option
Required".  Additionally, if the IPv4 HoA received in the IPv4
Home Address Option is NOT the one assigned to the mobile node,
the mobile node SHOULD reject the Binding Revocation Indication
with status code "Binding Does NOT Exist".

o  The mobile node MUST verify that the (P) bit in the Binding
   Revocation Indication is NOT set.  If the (P) bit is set, the
   mobile node MUST reject the Binding Revocation Indication using
   status code "Proxy Binding Revocation NOT Supported".

o  If the mobile node has registered multiple care-of addresses with
   its home agent, the mobile node MUST verify which binding is being
   revoked by examining the content of the Binding Revocation
   Indication message.  If the mobile node received a Binding
   Revocation Indication with one or more BID options and its home
   address is included in the Type 2 routing header, the mobile node
   MUST consider all of the care-of addresses bindings, identified in
   the BID options, with this home address as being revoked.  In this
   case, if the BRI validation is successful, the mobile node MUST
   accept the Binding Revocation Indication message with status code
   "success".

o  If the mobile node has multiple care-of address bindings with its
   home agent and received a Binding Revocation Indication, without
   any BID option included and its home address was included in the
   Type 2 routing header, the mobile node MUST consider all of its
   registered care-of address bindings with this home address as
   being revoked.  If the mobile node validates the BRI successfully,
   the mobile node MUST accept the Binding Revocation Indication
   message with status code "success".

If the mobile node accepts or rejects the Binding Revocation
Indication message, the mobile node MUST follow Sections 6.1 and
6.1.2 to send a Binding Revocation Acknowledgement message to the
home agent.  Note that anytime the MN does not send a Binding

Revocation Acknowledgement to a BRI, the initiator is likely to
retransmit the BRI at least one time.  This causes additional load on
the initiator who sends the retransmissions, as well as on the MN
that will receive and process them.

The Revocation Trigger field value in the received Binding Revocation
Indication could be used by the mobile node to define what action the
mobile node could do to be able to register again and receive its IP
mobility service, e.g., contacting its home operator.

## 11.  Protocol Configuration Variables

Any mobility entity that is allowed to invoke the binding revocation
procedure by sending a Binding Revocation Indication message SHOULD
allow the following variables to be configured.

BRI Maximum Number of Retries (BRIMaxRetriesNumber)

   This variable specifies the maximum Number of times a mobility
   entity can retransmit a Binding Revocation Indication message
   before receiving a Binding Revocation Acknowledgement message.
   The default value for this parameter is 1.

Initial Minimum Delay Between BRI messages (InitMINDelayBRIs)

   This variable specifies the initial delay timeout in seconds
   before the revoking mobility entity retransmits a BRI message.
   The default is 1 second but is not to be configured to less than
   0.5 seconds.

Maximum BRA TIMEOUT (MAX_BRACK_TIMEOUT)

   This variable specifies the maximum delay timeout in seconds
   before the revoking mobility entity retransmits a BRI message.
   The default is 2 seconds.

## 12.  IANA Considerations

This specification defines a new Binding Revocation Message using a
new Mobility Header Type 16, as described in Section 5.  The new
Mobility Header type value needs to be assigned from the same
numbering space as allocated for the other Mobility Header types
registry.

This document also creates a new registry "Binding Revocation Type"
that indicates the type of the binding revocation message.  The
current binding revocation message types are described in Sections
5.1 and 5.2, and are the following:

          0   Reserved
          1   Binding Revocation Indication
          2   Binding Revocation Acknowledgement
          All other values are unassigned

   Future values of the Binding Revocation Type can be allocated using
   Standards Action or IESG Approval [RFC5226].

   In addition, this document also creates a second new registry for the
   Revocation Trigger that indicates the reason behind sending the
   Binding Revocation Indication message.  The current Revocation
   Trigger values are described in Section 5.1, and are the following:

   Per-MN Revocation Trigger Values:
          0   Unspecified
          1   Administrative Reason
          2   Inter-MAG Handover - same Access Type
          3   Inter-MAG Handover - different Access Type
          4   Inter-MAG Handover - Unknown
          5   User-Initiated Session(s) Termination
          6   Access Network Session(s) Termination
          7   Possible Out-of-Sync BCE State

   Global Revocation Trigger Values:
          128  Per-Peer Policy
          129  Revoking Mobility Node Local Policy

   Reserved Revocation Trigger Values:
          250-255 Reserved For Testing Purposes only
          All other values are Unassigned

   Future values of the Revocation Trigger can be allocated using
   Standards Action or IESG Approval [RFC5226].

   Furthermore, this document creates a third new registry "Binding
   Revocation Acknowledgement Status Codes".  The current values are
   described in Section 5.2, and are the following:

           0   success
           1   partial success
         128   Binding Does NOT Exist
         129   IPv4 Home Address Option Required
         130   Global Revocation NOT Authorized
         131   Revoked Mobile Nodes Identity Required
         132   Revocation Failed - MN is Attached
         133   Revocation Trigger NOT Supported
         134   Revocation Function NOT Supported
         135   Proxy Binding Revocation NOT Supported

Future values of the Status field can be allocated using Standards
Action or IESG Approval [RFC5226].

All fields labeled "Reserved" are only to be assigned through
Standards Action or IESG Approval.

## 13.  Security Considerations

This specification allows the mobility node that initiates the
binding revocation procedure to revoke a mobility session(s) that is
currently registered with it.  It is NOT allowed for any mobility
node to revoke a mobile node mobility session that is not registered
with this mobility node.

The binding revocation protocol described in this specification uses
the same security association between the mobile node and the home
agent or the mobile access gateway and the local mobility anchor that
is being used to exchange the MIPv6 or PMIPv6 Binding Update and
Binding Acknowledgement signaling.  If IPsec is used, the traffic
selectors associated with the Security Policy Database (SPD) entry
protecting the Binding Update and Binding Acknowledgement MUST be
extended to include Binding Revocation Message MH type 16.  Extending
the traffic selectors of the SPD entry in order to reuse the SA
protecting the Binding Update and Binding Acknowledgement (instead of
creating new ones) ensures that those SAs will be up and running when
the revoking entity needs to send a binding revocation signaling
message.

On the other hand, if IPsec is not used as the underlying security
mechanism to protect the Mobile IPv6 and its extensions binding
registration signaling, the used underlying security mechanism MUST
provide protection against all identified security threats as
described under "Security Considerations" in [RFC3775] and [RFC5213].

Since some mobility entities, e.g., local mobility anchor and mobile
access gateway, are allowed to send and receive Binding Revocation
Indications and Binding Revocation Acknowledgements for different
cases, when IPsec is used to secure signaling between the local
mobility anchor and mobile access gateway, it prevents any of them
from processing a Binding Revocation Message that was not constructed
by an authorized party.

The Proxy Mobile IPv6 [RFC5213] requires the local mobility anchor to
restrict the creation and manipulation of proxy bindings to
specifically authorized mobile access gateways.  Therefore, the
mobile access gateway that is authorized to create or manipulate the
mobile node proxy BCE is also authorized to revoke such mobile node
registration by sending a de-registration with lifetime of zero.

However, since bulk termination using Binding Revocation Indication
with the Global (G) bit set and the Revocation Trigger field set to
"Per-Peer Policy" impacts all mobility sessions that are registered
with the mobile access gateway and its local mobility anchor peer,
the local mobility anchor MUST be locally configurable to authorize
such specific functionality.  Additional mechanisms, such as a policy
store or Authentication, Authorization, and Accounting (AAA) may be
employed, but these are outside the scope of this specification.

## [14](#).  Acknowledgements

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## [15](#).  References

### [15.1](#).  Normative References

[RFC2119]   Bradner, S., "Key words for use in RFCs to Indicate
            Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.

[RFC5226]   Narten, T. and H. Alvestrand, "Guidelines for Writing an
            IANA Considerations Section in RFCs", [BCP 26](#), [RFC 5226](#),
            May 2008.

[RFC3775]   Johnson, D., Perkins, C., and J. Arkko, "Mobility Support
            in IPv6", [RFC 3775](#), June 2004.

[RFC4283]   Patel, A., Leung, K., Khalil, M., Akhtar, H., and K.
            Chowdhury, "Mobile Node Identifier Option for Mobile IPv6
            (MIPv6)", [RFC 4283](#), November 2005.

[RFC5213]   Gundavelli, S., Leung, K., Devarapalli, V., Chowdhury, K.,
            and B. Patil, "Proxy Mobile IPv6", [RFC 5213](#), August 2008.

[RFC5844]   Wakikawa, R. and S. Gundavelli, "IPv4 Support for Proxy
            Mobile IPv6", [RFC 5844](#), May 2010.

   [RFC5648]  Wakikawa, R., Devarapalli, V., Tsirtsis, G., Ernst, T.,
              and K. Nagami, "Multiple Care-of Addresses Registration",
              RFC 5648, October 2009.

   [RFC5555]  Soliman, H., "Mobile IPv6 Support for Dual Stack Hosts and
              Routers", RFC 5555, June 2009.

## 15.2.  Informative References

   [RFC3344]  Perkins, C., "IP Mobility Support for IPv4", RFC 3344,
              August 2002.

   [RFC3543]  Glass, S. and M. Chandra, "Registration Revocation in
              Mobile IPv4", RFC 3543, August 2003.

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