                        Diameter Mobile IPv6:
          Support for Home Agent to Diameter Server Interaction

Abstract

   Mobile IPv6 deployments may want to bootstrap their operations
   dynamically based on an interaction between the home agent and the
   Diameter server of the Mobile Service Provider. This document
   specifies the interaction between a Mobile IP home agent and a
   Diameter server.

   This document defines the home agent to the Diameter server
   communication when the mobile node authenticates using the Internet
   Key Exchange v2 protocol with the Extensible Authentication Protocol
   or using the Mobile IPv6 Authentication Protocol. In addition to
   authentication and authorization, the configuration of Mobile IPv6-
   specific parameters and accounting is specified in this document.

Status of This Memo

   This is an Internet Standards Track document.

   This document is a product of the Internet Engineering Task Force
   (IETF). It represents the consensus of the IETF community. It has
   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG). Further information on
   Internet Standards is available in Section 2 of RFC 5741.

   Information about the current status of this document, any errata,
   and how to provide feedback on it may be obtained at
   http://www.rfc-editor.org/info/rfc5778.

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1. Introduction

   Performing the Mobile IPv6 protocol [RFC3775] requires the mobile
   node (MN) to own a home address and to have an assigned home agent
   (HA) to the MN. The MN needs to register with the HA in order to
   enable its reachability and mobility, when away from its home link.
   The registration process itself may require an establishment of IPsec
   security associations (SAs) and cryptographic material between the MN
   and the HA. Alternatively, the registration process may be secured
   using a mobility message authentication option, which enables IPv6
   mobility in an MN without having to establish an IPsec SA with its
   HA. Providing the collection of home address, HA address, and keying
   material is generally referred to as the Mobile IPv6 bootstrapping
   problem [RFC4640]. The purpose of this specification is to provide
   Diameter support for the interaction between the HA and the
   Authentication, Authorization, and Accounting (AAA) server. This
   specification satisfies the requirements defined in [RFC5637] for the
   bootstrapping problem in the split scenario [RFC5026] and also
   specifies Diameter support for the Authentication Protocol for Mobile
   IPv6 [RFC4285]. The Diameter support defined in this specification
   also applies to Dual Stack Mobile IPv6 [RFC5555].

   From a Mobility Service Provider (MSP) perspective, it is important
   to verify that the MN is authenticated and authorized to utilize
   Mobile IPv6 service, and is accounted for those. Only when the MN is
   authenticated and authorized does the MSP allow the bootstrapping of
   Mobile IPv6 parameters. Thus, prior to processing the Mobile IPv6
   registrations, the HA participates in the authentication of the MN to
   verify the MN's identity. The HA also participates in the Mobile
   IPv6 authorization process involving the Diameter infrastructure.
   The HA, due to its role in traffic forwarding, may also perform
   accounting for the Mobile IPv6 service provided to the MN.

   This document enables the following functionality:

   Authentication: The MN's identity needs to be verified. As a
      Diameter client supporting the new Diameter Mobile IPv6
      application, the HA may need to support more than one
      authentication type depending on the environment. Although the
      authentication is performed by the AAA server, there is an impact
      for the HA as different sets of command codes are needed for the
      respective authentication procedures.

   Authorization: The HA must verify that the user is authorized to the
      Mobile IPv6 service using the assistance of the MSP Diameter
      servers. This is accomplished through the use of new Diameter
      applications specifically designed for performing Mobile IPv6

authorization decisions. This document defines required AAA
procedures and requires the HA to support them and to participate
in this authorization signaling.

Accounting: For accounting purposes and capacity planning, it is
required that the HA provides accounting reports to the Diameter
infrastructure and thus supports the related Diameter accounting
procedures.

Session Management: The management of the mobility services may
require the Diameter server or the HA to terminate the Mobile IPv6
service before the binding expires. This document defines
procedures for the AAA-based session management.

Figure 1 depicts the reference architecture for this document.

```
                              +--------+
                              |Diameter|
                              |Server  |
                              +--------+
                                  ^
                         Back-End | Diameter Mobile IPv6
                         Protocol | HA<->AAA Server
                         Support  | Interaction
                                  | (this document)
                                  v
    +---------+              +---------------+
    | Mobile  |  Front-End Protocol |Home Agent /   |
    | Node    |<-------------------->|Diameter Client|
    +---------+  IKEv2 or RFC 4285  +---------------+
```
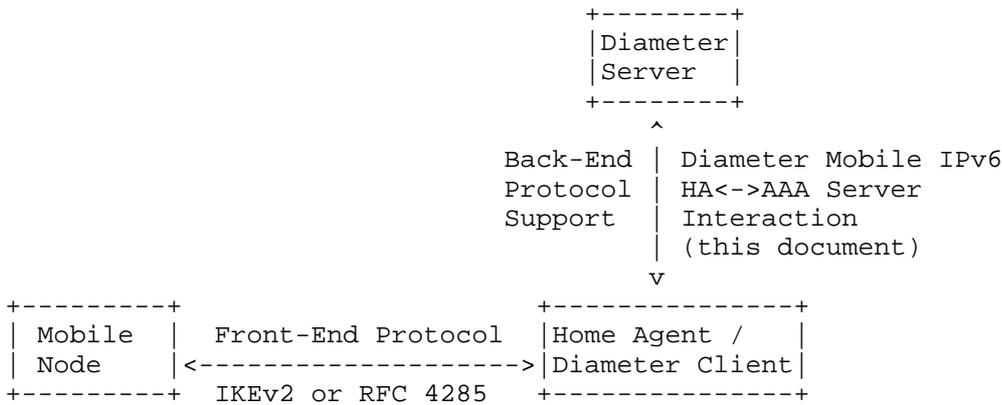
                Figure 1: Architecture Overview

Mobile IPv6 signaling between the MN and the HA can be protected
using two different mechanisms, namely, using IPsec or the
Authentication Protocol for Mobile IPv6 [RFC4285]. For these two
approaches, several different authentication and key exchange
solutions are available. When IPsec is used to protect Mobile IPv6
signaling messages, Internet Key Exchange v2 (IKEv2) is used
[RFC4877] for the setup of the IPsec SAs. IKEv2 supports EAP-based
(Extensible Authentication Protocol) initiator authentication,
certificates, and pre-shared secrets. Alternatively, the
Authentication Protocol for Mobile IPv6 uses a mechanism that is very
similar to the one used for protecting Mobile IPv4 signaling
messages.

The ability to use different credentials and methods to authenticate
the MN has an impact on the AAA interactions between the HA (acting
as a Diameter client) and the Diameter server. This specification is
only limited to the following MN authentication methods:

o IKEv2 usage with EAP

o Mobile IPv6 Authentication Protocol

New authentication mechanisms may be added later by separate
specifications.

For accounting of Mobile IPv6 services provided to the MN, this
specification uses the Diameter base protocol accounting defined in
[RFC3588].

2. 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 [RFC2119].

The Mobile IPv6 bootstrapping terminology is taken from [RFC4640].
Additional terminology is defined below:

Authentication, Authorization, and Accounting (AAA):

   AAA protocol based on Diameter [RFC3588] with required EAP support
   [RFC4072].

Home AAA (AAAH):

   An authentication, authorization, and accounting server located in
   the user's home network, i.e., in the home realm.

3. Application Identifiers

This specification defines two new Diameter applications and their
respective Application Identifiers:

   Diameter Mobile IPv6 IKE   (MIP6I) 7
   Diameter Mobile IPv6 Auth (MIP6A) 8

The MIP6I Application Identifier is used when the MN is authenticated
and authorized using IKEv2. The MIP6A Application Identifier is used
when the MN is authenticated and authorized using the Mobile IPv6
Authentication Protocol.

Mobile IPv6-related accounting information generated by the HA uses
either the MIP6I or the MIP6A Application Identifier in the case of
the coupled accounting model. The Diameter Base Accounting
Application Identifier (value of 3) is used in the case of the split
accounting model. Refer to Section 4.4 for more information
regarding the accounting models.

4. Protocol Description

4.1. Support for Mobile IPv6 with IKEv2 and EAP

The use of IKEv2 with EAP between the MN and the HA allows the AAA to
authenticate the MN. When EAP is used with IKEv2, the Diameter EAP
application logic and procedures, as defined in [RFC4072], are re-
used. EAP methods that do not establish a shared key SHOULD NOT be
used, as they are subject to a number of man-in-the-middle attacks as
stated in Section 2.16 and Section 5 of [RFC4306]. Attribute-value
pairs (AVPs) specific to Mobile IPv6 bootstrapping are added to the
EAP application commands.

Figure 2 shows the message flow involved during the authentication
phase when EAP is used. The communication between the mobile node
and the home agent uses the conventions defined in [RFC4306].
Similarly, the communication between the home agent and the Diameter
server uses the conventions defined in [RFC4072].

```
       Mobile                        Home                     Diameter
       Node                          Agent                    Server
        |                              |                           |
        | HDR, SAi1, KEi, Ni  (1)      |                           |
        |----------------------------->|                           |
        |                              |                           |
        | HDR, SAr1, KEr, Nr, [CERTREQ](2)                         |
        |<-----------------------------|                           |
        |                              |                           |
        | HDR, SK{IDi,[CERTREQ,] [IDr,]|                           |
        | [CP(CFG_REQUEST),]           |                           |
        | SAi2, TSi, TSr} (3)          | DER (EAP-Response) (4) +  |
        |----------------------------->| MIP6 Bootstrapping AVPs   |
        |                              |-------------------------->|
        |                              |                           |
        |                              | DEA (EAP-Request) (5)     |
        | HDR, SK{IDr, [CERT,] AUTH, EAP}|<-----------------------|
        |<-----------------------------|                           |
        |                              |                           |
        | HDR, SK{EAP}                 |                           |
        |----------------------------->| DER (EAP-Response)        |
        |                              |-------------------------->|
        |                              |                           |
        |                              | DEA (EAP-Request)         |
        | HDR, SK{EAP-Request}         |<-------------------------|
        |<-----------------------------|                           |
        |                              |                           |
        | HDR, SK{EAP-Response}        |                           |
        |----------------------------->| DER (EAP-Response)        |
        |                              |-------------------------->|
        :             ...              :          ...              :
        |                              |                           |
        |                              | DEA (EAP-Success) +       |
        |                              | MIP6 Bootstrapping AVPs   |
        | HDR, SK{EAP-Success}         |<-------------------------|
        |<-----------------------------|                           |
        |                              |                           |
        | HDR, SK{AUTH}                |                           |
        |----------------------------->|                           |
        |                              |                           |
        | HDR, SK{AUTH, [CP(CFG_REPLY,]|                           |
        | SAr2, TSi, TSr}              |                           |
        |<-----------------------------|                           |
        |                              |                           |
```
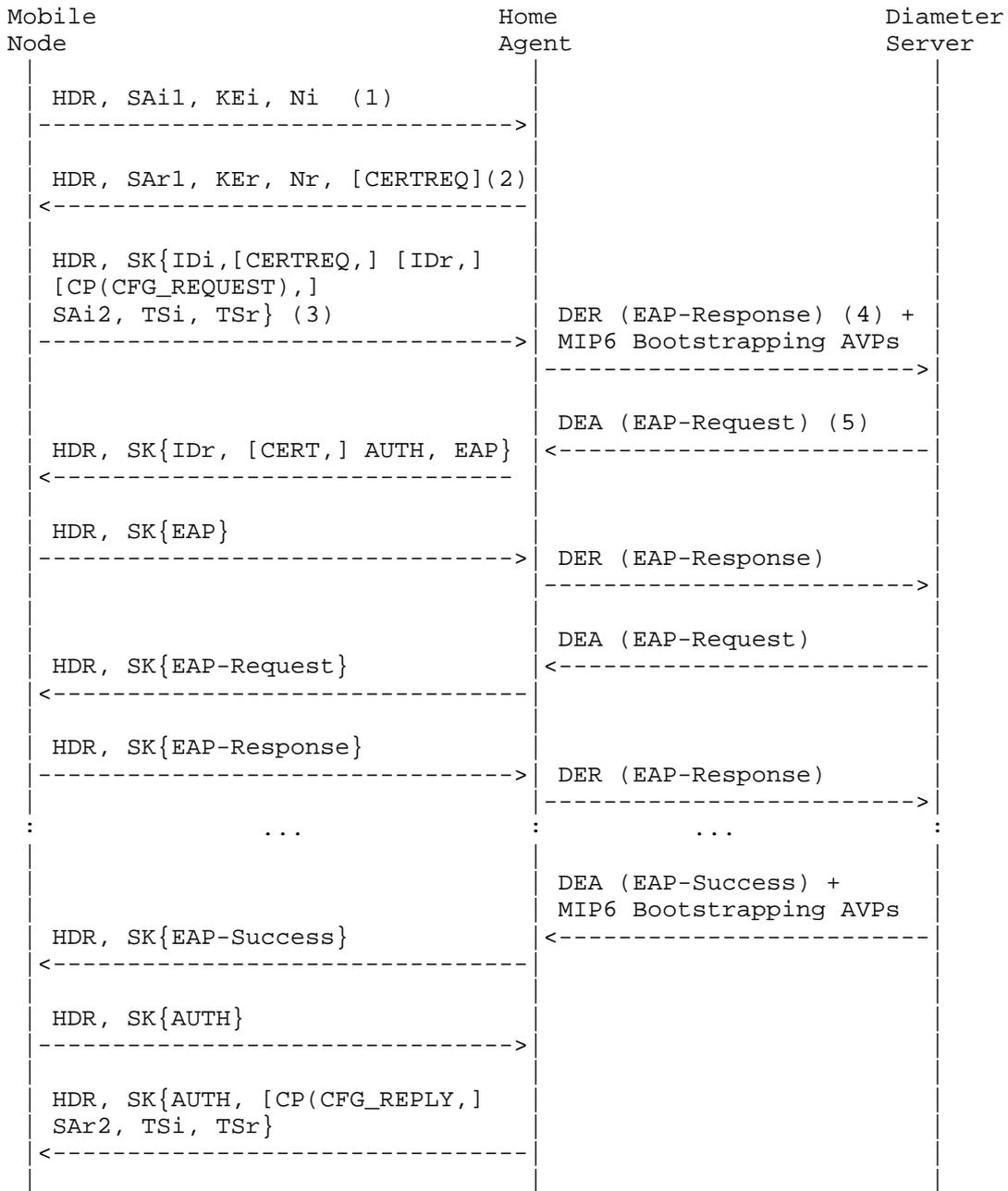
           Figure 2: Mobile IPv6 Bootstrapping Using IKEv2 and EAP

    The MN and the HA start the interaction with an IKE_SA_INIT exchange.

In this phase, cryptographic algorithms are negotiated, and nonces
and Diffie-Hellman parameters are exchanged. Message (3) starts the
IKE_AUTH phase. This second phase authenticates the previous
messages, exchanges identities and certificates, and establishes the
first CHILD_SA. It is used to mutually authenticate the MN (acting
as an IKEv2 initiator) and the HA (acting as an IKEv2 responder).
The identity of the user/MN is provided in the IDi field. The MN
indicates its willingness to be authenticated via EAP by omitting the
AUTH field in message (3) (see Section 2.16 of [RFC4306]).

As part of the authentication process, the MN MAY request a home
address or a home prefix or suggest one (see [RFC4877]), using a
CFG_REQUEST payload in the message (3).

The HA extracts the IDi field from the message (3) and sends a
Diameter-EAP-Request (DER) message (4) towards the authenticating
Diameter server. The EAP-Payload AVP contains a EAP-Response/
Identity with the identity extracted from the IDi field.

This message is routed to the MN's Diameter server/EAP server. The
Diameter server selects the EAP method and replies with the Diameter-
EAP-Answer (DEA) message. Depending on the type of EAP method
chosen, a number of DER and DEA messages carry the method-specific
exchanges between the MN and the Diameter server/EAP server.

At the end of the EAP authentication phase, the Diameter server
indicates the result of the authentication in the Result-Code AVP and
provides the corresponding EAP packet (EAP Success or EAP Failure).
The last IKEv2 message sent by the HA contains the home address or
the home prefix. In the latter case, a CREATE_CHILD_SA exchange is
necessary to set up IPsec SAs for Mobile IPv6 signaling.

In some deployment scenarios, the HA may also act as an IKEv2
responder for a conventional IPsec VPN access. The challenge in this
case is that the IKEv2 responder may not know if IKEv2 is used for
Mobile IPv6 service or for IPsec VPN access service. A network
operator needs to be aware of this limitation. One solution already
supported by IKEv2 is to use different responder identities when
operating as a conventional IPsec VPN gateway or as an HA. The MN
can then indicate the preferred responder type using the appropriate
IDr payload in the IKE_AUTH message.

Eventually, when the HA receives a Binding Update (BU), the HA
authenticates and authorizes the MN. It is RECOMMENDED that the HA
sends an accounting request message every time it receives a BU.

4.2. Support for the Mobile IPv6 Authentication Protocol

   Figure 3 shows the message sequence between the MN, the HA, and the
   Diameter server during the registration when Mobile IPv6
   Authentication Protocol is used. A BU and a Binding Acknowledgement
   (BA) messages are used in the binding registration process.

   Receiving a BU at the HA initiates a MIP6-Request to be sent to the
   Diameter server. The Diameter server in turn responds with a MIP6-
   Answer. The HA may assign a home address to the MN and provide it to
   the Diameter server in the MIP-Mobile-Node-Address AVP.

   According to [RFC4285], the MN uses the Mobile Node Identifier
   Option, specifically the MN-NAI mobility option (as defined in
   [RFC4283]) to identify itself. The HA MUST copy the MN-NAI mobility
   option value to the User-Name AVP in the subsequent request messages.

   The procedure described in this specification for the Mobile IPv6
   Authentication Protocol is only needed for the initially received BU
   for which the HA does not have an existing security association.
   When the HA receives subsequent BUs, they are processed locally in
   the HA. It is RECOMMENDED that the HA sends an accounting request
   message every time it receives a Binding Update. However, the HA MAY
   re-authorize the MN with the Diameter server at any time depending on
   the deployment and the local policy.

   This specification assumes that in the case where Mobile IPv6
   Authentication Protocol is used, the MN-AAA option is included in the
   BU as defined in [RFC4285] and the Diameter server computes required
   session keys after having successfully authenticated the MN. The
   computation of the session keys is out of scope of this
   specification. Other possible ways of using the Mobile IPv6
   Authentication Protocol are also out of scope of this specification
   and would require a new specification to describe the detailed
   behavior of the HA-AAAH interface and corresponding session key
   derivation.

```
      Mobile                            Home                  Diameter
      Node                              Agent                   Server
       |                                 |                        |
       |                                 | MIP6-Request + MIP6    |
       |          Binding Update         | Bootstrapping AVPs     |
       |-------------------------------->|-------------------->|
       | (Mobile Node Identifier Option, |                        |
       |  Mobility Message Replay Protection |                    |
       |  Option, Authentication Option) |                        |
       |                                 |                        |
       |                                 | MIP6-Answer + MIP6     |
       |      Binding Acknowledgement    | Bootstrapping AVPs     |
       |<--------------------------------|<--------------------|
       | (Mobile Node Identifier Option  |                        |
       |  Mobility Message Replay Protection |                    |
       |  Option, Authentication Option) |                        |
```

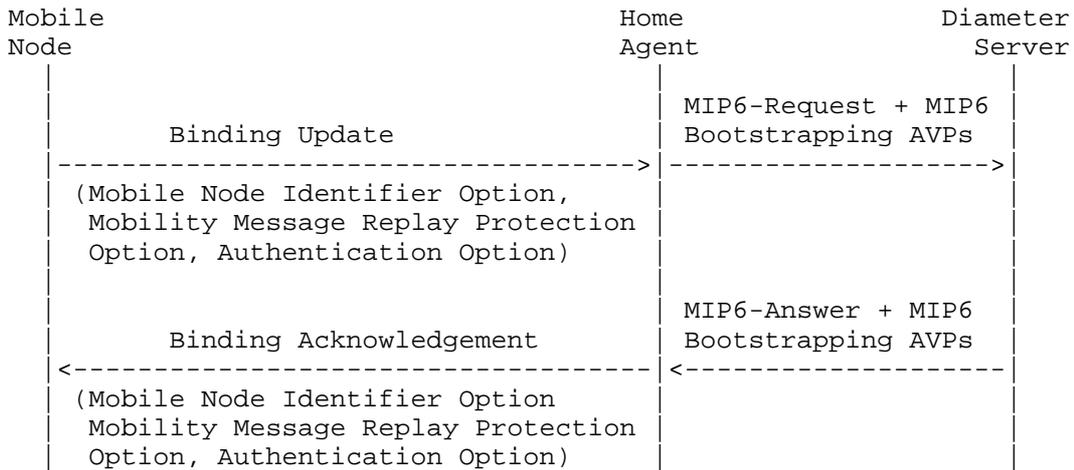   Figure 3: Mobile IPv6 Bootstrapping Using the Mobile IPv6
                           Authentication Protocol

4.3. Mobile IPv6 Session Management

   The Diameter server may maintain state or may be stateless. This is
   indicated in the Auth-Session-State AVP (or its absence). The HA
   MUST support the Authorization Session State Machine defined in
   [RFC3588].

   This specification makes an assumption that each SA created between
   the MN and the HA as a result of a successful IKEv2 negotiation or a
   Mobile IPv6 Authentication Protocol exchange corresponds to one
   Diameter session. In the IKEv2 case, we specifically mean the
   created IKE SA.

4.3.1. Session-Termination-Request

   The Session-Termination-Request (STR) message [RFC3588] is sent by
   the HA to inform the Diameter server that an authorized session is
   being terminated. This means that the HA MUST terminate the
   corresponding Mobile IPv6 binding and also terminate the
   corresponding SA.

4.3.2. Session-Termination-Answer

   The Session-Termination-Answer (STA) message [RFC3588] is sent by the
   Diameter server to acknowledge the notification that the session has
   been terminated.

4.3.3. Abort-Session-Request

   The Abort-Session-Request (ASR) message [RFC3588] is sent by the
   Diameter server to the HA to terminate the authorized session. This
   fulfills one of the requirement described in [RFC5637]. When the HA
   receives the ASR message, it MUST terminate the corresponding SA.
   Subsequently, the HA MUST take further actions to terminate the
   corresponding Mobile IPv6 binding.

4.3.4. Abort-Session-Answer

   The Abort-Session-Answer (ASA) message [RFC3588] is sent by the home
   agent in response to an ASR message.

4.4. Accounting for Mobile IPv6 Services

   The HA MUST be able act as a Diameter client collecting accounting
   records needed for service control and charging. The HA MUST support
   the accounting procedures (specifically the command codes mentioned
   below) and the Accounting Session State Machine as defined in
   [RFC3588]. The command codes, exchanged between the HA and Diameter
   server for accounting purposes, are provided in the following
   subsections.

   The Diameter application design guideline [DIME-APP] defines two
   separate models for accounting:

   Split accounting model:

      According to this model, the accounting messages use the Diameter
      Base Accounting Application Identifier (value of 3). Since
      accounting is treated as an independent application, accounting
      commands may be routed separately from the rest of application
      messages and thus the accounting messages generally end up in a
      central accounting server. Since the Diameter Mobile IPv6
      application does not define its own unique accounting commands,
      this is the preferred choice, since it permits use of centralized
      accounting for several applications.

   Coupled accounting model:

      In this model, the accounting messages will use either the MIP6I
      or the MIP6A Application Identifiers. This means that accounting
      messages will be routed like any other Mobile IPv6 application
      messages. This requires the Diameter server in charge of Mobile
      IPv6 application to handle the accounting records (e.g., sends
      them to a proper accounting server).

As mentioned above, the preferred choice is to use the split
accounting model and thus to choose Diameter Base Accounting
Application Identifier (value of 3) for accounting messages.

4.4.1. Accounting-Request

The Accounting-Request command [RFC3588] is sent by the HA to the
Diameter server to exchange accounting information regarding the MN
with the Diameter server.

4.4.2. Accounting-Answer

The Accounting-Answer command [RFC3588] is sent by the Diameter
server to the HA to acknowledge an Accounting-Request.

5. Command Codes

5.1. Command Code for Mobile IPv6 with IKEv2 and EAP

For the use of Mobile IPv6 with IKEv2 and EAP, this document reuses
the Diameter EAP application [RFC4072] commands: Diameter-EAP-Request
(DER) and Diameter-EAP-Answer (DEA). This specification extends the
existing DER and DEA command ABNFs with a number of AVPs to support
Mobile IPv6 split scenario bootstrapping. Other than new additional
AVPs and the corresponding additions to the command ABNFs, the
Diameter EAP application command ABNFs remain unchanged. The ABNF
language is defined in [RFC3588].

```
Command-Name          Abbrev. Code Reference Application
---------------------------------------------------------------------
Diameter-EAP-Request  DER     268  RFC 4072  Diameter Mobile IPv6 IKE
Diameter-EAP-Answer   DEA     268  RFC 4072  Diameter Mobile IPv6 IKE
```

Figure 4: Command Codes

5.1.1. Diameter-EAP-Request

The Diameter-EAP-Request (DER) message, indicated by the Command-Code
field set to 268 and the 'R' bit set in the Command Flags field, is
sent by the HA to the Diameter server to initiate a Mobile IPv6
service authentication and authorization procedure. The
Application-ID field of the Diameter Header MUST be set to the
Diameter Mobile IPv6 IKE Application ID (value of 7). The grouped
AVP has the following modified ABNF (as defined in [RFC3588]):

```
<Diameter-EAP-Request> ::= < Diameter Header: 268, REQ, PXY >
                            < Session-Id >
                            { Auth-Application-Id }
                            { Origin-Host }
                            { Origin-Realm }
                            { Destination-Realm }
                            { Auth-Request-Type }
                            [ Destination-Host ]
                            [ NAS-Identifier ]
                            [ NAS-IP-Address ]
                            [ NAS-IPv6-Address ]
                            [ NAS-Port-Type ]
                            [ User-Name ]
                            ...
                            { EAP-Payload }
                            ...
                            [ MIP6-Feature-Vector ]
                            [ MIP6-Agent-Info ]
                          *2[ MIP-Mobile-Node-Address ]
                            [ Chargeable-User-Identity ]
                            [ Service-Selection ]
                            [ QoS-Capability ]
                          * [ QoS-Resources ]
                            ...
                          * [ AVP ]
```

   Mobile IPv6 bootstrapping AVPs are only included in the first DER
   message send by the HA. The subsequent DER messages required by the
   EAP method do not need to include any Mobile IPv6 bootstrapping AVPs.
   The MN is both authenticated and authorized for the mobility service
   during the EAP authentication. Thus, the Auth-Request-Type AVP MUST
   be set to the value AUTHORIZE_AUTHENTICATE.

5.1.2. Diameter-EAP-Answer

   The Diameter-EAP-Answer (DEA) message, indicated by the Command-Code
   field set to 268 and 'R' bit cleared in the Command Flags field, is
   sent in response to the Diameter-EAP-Request (DER) message. The
   Application-Id field in the Diameter message header MUST be set to
   the Diameter Mobile IPv6 IKE Application-Id (value of 7). If the
   Mobile IPv6 authentication procedure was successful, then the
   response MAY include any set of bootstrapping AVPs.

```
<Diameter-EAP-Answer> ::= < Diameter Header: 268, PXY >
                          < Session-Id >
                          { Auth-Application-Id }
                          { Auth-Request-Type }
                          { Result-Code }
                          { Origin-Host }
                          { Origin-Realm }
                          [ User-Name ]
                          [ EAP-Payload ]
                          [ EAP-Reissued-Payload ]
                          [ EAP-Master-Session-Key ]
                          [ EAP-Key-Name ]
                          [ Multi-Round-Time ]
                          ...
                       *2[ MIP-Mobile-Node-Address ]
                          [ MIP6-Feature-Vector ]
                          [ MIP6-Agent-Info ]
                          [ Service-Selection ]
                       * [ QoS-Resources ]
                          [ Chargeable-User-Identity ]
                          ...
                       * [ AVP ]
```

If the EAP-based authentication and the authorization for the
mobility service succeeds, then the Mobile IPv6 bootstrapping AVPs
are included in the last DEA message that also carries the EAP-
Success EAP payload. The other DEA messages required by the used
EAP-method do not include any Mobile IPv6 bootstrapping AVPs.

5.2. Command Codes for Mobile IPv6 Authentication Protocol Support

   This section defines the commands that are used for support with the
   Mobile IPv6 Authentication Protocol.

   There are multiple ways of deploying and utilizing the Mobile IPv6
   Authentication Protocol, especially regarding the associated AAA
   interactions. In order to support multiple deployment models, this
   specification defines the MIP6-Auth-Mode AVP that in the request
   message tells the mode that the HA supports. This specification
   defines a method that requires the use of the MN-AAA option with the
   Mobile IPv6 Authentication Protocol.

```
Command-Name        Abbrev.  Code   Reference  Application
-------------------------------------------------------------------
MIP6-Request        MIR      325    5.3.1      Diameter Mobile IPv6 Auth
MIP6-Answer         MIA      325    5.3.2      Diameter Mobile IPv6 Auth
```

Command Codes

5.2.1. MIP6-Request

   The MIP6-Request (MIR), indicated by the Command-Code field set to
   325 and the 'R' bit set in the Command Flags field, is sent by the
   HA, acting as a Diameter client, in order to request the
   authentication and authorization of an MN.

   Although the HA provides the Diameter server with replay protection-
   related information, the HA is responsible for the replay protection.

   The message format is shown below.

```
   <MIP6-Request> ::= < Diameter Header: 325, REQ, PXY >
                      < Session-ID >
                      { Auth-Application-Id }
                      { User-Name }
                      { Destination-Realm }
                      { Origin-Host }
                      { Origin-Realm }
                      { Auth-Request-Type }
                      [ Destination-Host ]
                      [ Origin-State-Id ]
                      [ NAS-Identifier ]
                      [ NAS-IP-Address ]
                      [ NAS-IPv6-Address ]
                      [ NAS-Port-Type ]
                      [ Called-Station-Id ]
                      [ Calling-Station-Id ]
                      [ MIP6-Feature-Vector ]
                      { MIP6-Auth-Mode }
                      [ MIP-MN-AAA-SPI ]
                      [ MIP-MN-HA-SPI ]
                   1*2{ MIP-Mobile-Node-Address }
                      { MIP6-Agent-Info }
                      { MIP-Careof-Address }
                      [ MIP-Authenticator ]
                      [ MIP-MAC-Mobility-Data ]
                      [ MIP-Timestamp ]
                      [ QoS-Capability ]
                    * [ QoS-Resources ]
                      [ Chargeable-User-Identity ]
                      [ Service-Selection ]
                      [ Authorization-Lifetime ]
                      [ Auth-Session-State ]
                    * [ Proxy-Info ]
                    * [ Route-Record ]
                    * [ AVP ]
```

   If the MN is both authenticated and authorized for the mobility
   service, then the Auth-Request-Type AVP is set to the value
   AUTHORIZE_AUTHENTICATE. This is the case when the MIP6-Auth-Mode is
   set to the value MIP6_AUTH_MN_AAA.

5.2.2. MIP6-Answer

   The MIP6-Answer (MIA) message, indicated by the Command-Code field
   set to 325 and the 'R' bit cleared in the Command Flags field, is
   sent by the Diameter server in response to the MIP6-Request message.

The User-Name AVP MAY be included in the MIA if it is present in the
MIR. The Result-Code AVP MAY contain one of the values defined in
Section 7, in addition to the values defined in [RFC3588].

An MIA message with the Result-Code AVP set to DIAMETER_SUCCESS MUST
include the MIP-Mobile-Node-Address AVP.

The message format is shown below.

```
<MIP6-Answer> ::= < Diameter Header: 325, PXY >
                  < Session-Id >
                  { Auth-Application-Id }
                  { Result-Code }
                  { Origin-Host }
                  { Origin-Realm }
                  { Auth-Request-Type }
                  [ User-Name ]
                  [ Authorization-Lifetime ]
                  [ Auth-Session-State ]
                  [ Error-Message ]
                  [ Error-Reporting-Host ]
                  [ Re-Auth-Request-Type ]
                  [ MIP6-Feature-Vector ]
                  [ MIP-Agent-Info ]
                *2[ MIP-Mobile-Node-Address ]
                  [ MIP-MN-HA-MSA ]
                * [ QoS-Resources ]
                  [ Chargeable-User-Identity ]
                  [ Service-Selection ]
                  [ Origin-State-Id ]
                * [ Proxy-Info ]
                * [ Redirect-Host ]
                  [ Redirect-Host-Usage ]
                  [ Redirect-Max-Cache-Time ]
                * [ Failed-AVP ]
                * [ AVP ]
```

6. AVPs

   To provide support for [RFC4285] and for [RFC4877], the AVPs in the
   following subsections are needed. [RFC3588], [RFC4004], and
   [RFC4005] defined AVPs are reused whenever possible without changing
   the existing semantics of those AVPs.

				AVP Flag Rules					
Attribute Name	AVP Code	Defined in	Value Type	MUST	MAY	SHOULD NOT	MUST NOT	MAY Encr
MIP6-Feature-Vector	124	RFC 5447	Unsigned64	M	P			V	Y
MIP-Mobile-Node-Address	333	RFC 4004	Address	M	P			V	Y
MIP6-Agent-Info	486	RFC 5447	Grouped	M	P			V	Y
User-Name	1	RFC 3588	UTF8String	M	P			V	Y
Service-Selection	493	6.2	UTF8String	M	P			V	Y
QoS-Capability	578	Note 1	Grouped	M	P			V	Y
QoS-Resources	508	Note 1	Grouped	M	P			V	Y
MIP-MN-HA-MSA	492	6.12	Grouped	M	P			V	Y
Chargeable-User-Identity	89	6.19	OctetString	M	P			V	Y

                 AVPs for Mobile IPv6 IKE Application

   Note 1: The QoS-Capability and the QoS-Resource AVPs are defined in
   Sections 4.1 and 4.3 of [RFC5777].

				AVP Flag Rules					
Attribute Name	AVP Code	Section Defined	Value Type	MUST	MAY	SHOULD NOT	MUST NOT	MAY Encr
MIP6-Feature-Vector	124	RFC 5447	Unsigned64	M	P			V	Y
User-Name	1	RFC 3588	UTF8String	M	P			V	Y
Service-Selection	493	6.2	UTF8String	M	P			V	Y

				M	P			V	Y
MIP-MN-AAA-SPI	341	RFC 4004	Unsigned32	M	P			V	Y
MIP-MN-HA-SPI	491	6.4	Unsigned32	M	P			V	Y
MIP-Mobile-Node-Address	333	RFC 4004	Address	M	P			V	Y
MIP6-Agent-Info	486	RFC 5447	Grouped	M	P			V	Y
MIP-Careof-Address	487	6.7	Address	M	P			V	Y
MIP-Authenticator	488	6.8	OctetString	M	P			V	Y
MIP-MAC-Mobility-Data	489	6.9	OctetString	M	P			V	Y
MIP-Session-Key	343	6.10	OctetString	M	P			V	Y
MIP-MSA-Lifetime	367	RFC 4004	Unsigned32	M	P			V	Y
MIP-MN-HA-MSA	492	6.12	Grouped	M	P			V	Y
MIP-Algorithm-Type	345	6.13	Enumerated	M	P			V	Y
MIP-Replay-Mode	346	6.14	Enumerated	M	P			V	Y
MIP-Timestamp	490	6.16	OctetString	M	P			V	Y
QoS-Capability	578	Note 1	Grouped	M	P			V	Y
QoS-Resources	508	Note 1	Grouped	M	P			V	Y
Chargeable-User-Identity	89	6.19	OctetString	M	P			V	Y
MIP6-Auth-Mode	494	6.20	Enumerated	M	P			V	Y
Rest of the AVPs in the MIR & MIA excluding *[AVP]		RFC 3588 RFC 4005		M	P			V	Y

AVPs for the Mobile IPv6 Auth Application

   Note 1: The QoS-Capability and the QoS-Resource AVPs are defined in
   Sections 4.1 and 4.3 of [RFC5777].

6.1. User-Name AVP

   The User-Name AVP (AVP Code 1) is of type UTF8String and contains a
   Network Access Identifier (NAI) extracted from the MN-NAI mobility
   option included in the received BU message. Alternatively, the NAI
   can be extracted from the IKEv2 IDi payload included in the IKE_AUTH
   message sent by the IKE initiator.

6.2. Service-Selection AVP

   The Service-Selection AVP (AVP Code 493) is of type UTF8String and
   contains the name of the service or the external network with which
   the mobility service should be associated. In the scope of this
   specification, the value can be extracted from the IKEv2 IDr payload,
   if available in the IKE_AUTH message sent by the IKE initiator.
   Alternatively, if the Mobile IPv6 Authentication Protocol is used,
   then the Service-Selection AVP contains the string extracted from the
   Service Selection Mobility Option [RFC5149], if available in the
   received BU. Future specifications may define additional ways to
   populate the Service-Selection AVP with the required information.

   The AVP is also available to be used in messages sent from the
   Diameter server to the Diameter client. For example, if the request
   message did not contain the Service-Selection AVP but the MN was
   assigned with a default service, the Diameter server MAY return the
   name of the assigned default service to the HA.

   If the Service-Selection AVP is present in both the request and the
   reply messages, it SHOULD contain the same service name. If the
   services differ, the HA MAY treat that as authorization failure.

6.3. MIP-MN-AAA-SPI AVP

   The MIP-MN-AAA-SPI AVP (AVP Code 341) is of type Unsigned32 and
   contains a Security Parameter Index (SPI) code extracted from the
   Mobility Message Authentication Option included in the received BU
   message. This AVP is reused from [RFC4004].

   When the MIP6-Auth-Mode AVP is set to value MIP6_AUTH_MN_AAA, this
   AVP MUST be present in the MIR message.

6.4. MIP-MN-HA-SPI AVP

   The MIP-MN-HA-SPI AVP (AVP Code 491) is of type Unsigned32 and
   contains an SPI value that can be used with other parameters for
   identifying the security association required for the validation of
   the Mobile IPv6 MN-HA Authentication Option.

   When the MIP6-Auth-Mode AVP is set to value MIP6_AUTH_MN_AAA, and the
   Diameter server returns a valid MIP-MN-HA-MSA AVP in the MIA message,
   this AVP MUST be present inside the MIP-MN-HA-MSA AVP.

6.5. MIP-Mobile-Node-Address AVP

   The MIP-Mobile-Node-Address AVP (AVP Code 333) is of type Address and
   contains the HA assigned IPv6 or IPv4 home address of the mobile
   node.

   If the MIP-Mobile-Node-Address AVP contains the unspecified IPv6
   address (0::0) or the all-zeroes IPv4 address (0.0.0.0) in a request
   message, then the HA expects the Diameter server to assign the home
   address in a subsequent answer message. If the Diameter server
   assigns only an IPv6 home network prefix to the mobile node, the
   lower 64 bits of the MIP-Mobile-Node-Address AVP provided address
   MUST be set to zero.

   This AVP is reused from [RFC4004].

6.6. MIP6-Agent-Info AVP

   The MIP6-Agent-Info AVP (AVP Code 486) is defined in Section 4.2.1 of
   [RFC5447] and contains the IPv6 or the IPv4 address information of
   the HA. The HA address in a request message is the same as in the
   received BU message that triggered the authentication and
   authorization procedure towards the Diameter server. One use case
   is, e.g., to inform the Diameter server of the dynamically assigned
   HA.

   If the MIP6-Agent-Info AVP is present in an answer message and the
   Result-Code AVP is set to DIAMETER_SUCCESS_RELOCATE_HA, then the
   Diameter server is indicating to the HA that it MUST initiate an HA
   switch procedure towards the MN (e.g., using the procedure defined in
   [RFC5142]). If the Result-Code AVP is set to any other value, then
   the HA SHOULD initiate the HA switch procedure towards the MN. The
   address information of the assigned HA is defined in the MIP6-Agent-
   Info AVP.

6.7. MIP-Careof-Address AVP

   The MIP-Careof-Address AVP (AVP Code 487) is of type Address and
   contains the IPv6 or the IPv4 care-of address of the mobile node.
   The HA extracts this IP address from the received BU message.

6.8. MIP-Authenticator AVP

   The MIP-Authenticator AVP (AVP Code 488) is of type OctetString and
   contains the Authenticator Data from the received BU message. The HA
   extracts this data from the MN-AAA Mobility Message Authentication
   Option included in the received BU message.

   When the MIP6-Auth-Mode AVP is set to value MIP6_AUTH_MN_AAA, this
   AVP MUST be present in the MIR message.

6.9. MIP-MAC-Mobility-Data AVP

   The MIP-MAC-Mobility-Data AVP (AVP Code 489) is of type OctetString
   and contains the MAC_Mobility_Data calculated by the HA as defined in
   [RFC4285] for the MN-AAA Mobility Message Authentication Option.

   When the MIP6-Auth-Mode AVP is set to value MIP6_AUTH_MN_AAA, this
   AVP MUST be present in the MIR message.

6.10. MIP-Session-Key AVP

   The MIP-Session-Key AVP (AVP Code 343) is of type OctetString and
   contains the MN-HA shared secret (i.e., the session key) for the
   associated Mobile IPv6 MN-HA authentication option. When the
   Diameter server computes the session key, it is placed in this AVP.
   How the Diameter server computes the session key is not defined in
   this specification. The Session key derivation is deployment
   specific and needs to be defined in a respective deployment-specific
   system specification.

   This AVP is reused from [RFC4004].

6.11. MIP-MSA-Lifetime AVP

   The MIP-MSA-Lifetime AVP (AVP Code 367) is of type Unsigned32 and
   represents the period of time (in seconds) for which the session key
   (see Section 6.10) is valid. The associated session key MUST NOT be
   used if the lifetime has expired.

   This AVP is reused from [RFC4004].

6.12. MIP-MN-HA-MSA AVP

   The MIP-MN-HA-MSA AVP (AVP Code 492) is of type Grouped and contains
   the session-related information for use with the Mobile IPv6
   Authentication Protocol.

       MIP-MN-HA-MSA ::= < AVP Header: 492 >
                         { MIP-Session-Key }
                         { MIP-MSA-Lifetime }
                         [MIP-MN-HA-SPI]
                         [MIP-Algorithm-Type]
                         [MIP-Replay-Mode]
                       * [AVP]

   The MIP-MN-HA-SPI sub-AVP within the MIP-MN-HA-MSA grouped AVP
   identifies the security association required for the validation of
   the Mobile IPv6 MN-HA Authentication Option. The absence of the MIP-
   Replay-Mode AVP MUST be treated as no replay protection was selected.

6.13. MIP-Algorithm-Type AVP

   The MIP-Algorithm-Type AVP (AVP Code 345) is of type Enumerated and
   contains the Algorithm identifier for the associated Mobile IPv6
   MN-HA Authentication Option. The Diameter server selects the
   algorithm type. Existing algorithm types are defined in [RFC4004]
   that also fulfill current RFC 4285 requirements. This AVP is reused
   from [RFC4004].

   When the MIP6-Auth-Mode AVP is set to value MIP6_AUTH_MN_AAA, and the
   Diameter server returns a valid MIP-MN-HA-MSA AVP in the MIA message,
   this AVP MUST be present inside the MIP-MN-HA-MSA AVP.

6.14. MIP-Replay-Mode AVP

   The MIP-Replay-Mode AVP (AVP Code 346) is of type Enumerated and
   contains the replay mode of the HA for authenticating the mobile
   node. Out of all possible replay modes defined in [RFC4004], the
   following are supported by this specification:

       1   None
       2   Timestamp

   This AVP is reused from [RFC4004].

6.15. MIP6-Feature-Vector AVP

   The MIP6-Feature-Vector AVP (AVP Code 124) is defined in [RFC5447].
   However, this specification does not define any Mobile IPv6 split
   scenario bootstrapping specific capability flag.

6.16. MIP-Timestamp AVP

   The MIP-Timestamp AVP (AVP Code 490) is of type OctetString and
   contains an 8-octet timestamp value (i.e., 64-bit timestamp) from the
   Mobility message replay protection option, defined in [RFC4285]. The
   HA extracts this value from the received BU message, if available.
   The HA includes this AVP in the MIR message when the MN-AAA Mobility
   Message Authentication Option is available in the received BU and the
   Diameter server is expected to return the key material required for
   the calculation and validation of the Mobile IPv6 MN-HA
   Authentication Option (and the MIP6-Auth-Mode AVP is set to value
   MIP6_AUTH_MN_AAA).

6.17. QoS-Capability AVP

   The QoS-Capability AVP is defined in [RFC5777] and contains a list of
   supported Quality of Service profiles.

6.18. QoS-Resources AVP

   The QoS-Resources AVP is defined in [RFC5777] and provides QoS and
   packet filtering capabilities.

6.19. Chargeable-User-Identity AVP

   The Chargeable-User-Identity AVP (AVP Code 89) is of type OctetString
   and contains a unique temporary handle of the user. The Chargeable-
   User-Identity is defined in [RFC4372].

6.20. MIP6-Auth-Mode AVP

   The MIP6-Auth-Mode (AVP Code 494) is of type Enumerated and contains
   information of the used Mobile IPv6 Authentication Protocol mode.
   This specification defines only one value MIP6_AUTH_MN_AAA and the
   corresponding AAA interactions when MN-AAA security association is
   used to authenticate the Binding Update as described in [RFC4285].
   When the MIP6-Auth_Mode AVP is set to the value of MIP6_AUTH_MN_AAA,
   the Auth-Request-Type AVP MUST be set to the value of
   AUTHORIZE_AUTHENTICATE.

If the Diameter server does not support the Mobile IPv6
Authentication Protocol usage mode proposed by the HA, then the
Diameter server MUST fail the authentication/authorization and MUST
set the Result-Code AVP to the value of DIAMETER_ERROR_AUTH_MODE.

6.21. Accounting AVPs

Diameter Mobile IPv6 applications, either MIP6I or MIP6A, are used in
the case of the coupled account model. Diameter Mobile IPv4
application [RFC4004] accounting AVPs are reused in this document.
The following AVPs SHOULD be included in the accounting request
message:

o Accounting-Input-Octets: Number of octets in IP packets received
   from the mobile node.

o Accounting-Output-Octets: Number of octets in IP packets sent by
   the mobile node.

o Accounting-Input-Packets: Number of IP packets received from the
   mobile node.

o Accounting-Output-Packets: Number of IP packets sent by the mobile
   node.

o Acct-Multi-Session-Id: Used to link together multiple related
   accounting sessions, where each session would have a unique
   Session-Id, but the same Acct-Multi-Session-Id AVP.

o Acct-Session-Time: Indicates the length of the current session in
   seconds.

o MIP6-Feature-Vector: The supported features for this mobility
   service session.

o MIP-Mobile-Node-Address: The home address of the mobile node.

o MIP-Agent-Info: The current home agent of the mobile node.

o Chargeable-User-Identity: The unique temporary identity of the
   user. This AVP MUST be included if it is available in the home
   agent.

o Service-Selection: Currently selected mobility service.

o QoS-Resources: Assigned Quality-of-Service (QoS) resources for the
   mobile node.

    o QoS-Capability: The QoS capability related to the assigned QoS-
       Resources.

    o MIP-Careof-Address: The current care-of address of the mobile
       node.

7. Result-Code AVP Values

    This section defines new Result-Code [RFC3588] values that MUST be
    supported by all Diameter implementations that conform to this
    specification.

7.1. Success

    Errors that fall within the Success category are used to inform a
    peer that a request has been successfully completed.

    DIAMETER_SUCCESS_RELOCATE_HA (Status Code 2009)

       This result code is used by the Diameter server to inform the HA
       that the MN MUST be switched to another HA.

7.2. Permanent Failures

    Errors that fall within the Permanent Failures category are used to
    inform the peer that the request failed and SHOULD NOT be attempted
    again.

    DIAMETER_ERROR_MIP6_AUTH_MODE (Status Code 5041)

       This error code is used by the Diameter server to inform the peer
       that the requested Mobile IPv6 Authentication Protocol usage mode
       is not supported.

8. AVP Occurrence Tables

    The following tables present the AVPs defined in this document and
    their occurrences in Diameter messages. Note that AVPs that can only
    be present within a Grouped AVP are not represented in this table.

    The tables use the following symbols:

    0:

       The AVP MUST NOT be present in the message.

    0+:

       Zero or more instances of the AVP MAY be present in the message.

    0-1:

       Zero or one instance of the AVP MAY be present in the message.

    1:

       One instance of the AVP MUST be present in the message.

8.1. DER, DEA, MIR, and MIA AVP/Command-Code Table

                                +----------------------+
                                | Command-Code |
                                |-----+-----+-----+-----+
       AVP Name | DER | DEA | MIR | MIA |
       -------------------------|-----+-----+-----+-----+
       MIP6-Feature-Vector | 0-1 | 0-1 | 0-1 | 0-1 |
       MIP-Mobile-Node-Address | 1-2 | 0-2 | 1-2 | 0-2 |
       MIP-MN-AAA-SPI | 0 | 0 | 0-1 | 0 |
       MIP-MN-HA-SPI | 0 | 0 | 0-1 | 0 |
       MIP6-Agent-Info | 1 | 0-1 | 1 | 0-1 |
       MIP-Careof-Address | 0 | 0 | 0-1 | 0 |
       MIP-Authenticator | 0 | 0 | 0-1 | 0 |
       MIP-MAC-Mobility-Data | 0 | 0 | 0-1 | 0 |
       MIP-MSA-Lifetime | 0 | 0 | 0 | 1 |
       MIP-MN-HA-MSA | 0 | 0 | 0 | 0-1 |
       MIP-Timestamp | 0 | 0 | 0-1 | 0-1 |
       User-Name | 0-1 | 0-1 | 1 | 0-1 |
       Service-Selection | 0-1 | 0-1 | 0-1 | 0-1 |
       QoS-Resources | 0+ | 0+ | 0+ | 0+ |
       QoS-Capability | 0-1 | 0 | 0-1 | 0 |
       Chargeable-User-Identity | 0-1 | 0-1 | 0-1 | 0-1 |
       MIP6-Auth-Mode | 0 | 0 | 1 | 0 |
                                +-----+-----+-----+-----+

8.2. Coupled Accounting Model AVP Table

   The table in this section is used to represent which AVPs defined in
   this document are to be present in the Accounting messages, as
   defined in [RFC3588].

```
                              +------------+
                              | Command-Code|
                              |------+------+
            Attribute Name    | ACR  | ACA  |
        ------------------------------|------+------+
        Accounting-Input-Octets       | 0-1  | 0-1  |
        Accounting-Input-Packets      | 0-1  | 0-1  |
        Accounting-Output-Octets      | 0-1  | 0-1  |
        Accounting-Output-Packets     | 0-1  | 0-1  |
        Acct-Multi-Session-Id         | 0-1  | 0-1  |
        Acct-Session-Time             | 0-1  | 0-1  |
        MIP6-Feature-Vector           | 0-1  | 0-1  |
        MIP6-Agent-Info               | 0-1  | 0-1  |
        MIP-Mobile-Node-Address       | 0-2  | 0-2  |
        Event-Timestamp               | 0-1  |  0   |
        MIP-Careof-Address            | 0-1  |  0   |
        Service-Selection             | 0-1  |  0   |
        QoS-Capability                |  0+  |  0+  |
        QoS-Resources                 |  0+  |  0+  |
        Chargeable-User-Identity      | 0-1  |  0   |
        ------------------------------|------+------+
```

9. IANA Considerations

   This section contains the namespaces that have either been created in
   this specification or had their values assigned to existing
   namespaces managed by IANA.

9.1. Command Codes

   IANA has allocated a command code value for the following new command
   from the Command Code namespace defined in [RFC3588]. See Section 5
   for the assignment of the namespace in this specification.

```
   Command Code                    | Value
   --------------------------------+------
   MIP6-Request/Answer (MIR/MIA)   | 325
```

9.2. AVP Codes

   IANA has registered the following new AVPs from the AVP Code
   namespace defined in [RFC3588].

   o MIP-Careof-Address

    o MIP-Authenticator

    o MIP-MAC-Mobility-Data

    o MIP-Timestamp

    o MIP-MN-HA-SPI

    o MIP-MN-HA-MSA

    o Service-Selection

    o MIP6-Auth-Mode

    The AVPs are defined in Section 6.

9.3. Result-Code AVP Values

    IANA has allocated new values to the Result-Code AVP (AVP Code 268)
    namespace defined in [RFC3588]. See Section 7 for the assignment of
    the namespace in this specification.

    Result-Code | Value
    ---+------
    DIAMETER_SUCCESS_RELOCATE_HA | 2009
    DIAMETER_ERROR_MIP6_AUTH_MODE | 5041

9.4. Application Identifier

    IANA has allocated two new values "Diameter Mobile IPv6 IKE" and
    "Diameter Mobile IPv6 Auth" from the Application Identifier namespace
    defined in [RFC3588].

    Application Identifier | Value
    ---------------------------------+------
    Diameter Mobile IPv6 IKE (MIP6I) | 7
    Diameter Mobile IPv6 Auth (MIP6A) | 8

9.5. Namespaces

    IANA has created a new registry, "MIP6 Authentication Mode Registry",
    for use with the enumerated MIP6-Auth-Mode AVP. The registry
    initially contains the following value:

```
   Token                                    | Value    | Description
   ------------------------------------------+----------+------------
   MIP6_AUTH_MN_AAA                         | 1        | RFC 5778
```

   Allocation of new values follow the example policies described in
   [RFC5226]. New values for the MIP6-Auth-Mode AVP will be assigned
   based on the "Specification Required" policy. The value 0 (zero) is
   reserved, and the maximum value is 4294967295 (i.e., 2^32-1).

10. Security Considerations

   The security considerations for the Diameter interaction required to
   accomplish the split scenario are described in [RFC5026].
   Additionally, the security considerations of the Diameter base
   protocol [RFC3588], and Diameter EAP application [RFC4072] are
   applicable to this document.

   The Diameter messages may be transported between the HA and the
   Diameter server via one or more AAA brokers or Diameter agents. In
   this case, the HA to the Diameter server AAA communication relies on
   the security properties of the intermediating AAA inter-connection
   networks, AAA brokers, and Diameter agents (such as proxies).

   In the case of the Authentication Protocol for Mobile IPv6 [RFC4285],
   this specification expects that the Diameter server derives the MN-HA
   Security Association and returns the associated session key (i.e.,
   the MN-HA shared session key) to the HA. However, this specification
   does not define nor do other IETF specifications define how the
   Diameter server actually derives required keys. The details of the
   key derivation depends on the deployment where this specification is
   used and therefore the security properties of the system depend on
   how this is done.

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