

Diameter

Copyright © 2011-2017 Ericsson AB. All Rights Reserved.
Diameter 1.11.2
December 1, 2017

Copyright © 2011-2017 Ericsson AB. All Rights Reserved.
Licensed under the Apache License, Version 2.0 (the "License"); you may not use this file except in compliance with the License. You may obtain a copy of the License at http://www.apache.org/licenses/LICENSE-2.0 Unless required by applicable law or agreed to in writing, software distributed under the License is distributed on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied. See the License for the specific language governing permissions and limitations under the License. Ericsson AB. All Rights Reserved..

December 1, 2017

1 Diameter Users Guide

The diameter application is a framework for building applications on top of the Diameter protocol.

1.1 Introduction

The diameter application is an implementation of the Diameter protocol as defined by RFC 6733. It supports arbitrary Diameter applications by way of a *dictionary* interface that allows messages and AVPs to be defined and input into diameter as configuration. It has support for all roles defined in the RFC: client, server and agent. This chapter provides a short overview of the application.

A Diameter node is implemented by configuring a *service* and one or more *transports* using the interface module *diameter*. The service configuration defines the Diameter applications to be supported by the node and, typically, the capabilities that it should send to remote peers at capabilities exchange upon the establishment of transport connections. A transport is configured on a service and provides protocol-specific send/receive functionality by way of a transport interface defined by diameter and implemented by a transport module. The diameter application provides two transport modules: *diameter_tcp* and *diameter_sctp* for transport over TCP (using *gen_tcp*) and SCTP (using *gen_sctp*) respectively. Other transports can be provided by any module that implements diameter's *transport interface*.

While a service typically implements a single Diameter node (as identified by an Origin-Host AVP), transports can themselves be associated with capabilities AVPs so that a single service can be used to implement more than one Diameter node.

Each Diameter application defined on a service is configured with a callback module that implements the *application interface* through which diameter communicates the connectivity of remote peers, requests peer selection for outgoing requests, and communicates the reception of incoming Diameter request and answer messages. An application using diameter implements these application callback modules to provide the functionality of the Diameter node(s) it implements.

Each Diameter application is also configured with a dictionary module that provide encode/decode functionality for outgoing/incoming Diameter messages belonging to the application. A dictionary module is generated from a *dictionary file* using the *diameterc* utility. Dictionaries for the RFC 6733 Diameter Common Messages, Base Accounting and Relay applications are provided with the diameter application.

1.2 Usage

To be written.

1.3 Examples

Example code can be found in the diameter application's `examples` subdirectory.

1.4 Standards Compliance

Known points of questionable or non-compliance.

1.4.1 RFC 6733

- There is no support for DTLS over SCTP.

- There is no explicit support for peer discovery (section 5.2). It can possibly be implemented on top of diameter as is but this is probably something that diameter should do.
- The peer state machine's election process (section 5.6.4) isn't implemented as specified since it assumes knowledge of a peer's Origin-Host before sending it a CER. (The identity becoming known upon reception of CEA.) The possibility of configuring the peer's Origin-Host could be added, along with handling of the case that it sends something else, but for many applications this will just be unnecessary configuration of a value that it has no control over.

Commentary

A more detailed commentary on RFC 6733 follows. Its purpose is to (hopefully) clarify not only what is supported but how, given that semantics and features discussed in the RFC are not solely the responsibility of the diameter application: in many cases much depends on the configuration a user passes to diameter, the implementation of *diameter_app(3)* callback modules in particular.

Comments apply to all text following the preceding comment. Be sure to distinguish between capitalized *Diameter*, the protocol defined by the RFC, and lowercase *diameter*, the Erlang application to which the commentary applies.

Warning:

The commentary is not yet complete. Comments currently stop at chapter 4.

```
Fajardo, et al.              Standards Track                    [Page 6]

RFC 6733                Diameter Base Protocol             October 2012


1.  Introduction

   Authentication, Authorization, and Accounting (AAA) protocols such as
   TACACS [RFC1492] and RADIUS [RFC2865] were initially deployed to
   provide dial-up PPP [RFC1661] and terminal server access.  Over time,
   AAA support was needed on many new access technologies, the scale and
   complexity of AAA networks grew, and AAA was also used on new
   applications (such as voice over IP).  This led to new demands on AAA
   protocols.
```

Note that diameter implements the Diameter protocol as defined in RFC 6733. It also supported the previous version of the protocol, as defined in RFC 3588, when there are differences. (Which will be noted below.) It does not support RADIUS.

```
   Network access requirements for AAA protocols are summarized in
   Aboba, et al. [RFC2989].  These include:

   Failover

      [RFC2865] does not define failover mechanisms and, as a result,
      failover behavior differs between implementations.  In order to
      provide well-defined failover behavior, Diameter supports
      application-layer acknowledgements and defines failover algorithms
      and the associated state machine.
```

No comment.

```
   Transmission-level security

      RADIUS [RFC2865] defines an application-layer authentication and
      integrity scheme that is required only for use with response
      packets.  While [RFC2869] defines an additional authentication and
      integrity mechanism, use is only required during Extensible
      Authentication Protocol (EAP) [RFC3748] sessions.  While attribute
      hiding is supported, [RFC2865] does not provide support for per-
      packet confidentiality.  In accounting, [RFC2866] assumes that
      replay protection is provided by the backend billing server rather
      than within the protocol itself.

      While [RFC3162] defines the use of IPsec with RADIUS, support for
      IPsec is not required.  In order to provide universal support for
      transmission-level security, and enable both intra- and inter-
      domain AAA deployments, Diameter provides support for TLS/TCP and
      DTLS/SCTP.  Security is discussed in Section 13.
```

Whether or not IPsec is used is transparent to diameter.

The transport protocol used on a given peer connection is also transparent to diameter in that transport to diameter is simply a module that implements the transport protocol documented in *diameter_transport(3)*. A diameter user configures this module as the *diameter:transport_opt()* `transport_module`.

While a user can implement their own transport modules, diameter includes implementations for TCP and SCTP: *diameter_tcp(3)* based on *gen_tcp(3)* and *diameter_sctp(3)* based on *gen_sctp(3)*. The former supports TLS but the latter does not currently support DTLS.

```
   Reliable transport

      RADIUS runs over UDP, and does not define retransmission behavior;
      as a result, reliability varies between implementations.  As
      described in [RFC2975], this is a major issue in accounting, where
      packet loss may translate directly into revenue loss.  In order to
```



```
      provide well-defined transport behavior, Diameter runs over
      reliable transport mechanisms (TCP, Stream Control Transmission
      Protocol (SCTP)) as defined in [RFC3539].

   Agent support

      RADIUS does not provide for explicit support for agents, including
      proxies, redirects, and relays.  Since the expected behavior is
      not defined, it varies between implementations.  Diameter defines
      agent behavior explicitly; this is described in Section 2.8.
```

No comment.

```
   Server-initiated messages

      While server-initiated messages are defined in RADIUS [RFC5176],
      support is optional.  This makes it difficult to implement
      features such as unsolicited disconnect or re-authentication/
      re-authorization on demand across a heterogeneous deployment.  To
      address this issue, support for server-initiated messages is
      mandatory in Diameter.
```

A diameter user can both send and receive messages.

```
   Transition support

      While Diameter does not share a common protocol data unit (PDU)
      with RADIUS, considerable effort has been expended in enabling
      backward compatibility with RADIUS so that the two protocols may
      be deployed in the same network.  Initially, it is expected that
      Diameter will be deployed within new network devices, as well as
      within gateways enabling communication between legacy RADIUS
      devices and Diameter agents.  This capability enables Diameter
      support to be added to legacy networks, by addition of a gateway
      or server speaking both RADIUS and Diameter.
```

RADIUS Attributes can be redefined as Diameter AVP's using diameter's *diameter_dict(4)* interface but diameter provides no such definitions.

```
   In addition to addressing the above requirements, Diameter also
   provides support for the following:

   Capability negotiation

      RADIUS does not support error messages, capability negotiation, or
      a mandatory/non-mandatory flag for attributes.  Since RADIUS
      clients and servers are not aware of each other's capabilities,
      they may not be able to successfully negotiate a mutually
      acceptable service or, in some cases, even be aware of what
      service has been implemented.  Diameter includes support for error
      handling (Section 7), capability negotiation (Section 5.3), and
      mandatory/non-mandatory Attribute-Value Pairs (AVPs)
      (Section 4.1).




Fajardo, et al.              Standards Track                    [Page 8]

RFC 6733                 Diameter Base Protocol             October 2012


   Peer discovery and configuration

      RADIUS implementations typically require that the name or address
```

```
      of servers or clients be manually configured, along with the
      corresponding shared secrets.  This results in a large
      administrative burden and creates the temptation to reuse the
      RADIUS shared secret, which can result in major security
      vulnerabilities if the Request Authenticator is not globally and
      temporally unique as required in [RFC2865].  Through DNS, Diameter
      enables dynamic discovery of peers (see Section 5.2).  Derivation
      of dynamic session keys is enabled via transmission-level
      security.

   Over time, the capabilities of Network Access Server (NAS) devices
   have increased substantially.  As a result, while Diameter is a
   considerably more sophisticated protocol than RADIUS, it remains
   feasible to implement it within embedded devices.
```

No comment.

```
1.1.  Diameter Protocol

   The Diameter base protocol provides the following facilities:

   o  Ability to exchange messages and deliver AVPs
```

There are two interfaces directly involved in message exchange when using diameter: the function *diameter:call/4* for sending outgoing requests, and the application callback interface, documented in *diameter_app(3)* for receiving incoming request and answers.

```
   o  Capabilities negotiation
```

Capabilities negotiation is the responsibility of diameter: a user configures a diameter service and/or transport with *capabilities* to provide AVP values for CER and CEA messages but it is diameter itself that sends these messages. A user receives notification of a successful capabilities exchange by way of *peer_up/3* callbacks.

```
   o  Error notification
```

A user can subscribe to *events*, using *diameter:subscribe/1*, in order to receive notification of various failures. Errors in Diameter messaging are communicated via the application callbacks *handle_request/3*, *handle_answer/4* and *handle_error/4*.

```
   o  Extensibility, required in [RFC2989], through addition of new
      applications, commands, and AVPs
```

Support for applications, commands and AVP's is extensible using diameter's dictionary interface, as documented in *diameter_dict(4)*. Dictionaries are compiled to Erlang encode/decode modules using *diameterc(1)* or *diameter_make(3)*.

```
   o  Basic services necessary for applications, such as the handling of
      user sessions or accounting
```

Compiled dictionaries are provided for the RFC 3588 and RFC 6733 Diameter applications: common, base accounting and relay. Dictionaries for a number of standardized applications are provided in uncompiled form below the `examples` subdirectory of the diameter application directory.

```
   All data delivered by the protocol is in the form of AVPs.  Some of
   these AVP values are used by the Diameter protocol itself, while
   others deliver data associated with particular applications that
   employ Diameter.  AVPs may be arbitrarily added to Diameter messages,
   the only restriction being that the Command Code Format (CCF)
   specification (Section 3.2) be satisfied.  AVPs are used by the base
   Diameter protocol to support the following required features:

   o  Transporting of user authentication information, for the purposes
      of enabling the Diameter server to authenticate the user

   o  Transporting of service-specific authorization information,
      between client and servers, allowing the peers to decide whether a
      user's access request should be granted



Fajardo, et al.              Standards Track                    [Page 9]

RFC 6733                 Diameter Base Protocol             October 2012


   o  Exchanging resource usage information, which may be used for
      accounting purposes, capacity planning, etc.

   o  Routing, relaying, proxying, and redirecting of Diameter messages
      through a server hierarchy

   The Diameter base protocol satisfies the minimum requirements for a
   AAA protocol, as specified by [RFC2989].  The base protocol may be
   used by itself for accounting purposes only, or it may be used with a
   Diameter application, such as Mobile IPv4 [RFC4004], or network
   access [RFC4005].  It is also possible for the base protocol to be
   extended for use in new applications, via the addition of new
   commands or AVPs.  The initial focus of Diameter was network access
   and accounting applications.  A truly generic AAA protocol used by
   many applications might provide functionality not provided by
   Diameter.  Therefore, it is imperative that the designers of new
   applications understand their requirements before using Diameter.
   See Section 1.3.4 for more information on Diameter applications.

   Any node can initiate a request.  In that sense, Diameter is a peer-
   to-peer protocol.  In this document, a Diameter client is a device at
   the edge of the network that performs access control, such as a
   Network Access Server (NAS) or a Foreign Agent (FA).  A Diameter
   client generates Diameter messages to request authentication,
   authorization, and accounting services for the user.  A Diameter
   agent is a node that does not provide local user authentication or
   authorization services; agents include proxies, redirects, and relay
   agents.  A Diameter server performs authentication and/or
   authorization of the user.  A Diameter node may act as an agent for
   certain requests while acting as a server for others.
```

```
   The Diameter protocol also supports server-initiated messages, such
   as a request to abort service to a particular user.
```

No comment.

```
1.1.1.  Description of the Document Set

   The Diameter specification consists of an updated version of the base
   protocol specification (this document) and the Transport Profile
   [RFC3539].  This document obsoletes both RFC 3588 and RFC 5719.  A
   summary of the base protocol updates included in this document can be
   found in Section 1.1.3.

   This document defines the base protocol specification for AAA, which
   includes support for accounting.  There are also a myriad of
   applications documents describing applications that use this base
   specification for Authentication, Authorization, and Accounting.
   These application documents specify how to use the Diameter protocol
   within the context of their application.



Fajardo, et al.              Standards Track                   [Page 10]

RFC 6733                 Diameter Base Protocol             October 2012


   The Transport Profile document [RFC3539] discusses transport layer
   issues that arise with AAA protocols and recommendations on how to
   overcome these issues.  This document also defines the Diameter
   failover algorithm and state machine.

   "Clarifications on the Routing of Diameter Request Based on the
   Username and the Realm" [RFC5729] defines specific behavior on how to
   route requests based on the content of the User-Name AVP (Attribute
   Value Pair).

1.1.2.  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].
```

No comment.

```
1.1.3.  Changes from RFC 3588

   This document obsoletes RFC 3588 but is fully backward compatible
   with that document.  The changes introduced in this document focus on
   fixing issues that have surfaced during the implementation of
   Diameter (RFC 3588).  An overview of some the major changes are given
   below.
```

RFC 6733 is not fully backwards compatible with RFC 3588. (For example, in what values of Result-Code values are permissible with the E-bit.) The implications of incompatibilities for diameter are noted where appropriate.

```
   o  Deprecated the use of the Inband-Security AVP for negotiating
      Transport Layer Security (TLS) [RFC5246].  It has been generally
      considered that bootstrapping of TLS via Inband-Security AVP
      creates certain security risks because it does not completely
      protect the information carried in the CER/CEA (Capabilities-
      Exchange-Request/Capabilities-Exchange-Answer).  This version of
      Diameter adopts the common approach of defining a well-known
      secured port that peers should use when communicating via TLS/TCP
      and DTLS/SCTP.  This new approach augments the existing in-band
      security negotiation, but it does not completely replace it.  The
      old method is kept for backward compatibility reasons.
```

diameter_tcp(3) supports both methods of negotiating TLS: bootstrapping via Inband-Security and directly following connection establishment.

```
   o  Deprecated the exchange of CER/CEA messages in the open state.
      This feature was implied in the peer state machine table of RFC
      3588, but it was not clearly defined anywhere else in that
      document.  As work on this document progressed, it became clear
      that the multiplicity of meaning and use of Application-Id AVPs in
      the CER/CEA messages (and the messages themselves) is seen as an
      abuse of the Diameter extensibility rules and thus required
      simplification.  Capabilities exchange in the open state has been
      re-introduced in a separate specification [RFC6737], which clearly
      defines new commands for this feature.
```

Capabilities exchange in the open state is not supported: an incoming CER in the open state will cause diameter to ask the relevant transport process to terminate, which implies the loss of the peer connection in the case of *diameter_tcp(3)* and *diameter_sctp(3)*.

Capabilities update, as defined by RFC 6737, is not yet supported. Support will require diameter to handle CUR/CUA in the same way that it handles CER/CEA.

```
Fajardo, et al.              Standards Track                    [Page 11]

RFC 6733                Diameter Base Protocol             October 2012


   o  Simplified security requirements.  The use of a secured transport
      for exchanging Diameter messages remains mandatory.  However, TLS/
      TCP and DTLS/SCTP have become the primary methods of securing
      Diameter with IPsec as a secondary alternative.  See Section 13
      for details.  The support for the End-to-End security framework
      (E2E-Sequence AVP and 'P'-bit in the AVP header) has also been
      deprecated.
```

The End-to-End security framework is not supported since it's use is largely unspecified: diameter will set the P-bit in outgoing AVP's as directed by the relevant dictionary and/or *prepare_request/3* or *handle_request/3* callbacks, but whether or not the P-bit is set on incoming AVP's has no consequence.

As noted above, DTLS is not currently supported and whether or not IPsec is used is transparent to diameter.

```
   o  Changed Diameter extensibility.  This includes fixes to the
      Diameter extensibility description (Section 1.3 and others) to
      better aid Diameter application designers; in addition, the new
      specification relaxes the policy with respect to the allocation of
      Command Codes for vendor-specific uses.

   o  Clarified Application Id usage.  Clarify the proper use of
      Application Id information, which can be found in multiple places
      within a Diameter message.  This includes correlating Application
      Ids found in the message headers and AVPs.  These changes also
      clearly specify the proper Application Id value to use for
      specific base protocol messages (ASR/ASA, STR/STA) as well as
      clarify the content and use of Vendor-Specific-Application-Id.

   o  Clarified routing fixes.  This document more clearly specifies
      what information (AVPs and Application Ids) can be used for making
      general routing decisions.  A rule for the prioritization of
      redirect routing criteria when multiple route entries are found
      via redirects has also been added (see Section 6.13).

   o  Simplified Diameter peer discovery.  The Diameter discovery
      process now supports only widely used discovery schemes; the rest
      have been deprecated (see Section 5.2 for details).
```

Peer discover is not currently supported: peers to which a node should connect must be configured. Connection requests are accepted from arbitrary peers but a *diameter:transport_opt()* `capabilities_cb` can be used to reject a peer based on an incoming CER or CEA.

```
   There are many other miscellaneous fixes that have been introduced in
   this document that may not be considered significant, but they have
   value nonetheless.  Examples are removal of obsolete types, fixes to
   the state machine, clarification of the election process, message
   validation, fixes to Failed-AVP and Result-Code AVP values, etc.  All
   of the errata filed against RFC 3588 prior to the publication of this
   document have been addressed.  A comprehensive list of changes is not
   shown here for practical reasons.

1.2.  Terminology

   AAA

      Authentication, Authorization, and Accounting.




Fajardo, et al.              Standards Track                   [Page 12]

RFC 6733                Diameter Base Protocol             October 2012


   ABNF

      Augmented Backus-Naur Form [RFC5234].  A metalanguage with its own
      formal syntax and rules.  It is based on the Backus-Naur Form and
```

```
      is used to define message exchanges in a bi-directional
      communications protocol.

   Accounting

      The act of collecting information on resource usage for the
      purpose of capacity planning, auditing, billing, or cost
      allocation.

   Accounting Record

      An accounting record represents a summary of the resource
      consumption of a user over the entire session.  Accounting servers
      creating the accounting record may do so by processing interim
      accounting events or accounting events from several devices
      serving the same user.

   Authentication

      The act of verifying the identity of an entity (subject).

   Authorization

      The act of determining whether a requesting entity (subject) will
      be allowed access to a resource (object).

   Attribute-Value Pair (AVP)

      The Diameter protocol consists of a header followed by one or more
      Attribute-Value-Pairs (AVPs).  An AVP includes a header and is
      used to encapsulate protocol-specific data (e.g., routing
      information) as well as authentication, authorization, or
      accounting information.
```

No comment.

```


   Command Code Format (CCF)

      A modified form of ABNF used to define Diameter commands (see
      Section 3.2).
```

The `@messages` section of the *diameter_dict(4)* format has the CCF as content.

```


   Diameter Agent

      A Diameter Agent is a Diameter node that provides relay, proxy,
      redirect, or translation services.




Fajardo, et al.              Standards Track                   [Page 13]

RFC 6733                 Diameter Base Protocol             October 2012


   Diameter Client
```

```
      A Diameter client is a Diameter node that supports Diameter client
      applications as well as the base protocol.  Diameter clients are
      often implemented in devices situated at the edge of a network and
      provide access control services for that network.  Typical
      examples of Diameter clients include the Network Access Server
      (NAS) and the Mobile IP Foreign Agent (FA).

   Diameter Node

      A Diameter node is a host process that implements the Diameter
      protocol and acts as either a client, an agent, or a server.

   Diameter Peer

      Two Diameter nodes sharing a direct TCP or SCTP transport
      connection are called Diameter peers.

   Diameter Server

      A Diameter server is a Diameter node that handles authentication,
      authorization, and accounting requests for a particular realm.  By
      its very nature, a Diameter server must support Diameter server
      applications in addition to the base protocol.
```

A Diameter Node is implemented by configuring a service using *diameter:start_service/2* and one or more transports using *diameter:add_transport/2*. The service typically represents a Diameter Node but since capabilities can be configured on individual transports it's more accurate to say that the node is a collection of transports advertising the same Origin-Host.

The role of a node (agent, client or server) is not something that's configured explicitly. Transports are either connecting or listening, depending on whether diameter should establish a peer connection and send CER or accept connections and receive CER, but the role a node implements depends largely on dictionary configuration and *diameter_app(3)* callback implementation.

```
   Downstream

      Downstream is used to identify the direction of a particular
      Diameter message from the home server towards the Diameter client.

   Home Realm

      A Home Realm is the administrative domain with which the user
      maintains an account relationship.

   Home Server

      A Diameter server that serves the Home Realm.

   Interim Accounting

      An interim accounting message provides a snapshot of usage during
      a user's session.  Typically, it is implemented in order to
      provide for partial accounting of a user's session in case a
      device reboot or other network problem prevents the delivery of a
      session summary message or session record.



Fajardo, et al.             Standards Track                  [Page 14]
```

Local Realm

A local realm is the administrative domain providing services to a user. An administrative domain may act as a local realm for certain users while being a home realm for others.

Multi-session

A multi-session represents a logical linking of several sessions. Multi-sessions are tracked by using the Acct-Multi-Session-Id. An example of a multi-session would be a Multi-link PPP bundle. Each leg of the bundle would be a session while the entire bundle would be a multi-session.

Network Access Identifier

The Network Access Identifier, or NAI [RFC4282], is used in the Diameter protocol to extract a user's identity and realm. The identity is used to identify the user during authentication and/or authorization while the realm is used for message routing purposes.

Proxy Agent or Proxy

In addition to forwarding requests and responses, proxies make policy decisions relating to resource usage and provisioning. Typically, this is accomplished by tracking the state of NAS devices. While proxies usually do not respond to client requests prior to receiving a response from the server, they may originate Reject messages in cases where policies are violated. As a result, proxies need to understand the semantics of the messages passing through them, and they may not support all Diameter applications.

Realm

The string in the NAI that immediately follows the '@' character. NAI realm names are required to be unique and are piggybacked on the administration of the DNS namespace. Diameter makes use of the realm, also loosely referred to as domain, to determine whether messages can be satisfied locally or whether they must be routed or redirected. In RADIUS, realm names are not necessarily piggybacked on the DNS namespace but may be independent of it.

Real-Time Accounting

Real-time accounting involves the processing of information on resource usage within a defined time window. Typically, time constraints are imposed in order to limit financial risk. The

```
      Diameter Credit-Control Application [RFC4006] is an example of an
      application that defines real-time accounting functionality.

   Relay Agent or Relay

      Relays forward requests and responses based on routing-related
      AVPs and routing table entries.  Since relays do not make policy
      decisions, they do not examine or alter non-routing AVPs.  As a
      result, relays never originate messages, do not need to understand
      the semantics of messages or non-routing AVPs, and are capable of
      handling any Diameter application or message type.  Since relays
      make decisions based on information in routing AVPs and realm
      forwarding tables, they do not keep state on NAS resource usage or
      sessions in progress.

   Redirect Agent

      Rather than forwarding requests and responses between clients and
      servers, redirect agents refer clients to servers and allow them
      to communicate directly.  Since redirect agents do not sit in the
      forwarding path, they do not alter any AVPs transiting between
      client and server.  Redirect agents do not originate messages and
      are capable of handling any message type, although they may be
      configured only to redirect messages of certain types, while
      acting as relay or proxy agents for other types.  As with relay
      agents, redirect agents do not keep state with respect to sessions
      or NAS resources.
```

No comment.

```
   Session

      A session is a related progression of events devoted to a
      particular activity.  Diameter application documents provide
      guidelines as to when a session begins and ends.  All Diameter
      packets with the same Session-Id are considered to be part of the
      same session.
```

Sessions are not something that diameter is aware of. The function *diameter:session_id/1* can be used to construct appropriate values for Session-Id AVP's but logic connecting events in the same session is the responsibility of the diameter user.

```
   Stateful Agent

      A stateful agent is one that maintains session state information,
      by keeping track of all authorized active sessions.  Each
      authorized session is bound to a particular service, and its state
      is considered active either until it is notified otherwise or
      until expiration.



Fajardo, et al.              Standards Track                   [Page 16]

RFC 6733                Diameter Base Protocol             October 2012
```

```
   Sub-session

      A sub-session represents a distinct service (e.g., QoS or data
      characteristics) provided to a given session.  These services may
      happen concurrently (e.g., simultaneous voice and data transfer
      during the same session) or serially.  These changes in sessions
      are tracked with the Accounting-Sub-Session-Id.

   Transaction State

      The Diameter protocol requires that agents maintain transaction
      state, which is used for failover purposes.  Transaction state
      implies that upon forwarding a request, the Hop-by-Hop Identifier
      is saved; the field is replaced with a locally unique identifier,
      which is restored to its original value when the corresponding
      answer is received.  The request's state is released upon receipt
      of the answer.  A stateless agent is one that only maintains
      transaction state.

   Translation Agent

      A translation agent (TLA in Figure 4) is a stateful Diameter node
      that performs protocol translation between Diameter and another
      AAA protocol, such as RADIUS.

   Upstream

      Upstream is used to identify the direction of a particular
      Diameter message from the Diameter client towards the home server.

   User

      The entity or device requesting or using some resource, in support
      of which a Diameter client has generated a request.
```

No comment.

```
1.3.  Approach to Extensibility

   The Diameter protocol is designed to be extensible, using several
   mechanisms, including:

   o  Defining new AVP values

   o  Creating new AVPs

   o  Creating new commands

   o  Creating new applications



Fajardo, et al.              Standards Track                  [Page 17]

RFC 6733                Diameter Base Protocol             October 2012


   From the point of view of extensibility, Diameter authentication,
   authorization, and accounting applications are treated in the same
   way.
```

Extensibility in diameter is by way of the dictionary interface documented in *diameter_dict(4)*: a diameter user creates applications, commands and AVP's by implementing a new dictionary, compiling the dictionary to a codec module using *diameterc(1)* or *diameter_make(3)*, and configuring the resulting dictionary module on a service. The dictionary modules provided with diameter are all implemented in this manner.

```
   Note: Protocol designers should try to reuse existing functionality,
   namely AVP values, AVPs, commands, and Diameter applications.  Reuse
   simplifies standardization and implementation.  To avoid potential
   interoperability issues, it is important to ensure that the semantics
   of the reused features are well understood.  Given that Diameter can
   also carry RADIUS attributes as Diameter AVPs, such reuse
   considerations also apply to existing RADIUS attributes that may be
   useful in a Diameter application.
```

Reuse in dictionary files is achieved by way of the `@inherits` section. AVP's are inherited, commands are not.

```
1.3.1.  Defining New AVP Values

   In order to allocate a new AVP value for AVPs defined in the Diameter
   base protocol, the IETF needs to approve a new RFC that describes the
   AVP value.  IANA considerations for these AVP values are discussed in
   Section 11.3.

   The allocation of AVP values for other AVPs is guided by the IANA
   considerations of the document that defines those AVPs.  Typically,
   allocation of new values for an AVP defined in an RFC would require
   IETF Review [RFC5226], whereas values for vendor-specific AVPs can be
   allocated by the vendor.

1.3.2.  Creating New AVPs

   A new AVP being defined MUST use one of the data types listed in
   Sections 4.2 or 4.3.  If an appropriate derived data type is already
   defined, it SHOULD be used instead of a base data type to encourage
   reusability and good design practice.

   In the event that a logical grouping of AVPs is necessary, and
   multiple "groups" are possible in a given command, it is recommended
   that a Grouped AVP be used (see Section 4.4).

   The creation of new AVPs can happen in various ways.  The recommended
   approach is to define a new general-purpose AVP in a Standards Track
   RFC approved by the IETF.  However, as described in Section 11.1.1,
   there are other mechanisms.
```

Creating new AVP's is an issue for the dictionary designer, not diameter.

```
1.3.3.  Creating New Commands

   A new Command Code MUST be allocated when required AVPs (those
   indicated as {AVP} in the CCF definition) are added to, deleted from,
   or redefined in (for example, by changing a required AVP into an
   optional one) an existing command.
```

```
Fajardo, et al.              Standards Track                   [Page 18]

RFC 6733                 Diameter Base Protocol             October 2012


   Furthermore, if the transport characteristics of a command are
   changed (for example, with respect to the number of round trips
   required), a new Command Code MUST be registered.

   A change to the CCF of a command, such as described above, MUST
   result in the definition of a new Command Code.  This subsequently
   leads to the need to define a new Diameter application for any
   application that will use that new command.

   The IANA considerations for Command Codes are discussed in
   Section 3.1.
```

Creating new commands is an issue for the dictionary designer, not diameter.

```
1.3.4.  Creating New Diameter Applications

   Every Diameter application specification MUST have an IANA-assigned
   Application Id (see Section 2.4).  The managed Application ID space
   is flat, and there is no relationship between different Diameter
   applications with respect to their Application Ids.  As such, there
   is no versioning support provided by these Application Ids
   themselves; every Diameter application is a standalone application.
   If the application has a relationship with other Diameter
   applications, such a relationship is not known to Diameter.
```

Creating new applications is an issue for the dictionary designer, not diameter.

An application's Application Id is specified in the `@id` section of a dictionary file.

```
   Before describing the rules for creating new Diameter applications,
   it is important to discuss the semantics of the AVP occurrences as
   stated in the CCF and the M-bit flag (Section 4.1) for an AVP.  There
   is no relationship imposed between the two; they are set
   independently.

   o  The CCF indicates what AVPs are placed into a Diameter command by
      the sender of that command.  Often, since there are multiple modes
      of protocol interactions, many of the AVPs are indicated as
      optional.

   o  The M-bit allows the sender to indicate to the receiver whether or
      not understanding the semantics of an AVP and its content is
      mandatory.  If the M-bit is set by the sender and the receiver
      does not understand the AVP or the values carried within that AVP,
      then a failure is generated (see Section 7).
```

The M-bit is set on outgoing AVP's as directed by the relevant dictionary. For incoming AVP's, an M-bit set on an AVP that isn't explicitly included in the definition of the command in question is interpreted as a 5001 error, DIAMETER_AVP_UNSUPPORTED, the consequences of which depend on the value of the *diameter:application_opt()* `answer_errors` or `request_errors`.

```
   It is the decision of the protocol designer when to develop a new
   Diameter application rather than extending Diameter in other ways.
   However, a new Diameter application MUST be created when one or more
   of the following criteria are met:




Fajardo, et al.              Standards Track                   [Page 19]

RFC 6733                 Diameter Base Protocol             October 2012


   M-bit Setting

      An AVP with the M-bit in the MUST column of the AVP flag table is
      added to an existing Command/Application.  An AVP with the M-bit
      in the MAY column of the AVP flag table is added to an existing
      Command/Application.

      Note: The M-bit setting for a given AVP is relevant to an
      Application and each command within that application that includes
      the AVP.  That is, if an AVP appears in two commands for
      application Foo and the M-bit settings are different in each
      command, then there should be two AVP flag tables describing when
      to set the M-bit.

   Commands

      A new command is used within the existing application because
      either an additional command is added, an existing command has
      been modified so that a new Command Code had to be registered, or
      a command has been deleted.

   AVP Flag bits

      If an existing application changes the meaning/semantics of its
      AVP Flags or adds new flag bits, then a new Diameter application
      MUST be created.

   If the CCF definition of a command allows it, an implementation may
   add arbitrary optional AVPs with the M-bit cleared (including vendor-
   specific AVPs) to that command without needing to define a new
   application.  Please refer to Section 11.1.1 for details.
```

No comment.

```
2.  Protocol Overview

   The base Diameter protocol concerns itself with establishing
   connections to peers, capabilities negotiation, how messages are sent
   and routed through peers, and how the connections are eventually torn
   down.  The base protocol also defines certain rules that apply to all
   message exchanges between Diameter nodes.

   Communication between Diameter peers begins with one peer sending a
```

```
   message to another Diameter peer.  The set of AVPs included in the
   message is determined by a particular Diameter application.  One AVP
   that is included to reference a user's session is the Session-Id.

   The initial request for authentication and/or authorization of a user
   would include the Session-Id AVP.  The Session-Id is then used in all
   subsequent messages to identify the user's session (see Section 8 for


Fajardo, et al.              Standards Track                  [Page 20]

RFC 6733                 Diameter Base Protocol            October 2012


   more information).  The communicating party may accept the request or
   reject it by returning an answer message with the Result-Code AVP set
   to indicate that an error occurred.  The specific behavior of the
   Diameter server or client receiving a request depends on the Diameter
   application employed.

   Session state (associated with a Session-Id) MUST be freed upon
   receipt of the Session-Termination-Request, Session-Termination-
   Answer, expiration of authorized service time in the Session-Timeout
   AVP, and according to rules established in a particular Diameter
   application.
```

Like Session-Id, session state is maintained by the diameter user: diameter has no session state of its own and does not interpret STR/STA in any way.

```
   The base Diameter protocol may be used by itself for accounting
   applications.  For authentication and authorization, it is always
   extended for a particular application.

   Diameter clients MUST support the base protocol, which includes
   accounting.  In addition, they MUST fully support each Diameter
   application that is needed to implement the client's service, e.g.,
   Network Access Server Requirements (NASREQ) [RFC2881] and/or Mobile
   IPv4.  A Diameter client MUST be referred to as "Diameter X Client"
   where X is the application that it supports and not a "Diameter
   Client".

   Diameter servers MUST support the base protocol, which includes
   accounting.  In addition, they MUST fully support each Diameter
   application that is needed to implement the intended service, e.g.,
   NASREQ and/or Mobile IPv4.  A Diameter server MUST be referred to as
   "Diameter X Server" where X is the application that it supports, and
   not a "Diameter Server".

   Diameter relays and redirect agents are transparent to the Diameter
   applications, but they MUST support the Diameter base protocol, which
   includes accounting, and all Diameter applications.

   Diameter proxies MUST support the base protocol, which includes
   accounting.  In addition, they MUST fully support each Diameter
   application that is needed to implement proxied services, e.g.,
   NASREQ and/or Mobile IPv4.  A Diameter proxy MUST be referred to as
   "Diameter X Proxy" where X is the application which it supports, and
   not a "Diameter Proxy".
```

No comment.

```
Fajardo, et al.              Standards Track                   [Page 21]

RFC 6733                 Diameter Base Protocol             October 2012


2.1.  Transport

   The Diameter Transport profile is defined in [RFC3539].

   The base Diameter protocol is run on port 3868 for both TCP [RFC0793]
   and SCTP [RFC4960].  For TLS [RFC5246] and Datagram Transport Layer
   Security (DTLS) [RFC6347], a Diameter node that initiates a
   connection prior to any message exchanges MUST run on port 5658.  It
   is assumed that TLS is run on top of TCP when it is used, and DTLS is
   run on top of SCTP when it is used.
```

Which port a transport connects to or listens on is a matter of configuration. Both *diameter_tcp(3)* and *diameter_sctp(3)* will default to 3868 if no other value is specified.

```
   If the Diameter peer does not support receiving TLS/TCP and DTLS/SCTP
   connections on port 5658 (i.e., the peer complies only with RFC
   3588), then the initiator MAY revert to using TCP or SCTP on port
   3868.  Note that this scheme is kept only for the purpose of backward
   compatibility and that there are inherent security vulnerabilities
   when the initial CER/CEA messages are sent unprotected (see
   Section 5.6).

   Diameter clients MUST support either TCP or SCTP; agents and servers
   SHOULD support both.

   A Diameter node MAY initiate connections from a source port other
   than the one that it declares it accepts incoming connections on, and
   it MUST always be prepared to receive connections on port 3868 for
   TCP or SCTP and port 5658 for TLS/TCP and DTLS/SCTP connections.
   When DNS-based peer discovery (Section 5.2) is used, the port numbers
   received from SRV records take precedence over the default ports
   (3868 and 5658).

   A given Diameter instance of the peer state machine MUST NOT use more
   than one transport connection to communicate with a given peer,
   unless multiple instances exist on the peer, in which, case a
   separate connection per process is allowed.
```

The *diameter:service_opt()* `restrict_connection` controls to what extent a diameter service allows multiple connections to the same peer. (As identified by the value of Origin-Host received from it during capabilities exchange.)

```
   When no transport connection exists with a peer, an attempt to
   connect SHOULD be made periodically.  This behavior is handled via
   the Tc timer (see Section 12 for details), whose recommended value is
   30 seconds.  There are certain exceptions to this rule, such as when
   a peer has terminated the transport connection stating that it does
   not wish to communicate.
```

The frequency of reconnection attempts is configured with the *diameter:transport_opt()* `connect_timer` and `watchdog_timer`.

```
   When connecting to a peer and either zero or more transports are
   specified, TLS SHOULD be tried first, followed by DTLS, then by TCP,
   and finally by SCTP.  See Section 5.2 for more information on peer
   discovery.
```

The order in which different transports are attempted depends on the order of *diameter:transport_opt()* `transport_module` and `transport_config` tuples in transport configuration.

```
Fajardo, et al.              Standards Track                   [Page 22]

RFC 6733                 Diameter Base Protocol             October 2012


   Diameter implementations SHOULD be able to interpret ICMP protocol
   port unreachable messages as explicit indications that the server is
   not reachable, subject to security policy on trusting such messages.
   Further guidance regarding the treatment of ICMP errors can be found
   in [RFC5927] and [RFC5461].  Diameter implementations SHOULD also be
   able to interpret a reset from the transport and timed-out connection
   attempts.  If Diameter receives data from the lower layer that cannot
   be parsed or identified as a Diameter error made by the peer, the
   stream is compromised and cannot be recovered.  The transport
   connection MUST be closed using a RESET call (send a TCP RST bit) or
   an SCTP ABORT message (graceful closure is compromised).
```

ICMP messages and other transport-level errors aren't directly visible to diameter but transport implementations like *diameter_tcp(3)* and *diameter_sctp(3)* propagate these as terminating transport processes.

```
2.1.1.  SCTP Guidelines

   Diameter messages SHOULD be mapped into SCTP streams in a way that
   avoids head-of-the-line (HOL) blocking.  Among different ways of
   performing the mapping that fulfill this requirement it is
   RECOMMENDED that a Diameter node send every Diameter message (request
   or response) over stream zero with the unordered flag set.  However,
   Diameter nodes MAY select and implement other design alternatives for
   avoiding HOL blocking such as using multiple streams with the
   unordered flag cleared (as originally instructed in RFC 3588).  On
   the receiving side, a Diameter entity MUST be ready to receive
```

```
   Diameter messages over any stream, and it is free to return responses
   over a different stream.  This way, both sides manage the available
   streams in the sending direction, independently of the streams chosen
   by the other side to send a particular Diameter message.  These
   messages can be out-of-order and belong to different Diameter
   sessions.
```

diameter_sctp(3) allows the sender to specify a stream number explicitly. The stream on which an incoming message is received it passed to *handle_request/3* and *handle_answer/4* callbacks as `transport_data` in a `#diameter_packet{}`.

Ordered or unordered delivery can be configured per transport.

```
   Out-of-order delivery has special concerns during a connection
   establishment and termination.  When a connection is established, the
   responder side sends a CEA message and moves to R-Open state as
   specified in Section 5.6.  If an application message is sent shortly
   after the CEA and delivered out-of-order, the initiator side, still
   in Wait-I-CEA state, will discard the application message and close
   the connection.  In order to avoid this race condition, the receiver
   side SHOULD NOT use out-of-order delivery methods until the first
   message has been received from the initiator, proving that it has
   moved to I-Open state.  To trigger such a message, the receiver side
   could send a DWR immediately after sending a CEA.  Upon reception of
   the corresponding DWA, the receiver side should start using out-of-
   order delivery methods to counter the HOL blocking.
```

diameter_sctp(3) does not currently allow the user to switch between ordered and unordered delivery, or to specify the manner of sending per message: one or the other must be configured, the defaults being ordered.

```
   Another race condition may occur when DPR and DPA messages are used.
   Both DPR and DPA are small in size; thus, they may be delivered to
   the peer faster than application messages when an out-of-order
   delivery mechanism is used.  Therefore, it is possible that a DPR/DPA



Fajardo, et al.              Standards Track                   [Page 23]

RFC 6733                 Diameter Base Protocol             October 2012


   exchange completes while application messages are still in transit,
   resulting in a loss of these messages.  An implementation could
   mitigate this race condition, for example, using timers, and wait for
   a short period of time for pending application level messages to
   arrive before proceeding to disconnect the transport connection.
   Eventually, lost messages are handled by the retransmission mechanism
   described in Section 5.5.4.

   A Diameter agent SHOULD use dedicated payload protocol identifiers
   (PPIDs) for clear text and encrypted SCTP DATA chunks instead of only
   using the unspecified payload protocol identifier (value 0).  For
   this purpose, two PPID values are allocated: the PPID value 46 is for
   Diameter messages in clear text SCTP DATA chunks, and the PPID value
   47 is for Diameter messages in protected DTLS/SCTP DATA chunks.
```

No comment.

```
2.2.  Securing Diameter Messages

   Connections between Diameter peers SHOULD be protected by TLS/TCP and
   DTLS/SCTP.  All Diameter base protocol implementations MUST support
   the use of TLS/TCP and DTLS/SCTP.  If desired, alternative security
   mechanisms that are independent of Diameter, such as IPsec [RFC4301],
   can be deployed to secure connections between peers.  The Diameter
   protocol MUST NOT be used without one of TLS, DTLS, or IPsec.
```

As noted above, DTLS is not currently supported and IPsec usage is transparent to diameter. Security is not enforced by diameter.

```
2.3.  Diameter Application Compliance

   Application Ids are advertised during the capabilities exchange phase
   (see Section 5.3).  Advertising support of an application implies
   that the sender supports the functionality specified in the
   respective Diameter application specification.

   Implementations MAY add arbitrary optional AVPs with the M-bit
   cleared (including vendor-specific AVPs) to a command defined in an
   application, but only if the command's CCF syntax specification
   allows for it.  Please refer to Section 11.1.1 for details.
```

No comment.

```
2.4.  Application Identifiers

   Each Diameter application MUST have an IANA-assigned Application ID.
   The base protocol does not require an Application Id since its
   support is mandatory.  During the capabilities exchange, Diameter
   nodes inform their peers of locally supported applications.
   Furthermore, all Diameter messages contain an Application Id, which
   is used in the message forwarding process.
```



```
   The following Application Id values are defined:

         Diameter common message       0
         Diameter base accounting      3
         Relay                         0xffffffff
```

These applications are implemented in the dictionary modules `diameter_gen_base_rfc6733`, `diameter_gen_acct_rfc6733` and `diameter_relay` respectively. There are also RFC 3588 versions or the common and accounting dictionaries: `diameter_gen_base_rfc3588` and `diameter_base_accounting`. (The inconsistent naming is historical.) Dictionary modules are configured using the *diameter:application_opt()* `dictionary`.

```
   Relay and redirect agents MUST advertise the Relay Application ID,
   while all other Diameter nodes MUST advertise locally supported
   applications.  The receiver of a Capabilities Exchange message
   advertising relay service MUST assume that the sender supports all
   current and future applications.

   Diameter relay and proxy agents are responsible for finding an
   upstream server that supports the application of a particular
   message.  If none can be found, an error message is returned with the
   Result-Code AVP set to DIAMETER_UNABLE_TO_DELIVER.
```

No comment.

```
2.5.  Connections vs. Sessions

   This section attempts to provide the reader with an understanding of
   the difference between "connection" and "session", which are terms
   used extensively throughout this document.

   A connection refers to a transport-level connection between two peers
   that is used to send and receive Diameter messages.  A session is a
   logical concept at the application layer that exists between the
   Diameter client and the Diameter server; it is identified via the
   Session-Id AVP.

             +--------+          +-------+          +--------+
             | Client |          | Relay |          | Server |
             +--------+          +-------+          +--------+
                      <---------->       <---------->
                    peer connection A   peer connection B

                       <----------------------------->
                                User session x

                  Figure 1: Diameter Connections and Sessions

   In the example provided in Figure 1, peer connection A is established
   between the client and the relay.  Peer connection B is established
   between the relay and the server.  User session X spans from the
   client via the relay to the server.  Each "user" of a service causes
   an auth request to be sent, with a unique session identifier.  Once
   accepted by the server, both the client and the server are aware of
   the session.



Fajardo, et al.              Standards Track                   [Page 25]

RFC 6733                 Diameter Base Protocol             October 2012


   It is important to note that there is no relationship between a
```

```
   connection and a session, and that Diameter messages for multiple
   sessions are all multiplexed through a single connection.  Also, note
   that Diameter messages pertaining to the session, both application-
   specific and those that are defined in this document such as ASR/ASA,
   RAR/RAA, and STR/STA, MUST carry the Application Id of the
   application.  Diameter messages pertaining to peer connection
   establishment and maintenance such as CER/CEA, DWR/DWA, and DPR/DPA
   MUST carry an Application Id of zero (0).
```

As noted above, diameter is not involved in session management. This is the responsibility of the diameter user.

```
2.6.  Peer Table

   The Diameter peer table is used in message forwarding and is
   referenced by the routing table.  A peer table entry contains the
   following fields:

   Host Identity

      Following the conventions described for the DiameterIdentity-
      derived AVP data format in Section 4.3.1, this field contains the
      contents of the Origin-Host (Section 6.3) AVP found in the CER or
      CEA message.

   StatusT

      This is the state of the peer entry, and it MUST match one of the
      values listed in Section 5.6.

   Static or Dynamic

      Specifies whether a peer entry was statically configured or
      dynamically discovered.

   Expiration Time

      Specifies the time at which dynamically discovered peer table
      entries are to be either refreshed or expired.  If public key
      certificates are used for Diameter security (e.g., with TLS), this
      value MUST NOT be greater than the expiry times in the relevant
      certificates.

   TLS/TCP and DTLS/SCTP Enabled

      Specifies whether TLS/TCP and DTLS/SCTP is to be used when
      communicating with the peer.

   Additional security information, when needed (e.g., keys,
   certificates).
```

The Peer Table is not directly accessible to the diameter user. Information about connected peers can be retrieved using *diameter:service_info/2*.

```
Fajardo, et al.              Standards Track                   [Page 26]

RFC 6733                 Diameter Base Protocol             October 2012
```

2.7. Routing Table

All Realm-Based routing lookups are performed against what is commonly known as the routing table (see Section 12). Each routing table entry contains the following fields:

Realm Name

This is the field that MUST be used as a primary key in the routing table lookups. Note that some implementations perform their lookups based on longest-match-from-the-right on the realm rather than requiring an exact match.

Application Identifier

An application is identified by an Application Id. A route entry can have a different destination based on the Application Id in the message header. This field MUST be used as a secondary key field in routing table lookups.

Local Action

The Local Action field is used to identify how a message should be treated. The following actions are supported:

1. LOCAL - Diameter messages that can be satisfied locally and do not need to be routed to another Diameter entity.

2. RELAY - All Diameter messages that fall within this category MUST be routed to a next-hop Diameter entity that is indicated by the identifier described below. Routing is done without modifying any non-routing AVPs. See Section 6.1.9 for relaying guidelines.

3. PROXY - All Diameter messages that fall within this category MUST be routed to a next Diameter entity that is indicated by the identifier described below. The local server MAY apply its local policies to the message by including new AVPs to the message prior to routing. See Section 6.1.9 for proxying guidelines.

4. REDIRECT - Diameter messages that fall within this category MUST have the identity of the home Diameter server(s) appended, and returned to the sender of the message. See Section 6.1.8 for redirection guidelines.

Server Identifier

The identity of one or more servers to which the message is to be routed. This identity MUST also be present in the Host Identity field of the peer table (Section 2.6). When the Local Action is set to RELAY or PROXY, this field contains the identity of the server(s) to which the message MUST be routed. When the Local

```
      Action field is set to REDIRECT, this field contains the identity
      of one or more servers to which the message MUST be redirected.

   Static or Dynamic

      Specifies whether a route entry was statically configured or
      dynamically discovered.

   Expiration Time

      Specifies the time at which a dynamically discovered route table
      entry expires.  If public key certificates are used for Diameter
      security (e.g., with TLS), this value MUST NOT be greater than the
      expiry time in the relevant certificates.

   It is important to note that Diameter agents MUST support at least
   one of the LOCAL, RELAY, PROXY, or REDIRECT modes of operation.
   Agents do not need to support all modes of operation in order to
   conform with the protocol specification, but they MUST follow the
   protocol compliance guidelines in Section 2.  Relay agents and
   proxies MUST NOT reorder AVPs.

   The routing table MAY include a default entry that MUST be used for
   any requests not matching any of the other entries.  The routing
   table MAY consist of only such an entry.

   When a request is routed, the target server MUST have advertised the
   Application Id (see Section 2.4) for the given message or have
   advertised itself as a relay or proxy agent.  Otherwise, an error is
   returned with the Result-Code AVP set to DIAMETER_UNABLE_TO_DELIVER.
```

Routing does not need specific support in diameter: a user can maintain their own routing table if desired and implement any desired routing in *diameter_app(3)* callbacks. However, it may be convenient to add more specific routing support to diameter in the future.

```


2.8.  Role of Diameter Agents

   In addition to clients and servers, the Diameter protocol introduces
   relay, proxy, redirect, and translation agents, each of which is
   defined in Section 1.2.  Diameter agents are useful for several
   reasons:
```

An noted above, the role a node plays is largely a question of configuration and *diameter_app(3)* callback implementation.

```


   o  They can distribute administration of systems to a configurable
      grouping, including the maintenance of security associations.



Fajardo, et al.              Standards Track                   [Page 28]

RFC 6733                Diameter Base Protocol             October 2012


   o  They can be used for concentration of requests from a number of
```

```
      co-located or distributed NAS equipment sets to a set of like user
      groups.

   o  They can do value-added processing to the requests or responses.

   o  They can be used for load balancing.

   o  A complex network will have multiple authentication sources, they
      can sort requests and forward towards the correct target.

   The Diameter protocol requires that agents maintain transaction
   state, which is used for failover purposes.  Transaction state
   implies that upon forwarding a request, its Hop-by-Hop Identifier is
   saved; the field is replaced with a locally unique identifier, which
   is restored to its original value when the corresponding answer is
   received.  The request's state is released upon receipt of the
   answer.  A stateless agent is one that only maintains transaction
   state.

   The Proxy-Info AVP allows stateless agents to add local state to a
   Diameter request, with the guarantee that the same state will be
   present in the answer.  However, the protocol's failover procedures
   require that agents maintain a copy of pending requests.

   A stateful agent is one that maintains session state information by
   keeping track of all authorized active sessions.  Each authorized
   session is bound to a particular service, and its state is considered
   active until either the agent is notified otherwise or the session
   expires.  Each authorized session has an expiration, which is
   communicated by Diameter servers via the Session-Timeout AVP.

   Maintaining session state may be useful in certain applications, such
   as:

   o  Protocol translation (e.g., RADIUS <-> Diameter)

   o  Limiting resources authorized to a particular user

   o  Per-user or per-transaction auditing

   A Diameter agent MAY act in a stateful manner for some requests and
   be stateless for others.  A Diameter implementation MAY act as one
   type of agent for some requests and as another type of agent for
   others.
```

No comment.

```
Fajardo, et al.              Standards Track                   [Page 29]

RFC 6733                 Diameter Base Protocol             October 2012


2.8.1.  Relay Agents

   Relay agents are Diameter agents that accept requests and route
   messages to other Diameter nodes based on information found in the
```

```
   messages (e.g., the value of the Destination-Realm AVP Section 6.6).
   This routing decision is performed using a list of supported realms
   and known peers.  This is known as the routing table, as is defined
   further in Section 2.7.

   Relays may, for example, be used to aggregate requests from multiple
   Network Access Servers (NASes) within a common geographical area
   (Point of Presence, POP).  The use of relays is advantageous since it
   eliminates the need for NASes to be configured with the necessary
   security information they would otherwise require to communicate with
   Diameter servers in other realms.  Likewise, this reduces the
   configuration load on Diameter servers that would otherwise be
   necessary when NASes are added, changed, or deleted.

   Relays modify Diameter messages by inserting and removing routing
   information, but they do not modify any other portion of a message.
   Relays SHOULD NOT maintain session state but MUST maintain
   transaction state.

       +------+    --------->     +------+     --------->    +------+
       |      |    1. Request     |      |     2. Request    |      |
       | NAS  |                   | DRL  |                   | HMS  |
       |      |    4. Answer      |      |     3. Answer     |      |
       +------+    <---------     +------+     <---------    +------+
    example.net                example.net                example.com

                  Figure 2: Relaying of Diameter messages

   The example provided in Figure 2 depicts a request issued from a NAS,
   which is an access device, for the user bob@example.com.  Prior to
   issuing the request, the NAS performs a Diameter route lookup, using
   "example.com" as the key, and determines that the message is to be
   relayed to a DRL, which is a Diameter relay.  The DRL performs the
   same route lookup as the NAS, and relays the message to the HMS,
   which is example.com's home server.  The HMS identifies that the
   request can be locally supported (via the realm), processes the
   authentication and/or authorization request, and replies with an
   answer, which is routed back to the NAS using saved transaction
   state.

   Since relays do not perform any application-level processing, they
   provide relaying services for all Diameter applications; therefore,
   they MUST advertise the Relay Application Id.
```

Requests are relayed by returning a `relay` tuple from a *handle_request/3* callback.

```
Fajardo, et al.              Standards Track                   [Page 30]

RFC 6733                Diameter Base Protocol             October 2012


2.8.2.  Proxy Agents

   Similar to relays, proxy agents route Diameter messages using the
   Diameter routing table.  However, they differ since they modify
   messages to implement policy enforcement.  This requires that proxies
   maintain the state of their downstream peers (e.g., access devices)
   to enforce resource usage, provide admission control, and provide
   provisioning.
```

```
   Proxies may, for example, be used in call control centers or access
   ISPs that provide outsourced connections; they can monitor the number
   and type of ports in use and make allocation and admission decisions
   according to their configuration.

   Since enforcing policies requires an understanding of the service
   being provided, proxies MUST only advertise the Diameter applications
   they support.
```

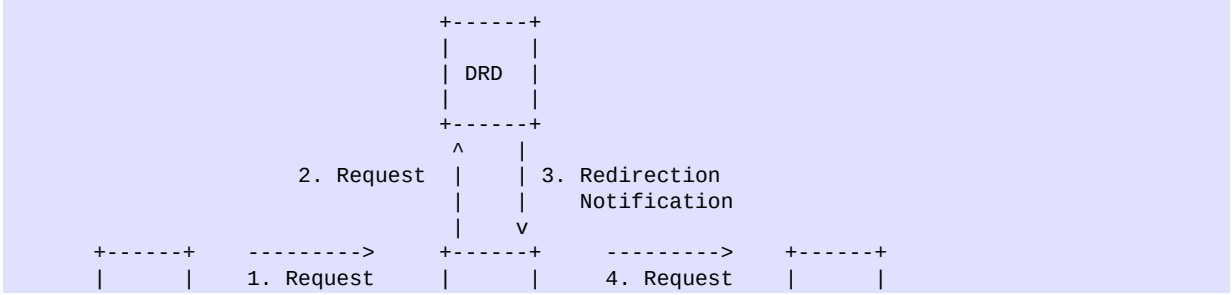
No comment.

```
2.8.3.  Redirect Agents

   Redirect agents are useful in scenarios where the Diameter routing
   configuration needs to be centralized.  An example is a redirect
   agent that provides services to all members of a consortium, but does
   not wish to be burdened with relaying all messages between realms.
   This scenario is advantageous since it does not require that the
   consortium provide routing updates to its members when changes are
   made to a member's infrastructure.

   Since redirect agents do not relay messages, and only return an
   answer with the information necessary for Diameter agents to
   communicate directly, they do not modify messages.  Since redirect
   agents do not receive answer messages, they cannot maintain session
   state.

   The example provided in Figure 3 depicts a request issued from the
   access device, NAS, for the user bob@example.com.  The message is
   forwarded by the NAS to its relay, DRL, which does not have a routing
   entry in its Diameter routing table for example.com.  The DRL has a
   default route configured to DRD, which is a redirect agent that
   returns a redirect notification to DRL, as well as the HMS' contact
   information.  Upon receipt of the redirect notification, the DRL
   establishes a transport connection with the HMS, if one doesn't
   already exist, and forwards the request to it.
```

```
      | NAS  |                   | DRL  |                   | HMS  |
      |      |    6. Answer      |      |     5. Answer     |      |
      +------+    <---------     +------+     <---------    +------+
     example.net                example.net                example.com

                Figure 3: Redirecting a Diameter Message

   Since redirect agents do not perform any application-level
   processing, they provide relaying services for all Diameter
   applications; therefore, they MUST advertise the Relay Application
   ID.
```

No comment.

```
2.8.4.  Translation Agents

   A translation agent is a device that provides translation between two
   protocols (e.g., RADIUS<->Diameter, TACACS+<->Diameter).  Translation
   agents are likely to be used as aggregation servers to communicate
   with a Diameter infrastructure, while allowing for the embedded
   systems to be migrated at a slower pace.

   Given that the Diameter protocol introduces the concept of long-lived
   authorized sessions, translation agents MUST be session stateful and
   MUST maintain transaction state.

   Translation of messages can only occur if the agent recognizes the
   application of a particular request; therefore, translation agents
   MUST only advertise their locally supported applications.

      +------+    --------->     +------+     --------->    +------+
      |      |  RADIUS Request   |      |  Diameter Request |      |
      | NAS  |                   | TLA  |                   | HMS  |
      |      |  RADIUS Answer    |      |  Diameter Answer  |      |
      +------+    <---------     +------+     <---------    +------+
     example.net                example.net                example.com

                Figure 4: Translation of RADIUS to Diameter
```

No comment.


```
2.9.  Diameter Path Authorization

   As noted in Section 2.2, Diameter provides transmission-level
   security for each connection using TLS/TCP and DTLS/SCTP.  Therefore,
   each connection can be authenticated and can be replay and integrity
   protected.

   In addition to authenticating each connection, the entire session
   MUST also be authorized.  Before initiating a connection, a Diameter
```

```
   peer MUST check that its peers are authorized to act in their roles.
   For example, a Diameter peer may be authentic, but that does not mean
   that it is authorized to act as a Diameter server advertising a set
   of Diameter applications.

   Prior to bringing up a connection, authorization checks are performed
   at each connection along the path.  Diameter capabilities negotiation
   (CER/CEA) also MUST be carried out, in order to determine what
   Diameter applications are supported by each peer.  Diameter sessions
   MUST be routed only through authorized nodes that have advertised
   support for the Diameter application required by the session.

   As noted in Section 6.1.9, a relay or proxy agent MUST append a
   Route-Record AVP to all requests forwarded.  The AVP contains the
   identity of the peer from which the request was received.

   The home Diameter server, prior to authorizing a session, MUST check
   the Route-Record AVPs to make sure that the route traversed by the
   request is acceptable.  For example, administrators within the home
   realm may not wish to honor requests that have been routed through an
   untrusted realm.  By authorizing a request, the home Diameter server
   is implicitly indicating its willingness to engage in the business
   transaction as specified by any contractual relationship between the
   server and the previous hop.  A DIAMETER_AUTHORIZATION_REJECTED error
   message (see Section 7.1.5) is sent if the route traversed by the
   request is unacceptable.

   A home realm may also wish to check that each accounting request
   message corresponds to a Diameter response authorizing the session.
   Accounting requests without corresponding authorization responses
   SHOULD be subjected to further scrutiny, as should accounting
   requests indicating a difference between the requested and provided
   service.

   Forwarding of an authorization response is considered evidence of a
   willingness to take on financial risk relative to the session.  A
   local realm may wish to limit this exposure, for example, by
   establishing credit limits for intermediate realms and refusing to
   accept responses that would violate those limits.  By issuing an



Fajardo, et al.              Standards Track                   [Page 33]

RFC 6733                 Diameter Base Protocol             October 2012


   accounting request corresponding to the authorization response, the
   local realm implicitly indicates its agreement to provide the service
   indicated in the authorization response.  If the service cannot be
   provided by the local realm, then a DIAMETER_UNABLE_TO_COMPLY error
   message MUST be sent within the accounting request; a Diameter client
   receiving an authorization response for a service that it cannot
   perform MUST NOT substitute an alternate service and then send
   accounting requests for the alternate service instead.
```

No comment.

```
3.  Diameter Header

   A summary of the Diameter header format is shown below.  The fields
```

```
   are transmitted in network byte order.

       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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |    Version    |                 Message Length                |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      | Command Flags |                  Command Code                 |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                         Application-ID                        |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      Hop-by-Hop Identifier                    |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                      End-to-End Identifier                    |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |  AVPs ...
      +-+-+-+-+-+-+-+-+-+-+-+-
```

The Diameter Header is represented by the `diameter_header` record defined in `diameter.hrl`. The `diameter_packet` record contains a `header` field whose value will be a decoded `#diameter_header{}` for incoming messages passed to *handle_request/3* and *handle_answer/4* callbacks. In the case of outgoing messages, diameter and the relevant dictionary populate the Diameter Header appropriately, although *prepare_request/3* and *handle_request/3* callbacks can modify header values. (Which can be useful in test.)

```
   Version

      This Version field MUST be set to 1 to indicate Diameter Version
      1.

    Message Length

      The Message Length field is three octets and indicates the length
      of the Diameter message including the header fields and the padded
      AVPs.  Thus, the Message Length field is always a multiple of 4.

   Command Flags

      The Command Flags field is eight bits.  The following bits are
      assigned:




Fajardo, et al.              Standards Track                   [Page 34]

RFC 6733                Diameter Base Protocol             October 2012


            0 1 2 3 4 5 6 7
           +-+-+-+-+-+-+-+-+
           |R P E T r r r r|
           +-+-+-+-+-+-+-+-+

      R(equest)

         If set, the message is a request.  If cleared, the message is
         an answer.
```

```
     P(roxiable)

        If set, the message MAY be proxied, relayed, or redirected.  If
        cleared, the message MUST be locally processed.

     E(rror)

        If set, the message contains a protocol error, and the message
        will not conform to the CCF described for this command.
        Messages with the 'E' bit set are commonly referred to as error
        messages.  This bit MUST NOT be set in request messages (see
        Section 7.2).

     T(Potentially retransmitted message)

        This flag is set after a link failover procedure, to aid the
        removal of duplicate requests.  It is set when resending
        requests not yet acknowledged, as an indication of a possible
        duplicate due to a link failure.  This bit MUST be cleared when
        sending a request for the first time; otherwise, the sender
        MUST set this flag.  Diameter agents only need to be concerned
        about the number of requests they send based on a single
        received request; retransmissions by other entities need not be
        tracked.  Diameter agents that receive a request with the T
        flag set, MUST keep the T flag set in the forwarded request.
        This flag MUST NOT be set if an error answer message (e.g., a
        protocol error) has been received for the earlier message.  It
        can be set only in cases where no answer has been received from
        the server for a request, and the request has been sent again.
        This flag MUST NOT be set in answer messages.

     r(eserved)

        These flag bits are reserved for future use; they MUST be set
        to zero and ignored by the receiver.
```

Reserved bits are set to 0 in outgoing messages.

```
Fajardo, et al.              Standards Track                   [Page 35]

RFC 6733                 Diameter Base Protocol             October 2012


   Command Code

      The Command Code field is three octets and is used in order to
      communicate the command associated with the message.  The 24-bit
      address space is managed by IANA (see Section 3.1).  Command Code
      values 16,777,214 and 16,777,215 (hexadecimal values FFFFFE-
      FFFFFF) are reserved for experimental use (see Section 11.2).

   Application-ID

      Application-ID is four octets and is used to identify for which
      application the message is applicable.  The application can be an
      authentication application, an accounting application, or a
```

```
      vendor-specific application.

      The value of the Application-ID field in the header MUST be the
      same as any relevant Application-Id AVPs contained in the message.

   Hop-by-Hop Identifier

      The Hop-by-Hop Identifier is an unsigned 32-bit integer field (in
      network byte order) that aids in matching requests and replies.
      The sender MUST ensure that the Hop-by-Hop Identifier in a request
      is unique on a given connection at any given time, and it MAY
      attempt to ensure that the number is unique across reboots.  The
      sender of an answer message MUST ensure that the Hop-by-Hop
      Identifier field contains the same value that was found in the
      corresponding request.  The Hop-by-Hop Identifier is normally a
      monotonically increasing number, whose start value was randomly
      generated.  An answer message that is received with an unknown
      Hop-by-Hop Identifier MUST be discarded.

   End-to-End Identifier

      The End-to-End Identifier is an unsigned 32-bit integer field (in
      network byte order) that is used to detect duplicate messages.
      Upon reboot, implementations MAY set the high order 12 bits to
      contain the low order 12 bits of current time, and the low order
      20 bits to a random value.  Senders of request messages MUST
      insert a unique identifier on each message.  The identifier MUST
      remain locally unique for a period of at least 4 minutes, even
      across reboots.  The originator of an answer message MUST ensure
      that the End-to-End Identifier field contains the same value that
      was found in the corresponding request.  The End-to-End Identifier
      MUST NOT be modified by Diameter agents of any kind.  The
      combination of the Origin-Host AVP (Section 6.3) and this field is
      used to detect duplicates.  Duplicate requests SHOULD cause the
      same answer to be transmitted (modulo the Hop-by-Hop Identifier



Fajardo, et al.              Standards Track                   [Page 36]

RFC 6733                 Diameter Base Protocol             October 2012


      field and any routing AVPs that may be present), and they MUST NOT
      affect any state that was set when the original request was
      processed.  Duplicate answer messages that are to be locally
      consumed (see Section 6.2) SHOULD be silently discarded.

   AVPs

      AVPs are a method of encapsulating information relevant to the
      Diameter message.  See Section 4 for more information on AVPs.
```

No comment.

```
3.1.  Command Codes

   Each command Request/Answer pair is assigned a Command Code, and the
   sub-type (i.e., request or answer) is identified via the 'R' bit in
   the Command Flags field of the Diameter header.
```

```
   Every Diameter message MUST contain a Command Code in its header's
   Command Code field, which is used to determine the action that is to
   be taken for a particular message.  The following Command Codes are
   defined in the Diameter base protocol:

                                                 Section
    Command Name             Abbrev.    Code     Reference
      ---------------------------------------------------------
      Abort-Session-Request     ASR       274        8.5.1
      Abort-Session-Answer      ASA       274        8.5.2
      Accounting-Request        ACR       271        9.7.1
      Accounting-Answer         ACA       271        9.7.2
      Capabilities-Exchange-    CER       257        5.3.1
         Request
      Capabilities-Exchange-    CEA       257        5.3.2
         Answer
      Device-Watchdog-Request   DWR       280        5.5.1
      Device-Watchdog-Answer    DWA       280        5.5.2
      Disconnect-Peer-Request   DPR       282        5.4.1
      Disconnect-Peer-Answer    DPA       282        5.4.2
      Re-Auth-Request           RAR       258        8.3.1
      Re-Auth-Answer            RAA       258        8.3.2
      Session-Termination-      STR       275        8.4.1
         Request
      Session-Termination-      STA       275        8.4.2
         Answer
```

These messages are all defined in diameter's implementation of the common dictionary in modules `diameter_gen_base_rfc6733` and `diameter_gen_base_rfc3588`. Corresponding record definitions are found in `diameter_gen_base_rfc6733.hrl` and `diameter_gen_base_rfc3588.hrl`.

```
Fajardo, et al.              Standards Track                   [Page 37]

RFC 6733                Diameter Base Protocol             October 2012


3.2.  Command Code Format Specification

   Every Command Code defined MUST include a corresponding Command Code
   Format (CCF) specification, which is used to define the AVPs that
   MUST or MAY be present when sending the message.  The following ABNF
   specifies the CCF used in the definition:
```

The CCF is what is specified in the `@messages` section of the *diameter_dict(4)* format, except as noted below.

```
   command-def      = "<" command-name ">" "::=" diameter-message
```

Angle brackets are currently not allowed here. This was a change between RFC 3588 and RFC 6733: the former disallowed them in the grammar but included them in its own command definitions.

```
   command-name     = diameter-name

   diameter-name    = ALPHA *(ALPHA / DIGIT / "-")

   diameter-message = header   *fixed  *required *optional

   header           = "<Diameter-Header:" command-id
                        [r-bit] [p-bit] [e-bit] [application-id]">"

   application-id   = 1*DIGIT

   command-id       = 1*DIGIT
                      ; The Command Code assigned to the command.

   r-bit            = ", REQ"
                      ; If present, the 'R' bit in the Command
                      ; Flags is set, indicating that the message
                      ; is a request as opposed to an answer.

   p-bit            = ", PXY"
                      ; If present, the 'P' bit in the Command
                      ; Flags is set, indicating that the message
                      ; is proxiable.

   e-bit            = ", ERR"
                      ; If present, the 'E' bit in the Command
                      ; Flags is set, indicating that the answer
                      ; message contains a Result-Code AVP in
                      ; the "protocol error" class.

   fixed            = [qual] "<" avp-spec ">"
                      ; Defines the fixed position of an AVP.

   required         = [qual] "{" avp-spec "}"
                      ; The AVP MUST be present and can appear
                      ; anywhere in the message.
```



```
   optional         = [qual] "[" avp-name "]"
                      ; The avp-name in the 'optional' rule cannot
                      ; evaluate to any AVP Name that is included
                      ; in a fixed or required rule.  The AVP can
                      ; appear anywhere in the message.
                      ;
                      ; NOTE:  "[" and "]" have a slightly different
                      ; meaning than in ABNF.  These braces
                      ; cannot be used to express optional fixed rules
                      ; (such as an optional ICV at the end).  To do
                      ; this, the convention is '0*1fixed'.
```

```
   qual             = [min] "*" [max]
                      ; See ABNF conventions, RFC 5234, Section 4.
                      ; The absence of any qualifier depends on
                      ; whether it precedes a fixed, required, or
                      ; optional rule.  If a fixed or required rule has
                      ; no qualifier, then exactly one such AVP MUST
                      ; be present.  If an optional rule has no
                      ; qualifier, then 0 or 1 such AVP may be
                      ; present.  If an optional rule has a qualifier,
                      ; then the value of min MUST be 0 if present.

   min              = 1*DIGIT
                      ; The minimum number of times the element may
                      ; be present.  If absent, the default value is 0
                      ; for fixed and optional rules and 1 for
                      ; required rules.  The value MUST be at least 1
                      ; for required rules.

   max              = 1*DIGIT
                      ; The maximum number of times the element may
                      ; be present.  If absent, the default value is
                      ; infinity.  A value of 0 implies the AVP MUST
                      ; NOT be present.

   avp-spec         = diameter-name
                      ; The avp-spec has to be an AVP Name, defined
                      ; in the base or extended Diameter
                      ; specifications.

   avp-name         = avp-spec / "AVP"
                      ; The string "AVP" stands for *any* arbitrary AVP
                      ; Name, not otherwise listed in that Command Code
                      ; definition.  The inclusion of this string
                      ; is recommended for all CCFs to allow for
                      ; extensibility.
```



```
   The following is a definition of a fictitious Command Code:

   Example-Request ::= < Diameter Header: 9999999, REQ, PXY >
                       { User-Name }
                      1* { Origin-Host }
                       * [ AVP ]
```

No comment.

```
3.3.  Diameter Command Naming Conventions

   Diameter command names typically includes one or more English words
   followed by the verb "Request" or "Answer".  Each English word is
   delimited by a hyphen.  A three-letter acronym for both the request
   and answer is also normally provided.

   An example is a message set used to terminate a session.  The command
```

```
   name is Session-Terminate-Request and Session-Terminate-Answer, while
   the acronyms are STR and STA, respectively.

   Both the request and the answer for a given command share the same
   Command Code.  The request is identified by the R(equest) bit in the
   Diameter header set to one (1), to ask that a particular action be
   performed, such as authorizing a user or terminating a session.  Once
   the receiver has completed the request, it issues the corresponding
   answer, which includes a result code that communicates one of the
   following:

   o  The request was successful

   o  The request failed

   o  An additional request has to be sent to provide information the
      peer requires prior to returning a successful or failed answer.

   o  The receiver could not process the request, but provides
      information about a Diameter peer that is able to satisfy the
      request, known as redirect.

   Additional information, encoded within AVPs, may also be included in
   answer messages.
```

The *diameter_dict(4)* format places no requirement on the naming of commands.

```
4.  Diameter AVPs

   Diameter AVPs carry specific authentication, accounting,
   authorization, and routing information as well as configuration
   details for the request and reply.




Fajardo, et al.              Standards Track                   [Page 40]

RFC 6733                Diameter Base Protocol             October 2012


   Each AVP of type OctetString MUST be padded to align on a 32-bit
   boundary, while other AVP types align naturally.  A number of zero-
   valued bytes are added to the end of the AVP Data field until a word
   boundary is reached.  The length of the padding is not reflected in
   the AVP Length field.

4.1.  AVP Header

   The fields in the AVP header MUST be sent in network byte order.  The
   format of the header is:

       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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |                           AVP Code                            |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |V M P r r r r r|                  AVP Length                   |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
      |                       Vendor-ID (opt)                         |
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |    Data ...
      +-+-+-+-+-+-+-+-+
```

AVP Code

The AVP Code, combined with the Vendor-Id field, identifies the attribute uniquely. AVP numbers 1 through 255 are reserved for reuse of RADIUS attributes, without setting the Vendor-Id field. AVP numbers 256 and above are used for Diameter, which are allocated by IANA (see Section 11.1.1).

AVP Flags

The AVP Flags field informs the receiver how each attribute must be handled. New Diameter applications SHOULD NOT define additional AVP Flag bits. However, note that new Diameter applications MAY define additional bits within the AVP header, and an unrecognized bit SHOULD be considered an error. The sender of the AVP MUST set 'R' (reserved) bits to 0 and the receiver SHOULD ignore all 'R' (reserved) bits. The 'P' bit has been reserved for future usage of end-to-end security. At the time of writing, there are no end-to-end security mechanisms specified; therefore, the 'P' bit SHOULD be set to 0.

The 'M' bit, known as the Mandatory bit, indicates whether the receiver of the AVP MUST parse and understand the semantics of the AVP including its content. The receiving entity MUST return an appropriate error message if it receives an AVP that has the M-bit

set but does not understand it. An exception applies when the AVP is embedded within a Grouped AVP. See Section 4.4 for details. Diameter relay and redirect agents MUST NOT reject messages with unrecognized AVPs.

The 'M' bit MUST be set according to the rules defined in the application specification that introduces or reuses this AVP. Within a given application, the M-bit setting for an AVP is defined either for all command types or for each command type.

AVPs with the 'M' bit cleared are informational only; a receiver that receives a message with such an AVP that is not supported, or whose value is not supported, MAY simply ignore the AVP.

The 'V' bit, known as the Vendor-Specific bit, indicates whether the optional Vendor-ID field is present in the AVP header. When set, the AVP Code belongs to the specific vendor code address space.

AVP Length

The AVP Length field is three octets, and indicates the number of octets in this AVP including the AVP Code field, AVP Length field, AVP Flags field, Vendor-ID field (if present), and the AVP Data field. If a message is received with an invalid attribute length, the message MUST be rejected.

4.1.1. Optional Header Elements

The AVP header contains one optional field. This field is only present if the respective bit-flag is enabled.

Vendor-ID

The Vendor-ID field is present if the 'V' bit is set in the AVP Flags field. The optional four-octet Vendor-ID field contains the IANA-assigned "SMI Network Management Private Enterprise Codes" [ENTERPRISE] value, encoded in network byte order. Any vendors or standardization organizations that are also treated like vendors in the IANA-managed "SMI Network Management Private Enterprise Codes" space wishing to implement a vendor-specific Diameter AVP MUST use their own Vendor-ID along with their privately managed AVP address space, guaranteeing that they will not collide with any other vendor's vendor-specific AVP(s) or with future IETF AVPs.

A Vendor-ID value of zero (0) corresponds to the IETF-adopted AVP values, as managed by IANA. Since the absence of the Vendor-ID field implies that the AVP in question is not vendor specific, implementations MUST NOT use the value of zero (0) for the Vendor-ID field.

4.2. Basic AVP Data Formats

The Data field is zero or more octets and contains information specific to the Attribute. The format and length of the Data field is determined by the AVP Code and AVP Length fields. The format of the Data field MUST be one of the following base data types or a data type derived from the base data types. In the event that a new Basic AVP Data Format is needed, a new version of this RFC MUST be created.

OctetString

The data contains arbitrary data of variable length. Unless otherwise noted, the AVP Length field MUST be set to at least 8 (12 if the 'V' bit is enabled). AVP values of this type that are not a multiple of 4 octets in length are followed by the necessary padding so that the next AVP (if any) will start on a 32-bit boundary.

Integer32

32-bit signed value, in network byte order. The AVP Length field MUST be set to 12 (16 if the 'V' bit is enabled).

Integer64

64-bit signed value, in network byte order. The AVP Length field MUST be set to 16 (20 if the 'V' bit is enabled).

Unsigned32

```
      32-bit unsigned value, in network byte order.  The AVP Length
      field MUST be set to 12 (16 if the 'V' bit is enabled).

   Unsigned64

      64-bit unsigned value, in network byte order.  The AVP Length
      field MUST be set to 16 (20 if the 'V' bit is enabled).
```



```
   Float32

      This represents floating point values of single precision as
      described by [FLOATPOINT].  The 32-bit value is transmitted in
      network byte order.  The AVP Length field MUST be set to 12 (16 if
      the 'V' bit is enabled).

   Float64

      This represents floating point values of double precision as
      described by [FLOATPOINT].  The 64-bit value is transmitted in
      network byte order.  The AVP Length field MUST be set to 16 (20 if
      the 'V' bit is enabled).

   Grouped

      The Data field is specified as a sequence of AVPs.  These AVPs are
      concatenated -- including their headers and padding -- in the
      order in which they are specified and the result encapsulated in
      the Data field.  The AVP Length field is set to 8 (12 if the 'V'
      bit is enabled) plus the total length of all included AVPs,
      including their headers and padding.  Thus, the AVP Length field
      of an AVP of type Grouped is always a multiple of 4.

4.3.  Derived AVP Data Formats

   In addition to using the Basic AVP Data Formats, applications may
   define data formats derived from the Basic AVP Data Formats.  An
   application that defines new Derived AVP Data Formats MUST include
   them in a section titled "Derived AVP Data Formats", using the same
   format as the definitions below.  Each new definition MUST be either
   defined or listed with a reference to the RFC that defines the
   format.

4.3.1.  Common Derived AVP Data Formats

   The following are commonly used Derived AVP Data Formats.

   Address

      The Address format is derived from the OctetString Basic AVP
      Format.  It is a discriminated union representing, for example, a
      32-bit (IPv4) [RFC0791] or 128-bit (IPv6) [RFC4291] address, most
      significant octet first.  The first two octets of the Address AVP
      represent the AddressType, which contains an Address Family,
```

```
      defined in [IANAADFAM].  The AddressType is used to discriminate
      the content and format of the remaining octets.




Fajardo, et al.              Standards Track                   [Page 44]

RFC 6733                 Diameter Base Protocol             October 2012


   Time

      The Time format is derived from the OctetString Basic AVP Format.
      The string MUST contain four octets, in the same format as the
      first four bytes are in the NTP timestamp format.  The NTP
      timestamp format is defined in Section 3 of [RFC5905].

      This represents the number of seconds since 0h on 1 January 1900
      with respect to the Coordinated Universal Time (UTC).

      On 6h 28m 16s UTC, 7 February 2036, the time value will overflow.
      Simple Network Time Protocol (SNTP) [RFC5905] describes a
      procedure to extend the time to 2104.  This procedure MUST be
      supported by all Diameter nodes.

   UTF8String

      The UTF8String format is derived from the OctetString Basic AVP
      Format.  This is a human-readable string represented using the
      ISO/IEC IS 10646-1 character set, encoded as an OctetString using
      the UTF-8 transformation format [RFC3629].

      Since additional code points are added by amendments to the 10646
      standard from time to time, implementations MUST be prepared to
      encounter any code point from 0x00000001 to 0x7fffffff.  Byte
      sequences that do not correspond to the valid encoding of a code
      point into UTF-8 charset or are outside this range are prohibited.

      The use of control codes SHOULD be avoided.  When it is necessary
      to represent a new line, the control code sequence CR LF SHOULD be
      used.

      The use of leading or trailing white space SHOULD be avoided.

      For code points not directly supported by user interface hardware
      or software, an alternative means of entry and display, such as
      hexadecimal, MAY be provided.

      For information encoded in 7-bit US-ASCII, the UTF-8 charset is
      identical to the US-ASCII charset.

      UTF-8 may require multiple bytes to represent a single character /
      code point; thus, the length of a UTF8String in octets may be
      different from the number of characters encoded.

      Note that the AVP Length field of an UTF8String is measured in
      octets not characters.




Fajardo, et al.              Standards Track                   [Page 45]

RFC 6733                 Diameter Base Protocol             October 2012
```

```
   DiameterIdentity

      The DiameterIdentity format is derived from the OctetString Basic
      AVP Format.

                          DiameterIdentity  = FQDN/Realm

   The DiameterIdentity value is used to uniquely identify either:

      *  A Diameter node for purposes of duplicate connection and
         routing loop detection.

      *  A Realm to determine whether messages can be satisfied locally
         or whether they must be routed or redirected.

      When a DiameterIdentity value is used to identify a Diameter node,
      the contents of the string MUST be the Fully Qualified Domain Name
      (FQDN) of the Diameter node.  If multiple Diameter nodes run on
      the same host, each Diameter node MUST be assigned a unique
      DiameterIdentity.  If a Diameter node can be identified by several
      FQDNs, a single FQDN should be picked at startup and used as the
      only DiameterIdentity for that node, whatever the connection on
      which it is sent.  In this document, note that DiameterIdentity is
      in ASCII form in order to be compatible with existing DNS
      infrastructure.  See Appendix D for interactions between the
      Diameter protocol and Internationalized Domain Names (IDNs).

   DiameterURI

      The DiameterURI MUST follow the Uniform Resource Identifiers (RFC
      3986) syntax [RFC3986] rules specified below:

      "aaa://" FQDN [ port ] [ transport ] [ protocol ]

                      ; No transport security

      "aaas://" FQDN [ port ] [ transport ] [ protocol ]

                      ; Transport security used

      FQDN               = < Fully Qualified Domain Name >
```



```
      port               = ":" 1*DIGIT

                      ; One of the ports used to listen for
                      ; incoming connections.
                      ; If absent, the default Diameter port
                      ; (3868) is assumed if no transport
                      ; security is used and port 5658 when
```

```
                    ; transport security (TLS/TCP and DTLS/SCTP)
                    ; is used.

      transport          = ";transport=" transport-protocol

                    ; One of the transports used to listen
                    ; for incoming connections.  If absent,
                    ; the default protocol is assumed to be TCP.
                    ; UDP MUST NOT be used when the aaa-protocol
                    ; field is set to diameter.

      transport-protocol = ( "tcp" / "sctp" / "udp" )

      protocol           = ";protocol=" aaa-protocol

                    ; If absent, the default AAA protocol
                    ; is Diameter.

      aaa-protocol       = ( "diameter" / "radius" / "tacacs+" )

      The following are examples of valid Diameter host identities:

      aaa://host.example.com;transport=tcp
      aaa://host.example.com:6666;transport=tcp
      aaa://host.example.com;protocol=diameter
      aaa://host.example.com:6666;protocol=diameter
      aaa://host.example.com:6666;transport=tcp;protocol=diameter
      aaa://host.example.com:1813;transport=udp;protocol=radius

   Enumerated

      The Enumerated format is derived from the Integer32 Basic AVP
      Format.  The definition contains a list of valid values and their
      interpretation and is described in the Diameter application
      introducing the AVP.
```



```
   IPFilterRule

      The IPFilterRule format is derived from the OctetString Basic AVP
      Format and uses the ASCII charset.  The rule syntax is a modified
      subset of ipfw(8) from FreeBSD.  Packets may be filtered based on
      the following information that is associated with it:

            Direction                          (in or out)
            Source and destination IP address  (possibly masked)
            Protocol
            Source and destination port        (lists or ranges)
            TCP flags
            IP fragment flag
            IP options
            ICMP types
```

```
   Rules for the appropriate direction are evaluated in order, with the
   first matched rule terminating the evaluation.  Each packet is
   evaluated once.  If no rule matches, the packet is dropped if the
   last rule evaluated was a permit, and passed if the last rule was a
   deny.

   IPFilterRule filters MUST follow the format:

         action dir proto from src to dst [options]

         action       permit - Allow packets that match the rule.
                      deny   - Drop packets that match the rule.

         dir          "in" is from the terminal, "out" is to the
                      terminal.

         proto        An IP protocol specified by number.  The "ip"
                      keyword means any protocol will match.

         src and dst  <address/mask> [ports]

                      The <address/mask> may be specified as:
                      ipno       An IPv4 or IPv6 number in dotted-
                                 quad or canonical IPv6 form.  Only
                                 this exact IP number will match the
                                 rule.
```



```
                      ipno/bits  An IP number as above with a mask
                                 width of the form 192.0.2.10/24.  In
                                 this case, all IP numbers from
                                 192.0.2.0 to 192.0.2.255 will match.
                                 The bit width MUST be valid for the
                                 IP version, and the IP number MUST
                                 NOT have bits set beyond the mask.
                                 For a match to occur, the same IP
                                 version must be present in the
                                 packet that was used in describing
                                 the IP address.  To test for a
                                 particular IP version, the bits part
                                 can be set to zero.  The keyword
                                 "any" is 0.0.0.0/0 or the IPv6
                                 equivalent.  The keyword "assigned"
                                 is the address or set of addresses
                                 assigned to the terminal.  For IPv4,
                                 a typical first rule is often "deny
                                 in ip! assigned".

                      The sense of the match can be inverted by
                      preceding an address with the not modifier (!),
                      causing all other addresses to be matched
                      instead.  This does not affect the selection of
                      port numbers.
```

```
                    With the TCP, UDP, and SCTP protocols, optional
                    ports may be specified as:

                       {port/port-port}[,ports[,...]]

                     The '-' notation specifies a range of ports
                    (including boundaries).

                    Fragmented packets that have a non-zero offset
                    (i.e., not the first fragment) will never match
                    a rule that has one or more port
                    specifications.  See the frag option for
                    details on matching fragmented packets.

        options:
           frag    Match if the packet is a fragment and this is not
                   the first fragment of the datagram.  frag may not
                   be used in conjunction with either tcpflags or
                   TCP/UDP port specifications.
```



```
           ipoptions spec
                   Match if the IP header contains the comma-separated
                   list of options specified in spec.  The
                   supported IP options are:

                   ssrr (strict source route), lsrr (loose source
                   route), rr (record packet route), and ts
                   (timestamp).  The absence of a particular option
                   may be denoted with a '!'.

           tcpoptions spec
                   Match if the TCP header contains the comma-separated
                   list of options specified in spec.  The
                   supported TCP options are:

                   mss (maximum segment size), window (tcp window
                   advertisement), sack (selective ack), ts (rfc1323
                   timestamp), and cc (rfc1644 t/tcp connection
                   count).  The absence of a particular option may
                   be denoted with a '!'.

           established
                   TCP packets only.  Match packets that have the RST
                   or ACK bits set.

           setup   TCP packets only.  Match packets that have the SYN
                   bit set but no ACK bit.


           tcpflags spec
                   TCP packets only.  Match if the TCP header
                   contains the comma-separated list of flags
                   specified in spec.  The supported TCP flags are:
```

```
                    fin, syn, rst, psh, ack, and urg.  The absence of a
                    particular flag may be denoted with a '!'.  A rule
                    that contains a tcpflags specification can never
                    match a fragmented packet that has a non-zero
                    offset.  See the frag option for details on
                    matching fragmented packets.

            icmptypes types
                    ICMP packets only.  Match if the ICMP type is in
                    the list types.  The list may be specified as any
                    combination of ranges or individual types
                    separated by commas.  Both the numeric values and
                    the symbolic values listed below can be used.  The
                    supported ICMP types are:



Fajardo, et al.              Standards Track                  [Page 50]

RFC 6733                 Diameter Base Protocol             October 2012


                    echo reply (0), destination unreachable (3),
                    source quench (4), redirect (5), echo request
                    (8), router advertisement (9), router
                    solicitation (10), time-to-live exceeded (11), IP
                    header bad (12), timestamp request (13),
                    timestamp reply (14), information request (15),
                    information reply (16), address mask request (17),
                    and address mask reply (18).

   There is one kind of packet that the access device MUST always
   discard, that is an IP fragment with a fragment offset of one.  This
   is a valid packet, but it only has one use, to try to circumvent
   firewalls.

   An access device that is unable to interpret or apply a deny rule
   MUST terminate the session.  An access device that is unable to
   interpret or apply a permit rule MAY apply a more restrictive rule.
   An access device MAY apply deny rules of its own before the supplied
   rules, for example to protect the access device owner's
   infrastructure.

4.4.   Grouped AVP Values

   The Diameter protocol allows AVP values of type 'Grouped'.  This
   implies that the Data field is actually a sequence of AVPs.  It is
   possible to include an AVP with a Grouped type within a Grouped type,
   that is, to nest them.  AVPs within an AVP of type Grouped have the
   same padding requirements as non-Grouped AVPs, as defined in
   Section 4.4.

   The AVP Code numbering space of all AVPs included in a Grouped AVP is
   the same as for non-Grouped AVPs.  Receivers of a Grouped AVP that
   does not have the 'M' (mandatory) bit set and one or more of the
   encapsulated AVPs within the group has the 'M' (mandatory) bit set
   MAY simply be ignored if the Grouped AVP itself is unrecognized.  The
   rule applies even if the encapsulated AVP with its 'M' (mandatory)
   bit set is further encapsulated within other sub-groups, i.e., other
   Grouped AVPs embedded within the Grouped AVP.

   Every Grouped AVP definition MUST include a corresponding grammar,
   using ABNF [RFC5234] (with modifications), as defined below.

         grouped-avp-def  = "<" name ">" "::=" avp
```

```
        name-fmt         = ALPHA *(ALPHA / DIGIT / "-")




Fajardo, et al.              Standards Track                  [Page 51]

RFC 6733                 Diameter Base Protocol             October 2012


        name             = name-fmt
                           ; The name has to be the name of an AVP,
                           ; defined in the base or extended Diameter
                           ; specifications.

        avp              = header *fixed *required *optional

        header           = "<" "AVP-Header:" avpcode [vendor] ">"

        avpcode          = 1*DIGIT
                           ; The AVP Code assigned to the Grouped AVP.

        vendor           = 1*DIGIT
                           ; The Vendor-ID assigned to the Grouped AVP.
                           ; If absent, the default value of zero is
                           ; used.
```

4.4.1. Example AVP with a Grouped Data Type

The Example-AVP (AVP Code 999999) is of type Grouped and is used to clarify how Grouped AVP values work. The Grouped Data field has the following CCF grammar:

```
      Example-AVP  ::= < AVP Header: 999999 >
                       { Origin-Host }
                     1*{ Session-Id }
                      *[ AVP ]
```

An Example-AVP with Grouped Data follows.

The Origin-Host AVP (Section 6.3) is required. In this case:

```
   Origin-Host = "example.com".
```

One or more Session-Ids must follow. Here there are two:

```
   Session-Id =
     "grump.example.com:33041;23432;893;0AF3B81"

   Session-Id =
     "grump.example.com:33054;23561;2358;0AF3B82"
```

```
Fajardo, et al.              Standards Track                  [Page 52]
```

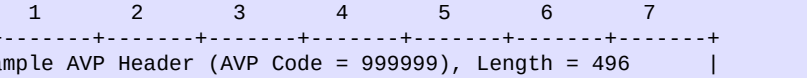
optional AVPs included are

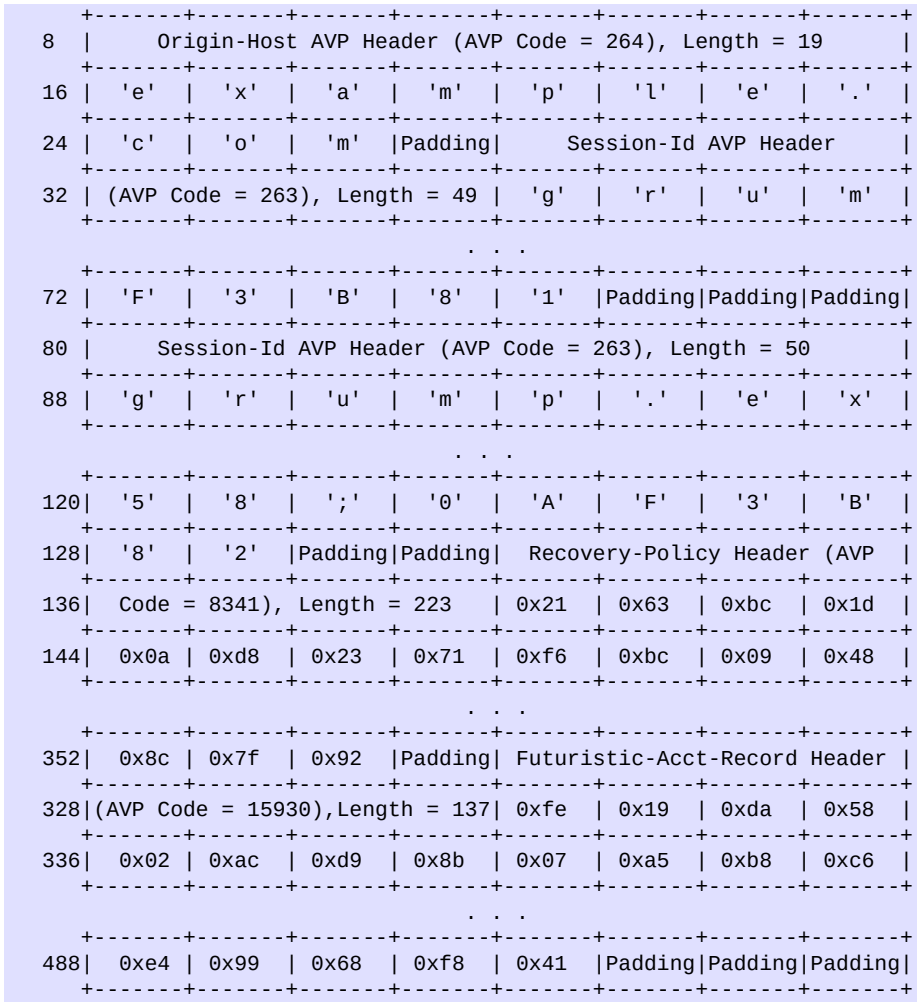
Recovery-Policy = <binary>
2163bc1d0ad82371f6bc09484133c3f09ad74a0dd5346d54195a7cf0b35
2cabc881839a4fdcfbc1769e2677a4c1fb499284c5f70b48f58503a45c5
c2d6943f82d5930f2b7c1da640f476f0e9c9572a50db8ea6e51e1c2c7bd
f8bb43dc995144b8dbe297ac739493946803e1cee3e15d9b765008a1b2a
cf4ac777c80041d72c01e691cf751dbf86e85f509f3988e5875dc905119
26841f00f0e29a6d1ddc1a842289d440268681e052b30fb638045f7779c
1d873c784f054f688f5001559ecff64865ef975f3e60d2fd7966b8c7f92

Futuristic-Acct-Record = <binary>
fe19da5802acd98b07a5b86cb4d5d03f0314ab9ef1ad0b67111ff3b90a0
57fe29620bf3585fd2dd9fcc38ce62f6cc208c6163c008f4258d1bc88b8
17694a74ccad3ec69269461b14b2e7a4c111fb239e33714da207983f58c
41d018d56fe938f3cbf089aac12a912a2f0d1923a9390e5f789cb2e5067
d3427475e49968f841

The data for the optional AVPs is represented in hexadecimal form since the format of these AVPs is not known at the time of definition of the Example-AVP group nor (likely) at the time when the example instance of this AVP is interpreted -- except by Diameter implementations that support the same set of AVPs. The encoding example illustrates how padding is used and how length fields are calculated. Also, note that AVPs may be present in the Grouped AVP value that the receiver cannot interpret (here, the Recover-Policy and Futuristic-Acct-Record AVPs). The length of the Example-AVP is the sum of all the length of the member AVPs, including their padding, plus the Example-AVP header size.

This AVP would be encoded as follows:





4.5. Diameter Base Protocol AVPs

The following table describes the Diameter AVPs defined in the base protocol, their AVP Code values, types, and possible flag values.

Due to space constraints, the short form DiamIdent is used to represent DiameterIdentity.

Attribute Name	AVP Code	Section Defined	Data Type	AVP Flag rules: MUST	AVP Flag rules: MUST NOT
Acct-Interim-Interval	85	9.8.2	Unsigned32	M	V
Accounting-Realtime-Required	483	9.8.7	Enumerated	M	V
Acct-Multi-Session-Id	50	9.8.5	UTF8String	M	V
Accounting-Record-Number	485	9.8.3	Unsigned32	M	V
Accounting-Record-Type	480	9.8.1	Enumerated	M	V
Acct-Session-Id	44	9.8.4	OctetString	M	V
Accounting-Sub-Session-Id	287	9.8.6	Unsigned64	M	V
Acct-Application-Id	259	6.9	Unsigned32	M	V

Attribute Name	AVP Code	Section Defined	Data Type	AVP Flag rules: MUST	AVP Flag rules: MUST NOT
Auth-Application-Id	258	6.8	Unsigned32	M	V
Auth-Request-Type	274	8.7	Enumerated	M	V
Authorization-Lifetime	291	8.9	Unsigned32	M	V
Auth-Grace-Period	276	8.10	Unsigned32	M	V
Auth-Session-State	277	8.11	Enumerated	M	V
Re-Auth-Request-Type	285	8.12	Enumerated	M	V
Class	25	8.20	OctetString	M	V
Destination-Host	293	6.5	DiamIdent	M	V
Destination-Realm	283	6.6	DiamIdent	M	V
Disconnect-Cause	273	5.4.3	Enumerated	M	V
Error-Message	281	7.3	UTF8String		V,M
Error-Reporting-Host	294	7.4	DiamIdent		V,M
Event-Timestamp	55	8.21	Time	M	V
Experimental-Result	297	7.6	Grouped	M	V

Attribute Name	AVP Code	Section Defined	Data Type	AVP Flag rules: MUST	AVP Flag rules: MUST NOT
Experimental-Result-Code	298	7.7	Unsigned32	M	V
Failed-AVP	279	7.5	Grouped	M	V
Firmware-Revision	267	5.3.4	Unsigned32		V,M
Host-IP-Address	257	5.3.5	Address	M	V
Inband-Security-Id	299	6.10	Unsigned32	M	V
Multi-Round-Time-Out	272	8.19	Unsigned32	M	V
Origin-Host	264	6.3	DiamIdent	M	V
Origin-Realm	296	6.4	DiamIdent	M	V
Origin-State-Id	278	8.16	Unsigned32	M	V
Product-Name	269	5.3.7	UTF8String		V,M
Proxy-Host	280	6.7.3	DiamIdent	M	V
Proxy-Info	284	6.7.2	Grouped	M	V
Proxy-State	33	6.7.4	OctetString	M	V
Redirect-Host	292	6.12	DiamURI	M	V
Redirect-Host-Usage	261	6.13	Enumerated	M	V
Redirect-Max-Cache-Time	262	6.14	Unsigned32	M	V
Result-Code	268	7.1	Unsigned32	M	V
Route-Record	282	6.7.1	DiamIdent	M	V
Session-Id	263	8.8	UTF8String	M	V

Session-Timeout	27	8.13	Unsigned32	M		V
Session-Binding	270	8.17	Unsigned32	M		V
Session-Server-Failover	271	8.18	Enumerated	M		V
Supported-Vendor-Id	265	5.3.6	Unsigned32	M		V
Termination-Cause	295	8.15	Enumerated	M		V
User-Name	1	8.14	UTF8String	M		V
Vendor-Id	266	5.3.3	Unsigned32	M		V
Vendor-Specific-Application-Id	260	6.11	Grouped	M		V

5. Diameter Peers

This section describes how Diameter nodes establish connections and communicate with peers.

5.1. Peer Connections

Connections between diameter peers are established using their valid DiameterIdentity. A Diameter node initiating a connection to a peer MUST know the peer's DiameterIdentity. Methods for discovering a Diameter peer can be found in Section 5.2.

Although a Diameter node may have many possible peers with which it is able to communicate, it may not be economical to have an established connection to all of them. At a minimum, a Diameter node SHOULD have an established connection with two peers per realm, known as the primary and secondary peers. Of course, a node MAY have additional connections, if it is deemed necessary. Typically, all messages for a realm are sent to the primary peer but, in the event that failover procedures are invoked, any pending requests are sent to the secondary peer. However, implementations are free to load balance requests between a set of peers.

Note that a given peer MAY act as a primary for a given realm while acting as a secondary for another realm.

When a peer is deemed suspect, which could occur for various reasons, including not receiving a DWA within an allotted time frame, no new requests should be forwarded to the peer, but failover procedures are invoked. When an active peer is moved to this mode, additional connections SHOULD be established to ensure that the necessary number of active connections exists.

There are two ways that a peer is removed from the suspect peer list:

1. The peer is no longer reachable, causing the transport connection to be shut down. The peer is moved to the closed state.

2. Three watchdog messages are exchanged with accepted round-trip times, and the connection to the peer is considered stabilized.

```
   In the event the peer being removed is either the primary or
   secondary, an alternate peer SHOULD replace the deleted peer and
   assume the role of either primary or secondary.




Fajardo, et al.              Standards Track                  [Page 58]

RFC 6733                 Diameter Base Protocol             October 2012


5.2.  Diameter Peer Discovery

   Allowing for dynamic Diameter agent discovery makes possible simpler
   and more robust deployment of Diameter services.  In order to promote
   interoperable implementations of Diameter peer discovery, the
   following mechanisms (manual configuration and DNS) are described.
   These are based on existing IETF standards.  Both mechanisms MUST be
   supported by all Diameter implementations; either MAY be used.

   There are two cases where Diameter peer discovery may be performed.
   The first is when a Diameter client needs to discover a first-hop
   Diameter agent.  The second case is when a Diameter agent needs to
   discover another agent for further handling of a Diameter operation.
   In both cases, the following 'search order' is recommended:

   1.  The Diameter implementation consults its list of statically
       (manually) configured Diameter agent locations.  These will be
       used if they exist and respond.

   2.  The Diameter implementation performs a NAPTR query for a server
       in a particular realm.  The Diameter implementation has to know,
       in advance, in which realm to look for a Diameter agent.  This
       could be deduced, for example, from the 'realm' in an NAI on
       which a Diameter implementation needed to perform a Diameter
       operation.

       The NAPTR usage in Diameter follows the S-NAPTR DDDS application
       [RFC3958] in which the SERVICE field includes tags for the
       desired application and supported application protocol.  The
       application service tag for a Diameter application is 'aaa' and
       the supported application protocol tags are 'diameter.tcp',
       'diameter.sctp', 'diameter.dtls', or 'diameter.tls.tcp'
       [RFC6408].

       The client can follow the resolution process defined by the
       S-NAPTR DDDS [RFC3958] application to find a matching SRV, A, or
       AAAA record of a suitable peer.  The domain suffixes in the NAPTR
       replacement field SHOULD match the domain of the original query.
       An example can be found in Appendix B.

   3.  If no NAPTR records are found, the requester directly queries for
       one of the following SRV records: for Diameter over TCP, use
       "_diameter._tcp.realm"; for Diameter over TLS, use
       "_diameters._tcp.realm"; for Diameter over SCTP, use
       "_diameter._sctp.realm"; for Diameter over DTLS, use
       "_diameters._sctp.realm".  If SRV records are found, then the
       requester can perform address record query (A RR's and/or AAAA
```

RR's) for the target hostname specified in the SRV records following the rules given in [RFC2782]. If no SRV records are found, the requester gives up.

If the server is using a site certificate, the domain name in the NAPTR query and the domain name in the replacement field MUST both be valid based on the site certificate handed out by the server in the TLS/TCP and DTLS/SCTP or Internet Key Exchange Protocol (IKE) exchange. Similarly, the domain name in the SRV query and the domain name in the target in the SRV record MUST both be valid based on the same site certificate. Otherwise, an attacker could modify the DNS records to contain replacement values in a different domain, and the client could not validate whether this was the desired behavior or the result of an attack.

Also, the Diameter peer MUST check to make sure that the discovered peers are authorized to act in its role. Authentication via IKE or TLS/TCP and DTLS/SCTP, or validation of DNS RRs via DNSSEC is not sufficient to conclude this. For example, a web server may have obtained a valid TLS/TCP and DTLS/SCTP certificate, and secured RRs may be included in the DNS, but this does not imply that it is authorized to act as a Diameter server.

Authorization can be achieved, for example, by the configuration of a Diameter server Certification Authority (CA). The server CA issues a certificate to the Diameter server, which includes an Object Identifier (OID) to indicate the subject is a Diameter server in the Extended Key Usage extension [RFC5280]. This certificate is then used during TLS/TCP, DTLS/SCTP, or IKE security negotiation. However, note that, at the time of writing, no Diameter server Certification Authorities exist.

A dynamically discovered peer causes an entry in the peer table (see Section 2.6) to be created. Note that entries created via DNS MUST expire (or be refreshed) within the DNS Time to Live (TTL). If a peer is discovered outside of the local realm, a routing table entry (see Section 2.7) for the peer's realm is created. The routing table entry's expiration MUST match the peer's expiration value.

5.3. Capabilities Exchange

When two Diameter peers establish a transport connection, they MUST exchange the Capabilities Exchange messages, as specified in the peer state machine (see Section 5.6). This message allows the discovery of a peer's identity and its capabilities (protocol version number, the identifiers of supported Diameter applications, security mechanisms, etc.).

The receiver only issues commands to its peers that have advertised support for the Diameter application that defines the command. A Diameter node MUST cache the supported Application Ids in order to

ensure that unrecognized commands and/or AVPs are not unnecessarily sent to a peer.

A receiver of a Capabilities-Exchange-Request (CER) message that does not have any applications in common with the sender MUST return a Capabilities-Exchange-Answer (CEA) with the Result-Code AVP set to DIAMETER_NO_COMMON_APPLICATION and SHOULD disconnect the transport layer connection. Note that receiving a CER or CEA from a peer advertising itself as a relay (see Section 2.4) MUST be interpreted as having common applications with the peer.

The receiver of the Capabilities-Exchange-Request (CER) MUST determine common applications by computing the intersection of its own set of supported Application Ids against all of the Application-Id AVPs (Auth-Application-Id, Acct-Application-Id, and Vendor-Specific-Application-Id) present in the CER. The value of the Vendor-Id AVP in the Vendor-Specific-Application-Id MUST NOT be used during computation. The sender of the Capabilities-Exchange-Answer (CEA) SHOULD include all of its supported applications as a hint to the receiver regarding all of its application capabilities.

Diameter implementations SHOULD first attempt to establish a TLS/TCP and DTLS/SCTP connection prior to the CER/CEA exchange. This protects the capabilities information of both peers. To support older Diameter implementations that do not fully conform to this document, the transport security MAY still be negotiated via an Inband-Security AVP. In this case, the receiver of a Capabilities-Exchange-Request (CER) message that does not have any security mechanisms in common with the sender MUST return a Capabilities-Exchange-Answer (CEA) with the Result-Code AVP set to DIAMETER_NO_COMMON_SECURITY and SHOULD disconnect the transport layer connection.

CERs received from unknown peers MAY be silently discarded, or a CEA MAY be issued with the Result-Code AVP set to DIAMETER_UNKNOWN_PEER. In both cases, the transport connection is closed. If the local policy permits receiving CERs from unknown hosts, a successful CEA MAY be returned. If a CER from an unknown peer is answered with a successful CEA, the lifetime of the peer entry is equal to the lifetime of the transport connection. In case of a transport failure, all the pending transactions destined to the unknown peer can be discarded.

The CER and CEA messages MUST NOT be proxied, redirected, or relayed.

Since the CER/CEA messages cannot be proxied, it is still possible that an upstream agent will receive a message for which it has no available peers to handle the application that corresponds to the Command Code. In such instances, the 'E' bit is set in the answer message (Section 7) with the Result-Code AVP set to DIAMETER_UNABLE_TO_DELIVER to inform the downstream agent to take action (e.g., re-routing request to an alternate peer).

With the exception of the Capabilities-Exchange-Request message, a message of type Request that includes the Auth-Application-Id or Acct-Application-Id AVPs, or a message with an application-specific Command Code MAY only be forwarded to a host that has explicitly

```
   advertised support for the application (or has advertised the Relay
   Application Id).

5.3.1.  Capabilities-Exchange-Request

   The Capabilities-Exchange-Request (CER), indicated by the Command
   Code set to 257 and the Command Flags' 'R' bit set, is sent to
   exchange local capabilities.  Upon detection of a transport failure,
   this message MUST NOT be sent to an alternate peer.

   When Diameter is run over SCTP [RFC4960] or DTLS/SCTP [RFC6083],
   which allow for connections to span multiple interfaces and multiple
   IP addresses, the Capabilities-Exchange-Request message MUST contain
   one Host-IP-Address AVP for each potential IP address that MAY be
   locally used when transmitting Diameter messages.

      Message Format

         <CER> ::= < Diameter Header: 257, REQ >
                   { Origin-Host }
                   { Origin-Realm }
                 1* { Host-IP-Address }
                   { Vendor-Id }
                   { Product-Name }
                   [ Origin-State-Id ]
                  * [ Supported-Vendor-Id ]
                  * [ Auth-Application-Id ]
                  * [ Inband-Security-Id ]
                  * [ Acct-Application-Id ]
                  * [ Vendor-Specific-Application-Id ]
                   [ Firmware-Revision ]
                  * [ AVP ]









Fajardo, et al.              Standards Track                   [Page 62]

RFC 6733                Diameter Base Protocol             October 2012


5.3.2.  Capabilities-Exchange-Answer

   The Capabilities-Exchange-Answer (CEA), indicated by the Command Code
   set to 257 and the Command Flags' 'R' bit cleared, is sent in
   response to a CER message.

   When Diameter is run over SCTP [RFC4960] or DTLS/SCTP [RFC6083],
   which allow connections to span multiple interfaces, hence, multiple
   IP addresses, the Capabilities-Exchange-Answer message MUST contain
   one Host-IP-Address AVP for each potential IP address that MAY be
   locally used when transmitting Diameter messages.

   Message Format

         <CEA> ::= < Diameter Header: 257 >
                   { Result-Code }
                   { Origin-Host }
                   { Origin-Realm }
                 1* { Host-IP-Address }
                   { Vendor-Id }
                   { Product-Name }
```

```
                  [ Origin-State-Id ]
                  [ Error-Message ]
                  [ Failed-AVP ]
                * [ Supported-Vendor-Id ]
                * [ Auth-Application-Id ]
                * [ Inband-Security-Id ]
                * [ Acct-Application-Id ]
                * [ Vendor-Specific-Application-Id ]
                  [ Firmware-Revision ]
                * [ AVP ]
```

5.3.3. Vendor-Id AVP

The Vendor-Id AVP (AVP Code 266) is of type Unsigned32 and contains the IANA "SMI Network Management Private Enterprise Codes" [ENTERPRISE] value assigned to the Diameter Software vendor. It is envisioned that the combination of the Vendor-Id, Product-Name (Section 5.3.7), and Firmware-Revision (Section 5.3.4) AVPs may provide useful debugging information.

A Vendor-Id value of zero in the CER or CEA message is reserved and indicates that this field is ignored.

5.3.4. Firmware-Revision AVP

The Firmware-Revision AVP (AVP Code 267) is of type Unsigned32 and is used to inform a Diameter peer of the firmware revision of the issuing device.

For devices that do not have a firmware revision (general-purpose computers running Diameter software modules, for instance), the revision of the Diameter software module may be reported instead.

5.3.5. Host-IP-Address AVP

The Host-IP-Address AVP (AVP Code 257) is of type Address and is used to inform a Diameter peer of the sender's IP address. All source addresses that a Diameter node expects to use with SCTP [RFC4960] or DTLS/SCTP [RFC6083] MUST be advertised in the CER and CEA messages by including a Host-IP-Address AVP for each address.

5.3.6. Supported-Vendor-Id AVP

The Supported-Vendor-Id AVP (AVP Code 265) is of type Unsigned32 and contains the IANA "SMI Network Management Private Enterprise Codes" [ENTERPRISE] value assigned to a vendor other than the device vendor but including the application vendor. This is used in the CER and CEA messages in order to inform the peer that the sender supports (a subset of) the Vendor-Specific AVPs defined by the vendor identified in this AVP. The value of this AVP MUST NOT be set to zero. Multiple instances of this AVP containing the same value SHOULD NOT be sent.

```
5.3.7.  Product-Name AVP

   The Product-Name AVP (AVP Code 269) is of type UTF8String and
   contains the vendor-assigned name for the product.  The Product-Name
   AVP SHOULD remain constant across firmware revisions for the same
   product.

5.4.  Disconnecting Peer Connections

   When a Diameter node disconnects one of its transport connections,
   its peer cannot know the reason for the disconnect and will most
   likely assume that a connectivity problem occurred or that the peer
   has rebooted.  In these cases, the peer may periodically attempt to
   reconnect, as stated in Section 2.1.  In the event that the
   disconnect was a result of either a shortage of internal resources or
   simply that the node in question has no intentions of forwarding any
   Diameter messages to the peer in the foreseeable future, a periodic




Fajardo, et al.              Standards Track                   [Page 64]

RFC 6733                Diameter Base Protocol             October 2012


   connection request would not be welcomed.  The Disconnection-Reason
   AVP contains the reason the Diameter node issued the Disconnect-Peer-
   Request message.

   The Disconnect-Peer-Request message is used by a Diameter node to
   inform its peer of its intent to disconnect the transport layer and
   that the peer shouldn't reconnect unless it has a valid reason to do
   so (e.g., message to be forwarded).  Upon receipt of the message, the
   Disconnect-Peer-Answer message is returned, which SHOULD contain an
   error if messages have recently been forwarded, and are likely in
   flight, which would otherwise cause a race condition.

   The receiver of the Disconnect-Peer-Answer message initiates the
   transport disconnect.  The sender of the Disconnect-Peer-Answer
   message should be able to detect the transport closure and clean up
   the connection.

5.4.1.  Disconnect-Peer-Request

   The Disconnect-Peer-Request (DPR), indicated by the Command Code set
   to 282 and the Command Flags' 'R' bit set, is sent to a peer to
   inform it of its intentions to shut down the transport connection.
   Upon detection of a transport failure, this message MUST NOT be sent
   to an alternate peer.

      Message Format

         <DPR>  ::= < Diameter Header: 282, REQ >
                    { Origin-Host }
                    { Origin-Realm }
                    { Disconnect-Cause }
                  * [ AVP ]

5.4.2.   Disconnect-Peer-Answer

   The Disconnect-Peer-Answer (DPA), indicated by the Command Code set
   to 282 and the Command Flags' 'R' bit cleared, is sent as a response
   to the Disconnect-Peer-Request message.  Upon receipt of this
   message, the transport connection is shut down.
```

```
      Message Format

         <DPA>  ::= < Diameter Header: 282 >
                    { Result-Code }
                    { Origin-Host }
                    { Origin-Realm }
                    [ Error-Message ]
                    [ Failed-AVP ]
                  * [ AVP ]
```

5.4.3. Disconnect-Cause AVP

The Disconnect-Cause AVP (AVP Code 273) is of type Enumerated. A Diameter node MUST include this AVP in the Disconnect-Peer-Request message to inform the peer of the reason for its intention to shut down the transport connection. The following values are supported:

REBOOTING 0
: A scheduled reboot is imminent. A receiver of a DPR with above result code MAY attempt reconnection.

BUSY 1
: The peer's internal resources are constrained, and it has determined that the transport connection needs to be closed. A receiver of a DPR with above result code SHOULD NOT attempt reconnection.

DO_NOT_WANT_TO_TALK_TO_YOU 2
: The peer has determined that it does not see a need for the transport connection to exist, since it does not expect any messages to be exchanged in the near future. A receiver of a DPR with above result code SHOULD NOT attempt reconnection.

5.5. Transport Failure Detection

Given the nature of the Diameter protocol, it is recommended that transport failures be detected as soon as possible. Detecting such failures will minimize the occurrence of messages sent to unavailable agents, resulting in unnecessary delays, and will provide better failover performance. The Device-Watchdog-Request and Device-Watchdog-Answer messages, defined in this section, are used to pro-actively detect transport failures.

5.5.1. Device-Watchdog-Request

The Device-Watchdog-Request (DWR), indicated by the Command Code set to 280 and the Command Flags' 'R' bit set, is sent to a peer when no traffic has been exchanged between two peers (see Section 5.5.3). Upon detection of a transport failure, this message MUST NOT be sent to an alternate peer.

Message Format

```
<DWR>  ::= < Diameter Header: 280, REQ >
           { Origin-Host }
           { Origin-Realm }
           [ Origin-State-Id ]
         * [ AVP ]
```

5.5.2. Device-Watchdog-Answer

The Device-Watchdog-Answer (DWA), indicated by the Command Code set to 280 and the Command Flags' 'R' bit cleared, is sent as a response to the Device-Watchdog-Request message.

Message Format

```
<DWA>  ::= < Diameter Header: 280 >
           { Result-Code }
           { Origin-Host }
           { Origin-Realm }
           [ Error-Message ]
           [ Failed-AVP ]
           [ Origin-State-Id ]
         * [ AVP ]
```

5.5.3. Transport Failure Algorithm

The transport failure algorithm is defined in [RFC3539]. All Diameter implementations MUST support the algorithm defined in that specification in order to be compliant to the Diameter base protocol.

5.5.4. Failover and Failback Procedures

In the event that a transport failure is detected with a peer, it is necessary for all pending request messages to be forwarded to an alternate agent, if possible. This is commonly referred to as "failover".

In order for a Diameter node to perform failover procedures, it is

```
   necessary for the node to maintain a pending message queue for a
   given peer.  When an answer message is received, the corresponding
   request is removed from the queue.  The Hop-by-Hop Identifier field
   is used to match the answer with the queued request.

   When a transport failure is detected, if possible, all messages in
   the queue are sent to an alternate agent with the T flag set.  On
   booting a Diameter client or agent, the T flag is also set on any
   remaining records in non-volatile storage that are still waiting to
   be transmitted.  An example of a case where it is not possible to
   forward the message to an alternate server is when the message has a
   fixed destination, and the unavailable peer is the message's final
   destination (see Destination-Host AVP).  Such an error requires that
   the agent return an answer message with the 'E' bit set and the
   Result-Code AVP set to DIAMETER_UNABLE_TO_DELIVER.

   It is important to note that multiple identical requests or answers
   MAY be received as a result of a failover.  The End-to-End Identifier
   field in the Diameter header along with the Origin-Host AVP MUST be
   used to identify duplicate messages.

   As described in Section 2.1, a connection request should be
   periodically attempted with the failed peer in order to re-establish
   the transport connection.  Once a connection has been successfully
   established, messages can once again be forwarded to the peer.  This
   is commonly referred to as "failback".

5.6.  Peer State Machine

   This section contains a finite state machine that MUST be observed by
   all Diameter implementations.  Each Diameter node MUST follow the
   state machine described below when communicating with each peer.
   Multiple actions are separated by commas, and may continue on
   succeeding lines, as space requires.  Similarly, state and next state
   may also span multiple lines, as space requires.

   This state machine is closely coupled with the state machine
   described in [RFC3539], which is used to open, close, failover,
   probe, and reopen transport connections.  In particular, note that
   [RFC3539] requires the use of watchdog messages to probe connections.
   For Diameter, DWR and DWA messages are to be used.

   The I- prefix is used to represent the initiator (connecting)
   connection, while the R- prefix is used to represent the responder
   (listening) connection.  The lack of a prefix indicates that the
   event or action is the same regardless of the connection on which the
   event occurred.



Fajardo, et al.              Standards Track                   [Page 68]

RFC 6733                 Diameter Base Protocol             October 2012


   The stable states that a state machine may be in are Closed, I-Open,
   and R-Open; all other states are intermediate.  Note that I-Open and
   R-Open are equivalent except for whether the initiator or responder
   transport connection is used for communication.

   A CER message is always sent on the initiating connection immediately
   after the connection request is successfully completed.  In the case
   of an election, one of the two connections will shut down.  The
   responder connection will survive if the Origin-Host of the local
   Diameter entity is higher than that of the peer; the initiator
```

connection will survive if the peer's Origin-Host is higher. All subsequent messages are sent on the surviving connection. Note that the results of an election on one peer are guaranteed to be the inverse of the results on the other.

For TLS/TCP and DTLS/SCTP usage, a TLS/TCP and DTLS/SCTP handshake SHOULD begin when both ends are in the closed state prior to any Diameter message exchanges. The TLS/TCP and DTLS/SCTP connection SHOULD be established before sending any CER or CEA message to secure and protect the capabilities information of both peers. The TLS/TCP and DTLS/SCTP connection SHOULD be disconnected when the state machine moves to the closed state. When connecting to responders that do not conform to this document (i.e., older Diameter implementations that are not prepared to received TLS/TCP and DTLS/SCTP connections in the closed state), the initial TLS/TCP and DTLS/SCTP connection attempt will fail. The initiator MAY then attempt to connect via TCP or SCTP and initiate the TLS/TCP and DTLS/SCTP handshake when both ends are in the open state. If the handshake is successful, all further messages will be sent via TLS/TCP and DTLS/SCTP. If the handshake fails, both ends move to the closed state.

The state machine constrains only the behavior of a Diameter implementation as seen by Diameter peers through events on the wire.

Any implementation that produces equivalent results is considered compliant.

state	event	action	next state
Closed	Start	I-Snd-Conn-Req	Wait-Conn-Ack
	R-Conn-CER	R-Accept, Process-CER, R-Snd-CEA	R-Open
Wait-Conn-Ack	I-Rcv-Conn-Ack	I-Snd-CER	Wait-I-CEA
	I-Rcv-Conn-Nack	Cleanup	Closed
	R-Conn-CER	R-Accept, Process-CER	Wait-Conn-Ack/ Elect
	Timeout	Error	Closed
Wait-I-CEA	I-Rcv-CEA	Process-CEA	I-Open
	R-Conn-CER	R-Accept, Process-CER, Elect	Wait-Returns
	I-Peer-Disc	I-Disc	Closed
	I-Rcv-Non-CEA	Error	Closed

```
                      Timeout          Error            Closed

      Wait-Conn-Ack/  I-Rcv-Conn-Ack   I-Snd-CER,Elect  Wait-Returns
      Elect           I-Rcv-Conn-Nack  R-Snd-CEA        R-Open
                      R-Peer-Disc      R-Disc           Wait-Conn-Ack
                      R-Conn-CER       R-Reject         Wait-Conn-Ack/
                                                        Elect
                      Timeout          Error            Closed

      Wait-Returns    Win-Election     I-Disc,R-Snd-CEA R-Open
                      I-Peer-Disc      I-Disc,          R-Open
                                       R-Snd-CEA
                      I-Rcv-CEA        R-Disc           I-Open
                      R-Peer-Disc      R-Disc           Wait-I-CEA
                      R-Conn-CER       R-Reject         Wait-Returns
                      Timeout          Error            Closed

      R-Open          Send-Message     R-Snd-Message    R-Open
                      R-Rcv-Message    Process          R-Open
                      R-Rcv-DWR        Process-DWR,     R-Open
                                       R-Snd-DWA
                      R-Rcv-DWA        Process-DWA      R-Open
                      R-Conn-CER       R-Reject         R-Open
                      Stop             R-Snd-DPR        Closing
                      R-Rcv-DPR        R-Snd-DPA        Closing
                      R-Peer-Disc      R-Disc           Closed
```



```
      I-Open          Send-Message     I-Snd-Message    I-Open
                      I-Rcv-Message    Process          I-Open
                      I-Rcv-DWR        Process-DWR,     I-Open
                                       I-Snd-DWA
                      I-Rcv-DWA        Process-DWA      I-Open
                      R-Conn-CER       R-Reject         I-Open
                      Stop             I-Snd-DPR        Closing
                      I-Rcv-DPR        I-Snd-DPA        Closing
                      I-Peer-Disc      I-Disc           Closed

      Closing         I-Rcv-DPA        I-Disc           Closed
                      R-Rcv-DPA        R-Disc           Closed
                      Timeout          Error            Closed
                      I-Peer-Disc      I-Disc           Closed
                      R-Peer-Disc      R-Disc           Closed
```

5.6.1. Incoming Connections

When a connection request is received from a Diameter peer, it is not, in the general case, possible to know the identity of that peer until a CER is received from it. This is because host and port determine the identity of a Diameter peer; the source port of an incoming connection is arbitrary. Upon receipt of a CER, the identity of the connecting peer can be uniquely determined from the Origin-Host.

For this reason, a Diameter peer must employ logic separate from the state machine to receive connection requests, accept them, and await

the CER. Once the CER arrives on a new connection, the Origin-Host that identifies the peer is used to locate the state machine associated with that peer, and the new connection and CER are passed to the state machine as an R-Conn-CER event.

The logic that handles incoming connections SHOULD close and discard the connection if any message other than a CER arrives or if an implementation-defined timeout occurs prior to receipt of CER.

Because handling of incoming connections up to and including receipt of a CER requires logic, separate from that of any individual state machine associated with a particular peer, it is described separately in this section rather than in the state machine above.

5.6.2. Events

Transitions and actions in the automaton are caused by events. In this section, we will ignore the I- and R- prefixes, since the actual event would be identical, but it would occur on one of two possible connections.

Start	The Diameter application has signaled that a connection should be initiated with the peer.
R-Conn-CER	An acknowledgement is received stating that the transport connection has been established, and the associated CER has arrived.
Rcv-Conn-Ack	A positive acknowledgement is received confirming that the transport connection is established.
Rcv-Conn-Nack	A negative acknowledgement was received stating that the transport connection was not established.
Timeout	An application-defined timer has expired while waiting for some event.
Rcv-CER	A CER message from the peer was received.
Rcv-CEA	A CEA message from the peer was received.
Rcv-Non-CEA	A message, other than a CEA, from the peer was received.
Peer-Disc	A disconnection indication from the peer was received.
Rcv-DPR	A DPR message from the peer was received.
Rcv-DPA	A DPA message from the peer was received.
Win-Election	An election was held, and the local node was the winner.
Send-Message	A message is to be sent.
Rcv-Message	A message other than CER, CEA, DPR, DPA, DWR, or DWA was received.

```
   Stop           The Diameter application has signaled that a
                  connection should be terminated (e.g., on system
                  shutdown).

5.6.3.  Actions

   Actions in the automaton are caused by events and typically indicate
   the transmission of packets and/or an action to be taken on the
   connection.  In this section, we will ignore the I- and R- prefixes,
   since the actual action would be identical, but it would occur on one
   of two possible connections.



Fajardo, et al.              Standards Track                  [Page 72]

RFC 6733                Diameter Base Protocol             October 2012


   Snd-Conn-Req   A transport connection is initiated with the peer.

   Accept         The incoming connection associated with the R-Conn-CER
                  is accepted as the responder connection.

   Reject         The incoming connection associated with the R-Conn-CER
                  is disconnected.

   Process-CER    The CER associated with the R-Conn-CER is processed.

   Snd-CER        A CER message is sent to the peer.

   Snd-CEA        A CEA message is sent to the peer.

   Cleanup        If necessary, the connection is shut down, and any
                  local resources are freed.

   Error          The transport layer connection is disconnected,
                  either politely or abortively, in response to
                  an error condition.  Local resources are freed.

   Process-CEA    A received CEA is processed.

   Snd-DPR        A DPR message is sent to the peer.

   Snd-DPA        A DPA message is sent to the peer.

   Disc           The transport layer connection is disconnected,
                  and local resources are freed.

   Elect          An election occurs (see Section 5.6.4 for more
                  information).

   Snd-Message    A message is sent.

   Snd-DWR        A DWR message is sent.

   Snd-DWA        A DWA message is sent.

   Process-DWR    The DWR message is serviced.

   Process-DWA    The DWA message is serviced.

   Process        A message is serviced.
```

5.6.4. The Election Process

The election is performed on the responder. The responder compares the Origin-Host received in the CER with its own Origin-Host as two streams of octets. If the local Origin-Host lexicographically succeeds the received Origin-Host, a Win-Election event is issued locally. Diameter identities are in ASCII form; therefore, the lexical comparison is consistent with DNS case insensitivity, where octets that fall in the ASCII range 'a' through 'z' MUST compare equally to their uppercase counterparts between 'A' and 'Z'. See Appendix D for interactions between the Diameter protocol and Internationalized Domain Name (IDNs).

The winner of the election MUST close the connection it initiated. Historically, maintaining the responder side of a connection was more efficient than maintaining the initiator side. However, current practices makes this distinction irrelevant.

6. Diameter Message Processing

This section describes how Diameter requests and answers are created and processed.

6.1. Diameter Request Routing Overview

A request is sent towards its final destination using one of the following three combinations of the Destination-Realm and Destination-Host AVPs:

- A request that is not able to be proxied (such as a CER) MUST NOT contain either Destination-Realm or Destination-Host AVPs.
- A request that needs to be sent to a home server serving a specific realm, but not to a specific server (such as the first request of a series of round trips), MUST contain a Destination-Realm AVP but MUST NOT contain a Destination-Host AVP. For Diameter clients, the value of the Destination-Realm AVP MAY be extracted from the User-Name AVP, or other methods.
- Otherwise, a request that needs to be sent to a specific home server among those serving a given realm MUST contain both the Destination-Realm and Destination-Host AVPs.

The Destination-Host AVP is used as described above when the destination of the request is fixed, which includes:

- Authentication requests that span multiple round trips.

```
   o  A Diameter message that uses a security mechanism that makes use
      of a pre-established session key shared between the source and the
      final destination of the message.

   o  Server-initiated messages that MUST be received by a specific
      Diameter client (e.g., access device), such as the Abort-Session-
      Request message, which is used to request that a particular user's
      session be terminated.

   Note that an agent can only forward a request to a host described in
   the Destination-Host AVP if the host in question is included in its
   peer table (see Section 2.6).  Otherwise, the request is routed based
   on the Destination-Realm only (see Section 6.1.6).

   When a message is received, the message is processed in the following
   order:

   o  If the message is destined for the local host, the procedures
      listed in Section 6.1.4 are followed.

   o  If the message is intended for a Diameter peer with whom the local
      host is able to directly communicate, the procedures listed in
      Section 6.1.5 are followed.  This is known as "Request
      Forwarding".

   o  The procedure listed in Section 6.1.6 is followed, which is known
      as "Request Routing".

   o  If none of the above are successful, an answer is returned with
      the Result-Code set to DIAMETER_UNABLE_TO_DELIVER, with the 'E'
      bit set.

   For routing of Diameter messages to work within an administrative
   domain, all Diameter nodes within the realm MUST be peers.

   The overview contained in this section (6.1) is intended to provide
   general guidelines to Diameter developers.  Implementations are free
   to use different methods than the ones described here as long as they
   conform to the requirements specified in Sections 6.1.1 through
   6.1.9.  See Section 7 for more details on error handling.

6.1.1.  Originating a Request

   When creating a request, in addition to any other procedures
   described in the application definition for that specific request,
   the following procedures MUST be followed:




Fajardo, et al.              Standards Track                   [Page 75]

RFC 6733                Diameter Base Protocol             October 2012


   o  the Command Code is set to the appropriate value;

   o  the 'R' bit is set;

   o  the End-to-End Identifier is set to a locally unique value;

   o  the Origin-Host and Origin-Realm AVPs MUST be set to the
      appropriate values, used to identify the source of the message;
```

and

- the Destination-Host and Destination-Realm AVPs MUST be set to the appropriate values, as described in Section 6.1.

6.1.2. Sending a Request

When sending a request, originated either locally or as the result of a forwarding or routing operation, the following procedures SHOULD be followed:

- The Hop-by-Hop Identifier SHOULD be set to a locally unique value.
- The message SHOULD be saved in the list of pending requests.

Other actions to perform on the message based on the particular role the agent is playing are described in the following sections.

6.1.3. Receiving Requests

A relay or proxy agent MUST check for forwarding loops when receiving requests. A loop is detected if the server finds its own identity in a Route-Record AVP. When such an event occurs, the agent MUST answer with the Result-Code AVP set to DIAMETER_LOOP_DETECTED.

6.1.4. Processing Local Requests

A request is known to be for local consumption when one of the following conditions occurs:

- The Destination-Host AVP contains the local host's identity;
- The Destination-Host AVP is not present, the Destination-Realm AVP contains a realm the server is configured to process locally, and the Diameter application is locally supported; or
- Both the Destination-Host and the Destination-Realm are not present.

When a request is locally processed, the rules in Section 6.2 should be used to generate the corresponding answer.

6.1.5. Request Forwarding

Request forwarding is done using the Diameter peer table. The Diameter peer table contains all of the peers with which the local node is able to directly communicate.

When a request is received, and the host encoded in the Destination-Host AVP is one that is present in the peer table, the message SHOULD be forwarded to the peer.

6.1.6. Request Routing

Diameter request message routing is done via realms and Application Ids. A Diameter message that may be forwarded by Diameter agents

(proxies, redirect agents, or relay agents) MUST include the target realm in the Destination-Realm AVP. Request routing SHOULD rely on the Destination-Realm AVP and the Application Id present in the request message header to aid in the routing decision. The realm MAY be retrieved from the User-Name AVP, which is in the form of a Network Access Identifier (NAI). The realm portion of the NAI is inserted in the Destination-Realm AVP.

Diameter agents MAY have a list of locally supported realms and applications, and they MAY have a list of externally supported realms and applications. When a request is received that includes a realm and/or application that is not locally supported, the message is routed to the peer configured in the routing table (see Section 2.7).

Realm names and Application Ids are the minimum supported routing criteria, additional information may be needed to support redirect semantics.

6.1.7. Predictive Loop Avoidance

Before forwarding or routing a request, Diameter agents, in addition to performing the processing described in Section 6.1.3, SHOULD check for the presence of a candidate route's peer identity in any of the Route-Record AVPs. In the event of the agent detecting the presence of a candidate route's peer identity in a Route-Record AVP, the agent MUST ignore such a route for the Diameter request message and attempt alternate routes if any exist. In case all the candidate routes are eliminated by the above criteria, the agent SHOULD return a DIAMETER_UNABLE_TO_DELIVER message.

6.1.8. Redirecting Requests

When a redirect agent receives a request whose routing entry is set to REDIRECT, it MUST reply with an answer message with the 'E' bit set, while maintaining the Hop-by-Hop Identifier in the header, and include the Result-Code AVP to DIAMETER_REDIRECT_INDICATION. Each of the servers associated with the routing entry are added in a separate Redirect-Host AVP.

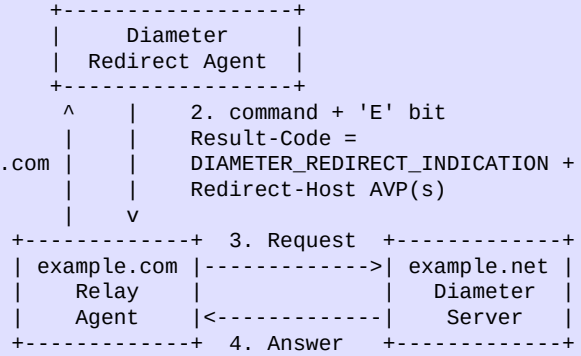


Figure 5: Diameter Redirect Agent

The receiver of an answer message with the 'E' bit set and the Result-Code AVP set to DIAMETER_REDIRECT_INDICATION uses the Hop-by-Hop Identifier in the Diameter header to identify the request in the pending message queue (see Section 5.5.4) that is to be redirected. If no transport connection exists with the new peer, one is created, and the request is sent directly to it.

Multiple Redirect-Host AVPs are allowed. The receiver of the answer message with the 'E' bit set selects exactly one of these hosts as the destination of the redirected message.

When the Redirect-Host-Usage AVP included in the answer message has a non-zero value, a route entry for the redirect indications is created and cached by the receiver. The redirect usage for such a route entry is set by the value of Redirect-Host-Usage AVP and the lifetime of the cached route entry is set by Redirect-Max-Cache-Time AVP value.

It is possible that multiple redirect indications can create multiple cached route entries differing only in their redirect usage and the peer to forward messages to. As an example, two(2) route entries that are created by two(2) redirect indications results in two(2)

cached routes for the same realm and Application Id. However, one has a redirect usage of ALL_SESSION, where matching requests will be forwarded to one peer; the other has a redirect usage of ALL_REALM, where request are forwarded to another peer. Therefore, an incoming request that matches the realm and Application Id of both routes will need additional resolution. In such a case, a routing precedence rule MUST be used against the redirect usage value to resolve the contention. The precedence rule can be found in Section 6.13.

6.1.9. Relaying and Proxying Requests

A relay or proxy agent MUST append a Route-Record AVP to all requests forwarded. The AVP contains the identity of the peer from which the request was received.

The Hop-by-Hop Identifier in the request is saved and replaced with a locally unique value. The source of the request is also saved, which includes the IP address, port, and protocol.

A relay or proxy agent MAY include the Proxy-Info AVP in requests if it requires access to any local state information when the corresponding response is received. The Proxy-Info AVP has security implications as state information is distributed to other entities. As such, it is RECOMMENDED that the content of the Proxy-Info AVP be protected with cryptographic mechanisms, for example, by using a keyed message digest such as HMAC-SHA1 [RFC2104]. Such a mechanism, however, requires the management of keys, although only locally at the Diameter server. Still, a full description of the management of the keys used to protect the Proxy-Info AVP is beyond the scope of this document. Below is a list of common recommendations:

- The keys should be generated securely following the randomness recommendations in [RFC4086].
- The keys and cryptographic protection algorithms should be at

least 128 bits in strength.

- The keys should not be used for any other purpose than generating and verifying instances of the Proxy-Info AVP.
- The keys should be changed regularly.
- The keys should be changed if the AVP format or cryptographic protection algorithms change.

The message is then forwarded to the next hop, as identified in the routing table.

Figure 6 provides an example of message routing using the procedures listed in these sections.

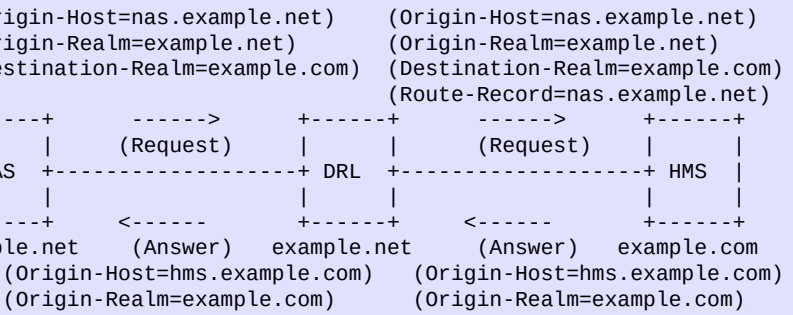


Figure 6: Routing of Diameter messages

Relay and proxy agents are not required to perform full inspection of incoming messages. At a minimum, validation of the message header and relevant routing AVPs has to be done when relaying messages. Proxy agents may optionally perform more in-depth message validation for applications in which it is interested.

6.2. Diameter Answer Processing

When a request is locally processed, the following procedures MUST be applied to create the associated answer, in addition to any additional procedures that MAY be discussed in the Diameter application defining the command:

- The same Hop-by-Hop Identifier in the request is used in the answer.
- The local host's identity is encoded in the Origin-Host AVP.
- The Destination-Host and Destination-Realm AVPs MUST NOT be present in the answer message.
- The Result-Code AVP is added with its value indicating success or failure.
- If the Session-Id is present in the request, it MUST be included in the answer.

   o Any Proxy-Info AVPs in the request MUST be added to the answer
      message, in the same order they were present in the request.

   o The 'P' bit is set to the same value as the one in the request.

   o The same End-to-End identifier in the request is used in the
      answer.

   Note that the error messages (see Section 7) are also subjected to
   the above processing rules.

6.2.1. Processing Received Answers

   A Diameter client or proxy MUST match the Hop-by-Hop Identifier in an
   answer received against the list of pending requests. The
   corresponding message should be removed from the list of pending
   requests. It SHOULD ignore answers received that do not match a
   known Hop-by-Hop Identifier.

6.2.2. Relaying and Proxying Answers

   If the answer is for a request that was proxied or relayed, the agent
   MUST restore the original value of the Diameter header's Hop-by-Hop
   Identifier field.

   If the last Proxy-Info AVP in the message is targeted to the local
   Diameter server, the AVP MUST be removed before the answer is
   forwarded.

   If a relay or proxy agent receives an answer with a Result-Code AVP
   indicating a failure, it MUST NOT modify the contents of the AVP.
   Any additional local errors detected SHOULD be logged but not
   reflected in the Result-Code AVP. If the agent receives an answer
   message with a Result-Code AVP indicating success, and it wishes to
   modify the AVP to indicate an error, it MUST modify the Result-Code
   AVP to contain the appropriate error in the message destined towards
   the access device as well as include the Error-Reporting-Host AVP; it
   MUST also issue an STR on behalf of the access device towards the
   Diameter server.

   The agent MUST then send the answer to the host that it received the
   original request from.

6.3. Origin-Host AVP

   The Origin-Host AVP (AVP Code 264) is of type DiameterIdentity, and
   it MUST be present in all Diameter messages. This AVP identifies the
   endpoint that originated the Diameter message. Relay agents MUST NOT
   modify this AVP.

The value of the Origin-Host AVP is guaranteed to be unique within a single host.

Note that the Origin-Host AVP may resolve to more than one address as the Diameter peer may support more than one address.

This AVP SHOULD be placed as close to the Diameter header as possible.

6.4. Origin-Realm AVP

The Origin-Realm AVP (AVP Code 296) is of type DiameterIdentity. This AVP contains the Realm of the originator of any Diameter message and MUST be present in all messages.

This AVP SHOULD be placed as close to the Diameter header as possible.

6.5. Destination-Host AVP

The Destination-Host AVP (AVP Code 293) is of type DiameterIdentity. This AVP MUST be present in all unsolicited agent initiated messages, MAY be present in request messages, and MUST NOT be present in answer messages.

The absence of the Destination-Host AVP will cause a message to be sent to any Diameter server supporting the application within the realm specified in Destination-Realm AVP.

This AVP SHOULD be placed as close to the Diameter header as possible.

6.6. Destination-Realm AVP

The Destination-Realm AVP (AVP Code 283) is of type DiameterIdentity and contains the realm to which the message is to be routed. The Destination-Realm AVP MUST NOT be present in answer messages. Diameter clients insert the realm portion of the User-Name AVP. Diameter servers initiating a request message use the value of the Origin-Realm AVP from a previous message received from the intended target host (unless it is known a priori). When present, the Destination-Realm AVP is used to perform message routing decisions.

The CCF for a request message that includes the Destination-Realm AVP SHOULD list the Destination-Realm AVP as a required AVP (an AVP indicated as {AVP}); otherwise, the message is inherently a non-routable message.

This AVP SHOULD be placed as close to the Diameter header as possible.

6.7. Routing AVPs

The AVPs defined in this section are Diameter AVPs used for routing

purposes. These AVPs change as Diameter messages are processed by agents.

6.7.1. Route-Record AVP

The Route-Record AVP (AVP Code 282) is of type DiameterIdentity. The identity added in this AVP MUST be the same as the one received in the Origin-Host of the Capabilities Exchange message.

6.7.2. Proxy-Info AVP

The Proxy-Info AVP (AVP Code 284) is of type Grouped. This AVP contains the identity and local state information of the Diameter node that creates and adds it to a message. The Grouped Data field has the following CCF grammar:

```
      Proxy-Info ::= < AVP Header: 284 >
                     { Proxy-Host }
                     { Proxy-State }
                   * [ AVP ]
```

6.7.3. Proxy-Host AVP

The Proxy-Host AVP (AVP Code 280) is of type DiameterIdentity. This AVP contains the identity of the host that added the Proxy-Info AVP.

6.7.4. Proxy-State AVP

The Proxy-State AVP (AVP Code 33) is of type OctetString. It contains state information that would otherwise be stored at the Diameter entity that created it. As such, this AVP MUST be treated as opaque data by other Diameter entities.

6.8. Auth-Application-Id AVP

The Auth-Application-Id AVP (AVP Code 258) is of type Unsigned32 and is used in order to advertise support of the Authentication and Authorization portion of an application (see Section 2.4). If present in a message other than CER and CEA, the value of the Auth-Application-Id AVP MUST match the Application Id present in the Diameter message header.

6.9. Acct-Application-Id AVP

The Acct-Application-Id AVP (AVP Code 259) is of type Unsigned32 and is used in order to advertise support of the accounting portion of an application (see Section 2.4). If present in a message other than CER and CEA, the value of the Acct-Application-Id AVP MUST match the Application Id present in the Diameter message header.

6.10. Inband-Security-Id AVP

The Inband-Security-Id AVP (AVP Code 299) is of type Unsigned32 and is used in order to advertise support of the security portion of the application. The use of this AVP in CER and CEA messages is NOT RECOMMENDED. Instead, discovery of a Diameter entity's security capabilities can be done either through static configuration or via

```
   Diameter Peer Discovery as described in Section 5.2.

   The following values are supported:


   NO_INBAND_SECURITY 0

      This peer does not support TLS/TCP and DTLS/SCTP.  This is the
      default value, if the AVP is omitted.

   TLS 1

      This node supports TLS/TCP [RFC5246] and DTLS/SCTP [RFC6083]
      security.

6.11.  Vendor-Specific-Application-Id AVP

   The Vendor-Specific-Application-Id AVP (AVP Code 260) is of type
   Grouped and is used to advertise support of a vendor-specific
   Diameter application.  Exactly one instance of either Auth-
   Application-Id or Acct-Application-Id AVP MUST be present.  The
   Application Id carried by either Auth-Application-Id or Acct-
   Application-Id AVP MUST comply with vendor-specific Application Id
   assignment described in Section 11.3.  It MUST also match the
   Application Id present in the Diameter header except when used in a
   CER or CEA message.

   The Vendor-Id AVP is an informational AVP pertaining to the vendor
   who may have authorship of the vendor-specific Diameter application.
   It MUST NOT be used as a means of defining a completely separate
   vendor-specific Application Id space.




Fajardo, et al.              Standards Track                   [Page 84]

RFC 6733                 Diameter Base Protocol             October 2012


   The Vendor-Specific-Application-Id AVP SHOULD be placed as close to
   the Diameter header as possible.

      AVP Format

      <Vendor-Specific-Application-Id> ::= < AVP Header: 260 >
                                           { Vendor-Id }
                                           [ Auth-Application-Id ]
                                           [ Acct-Application-Id ]

   A Vendor-Specific-Application-Id AVP MUST contain exactly one of
   either Auth-Application-Id or Acct-Application-Id.  If a Vendor-
   Specific-Application-Id is received without one of these two AVPs,
   then the recipient SHOULD issue an answer with a Result-Code set to
   DIAMETER_MISSING_AVP.  The answer SHOULD also include a Failed-AVP,
   which MUST contain an example of an Auth-Application-Id AVP and an
   Acct-Application-Id AVP.

   If a Vendor-Specific-Application-Id is received that contains both
   Auth-Application-Id and Acct-Application-Id, then the recipient MUST
   issue an answer with Result-Code set to
   DIAMETER_AVP_OCCURS_TOO_MANY_TIMES.  The answer MUST also include a
   Failed-AVP, which MUST contain the received Auth-Application-Id AVP
   and Acct-Application-Id AVP.
```

6.12. Redirect-Host AVP

The Redirect-Host AVP (AVP Code 292) is of type DiameterURI. One or more instances of this AVP MUST be present if the answer message's 'E' bit is set and the Result-Code AVP is set to DIAMETER_REDIRECT_INDICATION.

Upon receiving the above, the receiving Diameter node SHOULD forward the request directly to one of the hosts identified in these AVPs. The server contained in the selected Redirect-Host AVP SHOULD be used for all messages matching the criteria set by the Redirect-Host-Usage AVP.

6.13. Redirect-Host-Usage AVP

The Redirect-Host-Usage AVP (AVP Code 261) is of type Enumerated. This AVP MAY be present in answer messages whose 'E' bit is set and the Result-Code AVP is set to DIAMETER_REDIRECT_INDICATION.

When present, this AVP provides hints about how the routing entry resulting from the Redirect-Host is to be used. The following values are supported:

DONT_CACHE 0

The host specified in the Redirect-Host AVP SHOULD NOT be cached. This is the default value.

ALL_SESSION 1

All messages within the same session, as defined by the same value of the Session-ID AVP SHOULD be sent to the host specified in the Redirect-Host AVP.

ALL_REALM 2

All messages destined for the realm requested SHOULD be sent to the host specified in the Redirect-Host AVP.

REALM_AND_APPLICATION 3

All messages for the application requested to the realm specified SHOULD be sent to the host specified in the Redirect-Host AVP.

ALL_APPLICATION 4

All messages for the application requested SHOULD be sent to the host specified in the Redirect-Host AVP.

ALL_HOST 5

All messages that would be sent to the host that generated the Redirect-Host SHOULD be sent to the host specified in the Redirect-Host AVP.

ALL_USER 6

```
      All messages for the user requested SHOULD be sent to the host
      specified in the Redirect-Host AVP.

   When multiple cached routes are created by redirect indications and
   they differ only in redirect usage and peers to forward requests to
   (see Section 6.1.8), a precedence rule MUST be applied to the
   redirect usage values of the cached routes during normal routing to
   resolve contentions that may occur.  The precedence rule is the order
   that dictate which redirect usage should be considered before any
   other as they appear.  The order is as follows:
```



```
   1.  ALL_SESSION

   2.  ALL_USER

   3.  REALM_AND_APPLICATION

   4.  ALL_REALM

   5.  ALL_APPLICATION

   6.  ALL_HOST

6.14.  Redirect-Max-Cache-Time AVP

   The Redirect-Max-Cache-Time AVP (AVP Code 262) is of type Unsigned32.
   This AVP MUST be present in answer messages whose 'E' bit is set,
   whose Result-Code AVP is set to DIAMETER_REDIRECT_INDICATION, and
   whose Redirect-Host-Usage AVP set to a non-zero value.

   This AVP contains the maximum number of seconds the peer and route
   table entries, created as a result of the Redirect-Host, SHOULD be
   cached.  Note that once a host is no longer reachable, any associated
   cache, peer, and routing table entries MUST be deleted.

7.  Error Handling

   There are two different types of errors in Diameter; protocol errors
   and application errors.  A protocol error is one that occurs at the
   base protocol level and MAY require per-hop attention (e.g., a
   message routing error).  Application errors, on the other hand,
   generally occur due to a problem with a function specified in a
   Diameter application (e.g., user authentication, missing AVP).

   Result-Code AVP values that are used to report protocol errors MUST
   only be present in answer messages whose 'E' bit is set.  When a
   request message is received that causes a protocol error, an answer
   message is returned with the 'E' bit set, and the Result-Code AVP is
   set to the appropriate protocol error value.  As the answer is sent
   back towards the originator of the request, each proxy or relay agent
   MAY take action on the message.
```

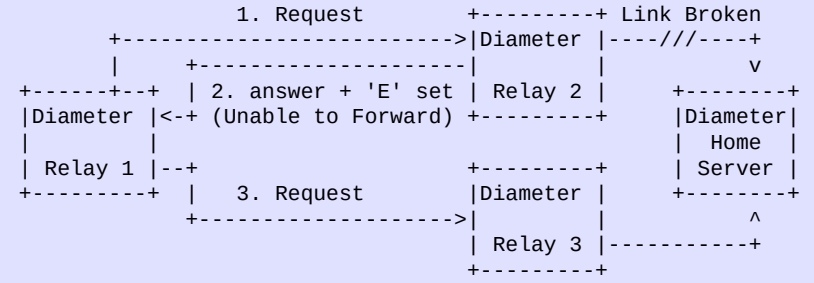


Figure 7: Example of Protocol Error Causing Answer Message

Figure 7 provides an example of a message forwarded upstream by a Diameter relay. When the message is received by Relay 2, and it detects that it cannot forward the request to the home server, an answer message is returned with the 'E' bit set and the Result-Code AVP set to DIAMETER_UNABLE_TO_DELIVER. Given that this error falls within the protocol error category, Relay 1 would take special action, and given the error, attempt to route the message through its alternate Relay 3.

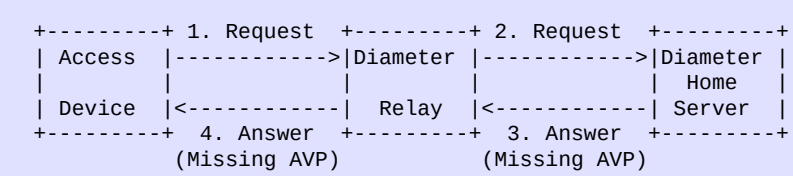


Figure 8: Example of Application Error Answer Message

Figure 8 provides an example of a Diameter message that caused an application error. When application errors occur, the Diameter entity reporting the error clears the 'R' bit in the Command Flags and adds the Result-Code AVP with the proper value. Application errors do not require any proxy or relay agent involvement; therefore, the message would be forwarded back to the originator of the request.

In the case where the answer message itself contains errors, any related session SHOULD be terminated by sending an STR or ASR message. The Termination-Cause AVP in the STR MAY be filled with the appropriate value to indicate the cause of the error. An application MAY also send an application-specific request instead of an STR or ASR message to signal the error in the case where no state is maintained or to allow for some form of error recovery with the corresponding Diameter entity.

There are certain Result-Code AVP application errors that require additional AVPs to be present in the answer. In these cases, the Diameter node that sets the Result-Code AVP to indicate the error MUST add the AVPs. Examples are as follows:

- A request with an unrecognized AVP is received with the 'M' bit (Mandatory bit) set causes an answer to be sent with the Result-Code AVP set to DIAMETER_AVP_UNSUPPORTED and the Failed-AVP AVP containing the offending AVP.
- A request with an AVP that is received with an unrecognized value causes an answer to be returned with the Result-Code AVP set to DIAMETER_INVALID_AVP_VALUE, with the Failed-AVP AVP containing the AVP causing the error.
- A received command that is missing AVPs that are defined as required in the commands CCF; examples are AVPs indicated as {AVP}. The receiver issues an answer with the Result-Code set to DIAMETER_MISSING_AVP and creates an AVP with the AVP Code and other fields set as expected in the missing AVP. The created AVP is then added to the Failed-AVP AVP.

The Result-Code AVP describes the error that the Diameter node encountered in its processing. In case there are multiple errors, the Diameter node MUST report only the first error it encountered (detected possibly in some implementation-dependent order). The specific errors that can be described by this AVP are described in the following section.

7.1. Result-Code AVP

The Result-Code AVP (AVP Code 268) is of type Unsigned32 and indicates whether a particular request was completed successfully or an error occurred. All Diameter answer messages in IETF-defined Diameter application specifications MUST include one Result-Code AVP. A non-successful Result-Code AVP (one containing a non-2xxx value other than DIAMETER_REDIRECT_INDICATION) MUST include the Error-Reporting-Host AVP if the host setting the Result-Code AVP is different from the identity encoded in the Origin-Host AVP.

The Result-Code data field contains an IANA-managed 32-bit address space representing errors (see Section 11.3.2). Diameter provides the following classes of errors, all identified by the thousands digit in the decimal notation:

- 1xxx (Informational)
- 2xxx (Success)

```
   o  3xxx (Protocol Errors)

   o  4xxx (Transient Failures)

   o  5xxx (Permanent Failure)

   An unrecognized class (one whose first digit is not defined in this
   section) MUST be handled as a permanent failure.

7.1.1.  Informational

   Errors that fall within this category are used to inform the
   requester that a request could not be satisfied, and additional
   action is required on its part before access is granted.

   DIAMETER_MULTI_ROUND_AUTH 1001

      This informational error is returned by a Diameter server to
      inform the access device that the authentication mechanism being
      used requires multiple round trips, and a subsequent request needs
      to be issued in order for access to be granted.

7.1.2.  Success

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

   DIAMETER_SUCCESS 2001

      The request was successfully completed.

   DIAMETER_LIMITED_SUCCESS 2002

      When returned, the request was successfully completed, but
      additional processing is required by the application in order to
      provide service to the user.

7.1.3.  Protocol Errors

   Errors that fall within the Protocol Error category SHOULD be treated
   on a per-hop basis, and Diameter proxies MAY attempt to correct the
   error, if it is possible.  Note that these errors MUST only be used
   in answer messages whose 'E' bit is set.
```



```
   DIAMETER_COMMAND_UNSUPPORTED 3001

      This error code is used when a Diameter entity receives a message
      with a Command Code that it does not support.

   DIAMETER_UNABLE_TO_DELIVER 3002

      This error is given when Diameter cannot deliver the message to
      the destination, either because no host within the realm
      supporting the required application was available to process the
      request or because the Destination-Host AVP was given without the
      associated Destination-Realm AVP.
```

```
   DIAMETER_REALM_NOT_SERVED 3003

      The intended realm of the request is not recognized.

   DIAMETER_TOO_BUSY 3004

      When returned, a Diameter node SHOULD attempt to send the message
      to an alternate peer.  This error MUST only be used when a
      specific server is requested, and it cannot provide the requested
      service.

   DIAMETER_LOOP_DETECTED 3005

      An agent detected a loop while trying to get the message to the
      intended recipient.  The message MAY be sent to an alternate peer,
      if one is available, but the peer reporting the error has
      identified a configuration problem.

   DIAMETER_REDIRECT_INDICATION 3006

      A redirect agent has determined that the request could not be
      satisfied locally, and the initiator of the request SHOULD direct
      the request directly to the server, whose contact information has
      been added to the response.  When set, the Redirect-Host AVP MUST
      be present.

   DIAMETER_APPLICATION_UNSUPPORTED 3007

      A request was sent for an application that is not supported.

   DIAMETER_INVALID_HDR_BITS 3008

      A request was received whose bits in the Diameter header were set
      either to an invalid combination or to a value that is
      inconsistent with the Command Code's definition.



Fajardo, et al.              Standards Track                   [Page 91]

RFC 6733                Diameter Base Protocol             October 2012


   DIAMETER_INVALID_AVP_BITS 3009

      A request was received that included an AVP whose flag bits are
      set to an unrecognized value or that is inconsistent with the
      AVP's definition.

   DIAMETER_UNKNOWN_PEER 3010

      A CER was received from an unknown peer.

7.1.4.  Transient Failures

   Errors that fall within the transient failures category are used to
   inform a peer that the request could not be satisfied at the time it
   was received but MAY be able to satisfy the request in the future.
   Note that these errors MUST be used in answer messages whose 'E' bit
   is not set.

   DIAMETER_AUTHENTICATION_REJECTED 4001

      The authentication process for the user failed, most likely due to
      an invalid password used by the user.  Further attempts MUST only
```

be tried after prompting the user for a new password.

DIAMETER_OUT_OF_SPACE 4002

A Diameter node received the accounting request but was unable to commit it to stable storage due to a temporary lack of space.

ELECTION_LOST 4003

The peer has determined that it has lost the election process and has therefore disconnected the transport connection.

7.1.5. 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. Note that these errors SHOULD be used in answer messages whose 'E' bit is not set. In error conditions where it is not possible or efficient to compose application-specific answer grammar, answer messages with the 'E' bit set and which comply to the grammar described in Section 7.2 MAY also be used for permanent errors.

DIAMETER_AVP_UNSUPPORTED 5001

The peer received a message that contained an AVP that is not recognized or supported and was marked with the 'M' (Mandatory) bit. A Diameter message with this error MUST contain one or more Failed-AVP AVPs containing the AVPs that caused the failure.

DIAMETER_UNKNOWN_SESSION_ID 5002

The request contained an unknown Session-Id.

DIAMETER_AUTHORIZATION_REJECTED 5003

A request was received for which the user could not be authorized. This error could occur if the service requested is not permitted to the user.

DIAMETER_INVALID_AVP_VALUE 5004

The request contained an AVP with an invalid value in its data portion. A Diameter message indicating this error MUST include the offending AVPs within a Failed-AVP AVP.

DIAMETER_MISSING_AVP 5005

The request did not contain an AVP that is required by the Command Code definition. If this value is sent in the Result-Code AVP, a Failed-AVP AVP SHOULD be included in the message. The Failed-AVP AVP MUST contain an example of the missing AVP complete with the Vendor-Id if applicable. The value field of the missing AVP should be of correct minimum length and contain zeroes.

```
   DIAMETER_RESOURCES_EXCEEDED 5006

      A request was received that cannot be authorized because the user
      has already expended allowed resources.  An example of this error
      condition is when a user that is restricted to one dial-up PPP
      port attempts to establish a second PPP connection.

   DIAMETER_CONTRADICTING_AVPS 5007

      The Home Diameter server has detected AVPs in the request that
      contradicted each other, and it is not willing to provide service
      to the user.  The Failed-AVP AVP MUST be present, which contain
      the AVPs that contradicted each other.
```



```
   DIAMETER_AVP_NOT_ALLOWED 5008

      A message was received with an AVP that MUST NOT be present.  The
      Failed-AVP AVP MUST be included and contain a copy of the
      offending AVP.

   DIAMETER_AVP_OCCURS_TOO_MANY_TIMES 5009

      A message was received that included an AVP that appeared more
      often than permitted in the message definition.  The Failed-AVP
      AVP MUST be included and contain a copy of the first instance of
      the offending AVP that exceeded the maximum number of occurrences.

   DIAMETER_NO_COMMON_APPLICATION 5010

      This error is returned by a Diameter node that receives a CER
      whereby no applications are common between the CER sending peer
      and the CER receiving peer.

   DIAMETER_UNSUPPORTED_VERSION 5011

      This error is returned when a request was received, whose version
      number is unsupported.

   DIAMETER_UNABLE_TO_COMPLY 5012

      This error is returned when a request is rejected for unspecified
      reasons.

   DIAMETER_INVALID_BIT_IN_HEADER 5013

      This error is returned when a reserved bit in the Diameter header
      is set to one (1) or the bits in the Diameter header are set
      incorrectly.

   DIAMETER_INVALID_AVP_LENGTH 5014

      The request contained an AVP with an invalid length.  A Diameter
      message indicating this error MUST include the offending AVPs
      within a Failed-AVP AVP.  In cases where the erroneous AVP length
```

```
      value exceeds the message length or is less than the minimum AVP
      header length, it is sufficient to include the offending AVP
      header and a zero filled payload of the minimum required length
      for the payloads data type.  If the AVP is a Grouped AVP, the
      Grouped AVP header with an empty payload would be sufficient to
      indicate the offending AVP.  In the case where the offending AVP
      header cannot be fully decoded when the AVP length is less than
```



```
      the minimum AVP header length, it is sufficient to include an
      offending AVP header that is formulated by padding the incomplete
      AVP header with zero up to the minimum AVP header length.

   DIAMETER_INVALID_MESSAGE_LENGTH 5015

      This error is returned when a request is received with an invalid
      message length.

   DIAMETER_INVALID_AVP_BIT_COMBO 5016

      The request contained an AVP with which is not allowed to have the
      given value in the AVP Flags field.  A Diameter message indicating
      this error MUST include the offending AVPs within a Failed-AVP
      AVP.

   DIAMETER_NO_COMMON_SECURITY 5017

      This error is returned when a CER message is received, and there
      are no common security mechanisms supported between the peers.  A
      Capabilities-Exchange-Answer (CEA) message MUST be returned with
      the Result-Code AVP set to DIAMETER_NO_COMMON_SECURITY.

7.2.  Error Bit

   The 'E' (Error Bit) in the Diameter header is set when the request
   caused a protocol-related error (see Section 7.1.3).  A message with
   the 'E' bit MUST NOT be sent as a response to an answer message.
   Note that a message with the 'E' bit set is still subjected to the
   processing rules defined in Section 6.2.  When set, the answer
   message will not conform to the CCF specification for the command;
   instead, it and will conform to the following CCF:

      Message Format

      <answer-message> ::= < Diameter Header: code, ERR [, PXY] >
                          0*1< Session-Id >
                             { Origin-Host }
                             { Origin-Realm }
                             { Result-Code }
                             [ Origin-State-Id ]
                             [ Error-Message ]
                             [ Error-Reporting-Host ]
                             [ Failed-AVP ]
                             [ Experimental-Result ]
                           * [ Proxy-Info ]
                           * [ AVP ]
```

Note that the code used in the header is the same than the one found in the request message, but with the 'R' bit cleared and the 'E' bit set. The 'P' bit in the header is set to the same value as the one found in the request message.

7.3. Error-Message AVP

The Error-Message AVP (AVP Code 281) is of type UTF8String. It MAY accompany a Result-Code AVP as a human-readable error message. The Error-Message AVP is not intended to be useful in an environment where error messages are processed automatically. It SHOULD NOT be expected that the content of this AVP be parsed by network entities.

7.4. Error-Reporting-Host AVP

The Error-Reporting-Host AVP (AVP Code 294) is of type DiameterIdentity. This AVP contains the identity of the Diameter host that sent the Result-Code AVP to a value other than 2001 (Success), only if the host setting the Result-Code is different from the one encoded in the Origin-Host AVP. This AVP is intended to be used for troubleshooting purposes, and it MUST be set when the Result-Code AVP indicates a failure.

7.5. Failed-AVP AVP

The Failed-AVP AVP (AVP Code 279) is of type Grouped and provides debugging information in cases where a request is rejected or not fully processed due to erroneous information in a specific AVP. The value of the Result-Code AVP will provide information on the reason for the Failed-AVP AVP. A Diameter answer message SHOULD contain an instance of the Failed-AVP AVP that corresponds to the error indicated by the Result-Code AVP. For practical purposes, this Failed-AVP would typically refer to the first AVP processing error that a Diameter node encounters.

The possible reasons for this AVP are the presence of an improperly constructed AVP, an unsupported or unrecognized AVP, an invalid AVP value, the omission of a required AVP, the presence of an explicitly excluded AVP (see tables in Section 10) or the presence of two or more occurrences of an AVP that is restricted to 0, 1, or 0-1 occurrences.

A Diameter message SHOULD contain one Failed-AVP AVP, containing the entire AVP that could not be processed successfully. If the failure reason is omission of a required AVP, an AVP with the missing AVP code, the missing Vendor-Id, and a zero-filled payload of the minimum required length for the omitted AVP will be added. If the failure reason is an invalid AVP length where the reported length is less

than the minimum AVP header length or greater than the reported message length, a copy of the offending AVP header and a zero-filled

payload of the minimum required length SHOULD be added.

In the case where the offending AVP is embedded within a Grouped AVP, the Failed-AVP MAY contain the grouped AVP, which in turn contains the single offending AVP. The same method MAY be employed if the grouped AVP itself is embedded in yet another grouped AVP and so on. In this case, the Failed-AVP MAY contain the grouped AVP hierarchy up to the single offending AVP. This enables the recipient to detect the location of the offending AVP when embedded in a group.

AVP Format

```
      <Failed-AVP> ::= < AVP Header: 279 >
                       1* {AVP}
```

7.6. Experimental-Result AVP

The Experimental-Result AVP (AVP Code 297) is of type Grouped, and indicates whether a particular vendor-specific request was completed successfully or whether an error occurred. This AVP has the following structure:

AVP Format

```
      Experimental-Result ::= < AVP Header: 297 >
                              { Vendor-Id }
                              { Experimental-Result-Code }
```

The Vendor-Id AVP (see Section 5.3.3) in this grouped AVP identifies the vendor responsible for the assignment of the result code that follows. All Diameter answer messages defined in vendor-specific applications MUST include either one Result-Code AVP or one Experimental-Result AVP.

7.7. Experimental-Result-Code AVP

The Experimental-Result-Code AVP (AVP Code 298) is of type Unsigned32 and contains a vendor-assigned value representing the result of processing the request.

It is recommended that vendor-specific result codes follow the same conventions given for the Result-Code AVP regarding the different types of result codes and the handling of errors (for non-2xxx values).

8. Diameter User Sessions

In general, Diameter can provide two different types of services to applications. The first involves authentication and authorization, and it can optionally make use of accounting. The second only makes use of accounting.

When a service makes use of the authentication and/or authorization portion of an application, and a user requests access to the network, the Diameter client issues an auth request to its local server. The auth request is defined in a service-specific Diameter application

(e.g., NASREQ). The request contains a Session-Id AVP, which is used in subsequent messages (e.g., subsequent authorization, accounting, etc.) relating to the user's session. The Session-Id AVP is a means for the client and servers to correlate a Diameter message with a user session.

When a Diameter server authorizes a user to implement network resources for a finite amount of time, and it is willing to extend the authorization via a future request, it MUST add the Authorization- Lifetime AVP to the answer message. The Authorization-Lifetime AVP defines the maximum number of seconds a user MAY make use of the resources before another authorization request is expected by the server. The Auth-Grace-Period AVP contains the number of seconds following the expiration of the Authorization-Lifetime, after which the server will release all state information related to the user's session. Note that if payment for services is expected by the serving realm from the user's home realm, the Authorization-Lifetime AVP, combined with the Auth-Grace-Period AVP, implies the maximum length of the session for which the home realm is willing to be fiscally responsible. Services provided past the expiration of the Authorization-Lifetime and Auth-Grace-Period AVPs are the responsibility of the access device. Of course, the actual cost of services rendered is clearly outside the scope of the protocol.

An access device that does not expect to send a re-authorization or a session termination request to the server MAY include the Auth-Session-State AVP with the value set to NO_STATE_MAINTAINED as a hint to the server. If the server accepts the hint, it agrees that since no session termination message will be received once service to the user is terminated, it cannot maintain state for the session. If the answer message from the server contains a different value in the Auth-Session-State AVP (or the default value if the AVP is absent), the access device MUST follow the server's directives. Note that the value NO_STATE_MAINTAINED MUST NOT be set in subsequent re-authorization requests and answers.

The base protocol does not include any authorization request messages, since these are largely application-specific and are defined in a Diameter application document. However, the base protocol does define a set of messages that are used to terminate user sessions. These are used to allow servers that maintain state information to free resources.

When a service only makes use of the accounting portion of the Diameter protocol, even in combination with an application, the Session-Id is still used to identify user sessions. However, the session termination messages are not used, since a session is signaled as being terminated by issuing an accounting stop message.

Diameter may also be used for services that cannot be easily categorized as authentication, authorization, or accounting (e.g., certain Third Generation Partnership Project Internet Multimedia System (3GPP IMS) interfaces). In such cases, the finite state machine defined in subsequent sections may not be applicable. Therefore, the application itself MAY need to define its own finite state machine. However, such application-specific state machines

```
   SHOULD follow the general state machine framework outlined in this
   document such as the use of Session-Id AVPs and the use of STR/STA,
   ASR/ASA messages for stateful sessions.

8.1.  Authorization Session State Machine

   This section contains a set of finite state machines, which represent
   the life cycle of Diameter sessions and which MUST be observed by all
   Diameter implementations that make use of the authentication and/or
   authorization portion of a Diameter application.  The term "Service-
   Specific" below refers to a message defined in a Diameter application
   (e.g., Mobile IPv4, NASREQ).

   There are four different authorization session state machines
   supported in the Diameter base protocol.  The first two describe a
   session in which the server is maintaining session state, indicated
   by the value of the Auth-Session-State AVP (or its absence).  One
   describes the session from a client perspective, the other from a
   server perspective.  The second two state machines are used when the
   server does not maintain session state.  Here again, one describes
   the session from a client perspective, the other from a server
   perspective.

   When a session is moved to the Idle state, any resources that were
   allocated for the particular session must be released.  Any event not
   listed in the state machines MUST be considered an error condition,
   and an answer, if applicable, MUST be returned to the originator of
   the message.



Fajardo, et al.              Standards Track                   [Page 99]

RFC 6733                Diameter Base Protocol             October 2012


   In the case that an application does not support re-auth, the state
   transitions related to server-initiated re-auth, when both client and
   server sessions maintain state (e.g., Send RAR, Pending, Receive
   RAA), MAY be ignored.

   In the state table, the event "Failure to send X" means that the
   Diameter agent is unable to send command X to the desired
   destination.  This could be due to the peer being down or due to the
   peer sending back a transient failure or temporary protocol error
   notification DIAMETER_TOO_BUSY or DIAMETER_LOOP_DETECTED in the
   Result-Code AVP of the corresponding Answer command.  The event 'X
   successfully sent' is the complement of 'Failure to send X'.

   The following state machine is observed by a client when state is
   maintained on the server:

                             CLIENT, STATEFUL
      State     Event                          Action       New State
      ------------------------------------------------------------
      Idle      Client or device requests      Send         Pending
                access                         service-
                                               specific
                                               auth req

      Idle      ASR Received                   Send ASA     Idle
                for unknown session            with
                                               Result-Code =
                                               UNKNOWN_
                                               SESSION_ID
```

```
      Idle      RAR Received                    Send RAA     Idle
                for unknown session             with
                                                Result-Code =
                                                UNKNOWN_
                                                SESSION_ID

      Pending   Successful service-specific     Grant        Open
                authorization answer            Access
                received with default
                Auth-Session-State value

      Pending   Successful service-specific     Sent STR     Discon
                authorization answer received,
                but service not provided

      Pending   Error processing successful     Sent STR     Discon
                service-specific authorization
                answer



Fajardo, et al.              Standards Track                  [Page 100]

RFC 6733                Diameter Base Protocol             October 2012


      Pending   Failed service-specific         Clean up     Idle
                authorization answer received

      Open      User or client device           Send         Open
                requests access to service      service-
                                                specific
                                                auth req

      Open      Successful service-specific     Provide      Open
                authorization answer received   service

      Open      Failed service-specific         Discon.      Idle
                authorization answer            user/device
                received.

      Open      RAR received and client will    Send RAA     Open
                perform subsequent re-auth      with
                                                Result-Code =
                                                SUCCESS

      Open      RAR received and client will    Send RAA     Idle
                not perform subsequent          with
                re-auth                         Result-Code !=
                                                SUCCESS,
                                                Discon.
                                                user/device

      Open      Session-Timeout expires on      Send STR     Discon
                access device

      Open      ASR received,                   Send ASA     Discon
                client will comply              with
                with request to end the         Result-Code =
                session                         = SUCCESS,
                                                Send STR.

      Open      ASR Received,                   Send ASA     Open
                client will not comply          with
```

```
                with request to end the        Result-Code !=
                session                        != SUCCESS

     Open       Authorization-Lifetime +       Send STR     Discon
                Auth-Grace-Period expires on
                access device

     Discon     ASR received                   Send ASA     Discon




Fajardo, et al.              Standards Track                  [Page 101]

RFC 6733                 Diameter Base Protocol             October 2012


     Discon     STA received                   Discon.      Idle
                                               user/device

   The following state machine is observed by a server when it is
   maintaining state for the session:

                              SERVER, STATEFUL
     State      Event                          Action       New State
     ------------------------------------------------------------------
     Idle       Service-specific authorization Send         Open
                request received, and          successful
                user is authorized             service-
                                               specific
                                               answer

     Idle       Service-specific authorization Send         Idle
                request received, and          failed
                user is not authorized         service-
                                               specific
                                               answer

     Open       Service-specific authorization Send         Open
                request received, and user     successful
                is authorized                  service-
                                               specific
                                               answer

     Open       Service-specific authorization Send         Idle
                request received, and user     failed
                is not authorized              service-
                                               specific
                                               answer,
                                               Clean up

     Open       Home server wants to confirm   Send RAR     Pending
                authentication and/or
                authorization of the user

     Pending    Received RAA with a failed     Clean up     Idle
                Result-Code

     Pending    Received RAA with Result-Code  Update       Open
                = SUCCESS                      session

     Open       Home server wants to           Send ASR     Discon
                terminate the service
```

Open	Authorization-Lifetime (and Auth-Grace-Period) expires on home server	Clean up	Idle
Open	Session-Timeout expires on home server	Clean up	Idle
Discon	Failure to send ASR	Wait, resend ASR	Discon
Discon	ASR successfully sent and ASA Received with Result-Code	Clean up	Idle
Not Discon	ASA Received	None	No Change
Any	STR Received	Send STA, Clean up	Idle

The following state machine is observed by a client when state is not maintained on the server:

CLIENT, STATELESS

State	Event	Action	New State
Idle	Client or device requests access	Send service-specific auth req	Pending
Pending	Successful service-specific authorization answer received with Auth-Session-State set to NO_STATE_MAINTAINED	Grant access	Open
Pending	Failed service-specific authorization answer received	Clean up	Idle
Open	Session-Timeout expires on access device	Discon. user/device	Idle
Open	Service to user is terminated	Discon. user/device	Idle

The following state machine is observed by a server when it is not maintaining state for the session:

		SERVER, STATELESS	
State	Event	Action	New State
Idle	Service-specific authorization request received, and successfully processed	Send service-specific answer	Idle

8.2. Accounting Session State Machine

The following state machines MUST be supported for applications that have an accounting portion or that require only accounting services. The first state machine is to be observed by clients.

See Section 9.7 for Accounting Command Codes and Section 9.8 for Accounting AVPs.

The server side in the accounting state machine depends in some cases on the particular application. The Diameter base protocol defines a default state machine that MUST be followed by all applications that have not specified other state machines. This is the second state machine in this section described below.

The default server side state machine requires the reception of accounting records in any order and at any time, and it does not place any standards requirement on the processing of these records. Implementations of Diameter may perform checking, ordering, correlation, fraud detection, and other tasks based on these records. AVPs may need to be inspected as a part of these tasks. The tasks can happen either immediately after record reception or in a post-processing phase. However, as these tasks are typically application or even policy dependent, they are not standardized by the Diameter specifications. Applications MAY define requirements on when to accept accounting records based on the used value of Accounting-Realtime-Required AVP, credit-limit checks, and so on.

However, the Diameter base protocol defines one optional server side state machine that MAY be followed by applications that require keeping track of the session state at the accounting server. Note that such tracking is incompatible with the ability to sustain long duration connectivity problems. Therefore, the use of this state machine is recommended only in applications where the value of the Accounting-Realtime-Required AVP is DELIVER_AND_GRANT; hence, accounting connectivity problems are required to cause the serviced user to be disconnected. Otherwise, records produced by the client

may be lost by the server, which no longer accepts them after the connectivity is re-established. This state machine is the third state machine in this section. The state machine is supervised by a supervision session timer Ts, whose value should be reasonably higher than the Acct_Interim_Interval value. Ts MAY be set to two times the value of the Acct_Interim_Interval so as to avoid the accounting session in the Diameter server to change to Idle state in case of short transient network failure.

```
   Any event not listed in the state machines MUST be considered as an
   error condition, and a corresponding answer, if applicable, MUST be
   returned to the originator of the message.

   In the state table, the event "Failure to send" means that the
   Diameter client is unable to communicate with the desired
   destination.  This could be due to the peer being down, or due to the
   peer sending back a transient failure or temporary protocol error
   notification DIAMETER_OUT_OF_SPACE, DIAMETER_TOO_BUSY, or
   DIAMETER_LOOP_DETECTED in the Result-Code AVP of the Accounting
   Answer command.

   The event "Failed answer" means that the Diameter client received a
   non-transient failure notification in the Accounting Answer command.

   Note that the action "Disconnect user/dev" MUST also have an effect
   on the authorization session state table, e.g., cause the STR message
   to be sent, if the given application has both authentication/
   authorization and accounting portions.

   The states PendingS, PendingI, PendingL, PendingE, and PendingB stand
   for pending states to wait for an answer to an accounting request
   related to a Start, Interim, Stop, Event, or buffered record,
   respectively.

                          CLIENT, ACCOUNTING
      State     Event                           Action       New State
      ------------------------------------------------------------
      Idle      Client or device requests       Send         PendingS
                access                          accounting
                                                start req.

      Idle      Client or device requests       Send         PendingE
                a one-time service              accounting
                                                event req

      Idle      Records in storage              Send         PendingB
                                                record




Fajardo, et al.              Standards Track                  [Page 105]

RFC 6733                Diameter Base Protocol             October 2012


      PendingS  Successful accounting                       Open
                start answer received

      PendingS  Failure to send and buffer    Store        Open
                space available and real time Start
                not equal to DELIVER_AND_GRANT Record

      PendingS  Failure to send and no buffer               Open
                space available and real time
                equal to GRANT_AND_LOSE

      PendingS  Failure to send and no        Disconnect   Idle
                buffer space available and    user/dev
                real time not equal to
                GRANT_AND_LOSE

      PendingS  Failed accounting start answer              Open
                received and real time equal
```

```
                to GRANT_AND_LOSE

      PendingS  Failed accounting start answer Disconnect   Idle
                received and real time not     user/dev
                equal to GRANT_AND_LOSE

      PendingS  User service terminated        Store        PendingS
                                               stop
                                               record

      Open      Interim interval elapses       Send         PendingI
                                               accounting
                                               interim
                                               record

      Open      User service terminated        Send         PendingL
                                               accounting
                                               stop req.

      PendingI  Successful accounting interim               Open
                answer received

      PendingI  Failure to send and (buffer    Store        Open
                space available or old         interim
                record can be overwritten)     record
                and real time not equal to
                DELIVER_AND_GRANT
```



```
      PendingI  Failure to send and no buffer              Open
                space available and real time
                equal to GRANT_AND_LOSE

      PendingI  Failure to send and no         Disconnect   Idle
                buffer space available and     user/dev
                real time not equal to
                GRANT_AND_LOSE

      PendingI  Failed accounting interim                  Open
                answer received and real time
                equal to GRANT_AND_LOSE

      PendingI  Failed accounting interim      Disconnect   Idle
                answer received and            user/dev
                real time not equal to
                GRANT_AND_LOSE

      PendingI  User service terminated        Store        PendingI
                                               stop
                                               record
      PendingE  Successful accounting                       Idle
                event answer received

      PendingE  Failure to send and buffer     Store        Idle
                space available                event
                                               record
```

```
      PendingE  Failure to send and no buffer              Idle
                space available

      PendingE  Failed accounting event answer            Idle
                received

      PendingB  Successful accounting answer   Delete     Idle
                received                       record

      PendingB  Failure to send                           Idle

      PendingB  Failed accounting answer       Delete     Idle
                received                       record

      PendingL  Successful accounting                     Idle
                stop answer received

      PendingL  Failure to send and buffer     Store      Idle
                space available                stop
                                               record



Fajardo, et al.              Standards Track                [Page 107]

RFC 6733                Diameter Base Protocol             October 2012


      PendingL  Failure to send and no buffer              Idle
                space available

      PendingL  Failed accounting stop answer             Idle
                received


                      SERVER, STATELESS ACCOUNTING
      State     Event                          Action     New State
      ------------------------------------------------------------

      Idle      Accounting start request       Send       Idle
                received and successfully      accounting
                processed.                     start
                                               answer

      Idle      Accounting event request       Send       Idle
                received and successfully      accounting
                processed.                     event
                                               answer

      Idle      Interim record received        Send       Idle
                and successfully processed.    accounting
                                               interim
                                               answer

      Idle      Accounting stop request        Send       Idle
                received and successfully      accounting
                processed                      stop answer

      Idle      Accounting request received;   Send       Idle
                no space left to store         accounting
                records                        answer;
                                               Result-Code =
                                               OUT_OF_
                                               SPACE
```

SERVER, STATEFUL ACCOUNTING

State	Event	Action	New State
Idle	Accounting start request received and successfully processed.	Send accounting start answer; Start Ts	Open
Idle	Accounting event request received and successfully processed.	Send accounting event answer	Idle
Idle	Accounting request received; no space left to store records	Send accounting answer; Result-Code = OUT_OF_ SPACE	Idle
Open	Interim record received and successfully processed.	Send accounting interim answer; Restart Ts	Open
Open	Accounting stop request received and successfully processed	Send accounting stop answer; Stop Ts	Idle
Open	Accounting request received; no space left to store records	Send accounting answer; Result-Code = OUT_OF_ SPACE; Stop Ts	Idle
Open	Session supervision timer Ts expired	Stop Ts	Idle

8.3. Server-Initiated Re-Auth

A Diameter server may initiate a re-authentication and/or re-authorization service for a particular session by issuing a Re-Auth-Request (RAR).

For example, for prepaid services, the Diameter server that originally authorized a session may need some confirmation that the user is still using the services.

An access device that receives an RAR message with the Session-Id equal to a currently active session MUST initiate a re-auth towards the user, if the service supports this particular feature. Each Diameter application MUST state whether server-initiated re-auth is supported, since some applications do not allow access devices to prompt the user for re-auth.

8.3.1. Re-Auth-Request

The Re-Auth-Request (RAR), indicated by the Command Code set to 258 and the message flags' 'R' bit set, may be sent by any server to the access device that is providing session service, to request that the user be re-authenticated and/or re-authorized.

Message Format

```
     <RAR>  ::= < Diameter Header: 258, REQ, PXY >
                < Session-Id >
                { Origin-Host }
                { Origin-Realm }
                { Destination-Realm }
                { Destination-Host }
                { Auth-Application-Id }
                { Re-Auth-Request-Type }
                [ User-Name ]
                [ Origin-State-Id ]
              * [ Proxy-Info ]
              * [ Route-Record ]
              * [ AVP ]
```

8.3.2. Re-Auth-Answer

The Re-Auth-Answer (RAA), indicated by the Command Code set to 258 and the message flags' 'R' bit clear, is sent in response to the RAR. The Result-Code AVP MUST be present, and it indicates the disposition of the request.

```
   A successful RAA message MUST be followed by an application-specific
   authentication and/or authorization message.

    Message Format

         <RAA>  ::= < Diameter Header: 258, PXY >
                    < Session-Id >
                    { Result-Code }
                    { Origin-Host }
                    { Origin-Realm }
                    [ User-Name ]
                    [ Origin-State-Id ]
                    [ Error-Message ]
                    [ Error-Reporting-Host ]
                    [ Failed-AVP ]
                  * [ Redirect-Host ]
                    [ Redirect-Host-Usage ]
                    [ Redirect-Max-Cache-Time ]
                  * [ Proxy-Info ]
                  * [ AVP ]

8.4.  Session Termination

   It is necessary for a Diameter server that authorized a session, for
   which it is maintaining state, to be notified when that session is no
   longer active, both for tracking purposes as well as to allow
   stateful agents to release any resources that they may have provided
   for the user's session.  For sessions whose state is not being
   maintained, this section is not used.

   When a user session that required Diameter authorization terminates,
   the access device that provided the service MUST issue a Session-
   Termination-Request (STR) message to the Diameter server that
   authorized the service, to notify it that the session is no longer
   active.  An STR MUST be issued when a user session terminates for any
   reason, including user logoff, expiration of Session-Timeout,
   administrative action, termination upon receipt of an Abort-Session-
   Request (see below), orderly shutdown of the access device, etc.

   The access device also MUST issue an STR for a session that was
   authorized but never actually started.  This could occur, for
   example, due to a sudden resource shortage in the access device, or
   because the access device is unwilling to provide the type of service
   requested in the authorization, or because the access device does not
   support a mandatory AVP returned in the authorization, etc.

   It is also possible that a session that was authorized is never
   actually started due to action of a proxy.  For example, a proxy may



Fajardo, et al.              Standards Track                  [Page 111]

RFC 6733                 Diameter Base Protocol             October 2012


   modify an authorization answer, converting the result from success to
   failure, prior to forwarding the message to the access device.  If
   the answer did not contain an Auth-Session-State AVP with the value
   NO_STATE_MAINTAINED, a proxy that causes an authorized session not to
   be started MUST issue an STR to the Diameter server that authorized
   the session, since the access device has no way of knowing that the
   session had been authorized.
```

```
   A Diameter server that receives an STR message MUST clean up
   resources (e.g., session state) associated with the Session-Id
   specified in the STR and return a Session-Termination-Answer.

   A Diameter server also MUST clean up resources when the Session-
   Timeout expires, or when the Authorization-Lifetime and the Auth-
   Grace-Period AVPs expire without receipt of a re-authorization
   request, regardless of whether an STR for that session is received.
   The access device is not expected to provide service beyond the
   expiration of these timers; thus, expiration of either of these
   timers implies that the access device may have unexpectedly shut
   down.

8.4.1.  Session-Termination-Request

   The Session-Termination-Request (STR), indicated by the Command Code
   set to 275 and the Command Flags' 'R' bit set, is sent by a Diameter
   client or by a Diameter proxy to inform the Diameter server that an
   authenticated and/or authorized session is being terminated.

    Message Format

        <STR>  ::= < Diameter Header: 275, REQ, PXY >
                   < Session-Id >
                   { Origin-Host }
                   { Origin-Realm }
                   { Destination-Realm }
                   { Auth-Application-Id }
                   { Termination-Cause }
                   [ User-Name ]
                   [ Destination-Host ]
                 * [ Class ]
                   [ Origin-State-Id ]
                 * [ Proxy-Info ]
                 * [ Route-Record ]
                 * [ AVP ]
```



```
8.4.2.  Session-Termination-Answer

   The Session-Termination-Answer (STA), indicated by the Command Code
   set to 275 and the message flags' 'R' bit clear, is sent by the
   Diameter server to acknowledge the notification that the session has
   been terminated.  The Result-Code AVP MUST be present, and it MAY
   contain an indication that an error occurred while servicing the STR.

   Upon sending or receipt of the STA, the Diameter server MUST release
   all resources for the session indicated by the Session-Id AVP.  Any
   intermediate server in the Proxy-Chain MAY also release any
   resources, if necessary.

    Message Format

         <STA> ::= < Diameter Header: 275, PXY >
```

```
                    < Session-Id >
                    { Result-Code }
                    { Origin-Host }
                    { Origin-Realm }
                    [ User-Name ]
                  * [ Class ]
                    [ Error-Message ]
                    [ Error-Reporting-Host ]
                    [ Failed-AVP ]
                    [ Origin-State-Id ]
                  * [ Redirect-Host ]
                    [ Redirect-Host-Usage ]
                    [ Redirect-Max-Cache-Time ]
                  * [ Proxy-Info ]
                  * [ AVP ]
```

8.5. Aborting a Session

A Diameter server may request that the access device stop providing service for a particular session by issuing an Abort-Session-Request (ASR).

For example, the Diameter server that originally authorized the session may be required to cause that session to be stopped for lack of credit or other reasons that were not anticipated when the session was first authorized.

An access device that receives an ASR with Session-ID equal to a currently active session MAY stop the session. Whether the access device stops the session or not is implementation and/or configuration dependent. For example, an access device may honor ASRs from certain agents only. In any case, the access device MUST

respond with an Abort-Session-Answer, including a Result-Code AVP to indicate what action it took.

8.5.1. Abort-Session-Request

The Abort-Session-Request (ASR), indicated by the Command Code set to 274 and the message flags' 'R' bit set, may be sent by any Diameter server or any Diameter proxy to the access device that is providing session service, to request that the session identified by the Session-Id be stopped.

Message Format

```
      <ASR>  ::= < Diameter Header: 274, REQ, PXY >
                 < Session-Id >
                 { Origin-Host }
                 { Origin-Realm }
                 { Destination-Realm }
                 { Destination-Host }
                 { Auth-Application-Id }
                 [ User-Name ]
                 [ Origin-State-Id ]
               * [ Proxy-Info ]
               * [ Route-Record ]
               * [ AVP ]
```

```
8.5.2.  Abort-Session-Answer

   The Abort-Session-Answer (ASA), indicated by the Command Code set to
   274 and the message flags' 'R' bit clear, is sent in response to the
   ASR.  The Result-Code AVP MUST be present and indicates the
   disposition of the request.

   If the session identified by Session-Id in the ASR was successfully
   terminated, the Result-Code is set to DIAMETER_SUCCESS.  If the
   session is not currently active, the Result-Code is set to
   DIAMETER_UNKNOWN_SESSION_ID.  If the access device does not stop the
   session for any other reason, the Result-Code is set to
   DIAMETER_UNABLE_TO_COMPLY.
```



```
    Message Format

         <ASA>  ::= < Diameter Header: 274, PXY >
                    < Session-Id >
                    { Result-Code }
                    { Origin-Host }
                    { Origin-Realm }
                    [ User-Name ]
                    [ Origin-State-Id ]
                    [ Error-Message ]
                    [ Error-Reporting-Host ]
                    [ Failed-AVP ]
                  * [ Redirect-Host ]
                    [ Redirect-Host-Usage ]
                    [ Redirect-Max-Cache-Time ]
                  * [ Proxy-Info ]
                  * [ AVP ]

8.6.  Inferring Session Termination from Origin-State-Id

   The Origin-State-Id is used to allow detection of terminated sessions
   for which no STR would have been issued, due to unanticipated
   shutdown of an access device.

   A Diameter client or access device increments the value of the
   Origin-State-Id every time it is started or powered up.  The new
   Origin-State-Id is then sent in the CER/CEA message immediately upon
   connection to the server.  The Diameter server receiving the new
   Origin-State-Id can determine whether the sending Diameter client had
   abruptly shut down by comparing the old value of the Origin-State-Id
   it has kept for that specific client is less than the new value and
   whether it has un-terminated sessions originating from that client.

   An access device can also include the Origin-State-Id in request
```

messages other than the CER if there are relays or proxies in between the access device and the server. In this case, however, the server cannot discover that the access device has been restarted unless and until it receives a new request from it. Therefore, this mechanism is more opportunistic across proxies and relays.

The Diameter server may assume that all sessions that were active prior to detection of a client restart have been terminated. The Diameter server MAY clean up all session state associated with such lost sessions, and it MAY also issue STRs for all such lost sessions that were authorized on upstream servers, to allow session state to be cleaned up globally.

8.7. Auth-Request-Type AVP

The Auth-Request-Type AVP (AVP Code 274) is of type Enumerated and is included in application-specific auth requests to inform the peers whether a user is to be authenticated only, authorized only, or both. Note any value other than both MAY cause RADIUS interoperability issues. The following values are defined:

AUTHENTICATE_ONLY 1

The request being sent is for authentication only, and it MUST contain the relevant application-specific authentication AVPs that are needed by the Diameter server to authenticate the user.

AUTHORIZE_ONLY 2

The request being sent is for authorization only, and it MUST contain the application-specific authorization AVPs that are necessary to identify the service being requested/offered.

AUTHORIZE_AUTHENTICATE 3

The request contains a request for both authentication and authorization. The request MUST include both the relevant application-specific authentication information and authorization information necessary to identify the service being requested/offered.

8.8. Session-Id AVP

The Session-Id AVP (AVP Code 263) is of type UTF8String and is used to identify a specific session (see Section 8). All messages pertaining to a specific session MUST include only one Session-Id AVP, and the same value MUST be used throughout the life of a session. When present, the Session-Id SHOULD appear immediately following the Diameter header (see Section 3).

The Session-Id MUST be globally and eternally unique, as it is meant to uniquely identify a user session without reference to any other information, and it may be needed to correlate historical authentication information with accounting information. The Session-Id includes a mandatory portion and an implementation-defined portion; a recommended format for the implementation-defined portion

```
   is outlined below.

   The Session-Id MUST begin with the sender's identity encoded in the
   DiameterIdentity type (see Section 4.3.1).  The remainder of the
   Session-Id is delimited by a ";" character, and it MAY be any



Fajardo, et al.              Standards Track                  [Page 116]

RFC 6733                 Diameter Base Protocol             October 2012


   sequence that the client can guarantee to be eternally unique;
   however, the following format is recommended, (square brackets []
   indicate an optional element):

      <DiameterIdentity>;<high 32 bits>;<low 32 bits>[;<optional value>]

   <high 32 bits> and <low 32 bits> are decimal representations of the
   high and low 32 bits of a monotonically increasing 64-bit value.  The
   64-bit value is rendered in two part to simplify formatting by 32-bit
   processors.  At startup, the high 32 bits of the 64-bit value MAY be
   initialized to the time in NTP format [RFC5905], and the low 32 bits
   MAY be initialized to zero.  This will for practical purposes
   eliminate the possibility of overlapping Session-Ids after a reboot,
   assuming the reboot process takes longer than a second.
   Alternatively, an implementation MAY keep track of the increasing
   value in non-volatile memory.


   <optional value> is implementation specific, but it may include a
   modem's device Id, a Layer 2 address, timestamp, etc.

   Example, in which there is no optional value:

      accesspoint7.example.com;1876543210;523

   Example, in which there is an optional value:

     accesspoint7.example.com;1876543210;523;mobile@200.1.1.88

   The Session-Id is created by the Diameter application initiating the
   session, which, in most cases, is done by the client.  Note that a
   Session-Id MAY be used for both the authentication, authorization,
   and accounting commands of a given application.

8.9.  Authorization-Lifetime AVP

   The Authorization-Lifetime AVP (AVP Code 291) is of type Unsigned32
   and contains the maximum number of seconds of service to be provided
   to the user before the user is to be re-authenticated and/or re-
   authorized.  Care should be taken when the Authorization-Lifetime
   value is determined, since a low, non-zero value could create
   significant Diameter traffic, which could congest both the network
   and the agents.

   A value of zero (0) means that immediate re-auth is necessary by the
   access device.  The absence of this AVP, or a value of all ones
   (meaning all bits in the 32-bit field are set to one) means no re-
   auth is expected.



Fajardo, et al.              Standards Track                  [Page 117]
```

If both this AVP and the Session-Timeout AVP are present in a message, the value of the latter MUST NOT be smaller than the Authorization-Lifetime AVP.

An Authorization-Lifetime AVP MAY be present in re-authorization messages, and it contains the number of seconds the user is authorized to receive service from the time the re-auth answer message is received by the access device.

This AVP MAY be provided by the client as a hint of the maximum lifetime that it is willing to accept. The server MUST return a value that is equal to, or smaller than, the one provided by the client.

8.10. Auth-Grace-Period AVP

The Auth-Grace-Period AVP (AVP Code 276) is of type Unsigned32 and contains the number of seconds the Diameter server will wait following the expiration of the Authorization-Lifetime AVP before cleaning up resources for the session.

8.11. Auth-Session-State AVP

The Auth-Session-State AVP (AVP Code 277) is of type Enumerated and specifies whether state is maintained for a particular session. The client MAY include this AVP in requests as a hint to the server, but the value in the server's answer message is binding. The following values are supported:

STATE_MAINTAINED 0

This value is used to specify that session state is being maintained, and the access device MUST issue a session termination message when service to the user is terminated. This is the default value.

NO_STATE_MAINTAINED 1

This value is used to specify that no session termination messages will be sent by the access device upon expiration of the Authorization-Lifetime.

8.12. Re-Auth-Request-Type AVP

The Re-Auth-Request-Type AVP (AVP Code 285) is of type Enumerated and is included in application-specific auth answers to inform the client of the action expected upon expiration of the Authorization-Lifetime.

If the answer message contains an Authorization-Lifetime AVP with a positive value, the Re-Auth-Request-Type AVP MUST be present in an answer message. The following values are defined:

AUTHORIZE_ONLY 0

```
      An authorization only re-auth is expected upon expiration of the
      Authorization-Lifetime.  This is the default value if the AVP is
      not present in answer messages that include the Authorization-
      Lifetime.

   AUTHORIZE_AUTHENTICATE 1

      An authentication and authorization re-auth is expected upon
      expiration of the Authorization-Lifetime.

8.13.  Session-Timeout AVP

   The Session-Timeout AVP (AVP Code 27) [RFC2865] is of type Unsigned32
   and contains the maximum number of seconds of service to be provided
   to the user before termination of the session.  When both the
   Session-Timeout and the Authorization-Lifetime AVPs are present in an
   answer message, the former MUST be equal to or greater than the value
   of the latter.

   A session that terminates on an access device due to the expiration
   of the Session-Timeout MUST cause an STR to be issued, unless both
   the access device and the home server had previously agreed that no
   session termination messages would be sent (see Section 8).

   A Session-Timeout AVP MAY be present in a re-authorization answer
   message, and it contains the remaining number of seconds from the
   beginning of the re-auth.

   A value of zero, or the absence of this AVP, means that this session
   has an unlimited number of seconds before termination.

   This AVP MAY be provided by the client as a hint of the maximum
   timeout that it is willing to accept.  However, the server MAY return
   a value that is equal to, or smaller than, the one provided by the
   client.

8.14.  User-Name AVP

   The User-Name AVP (AVP Code 1) [RFC2865] is of type UTF8String, which
   contains the User-Name, in a format consistent with the NAI
   specification [RFC4282].



Fajardo, et al.              Standards Track                  [Page 119]

RFC 6733                Diameter Base Protocol             October 2012


8.15.  Termination-Cause AVP

   The Termination-Cause AVP (AVP Code 295) is of type Enumerated, and
   is used to indicate the reason why a session was terminated on the
   access device.  The currently assigned values for this AVP can be
   found in the IANA registry for Termination-Cause AVP Values
   [IANATCV].

8.16.  Origin-State-Id AVP

   The Origin-State-Id AVP (AVP Code 278), of type Unsigned32, is a
   monotonically increasing value that is advanced whenever a Diameter
   entity restarts with loss of previous state, for example, upon
   reboot.  Origin-State-Id MAY be included in any Diameter message,
```

including CER.

A Diameter entity issuing this AVP MUST create a higher value for this AVP each time its state is reset. A Diameter entity MAY set Origin-State-Id to the time of startup, or it MAY use an incrementing counter retained in non-volatile memory across restarts.

The Origin-State-Id, if present, MUST reflect the state of the entity indicated by Origin-Host. If a proxy modifies Origin-Host, it MUST either remove Origin-State-Id or modify it appropriately as well. Typically, Origin-State-Id is used by an access device that always starts up with no active sessions; that is, any session active prior to restart will have been lost. By including Origin-State-Id in a message, it allows other Diameter entities to infer that sessions associated with a lower Origin-State-Id are no longer active. If an access device does not intend for such inferences to be made, it MUST either not include Origin-State-Id in any message or set its value to 0.

8.17. Session-Binding AVP

The Session-Binding AVP (AVP Code 270) is of type Unsigned32, and it MAY be present in application-specific authorization answer messages. If present, this AVP MAY inform the Diameter client that all future application-specific re-auth and Session-Termination-Request messages for this session MUST be sent to the same authorization server.

This field is a bit mask, and the following bits have been defined:

RE_AUTH 1

When set, future re-auth messages for this session MUST NOT include the Destination-Host AVP. When cleared, the default value, the Destination-Host AVP MUST be present in all re-auth messages for this session.

STR 2

When set, the STR message for this session MUST NOT include the Destination-Host AVP. When cleared, the default value, the Destination-Host AVP MUST be present in the STR message for this session.

ACCOUNTING 4

When set, all accounting messages for this session MUST NOT include the Destination-Host AVP. When cleared, the default value, the Destination-Host AVP, if known, MUST be present in all accounting messages for this session.

8.18. Session-Server-Failover AVP

The Session-Server-Failover AVP (AVP Code 271) is of type Enumerated and MAY be present in application-specific authorization answer messages that either do not include the Session-Binding AVP or include the Session-Binding AVP with any of the bits set to a zero value. If present, this AVP MAY inform the Diameter client that if a re-auth or STR message fails due to a delivery problem, the Diameter client SHOULD issue a subsequent message without the Destination-Host AVP. When absent, the default value is REFUSE_SERVICE.

The following values are supported:

REFUSE_SERVICE 0

If either the re-auth or the STR message delivery fails, terminate service with the user and do not attempt any subsequent attempts.

TRY_AGAIN 1

If either the re-auth or the STR message delivery fails, resend the failed message without the Destination-Host AVP present.

ALLOW_SERVICE 2

If re-auth message delivery fails, assume that re-authorization succeeded. If STR message delivery fails, terminate the session.

TRY_AGAIN_ALLOW_SERVICE 3

If either the re-auth or the STR message delivery fails, resend the failed message without the Destination-Host AVP present. If the second delivery fails for re-auth, assume re-authorization succeeded. If the second delivery fails for STR, terminate the session.

8.19. Multi-Round-Time-Out AVP

The Multi-Round-Time-Out AVP (AVP Code 272) is of type Unsigned32 and SHOULD be present in application-specific authorization answer messages whose Result-Code AVP is set to DIAMETER_MULTI_ROUND_AUTH. This AVP contains the maximum number of seconds that the access device MUST provide the user in responding to an authentication request.

8.20. Class AVP

The Class AVP (AVP Code 25) is of type OctetString and is used by Diameter servers to return state information to the access device. When one or more Class AVPs are present in application-specific

authorization answer messages, they MUST be present in subsequent re-authorization, session termination and accounting messages. Class AVPs found in a re-authorization answer message override the ones found in any previous authorization answer message. Diameter server implementations SHOULD NOT return Class AVPs that require more than 4096 bytes of storage on the Diameter client. A Diameter client that receives Class AVPs whose size exceeds local available storage MUST terminate the session.

8.21. Event-Timestamp AVP

The Event-Timestamp (AVP Code 55) is of type Time and MAY be included in an Accounting-Request and Accounting-Answer messages to record the time that the reported event occurred, in seconds since January 1, 1900 00:00 UTC.

9. Accounting

This accounting protocol is based on a server directed model with capabilities for real-time delivery of accounting information. Several fault resilience methods [RFC2975] have been built into the protocol in order minimize loss of accounting data in various fault situations and under different assumptions about the capabilities of the used devices.

9.1. Server Directed Model

The server directed model means that the device generating the accounting data gets information from either the authorization server (if contacted) or the accounting server regarding the way accounting data shall be forwarded. This information includes accounting record timeliness requirements.

As discussed in [RFC2975], real-time transfer of accounting records is a requirement, such as the need to perform credit-limit checks and fraud detection. Note that batch accounting is not a requirement, and is therefore not supported by Diameter. Should batched accounting be required in the future, a new Diameter application will need to be created, or it could be handled using another protocol. Note, however, that even if at the Diameter layer, accounting requests are processed one by one; transport protocols used under Diameter typically batch several requests in the same packet under heavy traffic conditions. This may be sufficient for many applications.

The authorization server (chain) directs the selection of proper transfer strategy, based on its knowledge of the user and relationships of roaming partnerships. The server (or agents) uses the Acct-Interim-Interval and Accounting-Realtime-Required AVPs to control the operation of the Diameter peer operating as a client. The Acct-Interim-Interval AVP, when present, instructs the Diameter node acting as a client to produce accounting records continuously even during a session. Accounting-Realtime-Required AVP is used to control the behavior of the client when the transfer of accounting records from the Diameter client is delayed or unsuccessful.

The Diameter accounting server MAY override the interim interval or

the real-time requirements by including the Acct-Interim-Interval or Accounting-Realtime-Required AVP in the Accounting-Answer message. When one of these AVPs is present, the latest value received SHOULD be used in further accounting activities for the same session.

9.2. Protocol Messages

A Diameter node that receives a successful authentication and/or authorization message from the Diameter server SHOULD collect accounting information for the session. The Accounting-Request message is used to transmit the accounting information to the Diameter server, which MUST reply with the Accounting-Answer message to confirm reception. The Accounting-Answer message includes the Result-Code AVP, which MAY indicate that an error was present in the accounting message. The value of the Accounting-Realtime-Required AVP received earlier for the session in question may indicate that the user's session has to be terminated when a rejected Accounting-Request message was received.

9.3. Accounting Application Extension and Requirements

Each Diameter application (e.g., NASREQ, Mobile IP) SHOULD define its service-specific AVPs that MUST be present in the Accounting-Request message in a section titled "Accounting AVPs". The application MUST assume that the AVPs described in this document will be present in all Accounting messages, so only their respective service-specific AVPs need to be defined in that section.

Applications have the option of using one or both of the following accounting application extension models:

Split Accounting Service

The accounting message will carry the Application Id of the Diameter base accounting application (see Section 2.4). Accounting messages may be routed to Diameter nodes other than the corresponding Diameter application. These nodes might be centralized accounting servers that provide accounting service for multiple different Diameter applications. These nodes MUST advertise the Diameter base accounting Application Id during capabilities exchange.

Coupled Accounting Service

The accounting message will carry the Application Id of the application that is using it. The application itself will process the received accounting records or forward them to an accounting server. There is no accounting application advertisement required during capabilities exchange, and the accounting messages will be routed the same way as any of the other application messages.

In cases where an application does not define its own accounting service, it is preferred that the split accounting model be used.

9.4. Fault Resilience

Diameter base protocol mechanisms are used to overcome small message loss and network faults of a temporary nature.

Diameter peers acting as clients MUST implement the use of failover to guard against server failures and certain network failures. Diameter peers acting as agents or related off-line processing systems MUST detect duplicate accounting records caused by the sending of the same record to several servers and duplication of messages in transit. This detection MUST be based on the inspection of the Session-Id and Accounting-Record-Number AVP pairs. Appendix C discusses duplicate detection needs and implementation issues.

Diameter clients MAY have non-volatile memory for the safe storage of accounting records over reboots or extended network failures, network partitions, and server failures. If such memory is available, the client SHOULD store new accounting records there as soon as the records are created and until a positive acknowledgement of their reception from the Diameter server has been received. Upon a reboot, the client MUST start sending the records in the non-volatile memory to the accounting server with the appropriate modifications in termination cause, session length, and other relevant information in the records.

A further application of this protocol may include AVPs to control the maximum number of accounting records that may be stored in the Diameter client without committing them to the non-volatile memory or transferring them to the Diameter server.

The client SHOULD NOT remove the accounting data from any of its memory areas before the correct Accounting-Answer has been received. The client MAY remove the oldest, undelivered, or as yet unacknowledged accounting data if it runs out of resources such as memory. It is an implementation-dependent matter for the client to accept new sessions under this condition.

9.5. Accounting Records

In all accounting records, the Session-Id AVP MUST be present; the User-Name AVP MUST be present if it is available to the Diameter client.

Different types of accounting records are sent depending on the actual type of accounted service and the authorization server's directions for interim accounting. If the accounted service is a

one-time event, meaning that the start and stop of the event are simultaneous, then the Accounting-Record-Type AVP MUST be present and set to the value EVENT_RECORD.

If the accounted service is of a measurable length, then the AVP MUST use the values START_RECORD, STOP_RECORD, and possibly, INTERIM_RECORD. If the authorization server has not directed interim accounting to be enabled for the session, two accounting records MUST be generated for each service of type session. When the initial Accounting-Request for a given session is sent, the Accounting-Record-Type AVP MUST be set to the value START_RECORD. When the last Accounting-Request is sent, the value MUST be STOP_RECORD.

If the authorization server has directed interim accounting to be enabled, the Diameter client MUST produce additional records between the START_RECORD and STOP_RECORD, marked INTERIM_RECORD. The production of these records is directed by Acct-Interim-Interval as well as any re-authentication or re-authorization of the session. The Diameter client MUST overwrite any previous interim accounting records that are locally stored for delivery, if a new record is being generated for the same session. This ensures that only one pending interim record can exist on an access device for any given session.

A particular value of Accounting-Sub-Session-Id MUST appear only in one sequence of accounting records from a Diameter client, except for the purposes of retransmission. The one sequence that is sent MUST be either one record with Accounting-Record-Type AVP set to the value EVENT_RECORD or several records starting with one having the value START_RECORD, followed by zero or more INTERIM_RECORDs and a single STOP_RECORD. A particular Diameter application specification MUST define the type of sequences that MUST be used.

9.6. Correlation of Accounting Records

If an application uses accounting messages, it can correlate accounting records with a specific application session by using the Session-Id of the particular application session in the accounting messages. Accounting messages MAY also use a different Session-Id from that of the application sessions, in which case, other session-related information is needed to perform correlation.

In cases where an application requires multiple accounting sub-sessions, an Accounting-Sub-Session-Id AVP is used to differentiate each sub-session. The Session-Id would remain constant for all sub-sessions and is used to correlate all the sub-sessions to a particular application session. Note that receiving a STOP_RECORD

with no Accounting-Sub-Session-Id AVP when sub-sessions were originally used in the START_RECORD messages implies that all sub-sessions are terminated.

There are also cases where an application needs to correlate multiple application sessions into a single accounting record; the accounting record may span multiple different Diameter applications and sessions used by the same user at a given time. In such cases, the Acct-Multi-Session-Id AVP is used. The Acct-Multi-Session-Id AVP SHOULD be signaled by the server to the access device (typically, during authorization) when it determines that a request belongs to an existing session. The access device MUST then include the Acct-

```
   Multi-Session-Id AVP in all subsequent accounting messages.

   The Acct-Multi-Session-Id AVP MAY include the value of the original
   Session-Id.  Its contents are implementation specific, but the MUST
   be globally unique across other Acct-Multi-Session-Ids and MUST NOT
   change during the life of a session.

   A Diameter application document MUST define the exact concept of a
   session that is being accounted, and it MAY define the concept of a
   multi-session.  For instance, the NASREQ DIAMETER application treats
   a single PPP connection to a Network Access Server as one session and
   a set of Multilink PPP sessions as one multi-session.

9.7.  Accounting Command Codes

   This section defines Command Code values that MUST be supported by
   all Diameter implementations that provide accounting services.

9.7.1.  Accounting-Request

   The Accounting-Request (ACR) command, indicated by the Command Code
   field set to 271 and the Command Flags' 'R' bit set, is sent by a
   Diameter node, acting as a client, in order to exchange accounting
   information with a peer.

   In addition to the AVPs listed below, Accounting-Request messages
   SHOULD include service-specific accounting AVPs.
```



```
      Message Format

         <ACR> ::= < Diameter Header: 271, REQ, PXY >
                   < Session-Id >
                   { Origin-Host }
                   { Origin-Realm }
                   { Destination-Realm }
                   { Accounting-Record-Type }
                   { Accounting-Record-Number }
                   [ Acct-Application-Id ]
                   [ Vendor-Specific-Application-Id ]
                   [ User-Name ]
                   [ Destination-Host ]
                   [ Accounting-Sub-Session-Id ]
                   [ Acct-Session-Id ]
                   [ Acct-Multi-Session-Id ]
                   [ Acct-Interim-Interval ]
                   [ Accounting-Realtime-Required ]
                   [ Origin-State-Id ]
                   [ Event-Timestamp ]
                 * [ Proxy-Info ]
```

```
                * [ Route-Record ]
                * [ AVP ]

9.7.2.  Accounting-Answer

   The Accounting-Answer (ACA) command, indicated by the Command Code
   field set to 271 and the Command Flags' 'R' bit cleared, is used to
   acknowledge an Accounting-Request command.  The Accounting-Answer
   command contains the same Session-Id as the corresponding request.

   Only the target Diameter server, known as the home Diameter server,
   SHOULD respond with the Accounting-Answer command.

   In addition to the AVPs listed below, Accounting-Answer messages
   SHOULD include service-specific accounting AVPs.
```



```
      Message Format

         <ACA> ::= < Diameter Header: 271, PXY >
                   < Session-Id >
                   { Result-Code }
                   { Origin-Host }
                   { Origin-Realm }
                   { Accounting-Record-Type }
                   { Accounting-Record-Number }
                   [ Acct-Application-Id ]
                   [ Vendor-Specific-Application-Id ]
                   [ User-Name ]
                   [ Accounting-Sub-Session-Id ]
                   [ Acct-Session-Id ]
                   [ Acct-Multi-Session-Id ]
                   [ Error-Message ]
                   [ Error-Reporting-Host ]
                   [ Failed-AVP ]
                   [ Acct-Interim-Interval ]
                   [ Accounting-Realtime-Required ]
                   [ Origin-State-Id ]
                   [ Event-Timestamp ]
                 * [ Proxy-Info ]
                 * [ AVP ]

9.8.  Accounting AVPs

   This section contains AVPs that describe accounting usage information
   related to a specific session.
```

9.8.1. Accounting-Record-Type AVP

The Accounting-Record-Type AVP (AVP Code 480) is of type Enumerated and contains the type of accounting record being sent. The following values are currently defined for the Accounting-Record-Type AVP:

EVENT_RECORD 1

An Accounting Event Record is used to indicate that a one-time event has occurred (meaning that the start and end of the event are simultaneous). This record contains all information relevant to the service, and it is the only record of the service.

START_RECORD 2

Accounting Start, Interim, and Stop Records are used to indicate that a service of a measurable length has been given. An Accounting Start Record is used to initiate an accounting session and contains accounting information that is relevant to the initiation of the session.

INTERIM_RECORD 3

An Interim Accounting Record contains cumulative accounting information for an existing accounting session. Interim Accounting Records SHOULD be sent every time a re-authentication or re-authorization occurs. Further, additional interim record triggers MAY be defined by application-specific Diameter applications. The selection of whether to use INTERIM_RECORD records is done by the Acct-Interim-Interval AVP.

STOP_RECORD 4

An Accounting Stop Record is sent to terminate an accounting session and contains cumulative accounting information relevant to the existing session.

9.8.2. Acct-Interim-Interval AVP

The Acct-Interim-Interval AVP (AVP Code 85) is of type Unsigned32 and is sent from the Diameter home authorization server to the Diameter client. The client uses information in this AVP to decide how and when to produce accounting records. With different values in this AVP, service sessions can result in one, two, or two+N accounting records, based on the needs of the home organization. The following accounting record production behavior is directed by the inclusion of this AVP:

1. The omission of the Acct-Interim-Interval AVP or its inclusion with Value field set to 0 means that EVENT_RECORD, START_RECORD, and STOP_RECORD are produced, as appropriate for the service.

2. The inclusion of the AVP with Value field set to a non-zero value means that INTERIM_RECORD records MUST be produced between the START_RECORD and STOP_RECORD records. The Value field of this AVP is the nominal interval between these records in seconds. The Diameter node that originates the accounting information, known as the client, MUST produce the first INTERIM_RECORD record roughly at the time when this nominal interval has elapsed from

the START_RECORD, the next one again as the interval has elapsed once more, and so on until the session ends and a STOP_RECORD record is produced.

The client MUST ensure that the interim record production times are randomized so that large accounting message storms are not created either among records or around a common service start time.

9.8.3. Accounting-Record-Number AVP

The Accounting-Record-Number AVP (AVP Code 485) is of type Unsigned32 and identifies this record within one session. As Session-Id AVPs are globally unique, the combination of Session-Id and Accounting-Record-Number AVPs is also globally unique and can be used in matching accounting records with confirmations. An easy way to produce unique numbers is to set the value to 0 for records of type EVENT_RECORD and START_RECORD and set the value to 1 for the first INTERIM_RECORD, 2 for the second, and so on until the value for STOP_RECORD is one more than for the last INTERIM_RECORD.

9.8.4. Acct-Session-Id AVP

The Acct-Session-Id AVP (AVP Code 44) is of type OctetString is only used when RADIUS/Diameter translation occurs. This AVP contains the contents of the RADIUS Acct-Session-Id attribute.

9.8.5. Acct-Multi-Session-Id AVP

The Acct-Multi-Session-Id AVP (AVP Code 50) is of type UTF8String, following the format specified in Section 8.8. The Acct-Multi-Session-Id AVP is used to link multiple related accounting sessions, where each session would have a unique Session-Id but the same Acct-Multi-Session-Id AVP. This AVP MAY be returned by the Diameter server in an authorization answer, and it MUST be used in all accounting messages for the given session.

9.8.6. Accounting-Sub-Session-Id AVP

The Accounting-Sub-Session-Id AVP (AVP Code 287) is of type Unsigned64 and contains the accounting sub-session identifier. The combination of the Session-Id and this AVP MUST be unique per sub-session, and the value of this AVP MUST be monotonically increased by one for all new sub-sessions. The absence of this AVP implies no sub-sessions are in use, with the exception of an Accounting-Request whose Accounting-Record-Type is set to STOP_RECORD. A STOP_RECORD message with no Accounting-Sub-Session-Id AVP present will signal the termination of all sub-sessions for a given Session-Id.

9.8.7. Accounting-Realtime-Required AVP

The Accounting-Realtime-Required AVP (AVP Code 483) is of type Enumerated and is sent from the Diameter home authorization server to the Diameter client or in the Accounting-Answer from the accounting server. The client uses information in this AVP to decide what to do if the sending of accounting records to the accounting server has been temporarily prevented due to, for instance, a network problem.

DELIVER_AND_GRANT 1

The AVP with Value field set to DELIVER_AND_GRANT means that the service MUST only be granted as long as there is a connection to an accounting server. Note that the set of alternative accounting servers are treated as one server in this sense. Having to move the accounting record stream to a backup server is not a reason to discontinue the service to the user.

GRANT_AND_STORE 2

The AVP with Value field set to GRANT_AND_STORE means that service SHOULD be granted if there is a connection, or as long as records can still be stored as described in Section 9.4.

This is the default behavior if the AVP isn't included in the reply from the authorization server.

GRANT_AND_LOSE 3

The AVP with Value field set to GRANT_AND_LOSE means that service SHOULD be granted even if the records cannot be delivered or stored.

10. AVP Occurrence Tables

The following tables present the AVPs defined in this document and specify in which Diameter messages they MAY or MAY NOT be present. AVPs that occur only inside a Grouped AVP are not shown in these tables.

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.

```
         It is considered an error if there are more than one instance
         of the AVP.

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

   1+    At least one instance of the AVP MUST be present in the
         message.

10.1.  Base Protocol Command AVP Table

   The table in this section is limited to the non-Accounting Command
   Codes defined in this specification.

                      +-----------------------------------------------+
                      |                  Command Code                 |
                      +---+---+---+---+---+---+---+---+---+---+---+---+
   Attribute Name     |CER|CEA|DPR|DPA|DWR|DWA|RAR|RAA|ASR|ASA|STR|STA|
   -------------------+---+---+---+---+---+---+---+---+---+---+---+---+
   Acct-Interim-      |0  |0  |0  |0  |0  |0  |0-1|0  |0  |0  |0  |0  |
     Interval         |   |   |   |   |   |   |   |   |   |   |   |   |
   Accounting-Realtime-|0  |0  |0  |0  |0  |0  |0-1|0  |0  |0  |0  |0  |
     Required         |   |   |   |   |   |   |   |   |   |   |   |   |
   Acct-Application-Id |0+ |0+ |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Auth-Application-Id |0+ |0+ |0  |0  |0  |0  |1  |0  |1  |0  |1  |0  |
   Auth-Grace-Period   |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Auth-Request-Type   |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Auth-Session-State  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Authorization-      |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
     Lifetime         |   |   |   |   |   |   |   |   |   |   |   |   |
   Class              |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0+ |0+ |
   Destination-Host   |0  |0  |0  |0  |0  |0  |1  |0  |1  |0  |0-1|0  |
   Destination-Realm  |0  |0  |0  |0  |0  |0  |1  |0  |1  |0  |1  |0  |
   Disconnect-Cause   |0  |0  |1  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Error-Message      |0  |0-1|0  |0-1|0  |0-1|0  |0-1|0  |0-1|0  |0-1|
   Error-Reporting-Host|0  |0  |0  |0  |0  |0  |0  |0-1|0  |0-1|0  |0-1|
   Failed-AVP         |0  |0-1|0  |0-1|0  |0-1|0  |0-1|0  |0-1|0  |0-1|
   Firmware-Revision  |0-1|0-1|0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Host-IP-Address    |1+ |1+ |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Inband-Security-Id |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Multi-Round-Time-Out|0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
```



```
   Origin-Host        |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |
   Origin-Realm       |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |1  |
   Origin-State-Id    |0-1|0-1|0  |0  |0-1|0-1|0-1|0-1|0-1|0-1|0-1|0-1|
   Product-Name       |1  |1  |0  |0  |0  |0  |0  |0  |0  |0  |0  |0  |
   Proxy-Info         |0  |0  |0  |0  |0  |0  |0+ |0+ |0+ |0+ |0+ |0+ |
   Redirect-Host      |0  |0  |0  |0  |0  |0  |0  |0+ |0  |0+ |0  |0+ |
   Redirect-Host-Usage|0  |0  |0  |0  |0  |0  |0  |0-1|0  |0-1|0  |0-1|
   Redirect-Max-Cache-|0  |0  |0  |0  |0  |0  |0  |0-1|0  |0-1|0  |0-1|
     Time             |   |   |   |   |   |   |   |   |   |   |   |   |
   Result-Code        |0  |1  |0  |1  |0  |1  |0  |1  |0  |1  |0  |1  |
```

Re-Auth-Request-Type	0	0	0	0	0	1	0	0	0	0	0	
Route-Record	0	0	0	0	0	0+	0	0+	0	0+	0	
Session-Binding	0	0	0	0	0	0	0	0	0	0	0	
Session-Id	0	0	0	0	0	1	1	1	1	1	1	
Session-Server-Failover	0	0	0	0	0	0	0	0	0	0	0	
Session-Timeout	0	0	0	0	0	0	0	0	0	0	0	
Supported-Vendor-Id	0+	0+	0	0	0	0	0	0	0	0	0	
Termination-Cause	0	0	0	0	0	0	0	0	0	0	1	0
User-Name	0	0	0	0	0	0	0-1	0-1	0-1	0-1	0-1	0-1
Vendor-Id	1	1	0	0	0	0	0	0	0	0	0	0
Vendor-Specific-Application-Id	0+	0+	0	0	0	0	0	0	0	0	0	0

10.2. Accounting 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. These AVP occurrence requirements are guidelines, which may be expanded, and/or overridden by application-specific requirements in the Diameter applications documents.

Attribute Name	Command Code ACR	Command Code ACA
Acct-Interim-Interval	0-1	0-1
Acct-Multi-Session-Id	0-1	0-1
Accounting-Record-Number	1	1
Accounting-Record-Type	1	1
Acct-Session-Id	0-1	0-1
Accounting-Sub-Session-Id	0-1	0-1
Accounting-Realtime-Required	0-1	0-1
Acct-Application-Id	0-1	0-1
Auth-Application-Id	0	0
Class	0+	0+
Destination-Host	0-1	0
Destination-Realm	1	0
Error-Reporting-Host	0	0+

```
      Event-Timestamp                | 0-1 | 0-1 |
      Failed-AVP                     | 0   | 0-1 |
      Origin-Host                    | 1   | 1   |
      Origin-Realm                   | 1   | 1   |
      Proxy-Info                     | 0+  | 0+  |
      Route-Record                   | 0+  | 0   |
      Result-Code                    | 0   | 1   |
      Session-Id                     | 1   | 1   |
      Termination-Cause              | 0   | 0   |
      User-Name                      | 0-1 | 0-1 |
      Vendor-Specific-Application-Id| 0-1 | 0-1 |
      -------------------------------+-----+-----+
```

11. IANA Considerations

This section provides guidance to the Internet Assigned Numbers Authority (IANA) regarding registration of values related to the Diameter protocol, in accordance with [RFC5226]. Existing IANA registries and assignments put in place by RFC 3588 remain the same unless explicitly updated or deprecated in this section.

11.1. AVP Header

As defined in Section 4, the AVP header contains three fields that require IANA namespace management: the AVP Code, Vendor-ID, and Flags fields.

11.1.1. AVP Codes

There are multiple namespaces. Vendors can have their own AVP Codes namespace that will be identified by their Vendor-ID (also known as Enterprise-Number), and they control the assignments of their vendor-specific AVP Codes within their own namespace. The absence of a Vendor-ID or a Vendor-ID value of zero (0) identifies the IETF AVP Codes namespace, which is under IANA control. The AVP Codes and sometimes possible values in an AVP are controlled and maintained by IANA. AVP Code 0 is not used. AVP Codes 1-255 are managed separately as RADIUS Attribute Types. Where a Vendor-Specific AVP is implemented by more than one vendor, allocation of global AVPs should be encouraged instead.

AVPs may be allocated following Expert Review (by a Designated Expert) with Specification Required [RFC5226]. A block allocation (release of more than three AVPs at a time for a given purpose) requires IETF Review [RFC5226].

11.1.2. AVP Flags

Section 4.1 describes the existing AVP Flags. The remaining bits can only be assigned via a Standards Action [RFC5226].

11.2. Diameter Header

11.2.1. Command Codes

For the Diameter header, the Command Code namespace allocation has changed. The new allocation rules are as follows:

The Command Code values 256 - 8,388,607 (0x100 to 0x7fffff) are for permanent, standard commands, allocated by IETF Review [RFC5226].

The values 8,388,608 - 16,777,213 (0x800000 - 0xfffffd) are reserved for vendor-specific Command Codes, to be allocated on a First Come, First Served basis by IANA [RFC5226]. The request to IANA for a Vendor-Specific Command Code SHOULD include a reference to a publicly available specification that documents the command in sufficient detail to aid in interoperability between independent implementations. If the specification cannot be made publicly available, the request for a vendor-specific Command Code MUST include the contact information of persons and/or entities responsible for authoring and maintaining the command.

The values 16,777,214 and 16,777,215 (hexadecimal values 0xfffffe - 0xffffff) are reserved for experimental commands. As these codes are only for experimental and testing purposes, no guarantee is made for interoperability between Diameter peers using experimental commands.

11.2.2. Command Flags

Section 3 describes the existing Command Flags field. The remaining bits can only be assigned via a Standards Action [RFC5226].

11.3. AVP Values

For AVP values, the Experimental-Result-Code AVP value allocation has been added; see Section 11.3.1. The old AVP value allocation rule, IETF Consensus, has been updated to IETF Review as per [RFC5226], and affected AVPs are listed as reminders.

11.3.1. Experimental-Result-Code AVP

Values for this AVP are purely local to the indicated vendor, and no IANA registry is maintained for them.

11.3.2. Result-Code AVP Values

New values are available for assignment via IETF Review [RFC5226].

11.3.3. Accounting-Record-Type AVP Values

New values are available for assignment via IETF Review [RFC5226].

11.3.4. Termination-Cause AVP Values

New values are available for assignment via IETF Review [RFC5226].

11.3.5. Redirect-Host-Usage AVP Values

```
   New values are available for assignment via IETF Review [RFC5226].

11.3.6.  Session-Server-Failover AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.7.  Session-Binding AVP Values

   New values are available for assignment via IETF Review [RFC5226].




Fajardo, et al.              Standards Track                  [Page 137]

RFC 6733                 Diameter Base Protocol             October 2012


11.3.8.  Disconnect-Cause AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.9.  Auth-Request-Type AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.10.  Auth-Session-State AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.11.  Re-Auth-Request-Type AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.12.  Accounting-Realtime-Required AVP Values

   New values are available for assignment via IETF Review [RFC5226].

11.3.13.  Inband-Security-Id AVP (code 299)

   The use of this AVP has been deprecated.

11.4.  _diameters Service Name and Port Number Registration

   IANA has registered the "_diameters" service name and assigned port
   numbers for TLS/TCP and DTLS/SCTP according to the guidelines given
   in [RFC6335].

      Service Name:         _diameters

      Transport Protocols:  TCP, SCTP

      Assignee:             IESG <iesg@ietf.org>

      Contact:              IETF Chair <chair@ietf.org>

      Description:          Diameter over TLS/TCP and DTLS/SCTP

      Reference:            RFC 6733

      Port  Number:         5868, from the User Range
```

11.5. SCTP Payload Protocol Identifiers

Two SCTP payload protocol identifiers have been registered in the SCTP Payload Protocol Identifiers registry:

Value	SCTP Payload Protocol Identifier
46	Diameter in a SCTP DATA chunk
47	Diameter in a DTLS/SCTP DATA chunk

11.6. S-NAPTR Parameters

The following tag has been registered in the S-NAPTR Application Protocol Tags registry:

Tag	Protocol
diameter.dtls.sctp	DTLS/SCTP

12. Diameter Protocol-Related Configurable Parameters

This section contains the configurable parameters that are found throughout this document:

Diameter Peer

A Diameter entity MAY communicate with peers that are statically configured. A statically configured Diameter peer would require that either the IP address or the fully qualified domain name (FQDN) be supplied, which would then be used to resolve through DNS.

Routing Table

A Diameter proxy server routes messages based on the realm portion of a Network Access Identifier (NAI). The server MUST have a table of Realm Names, and the address of the peer to which the message must be forwarded. The routing table MAY also include a "default route", which is typically used for all messages that cannot be locally processed.

Tc timer

The Tc timer controls the frequency that transport connection attempts are done to a peer with whom no active transport connection exists. The recommended value is 30 seconds.

13. Security Considerations

The Diameter base protocol messages SHOULD be secured by using TLS [RFC5246] or DTLS/SCTP [RFC6083]. Additional security mechanisms such as IPsec [RFC4301] MAY also be deployed to secure connections between peers. However, all Diameter base protocol implementations MUST support the use of TLS/TCP and DTLS/SCTP, and the Diameter protocol MUST NOT be used without one of TLS, DTLS, or IPsec.

If a Diameter connection is to be protected via TLS/TCP and DTLS/SCTP or IPsec, then TLS/TCP and DTLS/SCTP or IPsec/IKE SHOULD begin prior to any Diameter message exchange. All security parameters for TLS/TCP and DTLS/SCTP or IPsec are configured independent of the Diameter protocol. All Diameter messages will be sent through the TLS/TCP and DTLS/SCTP or IPsec connection after a successful setup.

For TLS/TCP and DTLS/SCTP connections to be established in the open state, the CER/CEA exchange MUST include an Inband-Security-ID AVP with a value of TLS/TCP and DTLS/SCTP. The TLS/TCP and DTLS/SCTP handshake will begin when both ends successfully reach the open state, after completion of the CER/CEA exchange. If the TLS/TCP and DTLS/SCTP handshake is successful, all further messages will be sent via TLS/TCP and DTLS/SCTP. If the handshake fails, both ends MUST move to the closed state. See Section 13.1 for more details.

13.1. TLS/TCP and DTLS/SCTP Usage

Diameter nodes using TLS/TCP and DTLS/SCTP for security MUST mutually authenticate as part of TLS/TCP and DTLS/SCTP session establishment. In order to ensure mutual authentication, the Diameter node acting as the TLS/TCP and DTLS/SCTP server MUST request a certificate from the Diameter node acting as TLS/TCP and DTLS/SCTP client, and the Diameter node acting as the TLS/TCP and DTLS/SCTP client MUST be prepared to supply a certificate on request.

Diameter nodes MUST be able to negotiate the following TLS/TCP and DTLS/SCTP cipher suites:

```
TLS_RSA_WITH_RC4_128_MD5
TLS_RSA_WITH_RC4_128_SHA
TLS_RSA_WITH_3DES_EDE_CBC_SHA
```

Diameter nodes SHOULD be able to negotiate the following TLS/TCP and DTLS/SCTP cipher suite:

```
TLS_RSA_WITH_AES_128_CBC_SHA
```


Note that it is quite possible that support for the TLS_RSA_WITH_AES_128_CBC_SHA cipher suite will be REQUIRED at some future date. Diameter nodes MAY negotiate other TLS/TCP and DTLS/SCTP cipher suites.

If public key certificates are used for Diameter security (for example, with TLS), the value of the expiration times in the routing and peer tables MUST NOT be greater than the expiry time in the

relevant certificates.

13.2. Peer-to-Peer Considerations

As with any peer-to-peer protocol, proper configuration of the trust model within a Diameter peer is essential to security. When certificates are used, it is necessary to configure the root certificate authorities trusted by the Diameter peer. These root CAs are likely to be unique to Diameter usage and distinct from the root CAs that might be trusted for other purposes such as Web browsing. In general, it is expected that those root CAs will be configured so as to reflect the business relationships between the organization hosting the Diameter peer and other organizations. As a result, a Diameter peer will typically not be configured to allow connectivity with any arbitrary peer. With certificate authentication, Diameter peers may not be known beforehand and therefore peer discovery may be required.

13.3. AVP Considerations

Diameter AVPs often contain security-sensitive data; for example, user passwords and location data, network addresses and cryptographic keys. The following AVPs defined in this document are considered to be security-sensitive:

- Acct-Interim-Interval
- Accounting-Realtime-Required
- Acct-Multi-Session-Id
- Accounting-Record-Number
- Accounting-Record-Type
- Accounting-Session-Id
- Accounting-Sub-Session-Id
- Class

- Session-Id
- Session-Binding
- Session-Server-Failover
- User-Name

Diameter messages containing these or any other AVPs considered to be security-sensitive MUST only be sent protected via mutually authenticated TLS or IPsec. In addition, those messages MUST NOT be sent via intermediate nodes unless there is end-to-end security between the originator and recipient or the originator has locally trusted configuration that indicates that end-to-end security is not needed. For example, end-to-end security may not be required in the case where an intermediary node is known to be operated as part of the same administrative domain as the endpoints so that an ability to

```
   successfully compromise the intermediary would imply a high
   probability of being able to compromise the endpoints as well.  Note
   that no end-to-end security mechanism is specified in this document.

14.  References

14.1.  Normative References

   [FLOATPOINT]
              Institute of Electrical and Electronics Engineers, "IEEE
              Standard for Binary Floating-Point Arithmetic, ANSI/IEEE
              Standard 754-1985", August 1985.

   [IANAADFAM]
              IANA, "Address Family Numbers",
              <http://www.iana.org/assignments/address-family-numbers>.

   [RFC0791]  Postel, J., "Internet Protocol", STD 5, RFC 791,
              September 1981.

   [RFC0793]  Postel, J., "Transmission Control Protocol", STD 7,
              RFC 793, September 1981.

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

   [RFC3492]  Costello, A., "Punycode: A Bootstring encoding of Unicode
              for Internationalized Domain Names in Applications
              (IDNA)", RFC 3492, March 2003.
```



```
   [RFC3539]  Aboba, B. and J. Wood, "Authentication, Authorization and
              Accounting (AAA) Transport Profile", RFC 3539, June 2003.

   [RFC3629]  Yergeau, F., "UTF-8, a transformation format of ISO
              10646", STD 63, RFC 3629, November 2003.

   [RFC3958]  Daigle, L. and A. Newton, "Domain-Based Application
              Service Location Using SRV RRs and the Dynamic Delegation
              Discovery Service (DDDS)", RFC 3958, January 2005.

   [RFC3986]  Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform
              Resource Identifier (URI): Generic Syntax", STD 66,
              RFC 3986, January 2005.

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

   [RFC4005]  Calhoun, P., Zorn, G., Spence, D., and D. Mitton,
              "Diameter Network Access Server Application", RFC 4005,
              August 2005.

   [RFC4006]  Hakala, H., Mattila, L., Koskinen, J-P., Stura, M., and J.
              Loughney, "Diameter Credit-Control Application", RFC 4006,
              August 2005.
```

[RFC4086] Eastlake, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", BCP 106, RFC 4086, June 2005.

[RFC4282] Aboba, B., Beadles, M., Arkko, J., and P. Eronen, "The Network Access Identifier", RFC 4282, December 2005.

[RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", RFC 4291, February 2006.

[RFC4960] Stewart, R., "Stream Control Transmission Protocol", RFC 4960, September 2007.

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

[RFC5234] Crocker, D. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", STD 68, RFC 5234, January 2008.

[RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, August 2008.

[RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 5280, May 2008.

[RFC5729] Korhonen, J., Jones, M., Morand, L., and T. Tsou, "Clarifications on the Routing of Diameter Requests Based on the Username and the Realm", RFC 5729, December 2009.

[RFC5890] Klensin, J., "Internationalized Domain Names for Applications (IDNA): Definitions and Document Framework", RFC 5890, August 2010.

[RFC5891] Klensin, J., "Internationalized Domain Names in Applications (IDNA): Protocol", RFC 5891, August 2010.

[RFC6083] Tuexen, M., Seggelmann, R., and E. Rescorla, "Datagram Transport Layer Security (DTLS) for Stream Control Transmission Protocol (SCTP)", RFC 6083, January 2011.

[RFC6347] Rescorla, E. and N. Modadugu, "Datagram Transport Layer Security Version 1.2", RFC 6347, January 2012.

[RFC6408] Jones, M., Korhonen, J., and L. Morand, "Diameter Straightforward-Naming Authority Pointer (S-NAPTR) Usage", RFC 6408, November 2011.

14.2. Informative References

[ENTERPRISE] IANA, "SMI Network Management Private Enterprise Codes", <http://www.iana.org/assignments/enterprise-numbers>.

[IANATCV] IANA, "Termination-Cause AVP Values (code 295)", <http://www.iana.org/assignments/aaa-parameters/

aaa-parameters.xml#aaa-parameters-16>.

[RFC1492] Finseth, C., "An Access Control Protocol, Sometimes Called TACACS", RFC 1492, July 1993.

[RFC1661] Simpson, W., "The Point-to-Point Protocol (PPP)", STD 51, RFC 1661, July 1994.

[RFC2104] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, February 1997.

[RFC2782] Gulbrandsen, A., Vixie, P., and L. Esibov, "A DNS RR for specifying the location of services (DNS SRV)", RFC 2782, February 2000.

[RFC2865] Rigney, C., Willens, S., Rubens, A., and W. Simpson, "Remote Authentication Dial In User Service (RADIUS)", RFC 2865, June 2000.

[RFC2866] Rigney, C., "RADIUS Accounting", RFC 2866, June 2000.

[RFC2869] Rigney, C., Willats, W., and P. Calhoun, "RADIUS Extensions", RFC 2869, June 2000.

[RFC2881] Mitton, D. and M. Beadles, "Network Access Server Requirements Next Generation (NASREQNG) NAS Model", RFC 2881, July 2000.

[RFC2975] Aboba, B., Arkko, J., and D. Harrington, "Introduction to Accounting Management", RFC 2975, October 2000.

[RFC2989] Aboba, B., Calhoun, P., Glass, S., Hiller, T., McCann, P., Shiino, H., Walsh, P., Zorn, G., Dommety, G., Perkins, C., Patil, B., Mitton, D., Manning, S., Beadles, M., Chen, X., Sivalingham, S., Hameed, A., Munson, M., Jacobs, S., Lim, B., Hirschman, B., Hsu, R., Koo, H., Lipford, M., Campbell, E., Xu, Y., Baba, S., and E. Jaques, "Criteria for Evaluating AAA Protocols for Network Access", RFC 2989, November 2000.

[RFC3162] Aboba, B., Zorn, G., and D. Mitton, "RADIUS and IPv6", RFC 3162, August 2001.

[RFC3748] Aboba, B., Blunk, L., Vollbrecht, J., Carlson, J., and H. Levkowetz, "Extensible Authentication Protocol (EAP)", RFC 3748, June 2004.

[RFC4301] Kent, S. and K. Seo, "Security Architecture for the Internet Protocol", RFC 4301, December 2005.

[RFC4690] Klensin, J., Faltstrom, P., Karp, C., and IAB, "Review and Recommendations for Internationalized Domain Names (IDNs)", RFC 4690, September 2006.

[RFC5176] Chiba, M., Dommety, G., Eklund, M., Mitton, D., and B.

Aboba, "Dynamic Authorization Extensions to Remote
Authentication Dial In User Service (RADIUS)",
RFC 5176, January 2008.

[RFC5461] Gont, F., "TCP's Reaction to Soft Errors", RFC 5461,
February 2009.

[RFC5905] Mills, D., Martin, J., Burbank, J., and W. Kasch,
"Network Time Protocol Version 4: Protocol and
Algorithms Specification", RFC 5905, June 2010.

[RFC5927] Gont, F., "ICMP Attacks against TCP", RFC 5927,
July 2010.

[RFC6335] Cotton, M., Eggert, L., Touch, J., Westerlund, M., and
S. Cheshire, "Internet Assigned Numbers Authority
(IANA) Procedures for the Management of the Service
Name and Transport Protocol Port Number Registry",
BCP 165, RFC 6335, August 2011.

[RFC6737] Kang, J. and G. Zorn, "The Diameter Capabilities Update
Application", RFC 6737, October 2012.

Appendix A. Acknowledgements

A.1. This Document

The authors would like to thank the following people that have provided proposals and contributions to this document:

To Vishnu Ram and Satendra Gera for their contributions on capabilities updates, predictive loop avoidance, as well as many other technical proposals. To Tolga Asveren for his insights and contributions on almost all of the proposed solutions incorporated into this document. To Timothy Smith for helping on the capabilities Update and other topics. To Tony Zhang for providing fixes to loopholes on composing Failed-AVPs as well as many other issues and topics. To Jan Nordqvist for clearly stating the usage of Application Ids. To Anders Kristensen for providing needed technical opinions. To David Frascone for providing invaluable review of the document. To Mark Jones for providing clarifying text on vendor command codes and other vendor-specific indicators. To Victor Pascual and Sebastien Decugis for new text and recommendations on SCTP/DTLS. To Jouni Korhonen for taking over the editing task and resolving last bits from versions 27 through 29.

Special thanks to the Diameter extensibility design team, which helped resolve the tricky question of mandatory AVPs and ABNF semantics. The members of this team are as follows:

Avi Lior, Jari Arkko, Glen Zorn, Lionel Morand, Mark Jones, Tolga Asveren, Jouni Korhonen, and Glenn McGregor.

Special thanks also to people who have provided invaluable comments and inputs especially in resolving controversial issues:

Glen Zorn, Yoshihiro Ohba, Marco Stura, Stephen Farrel, Pete Resnick, Peter Saint-Andre, Robert Sparks, Krishna Prasad, Sean Turner, Barry Leiba, and Pasi Eronen.

Finally, we would like to thank the original authors of this document:

Pat Calhoun, John Loughney, Jari Arkko, Erik Guttman, and Glen Zorn.

Their invaluable knowledge and experience has given us a robust and flexible AAA protocol that many people have seen great value in adopting. We greatly appreciate their support and stewardship for the continued improvements of Diameter as a protocol. We would also like to extend our gratitude to folks aside from the authors who have

assisted and contributed to the original version of this document. Their efforts significantly contributed to the success of Diameter.

A.2. RFC 3588

The authors would like to thank Nenad Trifunovic, Tony Johansson and

```
   Pankaj Patel for their participation in the pre-IETF Document Reading
   Party.  Allison Mankin, Jonathan Wood, and Bernard Aboba provided
   invaluable assistance in working out transport issues and this was
   also the case with Steven Bellovin in the security area.

   Paul Funk and David Mitton were instrumental in getting the Peer
   State Machine correct, and our deep thanks go to them for their time.

   Text in this document was also provided by Paul Funk, Mark Eklund,
   Mark Jones, and Dave Spence.  Jacques Caron provided many great
   comments as a result of a thorough review of the spec.

   The authors would also like to acknowledge the following people for
   their contribution in the development of the Diameter protocol:

   Allan C. Rubens, Haseeb Akhtar, William Bulley, Stephen Farrell,
   David Frascone, Daniel C. Fox, Lol Grant, Ignacio Goyret, Nancy
   Greene, Peter Heitman, Fredrik Johansson, Mark Jones, Martin Julien,
   Bob Kopacz, Paul Krumviede, Fergal Ladley, Ryan Moats, Victor Muslin,
   Kenneth Peirce, John Schnizlein, Sumit Vakil, John R. Vollbrecht, and
   Jeff Weisberg.

   Finally, Pat Calhoun would like to thank Sun Microsystems since most
   of the effort put into this document was done while he was in their
   employ.

Appendix B.  S-NAPTR Example

   As an example, consider a client that wishes to resolve aaa:
   ex1.example.com.  The client performs a NAPTR query for that domain,
   and the following NAPTR records are returned:

    ;;        order pref flags service   regexp replacement
    IN NAPTR  50    50   "s"   "aaa:diameter.tls.tcp" ""
                 _diameter._tls.ex1.example.com
    IN NAPTR  100   50   "s"   "aaa:diameter.tcp"     ""
                 _aaa._tcp.ex1.example.com
    IN NAPTR  150   50   "s"   "aaa:diameter.sctp"    ""
                 _diameter._sctp.ex1.example.com

   This indicates that the server supports TLS, TCP, and SCTP in that
   order.  If the client supports TLS, TLS will be used, targeted to a



Fajardo, et al.              Standards Track                  [Page 148]

RFC 6733                Diameter Base Protocol             October 2012


   host determined by an SRV lookup of _diameter._tls.ex1.example.com.
   That lookup would return:

    ;;       Priority  Weight  Port    Target
    IN SRV   0         1       5060    server1.ex1.example.com
    IN SRV   0         2       5060    server2.ex1.example.com

   As an alternative example, a client that wishes to resolve aaa:
   ex2.example.com.  The client performs a NAPTR query for that domain,
   and the following NAPTR records are returned:

    ;;        order pref flags service   regexp replacement
    IN NAPTR  150   50   "a"   "aaa:diameter.tls.tcp"  ""
                 server1.ex2.example.com
    IN NAPTR  150   50   "a"   "aaa:diameter.tls.tcp"  ""
```

```
                server2.ex2.example.com

   This indicates that the server supports TCP available at the returned
   host names.

Appendix C.  Duplicate Detection

   As described in Section 9.4, accounting record duplicate detection is
   based on session identifiers.  Duplicates can appear for various
   reasons:

   o  Failover to an alternate server.  Where close to real-time
      performance is required, failover thresholds need to be kept low.
      This may lead to an increased likelihood of duplicates.  Failover
      can occur at the client or within Diameter agents.

   o  Failure of a client or agent after sending a record from non-
      volatile memory, but prior to receipt of an application-layer ACK
      and deletion of the record to be sent.  This will result in
      retransmission of the record soon after the client or agent has
      rebooted.

   o  Duplicates received from RADIUS gateways.  Since the
      retransmission behavior of RADIUS is not defined within [RFC2865],
      the likelihood of duplication will vary according to the
      implementation.

   o  Implementation problems and misconfiguration.

   The T flag is used as an indication of an application-layer
   retransmission event, e.g., due to failover to an alternate server.
   It is defined only for request messages sent by Diameter clients or
   agents.  For instance, after a reboot, a client may not know whether



Fajardo, et al.              Standards Track                  [Page 149]

RFC 6733                 Diameter Base Protocol             October 2012


   it has already tried to send the accounting records in its non-
   volatile memory before the reboot occurred.  Diameter servers MAY use
   the T flag as an aid when processing requests and detecting duplicate
   messages.  However, servers that do this MUST ensure that duplicates
   are found even when the first transmitted request arrives at the
   server after the retransmitted request.  It can be used only in cases
   where no answer has been received from the server for a request and
   the request is sent again, (e.g., due to a failover to an alternate
   peer, due to a recovered primary peer or due to a client re-sending a
   stored record from non-volatile memory such as after reboot of a
   client or agent).

   In some cases, the Diameter accounting server can delay the duplicate
   detection and accounting record processing until a post-processing
   phase takes place.  At that time records are likely to be sorted
   according to the included User-Name and duplicate elimination is easy
   in this case.  In other situations, it may be necessary to perform
   real-time duplicate detection, such as when credit limits are imposed
   or real-time fraud detection is desired.

   In general, only generation of duplicates due to failover or re-
   sending of records in non-volatile storage can be reliably detected
   by Diameter clients or agents.  In such cases, the Diameter client or
   agents can mark the message as a possible duplicate by setting the T
```

flag. Since the Diameter server is responsible for duplicate detection, it can choose whether or not to make use of the T flag, in order to optimize duplicate detection. Since the T flag does not affect interoperability, and it may not be needed by some servers, generation of the T flag is REQUIRED for Diameter clients and agents, but it MAY be implemented by Diameter servers.

As an example, it can be usually be assumed that duplicates appear within a time window of longest recorded network partition or device fault, perhaps a day. So only records within this time window need to be looked at in the backward direction. Secondly, hashing techniques or other schemes, such as the use of the T flag in the received messages, may be used to eliminate the need to do a full search even in this set except for rare cases.

The following is an example of how the T flag may be used by the server to detect duplicate requests.

A Diameter server MAY check the T flag of the received message to determine if the record is a possible duplicate. If the T flag is set in the request message, the server searches for a duplicate within a configurable duplication time window backward and forward. This limits database searching to those records where the T flag is set. In a well-run network, network partitions and

device faults will presumably be rare events, so this approach represents a substantial optimization of the duplicate detection process. During failover, it is possible for the original record to be received after the T-flag-marked record, due to differences in network delays experienced along the path by the original and duplicate transmissions. The likelihood of this occurring increases as the failover interval is decreased. In order to be able to detect duplicates that are out of order, the Diameter server should use backward and forward time windows when performing duplicate checking for the T-flag-marked request. For example, in order to allow time for the original record to exit the network and be recorded by the accounting server, the Diameter server can delay processing records with the T flag set until a time period TIME_WAIT + RECORD_PROCESSING_TIME has elapsed after the closing of the original transport connection. After this time period, it may check the T-flag-marked records against the database with relative assurance that the original records, if sent, have been received and recorded.

Appendix D. Internationalized Domain Names

To be compatible with the existing DNS infrastructure and simplify host and domain name comparison, Diameter identities (FQDNs) are represented in ASCII form. This allows the Diameter protocol to fall in-line with the DNS strategy of being transparent from the effects of Internationalized Domain Names (IDNs) by following the recommendations in [RFC4690] and [RFC5890]. Applications that provide support for IDNs outside of the Diameter protocol but interacting with it SHOULD use the representation and conversion framework described in [RFC5890], [RFC5891], and [RFC3492].

1.4.2 RFC 3539

RFC 3539 is more difficult to comply to since it discusses problems as much as it requires functionality but all the MUST's are covered, the watchdog state machine being the primary one. Of the optional functionality, load balancing is left to the diameter user (since it's the one deciding who to send to) and there is no Congestion Manager.

2 Reference Manual

The Diameter application is a framework for building applications on top of the Diameter protocol.

diameter

Erlang module

This module provides the interface with which a user can implement a Diameter node that sends and receives messages using the Diameter protocol as defined in RFC 6733.

Basic usage consists of creating a representation of a locally implemented Diameter node and its capabilities with *start_service/2*, adding transport capability using *add_transport/2* and sending Diameter requests and receiving Diameter answers with *call/4*. Incoming Diameter requests are communicated as callbacks to a *diameter_app(3)* callback modules as specified in the service configuration.

Beware the difference between *diameter* (not capitalized) and *Diameter* (capitalized). The former refers to the Erlang application named diameter whose main api is defined here, the latter to Diameter protocol in the sense of RFC 6733.

The diameter application must be started before calling most functions in this module.

DATA TYPES

```
Address()
DiameterIdentity()
Grouped()
OctetString()
Time()
Unsigned32()
UTF8String()
```

Types corresponding to RFC 6733 AVP Data Formats. Defined in *diameter_dict(4)*.

```
application_alias() = term()
```

Name identifying a Diameter application in service configuration. Passed to *call/4* when sending requests defined by the application.

```
application_module() = Mod | [Mod | ExtraArgs] | #diameter_callback{}
```

```
Mod = atom()
ExtraArgs = list()
```

Module implementing the callback interface defined in *diameter_app(3)*, along with any extra arguments to be appended to those documented. Note that extra arguments specific to an outgoing request can be specified to *call/4*, in which case those are are appended to any module-specific extra arguments.

Specifying a `#diameter_callback{}` record allows individual functions to be configured in place of the usual *diameter_app(3)* callbacks. See `diameter_callback.erl` for details.

```
application_opt()
```

Options defining a Diameter application. Has one the following types.

`{alias, application_alias()}`

Unique identifier for the application in the scope of the service. Defaults to the value of the `dictionary` option if unspecified.

`{dictionary, atom()}`

Name of an encode/decode module for the Diameter messages defined by the application. These modules are generated from files whose format is documented in *diameter_dict(4)*.

`{module, application_module()}`

Callback module in which messages of the Diameter application are handled. See *diameter_app(3)* for the required interface and semantics.

`{state, term()}`

Initial callback state. The prevailing state is passed to some *diameter_app(3)* callbacks, which can then return a new state. Defaults to the value of the `alias` option if unspecified.

`{call_mutates_state, true|false}`

Whether or not the *pick_peer/4* application callback can modify the application state. Defaults to `false` if unspecified.

> Warning:
>
> *pick_peer/4* callbacks are serialized when this option is `true`, which is a potential performance bottleneck. A simple Diameter client may suffer no ill effects from using mutable state but a server or agent that responds to incoming request should probably avoid it.

`{answer_errors, callback|report|discard}`

Manner in which incoming answer messages containing decode errors are handled.

If `callback` then errors result in a *handle_answer/4* callback in the same fashion as for *handle_request/3*, with errors communicated in the `errors` field of the `#diameter_packet{}` passed to the callback. If `report` then an answer containing errors is discarded without a callback and a warning report is written to the log. If `discard` then an answer containing errors is silently discarded without a callback. In both the `report` and `discard` cases the return value for the *call/4* invocation in question is as if a callback had taken place and returned `{error, failure}`.

Defaults to `discard` if unspecified.

`{request_errors, answer_3xxx|answer|callback}`

Manner in which incoming requests are handled when an error other than 3007 (DIAMETER_APPLICATION_UNSUPPORTED, which cannot be associated with an application callback module), is detected.

If `answer_3xxx` then requests are answered without a *handle_request/3* callback taking place. If `answer` then even 5xxx errors are answered without a callback unless the connection in question has configured the RFC 3588 common dictionary as noted below. If `callback` then a *handle_request/3* callback always takes place and its return value determines the answer sent to the peer, if any.

Defaults to `answer_3xxx` if unspecified.

> **Note:**
>
> Answers sent by diameter set the E-bit in the Diameter Header. Since RFC 3588 allows only 3xxx result codes in an `answer-message`, `answer` has the same semantics as `answer_3xxx` when the transport in question has been configured with `diameter_gen_base_rfc3588` as its common dictionary. Since RFC 6733 allows both 3xxx and 5xxx result codes in an `answer-message`, a transport with `diameter_gen_base_rfc6733` as its common dictionary does distinguish between `answer_3xxx` and `answer`.

`call_opt()`

Options available to *call/4* when sending an outgoing Diameter request. Has one of the following types.

`{extra, list()}`

Extra arguments to append to callbacks to the callback module in question. These are appended to any extra arguments configured on the callback itself. Multiple options append to the argument list.

`{filter, peer_filter()}`

Filter to apply to the list of available peers before passing it to the *pick_peer/4* callback for the application in question. Multiple options are equivalent a single `all` filter on the corresponding list of filters. Defaults to `none`.

`{timeout, Unsigned32()}`

Number of milliseconds after which the request should timeout. Defaults to 5000.

`detach`

Cause *call/4* to return `ok` as soon as the request in question has been encoded, instead of waiting for and returning the result from a subsequent *handle_answer/4* or *handle_error/4* callback.

An invalid option will cause *call/4* to fail.

`capability()`

AVP values sent in outgoing CER or CEA messages during capabilities exchange. Can be configured both on a service and a transport, values on the latter taking precedence. Has one of the following types.

```
{'Origin-Host', DiameterIdentity()}
{'Origin-Realm', DiameterIdentity()}
{'Host-IP-Address', [Address()]}
```

An address list is available to the start function of a *transport module*, which can return a new list for use in the subsequent CER or CEA. Host-IP-Address need not be specified if the transport module in question communicates an address list as described in *diameter_transport(3)*

```
{'Vendor-Id', Unsigned32()}
{'Product-Name', UTF8String()}
{'Origin-State-Id', Unsigned32()}
```

Origin-State-Id is optional but, if configured, will be included in outgoing CER/CEA and DWR/DWA messages. Setting a value of `0` (zero) is equivalent to not setting a value, as documented in RFC 6733. The function *origin_state_id/0* can be used as to retrieve a value that is computed when the diameter application is started.

```
{'Supported-Vendor-Id', [Unsigned32()]}
{'Auth-Application-Id', [Unsigned32()]}
{'Inband-Security-Id', [Unsigned32()]}
```

Inband-Security-Id defaults to the empty list, which is equivalent to a list containing only 0 (NO_INBAND_SECURITY). If 1 (TLS) is specified then TLS is selected if the CER/CEA received from the peer offers it.

```
{'Acct-Application-Id', [Unsigned32()]}
{'Vendor-Specific-Application-Id', [Grouped()]}
{'Firmware-Revision', Unsigned32()}
```

Note that each tuple communicates one or more AVP values. It is an error to specify duplicate tuples.

`evaluable() = {M,F,A} | fun() | [evaluable() | A]`

An expression that can be evaluated as a function in the following sense.

```
eval([{M,F,A} | T]) ->
    apply(M, F, T ++ A);
eval([[F|A] | T]) ->
    eval([F | T ++ A]);
eval([F|A]) ->
    apply(F, A);
eval(F) ->
    eval([F]).
```

Applying an *`evaluable()`* `E` to an argument list `A` is meant in the sense of `eval([E|A])`.

> **Warning:**
>
> Beware of using fun expressions of the form `fun Name/Arity` in situations in which the fun is not short-lived and code is to be upgraded at runtime since any processes retaining such a fun will have a reference to old code. In particular, such a value is typically inappropriate in configuration passed to *start_service/2* or *add_transport/2*.

`peer_filter() = term()`

Filter passed to *call/4* in order to select candidate peers for a *pick_peer/4* callback. Has one of the following types.

`none`

Matches any peer. This is a convenience that provides a filter equivalent to no filter.

`host`

Matches only those peers whose Origin-Host has the same value as Destination-Host in the outgoing request in question, or any peer if the request does not contain a Destination-Host AVP.

`realm`

Matches only those peers whose Origin-Realm has the same value as Destination-Realm in the outgoing request in question, or any peer if the request does not contain a Destination-Realm AVP.

`{host, any|DiameterIdentity()}`

Matches only those peers whose Origin-Host has the specified value, or all peers if the atom `any`.

`{realm, any|DiameterIdentity()}`

Matches only those peers whose Origin-Realm has the specified value, or all peers if the atom `any`.

`{eval, evaluable()}`

Matches only those peers for which the specified *`evaluable()`* returns `true` when applied to the connection's `diameter_caps` record. Any other return value or exception is equivalent to `false`.

`{neg, peer_filter()}`

Matches only those peers not matched by the specified filter.

`{all, [peer_filter()]}`

Matches only those peers matched by each filter in the specified list.

`{any, [peer_filter()]}`

Matches only those peers matched by at least one filter in the specified list. The resulting list will be in match order, peers matching the first filter of the list sorting before those matched by the second, and so on.

`{first, [peer_filter()]}`

Like `any`, but stops at the first filter for which there are matches, which can be much more efficient when there are many peers. For example, the following filter causes only peers best matching both the host and realm filters to be presented.

```
{first, [{all, [host, realm]}, realm]}
```

An invalid filter is equivalent to `{any,[]}`, a filter that matches no peer.

> **Note:**
>
> The `host` and `realm` filters cause the Destination-Host and Destination-Realm AVPs to be extracted from the outgoing request, assuming it to be a record- or list-valued *`diameter_codec:message()`*, and assuming at most one of each AVP. If this is not the case then the `{host|realm, DiameterIdentity()}` filters must be used to achieve the desired result. An empty *`DiameterIdentity()`* (which should not be typical) matches all hosts/realms for the purposes of filtering.

> **Warning:**
>
> A `host` filter is not typically desirable when setting Destination-Host since it will remove peer agents from the candidates list.

`service_event() = #diameter_event{service = service_name(), info = service_event_info()}`

An event message sent to processes that have subscribed to these using *subscribe/1*.

`service_event_info() = term()`

The `info` field of a *service_event()* record. Can have one of the following types.

`start`
`stop`

The service is being started or stopped. No event precedes a `start` event. No event follows a `stop` event, and this event implies the termination of all transport processes.

```
{up, Ref, Peer, Config, Pkt}
{up, Ref, Peer, Config}
{down, Ref, Peer, Config}
```

```
Ref    = transport_ref()
Peer   = diameter_app:peer()
Config = {connect|listen, [transport_opt()]}
Pkt    = #diameter_packet{}
```

The RFC 3539 watchdog state machine has transitioned into (`up`) or out of (`down`) the OKAY state. If a `#diameter_packet{}` is present in an `up` event then there has been a capabilities exchange on a newly established transport connection and the record contains the received CER or CEA.

Note that a single `up` or `down` event for a given peer corresponds to multiple *peer_up/3* or *peer_up/3* callbacks, one for each of the Diameter applications negotiated during capabilities exchange. That is, the event communicates connectivity with the peer as a whole while the callbacks communicate connectivity with respect to individual Diameter applications.

```
{reconnect, Ref, Opts}
```

```
Ref  = transport_ref()
Opts = [transport_opt()]
```

A connecting transport is attempting to establish/reestablish a transport connection with a peer following *connect_timer* or *watchdog_timer* expiry.

```
{closed, Ref, Reason, Config}
```

```
Ref = transport_ref()
Config = {connect|listen, [transport_opt()]}
```

Capabilities exchange has failed. `Reason` can have one of the following types.

```
{'CER', Result, Caps, Pkt}
```

```
Result = ResultCode | {capabilities_cb, CB, ResultCode|discard}
Caps = #diameter_caps{}
Pkt  = #diameter_packet{}
ResultCode = integer()
CB = evaluable()
```

An incoming CER has been answered with the indicated result code, or discarded. `Caps` contains pairs of values, for the local node and remote peer respectively. `Pkt` contains the CER in question. In the case of rejection by a capabilities callback, the tuple contains the rejecting callback.

`{'CER', Caps, {ResultCode, Pkt}}`

```
ResultCode = integer()
Caps = #diameter_caps{}
Pkt  = #diameter_packet{}
```

An incoming CER contained errors and has been answered with the indicated result code. `Caps` contains values for the local node only. `Pkt` contains the CER in question.

`{'CER', timeout}`

An expected CER was not received within *capx_timeout* of connection establishment.

`{'CEA', Result, Caps, Pkt}`

```
Result = ResultCode | atom() | {capabilities_cb, CB, ResultCode|discard}
Caps = #diameter_caps{}
Pkt  = #diameter_packet{}
ResultCode = integer()
```

An incoming CEA has been rejected for the indicated reason. An integer-valued `Result` indicates the result code sent by the peer. `Caps` contains pairs of values for the local node and remote peer. `Pkt` contains the CEA in question. In the case of rejection by a capabilities callback, the tuple contains the rejecting callback.

`{'CEA', Caps, Pkt}`

```
Caps = #diameter_caps{}
Pkt  = #diameter_packet{}
```

An incoming CEA contained errors and has been rejected. `Caps` contains only values for the local node. `Pkt` contains the CEA in question.

`{'CEA', timeout}`

An expected CEA was not received within *capx_timeout* of connection establishment.

`{watchdog, Ref, PeerRef, {From, To}, Config}`

```
Ref = transport_ref()
PeerRef = diameter_app:peer_ref()
From, To = initial | okay | suspect | down | reopen
Config = {connect|listen, [transport_opt()]}
```

An RFC 3539 watchdog state machine has changed state.

`any()`

For forward compatibility, a subscriber should be prepared to receive info fields of forms other than the above.

`service_name() = term()`

Name of a service as passed to *start_service/2* and with which the service is identified. There can be at most one service with a given name on a given node. Note that *erlang:make_ref/0* can be used to generate a service name that is somewhat unique.

`service_opt()`

Option passed to *start_service/2*. Can be any *`capability()`* as well as the following.

`{application, [application_opt()]}`

A Diameter application supported by the service.

A service must configure one tuple for each Diameter application it intends to support. For an outgoing request, the relevant *`application_alias()`* is passed to *call/4*, while for an incoming request the application identifier in the message header determines the application, the identifier being specified in the application's *dictionary* file.

> **Warning:**
>
> The capabilities advertised by a node must match its configured applications. In particular, `application` configuration must be matched by corresponding *capability()* configuration, of *-Application-Id AVPs in particular.

`{incoming_maxlen, 0..16777215}`

Bound on the expected size of incoming Diameter messages. Messages larger than the specified number of bytes are discarded.

Defaults to `16777215`, the maximum value of the 24-bit Message Length field in a Diameter Header.

`{restrict_connections, false | node | nodes | [node()] | evaluable()}`

The degree to which the service allows multiple transport connections to the same peer, as identified by its Origin-Host at capabilities exchange.

If `[node()]` then a connection is rejected if another already exists on any of the specified nodes. Types `false`, `node`, `nodes` and *evaluable()* are equivalent to `[]`, `[node()]`, `[node()|nodes()]` and the evaluated value respectively, evaluation of each expression taking place whenever a new connection is to be established. Note that `false` allows an unlimited number of connections to be established with the same peer.

Multiple connections are independent and governed by their own peer and watchdog state machines.

Defaults to `nodes`.

`{sequence, {H,N} | evaluable()}`

A constant value `H` for the topmost `32-N` bits of of 32-bit End-to-End and Hop-by-Hop Identifiers generated by the service, either explicitly or as a return value of a function to be evaluated at *start_service/2*. In particular, an identifier `Id` is mapped to a new identifier as follows.

```
(H bsl N) bor (Id band ((1 bsl N) - 1))
```

Note that RFC 6733 requires that End-to-End Identifiers remain unique for a period of at least 4 minutes and that this and the call rate places a lower bound on appropriate values of `N`: at a rate of `R` requests per

second, an N-bit counter traverses all of its values in `(1 bsl N) div (R*60)` minutes, so the bound is `4*R*60 =< 1 bsl N`.

`N` must lie in the range `0..32` and `H` must be a non-negative integer less than `1 bsl (32-N)`.

Defaults to `{0,32}`.

> **Warning:**
>
> Multiple Erlang nodes implementing the same Diameter node should be configured with different sequence masks to ensure that each node uses a unique range of End-to-End and Hop-by-Hop Identifiers for outgoing requests.

`{share_peers, boolean() | [node()] | evaluable()}`

Nodes to which peer connections established on the local Erlang node are communicated. Shared peers become available in the remote candidates list passed to *pick_peer/4* callbacks on remote nodes whose services are configured to use them: see `use_shared_peers` below.

If `false` then peers are not shared. If `[node()]` then peers are shared with the specified list of nodes. If `evaluable()` then peers are shared with the nodes returned by the specified function, evaluated whenever a peer connection becomes available or a remote service requests information about local connections. The value `true` is equivalent to `fun erlang:nodes/0`. The value `node()` in a list is ignored, so a collection of services can all be configured to share with the same list of nodes.

Defaults to `false`.

> **Note:**
>
> Peers are only shared with services of the same name for the purpose of sending outgoing requests. Since the value of the *application_opt()* `alias`, passed to *call/4*, is the handle for identifying a peer as a suitable candidate, services that share peers must use the same aliases to identify their supported applications. They should typically also configure identical *capabilities()*, since by sharing peer connections they are distributing the implementation of a single Diameter node across multiple Erlang nodes.

`{spawn_opt, [term()]}`

Options list passed to *erlang:spawn_opt/2* when spawning a process for an incoming Diameter request, unless the transport in question specifies another value. Options `monitor` and `link` are ignored.

Defaults to the empty list.

`{strict_mbit, boolean()}`

Whether or not to regard an AVP setting the M-bit as erroneous when the command grammar in question does not explicitly allow the AVP. If `true` then such AVPs are regarded as 5001 errors, DIAMETER_AVP_UNSUPPORTED. If `false` then the M-bit is ignored and policing it becomes the receiver's responsibility.

Defaults to `true`.

> ### Warning:
>
> RFC 6733 is unclear about the semantics of the M-bit. One the one hand, the CCF specification in section 3.2 documents AVP in a command grammar as meaning **any** arbitrary AVP; on the other hand, 1.3.4 states that AVPs setting the M-bit cannot be added to an existing command: the modified command must instead be placed in a new Diameter application.
>
> The reason for the latter is presumably interoperability: allowing arbitrary AVPs setting the M-bit in a command makes its interpretation implementation-dependent, since there's no guarantee that all implementations will understand the same set of arbitrary AVPs in the context of a given command. However, interpreting `AVP` in a command grammar as **any** AVP, regardless of M-bit, renders 1.3.4 meaningless, since the receiver can simply ignore any AVP it thinks isn't relevant, regardless of the sender's intent.
>
> Beware of confusing mandatory in the sense of the M-bit with mandatory in the sense of the command grammar. The former is a semantic requirement: that the receiver understand the semantics of the AVP in the context in question. The latter is a syntactic requirement: whether or not the AVP must occur in the message in question.

`{string_decode, boolean()}`

Whether or not to decode AVPs of type *OctetString()* and its derived types *DiameterIdentity()*, *DiameterURI()*, *IPFilterRule()*, *QoSFilterRule()*, and *UTF8String()*. If `true` then AVPs of these types are decoded to string(). If `false` then values are retained as binary().

Defaults to `true`.

> ### Warning:
>
> This option should be set to `false` since a sufficiently malicious peer can otherwise cause large amounts of memory to be consumed when decoded Diameter messages are passed between processes. The default value is for backwards compatibility.

`{use_shared_peers, boolean() | [node()] | evaluable()}`

Nodes from which communicated peers are made available in the remote candidates list of *pick_peer/4* callbacks.

If `false` then remote peers are not used. If `[node()]` then only peers from the specified list of nodes are used. If `evaluable()` then only peers returned by the specified function are used, evaluated whenever a remote service communicates information about an available peer connection. The value `true` is equivalent to `fun erlang:nodes/0`. The value `node()` in a list is ignored.

Defaults to `false`.

> ### Note:
>
> A service that does not use shared peers will always pass the empty list as the second argument of *pick_peer/4* callbacks.

> **Warning:**
>
> Sending a request over a peer connection on a remote node is less efficient than sending it over a local connection. It may be preferable to make use of the *service_opt()* `restrict_connections` and maintain a dedicated connection on each node from which requests are sent.

`transport_opt()`

Option passed to *add_transport/2*. Has one of the following types.

`{applications, [application_alias()]}`

Diameter applications to which the transport should be restricted. Defaults to all applications configured on the service in question. Applications not configured on the service in question are ignored.

> **Warning:**
>
> The capabilities advertised by a node must match its configured applications. In particular, setting `applications` on a transport typically implies having to set matching *-Application-Id AVPs in a *capabilities()* tuple.

`{capabilities, [capability()]}`

AVPs used to construct outgoing CER/CEA messages. Values take precedence over any specified on the service in question.

Specifying a capability as a transport option may be particularly appropriate for Inband-Security-Id, in case TLS is desired over TCP as implemented by *diameter_tcp(3)*.

`{capabilities_cb, evaluable()}`

Callback invoked upon reception of CER/CEA during capabilities exchange in order to ask whether or not the connection should be accepted. Applied to the `transport_ref()` and `#diameter_caps{}` record of the connection.

The return value can have one of the following types.

`ok`

Accept the connection.

`integer()`

Causes an incoming CER to be answered with the specified Result-Code.

`discard`

Causes an incoming CER to be discarded without CEA being sent.

`unknown`

Equivalent to returning `3010`, DIAMETER_UNKNOWN_PEER.

Returning anything but `ok` or a 2xxx series result code causes the transport connection to be broken. Multiple *capabilities_cb* options can be specified, in which case the corresponding callbacks are applied until either all return `ok` or one does not.

`{capx_timeout, Unsigned32()}`

Number of milliseconds after which a transport process having an established transport connection will be terminated if the expected capabilities exchange message (CER or CEA) is not received from the peer. For a connecting transport, the timing of connection attempts is governed by *connect_timer* or *watchdog_timer* expiry. For a listening transport, the peer determines the timing.

Defaults to 10000.

`{connect_timer, Tc}`

```
Tc = Unsigned32()
```

For a connecting transport, the RFC 6733 Tc timer, in milliseconds. This timer determines the frequency with which a transport attempts to establish an initial connection with its peer following transport configuration. Once an initial connection has been established, *watchdog_timer* determines the frequency of reconnection attempts, as required by RFC 3539.

For a listening transport, the timer specifies the time after which a previously connected peer will be forgotten: a connection after this time is regarded as an initial connection rather than reestablishment, causing the RFC 3539 state machine to pass to state OKAY rather than REOPEN. Note that these semantics are not governed by the RFC and that a listening transport's *connect_timer* should be greater than its peer's Tw plus jitter.

Defaults to 30000 for a connecting transport and 60000 for a listening transport.

`{disconnect_cb, evaluable()}`

Callback invoked prior to terminating the transport process of a transport connection having watchdog state `OKAY`. Applied to `application|service|transport` and the *`transport_ref()`* and *`diameter_app:peer()`* in question: `application` indicates that the diameter application is being stopped, `service` that the service in question is being stopped by *stop_service/1*, and `transport` that the transport in question is being removed by *remove_transport/2*.

The return value can have one of the following types.

`{dpr, [option()]}`

Send Disconnect-Peer-Request to the peer, the transport process being terminated following reception of Disconnect-Peer-Answer or timeout. An `option()` can be one of the following.

`{cause, 0|rebooting|1|busy|2|goaway}`

Disconnect-Cause to send, `REBOOTING`, `BUSY` and `DO_NOT_WANT_TO_TALK_TO_YOU` respectively. Defaults to `rebooting` for `Reason=service|application` and `goaway` for `Reason=transport`.

`{timeout, Unsigned32()}`

Number of milliseconds after which the transport process is terminated if DPA has not been received. Defaults to the value of *dpa_timeout*.

`dpr`

Equivalent to `{dpr, []}`.

`close`

Terminate the transport process without Disconnect-Peer-Request being sent to the peer.

`ignore`

Equivalent to not having configured the callback.

Multiple *disconnect_cb* options can be specified, in which case the corresponding callbacks are applied until one of them returns a value other than `ignore`. All callbacks returning `ignore` is equivalent to not having configured them.

Defaults to a single callback returning `dpr`.

`{dpa_timeout, Unsigned32()}`

Number of milliseconds after which a transport connection is terminated following an outgoing DPR if DPA is not received.

Defaults to 1000.

`{dpr_timeout, Unsigned32()}`

Number of milliseconds after which a transport connection is terminated following an incoming DPR if the peer does not close the connection.

Defaults to 5000.

`{length_errors, exit|handle|discard}`

How to deal with errors in the Message Length field of the Diameter Header in an incoming message. An error in this context is that the length is not at least 20 bytes (the length of a Header), is not a multiple of 4 (a valid length) or is not the length of the message in question, as received over the transport interface documented in *diameter_transport(3)*.

If `exit` then the transport process in question exits. If `handle` then the message is processed as usual, a resulting *handle_request/3* or *handle_answer/4* callback (if one takes place) indicating the `5015` error (DIAMETER_INVALID_MESSAGE_LENGTH). If `discard` then the message in question is silently discarded.

Defaults to `exit`.

> **Note:**
>
> The default value reflects the fact that a transport module for a stream-oriented transport like TCP may not be able to recover from a message length error since such a transport must use the Message Length header to divide the incoming byte stream into individual Diameter messages. An invalid length leaves it with no reliable way to rediscover message boundaries, which may result in the failure of subsequent messages. See *diameter_tcp(3)* for the behaviour of that module.

`{pool_size, pos_integer()}`

Number of transport processes to start. For a listening transport, determines the size of the pool of accepting transport processes, a larger number being desirable for processing multiple concurrent peer connection attempts. For a connecting transport, determines the number of connections to the peer in question that will be attempted to be establshed: the *service_opt()*: `restrict_connections` should also be configured on the service in question to allow multiple connections to the same peer.

`{spawn_opt, [term()]}`

Options passed to *erlang:spawn_opt/2* when spawning a process for an incoming Diameter request. Options `monitor` and `link` are ignored.

Defaults to the list configured on the service if not specified.

`{transport_config, term()}`
`{transport_config, term(), Unsigned32() | infinity}`

Term passed as the third argument to the *start/3* function of the relevant *transport module* in order to start a transport process. Defaults to the empty list if unspecified.

The 3-tuple form additionally specifies an interval, in milliseconds, after which a started transport process should be terminated if it has not yet established a connection. For example, the following options on a connecting transport request a connection with one peer over SCTP or another (typically the same) over TCP.

```
{transport_module, diameter_sctp}
{transport_config, SctpOpts, 5000}
{transport_module, diameter_tcp}
{transport_config, TcpOpts}
```

To listen on both SCTP and TCP, define one transport for each.

`{transport_module, atom()}`

Module implementing a transport process as defined in *diameter_transport(3)*. Defaults to `diameter_tcp` if unspecified.

Multiple `transport_module` and *transport_config* options are allowed. The order of these is significant in this case (and only in this case), a `transport_module` being paired with the first *transport_config* following it in the options list, or the default value for trailing modules. Transport starts will be attempted with each of the modules in order until one establishes a connection within the corresponding timeout (see below) or all fail.

`{watchdog_config, [{okay|suspect, non_neg_integer()}]}`

Configuration that alters the behaviour of the watchdog state machine. On key `okay`, the non-negative number of answered DWR messages before transitioning from REOPEN to OKAY. On key `suspect`, the number of watchdog timeouts before transitioning from OKAY to SUSPECT when DWR is unanswered, or 0 to not make the transition.

Defaults to `[{okay, 3}, {suspect, 1}]`. Not specifying a key is equivalent to specifying the default value for that key.

> **Warning:**
>
> The default value is as required by RFC 3539: changing it results in non-standard behaviour that should only be used to simulate misbehaving nodes during test.

`{watchdog_timer, TwInit}`

```
TwInit = Unsigned32()
       | {M,F,A}
```

The RFC 3539 watchdog timer. An integer value is interpreted as the RFC's TwInit in milliseconds, a jitter of ± 2 seconds being added at each rearming of the timer to compute the RFC's Tw. An MFA is expected to return the RFC's Tw directly, with jitter applied, allowing the jitter calculation to be performed by the callback.

An integer value must be at least 6000 as required by RFC 3539. Defaults to 30000 if unspecified.

Unrecognized options are silently ignored but are returned unmodified by *service_info/2* and can be referred to in predicate functions passed to *remove_transport/2*.

`transport_ref() = reference()`

Reference returned by *add_transport/2* that identifies the configuration.

Exports

`add_transport(SvcName, {connect|listen, [Opt]}) -> {ok, Ref} | {error, Reason}`

Types:

`SvcName = service_name()`
`Opt = transport_opt()`
`Ref = transport_ref()`
`Reason = term()`

Add transport capability to a service.

The service will start transport processes as required in order to establish a connection with the peer, either by connecting to the peer (`connect`) or by accepting incoming connection requests (`listen`). A connecting transport establishes transport connections with at most one peer, an listening transport potentially with many.

The diameter application takes responsibility for exchanging CER/CEA with the peer. Upon successful completion of capabilities exchange the service calls each relevant application module's *peer_up/3* callback after which the caller can exchange Diameter messages with the peer over the transport. In addition to CER/CEA, the service takes responsibility for the handling of DWR/DWA and required by RFC 3539, as well as for DPR/DPA.

The returned reference uniquely identifies the transport within the scope of the service. Note that the function returns before a transport connection has been established.

> ### Note:
>
> It is not an error to add a transport to a service that has not yet been configured: a service can be started after configuring its transports.

`call(SvcName, App, Request, [Opt]) -> Answer | ok | {error, Reason}`

Types:

`SvcName = service_name()`
`App = application_alias()`
`Request = diameter_codec:message()`
`Answer = term()`
`Opt = call_opt()`

Send a Diameter request message.

`App` specifies the Diameter application in which the request is defined and callbacks to the corresponding callback module will follow as described below and in *diameter_app(3)*. Unless the `detach` option is specified, the call returns either when an answer message is received from the peer or an error occurs. In the answer case, the return value is as returned by a *handle_answer/4* callback. In the error case, whether or not the error is returned directly by diameter or from a *handle_error/4* callback depends on whether or not the outgoing request is successfully encoded for transmission to the peer, the cases being documented below.

If there are no suitable peers, or if *pick_peer/4* rejects them by returning `false`, then `{error,no_connection}` is returned. Otherwise *pick_peer/4* is followed by a *prepare_request/3* callback, the message is encoded and then sent.

There are several error cases which may prevent an answer from being received and passed to a *handle_answer/4* callback:

- If the initial encode of the outgoing request fails, then the request process fails and `{error,encode}` is returned.
- If the request is successfully encoded and sent but the answer times out then a *handle_error/4* callback takes place with `Reason = timeout`.
- If the request is successfully encoded and sent but the service in question is stopped before an answer is received then a *handle_error/4* callback takes place with `Reason = cancel`.
- If the transport connection with the peer goes down after the request has been sent but before an answer has been received then an attempt is made to resend the request to an alternate peer. If no such peer is available, or if the subsequent *pick_peer/4* callback rejects the candidates, then a *handle_error/4* callback takes place with `Reason = failover`. If a peer is selected then a *prepare_retransmit/3* callback takes place, after which the semantics are the same as following an initial *prepare_request/3* callback.
- If an encode error takes place during retransmission then the request process fails and `{error,failure}` is returned.
- If an application callback made in processing the request fails (pick_peer, prepare_request, prepare_retransmit, handle_answer or handle_error) then either `{error,encode}` or `{error,failure}` is returned depending on whether or not there has been an attempt to send the request over the transport.

Note that `{error,encode}` is the only return value which guarantees that the request has *not* been sent over the transport connection.

`origin_state_id() -> Unsigned32()`

Return a reasonable value for use as Origin-State-Id in outgoing messages.

The value returned is the number of seconds since 19680120T031408Z, the first value that can be encoded as a Diameter *`Time()`*, at the time the diameter application was started.

`remove_transport(SvcName, Pred) -> ok | {error, Reason}`

Types:

```
SvcName = service_name()
Pred = Fun | MFA | transport_ref() | list() | true | false
Fun = fun((transport_ref(), connect|listen, list()) -> boolean())
    | fun((transport_ref(), list()) -> boolean())
    | fun((list()) -> boolean())
MFA = {atom(), atom(), list()}
Reason = term()
```

Remove previously added transports.

`Pred` determines which transports to remove. An arity-3-valued `Pred` removes all transports for which `Pred(Ref, Type, Opts)` returns `true`, where `Type` and `Opts` are as passed to *add_transport/2* and `Ref` is as returned by it. The remaining forms are equivalent to an arity-3 fun as follows.

```
Pred = fun(transport_ref(), list()):  fun(Ref, _, Opts) -> Pred(Ref, Opts) end
Pred = fun(list()):                   fun(_, _, Opts) -> Pred(Opts) end
Pred = transport_ref():               fun(Ref, _, _)  -> Pred == Ref end
```

```
Pred = list():                          fun(_, _, Opts) -> [] == Pred -- Opts end
Pred = true:                            fun(_, _, _) -> true end
Pred = false:                           fun(_, _, _) -> false end
Pred = {M,F,A}:  fun(Ref, Type, Opts) -> apply(M, F, [Ref, Type, Opts | A]) end
```

Removing a transport causes the corresponding transport processes to be terminated. Whether or not a DPR message is sent to a peer is controlled by value of *disconnect_cb* configured on the transport.

service_info(SvcName, Info) -> term()

Types:

SvcName = *service_name()*

Info = Item | [Info]

Item = atom()

Return information about a started service. Requesting info for an unknown service causes `undefined` to be returned. Requesting a list of items causes a tagged list to be returned.

`Item` can be one of the following.

```
'Origin-Host'
'Origin-Realm'
'Vendor-Id'
'Product-Name'
'Origin-State-Id'
'Host-IP-Address'
'Supported-Vendor'
'Auth-Application-Id'
'Inband-Security-Id'
'Acct-Application-Id'
'Vendor-Specific-Application-Id'
'Firmware-Revision'
```

Return a capability value as configured with *start_service/2*.

`applications`

Return the list of applications as configured with *start_service/2*.

`capabilities`

Return a tagged list of all capabilities values as configured with *start_service/2*.

`transport`

Return a list containing one entry for each of the service's transport as configured with *add_transport/2*. Each entry is a tagged list containing both configuration and information about established peer connections. An example return value with for a client service with Origin-Host "client.example.com" configured with a single transport connected to "server.example.com" might look as follows.

```
[[{ref,#Ref<0.0.0.93>},
  {type,connect},
  {options,[{transport_module,diameter_tcp},
            {transport_config,[{ip,{127,0,0,1}},
                               {raddr,{127,0,0,1}},
                               {rport,3868},
                               {reuseaddr,true}]}]},
  {watchdog,{<0.66.0>,{1346,171491,996448},okay}},
  {peer,{<0.67.0>,{1346,171491,999906}}},
```

```
  {apps,[{0,common}]},
  {caps,[{origin_host,{"client.example.com","server.example.com"}},
         {origin_realm,{"example.com","example.com"}},
         {host_ip_address,{[{127,0,0,1}],[{127,0,0,1}]}},
         {vendor_id,{0,193}},
         {product_name,{"Client","Server"}},
         {origin_state_id,{[],[]}},
         {supported_vendor_id,{[],[]}},
         {auth_application_id,{[0],[0]}},
         {inband_security_id,{[],[0]}},
         {acct_application_id,{[],[]}},
         {vendor_specific_application_id,{[],[]}},
         {firmware_revision,{[],[]}},
         {avp,{[],[]}}]},
  {port,[{owner,<0.69.0>},
         {module,diameter_tcp},
         {socket,{{127,0,0,1},48758}},
         {peer,{{127,0,0,1},3868}},
         {statistics,[{recv_oct,656},
                      {recv_cnt,6},
                      {recv_max,148},
                      {recv_avg,109},
                      {recv_dvi,19},
                      {send_oct,836},
                      {send_cnt,6},
                      {send_max,184},
                      {send_avg,139},
                      {send_pend,0}]}]},
  {statistics,[{{{0,258,0},recv},3},
               {{{0,258,1},send},3},
               {{{0,257,0},recv},1},
               {{{0,257,1},send},1},
               {{{0,258,0},recv,{'Result-Code',2001}},3},
               {{{0,280,1},recv},2},
               {{{0,280,0},send},2}]}]]
```

Here `ref` is a *`transport_ref()`* and `options` the corresponding *`transport_opt()`* list passed to *add_transport/2*. The `watchdog` entry shows the state of a connection's RFC 3539 watchdog state machine. The `peer` entry identifies the *`diameter_app:peer_ref()`* for which there will have been *peer_up/3* callbacks for the Diameter applications identified by the `apps` entry, `common` being the *`application_alias()`*. The `caps` entry identifies the capabilities sent by the local node and received from the peer during capabilities exchange. The `port` entry displays socket-level information about the transport connection. The `statistics` entry presents Diameter-level counters, an entry like `{{{0,280,1},recv},2}` saying that the client has received 2 DWR messages: `{0,280,1} = {Application_Id, Command_Code, R_Flag}`.

Note that `watchdog`, `peer`, `apps`, `caps` and `port` entries depend on connectivity with the peer and may not be present. Note also that the `statistics` entry presents values accumulated during the lifetime of the transport configuration.

A listening transport presents its information slightly differently since there may be multiple accepted connections for the same *`transport_ref()`*. The `transport` info returned by a server with a single client connection might look as follows.

```
[[{ref,#Ref<0.0.0.61>},
  {type,listen},
  {options,[{transport_module,diameter_tcp},
            {transport_config,[{reuseaddr,true},
                               {ip,{127,0,0,1}},
                               {port,3868}]}]},
  {accept,[[{watchdog,{<0.56.0>,{1346,171481,226895},okay}},
```

```
           {peer,{<0.58.0>,{1346,171491,999511}}},
           {apps,[{0,common}]},
           {caps,[{origin_host,{"server.example.com","client.example.com"}},
                  {origin_realm,{"example.com","example.com"}},
                  {host_ip_address,{[{127,0,0,1}],[{127,0,0,1}]}},
                  {vendor_id,{193,0}},
                  {product_name,{"Server","Client"}},
                  {origin_state_id,{[],[]}},
                  {supported_vendor_id,{[],[]}},
                  {auth_application_id,{[0],[0]}},
                  {inband_security_id,{[],[]}},
                  {acct_application_id,{[],[]}},
                  {vendor_specific_application_id,{[],[]}},
                  {firmware_revision,{[],[]}},
                  {avp,{[],[]}}]},
           {port,[{owner,<0.62.0>},
                  {module,diameter_tcp},
                  {socket,{{127,0,0,1},3868}},
                  {peer,{{127,0,0,1},48758}},
                  {statistics,[{recv_oct,1576},
                               {recv_cnt,16},
                               {recv_max,184},
                               {recv_avg,98},
                               {recv_dvi,26},
                               {send_oct,1396},
                               {send_cnt,16},
                               {send_max,148},
                               {send_avg,87},
                               {send_pend,0}]}]}],
         [{watchdog,{<0.72.0>,{1346,171491,998404},initial}}]]},
 {statistics,[{{{0,280,0},recv},7},
              {{{0,280,1},send},7},
              {{{0,258,0},send,{'Result-Code',2001}},3},
              {{{0,258,1},recv},3},
              {{{0,258,0},send},3},
              {{{0,280,1},recv},5},
              {{{0,280,0},send},5},
              {{{0,257,1},recv},1},
              {{{0,257,0},send},1}]}]]
```

The information presented here is as in the `connect` case except that the client connections are grouped under an `accept` tuple.

Whether or not the *transport_opt()* `pool_size` has been configured affects the format of the listing in the case of a connecting transport, since a value greater than 1 implies multiple transport processes for the same *`transport_ref()`*, as in the listening case. The format in this case is similar to the listening case, with a `pool` tuple in place of an `accept` tuple.

`connections`

Return a list containing one entry for every established transport connection whose watchdog state machine is not in the `down` state. This is a flat view of `transport` info which lists only active connections and for which Diameter-level statistics are accumulated only for the lifetime of the transport connection. A return value for the server above might look as follows.

```
[[{ref,#Ref<0.0.0.61>},
  {type,accept},
  {options,[{transport_module,diameter_tcp},
            {transport_config,[{reuseaddr,true},
                               {ip,{127,0,0,1}},
                               {port,3868}]}]},
```

```
 {watchdog,{<0.56.0>,{1346,171481,226895},okay}},
 {peer,{<0.58.0>,{1346,171491,999511}}},
 {apps,[{0,common}]},
 {caps,[{origin_host,{"server.example.com","client.example.com"}},
        {origin_realm,{"example.com","example.com"}},
        {host_ip_address,{[{127,0,0,1}],[{127,0,0,1}]}},
        {vendor_id,{193,0}},
        {product_name,{"Server","Client"}},
        {origin_state_id,{[],[]}},
        {supported_vendor_id,{[],[]}},
        {auth_application_id,{[0],[0]}},
        {inband_security_id,{[],[]}},
        {acct_application_id,{[],[]}},
        {vendor_specific_application_id,{[],[]}},
        {firmware_revision,{[],[]}},
        {avp,{[],[]}}]},
 {port,[{owner,<0.62.0>},
        {module,diameter_tcp},
        {socket,{{127,0,0,1},3868}},
        {peer,{{127,0,0,1},48758}},
        {statistics,[{recv_oct,10124},
                     {recv_cnt,132},
                     {recv_max,184},
                     {recv_avg,76},
                     {recv_dvi,9},
                     {send_oct,10016},
                     {send_cnt,132},
                     {send_max,148},
                     {send_avg,75},
                     {send_pend,0}]}]},
 {statistics,[{{{0,280,0},recv},62},
              {{{0,280,1},send},62},
              {{{0,258,0},send,{'Result-Code',2001}},3},
              {{{0,258,1},recv},3},
              {{{0,258,0},send},3},
              {{{0,280,1},recv},66},
              {{{0,280,0},send},66},
              {{{0,257,1},recv},1},
              {{{0,257,0},send},1}]}]]
```

Note that there may be multiple entries with the same `ref`, in contrast to `transport` info.

`statistics`

Return a `{{Counter, Ref}, non_neg_integer()}` list of counter values. `Ref` can be either a *`transport_ref()`* or a *`diameter_app:peer_ref()`*. Entries for the latter are folded into corresponding entries for the former as peer connections go down. Entries for both are removed at *remove_transport/2*. The Diameter-level statistics returned by `transport` and `connections` info are based upon these entries.

`diameter_app:peer_ref()`

Return transport configuration associated with a single peer, as passed to *add_transport/2*. The returned list is empty if the peer is unknown. Otherwise it contains the `ref`, `type` and `options` tuples as in `transport` and `connections` info above. For example:

```
[{ref,#Ref<0.0.0.61>},
 {type,accept},
 {options,[{transport_module,diameter_tcp},
           {transport_config,[{reuseaddr,true},
                              {ip,{127,0,0,1}},
                              {port,3868}]}]}]
```

services() -> [SvcName]

Types:

SvcName = *service_name()*

Return the list of started services.

session_id(Ident) -> OctetString()

Types:

Ident = *DiameterIdentity()*

Return a value for a Session-Id AVP.

The value has the form required by section 8.8 of RFC 6733. Ident should be the Origin-Host of the peer from which the message containing the returned value will be sent.

start() -> ok | {error, Reason}

Start the diameter application.

The diameter application must be started before starting a service. In a production system this is typically accomplished by a boot file, not by calling `start/0` explicitly.

start_service(SvcName, Options) -> ok | {error, Reason}

Types:

SvcName = *service_name()*
Options = [*service_opt()*]
Reason = term()

Start a diameter service.

A service defines a locally-implemented Diameter node, specifying the capabilities to be advertised during capabilities exchange. Transports are added to a service using *add_transport/2*.

> Note:
>
> A transport can both override its service's capabilities and restrict its supported Diameter applications so "service = Diameter node as identified by Origin-Host" is not necessarily the case.

stop() -> ok | {error, Reason}

Stop the diameter application.

stop_service(SvcName) -> ok | {error, Reason}

Types:

SvcName = *service_name()*
Reason = term()

Stop a diameter service.

Stopping a service causes all associated transport connections to be broken. A DPR message with be sent as in the case of *remove_transport/2*.

> Note:
>
> Stopping a service does not remove any associated transports: *remove_transport/2* must be called to remove transport configuration.

`subscribe(SvcName) -> true`

Types:

`SvcName = service_name()`

Subscribe to `service_event()` messages from a service.

It is not an error to subscribe to events from a service that does not yet exist. Doing so before adding transports is required to guarantee the reception of all transport-related events.

`unsubscribe(SvcName) -> true`

Types:

`SvcName = service_name()`

Unsubscribe to event messages from a service.

SEE ALSO

diameter_app(3), *diameter_transport(3)*, *diameter_dict(4)*

diameterc

Command

The diameterc utility is used to compile a diameter *dictionary file* into Erlang source. The resulting source implements the interface diameter required to encode and decode the dictionary's messages and AVPs.

The module *diameter_make(3)* provides an alternate compilation interface.

USAGE

diameterc [<options>] <file>

Compile a single dictionary file to Erlang source. Valid options are as follows.

-i <dir>

Prepend the specified directory to the code path. Use to point at beam files compiled from inherited dictionaries, `@inherits` in a dictionary file creating a beam dependency, not an erl/hrl dependency.

Multiple `-i` options can be specified.

-o <dir>

Write generated source to the specified directory. Defaults to the current working directory.

-E
-H

Suppress erl and hrl generation, respectively.

--name <name>
--prefix <prefix>

Transform the input dictionary before compilation, setting `@name` or `@prefix` to the specified string.

--inherits <arg>

Transform the input dictionary before compilation, appending `@inherits` of the specified string.

Two forms of `--inherits` have special meaning:

```
--inherits -
--inherits Prev/Mod
```

The first has the effect of clearing any previous inherits, the second of replacing a previous inherits of `Prev` to one of `Mod`. This allows the semantics of the input dictionary to be changed without modifying the file itself.

Multiple `--inherits` options can be specified.

EXIT STATUS

Returns 0 on success, non-zero on failure.

SEE ALSO

diameter_make(3), diameter_dict(4)

diameter_app

Erlang module

A diameter service as started by *diameter:start_service/2* configures one of more Diameter applications, each of whose configuration specifies a callback that handles messages specific to the application. The messages and AVPs of the application are defined in a dictionary file whose format is documented in *diameter_dict(4)* while the callback module is documented here. The callback module implements the Diameter application-specific functionality of a service.

A callback module must export all of the functions documented below. The functions themselves are of three distinct flavours:

- *peer_up/3* and *peer_up/3* signal the attainment or loss of connectivity with a Diameter peer.
- *pick_peer/4*, *prepare_request/3*, *prepare_retransmit/3*, *handle_answer/4* and *handle_error/4* are (or may be) called as a consequence of a call to *diameter:call/4* to send an outgoing Diameter request message.
- *handle_request/3* is called in response to an incoming Diameter request message.

> **Note:**
>
> The arities given for the the callback functions here assume no extra arguments. All functions will also be passed any extra arguments configured with the callback module itself when calling *diameter:start_service/2* and, for the call-specific callbacks, any extra arguments passed to *diameter:call/4*.

DATA TYPES

`capabilities() = #diameter_caps{}`

A record containing the identities of the local Diameter node and the remote Diameter peer having an established transport connection, as well as the capabilities as determined by capabilities exchange. Each field of the record is a 2-tuple consisting of values for the (local) host and (remote) peer. Optional or possibly multiple values are encoded as lists of values, mandatory values as the bare value.

`message() = diameter_codec:message()`

The representation of a Diameter message as passed to *diameter:call/4* or returned from a *handle_request/3* callback.

`packet() = diameter_codec:packet()`

A container for incoming and outgoing Diameter messages that's passed through encode/decode and transport. Fields should not be set in return values except as documented.

`peer_ref() = term()`

A term identifying a transport connection with a Diameter peer.

`peer() = {peer_ref(), capabilities()}`

A tuple representing a Diameter peer connection.

`state() = term()`

The state maintained by the application callback functions *peer_up/3*, *peer_up/3* and (optionally) *pick_peer/4*. The initial state is configured in the call to *diameter:start_service/2* that configures the application on a service. Callback functions returning a state are evaluated in a common service-specific process while those not returning state are evaluated in a request-specific process.

Exports

`Mod:peer_up(SvcName, Peer, State) -> NewState`

Types:

`SvcName = diameter:service_name()`
`Peer = peer()`
`State = NewState = state()`

Invoked to signal the availability of a peer connection on the local Erlang node. In particular, capabilities exchange with the peer has indicated support for the application in question, the RFC 3539 watchdog state machine for the connection has reached state `OKAY` and Diameter messages can be both sent and received.

> **Note:**
>
> A watchdog state machine can reach state `OKAY` from state `SUSPECT` without a new capabilities exchange taking place. A new transport connection (and capabilities exchange) results in a new peer_ref().

> **Note:**
>
> There is no requirement that a callback return before incoming requests are received: *handle_request/3* callbacks must be handled independently of *peer_up/3* and *peer_up/3*.

`Mod:peer_down(SvcName, Peer, State) -> NewState`

Types:

`SvcName = diameter:service_name()`
`Peer = peer()`
`State = NewState = state()`

Invoked to signal that a peer connection on the local Erlang node is no longer available following a previous call to *peer_up/3*. In particular, that the RFC 3539 watchdog state machine for the connection has left state `OKAY` and the peer will no longer be a candidate in *pick_peer/4* callbacks.

`Mod:pick_peer(LocalCandidates, RemoteCandidates, SvcName, State) -> Selection | false`

Types:

`LocalCandidates = RemoteCandidates = [peer()]`
`SvcName = diameter:service_name()`
`State = NewState = state()`
`Selection = {ok, Peer} | {Peer, NewState}`
`Peer = peer() | false`

Invoked as a consequence of a call to *diameter:call/4* to select a destination peer for an outgoing request. The return value indicates the selected peer.

The candidate lists contain only those peers that have advertised support for the Diameter application in question during capabilities exchange, that have not be excluded by a `filter` option in the call to *diameter:call/4* and whose

watchdog state machine is in the `OKAY` state. The order of the elements is unspecified except that any peers whose Origin-Host and Origin-Realm matches that of the outgoing request (in the sense of a `{filter, {all, [host, realm]}}` option to *diameter:call/4*) will be placed at the head of the list. `LocalCandidates` contains peers whose transport process resides on the local Erlang node while `RemoteCandidates` contains peers that have been communicated from other nodes by services of the same name.

A callback that returns a peer() will be followed by a *prepare_request/3* callback and, if the latter indicates that the request should be sent, by either *handle_answer/4* or *handle_error/4* depending on whether or not an answer message is received from the peer. If the transport becomes unavailable after *prepare_request/3* then a new *pick_peer/4* callback may take place to failover to an alternate peer, after which *prepare_retransmit/3* takes the place of *prepare_request/3* in resending the request. There is no guarantee that a *pick_peer/4* callback to select an alternate peer will be followed by any additional callbacks since a retransmission to an alternate peer is abandoned if an answer is received from a previously selected peer.

The return values `false` and `{false, State}` (that is, `NewState = State`) are equivalent, as are `{ok, Peer}` and `{Peer, State}`.

> ### Note:
>
> The *diameter:service_opt()* `use_shared_peers` determines whether or not a service uses peers shared from other nodes. If not then `RemoteCandidates` is the empty list.

> ### Warning:
>
> The return value `{Peer, NewState}` is only allowed if the Diameter application in question was configured with the *diameter:application_opt()* `{call_mutates_state, true}`. Otherwise, the `State` argument is always the initial value as configured on the application, not any subsequent value returned by a *peer_up/3* or *peer_up/3* callback.

`Mod:prepare_request(Packet, SvcName, Peer) -> Action`

Types:

```
Packet = packet()
SvcName = diameter:service_name()
Peer = peer()
Action = Send | Discard | {eval_packet, Action, PostF}
Send = {send, packet() | message()}
Discard = {discard, Reason} | discard
PostF = diameter:evaluable()}
```

Invoked to return a request for encoding and transport. Allows the sender to use the selected peer's capabilities to modify the outgoing request. Many implementations may simply want to return `{send, Packet}`

A returned *packet()* should set the request to be encoded in its `msg` field and can set the `transport_data` field in order to pass information to the transport process. Extra arguments passed to *diameter:call/4* can be used to communicate transport (or any other) data to the callback.

A returned *packet()* can set the `header` field to a `#diameter_header{}` to specify values that should be preserved in the outgoing request, values otherwise being those in the header record contained in `Packet`. A returned `length`, `cmd_code` or `application_id` is ignored.

A returned `PostF` will be evaluated on any encoded `#diameter_packet{}` prior to transmission, the `bin` field containing the encoded binary. The return value is ignored.

Returning `{discard, Reason}` causes the request to be aborted and the *diameter:call/4* for which the callback has taken place to return `{error, Reason}`. Returning `discard` is equivalent to returning `{discard, discarded}`.

`Mod:prepare_retransmit(Packet, SvcName, Peer) -> Action`

Types:

```
Packet = packet()
SvcName = diameter:service_name()
Peer = peer()
Action = Send | Discard | {eval_packet, Action, PostF}
Send = {send, packet() | message()}
Discard = {discard, Reason} | discard
PostF = diameter:evaluable()}
```

Invoked to return a request for encoding and retransmission. Has the same role as *prepare_request/3* in the case that a peer connection is lost an an alternate peer selected but the argument *packet()* is as returned by the initial *prepare_request/3*.

Returning `{discard, Reason}` causes the request to be aborted and a *handle_error/4* callback to take place with `Reason` as initial argument. Returning `discard` is equivalent to returning `{discard, discarded}`.

`Mod:handle_answer(Packet, Request, SvcName, Peer) -> Result`

Types:

```
Packet = packet()
Request = message()
SvcName = diameter:service_name()
Peer = peer()
Result = term()
```

Invoked when an answer message is received from a peer. The return value is returned from *diameter:call/4* unless the `detach` option was specified.

The decoded answer record and undecoded binary are in the `msg` and `bin` fields of the argument *packet()* respectively. `Request` is the outgoing request message as was returned from *prepare_request/3* or *prepare_retransmit/3*.

For any given call to *diameter:call/4* there is at most one *handle_answer/4* callback: any duplicate answer (due to retransmission or otherwise) is discarded. Similarly, only one of *handle_answer/4* or *handle_error/4* is called.

By default, an incoming answer message that cannot be successfully decoded causes the request process to fail, causing *diameter:call/4* to return `{error, failure}` unless the `detach` option was specified. In particular, there is no *handle_error/4* callback in this case. The *diameter:application_opt()* `answer_errors` can be set to change this behaviour.

`Mod:handle_error(Reason, Request, SvcName, Peer) -> Result`

Types:

```
Reason = timeout | failover | term()
Request = message()
SvcName = diameter:service_name()
```

Peer = *peer()*
Result = term()

Invoked when an error occurs before an answer message is received in response to an outgoing request. The return value is returned from *diameter:call/4* unless the `detach` option was specified.

Reason `timeout` indicates that an answer message has not been received within the time specified with the corresponding *diameter:call_opt()*. Reason `failover` indicates that the transport connection to the peer to which the request has been sent has become unavailable and that not alternate peer was not selected.

Mod:handle_request(Packet, SvcName, Peer) -> Action

Types:

Packet = *packet()*
SvcName = term()
Peer = *peer()*
Action = Reply | {relay, [Opt]} | discard | {eval|eval_packet, Action, PostF}
Reply = {reply, *packet()* | *message()*} | {answer_message, 3000..3999| 5000..5999} | {protocol_error, 3000..3999}
Opt = *diameter:call_opt()*
PostF = *diameter:evaluable()*

Invoked when a request message is received from a peer. The application in which the callback takes place (that is, the callback module as configured with *diameter:start_service/2*) is determined by the Application Identifier in the header of the incoming request message, the selected module being the one whose corresponding dictionary declares itself as defining either the application in question or the Relay application.

The argument *packet()* has the following signature.

```
#diameter_packet{header = #diameter_header{},
                 avps   = [#diameter_avp{}],
                 msg    = record() | undefined,
                 errors = [Unsigned32() | {Unsigned32(), #diameter_avp{}}],
                 bin    = binary(),
                 transport_data = term()}
```

The `msg` field will be `undefined` in case the request has been received in the relay application. Otherwise it contains the record representing the request as outlined in *diameter_dict(4)*.

The `errors` field specifies any results codes identifying errors found while decoding the request. This is used to set Result-Code and/or Failed-AVP in a returned answer unless the callback returns a `#diameter_packet{}` whose `errors` field is set to either a non-empty list of its own, in which case this list is used instead, or the atom `false` to disable any setting of Result-Code and Failed-AVP. Note that the errors detected by diameter are of the 3xxx and 5xxx series, Protocol Errors and Permanent Failures respectively. The `errors` list is empty if the request has been received in the relay application.

The `transport_data` field contains an arbitrary term passed into diameter from the transport module in question, or the atom `undefined` if the transport specified no data. The term is preserved if a *message()* is returned but must be set explicitly in a returned *packet()*.

The semantics of each of the possible return values are as follows.

`{reply, packet() | message()}`

Send the specified answer message to the peer. In the case of a *packet()*, the message to be sent must be set in the `msg` field and the `header` field can be set to a `#diameter_header{}` to specify values that should be preserved in the outgoing answer, appropriate values otherwise being set by diameter.

`{answer_message, 3000..3999|5000..5999}`

Send an answer message to the peer containing the specified Result-Code. Equivalent to

```
{reply, ['answer-message' | Avps]
```

where `Avps` sets the Origin-Host, Origin-Realm, the specified Result-Code and (if the request contained one) Session-Id AVPs, and possibly Failed-AVP as described below.

Returning a value other than 3xxx or 5xxx will cause the request process in question to fail, as will returning a 5xxx value if the peer connection in question has been configured with the RFC 3588 common dictionary `diameter_gen_base_rfc3588`. (Since RFC 3588 only allows 3xxx values in an answer-message.)

When returning 5xxx, Failed-AVP will be populated with the AVP of the first matching Result-Code/AVP pair in the `errors` field of the argument *packet()*, if found. If this is not appropriate then an answer-message should be constructed explicitly and returned in a `reply` tuple instead.

`{relay, Opts}`

Relay a request to another peer in the role of a Diameter relay agent. If a routing loop is detected then the request is answered with 3005 (DIAMETER_LOOP_DETECTED). Otherwise a Route-Record AVP (containing the sending peer's Origin-Host) is added to the request and *pick_peer/4* and subsequent callbacks take place just as if *diameter:call/4* had been called explicitly. The End-to-End Identifier of the incoming request is preserved in the header of the relayed request.

The returned `Opts` should not specify `detach`. A subsequent *handle_answer/4* callback for the relayed request must return its first argument, the *packet()* containing the answer message. Note that the `extra` option can be specified to supply arguments that can distinguish the relay case from others if so desired. Any other return value (for example, from a *handle_error/4* callback) causes the request to be answered with 3002 (DIAMETER_UNABLE_TO_DELIVER).

`discard`

Discard the request. No answer message is sent to the peer.

`{eval, Action, PostF}`

Handle the request as if `Action` has been returned and then evaluate `PostF` in the request process. The return value is ignored.

`{eval_packet, Action, PostF}`

Like `eval` but evaluate `PostF` on any encoded `#diameter_packet{}` prior to transmission, the `bin` field containing the encoded binary. The return value is ignored.

`{protocol_error, 3000..3999}`

Equivalent to `{answer_message, 3000..3999}`.

Note:

Requests containing errors may be answered by diameter, without a callback taking place, depending on the value of the *diameter:application_opt()* `request_errors`.

diameter_codec

Erlang module

Incoming Diameter messages are decoded from binary() before being communicated to *diameter_app(3)* callbacks. Similarly, outgoing Diameter messages are encoded into binary() before being passed to the appropriate *diameter_transport(3)* module for transmission. The functions in this module implement this encode/decode.

> ### Note:
>
> Calls to this module are made by diameter itself as a consequence of configuration passed to *diameter:start_service/2*. The encode/decode functions may also be useful for other purposes (eg. test) but the diameter user does not need to call them explicitly when sending and receiving messages using *diameter:call/4* and the callback interface documented in *diameter_app(3)*.

The *header()* and *packet()* records below are defined in diameter.hrl, which can be included as follows.

```
-include_lib("diameter/include/diameter.hrl").
```

Application-specific records are defined in the hrl files resulting from dictionary file compilation.

DATA TYPES

```
uint8()  = 0..255
uint24() = 0..16777215
uint32() = 0..4294967295
```

8-bit, 24-bit and 32-bit integers occurring in Diameter and AVP headers.

`avp() = #diameter_avp{}`

The application-neutral representation of an AVP. Primarily intended for use by relay applications that need to handle arbitrary Diameter applications. A service implementing a specific Diameter application (for which it configures a dictionary) can manipulate values of type *message()* instead.

Fields have the following types.

```
code = uint32()
is_mandatory = boolean()
need_encryption = boolean()
vendor_id = uint32() | undefined
```

Values in the AVP header, corresponding to AVP Code, the M flag, P flags and Vendor-ID respectively. A Vendor-ID other than `undefined` implies a set V flag.

`data = iolist()`

The data bytes of the AVP.

`name = atom()`

The name of the AVP as defined in the dictionary file in question, or `undefined` if the AVP is unknown to the dictionary file in question.

`value = term()`

The decoded value of an AVP. Will be `undefined` on decode if the data bytes could not be decoded or the AVP is unknown. The type of a decoded value is as document in *diameter_dict(4)*.

`type = atom()`

The type of the AVP as specified in the dictionary file in question (or one it inherits). Possible types are `undefined` and the Diameter types: `OctetString`, `Integer32`, `Integer64`, `Unsigned32`, `Unsigned64`, `Float32`, `Float64`, `Grouped`, `Enumerated`, `Address`, `Time`, `UTF8String`, `DiameterIdentity`, `DiameterURI`, `IPFilterRule` and `QoSFilterRule`.

`dictionary() = module()`

The name of a generated dictionary module as generated by *diameterc(1)* or *diameter_make:codec/2*. The interface provided by a dictionary module is an implementation detail that may change.

`header() = #diameter_header{}`

The record representation of the Diameter header. Values in a *packet()* returned by *decode/2* are as extracted from the incoming message. Values set in an *packet()* passed to *encode/2* are preserved in the encoded binary(), with the exception of `length`, `cmd_code` and `application_id`, all of which are determined by the *dictionary()* in question.

> **Note:**
>
> It is not necessary to set header fields explicitly in outgoing messages as diameter itself will set appropriate values. Setting inappropriate values can be useful for test purposes.

Fields have the following types.

```
version = uint8()
length = uint24()
cmd_code = uint24()
application_id = uint32()
hop_by_hop_id = uint32()
end_to_end_id = uint32()
```

Values of the Version, Message Length, Command-Code, Application-ID, Hop-by-Hop Identifier and End-to-End Identifier fields of the Diameter header.

```
is_request = boolean()
is_proxiable = boolean()
is_error = boolean()
is_retransmitted = boolean()
```

Values corresponding to the R(equest), P(roxiable), E(rror) and T(Potentially re-transmitted message) flags of the Diameter header.

`message() = record() | list()`

The representation of a Diameter message as passed to *diameter:call/4* or returned from a *handle_request/3* callback. The record representation is as outlined in *diameter_dict(4)*: a message as defined in a dictionary file is encoded as a record with one field for each component AVP. Equivalently, a message can also be encoded as a list whose head is the atom-valued message name (as specified in the relevant dictionary file) and whose tail is a list of `{AvpName, AvpValue}` pairs.

Another list-valued representation allows a message to be specified as a list whose head is a *header()* and whose tail is an *avp()* list. This representation is used by diameter itself when relaying requests as directed by the return value of a *handle_request/3* callback. It differs from the other other two in that it bypasses the checks for messages that do not agree with their definitions in the dictionary in question: messages are sent exactly as specified.

`packet() = #diameter_packet{}`

A container for incoming and outgoing Diameter messages. Fields have the following types.

`header = header() | undefined`

The Diameter header of the message. Can be (and typically should be) `undefined` for an outgoing message in a non-relay application, in which case diameter provides appropriate values.

`avps = [avp()] | undefined`

The AVPs of the message. Ignored for an outgoing message if the `msg` field is set to a value other than `undefined`.

`msg = message() | undefined`

The incoming/outgoing message. For an incoming message, a record if the message can be decoded in a non-relay application, `undefined` otherwise. For an outgoing message, setting a `[header() | avp()]` list is equivalent to setting the `header` and `avps` fields to the corresponding values.

> ### Warning:
>
> A record-valued `msg` field does **not** imply an absence of decode errors. The `errors` field should also be examined.

`bin = binary()`

The incoming message prior to encode or the outgoing message after encode.

`errors = [5000..5999 | {5000..5999, avp()}]`

Errors detected at decode of an incoming message, as identified by a corresponding 5xxx series Result-Code (Permanent Failures). For an incoming request, these should be used to formulate an appropriate answer as documented for the *handle_request/3* callback in *diameter_app(3)*. For an incoming answer, the *diameter:application_opt()* `answer_errors` determines the behaviour.

`transport_data = term()`

An arbitrary term of meaning only to the transport process in question, as documented in *diameter_transport(3)*.

Exports

`decode(Mod, Bin) -> Pkt`

Types:

`Mod = dictionary()`
`Bin = binary()`
`Pkt = packet()`

Decode a Diameter message.

encode(Mod, Msg) -> Pkt

Types:

Mod = *dictionary()*

Msg = *message() | packet()*

Pkt = *packet()*

Encode a Diameter message.

SEE ALSO

diameterc(1), *diameter_app(3)*, *diameter_dict(4)*, *diameter_make(3)*

diameter_dict

Name

A diameter service, as configured with *diameter:start_service/2*, specifies one or more supported Diameter applications. Each Diameter application specifies a dictionary module that knows how to encode and decode its messages and AVPs. The dictionary module is in turn generated from a file that defines these messages and AVPs. The format of such a file is defined in *FILE FORMAT* below. Users add support for their specific applications by creating dictionary files, compiling them to Erlang modules using either *diameterc(1)* or *diameter_make(3)* and configuring the resulting dictionaries modules on a service.

Dictionary module generation also results in a hrl file that defines records for the messages and Grouped AVPs defined by the dictionary, these records being what a user of the diameter application sends and receives, modulo other possible formats as discussed in *diameter_app(3)*. These records and the underlying Erlang data types corresponding to Diameter data formats are discussed in *MESSAGE RECORDS* and *DATA TYPES* respectively. The generated hrl also contains macro definitions for the possible values of AVPs of type Enumerated.

The diameter application includes five dictionary modules corresponding to applications defined in section 2.4 of RFC 6733: `diameter_gen_base_rfc3588` and `diameter_gen_base_rfc6733` for the Diameter Common Messages application with application identifier 0, `diameter_gen_accounting` (for RFC 3588) and `diameter_gen_acct_rfc6733` for the Diameter Base Accounting application with application identifier 3 and `diameter_gen_relay` the Relay application with application identifier 0xFFFFFFFF.

The Common Message and Relay applications are the only applications that diameter itself has any specific knowledge of. The Common Message application is used for messages that diameter itself handles: CER/CEA, DWR/DWA and DPR/DPA. The Relay application is given special treatment with regard to encode/decode since the messages and AVPs it handles are not specifically defined.

FILE FORMAT

A dictionary file consists of distinct sections. Each section starts with a tag followed by zero or more arguments and ends at the the start of the next section or end of file. Tags consist of an ampersand character followed by a keyword and are separated from their arguments by whitespace. Whitespace separates individual tokens but is otherwise insignificant.

The tags, their arguments and the contents of each corresponding section are as follows. Each section can occur multiple times unless otherwise specified. The order in which sections are specified is unimportant.

`@id Number`

Defines the integer Number as the Diameter Application Id of the application in question. Can occur at most once and is required if the dictionary defines `@messages`. The section has empty content.

The Application Id is set in the Diameter Header of outgoing messages of the application, and the value in the header of an incoming message is used to identify the relevant dictionary module.

Example:

```
@id 16777231
```

`@name Mod`

Defines the name of the generated dictionary module. Can occur at most once and defaults to the name of the dictionary file minus any extension if unspecified. The section has empty content.

Note that a dictionary module should have a unique name so as not collide with existing modules in the system.

Example:

```
@name etsi_e2
```

`@prefix Name`

Defines Name as the prefix to be added to record and constant names (followed by a `'_'` character) in the generated dictionary module and hrl. Can occur at most once. The section has empty content.

A prefix is optional but can be be used to disambiguate between record and constant names resulting from similarly named messages and AVPs in different Diameter applications.

Example:

```
@prefix etsi_e2
```

`@vendor Number Name`

Defines the integer Number as the the default Vendor-Id of AVPs for which the V flag is set. Name documents the owner of the application but is otherwise unused. Can occur at most once and is required if an AVP sets the V flag and is not otherwise assigned a Vendor-Id. The section has empty content.

Example:

```
@vendor 13019 ETSI
```

`@avp_vendor_id Number`

Defines the integer Number as the Vendor-Id of the AVPs listed in the section content, overriding the `@vendor` default. The section content consists of AVP names.

Example:

```
@avp_vendor_id 2937

WWW-Auth
Domain-Index
Region-Set
```

`@inherits Mod`

Defines the name of a dictionary module containing AVP definitions that should be imported into the current dictionary. The section content consists of the names of those AVPs whose definitions should be imported from the dictionary, an empty list causing all to be imported. Any listed AVPs must not be defined in the current dictionary and it is an error to inherit the same AVP from more than one dictionary.

Note that an inherited AVP that sets the V flag takes its Vendor-Id from either `@avp_vendor_id` in the inheriting dictionary or `@vendor` in the inherited dictionary. In particular, `@avp_vendor_id` in the inherited dictionary is ignored. Inheriting from a dictionary that specifies the required `@vendor` is equivalent to using `@avp_vendor_id` with a copy of the dictionary's definitions but the former makes for easier reuse.

All dictionaries should typically inherit RFC 6733 AVPs from `diameter_gen_base_rfc6733`.

Example:

```
@inherits diameter_gen_base_rfc6733
```

`@avp_types`

Defines the name, code, type and flags of individual AVPs. The section consists of definitions of the form

`Name Code Type Flags`

where Code is the integer AVP code, Type identifies an AVP Data Format as defined in section *DATA TYPES* below, and Flags is a string of V, M and P characters indicating the flags to be set on an outgoing AVP or a single `'-'` (minus) character if none are to be set.

Example:

```
@avp_types

Location-Information   350  Grouped     MV
Requested-Information  353  Enumerated   V
```

> **Warning:**
>
> The P flag has been deprecated by RFC 6733.

`@custom_types Mod`

Specifies AVPs for which module Mod provides encode/decode functions. The section contents consists of AVP names. For each such name, `Mod:Name(encode|decode, Type, Data)` is expected to provide encode/decode for values of the AVP, where Name is the name of the AVP, Type is it's type as declared in the `@avp_types` section of the dictionary and Data is the value to encode/decode.

Example:

```
@custom_types rfc4005_avps

Framed-IP-Address
```

`@codecs Mod`

Like `@custom_types` but requires the specified module to export `Mod:Type(encode|decode, Name, Data)` rather than `Mod:Name(encode|decode, Type, Data)`.

Example:

```
@codecs rfc4005_avps

Framed-IP-Address
```

`@messages`

Defines the messages of the application. The section content consists of definitions of the form specified in section 3.2 of RFC 6733, "Command Code Format Specification".

```
@messages

RTR ::= < Diameter Header: 287, REQ, PXY >
        < Session-Id >
        { Auth-Application-Id }
        { Auth-Session-State }
        { Origin-Host }
        { Origin-Realm }
        { Destination-Host }
        { SIP-Deregistration-Reason }
        [ Destination-Realm ]
        [ User-Name ]
      * [ SIP-AOR ]
      * [ Proxy-Info ]
      * [ Route-Record ]
      * [ AVP ]

RTA ::= < Diameter Header: 287, PXY >
        < Session-Id >
        { Auth-Application-Id }
        { Result-Code }
        { Auth-Session-State }
        { Origin-Host }
        { Origin-Realm }
        [ Authorization-Lifetime ]
        [ Auth-Grace-Period ]
        [ Redirect-Host ]
        [ Redirect-Host-Usage ]
        [ Redirect-Max-Cache-Time ]
      * [ Proxy-Info ]
      * [ Route-Record ]
      * [ AVP ]
```

`@grouped`

Defines the contents of the AVPs of the application having type Grouped. The section content consists of definitions of the form specified in section 4.4 of RFC 6733, "Grouped AVP Values".

Example:

```
@grouped

SIP-Deregistration-Reason ::= < AVP Header: 383 >
                              { SIP-Reason-Code }
                              [ SIP-Reason-Info ]
                            * [ AVP ]
```

Specifying a Vendor-Id in the definition of a grouped AVP is equivalent to specifying it with `@avp_vendor_id`.

`@enum Name`

Defines values of AVP Name having type Enumerated. Section content consists of names and corresponding integer values. Integer values can be prefixed with 0x to be interpreted as hexadecimal.

Note that the AVP in question can be defined in an inherited dictionary in order to introduce additional values to an enumeration otherwise defined in another dictionary.

Example:

```
@enum SIP-Reason-Code

PERMANENT_TERMINATION    0
NEW_SIP_SERVER_ASSIGNED  1
SIP_SERVER_CHANGE        2
REMOVE_SIP_SERVER        3
```

`@end`

Causes parsing of the dictionary to terminate: any remaining content is ignored.

Comments can be included in a dictionary file using semicolon: characters from a semicolon to end of line are ignored.

MESSAGE RECORDS

The hrl generated from a dictionary specification defines records for the messages and grouped AVPs defined in `@messages` and `@grouped` sections. For each message or grouped AVP definition, a record is defined whose name is the message or AVP name, prefixed with any dictionary prefix defined with `@prefix`, and whose fields are the names of the AVPs contained in the message or grouped AVP in the order specified in the definition in question. For example, the grouped AVP

```
SIP-Deregistration-Reason ::= < AVP Header: 383 >
                              { SIP-Reason-Code }
                              [ SIP-Reason-Info ]
                            * [ AVP ]
```

will result in the following record definition given an empty prefix.

```
-record('SIP-Deregistration-Reason' {'SIP-Reason-Code',
                                     'SIP-Reason-Info',
                                     'AVP'}).
```

The values encoded in the fields of generated records depends on the type and number of times the AVP can occur. In particular, an AVP which is specified as occurring exactly once is encoded as a value of the AVP's type while an AVP with any other specification is encoded as a list of values of the AVP's type. The AVP's type is as specified in the AVP definition, the RFC 6733 types being described below.

DATA TYPES

The data formats defined in sections 4.2 ("Basic AVP Data Formats") and 4.3 ("Derived AVP Data Formats") of RFC 6733 are encoded as values of the types defined here. Values are passed to *diameter:call/4* in a request record when sending a request, returned in a resulting answer record and passed to a *handle_request/3* callback upon reception of an incoming request.

In cases in which there is a choice between string() and binary() types for OctetString() and derived types, the representation is determined by the value of *diameter:service_opt() string_decode*.

Basic AVP Data Formats

```
OctetString() = string() | binary()
Integer32()   = -2147483647..2147483647
Integer64()   = -9223372036854775807..9223372036854775807
Unsigned32()  = 0..4294967295
```

```
Unsigned64()  = 0..18446744073709551615
Float32()     = '-infinity' | float() | infinity
Float64()     = '-infinity' | float() | infinity
Grouped()     = record()
```

On encode, an OctetString() can be specified as an iolist(), excessively large floats (in absolute value) are equivalent to `infinity` or `'-infinity'` and excessively large integers result in encode failure. The records for grouped AVPs are as discussed in the previous section.

Derived AVP Data Formats

```
Address() = OctetString()
          | tuple()
```

On encode, an OctetString() IPv4 address is parsed in the usual x.x.x.x format while an IPv6 address is parsed in any of the formats specified by section 2.2 of RFC 2373, "Text Representation of Addresses". An IPv4 tuple() has length 4 and contains values of type 0..255. An IPv6 tuple() has length 8 and contains values of type 0..65535. The tuple representation is used on decode.

```
Time() = {date(), time()}

where

  date() = {Year, Month, Day}
  time() = {Hour, Minute, Second}

  Year   = integer()
  Month  = 1..12
  Day    = 1..31
  Hour   = 0..23
  Minute = 0..59
  Second = 0..59
```

Additionally, values that can be encoded are limited by way of their encoding as four octets as required by RFC 6733 with the required extension from RFC 2030. In particular, only values between `{{1968,1,20},{3,14,8}}` and `{{2104,2,26},{9,42,23}}` (both inclusive) can be encoded.

```
UTF8String() = [integer()] | binary()
```

List elements are the UTF-8 encodings of the individual characters in the string. Invalid codepoints will result in encode/decode failure. On encode, a UTF8String() can be specified as a binary, or as a nested list of binaries and codepoints.

```
DiameterIdentity() = OctetString()
```

A value must have length at least 1.

```
DiameterURI() = OctetString()
              | #diameter_URI{type = Type,
                              fqdn = FQDN,
```

```
                              port = Port,
                              transport = Transport,
                              protocol  = Protocol}

where

  Type = aaa | aaas
  FQDN = OctetString()
  Port = integer()
  Transport = sctp | tcp
  Protocol  = diameter | radius | 'tacacs+'
```

On encode, fields port, transport and protocol default to 3868, sctp and diameter respectively. The grammar of an OctetString-valued DiameterURI() is as specified in section 4.3 of RFC 6733. The record representation is used on decode.

```
Enumerated() = Integer32()
```

On encode, values can be specified using the macros defined in a dictionary's hrl file.

```
IPFilterRule()  = OctetString()
QoSFilterRule() = OctetString()
```

Values of these types are not currently parsed by diameter.

SEE ALSO

diameterc(1), *diameter(3)*, *diameter_app(3)*, *diameter_codec(3)*, *diameter_make(3)*

diameter_make

Erlang module

The function *codec/2* is used to compile a diameter *dictionary file* into Erlang source. The resulting source implements the interface diameter requires to encode and decode the dictionary's messages and AVPs.

The utility *diametercc(1)* provides an alternate compilation interface.

Exports

`codec(File :: iolist() | binary(), [Opt]) -> ok | {ok, [Out]} | {error, Reason}`

Compile a single dictionary file. The input `File` can be either a path or a literal dictionary, the occurrence of newline (ascii NL) or carriage return (ascii CR) identifying the latter. `Opt` determines the format of the results and whether they are written to file or returned, and can have the following types.

`parse | forms | erl | hrl`

Specifies an output format. Whether the output is returned or written to file depends on whether or not option `return` is specified. When written to file, the resulting file(s) will have extensions `.D`, `.F`, `.erl`, and `.hrl` respectively, basenames defaulting to `dictionary` if the input dictionary is literal and does not specify *`@name`*. When returned, results are in the order of the corresponding format options. Format options default to `erl` and `hrl` (in this order) if unspecified.

The `parse` format is an internal representation that can be passed to *flatten/1* and *format/1*, while the `forms` format can be passed to *compile:forms/2*. The `erl` and `hrl` formats are returned as iolists.

`{include, string()}`

Prepend the specified directory to the code path. Use to point at beam files compiled from inherited dictionaries, *`@inherits`* in a dictionary file creating a beam dependency, not an erl/hrl dependency.

Multiple `include` options can be specified.

`{outdir, string()}`

Write generated source to the specified directory. Defaults to the current working directory. Has no effect if option `return` is specified.

`return`

Return results in a `{ok, [Out]}` tuple instead of writing to file and returning `ok`.

`{name|prefix, string()}`

Transform the input dictionary before compilation, setting *`@name`* or *`@prefix`* to the specified string.

`{inherits, string()}`

Transform the input dictionary before compilation, appending *`@inherits`* of the specified string.

Two forms have special meaning:

```
{inherits, "-"}
{inherits, "Prev/Mod"}
```

The first has the effect of clearing any previous inherits, the second of replacing a previous inherits of `Prev` to one of `Mod`. This allows the semantics of the input dictionary to be changed without modifying the file itself.

Multiple `inherits` options can be specified.

Note that a dictionary's *`@name`*, together with the `outdir` option, determine the output paths when the `return` option is not specified. The *`@name`* of a literal input dictionary defaults to `dictionary`.

A returned error reason can be converted into a readable string using *format_error/1*.

`format(Parsed) -> iolist()`

Turns a parsed dictionary, as returned by *codec/2*, back into the dictionary format.

`flatten(Parsed) -> term()`

Reconstitute a parsed dictionary, as returned by *codec/2*, without using *`@inherits`*. That is, construct an equivalent dictionary in which all AVP's are definined in the dictionary itself. The return value is also a parsed dictionary.

`format_error(Reason) -> string()`

Turn an error reason returned by *codec/2* into a readable string.

BUGS

Unrecognized options are silently ignored.

SEE ALSO

diameterc(1), *diameter_dict(4)*

diameter_transport

Erlang module

A module specified as a `transport_module` to *diameter:add_transport/2* must implement the interface documented here. The interface consists of a function with which diameter starts a transport process and a message interface with which the transport process communicates with the process that starts it (aka its parent).

DATA TYPES

`message() = binary() | diameter_codec:packet()`

A Diameter message as passed over the transport interface.

For an inbound message from a transport process, a *diameter_codec:packet()* must contain the received message in its `bin` field. In the case of an inbound request, any value set in the `transport_data` field will passed back to the transport module in the corresponding answer message, unless the sender supplies another value.

For an outbound message to a transport process, a *diameter_codec:packet()* has a value other than `undefined` in its `transport_data` field and has the binary() to send in its `bin` field.

Exports

`Mod:start({Type, Ref}, Svc, Config) -> {ok, Pid} | {ok, Pid, LAddrs} | {error, Reason}`

Types:

```
Type = connect | accept
Ref = diameter:transport_ref()
Svc = #diameter_service{}
Config = term()
Pid = pid()
LAddrs = [inet:ip_address()]
Reason = term()
```

Start a transport process. Called by diameter as a consequence of a call to *diameter:add_transport/2* in order to establish or accept a transport connection respectively. A transport process maintains a connection with a single remote peer.

`Type` indicates whether the transport process in question is being started for a connecting (`Type=connect`) or listening (`Type=accept`) transport. In the latter case, transport processes are started as required to accept connections from multiple peers.

Ref is the value that was returned from the call to *diameter:add_transport/2* that has lead to starting of a transport process.

`Svc` contains capabilities passed to *diameter:start_service/2* and *diameter:add_transport/2*, values passed to the latter overriding those passed to the former.

`Config` is as passed in `transport_config` tuple in the *diameter:transport_opt()* list passed to *diameter:add_transport/2*.

The start function should use the `Host-IP-Address` list in `Svc` and/or `Config` to select and return an appropriate list of local IP addresses. In the connecting case, the local address list can instead be communicated in a `connected` message (see *MESSAGES* below) following connection establishment. In either case, the local address list is used

to populate `Host-IP-Address` AVPs in outgoing capabilities exchange messages if `Host-IP-Address` is unspecified.

A transport process must implement the message interface documented below. It should retain the pid of its parent, monitor the parent and terminate if it dies. It should not link to the parent. It should exit if its transport connection with its peer is lost.

MESSAGES

All messages sent over the transport interface are of the form `{diameter, term()}`.

A transport process can expect messages of the following types from its parent.

`{diameter, {send, message()}}`

An outbound Diameter message.

`{diameter, {close, Pid}}`

A request to terminate the transport process after having received DPA in response to DPR. The transport process should exit. `Pid` is the pid() of the parent process.

`{diameter, {tls, Ref, Type, Bool}}`

Indication of whether or not capabilities exchange has selected inband security using TLS. `Ref` is a reference() that must be included in the `{diameter, {tls, Ref}}` reply message to the transport's parent process (see below). `Type` is either `connect` or `accept` depending on whether the process has been started for a connecting or listening transport respectively. `Bool` is a boolean() indicating whether or not the transport connection should be upgraded to TLS.

If TLS is requested (`Bool=true`) then a connecting process should initiate a TLS handshake with the peer and an accepting process should prepare to accept a handshake. A successful handshake should be followed by a `{diameter, {tls, Ref}}` message to the parent process. A failed handshake should cause the process to exit.

This message is only sent to a transport process over whose `Inband-Security-Id` configuration has indicated support for TLS.

A transport process should send messages of the following types to its parent.

`{diameter, {self(), connected}}`

Inform the parent that the transport process with `Type=accept` has established a connection with the peer. Not sent if the transport process has `Type=connect`.

`{diameter, {self(), connected, Remote}}`
`{diameter, {self(), connected, Remote, [LocalAddr]}}`

Inform the parent that the transport process with `Type=connect` has established a connection with a peer. Not sent if the transport process has `Type=accept`. `Remote` is an arbitrary term that uniquely identifies the remote endpoint to which the transport has connected. A `LocalAddr` list has the same semantics as one returned from *start/3*.

`{diameter, {recv, message()}}`

An inbound Diameter message.

`{diameter, {tls, Ref}}`

Acknowledgment of a successful TLS handshake. `Ref` is the reference() received in the `{diameter, {tls, Ref, Type, Bool}}` message in response to which the reply is sent. A transport must exit if a handshake is not successful.

SEE ALSO

diameter_tcp(3), diameter_sctp(3)

diameter_tcp

Erlang module

This module implements diameter transport over TCP using *gen_tcp(3)*. It can be specified as the value of a `transport_module` option to *diameter:add_transport/2* and implements the behaviour documented in *diameter_transport(3)*. TLS security is supported, either as an upgrade following capabilities exchange or at connection establishment.

Note that the ssl application is required for TLS and must be started before configuring TLS capability on diameter transports.

Exports

`start({Type, Ref}, Svc, [Opt]) -> {ok, Pid} | {ok, Pid, [LAddr]} | {error, Reason}`

Types:

```
Type = connect | accept
Ref = diameter:transport_ref()
Svc = #diameter_service{}
Opt = OwnOpt | SslOpt | TcpOpt
Pid = pid()
LAddr = inet:ip_address()
Reason = term()
OwnOpt = {raddr, inet:ip_address()} | {rport, integer()} | {accept, Match}
| {port, integer()} | {fragment_timer, infinity | 0..16#FFFFFFFF}
SslOpt = {ssl_options, true | list()}
TcpOpt = term()
Match = inet:ip_address() | string() | [Match]
```

The start function required by *diameter_transport(3)*.

Options `raddr` and `rport` specify the remote address and port for a connecting transport and are not valid for a listening transport.

Option `accept` specifies remote addresses for a listening transport and is not valid for a connecting transport. If specified, a remote address that does not match one of the specified addresses causes the connection to be aborted. Multiple `accept` options can be specified. A string-valued `Match` that does not parse as an address is interpreted as a regular expression.

Option `ssl_options` must be specified for a transport that should support TLS: a value of `true` results in a TLS handshake immediately upon connection establishment while `list()` specifies options to be passed to *ssl:connect/2* or *ssl:ssl_accept/2* after capabilities exchange if TLS is negotiated.

Option `fragment_timer` specifies the timeout, in milliseconds, of a timer used to flush messages from the incoming byte stream even if the number of bytes indicated in the Message Length field of its Diameter Header have not yet been accumulated: such a message is received over the transport interface after two successive timeouts without the reception of additional bytes. Defaults to 1000.

Remaining options are any accepted by *ssl:connect/3* or *gen_tcp:connect/3* for a connecting transport, or *ssl:listen/2* or *gen_tcp:listen/2* for a listening transport, depending on whether or not `{ssl_options, true}` has been specified. Options `binary`, `packet` and `active` cannot be specified. Also, option `port` can be specified for a listening

transport to specify the local listening port, the default being the standardized 3868 if unspecified. Note that the option `ip` specifies the local address.

An `ssl_options` list must be specified if and only if the transport in question has set `Inband-Security-Id` to 1 (`TLS`), as specified to either *diameter:start_service/2* or *diameter:add_transport/2*, so that the transport process will receive notification of whether or not to commence with a TLS handshake following capabilities exchange. Failing to specify an options list on a TLS-capable transport for which TLS is negotiated will cause TLS handshake to fail. Failing to specify TLS capability when `ssl_options` has been specified will cause the transport process to wait for a notification that will not be forthcoming, which will eventually cause the RFC 3539 watchdog to take down the connection.

If an `ip` option is not specified then the first element of a non-empty `Host-IP-Address` list in `Svc` provides the local IP address. If neither is specified then the default address selected by *gen_tcp(3)* is used. In all cases, the selected address is either returned from *start/3* or passed in a `connected` message over the transport interface.

SEE ALSO

diameter(3), *diameter_transport(3)*, *gen_tcp(3)*, *inet(3)*, *ssl(3)*

diameter_sctp

Erlang module

This module implements diameter transport over SCTP using *gen_sctp(3)*. It can be specified as the value of a transport_module option to *diameter:add_transport/2* and implements the behaviour documented in *diameter_transport(3)*.

Exports

start({Type, Ref}, Svc, [Opt]) -> {ok, Pid, [LAddr]} | {error, Reason}

Types:

Type = connect | accept
Ref = *diameter:transport_ref()*
Svc = #diameter_service{}
Opt = OwnOpt | SctpOpt
Pid = pid()
LAddr = *inet:ip_address()*
Reason = term()
OwnOpt = {raddr, *inet:ip_address()*} | {rport, integer()} | {accept, Match}
SctpOpt = term()
Match = *inet:ip_address()* | string() | [Match]

The start function required by *diameter_transport(3)*.

Options `raddr` and `rport` specify the remote address and port for a connecting transport and not valid for a listening transport: the former is required while latter defaults to 3868 if unspecified. Multiple `raddr` options can be specified, in which case the connecting transport in question attempts each in sequence until an association is established.

Option `accept` specifies remote addresses for a listening transport and is not valid for a connecting transport. If specified, a remote address that does not match one of the specified addresses causes the association to be aborted. Multiple `accept` options can be specified. A string-valued `Match` that does not parse as an address is interpreted as a regular expression.

Remaining options are any accepted by *gen_sctp:open/1*, with the exception of options `mode`, `binary`, `list`, `active` and `sctp_events`. Note that options `ip` and `port` specify the local address and port respectively.

Multiple `ip` options can be specified for a multihomed peer. If none are specified then the values of `Host-IP-Address` in the `diameter_service` record are used. (In particular, one of these must be specified.) Option `port` defaults to 3868 for a listening transport and 0 for a connecting transport.

Warning:

An insufficiently large receive buffer may result in a peer having to resend incoming messages: set the *inet(3)* option `recbuf` to increase the buffer size.

An insufficiently large send buffer may result in outgoing messages being discarded: set the *inet(3)* option `sndbuf` to increase the buffer size.

The `transport_data` field of record `diameter_packet` is used to communicate the stream on which an inbound message has been received, or on which an outbound message should be sent. The value will be of the form `{stream, Id}` for an inbound message passed to a *handle_request/3* or *handle_answer/4* callback. For an outbound message, `{outstream, Id}` in the return value of *handle_request/3* or *prepare_retransmit/3* sets the outbound stream, the stream id being interpreted modulo the number of outbound streams. Any other value, or not setting a value, causes successive such sends to cycle though all outbound streams.

SEE ALSO

diameter(3), *diameter_transport(3)*, *gen_sctp(3)*, *inet(3)*