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DIAMETER
Secure Proxying

Status of this Memo

Abstract

The DIAMETER base protocol [2] allows for secure communication between two DIAMETER nodes, and introduces the concept of proxying through the Proxy-State AVP. However, the base protocol only allows for hop-by-hop security, and the work done in the ROAMOPS WG [8] shows that support for end-to-end security through proxies. This document describes the extensions necessary to provide for secure

communication through DIAMETER proxies.

Table of Contents

1.0 Introduction

Many services, including ROAMOPS and MobileIP, have a requirement for DIAMETER Server to proxy a request to another DIAMETER Server. The concept of proxying AAA requests was introduced by RADIUS and has been in use for many years.

The DIAMETER base protocol [2] does provide the basic capability for proxying, but only defines hop-by-hop security, which has some known security flaws. Specifically a fraudulent proxy server can modify some portions of an AAA request in order to make the next hop improperly believe that some services were rendered. For example, a DIAMETER Proxy Server could modify an accounting request, such as the number of bytes that a user transfered, and the end system would have no way of determining that this change occured.

This specification contains the extensions necessary to DIAMETER to allow for end-to-end AVP integrity and privacy. The document also describes a method that DIAMETER can provide referal services to clients.

The Extension number for this draft is two (2). This value is used in the Extension-Id AVP as defined in [2].

1.1 Copyright Statement

1.2 Requirements language

In this document, the key words "MAY", "MUST, "MUST NOT", "optional", "recommended", "SHOULD", and "SHOULD NOT", are to be interpreted as described in [13].

1.3 Changes in version -02

The following changes were made in version 02 of the document:

- New title

- A good cleanup of the abstract and the introduction.

- Fixed up text in section 3.2 that stated that all AVPs with the 'P' disabled were protected. This should have stated enabled.

- Added Section 2 which describes the extended AVP Header Format.

- Moved the Proxy State AVP to the base protocol.

- Changed the description of the Digital-Signature AVP.

- The Next-Hop AVP now requires a preceeding Digital-Signature AVP instead of a Host-IP-Address AVP. This change was necessary since the base protocol does not explicitely state that the Host-IP-Address AVP may appear multiple times in a single message. Such a change would be a big departure from the current RADIUS model where the Host-IP-Address contains the IP address of the originator of the message, not the address of intermediate hops.

- Fixed various references to sections that were incorrect.

- Added clarification about the use of ICV and Digital Signatures within a single message.

- Updated the AVP Header flags.

- Re-wrote a good portion of section 4.1 ...

- ... well, re-wrote a good portion of all everything in section 4.

- Added a reference to RFC 2459 (x.509 certs)

- Added an IANA Considerations section.

1.3 Changes in version -03

The following changes were made in version 03 of the document:

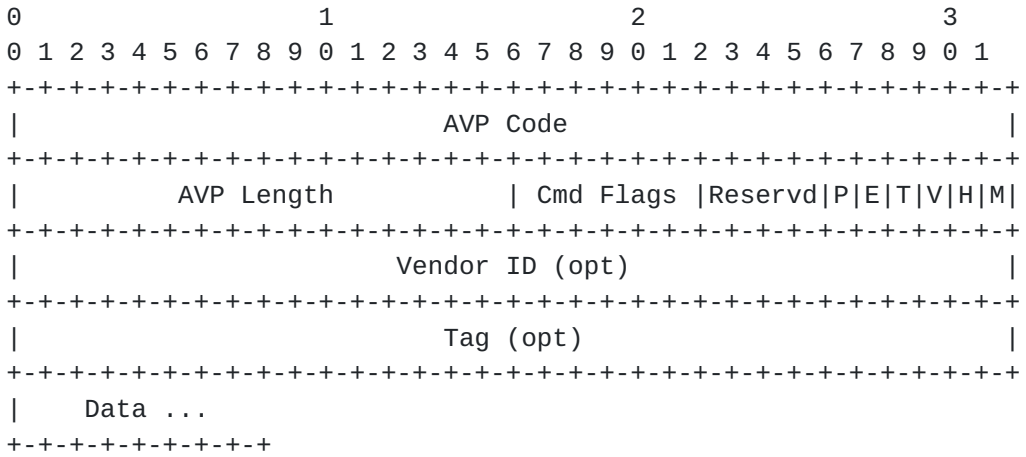
- Removed the DDR and DDA Commands. The new base protocol defines an error message that allows a broker to return a redirect indication. This new method really simplifies the protocol.

- Changed the AVP Command Code for Next-Hop from 278 to 290.

2.0 Extended AVP Format

The DIAMETER Proxy specification introduces a new bit in the AVP flags field of the AVP Header. The following AVP header is used when proxy support is enabled.

The attribute format is shown below and MUST be sent in network byte order.



Command Flags

All Command Codes defined in this spec MUST set all bits in this field to zero (0).

AVP Flags

The AVP Flags field informs the DIAMETER host how each attribute must be handled.

The 'P' bit, known as the protected AVP bit, is used to indicate whether the AVP is protected by a Digital Signature AVP. When set, the AVP is protected and the contents cannot be changed by a DIAMETER proxy server. An AVP MUST NOT have both the 'P' and the 'H' bits set simultaneously, since the 'H' bit implies that the AVP will change on a hop-by-hop basis, and the 'P' requires that the AVP NOT change along a proxy chain.

Note that unless noted, the 'P' bit can be set on any DIAMETER AVP. The Proxy-State AVP MUST not have the 'P' bit set since this AVP will be removed at each hop. Any other AVP that have similar properties (e.g. it will be removed or modified at each hop) MUST NOT have the 'P' bit enabled.

When the 'E' bit is enabled it indicates that the AVP data is encrypted using end-to-end encryption.

Note that the User-Name AVP [2] MUST NOT have the 'E' bit set since intermediate proxies require the domain information in order to determine the target proxy.

3.0 DIAMETER AVPs

This section will define the mandatory AVPs which MUST be supported by all DIAMETER implementations claiming support for this specification.

The following AVPs are defined in this document:

Attribute Name	Attribute Code	Definition in Section
Digital-Signature	260	3.1
X509-Certificate	264	3.2
X509-Certificate-URL	265	3.3
Next-Hop	290	3.4

3.1 Digital-Signature

Description

The Digital-Signature AVP is used to provide for authentication, integrity and non-repudiation of DIAMETER AVPs. A DIAMETER entity adding AVPs to a message that must be protected by the Digital Signature MUST ensure that they apprear prior to this AVP. Two are two exceptions to this rule. The Integrity-Check-Value AVP, which MUST appear after the Digital-Signature AVP, since it is stripped at each hop. Any AVP that has the 'H' bit set CANNOT be included in the Digital-Signature. Any other AVP that is stripped at each hop (e.g. Proxy-State AVP) also MUST NOT be protected by the Digital-Signature AVP. AVPs are marked as being protected by enabling their 'P' bit.

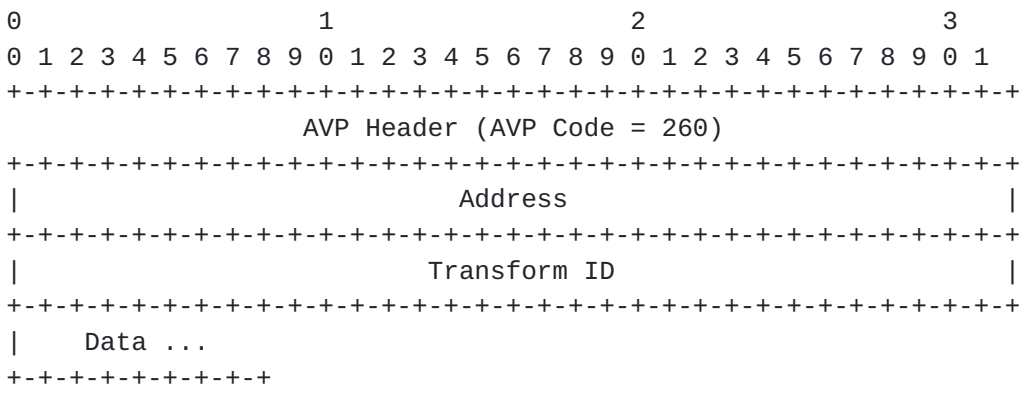
A DIAMETER node adding a Digital-Signature to a message that already has such an AVP MUST sign all of the existing AVP that have the 'P' bit set in addition to the new protected AVPs added.

It is imperative that Proxy servers NOT change the order of the AVPs with the 'P' bit set, otherwise the signature verification would fail. Proxy servers also MUST NOT remove, add, or change any AVP that has the 'P' bit set.

The Digital Signature also includes the DIAMETER header. However, when computing the signature, it is necessary for the header's length, Ns and Nr fields to be set to zero (0). This is necessary since the message size and windowing information may change from one proxy server to another as AVPs are added and others are deleted.

The Digital-Signature is generated in the method described in section 4.4.1.

All DIAMETER implementations supporting this extension MUST support this AVP.



AVP Length
The length of this attribute MUST be at least 17.

AVP Flags
The 'M' bit MUST be set. The 'P', 'V', 'H' and 'T' bits MUST NOT be set.

Address
The Address field contains the IP address of the DIAMETER host which generated the Digital-Signature.

Transform ID
The Transform ID field contains a value that identifies the transform that was used to compute the signature. The following values are defined in this document:

RSA [9]	1

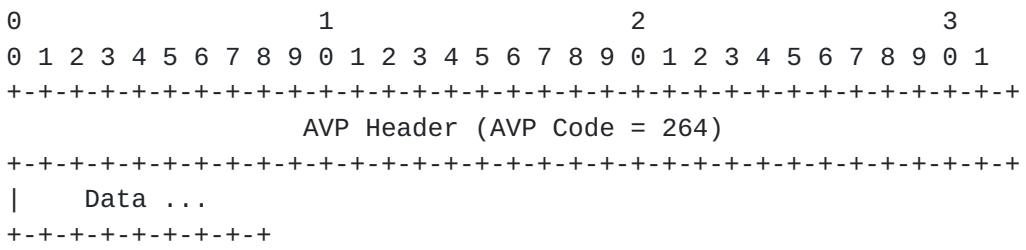
Data
The Data field contains the digital signature of the message up to this AVP.

3.2 X509-Certificate

Description

The X509-Certificate [12] is used in order to send a DIAMETER peer the local system's X.509 certificate chain, which is used in order to validate the Digital-Signature attribute.

Section 4.6 contains more information about the use of certificates.



AVP Flags

The 'M' bit MUST be set. The 'P' bits MAY be set if end to end message integrity is required. The 'V', 'H' and 'T' bits MUST NOT be set.

Data

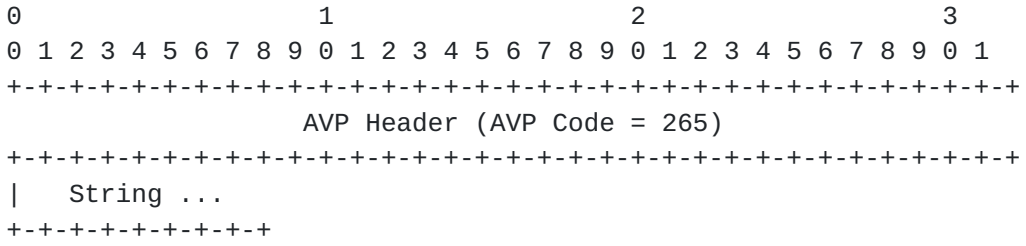
The Data field contains the X.509 Certificate Chain.

3.3 X509-Certificate-URL

Description

The X509-Certificate-URL is used in order to send a DIAMETER peer a URL to the local system's X.509 certificate chain [12], which is used in order to validate the Digital-Signature attribute.

Section 4.6 contains more information about the use of certificates.



AVP Flags

The 'M' bit MUST be set. The 'P' bits MAY be set if end to end message integrity is required. The 'V', 'H' and 'T' bits MUST NOT be set.

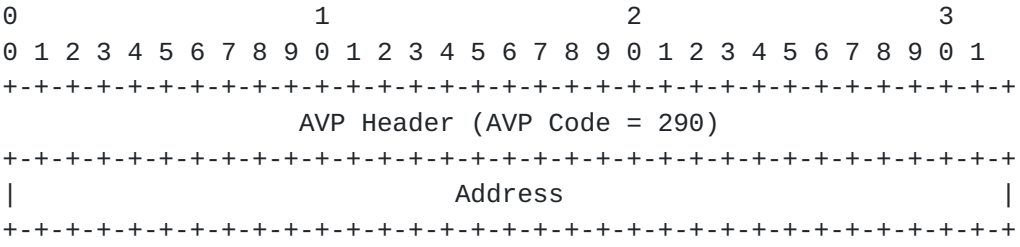
String

The String field contains the X.509 Certificate Chain URL.

3.4 Next-Hop

Description

The Next-Hop AVP MUST preceed a Digital-Signature AVP and is used to validate that a message traversed the proxy chain that was intended. A DIAMETER message with the Next-Hop Address being different than the address found in the preceeding Digital-Signature AVP is considered invalid.



AVP Flags

The 'M' bit and 'P' bits MUST be set. The 'V', 'H' and 'T' bits MUST NOT be set.

Address

This field contains the IP Address of the next DIAMETER Server.

4.0 Protocol Definition

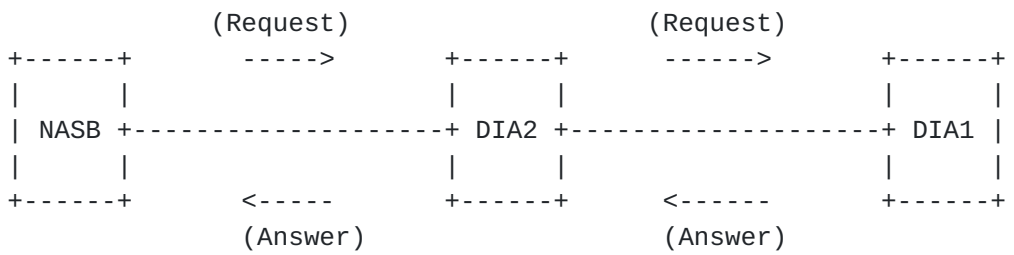
This section will describe how the base protocol works (or is at least an attempt to).

4.1 Feature Advertisement/Discovery

As defined in [2], the Reboot-Ind and Device-Feature-Query messages can be used to inform a peer about locally supported DIAMETER Extensions. In order to advertise support of this extension, the Extension-Id AVP must be transmitted with a value of two (2).

4.2 DIAMETER Secure Proxying

The ROAMOPS specification [11] discusses how RADIUS servers can be arranged in a hierarchical manner, allowing message exchanges across domain boundaries. The specification also describes some security flaws encountered when RADIUS is used in a proxy environment. The DIAMETER extension described in this document introduces end-to-end security, which solves many of the problems encountered when RADIUS is used.



In this example NASB generates a Request that is forwarded to DIA2. The Request contains a Digital-Signature AVP which "protects" all preceeding AVPs bit the 'P' bit set (known as protected AVPs) within the request. All AVPs which may be modified, or removed by intermediate DIAMETRE Proxies MUST NOT have the 'P' bit set. Such AVPs include the Integrity-Check-Value, Proxy-State, etc. Once DIA2 receives the request, it MAY validate the signature in the request to ensure that it was originated by NASB. Verification may not be necessary if the signature was added by a DIAMETER node one hop away since the Integrity-Check-Value (or any whatever security mechanism used for hop-by-hop security) may be sufficient.

The DIA2 Server SHOULD add the Proxy-State AVP [2], which contains opaque data that MUST be present in the response and is used to identify state information related to the request or response. If a Proxy-State AVP is found in the request, it SHOULD be replaced with a locally generated Proxy-State AVP. This means that the Proxy-State AVP cannot have the 'P' bit set. The Server MAY also add other new AVPs to the request. All new AVPs that are protected by the new Digital-Signature AVP MUST have the 'P' bit set, and MUST preceed the Digital-Signature AVP. The message is then forwarded towards the DIA1 server.

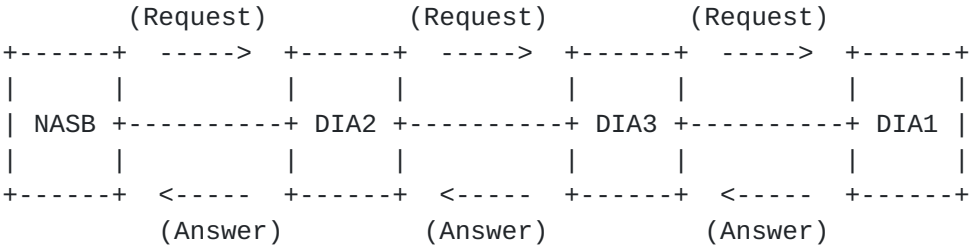
The use of network level encryption, such as IPSec, cannot be used for end-to-end AVP integrity between NASB and DIA1, since all messages are processed by DIA2. What is needed is an application level security mechanism, which is what the Digital-Signature AVP provides. However, Digital-Signatures may not be necessary if the messages do not traverse proxies, unless non-repudiation is required.

This mechanism now provides a method for DIA1 to be able to identify that NAS was the initiator of the request, and that no "critial" AVPs were modified mid-stream by intermediate proxies. Therefore, DIA2 cannot modify any protected AVPs (such as duration of a call, number of bytes transfered, etc). This mechanism also provides the application with the integrity, and non-repudiation, information it may need should it deem it necessary to log such information.

This extension also provides for end-to-end AVP encryption, by using the peer's public key. However, given that asymetric encryption is

very costly, it's use should be minimal.

An attack has been identified in this proposal which allows a malicous man in the middle attack as shown in the following diagram.



In this example, DIA3 traps messages generated from DIA2 towards DIA1, removes the AVPs added by DIA2 and inserts its own AVPs (possibly by trying to convince DIA1 to pay DIA3 for the services). This attack can be prevented by supporting a new Next-Hop AVP. In this case when NASB prepares a request it inserts a protected Next-Hop AVP which contains DIA2's identitity. DIA2 also adds a Next-Hop AVP with DIA1 as the next hop.

This mechanism ensures that a man in the middle cannot alter the message by overriding the previous hop's additions and signature. DIA1 could easily validate the message's path with the use of the Next-Hop AVPs.

4.3 Data Integrity

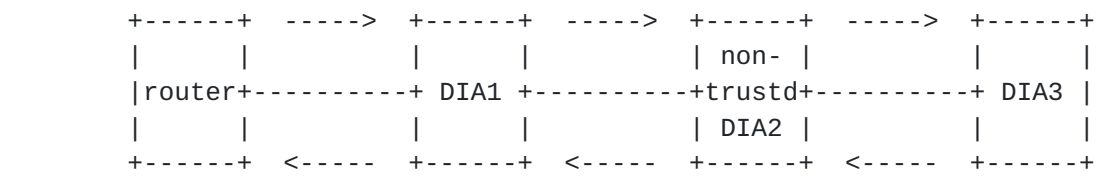
This section will describe how data integrity and non-repudiation is achieved using the Digital-Signature AVP.

Note that the Timestamp and Nonce AVPs MUST be present in the message PRIOR to the Digital-Signature AVPs discussed in this section. The Timestamp AVP provides replay protection and the Nonce AVP provides randomness.

4.3.1 Using Digital Signatures

In the case of a simple peer to peer relationship the use of IPSEC is sufficient for data integrity and confidentiality. However there are instances where a peer must communicate with another peer through the use of a proxy server. IPSEC does not provide a mechanism to protect traffic when two peers must use an intermediary node to communicate at the application layer therefore the Digital-Signature AVP MUST be used.

The following diagram shows an example of a router initiating a DIAMETER message to DIA1. Once DIA1 has finished processing the message it adds its signature and forwards the message to the non-trusted DIA2 proxy server. If DIA2 needs to add any protected AVPs it SHOULD add its digital signature before forwarding the message to DIA3.



Since intermediate DIAMETER proxies may add, or delete unprotected AVPs "en route" towards the final DIAMETER destination, it is necessary for the length, Ns and Nr in the header to be set to zero (0) prior to the signature computation. The fields must be restored once the computation is complete.

The following is an example of a message that include end-to-end security:

```
<DIAMETER Message> ::= <DIAMETER Header>
                       <Command AVP>
                       [<Additional AVPs>]
                       <Next-Hop AVP>
                       <Timestamp AVP>
                       <Nonce AVP>
                       <Digital-Signature AVP>
```

The AVP Header's 'P' bit is used to identify which AVPs are considered protected when applying a digital signature to a DIAMETER message. Protected AVPs cannot be changed "en route" since they are protected by the Digital Signature AVP. All protected AVPs added by a DIAMETER entity MUST appear prior to the new Digital Signature AVP.

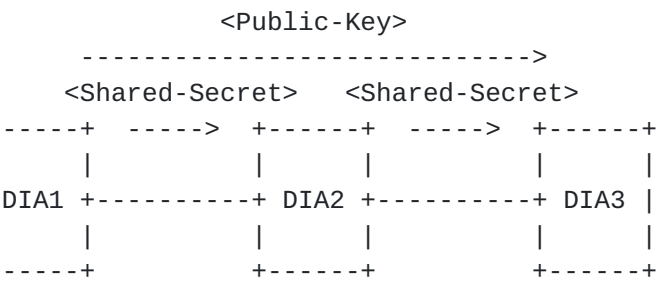
The Next-Hop AVP indicates the intended recipient of the DIAMETER message. When a DIAMETER message is received with a Next-Hop AVP that does not correspond with the address information with the preceeding Digital-Signature AVP, the message MUST be considered invalid and MUST be rejected. The Next-Hop AVP MUST be protected.

The Data field of the Digital-Signature AVP contains the RSA/MD5 signature algorithm as defined in [9].

4.3.2 Using Mixed Data Integrity AVPs

The previous sections described the Integrity-Check-Value and the Digital-Signature AVP. Since the ICV offers hop-by-hop integrity and the digital signature offers end to end integrity, it is possible to use both AVPs within a single DIAMETER message. In fact, the use of the ICV and the Digital-Signature is recommended to provide both types of AVP integrity, which is necessary when messages are proxied. In the event that two peers use an underlying integrity mechanism (e.g. IPSec) for hop-by-hop AVP integrity, the ICV AVP is not necessary and should not be used.

The following diagram provides an example where DIAMETER Server 1 (DIA1) communicates with DIA3 using Digital-Signatures through DIA2. In this example ICVs are used between DIA1 and DIA2 as well as between DIA2 and DIA3.



Using the previous diagram, the following message would be sent between DIA1 and DIA2:

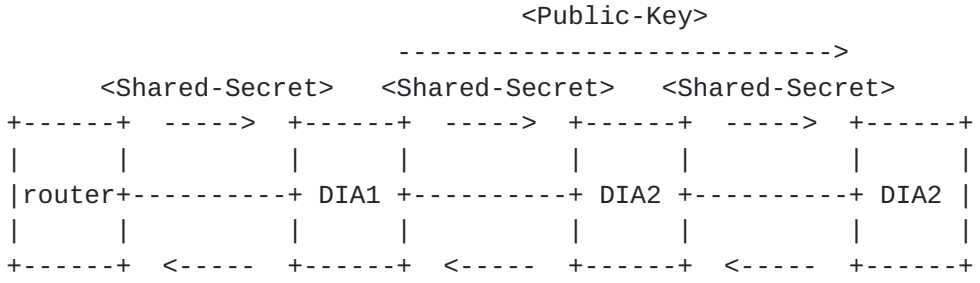
```
<DIAMETER Message> ::= <DIAMETER Header>
                       <Command AVP>
                       [<Additional AVPs>]
                       <Timestamp AVP>
                       <Nonce AVP>
                       <Digital-Signature AVP>
                       <Integrity-Check-Value AVP (DIA1->DIA2)>
```

The following message would be sent between DIA2 and DIA3:

```
<DIAMETER Message> ::= <DIAMETER Header>
                       <Command AVP>
                       [<Additional AVPs>]
                       <Timestamp AVP>
                       <Nonce AVP>
                       <Digital-Signature AVP>
                       <Timestamp AVP>
                       <Nonce AVP>
                       <Integrity-Check-Value AVP (DIA2->DIA3)>
```

Note that in the above example messages the ICV AVP appear after the

Digital-Signature AVP. This is necessary since DIA2 above removes the ICV AVP (DIA1->DIA2) and adds its own ICV AVP (DIA2->DIA3). The ICVs provide hop-by-hop security while the Digital-Signature provides integrity of the message between DIA1 and DIA3.



There are cases, such as in remote access, where the device initiating the DIAMETER request does not have the processing power to generate Digital-Signatures as required by the protocol. In such an arrangement, there normally exists a first hop DIAMETER Server (DIA1) which acts as a proxy to relay the request to the final authenticating DIAMETER server (DIA2). It is valid for the first hop server to remove the Integrity-Check-Value AVP inserted by the router and replace it with a Digital-Signature AVP.

4.4 AVP Encryption with Public Keys

AVP encryption using public keys is much more complex than the previously decribed method, yet it is desirable to use it in cases where the DIAMETER message will be processed by an untrusted intermediate node (proxy).

Public Key encryption SHOULD be supported, however it is permissible for a low powered device initiating the DIAMETER message to use shared secret encryption with the first hop (proxy) DIAMETER server, which would decrypt and encrypt using the Public Key method.

The PK-Encrypted-Data bit MUST only be set if the final DIAMETER host is aware of the sender's public key. This information can be relayed in three different methods as described in section 4.6.

The AVP is encrypted in the method described in [9].

4.5 Public Key Cryptography Support

A DIAMETER peer's public key is required in order to validate a message which includes the the Digital-Signature AVP. There are three possibilities on retrieving public keys:

4.5.1 X509-Certificate

A message which includes a Digital-Signature MAY include the X509-Certificate AVP. Given the size of a typical certificate, this is very wasteful and in most cases DIAMETER peers would cache such information in order to minimize per message processing overhead.

It is however valid for a DIAMETER host to provide its X509-Certificate in certain cases, such as when issuing the Device-Reboot-Indication, or in the Domain-Discovery messages. It is envisioned that the peer would validate and cache the certificate at that time.

4.5.2 X509-Certificate-URL

The X509-Certificate-URL is a method for a DIAMETER host sending a message that includes the Digital-Signature to provide a pointer to its certificate.

Upon receiving such a message a DIAMETER host MAY choose to retrieve the certificate if it is not locally cached. Of course the process of retrieving and validating a certificate is lengthy and will require the initiator of the message to retransmit the request. However once cached the certificate can be used until it expires.

4.5.3 Static Public Key Configuration

Given that using certificates requires a PKI infrastructure which is very costly, it is also possible to use this technology by locally configuring DIAMETER peers' public keys.

Note that in a network involving many DIAMETER proxies this may not scale well.

5.0 IANA Considerations

The numbers for the Command Code AVPs (section 3) is taken from the numbering space defined for Command Codes in [2]. The numbers for the various AVPs defined in section 4 were taken from the AVP numbering space defined in [2]. The numbering for the AVP and Command Codes MUST NOT conflict with values specified in [2] and other DIAMETER related Internet Drafts.

This document also introduces two new bits to the AVP Header, which MUST NOT conflict with the base protocol [2] and any other DIAMETER

extension.

6.0 References

[1] Rigney, et alia, "RADIUS", RFC-2138, April 1997
[2] Calhoun, Rubens, "DIAMETER Base Protocol", Internet-Draft, draft-calhoun-diameter-08.txt, August 1999.
[3] Rivest, Dusse, "The MD5 Message-Digest Algorithm", RFC 1321, April 1992.
[4] Kaufman, Perlman, Speciner, "Network Security: Private Communications in a Public World", Prentice Hall, March 1995, ISBN 0-13-061466-1.
[5] Krawczyk, Bellare, Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, January 1997.
[6] Calhoun, Bulley, "DIAMETER User Authentication Extensions", draft-calhoun-diameter-authen-06.txt, August 1999.
[7] Aboba, Beadles "The Network Access Identifier." RFC 2486. January 1999.
[8] Aboba, Zorn, "Criteria for Evaluating Roaming Protocols", RFC 2477, January 1999.
[9] Kaliski, "PKCS #1: RSA Encryption Version 1.5", Internet-Draft, draft-hoffman-pkcs-rsa-encrypt-03.txt, October 1997.
[10] Calhoun, Zorn, Pan, "DIAMETER Framework", draft-calhoun-diameter-framework-02.txt, Work in Progress, December 1998.
[11] Aboba, Vollbrecht, "Proxy Chaining and Policy Implementation in Roaming", RFC 2607, June 1999.
[12] Housley, Ford, Polk, Solo, "Internet X.509 Public Key Infrastructure Certificate and CRL Profile", RFC 2459, January 1999.
[13] S. Bradner, "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

7.0 Acknowledgements

The Authors would like to acknowledge the following people for their contribution in the development of the DIAMETER protocol:

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