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Port Control Protocol (PCP) Authentication Mechanism
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Abstract

An IPv4 or IPv6 host can use the Port Control Protocol (PCP) to flexibly manage the IP address and port mapping information on Network Address Translators (NATs) or firewalls, to facilitate communications with remote hosts. However, the un-controlled generation or deletion of IP address mappings on such network devices may cause security risks and should be avoided. In some cases the client may need to prove that it is authorized to modify, create or delete PCP mappings. This document proposes an in-band authentication mechanism for PCP that can be used in those cases. The Extensible Authentication Protocol (EAP) is used to perform authentication between PCP devices.

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1. Introduction

Using the Port Control Protocol (PCP) [[I-D.ietf-pcp-base](#)], an IPv4 or IPv6 host can flexibly manage the IP address mapping information on its network address translators (NATs) and firewalls, and control their policies in processing incoming and outgoing IP packets. Because NATs and firewalls both play important roles in network security architectures, there are many situations in which authentication and access control are required to prevent unauthorized users from accessing such devices. This document proposes a PCP security extension which enables PCP servers to authenticate the clients that they are communicating with using Extensible Authentication Protocol (EAP). The following issues are considered in the design of this extension:

- o Loss of EAP messages during transportation
- o Disordered delivery of EAP messages
- o Generation of transport keys
- o Integrity protection and data origin authentication for PCP messages
- o Algorithm agility

The mechanism described in this document meets the security requirements to address the Advanced Threat Model described in the base PCP specification [[I-D.ietf-pcp-base](#)]. This mechanism can be used to secure PCP in the following situations::

- o On security infrastructure equipment, such as corporate firewalls, that does not create implicit mappings.
- o On equipment (such as CGNs or service provider firewalls) that serve multiple administrative domains and do not have a mechanism to securely partition traffic from those domains.
- o For any implementation that wants to be more permissive in authorizing explicit mappings than it is in authorizing implicit mappings.
- o For implementations that support the THIRD_PARTY Option (unless they can meet the constraints outlined in [Section 14.1.2.2](#)).
- o For implementations that wish to support any deployment scenario that does not meet the constraints described in [Section 14.1](#).

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

Most of the terms used in this document are introduced in [[I-D.ietf-pcp-base](#)].

PCP Client (PCC): A PCP device (e.g., a host) which is responsible for issuing PCP requests to a PCP server. In this document, a PCC is also a EAP peer [[RFC3748](#)], and it is the responsibility of a PCC to provide the credentials when authentication is required.

PCP Server (PCS): A PCP device (e.g., a NAT or a firewall) that implements the server-side of the PCP protocol, via which PCCs request and manage explicit mappings. In this document, a PCS is integrated with an EAP authenticator [[RFC3748](#)]. Therefore, when necessary, a PCS can verify the credentials provided by a PCC and make an access control decision based on the authentication result.

PCP Authentication (PA) Session: A series of PCP message exchanges transferred between a PCC and a PCS in order to perform authentication, authorization, key distribution and secured PCP communication. Each PA session is assigned a distinctive Session ID. The PCP devices involved within a PA session are called session partners. A typical PA session has two session partners.

Session Lifetime: The life period associated with a PA session, which decided the lifetime of the current authorization given to the PCC.

PCP Security Association (PCP SA): A PCP security association is formed between a PCC and a PCS by sharing cryptographic keying material and associated context. The formed duplex security association is used to protect the bidirectional PCP signaling traffic between the PCC and PCS.

Master Session Key (MSK): A key derived by the partners of a PA session, using a EAP key generating method specified in [[RFC3748](#)].

PA (PCP for Authentication) message: A PCP message containing an Authentication OpCode for EAP authentication.

3. Protocol Details

3.1. Session Initiation

To carry out an EAP authentication process between two PCP devices, a set of PA messages need to be exchanged. Each PA message contains an Authentication OpCode (and additional Options if needed). The Authentication OpCode consists of four fields: Session ID, Flag, EAP Type, and Sequence Number. The Session ID field is used to identify the session which the message belongs to. The Flag field indicates the type of the PCP message, while EAP Type is used to identify the type of the attached EAP message. The sequence number field is used to detect the disorder or the duplication occurred during packet delivery.

The message exchanges conveyed within an PA session is introduced in the remainder section.

When a PCC intends to initiate a PA session with a PCS, it sends a PCC-Initiation message to the PCS. The Session ID and Sequence Number fields of the Authentication OpCode in the PCC-Initiation message are set as 0, and the I bit is set. the PCC also needs to select a random nonce and append it with the PCC-Initiation message in order to deal with off-line attacks. Specifically, the nonce is transported within a nonce option. After receiving the PCC-Initiation, if the PCS would like to initiate a PA session, it will reply with a PA-Request which contains an EAP Identity Request. The Sequence Number field in the PA-Request is set as 0, and the Session ID field MUST be filled with the session identifier assigned by the PCS for this session. the PA-Request also needs to be attached with the nonce. From now on, every PA message within this session must be attached with the session identifier. Otherwise, the session partner receiving the message will discard the message silently. If the PCC intends to simplify the authentication process, it can append an EAP Identity Response message within the PCC-Initiation request so as to skip over the step of waiting for the EAP Identity Request and inform the PCS that it would like to perform EAP authentication.

In the scenario where a PCS receives a non-PA PCP message from a PCC which needs to be authenticated, the PCS can reply with a PA-Request to initiate a PA session; the result code field of the PA-Request is set as AUTHENTICATION-REQUIRED. In addition, the PCS MUST assign a session ID for the session and transfer it within the PA-Request. In the PA messages exchanged afterwards in this session, the session ID MUST be appended. Therefore, in the subsequent communication, the PCC can distinguish the messages in this session from those in other sessions through the PCS IP address and the session ID. When the PCC receives the initial PA-Request message from the PCS, it can reply with a PA-Answer message to continue the session or silently discards the request message according to its local policies.

In a PA session, PA-Request messages are sent from PCSs to PCCs while PA-Answer messages are only sent from PCCs to PCSs. Correspondently, an EAP request messages MUST be transported within a PA-Request message, and an EAP answer messages MUST be transported within a PA-Answer message. Particularly, when a PCP device receives a PA-Request or a PA-Answer message from its partner, the PCP device needs to reply with a PA-Acknowledge message to indicate that the message has been received. This solution is used to deal with the conditions where the device cannot generate a response within a pre-specified period due to certain reasons (e.g., waiting for human input to construct a EAP message). Therefore, the partner does not have to un-necessarily retransfer the PCP message.

In this work, it is mandated for a PCC and a PCS to perform a key-generating EAP method in authentication, and so a successful EAP authentication process will result in a Master Session Key (MSK). If the PCC and the PCS want to generate a traffic key using the MSK, they need to agree upon a Pseudo-Random Function (PRF) for the transport key derivation and a MAC algorithm to provide data origin authentication for subsequent PCP packets. On this occasion, the PCS needs to append the initial PA-Request message with a set of PRF Options and MAC Algorithm Options. Each PRF Option (MAC Algorithm Option) contains a PRF (MAC (Message Authentication Code) algorithm) that the PCS supports. After receiving the request, the PCC selects a PRF and a MAC algorithm which it intends to support, and sends back a PA-Answer with a PRF Option and a MAC Algorithm Option for the selected algorithms.

The last PA-Request message transported within a PA session carries the EAP authentication and PCP authorization results. The last PA-Request and PA-Answer messages MUST have their the 'C' (Complete) bit set.

If the EAP authentication successes, the result code of the last PA-Request is AUTHENTICATION-SUCCESS. In this case, before sending out the PA-Request, the PCS must derive a transport key and use it to generate digests to protect the integrity and authenticity of the PA-Request and any subsequent PCP message. Such digests are transported within Authentication Tag Options. In addition, the PA-Request needs to be appended with a Session Lifetime Option which indicates the life time of the PA session (i.e., the life time of the MSK).

If the EAP authentication fails, the result code of the last PA-Request is AUTHENTICATION-FAILED. If the EAP authentication successes but Authorization fails, the result code of the last PA-Request is AUTHORIZATION-FAILED. In the latter two cases, the PA session MUST be terminated immediately after the last PCP authentication message exchange.

3.2. Session Termination

A PA session can be explicitly terminated by sending a termination-indicating PA acknowledge message from either session partner. After receiving a termination-indicating message from the session partner, a PCP device MUST response with a termination-indicating PA Acknowledge message and remove the PA SA immediately. When the session partner initiating the termination process receives the acknowledge message, it will remove the associated PA SA immediately.

3.3. Result Codes

Following result codes are defined in the solution:

XXX AUTHENTICATION-REQUIRED

XXX AUTHENTICATION-FAILED

XXX AUTHENTICATION-SUCCESS

XXX AUTHORIZATION-FAILED

4. PA Security Association

At the beginning a PA session, a session SHOULD generate a PA SA to maintain its state information during the session. A The parameters of a PA SA is listed as follows:

- o IP address and UDP port number of the PCC
- o IP address and UDP port number of the PCS
- o Session Identifier
- o Sequence number for the next outgoing PCP message
- o Sequence number for the next incoming PCP message
- o Last outgoing message payload
- o Retransmission interval
- o MSK
- o MAC algorithm: The algorithm that the transport key should use to generate digests for PCP messages.

- o Pseudo-random function: The pseudo random function negotiated in the initial PA-Request and PA-Answer exchange for the transport key derivation
- o Transport key: the key derived from the MSK to provide integrity protection and data origin authentication for the messages in the PA session. The life time of the transport key SHOULD be identical to the life time of the session.

Particularly, the transport key is computed in the following way:

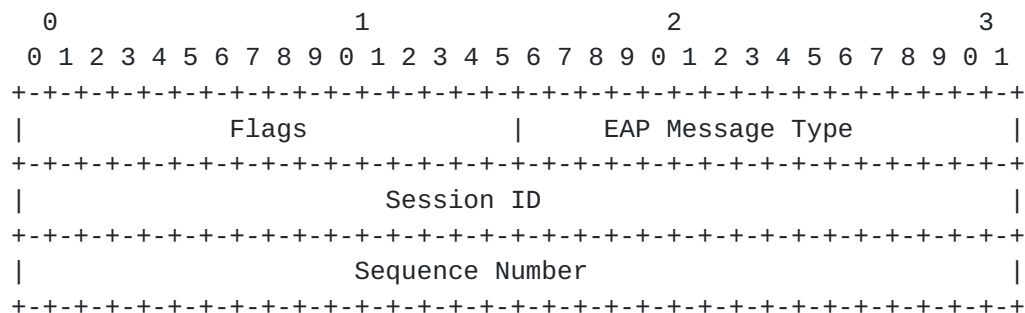
Transport key = prf(MSK, "IETF PCP"| Session_ID, key ID), where:

- o The prf: The pseudo-random function assigned in the Pseudo-random function parameter.
- o MSK: The master session key generated by the EAP method.
- o "IETF PCP": The ASCII code representation of the non-NULL terminated string (excluding the double quotes around it).
- o Session_ID: The ID of the session which the MSK is derived from
- o Key ID: The ID assigned for the traffic key

5. Packet Format

5.1. Authentication OpCode Format

The following figure illustrates the format of an authentication OpCode:



Flags: The Flags field is two octets. The following bits are assigned:


```

      0                               1
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+--+--+--+--+--+--+--+--+--+--+
|I C R A K T S E r r r r r r r r|
+-+--+--+--+--+--+--+--+--+--+--+

```

- * I (Initiation): This bit is set in a PCC-Initiation message.
- * C (Complete): If the message is the last PA-Request or PA-Answer message in the session, this bit MUST be set. For other messages, this bit MUST be cleared.
- * R (Request): This bit is set in a PA-Request message.
- * A (Answer): This bit is set in a PA-Answer message.
- * K (acknowledgement): This bit is set and only set in a PA-Acknowledgement message.
- * T (Termination): If this bit is set in a PA-Acknowledgement message, the message is used for session-termination indication.
- * S (Fragmentation start): This bit is set in a PA message which contain the first fragment of a EAP message.
- * E (Fragmentation start): This bit is set in a PA message which contain the last fragment of a EAP message.

Message Type: The Message Type field is two octets. This field is used to indicate the type of the EAP message attached within the message. Message Type allocation is managed by IANA [IANAWEB].

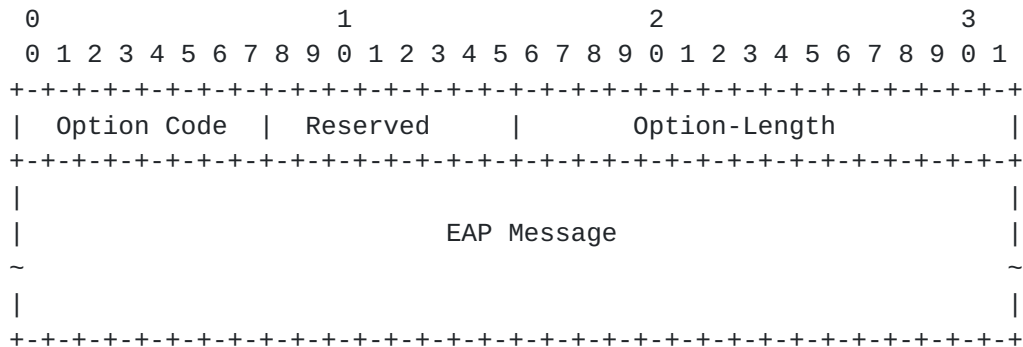
Session ID: This field contains a 32-bit PA session identifier.

Sequence Number: This field contains a 32-bit sequence number. In this solution, a sequence number needs to be incremented on every new (non-retransmission) outgoing packet in order to provide ordering guarantee for PCP.

[5.2.](#) Nonce Option

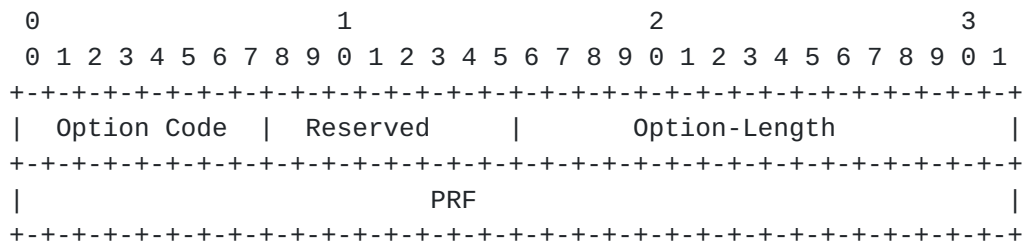
different PCP SAs.

5.4. EAP Payload Option



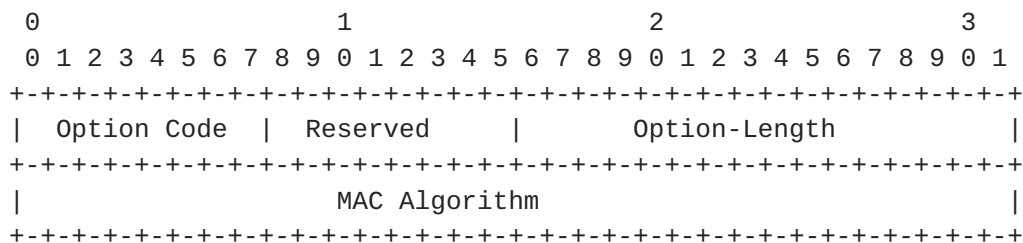
EAP Message: The EAP message transferred. Note this field MUST end on a 32-bit boundary, padded with 0's when necessary.

5.5. PRF Option



PRF: The pseudo-random Function which the sender supports to generate a MSK.

5.6. Hash Algorithm Option



MAC Algorithm: The MAC algorithm which the sender supports to generate authentication data.

5.7. Session Lifetime Option

```

      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
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Option Code | Reserved | Option-Length |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Session Lifetime |
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
Session Lifetime: The life period of the PA Session, which is decided
by the authorization result.

```

6. Processing Rules

6.1. Authentication Data Generation

If a PCP SA is generated as the result of an successful EAP authentication process, every subsequent PCP message within the session needs carry an Authentication Tag Option which contains the digest of the PCP message for data origin authentication and integrity protection.

Before generating a digest for a PCP message, a device needs to first select a traffic key in the session and append the Authentication Tag Option at the end of the protected PCP message. The length of the Authentication Data field is decided by the MAC algorithm adopted in the session. The device then fills the Session ID field and the PCP SA ID field, and sets the Authentication Data field as 0. After this, the device generates a digest for the PCP message with the MAC algorithm and the selected traffic key, and input the generated digest into the Authentication Data field.

6.2. Authentication Data Validation

When a device receives a PCP packet with an Authentication Tag Option, it needs to use the session ID transported in the option to locate the proper SA, and then find out the associated transport key and the MAC algorithm. After storing the value of the Authentication field of the Authentication Tag Option, the device fills the Authentication field with zeros. Then, the device generates a digest for the packet with the transport key and the MAC algorithm found in the first step. If the value of the newly generated digest is identical to the stored one, the device can ensure that the packet has not been tampered during the transportation. The validation succeeds. Otherwise, the packet MUST be discarded.

6.3. Sequence Number

PCP adopts UDP to transport signaling messages. As an un-reliable transporting protocol, UDP does not guarantee the ordered packet delivery and does not provide any protection from packet loss. In order to ensure the EAP messages are exchanged in a reliable way, every PCP packet exchanged during EAP authentication must carries an monotonically increased sequence number. During a PA session, a PCP device needs to maintain two sequence numbers, one for incoming packets and one for outgoing packets. When generating an outgoing PCP packet, the device attaches the outgoing sequence number to the packet and increments the sequence number by 1. When receiving a PCP packet from its session partner, the device will not accept it if the sequence number carried in the packet does not matche the incoming sequence number the device maintains.

After confirming that the received packet is valid, the device increments the incoming sequence number by 1. However, the above rules are not applied to PA-Acknowledgement messages. When receiving or sending out a PA-Acknowledgement message, the device does not inincrease the correspondent sequence number. Another exception is message retransmission. When a device does not receive any response message from its session partner in a certain period, it needs to retransmit the last sent message with a limited rate. The duplicate messages and the original message MUST use the identical sequence number. When the device receives such duplicate messages from its session partner, it MUST tries to answer them by sending the last outgoing message with a limited rate unless it has received another valid message with a larger sequence number from its session. Note that in these cases the incoming and outgoing sequence number will not be affected by the message retransmission.

6.4. Retransmission Policies

This work provides a retransmission mechanism for reliable PA message delivery. The timer, the variables, and the rules used in this mechanism is mostly brought from PANA[RFC5191].

The retransmission behavior is controlled and described by the following variables:

RT: Retransmission timeout from the previous (re)transmission

IRT: Base value for RT for the initial retransmission

MRC: Maximum retransmission count

MRT: Maximum retransmitting time interval

RAND: Randomization factor

With each message transmission or retransmission, the sender sets RT according to the rules given below.

If RT expires before receiving any reply, the sender re-calculates RT and retransmits the message. Each of the computations of a new RT include a randomization factor (RAND), which is a random number chosen with a uniform distribution between -0.1 and +0.1. The randomization factor is included to minimize the synchronization of messages. The algorithm for choosing a random number does not need to be cryptographically sound. The algorithm SHOULD produce a different sequence of random numbers from each invocation. RT for the first message retransmission is based on IRT:

$$RT = IRT$$

RT for each subsequent message retransmission is based on the previous value of RT (RTprev):

$$RT = (2 + RAND) * RT_{prev}$$

MRT specifies an upper bound on the value of RT (disregarding the randomization added by the use of RAND). If MRT has a value of 0, there is no upper limit on the value of RT. Otherwise:

if (RT > MRT)

$$RT = (1 + RAND) * MRT$$

MRC specifies an upper bound on the number of times a sender may retransmit a message. Unless MRC is zero, the message exchange fails once the sender has transmitted the message MRC times. In this case, the sender needs to start a session termination process illustrated in [Section 3.2](#).

6.5. MTU Considerations

The fragmentation and reassembly of EAP messages must be provided in order to ensure the length of a PA message is not larger than the MTU of the link that it will be transported through. Therefore, a PA message may only transport a fragment of an EAP message. Because any loss or tamper of a EAP fragment will be detected and sequencing information is provided, fragmentation support can be added in a simple manner. Particularly, the S bit is set in a PA message which contain the first fragment of a EAP message, and the The E bit is set

in a PA message which contain the last fragment of a EAP message.

7. IANA Considerations

TBD

8. Security Considerations

In this work, a successful EAP authentication process performed between two PCP devices will result in the generation of a MSK which can be used to derive the transport keys to generate MAC digests for subsequent PCP message exchanges. This work does not exclude the possibility of using the MSK to generate keys for different security protocols to enable per-packet cryptographic protection. The methods of deriving the transport key for the security protocols is out of scope of this document.

However, before a transport key has been generated, the PA messages exchanged within a PA session have little cryptographic protection, and if there is no already established security channel between two session partners, these messages are subject to man-in-the-middle attacks and DOS attacks. For instance, the initial PA-Request and PA-Answer exchange is vulnerable to spoofing attacks as these messages are not authenticated and integrity protected. In order to prevent very basic DOS attacks, a PCP device SHOULD generate state information as little as possible in the initial PA-Request and PA-Answer exchanges. The choice of EAP method is also very important. The selected EAP method must be resilient to the attacks possibly occurred in a insecure network environment, and the user-identity confidentiality, protection against dictionary attacks, and session-key establishment must be supported.

9. Acknowledgements

This document was written using the xml2rfc tool described in [RFC 2629](#) [[RFC2629](#)].

Some of the ideas in this document were adopted from PANA[RFC5191].

10. Change Log

10.1. Changes from -00 to -01

- o Editorial changes, added use cases to introduction.

10.2. Changes from -01 to -02

- o Add a nonce into the first two exchanged PA message between the PCC and PCS. When a PCC initiate the session, it can use the nonce to detect offline attacks.
- o Add the key ID field into the authentication tag option so that a MSK can generate multiple traffic keys.
- o Specify that when a PCP device receives a PA-Request or a PA-Answer message from its partner the PCP device needs to reply with a PA-Acknowledge message to indicate that the message has been received.
- o Add the support of fragmenting EAP messages.

11. References

11.1. Normative References

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