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Port Control Protocol (PCP) Flow Examples  
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## Abstract

This document provides a set of examples to illustrate Port Control Protocol (PCP) operations. It is a companion document to the base PCP specification.

## Status of This Memo

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## [1.](#) Introduction

As a companion document to [\[RFC6887\]](#), this document provides examples to help understanding the PCP machinery and exchanged PCP messages in various usage contexts.

For more details about PCP protocol specification, the reader is invited to refer to [\[RFC6887\]](#).

Examples included in this document make use of the IPv4 and IPv6 address blocks for documentation purposes defined in [\[RFC5737\]](#) and [\[RFC3849\]](#).

## [2.](#) Basic MAP Operations

The following figure illustrates the messages which are exchanged to create a mapping in a PCP-controlled device with MAP opcode.

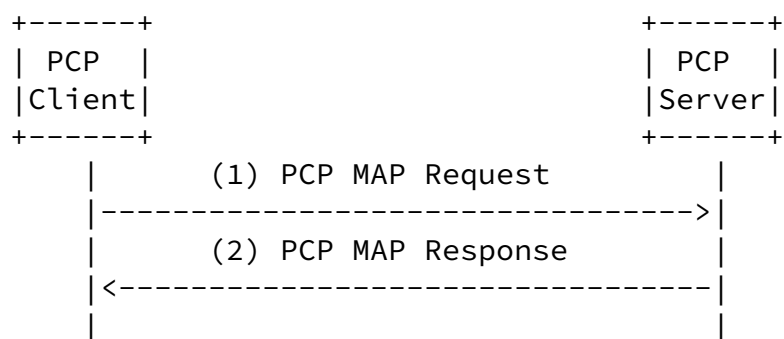


Figure 1: Example of creating a mapping

The following sub-sections provide several examples depending on the content of the MAP request and the decision of the PCP server.

### [2.1.](#) Suggested External Port Honored by the PCP Server

This example illustrates the content of exchanged PCP messages when the PCP client does not include any PCP Option in its request. In this example, the PCP server assigns the suggested port number. In reference to Figure 1, the content of exchanged PCP messages is as follows:

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 2: MAP request (suggested External Port Honored by the PCP Server)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Assigned External Port: 3938
  Assigned External IP Address: ::ffff:192.0.2.1
```

Figure 3: MAP response (suggested External Port Honored by the PCP Server)

Server)

## [2.2.](#) IPv6-enabled PCP Client

This example illustrates the content of exchanged PCP messages when the PCP client is assigned with an IPv6 address but the remote server controls a NAT44 device. In reference to Figure 1, the content of exchanged PCP messages is as follows:

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```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: 2001:db8:0:0:1::1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 4: MAP request (suggested External Port Honored by the PCP Server)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
```

Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Assigned External Port: 3938  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 5: MAP response (suggested External Port Honored by the PCP Server)

### [2.3.](#) Remove an Existing Mapping

This example illustrates the content of exchanged PCP messages when the PCP client request the removal of an existing mapping.

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 0 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Suggested External Port: 3938  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 6: MAP request (Remove an Existing Mapping)

R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 0 sec  
Epoch Time: 1250  
MAP Response:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Assigned External Port: 3938  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 7: MAP response (Remove an Existing Mapping)

#### [2.4.](#) Suggested External Port Not Honored by the PCP Server

This example illustrates the content of exchanged PCP messages when the PCP client does not include any PCP Option in its request. In this example, the PCP server does not assign the suggested external port number. In reference to Figure 1, the content of exchanged PCP messages is as follows:

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 15685  
Protocol: UDP (17)

Internal Port: 11000  
Suggested External Port: 11000  
Suggested External IP Address: ::ffff:0.0.0.0

Figure 8: MAP request (Suggested External Port Not Honored by the PCP Server)

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 20000 sec  
Epoch Time: 1250  
MAP Response:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 11000  
Assigned External Port: 15200  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 9: MAP response (Suggested External Port Not Honored by the PCP Server)

## [2.5.](#) Suggested External IP Address

This example illustrates the content of exchanged PCP messages when the PCP client does not include any PCP Option in its request. In this example, the PCP client indicates a hinted external IP address honored by the PCP server. In reference to Figure 1, the content of exchanged PCP messages is as follows:



R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Suggested External Port: 3938  
Suggested External IP Address: ::ffff:192.0.2.1

Figure 10: MAP request (Suggested External IP Address)

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 20000 sec  
Epoch Time: 1250  
MAP Response:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Assigned External Port: 15200  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 11: MAP response (Suggested External IP Address)

## [2.6.](#) Create Mapping with Distinct External IP Addresses

Figure 12 shows a PCP server with a pool of public IPv4 addresses (192.0.2/24) and two PCP clients associated with different subscribers. The PCP clients each make a port mapping request to the PCP server which creates the mapping from its 192.0.2/24 pool.

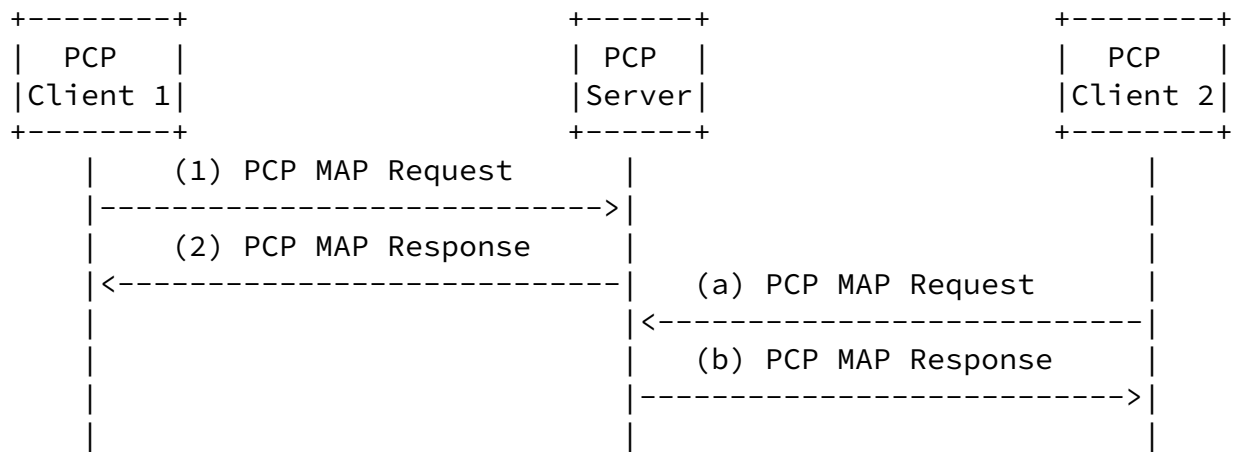


Figure 12: Example of creating mappings with distinct external IP addresses

In this example, the PCP clients were mapped to different public addresses as illustrated in the content of the PCP messages listed below.

The content of PCP messages exchanged between PCP client 1 and the PCP server is as follows:

```

Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: TCP (6)
  Internal Port: 15333
  Suggested External Port: 15333
  Suggested External IP Address: ::ffff:0.0.0.0
  
```

Figure 13: MAP request (PCP Client 1)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
  Mapping Nonce: 15685
  Protocol: TCP (6)
  Internal Port: 15333
  Assigned External Port: 12000
  Assigned External IP Address: ::ffff:192.0.2.1
```

Figure 14: MAP response (PCP Client 1)

The content of PCP messages exchanged between PCP client 2 and the PCP server is as follows:

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.2
MAP Request:
  Mapping Nonce: 59869
  Protocol: UDP (17)
  Internal Port: 12000
  Suggested External Port: 12000
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 15: MAP request (PCP Client 2)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
```

Mapping Nonce: 59869  
Protocol: UDP (17)  
Internal Port: 12000  
Assigned External Port: 6000  
Assigned External IP Address: ::ffff:192.0.2.2

Figure 16: MAP response (PCP Client 2)

## [2.7.](#) Mapping Nonce Doesn't Match: Base PCP Specification

CAUTION: The behavior described in this section is obsoleted by [\[I-D.cheshire-pcp-unsupp-family\]](#). This section records the behavior as initially specified the base PCP specification [\[RFC6887\]](#).

This example illustrates the content of exchanged PCP messages when the PCP client does not include any PCP Option in its request. In this example, the PCP client indicates a distinct Mapping Nonce than the one stored by the PCP server. In reference to Figure 1, the content of exchanged PCP messages is as follows:

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 45687  
Protocol: UDP (17)  
Internal Port: 3938  
Suggested External Port: 3938  
Suggested External IP Address: ::ffff:192.0.2.1

Figure 17: MAP request (Mapping Nonce Doesn't Match)

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: NOT\_AUTHORIZED (0x02)  
Lifetime: 35550 sec  
Epoch Time: 1300

Figure 18: MAP response (Mapping Nonce Doesn't Match)

## [2.8.](#) Mapping Nonce Doesn't Match: Updated Specification

Nonce validation checks are problematic in various scenarios as discussed in [[I-D.cheshire-pcp-unsupp-family](#)]. As a consequence, the nonce validation checks are relaxed as follows: If operating in the Simple Threat Model ([Section 18.1](#) of the PCP specification [[RFC6887](#)]), and the internal port, protocol, internal address, and external address family match an existing explicit dynamic mapping, but the mapping nonce does not match, then the existing mapping is not modified in any way, and a valid PCP reply is returned to the client, using the client-specified nonce, reporting the external address, port, and remaining lifetime of the existing mapping. An example is shown in Figure 19 and Figure 3.

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The request shown in Figure 19 matches an existing mapping (see Figure 3). Even if the nonce of the exiting mapping does not match the one indicated in the request, a positive answer is returned to the requesting PCP client without any change to the existing mapping. The nonce of the existing mapping (i.e., 15685) is not returned in the response.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 45687
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:192.0.2.1
```

Figure 19: MAP request

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
```

```
Lifetime: 10000 sec
Epoch Time: 3500
MAP Response:
  Mapping Nonce: 45687
  Protocol: UDP (17)
  Internal Port: 3938
  Assigned External Port: 3938
  Assigned External IP Address: ::ffff:192.0.2.1
```

Figure 20: MAP response

#### [2.9.](#) PREFER\_FAILURE Option: Requested Port is Honored

This flow shows an example of the content of PCP messages that will be exchanged to create a mapping in a PCP-controlled device. In this example, the PCP client indicates a requested external UDP port number and also a PREFER\_FAILURE Option. In this example, we suppose the requested port can be honored by the PCP server. In reference to Figure 1, the content of exchanged PCP messages is as follows:

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```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 1234
  Suggested External Port: 12536
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: PREFER_FAILURE (0x02) Option Length: 0 bytes Data: (NULL)
```

Figure 21: MAP request ( PREFER\_FAILURE Option: Requested Port is Honored)

```
Version: 2
R bit: Response (1)
```

opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 36000 sec  
Epoch Time: 1250  
MAP Response:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 1234  
Assigned External Port: 12536  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 22: MAP response ( PREFER\_FAILURE Option: Requested Port is Honored)

#### [2.10.](#) PREFER\_FAILURE Option: Requested Port is not Honored

This flow shows an example of the content of PCP messages that will be exchanged to create a mapping in a PCP-controlled device. In this example, the PCP client indicates a requested external UDP port number and also a PREFER\_FAILURE Option. In this example, we suppose the requested port cannot be honored by the PCP server. In reference to Figure 1, the content of exchanged PCP messages is as follows:

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 1234  
Suggested External Port: 1234  
Suggested External IP Address: ::ffff:0.0.0.0

Option Code: PREFER\_FAILURE (0x02) Option Length: 0 bytes Data: (NULL)

Figure 23: MAP request (PREFER\_FAILURE Option: Requested Port is not Honored)

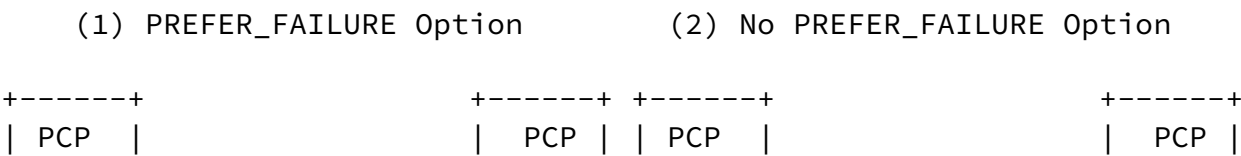
Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: CANNOT\_PROVIDE\_EXTERNAL (0x11)  
Lifetime: 1560 sec  
Epoch Time: 1300

Figure 24: MAP response (PREFER\_FAILURE Option: Requested Port is not Honored)

2.11. Negative Impact of PREFER\_FAILURE Option

The presence of PREFER\_FAILURE option in a request may have negative impact on an application which does not require it. Figure 25 shows two examples:

- 1. With PREFER\_FAILURE option: several round trips are needed for the client to retrieve the requested mapping.
- 2. Without PREFER\_FAILURE option: the client retrieves a mapping without any extra delay.





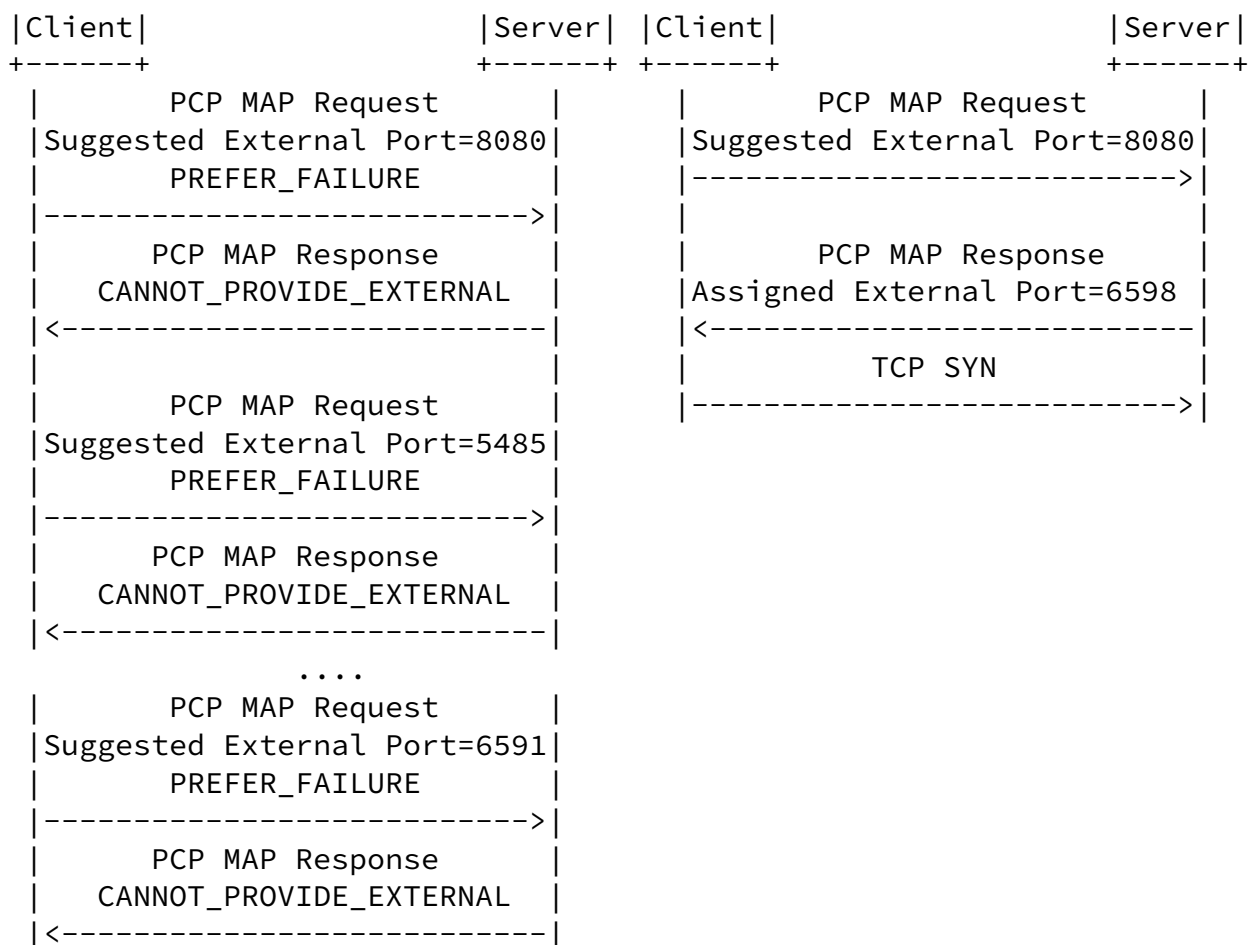


Figure 25: Negative Impact of the mis-usage of PREFER\_FAILURE option

## 2.12. Existing Implicit Mapping

This example illustrates the content of exchanged PCP messages when the PCP client requests a mapping which matches an existing implicit dynamic mapping (see Figure 26). In this example, the PCP-Controlled device assigns 10000 as external port number when translating the packet from the client having with source port set to 1234.

This behavior is specified in [Section 11.3 of \[RFC6887\]](#).

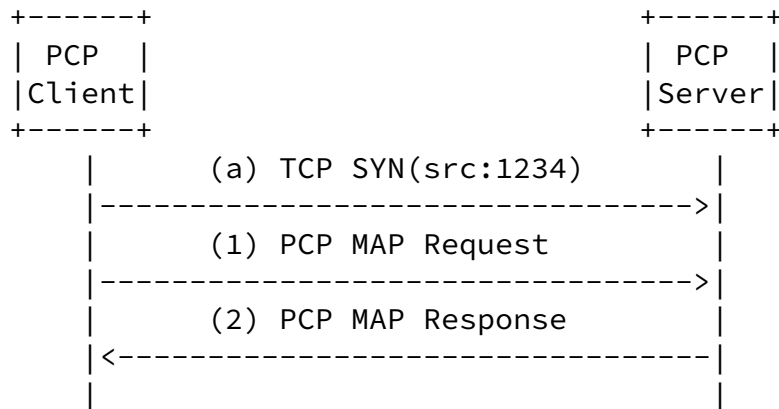


Figure 26: Example of creating a mapping

In reference to Figure 1, the content of exchanged PCP messages is as follows:

```

Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: TCP (0x06)
  Internal Port: 1234
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
  
```

Figure 27: MAP request (Existing Implicit Mapping)

```

Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
  Mapping Nonce: 15685
  Protocol: TCP (0x06)
  Internal Port: 1234
  Assigned External Port: 10000
  Assigned External IP Address: ::ffff:192.0.2.1
  
```

Figure 28: MAP response (Existing Implicit Mapping)

### [2.13.](#) Shortening a Mapping Lifetime in the Presence of Client- Originated Traffic

Figure 29 shows an example illustrating the impact of requesting the deletion of a mapping in the presence of traffic originated from the client. In this example, the PCP server does not remove the requested mapping immediately; the returned lifetime is set to the remaining lifetime.

This behavior is specified in [Section 15 of \[RFC6887\]](#).

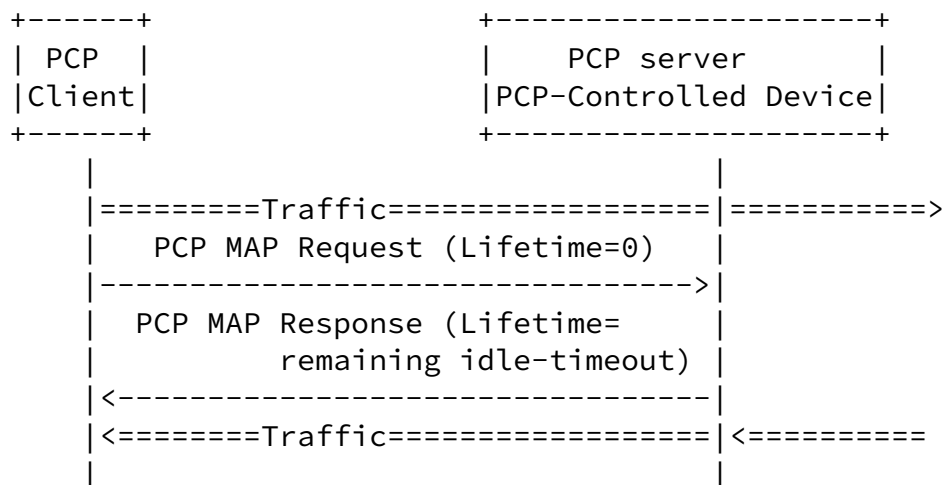


Figure 29: Shortening a Mapping Lifetime in the Presence of Client-  
Originated Traffic

### [2.14.](#) Create a Mapping for All Incoming Traffic of a Given Protocol

This example illustrates the content of the PCP MAP request to create a mapping for all incoming traffic of a given protocol (UDP is used in this example).

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 0
  Suggested External Port: 0
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 30: MAP request (Create a mapping for all incoming traffic of a given protocol)

The PCP server may honor the request or reject it by sending UNSUPP\_PROTOCOL (0x09) error.

#### [2.15.](#) Create a Mapping for All Protocols

This example illustrates the content of the PCP MAP request to create a mapping for the traffic of all protocols.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: ANY (0)
  Internal Port: 0
  Suggested External Port: 0
```

Suggested External IP Address: ::ffff:0.0.0.0

Figure 31: MAP request (Create a mapping for all protocols)

The PCP server may honor the request or reject it by sending UNSUPP\_PROTOCOL (0x09) error.

#### [2.16.](#) Malformed Request

This flow shows an example of the content of PCP messages that will be exchanged when a malformed request is received by the PCP server. In this example, the Protocol field is set to null.

---

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```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 45698
  Protocol: ANY (0)
  Internal Port: 5698
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: PREFER_FAILURE (0x02) Option Length: 0 bytes Data: (NULL)
```

Figure 32: MAP request (Malformed Request)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: MALFORMED_REQUEST (0x02)
Lifetime: 0 sec
Epoch Time: 1300
```

Figure 33: MAP response (Malformed Request)

#### [2.17.](#) Exceeded Port Quota

This flow shows an example of the content of PCP messages that will be exchanged when a per-user quota is reached. A short lifetime is returned so that the client may retry and see if the request can be honored because another state has been removed.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 45698
  Protocol: UDP (17)
  Internal Port: 8695
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: PREFER_FAILURE (0x02) Option Length: 0 bytes Data: (NULL)
```

Figure 34: MAP request (Exceeded Port Quota)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: USER_EX_QUOTA (10)
Lifetime: 300 sec
Epoch Time: 1300
```

Figure 35: MAP response (Exceeded Port Quota)

## [2.18.](#) Unsupported Address Family

This flow shows an example of the content of PCP messages that will be exchanged when the requested external address family is not supported by the PCP server. In this example, IPv6 is indicated as the requested AF. The PCP server answers with an UNSUPP\_FAMILY (14) error as defined in [[I-D.cheshire-pcp-unsupp-family](#)].

```
Version: 2
R bit: Request (0)
```

```
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 45698
  Protocol: UDP (17)
  Internal Port: 8695
  Suggested External Port: 3938
  Suggested External IP Address: ::
```

Figure 36: MAP request (Unsupported Address Family)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: UNSUPP_FAMILY (14)
Lifetime: 0 sec
Epoch Time: 1300
```

Figure 37: MAP response (Unsupported Address Family)

### [2.19.](#) Unsupported Protocol

This flow shows an example of the content of PCP messages that will be exchanged when the requested port is not supported by the PCP server. In this example, SCTP is indicated as the requested protocol.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 45698
  Protocol: SCTP (132)
  Internal Port: 8695
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 38: MAP request (Unsupported Protocol)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: UNSUPP_PROTOCOL (9)
Lifetime: 0 sec
Epoch Time: 1300
```

Figure 39: MAP response (Unsupported Protocol)

#### [2.20.](#) Unsolicited MAP Response

Suppose the client has instructed a UDP mapping for port 3938 (assigned external port is 15000 and assigned external IPv4 address is: 192.0.2.1). Upon a change of a state: e.g., change of the external IP Address, the PCP server issues an unsolicited MAP response. The content of the MAP response sent by the PCP server is shown below. The PCP client is now aware of the new assigned external IP address.

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
MAP Response:
  Mapping Nonce: 15685
  Protocol: TCP (0x06)
  Internal Port: 1234
  Assigned External Port: 10000
  Assigned External IP Address: ::ffff:192.0.2.2
```

Figure 40: Unsolicited MAP Response

#### [2.21.](#) Mapping Repair

An example of mapping repair is shown in Figure 41.

+-----+

+-----+



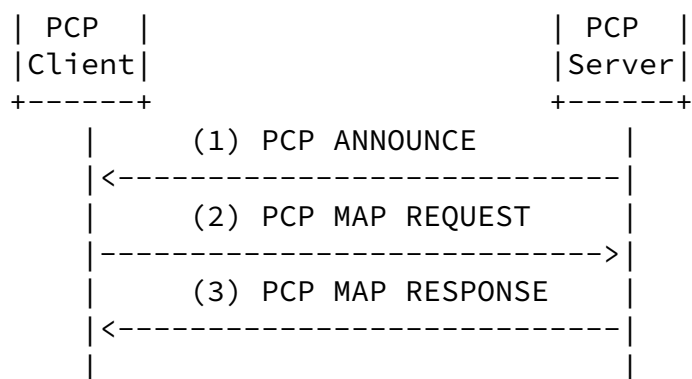


Figure 41: Flow Example of a PING/PONG exchange: Check the availability of the PCP Server

Version: 2  
 R bit: Response (1)  
 opcode: ANNOUNCE (0x00)  
 Result Code: 0  
 Lifetime: 0 sec  
 Epoch Time: 0

Figure 42: Unsolicited ANNOUNCE

Version: 2  
 R bit: Request (0)  
 opcode: MAP (0x01)  
 Requested Lifetime: 36000 sec  
 PCP client's IP Address: ::ffff:198.51.100.1  
 MAP Request:  
 Mapping Nonce: 15685  
 Protocol: UDP (17)  
 Internal Port: 11000  
 Assigned External Port: 15200  
 Assigned External IP Address: ::ffff:192.0.2.1

Figure 43: MAP request (Mapping Repair)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 10
MAP Response:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 11000
  Assigned External Port: 15200
  Assigned External IP Address: ::ffff:192.0.2.1
```

Figure 44: MAP response (Mapping Repair)

### 3. NAT Detect Example

Let us suppose a PCP-unaware NAT is located between the PCP server and the PCP client. An example of PCP MAP request issued by the PCP client is shown below.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 11000
  Assigned External Port: 15200
  Assigned External IP Address: ::ffff:0.0.0.0
```

Figure 45: MAP request (NAT Detect)

This message will be translated by the PCP-unaware NAT. The source IP address if the resulting message will be another address than 198.51.100.1. Upon receipt of this message, the PCP server compares the source IP address and the content of PCP client's IP Address field. Because the two addresses are not equal, the PCP server concludes there is PCP-unaware device in the path. As a result, the PCP server will issue the following error message:

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: ADDRESS_MISMATCH (12)
Lifetime: 0 sec
Epoch Time: 36000
```

Figure 46: MAP Response (NAT Detect)

This behavior is specified in [Section 8.2 of \[RFC6887\]](#).

#### 4. Retrieve the External IP Address

In order to retrieve the IP address used on the external side of the PCP-controlled device, the PCP client sends a short-lived mapping (e.g., Discard service (TCP/9 or UDP/9) or other port). The returned IP address can be displayed by any application requiring such information.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 5 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 9
  Suggested External Port: 9
  Suggested External IP Address: ::ffff:0.0.0.0
```

Figure 47: MAP request (Retrieve the External IP Address)

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 60 sec
Epoch Time: 1250
MAP Response:
  Mapping Nonce: 15685
  Protocol: UDP (17)
```

Internal Port: 9  
Suggested External Port: 9  
Assigned External IP Address: ::ffff:192.0.2.1

Figure 48: MAP Response (Retrieve the External IP Address)

This behavior is specified in [Section 11.6 of \[RFC6887\]](#).

## [5.](#) THIRD\_PARTY Examples

These examples follow the behavior specified in [Section 13.1 of \[RFC6887\]](#).

### [5.1.](#) THIRD\_PARTY Enabled at the Server Side

The following messages are exchanged when the THIRD\_PARTY option is enabled in the PCP server side. In this example the PCP client creates a mapping for the host assigned with 198.51.100.2.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 16584
  Protocol: UDP (17)
  Internal Port: 8080
  Suggested External Port: 8080
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: THIRD_PARTY (0x01) Option Length: 16 bytes Data:
  ::ffff:198.51.100.2
```

Figure 49: MAP request with THIRD\_PARTY

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
```

MAP Response:  
Mapping Nonce: 16584  
Protocol: UDP (17)  
Internal Port: 8080  
Assigned External Port: 15000  
Assigned External IP Address: ::ffff:161.105.194.14  
Option Code: THIRD\_PARTY (0x01) Option Length: 16 bytes Data:  
::ffff:198.51.100.2

Figure 50: MAP Response with THIRD\_PARTY

## [5.2.](#) THIRD\_PARTY Disabled at the Server Side

The following messages are exchanged when the THIRD\_PARTY option is disabled in the PCP server side. In this example the PCP client tries to create a mapping for the host assigned with 198.51.100.2.

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 16584  
Protocol: UDP (17)  
Internal Port: 8080  
Suggested External Port: 8080  
Suggested External IP Address: ::ffff:0.0.0.0  
Option Code: THIRD\_PARTY (0x01) Option Length: 16 bytes Data:  
::ffff:198.51.100.2

Figure 51: MAP request with THIRD\_PARTY

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: UNSUPP\_OPTION (0x05)  
Lifetime: 0 sec  
Epoch Time: 1562

Figure 52: MAP Response with THIRD\_PARTY

### [5.3.](#) Malformed Request

In this example the PCP client inserts a THIRD\_PARTY option which include the IP address of the PCP client.

```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 16584
  Protocol: UDP (17)
  Internal Port: 8080
  Suggested External Port: 8080
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: THIRD_PARTY (0x01) Option Length: 16 bytes Data:
  ::ffff:198.51.100.1
```

Figure 53: MAP request with THIRD\_PARTY

```
Version: 2
R bit: Response (1)
opcode: MAP (0x01)
Result Code: MALFORMED_REQUEST (0x03)
Lifetime: 0 sec
```

Epoch Time: 1562

Figure 54: MAP Response with THIRD\_PARTY

## 6. MAP with FILTER Examples

These examples follow the behavior specified in [Section 13.3 of \[RFC6887\]](#).

### 6.1. Basic Filter Usage

This example illustrates the content of exchanged PCP messages when the PCP client wants to receive traffic only from 192.0.2.200:5968. In reference to Figure 1, the content of exchanged PCP messages is as follows:

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```
Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: FILTER (0x03) Option Length: 20 bytes Data:
  Prefix Length: 128
  Remote Peer Port: 5968
```

Remote Peer IP Address: ::ffff:192.0.2.200

Figure 55: MAP request (Basic Filter Usage)

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 20000 sec  
Epoch Time: 1250  
MAP Response:  
Mapping Nonce: 15685  
Protocol: UDP (17)  
Internal Port: 3938  
Assigned External Port: 3938  
Assigned External IP Address: ::ffff:192.0.2.1  
Option Code: FILTER (0x03) Option Length: 20 bytes Data:  
Prefix Length: 128  
Remote Peer Port: 5968  
Remote Peer IP Address: ::ffff:192.0.2.200

Figure 56: MAP Response (Basic Filter Usage)

## [6.2.](#) Remove All Filters

This example illustrates the content of exchanged PCP messages when the PCP client wants to remove all filters. In reference to Figure 1, the content of exchanged PCP messages is as follows:

Version: 2  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
Mapping Nonce: 15685



Protocol: UDP (17)  
Internal Port: 3938  
Suggested External Port: 3938  
Suggested External IP Address: ::ffff:0.0.0.0  
Option Code: FILTER (0x03) Option Length: 20 bytes Data:  
    Prefix Length: 0  
    Remote Peer Port: 0  
    Remote Peer IP Address: ::ffff:0:0

Figure 57: MAP request (Remove All Filters)

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: 0  
Lifetime: 20000 sec  
Epoch Time: 1250  
MAP Response:  
    Mapping Nonce: 15685  
    Protocol: UDP (17)  
    Internal Port: 3938  
    Assigned External Port: 3938  
    Assigned External IP Address: ::ffff:192.0.2.1  
Option Code: FILTER (0x03) Option Length: 20 bytes Data:  
    Prefix Length: 0  
    Remote Peer Port: 0  
    Remote Peer IP Address: ::ffff:0:0

Figure 58: MAP response (Remove All Filters)

### [6.3.](#) Change an Existing Filter

This example illustrates the content of exchanged PCP messages when the PCP client wants to change an existing filter. In reference to Figure 1, the content of exchanged PCP messages is as follows:

```

Version: 2
R bit: Request (0)
opcode: MAP (0x01)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
MAP Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
Option Code: FILTER (0x03) Option Length: 20 bytes Data:
  Prefix Length: 0
  Remote Peer Port: 0
  Remote Peer IP Address: ::ffff:0:0
Option Code: FILTER (0x03) Option Length: 20 bytes Data:
  Prefix Length: 128
  Remote Peer Port: 5968
  Remote Peer IP Address: ::ffff:192.0.2.201

```

Figure 59: MAP request (Change an Existing Filter)

## 7. Assess the Reachability of the PCP Server

In this example, the PCP client issues a PCP ANNOUNCE request to a PCP server. Once received by the PCP server, since it is configured to reply to such request, it sends back a PCP ANNOUNCE response. This procedure can be used to retrieve the Epoch time.

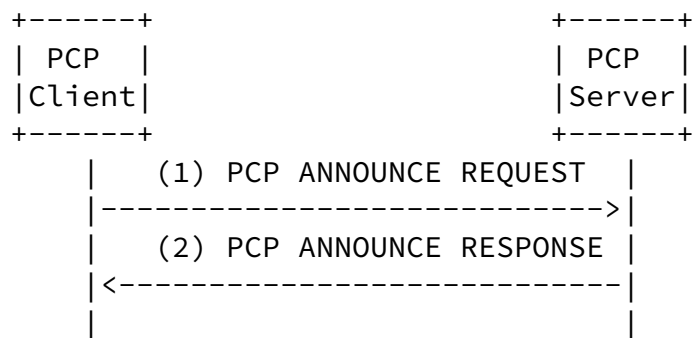


Figure 60: Flow example of a PING/PONG exchange: Check the availability of the PCP server

```

Version: 2
R bit: Request (0)
opcode: ANNOUNCE (0x00)
Requested Lifetime: 0 sec
PCP client's IP Address: ::ffff:198.51.100.1

```

Figure 61: ANNOUNCE request (Assess the Reachability of the PCP Server)

```

Version: 2
R bit: Response (1)
opcode: ANNOUNCE (0x00)
Result Code: 0
Lifetime: 0 sec
Epoch Time: 3600

```

Figure 62: ANNOUNCE response (Assess the Reachability of the PCP Server)

## 8. PEER Operations

The following figure illustrates the messages which are exchanged when PEER opcode is used:

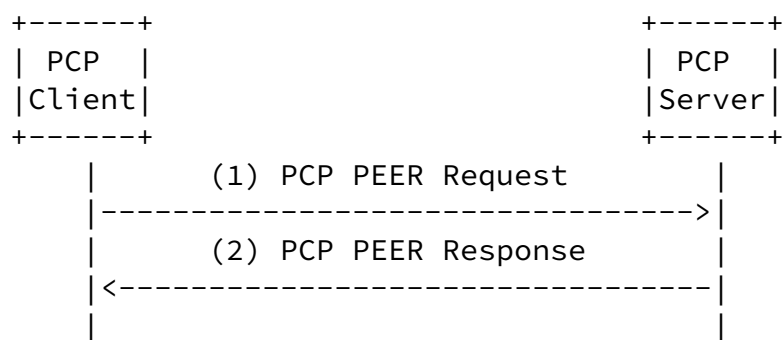


Figure 63: Typical usage of PEER message

Examples listed below follow the behavior specified in [Section 12.2](#) and [Section 12.3 of \[RFC6887\]](#).

### 8.1. No Mapping Exists for the Internal Port Number

In reference to Figure 63, the content of exchanged PEER messages

when no mapping is maintained by the PCP server for the indicated external port number:

Version: 2  
R bit: Request (0)  
opcode: PEER (0x02)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
PEER Request:  
  Mapping Nonce: 15685  
  Protocol: UDP (17)  
  Internal Port: 3938  
  Suggested External Port: 3938  
  Suggested External IP Address: ::ffff:0.0.0.0  
  Remote Peer Port: 12456  
  Remote IP Address: ::ffff:198.51.100.2

Figure 64: PEER request (No Mapping Exists for the Internal Port Number)

Version: 2  
R bit: Response (1)  
opcode: PEER (0x02)  
Result Code: 0  
Lifetime: 20000 sec  
Epoch Time: 1250  
PEER Response:  
  Mapping Nonce: 15685  
  Protocol: UDP (17)  
  Internal Port: 3938  
  Assigned External Port: 3938  
  Assigned External IP Address: ::ffff:192.0.2.1  
  Remote Peer Port: 12456  
  Remote IP Address: ::ffff:198.51.100.2

Figure 65: PEER response (No Mapping Exists for the Internal Port Number)

## [8.2.](#) A Mapping Exists for the External Port Number

In reference to Figure 63, the content of exchanged PEER messages when a mapping is maintained by the PCP server for the indicated external port number:

```
Version: 2
R bit: Request (0)
opcode: PEER (0x02)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
PEER Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:0.0.0.0
  Remote Peer Port: 12456
  Remote IP Address: ::ffff:198.51.100.2
```

Figure 66: PEER request (A Mapping Exists for the External Port Number)

```
Version: 2
R bit: Response (1)
opcode: PEER (0x02)
Result Code: CANNOT_PROVIDE_EXTERNAL
Lifetime: 0 sec
Epoch Time: 36000
```

Figure 67: PEER response (A Mapping Exists for the External Port Number)

### [8.3.](#) External IP Address Cannot be Honored

In reference to Figure 63, the content of exchanged PEER messages when the suggested external IP address does not match an existing mapping is shown below:

```
Version: 2
R bit: Request (0)
opcode: PEER (0x02)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
PEER Request:
  Mapping Nonce: 15685
  Protocol: UDP (17)
  Internal Port: 3938
  Suggested External Port: 3938
  Suggested External IP Address: ::ffff:192.0.2.5
  Remote Peer Port: 12456
  Remote IP Address: ::ffff:198.51.100.2
```

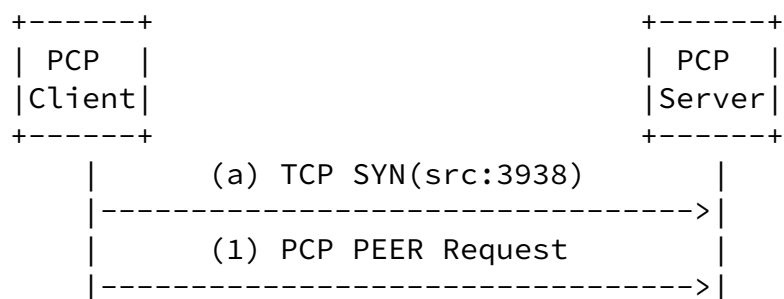
Figure 68: PEER request (External IP Address Cannot be Honored)

```
Version: 2
R bit: Response (1)
opcode: PEER (0x02)
Result Code: CANNOT_PROVIDE_EXTERNAL
Lifetime: 0 sec
Epoch Time: 36000
```

Figure 69: PEER response (External IP Address Cannot be Honored)

#### [8.4.](#) Extend the Lifetime

In reference to Figure 70, the content of exchanged PEER messages to extend the lifetime of a mapping.



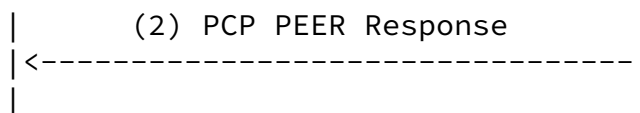


Figure 70: Example of creating a mapping

```
Version: 2
R bit: Request (0)
opcode: PEER (0x02)
Requested Lifetime: 36000 sec
PCP client's IP Address: ::ffff:198.51.100.1
PEER Request:
  Mapping Nonce: 15685
  Protocol: TCP (6)
  Internal Port: 3938
  Suggested External Port: 0
  Suggested External IP Address: ::ffff:0.0.0.0
  Remote Peer Port: 12456
  Remote IP Address: ::ffff:198.51.100.2
```

Figure 71: PEER request (Extend the Lifetime)

```
Version: 2
R bit: Response (1)
opcode: PEER (0x02)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
PEER Response:
  Mapping Nonce: 15685
  Protocol: TCP (6)
  Internal Port: 3938
  Assigned External Port: 11000
  Assigned External IP Address: ::ffff:192.0.2.1
  Remote Peer Port: 12456
  Remote IP Address: ::ffff:198.51.100.2
```

Figure 72: PEER response (Extend the Lifetime)

#### [8.5.](#) Learn the Lifetime of a Mapping

In reference to Figure 70, the content of exchanged PEER messages to learn the lifetime of a mapping is shown below:

```
Version: 2
R bit: Request (0)
opcode: PEER (0x02)
Requested Lifetime: 5 sec
PCP client's IP Address: ::ffff:198.51.100.1
PEER Request:
  Mapping Nonce: 15685
  Protocol: TCP (6)
  Internal Port: 3938
  Suggested External Port: 0
  Suggested External IP Address: ::ffff:0.0.0.0
  Remote Peer Port: 12456
  Remote IP Address: ::ffff:198.51.100.2
```

Figure 73: PEER request (Learn the Lifetime of a Mapping)

```
Version: 2
R bit: Response (1)
opcode: PEER (0x02)
Result Code: 0
Lifetime: 20000 sec
Epoch Time: 1250
PEER Response:
  Mapping Nonce: 15685
```



Protocol: TCP (6)  
Internal Port: 3938  
Assigned External Port: 11000  
Assigned External IP Address: ::ffff:192.0.2.1  
Remote Peer Port: 12456  
Remote IP Address: ::ffff:198.51.100.2

Figure 74: PEER response (Learn the Lifetime of a Mapping)

## [9.](#) Version Negotiation

The following exchange occurs between a PCP client that supports PCP version 1 and the PCP server that supports PCP version 2.

Version: 1  
R bit: Request (0)  
opcode: MAP (0x01)  
Requested Lifetime: 36000 sec  
PCP client's IP Address: ::ffff:198.51.100.1  
MAP Request:  
  Protocol: UDP (17)  
  Internal Port: 3938  
  Suggested External Port: 3938  
  Suggested External IP Address: ::ffff:0.0.0.0

Figure 75: MAP request with Version 1

Version: 2  
R bit: Response (1)  
opcode: MAP (0x01)  
Result Code: UNSUPP\_VERSION (1)  
Lifetime: 0 sec  
Epoch Time: 3600

Figure 76: MAP response (Unsupported Version)

Version negotiation is specified in [Section 9 of \[RFC6887\]](#).

## [10.](#) Security Considerations

PCP security considerations are discussed in [[RFC6887](#)].

## [11.](#) IANA Considerations

This document has no IANA actions.

## [12.](#) Acknowledgements

Many thanks to C. Jacquenet and D. Wing for the comments.

## [13.](#) References

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

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- [RFC5737] Arkko, J., Cotton, M., and L. Vegoda, "IPv4 Address Blocks Reserved for Documentation", [RFC 5737](#), January 2010.
- [RFC6887] Wing, D., Cheshire, S., Boucadair, M., Penno, R., and P. Selkirk, "Port Control Protocol (PCP)", [RFC 6887](#), April 2013.
- [RFC7220] Boucadair, M., Penno, R., and D. Wing, "Description Option for the Port Control Protocol (PCP)", [RFC 7220](#), May 2014.
- [RFC7225] Boucadair, M., "Discovering NAT64 IPv6 Prefixes Using the Port Control Protocol (PCP)", [RFC 7225](#), May 2014.

### [13.2.](#) Informative References

- [I-D.cheshire-pcp-unsupp-family]  
Cheshire, S. and S. Perreault, "Updates to the PCP Specification", [draft-cheshire-pcp-unsupp-family-06](#) (work in progress), October 2013.

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