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**Extensions to the Path Computation Element Communication Protocol for Traffic Engineering Label Switched Paths in GMPLS Networks**

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Abstract

This document defines the extensions for the Path Computation Element Communication Protocol (PCEP) to support the establishment of TE LSPs in GMPLS networks.

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].

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## 1. Introduction

RFC4655 defines the PCE based architecture and explains how a PCE may compute LSPs in MPLS Traffic Engineering (TE) and GMPLS) networks at the request of Path Computation Clients (PCCs).

RFC5440 specifies the PCEP for communication between a PCC and a PCE, or between two PCEs, in compliance with RFC4657. However, that it does not provide a mechanism to request path computation for establishing TE LSPs in GMPLS networks such as SDH network. [GMPLS-REQ] addresses the functional requirements for GMPLS in PCE application.

This document describes the protocol extensions to PCEP to support path computation for TE LSP in GMPLS networks.

### 1.1. Requirements Language

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.

## 2. Terminology

The following terminology is used in this document.

PCC: Path Computation Client. Any client application requesting a path computation to be performed by the Path Computation Element.

PCE: Path Computation Element. An entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints.

PCEP: Path Computation Element Communication Protocol. PCEP is a request/response protocol used for the communication between a PCC and a PCE, or between two PCEs.

PCEP Peer: An element involved in a PCEP session (For example, a PCC or a PCE).

PCEP Session: The PCEP session is a logical connection established automatically between the PCEP peers.

This document also uses the terminology defined in RFC4655, and RFC5440.

## 3. PCEP Requirements

This section summarizes the PCEP extensions for GMPLS. This document introduces no new messages for PCEP. However, extensions have been introduced to the existing PCEP objects, sub-objects and TLVs. Also,

a few new objects and TLVs have been introduced to support network type and QoS. The details on the PCEP objects and TLVs are mentioned below:

Enhanced Objects

- o PCEP End Point (IPv4/Node ID) Object
- o PCEP NO-PATH Object

Newly Introduced Object

- o PCEP QoS Object

Newly Introduced TLVs

- o Destination Prefix Information
- o Traffic Parameters
- o LSP Protection Information

## 4. Protocol Procedure and Extensions

### 4.1. SWITCH-LAYER Object

The PCE architecture can be extended to support various network types such as SDH, WDM, OTN, and PTN and so on. PCE MAY select the appropriate policy profile depending on the current path request which is applicable to a particular network type.

The SWITCH-LAYER object is an OPTIONAL object and MUST be carried only in PCReq and PCRep message specifying the encoding and switching type of the network, to which the path request belongs to. This object is defined in [INTER-LAYER] (Section 3.2).

### 4.2. END-POINTS Object Extension

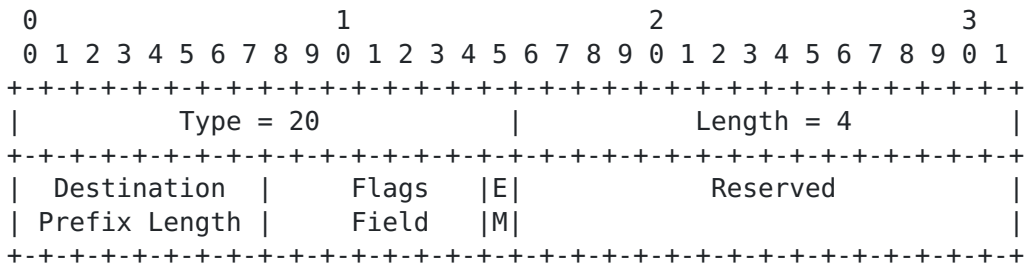
The END-POINTS object is used in a PCReq message to specify the source IP address and the destination IP address of the path for which a path computation is requested. New OPTIONAL TLV is defined that is to be carried in the END-POINTS object for the path that depends on destination prefix information.

#### 4.2.1. Destination Prefix Information TLV

The Destination Prefix Information TLV is a new OPTIONAL TLV. It MUST only appear inside END-POINTS (IPv4/Node ID) object. The receiver SHOULD ignore the Destination Prefix Information TLV if it appears in

any other object other than END-POINTS object. This TLV contains the prefix length for the destination IPv4 address and will appear when prefix length is in the range between 0 and 32 (inclusive).

The format of the Destination Prefix Information TLV is as follows:




Destination Prefix Length (8-bits) - Specifies the prefix length of the destination IPv4 address.

Flags Field (7-bits) - Reserved for future to define new flags. It MUST be filled with zeros and SHOULD be ignored by the receiver.

EM- Exact Prefix Match (1-bit) - Specifies whether exact prefix match is required for the destination IPv4 address.

| Bit | EM Type |
|---|---|
| 0 | Exact prefix match is not required |
| 1 | Exact prefix match is required |

Reserved (16-bits) - Reserved. MUST be set to zero and SHOULD be ignored by the receiver.

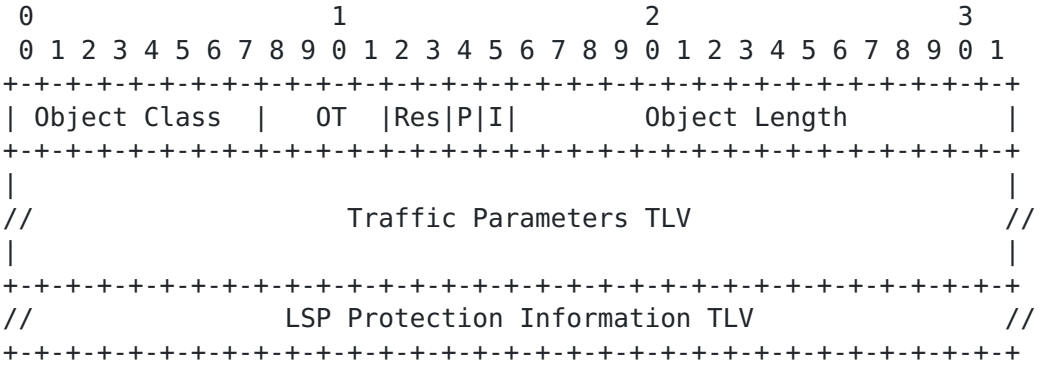
### 4.3. New Object - QoS

When a PCC requests a PCE for a route, and if PCE provides the response to the request, it MAY be useful for the PCC and the PCE to include the traffic parameters. These traffic parameters specify a base set of capabilities for GMPLS networks such as Service Level Agreement (SLA), protection scheme, segment recovery, concatenation, transparency, and so on. The QoS object handles the quality of service parameters for TE-LSPs in GMPLS networks.

The QoS object can be included in the PCReq and PCRep messages by the PCC and PCE respectively. It represents the parameters that become necessary to manage bandwidth in the networks. When a PCE cannot find a path by satisfying a set of constraints requested by the PCC, the

PCE may also include the original constraint so as to indicate the reason for an unsuccessful computation in the NO-PATH object. Based on the available service parameters proposed by a PCE, the PCC MAY decide to resend the path requests. These parameters ensure that the applications are guaranteed the network resources they need, despite varying traffic load.

The format of the QoS object is as follows:




Object Class (8-bits) - Specifies the class of the object (Value = 25).

OT - Object Type (4-bits) - Specifies the type of the object (Value = 1).

### 4.3.1. Traffic Parameters TLV

For different networks, different traffic parameters should be embedded in the Traffic Parameters TLV, which is a new OPTIONAL TLV. The following types are defined currently:

| Object Type | Name | Remarks |
|---|---|---|
| 34 | SDH-Traffic | SDH/Sonet networks |
| 35 | G.709-Traffic | OTN digital wrapper |
| 36 | WSON-Traffic | WSON |
| 37 | Ethernet-Traffic | Ethernet |
| 38 | PTN | TBD |

For SDH-Traffic, the contents of this object are identical in encoding to the contents of the Resource Reservation Protocol Traffic

Engineering Extensions (RSVP-TE)SONET and SDH Parameters defined in RFC4606 (section 2.1).

For G.709-Traffic, the contents of this object are identical with the Traffic Parameters defined in [OTN-SIG].

For WSON-Traffic and Ethernet-Traffic, we can refer to [WSON-SIG] and [Eth-Traffic].

### 4.3.2. LSP Protection Information TLV

The LSP Protection Information TLV is a new OPTIONAL TLV and MUST only appear inside QoS object. This TLV contains the LSP recovery attributes, LSP association and protection constraints that are required during signaling to support end-to-end LSP recovery.

The information of end-to-end LSP recovery during GMPLS signaling is already defined in RFC4872 and RFC4873. Henceforth, the contents of LSP Protection Information TLV defined in this document is identical to the Protection Object defined in RFC4873 (section 6.1).

LSP Protection Information TLV type is 40.

### 4.3.3. SWITCH-LAYER and QoS Object in PCReq and PCRep

As mentioned earlier the SWITCH-LAYER and QoS object MAY be included in the PCReq message. These objects are OPTIONAL, and if QoS object is present only one instance of SDH-ASON QoS parameters TLV or LSP protection TLV must be included. If multiple instances of TLV or some other TLV is present, then the complete message has to be discarded without performing any further processing.

The format of the PCReq message including the SWITCH-LAYER and QoS object is as follows:

```
<PCReq Message> ::= <Common Header>
                    [<svec-list>]
                    <request-list>
```

where:

```
       <svec-list> ::= <SVEC>[<svec-list>]

       <request-list> ::= <request>[<request-list>]

       <request> ::= <RP>
                     <SWITCH-LAYER>
```

```
                        <END-POINTS>
                        [<LSPA>]
                        [<BANDWIDTH>]
                        [<QoS>]
                        [<metric-list>]
                        [<RRO>[<BANDWIDTH>]]
                        [<IRO>]
                        [<LOAD-BALANCING>]
```

The format of the PCRep message is as follows:

```
<PCRep Message> ::= <Common Header>
                    <response-list>
```

where:

```
       <response-list> ::= <response>[<response-list>]

       <response> ::= <RP>
                      <SWITCH-LAYER>
                      [<NO-PATH>]
                      [<attribute-list>]
                      [<path-list>]

       <path-list> ::= <path>[<path-list>]

       <path> ::= <ERO><attribute-list>
```

where:

```
       <attribute-list> ::= [<LSPA>]
                            [<BANDWIDTH>]
                            [<QoS>]
                            [<metric-list>]
                            [<IRO>]

       <metric-list> ::= <METRIC>[<metric-list>]
```

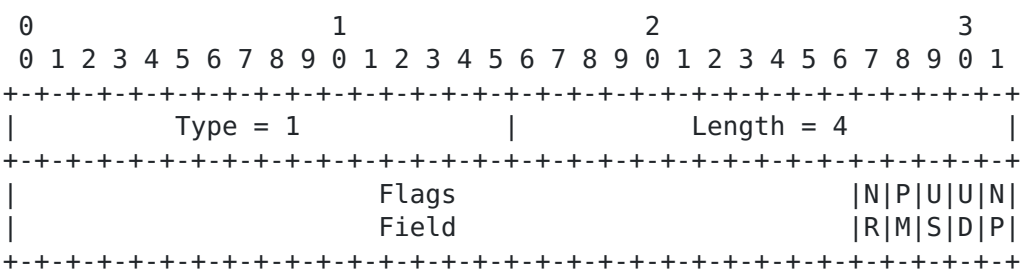
### 4.4. NO-PATH Object Extension

The NO-PATH object is used in PCRep messages in response to an unsuccessful path computation request (the PCE could not find a path by satisfying the set of constraints). In this scenario, PCE MUST include a NO-PATH object in the PCRep message.

The NO-PATH object carries the NO-PATH-VECTOR TLV that specifies more information on the reasons that led to a negative reply. In case of GMPLS networks there could be some more additional constraints that led to the failure like protection mismatch, lack of resources, and so on. Few new flags have been introduced in 32-bit flag field of the NO-PATH-VECTOR TLV and no modifications have been made in the NO-PATH object.

### 4.4.1. Extensions to NO-PATH-VECTOR TLV

The modified NO-PATH-VECTOR TLV carrying the additional information is as follows:




NP - PCE currently unavailable
UD - Unknown destination
US - Unknown source

New fields PM and NR are defined in the 28th and 27th bit of the Flags field respectively.

PM - Protection Mismatch (1-bit). Specifies the mismatch of the protection type in the request.

NR - No Resource (1-bit). Specifies that the resources are not

currently sufficient to provide the path.

## 4.5. Additional Error Type and Error Values Defined

A PCEP-ERROR object is used to report a PCEP error and is characterized by an Error-Type that specifies the type of error and an Error-value that provides additional information about the error type. An additional error type and few error values are defined to represent some of the errors related to the newly identified objects related to GMPLS networks.

For each PCEP error, an Error-Type and an Error-value are defined. Error-Type 1 to 10 is already defined in RFC5440. Additional Error-values are defined for Error-Type 10 and a new Error-Type 14 is introduced.

| Error-Type | Error-value |
|---|---|
| 10 | Reception of an invalid object |
| | Error-value=2: LSP Protection Information TLV missing in QoS object. |
| | Error-value=3: TLV missing in QoS object. |
| | Error-value=4: Multiple instance of TLV present in QoS object. |
| | Error-value=5: Unsupported TLV present in QoS object. |
| | Error-value=6: Traffic Parameters TLV missing in QoS object. |
| 14 | Path computation failure |
| | Error-value=1: Unacceptable response message. |
| | Error-value=2: QoS object missing in request message. |

## 5. Liveness Detection and Monitoring

This document makes no change to the basic operation of PCEP and so there are no changes to the requirements for liveness detection and monitoring set out in RFC4657 and RFC5440.

## 6. IANA Considerations

IANA assigns values to the PCEP protocol objects and TLVs. IANA is requested to make some allocations for the newly defined objects and TLVs introduced in this document. Also, IANA is requested to manage the space of flags that are newly added in the TLVs.

### 6.1. New PCEP Object

IANA is requested to make some allocations for the QoS object:

| Object-Class Value | Name | Reference |
|---|---|---|
| 25 | QoS Object-Type-1 | This document (section 4.5) |

## 6.2. New PCEP TLVs

IANA is requested to create a registry for the following TLVs:

| Value | Meaning | Reference |
|---|---|---|
| 20 | Destination Prefix Information | This document (section 4.1.1) |
| 34 | SDH-Traffic | This document (section 4.2.1) |
| 35 | G.709-Traffic | This document (section 4.2.1) |
| 36 | WSON-Traffic | This document (section 4.2.1) |
| 37 | Ethernet-Traffic | This document (section 4.2.1) |
| 40 | LSP Protection Information | This document (section 4.2.2) |

## 6.3. PCEP NO-PATH-VECTOR TLV Flag Field

IANA is requested to update the registry that manages the Flag field of the NO-PATH-VECTOR TLV.

New bit numbers may be allocated only by an IETF Consensus action. Each bit should be tracked with the following qualities:

- Bit number (counting from bit 0 as the most significant bit)
- Name Flag
- Reference

Code space of the Flag field (NO-PATH-VECTOR TLV).

| Bit Number | Name | Reference |
|---|---|---|
| 27 | No Resource (NR) | This document (section 4.2.1) |
| 28 | Protection Mismatch (PM) | This document (section 4.2.1) |

### 6.4. New PCEP Error Codes

As descried in Section 4.5, new PCEP Error-Type and Error Values are defined. IANA is requested to manage the code space of the Error object.

| Error-Type | Error-value |
|---|---|
| 10 | Reception of an invalid object |
| | Error-value=2: LSP Protection Information TLV missing in QoS object. |
| | Error-value=3: TLV missing in QoS object. |
| | Error-value=4: Multiple instance of TLV present in QoS object. |
| | Error-value=5: Unsupported TLV present in QoS object. |
| | Error-value=6: Traffic Parameters TLV missing in QoS object. |
| 14 | Path computation failure |
| | Error-value=1: Unacceptable response message. |
| | Error-value=2: QoS object missing in request message. |

## 7. Security Considerations

The protocol extensions defined in this document do not substantially change the nature of PCEP. Therefore, the security considerations set out in RFC5440 apply unchanged.

## 8. Acknowledgements

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