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C. Margaria, Ed.
Nokia Siemens Networks
O. Gonzalez de Dios, Ed.
Telefonica Investigacion y Desarrollo
F. Zhang, Ed.
Huawei Technologies
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PCEP extensions for GMPLS
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Abstract

This memo provides extensions for the Path Computation Element communication Protocol (PCEP) for the support of GMPLS control plane.

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on April 24, 2013.

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1. Introduction

Although [RFC4655] defines the PCE architecture and framework for both MPLS and GMPLS networks, current PCEP RFCs [RFC5440], [RFC5521], [RFC5541], [RFC5520] are focused on MPLS networks, and do not cover the wide range of GMPLS networks. This document complements these RFCs by addressing the extensions required for GMPLS applications and routing requests, for example for OTN and WSON networks.

The functional requirements to be considered by the PCEP extensions to support those application are described in [I-D.ietf-pce-gmpls-aps-req] and [I-D.ietf-pce-wson-routing-wavelength].

1.1. Contributing Authors

Elie Sfeir, Franz Rambach (Nokia Siemens Networks) Francisco Javier Jimenez Chico (Telefonica Investigacion y Desarrollo) Suresh BR, Young Lee, SenthilKumar S, Jun Sun (Huawei Technologies), Ramon Casellas (CTTC)

1.2. PCEP requirements for GMPLS

The document [I-D.ietf-pce-gmpls-aps-req] describes the set of PCEP requirements to support GMPLS TE-LSPs. When a PCC requests a PCE to perform a path computation (by means of a PCReq message), the PCC should be able to indicate the following additional information:

- Which data flow is switched by the LSP: a combination of Switching Type (for instance L2SC or TDM), Switching Encoding (e.g., Ethernet, SONET/SDH) and sometimes the Signal Type (e.g. in case of TDM/LSC switching capability)

- Data flow specific traffic parameters, which are technology specific. For instance, in SDH/SONET and G.709 OTN networks the Concatenation Type and the Concatenation Number have an influence on the switched data and on which link it can be supported

- Support for asymmetric bandwidth requests.

- Support for unnumbered interface identifiers, as defined in [RFC3477]

- Label information and technology specific label(s) such as wavelength labels as defined in [RFC6205]. A PCC should also be able to specify a Label restriction similar to the one supported by RSVP.

- Ability to indicate the requested granularity for the path ERO: node, link or label. This is to allow the use of the explicit label control feature of RSVP-TE.

We describe in this document a set of PCEP protocol extensions, including new objects, TLVs, encodings, error codes and procedures, in order to fulfill the aforementioned requirements.

1.3. Current GMPLS support and limitation of existing PCEP objects

PCEP as of [RFC5440], [RFC5521] and [I-D.ietf-pce-inter-layer-ext], supports the following objects, included in requests and responses related to the described requirements.

From [RFC5440]:

- ENDPOINTS: only numbered endpoints are considered. The context specifies whether they are node identifiers or numbered interfaces.

- BANDWIDTH: the data rate is encoded in the bandwidth object (as IEEE 32 bit float). [RFC5440] does not include the ability to convey a (Intserv) TSPEC object.

- ERO : Unnumbered endpoints are supported.

- LSPA: LSP attributes (setup and holding priorities)

From [RFC5521] :

- XRO object :

  * This object allows excluding (strict or not) resources, and includes the requested diversity (node, link or SRLG).

  * When the F bit is set, the request indicates that the existing route has failed and the resources present in the RRO can be reused.

From [I-D.ietf-pce-inter-layer-ext]:

- INTER-LAYER : indicates whether inter-layer computation is allowed

- SWITCH-LAYER : indicates which layer(s) should be considered, can be used to represent the RSVP-TE generalized label request

- REQ-ADAP-CAP : indicates the adaptation capabilities requested, can also be used for the endpoints in case of mono-layer

computation

The shortcomings of the existing PCEP object are:

The BANDWIDTH and LOAD-BALANCING objects do not describe the details of the traffic request (for example NVC, multiplier) in the context of GMPLS networks, for instance TDM or OTN networks.

The END-POINTS object does not allow specifying an unnumbered interface, nor potential label restrictions on the interface. Those parameters are of interest in case of switching constraints.

The IRO/XRO objects do not allow the inclusion/exclusion of labels

Current attributes do not allow expressing the requested link protection level and/or the end-to-end protection attributes.

The covered PCEP extensions are:

New objects are introduced (GENERALIZED-BANDWIDTH and GENERALIZED-LOAD-BALANCING) for flexible bandwidth encoding,

A new object type is introduced for the END-POINTS object (GENERALIZED-ENDPOINT),

A new TLV is added to the LSPA object.

A new TLV type for label is allowed in IRO and XRO objects.

In order to indicate the used routing granularity in the response, a new flag in the RP object is added.

1.4. 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 RFC 2119 [RFC2119].

2. PCEP objects and extensions

This section describes the required PCEP objects and extensions. The PCReq and PCRep messages are defined in [RFC5440]. The format of the PCEP request and response with the proposed extensions (GENERALIZED-BANDWIDTH, GENERALIZED-LOAD-BALANCING, SUGGESTED-LABEL-SET and LABEL-SET) is as follows:

```
<request>::= <RP>
             <segment-computation>|<path-key-expansion>

<segment-computation> ::=
  <END-POINTS>
  [<LSPA>]
  [<BANDWIDTH>][<GENERALIZED-BANDWIDTH>...]
  [<metric-list>]
  [<OF>]
  [<RRO> [<BANDWIDTH>][<GENERALIZED-BANDWIDTH>...]]
  [<IRO>]
  [<LOAD-BALANCING>]
  [<GENERALIZED-LOAD-BALANCING>...]
  [<XRO>]

<path-key-expansion> ::= <PATH-KEY>

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

<path-list>::=<path>[<path-list>]
<path>::= <ERO><attribute-list>
<metric-list>::=<METRIC>[<metric-list>]
```

Where:

```
<attribute-list>::=[<LSPA>]
[<BANDWIDTH>]
[<GENERALIZED-BANDWIDTH>...]
[<GENERALIZED-LOAD-BALANCING>...]
[<metric-list>]
[<IRO>]
```

For point-to-multipoint(P2MP) computations, the grammar is:

```
    <segment-computation> ::=
        <end-point-rro-pair-list>
        [<OF>]
        [<LSPA>]
        [<BANDWIDTH>]
        [<GENERALIZED-BANDWIDTH>...]
        [<metric-list>]
        [<IRO>]
        [<LOAD-BALANCING>]
        [<GENERALIZED-LOAD-BALANCING>...]
        [<XRO>]

     <end-point-rro-pair-list>::=
              <END-POINTS>[<RRO-List>][<BANDWIDTH>]
             [<GENERALIZED-BANDWIDTH>...]
             [<end-point-rro-pair-list>]

     <RRO-List>::=<RRO>[<BANDWIDTH>]
     [<GENERALIZED-BANDWIDTH>...][<RRO-List>]
```

2.1. RP object extension

Explicit label control (ELC) is a procedure supported by RSVP-TE, where the outgoing label(s) is(are) encoded in the ERO. In consequence, the PCE may be able to provide such label(s) directly in the path ERO. The PCC, depending on policies or switching layer, may be required to use explicit label control or expect explicit link, thus it need to indicate in the PCReq which granularity it is expecting in the ERO. This correspond to requirement 12 of [I-D.ietf-pce-gmpls-aps-req] The possible granularities can be node, link or label. The granularities are inter-dependent, in the sense that link granularity implies the presence of node information in the ERO; similarly, a label granularity implies that the ERO contains node, link and label information.

A new 2-bit routing granularity (RG) flag is defined in the RP object. The values are defined as follows

0 : node

1 : link

2 : label

3 : reserved

The flag in the RP object indicates the requested route granularity. The PCE MAY try to follow this granularity and MAY return a NO-PATH if the requested granularity cannot be provided. The PCE MAY return finer granularity on the route based on its policy. The PCC can decide if the ERO is acceptable based on its content.

If a PCE honored the the requested routing granularity for a request, it SHOULD indicate the selected routing granularity in the RP object included in the response . The RG flag is backward-compatible with [RFC5440]: the value sent by an implementation (PCC or PCE) not supporting it will indicate a node granularity.

2.2. Traffic parameters encoding, GENERALIZED-BANDWIDTH

The PCEP BANDWIDTH object does not describe the details of the signal (for example NVC, multiplier), hence the bandwidth information should be extended to use the RSVP Tspec object encoding. The PCEP BANDWIDTH object defines two types: 1 and 2. C-Type 2 is representing the existing bandwidth in case of re-optimization.

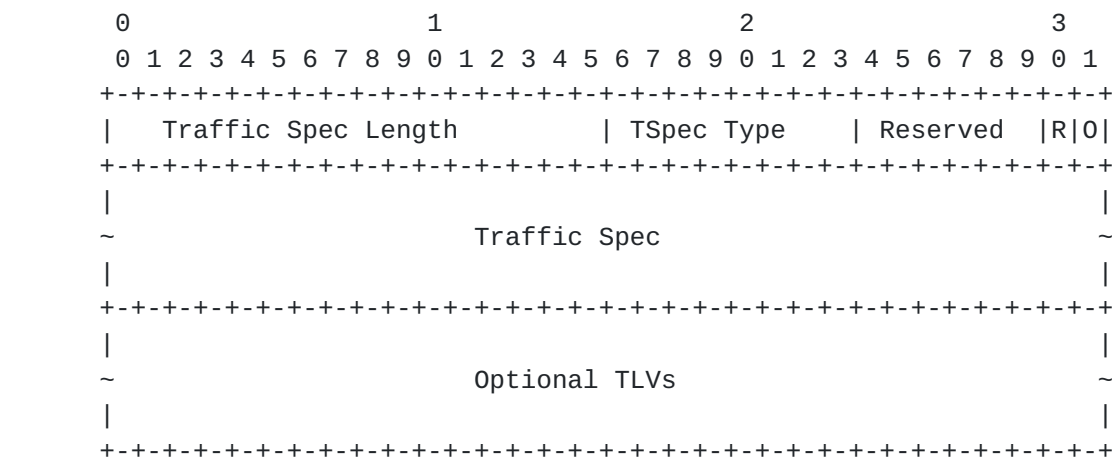
The following possibilities cannot be represented in the BANDWIDTH object:

- Asymmetric bandwidth (different bandwidth in forward and reverse direction), as described in [RFC6387]

- GMPLS (SDH/SONET, G.709, ATM, MEF etc) parameters are not supported.

This correspond to requirement 3,4,5 and 11 of [I-D.ietf-pce-gmpls-aps-req].

According to [RFC5440] the BANDWIDTH object has no TLV and has a fixed size of 4 bytes. This definition does not allow extending it with the required information. To express this information, a new object named GENERALIZED-BANDWIDTH with Object Type 1, having the following format is defined. The definitions below apply for Object Type 1. The payload of the GENERALIZED-BANDWIDTH is as follows:



The GENERALIZED-BANDWIDTH has a variable length. The Traffic spec length field indicates the length of the Traffic spec field. The bits R and O have the following meaning:

O bit : when set the value refers to the previous bandwidth in case of re-optimization

R bit : when set the value refers to the bandwidth of the reverse direction

The TSpec Type field determines which type of bandwidth is represented by the object.

The TSpec Type types correspond to the RSVPT-TE SENDER_TSPEC (Object Class 12) C-Types

The encoding of the field Traffic Spec is the same as in RSVP-TE, it can be found in the following references.

Object Type	Name	Reference
2	Intserv	[RFC2210]
4	SONET/SDH	[RFC4606]
5	G.709	[RFC4328]
6	Ethernet	[RFC6003]

Traffic Spec field encoding

The GENERALIZED-BANDWIDTH MAY appear more than once in a request message. If more than one GENERALIZED-BANDWIDTH objects have the same Tspec type, Reserved, R and O values, only the first one is

processed, the other objects are ignored.

A PCE MAY ignore GENERALIZED-BANDWIDTH objects, a PCC that requires a GENERALIZED-BANDWIDTH to be used can set the P (Processing) bit in the object header.

When a PCC needs to request a bi-directional path with asymmetric bandwidth, it SHOULD specify the different bandwidth in the forward and reverse directions through two separate GENERALIZED-BANDWIDTH objects. If the PCC set the P bit on both objects the PCE MUST compute a path that satisfies the asymmetric bandwidth constraint . If the P bit on the reverse or the forward GENERALIZED-BANDWIDTH object is not set the PCE MAY ignore this constraint.

A PCE MAY include the GENERALIZED-BANDWIDTH objects in the response to indicate the GENERALIZED-BANDWIDTH of the path

Optional TLVs may be included within the object body to specify more specific bandwidth requirements. No TLVs for the GENERALIZED-BANDWIDTH are defined by this document.

2.3. Traffic parameters encoding, GENERALIZED-LOAD-BALANCING

The LOAD-BALANCING object [RFC5440] is used to request a set of maximum Max-LSP TE-LSP having in total the bandwidth specified in BANDWIDTH, each TE-LSP having a minimum of bandwidth. The LOAD-BALANCING follows the bandwidth encoding of the BANDWIDTH object, and thus it does not describe enough details for the traffic specification expected by GMPLS. A PCC should be allowed to request a set of TE-LSP also in case of GMPLS traffic specification.

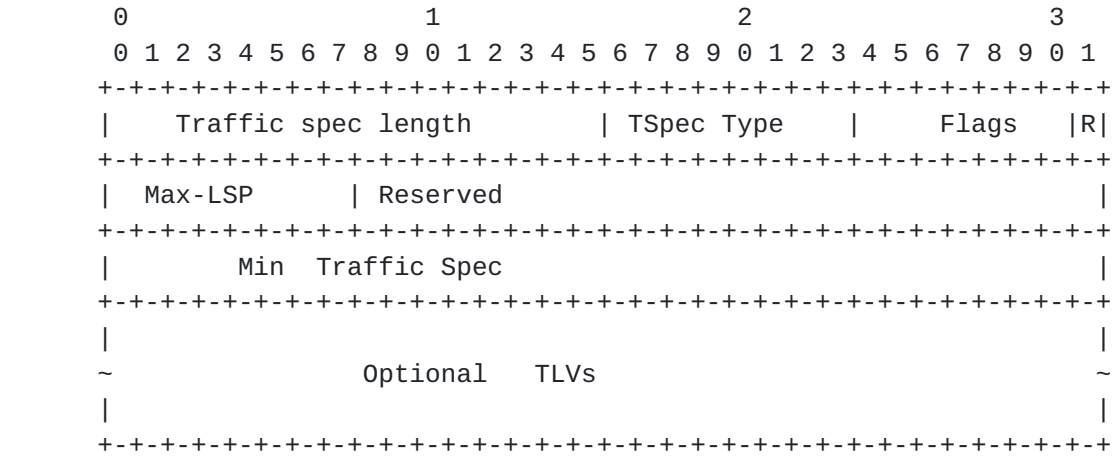
According to [RFC5440] the LOAD-BALANCING object has no optional TLVs and has a fixed size of 8 bytes. This definition does not allow extending it with the required information. To express this information, a new Object named GENERALIZED-LOAD-BALANCING is defined.

The GENERALIZED-LOAD-BALANCING object, as the LOAD-BALANCING object, allows the PCC to request a set of TE-LSP having in total the GENERALIZED-BANDWIDTH traffic specification with potentially Max-Lsp, each TE-LSP having a minimum of Min Traffic spec. The GENERALIZED-LOAD-BALANCING is optional.

GENERALIZED-LOAD-BALANCING Object-Class is to be assigned by IANA. GENERALIZED-LOAD-BALANCING Object Type 1 is defined below. The TSpec Type field determines which type of minimum bandwidth is represented by the object.

The GENERALIZED-LOAD-BALANCING has a variable length.

The format of the GENERALIZED-LOAD-BALANCING object body is as follows:



Traffic spec length (16 bits): the total length of the min traffic specification. It should be noted that the RSVP traffic specification may also include TLV different than the PCEP TLVs.

TSpec Type (8 bits) : the traffic specification type, it correspond to the RSVPT-TE SENDER_TSPEC (Object Class 12) C-Types

Flags (8 bits): The undefined Flags field MUST be set to zero on transmission and MUST be ignored on receipt. The following flag is defined:

R Flag : (1 bit) set when the value refer to the bandwidth of the reverse direction

Max-LSP (8 bits): maximum number of TE LSPs in the set.

Min-Traffic spec (variable): Specifies the minimum traffic spec of each element of the set of TE LSPs.

The encoding of the field Min Traffic Spec is the same as in RSVP-TE, it can be found in the following references.

Object Type	Name	Reference
2	Intserv	[RFC2210]
4	SONET/SDH	[RFC4606]
5	G.709	[RFC4328]
6	Ethernet	[RFC6003]

Traffic Spec field encoding

The GENERALIZED-LOAD-BALANCING MAY appear more than once in a PCEP request. If more than one GENERALIZED-LOAD-BALANCING have the same TSpec Type, and R Flag, only the first one is processed, the others are ignored.

A PCE MAY ignore GENERALIZED-LOAD-BALANCING objects. A PCC that requires a GENERALIZED-LOAD-BALANCING to be used can set the P (Processing) bit in the object header.

When a PCC needs to request a bi-directional path with asymmetric bandwidth while specifying load balancing constraints, it SHOULD specify the different bandwidth in forward and reverse directions through two separate GENERALIZED-LOAD-BALANCING objects with different R Flag. If the PCC set the P bit on both object the PCE MUST compute a path that satisfies the asymmetric bandwidth constraint . If the P bit is not set the reverse or forward GENERALIZED-LOAD-BALANCING object the PCE MAY ignore this constraint.

Optional TLVs may be included within the object body to specify more specific bandwidth requirements. No TLVs for the GENERALIZED-LOAD-BALANCING are defined by this document.

The GENERALIZED-LOAD-BALANCING object has the same semantic as the LOAD-BALANCING object; If a PCC requests the computation of a set of TE LSPs so that the total of their generalized bandwidth is X, the maximum number of TE LSPs is N, and each TE LSP must at least have a bandwidth of B, it inserts a GENERALIZED-BANDWIDTH object specifying X as the required bandwidth and a GENERALIZED-LOAD-BALANCING object with the Max-LSP and Min-traffic spec fields set to N and B, respectively.

For example a request for one co-signaled n x VC-4 TE-LSP will not use the GENERALIZED-LOAD-BALANCING. In case the V4 components can use different paths, the GENERALIZED-BANDWIDTH will contain a traffic specification indicating the complete n x VC4 traffic specification and the GENERALIZED-LOAD-BALANCING the minimum co-signaled VC4. For

a SDH network, a request to have a TE-LSP group with 10 VC4 container, each path using at minimum 2VC4 container, can be represented with a GENERALIZED-BANDWIDTH object with OT=4, the content of the Traffic specification is ST=6,RCC=0,NCC=0,NVC=10,MT=1. The GENERALIZED-LOAD-BALANCING, OT=4,R=0,Max-LSP=5, min Traffic spec is (ST=6,RCC=0,NCC=0,NVC=2,MT=1). The PCE can respond with a response with maximum 5 path, each of them having a GENERALIZED-BANDWIDTH OT=4,R=0, and traffic spec matching the minimum traffic spec from the GENERALIZED-LOAD-BALANCING object of the corresponding request.

2.4. END-POINTS Object extensions

The END-POINTS object is used in a PCEP request message to specify the source and the destination of the path for which a path computation is requested. From [RFC5440]the source IP address and the destination IP address are used to identify those. A new Object Type is defined to address the following possibilities:

- Different source and destination endpoint types.
- Label restrictions on the endpoint.
- Specification of unnumbered endpoints type as seen in GMPLS networks.

The Object encoding is described in the following sections.

In path computation within a GMPLS context the endpoints can:

- Be unnumbered as described in [RFC3477].
- Have label(s) associated to them, specifying a set of constraints in the allocation of labels.
- May have different switching capabilities

The IPv4 and IPv6 endpoints are used to represent the source and destination IP addresses. The scope of the IP address (Node or numbered Link) is not explicitly stated. It is also possible to request a Path between a numbered link and an unnumbered link, or a P2MP path between different type of endpoints.

This new C-Type also supports the specification of constraints on the endpoint label to be use. The PCE might know the interface restrictions but this is not a requirement. This corresponds to requirements 6 and 10 of [I-D.ietf-pce-gmpls-aps-req].

2.4.1. Generalized Endpoint Object Type

The Generalized Endpoint object type format consists of a body and a list of TLVs scoped to this object type object. The TLVs give the details of the endpoints and are described in Section 2.4.2. For each endpoint type, a different grammar is defined. The TLVs defined to describe an endpoint are:

1. IPv4 address endpoint.

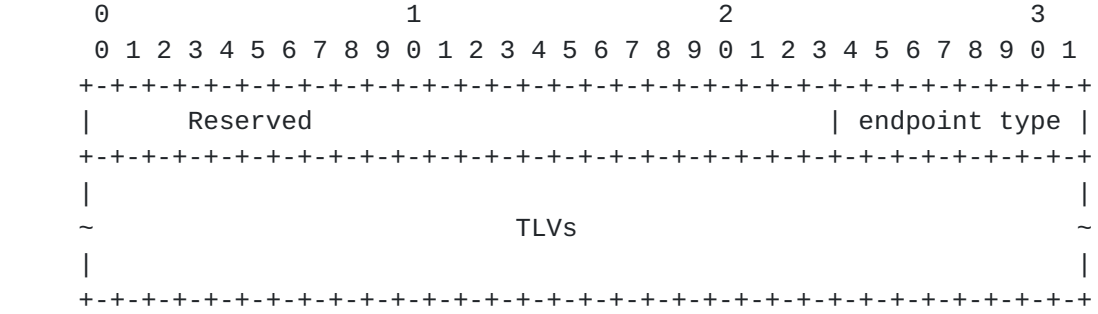
2. IPv6 address endpoint.

3. Unnumbered endpoint.

4. Label set restriction.

5. Suggested label set restriction.

The Label Set and Suggested label set TLVs are used to restrict the label allocation in the PCE. Those TLVs express the set of restrictions provided by signaling. Label restriction support can be an explicit value (Label set describing one label), mandatory range restrictions (Label set), optional range restriction (suggested label set) and single suggested value is using the suggested label set. Endpoints label restriction may not be part of the RRO or IRO, they may be included when following [RFC4003] in signaling for egress endpoint, but ingress endpoint properties may be local to the PCC and not signaled. To support this case the label set allows to indicate which label are used in case of reoptimization. The label range restrictions are valid in GMPLS networks, either by PCC policy or depending on the switching technology used, for instance on given Ethernet or ODU equipment having limited hardware capabilities restricting the label range. Label set restriction also applies to WSON networks where the optical sender and receivers are limited in their frequency tunability ranges, restricting then in GMPLS the possible label ranges on the interface. The END-POINTS Object with Generalized Endpoint object type is encoded as follow:



Reserved bits should be set to 0 when a message is sent and ignored when the message is received

the endpoint type is defined as follow:

Value	Type	Meaning
0	Point-to-Point	
1	Point-to-Multipoint	New leaves to add
2		Old leaves to remove
3		Old leaves whose path can be modified/reoptimized
4		Old leaves whose path must be left unchanged
5-244	Reserved	
245-255	Experimental range	

The endpoint type is used to cover both point-to-point and different point-to-multipoint endpoints. Endpoint type 0 MAY be accepted by the PCE, other endpoint type MAY be supported if the PCE implementation supports P2MP path calculation. A PCE not supporting a given endpoint type MUST respond with a PCErr with error code "Path computation failure", error type "Unsupported endpoint type in END-POINTS Generalized Endpoint object type". The TLVs present in the request object body MUST follow the following grammar:

```
<generalized-endpoint-tlvs>::=
  <p2p-endpoints> | <p2mp-endpoints>

<p2p-endpoints> ::=
  <source-endpoint>
  <destination-endpoint>

<source-endpoint> ::=
  <endpoint>
  [<endpoint-restriction-list>]

<destination-endpoint> ::=
  <endpoint>
  [<endpoint-restriction-list>]

<p2mp-endpoints> ::=
  <endpoint> [<endpoint-restriction-list>]
  [<endpoint> [<endpoint-restriction-list>]]...
```

For endpoint type Point-to-Multipoint several endpoint objects may be present in the message and represent a leave, exact meaning depend on the endpoint type defined of the object.

An endpoint is defined as follows:

```
<endpoint>::=<IPV4-ADDRESS>|<IPV6-ADDRESS>|<UNNUMBERED-ENDPOINT>
<endpoint-restriction-list> ::=              <endpoint-restriction>
            [<endpoint-restriction-list>]

<endpoint-restriction> ::=
                <LABEL-REQUEST><label-restriction-list>

<label-restriction-list> ::= <label-restriction>
                             [<label-restriction-list>]
<label-restriction> ::=  <LABEL-SET>|
                         <SUGGESTED-LABEL-SET>
```

The different TLVs are described in the following sections. A PCE MAY support IPV4-ADDRESS,IPV6-ADDRESS or UNNUMBERED-ENDPOINT TLV. A PCE not supporting one of those TLV in a PCReq MUST respond with a PCRep with NO-PATH with the bit "Unknown destination" or "Unknown source" in the NO-PATH-VECTOR TLV, the response SHOULD include the ENDPOINT object in the response with only the TLV it did not understood.

A PCE MAY support LABEL-REQUEST, LABEL-SET or SUGGESTED-LABEL-SET TLV. If a PCE finds a non-supported TLV in the END-POINTS the PCE

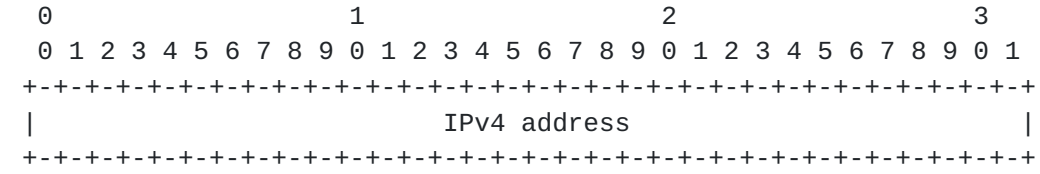
MUST respond with a PCErr message with error type="Path computation failure" error value="Unsupported TLV present in END-POINTS Generalized Endpoint object type" and the message SHOULD include the ENDPOINT object in the response with only the endpoint and endpoint restriction TLV it did not understand. A PCE not supporting those TLVs but not being able to fulfill the label restriction MUST respond with a response with NO-PATH with the bit "No endpoint label resource" or "No endpoint label resource in range" in the NO-PATH-VECTOR TLV, the response SHOULD include the ENDPOINT object in the response with only the TLV where it could not met the constraint.

2.4.2. END-POINTS TLVs extensions

All endpoint TLVs have the standard PCEP TLV header as defined in [RFC5440] section 7.1. In this object type the order of the TLVs MUST be followed according to the object type definition.

2.4.2.1. IPV4-ADDRESS

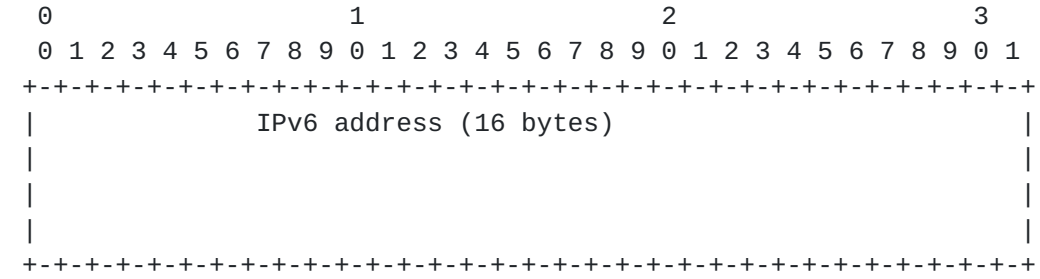
This TLV represent a numbered endpoint using IPv4 numbering, the format of the IPv4-ADDRESS TLV value (TLV-Type=TBA) is as follows:



This TLV MAY be ignored, in which case a PCRep with NO-PATH should be responded, as described in Section 2.4.1.

2.4.2.2. IPV6-ADDRESS TLV

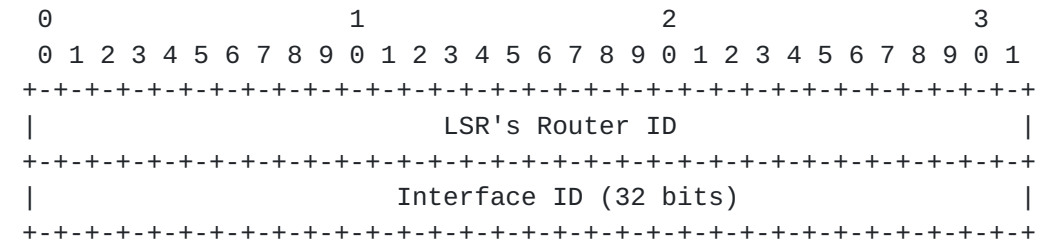
This TLV represent a numbered endpoint using IPV6 numbering, the format of the IPv6-ADDRESS TLV value (TLV-Type=TBA) is as follows:



This TLV MAY be ignored, in which case a PCRep with NO-PATH should be responded, as described in Section 2.4.1.

2.4.2.3. UNNUMBERED-ENDPOINT TLV

This TLV represent an unnumbered interface. This TLV has the same semantic as in [RFC3477] The TLV value is encoded as follow (TLV-Type=TBA)



This TLV MAY be ignored, in which case a PCRep with NO-PATH should be responded, as described in Section 2.4.1.

2.4.2.4. LABEL-REQUEST TLV

The LABEL-REQUEST TLV indicates the switching capability and encoding type of the following label restriction list for the endpoint. Its format is the same as described in [RFC3471] Section 3.1 Generalized label request. The LABEL-REQUEST TLV use TLV-Type=TBA. The fields are encoded as in the RSVP-TE. The Encoding Type indicates the encoding type, e.g., SONET/SDH/GigE etc., that will be used with the data associated. The Switching type indicates the type of switching that is being requested on the endpoint. G-PID identifies the payload. This TLV and the following one are introduced to satisfy requirement 13 for the endpoint. It is not directly related to the TE-LSP label request, which is expressed by the SWITCH-LAYER object.

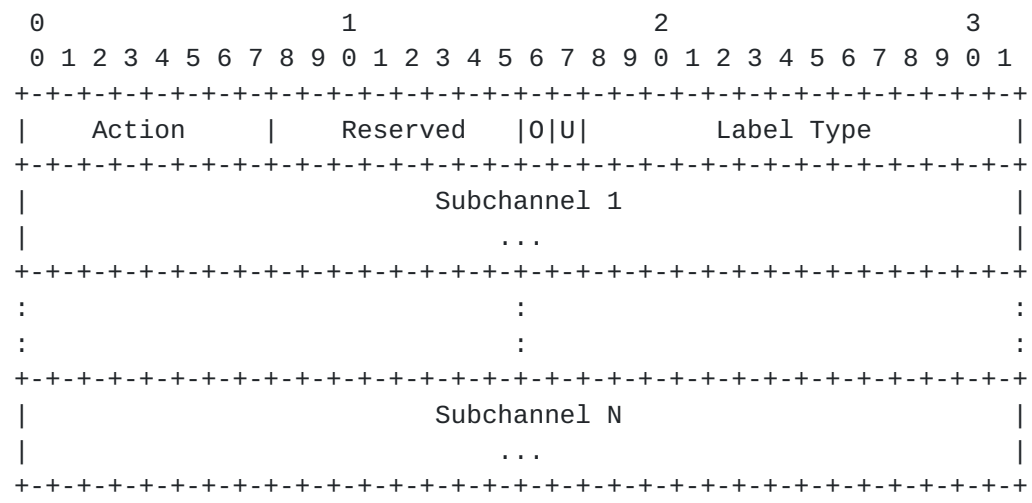
On the path calculation request only the Tspec and switch layer need to be coherent, the endpoint labels could be different (supporting a different Tspec). Hence the label restrictions include a Generalized label request in order to interpret the labels. This TLV MAY be ignored, in which case a PCRep with NO-PATH should be responded, as described in Section 2.4.1.

2.4.2.5. Labels TLV

Label or label range restrictions may be specified for the TE-LSP endpoints. Those are encoded using the LABEL-SET TLV. The label value need to be interpreted with a description on the Encoding and switching type. The REQ-ADAP-CAP object from [I-D.ietf-pce-inter-layer-ext] can be used in case of mono-layer request, however in case of multilayer it is possible to have in the future more than one object, so it is better to have a dedicated TLV for the label and label request (the scope is then more clear).

Those TLV MAY be ignored, in which case a response with NO-PATH should be responded, as described in Section 2.4.1. TLVs are encoded as follow (following [RFC5440]) :

o LABEL-SET TLV, Type=TBA. The TLV Length is variable, Encoding follows [RFC3471] Section 3.5 "Label set" with the addition of a U bit and O Bit. The U bit is set for upstream direction in case of bidirectional LSP and the O bit is used to represent an old label.



o SUGGESTED-LABEL-SET TLV Set, Type=TBA. The TLV length is variable and its encoding is as LABEL-SET TLV. The 0 bit SHOULD be set to 0.

A LABEL-SET TLV represents a set of possible labels that can be used on an interface. The label allocated on the first link SHOULD be within the label set range. The action parameter in the Label set indicates the type of list provided. Those parameters are described by [RFC3471] section 3.5.1 A SUGGESTED-LABEL-SET TLV has the same encoding as the LABEL-SET TLV, it indicates to the PCE a set of preferred (ordered) set of labels to be used. The PCE MAY use those labels for label allocation.

The U and 0 bits have the following meaning:

U: Upstream direction: set when the label or label set is in the reverse direction

O: Old Label: set when the TLV represent the old label in case in case of re-optimization. This Bit SHOULD be set to 0 in a SUGGESTED-LABEL-SET TLV Set. This Label MAY be reused. The R bit of the RP object MUST be set. When this bit is set the Action field MUST be set to 0 (Inclusive List) and the Label Set MUST contain one subchannel.

Several LABEL_SET TLVs MAY be present with the 0 bit cleared. At most 2 LABEL_SET TLV SHOULD be present with the 0 bit set, at most one with the U bit set and at most one with the U bit cleared. For a given U bit value if more than one LABEL_SET TLV with the O bit set is present, the first TLV SHOULD be processed and the following TLV with the same U and O bit SHOULD be ignored.

A SUGGESTED-LABEL-SET TLV with the O bit set MUST trigger a PCErr message with error type="Reception of an invalid object" error value="Wrong LABEL-SET or SUGGESTED-LABEL-SET TLV present with 0 bit set".

A LABEL-SET TLV with the O bit set and an Action Field not set to 0 (Inclusive list) or containing more than one subchannel MUST trigger a PCErr message with error type="Reception of an invalid object" error value="Wrong LABEL-SET or SUGGESTED-LABEL-SET TLV present with 0 bit set".

If a LABEL-SET TLV is present with O bit set, the R bit of the RP object MUST be set or a PCErr message with error type="Reception of an invalid object" error value="LABEL-SET TLV present with 0 bit set but without R bit set in RP".

2.5. IRO extension

The IRO as defined in [RFC5440] is used to include specific objects in the path. RSVP allows to include label definition, in order to fulfill requirement 13 the IRO should support the new subobject type as defined in [RFC3473]:

Type	Sub-object
3	LABEL

The L bit of such sub-object has no meaning within an IRO.

The Label subobject MUST follow a subobject identifying a link , currently an IP address subobject (Type 1 or 2) or an interface id (type 4) subobject. The procedure associated with this subobject is as follow

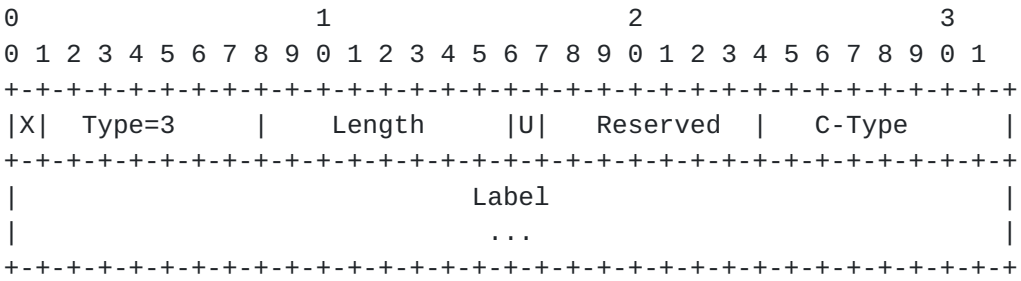
If the PCE allocates labels (e.g via explicit label control) the PCE MUST allocate one label of from within the set of label values for the given link. If the PCE does not assign labels a response with a NO-PATH and a NO-PATH-VECTOR-TLV with the bit .'No label resource in range' set.

2.6. XRO extension

The XRO as defined in [RFC5521] is used to exclude specific objects in the path. RSVP allows to exclude labels ([RFC6001], in order to fulfill requirement 13 of [I-D.ietf-pce-gmpls-aps-req] section 4.1, the XRO should support a new subobject to support label exclusion.

The encoding of the XRO Label subobject follows the encoding of the Label ERO subobject defined in [RFC3473] and XRO subobject defined in [RFC5521]. The XRO Label subobject is defined as follows:

XRO Subobject Type 3: Label Subobject.



X (1 bit)

See [RFC5521].

Type (7 bits)

The Type of the XRO Label subobject is 3.

Length (8 bits)

See [RFC5521],The total length of the subobject in bytes (including the Type and Length fields). The Length is always divisible by 4.

U (1 bit)

See [RFC3471].

C-Type (8 bits)

The C-Type of the included Label Object. Copied from the Label Object (see [RFC3471]).

Label

See [RFC3471].

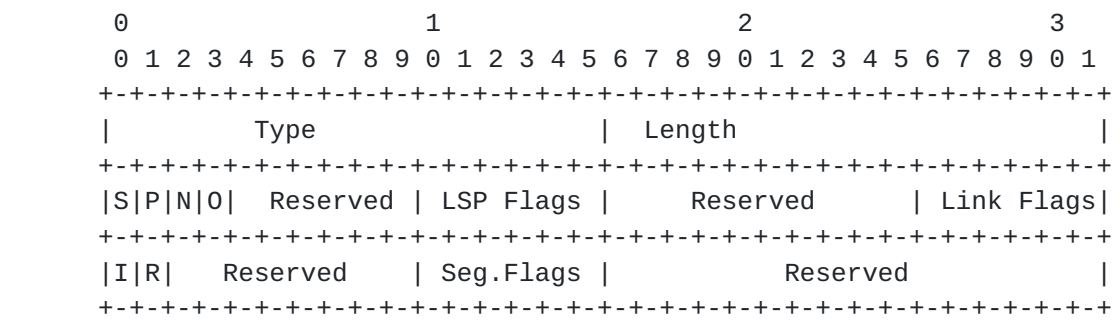
XRO Label subobjects MUST follow the numbered or unnumbered interface subobjects to which they refer. Several XRO Labels subobject MAY be present.

Type	Sub-object
3	LABEL

The L bit of such sub-object has no meaning within an XRO.

2.7. LSPA extensions

The LSPA carries the LSP attributes. In the end-to-end protection context this also includes the protection state information. This object is introduced to fulfill requirement 7 of [I-D.ietf-pce-gmpls-aps-req] section 4.1 and requirement 3 of [I-D.ietf-pce-gmpls-aps-req] section 4.2 and may be used as a policy input for route and label selection on request. The LSPA object MAY carry a PROTECTION-ATTRIBUTE TLV defined as : Type TBA: PROTECTION-ATTRIBUTE



The content is as defined in [RFC4872], [RFC4873].

LSP Flags can be considered for routing policy based on the protection type. The other attributes are only meaningful for a stateful PCE.

This TLV is optional and MAY be ignored by the PCE, in which case it MUST NOT include the TLV in the LSPA, if present, of the response. When the TLV is used by the PCE, a LSPA object and the PROTECTION-ATTRIBUTE TLV MUST be included in the response. Fields that were not considered MUST be set to 0.

2.8. 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 satisfying the set of constraints). In this scenario, PCE MUST include a NO-PATH object in the PCRep message. The NO-PATH object may 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 the 32-bit flag field of the NO-PATH-VECTOR TLV and no modifications have been made in the NO-PATH object.

2.8.1. Extensions to NO-PATH-VECTOR TLV

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

Bit number TBA - Protection Mismatch (1-bit). Specifies the mismatch of the protection type in the PROTECTION-ATTRIBUTE TLV in the request.

Bit number TBA - No Resource (1-bit). Specifies that the resources are not currently sufficient to provide the path.

Bit number TBA - Granularity not supported (1-bit). Specifies that the PCE is not able to provide a route with the requested granularity.

Bit number TBA - No endpoint label resource (1-bit). Specifies that the PCE is not able to provide a route because of the endpoint label restriction.

Bit number TBA - No endpoint label resource in range (1-bit). Specifies that the PCE is not able to provide a route because of the endpoint label set restriction.

Bit number TBA - No label resource in range (1-bit). Specifies that the PCE is not able to provide a route because of the label set restriction.

3. 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 while 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 SDH networks. For each PCEP error, an Error-Type and an Error-value are defined. Error-Type 1 to 10 are already defined in [RFC5440]. Additional Error- values are defined for Error-Type 10 and A new Error-Type is introduced (value TBA).

Error-Type	Error-value	
10	Reception of an invalid object	
	Error-value=TBA:	Bad Generalized Bandwidth Object value.
	Error-value=TBA:	Unsupported LSP Protection Type in PROTECTION-ATTRIBUTE TLV.
	Error-value=TBA:	Unsupported LSP Protection Flags in PROTECTION-ATTRIBUTE TLV.
	Error-value=TBA:	Unsupported Secondary LSP Protection Flags in PROTECTION-ATTRIBUTE TLV.
	Error-value=TBA:	Unsupported Link Protection Type in PROTECTION-ATTRIBUTE TLV.
	Error-value=TBA:	Unsupported Link Protection Type in PROTECTION-ATTRIBUTE TLV.
	Error-value=TBA:	LABEL-SET TLV present with 0 bit set but without R bit set in RP.
	Error-value=TBA:	Wrong LABEL-SET or SUGGESTED-LABEL-SET TLV present with 0 bit set.
TBA	Path computation failure	
	Error-value=TBA:	Unacceptable request message.
	Error-value=TBA:	Generalized bandwidth object not supported.

Error-value=TBA: Label Set constraint could not be met.

Error-value=TBA: Label constraint could not be met.

Error-value=TBA: Unsupported endpoint type in END-POINTS Generalized Endpoint object type

Error-value=TBA: Unsupported TLV present in END-POINTS Generalized Endpoint object type

Error-value=TBA: Unsupported granularity in the RP object flags

4. Manageability Considerations

This section follows the guidance of [RFC6123].

4.1. Control of Function through Configuration and Policy

This document makes no change to the basic operation of PCEP and so the requirements described in [RFC5440] Section 8.1. also apply to this document. In addition to those requirements a PCEP implementation MAY allow the configuration of the following parameters:

Accepted RG in the RP object.

Default RG to use (overriding the one present in the PCReq)

Accepted GENERALIZED-BANDWIDTH parameters in request, default mapping to use when not specified in the request

Accepted GENERALIZED-LOAD-BALANCING parameters in request.

Accepted endpoint type in END-POINTS object type Generalized Endpoint and allowed TLVs

Accepted range for label restrictions in label restriction in END-POINTS, or IRO or XRO objects

PROTECTION-ATTRIBUTE TLV acceptance and suppression.

Those parameters configuration are applicable to the different sessions as described in [RFC5440] Section 8.1 (by default, per PCEP peer, ..etc).

4.2. Information and Data Models

This document makes no change to the basic operation of PCEP and so the requirements described in [RFC5440] Section 8.2. also apply to this document. This document does not introduces new ERO sub object, ERO information model is already covered in [RFC4802].

4.3. 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] Section 8.3.

4.4. Verifying Correct Operation

This document makes no change to the basic operations of PCEP and considerations described in [RFC5440] Section 8.4. New errors introduced by this document should be covered by the requirement to log error events.

4.5. Requirements on Other Protocols and Functional Components

No new Requirements on Other Protocols and Functional Components are made by this document. This document does not require ERO object extensions. Any new ERO subobject defined in CCAMP working group can be adopted without modifying the operations defined in this document.

4.6. Impact on Network Operation

This document makes no change to the basic operations of PCEP and considerations described in [RFC5440] Section 8.6. In addition to the limit on the rate of messages sent by a PCEP speaker, a limit MAY be placed on the size of the PCEP messages.

5. 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.

5.1. PCEP Objects

As described in Section 2.2 and Section 2.3new Objects are defined IANA is requested to make the following Object-Type allocations from the "PCEP Objects" sub-registry.

Object Class to be assigned

Name GENERALIZED-BANDWIDTH

Object-Type 1

Reference This document (section Section 2.2)

Object Class to be assigned

Name GENERALIZED-LOAD-BALANCING

Object-Type 1

Reference This document (section Section 2.3)

As described in Section 2.4.1 a new Object type is defined IANA is requested to make the following Object-Type allocations from the "PCEP Objects" sub-registry. The values here are suggested for use by IANA.

Object Class 4

Name END-POINTS

Object-Type 5 : Generalized Endpoint

6-15 : unassigned

Reference This document (section Section 2.2)

5.2. END-POINTS object, Object Type Generalized Endpoint

IANA is requested to create a registry to manage the endpoint type field of the END-POINTS object, Object Type Generalized Endpoint and manage the code space.

New endpoint type in the Reserved range may be allocated by an IETF consensus action. Each endpoint type should be tracked with the following qualities:

- endpoint type
- Description
- Defining RFC

New endpoint type in the Experimental range are for experimental use; these will not be registered with IANA and MUST NOT be mentioned by RFCs.

The following values have been defined by this document. (Section 2.4.1, Table 4):

Value	Type	Meaning
0	Point-to-Point	
1	Point-to-Multipoint	New leaves to add
2		Old leaves to remove
3		Old leaves whose path can be modified/reoptimized
4		Old leaves whose path must be left unchanged
5-244	Reserved	
245-255	Experimental range	

5.3. New PCEP TLVs

IANA manages the PCEP TLV code point registry (see [RFC5440]). This is maintained as the "PCEP TLV Type Indicators" sub-registry of the "Path Computation Element Protocol (PCEP) Numbers" registry. This document defines new PCEP TLVs, to be carried in the END-POINTS object with Generalized Endpoint object Type. IANA is requested to

do the following allocation. The values here are suggested for use by IANA.

Value	Meaning	Reference
7	IPv4 endpoint	This document (section Section 2.4.2.1)
8	IPv6 endpoint	This document (section Section 2.4.2.2)
9	Unnumbered endpoint	This document (section Section 2.4.2.3)
10	Label request	This document (section Section 2.4.2.4)
11	Requested GMPLS Label Set	This document (section Section 2.4.2.5)
12	Suggested GMPLS Label Set	This document (section Section 2.4.2.5)
13	LSP Protection Information	This document (section Section 2.7)

5.4. RP Object Flag Field

As described in Section 2.1 new flag are defined in the RP Object Flag IANA is requested to make the following Object-Type allocations from the "RP Object Flag Field" sub-registry. The values here are suggested for use by IANA.

Bit	Description	Reference
bit 17-16	routing granularity (RG)	This document, Section 2.1

5.5. New PCEP Error Codes

As described in Section Section 3, new PCEP Error-Type and Error Values are defined. IANA is requested to make the following allocation in the "PCEP-ERROR Object Error Types and Values" registry. The values here are suggested for use by IANA.

Error	name	Reference
Type=10	Reception of an invalid object	[RFC5440]
Value=2:	Bad Generalized Bandwidth Object value.	This Document
Value=3:	Unsupported LSP Protection Type in PROTECTION-ATTRIBUTE TLV.	This Document
Value=4:	Unsupported LSP Protection Flags in PROTECTION-ATTRIBUTE TLV.	This Document
Value=5:	Unsupported Secondary LSP Protection Flags in PROTECTION-ATTRIBUTE TLV.	This Document
Value=6:	Unsupported Link Protection Type in PROTECTION-ATTRIBUTE TLV.	This Document
Value=7:	Unsupported Link Protection Type in PROTECTION-ATTRIBUTE TLV.	This Document
Value=8:	LABEL-SET TLV present with 0 bit set but without R bit set in RP.	This Document
Value=9:	Wrong LABEL-SET or SUGGESTED-LABEL-SET TLV present with 0 bit set.	This Document
Type=14	Path computation failure	This Document
Value=1:	Unacceptable request message.	This Document
Value=2:	Generalized bandwidth object not supported.	This Document
Value=3:	Label Set constraint could not be met.	This Document
Value=4:	Label constraint could not be met.	This Document
Value=5:	Unsupported endpoint type in END-POINTS Generalized Endpoint object type	This Document
Value=6:	Unsupported TLV present in END-POINTS Generalized Endpoint object type	This Document

Value=7: Unsupported granularity in the RP object flags	This Document

5.6. New NO-PATH-VECTOR TLV Fields

As described in Section Section 2.8.1, new NO-PATH-VECTOR TLV Flag Fields have been defined. IANA is requested to do the following allocations in the "NO-PATH-VECTOR TLV Flag Field" sub-registry. The values here are suggested for use by IANA.

Bit number 23 - Protection Mismatch (1-bit). Specifies the mismatch of the protection type of the PROTECTION-ATTRIBUTE TLV in the request.

Bit number 22 - No Resource (1-bit). Specifies that the resources are not currently sufficient to provide the path.

Bit number 21 - Granularity not supported (1-bit). Specifies that the PCE is not able to provide a route with the requested granularity.

Bit number 20 - No endpoint label resource (1-bit). Specifies that the PCE is not able to provide a route because of the endpoint label restriction.

Bit number 19 - No endpoint label resource in range (1-bit). Specifies that the PCE is not able to provide a route because of the endpoint label set restriction.

Bit number 18 - No label resource in range (1-bit). Specifies that the PCE is not able to provide a route because of the label set restriction.

5.7. New Subobject for the Include Route Object

The "PCEP Parameters" registry contains a subregistry "PCEP Objects" with an entry for the Include Route Object (IRO).

IANA is requested to add a further subobject that can be carried in the IRO as follows:

Subobject type	Reference
3 Label suboject	[RFC3473]

5.8. New Subobject for the Exclude Route Object

The "PCEP Parameters" registry contains a subregistry "PCEP Objects" with an entry for the XRO object (Exclude Route Object).

IANA is requested to add a further subobject that can be carried in the XRO as follows:

Subobject type		Reference
3	Label suboject	[RFC3473]

6. Security Considerations

None.

7. Contributing Authors

Nokia Siemens Networks:

Elie Sfeir
St Martin Strasse 76
Munich, 81541
Germany

Phone: +49 89 5159 16159
Email: elie.sfeir@nsn.com

Franz Rambach
St Martin Strasse 76
Munich, 81541
Germany

Phone: +49 89 5159 31188
Email: franz.rambach@nsn.com

Francisco Javier Jimenez Chico
Telefonica Investigacion y Desarrollo
C/ Emilio Vargas 6
Madrid, 28043
Spain

Phone: +34 91 3379037
Email: fjjc@tid.es

Huawei Technologies

Suresh BR
Shenzhen
China
Email: sureshbr@huawei.com

Young Lee
1700 Alma Drive, Suite 100
Plano, TX 75075
USA

Phone: (972) 509-5599 (x2240)
Email: ylee@huawei.com

SenthilKumar S
Shenzhen
China
Email: senthilkumars@huawei.com

Jun Sun
Shenzhen
China
Email: johnsun@huawei.com

CTTC - Centre Tecnologic de Telecomunicacions de Catalunya

Ramon Casellas
PMT Ed B4 Av. Carl Friedrich Gauss 7
08860 Castelldefels (Barcelona)
Spain
Phone: (34) 936452916
Email: ramon.casellas@cttc.es

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9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2210] Wroclawski, J., "The Use of RSVP with IETF Integrated Services", RFC 2210, September 1997.

[RFC3471] Berger, L., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description", RFC 3471, January 2003.

[RFC3473] Berger, L., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions", RFC 3473, January 2003.

[RFC3477] Kompella, K. and Y. Rekhter, "Signalling Unnumbered Links in Resource ReSerVation Protocol - Traffic Engineering (RSVP-TE)", RFC 3477, January 2003.

[RFC4003] Berger, L., "GMPLS Signaling Procedure for Egress Control", RFC 4003, February 2005.

[RFC4328] Papadimitriou, D., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control", RFC 4328, January 2006.

[RFC4606] Mannie, E. and D. Papadimitriou, "Generalized Multi-Protocol Label Switching (GMPLS) Extensions for Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH) Control", RFC 4606, August 2006.

[RFC4802] Nadeau, T. and A. Farrel, "Generalized Multiprotocol Label Switching (GMPLS) Traffic Engineering Management Information Base", RFC 4802, February 2007.

[RFC4872] Lang, J., Rekhter, Y., and D. Papadimitriou, "RSVP-TE Extensions in Support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS) Recovery", RFC 4872, May 2007.

[RFC4873] Berger, L., Bryskin, I., Papadimitriou, D., and A. Farrel, "GMPLS Segment Recovery", RFC 4873, May 2007.

[RFC5440] Vasseur, JP. and JL. Le Roux, "Path Computation Element (PCE) Communication Protocol (PCEP)", RFC 5440,

March 2009.

[RFC5520] Bradford, R., Vasseur, JP., and A. Farrel, "Preserving Topology Confidentiality in Inter-Domain Path Computation Using a Path-Key-Based Mechanism", RFC 5520, April 2009.

[RFC5521] Oki, E., Takeda, T., and A. Farrel, "Extensions to the Path Computation Element Communication Protocol (PCEP) for Route Exclusions", RFC 5521, April 2009.

[RFC5541] Le Roux, JL., Vasseur, JP., and Y. Lee, "Encoding of Objective Functions in the Path Computation Element Communication Protocol (PCEP)", RFC 5541, June 2009.

[RFC6001] Papadimitriou, D., Vigoureux, M., Shiomoto, K., Brungard, D., and JL. Le Roux, "Generalized MPLS (GMPLS) Protocol Extensions for Multi-Layer and Multi-Region Networks (MLN/MRN)", RFC 6001, October 2010.

[RFC6003] Papadimitriou, D., "Ethernet Traffic Parameters", RFC 6003, October 2010.

[RFC6205] Otani, T. and D. Li, "Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers", RFC 6205, March 2011.

[RFC6387] Takacs, A., Berger, L., Caviglia, D., Fedyk, D., and J. Meuric, "GMPLS Asymmetric Bandwidth Bidirectional Label Switched Paths (LSPs)", RFC 6387, September 2011.

9.2. Informative References

[I-D.ietf-pce-gmpls-aps-req]
Otani, T., Ogaki, K., Caviglia, D., and F. Zhang, "Document:", draft-ietf-pce-gmpls-aps-req-06 (work in progress), June 2012.

[I-D.ietf-pce-inter-layer-ext]
Oki, E., Takeda, T., Farrel, A., and F. Zhang, "Extensions to the Path Computation Element communication Protocol (PCEP) for Inter-Layer MPLS and GMPLS Traffic Engineering", draft-ietf-pce-inter-layer-ext-07 (work in progress), July 2012.

[I-D.ietf-pce-wson-routing-wavelength]
Lee, Y., Bernstein, G., Martensson, J., Takeda, T., Tsuritani, T., and O. Dios, "PCEP Requirements for WSON Routing and Wavelength Assignment",

draft-ietf-pce-wson-routing-wavelength-08 (work in progress), October 2012.

[RFC4655] Farrel, A., Vasseur, J., and J. Ash, "A Path Computation Element (PCE)-Based Architecture", RFC 4655, August 2006.

[RFC4657] Ash, J. and J. Le Roux, "Path Computation Element (PCE) Communication Protocol Generic Requirements", RFC 4657, September 2006.

[RFC6123] Farrel, A., "Inclusion of Manageability Sections in Path Computation Element (PCE) Working Group Drafts", RFC 6123, February 2011.

Authors' Addresses

Cyril Margaria (editor)
Nokia Siemens Networks
St Martin Strasse 76
Munich, 81541
Germany

Phone: +49 89 5159 16934
Email: cyril.margaria@nsn.com

Oscar Gonzalez de Dios (editor)
Telefonica Investigacion y Desarrollo
C/ Emilio Vargas 6
Madrid, 28043
Spain

Phone: +34 91 3374013
Email: ogondio@tid.es

Fatai Zhang (editor)
Huawei Technologies
F3-5-B R&D Center, Huawei Base
Bantian, Longgang District
Shenzhen, 518129
P.R.China

Email: zhangfatai@huawei.com