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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

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1. Introduction

PCEP RFCs [RFC5440], [RFC5521], [RFC5541], [RFC5520] are focused on path computation requests in MPLS networks. [RFC4655] defines the PCE framework also for GMPLS networks. This document complements these RFCs by providing some consideration of GMPLS applications and routing requests, for example for OTN and WSON networks.

The requirements on PCE extensions to support those characteristics are described in [I-D.ietf-pce-gmpls-aps-req] and [I-D.ietf-pce-wson-routing-wavelength].

1.1. Contributing Authors

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1.2. PCEP requirements for GMPLS

This section provides a set of PCEP requirements to support GMPLS LSPs and assure signal compatibility in the path. When requesting a path computation (PCReq) to PCE, the PCC should be able to indicate, according to [I-D.ietf-pce-gmpls-aps-req], the following additional attributes:

(1) Switching capability: PSC1-4, L2SC, TDM, LSC, FSC

(2) Encoding type: as defined in [RFC4202], [RFC4203], e.g., Ethernet, SONET/SDH, Lambda, etc.

(3) Signal Type: Indicates the type of elementary signal that constitutes the requested LSP. A lot of signal types with different granularity have been defined in SONET/SDH and G.709 ODUk, such as VC11, VC12, VC2, VC3 and VC4 in SDH, and ODU1, ODU2 and ODU3 in G.709 ODUk [RFC4606] and [RFC4328].

(4) Concatenation Type: In SDH/SONET and G.709 ODUk networks, two kinds of concatenation modes are defined: contiguous concatenation which requires co-route for each member signal and requires all the interfaces along the path to support this capability, and virtual concatenation which allows diverse routes for the member signals and only requires the ingress and egress interfaces to support this capability. Note that for the virtual concatenation, it also may specify co-routed or separated-routed. See [RFC4606] and [RFC4328] about concatenation information.

(5) Concatenation Number: Indicates the number of signals that are requested to be contiguously or virtually concatenated. Also see [RFC4606] and [RFC4328].

(6) Wavelength Label: as defined in [I-D.ietf-ccamp-gmpls-g-694-lambda-labels]

(7) e2e Path protection type: as defined in [RFC4872], e.g., 1+1 protection, 1:1 protection, (pre-planned) rerouting, etc.

(8) Link Protection type: as defined in [RFC4203]

(9) Support for unnumbered interfaces: as defined in [RFC3477]

(10) Support for asymmetric bandwidth request

We describe in this document a proposal to fulfill those requirements.

1.3. PCEP existing objects related to GMPLS

PCEP as of [RFC5440], [RFC5521] and [I-D.ietf-pce-inter-layer-ext], supports the following information (in the PCReq and PCRep) related to the described RSVP-TE information.

From [RFC5440]:

- numbered endpoints
- bandwidth (float)
- ERO
- LSP attribute (setup and holding priorities)
- Request attribute (include some LSP attributes)

From [RFC5521]:

- Extensions to PCEP for Route Exclusions define a XRO object and a new semantic (F bit): Fail bit indicating that the existing route is failed and resources present in the RRO can be reused. This object also allows to exclude (strict or not) resources; XRO include the diversity level (node, link, SRLG). The requested diversity is expressed in the XRO.

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

- INTER-LAYER : indicates if 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 information are:

BANDWIDTH does not describe the details of the signal (for example NVC, multiplier) in the context of TDM or OTN networks.

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

Current attributes do not allow to express the requested link level protection and end-to-end protection attributes.

In order to improve the PCEP, a new object is introduced (GENERALIZED-BANDWIDTH) , a new object type is introduced for the END-POINTS object (generalized-endpoint), and a TLV is added to the LSPA object. In order to allow to restrict the range of labels returned, an additional object is added : LABEL SET

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.

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 request and response messages with the proposed extensions (GENERALIZED BANDWIDTH, SUGGESTED LABEL SET and LABEL Set) is as follows:

```
  <request>::= <RP>
  <end-point-rro-pair-list>
  [<LSPA>]
  [<BANDWIDTH>]
  [<GENERALIZED-BANDWIDTH>][<GENERALIZED-BANDWIDTH>]
  [<metric-list>]
  [<IRO>]
  [<SUGGESTED LABEL SET>]
  [<LABEL SET>]
  [<LOAD-BALANCING>]


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

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

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

  <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>]

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

Where:

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

[<IRO>]

2.1. Traffic parameters encoding, GENERALIZED-BANDWIDTH

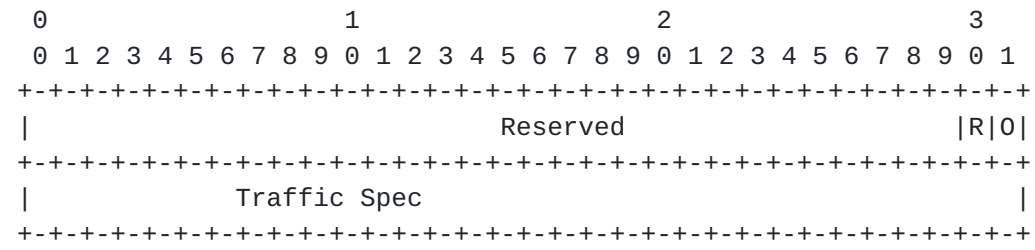
The PCEP BANDWIDTH does not describe the details of the signal (for example NVC, multiplier), hence the bandwidth information should be extended to use the RSVP Tspec. The PCEP BANDWIDTH object defines two types: 1 and 2. C-Type 2 is representing the existing bandwidth in case of re-optimization.

The following possibilities cannot be represented in the BANDWIDTH object:

- Asymmetric bandwidth (different bandwidth in forward and reverse direction), as described in [RFC5467]

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

We propose to add a new Object named GENERALIZED-BANDWIDTH having the following format:



The bits R and O have the following meaning:

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

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

The Object type determine which type of bandwidth is represented by the object. The Following object type are defined:

1. Intserv

2. SONET/SDH

3. G.709

4. Ethernet MEF (see [I-D.ietf-ccamp-ethernet-traffic-parameters])

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 (TBA by IANA)	Ethernet MEF	[I-D.ietf-ccamp-ethernet-traffic-parameters]

Traffic Spec field encoding

The GENERALIZED-BANDWIDTH MAY appear more than once in a PCReq message. If more than one GENERALIZED-BANDWIDTH have the same Object Type, Reserved, R and O values, only the first one is processed, the others are ignored. On the response the TLVs that were considered in the processing SHOULD.

When a PCC needs to get a bi-directional path with asymmetric bandwidth, it should specify the different bandwidth in forward and reverse directions through two separate GENERALIZED-BANDWIDTH objects. The PCE needs to compute a path that satisfies the asymmetric bandwidth constraint and return the path to PCC if the path computation is successful.

2.2. END-POINTS Object extensions

The END-POINTS object is used in a PCReq message to specify the source and destination of the path for which a path computation is requested. From [RFC3471] source IP address and the destination IP address are used to identify those. A new Object Type is defined to address the following possibilities:

- Possibility to have different 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.

2.2.1. Generalized endpoint Object Type

In GMPLS context the endpoints can:

- o Be unnumbered
- o Have label(s) associated to them
- o May have different switching capabilities

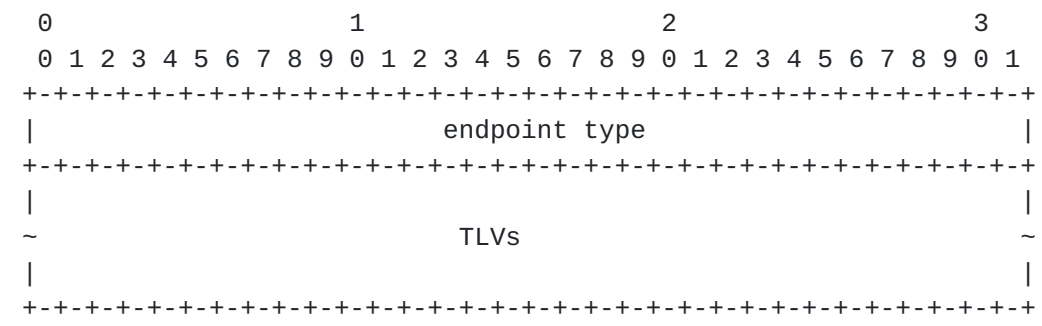
The IPV4 and IPV6 endpoint are used to represent the source and destination IP addresses. The scope of the IP address (Node or Link) is not explicitly stated. It should also be possible to request a Path between an numbered link and a unnumbered link, or a P2MP path between different type of endpoints.

Since the PCEP ENDPOINTS object only support endpoint of the same type a new C-Type are proposed that support different endpoint types, including unnumbered endpoint. This New C-Type also support the specification of constraints on the endpoint label to be use. The PCE might know the interface restrictions but this is not a requirement. 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.

The proposed object format consists of a body and a list of TLVs with the following defined TLVs (described in Section 2.2.2).

1. IPV4 address.
2. IPV6 address.
3. Unnumbered endpoint.
4. Label request.
5. Label.
6. Label set.
7. Suggested label set.

The Object is encoded as follow:



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

The TLVs present in the object body should follow the following :

```
<generalized-endpoint-tlvs>::=
                      <endpoint> ; -- Source endpoint
                      [<endpoint-restrictions>]
                      <endpoint> [<endpoint-restrictions>]
                      [<endpoint> [<endpoint-restrictions>] ...]
```

For endpoint type Point-to-Point the first endpoint and optional endpoint-restriction is the ingress endpoint. The second endpoint and optional endpoint-restriction is the egress endpoint The further endpoint and endpoint-restriction are ignored

For endpoint type Point-to-Multipoint the first endpoint and optional endpoint-restriction is the source endpoint. The further endpoint and endpoint-restriction are the leaves.

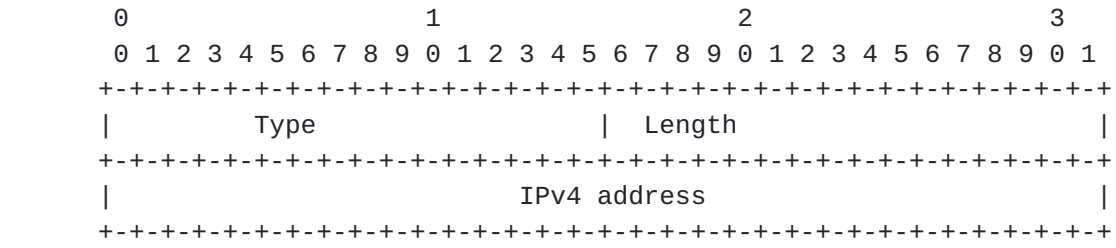
An endpoint is defined as follow:

```
<endpoint>::=<IPV4_ADDRESS>|<IPV6_ADDRESS>|<UNNUMBERED_ENDPOINT>
<endpoint-restrictions> ::= <LABEL_REQUEST><label-restriction>
                            [<endpoint-restrictions>]
<label-restriction> ::= ((<LABEL><UPSTREAM_LABEL>)|
                        <LABEL_SET>|
                        <SUGGESTED_LABEL_SET>)
                        [<label-restriction>]
```

2.2.2. END-POINTS TLVs extensions

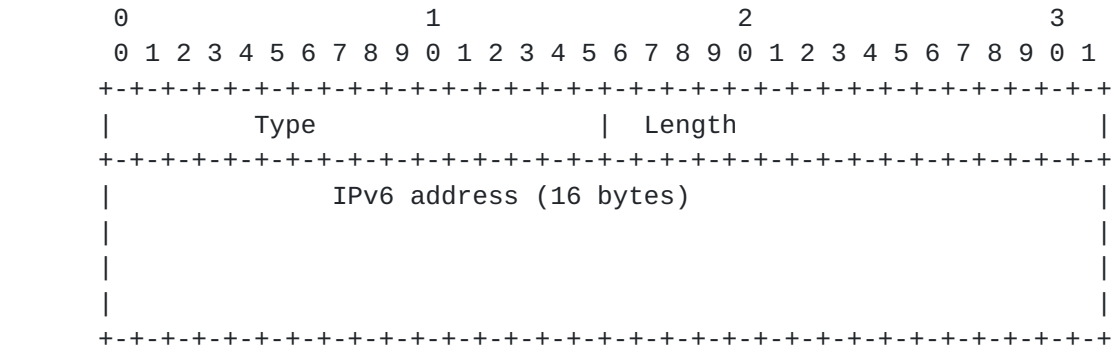
2.2.2.1. IPV4_ADDRESS

The format of the END-POINTS TLV object for IPv4 (TLV-Type=To be assigned) is as follows:



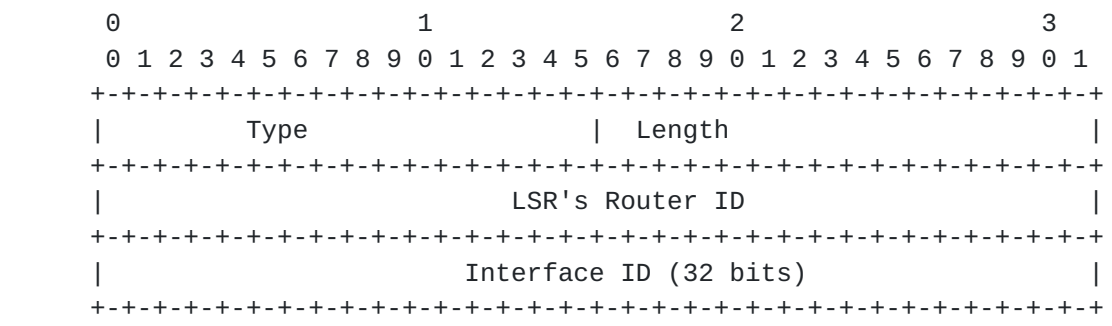
2.2.2.2. IPV6_ADDRESS TLV

The format of the END-POINTS TLV object for IPv6 (TLV-Type=To be assigned) is as follows:



2.2.2.3. UNNUMBERED_ENDPOINT TLV

This TLV represent an unnumbered interface. This TLV has the same semantic as in [RFC3477]



2.2.2.4. LABEL_REQUEST sub-tlv

The LABEL-REQUEST indicate the and encoding of the LABEL restriction present in the ENDPOINTS its format is the same as described in [RFC3471] Section 3.1 Generalized label request

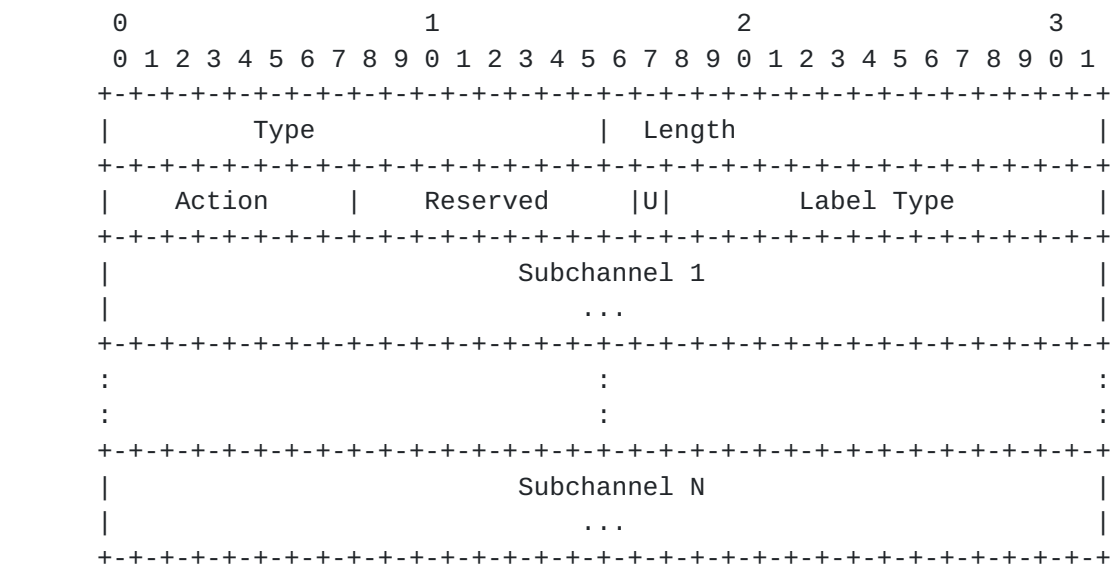
2.2.2.5. Labels sub-tlv

Label or label range may be specified for the TE-LSP endpoints. Those are encoded in the sub-TLVs. The label value cannot be interpreted without 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 (the scope is then more clear). TLVs are encoded as follow (following [RFC5440]) :

- LABEL Sub-TLV, Type = TBA by IANA, Length is variable, Encoding is as [RFC3471] Section 3.2 Generalized label. This represent the downstream label

- UPSTEAM-LABEL Sub-TLV , Type = TBA by IANA, Length is variable, Encoding is as [RFC3471] Section 3.2 Generalized label. This represent the upstream label

- LABEL_SET Sub-TLV, Type = TBA by IANA , Length is variable, Encoding follow :[RFC3471] Section 3.5 Label set with the addition of a U bit, the U bit is set for upstream direction in case of bidirectional LSP.



o SUGGESTED-LABEL_SET Sub-TLV Set, Type = TBA by IANA, Length is variable, Encoding is as Label Set.

A label Sub-TLV represent the label used on the unnumbered interface, bits I and U are used to indicate which exact unnumbered interface/ direction is considered. 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 with the LSP. The Switching type indicates the type of switching that is being requested on the link. G-PID identifies the payload of the TE-LSP. The label type indicates which type of label (2) for generalized label is carried. A Label Set Sub-TLV represents a set of possible labels that can be used on the unnumbered interface. The action parameter in the Label set indicates the type of list provided. Those parameters are described by [RFC3471] A Suggested Label Set Sub-TLV has the same encoding as the Label Set Sub-TLV, it represent the order preferred set of label to be used

The U bit has the following meaning:

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

2.3. LABEL SET object

The LABEL SET object is carried within a PCReq message to restrict the set of labels to be assigned during the routing. Any label included in the ERO object on the response must comply with the restrictions stated in the LABEL SET, whose encoding is defined as

following

<LABEL-SET-OBJECT> ::= <LABEL-REQUEST><LABEL-SET>[<LABEL-SET>]

The LABEL-REQUEST and LABEL-SET TLV are as defined in Section 2.2.2.5, See also [RFC3471] and [RFC3473] for the definitions of the fields.

It is allowed to have more than one LABEL SET object per PCReq (for example in case of multiple SWITCH-LAYER present).

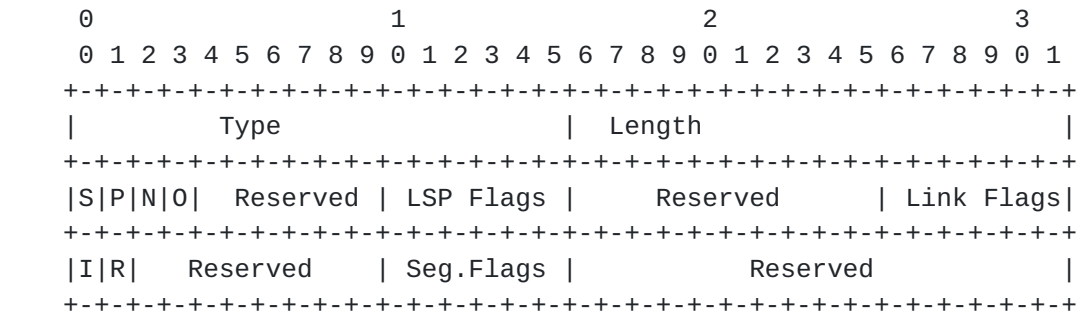
In the case of unsuccessful path computation, the PCRep message also contains a NO-PATH object, and the LABEL SET object MAY be used to indicate the set of constraint that could not be satisfied.

2.4. SUGGESTED LABEL SET object

The SUGGESTED LABEL SET object is carried within a PCReq message to indicate the preferred set of labels to be assigned during the routing. The encoding is the same as the LABEL SET object. It is allowed to have more than one SUGGESTED LABEL SET object per PCReq (for example in case of multiple SWITCH-LAYER present).

2.5. LSPA extensions

The LSPA carries the LSP attributes. In the end-to-end protection context this also includes the protection state information. The LSPA object can be extended by a protection TLV type: Type TBA by IANA: 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.

2.6. 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.

2.6.1. Extensions to NO-PATH-VECTOR TLV

The current NO-PATH-VECTOR TLV carry the following information:

Bit number 31 - PCE currently unavailable [RFC5440]

Bit number 30 - Unknown destination [RFC5440]

Bit number 29 - Unknown source [RFC5440]

Bit number 28 - BRPC Path computation chain unavailable [RFC5440]

Bit number 27 - PKS expansion failure [RFC5520]

Bit number 26 - No GCO migration path found [RFC5557]

Bit number 25 - No GCO solution found [RFC5557]

Bit number 24 - P2MP Reachability Problem [RFC5440]

The modified NO-PATH-VECTOR TLV carrying the additional information is as follows: New fields PM and NR are defined in the 23th and 22th bit of the Flags field respectively.

Bit number 23 (TBA by IANA) - Protection Mismatch (1-bit). Specifies the mismatch of the protection type in the request.

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

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 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 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 14 is introduced.

Error-Type	Error-value	
10	Reception of an invalid object	
	Error-value=:1	Bad Generalized Bandwidth Object value.
	Error-value=:2	Unsupported LSP Protection Type in protection attribute TLV.
	Error-value=:3	Unsupported LSP Protection Flags in protection attribute TLV.
	Error-value=:4	Unsupported Secondary LSP Protection Flags in protection attribute TLV.
	Error-value=:5	Unsupported Link Protection Type in protection attribute TLV.
	Error-value=:6	Unsupported Link Protection Type in protection attribute TLV.
14	Path computation failure	
	Error-value=1:	Unacceptable response message.
	Error-value=2:	Generalized bandwidth object not supported.
	Error-value=3:	Label Set constraint could not be met.
	Error-value=4:	Label constraint could not be met.
	Error-value=5:	Unsupported endpoint type in END-POINTS GENERALIZED-ENDPOINTS object type

Error-value=6: Unsupported TLV present in END-POINTS GENERALIZED-ENDPOINTS object type

4. Manageability Considerations

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].

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 2.1 a new Object is 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 2.1)

As described in Section 2.2.1 a new Object type is defined IANA is requested to make the following Object-Type allocations from the "PCEP Objects" sub-registry:

Object Class 4

Name END-POINTS

Object-Type 5 : Generalized Endpoint

6-15 : unassigned

Reference This document (section Section 2.1)

5.2. New PCEP TLVs

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

Value	Meaning	Reference
x	IPV4 endpoint	This document (section Section 2.2.2.1)
x	IPV6 endpoint	This document (section Section 2.2.2.2)
x	Unnumbered endpoint	This document (section Section 2.2.2.3)
x	Label request	This document (section Section 2.2.2.4)
x	Requested GMPLS Label	This document (section Section 2.2.2.5)
x	Requested GMPLS Upstream Label	This document (section Section 2.2.2.5)
x	Requested GMPLS Label Set	This document (section Section 2.2.2.5)
x	Suggested GMPLS Label Set	This document (section Section 2.2.2.5)
x	LSP Protection Information	This document (section Section 2.5)

5.3. New PCEP Error Codes

As described in Section Section 3, 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=:1	Bad Generalized Bandwidth Object value.
	Error-value=:2	Unsupported LSP Protection Type in protection attribute TLV.
	Error-value=:3	Unsupported LSP Protection Flags in protection attribute TLV.
	Error-value=:4	Unsupported Secondary LSP Protection Flags in protection attribute TLV.
	Error-value=:5	Unsupported Link Protection Type in protection attribute TLV.
	Error-value=:6	Unsupported Link Protection Type in protection attribute TLV.
14	Path computation failure	
	Error-value=1:	Unacceptable response message.
	Error-value=2:	Generalized bandwidth object not supported.
	Error-value=3:	Label Set constraint could not be met.
	Error-value=4:	Label constraint could not be met.
	Error-value=5:	Unsupported endpoint type in END-POINTS GENERALIZED-ENDPOINTS object type
	Error-value=6:	Unsupported TLV present in END-POINTS GENERALIZED-ENDPOINTS object type

6. Security Considerations

None.

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9. References

9.1. Normative References

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