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Authors: Y. Lee *Samsung*, H. Zheng *Huawei Technologies*, O. Gonzalez de Dios *Telefonica*, V. Lopez *Nokia*, Z. Ali *Cisco*

RFC 9504
Path Computation Element Communication Protocol (PCEP) Extensions for Stateful PCE Usage in GMPLS-Controlled Networks

Abstract

The Path Computation Element Communication Protocol (PCEP) has been extended to support stateful PCE functions where the stateful PCE maintains information about paths and resource usage within a network; however, these extensions do not cover all requirements for GMPLS networks.

This document provides the extensions required for PCEP so as to enable the usage of a stateful PCE capability in GMPLS-controlled networks.

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1. Introduction

[RFC4655] presents the architecture of a PCE-based model for computing Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineering Label Switched Paths (TE LSPs). To perform such a constrained computation, a PCE stores the network topology (i.e., TE links and nodes) and resource information (i.e., TE attributes) in its TE Database (TED). A PCE that only maintains a TED is referred to as a "stateless PCE". [RFC5440] describes the Path Computation Element Communication Protocol (PCEP) for interaction between a Path Computation Client (PCC) and a PCE or between two PCEs, enabling computation of TE LSPs. PCEP is further extended to support GMPLS-controlled networks as per [RFC8779].

Stateful PCEs are shown to be helpful in many application scenarios, in both MPLS and GMPLS networks, as illustrated in [RFC8051]. Further discussion of the concept of a stateful PCE can be found in [RFC7399]. In order for these applications to be able to exploit the capability of stateful PCEs, extensions to stateful PCEP for GMPLS are required.

[RFC8051] describes how a stateful PCE can be applied to solve various problems for MPLS-TE and GMPLS networks and the benefits it brings to such deployments.

[RFC8231] specifies a set of extensions to PCEP to enable stateful control of TE LSPs where they are configured on the PCC and control over them could be delegated to the PCE. Furthermore, [RFC8281] describes the setup and teardown of PCE-initiated LSPs under the active stateful PCE model, without the need for local configuration on the PCC. However, both documents omit the specification for technology-specific objects and TLVs, and they do not cover GMPLS-controlled networks (e.g., Wavelength Switched Optical Network (WSON), Optical Transport Network (OTN), Synchronous Optical Network (SONET) / Synchronous Digital Hierarchy (SDH)).

This document focuses on the extensions that are necessary in order for the deployment of stateful PCEs and the requirements for PCE-initiated LSPs in GMPLS-controlled networks. Section 3 provides a general context of the usage of stateful PCEs and PCEP for GMPLS. The various requirements for stateful GMPLS, including PCE initiation for GMPLS LSPs, are provided in Section 4. An overview of the PCEP extensions is specified in Section 5. A solution to address such requirements with PCEP object extensions is specified in Section 6.

1.1. Conventions Used in This Document

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Terminology

Terminology used in this document is the same as terminology used in [RFC5440], [RFC8231], [RFC8281], and [RFC8779].

3. General Context of Stateful PCE and PCEP for GMPLS

This section is built on the basis of stateful PCEs specified in [RFC8231] and PCEP for GMPLS specified in [RFC8779].

The operation of a stateful PCE on LSPs can be divided into two types: active stateful PCE and passive stateful PCE (as described in [RFC8051]).

- For active stateful PCEs, a Path Computation Update Request (PCUpd) message is sent from the PCE to the PCC to update the LSP state for the LSPs delegated to the PCE. Any changes to the delegated LSPs generate a Path Computation State Report (PCRpt) message from the PCC to the PCE to convey the changes of the LSPs. Any modifications to the objects and TLVs that are identified in this document to support GMPLS-specific attributes will be carried in the PCRpt and PCUpd messages.

- For passive stateful PCEs, Path Computation Request (PCReq) and Path Computation Reply (PCRep) messages are used to request path computation. GMPLS-specific objects and TLVs are defined in [RFC8779], which this document builds on and adds the stateful PCE aspects where applicable. A passive stateful PCE makes use of PCRpt messages when reporting LSP state changes sent by PCCs to PCEs. Any modifications to the objects and TLVs that are identified in this document to support GMPLS-specific attributes will be carried in the PCRpt message.

Furthermore, the LSP Initiation function of PCEP is defined in [RFC8281] to allow the PCE to initiate LSP establishment after the path is computed. An LSP Initiate Request (PCInitiate) message is used to trigger the end node to set up the LSP. Any modifications to the objects and TLVs that are identified in this document to support GMPLS-specific attributes will be carried in the PCInitiate messages.

[RFC8779] defines GMPLS-specific objects and TLVs in stateless PCEP; this document makes use of these objects and TLVs without modifications where applicable. Where these objects and TLVs require modifications to incorporate stateful PCEs, they are described in this document. PCE-initiated LSPs follow the principle specified in [RFC8281], and the GMPLS-specific extensions are also included in this document.

4. Main Requirements

This section notes the main functional requirements for PCEP extensions to support stateful PCEs for use in GMPLS-controlled networks, based on the description in [RFC8051]. Many requirements are common across a variety of network types (e.g., MPLS-TE networks and GMPLS networks) and the protocol extensions to meet the requirements are already described in [RFC8231] (such as LSP update, delegation, and state synchronization/report). Protection context information that describes the GMPLS requirement can also follow the description in [RFC8745]. This document does not repeat the description of those protocol extensions. This document presents protocol extensions for a set of requirements that are specific to the use of a stateful PCE in a GMPLS-controlled network.

The requirements for GMPLS-specific stateful PCEs are as follows:

- Advertisement of the stateful PCE capability. This generic requirement is covered in Section 5.4 of [RFC8231]. The GMPLS-CAPABILITY TLV specified in Section 2.1 of [RFC8779] and its extension in this document need to be advertised as well.
- All the PCEP messages need to be capable of indicating GMPLS-specific switching capabilities. GMPLS LSP creation, modification, and deletion require knowledge of LSP switching capabilities (e.g., Time-Division Multiplex Capable (TDM), Layer 2 Switch Capable (L2SC), OTN-TDM, Lambda Switch Capable (LSC), etc.) and the Generalized Payload Identifier (G-PID) to be used according to [RFC3471] and [RFC3473]. It also requires that traffic parameters that are both data flow and technology specific be defined. These traffic

parameters are also known as "Traffic Specification" or "Tspec". Such information would need to be included in various PCEP messages.

- In some technologies, path calculation is tightly coupled with label selection along the route. For example, path calculation in a Wavelength Division Multiplexing (WDM) network may include lambda continuity and/or lambda feasibility constraints; hence, a path computed by the PCE is associated with a specific lambda (label). Thus, in such networks, the label information needs to be provided to a PCC in order for a PCE to initiate GMPLS LSPs under the active stateful PCE model, i.e., Explicit Label Control (ELC) may be required.
- Stateful PCEP messages also need to indicate the protection context information for the LSP specified by GMPLS, as defined in [RFC4872] and [RFC4873].

5. Overview of Stateful PCEP Extensions for GMPLS Networks

5.1. Capability Advertisement for Stateful PCEP in GMPLS

Capability advertisement is specified in [RFC8231]; it can be achieved by using the STATEFUL-PCE-CAPABILITY TLV in the Open message. Another GMPLS-CAPABILITY TLV is defined in [RFC8779]. A subregistry to manage the Flag field of the GMPLS-CAPABILITY TLV has been created by IANA as requested by [RFC8779]. The following bits are introduced by this document in the GMPLS-CAPABILITY TLV as flags to indicate the capability for LSP report, update, and initiation in GMPLS networks: LSP-REPORT-CAPABILITY (31), LSP-UPDATE-CAPABILITY (30), and LSP-INSTANTIATION-CAPABILITY (29).

5.2. LSP Synchronization

After the session between the PCC and a stateful PCE is initialized, the PCE must learn the state of a PCC's LSPs (including its attributes) before it can perform path computations or update LSP attributes in a PCC. This process is known as "LSP state synchronization". The LSP attributes, including bandwidth, associated route, and protection information etc., are stored by the PCE in the LSP database (LSP-DB). Note that, as described in [RFC8231], the LSP state synchronization covers both the bulk reporting of LSPs at initialization as well as the reporting of new or modified LSPs during normal operation. Incremental LSP-DB synchronization may be desired in a GMPLS-controlled network; it is specified in [RFC8232].

The format of the PCRpt message is specified in [RFC8231] and extended in [RFC8623] to include the END-POINTS object. The END-POINTS object is extended for GMPLS in [RFC8779]. The END-POINTS object can be carried in the PCRpt message as specified in [RFC8623]. The END-POINTS object type for GMPLS is included in the PCRpt message as per the same.

The following objects are extended for GMPLS in [RFC8779] and are also used in the PCRpt in the same manner: BANDWIDTH, LSP Attributes (LSPA), Include Route Object (IRO), and Exclude Route Object (XRO). These objects are carried in the PCRpt message as specified in [RFC8231] (as the attribute-list defined in Section 6.5 of [RFC5440] and extended by many other documents that define PCEP extensions for specific scenarios).

The SWITCH-LAYER object is defined in [RFC8282]. This object is carried in the PCRpt message as specified in Section 3.2 of [RFC8282].

5.3. LSP Delegation and Cleanup

The LSP delegation and cleanup procedure specified in [RFC8281] are equally applicable to GMPLS LSPs and this document does not modify the associated usage.

5.4. LSP Operations

Both passive and active stateful PCE mechanisms in [RFC8231] are applicable in GMPLS-controlled networks. Remote LSP Initiation in [RFC8281] is also applicable in GMPLS-controlled networks.

6. PCEP Object Extensions

6.1. Existing Extensions Used for Stateful GMPLS

Existing extensions defined in [RFC8779] can be used in stateful PCEP with no or slight changes for GMPLS network control, including the following:

END-POINTS: The END-POINTS object was specified in [RFC8779] to include GMPLS capabilities. All stateful PCEP messages **MUST** include the END-POINTS object with Generalized Endpoint object type, containing the LABEL-REQUEST TLV. Further note that:

- As per [RFC8779], for stateless GMPLS path computation, the Generalized END-POINTS object may contain a LABEL-REQUEST and/or LABEL-SET TLV. In this document, only the LABEL-REQUEST TLV is used to specify the switching type, encoding type, and G-PID of the LSP.
- If unnumbered endpoint addresses are used for the LSP, the UNNUMBERED-ENDPOINT TLV [RFC8779] **MUST** be used to specify the unnumbered endpoint addresses.
- The Generalized END-POINTS object **MAY** contain other TLVs defined in [RFC8779].

RP: The Request Parameter (RP) object extension (together with the Routing Granularity (RG) flag defined in [RFC8779]) is applicable in stateful PCEP for GMPLS networks.

BANDWIDTH: Generalized BANDWIDTH is specified in [RFC8779] to represent GMPLS features, including asymmetric bandwidth and G-PID information.

LSPA: LSPA Extensions in Section 2.8 of [RFC8779] are applicable in stateful PCEP for GMPLS networks.

IRO: IRO Extensions in Section 2.6 of [RFC8779] are applicable in stateful PCEP for GMPLS networks.

XRO: XRO Extensions in Section 2.7 of [RFC8779] are applicable in stateful PCEP for GMPLS networks. A new flag is defined in Section 6.2.3 of this document.

ERO: The Explicit Route Object (ERO) is not extended in [RFC8779], nor is it in this document.

SWITCH-LAYER: The SWITCH-LAYER definition in Section 3.2 of [RFC8282] is applicable in stateful PCEP messages for GMPLS networks.

6.2. New Extensions

6.2.1. GMPLS-CAPABILITY TLV in OPEN Object

In [RFC8779], IANA allocates value 45 (GMPLS-CAPABILITY) from the "PCEP TLV Type Indicators" subregistry. This specification adds three flags to the Flag field of this TLV to indicate the Report, Update, and Initiation capabilities.

R (LSP-REPORT-CAPABILITY (31) -- 1 bit):
: If set to 1 by a PCC, the R flag indicates that the PCC is capable of reporting the current state of a GMPLS LSP whenever there's a change to the parameters or operational status of the GMPLS LSP. If set to 1 by a PCE, the R flag indicates that the PCE is interested in receiving GMPLS LSP State Reports whenever there is a parameter or operational status change to the LSP. The LSP-REPORT-CAPABILITY flag must be advertised by both a PCC and a PCE for PCRpt messages to be allowed on a PCEP session for GMPLS LSP.

U (LSP-UPDATE-CAPABILITY (30) -- 1 bit):
: If set to 1 by a PCC, the U flag indicates that the PCC allows modification of GMPLS LSP parameters. If set to 1 by a PCE, the U flag indicates that the PCE is capable of updating GMPLS LSP parameters. The LSP-UPDATE-CAPABILITY flag must be advertised by both a PCC and a PCE for PCUpd messages to be allowed on a PCEP session for GMPLS LSP.

I (LSP-INSTANTIATION-CAPABILITY (29) -- 1 bit):
: If set to 1 by a PCC, the I flag indicates that the PCC allows instantiation of a GMPLS LSP by a PCE. If set to 1 by a PCE, the I flag indicates that the PCE supports instantiating GMPLS LSPs. The LSP-INSTANTIATION-CAPABILITY flag must be set by both the PCC and PCE in order to enable PCE-initiated LSP instantiation.

6.2.2. New LSP Exclusion Subobject in the XRO

[RFC5521] defines a mechanism for a PCC to request or demand that specific nodes, links, or other network resources be excluded from paths computed by a PCE. A PCC may wish to request the computation of a path that avoids all links and nodes traversed by some other LSP.

To this end, this document defines a new subobject for use with route exclusion defined in [RFC5521]. The LSP Exclusion subobject is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|X|Type (11)    |     Length    |    Reserved     |    Flags    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
//                    Symbolic Path Name                       //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: New LSP Exclusion Subobject Format

X: This field is the same as the X-bit defined in the XRO subobjects in Section 2.1.1 of [RFC5521] where it says:

> The X-bit indicates whether the exclusion is mandatory or desired. 0 indicates that the resource specified **MUST** be excluded from the path computed by the PCE. 1 indicates that the resource specified **SHOULD** be excluded from the path computed by the PCE, but **MAY** be included subject to PCE policy and the absence of a viable path that meets the other constraints and excludes the resource.

Type: The subobject type for an LSP Exclusion subobject. Value of 11.

Length: The Length contains the total length of the subobject in bytes, including the Type and Length fields.

Reserved: Reserved **MUST** be set to zero on transmission and ignored on receipt.

Flags: This field may be used to further specify the exclusion constraint with regard to the LSP. Currently, no flags are defined.

Symbolic Path Name: This is the identifier given to an LSP. Its syntax and semantics are identical to those of the Symbolic Path Name field defined in Section 7.3.2 of [RFC8231] where it says: "symbolic name for the LSP, unique in the PCC. It **SHOULD** be a string of printable ASCII characters, without a NULL terminator." The symbolic path name in the LSP Exclusion subobject **MUST** only vary from being a string of printable ASCII characters without a NULL terminator when it is matching the value contained in another subobject. It is worth noting that given that the symbolic path name is unique in the context of the headnode, only LSPs that share the same headnode or PCC could be excluded.

This subobject **MAY** be present multiple times in the XRO to exclude resources from multiple LSPs. When a stateful PCE receives a PCReq message carrying this subobject, it **MUST** search for the identified LSP in its LSP-DB and then exclude from the new path computation all resources used by the identified LSP.

Note that this XRO subobject could also be used by non-GMPLS LSPs. The usage of the XRO subobject for any non-GMPLS LSPs is not in the scope of this document.

6.2.3. New Flags in the LSP-EXTENDED-FLAG TLV in LSP Object

The LSP object is defined in Section 7.3 of [RFC8231], and the new extended flags TLV is defined in [RFC9357]. This TLV is used in PCUpd, PCRpt and PCInitiate messages for GMPLS, with the following flags defined in this document:

G (GMPLS LSP (0) -- 1 bit):
: If set to 1, it indicates the LSP is a GMPLS LSP.

B (Bidirectional LSP (1) -- 1 bit):
: If set to 0, it indicates a request to create a unidirectional LSP. If set to 1, it indicates a request to create a bidirectional co-routed LSP.

RG (Routing Granularity (2-3) -- 2 bits):
: The RG flag for GMPLS is also defined in the LSP-EXTENDED-FLAG TLV. The values are defined as per [RFC8779]:

  00: reserved
  01: node
  10: link
  11: label

7. Update to Error Handling

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. This section adds additional error handling procedures to those specified in Section 3 of [RFC8779]. Please note that all error handling specified in Section 3 of [RFC8779] is applicable and **MUST** be supported for a stateful PCE in GMPLS networks.

7.1. Error Handling in PCEP Capabilities Advertisement

The PCEP extensions described in this document for stateful PCEs with GMPLS capabilities **MUST NOT** be used if the PCE has not advertised its capabilities with GMPLS as per Section 6.2.1.

If the PCC understands the U flag that indicates the stateful LSP-UPDATE-CAPABILITY, but did not advertise this capability, then upon receipt of a PCUpd message for GMPLS LSP from the PCE, it **SHOULD** generate a PCErr with Error-Type 19 ("Invalid Operation") Error-value 25 ("Attempted LSP update request for GMPLS if stateful PCE capability not advertised") and terminate the PCEP session. Such a PCC **MAY** decide to utilize the capability even though it did not advertise support for it.

If the PCE understands the R flag that indicates the stateful LSP-REPORT-CAPABILITY, but did not advertise this capability, then upon receipt of a PCRpt message for GMPLS LSP from the PCC, it **SHOULD** generate a PCErr with Error-Type 19 ("Invalid Operation") Error-value 26 ("Attempted

LSP State Report for GMPLS if stateful PCE capability not advertised") and terminate the PCEP session. Such a PCE **MAY** decide to utilize the capability even though it did not advertise support for it.

If the PCC understands the I flag that indicates LSP-INSTANTIATION-CAPABILITY, but did not advertise this capability, then upon receipt of a PCInitiate message for GMPLS LSP from the PCE, it **SHOULD** generate a PCErr with Error-Type 19 ("Invalid Operation") Error-value 27 ("Attempted LSP instantiation request for GMPLS if stateful PCE instantiation capability for not advertised") and terminate the PCEP session. Such a PCC **MAY** decide to utilize the capability even though it did not advertise support for it.

7.2. Error Handling in LSP Reoptimization

A stateful PCE is expected to perform an LSP reoptimization when receiving a message with the R bit set in the RP object. If no LSP state information is available to carry out reoptimization, the stateful PCE **SHOULD** report Error-Type 19 ("Invalid Operation") Error-value 23 ("LSP state info unavailable for reoptimization"), although such a PCE **MAY** consider the reoptimization to have successfully completed. Note that this error message could also be used by non-GMPLS LSPs.

7.3. Error Handling in Route Exclusion

The LSP Exclusion subobject in XRO, as defined in Section 6.2.2 of this document, **MAY** be present multiple times. When a stateful PCE receives a PCEP message carrying this subobject, it searches for the identified LSP in its LSP-DB. It then excludes from the new path computation all the resources used by the identified LSP. If the stateful PCE cannot recognize the symbolic path name of the identified LSP, it **SHOULD** send an error message PCErr reporting Error-Type 19 ("Invalid Operation") Error-value 24 ("LSP state info for route exclusion not found"). Along with the unrecognized symbolic path name, it **MAY** also provide information to the requesting PCC using the error-reporting techniques described in [RFC5440]. An implementation **MAY** choose to ignore the requested exclusion when the LSP cannot be found because it could claim that it has avoided using all resources associated with an LSP that doesn't exist.

7.4. Error Handling for the Generalized END-POINTS Object

Note that the END-POINTS object in stateful PCEP messages was introduced for Point-to-Multipoint (P2MP) [RFC8623]. Similarly, the END-POINTS object **MUST** be carried for the GMPLS LSP. If the END-POINTS object is missing and the GMPLS flag in LSP-EXTENDED-FLAG is set, the receiving PCE or PCC **MUST** send a PCErr message with Error-Type 6 ("Mandatory Object missing") and Error-value 3 ("END-POINTS object missing") (defined in [RFC5440]). Similarly, if the END-POINTS object with the Generalized Endpoint object type is received but the LSP-EXTENDED-FLAG TLV is missing in the LSP object or the G flag in the LSP-EXTENDED-FLAG TLV is not set, the receiving PCE or PCC **MUST** send a PCErr message with Error-Type 19 ("Invalid Operation") Error-value 28 ("Use of the Generalized Endpoint object type for non-GMPLS LSPs").

If the END-POINTS object with Generalized Endpoint object type is missing the LABEL-REQUEST TLV, the receiving PCE or PCC **MUST** send a PCErr message with Error-Type 6 ("Mandatory Object missing") Error-value 20 ("LABEL-REQUEST TLV missing").

8. IANA Considerations

8.1. New Flags in the GMPLS-CAPABILITY TLV

[RFC8779] defines the GMPLS-CAPABILITY TLV; per that RFC, IANA created the "GMPLS-CAPABILITY TLV Flag Field" registry to manage the values of the GMPLS-CAPABILITY TLV's Flag field. This document registers new bits in this registry as follows:

Bit	Capability Description	Reference
31	LSP-REPORT-CAPABILITY (R)	RFC 9504
30	LSP-UPDATE-CAPABILITY (U)	RFC 9504
29	LSP-INSTANTIATION-CAPABILITY (I)	RFC 9504

Table 1

8.2. New Subobject for the Exclude Route Object

IANA maintains the various XRO subobject types within the "XRO Subobjects" subregistry of the "Path Computation Element Protocol (PCEP) Numbers" registry. IANA has allocated a codepoint for another XRO subobject as follows:

Value	Description	Reference
11	LSP	RFC 9504

Table 2

8.3. Flags Field for the LSP Exclusion Subobject

IANA has created a registry named "LSP Exclusion Subobject Flag Field", within the "Path Computation Element Protocol (PCEP) Numbers" group, to manage the Flag field of the LSP Exclusion subobject in the XRO. No flag is currently defined for this Flag field in this document.

Codespace of the Flag field (LSP Exclusion Subobject)

Bit	Capability Description	Reference
0-7	Unassigned	RFC 9504

Table 3

New values are to be assigned by Standards Action [RFC8126]. Each bit should be registered with the following entries:

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

- Capability description
- Reference to defining RFC

8.4. New Flags in the LSP-EXTENDED-FLAGS TLV

[RFC9357] requested IANA to create a subregistry, named the "LSP-EXTENDED-FLAG TLV Flag Field", within the "Path Computation Element Protocol (PCEP) Numbers" registry, to manage the Flag field of the LSP-EXTENDED-FLAG TLV.

IANA has made assignments from this registry as follows:

Bit	Capability Description	Reference
0	GMPLS LSP (G)	RFC 9504
1	Bidirectional Co-routed LSP (B)	RFC 9504
2-3	Routing Granularity (RG)	RFC 9504

Table 4

8.5. New PCEP Error Codes

IANA has made the following allocations in the "PCEP-ERROR Object Error Types and Values" registry.

Error-Type	Meaning	Error-value	Reference
6	Mandatory Object missing	20: LABEL-REQUEST TLV missing	RFC 9504
19	Invalid Operation	23: LSP state info unavailable for reoptimization	RFC 9504
		24: LSP state info for route exclusion not found	RFC 9504
		25: Attempted LSP update request for GMPLS if stateful PCE capability not advertised	RFC 9504
		26: Attempted LSP State Report for GMPLS if stateful PCE capability not advertised	RFC 9504
		27: Attempted LSP instantiation request for GMPLS if stateful PCE instantiation capability not advertised	RFC 9504

Error-Type	Meaning	Error-value	Reference
		28: Use of the Generalized Endpoint object type for non-GMPLS LSPs	RFC 9504

Table 5

9. Manageability Considerations

General PCE management considerations are discussed in [RFC4655] and [RFC5440], and GMPLS-specific PCEP management considerations are described in [RFC8779]. In this document, the management considerations for stateful PCEP extension in GMPLS are described.

This section follows the guidance of [RFC6123].

9.1. Control of Function through Configuration and Policy

In addition to the parameters already listed in Section 8.1 of [RFC5440], a PCEP implementation **SHOULD** allow configuration of the following PCEP session parameters on a PCC. However, an implementation **MAY** choose to make these features available on all PCEP sessions:

- The ability to send stateful PCEP messages for GMPLS LSPs.
- The ability to use path computation constraints (e.g., XRO).

In addition to the parameters already listed in Section 8.1 of [RFC5440], a PCEP implementation **SHOULD** allow configuration of the following PCEP session parameters on a PCE:

- The ability to compute paths in a stateful manner in GMPLS networks.
- A set of GMPLS-specific constraints.

These parameters may be configured as default parameters for any PCEP session the PCEP speaker participates in or they may apply to a specific session with a given PCEP peer or a specific group of sessions with a specific group of PCEP peers.

9.2. Information and Data Models

The YANG module in [PCE-PCEP-YANG] can be used to configure and monitor PCEP states and messages. To make sure that the YANG module is useful for the extensions as described in this document, it would need to include advertised GMPLS stateful capabilities etc. A future version of [PCE-PCEP-YANG] will include this.

As described in [YANG-PATH-COMPUTATION], a YANG-based interface can be used in some cases to request GMPLS path computations, instead of PCEP. Refer to [YANG-PATH-COMPUTATION] for details.

9.3. Liveness Detection and Monitoring

This document makes no change to the basic operation of PCEP, so there are no changes to the requirements for liveness detection and monitoring in [RFC4657] and Section 8.3 of [RFC5440].

9.4. Verifying Correct Operation

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

9.5. Requirements on Other Protocols and Functional Components

When the detailed route information is included for LSP state synchronization (either at the initial stage or during the LSP State Report process), this requires the ingress node of an LSP to carry the Record Route Object (RRO) object in order to enable the collection of such information.

9.6. Impact on Network Operation

The management considerations concerning the impact on network operations described in Section 4.6 of [RFC8779] apply here.

10. Security Considerations

The security considerations elaborated in [RFC5440] apply to this document. The PCEP extensions to support GMPLS-controlled networks should be considered under the same security as for MPLS networks, as noted in [RFC7025]. Therefore, the PCEP extension to support GMPLS specified in [RFC8779] is used as the foundation of this document; the security considerations in [RFC8779] should also be applicable to this document. The secure transport of PCEP specified in [RFC8253] allows the usage of Transport Layer Security (TLS). The same can also be used by the PCEP extension defined in this document.

This document provides additional extensions to PCEP so as to facilitate stateful PCE usage in GMPLS-controlled networks, on top of [RFC8231] and [RFC8281]. Security issues caused by the extension in [RFC8231] and [RFC8281] are not altered by the additions in this document. The security considerations in [RFC8231] and [RFC8281], including both issues and solutions, apply to this document as well.

11. References

11.1. Normative References

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Appendix A. PCEP Messages

This section uses the Routing Backus-Naur Form (RBNF) [RFC5511] to illustrate the PCEP messages. The RBNF in this section is reproduced for informative purposes. It is also expanded to show the GMPLS-specific objects.

A.1. The PCRpt Message

According to [RFC8231], the PCRpt message is used to report the current state of an LSP. This document extends the message in reporting the status of LSPs with GMPLS characteristics.

The format of the PCRpt message is as follows:

```
<PCRpt Message> ::= <Common Header>
                    <state-report-list>
```

Where:

```
<state-report-list> ::= <state-report>[<state-report-list>]
<state-report> ::= [<SRP>]
                   <LSP>
                   [<END-POINTS>]
                   <path>
```

Where:

```
<path> ::= <intended-path>
           [<actual-attribute-list><actual-path>]
           <intended-attribute-list>
<actual-attribute-list> ::=[<BANDWIDTH>]
                           [<metric-list>]
```

Where:

- The END-POINTS object **MUST** be carried in a PCRpt message when the G flag is set in the LSP-EXTENDED-FLAG TLV in the LSP object for a GMPLS LSP.
- <intended-path> is represented by the ERO object defined in Section 7.9 of [RFC5440] and augmented in [RFC8779] with ELC.
- <actual-attribute-list> consists of the actual computed and signaled values of the <BANDWIDTH> and <metric-lists> objects defined in [RFC5440].
- <actual-path> is represented by the RRO object defined in Section 7.10 of [RFC5440].
- <intended-attribute-list> is the attribute-list defined in Section 6.5 of [RFC5440] and extended by many other documents that define PCEP extensions for specific scenarios as shown below:

```
<attribute-list> ::= [<of-list>]
                     [<LSPA>]
                     [<BANDWIDTH>]
                     [<metric-list>]
                     [<IRO>][<XRO>]
                     [<INTER-LAYER>]
                     [<SWITCH-LAYER>]
                     [<REQ-ADAP-CAP>]
                     [<SERVER-INDICATION>]
```

A.2. The PCUpd Message

The format of a PCUpd message is as follows:

```
<PCUpd Message> ::= <Common Header>
                    <update-request-list>
```

Where:

```
<update-request-list> ::= <update-request>[<update-request-list>]
<update-request> ::= <SRP>
                     <LSP>
                     [<END-POINTS>]
                     <path>
```

Where:

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

Where:

- The END-POINTS object **MUST** be carried in a PCUpd message for the GMPLS LSP.
- <intended-path> is represented by the ERO object defined in Section 7.9 of [RFC5440], augmented in [RFC8779] with ELC.
- <intended-attribute-list> is the attribute-list defined in [RFC5440] and extended by many other documents that define PCEP extensions for specific scenarios and as shown for PCRpt above.

A.3. The PCInitiate Message

According to [RFC8281], the PCInitiate message is used allow LSP Initiation. This document extends the message in initiating LSPs with GMPLS characteristics. The format of a PCInitiate message is as follows:

```
<PCInitiate Message> ::= <Common Header>
                         <PCE-initiated-lsp-list>
```

Where:

```
<Common Header> is defined in <xref target="RFC5440" />.
<PCE-initiated-lsp-list> ::= <PCE-initiated-lsp-request>
                             [<PCE-initiated-lsp-list>]
<PCE-initiated-lsp-request> ::= (<PCE-initiated-lsp-instantiation>|
                                 <PCE-initiated-lsp-deletion>)
<PCE-initiated-lsp-instantiation> ::= <SRP>
                                      <LSP>
                                      [<END-POINTS>]
                                      <ERO>
                                      [<attribute-list>]
<PCE-initiated-lsp-deletion> ::= <SRP>
                                 <LSP>
```

The format of the PCInitiate message is unchanged from Section 5.1 of [RFC8281]. All fields are similar to the PCRpt and the PCUpd messages.

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Contributors

Xian Zhang
Huawei Technologies
Email: zhang.xian@huawei.com

Dhruv Dhody
Huawei Technology
India
Email: dhruv.ietf@gmail.com

Yi Lin
Huawei Technologies
Email: yi.lin@huawei.com

Fatai Zhang
Huawei Technologies
Email: zhangfatai@huawei.com

Ramon Casellas
CTTC
Av. Carl Friedrich Gauss n7
08860 Barcelona Castelldefels
Spain
Email: ramon.casellas@cttc.es

Siva Sivabalan
Cisco Systems
Email: msiva@cisco.com

Clarence Filsfils
Cisco Systems
Email: cfilsfil@cisco.com

Robert Varga
Pantheon Technologies
Email: nite@hq.sk

Authors' Addresses

Young Lee
Samsung
Email: younglee.tx@gmail.com

Haomian Zheng
Huawei Technologies
Email: zhenghaomian@huawei.com

Oscar Gonzalez de Dios
Telefonica
Email: oscar.gonzalezdedios@telefonica.com

Victor Lopez
Nokia
Email: victor.lopez@nokia.com

Zafar Ali
Cisco
Email: zali@cisco.com