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Path Computation Element Communication Protocol (PCEP)  
Extensions for remote-initiated GMPLS LSP Setup  
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Abstract

Draft [I-D. draft-crabbe-pce-pce-initiated-lsp] specifies procedures that can be used for creation and deletion of PCE-initiated LSPs in the active stateful PCE model. However, this specification focuses on MPLS networks, and does not cover remote instantiation of paths in GMPLS-controlled networks. This document complements [I-D. draft-crabbe-pce-pce-initiated-lsp] by addressing the requirements for remote-initiated GMPLS LSPs.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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## 1. Introduction

The Path Computation Element communication Protocol (PCEP) provides mechanisms for Path Computation Elements (PCEs) to perform route computations in response to Path Computation Clients (PCCs) requests. PCEP Extensions for PCE-initiated LSP Setup in a Stateful PCE Model draft [I-D. draft-ietf-pce-stateful-pce] describes a set of extensions to PCEP to enable active control of MPLS-TE and GMPLS network.

[I-D. draft-crabbe-pce-pce-initiated-lsp] describes the setup and teardown of PCE-initiated LSPs under the active stateful PCE model, without the need for local configuration on the PCC. This enables realization of a dynamic network that is centrally controlled and deployed. However, this specification is focused on MPLS networks, and does not cover the GMPLS networks (e.g., WSON, OTN, SONET/ SDH, etc. technologies). This document complements [I-D. draft-crabbe-pce-pce-initiated-lsp] by addressing the requirements for remote-initiated GMPLS LSPs. These requirements are covered in Section 3 of this draft. The PCEP extensions for remote initiated GMPLS LSPs are specified in Section 4.

## 2. Use Cases

### 2.1. Single-layer provisioning from active stateful PCE

Figure 1 shows a single-layer topology with optical nodes with a GMPLS control plane. In this scenario, the active PCE can dynamically instantiate or delete L0 services between client interfaces. This process can be triggered by the deployment of a new network configuration or a re-optimization process. This operation can be human-driven (e.g. through an NMS) or an automatic process.

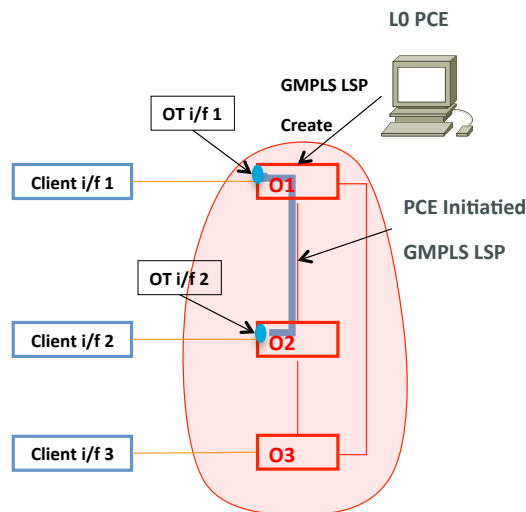


Figure 1. Single-layer provisioning from active stateful PCE.

L0 PCE obtains resources information via control plane collecting LSAs messages. The PCE computes the path and sends a message to the optical equipment with Explicite Route Object (ERO) information.

## 2.2. Multi-layer networks

This use case assumes there is a multi-layer network composed by routers and optical equipment. According to [RFC5623], there are four inter-layer path control models: (1) PCE-VNTM cooperation, (2) Higher-layer signaling trigger, (3) NMS-VNTM cooperation model (integrated flavor) and (4) NMS-VNTM cooperation model (separated flavor). In the following we have selected two use cases to explain the requirements considered in this draft, but the document is applicable to all four options.

### 2.2.1. Higher-layer signaling trigger

Figure 2 depicts a multi-layer network scenario similar to the one presented in section 4.2.2. [RFC5623], with the difference that PCE is an active stateful PCE [I-D. draft-ietf-pce-stateful-pce].

In this example, O1, O2 and O3 are optical nodes that are connected with router nodes R1, R2 and R3, respectively. The network is designed such that the interface between R1-O1, R2-O2 and R3-O3 are setup to provide bandwidth-on-demand via the optical network.

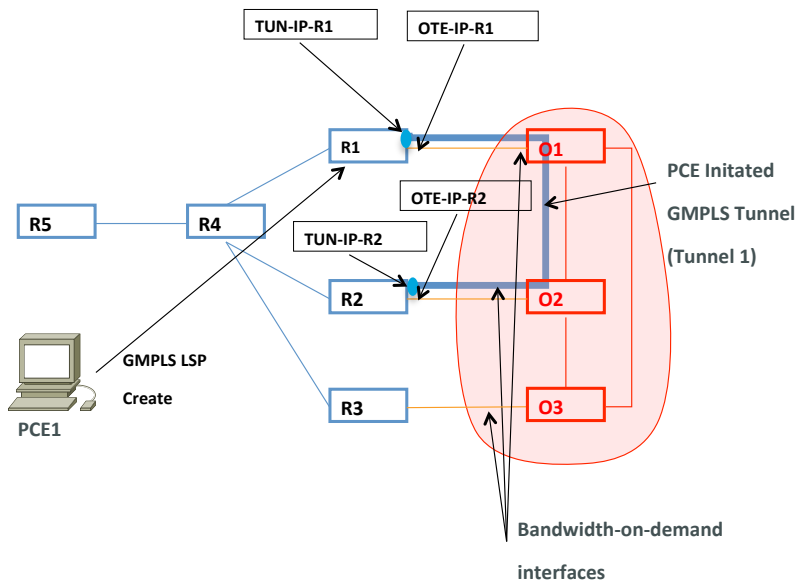


Figure 2. Use case higher-layer signaling trigger

The example assumes that an active stateful PCE is used for setting and tearing down bandwidth-on-demand connectivity. Although the simple use-case assumes a single PCE server (PCE1), the proposed technique is generalized to cover multiple co-operating PCE case. Similarly, although the use case assumes PCE1 only has knowledge of the L3 topology, the proposed technique is generalized to cover multi-layer PCE case.

The PCE server (PCE1) is assumed to be receiving L3 topology data. It is also assumed that PCE learns L0 (optical) addresses associated with bandwidth-on-demand interfaces R1-O1, R2-O2 and R3-O3. These addresses are referred by OTE-IP-R1 (optical TE link R1-O1 address at R1), OTE-IP-R2 (optical TE link R2-O2 address at R2) and OTE-IP-R3 (optical TE link R3-O3 address at R3), respectively. How PCE learns the optical addresses associated with the bandwidth-on-demand interfaces is beyond the scope of this document.

How knowledge of the bandwidth-on-demand interfaces is utilized by the PCE is exemplified in the following. Suppose an application requests 8 Gbps from R1 to R2 (recall all interfaces in Figure 1 are assumed to be 10G). PCE1 satisfies this by establishing a tunnel using R1-R4-R2 path. Remote initiated LSP using techniques specified in [I-D. draft-crabbe-pce-pce-initiated-lsp] can be used to establish a PSC tunnel using the R1-R4-R2 path. Now assume another application requests 7 Gbps service between R1 and R2. This request cannot be satisfied without establishing a GMPLS tunnel via optical network using bandwidth-on-demand interfaces. In this case, PCE1 initiates a

GMPLS tunnel using R1-O1-O2-R2 path (this is referred as GMPLS tunnel1 in the following). The remote initiated LSP using techniques specified in document is used for this purpose.

### 2.3. NMS-VNTM cooperation model (separated flavor)

Figure 3 depicts NMS-VNTM cooperation model. This is the separated flavor, because NMS and VNTM are not in the same location.

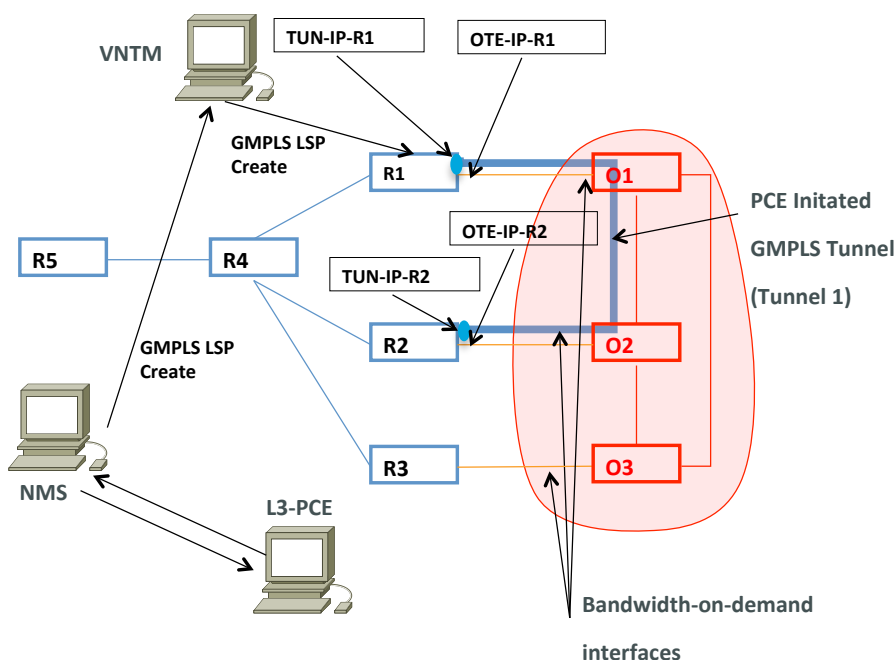


Figure 3. Use case NMS-VNTM cooperation model

A new L3 path is requested from NMS (e.g., via an automated process in the NMS or after human intervention). NMS does not have information about all network information, so it consults L3 PCE. For sake of simplicity L3-PCE is used, but any other multi-layer cooperating PCE model is applicable. In case that there are enough resources in the L3 layer, L3-PCE returns a L3 only path. On the other hand, if there is a lack of resources at the L3 layer, L3 PCE does not return a Path. Consequently, NMS sends a message to the VNTM to initiate a GMPLS LSP in the lower layer. When the VNTM receives this message, based on the local policies, accepts the suggestion and sends a similar message to the router, which can initiate the lower layer LSP via UNI signaling in the routers. Similarly, VNTM may talk with L0-PCE to set-up the path in the optical domain.

Requirements for the remote initiated GMPLS LSP from VNTM to the router are the same as discussed in the previous use case. The remote initiated LSP using techniques specified in document is used for this purpose.

### 3. Requirements for Remote-Initiated GMPLS LSPs

[I-D. draft-crabbe-pce-pce-initiated-lsp] specifies procedures that can be used for creation and deletion of PCE-initiated LSPs under the active stateful PCE model. However, this specification does not address GMPLS requirements outlined in the following:

- GMPLS support multiple switching capabilities on per TE link basis. GMPLS LSP creation requires knowledge of LSP switching capability (e.g., TDM, L2SC, OTN-TDM, LSC, etc.) to be used [RFC3471], [RFC3473].
- GMPLS LSP creation requires knowledge of the encoding type (e.g., lambda photonic, Ethernet, SONET/ SDH, G709 OTN, etc.) to be used by the LSP [RFC3471], [RFC3473].
- GMPLS LSP creation requires information of the generalized payload (G-PID) to be carried by the LSP [RFC3471], [RFC3473].
- GMPLS LSP creation requires specification of data flow specific traffic parameters (also known as Tspec), which are technology specific.
- GMPLS also specifics support for asymmetric bandwidth requests [RFC6387].
- GMPLS extends the addressing to include unnumbered interface identifiers, as defined in [RFC3477].
- In some technologies path calculation is tightly coupled with label selection along the route. For example, path calculation in a WDM network may include lambda continuity and/ or lambda feasibility constraints and hence a path computed by the PCE is associated with a specific lambda (label). Hence, 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 may be required.
- GMPLS specifics protection context for the LSP, as defined in [RFC4872] and [RFC4873].

### 4. PCEP Extensions for Remote-Initiated GMPLS LSPs

LSP initiate (PCInitiate) message defined in [I-D. draft-crabbe-pce-pce-initiated-lsp] needs to be extended to include GMPLS specific PCEP objects as follows:

#### 4.1. Generalized Endpoint in LSP Initiate Message

This document does not modify the usage of END-POINTS object for PCE initiated LSPs as specified in [I-D. draft-crabbe-pce-pce-initiated-lsp]. It augments the usage as specified below.

END-POINTS object has been extended by [I-D. draft-ietf-pcep-gmpls-ext] to include a new object type called "Generalized Endpoint". PCInitiate message sent by a PCE to a PCC to trigger a GMPLS LSP instantiation SHOULD include the END-POINTS with Generalized Endpoint object type. Furthermore, the END-POINTS object MUST contain "label request" TLV. The label request TLV is used to specify the switching type, encoding type and GPID of the LSP being instantiated by the PCE.

As mentioned earlier, the PCE server is assumed to be receiving topology data. In the use case of higher-layer signaling trigger, the addresses associated with bandwidth-on-demand interfaces are included, e.g., OTE-IP-R1, OTE-IP-R2 and OTE-IP-R3, in the use case example. These addresses and R1, R2 and R3 router IDs are used to derive source and destination address of the END-POINT object. As previously mentioned, in the case of NMS-VNMT cooperation model with L3 PCE, VNTM must receive such inter-layer interface association to configure the whole path.

The unnumbered endpoint TLV can be used to specify unnumbered endpoint addresses for the LSP being instantiated by the PCE. The END-POINTS MAY contain other TLVs defined in [I-D. draft-ietf-pcep-gmpls-ext].

If the END-POINTS Object of type Generalized Endpoint is missing the label request TLV, the PCC MUST send a PCErr message with Error-type=6 (Mandatory Object missing) and Error-value= TBA (LSP request TLV missing).

If the PCC does not support the END-POINTS Object of type Generalized Endpoint, the PCC MUST send a PCErr message with Error-type = 3 (Unknown Object), Error-value = 2 (unknown object type).

#### 4.2. GENERALIZED-BANDWIDTH object in LSP Initiate Message

LSP initiate message defined in [I-D. draft-crabbe-pce-pce-initiated-lsp] can optionally include the BANDWIDTH object. However, the following possibilities cannot be represented in the BANDWIDTH object:

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

- Technology specific GMPLS parameters (e.g., Tspec for SDH/SONET, G.709, ATM, MEF, etc.) are not supported.



GENERALIZED-BANDWIDTH object has been defined in [I-D. draft-ietf-pcep-gmpls-ext] to address the above-mentioned limitation of the BANDWIDTH object.

This document specifies the use of GENERALIZED-BANDWIDTH object in PCInitiate message. Specifically, GENERALIZED-BANDWIDTH object MAY be included in the PCInitiate message. The GENERALIZED-BANDWIDTH object in PCInitiate message is used to specify technology specific Tspec and asymmetrical bandwidth values for the LSP being instantiated by the PCE.

#### 4.3. Protection Attributes in LSP Initiate Message

This document does not modify the usage of LSPA object for PCE initiated LSPs as specified in [I-D. draft-crabbe-pce-pce-initiated-lsp]. It augments the usage of LSPA object in LSP Initiate Message to carry the end-to-end protection context this also includes the protection state information.

The LSP Protection Information TLV of LSPA in the PCInitiate message can be used to specify protection attributes of the LSP being instantiated by the PCE.

#### 4.4. ERO in LSP Initiate Object

This document does not modify the usage of ERO object for PCE initiated LSPs as specified in [I-D. draft-crabbe-pce-pce-initiated-lsp]. It augments the usage as specified in the following sections.

##### 4.4.1. ERO with explicit label control

As mentioned earlier, there are technologies and scenarios where active stateful PCE requires explicit label control in order to instantiate an LSP.

Explicit label control (ELC) is a procedure supported by RSVP-TE, where the outgoing label(s) is (are) encoded in the ERO. [I-D. draft-ietf-pcep-gmpls-ext] extends the <ERO> object of PCEP to include explicit label control. The ELC procedure enables the PCE to provide such label(s) directly in the path ERO.

The extended ERO object in PCInitiate message can be used to specify label along with ERO to PCC for the LSP being instantiated by the active stateful PCE.

##### 4.4.2. ERO with Path Keys

There are many scenarios in packet and optical networks where the route information of an LSP may not be provided to the PCC for confidentiality reasons. A multi-domain or multi-layer network is an example of such networks. Similarly, a GMPLS User-

Network Interface (UNI) [RFC4208] is also an example of such networks.

In such scenarios, ERO containing the entire route cannot be provided to PCC (by PCE). Instead, PCE provides an ERO with Path Keys to the PCC. For example, in the case UNI interface between the router and the optical nodes, the ERO in the LSP Initiate Message may be constructed as follows:

- The first hop is a strict hop that provides the egress interface information at PCC. This interface information is used to get to a network node that can extend the rest of the ERO. (Please note that in the cases where the network node is not directly connected with the PCC, this part of ERO may consist of multiple hops and may be loose).
- The following(s) hop in the ERO may provide the network node with the path key [RFC5520] that can be resolved to get the contents of the route towards the destination.
- There may be further hops but these hops may also be encoded with the path keys (if needed).

This document does not change encoding or processing roles for the path keys, which are defined in [RFC5520].

#### 4.4.3. Switch Layer Object

[draft-ietf-pce-inter-layer-ext-07] specifies the SWITCH-LAYER object which defines and specifies the switching layer (or layers) in which a path MUST or MUST NOT be established. A switching layer is expressed as a switching type and encoding type. [I-D. draft-ietf-pcep-gmpls-ext], which defines the GMPLS extensions for PCEP, suggests using the SWITCH-LAYER object. Thus, SWITCH-LAYER object can be used in the PCInitiate message to specify the switching layer (or layers) of the LSP being remotely initiated.

#### 4.5. LSP delegation and cleanup

LSP delegation and cleanup procedure specified in [I-D. draft-ietf-pcep-gmpls-ext] are equally applicable to GMPLS LSPs and this document does not modify the associated usage.

#### 5. Security Considerations

To be added in future revision of this document.

## 6. IANA Considerations

### 6.1. PCEP-Error Object

This document defines the following new Error-Value:

Error-Type	Error Value
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6	Error-value=TBA: LSP Request TLV missing
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## 7. Acknowledgments

The authors would like to thank George Swallow and Jan Medved for their comments.

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