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PCEP Procedures for Hierarchical Label Switched Paths
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Abstract

Label Switched Paths (LSPs) set up in Multiprotocol Label Switching (MPLS) or Generalized MPLS (GMPLS) networks can be used to form links to carry traffic in those networks or in other (client) networks. These LSPs can be referred to as Hierarchical LSPs (H-LSP). H-LSPs allow to improve the scalability of MPLS/GMPLS networks by creating hierarchies of TE-LSPs. Those hierarchies are an important state for optimal TE-Computation, therefore a stateful PCE should be able to discover and manage those H-LSPs. A PCE having a global view of the network, including Forwarding Adjacencies LSP (FA-LSP) and non FA-LSPs, can create more optimal hierachies and (re-)compute the TE-LSPs path to make use of the H-LSPs. In particular a PCE can better leverage the Private H-LSP introduced by RFC6107 without influencing the IGP, allowing a less disruptive use of Hierarchies.

RFC6107 defined Protocol mechanisms to facilitate the establishment of such LSPs and to bundle traffic engineering (TE) links to reduce the load on routing protocols.

This document defines PCEP extensions to learn about and control those H-LSPs.

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1. Introduction

Traffic Engineering (TE) links in a Multiprotocol Label Switching (MPLS) or a Generalized MPLS (GMPLS) network may be constructed from Label Switched Paths (LSPs) [RFC6107]. Such LSPs are defined as hierarchical LSPs (H-LSPs).

The mechanisms described in [RFC6107] enables the dynamically construction of provisioned hierarchical networks. The Path Computation Element Protocol (PCEP) defined in [RFC5440], [RFC5521], [RFC5541], [RFC5520], [I-D.ietf-pce-gmpls-pcep-extensions], [I-D.ietf-pce-stateful-pce] and [I-D.ietf-pce-pce-initiated-lsp] enable a PCE to compute paths for a range of switching technologies in a stateless and statefull manner, but does not allow a PCE to control the hierarchy of such LSPs. This document complements those RFCs to control H-LSPs.

This document provides the same level of control as [RFC6107], so that the PCE can provide the following information to the LSPs endpoints:

Whether the LSP is an ordinary LSP or an H-LSP.

In which IGP instances the LSP should be advertised as a link.

How the client networks should make use of H-LSP and corresponding TE-links.

Whether the TE-link should form part of a bundle (and if so, which bundle).

How the link endpoints should be identified when advertised.

1.1. Requirements Language

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

1.2. Solution overview

The encoding and semantics associated with the control of H-LSPs is already considered and defined by [RFC6107]. This document reuses those definitisns and adapts them to PCEP. The following section describes the new PCEP new objects and associated procedures.

2. H-LSP capability advertisement

2.1. PCE Discovery Protocol

IGP-based PCE Discovery (PCED) is defined in [RFC5088] and [RFC5089] for the OSPF and IS-IS protocols. A new flag (bit TBA-1) is defined to advertise the H-LSP capability:

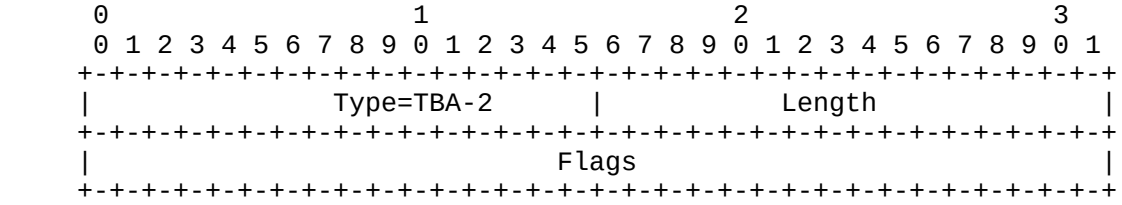
Bit Capabilities

TBA-1 : H-LSP Capability

2.2. OPEN Object extension HLSP-CAPABILITY TLV

In addition to the IGP advertisement, a PCEP speaker SHOULD be able to discover the other peer GMPLS capabilities during the Open message exchange. This capability is also useful to avoid misconfigurations. This document defines a new GMPLS-CAPABILITY TLV for use in the OPEN object to negotiate the H-LSP capability. The inclusion of this TLV in the OPEN message indicates that the PCC/PCE support the PCEP extensions defined in this document. A PCE that is able to support the extensions defined in this document MUST include the HLSP-CAPABILITY TLV in the OPEN message. If a PCEP Peer does not include the HLSP-CAPABILITY TLV in the OPEN message and the other PCEP peer does include the TLV, it is RECOMMENDED that each peer indicates a mismatch of capabilities. If any of the peers do not advertise the HLSP-CAPABILITY TLV, the extension defined in this document MUST NOT be used.

IANA has allocated value TBA-2 from the "PCEP TLV Type Indicators" sub-registry, as documented in Section 5.2 ("New PCEP TLVs"). The description is "HLSP-CAPABILITY". Its format is shown in the following figure.



No Flags are defined in this document, they are reserved for future use.

3. PCEP object and extensions

This section describes the required PCEP objects and extensions. The PCReq and PCRep messages are defined in [RFC5440]. The PCRpt and PCUpd messages are defined in [I-D.ietf-pce-stateful-pce] and the PCInitiate in [I-D.ietf-pce-pce-initiated-lsp]. The control of H-LSP by a PCE will reuse and adapt the information, encoding and procedure described in [RFC6107]. This document defines the LSP_TUNNEL_INTERFACE_ID PCEP object for that purposea and it is carried in the following messages:

PCReq: The PCC indicates that it will form a H-LSP.

PCRep: If the object was present in the corresponding PCReq, the PCE may suggest IDs.

PCRpt: The PCC reports the state of the H-LSP.

PCUpd: The PCE requests the LSP to be used as H-LSP.

PCInitiate: The PCE requests the creation of a H-LSP.

3.1. The PCReq message

The PCReq MAY include the LSP_TUNNEL_INTERFACE_ID object. Multiple instances of the object MAY be included in the message, in case multiple IGP instances are the target, following [RFC6107], section 3.4. The presence of the object indicates that the PCC will setup the TE-LSP as a H-LSP. This MAY be used by the PCE as policy input. The PCC MAY set the IDs to 0, as described in Section 3.6.1.

The PCReq is modified as follows:

```
 <request>::= <RP>
              <END-POINTS>
             [<LSPA>]
             [<BANDWIDTH>]
             [<metric-list>]
             [<OF>]
             [<RRO>[<BANDWIDTH>]]
             [<IRO>]
             [<LOAD-BALANCING>]
             [<XRO>]
             [<LSP_TUNNEL_INTERFACE_ID>...]
```

3.2. The PCRep message

The PCE MAY include the LSP_TUNNEL_INTERFACE_ID object from the corresponding PCReq. The PCE MUST NOT include the LSP_TUNNEL_INTERFACE_ID if it was not present in the corresponding PCReq. If the IDs were set to 0 on request, the PCE SHOULD provide a recommended value, as described in Section 3.6.1.

The PCRep uses the <attribute-list> definition, which is extended as follows:

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

3.3. The PCRpt message

The PCRpt MAY include the LSP_TUNNEL_INTERFACE_ID object. Multiple instances of the object MAY be included in the message, in the case where multiple IGP instances are the target, following [RFC6107], section 3.4 or to report the ingress and egress IDs. The presence of the object indicates that the PCC will setup the TE-LSP as a H-LSP. If the LSP object O(Operational) flag is DOWN, the PCC MAY set the IDs to 0, as described in Section 3.6.1. If the LSP object O flag is UP or ACTIVE the PCC SHOULD report at least 2 LSP_TUNNEL_INTERFACE_IDs for a given target IGP instance, one for ingress and one for egress.

The PCRpt uses the <attribute-list> definition, which is extended as described in Section 3.2.

3.4. The PCUpd message

The PCUpd MAY include the LSP_TUNNEL_INTERFACE_ID object. Multiple instances of the object MAY be included in the message, in the case where multiple IGP instances are the target, following [RFC6107], section 3.4 or to report the ingress and egress IDs. The presence of the object indicates that the PCC SHOULD setup the TE-LSP as a H-LSP. The PCE MUST NOT include any object type for the egress node. If the PCE includes the object type for the egress node the PCC MUST send a PCErr with error type TBA-5(PCC Hierarchy Issue) and error value 1(Egress LSP_TUNNEL_INTERFACE_ID Object type in PCUp, PCRep or PCInitiate message). The PCE MAY set the IDs in accordance to Section 3.6.1.

The PCUpd use the <attribute-list> definition, which is extended as described in Section 3.2

Upon receipt of a PCUpd message with LSP_TUNNEL_INTERFACE_ID, the PCC SHOULD try to setup the TE-LSP as a H-LSP based on its policies. If the PCC ignores the LSP_TUNNEL_INTERFACE_ID, it MUST set the I bit. If the PCE requires the LSP to be an H-LSP, it MUST set the P(Processing) Flag in the object header.

If the PCE is tearing down the LSP, the client LSPs may be impacted. It is RECOMMENDED that the PCC uses the Gracefull link shutdown procedures described in [RFC4203], [RFC5307] and [RFC5817]. It can be desirable for a PCE to know in advance if the LSP carries traffic before initiating the teardown as it would result in a smoother transition in the case where the gracefull teardown procedures are not used. This indication is not a H-LSP specific operation and MAY be used in a more general context, therefore it is out of the scope of this document.

3.5. The PCInitiate message

The procedure for PCInitiate are the same as for PCUpd, described in Section 3.4.

3.6. LSP_TUNNEL_INTERFACE_ID Object

IANA has allocated value TBA-3 from the "PCEP Objects" sub-registry, as documented in Section 5.1 ("New PCEP Object"). The description is "LSP_TUNNEL_INTERFACE_ID". The following object-type are defined by this document:

Object-Type	Description
1	Ingress Unnumbered Links with Action Identification.
2	Ingress IPv4 Numbered Links with Action Identification.
3	Ingress IPv6 Numbered Links with Action Identification.
4	Egress Unnumbered Links with Action Identification.
5	Egress IPv4 Numbered Links with Action Identification.
6	Egress IPv6 Numbered Links with Action Identification.

The content and TLVs are those defined in [RFC6107]. The TLVs are not PCEP TLVs.

3.6.1. Procedures

In [RFC6107] the interface IDs are allocated by the endpoints, this principle remains unchanged. In the context of PCEP the PCE does not manage the PCC ids. It may suggest IDs (numbered or unnumbered), but

the PCC remains in control of these allocations. The PCE can indicate to the PCC that the ID SHOULD be allocated by the PCC by setting the ID to the value of 0. This applies to the following fields:

Interface ID

LSR's Router ID

IPv4 Interface Address

IPv6 Interface Address

Component Link Identifier

IPv4 Numbered Component Link Identification

IPv6 Numbered Component Link Identification

The PCE MAY only set the Object-type (OT) in the range of 1 to 3, while the OT range of 4 to 6 are reserved for reporting the reverse Ids assigned by the egress node.

The ID MAY be 0 for OT 1 to 3 in the following cases:

PCReq: the PCC is indicating that the PCE SHOULD provide a value

PCRep: the PCE is indicating the PCC SHOULD do the allocation

PCRpt: when the LSP is DOWN or GOING-UP

PCUpd: the PCE is indicating the PCC SHOULD do the allocation

PCInitiate: the PCE is indicating the PCC SHOULD do the allocation

In case where the PCC is not able to allocate an address suitable for the H-LSP, it MUST reply with a PCErr with type TBA-5 (PCC Hierarchy Issue), value 9 (PCC Cannot allocate a IPv4 Interface Address), value 10 (PCC Cannot allocate a IPv6 Interface Address) or value 11 (PCC Cannot allocate an Unnumbered Interface Address).

The ID MAY be set by the PCE for OT in range of 1 to 3 in the following cases:

PCRep: the PCE is suggesting and ID to be used

PCUpd: the PCE is suggesting and ID to be used

PCInitiate: the PCE is suggesting and ID to be used

The PCC MAY use the suggested value. If the value is not used, the PCC SHOULD send a PCErr with type TBA-5 (PCC Hierarchy Issue) and a value 2 (Interface ID provided is invalid), 3 (LSR's Router ID provided is invalid), 4 (IPv4 Interface Address provided is invalid) 5 (IPv6 Interface Address provided is invalid), 6 (Component Link Identifier provided is invalid), 7 (IPv4 Numbered Component Link Identification provided is invalid) or 8 (IPv6 Numbered Component Link Identification provided is invalid).

The ID MUST NOT be 0 for OT 1 to 3 in the following cases:

PCRpt when the LSP is UP, ACTIVE or GOING-DOWN

4. 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. Additional errors types and error values are defined to represent some of the errors related to the newly identified objects. For each PCEP error, an Error-Type and an Error-value are defined. Error-Type 1 to 10 are already defined in [RFC5440]. Two new Error-Type are introduced (value TBA-4 and TBA-5).

Error-Type Error-value

Type=TBA-4		LSP Hierarchy Issue
	Value=1:	Link advertisement not supported.
	Value=2:	Link advertisement not allowed by policy.
	Value=3:	TE link creation not supported.
	Value=4:	TE link creation not allowed by policy.
	Value=5:	Routing adjacency creation not supported.
	Value=6:	Routing adjacency creation not allowed by policy.
	Value=7:	Bundle creation not supported.
	Value=8:	Bundle creation not allowed by policy.
	Value=9:	Hierarchical LSP not supported.
	Value=10:	LSP stitching not supported.
	Value=11:	Link address type or family not supported.
	Value=12:	IGP instance unknown.
	Value=13:	IGP instance advertisement not allowed by policy.
	Value=14:	Component link identifier not valid.
	Value=15:	Unsupported component link identifier address family.
Type=TBA-5		PCC Hierarchy Issue
	Value=1:	Egress LSP_TUNNEL_INTERFACE_ID Object type in PCUp, PCRep or PCInitiate message.
	Value=2:	Interface ID provided is invalid.
	Value=3:	LSR’s Router ID provided is invalid.
	Value=4:	IPv4 Interface Address provided is invalid.
	Value=5:	IPv6 Interface Address provided is invalid.
	Value=6:	Component Link Identifier provided is invalid.
	Value=7:	IPv4 Numbered Component Link Identification provided is invalid.
	Value=8:	IPv6 Numbered Component Link Identification provided is invalid.
	Value=9:	PCC Cannot allocate a IPv4 Interface Address.
	Value=10:	PCC Cannot allocate a IPv6 Interface Address.
	Value=11:	PCC Cannot allocate an Unnumbered Interface Address.

5. IANA Considerations

5.1. PCEP Objects

IANA is requested to make the following Object-Type allocations from the "PCEP Objects" sub-registry.

Object Class Value	Name	Object-Type	Reference
TBA-3	LSP_TUNNEL_INTERFACE_ID	1: Ingress Unnumbered Links with Action Identification.	This document
		2: Ingress IPv4 Numbered Links with Action Identification.	This document
		3:Ingress IPv6 Numbered Links with Action Identification.	This document
		4:Egress Unnumbered Links with Action Identification.	This document
		5:Egress IPv4 Numbered Links with Action Identification.	This document
		6:Egress IPv6 Numbered Links with Action Identification.	This document
		7-15: Unassigned	This document

5.2. 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
TBA-2	HLSP-CAPABILITY TLV	This document (section Section 2.2)

5.3. RP Object Flag Field

As described in new flag are defined in the RP Object Flag IANA is requested to make the following allocations from the OSPF registry, "PCE Capability Flags" sub-registry. The values here are suggested for use by IANA.

Bit	Description	Reference
TBA-1	H-LSP Capability	This document, Section 2.1

5.4. New PCEP Error Codes

As described in Section 4, 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=TBA-4	LSP Hierarchy Issue	This Document
Value=1:	Link advertisement not supported.	This Document
Value=2:	Link advertisement not allowed by policy.	This Document
Value=3:	TE link creation not supported.	This Document
Value=4:	TE link creation not allowed by policy.	This Document
Value=5:	Routing adjacency creation not supported.	This Document
Value=6:	Routing adjacency creation not allowed by policy.	This Document
Value=7:	Bundle creation not supported.	This Document
Value=8:	Bundle creation not allowed by policy.	This Document
Value=9:	Hierarchical LSP not supported.	This Document
Value=10:	LSP stitching not supported.	This Document
Value=11:	Link address type or family not supported.	This Document
Value=12:	IGP instance unknown.	This Document
Value=13:	IGP instance advertisement not allowed by policy.	This Document
Value=14:	Component link identifier not valid.	This Document
Value=15:	Unsupported component link identifier address family.	This Document
Type=TBA-5	PCC Hierarchy Issue	This Document
Value=1:	Egress LSP_TUNNEL_INTERFACE_ID Object type in PCUp, PCRep or PCInitiate message.	This Document
Value=2:	Interface ID provided is invalid.	This Document
Value=3:	LSR’s Router ID provided is invalid.	This Document
Value=4:	IPv4 Interface Address provided is invalid.	This Document
Value=5:	IPv6 Interface Address provided is invalid.	This Document
Value=6:	Component Link Identifier provided is invalid.	This Document
Value=7:	IPv4 Numbered Component Link Identification provided is invalid.	This Document
Value=8:	IPv6 Numbered Component Link Identification provided is invalid.	This Document
Value=9:	PCC Cannot allocate a IPv4 Interface Address.	This Document
Value=10:	PCC Cannot allocate a IPv6 Interface Address.	This Document
Value=11:	PCC Cannot allocate an Unnumbered Interface Address.	This Document
Value=:	.	This Document

6. Security Considerations

7. Acknowledgments

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