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**Extensions to the Path Computation Element communication Protocol
(PCEP) for Inter-Layer MPLS and GMPLS Traffic Engineering**

[draft-oki-pce-inter-layer-ext-00.txt](#)

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Abstract

The Path Computation Element (PCE) provides path computation functions in support of traffic engineering in Multi-Protocol Label Switching (MPLS) and Generalized MPLS (GMPLS) networks.

MPLS and GMPLS networks may be constructed from layered service networks. It is advantageous for overall network efficiency to provide end-to-end traffic engineering across multiple network layers through a process called inter-layer traffic engineering. PCE is a candidate solution for such requirements.

The PCE communication Protocol (PCEP) is designed as a communication protocol between Path Computation Clients (PCCs) and PCEs. This document presents PCEP extensions for inter-layer traffic engineering.

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](#)].

Table of Contents

1. Introduction.....	2
2. Overview of PCE-Based Inter-Layer Path Computation.....	3
3. Protocol Extensions.....	4
3.1. INTER-LAYER Object.....	4
3.2. SWITCH-LAYER Object.....	5
3.2.1. REQ-ADAP-CAP Object.....	7
4. Procedure.....	7
4.1. Path Computation Request.....	7
4.2. Path Computation Reply.....	8
5. Updated Format of PCEP Messages.....	8
6. Manageability considerations.....	9
7. IANA considerations.....	10
8. Security Considerations.....	10
9. Acknowledgments.....	10
10. References.....	10
10.1. Normative Reference.....	10
10.2. Informative Reference.....	11
11. Authors' Addresses.....	11
12. Intellectual Property Statement.....	11

[1. Introduction](#)

The Path Computation Element (PCE) defined in [[RFC4655](#)] is an entity that is capable of computing a network path or route based on a network graph, and applying computational constraints. A Path Computation Client (PCC) may make requests to a PCE for paths to be computed.

A network may comprise multiple layers. These layers may represent separations of technologies (e.g., packet switch capable (PSC), time division multiplex (TDM), lambda switch capable (LSC))

[[RFC3945](#)], separation of data plane switching granularity levels (e.g., PSC-1 and PSC-2, or VC4 and VC12) [[MLN-REQ](#)], or a distinction between client and server networking roles (e.g., commercial or administrative separation of client and server networks). In this multi-layer network, Label Switched Paths (LSPs) in lower layers are used to carry upper-layer LSPs. The network topology formed by lower-layer LSPs and advertised to the higher layer is called a Virtual Network Topology (VNT) [[MLN-REQ](#)].

It is important to optimize network resource utilization globally, i.e., taking into account all layers, rather than optimizing resource utilization at each layer independently. This allows better network efficiency to be achieved. This is what we call inter-layer traffic engineering. This includes mechanisms allowing the computation of end-to-end paths across layers (known as inter-layer path computation), and mechanisms for control and management of the VNT by setting up and releasing LSPs in the lower layers [[MLN-REQ](#)].

PCE can provide a suitable mechanism for resolving inter-layer path computation issues. The framework for applying the PCE-based path computation architecture to inter-layer traffic engineering is described in [[PCE-INTER-LAYER-FRWK](#)].

The PCE communication protocol (PCEP) is designed as a communication protocol between PCCs and PCEs and is defined in [[PCEP](#)]. A set of requirements for PCEP extensions to support inter-layer traffic engineering is described in [PCE-INTER-LAYER-REQ].

This document presents PCEP extensions for inter-layer traffic engineering that satisfy the requirements described in [PCE-INTER-LAYER-REQ].

2. Overview of PCE-Based Inter-Layer Path Computation

[RFC4206] defines a way to signal a higher-layer LSP which has an explicit route that includes hops traversed by LSPs in lower layers. The computation of end-to-end paths across layers is called Inter-Layer Path Computation.

A Label Switching Router (LSR) in the higher-layer might not have information on the lower-layer topology, particularly in an overlay or augmented model [[RFC3945](#)], and hence may not be able to compute an end-to-end path across layers.

PCE-based inter-layer path computation consists of using one or more PCEs to compute an end-to-end path across layers. This could be achieved by relying on a single PCE that has topology information about multiple layers and can directly compute an end-to-end path across layers considering the topology of all of the

PCEP Extensions for Inter-Layer TE October 2007
layers. Alternatively, the inter-layer path computation could be performed using multiple cooperating PCEs where each PCE has information about the topology of one or more layers (but not all layers) and where the PCEs collaborate to compute an end-to-end path.

[PCE-INTER-LAYER-FRWK] describes models for inter-layer path computation in more detail.

3. Protocol Extensions

This section describes PCEP extensions for inter-layer path computation. Three new objects are defined: the INTER-LAYER object, the SWITCH-LAYER object, and the REQ-ADAP-CAP object.

3.1. INTER-LAYER Object

The INTER-LAYER object is optional and can be used in PCReq and PCRep messages.

In a PCReq message, the INTER-LAYER object indicates whether inter-layer path computation is allowed, the type of path to be computed, and whether nested signaling is allowed. When the INTER-LAYER object is absent from a PCReq message, the receiving PCE SHOULD process as though inter-layer path computation had been explicitly disallowed (I-bit set to zero - see below).

In a PCRep message, the INTER-LAYER object indicates whether inter-layer path computation has been performed, the type of path that has been computed, and whether nested signaling is used.

When a PCReq message includes more than one request, an INTER-LAYER object is used per request. When a PCRep message includes more than one path per request, an INTER-LAYER object is used per path.

INTER-LAYER Object-Class is to be assigned by IANA (recommended

INTER-LAYER Object-Type is to be assigned by IANA (recommended value=1)

4

[illegible]

The I flag is used by a PCE in a PCRep message to indicate to a PCC whether the path returned is an inter-layer path. When the I flag is set (one), the path is an inter-layer path. When it is clear (zero), the path is contained within a single layer either because inter-layer path computation was not performed or because a mono-layer path was found notwithstanding the use of inter-layer path computation.

The N flag is used by a PCE in a PCRep message to indicate to a PCC whether nested signaling is required to support the returned path. When the N flag is set (one), nested signaling is required. When it is clear (zero), nested signaling is not required.

Note that nested signaling is used to support hierarchical [RFC4206] or stitched [LSP-STITCH] LSPs according to the physical attributes of the network layers.

If the I flag is clear (zero), the N flag has no meaning and MUST be ignored.

Reserved bits of the INTER-LAYER object SHOULD be transmitted as zero and SHOULD be ignored on receipt. A PCE that forwards a path computation request to other PCEs SHOULD preserve the settings of reserved bits in the PCReq messages it sends and in the PCRep messages it forwards to PCCs.

3.2. SWITCH-LAYER Object

The SWITCH-LAYER object is optional on a PCReq message and specifies switching layers in which a path MUST, or MUST NOT be

PCEP Extensions for Inter-Layer TE October 2007

established. A switching layer is expressed as a switching type and encoding type. The SWITCH-LAYER object MUST NOT be used on a PCRep unless an INTER-LAYER object is also present on the PCReq message.

The SWITCH-LAYER object is optional on a PCRep message, where it is used with the NO-PATH object in the case of unsuccessful path computation to indicate the set of constraints that could not be satisfied.

```
SWTICH-LAYER Object-Class is to be assigned by IANA (recommended
value=19)
```

```
SWTICH-LAYER Object-Type is to be assigned by IANA (recommended
value=1)
```

The format of the SWITCH-LAYER object body is as follows:

[illegible]

The REQ-ADAP-CAP object MAY be used in a mono-layer network to specify a requested adaptation capability for both ends of the LSP.

The REQ-ADAP-CAP object is optionally used to specify the interface switching capability of both ends of the lower layer LSP. The REQ-ADAP-CAP object is used in inter-PCE communication, where the PCE that is responsible for computing higher layer paths makes a request as a PCC to a PCE that is responsible for computing lower layer paths.

4.2. Path Computation Reply

The requested PCE replies to the requesting PCC for the inter-layer path computation result in a PCRep message including the INTER-LAYER object.

In the case of unsuccessful path computation, the PCRep message also contains a NO-PATH object, and the SWITCH-TYPE object and/or the REQ-ADAP-CAP MAY be used to indicate the set of constraints that could not be satisfied.

5. Updated Format of PCEP Messages

The format of the PCReq message is updated as follows:

```
<PCReq Message> ::= <Common Header>
                    [<SVEC-list>]
                    <request-list>
```

where:

```
<svec-list> ::= <SVEC>
                [<svec-list>]
```

```
<request-list> ::= <request> [<request-list>]
```

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

where:

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

The format of the PCRep message is updated as follows:

<PCRep Message> ::= <Common Header>
 <response-list>

where:

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

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

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

<path>::= <ERO>
 [<OF>]
 [<LSPA>]
 [<BANDWIDTH>]
 [<metric-list>]
 [<IRO>]
 [<INTER-LAYER>]
 [<SWITCH-LAYER>]
 [<REQ-ADAP-CAP>]

where:

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

6. Manageability considerations

TBD

Manageability of inter-layer traffic engineering with PCE must address the following consideration for [section 5.1](#).

- need for a MIB module for control and monitoring
- need for built-in diagnostic tools

7. IANA considerations

TBD

8. Security Considerations

TBD

Inter-layer traffic engineering with PCE may raise new security issues when PCE-PCE communication is done between different layer networks for inter-layer path computation. Security issues may also exist when a single PCE is granted full visibility of TE information that applies to multiple layers.

It is expected that solutions for inter-layer protocol extensions will address these issues in detail using security techniques such as authentication.

9. Acknowledgments

10. References

10.1. Normative Reference

[RFC2119] S. Bradner, "Key words for use in RFCs to indicate requirements levels", [RFC 2119](#), March 1997.

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[RFC4203] K. Kompella and Y. Rekhter, "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)", [RFC 4203](#), October 2005.

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PCEP Extensions for Inter-Layer TE October 2007
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[PCE-INTER-LAYER-FRWK] E. Oki et al., "Framework for PCE-Based Inter-Layer MPLS and GMPLS Traffic Engineering", [draft-oki-pce-inter-layer-frwk](#) (work in progress)

10.2. Informative Reference

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

[MLN-REQ] K. Shiomoto et al., "Requirements for GMPLS-based multi-region and multi-layer networks (MRN/MLN)", [draft-ietf-ccamp-gmpls-mln-reqs](#) (work in progress).

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Oki, Le Roux, and Farrel Expires April 2008

11

PCEP Extensions for Inter-Layer TE October 2007
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Oki, Le Roux, and Farrel Expires April 2008

12