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Q. Zhao
Z. Li
D. Dhody
S. Karunanithi
Huawei Technologies
A. Farrel
Juniper Networks, Inc
C. Zhou
Cisco Systems
June 30, 2017

PCEP Procedures and Protocol Extensions for Using PCE as a Central Controller (PCECC) of LSPs
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Abstract

In certain networks deployment scenarios, service providers would like to keep all the existing MPLS functionalities in both MPLS and GMPLS while removing the complexity of existing signalling protocols such as LDP and RSVP-TE. PCE has been proposed to be used as a central controller (PCECC) so that LSP can be calculated/setup/initiated and label forwarding entries are downloaded through a centralized PCE server to each network devices along the path while leveraging the existing PCE technologies as much as possible.

This draft specify the procedures and PCEP protocol extensions for using the PCE as the central controller, where LSPs are calculated/setup/initiated and label forwarding entries are downloaded through extending PCEP.

Status of This Memo

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1. Introduction

In certain network deployment scenarios, service providers would like to have the ability to dynamically adapt to a wide range of customer's requests for the sake of flexible network service delivery, Software Defined Networks(SDN) has provides additional flexibility in how the network is operated compared to the traditional network.

The existing networking ecosystem has become awfully complex and highly demanding in terms of robustness, performance, scalability, flexibility, agility, etc. By migrating to the SDN enabled network from the existing network, service providers and network operators must have a solution which they can evolve easily from the existing network into the SDN enabled network while keeping the network services remain scalable, guarantee robustness and availability etc.

Taking the smooth transition between traditional network and the new SDN enabled network into account, especially from a cost impact assessment perspective, using the existing PCE components from the current network to function as the central controller of the SDN network is one choice, which not only achieves the goal of having a

centralized controller, but also leverage the existing PCE network components.

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 [I-D.ietf-pce-stateful-pce] describes a set of extensions to PCEP to enable active control of MPLS-TE and GMPLS tunnels.

[I-D.ietf-pce-pce-initiated-lsp] describes the setup and tear down of PCE-initiated LSPs under the active stateful PCE model, without the need for local configuration on the PCC, thus allowing for a dynamic MPLS network that is centrally controlled and deployed.

[I-D.ietf-teas-pce-central-control] introduces the architecture for PCE as a central controller, examines the motivations and applicability for PCEP as a southbound interface, and introduces the implications for the protocol. [I-D.ietf-teas-pcecc-use-cases] describes the use cases for the PCECC architecture.

This draft specify the procedures and PCEP protocol extensions for using the PCE as the central controller and user cases where LSPs are calculated/setup/initiated/downloaded through extending the existing PCE architectures and PCEP.

The extension for PCECC in Segment Routing (SR) is specified in a seperate draft [I-D.zhao-pce-pcep-extension-pce-controller-sr].

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 [RFC2119].

2. Terminology

Terminologies used in this document is same as described in the draft [I-D.ietf-teas-pcecc-use-cases].

3. Basic PCECC Mode

In this mode LSPs are provisioned as explicit label instructions at each hop on the end-to-end path. Each router along the path must be told what label forwarding instructions to program and what resources to reserve. The controller uses PCEP to communicate with each router along the path of the end-to-end LSP.

Note that the PCE-based controller will take responsibility for managing some part of the MPLS label space for each of the routers that it controls, and may taker wider responsibility for partitioning the label space for each router and allocating different parts for different uses. This is also described in section 3.1.2. of [I-D.ietf-teas-pce-central-control]. For the purpose of this document, it is assumed that label range to be used by a PCE is set on both PCEP peers. A future extention MAY add capability to advertise the range via possible PCEP extention as well. The rest of processing is similar to the existing stateful PCE mechanism.

4. PCEP Requirements

Following key requirements associated PCECC should be considered when designing the PCECC based solution:

1. PCEP speaker supporting this draft MUST have the capability to advertise its PCECC capability to its peers.

2. PCEP speaker not supporting this draft MUST be able to reject PCECC related message with a reason code that indicates no support for PCECC.

3. PCEP SHOULD provide a means to identify PCECC based LSP in the PCEP messages.

4. PCEP SHOULD provide a means to update (or cleanup) the label-download entry to the PCC.

5. PCEP SHOULD provide a means to synchronize the labels between PCE to PCC in PCEP messages.

5. Procedures for Using the PCE as the Central Controller (PCECC)

5.1. Stateful PCE Model

Active stateful PCE is described in [I-D.ietf-pce-stateful-pce]. PCE as a central controller (PCECC) reuses existing Active stateful PCE mechanism as much as possible to control the LSP.

5.2. New LSP Functions

This document defines the following new PCEP messages and extends the existing messages to support PCECC:

(PCRpt): a PCEP message described in [I-D.ietf-pce-stateful-pce]. PCRpt message MAYBE used to send PCECC LSP Reports.

(PCInitiate): a PCEP message described in [I-D.ietf-pce-pce-initiated-lsp]. PCInitiate message is used to setup PCE-Initiated LSP based on PCECC mechanism.

(PCUpd): a PCEP message described in [I-D.ietf-pce-stateful-pce]. PCUpd message is used to send PCECC LSP Update.

(PCLabelUpd): a new PCEP message sent by a PCE to a PCC to download or cleanup the Label entry. The PCLabelUpd message described in Section 6.1.1.

(PCLabelRpt): a new PCEP message sent by a PCC to a PCE to report the set of labels for which explicit action is required from PCE to update or cleanup or do nothing for these Label entries. The PCLabelRpt message described in Section 6.1.2.

The new LSP functions defined in this document are mapped onto the messages as shown in the following table.

Function	Message
PCECC Capability advertisement	Open
Label entry Update	PCLabelUpd
Label entry Cleanup	PCLabelUpd
PCECC Initiated LSP	PCInitiate
PCECC LSP Update	PCUpd
PCECC LSP State Report	PCRpt
PCECC LSP Delegation	PCRpt
PCECC Label Report	PCLabelRpt

5.3. PCECC Capability Advertisement

During PCEP Initialization Phase, PCEP Speakers (PCE or PCC) advertise their support of PCECC extensions. A PCEP Speaker includes the "PCECC Capability" TLV, described in Section 7.1.1 of this document, in the OPEN Object to advertise its support for PCECC extensions.

The presence of the PCECC Capability TLV in PCC's OPEN Object indicates that the PCC is willing to function as a PCECC client.

The presence of the PCECC Capability TLV in PCE's OPEN message indicates that the PCE is interested in function as a PCECC server.

The PCEP protocol extensions for PCECC MUST NOT be used if one or both PCEP Speakers have not included the PCECC Capability TLV in their respective OPEN message. If the PCEP Speakers support the extensions of this draft but did not advertise this capability then a PCErr message with Error-Type=19(Invalid Operation) and Error-Value=TBD (Attempted LSP setup/download/label-range reservation if PCECC capability was not advertised) will be generated and the PCEP session will be terminated.

A PCC or a PCE MUST include both PCECC-CAPABILITY TLV and STATEFUL-PCE-CAPABILITY TLV ([I-D.ietf-pce-stateful-pce]) in OPEN Object to support the extensions defined in this document. If PCECC-CAPABILITY TLV is advertised and STATEFUL-PCE-CAPABILITY TLV is not advertised in OPEN Object, it SHOULD send a PCErr message with Error-Type=19 (Invalid Operation) and Error-value=TBD(stateful PCE capability was not advertised) and terminate the session.

5.4. LSP Operations

The PCEP messages pertaining to PCECC MUST include PATH-SETUP-TYPE TLV [I-D.ietf-pce-lsp-setup-type] in the SRP object to clearly identify the PCECC LSP is intended.

5.4.1. Basic PCECC LSP Setup

In order to setup a LSP based on PCECC mechanism, a PCC MUST delegate the LSP by sending a PCRpt message with Path Setup Type set for basic PCECC (see Section 7.2) and D (Delegate) flag (see [I-D.ietf-pce-stateful-pce]) set in the LSP object.

LSP-IDENTIFIER TLV MAY be included for PCECC LSP, the LSP-ID SHOULD be generated by the PCE for PCECC LSP. In the first PCRpt message of PCECC LSP, LSP ID of LSP-IDENTIFIER TLV is set to zero.

When a PCE receives PCRpt message with D flags and PST Type set, it MAY generates LSP ID; calculates the path and assigns labels along the path; and setups the path by sending PCLabelUpd message to each node along the path of the LSP.

In response to the delegate PCRpt message, the PCE SHOULD send the PCUpd message with the same PLSP-ID to the Ingress PCC.

The PCECC LSPs MUST be delegated to a PCE at all times.

LSP deletion operation for PCECC LSP is same as defined in [I-D.ietf-pce-stateful-pce]. If the PCE receives PCRpt message for LSP deletion then it does Label cleanup operation as described in Section 5.4.2.2 for the corresponding LSP.

The Basic PCECC LSP setup sequence is as shown below using a new message PCLabelUpd.

```
                +-------+                            +-------+
                |PCC    |                            |  PCE  |
                |Ingress|                            +-------+
         +------|       |                                |
         | PCC  +-------+                                |
         | Transit| |                                    |
 +------|        | |-- PCRpt,PLSP-ID=1, PST=TBD, D=1---->| PCECC LSP
 |PCC   +--------+ |       (LSP ID=0)                   |(LSPID=1)
 |Egress  |  |     |                                    |
 +--------+  |     |                                    |
     |       |     |                                    |
     |<------ PCLabelUpd,PLSP-ID=1  -------------------- | Label
     |       |     |       (LSP ID=1)                   | download
     |       |     |                                    |
     |       |<----- PCLabelUpd,PLSP-ID=1  ------------- | Label
     |       |     |      (LSP ID=1)                    | download
     |       |     |                                    |
     |       |     |<--- PCLabelUpd,PLSP-ID=1  --------- | Label
     |       |     |      (LSP ID=1)                    | download
     |       |     |                                    |
     |       |     |<-- PCUpd,PLSP-ID=1,PST=TBD, D=1-----| PCECC LSP
     |       |     |      (LSP ID=1)                    | Update
     |       |     |                                    |
```

Figure 2: Using PCLabelUpd For Label Operations

The PCECC LSP are considered to be 'up' by default. The Ingress MAY further choose to deploy a data plane check mechanism and report the status back to the PCE via PCRpt message.

5.4.2. Label Operations

The new label operations in PCEP can be done via a new PCLabelUpd message and by defining new PCEP Objects for Label operations. Local label range of each PCC can be configured at PCE and PCE.

5.4.2.1. Label Download

In order to setup an LSP based on PCECC, the PCE sends a PCLabelUpd message to each node of the LSP to download the Label entry as described in Section 5.4.1.

The LSP object in PCLabelUpd MUST include the LSP-IDENTIFIER TLV.

If a node (PCC) receives a PCLabelUpd message with a Label, out of the range set aside for the PCE, it MUST send a PCErr message with Error-type=TBD (label download failure) and Error-value=TBD (Label out of range) and MUST include the SRP object to specify the error is for the corresponding label update. If a PCC receives a PCLabelUpd message but failed to download the Label entry, it MUST send a PCErr message with Error-type=TBD (label download failure) and Error-value=TBD (label failed to be download)and MUST include the SRP object to specify the error is for the corresponding label update.

New PCEP object for LABEL is defined in Section 7.3 to encode the Label operations.

5.4.2.2. Label Cleanup

In order to delete an LSP based on PCECC, the PCE sends a PCLabelUpd message to each node along the path of the LSP to cleanup the Label entry.

If the PCC receives a PCLabelUpd message but does not recognize the label, the PCC MUST generate a PCErr message with Error-Type 19(Invalid operation) and Error-Value=TBD, "Unknown Label" and MUST include the SRP object to specify the error is for the corresponding label cleanup.

The R flag in SRP object defined in [I-D.ietf-pce-pce-initiated-lsp] specifies the deletion of Label Entry in the new PCLabelUpd message.

```
                 +-------+                              +-------+
                 |PCC    |                              |  PCE  |
                 |Ingress|                              +-------+
          +------|       |                                  |
          | PCC  +-------+                                  |
          | Transit| |                                     |
    +------|        | |-- PCRpt,PLSP-ID=1,PST=TBD,D=1,R=1--->| PCECC LSP
    |PCC   +--------+ |       (LSP ID=1)                    | remove
    |Egress  |  |     |                                     |
    +--------+  |     |                                     |
        |       |     |                                     |
        |<------ PCLabelUpd, PLSP-ID=1 --------------------- | Label
        |       |     |       (LSP ID=1, R=1)               | cleanup
        |       |     |                                     |
        |       |<----- PCLabelUpd, PLSP-ID=1 -------------- | Label
        |       |     |       (LSP ID=1, R=1)               | cleanup
        |       |     |                                     |
        |       |     |<--- PCLabelUpd, PLSP-ID=1 ---------- | Label
        |       |     |       (LSP ID=1, R=1)               | cleanup
        |       |     |                                     |
```

5.4.3. PCE Initiated PCECC LSP

The LSP Instantiation operation is same as defined in [I-D.ietf-pce-pce-initiated-lsp].

In order to setup a PCE Initiated LSP based on PCECC mechanism, a PCE sends PCInitiate message with Path Setup Type set for basic PCECC (see Section 7.2) to the Ingress PCC.

The Ingress PCC MUST also set D (Delegate) flag (see [I-D.ietf-pce-stateful-pce]) and C (Create) flag (see [I-D.ietf-pce-pce-initiated-lsp]) in LSP object of PCRpt message. The PCC responds with first PCRpt message with the status as "GOING-UP" and assigned PLSP-ID.

The rest of the PCECC LSP setup operations are same as those described in Section 5.4.1.

The LSP deletion operation for PCE Initiated PCECC LSP is same as defined in [I-D.ietf-pce-pce-initiated-lsp]. The PCE should further perform Label entry cleanup operation as described in Section 5.4.2.2 for the corresponding LSP.

The PCE Initiated PCECC LSP setup sequence is shown below using a new PCLabelUpd message.

```
                  +-------+                              +-------+
                  |PCC    |                              |  PCE  |
                  |Ingress|                              +-------+
           +------|       |                                  |
           | PCC  +-------+                                  |
           | Transit| |                                     |
    +------|        | |<--PCInitiate,PLSP-ID=0,PST=TBD,D=1---| PCECC LSP
    |PCC   +--------+ |                                     | Initiate
    |Egress  |  |     |--- PCRpt,PLSP-ID=2,P=1,D=1,C=1--->   | PCECC LSP
    +--------+  |     |       (LSP ID=0,GOING-UP)            |(LSPID=2
        |       |     |                                     | assigned)
        |<------ PCLabelUpd, PLSP-ID=2 --------------------- | Label
        |       |     |       (LSP ID=2)                    | download
        |       |     |                                     |
        |       |<----- PCLabelUpd, PLSP-ID=2 -------------- | Label
        |       |     |       (LSP ID=2)                    | download
        |       |     |                                     |
        |       |     |<--- PCLabelUpd, PLSP-ID=2 ---------- | Label
        |       |     |       (LSP ID=2)                    | download
        |       |     |                                     |
        |       |     |<-- PCUpd, PLSP-ID=2, PST=TBD, D=1--- | PCECC LSP
        |       |     |       (LSP ID=2)                    | Update
        |       |     |                                     |
```

5.4.4. PCECC LSP Update

Incase of a modification of PCECC LSP with a new path, a PCE sends a PCUpd message to the Ingress PCC.

When a PCC receives a PCUpd message for an existing LSP, a PCC MAY follow the make-before-break procedure i.e. first download labels for the updated LSP and then switch traffic, before cleaning up the old labels. On successful traffic switch over to the new LSP, PCC sends a PCRpt message to the PCE for the deletion of old LSP. Further the PCE does cleanup operation for the old LSP as described in Section 5.4.2.2.

The PCECC LSP Update and make-before-break sequence is shown below using a new PCLabelUpd message.

```
                  +-------+                            +-------+
                  |PCC    |                            |  PCE  |
                  |Ingress|                            +-------+
           +------|       |                                |
           | PCC  +-------+                                |
           | Transit| |                                    |
    +------|        | |                                    |
    |PCC   +--------+ |                                    |
    |Egress  |  |     |                                    |
    +--------+  |     |                                    |
        |       |     |                                    | Modify LSP
        |<------ PCLabelUpd, PLSP-ID=1 -------------------  | (LSPID=3
        |       |     |       (LSP ID=3)                   | assigned)
        |       |     |                                    |
        |       |<----- PCLabelUpd, PLSP-ID=1-------------  | Label
        |       |     |      (LSP ID=3)                    | download
        |       |     |                                    |
        |       |     |<--- PCLabelUpd, PLSP-ID=1 --------  | Label
        |       |     |      (LSP ID=3)                    | download
        |       |     |                                    |
        |       |     |<-- PCUpd, PLSP-ID=1, PST=TBD, D=1-- | PCECC
        |       |     |       (LSP ID=3)                   | LSP Update
        |       |     |                                    |
        |       |     |-- PCRpt,PLSP-ID=1,PST=TBD,D=1,R=1-->| Delete
        |       |     |       (LSP ID=1)                   | old LSP
        |       |     |                                    |
        |<------ PCLabelUpd, PLSP-ID=1 -------------------  | Label
        |       |     |       (LSP ID=1, R=1)              | cleanup
        |       |     |                                    |
        |       |<----- PCLabelUpd, PLSP-ID=1 ------------  | Label
        |       |     |      (LSP ID=1, R=1)               | cleanup
        |       |     |                                    |
        |       |     |<--- PCLabelUpd, PLSP-ID=1 --------  | Label
        |       |     |      (LSP ID=1, R=1)               | cleanup
```

The modified PCECC LSP are considered to be 'up' by default. The Ingress MAY further choose to deploy a data plane check mechanism and report the status back to the PCE via PCRpt message.

5.4.5. Session Termination

PCC MUST mark all labels that were previously reported by this PCE as stale on session down. [I-D.ietf-pce-stateful-pce] defines the State Timeout Interval. The labels which are marked stale and provisioned for the Basic PCECC LSP on this session MUST be cleaned up at the expiration of the State Timeout Interval. The labels will be retained when the Infinite State Timeout Interval is used.

5.4.6. LABEL-DB Synchronization

The purpose of LABEL-DB synchronization is to make sure that the PCE's view of LABEL-DB matches with the PCC's LABEL-DB. The LABEL-DB synchronization MUST be performed from PCE to PCC immediately after the LSP state synchronization. [I-D.ietf-pce-stateful-pce] describes the basic mechanism for LSP state synchronization. [I-D.ietf-pce-stateful-sync-optimizations] describes the optimizations for LSP state synchronization.

LABEL-DB synchronization is a two phase procedure. In first phase, immediately after the LSP state synchronization PCE MUST synchronize its LABEL-DB to PCC. In second phase, PCC MUST report all the stale marked labels to PCE.

5.4.6.1. LABEL-DB Synchronization procedure

During LABEL-DB Synchronization, a PCE first takes a snapshot of the label database for the session, then sends this snapshot to the PCC in a sequence of Label Update message (PCLabelUpd message). Each PCLabelUpd message sent during LABEL-DB Synchronization has the SYNC Flag in the SRP Object(see Section 7.4) set to 1.

The end of synchronization marker is a PCLabelUpd message with the SYNC Flag set to 0 for SRP Object and Label equal to a reserved value of 0 in the LABEL object (Section 7.3). If the PCE has no label to synchronize, it will only send the end of synchronization marker.

PCC MUST remove the stale marking for the all labels on receipt of correspoding PCLabelUpd message during the LABEL-DB Synchronization phase. The remaining stale marked labels after the LABEL-DB synchronization process MUST be reported to PCE in a sequence of Label Report message (PCLabelRpt message) with the SYNC Flag in the SRP Object(see Section 7.4) set to 1.

The end of report synchronization marker is a PCLabelRpt message with the SYNC Flag set to 0 for SRP Object with Label equal to reserved value 0 in the LABEL object ((Section 7.3)). If the PCC has no label to report, it will only send the end of report synchronization marker.

Either the PCE or the PCC MAY terminate the session using the PCEP session termination procedures during the LABEL-DB synchronization phase. The session reestablishment MUST be re-attempted as per the procedures defined in [RFC5440], including use of a back-off timer.

The PCC does not send positive acknowledgements for properly received label database synchronization messages. It MUST respond with a

PCErr message with Error-type TBD1 (Label Database Synchronization Error) and Error-value 1 (indicating an error in processing the PCLabelUpd) if it encounters a problem with the Label Update it received from the PCE and it MUST terminate the session.

If the PCE encounters a problem which prevents it from completing the label transfer, it MUST send a PCErr message with Error-type TBD1 (Label Database Synchronization Error) and Error-value 2 (indicating an internal PCE Error) to the PCC and terminate the session.

PCE MUST respond with a PCErr message with Error-type TBD1 (Label Database Report Synchronization Error) and Error-value 1 (indicating an error in processing the PCLabelRpt) if it encounters a problem with the Label Report it received from the PCC and it MUST terminate the session.

The successful LABEL-DB Synchronization sequence is shown below.

```
          + +-+-+-+-                          + +-+-+-+-
          |        |                          |  PCC   |
          |  PCE   |                          | Transit|
          |        |                          |  Node  |
          +-+-+-+-+-                          +-+-+-+-+-
              |                                   |
              |                                   |
              |                .                  |
              |                .                  |
              |                                   |
              |------- PCLabelUpd, PLSP-ID=2----->|(Label
              |            (LSP ID=2)             | Download
              |                                   | for LSP's)
              |------- PCLabelUpd, PLSP-ID=3----->|
              |            (LSP ID=3)             |
              |                                   |
              |------- PCLabelUpd, PLSP-ID=4----->|
              |            (LSP ID=4)             |
              |                .                  |
              |                .                  |(Session
              |                                   | down, mark
              |------- Session Down---------X     | all label's
              |                                   | Stale of this
              |                .                  | Session)
              |                .                  |
              |<------ Session Re-established---->|(Session up)
              |                .                  |
              |                .                  |
              |<-----PCRpt, SYNC=0----------------| (No LSP to SYNC)
              |                                   |
              |----PCLabelUpd,PLSP-ID=2,SYNC=1--->|(LABEL-DB
              |----PCLabelUpd,PLSP-ID=3,SYNC=1--->| SYNC, unmark
              |                                   | stale label)
              |------PCLabelUpd, SYNC=0---------->|
              |                                   |(End of LABEL-DB
              |                                   | SYNC)
              |                                   |
              |<-----PCLabelRpt,PLSP-ID=4,SYNC=1--|(Report all stale
              |                                   | Labels of this
              |<-----PCLabelRpt,SYNC=0------------| Session)
              |                                   |
              |------- PCLabelUpd, PLSP-ID=4 ---->|Label Cleanup
              |        (LSP ID=4, R=1)            |
              |                                   |
              |                                   |
```

5.4.7. PCECC LSP State Report

As mentioned before, an Ingress PCC MAY choose to apply any OAM mechanism to check the status of LSP in the Data plane and MAY further send its status in PCRpt message to the PCE.

6. PCEP messages

As defined in [RFC5440], a PCEP message consists of a common header followed by a variable-length body made of a set of objects that can be either mandatory or optional. An object is said to be mandatory in a PCEP message when the object must be included for the message to be considered valid. For each PCEP message type, a set of rules is defined that specify the set of objects that the message can carry. An implementation MUST form the PCEP messages using the object ordering specified in this document.

LSP-IDENTIFIERS TLV MAY be included in the LSP object for PCECC LSP.

6.1. Label Operations

6.1.1. The PCLabelUpd message

A new Label Update Message (also referred to as PCLabelUpd) is a PCEP message sent by a PCE to a PCC to download label or update the label map. The same message is also used to cleanup the Label entry. The Message-Type field of the PCEP common header for the PCLabelUpd message is set to TBD.

The format of the PCLabelUpd message is as follows:

```
<PCLabelUpd Message> ::= <Common Header>
                         <pce-label-update-list>
Where:
<pce-label-update-list> ::= <pce-label-update>
                   [<pce-label-update-list>]

<pce-label-update> ::= <pce-label-download>

Where:
<pce-label-download> ::= <SRP>
                         <LSP>
                         <label-list>

<label-list > ::=  <LABEL>
                  [<label-list>]
```

The PCLabelUpd message is used to download label along the path of the LSP.

The SRP object is defined in [I-D.ietf-pce-stateful-pce] and this document extends the use of SRP object in PCLabelUpd message. The SRP object is mandatory and MUST be included in PCLabelUpd message. If the SRP object is missing, the receiving PCC MUST send a PCErr message with Error-type=6 (Mandatory Object missing) and Error-value=10 (SRP object missing).

The LSP object is defined in [I-D.ietf-pce-stateful-pce] and this document extends the use of LSP object in PCLabelUpd message. LSP Identifiers TLV is defined in [I-D.ietf-pce-stateful-pce], it MAY be included in the LSP object in PCLabelUpd message. Either LSP object or FEC object defined in [I-D.zhao-pce-pcep-extension-pce-controller-sr] is mandatory in PCLabelUpd message.

The LABEL object is defined in Section 7.3. The LABEL is the mandatory object and MUST be included in PCLabelUpd message. If the LABEL object is missing, the receiving PCC MUST send a PCErr message with Error-type=6 (Mandatory Object missing) and Error-value=TBD (LABEL object missing). More than one LABEL object MAY be included in the PCLabelUpd message for the transit LSR.

To cleanup the SRP object must set the R (remove) bit.

6.1.2. The PCLabelRpt message

A new Label Report Message (also referred to as PCLabelRpt) is a PCEP message sent by a PCC to a PCE to report the label. The Message-Type field of the PCEP common header for the PCLabelRpt message is set to TBD.

The format of the PCLabelRpt message is as follows:

```
<PCLabelRpt Message> ::= <Common Header>
                         <pce-label-report-list>
Where:
<pce-label-report-list> ::= <pce-label-report>
                   [<pce-label-report-list>]

<pce-label-report> ::= <pce-label-delegate>

Where:
<pce-label-delegate> ::= <SRP>
                         <LSP>
                         <label-list>

<label-list > ::=  <LABEL>
                  [<label-list>]
```

The SRP object is defined in [I-D.ietf-pce-stateful-pce] and this document extends the use of SRP object in PCLabelRpt message. The SRP object is mandatory and MUST be included in PCLabelRpt message. If the SRP object is missing, the receiving PCE MUST send a PCErr message with Error-type=6 (Mandatory Object missing) and Error-value=10 (SRP object missing).

The LSP object is defined in [I-D.ietf-pce-stateful-pce] and this document extends the use of LSP object in PCLabelRpt message. LSP Identifiers TLV is defined in [I-D.ietf-pce-stateful-pce], it MAY be included in the LSP object in PCLabelRpt message. Either LSP object or FEC object defined in [I-D.zhao-pce-pcep-extension-pce-controller-sr] is mandatory in PCLabelRpt message.

The LABEL object is defined in Section 7.3. The LABEL is the mandatory object and MUST be included in PCLabelRpt message. If the LABEL object is missing, the receiving PCE MUST send a PCErr message with Error-type=6 (Mandatory Object missing) and Error-value=TBD (LABEL object missing). More than one LABEL object MAY be included in the PCLabelRpt message.

6.1.3. The PCInitiate message

Message described in [I-D.ietf-pce-pce-initiated-lsp] continue to apply.

7. PCEP Objects

The PCEP objects defined in this document are compliant with the PCEP object format defined in [RFC5440]. The P flag and the I flag of the PCEP objects defined in this document MUST always be set to 0 on transmission and MUST be ignored on receipt since these flags are exclusively related to path computation requests.

7.1. OPEN Object

This document defines a new optional TLVs for use in the OPEN Object.

7.1.1. PCECC Capability TLV

The PCECC-CAPABILITY TLV is an optional TLV for use in the OPEN Object for PCECC capability advertisement. Advertisement of the PCECC capability implies support of LSPs that are setup through PCECC as per PCEP extensions defined in this document.

Its format is shown in the following figure:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Type=TBD      |            Length=4           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             Flags                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The type of the TLV is TBD and it has a fixed length of 4 octets.

The value comprises a single field - Flags (32 bits).

No flags are assigned right now.

Unassigned bits are considered reserved. They MUST be set to 0 on transmission and MUST be ignored on receipt.

7.2. PATH-SETUP-TYPE TLV

The PATH-SETUP-TYPE TLV is defined in [I-D.ietf-pce-lsp-setup-type]; this document defines a new PST value:

o PST = TBD: Path is setup via Basic PCECC mode.

On a PCRpt/PCUpd/PCInitiate message, the PST=TBD in PATH-SETUP-TYPE TLV in SRP object indicates that this LSP was setup via a basic PCECC based mechanism.

7.3. Label Object

The LABEL Object is used to specify the Label information and MUST be carried within PCLabelUpd message.

LABEL Object-Class is TBD.

LABEL Object-Type is 1.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved             |              Flags          |O|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Label                 |     Reserved          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
//                       Optional TLV                          //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The fields in the LABEL object are as follows:

Flags: is used to carry any additional information pertaining to the label. Currently, the following flag bit is defined:

* O bit(Out-label) : If the bit is set, it specifies the label is the OUT label and it is mandatory to encode the nexthop information (via IPV4-ADDRESS TLV or IPV6-ADDRESS TLV or UNNUMBERED-IPV4-ID-ADDRESS TLV in LABEL object). If the bit is not set, it specifies the label is the IN label and it is optional to encode the local interface information (via IPV4-ADDRESS TLV or IPV6-ADDRESS TLV or UNNUMBERED-IPV4-ID-ADDRESS TLV in LABEL object).

Label (20-bit): The Label information encoded such that the 20 rightmost bits represent a label.

Reserved (12 bit): Set to zero while sending, ignored on receive.

7.3.1. Address TLVs

This document defines the following TLV for the LABEL object to associate the nexthop information incase of an outgoing label and local interface information incase of an incoming label.

IPV4-ADDRESS TLV:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type=TBD          |  Length = 4                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        IPv4 address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

IPV6-ADDRESS TLV:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type=TBD          |   Length = 16                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
//                IPv6 address (16 bytes)                      //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

UNNUMBERED-IPV4-ID-ADDRESS TLV:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type=TBD          |   Length = 8                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Node-ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Interface ID                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The address TLVs are as follows:

IPV4-ADDRESS TLV: an IPv4 address.

IPV6-ADDRESS TLV: an IPv6 address.

UNNUMBERED-IPV4-ID-ADDRESS TLV: a pair of Node ID / Interface ID tuples.

7.4. Extension of SRP object

SRP object is defined in [I-D.ietf-pce-stateful-pce] and extended in [I-D.ietf-pce-pce-initiated-lsp]. This draft defines a new 'SYNC' flag (S bit) to specify the LABEL-DB synchronization operation.

The format of the SRP object is shown Figure 12:

```
 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
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                         Flags                             |S|R|
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                     SRP-ID-number                             |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                                                               |
  //                       Optional TLVs                         //
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 12: SRP Object format

S (SYNC - 1 bit):The S Flag MUST be set to 1 on each PCLabelUpd and PCLabelRpt sent from a PCE and PCC respectively during LABEL-DB Synchronization. The S Flag MUST be set to 0 in other messages sent from the PCE and PCC.

8. Security Considerations

The security considerations described in [I-D.ietf-pce-stateful-pce] and [I-D.ietf-pce-pce-initiated-lsp] apply to the extensions described in this document. Additional considerations related to a malicious PCE are introduced.

8.1. Malicious PCE

PCE has complete control over PCC to update the labels and can cause the LSP's to behave inappropriate and cause cause major impact to the network. As a general precaution, it is RECOMMENDED that these PCEP extensions only be activated on authenticated and encrypted sessions across PCEs and PCCs belonging to the same administrative authority, using Transport Layer Security (TLS) [I-D.ietf-pce-pceps], as per the recommendations and best current practices in [RFC7525].

9. Manageability Considerations

9.1. Control of Function and Policy

A PCE or PCC implementation SHOULD allow to configure to enable/disable PCECC capability as a global configuration.

9.2. Information and Data Models

[RFC7420] describes the PCEP MIB, this MIB can be extended to get the PCECC capability status.

The PCEP YANG module [I-D.ietf-pce-pcep-yang] could be extended to enable/disable PCECC capability.

9.3. Liveness Detection and Monitoring

Mechanisms defined in this document do not imply any new liveness detection and monitoring requirements in addition to those already listed in [RFC5440].

9.4. Verify Correct Operations

Mechanisms defined in this document do not imply any new operation verification requirements in addition to those already listed in [RFC5440] and [I-D.ietf-pce-stateful-pce].

9.5. Requirements On Other Protocols

PCEP extensions defined in this document do not put new requirements on other protocols.

9.6. Impact On Network Operations

PCEP implementation SHOULD allow a limit to be placed on the rate of PCLabelUpd messages sent by PCE and processed by PCC. It SHOULD also allow sending a notification when a rate threshold is reached.

10. IANA Considerations

10.1. PCLabelUpd-PCLabelRpt message

IANA is requested to allocate a new message type within the "PCEP Messages" sub-registry of the PCEP Numbers registry for:

Value	Meaning	Reference
TBD	Label Update	This document
TBD	Label Report	This document

10.2. PCEP TLV Type Indicators

IANA is requested to confirm the early allocation of the following TLV Type Indicator values within the "PCEP TLV Type Indicators" sub-registry of the PCEP Numbers registry, and to update the reference in the registry to point to this document, when it is an RFC:

Value	Meaning	Reference
TBD	PCECC-CAPABILITY	This document
TBD	IPV4-ADDRESS TLV	This document
TBD	IPV6-ADDRESS TLV	This document
TBD	UNNUMBERED-IPV4-ID-ADDRESS TLV	This document

10.3. New Path Setup Type Registry

IANA is requested to allocate new PST Field in PATH- SETUP-TYPE TLV. The allocation policy for this new registry should be by IETF Consensus. The new registry should contain the following value:

Value	Description	Reference
TBD	Traffic engineering path is setup using Basic PCECC mode	This document

10.4. PCEP Object

IANA is requested to allocate new registry for LABEL PCEP object.

Object-Class Value	Name	Reference
TBD	LABEL Object-Type 1	This document

10.5. LABEL Object Flag Field

IANA is requestd to create a registry to manage the Flag field of the LABEL object.

One bit to be defined for the LABEL Object flag field in this document:

Codespace of the Flag field (LABEL Object)

Bit	Description	Reference
7	Specifies label is out label	This document

10.6. SRP Object Flag Field

SRP object is defined in [I-D.ietf-pce-stateful-pce] and extended in [I-D.ietf-pce-pce-initiated-lsp]. IANA is requested to allocate a new bit in SRP object flag. Field registry, as follows:

Bit	Description	Reference
30	S(SYNC Flag)	This document

10.7. PCEP-Error Object

IANA is requested to allocate new error types and error values within the "PCEP-ERROR Object Error Types and Values" sub-registry of the PCEP Numbers registry for the following errors:

Error-Type	Meaning	
19	Invalid operation.	
	Error-value = TBD :	Attempted LSP setup/download/ label-range reservation if PCECC capability was not advertised
	Error-value = TBD :	Stateful PCE capability was not advertised
	Error-value = TBD :	Unknown Label
6	Mandatory Object missing.	
	Error-value = TBD :	LABEL object missing
TBD	Label download failure.	
	Error-value = TBD :	Label out of range.
	Error-value = TBD :	Download of label Failed.
TBD	Label DB synchronization failed.	
	Error-value = TBD :	Processing label update Failed during synchronization.
	Error-value = TBD :	Internal PCE Error during synchronization.

11. Acknowledgments

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Appendix A. Contributor Addresses

Udayasree Palle
Huawei Technologies
Divyashree Techno Park, Whitefield
Bangalore, Karnataka 560066
India

EMail: udayasreereddy@gmail.com

Katherine Zhao
Huawei Technologies
2330 Central Expressway
Santa Clara, CA 95050
USA

EMail: katherine.zhao@huawei.com

Boris Zhang
Telus Ltd.
Toronto
Canada

EMail: boris.zhang@telus.com

Authors' Addresses

Quintin Zhao
Huawei Technologies
125 Nagog Technology Park
Acton, MA 01719
USA

EMail: quintin.zhao@huawei.com

Zhenbin Li
Huawei Technologies
Huawei Bld., No.156 Beiqing Rd.
Beijing 100095
China

EMail: lizhenbin@huawei.com

Dhruv Dhody
Huawei Technologies
Divyashree Techno Park, Whitefield
Bangalore, Karnataka 560066
India

EMail: dhruv.ietf@gmail.com

Satish Karunanithi
Huawei Technologies
Divyashree Techno Park, Whitefield
Bangalore, Karnataka 560066
India

EMail: satishk@huawei.com

Adrian Farrel
Juniper Networks, Inc
UK

EMail: adrian@olddog.co.uk

Chao Zhou
Cisco Systems

EMail: choa.zhou@cisco.com