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PCEP Extensions for Associated Bidirectional Segment Routing (SR) Paths
                  draft-li-pce-sr-bidir-path-07

Abstract

   The Path Computation Element Communication Protocol (PCEP) provides
   mechanisms for Path Computation Elements (PCEs) to perform path
   computations in response to Path Computation Clients (PCCs) requests.
   The Stateful PCE extensions allow stateful control of Multiprotocol
   Label Switching (MPLS) Traffic Engineering (TE) Label Switched Paths
   (LSPs) using PCEP. Furthermore, PCEP can be used for computing paths
   in Segment Routing (SR) TE networks.

   This document defines PCEP extensions for grouping two reverse
   unidirectional SR Paths into an Associated Bidirectional SR Path when
   using a Stateful PCE for both PCE-Initiated and PCC-Initiated LSPs as
   well as when using a Stateless PCE.

Status of This Memo

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1. Introduction

Segment routing (SR) [RFC8402] leverages the source routing and tunneling paradigms. SR supports to steer packets into an explicit forwarding path at the ingress node.

[RFC5440] describes the Path Computation Element (PCE) Communication Protocol (PCEP). PCEP enables the communication between a Path Computation Client (PCC) and a PCE, or between PCE and PCE, for the purpose of computation of Multiprotocol Label Switching (MPLS) as well as Generalized MPLS (GMPLS) Traffic Engineering Label Switched Path (TE LSP) characteristics.

[RFC8231] specifies a set of extensions to PCEP to enable stateful control of TE LSPs within and across PCEP sessions in compliance with [RFC4657]. It includes mechanisms to effect LSP State Synchronization between PCCs and PCEs, delegation of control over LSPs to PCEs, and PCE control of timing and sequence of path computations within and across PCEP sessions. The model of operation where LSPs are initiated from the PCE is described in [RFC8281].

[I-D.ietf-pce-segment-routing] specifies extensions to the Path Computation Element Protocol (PCEP) [RFC5440] for SR networks, that allow a stateful PCE to compute and initiate SR-TE paths, as well as a PCC to request, report or delegate SR Paths.

[I-D.ietf-pce-association-group] introduces a generic mechanism to create a grouping of LSPs which can then be used to define associations between a set of LSPs and/or a set of attributes, for example primary and secondary LSP associations, and is equally applicable to the active and passive modes of a Stateful PCE [RFC8231] or a stateless PCE [RFC5440].

Currently, SR networks only support unidirectional paths. However, bidirectional SR Paths are required in some networks, for example, in mobile backhaul transport networks. The requirement of bidirectional SR Path is specified in [I-D.ietf-spring-mpls-path-segment].

[I-D.ietf-pce-association-bidir] defines PCEP extensions for grouping two reverse unidirectional MPLS TE LSPs into an Associated Bidirectional LSP when using a Stateful PCE for both PCE-Initiated and PCC-Initiated LSPs as well as when using a Stateless PCE.

This document extends the bidirectional association to segment routing by specifying PCEP extensions for grouping two reverse unidirectional SR Paths into a bidirectional SR Path.

[I-D.ietf-pce-association-bidir] specifies the Double-sided
Bidirectional LSP Association procedure, where the PCE creates the
association and provisions at both endpoints, the RSVP-TE does the
signaling to the egress the status of the forward LSP and the ingress
about the reverse LSP. Thus, the both endpoints learn the reverse
LSPs forming the bidirectional LSP association. In case of SR, to
support the bidirectional path use-case, this is done using the PCEP
protocol. This is done so that both endpoints are aware of the the
unidirectional SR Path, as well as the status and other SR path
related information.

[I-D.li-pce-sr-path-segment] defines a procedure for Path Segment
Identifier (PSID) in PCEP for SR using PATH-SEGMENT TLV. The PSID
can be a Path Segment Identifier in SR-MPLS
[I-D.ietf-spring-mpls-path-segment]. The PSID can be used for an
associated bidirectional SR Path for identifying the SR Path.

2. Terminology

This document makes use of the terms defined in
[I-D.ietf-pce-segment-routing]. The reader is assumed to be familiar
with the terminology defined in [RFC5440], [RFC8231], [RFC8281],
[I-D.ietf-pce-association-group] and
[I-D.ietf-pce-association-bidir].

2.1. Requirements Language

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.

3. PCEP Extension for Bidirectional SR Path

As per [I-D.ietf-pce-association-group], LSPs are associated by
adding them to a common association group.
[I-D.ietf-pce-association-bidir] specifies PCEP extensions for
grouping two reverse unidirectional MPLS-TE LSPs into an Associated
Bidirectional LSP for both single-sided and double-sided initiation
cases by defining two new Bidirectional LSP Association Groups.

This document extends the procedure for associated bidirectional SR
Paths by defining a new bidirectional association group (Double-sided
Bidirectional SR Path Association Group). The document further
describes the mechanism for associating two unidirectional SR Paths
into a bidirectional SR Path. [I-D.li-pce-sr-path-segment] defines a
procedure for communicating Path Segment in PCEP for SR using PATH-

SEGMENT TLV. The bidirectional SR Path can also use the PATH-SEGMENT
TLV.

Note that an association group is defined in this document to define
procedures specific to SR Paths (and the procedures are different
than the RSVP-TE bidirectional association groups defined in
[I-D.ietf-pce-association-bidir]).

3.1. Double-sided Bidirectional SR Path Association Group Object

As defined in [I-D.ietf-pce-association-bidir], two LSPs are
associated as a bidirectional MPLS-TE LSP by a common bidirectional
LSP association group. For associating two SR paths, this document
defines a new association group called 'Double-sided Bidirectional SR
Path Association Group' as follows:

o Association Type (TBD1 to be assigned by IANA) = Double-sided
   Bidirectional SR Path Association Group

Similar to other bidirectional associations, this Association Type is
operator-configured in nature and statically created by the operator
on the PCEP peers. The paths belonging to this association is
conveyed via PCEP messages to the PCEP peer. Operator-configured
Association Range TLV [I-D.ietf-pce-association-group] MUST NOT be
sent for these Association Types, and MUST be ignored, so that the
entire range of association ID can be used for them. The handling of
the Association ID, Association Source, optional Global Association
Source and optional Extended Association ID in this association are
set in the same way as [I-D.ietf-pce-association-bidir].

A member of the 'Double-sided Bidirectional SR Path Association
Group' can take the role of a forward or reverse SR Path and follow
the similar rules defined in [I-D.ietf-pce-association-bidir] for
LSPs.

o An SR Path (forward or reverse) can not be part of more than one
   'Double-sided Bidirectional SR Path Association Group'.

o The endpoints of the SR Paths in this associations cannot be
   different.

For describing the SR Paths in this association group, such as
direction and co-routed information, this association group reuses
the Bidirectional LSP Association Group TLV defined in
[I-D.ietf-pce-association-bidir]. All fields and processing rules
are as per [I-D.ietf-pce-association-bidir].

4. **Bidirectional Flag**

   As defined in [RFC5440], the B-flag in RP object MUST be set when the
   PCC specifies that the path computation request relates to a
   bidirectional TE LSP. In this document, the B-flag also MUST be set
   when the PCC specifies that the path computation request relates to a
   bidirectional SR Path. When a stateful PCE initiates or updates a
   bidirectional SR Paths including LSPs and SR paths, the B-flag in SRP
   object [I-D.ietf-pce-pcep-stateful-pce-gmpls] MAY be set as well.

5. **Procedures for Associated Bidirectional SR Path Computation**

   Two unidirectional SR Paths can be associated by the association
   group object as specified in [I-D.ietf-pce-association-group]. A
   bidirectional LSP association group object is defined in
   [I-D.ietf-pce-association-bidir] (for MPLS-TE). This document
   extends these association mechanisms for bidirectional SR Paths. Two
   SR Paths can be associated together by using the Bidirectional SR
   Path Association Group defined in this document for PCEP messages.
   The PATH-SEGMENT TLV [I-D.li-pce-sr-path-segment] SHOULD also be
   included in the LSP object for these SR Paths to support required
   use-cases.

   For bidirectional SR Paths, there is a need to know the reverse
   direction SR paths. The PCE SHOULD inform the reverse SR Paths to
   the ingress PCCs and vice versa. To achieve this, a PCInitiate
   message for the reverse SR Path is sent to the ingress PCC and a
   PCInitiate message for the forward SR Path is sent to the egress PCC
   (with the same association group). These PCInitiate message MUST NOT
   trigger initiation of SR Paths. The reverse direction SR Path can be
   used for several use-cases, such as directed BFD
   [I-D.ietf-mpls-bfd-directed].

   For a bidirectional LSP computation when using both direction LSPs on
   a node, the same LSP would need to be identified using 2 different
   PLSP-IDs based on the PCEP session to the ingress or the egress. In
   other words, the LSP will have a PLSP-ID A at the ingress node while
   it will have the PLSP-ID B at the egress node. The PCE will maintain
   the two PLSP-IDs for the same LSP. For instance, an ingress PCC
   requests a bidirectional SR Path computation, and the PCE computes a
   forward LSP1 with PLSP-ID say 100. The reverse LSP2 from the egress
   to the ingress with PLSP-ID say 200 is allocated by the egress PCC.
   Since the PLSP-ID space is independent at each PCC, the PLSP-ID
   allocated by the egress PCC can not be used for the LSP at the
   ingress PCC (PLSP-ID conflict may occur). Hence, the PCE needs to
   allocate a PLSP-ID for LSP2 from the ingress PCC's PLSP-ID space ,
   say 101. Similarly for LSP1, it has PLSP-ID 100 at the ingress, and
   may have say PLSP-ID 201 at the egress node.

5.1. PCE Initiated Associated Bidirectional SR Paths

   As specified in [I-D.ietf-pce-association-group], Bidirectional SR
   Path Association Group can be created by a Stateful PCE.

   o Stateful PCE can create and update the forward and reverse SR
      Paths independently for a 'Double-sided Bidirectional SR Path
      Association Group'.

   o Stateful PCE can establish and remove the association relationship
      on a per SR Path basis.

   o Stateful PCE can create and update the SR Path and the association
      on a PCC via PCInitiate and PCUpd messages, respectively, using
      the procedures described in [I-D.ietf-pce-association-group].

   o The PATH-SEGMENT TLV SHOULD be included for each SR Path in the
      LSP object.

   o The reverse direction SR Path (LSP2(R) at node S, LSP1(R) at node
      D) SHOULD be informed by PCE via PCInitiate message with the
      matching association group.

```
                          +-----+
                          | PCE |
                          +-----+
   PCInitiate/PCUpd:          /      \          PCInitiate/PCUpd:
   Tunnel 1 (F)              /        \          Tunnel 2 (F)
   (LSP1 (F), LSP2 (R))     /          \         (LSP2 (F), LSP1 (R))
   Association #1          /            \        Association #1
                          /              \
                         v                v
                   +-----+    LSP1     +-----+
                   |  S  |------------>|  D  |
                   |     |<------------|     |
                   +-----+    LSP2     +-----+
                        <no signaling>
```

      Figure 1: PCE-Initiated Double-sided Bidirectional SR Path
               with Forward and Reverse Direction SR Paths

5.2. PCC Initiated Associated Bidirectional SR Paths

   As specified in [I-D.ietf-pce-association-group], Bidirectional SR
   Path Association Group can also be created by a PCC.

o PCC can create and update the forward and reverse SR Paths
   independently for a 'Double-sided Bidirectional SR Path
   Association Group'.

o PCC can establish and remove the association relationship on a per
   SR Path basis.

o PCC MUST report the change in the association group of an SR Path
   to PCE(s) via PCRpt message.

o PCC can report the forward and reverse SR Paths independently to
   PCE(s) via PCRpt message.

o PCC can delegate the forward and reverse SR Paths independently to
   a Stateful PCE, where PCE would control the SR Paths.

o Stateful PCE can update the SR Paths in the 'Double-sided
   Bidirectional SR Path Association Group' via PCUpd message, using
   the procedures described in [I-D.ietf-pce-association-group].

o The PATH-SEGMENT TLV MUST be handled as defined in
   [I-D.li-pce-sr-path-segment].

o The reverse direction SR Path (LSP2(R) at node S, LSP1(R) at node
   D) SHOULD be informed by PCE via PCInitiate message with the
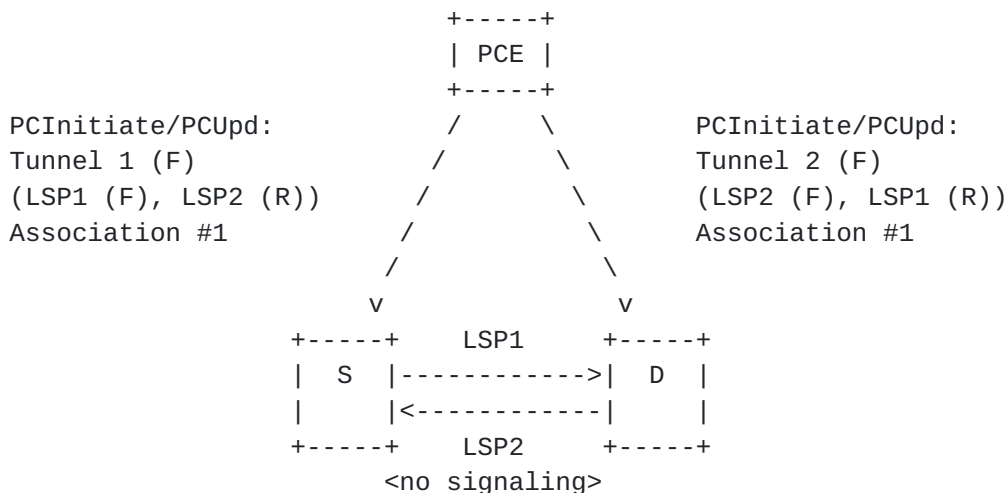   matching association group.

```
                        +-----+
                        | PCE |
                        +-----+
  Report/Delegate:         ^     ^          Report/Delegate:
  Tunnel 1 (F)            /       \          Tunnel 2 (F)
  (LSP1 (F))             /         \         (LSP2 (F))
  Association #2        /           \        Association #2
                       /             \
                      /               \
             +-----+    LSP1     +-----+
             |  S  |------------>|  D  |
             |     |<------------|     |
             +-----+    LSP2     +-----+
                   <no signaling>
```
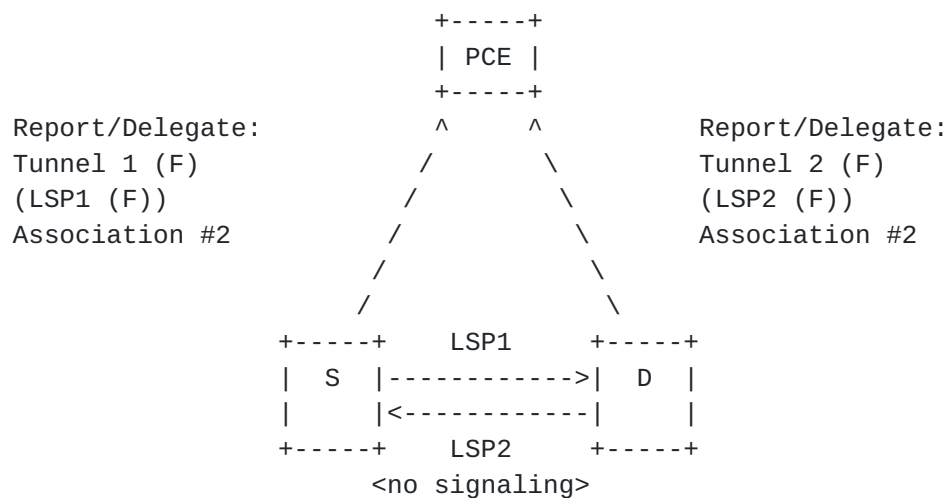
    Figure 2a: Step 1: PCC-Initiated Double-sided Bidirectional SR Path
               with Forward Direction SR Paths


```
                        +-----+
                        | PCE |
                        +-----+
  PCUpd/PCInitiate:        /     \          PCUpd/PCInitiate:
  Tunnel 1 (F)            /       \          Tunnel 2 (F)
  (LSP1 (F), LSP2 (R))   /         \         (LSP2 (F), LSP1 (R))
  Association #2        /           \        Association #2
                       /             \
                      v               v
             +-----+    LSP1     +-----+
             |  S  |------------>|  D  |
             |     |<------------|     |
             +-----+    LSP2     +-----+
                   <no signaling>
```
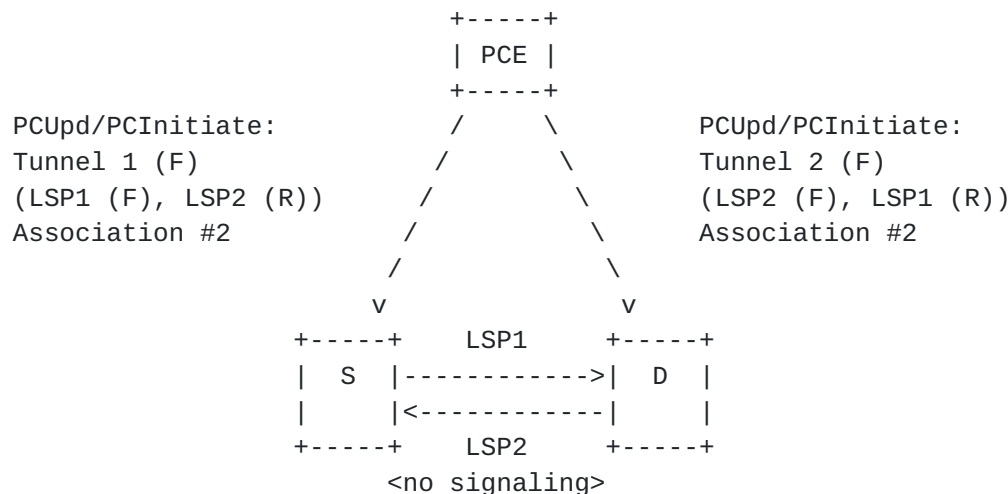
    Figure 2b: Step 2: PCE-Upd/Initiated Double-sided Bidirectional Path
              Along with Reverse Direction SR Paths

5.3. Error Handling

   The error handling as described in section 5.5 of
   [I-D.ietf-pce-association-bidir] continue to apply.

   The PCEP Path Setup Type (PST) MUST be set to 'TE Path is Setup using
   Segment Routing' [I-D.ietf-pce-segment-routing] for the LSP belonging
   to the 'Double-sided Bidirectional SR Path Association Group'. In
   case a PCEP speaker receives a different PST value for this
   association group, it MUST send a PCErr message with Error-Type = 29

(Early allocation by IANA) (Association Error) and Error-Value = TBD2
(Bidirectional LSP Association - Path Setup Type Mismatch).

6. Implementation Status

[Note to the RFC Editor - remove this section before publication, as
well as remove the reference to [RFC7942].

This section records the status of known implementations of the
protocol defined by this specification at the time of posting of this
Internet-Draft, and is based on a proposal described in [RFC7942].
The description of implementations in this section is intended to
assist the IETF in its decision processes in progressing drafts to
RFCs. Please note that the listing of any individual implementation
here does not imply endorsement by the IETF. Furthermore, no effort
has been spent to verify the information presented here that was
supplied by IETF contributors. This is not intended as, and must not
be construed to be, a catalog of available implementations or their
features. Readers are advised to note that other implementations may
exist.

According to [RFC7942], "this will allow reviewers and working groups
to assign due consideration to documents that have the benefit of
running code, which may serve as evidence of valuable experimentation
and feedback that have made the implemented protocols more mature.
It is up to the individual working groups to use this information as
they see fit".

6.1. Huawei's Commercial Delivery

The feature is developing based on Huawei VRP8.

o Organization: Huawei

o Implementation: Huawei's Commercial Delivery implementation based
   on VRP8.

o Description: The implementation is under development.

o Maturity Level: Product

o Contact: tanren@huawei.com

6.2. ZTE's Commercial Delivery

o Organization: ZTE

   o Implementation: ZTE's Commercial Delivery implementation based on
      Rosng v8.

   o Description: The implementation is under development.

   o Maturity Level: Product

   o Contact: zhan.shuangping@zte.com.cn

7. IANA Considerations

7.1. Association Type

   This document defines a new Association Type for the Association
   Object defined [I-D.ietf-pce-association-group]. IANA is requested
   to make the assignment of a value for the sub-registry "ASSOCIATION
   Type Field" (to be created in [I-D.ietf-pce-association-group]), as
   follows:

```
   Value  Name                                      Reference
   --------------------------------------------------------------------
   TBD1   Double-sided Bidirectional                This document
          SR Path Association Group
```

7.2. PCEP Errors

   This document defines new Error value for Error Type 29 (Association
   Error). IANA is requested to allocate new Error value within the
   "PCEP-ERROR Object Error Types and Values" sub-registry of the PCEP
   Numbers registry, as follows:

```
   Error Type  Description                          Reference
   --------------------------------------------------------------------
    29         Association Error

               Error value: TBD2                    This document
               Bidirectional LSP Association -
               Path Setup Type Mismatch
```

8. Security Considerations

   The security considerations described in [RFC5440], [RFC8231],
   [RFC8281], and [I-D.ietf-pce-segment-routing] apply to the extensions
   defined in this document as well.

   A new Association Type for the Association Object, 'Double-sided
   Associated Bidirectional SR Path Association Group' is introduced in

this document. Additional security considerations related to LSP
associations due to a malicious PCEP speaker is described in
[I-D.ietf-pce-association-group] and apply to this Association Type.
Hence, securing the PCEP session using Transport Layer Security (TLS)
[RFC8253] is recommended.

9. Manageability Considerations

All manageability requirements and considerations listed in
[RFC5440], [RFC8231], and [RFC8281] apply to PCEP protocol extensions
defined in this document. In addition, requirements and
considerations listed in this section apply.

9.1. Control of Function and Policy

The mechanisms defined in this document do not imply any control or
policy requirements in addition to those already listed in [RFC5440],
[RFC8231], and [RFC8281].

9.2. Information and Data Models

[RFC7420] describes the PCEP MIB, there are no new MIB Objects
defined for Bidirectional SR Path associations. The PCEP YANG module
[I-D.ietf-pce-pcep-yang] defines data model for Bidirectional SR Path
associations.

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], [RFC8231], and [RFC8281].

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], [RFC8231], and [I-D.ietf-pce-segment-routing] .

9.5. Requirements On Other Protocols

Mechanisms defined in this document do not imply any new requirements
on other protocols.

9.6. Impact On Network Operations

Mechanisms defined in [RFC5440], [RFC8231], and
[I-D.ietf-pce-segment-routing] also apply to PCEP extensions defined
in this document.

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11. Acknowledgments

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