       PCEP Extensions for Associated Bidirectional Segment Routing (SR) Paths
                    draft-ietf-pce-sr-bidir-path-02

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.
   Segment routing (SR) leverages the source routing and tunneling
   paradigms. The Stateful PCEP extensions allow stateful control of
   Segment Routing Traffic Engineering (TE) Paths. Furthermore, PCEP
   can be used for computing SR TE paths in the network.

   This document defines PCEP extensions for grouping two unidirectional
   SR Paths (one in each direction in the network) into a single
   Associated Bidirectional SR Path. The mechanisms defined in this
   document can also be applied using a Stateful PCE for both PCE-
   Initiated and PCC-Initiated LSPs, as well as when using a Stateless
   PCE.

Status of This Memo

   This Internet-Draft is submitted in full conformance with the
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1. Introduction

   Segment routing (SR) [RFC8402] leverages the source routing and
   tunneling paradigms. SR supports steering packets onto an explicit
   forwarding path at the ingress node. SR is specified for
   unidirectional paths. However, some applications require
   bidirectional paths in SR networks, for example, in mobile backhaul
   transport networks. The requirement for bidirectional SR Paths is
   specified in [I-D.ietf-spring-mpls-path-segment].

   [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 Traffic Engineering (TE) Label Switched
   Paths (LSP). [RFC8231] specifies a set of extensions to PCEP to
   enable stateful control of TE LSPs within and across PCEP sessions.
   The mode of operation where LSPs are initiated from the PCE is
   described in [RFC8281].

   [RFC8408] 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 them.

   [RFC8697] 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, and is equally applicable to the active
   and passive modes of a Stateful PCE [RFC8231] or a stateless PCE
   [RFC5440].

   [I-D.ietf-pce-association-bidir] defines PCEP extensions for grouping
   two unidirectional RSVP-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. It specifies the
   procedure for 'Double-sided Bidirectional LSP Association', where the
   PCE creates the association and provisions the forward LSPs at their
   ingress nodes. The RSVP-TE signals the forward LSPs to the egress
   nodes. Thus, both endpoints learn the reverse LSPs forming the
   bidirectional LSP association.

   This document extends the bidirectional LSP association to SR by
   specifying PCEP extensions for grouping two unidirectional SR Paths
   into a bidirectional SR Path. For bidirectional SR, there are use-
   cases such as directed BFD [I-D.ietf-mpls-bfd-directed] and SR
   Performance Measurement (PM) [I-D.gandhi-spring-twamp-srpm] those

require PCC to be aware of the reverse direction SR Path. For such
use-cases, the reverse SR Paths are also communicated to the ingress
nodes using the PCEP extensions defined in this document. This
allows both endpoints to be aware of the SR Paths in both directions,
including their status and all other path related information.
Associating an unidirectional SR Path with a reverse direction
unidirectional RSVP-TE LSP to form a bidirectional LSP and vice
versa, are outside the scope of this document.

2. Terminology

This document makes use of the terms defined in [RFC8408]. The
reader is assumed to be familiar with the terminology defined in
[RFC5440], [RFC8231], [RFC8281], [RFC8697], 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 Extensions

As per [RFC8697], TE LSPs are associated by adding them to a common
association group by a PCEP peer. [I-D.ietf-pce-association-bidir]
uses the association group object and the procedures as specified in
[RFC8697] to group two unidirectional RSVP-TE LSPs. Similarly, two
SR Paths can also be associated using similar technique. This
document extends these association mechanisms for bidirectional SR
Paths. Two unidirectional SR Paths (one in each direction in the
network) can be associated together by using the association group
defined in this document for PCEP messages.

Note that the procedure for using the association group defined in
this document is specific to the associated bidirectional SR Paths.
The procedure for this association group is different than the
bidirectional association groups defined in
[I-D.ietf-pce-association-bidir] for associated bidirectional RSVP-TE
LSPs.

[I-D.ietf-pce-sr-path-segment] defines a mechanism for communicating
Path Segment Identifier (PSID) in PCEP for SR. The PSID is defined
for SR-MPLS in [I-D.ietf-spring-mpls-path-segment]. The PSID can be
used for identifying an SR Path of an associated bidirectional SR
Path. The PATH-SEGMENT TLV MAY be included for each SR Path in the

LSP object to support required use-cases. The PATH-SEGMENT TLV MUST
be handled as defined in [I-D.ietf-pce-sr-path-segment] and is not
modified for associated bidirectional SR Path.

3.1. Double-sided Bidirectional with Reverse LSP Association Group

For associating two unidirectional SR Paths, this document defines a
new Association Type called 'Double-sided Bidirectional with Reverse
LSP Association Group' for Association Group Object (Class-Value 40)
as follows:

o Association Type (TBD1 to be assigned by IANA) = Double-sided
   Bidirectional with Reverse LSP Association Group

Similar to RSVP-TE bidirectional LSP associations, this Association
Type is also operator-configured in nature and statically created by
the operator on the PCEP peers. 'Operator-configured Association
Range' TLV (Value 29) [RFC8697] MUST NOT be sent for this Association
Type, and MUST be ignored, so that the entire range of association ID
can be used for it.

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 with Reverse LSP
Association Group' can take the role of a forward or reverse
direction SR Path and follow the similar rules defined in
[I-D.ietf-pce-association-bidir] for LSPs.

o An SR Path (forward or reverse) cannot be part of more than one
   'Double-sided Bidirectional with Reverse LSP Association Group'.

o The endpoints of the SR Paths in 'Double-sided Bidirectional with
   Reverse LSP Association Group' cannot be different.

3.1.1. Bidirectional LSP Association Group TLV

In 'Double-sided Bidirectional with Reverse LSP Association Group',
for properties such as forward and reverse direction and co-routed
path, it uses 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](#). **PCEP Procedures**

   For a Bidirectional SR Path, an ingress PCC is aware of the forward
   direction SR Path beginning from itself to the egress PCC using the
   existing PCEP procedures. For the use-cases which require the
   ingress PCC to be aware of the reverse direction SR Path, PCE informs
   the reverse SR Path to the ingress PCC. 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 matching association group). These PCInitiate
   message MUST NOT trigger initiation of SR Paths on PCCs.

   The SR Path can be identified by an LSP of an SR Policy as described
   in [[I-D.barth-pce-segment-routing-policy-cp](#)].

   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 node.
   Note that the PLSP-ID space is independent at each PCC, the PLSP-ID
   allocated by the egress PCC cannot be used for the LSP at the ingress
   PCC (PLSP-ID conflict may occur). As per normal PCInitiate
   operations, PCC assigns the PLSP-IDs for the local LSPs. Hence, when
   the PCE notifies an ingress PCC of the reverse LSP, it does so by
   using PCInitiate operations and sets PLSP-ID to zero and sets the R
   bit in the Bidirectional LSP Association Group TLV in the association
   object to indicate that this PCInitiate LSP is a reverse LSP. The
   PCC upon receiving the PCInitiate MUST locally assign a new PLSP-ID
   and it MUST issue a PCRpt to PCE for this LSP containing the new
   PLSP-ID. This reverse direction LSP MUST NOT be instantiated on the
   PCC.

   In other words, a given LSP will be identified by PLSP-ID A at the
   ingress node while it will be identified by PLSP-ID B at the egress
   node. The PCE will maintain two PLSP-IDs for the same LSP. For
   example, ingress PCC1 may report to PCE an LSP1 with PLSP-ID 100.
   Egress PCC2 may report to PCE an LSP2 with PLSP-ID 200. Both of
   these LSPs are part of a bidirectional association. When PCE
   notifies PCC1 of the reverse direction LSP2, it does so by sending a
   PCInitiate to PCC1 with PLSP-ID set to zero and R bit set in the
   Bidirectional LSP Association Group TLV. PCC1 upon reception of this
   generates a new PLSP-ID (example PLSP-ID 300) and issues a PCRpt to
   PCE. Thus there would two PLSP-ID associated for LSP2 (300 at PCC1
   and 200 at PCC2).

4.1. PCE Initiated Associated Bidirectional SR Paths

   As specified in [RFC8697], Associated Bidirectional SR Paths can be
   created by a Stateful PCE as shown in Figure 1.

   o Stateful PCE can create and update the forward and reverse SR
      Paths independently for 'Double-sided Bidirectional with Reverse
      LSP 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 [RFC8697].

   o The reverse direction SR Path (LSP2(R) at node S, LSP1(R) at node
      D as shown in Figure 1) SHOULD be informed by the PCE via
      PCInitiate message with the matching association group for the
      use-cases which require the PCC to be aware of the reverse
      direction SR Path.

```
                            +-----+
                            | 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 Associated Bidirectional SR Path
                    with Forward and Reverse Direction SR Paths

4.2. PCC Initiated Associated Bidirectional SR Paths

   As specified in [RFC8697], Associated Bidirectional SR Paths can also
   be created by a PCC as shown in Figure 2a and 2b.

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

o PCC cannot instantiate a reverse SR Path in a bidirectional SR
   Path.

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 with Reverse LSP Association Group' via PCUpd
   message, using the procedures described in [RFC8697].

o The reverse direction SR Path (LSP2(R) at node S, LSP1(R) at node
   D as shown in Figure 2b) SHOULD be informed by the PCE via
   PCInitiate message with the matching association group for the
   use-cases which require the PCC to be aware of the reverse
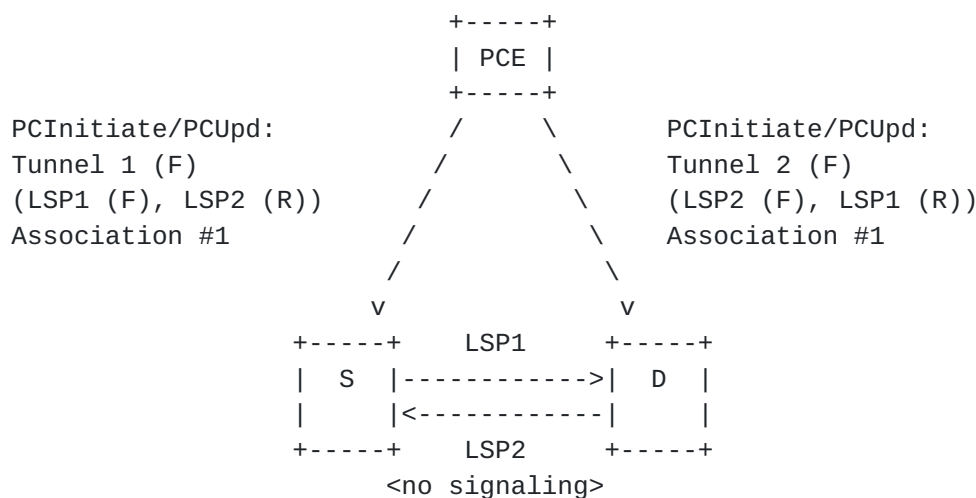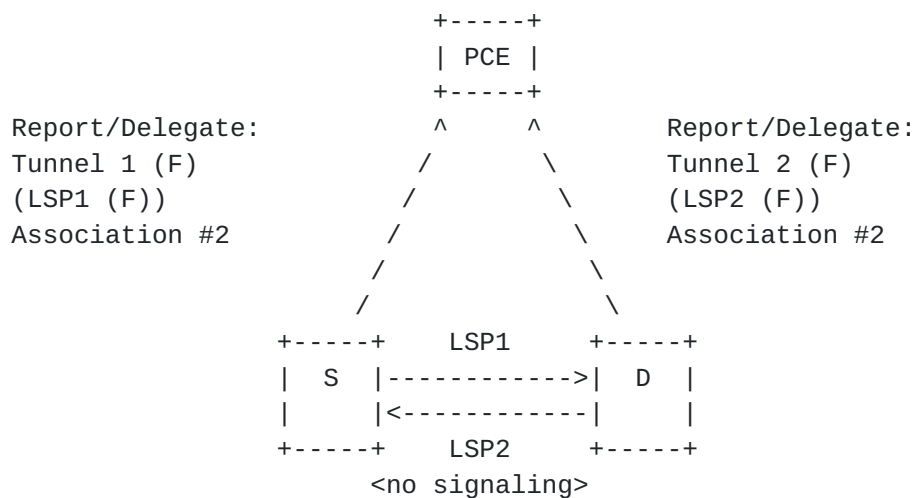   direction SR Path.

```
                            +-----+
                            | 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 Associated 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>
```
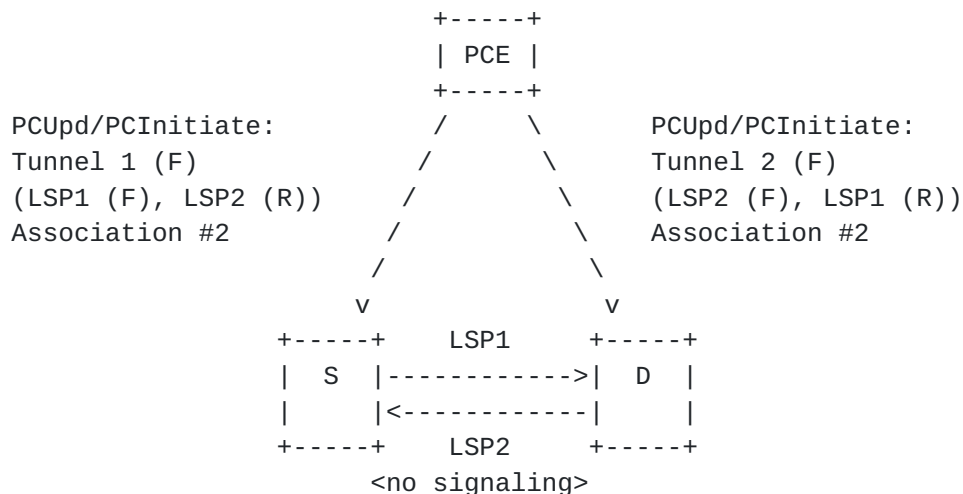
       Figure 2b: Step 2: PCE-Updated/Initiated Associated Bidirectional SR
                   Path with Reverse Direction SR Paths

4.3. Stateless PCE

   As defined in [I-D.ietf-pce-association-bidir], for a stateless PCE,
   it might be useful to associate a path computation request to an
   association group, thus enabling it to associate a common set of
   configuration parameters or behaviors with the request. A PCC can
   request co-routed or non-co-routed forward and reverse direction
   paths from a stateless PCE for a bidirectional SR association group.

4.4. Bidirectional (B) Flag

The Bidirectional (B) flag in Request Parameters (RP) object
[RFC5440] and Stateful PCE Request Parameter (SRP) object
[I-D.ietf-pce-pcep-stateful-pce-gmpls] follow the procedure defined
in [I-D.ietf-pce-association-bidir].

4.5. State Synchronization

During state synchronization, a PCC MUST report all the existing
Bidirectional Association Groups to the Stateful PCE as per
[RFC8697]. After the state synchronization, the PCE MUST remove all
stale Bidirectional Association Groups.

4.6. Error Handling

The error handling as described in section 5.7 of
[I-D.ietf-pce-association-bidir] continue to apply.

The PCEP Path Setup Type (PST) for SR is set to 'TE Path is Setup
using Segment Routing' [RFC8408]. If a PCEP speaker receives a
different PST value for 'Double-sided Bidirectional with Reverse LSP
Association Group' and it does not support; it MUST send a PCErr
message with Error-Type = 26 (Association Error) and Error-Value =
'Bidirectional LSP Association - Path Setup Type Not Supported'
defined in [I-D.ietf-pce-association-bidir].

5. 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".

5.1. 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

5.2. 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

6. Security Considerations

The security considerations described in [RFC5440], [RFC8231],
[RFC8281], and [RFC8408] apply to the extensions defined in this
document as well.

A new Association Type for the Association Object, 'Double-sided
Bidirectional with Reverse LSP Association Group' is introduced in
this document. Additional security considerations related to LSP
associations due to a malicious PCEP speaker is described in
[RFC8697] and apply to this Association Type. Hence, securing the
PCEP session using Transport Layer Security (TLS) [RFC8253] is
recommended.

7. 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.

7.1. 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].

7.2. Information and Data Models

[RFC7420] describes the PCEP MIB, there are no new MIB Objects
defined for 'Double-sided Bidirectional with Reverse LSP Association
Groups'. The PCEP YANG module [I-D.ietf-pce-pcep-yang] defines data
model for Associated Bidirectional SR Paths.

7.3. 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].

7.4. 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 [RFC8408].

7.5. Requirements On Other Protocols

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

7.6. Impact On Network Operations

Mechanisms defined in [RFC5440], [RFC8231], and [RFC8408] also apply
to PCEP extensions defined in this document.

8. IANA Considerations

8.1. Association Type

This document defines a new Association Type for the Association
Object (Class Value 40) defined [RFC8697]. IANA is requested to make
the assignment of a type for the sub-registry "ASSOCIATION Type" as
follows:

```
Type    Name                                        Reference
-------------------------------------------------------------------
TBD1    Double-sided Bidirectional with Reverse     This document
        LSP Association Group
```

9. References

9.1. Normative References

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9.2. Informative References

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Acknowledgments

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