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Path Computation Element Communication Protocol (PCEP) Extensions for  
Associated Bidirectional Segment Routing (SR) LSPs  
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Abstract

Segment Routing (SR) steers packets through a network using the IPv6 or MPLS data planes via source routing. Stateful Path Computation Element Communication Protocol (PCEP) extensions are defined for SR Traffic Engineering (TE) LSPs.

PCEP supports grouping two RSVP-TE-signaled, unidirectional MPLS-TE Label-Switched Paths (LSPs) with one in each direction in a network into an associated bidirectional LSP. This document extends PCEP support to group two unidirectional SR LSPs into an associated bidirectional SR LSP. The mechanisms defined in this document apply to both stateless and stateful PCEs for PCE-initiated and PCC-initiated LSPs.

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## 1. Introduction

Segment Routing (SR) [RFC8402] can be used to steer packets through a network employing source routing. SR can be applied to both MPLS (SR-MPLS) and IPv6 (SRv6) data planes.

[RFC5440] describes the Path Computation Element (PCE) Communication Protocol (PCEP). [RFC8231] specifies a set of extensions to PCEP to enable stateful control of Traffic Engineering (TE) Label Switched Paths (LSPs) within and across PCEP sessions. As described in [RFC4655], a PCE can be either stateful or stateless. [RFC8664] specifies extensions to the PCEP for SR networks that allow a stateful PCE to compute and initiate SR TE paths, as well as a Path Computation Client (PCC) to request, report, or delegate them.

There are features such as directed BFD [RFC9612] and Performance Measurement [RFC9503] that require the ingress node (PCC) to be aware of the reverse direction SR path. For such features, the reverse SR paths need to be communicated to the ingress nodes (PCCs) using PCEP mechanisms. This allows both endpoint nodes to be aware of the forward and reverse SR paths.

An SR Policy [RFC9256] contains one or more Candidate Paths (CPs), which may be computed by a PCE. A Candidate Path of an SR Policy can contain one or more Segment Lists (SLs). In PCEP messages, an SL is encoded as an Explicit Route Object (ERO) as described in Section 4.3 of [RFC8664]. [I-D.ietf-pce-multipath] defines PCEP extensions for carrying multiple SLs in the PCEP messages along with their opposite direction SLs, as described in Section 7.4 (Opposite Direction Tunnels) in [I-D.ietf-pce-multipath].

As per [RFC8697], TE LSPs can be associated by adding them to a common association group by a PCEP peer. [RFC9059] uses the association group object to group two unidirectional RSVP-TE LSPs into an associated bidirectional LSP for both stateful and stateless PCE. This document extends this procedure and allows grouping two unidirectional SR LSPs into an associated bidirectional SR LSP for co-routed [RFC9059] and non-co-routed paths. This extension also utilizes the procedure defined in [I-D.ietf-pce-multipath] to carry the multiple EROs and the associated reverse path EROs for an SR LSP. Note that the association group and the procedure introduced in this document are specific to SR-TE and SRv6 Path Setup Types.

## 2. Terminology

The reader is assumed to be familiar with the terminology defined in [RFC8231], [RFC8281], [RFC8697], [RFC8408], [RFC9059], and [I-D.ietf-pce-multipath].

This document uses the following terms defined in [RFC5440]:

Explicit Route Object (ERO), Path Computation Client (PCC), Path Computation Element (PCE), Path Computation Element Communication Protocol (PCEP), PCEP peer, and PCEP speaker.

This document extends the following term defined in [RFC3031]: Label Switched Path (LSP), while the base PCEP specification [RFC4655] originally defined the PCE architecture for MPLS and GMPLS networks with LSPs instantiated using the RSVP-TE signaling protocol. As specified in the Terminology Section of [RFC9603], the term "LSP" used in the PCEP specifications would be equivalent to an SRv6 path (represented as a list of SRv6 segments) in the context of supporting SRv6 in PCEP using the SRv6 Path Setup Type.

### 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. Overview

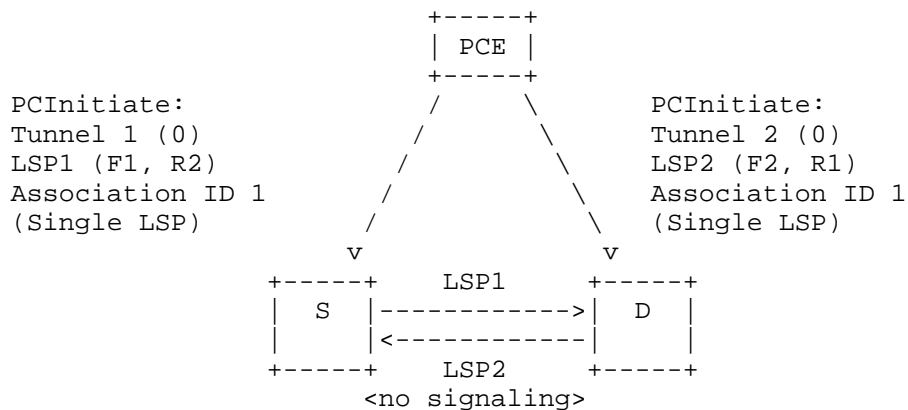
Associated bidirectional SR LSPs can be created and updated by a Stateful PCE or by a PCC as described in the sub-sections below for the case when there are no errors encountered and all operations are successful.

### 3.1. PCE-Initiated Associated Bidirectional SR LSPs

High-level steps for creating associated bidirectional SR LSPs by a Stateful PCE are shown in Figures 1a and 1b.

Step 1 - Stateful PCE Behaviour:

- \* Stateful PCE creates and updates the SR LSP and the associated reverse SR LSP EROs, for the 'Bidirectional SR LSP Association' with the association identifier 1 on a PCC via PCInitiate and PCUpd messages, respectively.



Legends: F1 and F2 = Forward LSP EROs, R1 and R2 = Reverse LSP EROs

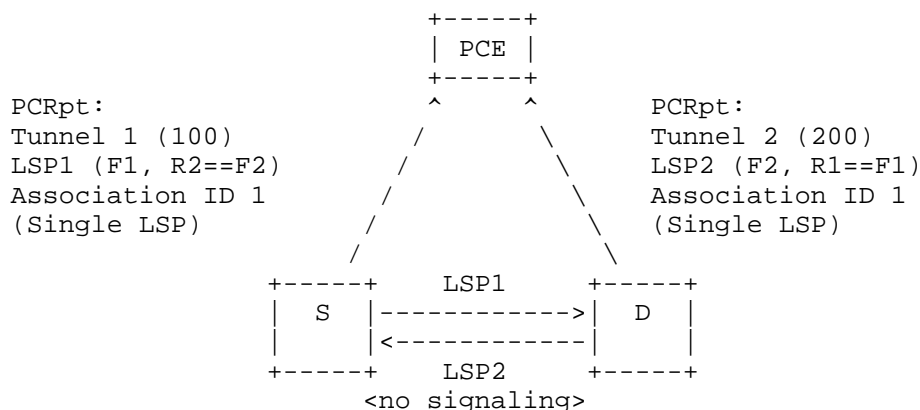
Legends: 0 = PLSP-ID

Legends: S = Source, D = Destination

Figure 1a: Step 1: PCE-Initiated Associated Bidirectional SR LSP  
with Forward Direction LSPs and Reverse Direction EROs

#### Step 2 - PCC Behaviour:

- \* The PCC, upon receiving the PCInitiate for the SR LSP and the associated reverse SR LSP EROs, locally assigns a PCEP-specific Identifier for the LSP (PLSP-ID) [RFC8231] and reports it to the PCE via a PCRpt message.



Legends: F1 and F2 = Forward LSP EROs, R1 and R2 = Reverse LSP EROs

Legends: 100 and 200 = PLSP-IDs

Legends: S = Source, D = Destination

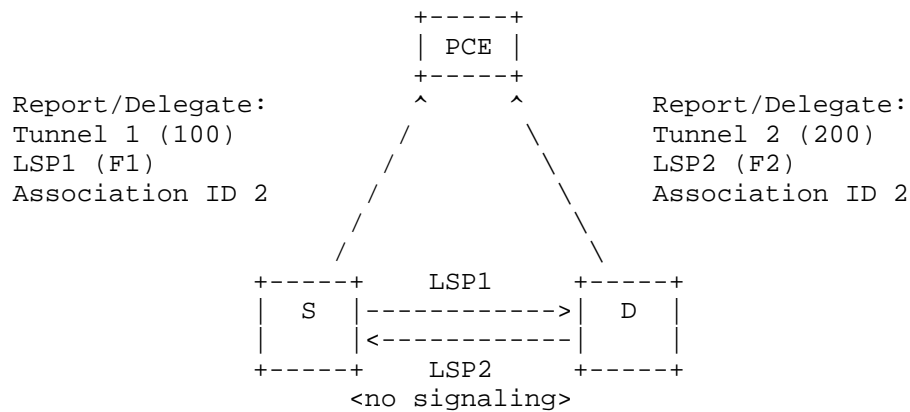
Figure 1b: Step 2: PCC-Reported Bidirectional SR LSP  
with Forward Direction LSPs and Reverse Direction EROs

### 3.2. PCC-Initiated Associated Bidirectional SR LSPs

High-level steps for creating associated bidirectional SR LSPs by a PCC are shown in Figures 2a and 2b.

Step 1 - PCC Behaviour:

- \* PCC creates and updates an SR LSP for the 'Bidirectional SR LSP Association' with the association identifier 2 and reports the change in the association group of an SR LSP to PCE(s) via a PCRpt message.



Legends: F1 and F2 = Forward LSP EROs

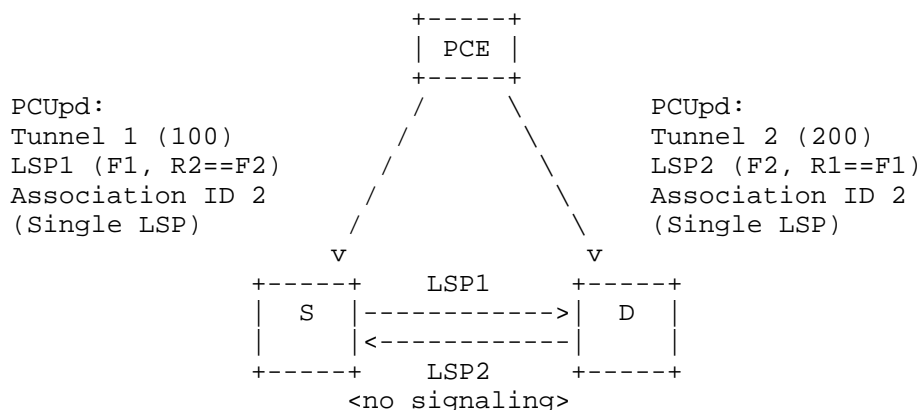
Legends: 100 and 200 = PLSP-IDs

Legends: S = Source, D = Destination

Figure 2a: Step 1: PCC-Initiated Associated Bidirectional SR LSP  
with Forward Direction LSPs

Step 2 - Stateful PCE Behaviour:

- \* Stateful PCE updates the SR LSP and the associated reverse SR LSP EROs, for the 'Bidirectional SR LSP Association' on a PCC via a PCUpd message.



Legends: F1 and F2 = Forward LSP EROs, R1 and R2 = Reverse LSP EROs

Legends: 100 and 200 = PLSP-IDs

Legends: S = Source, D = Destination

Figure 2b: Step 2: PCE-Updated Associated Bidirectional SR LSP  
with Forward Direction LSPs and Reverse Direction EROs

#### 4. PCEP Extensions

Two unidirectional SR LSPs (one in each direction between two nodes in a network) can be associated together by using the association group defined in this document for the PCEP messages and employing the procedures defined in [RFC9059] and [I-D.ietf-pce-multipath].

##### 4.1. Bidirectional SR LSP Association Group

For associating two unidirectional SR LSPs, this document defines a new Association Type called 'Bidirectional SR LSP Association' for the Association Group object (Class-Value 40) as follows:

\* Association Type (value 8) = Bidirectional SR LSP Association

The handling of the Association ID, Association Source, optional Global Association Source and optional Extended Association ID in this association are set as defined in [RFC8697].

[RFC8697] specifies the mechanism for the capability advertisement of the Association Types supported by a PCEP speaker by defining an ASSOC-Type-List TLV (value 35) to be carried within an OPEN object. The PCEP speaker MUST include the 'Bidirectional SR LSP Association' type in the ASSOC-Type-List TLV and MUST receive the same from the PCEP peer before using it in the PCEP messages.

An SR LSP MUST NOT be part of more than one 'Bidirectional SR LSP Association' on a PCE. A PCE, upon detecting this condition, MUST NOT send the associated reverse EROs to the ingress node PCC. This error condition MUST be logged and an alarm MUST be generated.

#### 4.2. Bidirectional LSP Association Group TLV

A PCEP message for an associated bidirectional SR LSP MAY include the 'Bidirectional LSP Association Group TLV' to indicate the co-routed path using the C flag defined in Section 4.2 of [RFC9059].

As there is no reverse SR LSP instantiated, the Reverse LSP (R flag) MUST NOT be set for an associated bidirectional SR LSP and MUST be ignored. This error condition MUST be logged and an alarm MUST be generated.

#### 4.3. PATH-ATTRIB Object

When a PCE informs an ingress node PCC about the associated reverse SR LSP EROs computed for an SR LSP with the 'Bidirectional SR LSP Association', it MUST include the 'PATH-ATTRIB' object with R flag (reverse LSP) set to 1 to indicate that the ERO is for the reverse direction [I-D.ietf-pce-multipath].

#### 4.4. MULTIPATH-OPPDIR-PATH TLV

The PCE MAY include the 'MULTIPATH-OPPDIR-PATH TLV' to indicate the co-routed path properties (in N and L flags) for the reverse ERO [I-D.ietf-pce-multipath] for an SR LSP.

The PCC MUST detect the mismatch between the co-routed path properties in the 'MULTIPATH-OPPDIR-PATH TLV' for the reverse ERO and the co-routed path (C) flag in the 'Bidirectional LSP Association Group TLV' for the (forward) SR LSP and log it as an error condition and generate an alarm.

### 5. Additional PCEP Considerations

Additional considerations for associating bidirectional SR LSPs are summarized in the sub-sections below.

### 5.1. PLSP-ID Usage

As per [RFC8231], an ingress node PCC reports a unique PLSP-ID for each LSP of an SR Policy. For an associated bidirectional SR LSP, the PCE will maintain two PLSP-IDs, one from the ingress node PCC and one from the egress node PCC. In the examples shown in Figure 1b and Figure 2a, the ingress node PCC (node S) reports the Tunnel 1, LSP1 to the PCE with PLSP-ID 100 whereas the egress node PCC (node D) reports the Tunnel 2, LSP2 to the PCE with PLSP-ID 200.

### 5.2. Error Handling

The error handling as described in Section 5.7 of [RFC9059] continues to apply for the 'Bidirectional SR LSP Association'.

The PCEP Path Setup Type (PST) for SR LSP uses either value "1: Traffic-engineering path is set up using Segment Routing" [RFC8664] or "3: Traffic engineering path is set up using SRv6" [RFC9603]. If a PCEP speaker receives a non-SR LSP PST value for the 'Bidirectional SR LSP Association', the PCEP speaker MUST return a PCErr message with Error-Type = 26 (Association Error) and Error-value = "16: Path Setup Type not supported" [RFC9059].

## 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.

- \* Organization: Huawei
- \* Implementation: Huawei's Commercial Delivery implementation based on VRP8.
- \* Description: The implementation is under development.
- \* Maturity Level: Product
- \* Contact: tanren@huawei.com

### 6.2. ZTE's Commercial Delivery

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- \* Implementation: ZTE's Commercial Delivery implementation based on Rosng v8.
- \* Description: The implementation is under development.
- \* Maturity Level: Product
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## 7. Security Considerations

The security considerations described in [RFC5440], [RFC8231], [RFC8281], [RFC8408], [RFC9059], and [I-D.ietf-pce-multipath] apply to the extensions defined in this document as well.

A new Association Type for the Association object, 'Bidirectional SR LSP Association' is introduced in this document. Additional security considerations related to LSP associations due to a malicious PCEP speaker are described in [RFC8697] and apply to this Association Type. Hence, securing the PCEP session using Transport Layer Security (TLS) [RFC8253] as per the recommendations and best current practices in [RFC9325].

## 8. Operational Considerations

The manageability requirements and considerations listed in [RFC5440], [RFC8231], [RFC8281], [RFC8697], and [I-D.ietf-pce-multipath] apply to the PCEP protocol extensions defined in this document. In addition, the operational requirements and considerations listed in this section apply.

### 8.1. Control of Function and Policy

The mechanisms defined in this document do not imply any new control or policy requirements.

### 8.2. Information and Data Models

[RFC7420] describes the PCEP MIB; there are no new MIB Objects defined for LSP associations.

The PCEP YANG module [RFC9826] defines a data model for LSP associations. However, it does not include information for associated bidirectional SR LSPs. It can be extended to include data related to the associated bidirectional SR LSPs, such as:

- \* Indication of whether the associated bidirectional SR LSPs are supported
- \* Enablement and disablement of the bidirectional SR LSP association
- \* Counters for the successfully associated bidirectional SR LSPs
- \* Counters for the SR LSPs that failed to form a bidirectional association

### 8.3. Liveness Detection and Monitoring

Mechanisms defined in this document do not imply any new liveness detection and monitoring requirements as they are performed independently on both sides of a bidirectional SR LSP, using the forward and reverse LSP paths of the bidirectional SR LSP. However, the monitoring on both sides of a bidirectional SR LSP needs to be correlated at the management level to ensure that the bidirectional service carried by the bidirectional SR LSP is operational.

### 8.4. Verify Correct Operations

Mechanisms defined in this document do not imply any new operation verification requirements.

## 8.5. Requirements On Other Protocols

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

## 8.6. Impact On Network Operations

Associating two SR LSPs to form an associated bidirectional SR LSP requires an operator to ensure that the correct LSP associations are employed on both sides of the bidirectional SR LSP. Tools such as directed BFD [RFC9612] and Performance Measurement [RFC9503] can be used to verify the correct operation of a bidirectional SR LSP.

## 9. IANA Considerations

### 9.1. Association Type

This document defines a new Association Type, originally described in [RFC8697]. IANA is requested to update the value it has assigned through the early allocation process in the "ASSOCIATION Type Field" registry [RFC8697] within the "Path Computation Element Protocol (PCEP) Numbers" registry group, making it permanent:

Type	Name	Reference
8	Bidirectional SR LSP Association	[This document]

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