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Path Computation Element Communication Protocol (PCEP) Extensions for Associated Bidirectional Segment Routing (SR) Paths
draft-ietf-pce-sr-bidir-path-20

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) can be used to steer packets through a network employing the source routing paradigm. Stateful PCEP extensions for SR allow a PCE to maintain state and to control and initiate SR Traffic Engineering (TE) paths.

PCEP supports grouping of two unidirectional MPLS-TE Label Switched Paths (LSPs), signaled via RSVP-TE, using association. 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 are applicable to both stateless and stateful PCEs for PCE-initiated and PCC-initiated LSPs.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

Segment Routing (SR) [RFC8402] can be used to steer packets through a network employing the source routing paradigm. 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 [RFC9545] and [I-D.ietf-spring-srv6-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 (LSPs). [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].

[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 PCC to request, report or delegate them. As specified in [RFC8664], an SR path corresponds to an MPLS Label Switching Path (LSP) in PCEP when using the SR-TE path setup type. As specified in [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 SRv6 path setup type.

[RFC8697] introduces a generic mechanism to create a grouping of LSPs. This grouping can then be used to define associations between sets of LSPs or between a set of LSPs and a set of attributes, and it is equally applicable to the stateful PCE (active and passive modes) [RFC8231] and the stateless PCE [RFC5440].

For bidirectional SR paths, there are use-cases such as directed BFD [RFC9612] and Performance Measurement (PM) [RFC9503] that require the ingress node (PCC) to be aware of the reverse direction SR path. For such use-cases, the reverse SR paths need to be communicated to the ingress nodes (PCCs) using PCEP mechanisms. This allows both endpoint ingress nodes to be aware of the SR paths in both directions.

[RFC9059] defines PCEP extensions for grouping two unidirectional Resource Reservation Protocol - Traffic Engineering (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. Specifically, it defines the procedure for 'Double-Sided Bidirectional LSP Association', where the PCE creates the association and provisions the forward LSPs at their ingress nodes. The forward LSPs to the egress nodes are signaled using RSVP-TE. Thus, both endpoints learn the corresponding reverse LSPs forming the bidirectional LSP association via RSVP signaling.

An SR Policy contains one or more Candidate Paths (CPs) [RFC9256], which may be computed by a PCE. A Candidate Path of an SR Policy can contain one or more Segment Lists (SLs) [RFC9256]. When a Candidate Path is computed by the PCE, the PCE computes one or more Segment Lists for that Candidate Path. [I-D.ietf-pce-multipath] defines PCEP extensions for carrying multiple SLs in a Candidate Path. In PCEP messages, an SR path SL is encoded as an Explicit Route Object (ERO) as described in Section 4.3 of [RFC8664]. In case of multiple SLs of a CP, multiple EROs are encoded in a PCEP message along with their path properties as specified in [I-D.ietf-pce-multipath].

This document extends the bidirectional LSP association to SR paths by specifying PCEP extensions for grouping two unidirectional SR paths into an associated bidirectional SR path. [I-D.ietf-pce-multipath] defines PCEP extensions for carrying multiple SLs along with their opposite direction SLs for each CP of an SR Policy, as shown in an example in Section 6.4 (Opposite Direction Tunnels) in [I-D.ietf-pce-multipath]. The procedure defined in this document for associating the forward and reverse SR paths, works in conjunction with the procedure defined in [I-D.ietf-pce-multipath] that carries multiple EROs and the associated reverse path EROs for an LSP.

Note that the procedure for using the association group defined in this document is specific to the associated bidirectional SR paths. Associating a unidirectional SR path with a reverse direction unidirectional RSVP-TE LSP to form a bidirectional LSP is 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], [RFC9059], and [I-D.ietf-pce-multipath].

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 paths can be created and updated by a Stateful PCE or by a PCC using the procedures defined in [RFC8697] and [I-D.ietf-pce-multipath] as described in the sub-sections below.

3.1. PCE-Initiated Associated Bidirectional SR Paths

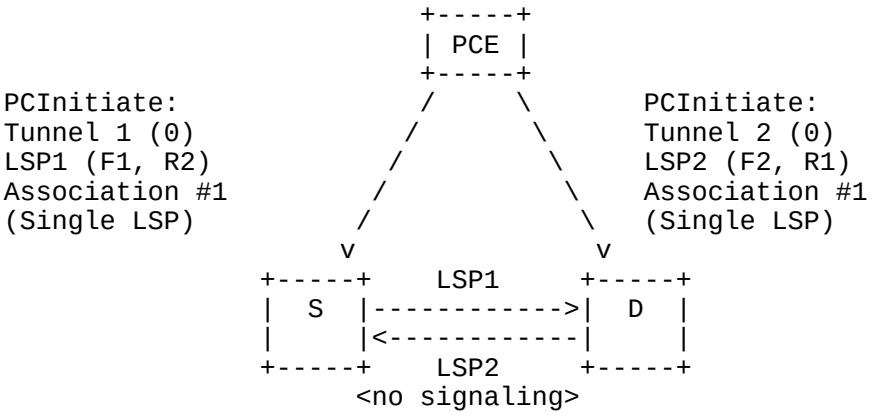
High-level steps for creating associated bidirectional SR paths by a Stateful PCE are shown in Figure 1.

Step 1 - Stateful PCE Behaviour:

* Stateful PCE creates and updates both the SR path EROs and the associated reverse SR path EROs, for the ’Double-Sided Bidirectional with Reverse LSP Association’ on a PCC via PCInitiate and PCUpd messages, respectively.

Step 2 - PCC Behaviour:

* The PCC upon receiving the PCInitiate for the SR path and the associated reverse SR path EROs, locally assigns a PLSP-ID and reports it to the PCE via a PCRpt message.



Legends: F=Forward LSP EROs, R=Reverse LSP EROs, (0)=PLSP-ID

Figure 1a: Step 1: PCE-Initiated Associated Bidirectional SR Path with Forward and Reverse Direction SR Paths

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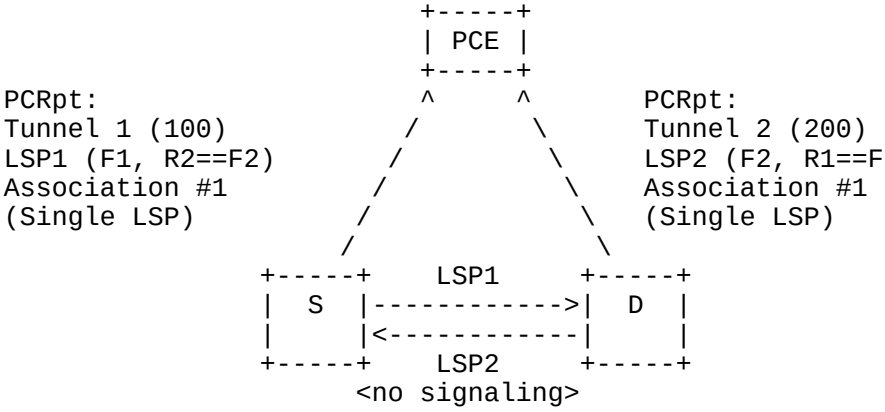


Legends: F=Forward LSP EROs, R=Reverse LSP EROs, (100,200)=PLSP-IDs

Figure 1b: Step 2: PCC-Reported Bidirectional SR Path with Forward and Reverse Direction SR Paths

3.2. PCC-Initiated Associated Bidirectional SR Paths

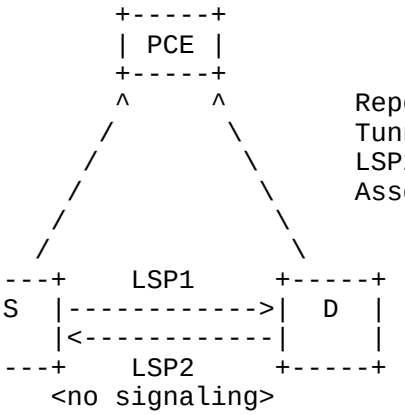
High-level steps for creating associated bidirectional SR paths by a PCC are shown in Figure 2.

Step 1 - PCC Behaviour:

* PCC creates and updates an SR path for the ’Double-Sided Bidirectional with Reverse LSP Association’ and reports the change in the association group of an SR path to PCE(s) via a PCRpt message.

Step 2 - Stateful PCE Behaviour:

* Stateful PCE updates both the SR path EROs and the associated reverse SR path EROs, for the ’Double-Sided Bidirectional with Reverse LSP Association’ on a PCC via a PCUpd message.



Legends: F=Forward LSP EROs, (100,200)=PLSP-IDs

Figure 2a: Step 1: PCC-Initiated Associated Bidirectional SR Path with Forward Direction SR Paths

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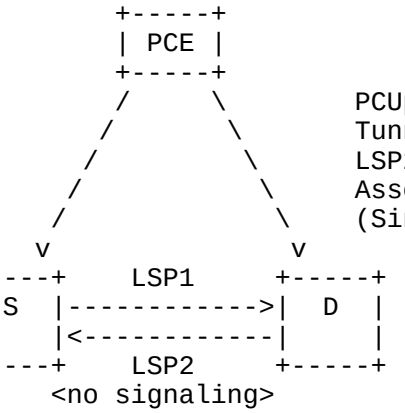

Legends: F=Forward LSP EROs, R=Reverse LSP EROs, (100,200)=PLSP-IDs

Figure 2b: Step 2: PCE-Updated Associated Bidirectional SR Path with Reverse Direction SR Paths

4. PCEP Extensions

As per [RFC8697], TE LSPs are associated by adding them to a common association group by a PCEP peer. [RFC9059] 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 a similar technique. This document extends these association mechanisms for bidirectional SR paths. Two unidirectional SR paths (one in each direction between two nodes in a network) can be associated together by using the association group defined in this document for PCEP messages.

4.1. Double-Sided Bidirectional with Reverse LSP Association

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

* Association Type (value 8) = Double-Sided Bidirectional with Reverse LSP Association

The bidirectional association can be either dynamic or operator-configured. As per [RFC8697], the association group could be manually created by the operator on the PCEP peers, and the LSP belonging to this association is conveyed to the PCEP peer; alternatively, the association group could be created dynamically by the PCEP speaker, and both the association group information and the LSP belonging to the association group is conveyed to the PCEP peer.

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. This capability exchange for the Bidirectional Association MUST be done before using the Bidirectional Association Type. Thus, the PCEP speaker MUST include the bidirectional Association Type in the ASSOC-Type-List TLV and MUST receive the same from the PCEP peer before using the Bidirectional Association in PCEP messages.

* An SR path (forward or reverse direction) MUST NOT be part of more than one "Double-Sided Bidirectional with Reverse LSP Association" on a PCE. A PCE, upon detecting this condition, MUST NOT send the associated reverse SR path EROs to the ingress node PCC. This error condition MUST be logged and an alarm MUST be generated.

* The endpoint nodes of the SR paths (forward and reverse direction) in "Double-Sided Bidirectional with Reverse LSP Association" MUST match in the reverse directions. Upon detecting a mismatch, the PCE speaker MUST return a PCErr message with Error-Type = 26 (Association Error) and Error-value = "19: Endpoint mismatch in the association group" [RFC9059].

4.2. Bidirectional LSP Association Group TLV

The 'Bidirectional LSP Association Group TLV' defined in Section 4.2 of [RFC9059] is also applicable to the 'Double-Sided Bidirectional with Reverse LSP Association' defined in this document. A PCEP message for an associated bidirectional SR path MAY include the 'Bidirectional LSP Association Group TLV' to indicate the co-routed path property using the C flag defined in Section 4.2 of [RFC9059]. The Reverse LSP (R flag) MUST NOT be set for the associated bidirectional SR path and MUST be ignored for this association group. The processing rules for this association group TLV are followed as described in Section 4.2 of [RFC9059].

4.3. PATH-ATTRIB Object

When a PCE informs an ingress node PCC about the associated reverse SR path EROs computed for an SR path with the 'Double-Sided Bidirectional with Reverse LSP Association', it MUST include the 'PATH-ATTRIB' object to indicate the reverse direction for each ERO, and it MAY optionally include the 'MULTIPATH-OPPDIR-PATH TLV' to indicate the co-routed path properties for the ERO using the procedure defined in Section 3 of [I-D.ietf-pce-multipath].

5. Additional PCEP Considerations

The PCEP extensions defined in this document for an associated bidirectional SR path are applicable to the three scenarios described in Section 5 of [RFC9059].

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

5.1. Stateless PCE

As defined in Section 5.3 of [RFC9059], 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 [RFC8697]. A PCC can request co-routed or non-co-routed forward and reverse direction SR paths from a stateless PCE for an associated bidirectional SR path using the 'Bidirectional Association Group TLV' as described in

Section 4.2 of [RFC9059].

5.2. Bidirectional (B) Flag

The Bidirectional (B) flag in the Request Parameters (RP) object [RFC5440] and Stateful PCE Request Parameter (SRP) object [RFC9504] follows the procedure defined in Section 5.4 of [RFC9059].

5.3. PLSP-ID Usage

For an SR Policy, the ingress PCC node reports a unique PLSP-ID [RFC8231] for each CP of the SR Policy.

For an associated bidirectional SR path, 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 1 and Figure 2, the ingress node PCC S reports the Tunnel 1, LSP1 to the PCE with PLSP-ID 100 whereas the egress node PCC D reports the Tunnel 2, LSP2 to the PCE with PLSP-ID 200.

5.4. Path Segment Identifier Applicability

[I-D.ietf-pce-sr-path-segment] defines a mechanism for communicating Path Segment Identifier (PSID) in PCEP for SR. The SR-MPLS PSID is defined in [RFC9545] and SRv6 PSID is defined in [I-D.ietf-spring-srv6-path-segment]. The PSID can be used to identify and correlate the traffic for the two unidirectional SR paths at both ends of an associated bidirectional SR path.

5.5. Error Handling

The error handling as described in Section 5.7 of [RFC9059] continues to apply for the "Double-Sided Bidirectional with Reverse LSP Association".

The PST for SR path is either "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 PST value for the "Double-Sided Bidirectional with Reverse LSP Association", the PCE 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

* Organization: ZTE
* Implementation: ZTE’s Commercial Delivery implementation based on Rosng v8.
* Description: The implementation is under development.
* Maturity Level: Product

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

7. Security Considerations

The security considerations described in [RFC5440], [RFC8231], [RFC8281], [RFC8408], and [I-D.ietf-pce-multipath] 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' 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. Manageability 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 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 associated bidirectional SR path information.

8.3. Liveness Detection and Monitoring

Mechanisms defined in this document do not imply any new liveness detection and monitoring requirements.

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 forward and reverse SR paths to form a bidirectional SR path requires an operator to ensure that the correct LSP associations are employed on both sides of the SR paths. New tools such as directed BFD [RFC9612] and Performance Measurement (PM) [RFC9503] can be used to verify the correct operation of a bidirectional SR path.

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	Double-Sided Bidirectional with Reverse LSP Association	[This document]

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