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Path Computation Element Communication Protocol (PCEP) Extensions for Associated Bidirectional Segment Routing (SR) Paths
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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 to allow a PCE to compute 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 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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This Internet-Draft will expire on 29 May 2026.

Table of Contents

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 [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 (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].

[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] which 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 node (PCCs) using PCEP mechanisms. This allows both endpoint ingress nodes to be aware of the SR Paths in both directions, including their status and all other path related information.

[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 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 paths by specifying PCEP extensions for grouping two unidirectional SR Paths into an associated bidirectional SR Path. Note that the procedure for using the association group defined in this document is specific to the associated bidirectional SR Paths. 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.

1.1. Bidirectional SR Policy Association

An SR Policy contains one or more SR Policy Candidate Paths (CPs) [RFC9256] where one or more Candidate Paths can be computed via PCE. Each CP maps to a unique PLSP-ID in PCEP and each LSP in a CP is identified using a unique LSP-ID. The two unidirectional Candidate Paths can be associated to form a bidirectional Candidate Path using the procedure defined in this document.

Each Candidate Path of an SR Policy can contain one or more Segment Lists (SLs) [RFC9256]. When a Candidate Path is computed by the PCE, it means that the PCE computed all SLs of that Candidate Path. [I-D.ietf-pce-multipath] defines a procedure for carrying multiple SLs in a Candidate Path. That procedure works at the SL level to identify the forward and the reverse direction SLs in a Candidate Path as shown in an Example in Section 7.4 (Opposite Direction Tunnels) in [I-D.ietf-pce-multipath]. Whereas the procedure defined in this document works at the Candidate Path level to identify the forward and the reverse direction LSPs of a Candidate Path in a bidirectional SR Policy.

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 [RFC9059].

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. [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 in the network) can be associated together by using the association group defined in this document for PCEP messages.

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

3.1. 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 LSPs belonging to this association are conveyed via PCEP messages to the PCEP peer; alternately, the association group could be created dynamically by the PCEP speaker, and both the association group information and the LSPs belonging to the association group are conveyed to the PCEP peer. The Operator-configured Association Range

MUST be set for this Association Type to mark a range of Association Identifiers that are used for operator-configured associations to avoid any Association Identifier clash within the scope of the Association Source (Refer to [RFC8697]). Specifically, for the PCE-initiated associated bidirectional SR Paths, the Association Type is dynamically created by the PCE on the PCE peers.

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.

A member of the ’Double-Sided Bidirectional with Reverse LSP Association’ can take the role of a forward or reverse direction SR Path and follow the similar rules as defined in Section 4.2 of [RFC9059] for LSPs.

* An SR Path (forward or reverse) MUST NOT be part of more than one ’Double-Sided Bidirectional with Reverse LSP Association’. A PCE, upon detecting this condition, MUST NOT send the reverse SR Path to ingress node PCC.

* The endpoint nodes of the SR Paths in ’Double-Sided Bidirectional with Reverse LSP Association’ MUST be matching in the reverse directions.

3.1.1. Bidirectional LSP Association Group TLV

When a PCE informs an ingress node PCC about the reverse SR Path using the ’Double-Sided Bidirectional with Reverse LSP Association’, it MUST include the ’Bidirectional LSP Association Group TLV’ to indicate the reverse direction and the co-routed path properties as defined in Section 4.2 of [RFC9059]. All fields and processing rules for this association group are followed as per Section 4 of [RFC9059].

4. PCEP Procedure

The PCEP procedure defined in this document for an associated bidirectional SR Path is applicable to the three scenarios described in Section 5 of [RFC9059]. Note that the procedure in this document differs from the procedure defined in Section 5 of [RFC9059] where the ingress and egress node PCCs learn the reverse LSPs via RSVP signaling and report them to the PCE.

4.1. PCE-Initiated Associated Bidirectional SR Paths

Using the procedures defined in [RFC8697] and [RFC9059], associated bidirectional SR Paths can be created and updated by a Stateful PCE and is summarized below as Stateful PCE and PCC behaviours as a reminder.

Stateful PCE Behaviours:

* Stateful PCE MAY create and update the forward and reverse SR Paths independently for the ’Double-Sided Bidirectional with Reverse LSP Association’.

* Stateful PCE MUST create and update the SR Paths and their association on a PCC via PCInitiate and PCUpd messages, respectively, using the procedures described in [RFC8697].

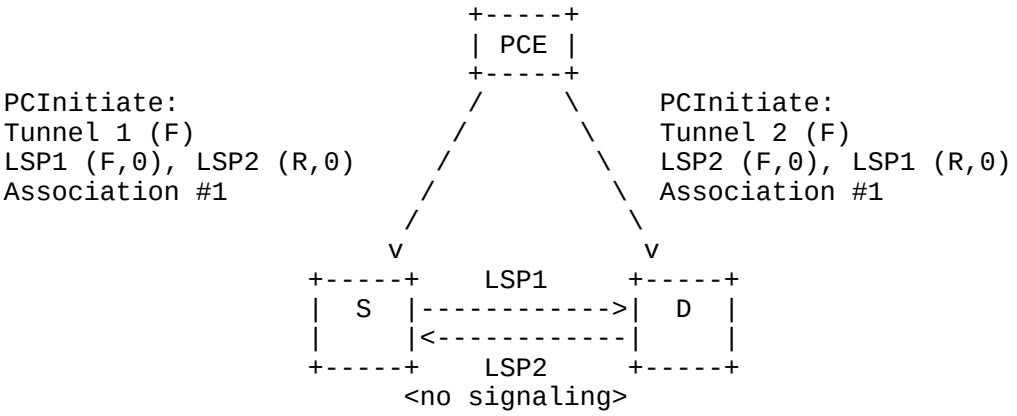
* The reverse direction SR Path SHOULD be informed by the Stateful PCE via PCInitiate message with the matching association group for the use-cases which require the PCC to be aware of the reverse direction SR Path.

PCC Behaviours:

* The PCC upon receiving the PCInitiate for reverse SR Path, MUST locally assign a new PLSP-ID and issue a PCRpt to the PCE containing the PLSP-ID.

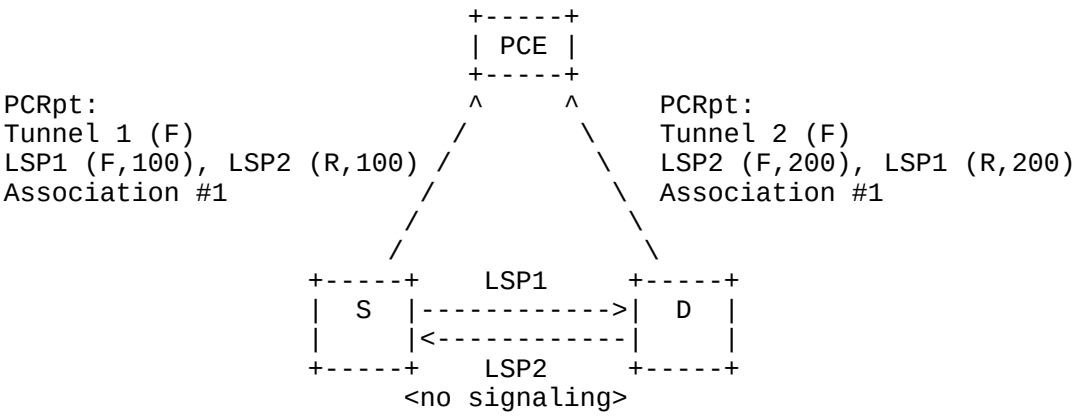
* PCC MUST NOT instantiate a reverse SR Path.

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



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

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



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

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

4.2. PCC-Initiated Associated Bidirectional SR Paths

Using the procedures defined in [RFC8697] and [RFC9059], associated bidirectional SR Paths can be created and updated by a PCC and and is summarized below as PCC and Stateful PCE behaviours as a reminder.

PCC Behaviours:

* PCC MAY create and update the forward SR Path and update the reverse SR Path independently for the 'Double-Sided Bidirectional with Reverse LSP Association'.

* PCC MUST NOT instantiate a reverse SR Path.

* PCC MAY establish and remove the association relationship for an SR Path.

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

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

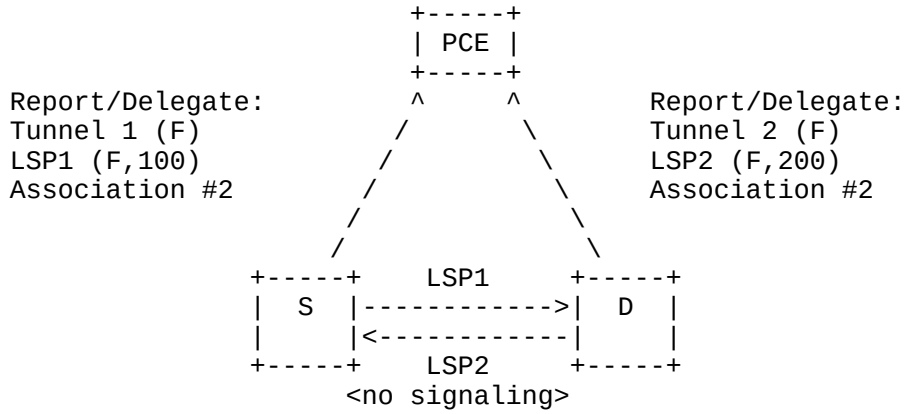
* The PCC upon receiving the PCInitiate for reverse SR Path, MUST locally assign a new PLSP-ID and issue a PCRpt to the PCE containing the PLSP-ID.

Stateful PCE Behaviours:

* Stateful PCE updates the SR Paths in the 'Double-Sided Bidirectional with Reverse LSP Association' via PCUpd message, using the procedures described in [RFC8697].

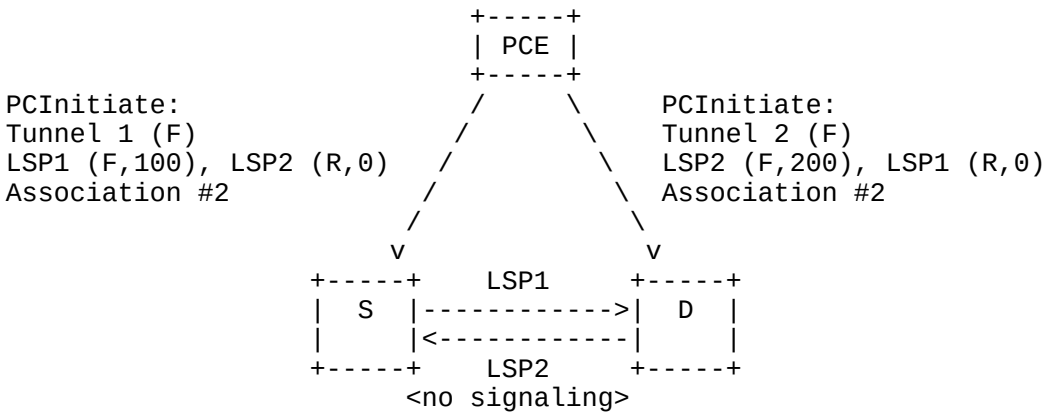
* The reverse direction SR Path SHOULD be informed by the Stateful PCE via PCInitiate message with the matching association group for the use-cases which require the PCC to be aware of the reverse direction SR Path.

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



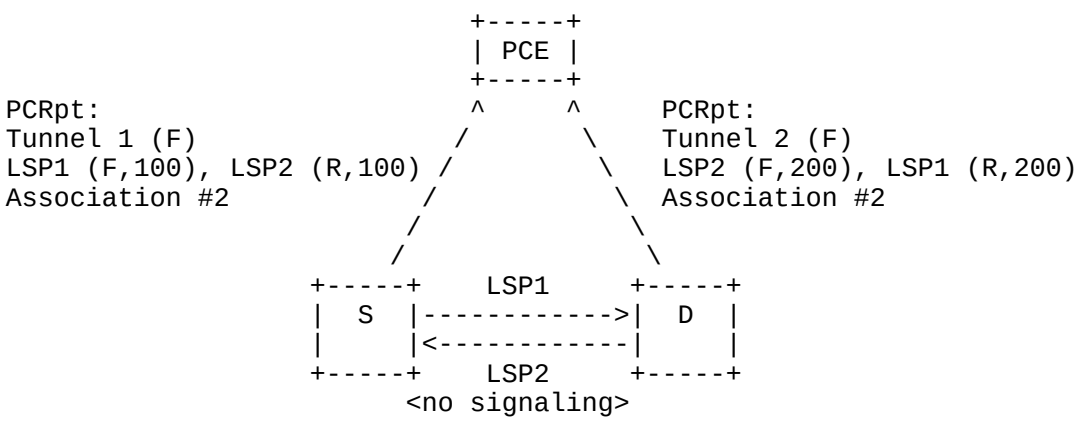
Legends: F = Forward LSP, R = Reverse LSP, (100,200) = PLSP-IDs

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



Legends: F = Forward LSP, R = Reverse LSP, (0,100,200) = PLSP-IDs

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



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

Figure 2c: Step 3: PCC-Reported Associated Bidirectional SR
Path with Reverse Direction SR Paths

4.3. 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 paths from a stateless PCE for a bidirectional SR Path.

4.4. Bidirectional (B) Flag

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

4.5. PLSP-ID Usage

For a bidirectional LSP computation when using both direction LSPs on a node, the LSPs on a node would need to be identified using the same PLSP-ID 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 might not be able to be used for the LSP at the ingress PCC (PLSP-ID conflict may occur). 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 bidirectional LSP.

In the examples shown in Figure 1 and Figure 2, the ingress PCC S may report to the PCE an LSP1 with PLSP-ID 100. The egress PCC D may report to the PCE an LSP2 with PLSP-ID 200. Both of these LSPs are part of a bidirectional LSP. When the PCE notifies PCC S of the reverse direction LSP2, it does so by sending a PCInitiate to PCC S with the PLSP-ID set to zero and the R bit set in the ’Bidirectional LSP Association Group TLV’. PCC S upon reception of this assigns a PLSP-ID (example PLSP-ID 100) and issues a PCRpt to the PCE. Thus, there would be two PLSP-IDs associated with LSP2 (100 at PCC S and 200 at PCC D).

For an associated bidirectional SR Path, the LSP-IDENTIFIERS TLV [RFC8231] MUST be included in all forward and reverse LSPs.

4.6. 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’.

[RFC9059] in Section 5.7, defines a PCErr message for the Path Setup Type (PST) of ’0: Path is set up using the RSVP-TE signaling protocol’ [RFC8408]. The PST for SR Path is set to ’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 an unsupported 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].

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.

* Organization: Huawei
* Implementation: Huawei’s Commercial Delivery implementation based on VRP8.
* Description: The implementation is under development.
* Maturity Level: Product

* Contact: tanren@huawei.com

5.2. 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

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’ 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] 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 LSP associations.

The PCEP YANG module [RFC9826] defines a data model for LSP associations. However, it does not include reverse LSP information.

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.

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.

8. IANA Considerations

8.1. 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]

9. References

9.1. Normative References

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