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PCEP Extensions for Associated Bidirectional Label Switched Paths (LSPs) draft-ietf-pce-association-bidir-04

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.

This document 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. The procedures defined are applicable to the LSPs using Resource Reservation Protocol (RSVP) for signaling.

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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Table of Contents

1. Introduction

[RFC5440] describes the Path Computation Element Protocol (PCEP) as a communication mechanism between a Path Computation Client (PCC) and a Path Control Element (PCE), or between PCE and PCC, that enables computation of Multiprotocol Label Switching (MPLS) Traffic Engineering (TE) Label Switched Paths (LSPs).

[RFC8231] specifies extensions to PCEP to enable stateful control of MPLS TE LSPs. It describes two modes of operation - Passive Stateful PCE and Active Stateful PCE. In [RFC8231], the focus is on Active Stateful PCE where LSPs are provisioned on the PCC and control over them is delegated to a PCE. Further, [RFC8281] describes the setup, maintenance and teardown of PCE-Initiated LSPs for the Stateful PCE model.

[I-D.ietf-pce-association] 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].

The MPLS Transport Profile (MPLS-TP) requirements document [RFC5654] specifies that MPLS-TP MUST support associated bidirectional point-to-point LSPs. [RFC7551] defines RSVP signaling extensions for binding two reverse unidirectional LSPs [RFC3209] into an associated bidirectional LSP. The fast reroute (FRR) procedures for associated bidirectional LSPs are described in [RFC8537].

This document defines PCEP extensions for grouping two reverse unidirectional MPLS-TE LSPs into an Associated Bidirectional LSP for both single-sided and double-sided initiation cases when using a Stateful (both active and passive modes) or Stateless PCE. The procedures defined are applicable to the LSPs using Resource Reservation Protocol (RSVP) for signaling [RFC3209]. The PCEP extensions cover the following cases:

- A PCC initiates the forward and/ or reverse LSP of a single-sided or double-sided bidirectional LSP and retains the control of the LSP. The PCC computes the path itself or makes a request for path computation to a PCE. After the path setup, it reports the information and state of the path to the PCE. This includes the association group identifying the bidirectional LSP. This is the Passive Stateful mode defined in [RFC8051].

- A PCC initiates the forward and/ or reverse LSP of a single-sided or double-sided bidirectional LSP and delegates the control of the LSP to a Stateful PCE. During delegation the association group identifying the bidirectional LSP is included. The PCE computes the path of the LSP and updates the PCC with the information about the path as long as it controls the LSP. This is the Active Stateful mode defined in [RFC8051].

- A PCE initiates the forward and/ or reverse LSP of a single-sided or double-sided bidirectional LSP on a PCC and retains the control of the LSP. The PCE is responsible for computing the path of the LSP and updating the PCC with the information about the path as well as the association group identifying the bidirectional LSP. This is the PCE-Initiated mode defined in [RFC8281].

- A PCC requests co-routed or non co-routed paths for forward and reverse LSPs of a bidirectional LSP from a Stateless PCE [RFC5440].

2. Conventions Used in This Document

2.1. Key Word Definitions

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.

2.2. Terminology

The reader is assumed to be familiar with the terminology defined in [RFC5440], [RFC7551], [RFC8231], and [I-D.ietf-pce-association].

3. Overview

As shown in Figure 1, two reverse unidirectional LSPs can be grouped to form an associated bidirectional LSP. There are two methods of

initiating the bidirectional LSP association, single-sided and double-sided, as defined in [RFC7551] and described in the following sections.

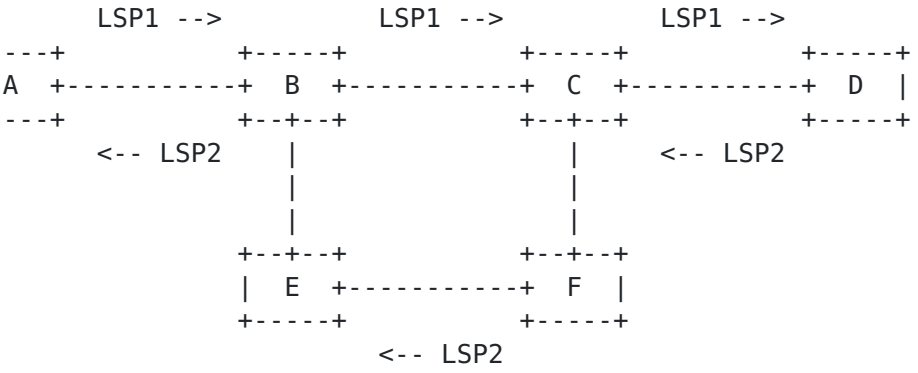


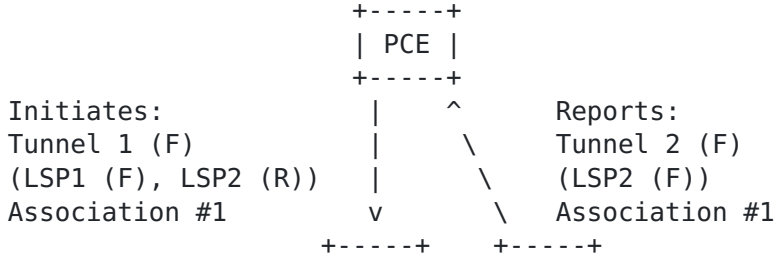
Figure 1: Example of Associated Bidirectional LSP

3.1. Single-sided Initiation

As specified in [RFC7551], in the single-sided case, the bidirectional tunnel is provisioned only on one endpoint node (PCC) of the tunnel. Both forward and reverse LSPs of this tunnel are initiated with the Association Type set to "Single-sided Bidirectional LSP Association" on the originating endpoint node. The forward and reverse LSPs are identified in the Bidirectional LSP Association Group TLV of their PCEP Association Objects.

The originating endpoint node signals the properties for the revere LSP in the RSVP REVERSE_LSP Object [RFC7551] of the forward LSP Path message. The remote endpoint then creates the corresponding reverse tunnel and signals the reverse LSP in response to the received RSVP Path message. Similarly, the remote endpoint node deletes the reverse LSP when it receives the RSVP Path delete message [RFC3209] for the forward LSP.

The originating endpoint (PCC) node may report/ delegate the forward and reverse direction LSPs to a PCE. The remote endpoint (PCC) node may report its forward direction LSP to a PCE.



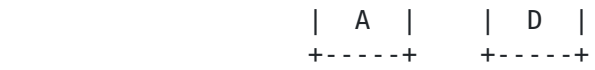


Figure 2A: Example of PCE-Initiated Single-sided Bidirectional LSP

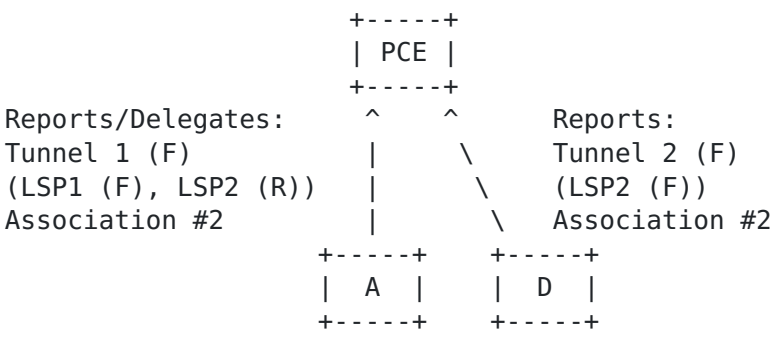


Figure 2B: Example of PCC-Initiated Single-sided Bidirectional LSP

As shown in Figures 2A and 2B, the forward tunnel and both forward LSP1 and reverse LSP2 are initiated on the originating endpoint node A, either by the PCE or the originating PCC, respectively. The originating endpoint node A signals the properties of reverse LSP2 in the RSVP REVERSE_LSP Object in the Path message of the forward LSP1. The creation of reverse tunnel and reverse LSP2 on the remote endpoint node D is triggered by the RSVP signaled forward LSP1.

As specified in [RFC8537], for fast reroute bypass tunnel assignment, the LSP starting from the originating node is identified as the forward LSP of the single-sided initiated bidirectional LSP.

3.2. Double-sided Initiation

As specified in [RFC7551], in the double-sided case, the bidirectional tunnel is provisioned on both endpoint nodes (PCCs) of the tunnel. The forward and reverse LSPs of this tunnel are initiated with the Association Type set to "Double-sided Bidirectional LSP Association" on both endpoint nodes. The forward and reverse LSPs are identified in the Bidirectional LSP Association Group TLV of their Association Objects.

The endpoint (PCC) nodes may report/ delegate the forward and reverse direction LSPs to a PCE.

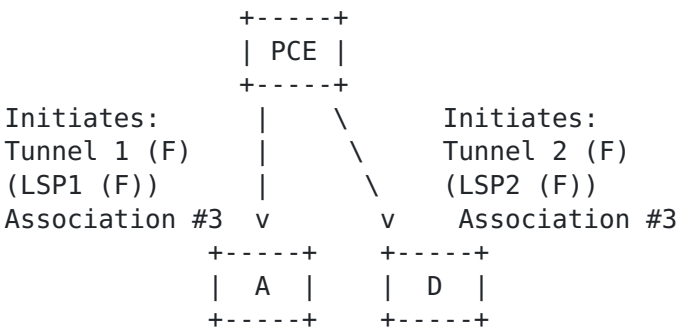


Figure 3A: Example of PCE-Initiated Double-sided Bidirectional LSP

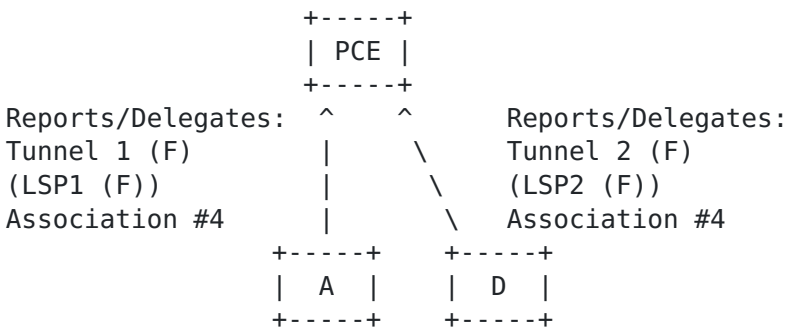


Figure 3B: Example of PCC-Initiated Double-sided Bidirectional LSP

As shown in Figures 3A and 3B, the forward tunnel and forward LSP1 are initiated on the endpoint node A and the reverse tunnel and reverse LSP2 are initiated on the endpoint node D, either by the PCE or the PCCs, respectively.

As specified in [RFC8537], for fast reroute bypass tunnel assignment, the LSP with the higher Source Address [RFC3209] is identified as the forward LSP of the double-sided initiated bidirectional LSP.

3.3. Co-routed Associated Bidirectional LSP

In both single-sided and double-sided initiation cases, forward and reverse LSPs may be co-routed as shown in Figure 4, where both forward and reverse LSPs of a bidirectional LSP follow the same congruent path in the forward and reverse directions, respectively.

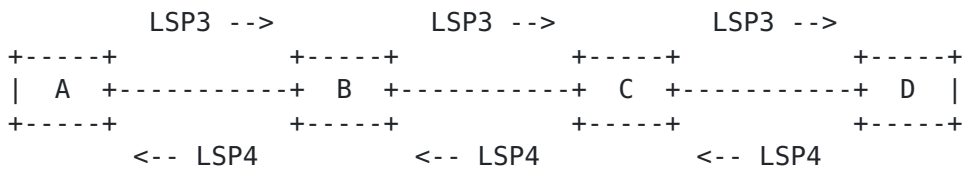


Figure 4: Example of Co-routed Associated Bidirectional LSP

4. Protocol Extensions

4.1. Association Object

As per [I-D.ietf-pce-association], LSPs are associated by adding them to a common association group. This document defines two new Bidirectional LSP Association Groups to be used by the associated bidirectional LSPs. A member of the Bidirectional LSP Association Group can take the role of a forward or reverse LSP and follows the following rules:

- An LSP (forward or reverse) can not be part of more than one Bidirectional LSP Association Group. More than one forward LSP and/ or reverse LSP can be part of a Bidirectional LSP Association Group.

- The Tunnel (as defined in [RFC3209]) of forward and reverse LSPs of the single-sided bidirectional LSP association on the originating node MUST be the same.

This document defines two new Association Types for the Association Object as follows:

- Association Type (TBD1) = Single-sided Bidirectional LSP Association Group

- Association Type (TBD2) = Double-sided Bidirectional LSP Association Group

These Association Types are operator-configured associations in nature and statically created by the operator on the PCEP peers. The LSP belonging to these associations is conveyed via PCEP messages to the PCEP peer. Operator-configured Association Range TLV [I-D.ietf-pce-association] 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 Association ID, Association Source, optional Global Association

Source and optional Extended Association ID in the Bidirectional LSP Association Group Object are initialized using the procedures defined in [I-D.ietf-pce-association] and [RFC7551].

4.2. Bidirectional LSP Association Group TLV

The Bidirectional LSP Association Group TLV is defined for use with the Single-sided and Double-sided Bidirectional LSP Association Group Object Types.

- The Bidirectional LSP Association Group TLV follows the PCEP TLV format from [RFC5440].
- The Type (16 bits) of the TLV is TBD3, to be assigned by IANA.
- The Length is 4 Bytes.
- The value comprises of a single field, the Bidirectional LSP Association Flags (32 bits), where each bit represents a flag option.
- If the Bidirectional LSP Association Group TLV is missing, it means the LSP is the forward LSP and it is not co-routed LSP.
- For co-routed LSPs, this TLV MUST be present.
- For reverse LSPs, this TLV MUST be present.
- The Bidirectional LSP Association Group TLV MUST NOT be present more than once. If it appears more than once, only the first occurrence is processed and any others MUST be ignored.

The format of the Bidirectional LSP Association Group TLV is shown in Figure 5:

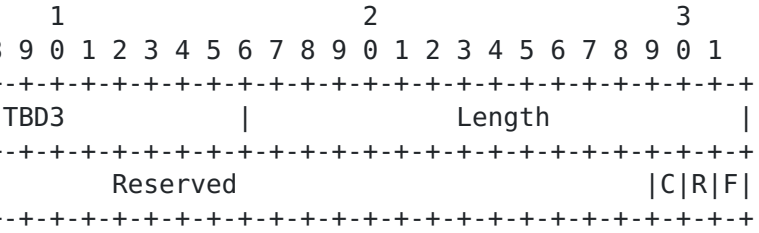


Figure 5: Bidirectional LSP Association Group TLV format

Bidirectional LSP Association Flags are defined as following.

F (Forward LSP, 1 bit) - Indicates whether the LSP associated is the forward LSP of the bidirectional LSP. If this flag is set, the LSP is a forward LSP.

R (Reverse LSP, 1 bit) - Indicates whether the LSP associated is the reverse LSP of the bidirectional LSP. If this flag is set, the LSP is a reverse LSP.

C (Co-routed LSP, 1 bit) - Indicates whether the bidirectional LSP is co-routed. This flag MUST be set for both the forward and reverse LSPs of a co-routed bidirectional LSP.

The C flag is used by the PCE (for both Stateful and Stateless) to compute bidirectional paths of the forward and reverse LSPs of a co-routed bidirectional LSP.

The Reserved flags MUST be set to 0 when sent and MUST be ignored when received.

5. PCEP Procedure

5.1. PCE Initiated LSPs

As specified in [I-D.ietf-pce-association], the Bidirectional LSP Association Groups can be created by a Stateful PCE.

- Stateful PCE can create and update the forward and reverse LSPs independently for both single-sided and double-sided bidirectional LSP association groups.

- Stateful PCE can establish and remove the association relationship on a per LSP basis.

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

5.2. PCC Initiated LSPs

As specified in [I-D.ietf-pce-association], Bidirectional LSP Association Groups can also be created by a PCC.

- PCC can create and update the forward and reverse LSPs independently for both single-sided and double-sided bidirectional LSP association groups.

- PCC can establish and remove the association relationship on a per

LSP basis.

- PCC MUST report the change in the association group of an LSP to PCE(s) via PCRpt message.
- PCC can report the forward and reverse LSPs independently to PCE(s) via PCRpt message.
- PCC can delegate the forward and reverse LSPs independently to a Stateful PCE, where PCE would control the LSPs. For single-sided case, originating (PCC) node can delegate both forward and reverse LSPs of a tunnel together to a Stateful PCE in order to avoid any race condition.
- Stateful PCE can update the LSPs in the bidirectional LSP association group via PCUpd message, using the procedures described in [I-D.ietf-pce-association].

5.3. Stateless PCE

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 LSP association group.

5.4. Bidirectional (B) Flag

As defined in [RFC5440], the Bidirectional (B) flag in the Request Parameters (RP) object is set when the PCC specifies that the path computation request is for a bidirectional TE LSP with the same TE requirements (e.g. latency) in each direction. For an associated bidirectional LSP, the B-flag MAY be set when the PCC makes the path computation request for the same TE requirements in the forward and reverse directions. When a stateful PCE initiates or updates the bidirectional LSPs, the B-flag in Stateful PCE Request Parameters (SRP) object [RFC8231] MAY also be set.

5.5. PLSP-ID Usage

As defined in [RFC8231], a PCEP-specific LSP Identifier (PLSP-ID) is created by a PCC to uniquely identify each LSP and is constant for the lifetime of a PCEP session.

In case of single-sided bidirectional LSP association, the reverse LSP of a bidirectional LSP on the originating node is identified using 2 different PLSP-IDs based on the PCEP session on the ingress

or egress nodes for the LSP. In other words, the reverse LSP on the originating node will have a PLSP-ID A at the ingress node while it will have a PLSP-ID B at the egress node. This is not the case for the forward LSP of the single-sided bidirectional LSP on the originating node and there is no change in the PLSP-ID allocation for it.

In case of double-sided bidirectional LSP association, there is no change in the PLSP-ID allocation.

For an Associated Bidirectional LSP, LSP-IDENTIFIERS TLV [RFC8231] MUST be included in all forward and reverse LSPs.

5.6. State Synchronization

During state synchronization, a PCC MUST report all the existing bidirectional LSP association groups to the Stateful PCE as per [I-D.ietf-pce-association]. After the state synchronization, the PCE MUST remove all stale bidirectional LSP associations.

5.7. Error Handling

An LSP (forward or reverse) can not be part of more than one Bidirectional LSP Association Group. If a PCE attempts to add an LSP not complying to this rule, the PCC MUST send PCErr with Error-Type = 29 (Early allocation by IANA) (Association Error) and Error-Value = TBD4 (Bidirectional LSP Association - Group Mismatch). Similarly, if a PCC attempts to add an LSP at PCE not complying to this rule, the PCE MUST send this PCErr.

The LSPs (forward or reverse) in a single-sided bidirectional LSP association group MUST belong to the same TE Tunnel (as defined in [RFC3209]). If a PCE attempts to add an LSP in a single-sided bidirectional LSP association group for a different Tunnel, the PCC MUST send PCErr with Error-Type = 29 (Early allocation by IANA) (Association Error) and Error-Value = TBD5 (Bidirectional LSP Association - Tunnel Mismatch). Similarly, if a PCC attempts to add an LSP to a single-sided bidirectional LSP association group at PCE not complying to this rule, the PCE MUST send this PCErr.

The PCEP Path Setup Type (PST) MUST be set to 'Path is set up using the RSVP-TE signaling protocol' (Value 0) [RFC8408] for the LSP belonging to the Bidirectional LSP Association Groups defined in this document. In case a PCEP speaker receives a different PST value for this association group, it MUST return a PCErr message with Error-Type = 29 (Early allocation by IANA) (Association Error) and Error-Value = TBD6 (Bidirectional LSP Association - Path Setup Type Mismatch).

The processing rules as specified in Section 5.4 of [I-D.ietf-pce-association] continue to apply for the Association Types defined in this document.

6. Implementation Status

[Note to the RFC Editor - remove this section before publication, as well as remove the reference to RFC 7942.]

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. Implementation

The PCEP extensions defined in this document has been implemented by a vendor on their product. No further information is available at this time.

7. Security Considerations

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

Two new Association Types for the Association Object, Single-sided Bidirectional LSP Association Group and Double-sided Associated Bidirectional LSP Group are 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] and apply to these Association Types. Hence, securing the PCEP session

using Transport Layer Security (TLS) [RFC8253] is recommended.

8. Manageability Considerations

8.1. 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].

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 [I-D.ietf-pce-pcep-yang] defines data model for LSP associations.

8.3. Liveness Detection and Monitoring

The 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].

8.4. Verify Correct Operations

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

8.5. Requirements On Other Protocols

The mechanisms defined in this document do not add any new requirements on other protocols.

8.6. Impact On Network Operations

The mechanisms defined in this document do not have any impact on network operations in addition to those already listed in [RFC5440], [RFC8231], and [RFC8281].

9. IANA Considerations

9.1. Association Types

This document adds new Association Types for the Association Object

defined [I-D.ietf-pce-association]. IANA is requested to make the assignment of values for the sub-registry "ASSOCIATION Type Field" (to be created in [I-D.ietf-pce-association]), as follows:

Value	Name	Reference
TBD1	Single-sided Bidirectional LSP Association Group	[This document]
TBD2	Double-sided Bidirectional LSP Association Group	[This document]

9.2. Bidirectional LSP Association Group TLV

This document defines a new TLV for carrying additional information of LSPs within a Bidirectional LSP Association Group. IANA is requested to add the assignment of a new value in the existing "PCEP TLV Type Indicators" registry as follows:

TLV-Type	Name	Reference
TBD3	Bidirectional LSP Association Group TLV	[This document]

9.2.1. Flag Fields in Bidirectional LSP Association Group TLV

This document requests that a new sub-registry, named "Bidirectional LSP Association Group TLV Flag Field", is created within the "Path Computation Element Protocol (PCEP) Numbers" registry to manage the Flag field in the Bidirectional LSP Association Group TLV. New values are to be assigned by Standards Action [RFC8126]. Each bit should be tracked with the following qualities:

- Bit number (count from 0 as the most significant bit)
- Description
- Reference

The following values are defined in this document for the Flag field.

Bit No.	Description	Reference
31	F - Forward LSP	[This document]
30	R - Reverse LSP	[This document]
29	C - Co-routed LSP	[This document]

9.3. 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: TBD4 Bidirectional LSP Association - Group Mismatch	[This document]
	Error value: TBD5 Bidirectional LSP Association - Tunnel Mismatch	[This document]
	Error value: TBD6 Bidirectional LSP Association - Path Setup Type Mismatch	[This document]

10. References

10.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997.

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[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8231] Crabbe, E., Minei, I., Medved, J., and R. Varga, "Pah Computation Element Communication Protocol (PCEP) Extensions for Stateful PCE", RFC 8231, DOI 10.17487/RFC8231, September 2017.

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10.2. Informative References

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[RFC7420] Koushik, A., Stephan, E., Zhao, Q., King, D., and J. Hardwick, "Path Computation Element Communication Protocol (PCEP) Management Information Base (MIB) Module", RFC 7420, December 2014.

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