PCE Working Group
Internet-Draft
Intended status: Standards Track
Expires: 8 August 2026

C. Li
M. Chen
Huawei Technologies
W. Cheng
China Mobile
R. Gandhi
Cisco Systems, Inc.
Q. Xiong
ZTE Corporation
4 February 2026

Path Computation Element Communication Protocol (PCEP) Extensions for Associated Bidirectional Segment Routing (SR) LSPs
draft-ietf-pce-sr-bidir-path-21

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. SR can be applied to both MPLS (SR-MPLS) and IPv6 (SRv6) data planes. Stateful PCEP extensions for SR allow a PCE to maintain state and to control and initiate SR Traffic Engineering (TE) LSPs.

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 LSPs (one in each direction in the network) into a single associated bidirectional SR LSP. 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.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Copyright Notice

Table of Contents

1. Introduction

Segment Routing (SR) [RFC8402] can be used to steer packets through a network employing the source routing paradigm. 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. [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.

There are some applications that require bidirectional paths in SR networks, for example, such as in mobile backhaul transport networks. 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. This document extends this procedure and allows to group two unidirectional SR LSPs into an associated bidirectional SR LSP. 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, PCEP speaker.

This document uses the following term defined in [RFC3031]:

Label Switched Path (LSP).

Note that the base PCEP specification [RFC4655] originally defined the use of the PCE architecture for MPLS and GMPLS networks with LSPs instantiated using the RSVP-TE signaling protocol. Over time, support for additional path setup types, such as SR-TE Path Setup Type [RFC8664] and SRv6 Path Setup Type [RFC9603], have been introduced. 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.

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.

3.1. PCE-Initiated Associated Bidirectional SR LSPs

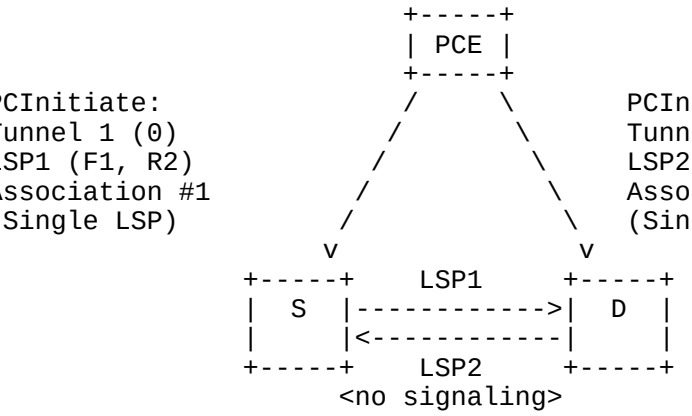
High-level steps for creating associated bidirectional SR LSPs by a Stateful PCE are shown in Figure 1.

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’ on a PCC via PCInitiate and PCUpd messages, respectively.

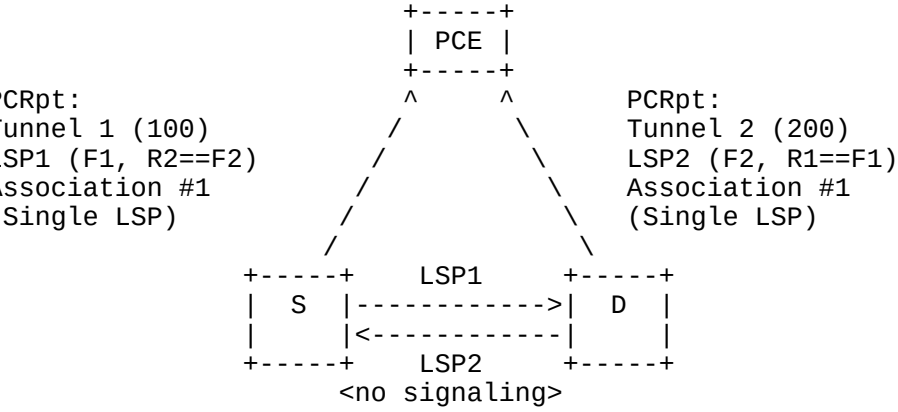
Step 2 - PCC Behaviour:

* The PCC upon receiving the PCInitiate for the SR LSP and the associated reverse SR LSP 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 LSP
with Forward Direction LSPs and Reverse Direction EROs



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

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

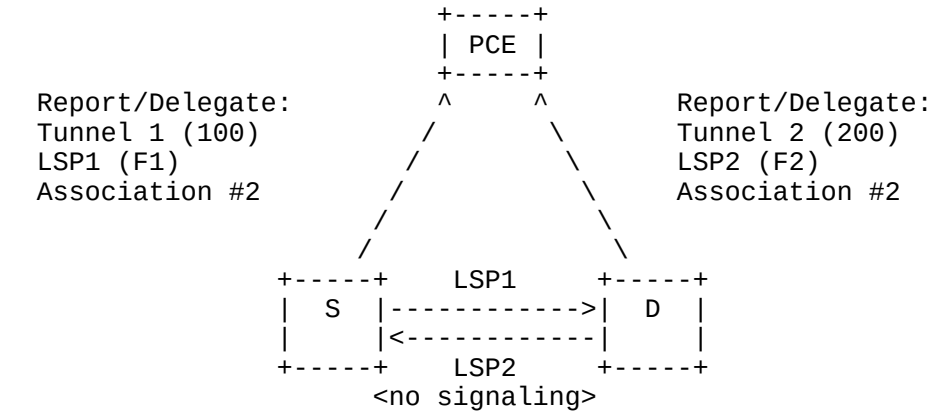
High-level steps for creating associated bidirectional SR LSPs by a PCC are shown in Figure 2.

Step 1 - PCC Behaviour:

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

Step 2 - Stateful PCE Behaviour:

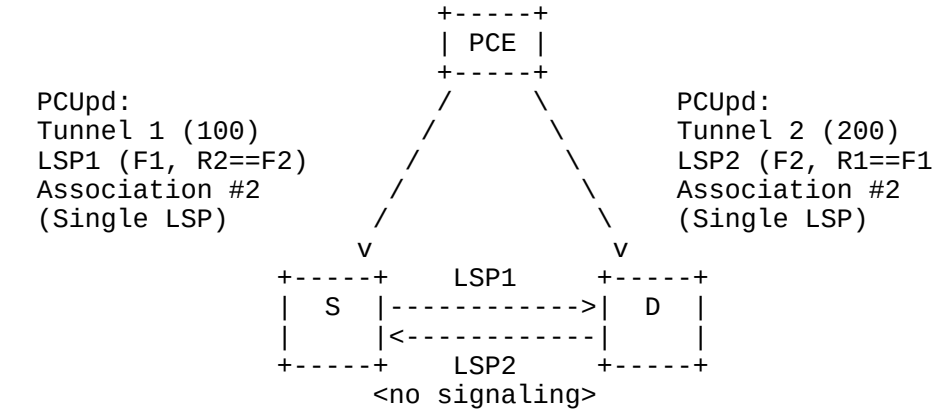
* Stateful PCE updates the SR LSP and the associated reverse SR LSP EROs, for the ’Bidirectional SR LSP Association’ on a PCC via a PCUpd message.



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

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

---



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

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 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 them 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 generate an alarm.

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 (reverse) flag 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 of 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 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 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.

5.2. Error Handling

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

The 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 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], [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. 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 information for associated bidirectional SR LSPs.

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 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. New 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]

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, <https://www.rfc-editor.org/info/rfc2119>.

[RFC5440] Vasseur, JP., Ed. and JL. Le Roux, Ed., "Path Computation Element (PCE) Communication Protocol (PCEP)", RFC 5440, DOI 10.17487/RFC5440, March 2009, <https://www.rfc-editor.org/info/rfc5440>.

[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, "Path Computation Element Communication Protocol (PCEP) Extensions for Stateful PCE", RFC 8231, DOI 10.17487/RFC8231, September 2017, <https://www.rfc-editor.org/info/rfc8231>.

[RFC8253] Lopez, D., Gonzalez de Dios, O., Wu, Q., and D. Dhody, "PCEPS: Usage of TLS to Provide a Secure Transport for the Path Computation Element Communication Protocol (PCEP)", RFC 8253, DOI 10.17487/RFC8253, October 2017, <https://www.rfc-editor.org/info/rfc8253>.

[RFC8281] Crabbe, E., Minei, I., Sivabalan, S., and R. Varga, "Path Computation Element Communication Protocol (PCEP) Extensions for PCE-Initiated LSP Setup in a Stateful PCE Model", RFC 8281, DOI 10.17487/RFC8281, December 2017, <https://www.rfc-editor.org/info/rfc8281>.

[RFC8402] Filsfils, C., Ed., Previdi, S., Ed., Ginsberg, L., Decraene, B., Litkowski, S., and R. Shakir, "Segment Routing Architecture", RFC 8402, DOI 10.17487/RFC8402, July 2018, <https://www.rfc-editor.org/info/rfc8402>.

[RFC8408] Sivabalan, S., Tantsura, J., Minei, I., Varga, R., and J. Hardwick, "Conveying Path Setup Type in PCE Communication Protocol (PCEP) Messages", RFC 8408, DOI 10.17487/RFC8408, July 2018, <https://www.rfc-editor.org/info/rfc8408>.

[RFC8664] Sivabalan, S., Filsfils, C., Tantsura, J., Henderickx, W., and J. Hardwick, "Path Computation Element Communication Protocol (PCEP) Extensions for Segment Routing", RFC 8664, DOI 10.17487/RFC8664, December 2019, <https://www.rfc-editor.org/info/rfc8664>.

[RFC8697] Minei, I., Crabbe, E., Sivabalan, S., Ananthakrishnan, H., Dhody, D., and Y. Tanaka, "Path Computation Element Communication Protocol (PCEP) Extensions for Establishing Relationships between Sets of Label Switched Paths (LSPs)", RFC 8697, DOI 10.17487/RFC8697, January 2020, <https://www.rfc-editor.org/info/rfc8697>.

[RFC9059] Gandhi, R., Ed., Barth, C., and B. Wen, "Path Computation Element Communication Protocol (PCEP) Extensions for Associated Bidirectional Label Switched Paths (LSPs)", RFC 9059, DOI 10.17487/RFC9059, June 2021, <https://www.rfc-editor.org/info/rfc9059>.

[RFC9256] Filsfils, C., Talaulikar, K., Ed., Voyer, D., Bogdanov, A., and P. Mattes, "Segment Routing Policy Architecture", RFC 9256, DOI 10.17487/RFC9256, July 2022, <https://www.rfc-editor.org/info/rfc9256>.

[RFC9325] Sheffer, Y., Saint-Andre, P., and T. Fossati, "Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", BCP 195, RFC 9325, DOI 10.17487/RFC9325, November 2022, <https://www.rfc-editor.org/info/rfc9325>.

[I-D.ietf-pce-multipath] Koldychev, M., Sivabalan, S., Saad, T., Beeram, V. P., Bidgoli, H., Peng, S., and S. Sidor, "Path Computation Element Communication Protocol (PCEP) Extensions for Signaling Multipath Information", Work in Progress, Internet-Draft, draft-ietf-pce-multipath-19, 2 February 2026, <https://datatracker.ietf.org/doc/html/draft-ietf-pce-multipath-19>.

10.2. Informative References

[RFC3031] Rosen, E., Viswanathan, A., and R. Callon, "Multiprotocol Label Switching Architecture", RFC 3031, DOI 10.17487/RFC3031, January 2001, <https://www.rfc-editor.org/info/rfc3031>.

[RFC4655] Farrel, A., Vasseur, J.-P., and J. Ash, "A Path Computation Element (PCE)-Based Architecture", RFC 4655, DOI 10.17487/RFC4655, August 2006, <https://www.rfc-editor.org/info/rfc4655>.

[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, DOI 10.17487/RFC7420, December 2014, <https://www.rfc-editor.org/info/rfc7420>.

[RFC7942] Sheffer, Y. and A. Farrel, "Improving Awareness of Running Code: The Implementation Status Section", BCP 205, RFC 7942, DOI 10.17487/RFC7942, July 2016, <https://www.rfc-editor.org/info/rfc7942>.

[RFC9503] Gandhi, R., Ed., Filsfils, C., Chen, M., Janssens, B., and R. Foote, "Simple Two-Way Active Measurement Protocol (STAMP) Extensions for Segment Routing Networks", RFC 9503, DOI 10.17487/RFC9503, October 2023, <https://www.rfc-editor.org/info/rfc9503>.

[RFC9603] Li, C., Ed., Kaladharan, P., Sivabalan, S., Koldychev, M., and Y. Zhu, "Path Computation Element Communication Protocol (PCEP) Extensions for IPv6 Segment Routing", RFC 9603, DOI 10.17487/RFC9603, July 2024, <https://www.rfc-editor.org/info/rfc9603>.

[RFC9612] Mirsky, G., Tantsura, J., Varlashkin, I., and M. Chen, "Bidirectional Forwarding Detection (BFD) Reverse Path for MPLS Label Switched Paths (LSPs)", RFC 9612, DOI 10.17487/RFC9612, July 2024, <https://www.rfc-editor.org/info/rfc9612>.

[RFC9826] Dhody, D., Ed., Beeram, V., Hardwick, J., and J. Tantsura, "A YANG Data Model for the Path Computation Element Communication Protocol (PCEP)", RFC 9826, DOI 10.17487/RFC9826, September 2025, <https://www.rfc-editor.org/info/rfc9826>.

Acknowledgments

Many thanks to Marina Fizgeer, Adrian Farrel, Andrew Stone, Tarek Saad, Samuel Sidor, and Mike Koldychev for the detailed review of this document and for providing many useful comments. Also, thank you, John Scudder, for the RtgDir Early review, Carlos Pignataro for the OpsDir review, Dhruv Dhody for the Shepherd review, Ketan Talaulikar for the WG AD review, which helped improve this document.

Contributors

The following people have substantially contributed to this document:

Dhruv Dhody
Huawei Technologies
Divyashree Techno Park, Whitefield
Bangalore, Karnataka 560066
India

Email: dhruv.ietf@gmail.com

Zhenbin Li
Huawei Technologies
Huawei Campus, No. 156 Beiqing Rd.
Beijing 100095
China

Email: lizhenbin@huawei.com

Jie Dong
Huawei Technologies
Huawei Campus, No. 156 Beiqing Rd.
Beijing 100095
China

Email: jie.dong@huawei.com

Authors' Addresses

Cheng Li
Huawei Technologies
Huawei Campus, No. 156 Beiqing Rd.
Beijing
100095
China
Email: c.l@huawei.com

Mach(Guoyi) Chen
Huawei Technologies
Huawei Campus, No. 156 Beiqing Rd.
Beijing
100095
China
Email: Mach.chen@huawei.com

Weiqiang Cheng
China Mobile
China
Email: chengweiqiang@chinamobile.com

Rakesh Gandhi
Cisco Systems, Inc.
Canada
Email: rgandhi@cisco.com

Quan Xiong
ZTE Corporation
China
Email: xiong.quan@zte.com.cn