
Stream: Internet Engineering Task Force (IETF)
RFC: 9353
Updates: 5088, 5089, 8231, 8306
Category: Standards Track
Published: January 2023
ISSN: 2070-1721
Authors: D. Lopez Q. Wu D. Dhody Q. Ma D. King
 Telefonica I+D *Huawei* *Huawei* *Huawei* *Old Dog Consulting*

RFC 9353

IGP Extension for Path Computation Element Communication Protocol (PCEP) Security Capability Support in PCE Discovery (PCED)

Abstract

When a Path Computation Element (PCE) is a Label Switching Router (LSR) or a server participating in the Interior Gateway Protocol (IGP), its presence and path computation capabilities can be advertised using IGP flooding. The IGP extensions for PCE Discovery (PCED) (RFCs 5088 and 5089) define a method to advertise path computation capabilities using IGP flooding for OSPF and IS-IS, respectively. However, these specifications lack a method to advertise Path Computation Element Communication Protocol (PCEP) security (e.g., Transport Layer Security (TLS) and TCP Authentication Option (TCP-AO)) support capability.

This document defines capability flag bits for the PCE-CAP-FLAGS sub-TLV that can be announced as an attribute in the IGP advertisement to distribute PCEP security support information. In addition, this document updates RFCs 5088 and 5089 to allow advertisement of a Key ID or KEY-CHAIN-NAME sub-TLV to support TCP-AO security capability. This document also updates RFCs 8231 and 8306.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc9353>.

Copyright Notice

Copyright (c) 2023 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

Table of Contents

1. Introduction
2. Conventions Used in This Document
3. IGP Extension for PCEP Security Capability Support
 - 3.1. Use of PCEP Security Capability Support for PCED
 - 3.2. KEY-ID Sub-TLV
 - 3.2.1. IS-IS
 - 3.2.2. OSPF
 - 3.3. KEY-CHAIN-NAME Sub-TLV
 - 3.3.1. IS-IS
 - 3.3.2. OSPF
4. Updates to RFCs
5. Backward Compatibility Considerations
6. Management Considerations
 - 6.1. Control of Policy and Functions
 - 6.2. Information and Data Model
 - 6.3. Liveness Detection and Monitoring
 - 6.4. Verification of Correct Operations
 - 6.5. Requirements on Other Protocols and Functional Components
 - 6.6. Impact on Network Operations
7. Security Considerations

8. IANA Considerations

8.1. PCE Capability Flags

8.2. PCED Sub-TLV Type Indicators

9. References

9.1. Normative References

9.2. Informative References

Acknowledgments

Authors' Addresses

1. Introduction

As described in [RFC5440], privacy and integrity are important issues for communication using the Path Computation Element Communication Protocol (PCEP); an attacker that intercepts a PCEP message could obtain sensitive information related to computed paths and resources. Authentication and integrity checks allow the receiver of a PCEP message to know that the message genuinely comes from the node that purports to have sent it and whether the message has been modified.

Among the possible solutions mentioned in [RFC5440], Transport Layer Security (TLS) [RFC8446] provides support for peer authentication, message encryption, and integrity while TCP-AO [RFC5925] and Cryptographic Algorithms for TCP-AO [RFC5926] offer significantly improved security for applications using TCP. As specified in Section 4 of [RFC8253], the PCC needs to know whether the PCE server supports TLS or TCP-AO as a secure transport in order for a Path Computation Client (PCC) to establish a connection with a PCE server using TLS or TCP-AO.

[RFC5088] and [RFC5089] define a method to advertise path computation capabilities using IGP flooding for OSPF and IS-IS, respectively. However, these specifications lack a method to advertise PCEP security (e.g., TLS and TCP-AO) support capability.

This document defines capability flag bits for the PCE-CAP-FLAGS sub-TLV that can be announced as attributes in the IGP advertisement to distribute PCEP security support information. In addition, this document updates [RFC5088] and [RFC5089] to allow advertisement of a KeyID or KEY-CHAIN-NAME sub-TLV to support TCP-AO security capability.

IANA created a top-level registry titled "Path Computation Element (PCE) Capability Flags" per [RFC5088]. This document updates [RFC5088] and moves it to follow the heading of the "Interior Gateway Protocol (IGP) Parameters" registry. [RFC5089] states that the IS-IS PCE-CAP-FLAGS sub-TLV uses the same registry as OSPF. This document updates [RFC5089] to refer to the new IGP registry. Further, this document updates [RFC8231] where it references the registry location as the "Open Shortest Path First v2 (OSPFv2) Parameters" registry to the "Interior Gateway Protocol

(IGP) Parameters" registry. This document also updates [RFC8306] by changing the term "OSPF PCE Capability Flag" to read as "Path Computation Element (PCE) Capability Flags" and to note the corresponding registry now exists in the "Interior Gateway Protocol (IGP) Parameters" registry.

Note that [RFC5557] uses the term "OSPF registry" instead of the "IGP registry", whereas [RFC8623] and [RFC9168] use the term "OSPF Parameters" instead of "IGP Parameters".

Note that the PCEP Open message exchange is another way to discover PCE capabilities information; however, in this instance, the TCP-security-related key parameters need to be known before the PCEP session is established and the PCEP Open messages are exchanged. Thus, the IGP advertisement and flooding mechanisms need to be leveraged for PCE discovery and capabilities advertisement.

2. Conventions Used in This Document

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. IGP Extension for PCEP Security Capability Support

[RFC5088] defines a PCE Discovery (PCED) TLV carried in an OSPF Router Information Link State Advertisement (LSA) as defined in [RFC7770] to facilitate PCED using OSPF. This document defines two capability flag bits in the OSPF PCE Capability Flags to indicate TCP-AO support [RFC5925] [RFC5926] and PCEP over TLS support [RFC8253], respectively.

Similarly, [RFC5089] defines the PCED sub-TLV for use in PCED using IS-IS. This document will use the same flag for the OSPF PCE Capability Flags sub-TLV to allow IS-IS to indicate TCP-AO support and PCEP over TLS support, respectively.

The IANA assignments for shared OSPF and IS-IS Security Capability Flags are documented in [Section 8.1](#) of this document.

3.1. Use of PCEP Security Capability Support for PCED

TCP-AO and PCEP over TLS support flag bits are advertised using IGP flooding.

- PCE supports TCP-AO: IGP advertisement **SHOULD** include a TCP-AO support flag bit.
- PCE supports TLS: IGP advertisement **SHOULD** include PCEP over TLS support flag bit.

If the PCE supports multiple security mechanisms, it **SHOULD** include all corresponding flag bits in its IGP advertisement.

A client's configuration **MAY** indicate that support for a given security capability is required. If a client is configured to require that its PCE server supports TCP-AO, the client **MUST** verify that the TCP-AO flag bit in the PCE-CAP-FLAGS sub-TLV for a given server is set before it opens a connection to that server. Similarly, if the client is configured to require that its PCE server supports TLS, the client **MUST** verify that the PCEP over TLS support flag bit in the PCE-CAP-FLAGS sub-TLV for a given server is set before it opens a connection to that server.

3.2. KEY-ID Sub-TLV

The KEY-ID sub-TLV specifies an identifier that can be used by the PCC to identify the TCP-AO key (referred to as "KeyID" in [RFC5925]).

3.2.1. IS-IS

The KEY-ID sub-TLV **MAY** be present in the PCED sub-TLV carried within the IS-IS Router CAPABILITY TLV when the capability flag bit of the PCE-CAP-FLAGS sub-TLV in IS-IS is set to indicate TCP-AO support.

The KEY-ID sub-TLV has the following format:

Type: 6

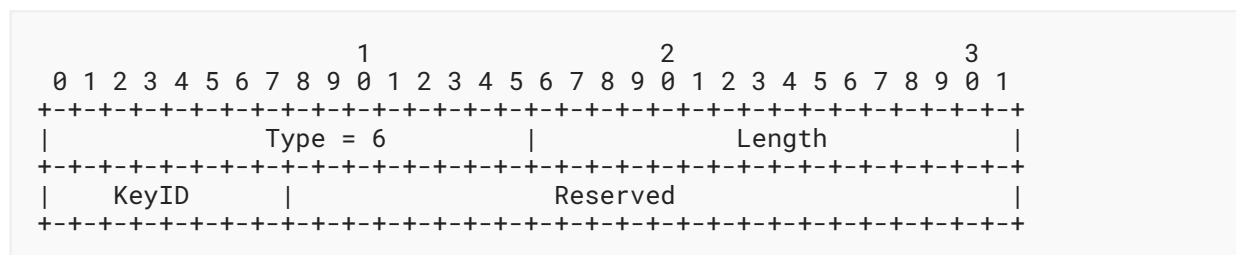
Length: 1

KeyID: The one-octet KeyID as per [RFC5925] to uniquely identify the Master Key Tuple (MKT).

3.2.2. OSPF

Similarly, this sub-TLV **MAY** be present in the PCED TLV carried within the OSPF Router Information LSA when the capability flag bit of the PCE-CAP-FLAGS sub-TLV in OSPF is set to indicate TCP-AO support.

The format of the KEY-ID sub-TLV is as follows:



Type: 6

Length: 4

KeyID: The one octet KeyID as per [RFC5925] to uniquely identify the MKT.

Reserved: **MUST** be set to zero while sending and ignored on receipt.

3.3. KEY-CHAIN-NAME Sub-TLV

The KEY-CHAIN-NAME sub-TLV specifies a key chain name that can be used by the PCC to identify the key chain. The key chain name could be manually configured via command-line interface (CLI) or installed in the YANG datastore (see [RFC8177]) at the PCC.

3.3.1. IS-IS

The KEY-CHAIN-NAME sub-TLV **MAY** be present in the PCED sub-TLV carried within the IS-IS Router CAPABILITY TLV when the capability flag bit of the PCE-CAP-FLAGS sub-TLV in IS-IS is set to indicate TCP-AO support.

The KEY-CHAIN-NAME sub-TLV has the following format:

Type: 7

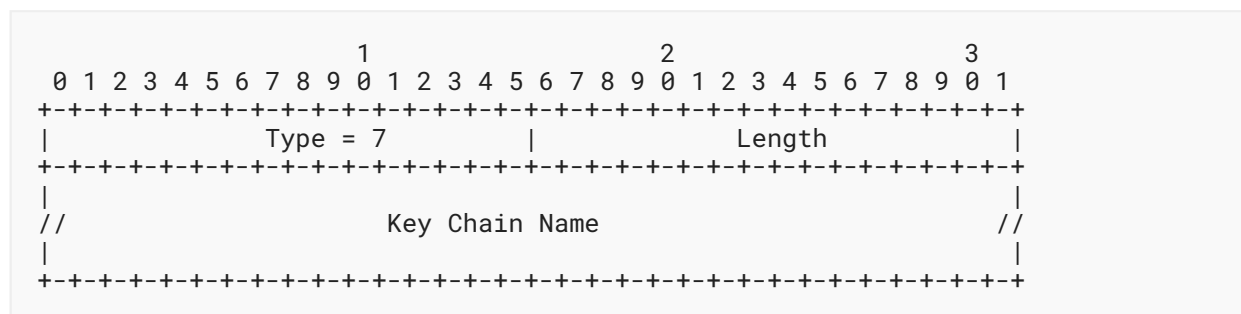
Length: Variable, encodes the length of the value field.

Key Chain Name: The Key Chain Name contains a string of 1 to 255 octets to be used to identify the key chain. It **MUST** be encoded using UTF-8. A receiving entity **MUST NOT** interpret invalid UTF-8 sequences and ignore them. This field is not NULL terminated. UTF-8 "Shortest Form" encoding is **REQUIRED** to guard against the technical issues outlined in [UTR36].

3.3.2. OSPF

Similarly, this sub-TLV **MAY** be present in the PCED TLV carried within the OSPF Router Information LSA when the capability flag bit of the PCE-CAP-FLAGS sub-TLV in OSPF is set to indicate TCP-AO support. The sub-TLV **MUST** be zero-padded so that the sub-TLV is 4-octet aligned.

The format of KEY-CHAIN-NAME sub-TLV is as follows:



Type: 7

Length: Variable, padding is not included in the Length field.

Key Chain Name: The Key Chain Name contains a string of 1 to 255 octets to be used to identify the key chain. It **MUST** be encoded using UTF-8. A receiving entity **MUST NOT** interpret invalid UTF-8 sequences and ignore them. This field is not NULL terminated. UTF-8 "Shortest Form" encoding is **REQUIRED** to guard against the technical issues outlined in [UTR36]. The sub-TLV **MUST** be zero-padded so that the sub-TLV is 4-octet aligned.

4. Updates to RFCs

Section 4 of [RFC5088] states that no new sub-TLVs will be added to the PCED TLV and no new PCE information will be carried in the Router Information LSA. This document updates [RFC5088] by allowing the two sub-TLVs defined in this document to be carried in the PCED TLV advertised in the Router Information LSA.

Section 4 of [RFC5089] states that no new sub-TLVs will be added to the PCED TLV and no new PCE information will be carried in the Router CAPABILITY TLV. This document updates [RFC5089] by allowing the two sub-TLVs defined in this document to be carried in the PCED TLV advertised in the Router CAPABILITY TLV.

This introduction of additional sub-TLVs should be viewed as an exception to the policies in [RFC5088] and [RFC5089], which is justified by the requirement to discover the PCEP security support prior to establishing a PCEP session. The restrictions defined in [RFC5088] and [RFC5089] should still be considered to be in place. If new advertisements are required in the future, alternative mechanisms such as using [RFC6823] or [LSR-OSPF-TRANSPORT-INSTANCE] should be considered.

The registry for the PCE Capability Flags assigned in Section 8.3 of [RFC5557], Section 8.1 of [RFC8231], Section 6.9 of [RFC8306], Section 11.1 of [RFC8623], and Section 10.5 of [RFC9168] has changed to the IGP Parameters "Path Computation Element (PCE) Capability Flags" registry created in this document.

5. Backward Compatibility Considerations

An LSR that does not support the IGP PCE capability bits specified in this document silently ignores those bits.

An LSR that does not support the KEY-ID and KEY-CHAIN-NAME sub-TLVs specified in this document silently ignores those sub-TLVs.

IGP extensions defined in this document do not introduce any new interoperability issues.

6. Management Considerations

Manageability considerations for PCED are addressed in Section 4.10 of [RFC4674], Section 9 of [RFC5088], and Section 9 of [RFC5089].

6.1. Control of Policy and Functions

A PCE implementation **SHOULD** allow the following parameters to be configured on the PCE:

- support for TCP-AO
- the KeyID used by TCP-AO
- Key Chain Name
- support for TLS

6.2. Information and Data Model

The YANG module for PCEP [[PCE-PCEP-YANG](#)] supports PCEP security parameters (key, key chain, and TLS).

6.3. Liveness Detection and Monitoring

Normal operations of the IGP meet the requirements for liveness detection and monitoring.

6.4. Verification of Correct Operations

The correlation of PCEP security information advertised against information received can be achieved by comparing the information in the PCED sub-TLV received by the PCC with that stored at the PCE using the PCEP YANG.

6.5. Requirements on Other Protocols and Functional Components

There are no new requirements on other protocols.

6.6. Impact on Network Operations

Frequent changes in PCEP security information advertised in the PCED sub-TLV may have a significant impact on IGP and might destabilize the operation of the network by causing the PCCs to reconnect sessions with PCEs. [Section 4.10.4](#) of [[RFC4674](#)], [Section 9.6](#) of [[RFC5088](#)], and [Section 9.6](#) of [[RFC5089](#)] list techniques that are applicable to this document as well.

7. Security Considerations

Security considerations as specified by [[RFC5088](#)] and [[RFC5089](#)] are applicable to this document.

As described in [Section 10.2](#) of [[RFC5440](#)], a PCEP speaker **MUST** support TCP MD5 [[RFC2385](#)], so no capability advertisement is needed to indicate support. However, as noted in [[RFC6952](#)], TCP MD5 has been obsoleted by TCP-AO [[RFC5925](#)] because of security concerns. TCP-AO is not widely implemented; therefore, it is **RECOMMENDED** that PCEP be secured using TLS per [[RFC8253](#)] (which updates [[RFC5440](#)]). An implementation **SHOULD** offer at least one of the two security capabilities defined in this document.

The information related to PCEP security is sensitive and due care needs to be taken by the operator. This document defines new capability bits that are susceptible to a downgrade attack by setting them to zero. The content of the Key-ID or KEY-CHAIN-NAME sub-TLV can be altered to enable an on-path attack. Thus, before advertising the PCEP security parameters by using the mechanism described in this document, the IGP **MUST** be known to provide authentication and integrity for the PCED TLV using the mechanisms defined in [RFC5304], [RFC5310], or [RFC5709].

Moreover, as stated in the security considerations of [RFC5088] and [RFC5089], there are no mechanisms defined in OSPF or IS-IS to protect the confidentiality of the PCED TLV. For this reason, the operator must ensure that no private data is carried in the TLV. For example, the operator must ensure that KeyIDs or key chain names do not reveal sensitive information about the network.

8. IANA Considerations

8.1. PCE Capability Flags

IANA has moved the "Path Computation Element (PCE) Capability Flags" registry from the "Open Shortest Path First v2 (OSPFv2) Parameters" grouping to the "Interior Gateway Protocol (IGP) Parameters" grouping.

IANA has made the following additional assignments from the "Path Computation Element (PCE) Capability Flags" registry:

Bit	Capability Description	Reference
17	TCP-AO Support	RFC 9353
18	PCEP over TLS support	RFC 9353

Table 1: Path Computation Element (PCE) Capability Flags Registrations

The grouping is located at: <<https://www.iana.org/assignments/igp-parameters/>>.

8.2. PCED Sub-TLV Type Indicators

The PCED sub-TLVs are defined in [RFC5088] and [RFC5089], but a corresponding IANA registry was not created. IANA has created a new registry called "PCE Discovery (PCED) Sub-TLV Type Indicators" under the "Interior Gateway Protocol (IGP) Parameters" registry. The registration policy for this registry is "Standards Action" [RFC8126]. Values in this registry come from the range 0-65535.

This registry is initially populated as follows:

Value	Description	Reference
0	Reserved	RFC 9353, RFC 5088
1	PCE-ADDRESS	RFC 9353, RFC 5088
2	PATH-SCOPE	RFC 9353, RFC 5088
3	PCE-DOMAIN	RFC 9353, RFC 5088
4	NEIG-PCE-DOMAIN	RFC 9353, RFC 5088
5	PCE-CAP-FLAGS	RFC 9353, RFC 5088
6	KEY-ID	RFC 9353
7	KEY-CHAIN-NAME	RFC 9353

Table 2: Initial Contents of the PCED Sub-TLV Type Indicators Registry

This registry is used by both the OSPF PCED TLV and the IS-IS PCED sub-TLV.

This grouping is located at: <<https://www.iana.org/assignments/igp-parameters/>>.

9. References

9.1. Normative References

- [RFC2119] Bradner, S. and RFC Publisher, "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>>.
- [RFC5088] Le Roux, JL., Ed., Vasseur, JP., Ed., Ikejiri, Y., Zhang, R., and RFC Publisher, "OSPF Protocol Extensions for Path Computation Element (PCE) Discovery", RFC 5088, DOI 10.17487/RFC5088, January 2008, <<https://www.rfc-editor.org/info/rfc5088>>.
- [RFC5089] Le Roux, JL., Ed., Vasseur, JP., Ed., Ikejiri, Y., Zhang, R., and RFC Publisher, "IS-IS Protocol Extensions for Path Computation Element (PCE) Discovery", RFC 5089, DOI 10.17487/RFC5089, January 2008, <<https://www.rfc-editor.org/info/rfc5089>>.
- [RFC5304] Li, T., Atkinson, R., and RFC Publisher, "IS-IS Cryptographic Authentication", RFC 5304, DOI 10.17487/RFC5304, October 2008, <<https://www.rfc-editor.org/info/rfc5304>>.
- [RFC5310] Bhatia, M., Manral, V., Li, T., Atkinson, R., White, R., Fanto, M., and RFC Publisher, "IS-IS Generic Cryptographic Authentication", RFC 5310, DOI 10.17487/RFC5310, February 2009, <<https://www.rfc-editor.org/info/rfc5310>>.

-
- [RFC5557] Lee, Y., Le Roux, J.L., King, D., Oki, E., and RFC Publisher, "Path Computation Element Communication Protocol (PCEP) Requirements and Protocol Extensions in Support of Global Concurrent Optimization", RFC 5557, DOI 10.17487/RFC5557, July 2009, <<https://www.rfc-editor.org/info/rfc5557>>.
- [RFC5709] Bhatia, M., Manral, V., Fanto, M., White, R., Barnes, M., Li, T., Atkinson, R., and RFC Publisher, "OSPFv2 HMAC-SHA Cryptographic Authentication", RFC 5709, DOI 10.17487/RFC5709, October 2009, <<https://www.rfc-editor.org/info/rfc5709>>.
- [RFC5925] Touch, J., Mankin, A., Bonica, R., and RFC Publisher, "The TCP Authentication Option", RFC 5925, DOI 10.17487/RFC5925, June 2010, <<https://www.rfc-editor.org/info/rfc5925>>.
- [RFC7770] Lindem, A., Ed., Shen, N., Vasseur, J.P., Aggarwal, R., Shaffer, S., and RFC Publisher, "Extensions to OSPF for Advertising Optional Router Capabilities", RFC 7770, DOI 10.17487/RFC7770, February 2016, <<https://www.rfc-editor.org/info/rfc7770>>.
- [RFC8126] Cotton, M., Leiba, B., Narten, T., and RFC Publisher, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <<https://www.rfc-editor.org/info/rfc8126>>.
- [RFC8174] Leiba, B. and RFC Publisher, "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>>.
- [RFC8177] Lindem, A., Ed., Qu, Y., Yeung, D., Chen, I., Zhang, J., and RFC Publisher, "YANG Data Model for Key Chains", RFC 8177, DOI 10.17487/RFC8177, June 2017, <<https://www.rfc-editor.org/info/rfc8177>>.
- [RFC8231] Crabbe, E., Minei, I., Medved, J., Varga, R., and RFC Publisher, "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., Dhody, D., and RFC Publisher, "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>>.
- [RFC8306] Zhao, Q., Dhody, D., Ed., Palleti, R., King, D., and RFC Publisher, "Extensions to the Path Computation Element Communication Protocol (PCEP) for Point-to-Multipoint Traffic Engineering Label Switched Paths", RFC 8306, DOI 10.17487/RFC8306, November 2017, <<https://www.rfc-editor.org/info/rfc8306>>.
- [RFC8623] Palle, U., Dhody, D., Tanaka, Y., Beeram, V., and RFC Publisher, "Stateful Path Computation Element (PCE) Protocol Extensions for Usage with Point-to-Multipoint TE Label Switched Paths (LSPs)", RFC 8623, DOI 10.17487/RFC8623, June 2019, <<https://www.rfc-editor.org/info/rfc8623>>.

- [RFC9168] Dhody, D., Farrel, A., Li, Z., and RFC Publisher, "Path Computation Element Communication Protocol (PCEP) Extension for Flow Specification", RFC 9168, DOI 10.17487/RFC9168, January 2022, <<https://www.rfc-editor.org/info/rfc9168>>.

9.2. Informative References

- [LSR-OSPF-TRANSPORT-INSTANCE] Lindem, A., Qu, Y., Roy, A., and S. Mirtorabi, "OSPF-GT (Generalized Transport)", Work in Progress, Internet-Draft, draft-ietf-lsr-ospf-transport-instance-04, 3 January 2023, <<https://datatracker.ietf.org/doc/html/draft-ietf-lsr-ospf-transport-instance-04>>.
- [PCE-PCEP-YANG] Dhody, D., Ed., Beeram, V., Hardwick, J., and J. Tantsura, "A YANG Data Model for Path Computation Element Communications Protocol (PCEP)", Work in Progress, Internet-Draft, draft-ietf-pce-pcep-yang-20, 23 October 2022, <<https://datatracker.ietf.org/doc/html/draft-ietf-pce-pcep-yang-20>>.
- [RFC2385] Heffernan, A. and RFC Publisher, "Protection of BGP Sessions via the TCP MD5 Signature Option", RFC 2385, DOI 10.17487/RFC2385, August 1998, <<https://www.rfc-editor.org/info/rfc2385>>.
- [RFC4674] Le Roux, J.L., Ed. and RFC Publisher, "Requirements for Path Computation Element (PCE) Discovery", RFC 4674, DOI 10.17487/RFC4674, October 2006, <<https://www.rfc-editor.org/info/rfc4674>>.
- [RFC5440] Vasseur, JP., Ed., Le Roux, JL., Ed., and RFC Publisher, "Path Computation Element (PCE) Communication Protocol (PCEP)", RFC 5440, DOI 10.17487/RFC5440, March 2009, <<https://www.rfc-editor.org/info/rfc5440>>.
- [RFC5926] Lebovitz, G., Rescorla, E., and RFC Publisher, "Cryptographic Algorithms for the TCP Authentication Option (TCP-AO)", RFC 5926, DOI 10.17487/RFC5926, June 2010, <<https://www.rfc-editor.org/info/rfc5926>>.
- [RFC6823] Ginsberg, L., Previdi, S., Shand, M., and RFC Publisher, "Advertising Generic Information in IS-IS", RFC 6823, DOI 10.17487/RFC6823, December 2012, <<https://www.rfc-editor.org/info/rfc6823>>.
- [RFC6952] Jethanandani, M., Patel, K., Zheng, L., and RFC Publisher, "Analysis of BGP, LDP, PCEP, and MSDP Issues According to the Keying and Authentication for Routing Protocols (KARP) Design Guide", RFC 6952, DOI 10.17487/RFC6952, May 2013, <<https://www.rfc-editor.org/info/rfc6952>>.
- [RFC8446] Rescorla, E. and RFC Publisher, "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/info/rfc8446>>.
- [UTR36] Davis, M., Ed. and M. Suignard, Ed., "Unicode Security Considerations", Unicode Technical Report #36, August 2010, <<https://www.unicode.org/unicode/reports/tr36/>>.

Acknowledgments

The authors of this document would like to thank Acee Lindem, Julien Meuric, Les Ginsberg, Ketan Talaulikar, Tom Petch, Aijun Wang, and Adrian Farrel for the review and comments.

The authors would also like to give special thanks to Michale Wang for his major contributions to the initial draft version.

Thanks to John Scudder for providing an excellent AD review. Thanks to Carlos Pignataro, Yaron Sheffer, Ron Bonica, and Will (Shucheng) LIU for directorate reviews.

Thanks to Lars Eggert, Robert Wilton, Roman Danyliw, Éric Vyncke, Paul Wouters, Murray Kucherawy, and Warren Kumari for IESG reviews.

Authors' Addresses

Diego R. Lopez

Telefonica I+D

Spain

Email: diego.r.lopez@telefonica.com

Qin Wu

Huawei Technologies

Yuhua District

101 Software Avenue

Nanjing

Jiangsu, 210012

China

Email: bill.wu@huawei.com

Dhruv Dhody

Huawei Technologies

Divyashree Techno Park, Whitefield

Bangalore 560037

Karnataka

India

Email: dhruv.ietf@gmail.com

Qiufang Ma

Huawei Technologies

Yuhua District

101 Software Avenue

Nanjing

Jiangsu, 210012

China

Email: maqiufang1@huawei.com**Daniel King**

Old Dog Consulting

United Kingdom

Email: daniel@olddog.co.uk