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**Carrying Binding Label/Segment-ID in PCE-based Networks.
draft-ietf-pce-binding-label-sid-06**

Abstract

In order to provide greater scalability, network opacity, and service independence, Segment Routing (SR) utilizes a Binding Segment Identifier (BSID). It is possible to associate a BSID to RSVP-TE signaled Traffic Engineering Label Switching Path or binding Segment-ID (SID) to SR Traffic Engineering path. Such a binding label/SID can be used by an upstream node for steering traffic into the appropriate TE path to enforce SR policies. This document proposes an approach for reporting binding label/SID to Path Computation Element (PCE) for supporting PCE-based Traffic Engineering policies.

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.

Status of This Memo

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[1.](#) Introduction

A PCE can compute Traffic Engineering paths (TE paths) through a network that are subject to various constraints. Currently, TE paths are either set up using the RSVP-TE signaling protocol or Segment Routing (SR). We refer to such paths as RSVP-TE paths and SR-TE paths respectively in this document.

As per [[RFC8402](#)] SR allows a headend node to steer a packet flow along any path. The headend node is said to steer a flow into an Segment Routing Policy (SR Policy). Further, as per [[I-D.ietf-spring-segment-routing-policy](#)], an SR Policy is a framework that enables instantiation of an ordered list of segments on a node for implementing a source routing policy with a specific intent for traffic steering from that node.

As described in [[RFC8402](#)], Binding Segment Identifier (BSID) is bound to an Segment Routed (SR) Policy, instantiation of which may involve a list of SIDs. Any packets received with an active segment equal to BSID are steered onto the bound SR Policy. A BSID may be either a local (SR Local Block (SRLB)) or a global (SR Global Block (SRGB)) SID. As per Section 6.4 of [[I-D.ietf-spring-segment-routing-policy](#)] a BSID can also be associated with any type of interfaces or tunnel to enable the use of a non-SR interface or tunnels as segments in a SID-list.

[[RFC5440](#)] describes the Path Computation Element Protocol (PCEP) for communication between a Path Computation Client (PCC) and a PCE or between a pair of PCEs as per [[RFC4655](#)]. [[RFC8231](#)] specifies extension to PCEP that allows a PCC to delegate its LSPs to a stateful PCE. A stateful PCE can then update the state of LSPs delegated to it. [[RFC8281](#)] specifies a mechanism allowing a PCE to dynamically instantiate an LSP on a PCC by sending the path and characteristics. The PCEP extension to setup and maintain SR-TE paths is specified in [[RFC8664](#)].

[[RFC8664](#)] provides a mechanism for a network controller (acting as a PCE) to instantiate candidate paths for an SR Policy onto a head-end node (acting as a PCC) using PCEP. For more information on the SR Policy Architecture, see [[I-D.ietf-spring-segment-routing-policy](#)].

Binding label/SID has local significance to the ingress node of the corresponding TE path. When a stateful PCE is deployed for setting up TE paths, it may be desirable to report the binding label or SID to the stateful PCE for the purpose of enforcing end-to-end TE/SR policy. A sample Data Center (DC) use-case is illustrated in the following diagram. In the MPLS DC network, an SR LSP (without traffic engineering) is established using a prefix SID advertised by BGP (see [RFC8669]). In IP/MPLS WAN, an SR-TE LSP is setup using the PCE. The list of SIDs of the SR-TE LSP is {A, B, C, D}. The gateway node 1 (which is the PCC) allocates a binding SID X and reports it to the PCE. In order for the access node to steer the traffic over the SR-TE LSP, the PCE passes the SID stack {Y, X} where Y is the prefix SID of the gateway node-1 to the access node. In the absence of the binding SID X, the PCE should pass the SID stack {Y, A, B, C, D} to the access node. This example also illustrates the additional benefit of using the binding SID to reduce the number of SIDs imposed on the access nodes with a limited forwarding capacity.

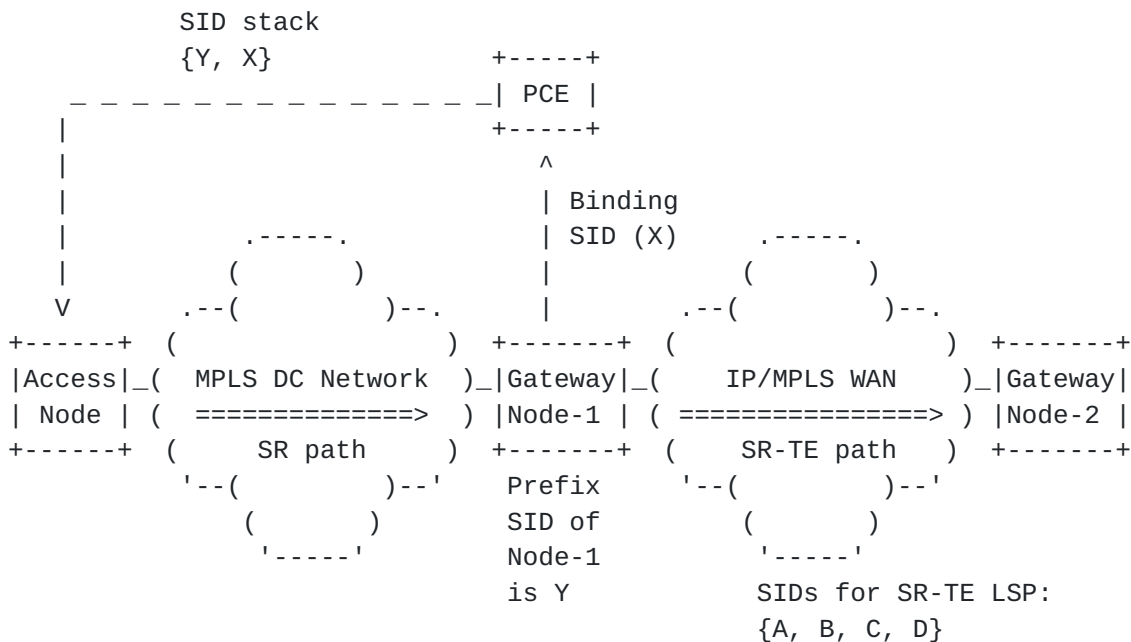


Figure 1: A sample Use-case of Binding SID

A PCC could report the binding label/SID allocated by it to the stateful PCE via Path Computation State Report (PCRpt) message. It is also possible for a stateful PCE to request a PCC to allocate a specific binding label/SID by sending a Path Computation Update Request (PCUpd) message. If the PCC can successfully allocate the specified binding value, it reports the binding value to the PCE.

Otherwise, the PCC sends an error message to the PCE indicating the cause of the failure. A local policy or configuration at the PCC SHOULD dictate if the binding label/SID needs to be assigned.

In this document, we introduce a new OPTIONAL TLV that a PCC can use in order to report the binding label/SID associated with a TE LSP, or a PCE to request a PCC to allocate a specific binding label/SID value. This TLV is intended for TE LSPs established using RSVP-TE, SR, or any other future method. Also, in the case of SR-TE LSPs, the TLV can carry a binding MPLS label (for SR-TE path with MPLS data-plane) or a binding IPv6 SID (e.g., IPv6 address for SR-TE paths with IPv6 data-plane). Binding value means either MPLS label or SID throughout this document.

Additionally, to support the PCE based central controller [[RFC8283](#)] operation where the PCE would take responsibility for managing some part of the MPLS label space for each of the routers that it controls, the PCE could directly make the binding label/SID allocation and inform the PCC. See [Section 7](#) for details.

2. Terminology

The following terminologies are used in this document:

BSID: Binding Segment Identifier.

LER: Label Edge Router.

LSP: Label Switched Path.

LSR: Label Switching Router.

PCC: Path Computation Client.

PCE: Path Computation Element

PCEP: Path Computation Element Protocol.

RSVP-TE: Resource ReserVation Protocol-Traffic Engineering.

SID: Segment Identifier.

SR: Segment Routing.

SRGB: Segment Routing Global Block.

SRLB: Segment Routing Local Block.

TLV: Type, Length, and Value.

3. Path Binding TLV

The new optional TLV is called "TE-PATH-BINDING TLV" (whose format is shown in the figure below) is defined to carry the binding label or SID for a TE path. This TLV is associated with the LSP object specified in ([[RFC8231](#)]). The type of this TLV is to be allocated by IANA.

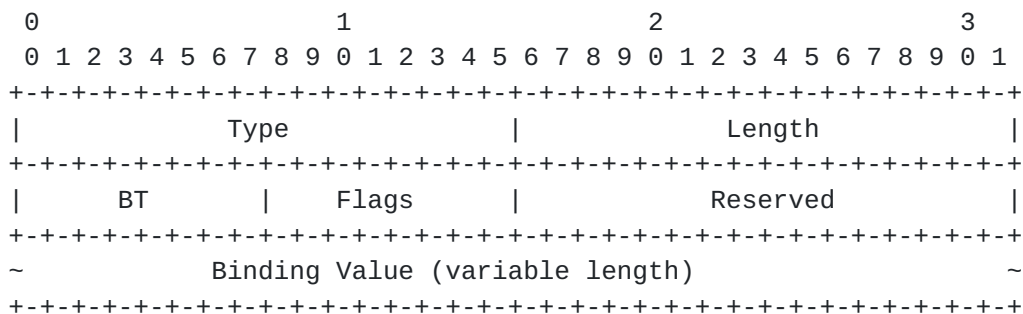


Figure 2: TE-PATH-BINDING TLV

TE-PATH-BINDING TLV is a generic TLV such that it is able to carry MPLS label binding as well as SRv6 Binding SID. It is formatted according to the rules specified in [[RFC5440](#)].

Binding Type (BT): A one-octet field identifies the type of binding included in the TLV. This document specifies the following BT values:

- o BT = 0: The binding value is an MPLS label carried in the format specified in [[RFC5462](#)] where only the label value is valid, and other fields MUST be considered invalid. The Length MUST be set to 7.
- o BT = 1: Similar to the case where BT is 0 except that all the fields on the MPLS label entry are set on transmission. However, the receiver MAY choose to override TC, S, and TTL values according its local policy. The Length MUST be set to 8.
- o BT = 2: The binding value is an SRv6 SID with a format of a 16 octet IPv6 address, representing the binding SID for SRv6. The Length MUST be set to 20.
- o BT = 3: The binding value is a 24 octet field, defined in [Section 3.1](#), that contains the SRv6 SID as well as its Behavior and Structure. The Length MUST be set to 28.

Flags: 1 octet of flags. Following flags are defined in the new registry "SR Policy Binding SID Flags" as described in [Section 11.1.2](#):

```

 0 1 2 3 4 5 6 7
+---+---+---+---+
|           |I|S|
+---+---+---+---+

```

where:

- o S-Flag: This flag encodes the "Specified-BSID-only" behavior. It is used as described in Section 6.2.3 of [\[I-D.ietf-spring-segment-routing-policy\]](#).
- o I-Flag: This flag encodes the "Drop Upon Invalid" behavior. It is used as described in Section 8.2 of [\[I-D.ietf-spring-segment-routing-policy\]](#).

Reserved: MUST be set to 0 while sending and ignored on receipt.

Binding Value: A variable-length field, padded with trailing zeros to a 4-octet boundary. For the BT as 0, the 20 bits represent the MPLS label. For the BT as 1, the 32-bits represent the label stack entry as per [\[RFC5462\]](#). For the BT as 2, the 128-bits represent the SRv6 SID. For the BT as 3, the Binding Value contains SRv6 Endpoint Behavior and SID Structure, defined in [Section 3.1](#).

[3.1](#). SRv6 Endpoint Behavior and SID Structure

Carried as the Binding Value in the TE-PATH-BINDING TLV when the BT is set to 3. Applicable for SRv6 Binding SIDs [\[I-D.ietf-spring-srv6-network-programming\]](#).

```

      0              1              2              3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               SRv6 Binding SID (16 octets)                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           Reserved           |           Endpoint Behavior           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   LB Length   |   LN Length   | Fun. Length   | Arg. Length   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Figure 4: SRv6 Endpoint Behavior and SID Structure

Reserved: 2 octets. MUST be set to 0 on transmit and ignored on receipt.

Endpoint Behavior: 2 octets. The Endpoint Behavior code point for this SRv6 SID as defined in section 9.2 of [\[I-D.ietf-spring-srv6-network-programming\]](#). When set with the value 0, the choice of behavior is considered unset.

LB Length: 1 octet. SRv6 SID Locator Block length in bits.

LN Length: 1 octet. SRv6 SID Locator Node length in bits.

Function Length: 1 octet. SRv6 SID Function length in bits.

Argument Length: 1 octet. SRv6 SID Arguments length in bits.

4. Operation

The binding value is allocated by the PCC and reported to a PCE via PCRpt message. If a PCE does not recognize the TE-PATH-BINDING TLV, it would ignore the TLV in accordance with ([\[RFC5440\]](#)). If a PCE recognizes the TLV but does not support the TLV, it MUST send PCerr with Error-Type = 2 (Capability not supported).

If a TE-PATH-BINDING TLV is absent in the PCRpt message, PCE MUST assume that the corresponding LSP does not have any binding. If a PCE recognizes an invalid binding value (e.g., label value from the reserved label space when MPLS label binding is used), it MUST send the PCerr message with Error-Type = 10 ("Reception of an invalid object") and Error Value = 2 ("Bad label value") as specified in [\[RFC8664\]](#).

Multiple TE-PATH-BINDING TLVs are allowed to be present in the same LSP object. This signifies the presence of multiple binding SIDs for the given LSP.

For SRv6 BSIDs, it is RECOMMENDED to always explicitly specify the SRv6 Endpoint Behavior and SID Structure in the TE-PATH-BINDING TLV by setting the BT (Binding Type) to 3, instead of 2. The choice of interpreting SRv6 Endpoint Behavior and SID Structure when none is explicitly specified is left up to the implementation.

If a PCE requires a PCC to allocate a specific binding value, it may do so by sending a PCUpd or PCInitiate message containing a TE-PATH-BINDING TLV. If the value can be successfully allocated, the PCC reports the binding value to the PCE. If the PCC considers the binding value specified by the PCE invalid, it MUST send a PCerr message with Error-Type = TBD2 ("Binding label/SID failure") and

Error Value = TBD3 ("Invalid SID"). If the binding value is valid, but the PCC is unable to allocate the binding value, it MUST send a PCErr message with Error-Type = TBD2 ("Binding label/SID failure") and Error Value = TBD4 ("Unable to allocate the specified label/SID").

If a PCC receives TE-PATH-BINDING TLV in any message other than PCUpd or PCInitiate, it MUST close the corresponding PCEP session with the reason "Reception of a malformed PCEP message" (according to [\[RFC5440\]](#)). Similarly, if a PCE receives a TE-PATH-BINDING TLV in any message other than a PCRpt or if the TE-PATH-BINDING TLV is associated with any object other than LSP object, the PCE MUST close the corresponding PCEP session with the reason "Reception of a malformed PCEP message" (according to [\[RFC5440\]](#)).

If a PCC wishes to withdraw or modify a previously reported binding value, it MUST send a PCRpt message without any TE-PATH-BINDING TLV or with the TE-PATH-BINDING TLV containing the new binding value respectively.

If a PCE wishes to modify a previously requested binding value, it MUST send a PCUpd message with TE-PATH-BINDING TLV containing the new binding value. The absence of TE-PATH-BINDING TLV in PCUpd message means that the PCE does not specify a binding value in which case the binding value allocation is governed by the PCC's local policy.

If a PCC receives a valid binding value from a PCE which is different than the current binding value, it MUST try to allocate the new value. If the new binding value is successfully allocated, the PCC MUST report the new value to the PCE. Otherwise, it MUST send a PCErr message with Error-Type = TBD2 ("Binding label/SID failure") and Error Value = TBD4 ("Unable to allocate the specified label/SID").

In some cases, a stateful PCE can request the PCC to allocate a binding value. It may do so by sending a PCUpd message containing an empty TE-PATH-BINDING TLV, i.e., no binding value is specified (making the length field of the TLV as 4). A PCE can also request PCC to allocate a binding value at the time of initiation by sending a PCInitiate message with an empty TE-PATH-BINDING TLV. If the PCC is unable to allocate a binding value, it MUST send a PCErr message with Error-Type = TBD2 ("Binding label/SID failure") and Error-Value = TBD5 ("Unable to allocate label/SID").

5. Binding SID in SR-ERO

In PCEP messages, LSP route information is carried in the Explicit Route Object (ERO), which consists of a sequence of subobjects. [RFC8664] defines a new ERO subobject "SR-ERO subobject" capable of carrying a SID as well as the identity of the node/adjacency (NAI) represented by the SID. The NAI Type (NT) field indicates the type and format of the NAI contained in the SR-ERO. In case of binding SID, the NAI MUST NOT be included and NT MUST be set to zero. So as per [Section 5.2.1 of \[RFC8664\]](#), for NT=0, the F bit is set to 1, the S bit needs to be zero and the Length is 8. Further, the M bit is set. If these conditions are not met, the entire ERO MUST be considered invalid and a PCErr message is sent with Error-Type = 10 ("Reception of an invalid object") and Error-Value = 11 ("Malformed object").

6. Binding SID in SRv6-ERO

[RFC8664] defines a new ERO subobject "SRv6-ERO subobject" for SRv6 SID. The NAI MUST NOT be included and NT MUST be set to zero. So as per [Section 5.2.1 of \[RFC8664\]](#), for NT=0, the F bit is set to 1, the S bit needs to be zero and the Length is 24. If these conditions are not met, the entire ERO is considered invalid and a PCErr message is sent with Error-Type = 10 ("Reception of an invalid object") and Error-Value = 11 ("Malformed object") (as per [\[RFC8664\]](#)).

7. PCE Allocation of Binding SID

[Section 4](#) already includes the scenario where a PCE requires a PCC to allocate a specified binding value by sending a PCUpd or PCInitiate message containing a TE-PATH-BINDING TLV. This section specifies an OPTIONAL feature for the PCE to allocate the binding label on its own accord in the case where the PCE also controls the label space of the PCC and can make the label allocation on its own as described in [\[RFC8283\]](#). Note that the act of requesting a specific binding value ([Section 4](#)) is different from the act of allocating a binding label/SID as described in this section.

[RFC8283] introduces the architecture for PCE as a central controller as an extension of the architecture described in [\[RFC4655\]](#) and assumes the continued use of PCEP as the protocol used between PCE and PCC. [\[I-D.ietf-pce-pcep-extension-for-pce-controller\]](#) specifies the procedures and PCEP extensions for using the PCE as the central controller.

For an implementation that supports PCECC operations as per [\[I-D.ietf-pce-pcep-extension-for-pce-controller\]](#), the binding label/SID MAY also be allocated by the PCE itself. Both peers need to

exchange the PCECC capability as described in [\[I-D.ietf-pce-pcep-extension-for-pce-controller\]](#) before PCE could allocate the binding label/SID on its own.

A new P flag in the LSP object [\[RFC8231\]](#) is introduced to indicate the allocation needs to be made by the PCE:

- o P (PCE-allocated binding label/SID - TBD6): If the bit is set to 1, it indicates that the PCC requests PCE to make allocations for this LSP. The TLV in LSP object identifies what should be allocated, such as Binding label/SID. A PCC would set this bit to 1 and include a TE-PATH-BINDING TLV in the LSP object to request for allocation of Binding label/SID by the PCE in the PCEP message. A PCE would also set this bit to 1 and include a TE-PATH-BINDING TLV to indicate that the Binding label/SID is allocated by PCE and encoded in the PCEP message towards PCC. Further, a PCE would set this bit to 0 and include a TE-PATH-BINDING TLV in the LSP object to indicate that the Binding label/SID should be allocated by the PCC as described in [Section 4](#).

Note that,

- o a PCE could allocate the binding label/SID on its own accord for a PCE-initiated or delegated LSP, and inform the PCC in the PCInitiate message or PCUpd message by setting P=1 and including TE-PATH-BINDING TLV in the LSP object.
- o to let the PCC allocates the binding label/SID, a PCE could set P=0 and empty TE-PATH-BINDING TLV (i.e., no binding value is specified) in the LSP object in PCInitiate/PCUpd message.
- o a PCC could request that the PCE allocate the binding label/SID by setting P=1, D=1, and empty TE-PATH-BINDING TLV in PCRpt message. The PCE would allocate it and respond to the PCC with PCUpd message including the allocated binding label/SID in the TE-PATH-BINDING TLV and P=1, D=1 in the LSP object.
- o if both peers have not exchanged the PCECC capabilities as per [\[I-D.ietf-pce-pcep-extension-for-pce-controller\]](#) and it receives P=1 in the LSP object, it needs to act as per [\[I-D.ietf-pce-pcep-extension-for-pce-controller\]](#):
 - * Send a PCErr message with Error-Type=19 (Invalid Operation) and Error-Value=TBD (Attempted PCECC operations when PCECC capability was not advertised)
 - * Terminate the PCEP session

It is assumed that the label range to be used by a PCE is known and set on both PCEP peers. The exact mechanism is out of scope of [[I-D.ietf-pce-pcep-extension-for-pce-controller](#)] or this document. Note that the specific BSID could be from the PCE-controlled or the PCC-controlled label space. PCE would directly allocate the label from the PCE-controlled label space using P=1 as described above, whereas PCE would request for the allocation of a specific BSID from the PCC-controlled label space with P=0 as described in [Section 4](#).

8. 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".

8.1. Huawei

- o Organization: Huawei
- o Implementation: Huawei's Router and Controller
- o Description: An experimental code-point is used and plan to request early code-point allocation from IANA after WG adoption.
- o Maturity Level: Production
- o Coverage: Full
- o Contact: chengli13@huawei.com

8.2. Cisco

- o Organization: Cisco Systems
- o Implementation: Head-end and controller.
- o Description: An experimental code-point is currently used.
- o Maturity Level: Production
- o Coverage: Full
- o Contact: mkoldych@cisco.com

9. Security Considerations

The security considerations described in [\[RFC5440\]](#), [\[RFC8231\]](#), [\[RFC8281\]](#) and [\[RFC8664\]](#) are applicable to this specification. No additional security measure is required.

As described [\[RFC8664\]](#), SR allows a network controller to instantiate and control paths in the network. A rouge PCE can manipulate binding SID allocations to move traffic around for some other LSPs that uses BSID in its SR-ERO.

Thus, as per [\[RFC8231\]](#), it is RECOMMENDED that these PCEP extensions only be activated on authenticated and encrypted sessions across PCEs and PCCs belonging to the same administrative authority, using Transport Layer Security (TLS) [\[RFC8253\]](#), as per the recommendations and best current practices in [BCP195](#) [\[RFC7525\]](#) (unless explicitly set aside in [\[RFC8253\]](#)).

10. Manageability Considerations

All manageability requirements and considerations listed in [\[RFC5440\]](#), [\[RFC8231\]](#), and [\[RFC8664\]](#) apply to PCEP protocol extensions defined in this document. In addition, requirements and considerations listed in this section apply.

10.1. Control of Function and Policy

A PCC implementation SHOULD allow the operator to configure the policy based on which PCC needs to allocate the binding label/SID.

10.2. Information and Data Models

The PCEP YANG module [[I-D.ietf-pce-pcep-yang](#)] could be extended to include policy configuration for binding label/SID allocation.

10.3. 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](#)].

10.4. 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 [[RFC8664](#)].

10.5. Requirements On Other Protocols

Mechanisms defined in this document do not imply any new requirements on other protocols.

10.6. Impact On Network Operations

Mechanisms defined in [[RFC5440](#)], [[RFC8231](#)], and [[RFC8664](#)] also apply to PCEP extensions defined in this document. Further, the mechanism described in this document can help the operator to request control of the LSPs at a particular PCE.

11. IANA Considerations

11.1. PCEP TLV Type Indicators

This document defines a new PCEP TLV; IANA is requested to make the following allocations from the "PCEP TLV Type Indicators" sub-registry of the PCEP Numbers registry, as follows:

Value	Name	Reference
TBD1	TE-PATH-BINDING	This document

11.1.1. TE-PATH-BINDING TLV

IANA is requested to create a sub-registry to manage the value of the Binding Type field in the TE-PATH-BINDING TLV.

Value	Description	Reference
0	MPLS Label	This document
1	MPLS Label Stack Entry	This document
2	SRv6 SID	This document
3	SRv6 SID with Behavior and Structure	This document

11.1.2. Binding SID Flags

IANA is requested to create a sub-registry to manage the value of the Binding SID Flags field in the TE-PATH-BINDING-TLV. New values are to be assigned by Standards Action [[RFC8126](#)]. Each bit should be tracked with the following qualities:

- o Bit number (count from 0 as the most significant bit)
- o Flag Name
- o Reference

Bit	Description	Reference
7	Specified-BSID-Only Flag (S-Flag)	This document
6	Drop Upon Invalid Flag (I-Flag)	This document

11.2. LSP Object

IANA is requested to allocate new code-point in the "LSP Object Flag Field" sub-registry for the new P flag as follows:

Bit	Description	Reference
TBD6	PCE-allocated binding label/SID	This document

11.3. PCEP Error Type and Value

This document defines a new Error-type and Error-Values for the PCErr message. IANA is requested to allocate new error-type and error-values within the "PCEP-ERROR Object Error Types and Values" subregistry of the PCEP Numbers registry, as follows:

Error-Type	Meaning
-----	-----
TBD2	Binding label/SID failure:
	Error-value = TBD3: Invalid SID
	Error-value = TBD4: Unable to allocate
	the specified
	label/SID
	Error-value = TBD5: Unable to allocate
	label/SID

12. Acknowledgements

We like to thank Milos Fabian, Mrinmoy Das, and Andrew Stone for their valuable comments.

13. References

13.1. Normative References

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