PCE Working Group
Internet-Draft
Intended status: Standards Track
Expires: June 20, 2019

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December 17, 2018

PCEP extension to support Segment Routing Policy Candidate Paths
draft-barth-pce-segment-routing-policy-cp-01

Abstract

This document introduces a mechanism to specify an Segment Routing (SR) policy, as a collection of SR candidate paths. An SR policy is identified by <headend, color, end-point> tuple. An SR policy can contain one or more candidate paths where each candidate path is identified in PCEP via an PLSP-ID. This document proposes extension to PCEP to support association among candidate paths of a given SR policy. The mechanism proposed in this document is applicable to both MPLS and IPv6 data planes.

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.

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1. Introduction

Path Computation Element (PCE) Communication Protocol (PCEP) [RFC5440] enables the communication between a Path Computation Client (PCC) and a Path Control Element (PCE), or between two PCEs based on the PCE architecture [RFC4655].

PCEP Extensions for the Stateful PCE Model [RFC8231] describes a set of extensions to PCEP to enable active control of Multiprotocol Label Switching Traffic Engineering (MPLS-TE) and Generalized MPLS (GMPLS) tunnels. [RFC8281] describes the setup and teardown of PCE-initiated LSPs under the active stateful PCE model, without the need for local configuration on the PCC, thus allowing for dynamic centralized control of a network.

PCEP Extensions for Segment Routing [I-D.ietf-pce-segment-routing] specifies extensions to the Path Computation Element Protocol (PCEP) that allow a stateful PCE to compute and initiate Traffic Engineering (TE) paths, as well as a PCC to request a path subject to certain constraint(s) and optimization criteria in SR networks.

PCEP Extensions for Establishing Relationships Between Sets of LSPs [I-D.ietf-pce-association-group] introduces a generic mechanism to create a grouping of LSPs which can then be used to define associations between a set of LSPs and a set of attributes (such as configuration parameters or behaviors) and is equally applicable to stateful PCE (active and passive modes) and stateless PCE.

Segment Routing Policy for Traffic Engineering [I-D.ietf-spring-segment-routing-policy] details the concepts of SR Policy and approaches to steering traffic into an SR Policy.

An SR policy contains one or more candidate paths where one or more such paths can be computed via PCE. This document specifies PCEP extensions to signal additional information to map candidate paths to their SR policies. Each candidate path maps to a unique PLSP-ID in PCEP. By associating multiple candidate paths together, a PCE becomes aware of the hierarchical structure of an SR policy. Thus the PCE can take computation and control decisions about the candidate paths, with the additional knowledge that these candidate paths belong to the same SR policy. This is accomplished via the use of the existing PCEP Association object, by defining a new association type specifically for associating SR candidate paths into a single SR policy.

[Editor's Note- Currently it is assumed that each candidate path has only one ERO (SID-List) within the scope of this document. A future

update or another document will deal with a way to allow multiple ERO/SID-Lists for a candidate path within PCEP.]

2. Terminology

The following terminologies are used in this document:

Endpoint: The IPv4 or IPv6 endpoint address of the SR policy in question, as described in [I-D.ietf-spring-segment-routing-policy].

Association parameters: As described in [I-D.ietf-pce-association-group], the combination of the mandatory fields Association type, Association ID and Association Source in the ASSOCIATION object uniquely identify the association group. If the optional TLVs - Global Association Source or Extended Association ID are included, then they MUST be included in combination with mandatory fields to uniquely identifying the association group.

Association information: As described in [I-D.ietf-pce-association-group], the ASSOCIATION object MAY include other optional TLVs based on the association types, that provides 'information' related to the association type.

PCC: Path Computation Client. Any client application requesting a path computation to be performed by a Path Computation Element.

PCE: Path Computation Element. An entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints.

PCEP: Path Computation Element Protocol.

3. Motivation

The new Association Type (SR Policy Association) and the new TLVs of the ASSOCIATION object, defined in this document, allow PCEP peers to exchange additional parameters of SR candidate paths and of their parent SR policy. For the SR policy, the parameters are: color and endpoint. For the candidate path, the parameters are: protocol origin, originator, discriminator and preference.

The motivation for signaling these parameters is summarized in the following subsections.

3.1. Group Candidate Paths belonging to the same SR policy

Since each candidate path of an SR policy appears as a different LSP (identified via a PLSP-ID) in PCEP, it is useful to group together all the candidate paths that belong to the same SR policy. Furthermore, it is useful for the PCE to have knowledge of the SR candidate path parameters such as color, protocol origin, discriminator, and preference.

3.2. Instantiation of SR policy candidate paths

A PCE may want to instantiate one or more candidate paths on the PCC, as specified in [RFC8281]. In this scenario, the PCE needs to signal to a PCC <headend, color, end-point, originator, discriminator, preference> tuple using which the PCC can instantiate a candidate path for the SR policy identified. Current PCEP standards (as of the time of this writing) do not provide a way to signal color and preference. Although end-point can be signaled via the PCEP END-POINTS object, this object may not be suitable because the end-point to which the path is computed is not required to be the same IPv4/IPv6 address as the actual endpoint of the SR policy. Thus, a separate way to specify SR policy's end-point is provided in this draft.

3.3. Avoid computing lower preference candidate paths

When a PCE knows that a given set of candidate paths all belong to the same SR policy, then path computation MAY be done on only the highest preference candidate-path(s). Path computation for lower preference paths is not necessary if one or two higher preference paths are already computed. Since computing their paths will not affect traffic steering, it MAY be postponed until the higher preference paths become invalid, thus saving computation resources on the PCE.

3.4. Minimal signaling overhead

When an SR policy contains multiple candidate paths computed by a PCE, such candidate paths can be created, updated and deleted independently of each other. This is achieved by making each candidate path correspond to a unique LSP (identified via PLSP-ID). For example, if an SR policy has 4 candidate paths, then if the PCE wants to update one of those candidate paths, only one set of PCUpd and PCRpt messages needs to be exchanged.

4. Overview

As per [I-D.ietf-pce-association-group], LSPs are placed into an association group. In our case, each LSP corresponds to a candidate path of an SR policy, and the association group corresponds to the SR policy itself. Segment-lists within a candidate path are NOT represented by different LSPs (and identified via PLSP-IDs).

[Editor's Note - The subject of encoding multiple segment lists within a candidate path is left to a future document and is not specified in this draft. It is not a good idea to have each segment-list correspond to a different LSP/PLSP-ID, because when the PCC wants to get a path, it must know in advance how many multipaths (i.e., segment-lists) there will be and create that many LSPs/PLSP-IDs. For example, if the PCC supports 32 multipaths, then it must delegate 32 LSPs/PLSP-IDs for every candidate path, which may not be scalable.]

A new Association Type is defined in this document, based on the generic ASSOCIATION object. Association type = TBD1 "SR Policy Association Type" for SR Policy Association Group (SRPAG).

The SRPAG Association is only meant to be used for SR LSPs and with PCEP peers which advertise SR capability.

An Association object of SRPAG group contains TLVs that carry Association Information. The association information can be subdivided into three parts: Policy identifiers, Candidate path identifiers, and Candidate path attributes.

Policy Identifiers uniquely identify the SR policy to which a given LSP belongs, within the context of the head-end. Policy Identifiers MUST be the same for all candidate paths in the same SRPAG. Policy Identifiers MUST NOT change for a given LSP during its lifetime. Policy Identifiers MUST be different for different SRPAG associations. When these rules are not satisfied, the PCE MUST send a PCErr message with Error Code = 26 "Association Error", Error Type = TBD5 "Conflicting SRPAG TLV". Policy Identifiers consist of:

- Color of SR policy.

- End-point of SR policy.

Candidate Path Identifiers uniquely identify the SR candidate path within the context of an SR policy. Candidate path Identifiers MUST NOT change for a given LSP during its lifetime. Candidate path Identifiers MUST be different for different LSPs within the same SRPAG. When these rules are not satisfied, the PCE MUST send a PCErr

message with Error Code = 26 "Association Error", Error Type = TBD5 "Conflicting SRPAG TLV". Candidate path Identifiers consist of:

- o Protocol Origin of candidate path.
- o Originator of candidate path.
- o Discriminator of candidate path.

Candidate Path Attributes MUST NOT be used to identify the candidate path. Candidate path attributes carry additional information about the candidate path and MAY change during the lifetime of the LSP. Candidate path Attributes consist of:

- o Preference of candidate path.

As described in [RFC8231], an LSP is uniquely identified in PCEP via PLSP-ID.

A mapping between he Association Parameters (see Section 2) and Policy Identifiers (the Color and End-point) needs to be maintained. The mapping is left up to the implementation. An implementation MAY choose Association Parameters in such a way that every possible Color and End-point maps to a unique value of Association Parameters, which may require the use of Extended Association ID TLV. Alternatively, an implementation MAY implement a lookup table to generate Association Parameters incrementally as new Color and End-point values are created, which may not require the use of Extended Association ID TLV.

As per the processing rules specified in section 5.4 of [I-D.ietf-pce-association-group], if a PCEP speaker does not support the SRPAG association type, it MUST return a PCErr message with Error-Type 26 (Early allocation by IANA) "Association Error" and Error-Value 1 "Association-type is not supported". Please note that the corresponding PCEP session is not reset.

5. SR Policy Association Group

Two object types for IPv4 and IPv6 are defined. The ASSOCIATION object includes "Association type" indicating the type of the association group. This document adds a new Association type.

Association type = TBD1 "SR Policy Association Type" for SR Policy Association Group (SRPAG).

The operator configured Association Range SHOULD NOT be set for this association type and MUST be ignored.

SRPAG MUST carry additional TLVs to communicate Association Information. This document specifies three new TLVs to carry Association Information: SRPAG-POL-ID-TLV, SRPAG-CPATH-ID-TLV, SRPAG-CPATH-ATTR-TLV. These three TLVs encode the Policy Identifiers, Candidate path Identifiers and Candidate path Attributes, respectively. When any of the mandatory TLVs are missing from the SRPAG association object, the PCE MUST send a PCErr message with Error Code = 26 "Association Error", Error Type = TBD6 "Missing mandatory SRPAG TLV".

A given LSP MUST belong to at most one SRPAG, since a candidate path cannot belong to multiple SR policies. If a PCEP speaker receives a PCEP message with more than one SRPAG for an LSP, then the PCEP speaker MUST send a PCErr message with Error-Type 26 "Association Error" and Error-Value TBD7 "Multiple SRPAG for one LSP". If the message is a PCRpt message, then the PCEP speaker MUST close the PCEP connection. Closing the PCEP connection is necessary because ignoring PCRpt messages may lead to inconsistent LSP DB state between the two PCEP peers.

5.1. SR Policy Association Group Policy Identifiers TLV

The SRPOLICY-POL-ID TLV is a mandatory TLV for the SRPAG Association. Only one SRPOLICY-POL-ID TLV can be carried and only the first occurrence is processed and any others MUST be ignored.

```
     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
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |             Type              |             Length            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                             Color                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    ~                           End-point                           ~
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: The SRPOLICY-POL-ID TLV format

Type: TBD2 for "SRPOLICY-POL-ID" TLV.

Length: 8 or 20, depending on length of End-point (IPv4 or IPv6)

Color: any unsigned 32-bit number.

End-point: can be either IPv4 or IPv6, depending on whether the policy endpoint has IPv4 or IPv6 address. This value may be different from the one contained in the END-POINTS object, or in the LSP IDENTIFIERS TLV of the LSP object. Endpoint is meant to strictly

correspond to the endpoint of the SR policy, as it is defined in [I-D.ietf-spring-segment-routing-policy].

5.2. SR Policy Association Group Candidate Path Identifiers TLV

The SRPOLICY-CPATH-ID TLV is a mandatory TLV for the SRPAG Association. Only one SRPOLICY-CPATH-ID TLV can be carried and only the first occurrence is processed and any others MUST be ignored.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type              |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Proto. Origin |                    Reserved                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Originator ASN                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                       Originator Address                      |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Discriminator                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: The SRPOLICY-CPATH-ID TLV format

Type: TBD3 for "SRPOLICY-CPATH-ID" TLV.

Length: 28.

Protocol Origin: 8-bit value that encodes the protocol origin, as specified in [I-D.ietf-spring-segment-routing-policy] Section 2.3.

Reserved: MUST be set to zero on transmission and ignored on receipt.

Originator ASN: Represented as 4 byte number, part of the originator identifier, as specified in [I-D.ietf-spring-segment-routing-policy] Section 2.4.

Originator Address: Represented as 128 bit value where IPv4 address are encoded in lowest 32 bits, part of the originator identifier, as specified in [I-D.ietf-spring-segment-routing-policy] Section 2.4.

Discriminator: 32-bit value that encodes the Discriminator of the candidate path.

5.3. SR Policy Association Group Candidate Path Attributes TLV

The SRPOLICY-CPATH-ATTR TLV is an optional TLV for the SRPAG Association. Only one SRPOLICY-CPATH-ATTR TLV can be carried and only the first occurrence is processed and any others MUST be ignored.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Type              |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Preference                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: The SRPOLICY-CPATH-ATTR TLV format

Type: TBD4 for "SRPOLICY-CPATH-ATTR" TLV.

Length: 4.

Preference: Numerical preference of the candidate path, as specified in [I-D.ietf-spring-segment-routing-policy] Section 2.7.

If the TLV is missing, a default preference of 100 as specified in [I-D.ietf-spring-segment-routing-policy] is used.

6. Examples

6.1. PCC Initiated SR Policy with single candidate-path

PCReq and PCRep messages are exchanged in the following sequence:

1. PCC sends PCReq message to the PCE, encoding the SRPAG ASSOCIATION object and TLVs in the PCReq message.

2. PCE returns the path in PCRep message, and echoes back the SRPAG object that was used in the computation.

PCRpt and PCUpd messages are exchanged in the following sequence:

1. PCC sends PCRpt message to the PCE, including the LSP object and the SRPAG ASSOCIATION object.

2. PCE computes path, possibly making use of the Association Information from the SRPAG ASSOCIATION object.

3. PCE updates the SR policy candidate path's ERO using PCUpd message.

6.2. PCC Initiated SR Policy with multiple candidate-paths

PCReq and PCRep messages are exchanged using the sequence specified in section 6.1 with individual query for each candidate-path.

PCRpt and PCUpd messages are exchanged in the following sequence:

1. Step 1: For each candidate path of the SR policy, the PCC generates a different PLSP-ID and symbolic-name and sends multiple PCRpt messages (or one message with multiple LSP objects) to the PCE. Each LSP object is followed by SRPAG ASSOCIATION object with identical Color and Endpoint values.

2. Step 2: PCE takes into account that all the LSPs belong to the same SR policy. PCE prioritizes computation for the highest preference LSP and sends PCUpd message(s) back to the PCC.

3. Step 3: If a new candidate path is added on the PCC by the operator, then a new PLSP-ID and symbolic name is generated for that candidate path and a new PCRpt is sent to the PCE.

4. Step 4: If an existing candidate path is removed from the PCC by the operator, then that PLSP-ID is deleted from the PCE by sending PCRpt with the R-flag in the LSP object set.

6.3. PCE Initiated SR Policy with single candidate-path

A candidate-path is created using the following steps:

1. PCE sends PCInit message, as usual containing the SRPAG Association object. PCE needs to generate a symbolic-name for this LSP that will not clash with other symbolic names on the same PCC.

2. PCC uses the color, endpoint and preference from the SRPAG object to create a new candidate path. If no SR policy exists to hold the candidate path, then a new SR policy is created to hold the new candidate-path. The Originator of the candidate path is set to be the address of the PCE that is sending the PCInit message.

3. PCC allocates a locally unique PLSP-ID for the newly created candidate path. This PLSP-ID is sent to the PCE in the PCRpt message.

A candidate-path is deleted using the following steps:

1. PCE sends PCInit message, setting the R-flag in the LSP object.

2. PCC uses the PLSP-ID from the LSP object to find the candidate path and delete it. If this is the last candidate path under the SR policy, then the containing SR policy is deleted as well.

6.4. PCE Initiated SR Policy with multiple candidate-paths

A candidate-path is created using the following steps:

1. PCE sends a separate PCInit message for every candidate path that it wants to create, or it sends multiple LSP objects within a single PCInit message. Each candidate-path must get a unique symbolic-name generated on the PCE. SRPAG object is sent for every LSP in the PCInit message.

2. PCC creates multiple candidate paths under the same SR policy, identified by Color and Endpoint. PCC generates a unique PLSP-ID for every candidate path.

3. PCC allocates a locally unique PLSP-ID for each newly created candidate path. This PLSP-ID is sent to the PCE in the PCRpt message.

A candidate path is deleted using the following steps:

1. PCE sends PCInit message, setting the R-flag in the LSP object.

2. PCC uses the PLSP-ID from the LSP object to find the candidate path and delete it.

7. IANA Considerations

7.1. Association Type

This document defines a new association type: SR Policy Association Group (SRPAG). IANA is requested to make the assignment of a new value for the sub-registry "ASSOCIATION Type Field" (request to be created in [I-D.ietf-pce-association-group]), as follows:

Association Type Value	Association Name	Reference
TBD1	SR Policy Association	This document

7.2. PCEP Errors

This document defines three new Error-Values within the "Association Error" Error-Type. IANA is requested to allocate new error values within the "PCEP-ERROR Object Error Types and Values" sub-registry of the PCEP Numbers registry, as follows:

Error Type	Error Value	Meaning	Reference
29	TBD5	Conflicting SRPAG TLV	This document
29	TBD6	Missing mandatory SRPAG TLV	This document
29	TBD7	Multiple SRPAG for one LSP	This document

7.3. SRPAG TLVs

This document defines three new TLVs for carrying additional information about SR policy and SR candidate paths. IANA is requested to make the assignment of a new value for the existing "PCEP TLV Type Indicators" registry as follows:

TLV Type Value	TLV Name	Reference
TBD2	SRPOLICY-POL-ID	This document
TBD3	SRPOLICY-CPATH-ID	This document
TBD4	SRPOLICY-CPATH-ATTR	This document

8. Security Considerations

None at this time.

9. Acknowledgement

10. References

10.1. Normative References

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10.2. Informative References

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