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Stateful PCE for SR-MPLS-TP Inter-domain
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Abstract

This document proposes two solutions to perform the Segment routing transport Profile with MPLS data plane(SR-MPLS-TP) inter-domain path computation and initiation with stateful PCEs including stitching Association Group and stitching labels.

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1. Introduction

The Path Computation Element (PCE) architecture is defined in [RFC4655] for MPLS Traffic Engineering (MPLS-TE) and Generalized MPLS (GMPLS) networks. The Path Computation Element Communication Protocol (PCEP) defined in [RFC5440] provides mechanisms for PCEs to perform path computations in response to Path Computation Clients (PCCs) requests.

[I-D.ietf-pce-segment-routing] proposes extensions to PCEP that allow a stateful PCE to compute TE paths in segment routing (SR) networks. As defined in [I-D.cheng-spring-mpls-path-segment], a path segment is used to identify a SR path and support bidirectional SR paths correlation. [I-D.xiong-pce-pcep-extension-sr-tp] proposed a mechanism to create the bidirectional SR tunnel in a single SR domain. [I-D.hu-mpls-sr-inter-domain-use-cases] defined a inter-domain path segment and related inter-domain use cases for Segment Routing in MPLS Transport Profile (SR-MPLS-TP) networks. It is required to perform the SR inter-domain path computation and initiation with PCE deployment.

The path computation requirments for Label Switched Paths (LSPs) across multiple domains are discussed in [RFC4105] and [RFC4216].

Inter-domain path computation can be performed by a single stateful PCE and multiple stateful PCEs. The PCE may has no ability to collect the topologies all over the domains. So the single PCE model is not applied in deployment. Three multiple PCEs models can be uesd to perform PCE-based inter-domain path computation including Per-Domain Path Computation [RFC5152], Backward-Recursive PCE-Based Computation (BRPC) [RFC5441] and Hierarchical PCE (H-PCE) [RFC6805]. Computing the optimum inter-domain path requires co-operation between multiple PCEs. But the sequence of domains need to be known before the path computation in BRPC mechanism. Stateful H-PCE architecture is appropriate to compute an optimal end-to-end path across multiple domains.

As defined in [I-D.hu-mpls-sr-inter-domain-use-cases], two SR-MPLS-TP inter-domain models includes stitching and nesting inter-domain models. This document proposes two solutions to perform the SR-MPLS-TP inter-domain path computation and initiation with stateful PCEs including stitching LSPs Association and stitching labels.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

1.2. Terminology

The terminology is defined as [RFC5440], [I-D.ietf-pce-segment-routing] , [I-D.cheng-spring-mpls-path-segment].

2. The SR-MPLS-TP Inter-domain with PCE

The SR-MPLS-TP stitching inter-domain scenario is described in [I-D.hu-mpls-sr-inter-domain-use-cases]. The SR nodes belong to three Autonomous Systems (AS) including SR-AS1, SR-AS2 and SR-AS3 which connecting with logical links or border nodes as the Figure 1 shown. The SR inter-domain LSP needs to be provided along the inter-AS paths. The Path 1~5 are forwarding path segments and Path 1'~5' are the related reverse path segments and these are all inter-domain path segments.

```
                                +-------+
             +------------------+ H-PCE +-------------------+
             |                  +---+---+                   |
             |                      |                       |
             v                      v                       v
          +--+--+                +--+--+                 +--+--+
          |PCE-1|                |PCE-2|                 |PCE-3|
          +--+--+                +--+--+                 +--+--+
             |                      |                       |
             v                      v                       v
 SR Border Node Network:
       ..................   ..................   ....................
       .                .   .                .   .                  .
   +-----+             +-----+             +-----+              +-----+
   |  A  |             |  X  |             |  Y  |              |  Z  |
   +-----+             +-----+             +-----+              +-----+
       .    SR-AS1      .   .   SR-AS2      .   .    SR-AS3        .
       ..................   ..................   ....................

    Forwarding Path Segments:
       |------Path1------->|-----Path2------->|--------Path3------>|
    Reverse Path Segments:
       |<-----Path1'-------|<----Path2'-------|<--------Path3'-----|

 SR Border Link Network:
    ....................   ....................    ....................
    .                  .   .                  .    .                  .
    . +---+      +---+ .   . +---+     +---+  .    . +---+     +----+  .
    . | A |------| B |-------| C |-----| X |---------| Y |-----| Z  |  .
    . +---+      +---+ .   . +---+     +---+  .    . +---+     +----+  .
    .    SR-AS1        .   .      SR-AS2      .    .     SR-AS3        .
    ....................   ....................    ....................

    Forwarding Path Segments:
    |----Path1---->|-Path2-->|----Path3--->|-Path4-->|-----Path5------>|
    Reverse Path Segments:
    |<---Path1'----|<-Path2'-|<---Path3'---|<-Path4'-|<----Path5'------|
```

Figure 1 The SR Stitching Inter-Domain with H-PCE

The hierarchical PCE architecture is described in [RFC6805], a parent PCE maintains a domain topology map that contains the child domains (seen as vertices in the topology) and their interconnections (links in the topology) but no information about the content of the child domains. Each child domain has one PCE taking in charge of computing paths across its own domain. These PCEs are known as child PCEs and have a relationship with the parent PCE. As the Figure 1 shown,

H-PCE is parent PCE and PCE-1, PCE-2 and PCE-3 are child PCEs which is responsible for each own SR-AS.

When an optimal inter-domain path is required, the ingress PCE sends a request to the parent PCE or the stateful parent PCE itself to initiate the path computation. The parent PCE selects a set of candidate domain paths based on the domain topology and the state of the inter-domain links. It then sends computation requests to the child PCEs responsible for each of the domains on the candidate domain paths. The stateful child PCE in each domain performs active stateful procedure as defined [RFC8231].

2.1. The Stitching LSP Association Solution

The LSPs of multiple domains can be stitched together by adding them to a stitching LSP association group as defined in [I-D.hu-pce-stitching-lsp-association]. As the Figure 2 shown, the stateful H-PCE sends the PCInit message defined in [RFC8281] to initiate the inter-domain path computation adding the forwarding LSP 1~3 to Assoc#1 and reverse LSP 1'~3' to Assoc#2. The child PCEs may initiate the intra-domain LSPs when receiving the message from parent PCE.

```
                                +-------+
              +-----------------+ H-PCE +-----------------+
      PCInit  |                 +---+---+                 |
(LSP1,Assoc#1) |  PCInit(LSP2,Assoc#1)| PCInit(LSP3,Assoc#1)|
      PCInit  | PCInit(LSP2',Assoc#2 |PCInit(LSP3',Assoc#2 |
(LSP1',Assoc#2)|                     |                     |
              v                     v                     v
           +-----+               +-----+               +-----+
           |PCE-1|               |PCE-2|               |PCE-3|
           +-----+               +-----+               +-----+
      PCInit/   \PCInit       PCInit/  \PCInit       PCInit/ \PCInit
       LSP1/     \LSP1'        LSP2/    \LSP2'        LSP3/   \LSP3'
   Assoc#1/       \Assoc#2 Assoc#1/      \Assoc#2 Assoc#1/     \Assoc#2
         v         v            v         v            v        v
   +-----+   LSP1  +-----------+   LSP2   +-----------+  LSP3   +-----+
   |  A  |-------->|     X     |--------->|     Y     |-------->|  Z  |
   |     |<--------|           |<---------|           |<--------|     |
   +-----+  LSP1'  +-----------|   LSP2'  +-----------+  LSP3'  +-----+
```

Figure 2 The SR inter-domain Stitching LSP Association

2.2. The Stitching Label Solution

This section defined the inter-domain path segments as stitching Labels which used to stitch per-domain LSP tunnels in order to form inter-domain path that cross multiple domains.

SR intra-domain path is setup as part of inter-domain SR path. When PCC requests the PCE or the PCE itself to initiate The SR path, the inter-domain path segments should be carried as a stitching Label with the associated link.

```
                                +-------+
             +------------------+ H-PCE +-----------------+
      PCInit |                  +---+---+                 |
 (LSP1,LSP1')|    PCInit(LSP2,LSP2')|   PCInit(LSP3,LSP3')|
    SL1,SL1' |    SL1,SL1',SL2,SL2' |            SL2,SL2' |
             v                      v                     v
 ....................   ....................    ....................
 .                  .   .                  .    .                  .
 . +---+ LSP1 +---+ .   . +---+ LSP2+---+  .    . +---+ LSP3+----+  .
 . | A |----->| B |--SL1->| C |---->| X |---SL2-->| Y |---->| Z  |  .
 . |   |<-----|   |<-SL1'-|   |<----|   |<--SL2'--|   |<----|    |  .
 . +---+ LSP1'+---+ .   . +---+LSP2'+---+  .    . +---+LSP3'+----+  .
 .    SR-AS1        .   .      SR-AS2      .    .     SR-AS3        .
 ....................   ....................    ....................

 SL:Stiching Label
```

Figure 3 The SR Inter-Domain Stitching Label

3. Inter-domain Path Segment Allocation

The inter-domain path segment may be allocated by PCC or PCE. The PCE may be the single domain PCE which taking in charge of the respective domain. The inter-domain path segments is a unique value in the domain which PCC or PCE belongs to. The mechanism of path segment request and reply may be the same with that in single domain as defined in [I-D.xiong-pce-pcep-extension-sr-tp].

3.1. PCC Allocated

As defined in [I-D.hu-mpls-sr-inter-domain-use-cases], an inter-domain path segment can be allocated by egress PCC and may be maintained on the PCC itself. The inter-domain path segment connects two domains and the ingress and egress PCC are belong to different

domains. The ingress and egress PCC need to exchange messages which carrying path segment information between the two PCEs.

The Ingress PCC may request to allocate a path segment from egress PCC. Once egress PCC allocated the inter-domain path segment, it need to inform the PCE in respective domain with the PCRpt message. The PCE need to communicate with the PCE which the ingress PCC belongs to inform the value allocated.

3.2. PCE Allocated

The ingress PCC may request the inter-domain path segment to be allocated by the PCE in PCC-Initiated LSP. The PCE may allocate the inter-domain path segment on its own domain in PCEs-Initiated LSP. The allocated path segment needs to be informed to the ingress and egress PCC.

The inter-domain path segments may be allocated separately by the PCEs which control the ingress and egress PCC along with the LSP initiation.

4. PCEP Procedure

[RFC8281] describes setup, maintenance and teardown of PCE-initiated LSPs under the stateful PCE model, without the need for local configuration on the PCC. Similar to LSP updation, the inter-domain LSP can be initiated by the ingress PCE using the PCInitiate message to the ingress LSR. The inter-domain path segment is viewed as stitching label. Per-domain LSP may also be initiated by respective domain's PCE and stitched together.

4.1. HPCE-initiated LSP

In H-PCE [RFC6805] architecture, the parent PCE is used to compute a multi-domain path based on the domain connectivity information. The stateful H-PCE in active model can be used to initiate the inter-domain bidirectional path for SR networks. PCE sends PCInitiate message to its domain SR nodes with ERO={SID LIST} and carrying stitching association group TLV and path segments. If the SR nodes is the border nodes of the SR domain, it correlates the two path segments and the related SID list if the related association ID is the same value.

The PECP procedure for the HPCE-initiated LSP is following:

The stateful H-PCE initiates the end-to-end path computation across multiple domains and selects a set of candidate domain paths based on the topology.

The stateful H-PCE sends PCInitiate message to every PCEs which the end-to-end path traversed, carrying inter-domain path segments allocated by H-PCE, stitching LSP association group and the SID list in the ERO object.

The stateful child PCE in each domain perform active stateful procedure as defined in [I-D.xiong-pce-pcep-extension-sr-tp].

4.2. PCC-initiated LSP

In case of passive path computation request to the ingress PCE from the ingress LSR, the H-PCE path computation procedure is applied to compute sequence of domains or end-to-end path by using PCReq and PCRep messages among stateful PCEs in passive mode.

In case of delegation to the ingress PCE (active stateful PCE), the ingress child PCE may further delegate to parent PCE as per [I-D.ietf-pce-stateful-hpce]. The parent PCE could update the path of the inter-domain LSP.

The ingress nodes of the source AS sends the PCReq message to its PCE, then the PCE sends PCReq message to the H-PCE or stateful PCEs in other domains. The PECP procedure for the PCC-initiated LSP in H-PCE model is as follow.

The ingress PCC from the ingress domain sends a PCReq request to the PCE which is responsible for the domain containing the destination information.

The ingress PCE sends the path computation request direct to the parent PCE.

The parent PCE computes the optimal end-to-end path and initiates the inter-domain paths to the child PCEs which the path traversed.

Each PCE sends PCInitiate message to ingress or egress nodes of its domain to initiate the LSPs.

5. Security Considerations

TBD.

6. IANA Considerations

TBD.

7. Acknowledgements

TBD.

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