The use of SVEC (Synchronization VECtor) list for Synchronized dependent path computations

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Abstract

A Path Computation Element (PCE) performing dependent path computations, for instance calculating a diverse working and protected path not sharing common network points, would need to synchronize the computations in order to increase the probability of meeting the working and protected path diversity (or disjointness) objective and network resource optimization objective. When a PCE computes multiple sets of dependent path computation requests concurrently, it is required to use Synchronization VECtor (SVEC) list for association among the sets of dependent path computation requests. SVEC is also applicable to end-to-end diverse path computation across multiple domains. This document describes the usage of SVECs in the SVEC list and diverse path computation guideline, for the synchronized computation of dependent paths.

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1. Terminology

This document uses PCE terminology defined in [RFC4655],[RFC4875], and [RFC5440].

GCO (Global Concurrent Optimization): A concurrent path computation application, defined in [RFC5557], where a set of TE paths is computed concurrently in order to efficiently utilize network resources.

Associated SVECs: A group of multiple SVECs (Synchronization Vectorts), defined in this document, to indicate a set of synchronized or concurrent path computations.

VSPT: Virtual Shortest Path Tree defined in [RFC5441].

Disjoint VSPT: A set of VSPTs, defined in this document, to indicate a set of virtual diverse path tree.

2. Introduction

[RFC5440] describes the specifications for PCEP (Path Computation Element communication Protocol). PCEP specifies the communication between a Path Computation Client (PCC) and a Path Computation Element (PCE), or between two PCEs based on the PCE architecture [RFC4655]. PCEP interactions include path computation requests and path computation replies.

[RFC5557] specifies the Global Concurrent Optimization (GCO) path computation mechanism. The GCO application provides the capability to re-optimize a set of services within the network, in order to maximize efficient use of network resources. A single or set of objective functions (OFs) can be applied to a GCO. To compute a set of such traffic-engineered paths for the GCO application, PCEP supports the synchronous and dependent path computation requests.
required in [RFC4657]. When a PCC or PCE sends such path computation requests to a PCE, Synchronization VECtor (SVEC) allows the PCC or PCE to specify a list of multiple path computation requests that must be synchronized along with a potential dependency. [RFC5440] defines two synchronous path computation modes using SVEC.

- Bundle a set of independent and synchronized path computation requests,
- Bundle a set of dependent and synchronized path computation requests.

These are exclusive modes in a single SVEC. If one of the dependency flags (i.e. Node, Link or Shared Risk Link Groups (SRLG) diverse flags) in a SVEC is set, the SVEC indicates a set of synchronous path computation requests with a dependency. In order to be synchronized among multiple sets of path computation requests with a dependency, it is necessary to use other SVECs.

It is important for the PCE, when performing path computations, to synchronize any path computation requests with a dependency. For example, consider a protected end-to-end service. Two diverse path computation requests are needed to compute the disjointed working and protected paths. If the diverse path requests are computed sequentially, fulfillment of the initial diverse path computation without consideration of the second diverse path computation and disjoint constraint may result in the PCE providing sub-optimal results for the second one, or may fail to meet the disjoint requirement altogether.

Additionally, SVEC can be applied to end-to-end diverse path computations that traverse multiple domains. [RFC5441] describes two approaches, synchronous (i.e. simultaneous) and 2-step approaches, for the end-to-end diverse path computation across a chain of domains. The path computation procedure is specified for the 2-step approaches in [RFC5521], but no guidelines are provided for a synchronous approach.

This document defines the handling of synchronous path computation for PCE and multiple set of path computation request with a dependency, based on the PCE architecture [RFC4655]. The following scenarios are specifically described:

- Single domain, single PCE, dependent and synchronized path computation request.
Single domain, multi-PCE, dependent and synchronized path computation request.

Multi-domain, dependent and synchronized path computation request, including end-to-end diverse path computation.

The association among multiple SVECs for multiple sets of synchronized dependent path computation is also described in this document, as well as disjoint Virtual Shortest Path Tree (VSPT) encoding rule for end-to-end diverse path computation across domains. Path computation algorithms for these path computation scenarios are out of the scope of this document.

The SVEC association and the disjoint VSPT described in this document do not require any extension to PCEP message and object formats, when computing a GCO for multiple or end-to-end diverse paths. In addition, the use of multiple SVECs is not restricted to only SRLG, Node and Link diversity currently defined in the SVEC object [RFC5440], but is also available for other dependent path computation requests.

The SVEC association and disjoint VSPT are available to both single PCE path computation and multi-PCE path computation.

3. SVEC association scenarios

This section clarifies several path computation scenarios, in which SVEC association can be applied. Also, any combination of scenarios described in this section could be applicable.

3.1. Synchronized computation for diverse path requests

A PCE may compute two or more point-to-point diverse paths, concurrently, in order to increase the probability of meeting primary and secondary path diversity (or disjointness) objective and network resource optimization objective.

Two scenarios can be considered for the SVEC association of point-to-point diverse paths.

- Two or more end-to-end diverse paths

When concurrent path computation of two or more end-to-end diverse paths is requested, SVEC association is needed among diverse path
requests. Note here that each diverse path request consists of primary, secondary, and tertiary and beyond path requests, in which all path requests are grouped with one SVEC association.

Example of this scenario: When there are two associated end-to-end diverse path requests with primary and secondary, all requests must be computed in a synchronized manner.

- **End-to-end primary path and its segmented secondary paths**

  When concurrent path computation of an end-to-end primary path and several segmented secondary paths is requested, SVEC association is needed among primary/segmented secondary-1 request, primary/segmented secondary-2 request, and etc.

  In this scenario, we assume that the primary path may be pre-computed, which is used for specifying the segment for secondary paths. Otherwise, segment for secondary path requests are specified in advance, by using Exclude Route Object (XRO) and/or Include Route Object (IRO) constraints in the primary request.

**3.2. Synchronized computation for point-to-multipoint path requests**

For point-to-multipoint path requests, SVEC association can be applied.

- **Two or more point-to-multipoint paths**

  If a point-to-multipoint paths request is represented as a set of point-to-point paths [ID.pce-p2mp-ext], two or more point-to-multipoint path computation requests can be associated for concurrent path computation, in order to optimize network resources.

- **Point-to-multipoint paths and their secondary paths**

  When concurrent path computation of a point-to-multipoint path and its point-to-point secondary paths [RFC4875], or a point-to-multipoint path and its point-to-multipoint secondary paths is requested, SVEC association is needed among these requests. In this scenario, we use the same assumption as "end-to-end primary path and its segmented secondary paths scenario" in section 3.1.
4. SVEC association

This section describes the associations among SVECs in a SVEC list.

4.1. Associated SVECs

"Associated SVECs" means that there are relationships among multiple SVECs. Request-IDs in the SVEC objects are used to indicate the association among SVEC objects. If the same request-IDs exist in more than two SVECs, this indicates associated SVECs. When associating among SVECs, only one request-ID in the SVEC object may be contained in the other SVEC object. This contributes to reducing the message size of PCEP request. Even in this case, all the path computation requests are synchronized.

Below is an example of associated SVECs. In this example, the first SVEC is associated with the other SVECs, and path computation requests from Request-ID#1 to Request-ID#Z must be synchronized.

<SVEC-list>

  <SVEC> without dependency flags
    Request-ID #1, Request-ID #3, ..., Request-ID #X
  <SVEC> with one or more dependency flags
    Request-ID #1, Request-ID #2
  <SVEC> with one or more dependency flags
    Request-ID #3, Request-ID #4

  .......

  <SVEC> without dependency flag
    Request-ID #X, Request-ID #Y, Request-ID #Z

4.2. Non-associated SVECs

Non-associated SVECs mean that there are no relationships among SVECs. If SVEC objects in PCEP request messages do not have the same request-ID, the relationship among these SVECs is not associated. Below is an example of non-associated SVECs that does not contain any same request-IDs.
5. Processing of SVEC list

5.1. Single PCE, single domain environments

When a PCE receives PCReq messages with more than two SVEC objects in the SVEC list, PCEP has to first check the request-IDs in all SVEC objects in order to identify any associations among them. The SVEC objects may be received in a single or multiple PCReq message(s). In the latter case, the PCE may start a SyncTimer as recommended in [RFC5440]. After receiving the entire set of path computation requests, the analysis for associated SVECs has to be started.

If there are no matching request-IDs in the different SVEC objects, these SVEC objects are not associated, and then each set of path computation requests in the non-associated SVEC objects has to be computed separately.

If there are matching request-IDs in the different SVEC objects, these SVEC objects are associated, and then all path computation requests in the associated SVEC objects are treated in a synchronous manner for GCO application.

If the PCE does not have capability to handle the associated SVEC objects, it may send a PCErr message with Error-Type="Capability not supported".
5.2. Multi-PCE, single domain environments

Currently no mechanisms exist to manage co-ordination of dependent SVEC requests between multiple PCEs in the same domain. If a PCC sends a path computation request to a PCE and then sends a second service path computation request, which is required to be disjoint from the first service, and this request is sent to a different PCE in the domain, no SVEC object correlation function between the PCEs is currently available. Equally, associated SVECs are not sent to the different PCEs in the domain.

5.3. Multi-PCE, multi-domain environments

When multiple PCEs located in separate domains are used to concurrently compute an end-to-end diverse path across multiple domains, additional processing may be required. The path computation process for the end-to-end diverse path is described in Section 6.

Furthermore, if the PCReq message contains multiple associated SVEC objects and these SVEC objects contain path computation requests that will be sent to the next PCE along the path computation chain, the following procedure is applied. Intermediate PCEs receiving such PCReq messages may re-construct associations among SVEC objects, and then send PCReq messages to corresponding PCEs located in neighboring domains. If the associated SVECs are re-constructed at the intermediate PCE, the PCE must not start path computation until all PCRep messages have been received from all neighbor PCEs. In addition, it is not recommended that SVEC objects coming from different PCReq messages are re-constructed. This may contribute to resource optimization from network operator’s point of view, but it is unrealistic in the case of multiple PCE path computation scenarios.

6. End-to-end diverse path computation

End-to-end diverse path is a set of primary path and secondary paths, which do not share common network resources across domains. To compute the end-to-end diverse path, the BRPC procedure can be used. [RFC5441] describes two approaches, synchronous (i.e. simultaneous) and 2-step approaches, for the end-to-end diverse path computation across a chain of domains. The 2-step approach computes primary and secondary paths sequentially, using XRO, and its procedure is described in [RFC5521]. In this section, the synchronous approach is provided to compute primary and secondary paths simultaneously.
6.1. Disjoint VSPT

The BRPC procedure constructs a VSPT to inform the enquiring PCE of potential paths to the destination node.

In the end-to-end diverse path computation, diversity (or disjointness) information among the potential paths must be preserved in the VSPT to ensure end-to-end disjoint path. In order to preserve diversity (or disjointness) information, disjoint VSPTs are sent in the PCEP PCRep message.

A definition of the disjoint VSPT is a collection of VSPTs, in which each VSPT contains a potential set of primary and secondary paths.

Figure-1 shows an example network. Here, transit nodes in domains are not depicted, and PCE1 and PCE2 may be located in border nodes. In this network, there are three VSPTs for the potential set of diverse paths shown in Figure 2, when the primary path and secondary path are requested from S1 to D1. These VSPTs consist of a disjoint VSPT, which is replied to PCE1. When receiving the disjoint VSPT, PCE1 recognizes the disjoint request and disjoint VSPT information. PCE1 will then continue to process the request and compute the diverse path using the BRPC procedure [RFC5441]. The detail encoding for the disjoint VSPT is described in Section 6.2.

```
Domain1        Domain2
  +----------+       +----------+
 |  PCE1    |       | PCE2    |  S1: Source node
 |          |       |         |  D1: Destination node
 |  S1      |       |  BN2    |  D1  |  BN1-BN6: Border nodes
 |          |       |  BN5    |     |          |
 |          |       |  BN6    |     |          |
  +----------+       +----------+
```

Figure-1: Example network for diverse path computation
6.2. Disjoint VSPT encoding

Encoding for disjoint VSPT follows the definition of PCEP message encoding in [RFC5440].

PCEP PCRep message returns a disjoint VSPT as <path list> for each RP object (Request Parameter object). The order of <path> in <path list> among <responses> implies a set of primary EROs (Explicit Route Objects) and secondary EROs.

A PCE sending PCRep with a disjoint VSPT can reply with a partial disjoint VSPT based on its network operation policy, but the order of <path> in <path list> must be aligned correctly.

If confidentiality is required between domains, path key mechanism defined in [RFC5520] is used for a disjoint VSPT.

Detailed disjoint VSPT encoding in Figure-2 is shown below, when a primary path and a secondary path are requested from S1 to D1.

- Request ID #1 (Primary)
  - ERO1 BN4(TE route ID) - ...-D1(TE-Router ID)  [for VSPT1]
  - ERO2 BN4(TE route ID) - ...-D1(TE-Router ID)  [for VSPT2]
  - ERO3 BN5(TE route ID) - ...-D1(TE-Router ID)  [for VSPT3]

- Request ID #2 (Secondary)
  - ERO4 BN5(TE route ID) - ...-D1(TE-Router ID)  [for VSPT1]
  - ERO5 BN6(TE route ID) - ...-D1(TE-Router ID)  [for VSPT2]
  - ERO6 BN6(TE route ID) - ...-D1(TE-Router ID)  [for VSPT3]
6.3. Path computation procedure

For end-to-end diverse path computation, the same mode of operation as BRPC procedure can be applied (i.e. Step 1 to Step n in Section 4.2 [RFC5441]). During this procedure, a question is how to recognize disjoint VSPTs.

The recognition of disjoint VSPT is achieved by the PCE sending PCReq to its neighbor PCE which maintains the path computation request (PCReq) information. If PCReq has one or more SVEC object(s) with the appropriate diverse flags, the received PCRep will contain the disjoint VSPT. If not, the received VSPT is a normal VSPT based on the shortest path computation.

Note that the PCE will apply a suitable algorithm for computing disjoint VSPT. The selection and application of the appropriate algorithm is out of scope in this draft.

7. Manageability considerations

This section describes manageability considerations specified in [ID.pce-mngabl-reqs].

7.1. Control of Function and Policy

In addition to [RFC5440], PCEP implementation should allow the configuration of association among SVECs on PCCs.

7.2. Information and Data Models, e.g. MIB modules

There are no additional parameters for MIB modules.

7.3. Liveness Detection and Monitoring

The associated SVEC in this document allows PCEs to compute optimal sets of diverse paths. This type of path computation may require more time to obtain its results. Therefore, it is recommended for PCEP to support PCE monitoring mechanism specified in [ID.pce-monitor].
7.4. Verifying Correct Operation

[RFC5440] provides the sufficient descriptions for this document. So, there are no additional considerations.

7.5. Requirements on Other Protocols and Functional Components

This document does not require any other protocol and functional components.

7.6. Impact on Network Operation

[RFC5440] provides the sufficient descriptions for this document. So, there are no additional considerations.

8. Security Considerations

This document defines the usage of SVEC list, and does not have any extensions for PCEP protocol. Therefore, the security of the procedures described in this document depends on PCEP protocol.

9. IANA Considerations

This document has no specific extension for PCEP messages, objects and its parameters and does not require any registry assignment.

10. References

10.1. Normative References


10.2. Informative References


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