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PCE support for Domain Diversity  
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## Abstract

The Path Computation Element (PCE) may be used for computing path for services that traverse multi-area and multi-AS Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineered (TE) networks.

Path computation should facilitate the selection of paths with domain diversity. This document examines the existing mechanisms to do so and further propose some extensions to Path Computation Element Protocol (PCEP).

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## 1. Introduction

The ability to compute shortest constrained TE LSPs in Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) networks across multiple domains has been identified as a key requirement. In this context, a domain is a collection of network elements within a common sphere of address management or path computational responsibility such as an Interior Gateway Protocol (IGP) area or an Autonomous Systems (AS).

In a multi-domain environment, Domain Diversity is defined in [RFC6805]. A pair of paths are domain-diverse if they do not traverse any of the same transit domains. Domain diversity may be maximized for a pair of paths by selecting paths that have the smallest number of shared domains. Path computation should facilitate the selection of domain diverse paths as a way to reduce the risk of shared failure and automatically helps to ensure path diversity for most of the route of a pair of LSPs.

This document examine a way to achieve domain diversity with existing inter-domain path computation mechanism like per-domain path computation technique [RFC5152], Backward Recursive Path Computation (BRPC) mechanism [RFC5441] and Hierarchical PCE [RFC6805]. This document also considers synchronized dependent path computations as well as non-synchronized path computation. Since independent and synchronized path computation cannot be used to apply diversity, it is not discussed in this document.

### 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].

## 2. Terminology

The terminology is as per [RFC5440].

## 3. Domain Diversity

As described in [RFC6805], a set of paths are considered to be domain diverse if they do not share any transit domains, apart from ingress and egress domains.

Some additional parameters to consider would be -

Minimize shared domain: When a fully domain diverse path is not possible, PCE could be requested to minimize the number of shared transit domains. This can also be termed as maximizing partial domain diversity.

Boundary Nodes: TBD

### 3.1. Per Domain Path Computation

The per domain path computation technique [RFC5152] defines a method where the path is computed during the signaling process (on a per-domain basis). The entry Boundary Node (BN) of each domain is responsible for performing the path computation for the section of the LSP that crosses the domain, or for requesting that a PCE for that domain computes that piece of the path.

**Non-Synchronized Path Computation:** Path computations are performed in a serialized and independent fashion. After the setup of primary path, a domain diverse path can be signaled by encoding the transit domain identifiers in XRO or EXRS using domain sub-objects defined in [DOMAIN-SUBOBJ] and [RFC3209] in RSVP-TE. Note that the head end LSR should be aware of transit domain identifiers of the primary path to be able to do so.

**Synchronized Path Computation:** Not Applicable.

### 3.2. Backward-Recursive PCE-based Computation

The BRPC [RFC5441] technique involves cooperation and communication between PCEs in order to compute an optimal end-to-end path across multiple domains. The sequence of domains to be traversed maybe known before the path computation, but it can also be used when the domain path is unknown and determined during path computation.

**Non-Synchronized Path Computation:** Path computations are performed in a serialized and independent fashion. After the path computation and setup of primary path, a domain diverse path computation request is sent by PCC to the PCE, by encoding the transit domain identifiers in XRO or EXRS using domain sub-objects defined in [PCE-DOMAIN] and [RFC3209] in PCEP. Note that the PCC should be aware of transit domain identifiers of the primary path to be able to do so.

**Synchronized Path Computation:** Not Applicable. [Since different transit domain PCEs are involved , there is no way to achieve synchronization for domain diverse paths]. BTW [RFC5440] describes other diversity parameters (node, link etc).

### 3.3. Hierarchical PCE

In H-PCE [RFC6805] architecture, the parent PCE is used to compute a multi-domain path based on the domain connectivity information. The parent PCE may be requested to provide a end to end path or only the sequence of domains.

### 3.3.1. End to End Path

**Non-Synchronized Path Computation:** Path computations are performed in a serialized and independent fashion. After the path computation and setup of primary path, a domain diverse path computation request is sent to the parent PCE, by encoding the transit domain identifiers in XRO or EXRS using domain sub-objects defined in [PCE-DOMAIN] and [RFC3209] in PCEP. Note that the PCC should be aware of transit domain identifiers of the primary path to be able to do so. The parent PCE should provide a domain diverse end to end path.

**Synchronized Path Computation:** Child PCE should be able to request dependent and synchronized domain diverse end to end paths from its parent PCE. A new flag is added in SVEC object for this (Refer Section 4.1).

### 3.3.2. Domain-Sequence

**Non-Synchronized Path Computation:** Path computations are performed in a serialized and independent fashion. After the primary path computation using H-PCE (involving domain-sequence selection by parent PCE and end-to-end path computation via BRPC or Per-Domain mechanisms) and setup, a domain diverse path computation request is sent to the parent PCE, by encoding the transit domain identifiers in XRO or EXRS using domain sub-objects defined in [PCE-DOMAIN] and [RFC3209] in PCEP. Note that the PCC should be aware of transit domain identifiers of the primary path to be able to do so. The parent PCE should provide a diverse domain sequence.

**Synchronized Path Computation:** Child PCE should be able to request dependent and synchronized diverse domain-sequence(s) from its parent PCE. A new flag is added in SVEC object for this (Refer Section 4.1). The parent PCE should reply with diverse domain sequence(s) encoded in ERO as described in [PCE-DOMAIN].

## 4. Extension to PCEP

### 4.1. SVEC Object

[RFC5440] defines SVEC object which includes flags for the potential dependency between the set of path computation requests (Link, Node and SRLG diverse). This document proposes a new flag 0 for domain diversity.

The format of the SVEC object body is as follows:

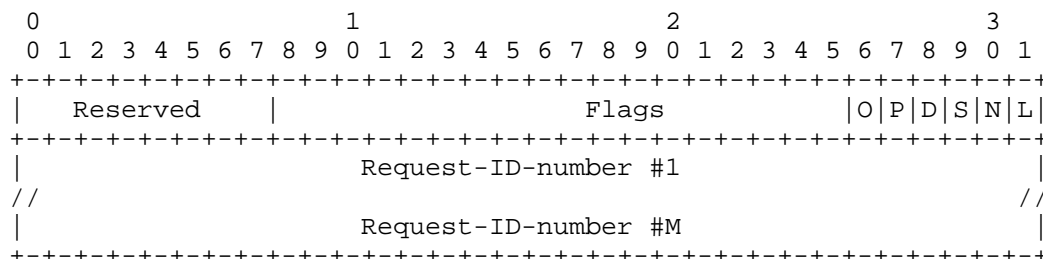


Figure 1: SVEC Body Object Format

Following new bit is added in the Flags field:

- \* O (Domain diverse) bit: when set, this indicates that the computed paths corresponding to the requests specified by the following RP objects MUST NOT have any transit domain(s) in common.

The Domain Diverse O-bit can be used in Hierarchical PCE path computation to compute synchronized domain diverse end to end path or diverse domain sequences as described in Section 3.3.

When domain diverse O bit is set, it is applied to the transit domains. The other bit in SVEC object (N, L etc) is set, should still be applied in the ingress and egress domain.

#### 4.2. Transit Domain Identifier

In case of non-synchronized path computation, Ingress node (i.e. a PCC) should be aware of transit domain identifiers of the primary path. So during the path computation or signaling of the primary path, the transit domain should be identified.

A possible solution for path computation could be a flag in RP object requesting domain identifier to be returned in the PCEP path reply message. Further details - TBD

#### 4.3. Minimize Shared Domains

A new Objective function (OF) [RFC5541] code for synchronized path computation requests is proposed:

MCTD

- \* Name: Minimize the number of Common Transit Domains.
- \* Objective Function Code: TBD

- \* Description: Find a set of paths such that it passes through the least number of common transit domains.

The MCTD OF can be used in Hierarchical PCE path computation to request synchronized domain diverse end to end paths or diverse domain sequences as described in Section 3.3.

For non synchronized diverse domain path computation the X bit in XRO or EXRS [RFC5521] sub-objects can be used, where X bit set as 1 indicates that the domain specified SHOULD be excluded from the path computed by the PCE, but MAY be included subject to PCE policy and the absence of a viable path that meets the other constraints and excludes the domain.

## 5. Security Considerations

TBD.

## 6. Manageability Considerations

### 6.1. Control of Function and Policy

TBD.

### 6.2. Information and Data Models

TBD.

### 6.3. Liveness Detection and Monitoring

TBD.

### 6.4. Verify Correct Operations

TBD.

### 6.5. Requirements On Other Protocols

TBD.

### 6.6. Impact On Network Operations

TBD.

## 7. IANA Considerations

TBD.

## 8. Acknowledgments

We would like to thank Qilei Wang for starting this discussion in the mailing list.

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