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Cooperative Stateful Path Computation Element (PCE)
for Inter-Domain Inter-Vendor PCE-initiated LSP Setup
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Abstract

A stateful Path Computation Element (PCE) maintains the information of Label Switched Path (LSP) and resource availability within a domain. Multiple stateful PCEs are able to provide traffic engineering inter-domain LSPs through cooperating with each other.

This document introduces the applicability of cooperative stateful PCE for establishing inter-domain inter-vendor LSPs which are initiated by PCE.

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](#)].

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Table of Contents

1. Introduction	3
2. Terminology	3
3. Overview of the Stateful PCE.....	3
4. Multiple Stateful PCEs Deployment and Operation	4
4.1. Traffic Engineering Database	5
4.2. Cooperative Inter-domain Path Computation	5
4.3. Cooperative Inter-domain LSP Setup	6
4.4. Vendor-specific Message Conversion	6
5. Applicability of Cooperative Stateful PCE	6
5.1. TED initialization.....	6
5.2. PCE-initiated LSP Setup.....	7
5.2.1. Inter-domain Inter-vendor LSP Setup Request.....	7
5.2.2. Inter-domain Path Computation	7
5.2.3. Inter-domain Path Segmentation	8
5.2.4. Intra-domain LSP Setup Procedure	8
5.2.5. Inter-domain Inter-vendor LSP Setup Response.....	9
5.3. TED Synchronization.....	9
6. Security Considerations.....	10
7. IANA Considerations	10
8. Acknowledgments	10
9. References	10
9.1. Normative References.....	10
9.2. Informative References.....	11
10. Authors' Addresses	11

1. Introduction

This document describes the setup procedure of PCE-initiated inter-domain inter-vendor LSPs under the cooperative stateful PCE model, which is distributed controlled and deployed.

2. Terminology

This document uses the following terms defined in [[RFC5440](#)]: PCE.

This document uses the following terms defined in [[RFC4655](#)]: TED.

This document uses the following terms defined in [[I-D.ietf-pce-stateful-pce-09](#)]: Stateful PCE.

This document uses the following terms defined in [[I-D.ietf-pce-pce-initiated-lsp-02](#)]: PCE-initiated LSP.

The following terms are defined in this document:

Source-PCE: PCE that covers the source node of LSP request.

Destination-PCE: PCE that covers the destination node of LSP request.

Upstream-PCE: The previous PCE that along the reversed direction of domain sequence.

Downstream-PCE: The next PCE that along the positive direction of domain sequence.

3. Overview of the Stateful PCE

[[RFC4655](#)] defines a stateful PCE to be one in which the PCE maintains "strict synchronization between the PCE and not only the network states (in term of topology and resource information), but also the set of computed paths and reserved resources in use in the network."

Stateful pce [[I-D.ietf-pce-stateful-pce-09](#)] specifies a set of extensions to PCEP to enable stateful control of TE LSPs between and across PCEP sessions in compliance with [[RFC4657](#)]. It includes mechanisms to effect LSP state synchronization between PCCs and PCEs, delegation of control of LSPs to PCEs, and PCE control of timing and sequence of path computations within and across PCEP sessions and focuses on a model where LSPs are configured on the PCC and control over them is delegated to the PCE.

4. Multiple Stateful PCEs Deployment and Operation

Multiple stateful PCEs can be deployed in a distributed way, shown in Figure 1. Each domain contains a single stateful PCE, which is responsible for maintaining intra-domain resource information and controlling intra-domain LSP setup. All the PCEs are mesh-connected and they may communicate with each other in a Virtual Local Area Network (VLAN).

The transport devices located in different domains may be supplied by various vendors and probably own private configuration parameters, such as IP address, port attribute, signaling protocol, etc. Therefore, each domain is equipped with a dedicated Interface Adapter (IA), which can convert different vendor-specific messages into unified interface messages.

Network Management System (NMS) is a centralized management entity, which is aware of entire network resources and connected with all the PCEs. NMS can initiate inter-domain LSP setup request that will be sent to the source-PCE.

The inter-domain path is computed by a set of distributed PCEs that collaborate during path computation. The source PCE initiates inter-domain inter-vendor LSP setup, which is completed through cooperation between multiple PCEs.

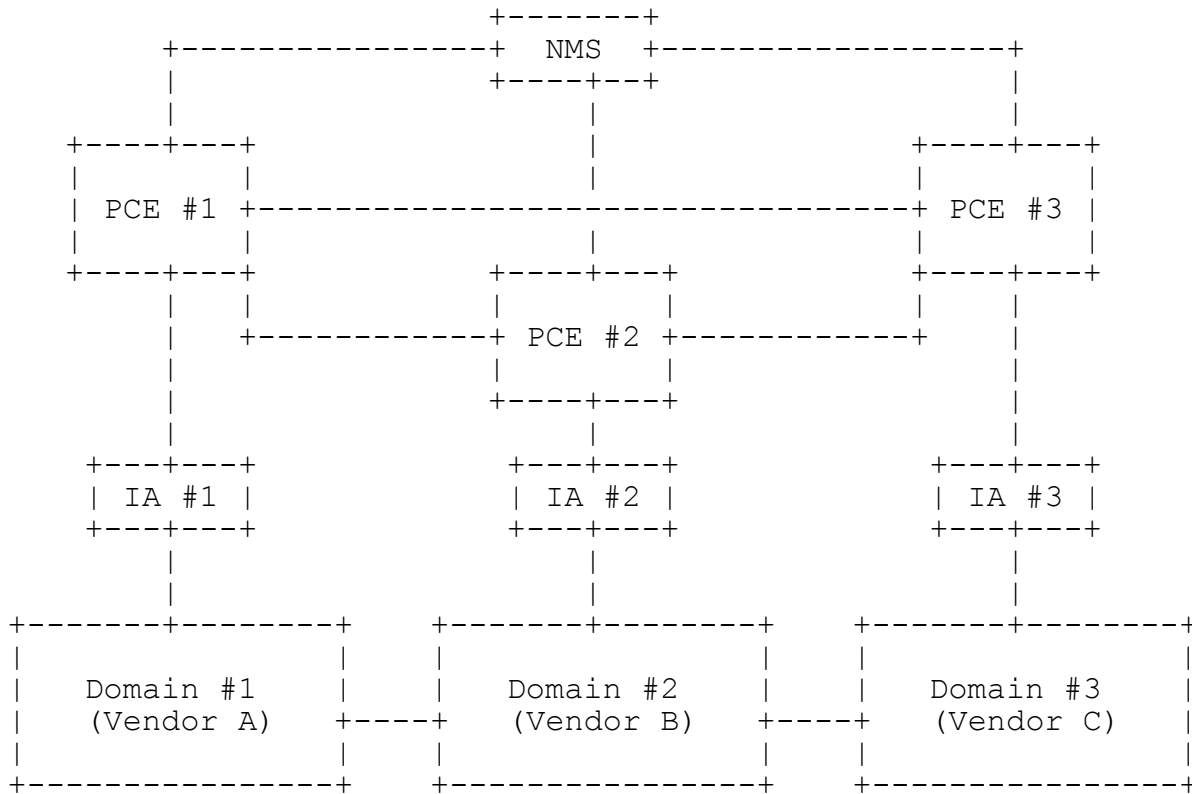


Figure 1 Cooperative PCEs Deployment

4.1. Traffic Engineering Database

Each PCE may collect local topology and TE information from transport plane. Besides, in order to complete inter-domain path computation, each PCE may collect all the inter-domain links and domains information from a specific management entity, such as Network Management System (NMS), which has the global visibility of network.

4.2. Cooperative Inter-domain Path Computation

When source-PCE receives an inter-domain path computation request from NMS, the source-PCE will first determine an optimal domain sequence and then cooperate with other PCEs to compute an optimal inter-domain path based on the required constraints. Considering the TED information asynchronization and inter-domain resource changing during the cooperative computation procedure, each PCE in the selected domain sequence may determine a new optimal domain sequence based on the required constraints. The source-PCE will generate the full set of strict hops from source node to destination node.

4.3. Cooperative Inter-domain LSP Setup

After inter-domain path computation, source-PCE splits the inter-domain path into multiple independent sub-paths according to the domain ID of each node. Then, the source-PCE simultaneously sends all the sub-paths to the relevant PCEs. Each PCE is responsible for its corresponding intra-domain LSP setup.

The source-PCE asynchronously receives the intra-domain LSP setup response from all the relevant PCEs. If all the intra-domain LSPs are successfully established and there are sufficient resources in the relevant inter-domain links, the inter-domain inter-vendor LSP is successfully established. Otherwise, the inter-domain inter-vendor LSP fails to be established.

4.4. Vendor-specific Message Conversion

In order to eliminate the differences in vendor-specific message formats of various vendors' domains, each domain is equipped with a dedicated Interface Adapter (IA), which can convert different vendor-specific messages into unified interface messages.

5. Applicability of Cooperative Stateful PCE

5.1. TED initialization

The Traffic Engineering Database (TED) of PCE includes intra-domain information and inter-domain information, shown in Figure 2.

In the process of TED initialization, every PCE sends TED request to the corresponding transport plane, which contains physical nodes and physical links. Every PCE receives TED response from the transport plane and stores the intra-domain resource information into its TED.

Meanwhile, every PCE sends TED request to Network Management System (NMS), which is responsible for maintaining inter-domain links and all the PCEs in the entire network. Every PCE receives TED response from NMS and generates a global domain topology for subsequent inter-domain path computation. The domain topology stored in every PCE should be the same.

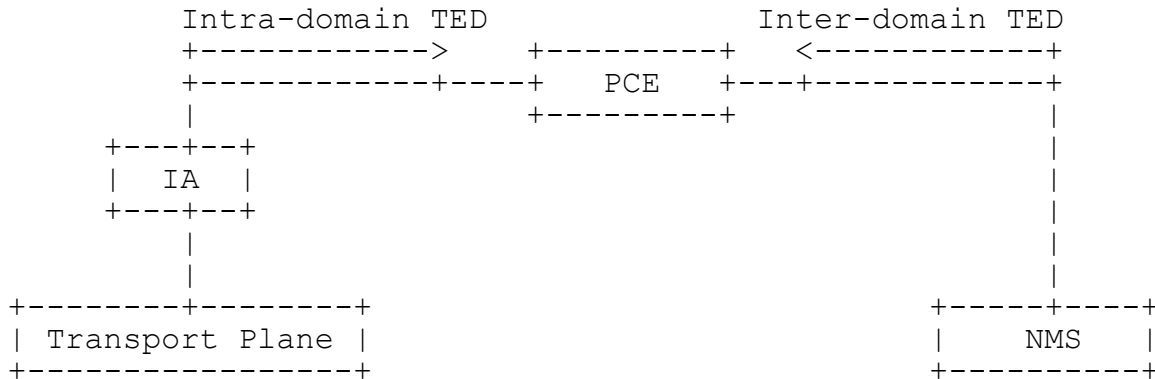


Figure 2 TED Initialization Procedure

5.2. PCE-initiated LSP Setup

5.2.1. Inter-domain Inter-vendor LSP Setup Request

The inter-domain inter-vendor LSP setup request is initiated through NMS. The request contains source node information (IP address, interface ID, timeslot), destination node information (IP address, interface ID, timeslot), required bandwidth, granularity type, protection type, and domain sequence. The request is sent to source-PCE.

5.2.2. Inter-domain Path Computation

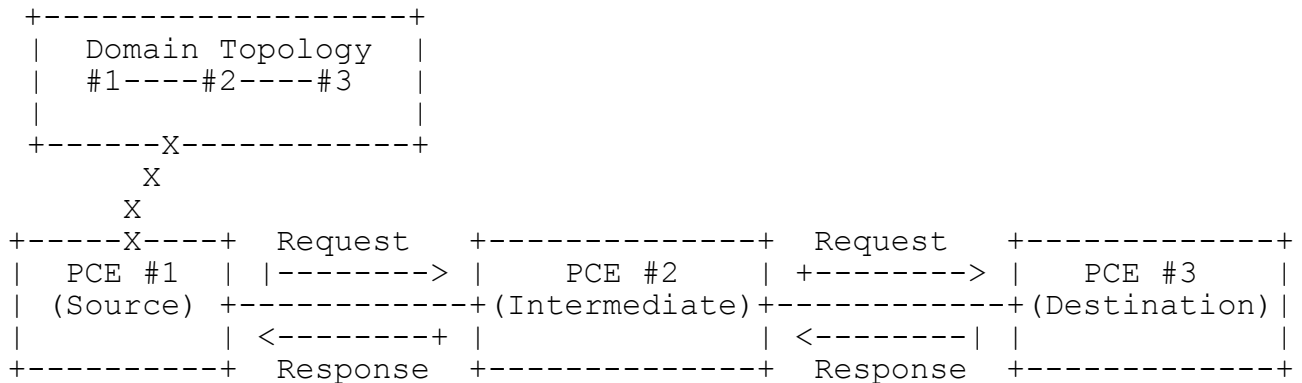


Figure 3 Inter-domain Path Computation Procedure

In the inter-domain path computation procedure (shown in Figure 3), source-PCE computes an optimal domain sequence according to global domain topology. The domain sequence is an ordered list which contains domain IDs from source-domain to destination-domain.

Source-PCE forwards the path computation request to downstream-PCE according to the domain sequence. The downstream-PCE keeps on forwarding the path computation request to its downstream-PCE until the request is arrived at destination-PCE.

Considering both the constraint requirements of request and local TED information, destination-PCE computes many candidate paths from local ingress border nodes to destination node. The path computation response (including the candidate paths) are sent to upstream-PCE according to the reversed domain sequence. If the upstream-PCE finds resource in any inter-domain link of the selected domain sequence is fully used, the upstream-PCE may determine a new optimal domain sequence including all the downstream-PCEs, based on the current TED information. The upstream-PCE generates an integrated topology including local physical topology, inter-domain links and the candidate paths derived from the downstream-PCE. The upstream-PCE computes many candidate paths from local ingress border nodes to destination node in the new integrated topology. The path computation response (including the candidate paths) and new domain sequence (if changed) are sent to its upstream-PCE. The above process is repeated until the path computation response is sent to source-PCE. Finally, the source PCE selects an optimal inter-domain path.

5.2.3. Inter-domain Path Segmentation

The source-PCE splits the inter-domain path into multiple independent sub-paths according to domain ID. Different sub-path belongs to different domain.

5.2.4. Intra-domain LSP Setup Procedure

In Figure 4, the source-PCE simultaneously sends all the sub-paths to the relevant PCEs. Each PCE is responsible for its corresponding intra-domain LSP setup. In the intra-domain LSP setup procedure, PCE sends intra-domain LSP setup request to local Interface Adapter (IA). IA converts the LSP setup request into vendor-specific message and then sends the message to transport plane. IA receives LSP setup response from transport plane and converts it into a unified message. PCE receives intra-domain LSP setup response from IA and the intra-domain LSP setup procedure is finished.

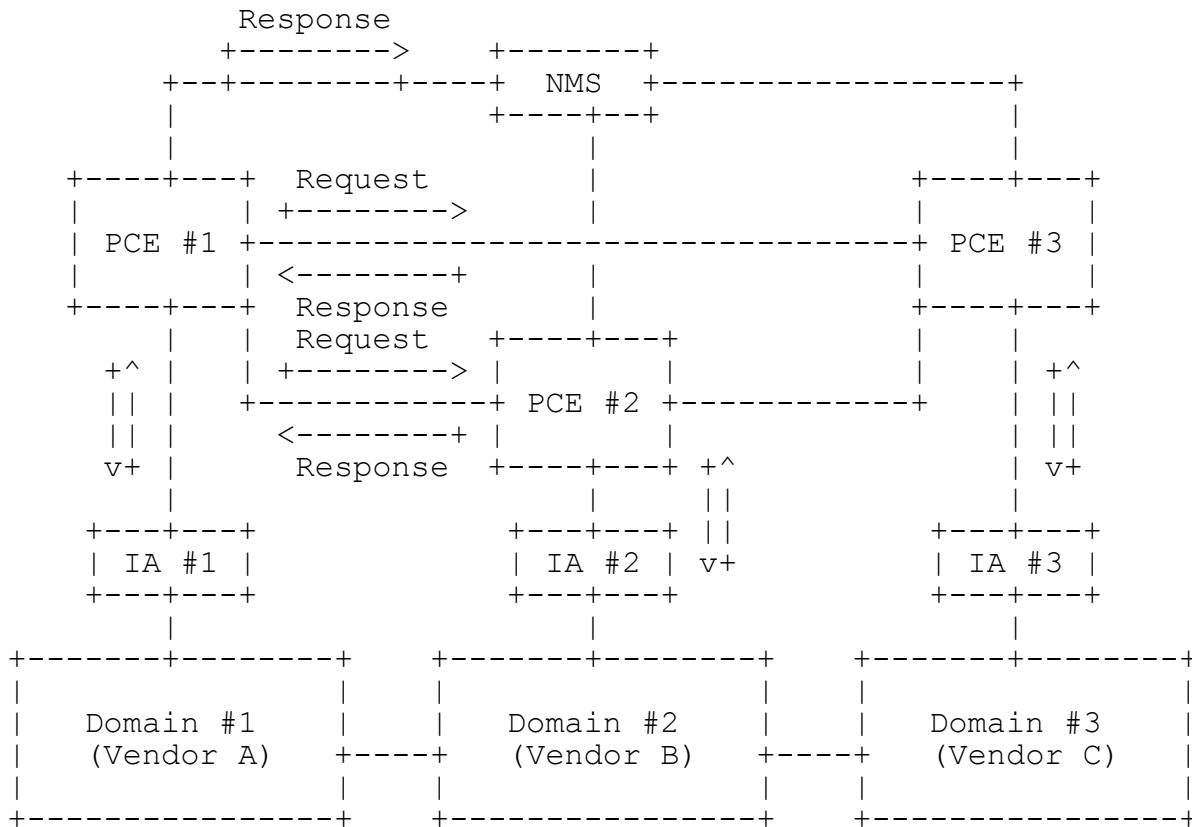


Figure 4 Inter-domain Inter-vendor LSP Setup Procedure

5.2.5. Inter-domain Inter-vendor LSP Setup Response

The source-PCE asynchronously receives the intra-domain LSP setup response from all the relevant PCEs. If all the intra-domain LSPs are successfully established and there are sufficient resources in the relevant inter-domain links, the inter-domain inter-vendor LSP is successfully established. Otherwise, the inter-domain inter-vendor LSP fails to be established.

5.3. TED Synchronization

In order to avoid resource conflicts, the TED stored in every PCE must be updated in time. Once an inter-domain inter-vendor LSP is successfully established, the modification of network resources must be announced to all the relevant PCEs.

TED synchronization process includes intra-domain TED synchronization process and inter-domain TED synchronization process. PCEs that are

involved to the inter-domain LSP should synchronize their intra-domain resources with underlying transport plane. And every PCE should synchronize inter-domain links to ensure that its global domain topology is identical to other PCEs.

In the process of intra-domain TED synchronization, source-PCE sends intra-domain links synchronization requests to the relevant PCEs. Each relevant PCE synchronizes intra-domain links information with underlying transport plane through message conversion by local Interface Adapter (IA).

In the process of inter-domain TED synchronization, source-PCE sends inter-domain links synchronization requests to all the PCEs. Every PCE should modify the information of inter-domain links and update its global domain topology for subsequent inter-domain path computation.

6. Security Considerations

PCEP security is defined [[RFC5440](#)]. Any multi-domain operation necessarily involves the exchange of information across domain boundaries. This does represent a significant security and confidentiality risk. PCEP allows individual PCEs to maintain confidentiality of their domain path information using path-keys [[RFC5520](#)].

For further considerations of the security issues related to inter-domain path computation, see [[RFC5376](#)].

7. IANA Considerations

This document makes no requests for IANA action.

8. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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