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IS-IS protocol extensions for Path Computation Element (PCE) Discovery

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Abstract

There are various circumstances where it is highly desirable for a Path Computation Client (PCC) to be able to dynamically and automatically discover a set of Path Computation Elements (PCE), along with some of information that can be used for PCE selection. When the PCE is a Label Switching Router (LSR) participating in the

Interior Gateway Protocol (IGP), or even a server participating

passively in the IGP, a simple and efficient way to discover PCEs consists of using IGP flooding. For that purpose this document defines extensions to the Intermediate System to Intermediate System (IS-IS) routing protocol for the advertisement of PCE Discovery information within an IS-IS area or within the entire IS-IS routing domain.

Conventions used in this document

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 RFC-2119.

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1. Terminology

Terminology used in this document

ABR: IGP Area Border Router (L1L2 router).

AS: Autonomous System.

Domain: any collection of network elements within a common sphere of address management or path computational responsibility. Examples of domains include IGP areas and Autonomous Systems.

IGP: Interior Gateway Protocol. Either of the two routing protocols Open Shortest Path First (OSPF) or Intermediate System to Intermediate system (IS-IS).

Intra-area TE LSP: A TE LSP whose path does not cross IGP area boundaries.

Intra-AS TE LSP: A TE LSP whose path does not cross AS boundaries.

Inter-area TE LSP: A TE LSP whose path transits two or more IGP areas. That is a TE-LSP that crosses at least one IGP area boundary.

Inter-AS TE LSP: A TE LSP whose path transits two or more ASes or sub-ASes (BGP confederations). That is a TE-LSP that

crosses at least one AS boundary.

IS-IS LSP: Link State PDU

LSR: Label Switching Router.

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 communication Protocol.

TE LSP: Traffic Engineered Label Switched Path.

2. Introduction

[RFC4655] describes the motivations and architecture for a Path Computation Element (PCE)-based path computation model for Multi Protocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineered Label Switched Paths (TE-LSPs). The model allows for the separation of the PCE from a PCC (also referred to as a non co-located PCE) and allows for cooperation between PCEs. This relies on a communication protocol between PCC and PCE, and between PCEs. The requirements for such a communication protocol can be found in [RFC4657] and the communication protocol is defined in [PCEP].

The PCE architecture requires that a PCC be aware of the location of one or more PCEs in its domain, and also potentially of some PCEs in other domains, e.g. in case of inter-domain TE LSP computation.

A network may contain a large number of PCEs with potentially distinct capabilities. In such a context it is highly desirable to have a mechanism for automatic and dynamic PCE discovery, which allows PCCs to automatically discover a set of PCEs, along with additional information about each PCE that may be required for the PCC to perform PCE selection. Additionally, it is valuable for a PCC to dynamically detect new PCEs or any modification of the PCE information. Detailed requirements for such a PCE discovery mechanism

are provided in [RFC4674].

Moreover, it may also be useful to discover when a PCE experiences processing congestion and when it exits such a state, in order for the PCCs to take some appropriate actions (e.g. redirect their requests to another PCE). Note that the PCE selection algorithm applied by a PCC is out of the scope of this document.

When PCCs are LSRs participating in the IGP (OSPF, IS-IS), and PCEs are either LSRs or servers also participating in the IGP, an effective mechanism for PCE discovery within an IGP routing domain consists of utilizing IGP advertisements.

This document defines IS-IS extensions to allow a PCE in an IS-IS routing domain to advertise its location along with some information useful to a PCC for PCE selection, so as to satisfy dynamic PCE discovery requirements set forth in [RFC4674]. This document also defines extensions allowing a PCE in an IS-IS routing domain to advertise its processing congestion state.

Generic capability advertisement mechanisms for IS-IS are defined in [IS-IS-CAP]. These allow a router to advertise its capabilities within an IS-IS area or an entire IS-IS routing domain. This document leverages this generic capability advertisement mechanism to fully satisfy the aforementioned dynamic PCE discovery requirements.

This document defines a new sub-TLV (named the PCE Discovery (PCED) to be carried within the IS-IS Router Capability TLV ([IS-IS-CAP]).

The PCE information advertised is detailed in section 3. Protocol extensions and procedures are defined in section 4 and 5.

This document does not define any new IS-IS elements of procedure. The procedures defined in [IS-IS-CAP] should be used.

The IS-IS extensions defined in this document allow for PCE discovery within an IS-IS Routing domain. Solutions for PCE discovery across AS boundaries are beyond the scope of this document, and for further study.

This document defines a set of sub-TLVs that are nested within each other. When the degree of nesting TLVs is 2 (a TLV is carried within another TLV) the TLV carried within a TLV is called a sub-TLV.

Strictly speaking, when the degree of nesting is 3, a subsub-TLV is carried within a sub-TLV that is itself carried within a TLV. For the sake of terminology simplicity, we refer to sub-TLV, a TLV carried within a TLV regardless of the degree of nesting.

3. Overview

3.1. PCE Information

The PCE information advertised via IS-IS falls into two categories: PCE Discovery information and PCE Status information.

3.1.1. PCE Discovery Information

The PCE Discovery information is comprised of:

- The PCE location: an IPv4 and/or IPv6 address that is used to reach the PCE. It is RECOMMENDED to use an address that is always reachable;

- The PCE inter-domain functions: PCE path computation scope (i.e. inter-area, inter-AS, inter-layer…);

- The PCE domain(s): set of one or more domain(s) into which the PCE has visibility and can compute paths;

- The PCE neighbor domain(s): set of one or more neighbor domain(s) towards which a PCE can compute paths;

- A set of communication capabilities (e.g. support for request prioritization) and path computation specific capabilities (e.g. supported constraints).

Optional elements to describe more complex capabilities may also be advertised.

PCE Discovery information is by nature fairly static and does not change with PCE activity. Changes in PCE Discovery information may occur as a result of PCE configuration updates, PCE deployment/activation, PCE deactivation/suppression, or PCE failure. Hence, this information is not expected to change frequently.

3.1.2. PCE Status Information

The PCE Status is optional and can be used to report a PCE's processing congestion state along with an estimated congestion duration. This is a dynamic information, which may change with PCE activity.

Procedures for a PCE to move from a processing congestion state to a non-congestion state are beyond the scope of this document, but the rate at which a PCE Status change is advertised MUST NOT impact by any means the IGP scalability. Particular attention should be given on procedures to avoid state oscillations.

3.2. Flooding scope

The flooding scope for PCE information advertised through IS-IS can be limited to one or more IS-IS areas the PCE belongs to, or can be extended across the entire IS-IS routing domain.
Note that some PCEs may belong to multiple areas, in which case the flooding scope may comprise these areas. This could be the case for a L1L2 router for instance advertising its PCE information within the L2 area and/or a subset of its attached L1 area(s).

4. IS-IS extensions

4.1. The IS-IS PCED TLV

The IS-IS PCED TLV is made of a set of non ordered sub-TLVs.

The format of the IS-IS PCED TLV and its sub-TLVs is the identical to the TLV format used by the Traffic Engineering Extensions to IS-IS [RFC3784]. That is, the TLV is composed of 1 octet for the type, 1 octet specifying the TLV length, and a value field. The Length field defines the length of the value portion in octets.

The IS-IS PCED TLV has the following format:

```
TYPE: To be assigned by IANA  (suggested value = 5)
LENGTH: Variable
VALUE: set of sub-TLVs
```

Sub-TLVs types are under IANA control.

Currently six sub-TLVs are defined (suggested type values to be assigned by IANA):

Sub-TLV type	Length	Name
1	variable	PCE-ADDRESS sub-TLV
2	3	PATH-SCOPE sub-TLV
3	variable	PCE-DOMAINS sub-TLV
4	variable	PCE-NEIG-DOMAINS sub-TLV
5	variable	PCE-CA-FLAGS sub-TLV
6	1	CONGESTION sub-TLV

The PCE-ADDRESS and PATH-SCOPE sub-TLVs MUST always be present within the PCED TLV.

The PCE-DOMAINS and PCE-NEIG-DOMAINS sub-TLVs are optional. They may be present in the PCED TLV to facilitate selection of inter-domain PCEs.

The PCE-CAP-FLAGS sub-TLVs are optional and MAY be present in the PCED TLV to facilitate the PCE selection process.

The CONGESTION sub-TLV is optional and MAY be present in the PCED TLV, to indicate a PCE's processing congestion state.

Any non recognized sub-TLV MUST be silently ignored.

Additional sub-TLVs could be added in the future to advertise additional PCE information.

The PCED TLV is carried within an IS-IS CAPABILITY TLV defined in [IS-IS-CAP].

4.1.1. PCE-ADDRESS sub-TLV

The PCE-ADDRESS sub-TLV specifies the IP address that can be used to reach the PCE. It is RECOMMENDED to make use of an address that is always reachable, provided the PCE is alive.

The PCE-ADDRESS sub-TLV is mandatory; it MUST be present within the PCED TLV. It MAY appear twice, when the PCE has both an IPv4 and IPv6 address. It MUST NOT appear more than once for the same address type.

The PCE-ADDRESS sub-TLV has the following format:

TYPE: To be assigned by IANA (Suggested value =1)
LENGTH: 5 for IPv4 address and 17 for IPv6 address
VALUE: This comprises one octet indicating the address-type and 4 or 16 octets encoding the IPv4 or IPv6 address to be used to reach the PCE

Address-type:
1   IPv4
2   IPv6

4.1.2. The PATH-SCOPE sub-TLV

The PATH-SCOPE sub-TLV indicates the PCE path computation scope, which refers to the PCE's ability to compute or take part in the computation of intra-area, inter-area, inter-AS, or inter-layer_TE LSP(s).

The PATH-SCOPE sub-TLV is mandatory; it MUST be present within the PCED TLV. There MUST be exactly one instance of the PATH-SCOPE sub-TLV within each PCED TLV.

The PATH-SCOPE sub-TLV contains a set of bit flags indicating the supported path scopes, and four fields indicating PCE preferences.

The PATH-SCOPE sub-TLV has the following format:

TYPE: To be assigned by IANA (Suggested value =2)
LENGTH: 3
VALUE: This comprises a one-byte flags field where flag represents a supported path scope, followed by a 2-bytes preferences field indicating PCE preferences.

Here is the structure of the bits flag:

```
+-+-+-+-+-+-+-+-+
|0|1|2|3|4|5|Res|
+-+-+-+-+-+-+-+-+
```

```
Bit      Path Scope

0      L bit:  Can compute intra-area path
1      R bit:  Can act as PCE for inter-area TE LSP computation
2      Rd bit: Can act as a default PCE for inter-area TE LSP
               computation
3      S bit:  Can act as PCE for inter-AS TE LSP computation
4      Sd bit: Can act as a default PCE for inter-AS TE LSPs
               computation
```



```
5      Y bit:  Can compute or take part into the computation of
               paths across layers
6-7    Reserved for future usage.
```

Here is the structure of the preferences field

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|PrefL|PrefR|PrefS|PrefY| Res   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Res: Reserved for future usage.

Pref-L field: PCE's preference for intra-area TE LSPs computation.

Pref-R field: PCE's preference for inter-area TE LSPs computation.

Pref-S field: PCE's preference for inter-AS TE LSPs computation.

Pref-Y field: PCE's preference for inter-layer TE LSPs computation.

Res: Reserved for future usage.

The bits L, R, S, and Y bits are set when the PCE can act as a PCE for intra-area, inter-area, inter-AS or inter-layer TE LSPs computation respectively. These bits are non-exclusive.

When set the Rd bit indicates that the PCE can act as a default PCE for inter-area TE LSP computation (that is the PCE can compute a path

towards any neighbor area). Similarly, when set, the Sd bit indicates that the PCE can act as a default PCE for inter-AS TE LSP computation (the PCE can compute a path towards any neighbor AS).

When the Rd bit is set, the PCE-NEIG-DOMAIN TLV (see 5.1.4) MUST NOT contain any Area ID DOMAIN sub-TLVs.

Similarly, when the Sd bit is set, the PCE-NEIG-DOMAIN TLV MUST NOT contain any AS-DOMAIN sub-TLVs.

When the R/S bit is cleared, the RD/Sd bit SHOULD be cleared and MUST be ignored.

The PrefL, PrefR, PrefS and PrefY fields are each three bits long and allow the PCE to specify a preference for each computation scope, where 7 reflects the highest preference. Such preference can be used for weighted load balancing of requests. An operator may decide to configure a preference for each computation scope to each PCE so as to balance the path computation load among them. The algorithms used by a PCC to balance its path computation requests according to such PCE preference are out of the scope of this document and is a matter for local or network wide policy. The same or distinct preferences may be used for each scopes. For instance an operator that wants a

PCE capable of both inter-area and inter-AS computation to be used preferably for inter-AS computation may configure a PrefS higher than the PrefR.

When the L bit, R bit, S bit or Y bit are cleared the PrefL, PrefR, PrefS, PrefY fields SHOULD respectively be set to 0 and MUST be ignored.

Both reserved fields SHOULD be set to zero on transmission and MUST be ignored on receipt.

4.1.3. PCE-DOMAINS sub-TLV

The PCE-DOMAINS sub-TLV specifies the set of domains (areas and/or ASes) where the PCE has topology visibility and through which the PCE can compute paths. It contains a set of one or more sub-TLVs where each sub-TLV identifies a domain.

The PCE-DOMAINS sub-TLV MAY be present when PCE domains cannot be inferred by other IGP information, for instance when the PCE is inter-domain capable (i.e. when the R bit or S bit is set) and the flooding scope is the entire routing domain (see section 5 for a discussion of how the flooding scope is set and interpreted).

The PCE-DOMAINS sub-TLV has the following format:

TYPE: To be assigned by IANA (Suggested value =3)
LENGTH: Variable
VALUE: This comprises a set of one or more DOMAIN sub-TLVs where each DOMAIN sub-TLV identifies a domain where the PCE has topology visibility and can compute paths.

Two DOMAIN sub-TLVs are defined

Sub-TLV type	Length	Name
1	Variable	Area ID sub-TLV
2	4	AS number sub-TLV

At least one DOMAIN sub-TLV MUST be present in the PCE-DOMAINS sub-TLV. Note than when the PCE visibility is an entire AS, the PCE-DOMAINS sub-TLV MUST include exactly one AS number sub-TLV, and MUST not contain an area-ID sub-TLV.

4.1.3.1. Area ID DOMAIN sub-TLV

This sub-TLV carries an IS-IS area ID. It has the following format

TYPE: 1
LENGTH: Variable

VALUE: This comprises a variable length IS-IS area ID. This is the combination of an Initial Domain Part (IDP) and High Order part of the Domain Specific part (HO-DSP)

4.1.3.2. AS Number DOMAIN sub-TLV

The AS Number sub-TLV carries an AS number. It has the following format:

TYPE: 2
LENGTH: 4

VALUE: AS number identifying an AS. When coded in two bytes (which is the current defined format as the time of writing this document), the AS Number field MUST have its left two bytes set to 0.

4.1.4. PCE-NEIG-DOMAINS sub-TLV

The PCE-NEIG-DOMAINS sub-TLV specifies the set of neighbour domains (areas, ASes) toward which a PCE can compute paths. It means that the PCE can compute or take part in the computation of inter-domain TE LSPs whose path transits one of these domains. It contains a set of one or more DOMAIN sub-TLVs where each DOMAIN sub-TLV identifies a domain.

The PCE-NEIG-DOMAINS sub-TLV has the following format:

TYPE: To be assigned by IANA (Suggested value =4)
LENGTH: Variable
VALUE: This comprises a set of one or more area or/and AS DOMAIN sub-TLVs where each sub-TLV identifies a neighbour domain toward which a PCE can compute path.

The PCE-NEIG-DOMAINS sub-TLV MUST be present if the R bit is set and the Rd bit is cleared, and/or, if the S bit is set and the Sd bit is cleared.

The PCE-NEIG-DOMAINS sub-TLV MUST include at least one DOMAIN sub-TLV. It MUST include at least one Area ID sub-TLV, if the R bit of the PATH-SCOPE TLV is set and the Rd bit of the PATH-SCOPE TLV is cleared. Similarly, it MUST include at least one AS number sub-TLV if the S bit of the PATH-SCOPE TLV is set and the Sd bit of the PATH-SCOPE TLV is cleared.

4.1.5. PCE-CAP-FLAGS sub-TLV

The PCE-CAP-FLAGs sub-TLV is an optional TLV used to indicate PCEP related capabilities. It MAY be present within the PCED TLV. It MUST NOT be present more than once.

The value field of the PCE-CAP-FLAGS sub-TLV is made up of an array of units of 32 bit flags numbered from the most significant as bit

zero, where each bit represents one PCE capability.

The GENERAL-CAP sub-TLV has the following format:

TYPE: To be assigned by IANA (Suggested value =4)
LENGTH: Multiple of 4
VALUE: This contains an array of units of 32 bit flags numbered from the most significant as bit zero, where each bit represents one PCE capability.

IANA is requested to manage the space of the PCE Capability Flags

The following bits are to be assigned by IANA:

Bit	Capabilities
0	Capability to handle GMPLS link constraints
1	Capability to compute bidirectional paths
2	Capability to compute PSC path
3	Capability to compute a TDM path
4	Capability to compute a LSC path
5	Capability to compute a FSC path
6	Capability to compute link/node/SRLG diverse paths
7	Capability to compute load-balanced paths
8	Capability to compute a set of paths in a synchronized Manner
9	Support for multiple objective functions
10	Capability to handle path constraints (e.g. max hop count, max path metric)
11	Support for Request prioritization.
12	Support for multiple requests within the same request message.
13-31	Reserved for future assignments by IANA.

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

4.1.6. The CONGESTION sub-TLV

The CONGESTION sub-TLV is used to indicate a PCE's experiences a processing congestion state and may optionally include expected PCE congestion duration.
The CONGESTION sub-TLV is optional, it MAY be carried within the PCED TLV. It MUST NOT be present more than once.

The format of the CONGESTION sub-TLV is as follows:

TYPE: To be assigned by IANA (Suggested value =6)
LENGTH: 3
VALUE: This comprises a one-byte bit flags indicating the
congestion status, followed by a 2-bytes field indicating the
congestion duration.

Here is the TLV structure

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|C|     Reserved|      Congestion Duration      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Value
-C bit: When set this indicates that the PCE is experiencing congestion and cannot accept any new request. When cleared this indicates that the PCE is not experiencing congestion and can accept new requests.

-Congestion Duration: 2-bytes, the estimated PCE congestion duration in seconds.

When C is set and the Congestion Duration field is equal to 0, this means that the Congestion Duration is unknown.
When C is cleared the Congestion Duration SHOULD be set to 0 and MUST be ignored.

5. Elements of Procedure

The PCED TLV is advertised within an IS-IS Router Capability TLV defined in [IS-IS-CAP]. A such, elements of procedures are inherited from those defined in [IS-IS-CAP].

The flooding scope is controlled by the S flag in the IS-IS Router Capability TLV (see [IS-IS-CAP]). When the scope of the PCED TLV is area local it MUST be carried within an IS-IS CAPABILITY TLV having the S bit cleared. When the scope of the PCED TLV is the entire IGP domain, itMUST be carried within an IS-IS CAPABILITY TLV having the S bit set. When only the L bit of the PATH-SCOPE sub-TLV is set, the flooding scope MUST be local.

A PCE MUST originate a new IS-IS LSP whenever the content of any of the PCED TLV changes or whenever required by the regular IS-IS procedure.

When the PCE function is deactivated on a node, the node MUST originate a new IS-IS LSP with no longer any PCED TLV. A PCC MUST be able to detect that the PCED TLV has been removed from an IS-IS LSP.

The PCE address, i.e. the address indicated within the PCE ADDRESS sub-TLV, MUST be distributed as part of IS-IS routing; this allows speeding up the detection of a PCE failure. Note that when the PCE address is no longer reachable, this means that the PCE node has failed or has been torn down, or that there is no longer IP connectivity to the PCE node.

The PCED TLV is OPTIONAL. When an IS-IS LSP does not contain any PCED TLV, this means that the PCE information of that node is unknown.

A change in PCED information MUST not trigger any SPF computation at a receiving router.

The way PCEs determine the information they advertise is out of the scope of this document. Some information may be configured (e.g., address, preferences, scope) and other information may be automatically determined by the PCE (e.g. areas of visibility).

5.1.1. CONGESTION sub-TLV specific procedures

When a PCE enters into a processing congestion state, the conditions of which are implementation dependent, it MAY originate a new IS-IS LSP with a CONGESTION sub-TLV with the C bit set and optionally a non-null expected congestion duration.

When a PCE exists from the processing congestion state, the conditions of which are implementation dependent, two cases are considered:

- If the congestion duration in the previously originated CONGESTION sub-TLV was null, it SHOULD originate a CONGESTION sub-TLV with the C bit cleared and a null congestion duration;
- If the congestion duration in the previously originated CONGESTION sub-TLV was non null, it MAY originate a CONGESTION sub-TLV with the C bit cleared. Note that in some particular cases it may

be desired to originate a PCES TLV with the C bit cleared if the congestion duration was over estimated.

The congestion duration allows a reduction in the amount of IS-IS flooding, as only uncongested-to-congested state transitions need advertised.

A PCE implementation SHOULD support an appropriate dampening algorithm so as to dampen IS-IS flooding in order to not impact the IS-IS scalability. It is RECOMMENDED to introduce some hysteresis for congestion state transition, so as to avoid state oscillations that may impact IS-IS performance. For instance two thresholds MAY be configured: a resource congestion upper-threshold and a resource congestion lower-threshold. An LSR enters the congested state when the CPU load reaches the upper threshold and leaves the congested state when the CPU load goes under the lower threshold.

Upon receipt of an updated CONGESTION sub-TLV a PCC should take appropriate actions. In particular, the PCC SHOULD stop sending requests to a congested PCE, and SHOULD gradually start sending again requests to a PCE that is no longer congested

6. Backward compatibility

The PCED TLV defined in this document does not introduce any interoperability issues.

An IS-IS router not supporting the PCED TLV will just silently ignore the TLV as specified in [IS-IS-CAP].

7. IANA considerations

7.1. IS-IS sub-TLV

Once a registry for the IS-IS Router Capability TLV defined in [IS-IS-CAP] will have been assigned, IANA will assign a new TLV code-point for the PCED TLV carried within the Router Capability TLV.

Value	Sub-TLV	References
5	PCED TLV	(this document)

7.2. PCED sub-TLVs registry

The PCED TLV referenced above is constructed from sub-TLVs. Each sub-TLV includes a 8-bit type identifier.

The IANA is requested to create a new registry and manage TLV type identifiers as follows:

- TLV Type
- TLV Name
- Reference

This document defines five TLVs as follows (suggested values):

Value	TLV name	References
-----	---------	-----------
1	PCE-ADDRESS	This document
2	PATH-SCOPE	This document
3	PCE-DOMAINS	This document
4	PCE-NEIG-DOMAINS	This document
5	PCE-CAP-FLAGS	This document
6	CONGESTION	This document

New TLV type values may be allocated only by an IETF Consensus action.

7.3. PCE Capability Flags registry

This document provides new capability bit flags, which are present in the PCE-CAP-FLAGS TLV referenced in section 4.1.5.

The IANA is requested to create a new registry and to manage the space of PCE capability bit flags numbering them in the usual IETF notation starting at zero, and continuing at least through 31, with the most significant bit as bit zero.

The same registry is defined for OSPF based PCE discovery [PCED-OSPF]. A single registry must be defined for both protocols.

New bit numbers may be allocated only by an IETF Consensus action.

Each bit should be tracked with the following qualities:

- Bit number
- Defining RFC
- Capability Description

Several bits are defined in this document. Here are the suggested values:

Bit	Capability Description
0	GMPLS link constraints
1	Bidirectional paths
2	PSC paths
3	TDM paths
4	LSC paths
5	FSC paths
6	Diverse paths
7	Load-balanced paths
8	Synchronized computation
9	Multiple objective functions
10	Additive path constraints (e.g. max hop count)
11	Request prioritization
12	Multiple requests per message

8. Security Considerations

This document defines IS-IS extensions for PCE discovery within an administrative domain. Hence the security of the PCE discovery relies on the security of IS-IS.

Mechanisms defined to ensure authenticity and integrity of IS-IS LSPs [RFC3567], and their TLVs, can be used to secure the PCED TLV as well.

IS-IS provides no mechanism for protecting the privacy of LSAs, and in particular the privacy PCE discovery information.

9. Manageability Considerations

Manageability considerations for PCE Discovery are addressed in section 4.10 of [RFC4674].

9.1. Control of Policy and Functions

Requirements on the configuration of PCE discovery parameters on PCCs and PCEs are discussed in section 4.10.1 of [RFC4674].

Particularly, a PCE implementation SHOULD allow configuring the following parameters on the PCE:

- The PCE IPv4/IPv6 address(es) (see section 4.1.1)
- The PCE Scope, including the inter-domain functions (inter-area, inter-AS, inter-layer), the preferences, and whether the PCE can act as default PCE (see section 4.1.2)
- The PCE domains (see section 4.1.3)
- The PCE neighbour domains (see section 4.1.4)
- The PCE capabilities (see section 4.1.5)

9.2. Information and Data Model

A MIB module for PCE Discovery is defined in [PCED-MIB].

9.3. Liveness Detection and Monitoring

PCE Discovery Protocol liveness detection relies upon OSPF liveness detection. IS-IS already includes a liveness detection mechanism (Hello PDUs), and PCE discovery does not require additional capabilities.

Procedures defined in section 5 allow a PCC detecting when a PCE has been deactivated, or is no longer reachable.

9.4. Verify Correct Operations

The correlation of information advertised against information received can be achieved by comparing the PCED information in the PCC and in the PCE, which is stored in the PCED MIB [PCED-MIB]. The number of dropped, corrupt, and rejected information elements are stored in the PCED MIB.

9.5. Requirements on Other Protocols and Functional Components

The IS-IS extensions defined in this documents does not imply any requirement on other protocols.

9.6. Impact on network operations

Frequent changes in PCE information, and particularly in PCE congestion information, may have a significant impact on IS-IS and might destabilize the operation of the network by causing the PCCs to swap between PCEs.

As discussed in section 5, a PCE implementation SHOULD support an appropriate dampening algorithm so as to dampen IS-IS flooding in order to not impact the IS-IS scalability.

Also, as discussed in section 4.10.4 of [RFC4674], it MUST be possible to apply at least the following controls:

- Configurable limit on the rate of announcement of changed parameters at a PCE.
- Control of the impact on PCCs such as through discovery messages rate-limiting.
- Configurable control of triggers that cause a PCC to swap to another PCE.

10. Acknowledgments

We would like to thank Lucy Wong and Adrian Farrel for their useful comments and suggestions.

11. References

11.1. Normative references

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

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14. Intellectual Property Statement