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Path Computation Element (PCE) Protocol Extension for Stateful PCE Usage in GMPLS Networks

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Status of this Memo

Abstract

The Path Computation Element (PCE) facilitates Traffic Engineering (TE) based path calculation in large, multi-domain, multi-region, or multi-layer networks. PCE can be stateless or stateful. With the LSP state information acquired from the network, a stateful PCE enables a wide variety of applications, especially in GMPLS networks, such as impairment-aware routing and wavelength assignment in wavelength-switched optical networks (WSON), time-based scheduling applications. This memo provides extensions required for PCE communication protocol (i.e. PCEP) so as to enable the usage of a stateful PCE capability in GMPLS networks. To be more specific, the PCEP extensions specified in this memo include not only new objects but also modification of existing objects in PCEP messages.

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 [RFC2119].

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1. Introduction

[RFC 4655] presents the architecture of a Path Computation Element (PCE)-based model for computing Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineering Label Switched Paths (TE LSPs). To perform such a constrained computation, a PCE stores the network topology (i.e., TE links and nodes) and resource information (i.e., TE attributes) in its TE Database (TED). To request path computation services to a PCE, [RFC 5440] defines the PCE Communication Protocol (PCEP) for communications between a Path Computation Client (PCC) and a PCE, or between two PCEs. A PCC can initiate a path computation request to a PCE through a Path Computation Request (PCReq) message, and then the PCE will return the computed route to the requesting PCC in response to a previously received PCReq message through a PCEP Path Computation Reply (PCRep) message.

As per [RFC 4655], a PCE can be stateless or stateful. Compared to a stateless PCE, a stateful PCE stores not only the network state, but also the set of computed paths and reserved resources in use in the network. Note that [RFC4655] further specifies that the TED contains link state and bandwidth availability as distributed by IGPs or collected via other means. Even if such information can provide finer granularity and more details, it is not state information in the PCE context and so a model that uses it is still described as a stateless PCE.

Stateful PCE(s) are shown to be helpful in many application scenarios, especially in GMPLS networks, as illustrated in [Stateful-APP]. In order for these applications to able to exploit the capability of stateful PCE(s), extensions to the PCE communication protocol (i.e., PCEP) are required.

It is expected that the PCEP extensions enabling stateful PCEs in GMPLS networks will share common aspects with the extensions developed for MPLS networks [Stateful-PCE]. Therefore, this document focuses on the extensions unique to GMPLS networks while maintains a complete picture of the PCEP extensions required for a stateful PCE in general. In summary, this draft gives an overview of PCEP extensions necessary for stateful PCE usage in GMPLS networks as well as the details of required PCEP extension unique to stateful PCE usage in GMPLS networks.

2. PCEP Extensions

2.1. Overview

According to the description in [Stateful-APP], the PCEP extensions required for a stateful PCE in GMPLS networks should cover, at least, the following two main functional requirements:

o Advertisement and negotiation of stateful PCE capability;

o LSP synchronization;

Attention should be paid in terms of the general considerations as discussed in [Stateful-APP]. Since the extensions to these two aspects are straightforward and have already been covered in [Stateful-PCE], we only cover the points that are either relevant to GMPLS or still missing in [Stateful-PCE].

In addition, the next functional requirements

o LSP Delegation;

As explained in [Stateful-APP], the ability to collect LSP state information should be mandatory. As for PCE's ability to modify the LSP attributes as presented in [Stateful-PCE] as well as how it is enabled (per PCE base, per LSP base, or per NE base?) should be operator-dependent and is for further study.

o Application-specific extensions;

[Stateful-APP] identifies the applications that a stateful PCE enables. Such applications require PCEP extensions that are provided in this document.

Since the LSP state is part of the information that a stateful PCE possesses, some simplifications to PCEP are possible and explained in this draft.

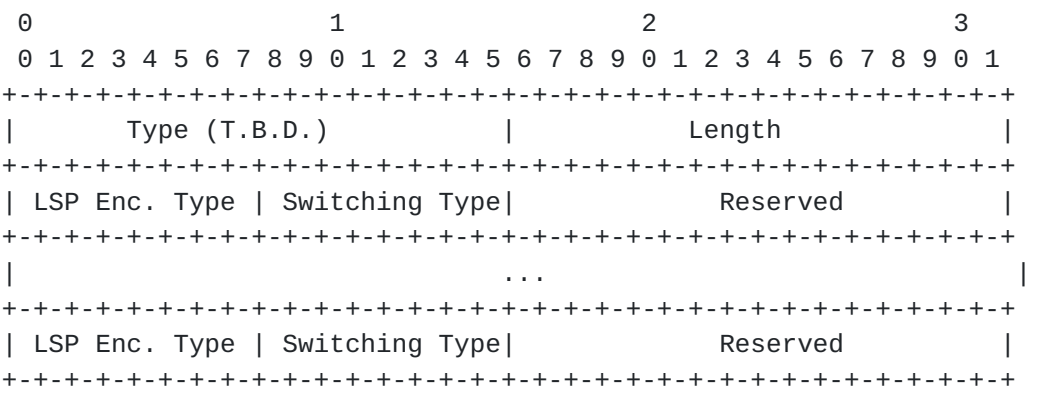
2.2. PCEP Extension for Stateful PCE Capability Advertisement and Negotiation

Whether a PCE has stateful capability or not can be negotiated during the PCEP session establishment process. It can also be advertised through routing protocols as described in [RFC5088]. In either case, the following additional aspects should also be considered.

2.2.1. PCE Capability Negotiation/Advertisement in Multi-layer Networks

In multi-layer network scenarios where there is a PCE responsible for each layer, then the PCCs should be informed of which PCE they should synchronize their LSP states with as well as send path computation requests to.

A new LayerCapability TLV is defined as shown below to denote to which layer a PCE is in charge of LSP synchronization as well as path computation. It can be included in the OPEN Object if applicable. Alternatively, the extension to current OSPF PCED TLV is needed.



2.3. LSP Delegation

The LSP state synchronization/update capability for LSPs that span multiple domains adds additional complexity for the stateful PCE(s). For instance, in a multi-domain networks where one PCE per domain is adopted, each PCE is responsible for synchronizing, updating or modifying the segment or part of the LSP within the network for which the PCE is deployed. Moreover, a modification action of a stateful PCE for partial LSP may trigger a chain of LSP updating actions (e.g., informing other PCEs of the modification or requesting other PCEs for additional modification).

This needs to be considered carefully and modification capability specifications might be needed to limit the scope of LSP attribute modification action to avoid conflicts.

[Editor Note: this needs clarification and further discussion. The scenario with mixed stateful/stateless PCE might also cause potential issues for LSP delegation ability. A use case and clearly

defined requirements are needed so not to try to cover all possible cases, in view of concrete implementations]

2.4. PCEP Extensions for LSP Synchronization

For LSP state synchronization of stateful PCE(s) in GMPLS networks, the LSP attributes, such as its bandwidth, associated label as well as protection information etc, should be updated by PCC(s) to PCE LSP database (LSP-DB).

As per [Stateful-PCE], it only covers LSP attributes pertaining to MPLS networks, based on [RFC5440]. Therefore, extensions of PCEP protocol for stateful PCE usage in GMPLS networks are required. The following presents a list of objects/TLVs that should be used by stateful PCE for LSP synchronization purpose when applied in GMPLS networks:

o GENERALIZED BANDWIDTH

o PROTECTION ATTRIBUTE

o Extended Objects to support the inclusion of label sub-object

- RP

- IRO

- XRO

Note that the list above should also be used for path computation requests/replies. Refer to [PCEP-GMPLS] for the details of these objects/TLVs.

2.5. Modification of Existing PCEP Messages and Procedures

One of the advantages mentioned in [Stateful-APP] is that the stateful nature of a PCE simplifies the information conveyed in PCEP messages, notably between PCC and PCE, since it is possible to refer to PCE managed state for active LSPs. To be more specific, with a stateful PCE, it is possible to refer to a LSP with a unique identifier in the scope of the PCC-PCEP session and thus use such identifier to refer to that LSP.

Example 1: a PCC (e.g. NMS) requesting for a re-optimization of one or several LSPs can send the request with ''R'' bit set and only provides the relevant LSP unique identifier(s).

In order to support these, the LSP identifier TLV defined in [Stateful-PCE] can be used in the RP Object to specify the request LSP ID(s). Upon receiving the PCReq message, PCE should be able to correlate with one or multiple LSPs with their detailed state information and carry out optimization accordingly. The handling of RP object specified in [RFC5440] is stated as following:

''The absence of an RRO in the PCReq message for a non-zero-bandwidth TE LSP (when the R bit of the RP object is set) MUST trigger the sending of a PCErr message with Error-Type="Required Object Missing" and Error-value="RRO Object missing for reoptimization."

If a PCE has stateful capabilities, and such capabilities have been negotiated and advertised, specific rules given in [RFC5440] may need to be relaxed. In particular, the re-optimization case: if the re-optimization request refers to a given LSP state, and the RRO information is available, the PCE can proceed.

Example 2: in order to set up a LSP which has a constraint that its route should not use resources used by one or more existing LSPs, a PCC can send a PCReq with the identifier(s) of these LSPs. A stateful PCE should be able to find the corresponding route and resource information so as to meet the constraints set by the requesting PCC. Hence, the LSP identifier TLV defined in [Stateful-PCE] can be used in XRO object for this purpose.

2.6. Application-specific PCEP extensions for stateful PCE

[Editor's Note: this is not a complete list of application-specific PCEP extensions. Suggestions are welcome on expansion on this section.]

2.6.1. Time-based Scheduling

[Editor's note: synchronization is complex and we cannot assume that the PCE and PCC clocks are equal and issues such as whether it should be kept centralized or not will be reflected in the later version.]

To support time-based scheduling, network operators need to reserve resources in advance according to customers' requests with specified starting time and duration. A simple utilization example of this service is to support scheduled data transmission between data centers or any generic scheduled based services.

Traditionally, this can be supported by NMS operation through path pre-establishment and activation on the agreed starting time. However, this does not provide efficient network usage since the

established paths exclude the possibility of being used by other services even when they are not used for undertaking any service due to the lack of a time-based mechanism. It can also be accomplished through GMPLS protocol extensions by carrying the related request information (e.g., starting time and duration) across the network. Nevertheless, this method inevitably increases the complexity of signaling and routing process.

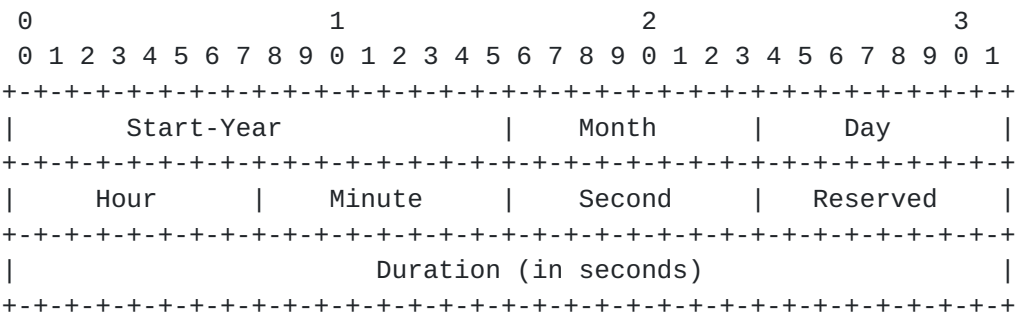
Since a stateful PCE needs to collect LSP related information for the whole network, it can naturally support this service with resource usage flexibility (i.e., only excluding the time slot(s) reserved for time-based scheduling requests). Moreover, it can avoid the need to add complexity on network elements in this regard. A stateful PCE should also maintain a database that stores all the reserved information with time reference. This can be achieved either by maintaining a separate database or having all the reserved information with time reference incorporated into LSP-DB. The details of organizing time-based scheduling related information are subject to network provider's policy and administrative consideration and thus outside of the scope of this document.

2.6.1.1. PCEP Extension

For a PCC to request a path computation for scheduled service, it MUST be able to specify the time-related information, including the starting time and LSP holding time, in PCEP request.

A SERVICE-TIME object is presented as follows to provide the required information (i.e. service starting time and holding time).

The Object-Class is TBD and the Object-Type is 1.



field	Length	range

Start-Year	16 bit	0..65536
Month	8 bit	1..12
Day	8 bit	1..31
Hour	8 bit	0..23
Minute	8 bit	0..59
Second	8 bit	0..59

The SERVICE-TIME object can be included in a PCEP request as specified in the following manner:

```
<PCReq Message>::=<Common Header>
                  [<SVEC-list>]
                  <request-list>
```

Where:

```
 [<svec-list>]::= <SVEC> [<svec-list>]
<request-list>::=<request>[<request-list>]
<request >::=<RP>
             <END-POINTS>
             [<LSPA>]
             [<BANDWIDTH>]
             [<SERVICE-TIME>]
             [<metric-list>]
             [<RRO>[<BANDWIDTH>]]
             [<IRO>]
             [<LOAD-BALANCING>]
```

WHERE:

```
<metric-list>::=<METRIC>[<metric-list>]
```

Upon receiving the PCReq message, PCE should compute the path taking into consideration the constraints of the TED, LSP-DB as well as other scheduled service information and return the computed route back to the requesting PCC. If no path can be found, PCE should return an error message specifying the reason.

2.6.2. RWA in Impairment-aware Wavelength-switched Optical Networks (WSON)

In impairment-ware WSON networks, the routing and wavelength assignment process needs to consider the constraints incurred by the physical impairments. As described in [Stateful-APP], stateful PCE can effectively reduce the control plane overhead by centrally maintaining the impairment-information related to each LSP.

In order to establish an impairment-aware LSP, a path computation request may need to specify the desired values and/or constraints for one or more of the following parameters:

- Power
- OSNR
- PMD
- T.B.D.

Upon receiving the path computation request, a stateful PCE should take into consideration the explicitly defined constraints as well as those of the existing LSPs, stored in LSP-DB. Furthermore, a PCE may need to reply in PCRep with the actual values of the one or more of the above-mentioned parameters to the requesting PCC as well as the adjustment needed. After receiving the reply message, the PCC can take appropriate actions along the to-be-established paths in tuning its power or changing other impairment-related parameters so as to achieve the desired signal quality.

To support the above-mentioned requirements, the METRIC object defined in [RFC5440] can be exploited with proper extension. A new type value should be added.

T=T.B.D.: Impairment-aware information

Furthermore, as described in [PCE-IA-WSON], there are two types of parameters that can be specified, i.e. path level or link level. If a stateful PCE needs to reply with adjustment needed for path level parameters. Then further extension to the METRIC object is desirable and this will be considered in the future.

3. IANA Considerations

IANA is requested to allocate new Types for the TLV/Object defined in this document.

3.1. LayerCapability TLV

3.2. SERVICE-TIME Object

3.3. Extension to METRIC Object

4. Manageability Considerations

TBD.

5. Security Considerations

TBD.

6. References

6.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to indicate requirements levels", RFC 2119, March 1997.

[RFC4655] Farrel, A., Vasseur, J.-P., and Ash, J., "A Path Computation Element (PCE)-Based Architecture", RFC 4655, August 2006.

[RFC5440] Vasseur, J.-P., and Le Roux, JL., "Path Computation Element (PCE) Communication Protocol (PCEP)", RFC 5440, March 2009.

[RFC5088] Le Roux, JL., Vasseur, J.-P., Ikejiri, Y., Zhang, R., ''OSPF Protocol Extensions for Path Computation Element (PCE) Discovery'', RFC 5088, April 2008.

6.2. Informative References

[Stateful-APP] Zhang, F., Zhang, X., Lee, Y., Casellas, R., Gonzalez de Dios, O., "Applicability of Stateful Path Computation Element (PCE) ", draft-zhang-pce-stateful-pce-app, work in progress.

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[PCE-IA-WSON] Lee, Y., Bernstein G., Takeda, T., Tsuritani, T., ''PCEP Extensions for WSON Impairments'', draft-lee-pce-wson-impairments, work in progress.

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