                   Requirements for GMPLS Applications of PCE

Abstract

   The initial effort of the PCE (Path Computation Element) WG focused
   mainly on MPLS. As a next step, this document describes functional
   requirements for GMPLS applications of PCE.

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1. Introduction

   The initial effort of the PCE (Path Computation Element) WG focused
   mainly on solving the path computation problem within a domain or
   over different domains in MPLS networks. As with MPLS, service
   providers (SPs) have also come up with requirements for path
   computation in GMPLS-controlled networks [RFC3945], such as those
   based on Wavelength Division Multiplexing (WDM), Time Division
   Multiplexing (TDM), or Ethernet.

   [RFC4655] and [RFC4657] discuss the framework and requirements for
   PCE on both packet MPLS networks and GMPLS-controlled networks. This
   document complements those RFCs by providing considerations of GMPLS
   applications in the intradomain and interdomain networking
   environments and indicating a set of requirements for the extended
   definition of PCE-related protocols.

Note that the requirements for interlayer and inter-area traffic
engineering (TE) described in [RFC6457] and [RFC4927] are outside of
the scope of this document.

Constrained Shortest Path First (CSPF) computation within a domain or
over domains for signaling GMPLS Label Switched Paths (LSPs) is
usually more stringent than that of MPLS TE LSPs [RFC4216], because
the additional constraints, e.g., interface switching capability,
link encoding, link protection capability, Shared Risk Link Group
(SRLG) [RFC4202], and so forth, need to be considered to establish
GMPLS LSPs. The GMPLS signaling protocol [RFC3473] is designed
taking into account bidirectionality, switching type, encoding type,
and protection attributes of the TE links spanned by the path, as
well as LSP encoding and switching type of the endpoints,
appropriately.

This document provides requirements for GMPLS applications of PCE in
support of GMPLS path computation, included are requirements for both
intradomain and interdomain environments.

2. GMPLS Applications of PCE

2.1. Path Computation in GMPLS Networks

Figure 1 depicts a model GMPLS network, consisting of an ingress
link, a transit link, as well as an egress link. We will use this
model to investigate consistent guidelines for GMPLS path
computation. Each link at each interface has its own switching
capability, encoding type, and bandwidth.

```
          Ingress              Transit              Egress
+-----+    link1-2  +-----+    link2-3  +-----+    link3-4  +-----+
|Node1|------------>|Node2|------------>|Node3|------------>|Node4|
|     |<------------|     |<------------|     |<------------|     |
+-----+    link2-1  +-----+    link3-2  +-----+    link4-3  +-----+
```
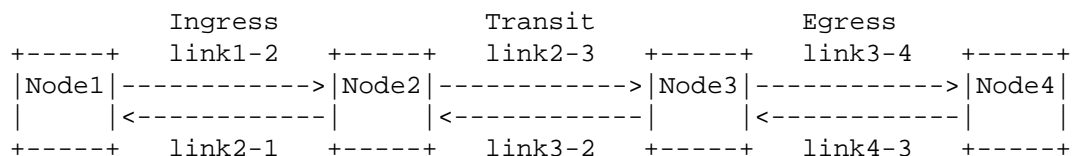
                 Figure 1: Path Computation in GMPLS Networks

For the simplicity in consideration, the following basic assumptions
are made when the LSP is created.

(1) Switching capabilities of outgoing links from the ingress and
     egress nodes (link1-2 and link4-3 in Figure 1) are consistent
     with each other.

(2) Switching capabilities of all transit links, including incoming
     links to the ingress and egress nodes (link2-1 and link3-4) are
     consistent with switching type of an LSP to be created.

(3) Encoding types of all transit links are consistent with the
     encoding type of an LSP to be created.

GMPLS-controlled networks (e.g., GMPLS-based TDM networks) are
usually responsible for transmitting data for the client layer.
These GMPLS-controlled networks can provide different types of
connections for customer services based on different service
bandwidth requests.

The applications and the corresponding additional requirements for
applying PCE to GMPLS-based TDM networks are described in this
section. In order to simplify the description, this document only
discusses the scenario in Synchronous Digital Hierarchy (SDH)
networks as an example (see Figure 2). The scenarios in Synchronous
Optical Network (SONET) or Optical Transport Network (OTN) are
similar.

```
                      N1                    N2
       +-----+     +------+           +------+
       |     |-------|      |------------|      |           +-------+
       +-----+     |      |---|          |      |      |     |       |
         A1        +------+   |          +------+      |     |       |
                      |       |             |          |     |       |
                      |       |             |          +-------+
                      |       |             |             PCE
                      |       |             |
                      |     +------+        |
                      |     |      |        |
                      |     |      |-----|  |
                      |     +------+     | |
                      |        N5        | |
                      |                  | |
       +------+     +------+        +------+
       |      |     |      |        |      |     +-----+
       |      |-------------|      |        |      |-------|     |
       +------+     +------+        +------+     +-----+
         N3                  N4                    A2
```
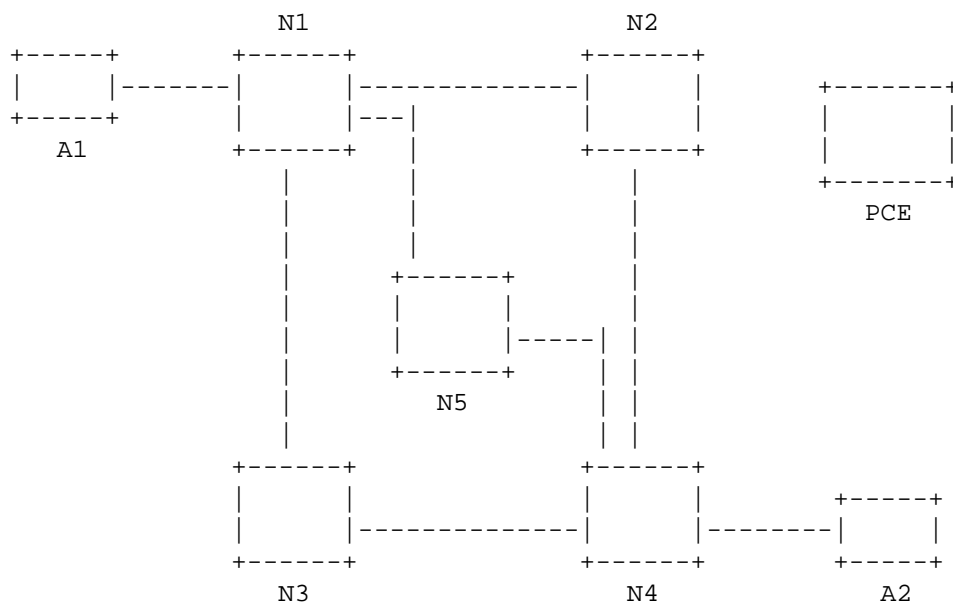
                    Figure 2: A Simple TDM (SDH) Network

Figure 2 shows a simple TDM (SDH) network topology, where N1, N2, N3,
N4, and N5 are all SDH switches; A1 and A2 are client devices (e.g.,
Ethernet switches). Assume that one Ethernet service with 100 Mbit/s
bandwidth is required from A1 to A2 over this network. The client
Ethernet service could be provided by a Virtual Container 4 (VC-4)
container from N1 to N4; it could also be provided by three
concatenated VC-3s (contiguous or virtual concatenation) from N1 to
N4.

In this scenario, when the ingress node (e.g., N1) receives a client
service transmitting request, the type of containers (one VC-4 or
three concatenated VC-3s) could be determined by the PCC (Path
Computation Client), e.g., N1 or Network Management System (NMS).
However, it could also be determined automatically by the PCE based
on policy [RFC5394]. If it is determined by the PCC, then the PCC
should be capable of specifying the ingress node and egress node,
signal type, the type of the concatenation, and the number of the
concatenation in a PCReq (Path Computation Request) message. The PCE
should consider those parameters during path computation. The route
information (co-routing or diverse routing) should be specified in a
PCRep (Path Computation Reply) message if path computation is
performed successfully.

As described above, the PCC should be capable of specifying TE
attributes defined in the next section, and the PCE should compute a
path accordingly.

Where a GMPLS network consists of interdomain (e.g., inter-AS or
inter-area) GMPLS-controlled networks, requirements on the path
computation follow [RFC5376] and [RFC4726].

2.2. Unnumbered Interface

GMPLS supports unnumbered interface IDs as defined in [RFC3477]; this
means that the endpoints of the path may be unnumbered. It should
also be possible to request a path consisting of the mixture of
numbered links and unnumbered links, or a P2MP (Point-to-Multipoint)
path with different types of endpoints. Therefore, the PCC should be
capable of indicating the unnumbered interface ID of the endpoints in
the PCReq message.

2.3. Asymmetric Bandwidth Path Computation

Per [RFC6387], GMPLS signaling can be used for setting up an
asymmetric bandwidth bidirectional LSP. If a PCE is responsible for
path computation, it should be capable of computing a path for the
bidirectional LSP with asymmetric bandwidth. This means that the PCC
should be able to indicate the asymmetric bandwidth requirements in
forward and reverse directions in the PCReq message.

3. Requirements for GMPLS Applications of PCE

3.1. Requirements on Path Computation Request

   As for path computation in GMPLS-controlled networks as discussed in
   Section 2, the PCE should appropriately consider the GMPLS TE
   attributes listed below once a PCC or another PCE requests a path
   computation. The path calculation request message from the PCC or
   the PCE must contain the information specifying appropriate
   attributes. According to [RFC5440], [PCE-WSON-REQ], and RSVP
   procedures such as explicit label control (ELC), the additional
   attributes introduced are as follows:

   (1)   Switching capability/type: as defined in [RFC3471], [RFC4203],
          and all current and future values.

   (2)   Encoding type: as defined in [RFC3471], [RFC4203], and all
          current and future values.

   (3)   Signal type: as defined in [RFC4606] and all current and future
          values.

   (4)   Concatenation type: In SDH/SONET and OTN, two kinds of
          concatenation modes are defined: contiguous concatenation,
          which requires co-routing for each member signal and that all
          the interfaces along the path support this capability, and
          virtual concatenation, which allows diverse routing for member
          signals and requires that only the ingress and egress
          interfaces support this capability. Note that for the virtual
          concatenation, it may also specify co-routing or diverse
          routing. See [RFC4606] and [RFC4328] about concatenation
          information.

   (5)   Concatenation number: Indicates the number of signals that are
          requested to be contiguously or virtually concatenated. Also
          see [RFC4606] and [RFC4328].

   (6)   Technology-specific label(s): as defined in [RFC4606],
          [RFC6060], [RFC6002], or [RFC6205].

   (7)   End-to-End (E2E) path protection type: as defined in [RFC4872],
          e.g., 1+1 protection, 1:1 protection, (pre-planned) rerouting,
          etc.

   (8)   Administrative group: as defined in [RFC3630].

   (9)   Link protection type: as defined in [RFC4203].

   (10) Support for unnumbered interfaces: as defined in [RFC3477].

   (11) Support for asymmetric bandwidth requests: as defined in
         [RFC6387].

   (12) Support for explicit label control during the path computation.

   (13) Support of label restrictions in the requests/responses,
         similar to RSVP-TE ERO (Explicit Route Object) and XRO (Exclude
         Route Object), as defined in [RFC3473] and [RFC4874].

3.2. Requirements on Path Computation Reply

   As described above, a PCE should compute the path that satisfies the
   constraints specified in the PCReq message. Then, the PCE should
   send a PCRep message, including the computation result, to the PCC.
   For a Path Computation Reply message (PCRep) in GMPLS networks, there
   are some additional requirements. The PCEP (PCE communication
   protocol) PCRep message must be extended to meet the following
   requirements.

   (1) Path computation with concatenation

        In the case of path computation involving concatenation, when a
        PCE receives the PCReq message specifying the concatenation
        constraints described in Section 3.1, the PCE should compute a
        path accordingly.

        For path computation involving contiguous concatenation, a
        single route is required, and all the interfaces along the route
        should support contiguous concatenation capability. Therefore,
        the PCE should compute a path based on the contiguous
        concatenation capability of each interface and only one ERO that
        should carry the route information for the response.

        For path computation involving virtual concatenation, only the
        ingress/egress interfaces need to support virtual concatenation
        capability, and there may be diverse routes for the different
        member signals. Therefore, multiple EROs may be needed for the
        response. Each ERO may represent the route of one or multiple
        member signals. When one ERO represents multiple member
        signals, the number must be specified.

   (2) Label constraint

        In the case that a PCC does not specify the exact label(s) when
        requesting a label-restricted path and the PCE is capable of
        performing the route computation and label assignment
        computation procedure, the PCE needs to be able to specify the
        label of the path in a PCRep message.

        Wavelength restriction is a typical case of label restriction.
        More generally, label switching and selection constraints may
        apply in GMPLS-controlled networks, and a PCC may request a PCE
        to take label constraint into account and return an ERO
        containing the label or set of labels that fulfill the PCC
        request.

   (3) Roles of the routes

        When a PCC specifies the protection type of an LSP, the PCE
        should compute the working route and the corresponding
        protection route(s). Therefore, the PCRep should allow to
        distinguish the working (nominal) and the protection routes.
        According to these routes, the RSVP-TE procedure appropriately
        creates both the working and the protection LSPs, for example,
        with the ASSOCIATION object [RFC6689].

3.3. GMPLS PCE Management

   This document does not change any of the management or operational
   details for networks that utilize PCE. (Please refer to [RFC4655]
   for manageability considerations for a PCE-based architecture.)
   However, this document proposes the introduction of several PCEP
   objects and data for the better integration of PCE with GMPLS
   networks. Those protocol elements will need to be visible in any
   management tools that apply to the PCE, PCC, and PCEP. That
   includes, but is not limited to, adding appropriate objects to
   existing PCE MIB modules that are used for modeling and monitoring
   PCEP deployments [PCEP-MIB]. Ideas for what objects are needed may
   be guided by the relevant GMPLS extensions in GMPLS-TE-STD-MIB
   [RFC4802].

4. Security Considerations

   PCEP extensions to support GMPLS should be considered under the same
   security as current PCE work, and this extension will not change the
   underlying security issues. Section 10 of [RFC5440] describes the
   list of security considerations in PCEP. At the time [RFC5440] was
   published, TCP Authentication Option (TCP-AO) had not been fully

   specified for securing the TCP connections that underlie PCEP
   sessions. TCP-AO [RFC5925] has now been published, and PCEP
   implementations should fully support TCP-AO according to [RFC6952].

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