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Interworking of GMPLS Control and Centralized Controller System

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Abstract

Generalized Multi-Protocol Label Switching (GMPLS) control allows each network element (NE) to perform resource discovery, routing and signaling in a distributed manner. On the other hand, with the development of software-defined transport networking technology, central controllers are introduced to transport networks to control a set of NEs.

In transport networks, the GMPLS control has many mature mechanisms such as RSVP-TE, OSPF-TE, and LMP, so that GMPLS can be applied for the NE-level control in the centralized controller systems.

This document describes how GMPLS control interworks with centralized controller systems (e.g. ACTN) in transport network.

Status of this Memo

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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 [RFC2119].

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1. Introduction

Generalized Multi-Protocol Label Switching (GMPLS) [RFC3945] extends MPLS to support different classes of interfaces and switching capabilities such as Time-Division Multiplex Capable (TDM), Lambda Switch Capable (LSC), and Fiber-Switch Capable (FSC). Each network element (NE) running a control plane collects network information from other NEs and provisions services through signaling in a distributed manner.

On the other hand, Software-Defined Networking (SDN) technologies have been introduced to control the transport network in a centralized manner. Central controllers, which can locate outside of the network, can collect network information from each node and provision services to corresponding nodes. One of the examples is the Abstraction and Control of Traffic Engineered Networks (ACTN) [I-D.ietf-teas-actn-framework], which defines a hierarchical architecture with PNC, MDSC and CNC as central controllers for different network abstraction levels.

In such centralized controller systems, GMPLS can be applied for the NE-level control. Introducing GMPLS in centralized controller system can reuse the mature mechanisms defined for GMPLS and be practical for legacy transport networks. This document describes how GMPLS control interworks with centralized controller system in transport network.

2. Overview

In this section, overviews of GMPLS control plane and centralized controller system are discussed as well as the cooperation between GMPLS control plane and centralized controller system.

2.1. Overview of GMPLS Control Plane

GMPLS separates the control plane and the data plane to support time-division, wavelength, and spatial switching, which are significant in transport networks. For the NE level control in GMPLS, each node has its controller to perform service provisioning, protection, and restoration. At the same time, the controller can negotiate available link resources with controllers in adjacent nodes, and it can also collect node and link resources in the network to construct the network topology and compute routing paths for serving service requests.

Several protocols have been designed for GMPLS control [RFC3945] including link management [RFC4204], signaling [RFC3471], and routing [RFC4202] protocols. The controllers applying these protocols communicate with each other to exchange resource information and establish LSP. In this way, controllers in different nodes in the network have the same network topology and provision services by their local policies.

2.2. Overview of Centralized Controller System

With the development of SDN technologies, centralized controller system has been introduced to transport networks such as ACTN. In centralized controller system, a controller is aware of the network topology and is responsible for provisioning incoming service requests. In ACTN, multiple abstraction levels are designed and controllers at different levels implement different functions. This kind of abstraction enables multi-vendor, multi-domain, and multi-technology control.

For example in ACTN, an MDSC coordinates several PNCs controlling different domains. Each PNC reports its topology, which can be abstracted, to the MDSC, so that the MDSC learns the picture of multiple domains. When a multi-domain service arrives at the MDSC, the MDSC first computes an end-to-end routing path. Then the MDSC splits this path to multiple segment according to domain boundaries and allocate each segment to corresponding PNC for detailed path computation and LSP segment setup. After each PNC reporting the establishment of corresponding LSP segment, this multi-domain service is accommodated.

2.3. GMPLS Control Interwork with Centralized Controller System

Centralized controller system as ACTN provides the architecture and communication between central controllers of different abstraction levels to coordinate multiple domains. Within each domain, GMPLS control can be applied to each NE. The bottom-level central controller like PNC can act as a NE to collect network information and initiate LSP. Following figure shows an example of GMPLS interworking with ACTN.

```
                        +----------+
                        |   MDSC   |
                        +----------+
                          ^      ^
                          |      |
                +---------+      +---------+
                |  RESTConf / YANG models  |
                V                          V
           +---------+                +---------+
           |   PNC   |                |   PNC   |
           +---------+                +---------+
              ^   ^                      ^   ^
              |   |                      |   |
       OSPF-TE|   |PCEP           OSPF-TE|   |PCEP
              |   |                      |   |
              |   V                      |   V
         .-------------.   Inter-   .-------------.
        /               \  domain  /               \
       |       LMP       |  link  |       LMP       |
      |      OSPF-TE     ==========     OSPF-TE      |
       |     RSVP-TE     |        |     RSVP-TE     |
        \               /          \               /
          '------------'             '------------'
           GMPLS domain               GMPLS domain
```

Figure 1: Example of GMPLS interworks with ACTN

In Figure 1, each domain runs GMPLS control. The PNC listens LSAs flooded in the domain and learns the topology. For path computation in the domain with PNC implementing a PCE, NEs use PCEP to ask the PNC for a path and get replies. The MDSC communicates with PNCs using RESTConf or YANG models. As a PNC has learned its domain topology, it can report the topology to the MDSC. When a service arrives, the MDSC computes the path and coordinates PNCs to establish the corresponding LSP segment.

3. Link Management Protocol

Link management protocol (LMP) [RFC4204] runs between a pair of nodes and is used to manage TE links. In addition to setup and maintain control channels, LMP can be used to verify the data link connectivity and correlate the link property. In this way, link resources, which are fundamental resources in the network, are discovered by both ends of the link.

4. Routing Options

In GMPLS control, link state information is flooded within the network as defined in [RFC4202]. Each node in the network can build the network topology according to the flooded link state information. Routing protocols such as OSPF-TE [RFC4203] and ISIS-TE [RFC5307] have been extended to support different interfaces in GMPLS.

In centralized controller system, central controller can be placed at the GMPLS network and passively receive the information flooded in the network. In this way, the central controller can construct and update the network topology.

4.1. OSPF-TE

OSPF-TE is introduced for TE networks in [RFC3630]. OSPF extensions have been defined in [RFC4203] to enable the capability of link state information for GMPLS network. Based on this work, OSPF protocol has been extended to support technology-specific routing. The routing protocol for OTN, WSON and optical flexi-grid network are defined in [RFC7138], [RFC7688] and [I-D.ietf-ccamp-flexible-grid-ospf-ext], respectively.

4.2. ISIS-TE

ISIS-TE is introduced for TE networks in [RFC5305] and is extended to support GMPLS routing functions [RFC5307], and has been updated to [RFC7074] to support the latest GMPLS switching capability and Types fields.

5. Path Computation

Once a controller learn the network topology, it can utilize the available resources to serve service requests by performing path computation. Path computation is one of the key objectives in various types of controllers. In the given architecture, it is possible for different components that have the capability to compute the path.

5.1. Constraint-based Path Computing in GMPLS Control

In GMPLS control, a routing path is computed by the ingress node [RFC3473] and is based on the ingress node TED. Constraint-based path computation is performed according to the local policy of the ingress node.

5.2. Path Computation Element (PCE)

PCE has been introduced in [RFC4655] as a functional component that provides services to compute path in a network. In [RFC5440], the path computation is accomplished by using the Traffic Engineering Database (TED), which maintains the link resources in the network. The emergence of PCE efficiently improve the quality of network planning and offline computation, but there is a risk that the computed path may be infeasible if there is a diversity requirement, because stateless PCE has no knowledge about the former computed paths.

To address this issue, stateful PCE has been proposed in [RFC8231]. Besides the TED, an additional LSP Database (LSP-DB) is introduced to archive each LSP computed by the PCE. In this way, PCE can easily figure out the relationship between the computing path and former computed paths. In this approach, PCE provides computed paths to PCC, and then PCC decides which path is deployed and when to be established.

In PCE Initiation [I-D.ietf-pce-pce-initiated-lsp], PCE is allowed to trigger the PCC to setup, maintenance, and teardown of the PCE-initiated LSP under the stateful PCE model. This would allow a dynamic network that is centrally controlled and deployed.

In centralized controller system, the PCE can be implement in a central controller, and the central controller performs path computation according to its local policies. On the other hand, the PCE can also be placed outside of the central controller. In this case, the central controller acts as a PCC to request path computation to the PCE through PCEP.

6. Signaling Options

Signaling mechanism is used to setup LSPs in GMPLS control. Messages are sent hop by hop between the ingress node and the egress node of the LSP to allocate labels. Once the labels are allocated along the path, the LSP setup is accomplished. Signaling protocols such as RSVP-TE [RFC3473] and CR-LDP [RFC3472] have been extended to support different interfaces in GMPLS.

In centralized controller system, the central controller can manage LSPs by using PCE-initiation [I-D.ietf-pce-pce-initiated-lsp] to notify the corresponding ingress node. The ingress node will maintain the LSP through GMPLS signaling.

6.1. RSVP-TE

RSVP-TE is introduced in [RFC3209] and extended to support GMPLS signaling in [RFC3473]. Several label formats are defined for a generalized label request, a generalized label, suggested label and label sets. Based on [RFC3473], RSVP-TE has been extended to support technology-specific signaling. The RSVP-TE extensions for OTN, WSON, optical flexi-grid network are defined in [RFC7139], [RFC7689], and [RFC7792], respectively.

6.2. CR-LDP

In order to support the label formats and signaling mechanism defined in [RFC3471], CR-LDP is extended in [RFC3472]. Several label formats are defined and bidirectional LSPs are supported.

7. Recovery

The GMPLS recovery functions are described in [RFC4426]. Two models, span protection and end-to-end protection and restoration, are discussed with different protection schemes and message exchange requirements. Related RSVP-TE extensions to support end-to-end recovery is described in [RFC4872]. The extensions in [RFC4872] include protection, restoration, preemption, and rerouting mechanisms for an end-to-end LSP.

Besides end-to-end recovery, a GMPLS segment recovery mechanism is defined in [RFC4873]. By introducing secondary record route objects, LSP segment can be switched to another path like fast rereoute [RFC4090].

8. Network Management

TBD.

9. Security Considerations

TBD.

10. IANA Considerations

This document requires no IANA actions.

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