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Considering Generalized Multiprotocol Label Switching Traffic Engineering Attributes During Path Computation

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Abstract

This document provides guidelines for the consideration of Generalized Multiprotocol Label Switching (GMPLS) Traffic-Engineering (TE) attributes for computation of routes for Label Switched Paths (LSPs) in a GMPLS network.

This document summarizes how GMPLS TE attributes on ingress links, transit links, and egress links may be treated as path computation constraints to determine the route of a GMPLS Label Switched Path (LSP).

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1. Introduction

A network is, in general, controlled and managed taking into account various attributes of the underlying technologies of the physical and logical links and nodes. In a network operated using Generalized Multiprotocol Label Switching (GMPLS) protocols, many of these Traffic Engineering (TE) attributes are advertised using routing protocols [RFC3945], [RFC4202].

To establish a GMPLS Label Switched Path (LSP) it is necessary to compute a route or path for that LSP either hop-by-hop or by the pre-calculation of part or all of the path. In order that the route selected is capable of satisfying the requirements of the user or application that will use the LSP the computation must be constrained by a set of LSP-specific requirements and the TE attributes advertised within the network. Further, considerations of technology and node or link capabilities may also provide restrictions to the feasibility of LSP establishment on certain routes, and this can be deduced from the TE attributes advertised within the network and used by the path computation algorithms to select only viable routes.

In a mixed, integrated network (for example, one containing optical switches and packet routers) these constraints may vary and are understood differently for different equipment and different LSPs. This document provides guidelines to facilitate path computation for GMPLS LSPs by summarizing how GMPLS TE attributes on ingress links, transit links, and egress links may be treated as path computation constraints to determine the route of a GMPLS Label Switched Path (LSP).

2. Problem Statements

A GMPLS network is assumed to be composed of different switching capabilities for nodes and different encoding types for TE links. Such a GMPLS network is usually deployed by adopting multiple vendors and each vendor usually has each constraint for a CSPF path calculation and then a problem appears that a signaling message including a calculated route at an ingress node may be rejected at a transit node and the path creation may fail because of the difference of the constraint for a CSPF path calculation between these nodes.

In an example network as shown in Figure 1, when ingress Router1 calculates a path to egress Router2 without considering the encoding type for transit TE links and sends path message to PXC1, PXC1 returns path error message to Router1 because PXC1 cannot crossconnect from ethernet encoding link to sonet/sdh encoding link. In this case, if ingress Router1 can calculate with the exact match for all the links through the ingress node to the egress node, the path can be established.

```
  Router1--(Ethernet)--PXC1--(SONET/SDH)--PXC2--(Ethernet)--Router2

*(): Encoding type
```

Figure 1: example network1

On the other hand, when a network includes optical switching nodes such as ROADMs which have a link with the encoding type of lambda between nodes as shown in Figure2 and ingress Router1 calculate with the exact match through all the links, the path calculation will fail. In this environment, even if the encoding type of ingress and egress links is different from transit links, the path should be established. Therefore, constraints for various cases of path calculation must be clearly defined.

```
          Router1                                           Router3
             \                                                /
              \                                              /
            (Ethernet)                                 (Ethernet)
                \                                          /
                 \                                        /
                 ROADM1--(Lambda)--ROADM2--(Lambda)--ROADM3
                 /                                        \
                /                                          \
            (SONET/SDH)                                (SONET/SDH)
              /                                              \
             /                                                \
          Router2                                           Router4
```

Figure 2: example network2

3. Assumed Network Model

3.1 GMPLS TE Attributes Consideration for Path Calculation

For path computation to establish GMPLS LSPs correctly, various GMPLS attributes [RFC4202], [RFC4203] of links as well as nodes, as indicated below, must be taken into account in a GMPLS network environment in addition to TE attributes of packet based network [RFC3630].

(1) Encoding-type: Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy (SDH), Lambda, Ethernet, etc.
(2) Switching capability: Time Division Multiplex (TDM), Lambda, Fiber, etc.

(3) Bandwidth: OC-192, OC-48, GbE, 10GbE, etc.

These logical attributes have a very tight relationship with underlying physical technologies such as SONET/SDH, Optical Transport Network (OTN) or Ethernet in terms of links, and all-optical switches, SONET/SDH-basis digital cross connect or electrical-basis optical switches in terms of nodes. Therefore, the GMPLS LSPs must satisfy logical constrains as well as corresponding physical constraints. These constraints are sometimes differently understood among different layers, and a logically computed GMPLS LSP may violate the physical constraints, therefore, a consistent guideline to solve this issue should be formulated.

3.2 Considered Network Model

Figure 3 depicts a typical GMPLS network, consisting of an ingress link, a transit link as well as an egress link, to investigate a consistent guideline for GMPLS path computation. Each link at each interface has its own switching capability, encoding type and bandwidth.
The consideration here is based on a single domain GMPLS network, but the analysis maybe applicable to an inter-domain GMPLS networks.

```
          Ingress             Transit             Egress
+-----+   link1-2   +-----+   link2-3   +-----+   link3-4   +-----+
|Node1|------------>|Node2|------------>|Node3|------------>|Node4|
|     |<------------|     |<------------|     |<------------|     |
+-----+   link2-1   +-----+   link3-2   +-----+   link4-3   +-----+
```

Figure 3: GMPLS Network Model

For the simplicity of the analysis in path consideration, the below basic assumptions are made when the LSP is created.

(1) Switching capabilities (SC) of outgoing links from the ingress and egress nodes (link1-2 and link4-3 in Figure 1) must be consistent with each other.
(2) SC of all transit links including incoming links to the ingress and egress nodes (link2-1 and link3-4) should be consistent with switching type of a LSP to be created.
(3) Encoding-types of all transit links should be consistent with encoding type of a LSP to be created.

A GMPLS network maybe a multi-layer network, which is composed of multiple nodes with different switching capabilities and interface encoding types. Therefore, a hierarchical structure may be considered in path computation. In such a case, the combination between the switching type and encoding type of a desired LSP, and those of all transit links described as the table in following section may be acceptable. One of advertised multiple interface switching capability descriptors for the same link [RFC4202] should be also appropriately chosen as the attribute for the link.

Bandwidth of each TE link is maximum LSP bandwidth in interface switching capability descriptor at the priority for a desired LSP [RFC4203], and encoding-types of incoming and outgoing links on the same interface (for example, link1-2 and link2-1) should be consistent with each other.

In case that the network is comprised of numbered links and unnumbered links [RFC3477], an ingress node, who is able to support numbered links and unnumbered links may choose both links being part of the same desired LSP.

4. Path Computation Considerations

In this section, we consider GMPLS constraints to be satisfied in different cases of link attributes. When a LSP indicated in below tables is created, the path computation must choose the route so as to satisfy switching capability, encoding type and bandwidth at the ingress link, transiting links and the egress link indicated in columns next to the created LSP, considering underlying physical constraints. Here, almost cases of GMPLS path computation consideration are summarized in this document, however, some cases will be added in a future version.

(1) TDM-Switch Capable

Table 1: Desired GMPLS Attributes in the Case of TDM-SC

LSP attribute		Ingress	Transit	Egress	Remarks
SC*	TDM	TDM L2SC PSC	TDM	TDM L2SC PSC	
Enc	SONET/SDH	SONET/SDH	SONET/SDH	SONET/SDH	Specified in G.691
	Ethernet	Ethernet	SONET/SDH or Ethernet	Ethernet	Specified in IEEE
	OTN*	OTN	OTN	OTN	

```
|BW*|X        |<=bw*    |<=bw        |<=bw     |                  |
```

```
+---+---------+---------+-----------+---------+-----------------+
```

*SC in LSP means a desired switching type of LSP.
*OTN interfaces are equivalent to digital wrapper technology in this document.
* BW is the desired bandwidth of the LSP
* bw is the bandwidth available on the link

In this case, since the interface with TDM SC supports sub-rate switching, BW X can be equal to or less than bw of ingress, transit and egress links, and must be larger than the minimum LSP bandwidth in the interface switching capability descriptor. Sub-rate switching is unsuited for a hierarchical LSP, because the lower-layer link usually has larger granular bandwidth than that layer except PSC-x, for example a TDM LSP with the desired bandwidth of OC-12 should not use a lambda switching capable link with the bandwidth of OC-48 as a transit link. In such a case, a lambda LSP as a forwarding adjacency (FA) LSP is created on the lower (lambda) layer in advance, then the FA-LSP [LSP-HIER] may be advertised as a TDM SC link.

(2) Lambda Switch Capable (LSC)

Table 2.1: The Case of End-Point(Ingress/Egress) Link Attributes without Lambda Encoding

```
+-------------+---------+-----------+---------+-----------------+
|LSP attribute|Ingress  |Transit    |Egress   |Remarks          |
+---+---------+---------+-----------+---------+-----------------+
|   |         |LSC      |           |LSC      |                 |
|   |         +---------+           +---------+                 |
|SC |LSC      |TDM      |LSC        |TDM      |                 |
|   |         +---------+           +---------+                 |
|   |         |L2SC     |           |L2SC     |                 |
|   |         +---------+           +---------+                 |
|   |         |PSC      |           |PSC      |                 |
+---+---------+---------+-----------+---------+[RFC4202]        |
|   |SONET/SDH|SONET/SDH|SONET/SDH  |SONET/SDH|section 3.6, 3.9 |
|   |         |         |or lambda  |         |Specified in G.691|
|   +---------+---------+-----------+---------+                 |
|Enc|Ethernet |Ethernet |Ethernet   |Ethernet |Specified in IEEE |
|   |         |         |or lambda  |         |                 |
|   +---------+---------+-----------+---------+                 |
|   |OTN      |OTN      |OTN        |OTN      |Specified in G.709|
|   |         |         |or lambda  |         |                 |
|---+---------+---------+-----------+---------+                 |
|BW |X        |=bw      |=bw        |=bw      |                 |
|   |         |         |or *<=bw   |         |                 |
```

```
+---+---------+---------+-----------+---------+-----------------+
```

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

Table 2.2: The Case of End-Point(Ingress/Egress) Link Attributes with Lambda Encoding

LSP attribute		Ingress	Transit	Egress	Remarks
SC	LSC	LSC TDM L2SC PSC	LSC	LSC TDM L2SC PSC	
Enc	lambda	lambda	lambda	lambda	[RFC4202] section 3.7, 3.10
	SONET/SDH		SONET/SDH or lambda		Specified in G.691
	Ethernet		Ethernet or lambda		Specified in IEEE
	OTN		OTN or lambda		Specified in G.709
BW	X	<=bw	=bw or *<=bw	<=bw	

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

Table 2.3: The Case of One End-Point (Ingress/Egress) Link Attribute with Lambda Encoding

LSP attribute		Ingress	Transit	Egress	Remarks
SC	LSC	LSC	LSC	LSC	
		TDM		TDM	
		L2SC		L2SC	
		PSC		PSC	
Enc	SONET/SDH	lambda	SONET/SDH or lambda	SONET/SDH	[RFC4202] section 3.6, 3.9 Specified in G.691
	Ethernet		Ethernet or lambda	Ethernet	Specified in IEEE
	OTN		OTN or lambda	OTN	Specified in G.709
BW	X	<=bw	=bw or *<=bw	=bw	

The case of ingress link with the specific encoding and egress link with lambda encoding also follows the same manner.

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

(3) Fiber Switch Capable (FSC)

Table 3.1: The Case of End-Point(Ingress/Egress) Link Attributes without Lambda or Fiber Encoding

LSP attribute		Ingress	Transit	Egress	Remarks
SC	FSC	FSC LSC TDM L2SC PSC	FSC	FSC LSC TDM L2SC PSC	
Enc	SONET/SDH	SONET/SDH	SONET/SDH or lambda or fiber	SONET/SDH	[RFC4202] section 3.6, 3.9 Specified in G.691
	Ethernet	Ethernet	Ethernet or lambda or fiber	Ethernet	Specified in IEEE
	OTN	OTN	OTN or lambda or fiber	OTN	Specified in G.709
BW	X	=bw	=bw or *<=bw	=bw	

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda or fiber encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

Table 3.2: The Case of End-Point(Ingress/Egress) Link Attributes with Lambda or Fiber Encoding

LSP attribute		Ingress	Transit	Egress	Remarks
SC	FSC	FSC LSC TDM L2SC PSC	FSC	FSC LSC TDM L2SC PSC	
Enc	fiber	fiber	fiber	fiber	[RFC4202] section 3.8
	lambda	lambda or fiber	lambda or fiber	lambda or fiber	section 3.7, 3.10
	SONET/SDH		SONET/SDH or lambda or fiber		section 3.6, 3.9 Specified in G.691
	Ethernet		Ethernet or lambda or fiber		Specified in IEEE
	OTN		OTN or lambda or fiber		Specified in G.709
BW	X	<=bw	=bw or *<=bw	<=bw	

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda or fiber encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

Table 3.3: The Case of One End-Point (Ingress/Egress) Link Attribute with Lambda or Fiber Encoding

LSP attribute		Ingress	Transit	Egress	Remarks
SC	FSC	FSC LSC TDM L2SC PSC	FSC	FSC LSC TDM L2SC PSC	
Enc	SONET/SDH	lambda or fiber	SONET/SDH or lambda or fiber	SONET/SDH	[RFC4202] section 3.6, 3.9 Specified in G.691
	Ethernet		Ethernet or lambda or fiber	Ethernet	Specified in IEEE
	OTN		OTN or lambda or fiber	OTN	Specified in G.709
BW	X	<=bw	=bw or *<=bw	=bw	

The case of ingress link with the specific encoding and egress link with lambda encoding also follows as the same manner.

If an interface supports only a specific bit-rate and format such as SONET/SDH or Ethernet encoding, BW X must be equal to bw so as to match bit-rate and its framing.

*In the case of an interface with a lambda encoding and a transparent to bit-rate and framing, BW X must be equal to or less than bw.

Although the interface with FSC can switch the entire contents to another interface, this interface should only be used for optical wavelength or waveband switching.

(4) Layer 2 Switch Capable (L2SC)

The guideline for the calculation must be created after the definition and discussion about L2SW are settled down.

(5) Packet Switch Capable (PSC)

Table 4: Desired GMPLS Attributes in the case of PSC

LSP attribute		Ingress	Transit	Egress	Remarks
SC	PSC	PSC	PSC	PSC	
Enc	Packet	Packet	Packet	Packet	
BW	X	<=bw	<=bw	<=bw	

Since the interface with PSC supports only packet-by-packet switching, BW X must be equal to or less than bw, and must be larger than the minimum LSP bandwidth.

These GMPLS constraints must be considered for computing paths and creating GMPLS LSPs.

This document does not discuss domain based multilayer path computation considerations where specific routing policies, which are sometimes independent from the underlying domains and sometimes take the underlying domains' policies into consideration, are required.

5. Security consideration

Anything that can be done to change the output of a path computation algorithm can significantly affect the operational stability of a network, could force traffic to traverse undesirable or costly links, and could place data into less secure parts of the network. Therefore, the integrity of the path computation mechanism is very significant in a GMPLS network.

The path computation algorithm, itself, and the mechanisms for conveying computed paths to and between the LSRs in the network are out of scope for this document. But misuse or confusion with respect of the handling of the attributes described in this document could leave a network open to various security attacks. In particular, if there is a known mismatch between the interpretation or handling of TE attributes within a network this might be exploited by an attacker to cause disruption or to waste network resources in an integrated multi-technology network. Therefore, network operators are Recommended to use a consistent approach across the whole network.

6. Acknowledgements

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8. IANA Considerations

This document does not require any IANA consideration.

9. References

9.1 Normative References

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