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GMPLS Inter-domain Traffic Engineering Requirements

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Abstract

This draft provides requirements for the support of generalized multi-protocol label switching (GMPLS) inter-domain traffic engineering (TE). Its main objective is to present the differences between MPLS inter-domain TE and GMPLS inter-domain TE. This draft covers not only GMPLS Inter-domain architecture but also functional requirements in terms of GMPLS signaling and routing in order to specify these in a GMPLS Inter-domain environment.

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1. Introduction

Initial efforts of MPLS/GMPLS traffic engineering mechanism were focused on solving the problem within an Autonomous System (AS). Service Providers (SPs) have come up with requirements for extending TE mechanisms across the domains (ASes as well as areas) [Inter-domain]. It discusses requirements for inter-domain Traffic Engineering mechanism with focus on packet MPLS networks and GMPLS packet switch capable (hereinafter MPLS). This document complements [Inter-domain] by providing some consideration for non-packet switch capable GMPLS networks (hereinafter GMPLS) scalability and operational efficiency in such a networking environment.

TE information exchanged over domains for signaling and routing GMPLS Label Switched Paths (LSPs) is more stringent than that of MPLS LSPs [MPLS-AS] from the point of an effective operation. This is because in order to dynamically or statically establish GMPLS LSPs, the additional TE information, e.g., interface switching capability, link encoding, protection, and so forth must be considered. Operators may use different switching capable nodes and TE links with different encoding type and bandwidth, decided by their business strategy and such TE information exchange is expected to improve operational efficiency in GMPLS-controlled networks.

In terms of signaling, GMPLS signaling must operate over multiple domains using routing information, exchanged TE information or a statistically configured domain-to-domain route. This signaling request should take into account bi-directionality, switching capability, encoding type, SRLG, and protection attributes of the TE links spanned by the path, as well as LSP encoding type and switching type for the end points. Furthermore, GMPLS LSP nesting may be applicable at the GMPLS domain borders and should be considered accordingly.

This document provides the requirements for the support of GMPLS inter-domain TE, investigates the necessity of dynamic or static TE information exchange between GMPLS-controlled domains and describes the TE link parameters for this routing operation. This document also outlines GMPLS inter-domain architecture, and provides functional requirements in terms of GMPLS signaling, routing and management in order to specify these in a GMPLS inter-domain environment.

2. 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](#)].

3. Assumed network model

3.1 GMPLS inter-domain network model

Figure 1 depicts a typical network, consisting of several GMPLS domains, assumed in this document. D1, D2, D3 and D4 have multiple GMPLS inter-domain connections, and D5 has only one GMPLS inter-domain connection. These domains follow the definition in [inter-domain].

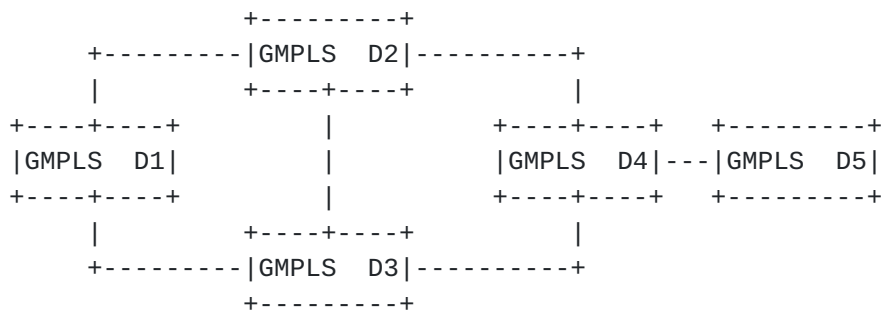


Figure 1: GMPLS Inter-domain network model

Each domain is configured using various switching and link technologies defined in [Arch] and an end-to-end route needs to respect TE link attributes like multiplexing type, encoding type, etc., making the problem a bit different from the case of classical (packet) MPLS. In order to route from one GMPLS domain to another GMPLS domain appropriately, each domain needs to advertise additional TE information, while concealing its internal topology information. In addition, a signaling mechanism is required to specify a route consisting of multiple domains, while respecting the end-point's encoding, switching and payload type. [Section 4](#) describes the TE link attributes that need to be exchanged across the domain boundary in detail.

3.2 Comparison between a GMPLS inter-domain and a MPLS inter-domain

(1) GMPLS network model

To investigate the difference between a GMPLS inter-domain and an MPLS inter-domain network, we assume the network model shown in Fig. 2. Without loss of generality, this network model consists of two GMPLS domains. The GMPLS domain border nodes (A3, A4, B1, B2) are connected via traffic engineering (TE) links (A3-B1 and A4-B2). These inter-domain TE links are assumed to have a certain amount of bandwidth (bw), e.g., 2.5Gbit/s, 10Gbit/s, etc. Moreover, each nodes in both domain 1 and domain 2 can support x and y switching capabilities (e.g., x or y means TDM, Lambda or fiber). The edge node of the network (possibly A1, A2, B3, and B4) may also have the

switching capability of packet (PSC1-4). Moreover, each TE link has a z or w encoding type (z or w means SONET/SDH, Lambda, Ethernet, etc.).

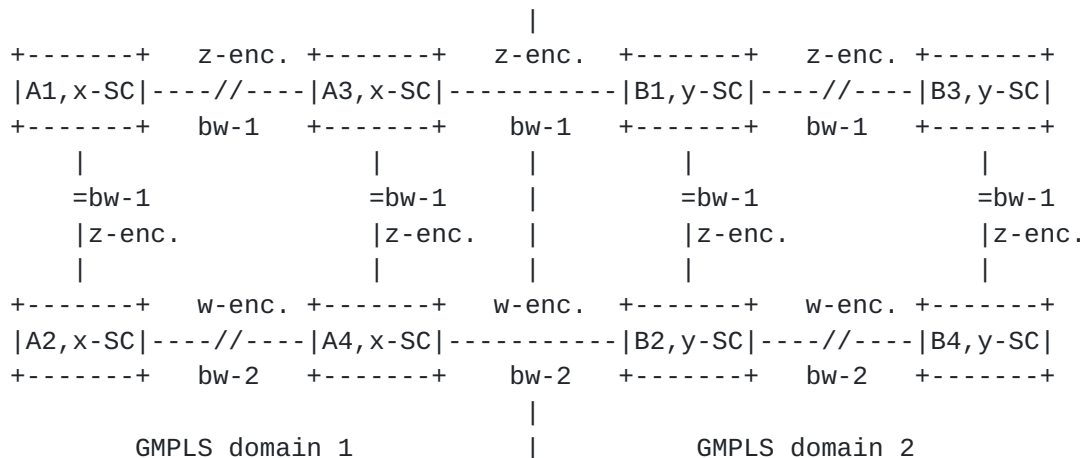


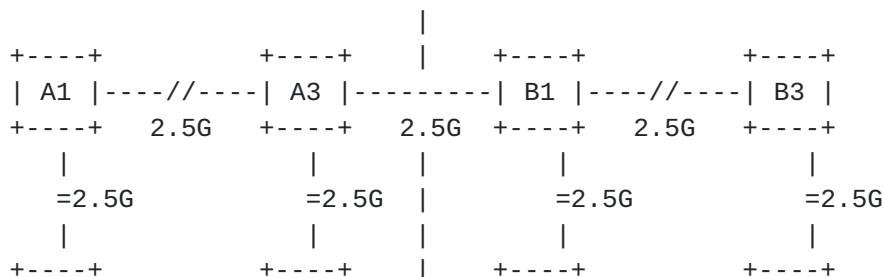
Figure 2: GMPLS Inter-domain network model (1)

Between GMPLS domain border nodes, the routing information is statically or dynamically exchanged. Link management protocol (LMP) [LMP] may be applied to maintain and manage TE links between GMPLS domain border nodes.

In general, the switching capability at each end of two TE-Links (A3-B1 and A4-B2) between domain border nodes shall not be always same. Therefore, GMPLS nodes shall need to identify the attributes of these TE-Links in order to create LSP over multiple domains. At present, GMPLS/ MPLS technology does not provide the functionality to discriminate such attributes through a flooding mechanism. Furthermore, these GMPLS specific requirements for inter-domain traffic engineering are not described in [Inter-domain].

(2) MPLS network model

In the packet MPLS network, we can assume the MPLS inter-domain network model as shown in Figure 3. There are no routing constraints such as switching capability and encoding type, compared to the GMPLS inter-domain network model. All nodes have the same switching capability of packet, therefore there is no need to distribute switching capability information between the domains.



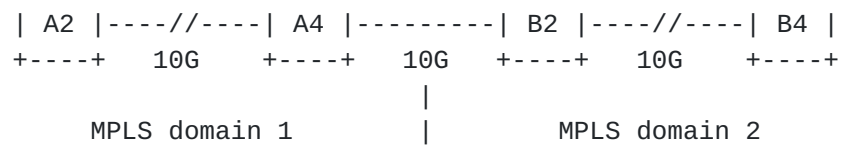


Figure 3: MPLS Inter-domain network model

In the following section, we consider an MPLS or GMPLS path setup from an edge node in domain 1 to an edge node in domain 2.

4. Requirement of exchanging TE information across domain boundaries

In this section, we describe the TE attributes that needs to be exchanged across the domain boundaries for computation of GMPLS Paths.

4.1 Interface Switching Capability

A constraint of bandwidth in a GMPLS controlled network is different from that in an IP/MPLS network. In Figure 3, two TE links with different values of bandwidth such as 2.5Gbit/s and 10Gbit/s are assumed. If an MPLS LSP with 2.5Gbit/s bandwidth is established from A2 to B4 in Figure 3, two sets of TE links (that is two possible paths) can be selected (A2-A4-B2-B4 and A2-A1-A3-B1-B3-B4).

In the case of inter-domain GMPLS, the ingress node needs to know the switching capabilities supported in each domain, while computing a route for a GMPLS-LSP across multiple domains. If the switching capabilities are exchanged across the domain boundaries, the ingress node can determine the appropriate next-hop domain that is capable of supporting the requesting switching capability.

In the example of Figure 4, we assume a switching capability as lambda and an encoding type as lambda. The bandwidth of each TE link is, for example, corresponding to the transponder's bit rate of each DWDM channel. In this case, both inter-domain links may be acceptable from A2 to B4 if only TE information within each domain is considered. However, a GMPLS LSP with 2.5Gbit/s bandwidth can not be established over a set of TE links (A2-A4-B2-B4) because all nodes support only LSC which can not deal with sub-rate switching, and the 10Gbit/s TE link can only support a GMPLS LSP with 10Gbit/s. The set of TE links (A2-A1-A3-B1-B3-B4) must be used instead so as to route it over the inter-domain link of A3-B1.

If multiple GMPLS routes exist for a given destination via different domains, a path should be selected satisfying these routing constraints, in addition to the conventional attributes which the intra-domain routing protocols. LMP protocol may assist to know attributes of the neighbor node, but it does not assure such attributes learned from LMP are consistent within the domain. Although an operator may want to specify a domain border node explicitly for such a destination, this TE information exchange will improve operational efficiency in GMPLS-controlled networks. Therefore, not only intra-domain routing protocols [GMPLS-Routing] but also inter-domain routing protocol needs to advertise some TE

parameters.

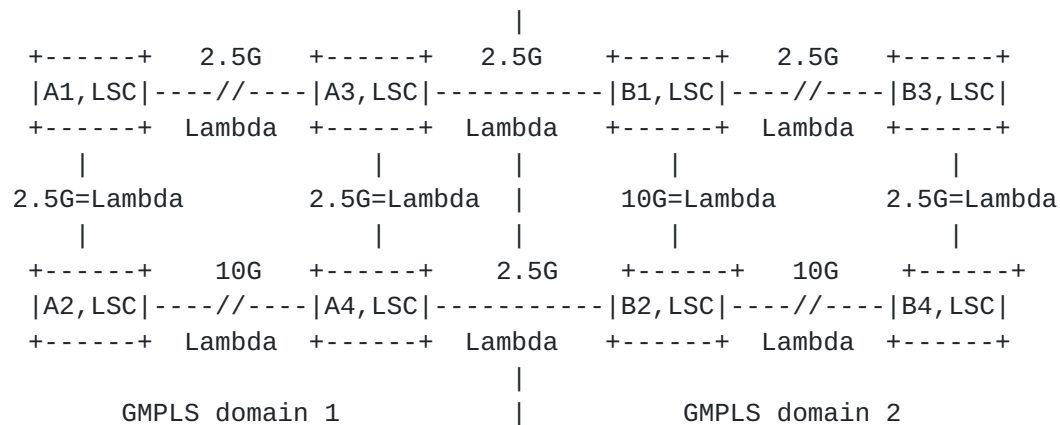


Figure 4: GMPLS inter-domain network model (2)

4.2 Bandwidth Policy

The advertisement of the bandwidth for traversing non-local domains is strongly dependent on the operational policy in each GMPLS domain. The resource available for different domains may be advertised over GMPLS inter-domain boundaries, although the actual local bandwidth is more than that for different domains. The GMPLS domain border nodes have the functionality to control the advertised resource bandwidth to reach a destination. For example, even if 4 times OC-48 bandwidth exists to a destination in one GMPLS domain, the domain may advertise only twice OC-48 bandwidth to another GMPLS domain, following the mutual policy between these two domains. Thus, inter-domain reachability information may need to be enhanced to include bandwidth information, however, such flooding information may degrade the network scalability, and policy features at the border node may be useful not so as to maintain the same scalability of a single domain.

4.3 Encoding type

In addition of the link switching type, an end-to-end GMPLS LSP needs to have the same encoding type at all intermediate hops. In this section, we discuss the need for exchanging link encoding types across the domain boundaries.

The example depicted in Figure 5 is considered where TE links with a different encoding type in a GMPLS Inter-domain network are assumed. In this case, differing from the case of a packet MPLS inter-domain network, a GMPLS LSP with a specific encoding type must be established to satisfy this constraint. Since physical layer technologies used to form TE links limit the signal encoding type to be transported, the ingress node should consider this by obtaining TE parameters exchanged between GMPLS-controlled inter-domains. In this

case, both inter-domain links may be acceptable for routing from A2 to B4 if only TE information within each domain is considered. The set of TE links (A2-A1-A3-B1-B3-B4) must be used instead so as to route over the inter domain-link of A3-B1, satisfying the constraint

of the encoding type. Therefore, inter-domain reachability information needs to be enhanced to include encoding type information.

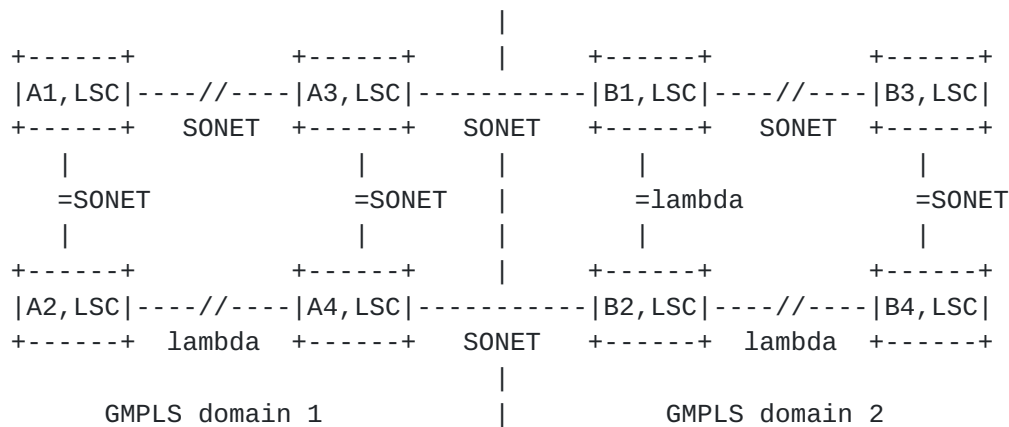


Figure 5: GMPLS inter-domain network model (3)

4.4 Hybrid case

In Figure 6, we consider a mixed case of 4.1, 4.2 and 4.3, and assume two domains: Domain 1 consisting of GMPLS nodes with TDM-SC and TE links with SONET/SDH encoding type, and domain 2 consisting of GMPLS nodes with LSC and TE links with lambda encoding type. GMPLS nodes in domain 2 support sub-rate switching, for example, of 2.5Gbit/s.

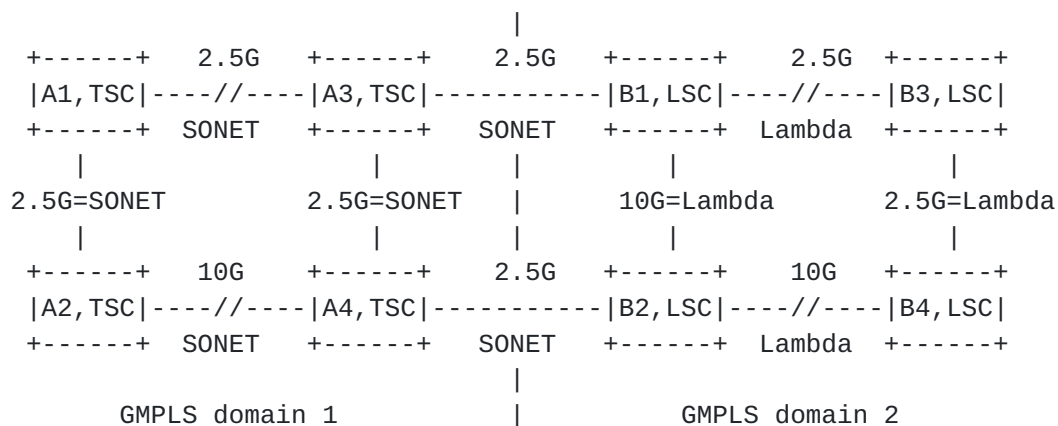


Figure 6: GMPLS Inter-domain network model (4)

If a GMPLS LSP with 2.5Gbit/s is established from A2 to B4, the ingress node should know not only the reachability of B4 in domain 2, but also the switching capability of nodes in domain 2. In this case, both inter-domain links may be acceptable for routing from A2 to B4

if only TE information within each domain is considered. However, since the switching capability supported in each domain is different, the set of TE links (A2-A1-A3-B1-B3-B4) must be used so as to route over the inter domain-link of A3-B1. Therefore, an end-point

(reachability) list such as node IDs, interface addresses, interface IDs per switching capability is very useful and may be advertised over GMPLS domains.

4.5 SRLG

To configure a secondary LSP in addition to a primary LSP over multiple GMPLS domains, the parameter of Shared Risk Link Group (SRLG) is very significant. By introducing this parameter, the source node can route these LSPs so as to across the different domain border node as well as satisfy a SRLG constraint. Although this SRLG is supported and defined within domains, the mechanism to maintain consistency of SRLG must be considered in a GMPLS inter-domain TE environment.

There are cases where two different SPs may be sharing the same fate (facility) for TE links within domains administrated by them. However, presently there is no mechanism to allow SRLG to have global significance; SRLG administration is completely up to interconnected SPs.

In this document we identify that, in order to guarantee the SRLG diversity requirement, the SRLGs in an inter-domain TE environment are required to be globally unique.

4.6 Protection Type

To guarantee the GMPLS LSP's resiliency over multiple GMPLS domains, the protection type in each domain should be carefully selected so as to satisfy resilient requirement of the LSP as an end-to-end manner. This enables us to establish a LSP with a protection mechanism per domain-basis, such as link or node protection. Each GMPLS domain will provide a type of the protection to a destination within itself. Otherwise, an end-to-end recovery may be provided by calculating at the source node with the consideration of SRLG. As the same with the SRLG case, protection type administration is also up to the interconnected SPs. Therefore, inter-domain reachability information needs to be enhanced to include protection type information.

5. Requirement for GMPLS inter-domain TE signaling, routing and management

5.1 Requirement for GMPLS inter-domain signaling for the support of TE

GMPLS inter-domain signaling should establish GMPLS LSPs over GMPLS multiple domains relying on a dynamic calculation of the domain-to-domain route and GMPLS domain border nodes by path computation functions spread through the domains. It also should support to

explicitly specify domain-to-domain routes, domain border nodes or GMPLS nodes. Moreover, specifying loose GMPLS nodes including GMPLS domain border nodes must be supported in GMPLS signaling. The domain border node received GMPLS signaling message from a source node in a

different domain should support recalculation mechanisms to specify the route within its domain, such as RSVP route expansion technique, followed by GMPLS inter-domain path computation.

5.1.1 GMPLS per-domain basis path calculation support

Firstly, GMPLS per-domain basis path calculation is described. In this path calculation model, a GMPLS LSP head-end specifies GMPLS domain border nodes as loose hops to tail-end statically or dynamically [Path-comp]. The route information may be learned from the GMPLS EGP. The source node also calculates the intermediate nodes to reach the selected egress domain border node.

Once the GMPLS path message has traversed to the connecting domain border node in the adjacent domain, another path calculation is conducted, for example, to expand the ERO carried in the RSVP-TE Path message to reach its destination, otherwise to reach an egress border node transiting to another domain. This path calculation will not necessarily guarantee the domain-to-domain path optimality.

5.1.2 GMPLS end-to-end basis path calculation support

GMPLS end-to-end basis path calculation is indicated next. In this path calculation, the GMPLS LSP head-end specifies a domain-to-domain route (for example, domain1-domain2-domain4-domain5 in Figure 1) as well as the intermediate nodes to the egress domain border node in its belonging domain. The domain border node in an adjacent domain will determine intermediate nodes followed by the specified domain path route. This path calculation will guarantee the domain path optimality, however, not necessarily guarantee end-to-end path optimality.

5.1.3 Fast Recovery support

Fast recovery operation based on the end-to-end [e2e] and segment [SEG-RECOVERY] based approach should be supported over multiple GMPLS domains, considering inter-domain link, SRLG and node diversity. These types of operation should interoperate with GMPLS intra-domain TE fast recovery mechanism. The domain border node may respond indicating a path setup error if it does not support the protection/restoration mechanism which is requested by the signaling messages generated from the source node in the different domain.

Depending on the recovery mode, re-optimization or revertive operations should be supported.

5.1.4 Policy Control

Depending on the policy between domains, the domain border GMPLS nodes may reject GMPLS inter-domain signaling messages if the

unapproved objects are included.

5.2 Requirement for GMPLS Inter-domain routing for the support of TE

In IP/MPLS networks, inter-AS routing such as the EGP is well-defined and widely deployed. However, the need for such inter-domain routing extension for MPLS TE does not exist at present. Nonetheless, inter-domain routing extensions are required to support multiple GMPLS domains as well as for layer 1 VPN [L1VPN]. GMPLS extension for multi-domain TE is required for guaranteeing inter-domain GMPLS constraints, when attempts are made to establish GMPLS LSPs over multiple domains as discussed in [section 4](#).

5.2.1 Reachability information exchange

GMPLS inter-domain routing mechanism should support the exchange of reachability information over each domain. Reachability information includes:

- (1) Node ID
- (2) Interface address
- (3) Interface ID

The reachability information should be advertised in accordance with their belonging domain information in order to calculate the GMPLS LSP over multiple domains. The reachability information may be aggregated depending on the domain's policy.

The scalability of inter-domain routing should be considered in designing GMPLS extensions to allow exchange of TE information in addition to the above reachability information. Furthermore, the GMPLS inter-domain routing should be designed to achieve such operation that defects in one domain do not affect the scalability of an intra-domain routing of IGPs in other domains, although the GMPLS inter-domain routing should promptly advertise the failure within the domain, ensuring the GMPLS inter-domain connection establishment.

GMPLS inter-domain routing should basically follow the GMPLS architecture [Arch], including the support of its exchange over out of band control channel.

5.2.2 TE parameters exchange

Coinciding with MPLS Inter-domain work, the TE parameters for GMPLS Inter-domain routing are considered to be added.

A GMPLS domain border node may be required to announce the following parameters in association with reachability information of node IDs, interface addresses and interface IDs.

- (1) Interface switching capability
 - (1-1) Bandwidth
 - A. Total link bandwidth
 - B. Max./Min. Reservable bandwidth

C. Maximum LSP bandwidth

D. minimum LSP Bandwidth

C. Unreserved bandwidth

(1-2)Switching capability: PSC1-4, L2SC, TDM, lambda, LSC, FSC

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- (2) Bandwidth Encoding type: As defined in [[RFC3471](#)], e.g., Ethernet, SONET/SDH, Lambda.
- (3) SRLG (Global view)
- (4) Protection type

As mentioned in [section 4.4](#), an end-point (reachability) list consisting of node IDs, interface addresses, interface IDs per switching capability is formed in order to be advertised over GMPLS domains.

For stitched, nested and contiguous GMPLS LSPs over multiple domains, a GMPLS LSP created within a domain will be announced as a (transit) link resource (FA-LSP) exposed to different domains with appropriate TE parameters, while abstracting intermediate nodes or indicating the profile of the TE information. LSP associated information indicating available resource may be exchanged as a part of TE routing information to support LSP stitching over multiple domains. Such LSP-associated information may include a LSP ID and its quality of service (QoS) information.

We may virtually provision logical TE links (virtual TE link) instead of such FA-LSPs for these purposes. A Virtual TE link is a new concept and will be utilized only to advertise link resources over multiple domains. Operators can create virtual TE links to use some of resource in their network only to permit other networks to use it. By doing this, the ingress and egress node will become selectable by even the source node in other domains.

The GMPLS inter-domain routing should support these functionalities and locally configure this on the domain border nodes. Moreover, to ensure future interworking operation between GMPLS and MPLS, the GMPLS inter-domain routing should be also applicable to MPLS inter-domain TE information exchange.

5.2.3 Reachability information redistribution requirement

GMPLS inter-domain routing must provide redistribution mechanisms within the domain in a scalable manner. These information redistribution mechanisms must be designed to achieve such operation that a defect in a domain does not affect the scalability of intra-domain routing in a different domain, although the GMPLS inter-domain routing must promptly advertise the failure within the domain, ensuring the GMPLS inter-domain connection establishment.

Mechanisms for redistributing GMPLS TE information within the GMPLS domain can be, for example, a path computation element (PCE), I-BGP session, or re-injection to IGP. Especially, it is useful to adopt GMPLS end-to-end basis path calculation. PCE based requirement may be incorporated with the PCE Architecture document [PCE].

GMPLS inter-domain routing should have the functionality to consider any policies for controlling TE routing information to be flooded, which will be defined between domains on a business or operational strategy basis. GMPLS inter-domain routing policy should be able to

be changed and configured on a per domain basis. This policy control especially in terms of switching capability may be applicable to the extensions of hierarchical routing. Each domain should control the advertisement of the switching capability or re-advertisement of received switching capability.

5.2.4 VPN-associated information exchange

In addition to reachability and TE information exchange, VPN-associated information may be exchanged as a part of routing information to support L1-VPN functionality, or by other means. VPN-associated information may include:

- (1) VPN identifier (such as VPN IP as specified in [RFC2685](#), or route target)
- (2) Scope of reachability information exchanged
- (3) VPN membership information
- (4) CE-CE arbitrary control plane communication
- (5) VPN performance related information

This is exchanged across domains, but may not be injected into other domains.

5.2.5 Inter-link TE information distribution

In the GMPLS inter-domain network, TE links are configured between domain border nodes, however, such TE link information should be either flooded by using IGP with TE extension only within each domain or by the GMPLS inter-domain routing.

5.3 GMPLS inter-domain TE Management

5.3.1 GMPLS inter-domain TE Fault Management

To maintain the control channel session as well as to provide fault isolation mechanism, link management mechanisms such as [LMP] should be applied to TE links between GMPLS domain border nodes. To validate LSPs created over multiple domains, a generic tunnel tracing protocol (GTTP) may be applied [GTTP].

5.3.2 GMPLS inter-domain TE MIB Requirements

GMPLS inter-domain TE Management Information Bases must be supported to manage and configure GMPLS inter-domain TE in terms of GMPLS LSPs, routing, TE links and so forth. These MIBs should extend the existing series of MIBs [GMPLS-TEMIB] to accommodate following functionalities;

- To manage GMPLS LSP characteristics at the tunnel head-end as well as any other points of the TE tunnel.

- To include both IPv4/v6 and domain identifier, or only domain identifier in the subobjects of GMPLS RSVP ERO. A label may be included in it. The example of the object is as follows;

EXPLICIT_ROUTE class object:

```
Address1 (loose IPv4 address prefix,label, /domain1)
Address2 (loose IPv4 address prefix,label, /domain1)
domain2 (domain number)
Address3 (loose IPv4 address prefix,label, /domain3)
Address4 (loose IPv4 address prefix,label, /domain3)-destination
```

Or

```
Address1 (loose IPv4 address prefix,label, /domain1)
Address2 (loose IPv4 address prefix,label, /domain1)
Address3 (loose IPv4 address prefix,label, /domain2)
Address4 (loose IPv4 address prefix,label, /domain2)
Address5 (loose IPv4 address prefix,label, /domain3)
Address6 (loose IPv4 address prefix,label, /domain3)-destination
```

- Inclusion of recording subobjects such as interface IPv4/v6 addresses, domain identifier, a label, a node-id and so on in the RRO of the RESV message, considering the established policies between GMPLS domains.

6. Security consideration

GMPLS inter-domain TE should be implemented under a certain security consideration such as authentication of signaling and routing on the control plane as well as a data plane itself. Indeed, this will not change the underlying security issues.

7. Acknowledgement

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