Framework for IP/MPLS-GMPLS interworking in support of IP/MPLS to GMPLS migration

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Abstract

MPLS to GMPLS migration is the process of evolving MPLS-TE-based control plane to GMPLS-based control plane. An appropriate migration strategy is selected based on various factors including the service provider’s network deployment plan, customer demand, available network equipment implementation, etc.

In the course of migration several interworking cases may exist where MPLS and GMPLS devices or networks must coexist. Such cases may arise as parts of the network are converted from MPLS protocols to GMPLS protocols, or may occur if a lower layer network is made GMPLS-capable (from having no MPLS or GMPLS control plane) in advance of the migration of the higher layer packet switched layer.

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Since GMPLS signaling and routing protocols are different from the MPLS protocols, in order for MPLS and GMPLS to interwork, we need mechanisms to compensate for the difference between MPLS and GMPLS.

This document provides a framework for MPLS and GMPLS interworking to allow transition from MPLS to GMPLS. We discuss issues, models, migration scenarios, and requirements. Solutions for MPLS and GMPLS interworking will be developed in companion documents.

We should note that both MPLS and GMPLS protocols can co-exist as "ships in the night" without any interworking issue. This document is mainly addressing interworking to allow transition from MPLS to GMPLS.

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1. Introduction

MPLS to GMPLS migration is the process of evolving MPLS-TE-based control plane to GMPLS-based control plane.

There are several motivations for such migration and they focus mainly on the desire to take advantage of new features and functions that have been added to the GMPLS protocols but which are not present in MPLS.

An appropriate migration strategy is selected based on various factors including the service provider’s network deployment plan, customer demand, available network equipment implementation, etc.

In the course of migration several interworking cases may arise where MPLS and GMPLS devices or networks must coexist. Such cases may occur as parts of the network are converted from MPLS protocols to GMPLS protocols, or may arise if a lower layer network is made GMPLS-capable (from having no MPLS or GMPLS control plane) in advance of the migration of the higher layer network.

This document examines the interworking scenarios that arise during migration, and examines the implications for network deployments and for protocol usage. Since GMPLS signaling and routing protocols are different from the MPLS protocols, interworking between MPLS and GMPLS networks or network elements needs mechanisms to compensate for the differences. This document provides a framework for MPLS and GMPLS interworking in support of migration from IP/MPLS to GMPLS by discussing issues, models, migration scenarios, and requirements. Solutions for interworking MPLS and GMPLS will be developed in companion documents.

We should note that both MPLS and GMPLS protocols can co-exist as "ships in the night" without any interworking issue. This document is mainly addressing interworking to allow transition from MPLS to GMPLS. We should also note that MPLS control plane means MPLS-TE control plane (RSVP-TE, IGP-TE) and not LDP-based control plane. This document does not address the migration from LDP controlled MPLS networks to GMPLS RSVP-TE.
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].

In the rest of this document, the term GMPLS includes both PSC and non-PSC. Otherwise the term "PSC GMPLS" or "non-PSC GMPLS" is explicitly used.

3. Motivations for Migration

Motivations for migration will vary for different service providers. This section is only present to provide background so that the migration discussions may be seen in context. Sections 5 and 6 illustrate the migration models and processes by means of some example scenarios.

Migration of an MPLS capable LSR to include GMPLS capabilities may be performed for one or more reasons.

- To add all GMPLS functions to an MPLS PSC network.
- To pick up specific GMPLS features and operate them within an MPLS PSC network.
- To allow interoperation of equipment with new LSRs that only support GMPLS.
- To integrate networks that have been under separate administration and where one network utilizes MPLS and another uses GMPLS.
- To build integrated PSC and non-PSC networks where the non-PSC networks can only be controlled by GMPLS since MPLS does not operate in non-PSC networks.

4. MPLS to GMPLS migration

4.1. Migration models

MPLS to GMPLS migration is a process of evolving MPLS-TE-based control plane to GMPLS-based control plane to GMPLS. Three migration models are considered as described below. Practically speaking, both migration models may be deployed at the same time.

4.1.1. Island model

In the island model, "islands" of network nodes operating one protocol exist within a "sea" of nodes using the other protocol.
The most obvious example is to consider an island of nodes with GMPLS capability that is introduced into the legacy network. Such an island might be composed of newly added network nodes, or might arise from the upgrade of existing nodes that previously operated MPLS protocols.

Clearly there is no requirement that an island be GMPLS-capable within an MPLS sea; the opposite is quite possible. That is, there is a possibility that an island happens to be MPLS-capable within an GMPLS sea in some cases. Such situation might arise in the later stages of migration when all but a few islands of MPLS-capable nodes have been upgraded to GMPLS.

It is also possible that a lower-layer manually-provisioned network (for example, a TDM network) supports an MPLS PSC network. During the process of migrating both networks to GMPLS the situation might arise where the lower-layer network has been migrated and operates GMPLS, but the packet network still operates MPLS. This would appear as a GMPLS island within an MPLS sea.

Lastly it is possible to consider individual nodes as islands. That is, it would be possible to upgrade or insert an individual GMPLS-capable node within an MPLS network, and to treat that GMPLS node as an island.

Over time, collections of MPLS devices are replaced or upgraded to create new GMPLS islands or to extend existing ones, and distinct GMPLS islands may be joined together until the whole network is GMPLS-capable.

From a migration interworking point of view, we need to examine how these islands are positioned and how LSPs run between the islands. Four categories of interworking scenarios are considered: (1) MPLS-GMPLS-MPLS, (2) GMPLS-MPLS-GMPLS, (3) MPLS-GMPLS and (4) GMPLS-MPLS. In each case, the interworking behavior is examined based on whether the GMPLS islands are PSC or non-PSC. These scenarios are considered further in section 5.

Figure 1 shows an example of the island model for the MPLS-GMPLS-MPLS interworking. The model consists of a transit GMPLS island in an MPLS sea. The nodes at the boundary of the GMPLS island (G1, G2, G5, and G6) are referred to as "island border nodes". If the GMPLS island was non-PSC, all nodes except the island border nodes in the GMPLS-based transit island (G3 and G4) would be non-PSC devices, i.e., optical equipment (TDM, LSC, and FSC).
4.1.2. Integrated model

The second model involves a more integrated migration strategy. New devices that are capable of operating both MPLS and GMPLS protocols are introduced into the MPLS network. Further, existing MPLS devices are upgraded to support both MPLS and GMPLS. The network continues to operate providing MPLS services, but where the service can be provided using only GMPLS functionality it may be routed accordingly over only such GMPLS-capable devices and achieve a higher level of functionality by utilizing GMPLS features. Once all devices in the network are GMPLS-capable, the MPLS protocols may be turned off, and no new devices need to support MPLS.

In this second model the questions to be addressed concern the co-existence of the two protocol sets within the network. Actual interworking is not a concern.

The integrated migration model results in a single network in which both MPLS-capable and GMPLS-capable LSRs co-exist. Some LSRs will be capable of only one protocol, and some of both. The migration strategy here involves introducing GMPLS-capable LSRs into an existing MPLS-capable network until such time as all LSRs are GMPLS-capable at which time all MPLS functionality is disabled. Since we are starting with an MPLS network all devices are PSC and there are no interworking issues in the data plane. In the control plane the migration issues concern the separation of MPLS and GMPLS protocols, and the choice of routes that may be signaled with only one protocol.

4.1.3. Phased model

The phased model introduces GMPLS features and protocol elements into an MPLS network one by one. For example, some object or sub-object...
(such as the ERO label sub-object, [RFC3473]) might be introduced into the signaling used by LSRs that are otherwise MPLS-capable. This would produce a kind of hybrid LSR.

This approach may appear simpler to implement as one is able to quickly and easily pick up key new functions without needing to upgrade their whole protocol implementation.

The interoperability concerns (LABEL REQUEST and LABEL object, for instance, when speaking about RSVP-TE signaling) are exacerbated by this migration model unless all LSRs in the network are updated simultaneously. Interworking between a hybrid LSR and an unchanged MPLS LSR would put the hybrid in the role of a GMPLS LSR as described in the previous sections, while interworking between a hybrid LSR and a GMPLS LSR puts the hybrid in the role of an MPLS LSR. The potential for different hybrids within the network only serves to complicate matters considerably. Thus the piecemeal migration from MPLS to GMPLS is NOT RECOMMENDED.

4.2. Migration strategies

An appropriate migration strategy is selected based on various factors including the service provider’s network deployment plan, customer demand, available network equipment, etc.

For PSC networks, the migration strategy involves the selection between the models described in the previous section. The choice will depend upon the final objective (full GMPLS capability or partial upgrade to include specific GMPLS features), and upon the immediate objectives (phased upgrade or staged upgrades).

For PSC networks supported by non-PSC networks, two basic migration strategies can be considered. In the first strategy, the non-PSC network is made GMPLS-capable first and then the PSC network is migrated to GMPLS. This might arise where, in order to expand the network capacity, GMPLS-based non-PSC sub-networks are introduced into or underneath the legacy MPLS-based networks. Subsequently, the legacy MPLS-based PSC network is migrated to be GMPLS-capable as described in the previous paragraph. Finally the entire network including both PSC and non-PSC nodes is controlled by GMPLS.

The second strategy for PSC and non-PSC networks is to migrate the PSC network to GMPLS first and then enable GMPLS within the non-PSC network. The PSC network is migrated as described before, and when the entire PSC network is completely converted to GMPLS, GMPLS-based non-PSC devices and networks may be introduced without any issues of interworking between MPLS and GMPLS.
These migration strategies and the migration models described in the previous section are not necessarily mutually exclusive. Mixtures of all strategies and models could be applied. The migration models and strategies selected will give rise to one or more of the interworking cases described in the following section.

5. Island model interworking cases

5.1. MPLS-GMPLS(PSC)-MPLS Islands

The migration of an MPLS-based packet network to become a GMPLS (PSC)-based network may be performed to provide GMPLS-based advanced features in the network or to facilitate interworking with GMPLS-based optical core network.

The migration may give rise to islands of GMPLS support within a sea of MPLS nodes such that an end-to-end LSP begins and ends on MPLS-capable LSRs. The GMPLS PSC island may be used to "hide" islands of GMPLS non-PSC functionality that are completely contained within the GMPLS PSC islands. This would protect the MPLS LSRs from having to be aware of non-PSC technologies.

5.2. MPLS-GMPLS(non-PSC)-MPLS Islands

The introduction of a GMPLS-based controlled optical core network to increase the capacity of a MPLS packet network is an example that may give rise to this scenario. Until the MPLS network is upgraded to be GMPLS-capable, the MPLS and GMPLS networks must interwork. The interworking challenges may be reduced by wrapping the non-PSC GMPLS island entirely within a GMPLS PSC island as described in the previous section.

5.3. GMPLS(PSC)-MPLS-GMPLS(PSC) Islands

This case might arise as the result of installing new GMPLS-capable islands around a legacy MPLS network, or as the result of controlled migration of some islands to become GMPLS-capable.

5.4. GMPLS(non-PSC)-MPLS-GMPLS(non-PSC) Islands

This case is out of scope for this document. Since the MPLS island is necessarily packet capable (i.e. PSC), this scenario requires that non-PSC LSPs are carried across a PSC network. Such a situation does not arise through simple control plane migration although the
interworking scenario might occur for other reasons and be supported, for example, by pseudowires.

5.5. GMPLS(PSC)-MPLS and MPLS-GMPLS(PSC) Islands

This case is likely to arise where the migration strategy is not based on a core infrastructure, but has edge nodes (ingress or egress) located in islands of different capabilities.

In this case an LSP starts or ends in a GMPLS (PSC) island and correspondingly ends or starts in an MPLS island. Some signaling and routing conversion is required on island border LSRs. Figure 2 shows the reference model for this migration scenario. Head-end and Tail-end LSR are in distinct control plane clouds.

Since both islands are PSC there is no data plane conversion at the island boundaries. However, from a control plane point of view this model may prove challenging because the protocols must share or convert information between the islands rather than tunnel it across an island.

It is also important to underline that this scenario is also impacted by the directionality of the LSP establishment. Indeed, a unidirectional packet LSP from R1 to G5 is more easily accommodated at G1 than a bi-directional PSC LSP from G5 to R1.

6. Interworking issues between MPLS and GMPLS
Issues of MPLS and GMPLS interworking stem from the difference between MPLS and GMPLS protocols and architecture. These issues are categorized into four groups:

1. control and data plane separation,
2. new features introduced by GMPLS,
3. new methods introduced by GMPLS, and
4. interworking between PSC and non-PSC.

Note that a GMPLS PSC island may be treated in the same way as an island of non-PSC LSRs, and much can be gained by applying the techniques described in section 6.4 to the other scenarios described here.

6.1. Control and data plane separation

In MPLS, the control plane traffic (signaling and routing) is carried in-band with data. This means that there is fate sharing between a data link and the control traffic on the link. The control plane keep-alive techniques can be used to detect some data plane failures.

TDM, LSC, FSC networks do not recognize packet delineation, so in-band control channels cannot be terminated, and GMPLS must support dedicated control channels (separated from the data channels). In GMPLS, the control channel can be logically or physically separated (i.e., in-fiber out-of-band or out-of-fiber out-of-bound) from the data channel depending on the capabilities of the network devices and the operational requirements.

The GMPLS control plane, which is designed to carry the control packets, offers the possibility to use dedicated control channels that must not be used to carry data. This is particularly important when the control channels are of low capacity and are not designed to carry user traffic.

Since GMPLS introduces a separation between control and data channels, control traffic may use different channels than the data traffic, and this requires new routing and signaling protocol elements (e.g. identification of data channels within the control plane).

6.2. New features

New features introduced by GMPLS and not available in MPLS include bidirectional LSPs, label suggestion, label restriction, graceful restart, and graceful teardown, as well as GMPLS’s support of networks with multiple switching capabilities (see [RFC3945]).
6.2.1. Signaling

GMPLS RSVP-TE signaling ([RFC3471]) introduces new RSVP-TE objects, and their associated procedures, that are not processed/generated by MPLS LSRs. Clearly an MPLS LSR cannot be expected to originate LSPs that use these objects and will, therefore, not have access to the additional GMPLS functions. However, the new RSVP-TE objects listed below will need to be handled in interworking scenarios where the LSP ingress and/or egress is GMPLS-capable, and MPLS LSRs are required to process the signaling messages:

- The (Generalized) Label Request object (new C-Type), used to identify the LSP encoding type, the switching type and the generalized protocol ID (G-PID) associated with the LSP.
- The (Generalized) Label object (new C-Type)
- The IF_ID RSVP_HOP objects, IF_ID ERROR_SPEC objects, and IF_ID ERO/RRO subobjects that handle the Control plane/Data plane separation in GMPLS network.
- The Suggested Label Object, used to reduce LSP setup delays.
- The Label Set Object, used to restrict label allocation to a set of labels, (particularly useful for wavelength conversion incapable nodes)
- The Upstream Label Object, used for bi-directional LSP setup
- The Restart Cap object, used for graceful restart.
- The Admin Status object, used for LSP administration, and particularly for graceful LSP teardown.
- The Recovery Label object used for Graceful Restart
- The Notify Request object used to solicit notification of errors and events.

Future GMPLS extensions are likely to add further new objects.

Some of these objects can be passed transparently by MPLS LSRs to carry them across MPLS islands because their C-Nums are of the form 1bbbbbbb, but others will cause an MPLS LSR to reject the message that carries them because their C-Nums are of the form 0bbbbbbb.

Even when objects are inherited from MPLS by GMPLS they can be expected to cause problems. For example, the Label object in GMPLS uses a new C-Type to indicate “Generalized Label” This C-Type is unknown to MPLS LSRs which will reject any message carrying it.

GMPLS also introduces new message flags and fields (including new sub-objects and TLVs) that will have no meaning to MPLS LSRs. This data will normally be forwarded untouched by transit MPLS LSRs, but they cannot be expected to act on it.

Also GMPLS introduces two new messages, the Notify message, and the RecoveryPath message that are not supported by MPLS nodes.
6.2.1.1 Bi-directional LSP

GMPLS provides bidirectional LSP setup - a single signaling session manages the bidirectional LSP, and forward and reverse data paths follow the same route in the GMPLS network. There is no equivalent in MPLS networks, forward and backward LSPs must be created in different signaling sessions - the route taken by those LSPs may be different from each other, and their sessions are treated differently from each other. Common routes and fate sharing require additional, higher-level coordination in MPLS.

If MPLS and GMPLS networks are inter-connected, bidirectional LSPs from the GMPLS network need to be carried in the MPLS network.

Note that this issue arises only in the cases where an LSP is originated by GMPLS-capable LSRs. In other words, it applies only to the GMPLS-MPLS-GMPLS island model and to the island migration model.

In the MPLS-GMPLS-MPLS and MPLS-GMPLS models, the ingress LSR is unaware of the concept of a bidirectional LSP and cannot attempt the service even if it could find some way to request it through the network. In the case of GMPLS-MPLS, a similar issue exists because the egress MPLS-capable LSR is unaware of the concept of bidirectional LSPs and cannot initiate a return LSP.

Note that the island border LSRs will bear the responsibility for achieving the bidirectional service across the central MPLS island.

6.2.2. Routing

TE-link information is advertised by the IGP using TE extensions. This allows LSRs to collect topology information for the whole TE network and to store it in the traffic-engineering database (TED). Traffic-engineered explicit routes are calculated using the network graphs derived from the TED.

GMPLS extends the TE information advertised by the IGPs to include non-PSC information and extended PSC information. Because the GMPLS information is provided as extensions to the MPLS information, MPLS LSRs are able to "see" GMPLS LSRs as though they were PSC LSRs. They will also see other GMPLS information, but will ignore it, passing it transparently across the MPLS network for use by other GMPLS LSRs.

This means that MPLS LSRs may use the combination of MPLS information advertised by MPLS LSRs and a restricted subset of the information advertised by GMPLS LSRs to compute a traffic-engineered explicit route across a mixed network. However, it is likely that a path
A computation component in an MPLS network will only be aware of MPLS TE information and will not understand concepts such as switching capability type. This may mean that an incorrect path will be computed for an e2e LSP from one MPLS island to another across a GMPLS island if different switching capabilities exist.

6.2.3. New mechanisms

GMPLS also provides several features in a distinct manner from MPLS. For instance local protection is provided using different mechanisms in MPLS (see [RFC4090]) and GMPLS (see [SEGMENT-RECOVERY]). Local protection of island border nodes may be a particular problem.

6.3. Interworking between PSC and non-PSC

Three issues of interworking between MPLS-based packet networks and GMPLS-based optical transport network result from the fact that control and data planes are separated in GMPLS-based optical transport networks. These three issues are:

(a) Lack of routing and signaling adjacencies,
(b) Control plane resource exhaustion, and
(c) TE path computation over the border between MPLS and GMPLS domains.

There are several architectural alternatives for interworking between packet network and optical transport network: overlay, peer and augmented models [RFC3945]. Impacts of each issue on each model are different.

These issues are explained using an example network shown in Figure 3.

Figure 3: Interworking of MPLS-TE networks and GMPLS-based optical transport networks.

6.3.1. Lack of routing and signaling adjacencies
The ingress MPLS and the egress MPLS domains are interconnected via a GMPLS-based optical network as shown in Fig 3. LSAs in the egress MPLS domain are not advertised in the ingress MPLS domain unless routing adjacencies are established between the IP/MPLS domain and GMPLS domain or unless routing adjacencies are established directly between IP/MPLS domains (overlay model). Therefore the ingress LSR in the ingress MPLS domain is not able to find the egress LSR in the egress MPLS domain. The signaling messages are not passed across the GMPLS domain between the ingress and the egress MPLS domains unless the signaling adjacencies are established between the MPLS domain and the GMPLS domain or directly between MPLS domains (overlay model).

This issue appears in the augmented and the overlay model when there are no links provided between MPLS domains across the GMPLS domain.

6.3.2. Control plane resource exhaustion

It is a danger that only arises at a PSC LSR that uses an out of band control channel at the border between MPLS and GMPLS domains. This issue is already mentioned at the head of section 6.1.

This issue can appear in the peer, the augmented, and the overlay models depending on how the border node handles the data forwarding and manages the address space.

6.3.3. TE path computation over the border between MPLS and GMPLS domains

If the ingress LSR in the ingress MPLS domain does not understand the GMPLS TE protocols and information elements, it assumes that there is no available TE-path across the GMPLS domain unless MPLS-compatible TE LSAs representing the available TE-paths in the GMPLS domain are advertised into the ingress and egress MPLS domains.

This issue appears in the peer and the augmented models.

A different issue, which has very similar results, appears in the overlay model. In the overlay model, mechanism to discover connectivity is out of scope and we need to find connectivity between IP/MPLS domains across the core GMPLS domain. This issue is referred to as the "unknown adjacency" problem.

7. History of this document work

This document has been spun off from the internet draft entitled "IP/MPLS-GMPLS interworking in support of IP/MPLS to GMPLS migration <draft-oki-ccamp-gmpls-ip-interworking-06.txt>".
This document provides a framework for IP/MPLS-GMPLS interworking in support of IP/MPLS to GMPLS migration. Solutions for IP/MPLS-GMPLS interworking in support of IP/MPLS to GMPLS migration will be developed in companion documents.
8. Security Considerations

Security and confidentiality is often applied (and attacked) at administrative boundaries. Some of the models described in this document introduce such boundaries, for example between MPLS and GMPLS islands. These boundaries offer the possibility of applying or modifying the security as one might when crossing an IGP area or AS boundary, even though these island boundaries might lie within an IGP area or AS.

No changes are proposed to the security procedures built into MPLS and GMPLS signaling and routing. GMPLS signaling and routing inherit their security mechanisms from MPLS signaling and routing without any changes. Hence, there will be no issues with security in interworking scenarios. Further, since the MPLS and GMPLS signaling and routing security is provided on a hop-by-hop basis, and since all signaling and routing exchanges described in this document for use between any pair of LSRs are either fully MPLS or fully GMPLS, there are no changes necessary to the security procedures.

9. IANA Considerations

This information framework document makes no requests for IANA action.
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12. Acknowledgements

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14. References
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14.2. Informative References

