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

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Abstract

The migration from Multiprotocol Label Switching (MPLS) to Generalized MPLS (GMPLS) is the process of evolving an MPLS traffic engineered (TE) control plane to a GMPLS control plane. An appropriate migration strategy can be selected based on various factors including the service provider's network deployment plan, customer demand, available network equipment implementation, operational policy, etc.

In the course of migration, several interworking cases may exist where MPLS and GMPLS devices or networks must coexist. During the migration process, standard interworking functions are needed to allow graceful deployment of GMPLS technologies while keeping existing IP/MPLS networks unaffected.

Since GMPLS signaling and routing protocols are different from the MPLS control protocols, in order for MPLS and GMPLS to interwork, we need mechanisms to compensate for the differences between MPLS and GMPLS. This document provides a landscape of techniques, practices and an overview of interworking between MPLS and GMPLS in support of IP/MPLS to GMPLS migration, which is also beneficial for graceful deployment of GMPLS technologies into existing IP/MPLS networks. We discuss issues, models, migration scenarios, operation, and requirements.

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1. Introduction

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

Although an appropriate migration strategy can be selected based on various factors including the service provider's network deployment plan, customer demand, available network equipment implementation, operational policy, etc, the smooth transition mechanism should be investigated from the consistent operation of GMPLS networks, while less impacting the operation of existing MPLS networks.

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 control 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, operation and requirements. Solutions for interworking MPLS and GMPLS will be developed in companion documents.

Note that both MPLS and GMPLS protocols can co-exist as "ships in the night" without any interworking issue. This document addresses interworking to allow migration from MPLS to GMPLS. We should also note that, in this document, a MPLS control plane means a MPLS-TE control plane (RSVP-TE [RFC3209], IGP-TE [RFC3630] [RFC3784]), and not a LDP-based control plane [RFC3036]. This document does not address the migration from LDP controlled MPLS networks to G/MPLS RSVP-TE at this moment, but may consider it in the future version.

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 packet switch capable (PSC) and non-PSC. Otherwise the term "PSC GMPLS" or "non-PSC GMPLS" is explicitly used.

The reader is assumed to be familiar with the terminology introduced in [RFC3495].

3. Motivations for Migration

Motivations for migration will vary for different service providers. This section is only presented to provide background so that the migration discussions may be seen in the context. Sections 4 and 5 illustrate the migration models and processes with possible examples.

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

- o To add all GMPLS capabilities to an existing MPLS PSC network.

- o To add a GMPLS network without sacrificing the existing MPLS PSC LSR implementation.

- o To pick up specific GMPLS features and operate them within an MPLS PSC network.

- o To allow MPLS capable LSRs to interoperate with new LSRs that only support GMPLS.

- o To integrate multiple networks managed by separate administrative organizations, which independently utilize MPLS or GMPLS.

- o 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 an MPLS-TE-based control plane to a GMPLS-based control plane. Three migration models are considered as described below. Practically speaking, multiple 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 GMPLS-capable nodes which is introduced into a legacy MPLS network. Such an island might be composed of newly added GMPLS network nodes, or might arise from the upgrade of existing nodes that previously operated MPLS protocols. The opposite is also quite possible. That is, there is a possibility that an island happens to be MPLS-capable within a GMPLS sea. Such a 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 from 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 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).

```
.................. .............................. ..................
:      MPLS      : :      GMPLS                 : :     MPLS       :
:+---+  +---+   +---+          +---+          +---+   +---+  +---+:
:|R1 |__|R11|___|G1 |__________|G3 |__________|G5 |___|R31|__|R3 |:
:+---+  +---+   +---+          +-+-+          +---+   +---+  +---+:
:      ________/ : :  ________/  |   ________/ : :  ________/     :
:     /          : : /           |  /          : : /              :
:+---+  +---+   +---+          +-+-+          +---+   +---+  +---+:
:|R2 |__|R21|___|G2 |__________|G4 |__________|G6 |___|R41|__|R4 |:
:+---+  +---+   +---+          +---+          +---+   +---+  +---+:
:................: :..........................: :................:

   |<---------------------------------------------------------->|
                              e2e LSP
```

Figure 1 Example of the island model for MPLS-GMPLS-MPLS interworking.

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. We should note that the GMPLS-capable device may not support a full set of MPLS functionalities. For example, a GMPLS-capable device may support protection and restoration mechanisms in [E2E-recovery, SEGMENT-recovery] but may

not support the fast reroute mechanism defined in [RFC4090]. This fact highlights the difference between the island and the integrated models. That is to say, in the island model, a GMPLS node does not support MPLS features (signaling code points, FRR, etc), while in the integrated model, the new device supports both MPLS and GMPLS features.

Further, existing MPLS devices will be 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 MPLS-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 specific protocol elements (signaling code points, FRR, etc) may be turned off, and no new devices need to support these elements.

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 MPLS-GMPLS-capable LSRs co-exist. Some LSRs will be capable of only MPLS, and some of both MPLS and GMPLS. The migration strategy here involves introducing MPLS-GMPLS-capable LSRs into an existing MPLS-capable network (i.e. upgrading MPLS LSRS) until all LSRs are MPLS-GMPLS-capable at which time all MPLS functionalities can be disabled, 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 the whole protocol implementation.

The interoperability concerns (e.g. LABEL REQUEST object [RFC3473] and LABEL object [RFC3209], for RSVP-TE signaling) though 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 will complicate matters considerably. Thus, this 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, operational policy, 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 or no change of existing IP/MPLS networks), and upon the immediate objectives (full, phased, or staged upgrade).

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 when, 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, may be controlled by GMPLS.

The second strategy for PSC and non-PSC networks is to migrate from 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 a 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 pseudo wires.

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

These cases are 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.

```
.............................  .............................
:            MPLS            : :    GMPLS (PSC)            :
:+---+        +---+        +---+        +---+        +---+:
:|R1 |________|R11|________|G1 |________|G3 |________|G5 |:
:+---+        +---+        +---+        +-+-+        +---+:
:      ______/  |   ______/ : :  ______/  |   ______/     :
:     /         |  /        : : /         |  /            :
:+---+        +---+        +---+        +-+-+        +---+:
:|R2 |________|R21|________|G2 |________|G4 |________|G6 |:
:+---+        +---+        +---+        +---+        +---+:
:............................: :..........................:

  |<-------------------------------------------------->|
                          e2e LSP
```

Figure 2 GMPLS-MPLS interworking model.

It is also important to underline that this scenario is also impacted by the directionality of the LSP, and the direction in which the LSP is established. Indeed, a unidirectional packet LSP from R1 to G5 is more easily accommodated at G1 than a bidirectional PSC LSP from G5 to R1.

6. Interworking issues between MPLS and GMPLS

As described in the previous sections, interworking between MPLS and GMPLS may form an essential part of a migration and deployment strategy. This section sets out some of the alternatives for achieving interworking between MPLS and GMPLS, and points out some of the issues that need to be addressed if the alternatives are adopted. This document does not describe solutions to these issues.

Note that it is possible to consider upgrading the routing and signaling capabilities of LSRs from MPLS to GMPLS separately.

6.1. Signaling

Signaling protocols are used to establish LSPs and are the principal concern for interworking. This section outlines some of the issues that may arise when MPLS and GMPLS signaling interworking is attempted. Solutions to these issues will be described in separate documents, but possibly rely on tunneling techniques (as described above) or message mapping.

6.1.1. GMPLS specific RSVP objects and Messages

GMPLS RSVP-TE signaling ([RFC3473]) 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 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 sub objects 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 bidirectional 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.

o The Protection and Association objects used for LSP recovery

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 11bbbbbb, but others would 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 that 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 Recovery Path message that are not supported by MPLS nodes.

6.1.1.1. Direct interworking

A possible solution is to allow direct signaling between MPLS and GMPLS LSRs. However, a fundamental issue is that MPLS and GMPLS use incompatible code points (C-Types) to request labels (LABEL_REQUEST and GENERALIZED_LABEL_REQUEST) and to signal labels (LABEL and GENERALIZED LABEL).

Note, however, that the Phased Model may offer a solution that resembles signaling interworking. In this approach LSRs are upgraded to support some GMPLS features but continue to use MPLS code points.

MPLS LSPs may be established across an island of enhanced signaling capabilities, where some GMPLS features have been added to MPLS LSRs. This may be relatively simple, and indeed may also be compatible with the Integrated Model.

On the other hand, enhanced MPLS LSPs (i.e. LSPs signaled using some GMPLS features) may be carried across an MPLS island. Success in this case will depend on the particular GMPLS features in use (some features, such as bi-directionality, cannot be achieved by a native MPLS network without additional assistance) and the code points that are used to signal the features (some objects can be carried transparently across an MPLS network by virtue of their Class Number

encoding, but others will be silently dropped or will cause the message to be rejected).

6.1.1.2. Mapping

An alternative to interworking signaling protocols is to map each other between MPLS and GMPLS. That is, to convert the objects carried in one message to different objects carried in the message that is actually sent. This mapping would be performed in an upgraded LSR at island borders since existing LSRs would not be aware of the required mappings. This mapping is local decision and should be pre-configured or dynamically done at border nodes.

It would be relatively simple to map signaling messages for LSPs initiated on MPLS LSRs (MPLS-GMPLS-MPLS and MPLS-GMPLS) since the LSPs will not need to implement advanced GMPLS features. On the other hand, however, mapping signaling messages for LSPs initiated by a GMPLS LSR (GMPLS-MPLS-GMPLS and GMPLS-MPLS) may be considerably harder depending on the GMPLS features demanded by the LSP. For example, if the GMPLS LSP is bidirectional, additional function will be needed at the border LSR that maps the signaling messages in order to create a pair of unidirectional MPLS LSPs to carry the bidirectional service across the MPLS network that does not have native support for bidirectionality. Indeed, in the GMPLS-MPLS case, a bidirectional service would not be possible unless the egress MPLS LSR was also upgraded to provide this function.

6.1.1.3. Transfer

A migration strategy may also imply moving an MPLS state to a GMPLS state. For instance, a LSR hosting MPLS states is upgraded such that its controller can run both MPLS and GMPLS. In this case, a signaling mechanism is needed to migrate from the MPLS LSP state to the GMPLS state.

6.1.2. Bidirectional LSP

GMPLS provides bidirectional LSP setup - a single signaling message exchange 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 separately. 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 and GMPLS-MPLS island model.

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

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.

6.1.3. Failure recovery

Failure recovery mechanism is provided using different mechanisms in MPLS (see [RFC4090]) and GMPLS (see [E2E-RECOVERY, SEGMENT-RECOVERY]). Local protection of island border nodes may be a particular problem.

6.2. Routing

Some attention should also be given to the use of routing protocols in interworking scenarios since this may allow routing information from islands to be visible within the surrounding seas.

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 additional TLVs that are carried along with 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 MPLS information advertised by MPLS LSRs and GMPLS LSRs to compute a traffic-engineered explicit route across a mixed network. However, it is likely that a path 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 result in 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.

6.2.1. Interworking of Routing Protocols

GMPLS TE advertisements are based on MPLS TE advertisements with the addition of extra sub-TLVs. The processing rules for unknown TLVs mean that they can be ignored by a router, but must be forwarded when the Link State Advertisement (OSPF LSA or IS-IS LSP) is flooded.

This means that MPLS and GMPLS LSRs may operate as routing peers, and will redistribute each other's TE information. MPLS LSRs will be granted full TE visibility at an MPLS level into GMPLS islands, while GMPLS LSRs will have limited (i.e. MPLS-level) TE visibility into MPLS islands.

This type of routing exchange may be very useful in particular for MPLS-GMPLS-MPLS PSC networks. GMPLS LSRs, however, must either modify their computation algorithms or must generate appropriate defaults for GMPLS TE parameters that are not advertised by MPLS LSRs.

6.2.2. Mapping of Routing Protocols

The alternatives to interworking routing protocols are to impose protocol boundaries (such as routing area, AS boundaries) or to attempt to map the protocol advertisements as they cross island borders. This latter option is simple for advertisements coming from GMPLS islands since the GMPLS sub-TLVs may be discarded, but is pointless because those sub-TLVs are benign within the MPLS network and are impossible to accurately recreate on re-entry into a GMPLS network. On the other hand, advertisements initiated by MPLS LSRs could have default GMPLS sub-TLVs added when they are flooded into a GMPLS network. These defaults would be similar to those described in the previous section, and would have the advantage that GMPLS LSRs within the network (i.e. not border nodes) would not need to apply the defaults. Care is needed to ensure that the mechanism for applying defaults is identical on all border nodes.

Note that any alternative using routing protocol mapping relies on each border LSR knowing which neighbors are MPLS or GMPLS capable.

6.3. Layered Networks

In addition to the difference between MPLS and GMPLS protocols, control and data plane separation needs to be considered at the boundary of PSC and non-PSC domains.

Note that the boundary of PSC and non-PSC domains may or may not be coincident with the boundary of MPLS and GMPLS domains. In the case where the boundaries are not coincident, the boundary between the PSC

and non-PSC domains must exist in the GMPLS domain because the MPLS domain cannot support a non-PSC data plane. Here we distinguish two cases: interworking between PSC and non-PSC networks, and interworking between MPLS and GMPLS networks.

Figure 3 shows the network model, where the ingress PSC domain and the egress PSC domains are interconnected via the transit non-PSC domain.

```
.................. ............................. ..................
: Ingress PSC    : :      Transit non-PSC      : :  Egress PSC    :
:+---+  +---+   +---+          +---+          +---+   +---+  +---+:
:|R1 |__|R11|___|G1 |__________|G3 |__________|G5 |___|R31|__|R3 |:
:+---+  +---+   +---+          +-+-+          +---+   +---+  +---+:
:      ________/ : :  ________/  |   ________/ : :  ________/     :
:     /          : : /           |  /          : : /              :
:+---+  +---+   +---+          +-+-+          +---+   +---+  +---+:
:|R2 |__|R21|___|G2 |__________|G4 |__________|G6 |___|R41|__|R4 |:
:+---+  +---+   +---+          +---+          +---+   +---+  +---+:
:................: :...........................: :................:
```

Figure 3 Interworking of PSC and non-PSC domains.

In the PSC domain, 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. On the other hand, in the non-PSC domain (TDM, LSC, and FSC domains), where packet delineation is not recognized, and in-band control channels cannot be terminated, dedicated control channels (separated from the data channels) are used. In the non-PSC domain, 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.

A dedicated control channel must not be used to carry user data traffic. This is particularly important when the control channels are of low capacity and are not designed to carry user traffic.

A possible method to protect the control plane channel of a non-PSC domain is that packets coming from PSC domains are not allowed to use the control plane channel. The method, however, causes another problem: lack of signaling and routing adjacencies across the non-PSC domain.

This problem is explained using Fig. 3. LSAs in the egress PSC domain are not advertised in the ingress PSC domain unless routing

adjacencies are established between the PSC domain and non-PSC domain or unless routing adjacencies are established directly between PSC domains. Therefore the ingress LSR in the ingress PSC domain is not able to find the egress LSR in the egress PSC domain unless these adjacencies are formed. The signaling messages are not passed across the non-PSC domain between the ingress and the egress PSC domains unless the signaling adjacencies are established between the PSC domain and the non-PSC domain or directly between PSC domains.

Interworking between PSC and non-PSC networks can be regarded as a layered network. Layered networks are described in many places including [RFC3945] and [RFC4206]. [MRN-REQ] gives a good background and discusses some of the requirements for multi-layered networks.

Network layering is often used to separate domains of different data plane technology. It can also be used to separate domains of different control plane technology (such as MPLS and GMPLS protocols), and the solutions developed for multiple data plane technologies can be usefully applied to this situation.

The GMPLS architecture [RFC3945] identifies three architectural models for supporting multi-layer GMPLS networks, and these models may be applied to the separation of MPLS and GMPLS control plane islands. The applicability of the different migration models to the three architectural models may provide additional input to the choice of an architectural model.

6.3.1. Peer Model

In the peer model, both MPLS and GMPLS nodes run the same routing instance and routing advertisements, from within islands of one level of protocol support are distributed to the whole network. This is achievable as described in section 6.2 either by direct distribution or by mapping of parameters.

If the entire network (MPLS and GMPLS capable LSRs) is PSC, signaling may establish end-to-end LSPs using the techniques described in section 6.1. On the other hand, if the GMPLS network is of some other switching type, or if the protocol islands are managed as separate network layers, the signaling request can give rise to the creation of a hierarchical LSP [RFC4206] or stitching segment [STITCH] that spans an island and is triggered when the LSP request reaches the island border. The end-to-end LSP from the higher layer network (the protocol sea) is carried across the lower layer network (the protocol island) by the tunnel or stitching segment.

Note that an MPLS sea is not capable of determining whether the entire network is of the same switching type and will consequently attempt to signal end-to-end LSPs assuming them to be PSC all the way. This requires that the island border take the appropriate action to set up tunnels across islands of different switching capabilities.

6.3.2. Overlay Model

The overlay model preserves strict separation of routing information between network layers. Thus, in the interworking case, there is no requirement to handle routing interworking. Signaling interworking is still required as described in section 6.1.

Note, however, that there is a requirement to create signaling higher layer adjacencies between island border nodes, and that it is highly desirable to create routing adjacencies in the same way. Such adjacencies may use the control plane of the lower layer network and be independent of the existence of data plane connectivity across the lower layer network. Care may be required to prevent the swamping of the lower layer control plane when it has limited capacity. Alternatively, such adjacencies may rely on the existence of data plane connectivity across the lower layer network.

6.3.3. Augmented Model

The augmented model allows limited routing exchange from the lower layer network to the higher layer network. Generally speaking, this assumes that the border nodes provide some form of filtering, mapping or aggregation of routing information advertised from the lower layer network, and this is compatible with the mechanisms described in section 6.2.2.

Note however, that part of this assumption allows the border nodes to have full visibility into both the higher and lower layer networks without further advertising the information from the lower layer network to the higher layer network meaning that no mapping or interworking of routing protocols is required. Particularly, this includes the case where MPLS and GMPLS clouds run distinct routing instances, and the border nodes run both routing instances.

Note that the same observations about routing and signaling adjacencies apply as for the overlay model.

7. Manageability Considerations

Some attention should be given during migration planning to how the network will be managed during and after migration. For example, will

the LSRs of different protocol capabilities be managed separately or as a whole. This is most clear in the Island Model where it is possible to consider managing islands of one capability separately from the surrounding sea. In the case of islands that have different switching capabilities, it is possible that the islands already had different management in place before the migration: the resultant migrated network may seek to merge the management or to preserve it.

7.1. Control of Function and Policy

The most important control to be applied is at the moment of changeover between different levels of protocol support. Such a change may be made dynamically or during a period of network maintenance.

Where island boundaries exist, it must be possible to manage the relationships between protocols and to indicate which interfaces support which protocols on a border LSR. Further, island borders are a natural place to apply policy, and management should allow configuration of such policies.

7.2. Information and Data Models

No special information or data models are required to support migration, but note that migration in the control plane implies migration from MPLS management tools to GMPLS management tools. During migration, therefore, it may be necessary for LSRs and management applications to support both MPLS and GMPLS variants of management data.

The GMPLS MIB modules are designed to allow support of the MPLS protocols and build on the MPLS MIB modules through extensions and augmentations. This may make it possible to migrate management applications ahead of the LSRs that they manage.

7.3. Liveness Detection and Monitoring

Migration will not imposes additional issues for OAM above those that already exist for inter-domain OAM and for OAM across multiple switching capabilities.

Note, however, that if a flat PSC MPLS network is migrated using the island model, and is treated as a layered network using tunnels to connect across GMPLS islands, then requirements for a multi-layer OAM technique may be introduced into what was previously defined in the flat OAM problem-space. The OAM framework of MPLS/GMPLS interworking may be described in more detail in a later version.

7.4. Verifying Correct Operation

The concerns for verifying correct operation (and in particular correct connectivity) are the same as for liveness detection and monitoring. Principally, the process of migration may introduce tunneling or stitching into what was previously a flat network.

7.5. Requirements on Other Protocols and Functional Components

No particular requirements are introduced on other protocols. As it has been observed, the management components may need to migrate in step with the control plane components, but this does not impact the management protocols, just the data that they carry.

It should also be observed that providing signaling and routing connectivity across a migration island in support of a layered architecture may require the use of protocol tunnels (such as GRE) between island border nodes. Such tunnels may impose additional configuration requirements at the border nodes.

7.6. Impact on Network Operation

The process of migration is likely to have significant impact on network operation while migration is in progress. The main objective of migration planning should be to reduce the impact on network operation and on the services perceived by the network users.

To this end, planners should consider reducing the number of migration steps that they perform, and minimizing the number of migration islands that are created.

A network manager may prefer the island model especially when migration will extend over a significant operational period because it allows the different network islands to be administered as separate management domains. This is particularly the case in the overlay and augmented network models where the details of the protocol islands remain hidden from the surrounding LSRs.

7.7. Other Considerations

No other management considerations arise.

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 based on either MPLS or GMPLS, there are no changes necessary to the security procedures.

9. IANA Considerations

This information framework document makes no requests for IANA action.

10. Full Copyright Statement

11. Intellectual Property

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14. References

14.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels," BCP 14, IETF RFC 2119, March 1997.

[RFC4090] Pan, P., Swallow, G. and A. Atlas, "Fast Reroute Extensions to RSVP-TE for LSP Tunnels", RFC 4090, May 2005.

[RFC3945] Mannie, E., "Generalized Multi-Protocol Label Switching Architecture", RFC 3945, October 2004.

[SEGMENT-RECOVERY]Berger, L., "GMPLS Based Segment Recovery", draft-ietf-ccamp-gmpls-segment-recovery, work in progress.

[E2E-RECOVERY] Lang, J. P., Rekhter, Y., Papadimitriou, D. (Editors), " RSVP-TE Extensions in support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS)-based Recovery", draft-ietf-ccamp-gmpls-recovery-e2e-signaling, work in progress.

[RFC3473] Berger, L., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions ", RFC 3473, January 2003.

14.2. Informative References

[MRN-REQ] Shiomoto, K., Papadimitriou, D., Le Roux, J.L., Vigoureux, M., Brungard, D., "Requirements for GMPLS-based multi-region and multi-layer networks (MRN/MLN)", draft-ietf-ccamp-gmpls-mln-reqs, work in progress.

[RFC4206] Kompella, K., and Rekhter, Y., "Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)", RFC 4206, October 2005.

[STITCH] Ayyangar, A., Vasseur, JP. "Label Switched Path Stitching with Generalized MPLS Traffic Engineering", draft-ietf-ccamp-lsp-stitching, work in progress.