MPLS-TP Control Plane Framework
draft-abfb-mpls-tp-control-plane-framework-00.txt

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This Internet-Draft will expire on August 22, 2009.
Abstract

The MPLS Transport Profile (MPLS-TP) supports both static provisioning of transport paths via an NMS/OSS, and dynamic provisioning of transport paths via a control plane. This document provides the framework for MPLS-TP dynamic provisioning, and covers control plane signaling, routing, addressing, traffic engineering, path computation, and recovery in the event of network failures. The document focuses on the control of Label Switched Paths (LSPs) as the Pseudowire (PW) control plane is not modified by MPLS-TP. MPLS-TP uses GMPLS as the control plane for MPLS-TP LSPs. Backwards compatibility to MPLS is required. Management plane, manual configuration, the triggering of LSP setup, label allocation schemes, and hybrid services are out of scope of this document.
1. Introduction

The MPLS Transport Profile (MPLS-TP) is being defined in a joint effort between the International Telecommunications Union (ITU) and the IETF. The requirements for MPLS-TP are defined in the requirements document, see [TP-REQ]. These requirements state that "A solution MUST be provided to support dynamic provisioning of MPLS-TP transport paths via a control plane."

This document provides the framework for such dynamic provisioning.

1.1. Scope

This document covers control plane related topics for MPLS-TP Label Switched Paths (LSPs) and Pseudowire (PW). The control plane requirements for MPLS-TP are defined in [TP-REQ]. These requirements defined the role of the control plane in MPLS-TP.
In particular, Sections 2.4 and 2.8 of [TP-REQ] provide specific control plane requirements.

The LSPs provided by MPLS-TP are used as a server layer for IP, MPLS and PWs, as well as other MPLS-TP LSPs. The PWs are used to carry client signal other than IP and MPLS. The relationship between pseudo wires carried and MPLS-TP LSPs is exactly the same as between pseudo wires and MPLS LSPs in a Packet switched network (PSN). The PW encapsulation over MPLS-TP LSPs used in MPLS-TP networks is the same as for PWs over MPLS in an MPLS network. MPLS-TP also defines protection and restoration (or, collectively, recovery) functions. The MPLS-TP control plane provides methods to establish, remove and control MPLS-TP LSP and PW functions. This includes control of data plane, OAM and recovery functions.

A general framework for MPLS-TP has been defined in [TP-FWK], and a survivability framework for MPLS-TP has been defined in [TP-SURVIVE]. These document scopes the approaches and protocols that will be used as the foundation for MPLS-TP. Notably, Section 3.5 of [TP-FWK] scopes the IETF protocols that serve as the foundation of the MPLS-TP control plane. The PW control plane is based on the existing PW control plane, see [RFC4447], and the PW end-to-end (PWE3) architecture, see [RFC3985]. The LSP control plane is based on Generalized MPLS (GMPLS), see [RFC3945], which is built on MPLS-TE and its numerous extensions. [TP-SURVIVE] focuses on LSPs, and the protection functions that must be supported within MPLS-TP. It does not specify which control plane mechanisms to be used.

This document discusses the impact of MPLS-TP requirements on the signaling that is used to provision pseudo wires as specified in RFC4447. This document also discusses the impact of the MPLS-TP requirements on the GMPLS signaling and routing protocols that is used to provision MPLS-TP LSPs.

1.2. Basic Approach

The basic approach taken in defining the MPLS-TP Control Plane framework is:

1) MPLS technology as defined by the IETF is the foundation for the MPLS Transport Profile.
2) The data plane for MPLS and MPLS-TP is identical, i.e. any extensions defined for MPLS-TP is also applicable to MPLS. And the same encapsulation used for MPLS over any layer 2 network is also used for MPLS-TP.
3) MPLS PWs are used as-is by MPLS-TP including the use of targeted-LDP for PW signaling [RFC4447], OSPF-TE, ISIS-TE or MP-BGP as they apply for (MS)-PW routing. However, the PW can be encapsulated over an MPLS-TP LSP in (established using methods and procedures for MPLS-TP LSP establishment) in addition to the present defined methods of carrying PWs over packet switched networks (PSNs). That is, the MPLS-TP domain is a packet switched network from PWE3 architecture aspect [RFC3985].

4) The MPLS-TP LSP control plane builds on the GMPLS control plane as defined by the IETF for transport LSPs, the protocols within scope are RSVP-TE [RFC3473], OSPF-TE [RFC4203][RFC5392], and ISIS-TE [RFC5307][RFC5316].

5) Existing IETF MPLS and GMPLS RFCs and evolving Working Group Internet-Drafts should be reused wherever possible.

6) If needed, extensions for the MPLS-TP control plane should first based on the existing and evolving IETF work, secondly based on work by other Standard bodies only when IETF decides that the work is out of IETF scope. New extensions may be defined otherwise.

7) Extensions to the GMPLS control plane may be required in order to fully automate MPLS-TP functions.

8) Control-plane software upgrades to existing equipment running MPLS is acceptable and expected.

9) It is permissible for functions present in the GMPLS control plane not to be used in MPLS-TP networks, e.g. the possibility to merge LSPs.

10) One possible use of the control plane is to configure, enable and empower OAM functionality; this will require extensions to existing control plane specifications.

1.3. Reference Model

The control plane reference model is based on the general MPLS-TP reference model as defined in MPLS-TP framework [TP-FWK]. Per MPLS-TP framework [TP-FWK], MPLS-TP control plane is based on GMPLS with RSVP-TE for LSP signaling and LDP for PW signaling. In both cases, OSPF-TE or ISIS-TE is used for dynamic routing.

From a service perspective, client interfaces are provided for both the PWs and LSPs. PW client interfaces are defined on an interface technology basis, e.g., Ethernet over PW [RFC4448]. In the context of MPLS-TP LSP, the client interface is expected to
be provided via a UNI, [RFC4208]. As discussed in [TP-FWK], MPLS-TP also presumes an LSP NNI reference point.

The MPLS-TP end-to-end control plane reference model is shown in Figure 1. It shows the control plane protocols used by MPLS-TP, as well as the UNI and NNI reference points.

Figure 1. End-to-End MPLS-TP Control Plane Reference Model

Legend:

CE: Customer Edge
Client signal: defined in MPLS-TP Requirements
L2: Any layer 2 signal that may be carried over a PW, e.g. Ethernet.
NNI: Network to Network Interface
PE: Provider Edge
SP: Service Provider
TE-RTG: OSPF-TE or ISIS-TE

Figure 2 adds three hierarchical LSP segments, labeled as "H-LSPs". These segments are present to support OAM and MEPs within each provider and across the inter-provider NNI. The MEPs are used to collect performance information and support OAM triggered survivability schemes as discussed in [TP-SURVIVE], and each H-LSP may be protected using any of the schemes discussed in [TP-SURVIVE].
2. Control plane requirements

The requirements for the MPLS-TP control plane are derived from the MPLS-TP requirements and framework documents, specifically...
[TP-REQ], [TP-FWK], [TP-OAM], and [TP-SURVIVE]. The requirements are summarized in this section, but do not replace those documents. If there are differences between this section and those documents, those documents shall be considered authoritative.

2.1. Primary Requirements

These requirements are based on [TP-REQ]:

1. The MPLS-TP control plane must be able to interoperate with existing IETF MPLS control planes where appropriate.

2. The MPLS-TP control plane must support a connection-oriented packet switching model with traffic engineering capabilities.

3. The MPLS-TP control plane must support traffic engineered point to point (P2P) and point to multipoint (P2MP) transport paths.

4. The MPLS-TP control plane must support the logical separation of the control and management planes from the data plane.

5. The MPLS-TP control plane must support the physical separation of the control and management planes from the data plane.

6. A control plane must be defined for MPLS-TP, but its use is a network operator’s choice.

7. A failure of the control plane must not interfere with the delivery of service or recovery of established transport paths.

8. The MPLS-TP control plane must work across domains.

9. The MPLS-TP control plane must not dictate any particular physical or logical topology, and must include support for ring topologies.

10. The MPLS-TP control plane must not provision transport paths which contain forwarding loops.

11. The MPLS-TP control plane must support multiple client layers.
12. The MPLS-TP control plane must be able to operate independently over server layer networks.

13. The MPLS-TP control plane must allow a server layer to hide addressing and topology information form a client layer.

14. The MPLS-TP control plane must allow for the identification of a transport path on each link and at the destination.

15. The MPLS-TP control plane must allow for P2MP capable server (sub-)layers.

16. The MPLS-TP control plane must support unidirectional, bidirectional and co-routed bidirectional point-to-point transport paths.

17. Intermediate nodes must be aware about the pairing relationship of the forward and the backward directions belonging to the same bidirectional transport path.

18. The MPLS-TP control plane may support transport paths with asymmetric bandwidth requirements.

19. The MPLS-TP control plane must support unidirectional point-to-multipoint transport paths.

20. The MPLS-TP control plane should support bandwidth modification.

21. The MPLS-TP control plane must support scale gracefully to support a large number of transport paths, nodes and links.

22. The MPLS-TP control plane must support configuration of protection functions and any associated maintenance (OAM) functions.

23. The MPLS-TP control plane must support the configuration and modification of OAM maintenance points as well as the activation/deactivation of OAM when the transport path or transport service is established or modified.

24. The MPLS-TP control plane must support protection and restoration mechanisms, i.e., recovery.
Note that the MPLS-TP Survivability Framework document, [TP-SURVIVE], provides additional useful information related to recovery.

25. The MPLS-TP control plane mechanisms used for P2P and P2MP recovery should be identical.

26. The MPLS-TP control plane must support recovery mechanisms that are applicable at various levels throughout the network including support for link, path segment and end-to-end path, and pseudowire segment, and end-to-end pseudowire recovery.

27. The MPLS-TP control plane must support recovery paths that meet the SLA protection objectives of the service. Including:
   a. Guarantee 50ms recovery times from the moment of fault detection in networks with spans less than 1200 km.
   b. Protection of 100% of the traffic on the protected path.
   c. Objectives SHOULD be configurable per transport path, and SHOULD include bandwidth and QoS.

28. The MPLS-TP control plane must support recovery mechanisms that are applicable to any topology.

29. The MPLS-TP control plane must operate in synergy with (including coordination of timing) the recovery mechanisms present in any underlying server transport network (for example, Ethernet, SDH, OTN, WDM) to avoid race conditions between the layers.

30. The MPLS-TP control plane must support priority logic to negotiate and accommodate coexisting requests (i.e., multiple requests) for protection switching (e.g., administrative requests and requests due to link/node failures).

31. The MPLS-TP control plane must support recovery and reversion mechanisms that prevent frequent operation of recovery in the event of an intermittent defect.

32. The MPLS-TP control plane must support 1+1 protection for P2P LSPs.
33. The MPLS-TP control plane must support 1+1 unidirectional protection for P2MP LSPs.

34. The MPLS-TP control plane must support 1:n protection for P2P LSPs.

35. The MPLS-TP control plane must support 1:n unidirectional protection for P2MP LSPs.

36. The MPLS-TP control plane must support the sharing of resources between a restoration LSP and the LSP being replaced.

37. The MPLS-TP control plane must support restoration priority.

38. The MPLS-TP control plane must support preemption priority.

39. The MPLS-TP control plane should support 1:n (including 1:1) shared mesh restoration.

40. The MPLS-TP control plane must support the definition of shared protection groups.

41. The MPLS-TP control plane must support sharing of protection resources.

42. The MPLS-TP control plane must support revertive and non-revertive protection behavior.

43. The MPLS-TP control plane may support revertive and non-revertive restoration behavior.

44. The MPLS-TP control plane must support recovery being triggered by physical (lower) layer fault indication.

45. The MPLS-TP control plane must support recovery being triggered by OAM.

46. The MPLS-TP control plane must support management plane recovery triggers (e.g., forced switch, etc.).

47. The MPLS-TP control plane should support control plane recovery triggers (e.g., forced switch, etc.).

48. The MPLS-TP control plane must support the establishment and maintenance of all recovery entities and functions.
49. The MPLS-TP control plane must support signaling of recovery administrative control.

50. The MPLS-TP control plane must support protection state coordination (PSC).

51. The MPLS-TP control plane must support transport services that provide differentiated services and different traffic types with traffic class separation associated with different traffic.

52. The MPLS-TP control plane must support the provisioning of services that provide a guaranteed Service Level Specifications (SLS), with support for hard and relative end-to-end bandwidth guaranteed.

53. The MPLS-TP control plane must support the provisioning of services which are sensitive to jitter and delay.

2.2. MPLS-TP Framework Derived Requirements

The following additional requirements are based on [TP-FWK]:

54. The address spaces used in the management, control and data planes are independent.

55. Penultimate hop popping (PHP) is disabled on MPLS-TP LSPs by default. The applicability of PHP to both MPLS-TP LSPs and MPLS networks general providing packet transport services will be clarified in a future version.

56. The MPLS-TP control plane must support both E-LSP and L-LSP.

57. The MPLS-TP control plane is based on the MPLS control plane for pseudowires, and more specifically, LDP is used for PW signaling.

58. Both single-segment and multi-segment PWs shall be supported by the MPLS-TP control plane. MPLS-TP shall use the definition of multi-segment PWs that is under development in the IETF independent from MPLS-TP.

59. The MPLS-TP control plane is based on the GMPLS control plane for MPLS-TP LSPs. More specifically, GMPLS RSVP-TE is used for LSP signaling, and GMPLS OSPF-TE and ISIS-TE are used for routing.
60. The MPLS-TP LSP control plane must allow for interoperation with the MPLS-TE LSP control plane.

61. The MPLS-TP control plane must be capable of performing fast restoration in the event of network failures.

62. The MPLS-TP control plane must ensure its own survivability and to enable it to recover gracefully from failures and degradations. These include graceful restart and hot redundant configurations.

63. The MPLS-TP control plane must support linear, ring and meshed protection schemes.

2.3. OAM Framework Derived Requirements

The following additional requirements are based on [TP-OAM]:

64. The MPLS-TP control plane must allow for the use of OAM proactive Continuity Check (CC) and Connectivity Verification (CV) function.

a. The CC and CV functions operate between MEPs.

b. All OAM packets coming to a MEP source are tunneled via label stacking, and therefore a MEP may only be present at an LSP’s ingress and egress nodes (and never at an LSP’s transit node).

c. The CC and CV functions may serve as a trigger for protection switching, see requirement 45 above.

d. This implies that LSP hierarchy must be used in cases where OAM is used to trigger recovery.

65. The MPLS-TP control plane must support the configuration of MEPs.

66. The MPLS-TP control plane must support the signaling of the transmission period and the ME identifier used in CC and CV.

2.4. Security Requirements

There are no specific MPLS-TP control plane security requirements. The existing framework for MPLS and GMPLS security is documented on [MPLS-SEC] and that document applies equally to MPLS-TP.
3. TE LSPs

[Editor’s note: This section (and the remainder of this document) is preliminary and will be edited/replaced in future versions.]

3.1. General reuse of existing GMPLS control plane mechanisms

As described in [RFC3945], Generalized MPLS (GMPLS) extends MPLS to support additional switching technologies. GMPLS is thus capable of controlling packet technologies. Most of the initial efforts on Generalized MPLS (GMPLS) have been related to delivering circuit connectivity. With the emergence of both multi-switching environments and the integrated control paradigm, there is a need to clarify the applicability of GMPLS to packet switching technologies. In particular, the formal definition of FAs and hierarchy in [RFC4206] led to the definition of four regions for PSC (Packet Switching Capable) interfaces: PSC-1, PSC-2, PSC-3, and PSC-4.

This document describes the GMPLS topics specifically related to Packet technologies. In particular, it will present how to signal packet- LSPs and how the four PSC-i regions could be used.

3.1.1. "In-band" and "out of band"

For an MPLS-TP network, "in-band" is defined such that the control plane runs over a network set up by that same control plane.

For an MPLS-TP network, "out of band" is defined such that the control plane runs over a network that has been established by other means than the control plane itself.

The term out-of-band is typically refers to the relationship of the management and control planes relative to the data plane. It may be used to refer to the management plane independent of the control plane, or to both of them in concert. There are multiple uses of the term out-of-band, and it may relate to a channel, a path or a network. Each of these can be used independently or in combination. Briefly, the terms are typically used as follows:

- **In-band**
  
  This term is used to refer to cases where management and/or control plane traffic is sent using or embedded in the same communication channel used to transport the associated data. IP forwarded, MPLS packet, and Ethernet networks are all
examples where control traffic is typically sent in-band with the data traffic.

- **Out-of-band, in-fiber**
  This term is used to refer to cases where management and/or control plane traffic is sent using a different communication channel from the associated data traffic, and the control/management communication channel resides in the same fiber as the data traffic. Optical transport networks typically operate in an out-of-band in-fiber configuration.

- **Out-of-band, aligned topology**
  This term is used to refer to the cases where management and/or control plane traffic is sent using a different communication channel from the associated data traffic, and the control/management communication must follow the same node-to-node path as the data traffic. Such topologies are usually supported using a parallel fiber or other configuration where multiple data channels are available and one is (dynamically) selected as the control channel.

- **Out-of-band, independent topology**
  This term is used to refer to the cases where management and/or control plane traffic is sent using a different communication channel from the associated data traffic, and the control/management communication may follow a path that is completely independent of the data traffic. Such configurations don't preclude the use of in-fiber or aligned topology links, but alignment is not required.

In the context of MPLS-TP, requirement 4 can be met using out-of-band in-fiber or aligned topology types of control. Requirement 5 can only be met by using Out-of-band, independent topology. GMPLS routing and signaling can be used to support in-band and all of the out-of-band forms of control, see [RFC3945].

### 3.1.2. Addressing

MPLS-TP uses the IPv4 and IPv6 address families to identify MPLS-TP nodes by default for network management and signaling purpose. The separation of the control and management planes from the data plane allows each plane to be independently addressable. Each plane may use addresses that are not mutually reachable, e.g., it is likely that the data plane will not be able to reach an address from the management or control planes and vice versa. Each plane may also use a different address family. It is even possible to reuse addresses in each plane,
but this is not recommended as it is likely to lead to operational confusion.

Unnumbered interfaces and links are also permitted and usage is at the discretion of the network operator.

3.2. Signaling

In this section, we reference the existing MPLS and GMPLS signaling and routing mechanisms which can be used to support MPLS-TP LSPs. When controlling a packet-switched data-plane with GMPLS, the packets have an MPLS (see [RFC3032]) format, with the so-called "shim header" including a 20-bit label. Unlike MPLS, GMPLS uses the Generalized Label Object defined in [RFC3471] to signal such labels.

In the current RSVP-TE signaling protocol, many objects make use of the Generalized Label.

According to [RFC3471], a Generalized Label has the following format: "Generic MPLS labels and Frame Relay labels are encoded right justified aligned in 32 bits (4 octets). ATM labels are encoded with the VPI right justified in bits 0-15 and the VCI right justified in bits 16-31". This is primarily used in RESV messages to encode the downstream assigned label which shall be used on a link or FA of an LSP, using the LABEL object (class = 16). When the C-Type is set to 2, this LABEL object is carrying a Generalized Label encoded as defined in [RFC3471].

When a node wishes to restrict the set of labels possibly assigned by its downstream neighbour (for the LSP), it can use the LABEL_SET object in PATH messages: the Label Type must be set to "Generalized Label" (value=2) and the Sub-Channels must be such Generalized Labels.

The SUGGESTED_LABEL, RECOVERY_LABEL and UPSTREAM_LABEL objects (respectively, class = 129, 34, 35; C-Type = 2) of the PATH messages have an identical format to that of the Generalized Label Object.

Similarly, the RECORD_ROUTE object of the PATH message can record the labels which are used along the LSP, using the label subobject TLV (type = 3). In this subobject, the C-type of the recorded label is copied (value is therefore 2 in the packet case), and the Label Object is copied into the appropriate field.

The Generalized Label Request Object must be used in PATH messages (C-Type = 4) instead of the simple Label Request
without range such as defined in [RFC3209] (C-Type = 1). In this object the Switching Type is then set to PSC-1, PSC-2, PSC-3 or PSC-4 (respectively values 1 to 4) according to the type of LSP being opened (see Section 3).

The ACCEPTABLE_LABEL_SET object (Class= 130, C-Type = 1) of the PathErr message has an identical format to that of the LABEL_SET object of PATH messages.

An MPLS-TP domain may be a switching point for an LSP that extends between client network islands. In this case, the MPLS-TP domain edge that connects to the respective client domain may have a static switching in the data plane done on the interface connecting to the respective client node. Alternatively, the LSP may be signaled between the client network and the MPLS-TP domain. There are two cases: (1) the client network connects via a GMPLS UNI to the MPLS-TP domain with knowledge of the remote MPLS-TP edge node and link that connects to the remote client node or there is some reachability information exchanged between the MPLS-TP domain and the client network via dynamic protocol, or (2) integrated model whereby the client network is an integrated part of the MPLS-TP domain, less likely option in some of the operation environments.

3.3. Routing

The major extension in the context of routing PSC-LSPs within the GMPLS framework is the use of the various PSC-regions introduced by [RFC3945]. With the introduction of the hierarchy, formally specified in [RFC4206], it is necessary to use PSC-x as Switching Capability (SC) and therefore, the nesting process is modified with regards to the MPLS procedures. In particular, the policy chosen for announcing the SC associated with a Forwarding Adjacency has a significant impact. That is an MPLS-TP announced as an FA in a client network in an integrated model to support hierarchical MPLS-TP in MPLS-TP domain.

3.3.1. ISIS-TE/OSPF-TE routing in support of MPLS-TP

The major extension in the context of routing PSC-LSPs within the GMPLS framework is the use of the various PSC-regions introduced by [RFC3945]. In MPLS, no hierarchy being formally defined, no limitations were applied on nesting packet LSPs within other packet LSPs. With the introduction of the hierarchy, formally specified in [RFC4206], it is necessary to use PSC-x as Switching Capability (SC) and therefore, the nesting process is modified with regards to the MPLS procedures. In particular, the policy chosen for announcing the SC associated with a Forwarding Adjacency has a significant impact.
3.3.1.1. ISIS-TE/OSPF-TE routing for MPLS-TP

Per [RFC4203] for OSPF and [RFC5307] for IS-IS, the Interface Switching Capability Descriptor (ISCD) is a sub-TLV (of type 15) of the Link TLV, which is used to indicate the Switching Capability (or Capabilities) of an interface. Per [RFC4203], this TLV indicates encoding, MTU and bandwidth available at each priority level. The TLV also carries a Switching Capability field which indicates the switching hierarchy level:

1: Packet-Switch Capable-1 (PSC-1)
2: Packet-Switch Capable-2 (PSC-2)
3: Packet-Switch Capable-3 (PSC-3)
4: Packet-Switch Capable-4 (PSC-4)

3.3.1.2. Multiple Switching Capabilities

To support interfaces that have more than one ISCD (see Section "Interface Switching Capability Descriptor" of [RFC4202]), the ISCD MAY occur more than once within a single routing protocol link description message. This allows a single packet TE-link or FA to be announced in multiple PSC regions, both as a PSC-1 and PSC-2 for instance.

The "regular" packet TE-links (non-FAs) can also be configured to be used by one or several of the regions. A TE-link set to a single PSC-x region will be reserved for establishing PSC-x LSPs, whereas one set to multiple PSC-x, PSC-y and PSC-z regions will be shared by PSC LSPs of these switching types.

When a TE-link or an FA is shared among regions, it is important for the nodes receiving traffic over this link/FA to have a single label- space shared across the regions. This is critical for the node to guarantee it will receive packets with different labels in different packet regions, even when they arrive on the same interface.

The fact that the label-space must be cross-region is independent from the fact that label-spaces may be per-interface, per-tunnel, per-upstream neighbor or per-platform.

3.3.1.3. Hierarchy

[RFC4206] defines network regions based on switching capabilities. The hierarchy of regions is novel in GMPLS and
this section intends to clarify the hierarchy for PSC nodes, and the use of the various PSC-regions.

According to [RFC4206], there are four PSC regions which are hierarchically ordered in the following way: PSC-1 < PSC-2 < PSC-3 < PSC-4, that is PSC-1 is the smallest SC and PSC-4 is the largest SC. Let us consider two consecutive nodes of an LSP, such that the first node’s SC is PSC-x and the second node’s is PSC-y. The first node is said to be at the border of two packet regions, with regard to that LSP, if PSC-y is larger than PSC-x (i.e.: x < y ). Similarly, the second node is said to be at the border of two packet regions, with regard to that LSP, if x > y.

According to [RFC4202], "a unidirectional LSP must have the same sets of SCs at both ends". Additionally, such an LSP will only be routed over TE-links and/or FAs which have (at least) that SC (since otherwise, the region crossing would trigger the setup of an FA-LSP, as described in [RFC4206]). This imposes that a PSC-x LSP be setup using only TE-links and/or FAs which include at least PSC-x. In the packet-switching context, this means that a PSC-x cannot directly use links/FAs which do not have a PSC-x set in their ISCD’s Switching Capability Field. Therefore, if one wants to establish a PSC-x LSP across a PSC-y region, an FA-LSP must either be available or set-up. It may be announced in the PSC-x region routing instance (which may be the same as the PSC-y region routing instance) as a PSC-x TE-link. The SC associated with an FA is announced using the routing protocol’s Interface Switching Capability Descriptor (ISCD) (see Section 3.1). For instance, if a PSC-1 LSP has to be setup across a PSC-3 region, the region border node will first have to establish a PSC-3 LSP in which the PSC-1 LSP will be nested. The PSC-3 LSP may then be used to announce an FA in the PSC-1 routing protocol.

In the four packet regions, the switching principles are the same, which means that a PSC node is most likely to have in fact all four PSC-1, PSC-2, PSC-3 and PSC-4 switching types. When using a packet LSP to nest other LSPs, the policy for deciding which PSCs to announce for the packet FAs and TE-links, and the policy for cross-region LSP triggering determine the type of interactions between the PSC-regions. This means there are in fact multiple ways of using the PSC regions.

3.3.2. TE link bundling

3.4. OAM, MEP (hierarchy) configuration & control

Current MPLS LSP and PW OAM capabilities are not suitable for transport applications. Hence IETF has started work to define a
comprehensive set of MPLS-TP OAM functions. Specific OAM requirements for MPLS-TP are documented in [draft-ietf-mpls-tp-oam-requirements]. In addition to the actual OAM requirements, it is also required that the control plane is able to configure and control OAM entities. This requirement is not yet addressed by the foreseen MPLS-TP control protocols (i.e., GMPLS for LSPs and T-LDP for PWs).

To emphasize the importance of OAM establishment via the control plane it must be noted that for proper OAM; OAM messages and the actual normal traffic must be congruent: taking the same path and relying on the same forwarding decisions at intermediate nodes. Hence, it is desirable that OAM is setup together with the establishment of the data path (i.e., with the same signaling). This way OAM setup is bound to connection establishment signaling, avoiding two separate management/configuration steps (connection setup followed by OAM configuration) which would increases delay, processing and more importantly may be prone to misconfiguration errors.

It must be noted that although the control plane is used to establish OAM entities, subsequently OAM is executed independently from the control plane. That is, OAM mechanisms are responsible for monitoring and initiating recovery actions (driving switches between primary and backup paths).

GMPLS RSVP-TE based OAM configuration and control should be general to be applicable to a wide range of data plane technologies and OAM solution and not be limited to the MPLS technology and MPLS-TP OAM. On the other hand, GMPLS based OAM configuration must satisfy all MPLS-TP requirements.

PW OAM establishment is FFS.

3.5. Traffic engineering and constraint-based path computation

Same approach as MPLS. Specific algorithms out of scope. Similar to MPLS, but adds bidirectional and recovery path computation.

3.5.1. Relation to PCE

Path Computation Element (PCE) may be used for path computation of a GMPLS LSP across domains and in a single domain. A Network Management System (NMS) may be used to trigger path computation for a GMPLS LSP and configure the cross-connects along the computed path. Alternatively, the path computation may be triggered by a network node via PCE Communication Protocol (PCECP) and the LSP signaled using GMPLS.
3.6. Applicability

3.7. Recovery

3.7.1. E2E, segment

3.7.2. P2P, P2MP

3.8. Diffserv object usage in GMPLS (E-LSPs, L-LSPs)

3.9. Management plane support

3.10. CP reference points (E-NNI, I-NNI, UNI)

3.11. MPLS to MPLS-TP interworking

   - Leverage current MPLS and GMPLS development
   - Backward compatibility

4. Pseudo Wires

[Editor’s note: This section is preliminary and will be edited/replaced in future versions.]

MPLS Pseudo Wires, as defined in [RFC3985], provide for emulated services over an MPLS Packet Switched Network (PSN). There are several types of pseudowires: (1) Ethernet PWs providing for Ethernet port or Ethernet VLAN over MPLS [RFC4448], (2) HDLC/PPP Pseudowire providing for HDLCP/PPP leased line transport of MPLS [RFC4618], (3) ATM PWs [RFC4816], (4) Frame Relay PWs [RFC4619], and (5) circulation Emulation PWs [RFC4553].

Today’s transport networks based on PDH, WDM, or SONET/SDH provide transport for PDH or SONET (e.g., ATM over SONET or Packet PPP over SONET) client signals with no payload awareness. Implementing PW capability allows the use of an existing technology to substitute the TDM transport with Packet-aware transport, using well-defined pseudowire encapsulation methods for carrying various packet services over MPLS, and providing for potentially better bandwidth utilization.

There are two types of pseudowires: (1) Single-Segment pseudowires (SS-PW), and (2) Multi-segment pseudowires (MS-PW). An MPLS-TP domain may transport a PW with endpoints within a client network transparently. Alternatively, an MPLS-TP edge...
node may be the Terminating PE (T-PE) for a PW, performing adaptation from the native attachment circuit technology (e.g. Ethernet 802.1q) to an MPLS PW for transport over an MPLS-TP domain, with a GMPLS LSP or a hierarchy of LSPs transporting the PW between the T-PEs. In this way, the PW is analogous to a transport channel in a TDM network and the LSP is equivalent to a container of multiple non-concatenated channels, albeit they are packet containers. The MPLS-TP domain may also contain Switching PEs (S-PEs) for a multi-segment PW whereby the T-PEs may be at the edge of the MPLS-TP domain or in a client network. In this latter case, a T-PE in a client network is a T-PE performing the adaptation of the native service to MPLS and the MPLS-TP domain performs Pseudo-wire switching.

SS-PW signaling control plane is based on LDP with specific procedures defined in [RFC4447]. [Segmented-PW] and [MS-PW] allow for static switching of multi-segment pseudowires in data and control plane and for dynamic routing and placement of an MS-PW whereby signaling is still based on Targeted LDP (T-LDP). The MPLS-TP domain shall use the same PW signaling protocols and procedures for placing SS-PWs and MS-PWs. This will leverage existing technology as well as facilitate interoperability with client networks with native attachment circuits or PW segment that is switched across the MPLS-TP domain.

The same control protocol and procedures are reused as much as possible. However, when using PWs in MPLS-TP, a set of new requirements are defined which may require extensions of the existing control mechanisms. This section identifies areas where extensions are needed based on the PW Control Plane related requirements documented in [draft-ietf-mpls-tp-requirements].

The baseline requirement for extensions to support transport applications is that any new mechanisms and capabilities must be able to interoperate with existing IETF MPLS [RFC3031] and IETF PWE3 [RFC3985] control and data planes where appropriate. Hence, extensions of the PW Control Plane must be in-line with the procedures defined in [RFC4447].

For MPLS-TP, it is required that the data and control planes are both logically and physically separated. That is, the PW Control Plane must be able to operate out-of-band (OOB). This ensures that in the case of control plane failures the data plane is not affected and can continue to operate normally. This was not a design requirement for the current PW Control Plane. However, due to the PW concept, i.e., PWs are connecting logical entities (‘forwarders’), and the operation of the PW control protocol, i.e., only edge PE nodes (T-PE, S-PE) take part in the signaling
exchanges: moving T-LDP out-of-band seems to be, theoretically, a straightforward exercise.

More precisely, if IP addressing is used in the MPLS-TP control plane then T-LDP addressing can be maintained, although all addresses will refer to control plane entities. Both, the PWid FEC and Generalized PWid FEC Elements can possibly be used in an OOB case as well (Detailed evaluation is FFS). The PW Label allocation and exchange mechanisms can be possibly reused unchanged (Detailed evaluation is FFS). Binding a PW to an LSP, or PW segments to LSPs can be left to networks elements acting as T-PEs and S-PEs or a control plane entity that may be the same one signaling the PW. If the control plane is physically separated from the forwarder, the control plane must be able to program the forwarders with necessary information.

For transport applications, it is mandatory that bidirectional traffic is following congruent paths. Today, each direction of a PW or a PW segment is bound to a unidirectional LSP that extends between two T-PEs, S-PEs, or a T-PE and an S-PE. The unidirectional LSPs in both directions are not required to following congruent paths, and therefore both directions of a PW may not follow congruent paths. The only requirement today is that a PW or a PW segment shares the same T-PEs in both directions, and same S-PEs in both directions. This poses a new requirement on the PW Control Plane, namely to ensure that both ends map the PW to the same transport path. When a bidirectional LSP is selected on one end to transport the PW, a mechanism is needed that signals to the remote end which LSP has been selected locally to transport the PW. This likely can be accomplished by adding a new TLV to PW signaling. This coincides with the gap identified for OOB support: a new mechanism may be needed to explicitly bind PWs to the supporting transport LSP.

Alternatively, two unidirectional LSPs may be used to support the PW. However, to meet the congruency requirement, the LSPs must be placed so that they are forced to follow the same path (switches and links). This maybe accomplished by placing one unidirectional TE-LSP in one direction at one endpoint, and forcing the other endpoint to setup a TE-LSP with an ERO that has the nodes/links in the reverse order from the RRO seen in the path message of the LSP in the reverse direction. In this case, when one endpoint selects an LSP to bind the PW to, it must identify to the remote end which LSP to bind the other direction of the PW to.

Transport applications require resource guarantees. In the case of transport LSPs, resource reservation mechanisms are provided via RSVP-TE and the use of DiffServ. If multiple PWs are
multiplexed into the same transport LSP resources, contention may occur. However, local policy at PEs may ensure proper resource sharing among PWs mapped into a resource guaranteed LSP. On the other hand, it is limited if any guarantees can be provided to PWs if the LSPs used to support MPLS-TP PWs do not support resource guarantees.

The PW control plane must be able to establish and configure all of the available features manageable for the PW, including protection and OAM entities and mechanisms. There is ongoing work on PW protection and MPLS-TP OAM.

To summarize, the main areas identified for potential PW Control Plane extensions to support MPLS-TP are the following.

- Move PW Control Plane out-of-band
- Explicit control of PW to LSP binding
- PW QoS and congestion control
- PW protection
- PW OAM configuration and control

4.1. General reuse of existing PW control plane mechanisms

4.2. Signaling

4.3. Recovery (Redundancy)

5. Security Considerations

[Editor’s note: This section is preliminary and will be edited/replaced in future versions.]

This document is a framework document and does not describe bits on the wire and have a very small impact on MPLS/GMPLS security issues. However it gives guidelines for future extension to existing MPLS and GMPLS protocols, it is understood that the documents that specify these extensions will address the security issues that relates to the extensions.

It is also understood that that the MPLS/GMPLS security framework [MPLS-SEC] is applicable to both this document and the documents that will be written as a result of the output of this document.
6. IANA Considerations

7. Acknowledgments

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).

The authors would like to acknowledge the contributions of Yannick Brehon to this work.

8. References

8.1. Normative References


8.2. Informative References


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