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Multiprotocol Label Switching Transport Profile (MPLS-TP) MIB-based Management Overview

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Abstract

A range of Management Information Base (MIB) modules has been developed to help model and manage the various aspects of Multiprotocol Label Switching (MPLS) networks. These MIB modules are defined in separate documents that focus on the specific areas of responsibility of the modules that they describe.

The MPLS Transport Profile (MPLS-TP) is a profile of MPLS functionality specific to the construction of packet-switched transport networks.

This document describes the MIB-based architecture for MPLS-TP, and indicates the interrelationships between different existing MIB modules that can be leveraged for MPLS-TP network management and identifies areas where additional MIB modules are required.

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Table of Contents

1. Introduction

The MPLS Transport Profile (MPLS-TP) is a packet transport technology based on a profile of the MPLS functionality specific to the construction of packet-switched transport networks. MPLS is described in [RFC3031] and requirements for MPLS-TP are specified in [RFC5654].

A range of Management Information Base (MIB) modules has been developed to help model and manage the various aspects of

Multiprotocol Label Switching (MPLS) networks. These MIB modules are defined in separate documents that focus on the specific areas of responsibility for the modules that they describe.

An MPLS-TP network can be operated via static provisioning of transport paths, Label Switched Paths (LSPs) and Pseudowires (PW). Or the elective use of a Generalized MPLS (GMPLS) control plane to support dynamic provisioning of transport paths, LSPs and PWs.

This document describes the MIB-based management architecture for MPLS, as extended for MPLS-TP. The document also indicates the interrelationships between existing MIB modules that should be leveraged for MPLS-TP network management and identifies areas where additional MIB modules are required.

Note that [RFC5951] does not specify a preferred management interface protocol to be used as the standard protocol for managing MPLS-TP networks.

1.1 MPLS-TP Management Function

The management of the MPLS-TP networks is separable from that of its client networks so that the same means of management can be used regardless of the client. The management function of MPLS-TP includes fault management, configuration management, performance monitoring, and security management.

The purpose of the management function is to provide control and monitoring of the MPLS transport profile protocol mechanisms and procedures. The requirements for the network management functionality are found in [RFC5951]. A description of the network and element management architectures that can be applied to the management of MPLS-based transport networks is found in [RFC5950].

2. Terminology

This document also uses terminology from the MPLS architecture document [RFC3031], PWE3 architecture [RFC4805], and the following MPLS related MIB modules: MPLS TC MIB [RFC3811], MPLS LSR MIB [RFC3813], MPLS TE MIB [RFC3812], MPLS LDP MIB [RFC3815], MPLS FTN MIB [RFC3814] and TE LINK MIB [RFC4220].

3. The SNMP Management Framework

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP).

Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI).

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to Section 7. of [RFC3410].

This document discusses MIB modules that are compliant to the SMIv2, which is described in [RFC2578], [RFC2579] and [RFC2580].

4. Overview of Existing Work

This section describes the existing tools and techniques for managing and modeling MPLS networks, devices, and protocols. It is intended to provide a description of the tool kit that is already available.

Section 5 of this document outlines the applicability of existing MPLS MIB modules to MPLS-TP, describes the optional use of GMPLS MIB modules in MPLS-TP networks, and examines the additional MIB modules and objects that would be required for managing an MPLS-TP network.

4.1. MPLS Management Overview and Requirements

[RFC4378] outlines how data plane protocols can assist in providing the Operations and Management (OAM) requirements outlined in [RFC4377] and how it is applied to the management functions of fault, configuration, accounting, performance, and security (commonly known as FCAPS) for MPLS networks.

[RFC4221] describes the management architecture for MPLS. In particular, it describes how the managed objects defined in various MPLS-related MIB modules model different aspects of MPLS, as well as the interactions and dependencies between each of these MIB modules.

[RFC4377] describes the requirements for user and data plane OAM and applications for MPLS.

[RFC5654] describes the requirements for the optional use of a control plane to support dynamic provisioning of MPLS-TP transport paths. The MPLS-TP LSP control plane is based on GMPLS and is described in [RFC3945].

4.2. An Introduction to the MPLS and Pseudowire MIB Modules

4.2.1. Structure of the MPLS MIB OID Tree

The MPLS MIB Object Identifiers (OID) tree has the following structure. It is based on the tree originally set out in section 4.1 of [RFC4221] and has been enhanced to include other relevant MIB modules.

```
    mib-2 -- RFC 2578 [RFC2578]
     |
     +-transmission
     |  |
     |  +- mplsStdMIB
     |  |    |
     |  |    +- mplsTCStdMIB -- MPLS-TC-STD-MIB [RFC3811]
     |  |    |
     |  |    +- mplsLsrStdMIB -- MPLS-LSR-STD-MIB [RFC3813]
     |  |    |
     |  |    +- mplsTeStdMIB -- MPLS-TE-STD-MIB [RFC3812]
     |  |    |
     |  |    +- mplsLdpStdMIB -- MPLS-LDP-STD-MIB [RFC3815]
     |  |    |
     |  |    +- mplsLdpGenericStdMIB
     |  |    |                -- MPLS-LDP-GENERIC-STD-MIB [RFC3815]
     |  |    |
     |  |    +- mplsFTNStdMIB -- MPLS-FTN-STD-MIB [RFC3814]
     |  |    |
     |  |    +- gmplsTCStdMIB -- GMPLS-TC-STD-MIB [RFC4801]
     |  |    |
     |  |    +- gmplsTeStdMIB -- GMPLS-TE-STD-MIB [RFC4802]
     |  |    |
     |  |    +- gmplsLsrStdMIB -- GMPLS-LSR-STD-MIB [RFC4803]
     |  |    |
     |  |    +- gmplsLabelStdMIB -- GMPLS-LABEL-STD-MIB [RFC4803]
     |  |
     |  +- teLinkStdMIB -- TE-LINK-STD-MIB [RFC4220]
     |  |
     |  +- pwStdMIB -- PW-STD-MIB [RFC5601]
     |
     +- ianaGmpls -- IANA-GMPLS-TC-MIB [RFC4802]
     |
     +- ianaPwe3MIB -- IANA-PWE3-MIB [RFC5601]
     |
     +- pwEnetStdMIB -- PW-ENET-STD-MIB [RFC5603]
     |
     +- pwMplsStdMIB -- PW-MPLS-STD-MIB [RFC5602]
     |
     +- pwTDMMIB -- PW-TDM-MIB [RFC5604]
     |
     +- pwTcStdMIB -- PW-TC-STD-MIB [RFC5542]
```

Note: The OIDs for MIB modules are assigned and managed by IANA. They can be found in the referenced MIB documents.

4.2.2. Textual Convention Modules

MPLS-TC-STD-MIB [RFC3811], GMPLS-TC-STD-MIB [RFC4801], IANA-GMPLS-TC-MIB [RFC4802] and PW-TC-STD-MIB [RFC5542] contains the Textual Conventions for MPLS and GMPLS networks. These Textual Conventions should be imported by MIB modules which manage MPLS and GMPLS networks. Section 4.2.11. highlights dependencies on additional external MIB modules

4.2.3. Label Switched Path (LSP) Modules

An LSP is a path over which a labeled packet travels across the sequence of LSRs for a given Forward Equivalence Class (FEC). When a packet, with or without label, arrives at an ingress LER of an LSP, it is encapsulated with the label corresponding to the FEC and sent across the LSP. The labeled packet traverses across the LSRs and arrives at the egress LER of the LSP, where, it gets forwarded depending on the packet type it came with. LSPs could be nested using label stacking, such that, an LSP could traverse over another LSP. A further description of an LSP can be found in [RFC3031].

MPLS-LSR-STD-MIB [RFC3813] describes the required objects to define the LSP.

4.2.4. Label Edge Router (LER) Modules

Ingress and Egress LSRs of an LSP are known as Label Edge Routers (LER). An ingress LER takes the incoming unlabeled or labeled packets and encapsulates it with the corresponding label of the LSP it represents, and forwards it, over to the adjacent LSR of the LSP. Each FEC is mapped to a label forwarding entry, so that packet could be encapsulated with one or more label entries, referred as label stack.

The packet traverses across the LSP, and upon reaching the Egress LER, further action will be taken to handle the packet, depending on the packet it received. MPLS Architecture [RFC3031] details the functionality of an Ingress and Egress LERs.

MPLS-FTN-STD-MIB [RFC3814] describes the managed objects for mapping FEC to label bindings.

4.2.5. Label Switching Router (LSR) Modules

A router which performs MPLS forwarding is known as an LSR. An LSR receives a labelled packet and performs forwarding action based on the label received.

LSR maintains a mapping of an incoming label and incoming interface to one or more outgoing label and outgoing interfaces in its forwarding database. When a labelled packet is received, LSR examines

the topmost label in the label stack and then does 'swap', 'push' or 'pop' operation based on the contents.

MPLS-LSR-STD-MIB [RFC3813] describes the managed objects for modeling a Multiprotocol Label Switching (MPLS) [RFC3031] LSR. MPLS-LSR-STD-MIB [RFC3813] contains the managed objects to maintain mapping of in-segments to out-segments.

4.2.6. Pseudowire Modules

The PW (Pseudowire) MIB architecture provides a layered modular model into which any supported emulated service such as Frame Relay, ATM, Ethernet, TDM and SONET/SDH can be connected to any supported Packet Switched Network (PSN) type. This MIB architecture is modeled based on PW3 architecture [RFC3985].

Emulated Service Layer, Generic PW Layer and PSN VC Layer constitute the different layers of the model. A combination of the MIB modules belonging to each layer provides the glue for mapping the emulated service onto the native PSN service. At least three MIB modules each belonging to a different layer are required to define a PW emulated service.

- Service-Specific module is dependent on the emulated signal type and helps in modeling emulated service layer.

PW-ENET-STD-MIB [RFC5603] describes a model for managing Ethernet pseudowire services for transmission over a PSN. This MIB module is generic and common to all types of PSNs supported in the Pseudowire Emulation Edge-to-Edge (PWE3) Architecture [RFC3985], which describes the transport and encapsulation of L1 and L2 services over supported PSN types.

In particular, the MIB module associates a port or specific VLANs on top of a physical Ethernet port or a virtual Ethernet interface (for Virtual Private LAN Service (VPLS)) to a point-to-point PW. It is complementary to the PW-STD-MIB [RFC5601], which manages the generic PW parameters common to all services, including all supported PSN types.

PW-TDM-MIB [RFC5604] describes a model for managing TDM pseudowires, i.e., TDM data encapsulated for transmission over a Packet Switched Network (PSN). The term TDM in this document is limited to the scope of Plesiochronous Digital Hierarchy (PDH). It is currently specified to carry any TDM Signals in either Structure Agnostic Transport mode (E1, T1, E3, and T3) or in Structure Aware Transport mode (E1, T1, and NxDS0) as defined in the Pseudowire Emulation Edge-to-Edge (PWE3) TDM Requirements document [RFC4197].

- Generic PW Module configures general parameters of the PW that are common to all types of emulated services and PSN types.

PW-STD-MIB [RFC5601] defines a MIB module that can be used to manage pseudowire (PW) services for transmission over a Packet Switched Network (PSN) [RFC3931] [RFC4447]. This MIB module provides generic management of PWs that is common to all types of PSN and PW services defined by the IETF PWE3 Working Group.

- PSN-specific module associate the PW with one or more "tunnels" that carry the service over the PSN. There is a different module for each type of PSN.

PW-MPLS-STD-MIB [RFC5602] describes a model for managing pseudowire services for transmission over different flavors of MPLS tunnels. The general PW MIB module [RFC5601] defines the parameters global to the PW regardless of the underlying Packet Switched Network (PSN) and emulated service. This document is applicable for PWs that use MPLS PSN type in the PW-STD-MIB. Additionally this document describes the MIB objects that define pseudowire association to the MPLS PSN, that is not specific to the carried service.

Together, [RFC3811], [RFC3812] and [RFC3813] describe the modeling of an MPLS tunnel, and a tunnel's underlying cross-connects. This MIB module supports MPLS-TE PSN, non-TE MPLS PSN (an outer tunnel created by the Label Distribution Protocol (LDP) or manually), and MPLS PW label only (no outer tunnel).

4.2.7. Routing and Traffic Engineering

In MPLS traffic engineering, it's possible to specify explicit routes or choose routes based on QOS metrics in setting up a path such that some specific data can be routed around network hot spots. TE LSPs can be setup through a management plane or a control plane.

MPLS-TE-STD-MIB [RFC3812] describes managed objects for modeling a Multiprotocol Label Switching (MPLS) [RFC3031] based traffic engineering. This MIB module should be used in conjunction with the companion document [RFC3813] for MPLS based traffic engineering configuration and management.

4.2.8. Resiliency

The purpose of MPLS resiliency is to ensure minimal interruption to traffic when the failure occurs within the system or network.

Various components of MPLS resiliency solutions are;

1) Graceful restart in LDP and RSVP-TE modules,

2) Make Before Break,
3) Protection Switching for LSPs,
4) Fast ReRoute for LSPs,
5) PW redundancy.

The below modules only support the SNMP based MIB management for MPLS resiliency.

MPLS Fast Reroute (FRR) is a restoration network resiliency mechanism used in MPLS TE to redirect the traffic onto the backup LSP's in 10s of milliseconds in case of link or node failure across the LSP.

MPLS-FRR-GENERAL-STD-MIB [draft-ietf-mpls-fastreroute-mib-14] contains objects that apply to any MPLS LSR implementing MPLS TE fast reroute functionality.

MPLS-FRR-ONE2ONE-STD-MIB [draft-ietf-mpls-fastreroute-mib-14] contains objects that apply to one-to-one backup method.
MPLS-FRR-FACILITY-STD-MIB [draft-ietf-mpls-fastreroute-mib-14] contains objects that apply to facility backup method.

Protection Switching mechanisms have been designed to provide network resiliency for MPLS network. Different types of protection switching mechanisms such as 1:1, 1:N, 1+1 have been designed.

4.2.9. Fault Management and Performance Management

MPLS manages the LSP and pseudowire faults through the use of LSP ping [RFC4379], VCCV [RFC5085], BFD for LSPs [RFC5884] and BFD for VCCV [RFC5885] tools.

Current MPLS focuses on the in and/or out packet counters, errored packets, discontinuity time.

Some of the MPLS and Pseudowire performance tables used for performance management are given below.

mplsTunnelPerfTable [RFC3812] provides several counters (packets forwarded, packets dropped because of errors) to measure the performance of the MPLS tunnels.

mplsInterfacePerfTable [RFC3813] provides performance information (incoming and outgoing labels in use and lookup failures) on a per-interface basis.

mplsInSegmentPerfTable [RFC3813] contains statistical information (total packets received by the insegment, total errored packets received, total packets discarded, discontinuity time) for incoming MPLS segments to an LSR.

mplsOutSegmentPerfTable [RFC3813] contains statistical information (total packets received, total errored packets received, total packets discarded, discontinuity time) for outgoing MPLS segments from an LSR.

mplsFTNPerfTable [RFC3814] contains performance information for the specified interface and an FTN entry mapped to this interface.

mplsLdpEntityStatsTable [RFC3815] and mplsLdpSessionStatsTable [RFC3815] contain statistical information (session attempts, errored packets, notifications) about an LDP entity.

pwPerfCurrentTable [RFC5601], pwPerfIntervalTable [RFC5601], pwPerf1DayIntervalTable [RFC5601] provides pseudowire performance information (in and/or out packets) based on time (current interval, preconfigured specific interval, 1day interval).

pwEnetStatsTable [RFC5603] contains statistical counters specific for Ethernet PW.

pwTDMPerfCurrentTable [RFC5604], pwTDMPerfIntervalTable [RFC5604] and pwTDMPerf1DayIntervalTable [RFC5604] contain statistical informations accumulated per 15-minute, 24 hour, 1 day respectively.

gmplsTunnelErrorTable [RFC4802] and gmplsTunnelReversePerfTable [RFC4802] provides information about performance errored packets and in/out packet counters.

4.2.10. MIB Module Interdependencies

This section provides an overview of the relationship between the MPLS MIB modules for managing MPLS networks. More details of these relationships are given below.

[RFC4221] mainly focuses on the MPLS MIB module interdependencies, this section also highlights the GMPLS and PW MIB modules interdependencies.

The relationship "A --> B" means A depends on B and that MIB module A uses an object, object identifier, or textual convention defined in MIB module B, or that MIB module A contains a pointer (index or RowPointer) to an object in MIB module B.

```
   +-------> MPLS-TC-STD-MIB <-----------------------------------------+
   ^            ^                                                      ^
   |            |                                                      |
   |         MPLS-LSR-STD-MIB <--------------------------------+       |
   |                                                           ^       |
   |                                                           |       |
   +<----------------------- MPLS-LDP-STD-MIB ---------------->+       |
   ^                                    ^                      ^       |
   |                                    |                      |       |
   +<-- MPLS-LDP-GENERIC-STD-MIB ------>+                      |       |
   ^                                                           |       |
   |                                                           |       |
   +<------ MPLS-FTN-STD-MIB --------------------------------->+       |
   ^                 |                                         ^       |
   |                 V                                         |       |
   +<------------- MPLS-TE-STD-MIB -->+----------------------->+       |
                                      ^  GMPLS-TC-STD-MIB ------------>+
                                      |    ^                           ^
                                      |    |                           |
                                  +---+    +<-- GMPLS-LABEL-STD-MIB -->+
                                  ^   ^    ^      ^                    ^
                                  |   |    |      |                    |
   +----> PW-TC-STD-MIB           |  GMPLS-LSR-STD-MIB --------------->+
   ^                              |      ^       ^                     ^
   |                              |      |       |                     |
   |   IANA-PWE3-MIB              |      |       | IANA-GMPLS-TC-MIB   |
   |         ^                    |      |       |    ^                |
   |         |                    |      |       |    |                |
   |         |                    +<--- GMPLS-TE-STD-MIB ------------->+
   |         |                    ^                                    ^
   +<--- PW-STD-MIB <------+      |                                    |
   ^                       ^      |                                    |
   |                       |      |                                    |
   +<--- PW-ENET-STD-MIB ->+      |                                    |
   ^                       ^      |                                    |
   |                       |      |                                    |
   |                       |      |                                    |
   +<---------------- PW-MPLS-STD-MIB -------------------------------->+
```

Thus:

- All the MPLS MIB modules depend on MPLS-TC-STD-MIB.

- All the GMPLS MIB modules depend on GMPLS-TC-STD-MIB.

- All the PW MIB modules depend on PW-TC-STD-MIB.

- MPLS-LDP-STD-MIB, MPLS-TE-STD-MIB, MPLS-FTN-STD-MIB,

GMPLS-LSR-STD-MIB, and PW-MPLS-STD-MIB contain references to
objects in MPLS-LSR-STD-MIB.

- MPLS-LDP-GENERIC-STD-MIB contains references to objects in MPLS-LDP-STD-MIB.

- MPLS-FTN-STD-MIB, PW-MPLS-STD-MIB, and GMPLS-TE-STD-MIB contain references to objects in MPLS-TE-STD-MIB.

- PW-MPLS-STD-MIB, and PW-ENET-STD-MIB contains references to objects in PW-STD-MIB.

- PW-STD-MIB contains references to objects in IANA-PWE3-MIB.

- GMPLS-TE-STD-MIB contains references to objects in IANA-GMPLS-TC-MIB.

- GMPLS-LSR-STD-MIB contains references to objects in GMPLS-LABEL-STD-MIB.

Note that there is a textual convention (MplsIndexType) defined in MPLS-LSR-STD-MIB that is imported by MPLS-LDP-STD-MIB.

4.2.11. Dependencies on External MIB Modules

With the exception of MPLS-TC-STD-MIB, all the MPLS MIB modules have dependencies on the Interfaces MIB [RFC2863]. MPLS-FTN-STD-MIB references IP-capable interfaces on which received traffic is to be classified using indexes in the Interface Table (ifTable) of IF-MIB [RFC2863]. The other MPLS MIB modules reference MPLS-capable interfaces in ifTable.

The Interfaces Group of IF-MIB [RFC2863] defines generic managed objects for managing interfaces. The MPLS MIB modules contain media-specific extensions to the Interfaces Group for managing MPLS interfaces.

The MPLS MIB modules assume the interpretation of the Interfaces Group to be in accordance with [RFC2863], which states that ifTable contains information on the managed resource's interfaces and that each sub-layer below the internetwork layer of a network interface is considered an interface. Thus, the MPLS interface is represented as an entry in ifTable.

The interrelation of entries in ifTable is defined by the Interfaces Stack Group defined in [RFC2863].

The MPLS MIB modules have dependencies with the TE-LINK-STD-MIB for maintaining the traffic engineering information.

The MPLS MIB modules depend on the constrained shortest path first (CSPF) module to obtain the path required for an MPLS tunnel to reach

the end point of the tunnel and Bidirectional Forwarding Detection (BFD) module to verify the data-plane failures of LSPs and PWs.

Finally, all of the MIB modules import standard textual conventions such as integers, strings, timestamps, etc., from the MIB modules in which they are defined.

5. Applicability of MPLS MIB modules to MPLS-TP

This section highlights gaps in existing MPLS MIB modules in order to determine extensions or additional MIB modules that are required to support MPLS-TP in MPLS networks

[RFC5951] specifies the requirements for the management of equipment used in networks supporting an MPLS-TP. It also details the essential network management capabilities for operating networks consisting of MPLS-TP equipment.

[RFC5950] provides the network management framework for MPLS-TP. The document explains how network elements and networks that support MPLS-TP can be managed using solutions that satisfy the requirements defined in [RFC5951]. The relationship between MPLS-TP management and OAM is described in the MPLS-TP framework [RFC5950] document.

The MPLS MIB modules MPLS-TE-STD-MIB [RFC3812], PW-STD-MIB [RFC5601] and MPLS-LSR-STD-MIB [RFC3813] and their associated MIB modules are reused for MPLS based transport network management.

Fault management and performance management form key parts of the Operations, Administration, and Maintenance (OAM) function. MPLS-TP OAM is described in [MPLS-TP-OAM-FWK].

5.1 MPLS-TP Tunnel

5.1.1 Gap Analysis

MPLS-TP tunnel can be operated over IP and/or ITU-T Carrier Code (ICC) environments, below points capture the gaps in existing MPLS MIB modules for managing the MPLS-TP networks.

- IP based environment
   i. MPLS-TE-STD-MIB [RFC3812] does not support tunnel Ingress/Egress identifier based on Global_ID and Node_ID [RFC6370].
   ii. MPLS-TE-STD-MIB [RFC3812] does not support co-routed/associated bidirectional tunnel configurations.

- ICC based environment
   i. MPLS-TE-STD-MIB [RFC3812] does not support tunnel LSR identifier based on ICC.

5.1.2 Recommendations

- New MIB definitions may be created for Global_Node_ID and/or ICC configurations.

- MPLS-LSR-STD-MIB [RFC3813] MIB modules may be enhanced to identify the nexthop based on MAC address for IP-less environments. OutSegment may be extended to hold the MAC-address also for IP-less environments.

- MPLS-TE-STD-MIB [RFC3812] and MPLS-LSR-STD-MIB may be enhanced to provide static and signalling MIB module extensions for co-routed/associated bidirectional LSPs.

5.2 MPLS-TP Pseudowire

5.2.1 Gap Analysis

MPLS-TP Pseudowire can be operated over IP and/or ICC environments, below points capture the gaps in existing PW MIB modules for managing the MPLS-TP networks.

[RFC6370] specifies an initial set of identifiers to be used in MPLS-TP. These identifiers were chosen to be compatible with existing MPLS, GMPLS, and PW definitions.

- IP based environment
  - i. PW-STD-MIB [RFC5601] does not support PW end point identifier based on Global_ID and Node_ID.
  - ii. PW-MPLS-STD-MIB [RFC5602] does not support its operation over co-routed/associated bidirectional tunnels.

- ICC based environment
  - i. PW-STD-MIB [RFC5601] does not support PW end point identifier based on ICC.

5.2.2 Recommendations

- PW-MPLS-STD-MIB [RFC5602] can be enhanced to operate over co-routed/associated bi-directional tunnel.

5.3 MPLS-TP Sections

5.3.1 Gap Analysis

The existing MPLS MIB modules does not support MPLS-TP sections.

5.3.2 Recommendations

Link specific and/or path/segment specific sections can be achieved by enhancing the IF-MIB [RFC2863], MPLS-TE-STD-MIB [RFC3812] and PW-STD-MIB [RFC5601] MIB modules.

5.4 MPLS-TP OAM

5.4.1 Gap Analysis

MPLS manages the LSP and pseudowire faults through LSP ping [RFC4379], VCCV [RFC5085], BFD for LSPs [RFC5884] and BFD for VCCV [RFC5885] tools.

The MPLS MIB modules do not support the below MPLS-TP OAM functions:

- o Continuity Check and Connectivity Verification
- o Remote Defect Indication
- o Alarm Reporting
- o Lock Reporting
- o Lock Instruct
- o Client Failure Indication
- o Packet Loss Measurement
- o Packet Delay Measurement

5.4.2 Recommendations

New MIB module for BFD can be created to address all the gaps mentioned in Section 5.4.1. (Gap Analysis).

5.5 MPLS-TP Protection Switching and Recovery

5.5.1 Gap Analysis

An important aspect that MPLS-TP technology provides is protection switching. In general, the mechanism of protection switching can be described as the substitution of a protection or standby facility for a working or primary facility.

The MPLS MIB modules do not provide support for protection switching and recovery of three different topologies (linear, ring and mesh) available.

5.5.2 Recommendations

New MIB modules can be created to address all the gaps mentioned in the 5.5.1 Gap Analysis section.

5.6 MPLS-TP Interfaces

5.6.1 Gap Analysis

As per [RFC6370], an LSR requires identification of the node itself and of its interfaces. An interface is the attachment point to a server layer MPLS-TP section or MPLS-TP tunnel.

The MPLS MIB modules do not provide support for configuring the interfaces within the context of an operator.

5.6.2 Recommendations

New MIB definitions can be created to address the gaps mentioned in the 5.6.1 Gap Analysis section.

6. An Introduction to the MPLS-TP MIB Modules

This section highlights MIB modules that have been identified as being required for MPLS-TP. This section also provides an overview of the following:

- the MPLS Object Identifier (OID) tree structure and the position of different MPLS related MIB modules on this tree;

- the purpose of each of the MIB modules within the MIB documents, what it can be used for, and how it relates to the other MIB modules.

Note that each new MIB module (apart from Textual Conventions modules) will contain one or more Compliance Statements to indicate which objects must be supported in what manner to claim a specific level of compliance. Additional text, either in the documents that define the MIB modules or in separate Applicability Statements, will define which Compliance Statements need to be conformed to in order to provide specific MPLS-TP function. This document does not set any requirements in that respect although some recommendations are included in the sections that follow.

6.1 MPLS-TP MIB Modules

6.1.1 Structure of the MPLS-TP MIB OID Tree

The MPLS-TP MIB OID tree as proposed in [MPLS-TP-TE-MIB] has the following structure:

```
      transmission -- RFC 2578 [RFC2578]
        |
        +- mplsStdMIB
             |
             +- Textual Conventions for MPLS-TP
             |
             +- Identifiers for MPLS-TP
             |
             +- LSR MIB Extensions for MPLS-TP
             |
             +- TE MIB Extensions for MPLS-TP
```

Note that the MIB modules described above are applicable for MPLS operations as well.

Note: The OIDs for MIB modules are yet to be assigned and managed by IANA.

6.1.2 Textual Conventions for MPLS-TP

A new MIB module needs to be written that will define textual conventions [RFC2579] for MPLS-TP related MIB modules. These conventions allow multiple MIB modules to use the same syntax and format for a concept that is shared between the MIB modules.

For example, MEP identifier is used to identify maintenance entity group end point within MPLS-TP networks. The textual convention representing the MEP identifier should be defined in a new textual convention MIB module.

All new extensions related to MPLS-TP are defined in the MIB module and will be referenced by other MIB modules to support MPLS-TP.

6.1.3 Identifiers for MPLS-TP

New Identifiers describe managed objects that are used to model common MPLS-TP identifiers [RFC6370].

6.1.4 LSR MIB Extensions for MPLS-TP

MPLS-LSR-STD-MIB describes managed objects for modeling an MPLS Label Switching Router (LSR). This puts it at the heart of the management architecture for MPLS.

In the case of MPLS-TP, the MPLS-LSR-STD-MIB is extended to support the MPLS-TP LSP's, which are co-routed or associated bidirectional. This extended MIB is also applicable for modeling MPLS-TP tunnels.

6.1.5 Tunnel Extensions for MPLS-TP

MPLS-TE-STD-MIB describes managed objects that are used to model and manage MPLS Traffic Engineered (TE) Tunnels.

MPLS-TP tunnels are very similar to MPLS-TE tunnels, but are co-routed or associated bidirectionally.

The MPLS-TE-STD-MIB must be extended to support the MPLS-TP specific attributes for the tunnel.

6.2 PWE3 MIB Modules for MPLS-TP

This section provides an overview of Pseudowire extension MIB modules to meet the MPLS based transport network requirements.

6.2.1 Structure of the PWE3 MIB OID Tree for MPLS-TP

```
 mib-2 -- RFC 2578 [RFC2578]
  |
  +-transmission
  |  |
  |  +- Pseudowire Extensions for MPLS-TP
  |
  +- Pseudowire MPLS Extensions for MPLS-TP
  |
  +- Pseudowire Textual Conventions for MPLS-TP
```

Note: The OIDs for MIB modules are yet to be assigned and managed by IANA.

6.2.2 Pseudowire Textual Conventions for MPLS-TP

PW-TC-STD-MIB MIB defines textual conventions used for pseudowire (PW) technology and for Pseudowire Edge-to-Edge Emulation (PWE3) MIB Modules. A new textual convention MIB module is required to define textual definitions for MPLS-TP specific Pseudowire attributes.

6.2.3 Pseudowire Extensions for MPLS-TP

PW-STD-MIB describes managed objects for modeling of Pseudowire Edge-to-Edge services carried over a general Packet Switched Network. This MIB module is extended to support MPLS-TP specific attributes related to Pseudowires.

6.2.4 Pseudowire MPLS Extensions for MPLS-TP

PW-MPLS-STD-MIB defines the managed objects for Pseudowire operations over MPLS LSR's. This MIB supports both, manual and dynamically signaled PW's, point-to-point connections, enables the use of any emulated service, MPLS-TE as outer tunnel and no outer tunnel as MPLS-TE.

The newly extended MIB defines the managed objects, extending PW-MPLS-STD-MIB, by supporting with or without MPLS-TP as outer tunnel.

6.3 OAM MIB Modules for MPLS-TP

This section provides an overview of Operations, Administration, and Maintenance (OAM) MIB modules for MPLS LSPs and Pseudowires.

6.3.1 Structure of the OAM MIB OID Tree for MPLS-TP

```
mib-2 -- RFC 2578 [RFC2578]
   |
   +-transmission
      |
      +- BFD MIB module
      |
      +- OAM MIB module
```

Note: The OIDs for MIB modules are yet to be assigned and managed by IANA.

6.3.2 BFD MIB module

BFD-STD-MIB defines managed objects for performing BFD operation in IP networks. This MIB is modeled to support BFD protocol [RFC5880]. A new MIB module needs to be written that will be an extension to BFD-STD-MIB managed objects to support BFD operations on MPLS LSPs and PWs.

6.3.3 Common OAM MIB modules

A new MIB module needs to be written that will define managed objects for OAM maintenance identifiers i.e. Maintenance Entity Group Identifiers (MEG), Maintenance Entity Group End-point (MEP), Maintenance Entity Group Intermediate Point (MIP). Maintenance points are uniquely associated with a MEG. Within the context of a MEG, MEPs and MIPs must be uniquely identified.

6.4. Protection Switching and Recovery MIB Modules for MPLS-TP

This section provides an overview of protection switching and recovery MIB modules for MPLS LSPs and Pseudowires.

6.4.1 Structure of the MPLS Protection Switching and Recovery MIB OID Tree for MPLS-TP

```
    mib-2 -- RFC 2578 [RFC2578]
     |
     +-transmission
        |
        +- Linear Protection Switching MIB module
        |
        +- Ring Protection Switching MIB module
        |
        +- Mesh Protection Switching MIB module
```

Note: The OIDs for MIB modules are yet to be assigned and managed by IANA.

6.4.2 Linear Protection Switching MIB module

A new MIB module needs to be written that will define managed objects for linear protection switching of MPLS LSPs and Pseudowires.

6.4.3 Ring Protection Switching MIB module

A new MIB module will define managed objects for ring protection switching of MPLS LSPs and Pseudowires.

6.4.4 Mesh Protection Switching MIB module

A new MIB module needs to be written that will define managed objects for Mesh protection switching of MPLS LSPs and Pseudowires.

7. Management Options

This document applies only to scenarios where MIB modules are used to manage the MPLS-TP network. It is not the intention of this document to provide instructions or advice to implementers of management systems, management agents, or managed entities. It is, however, useful to make some observations about how the MIB modules described above might be used to manage MPLS systems, if SNMP is used in the management interface.

For MPLS specific management options, refer to [RFC4221] Section 12. (Management Options).

8. Security Considerations

This document describes the interrelationships amongst the different MIB modules relevant to MPLS-TP management and as such does not have any security implications in and of itself.

Each IETF MIB document that specifies MIB objects for MPLS-TP must provide a proper security considerations section that explains the security aspects of those objects.

The attention of readers is particularly drawn to the security implications of making MIB objects available for create or write access through an access protocol such as SNMP. SNMPv1 by itself is an insecure environment. Even if the network itself is made secure (for example, by using IPSec), there is no control over who on the secure network is allowed to access the objects in this MIB. It is recommended that the implementers consider the security features as provided by the SNMPv3 framework. Specifically, the use of the User-based Security Model STD 62, RFC3414 [RFC3414], and the View-based Access Control Model STD 62, RFC 3415 [RFC3415], is recommended.

It is then a customer/user responsibility to ensure that the SNMP entity giving access to an instance of each MIB module is properly configured to give access to only those objects, and to those principals (users) that have legitimate rights to access them.

9. IANA Considerations

This document has identified areas where additional MIB modules are neccessary for MPLS-TP. The new MIB modules recommended by this document will require OID assignments from IANA. However, this document makes no specific request for IANA action.

10. Acknowledgements

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