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

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,
   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.

Status of This Memo

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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 (PWs),
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], Pseudowire Emulation Edge-to-Edge (PWE3)
architecture [RFC3985], and the following MPLS-related MIB modules:
the MPLS-TC-STD-MIB [RFC3811], MPLS-LSR-STD-MIB [RFC3813],
MPLS-TE-STD-MIB [RFC3812], MPLS-LDP-STD-MIB [RFC3815],
MPLS-FTN-STD-MIB [RFC3814], and TE-LINK-STD-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, Administration, and Maintenance (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 Identifier (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

   The MPLS-TC-STD-MIB [RFC3811], GMPLS-TC-STD-MIB [RFC4801],
   IANA-GMPLS-TC-MIB [RFC4802], and PW-TC-STD-MIB [RFC5542] contain the
   Textual Conventions for MPLS and GMPLS networks. These Textual
   Conventions should be imported by MIB modules that 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 Label Switching Routers (LSRs) for a given Forward
   Equivalence Class (FEC). When a packet, with or without a label,
   arrives at an ingress Label Edge Router (LER) of an LSP, it is
   encapsulated with the label corresponding to the FEC and sent across
   the LSP. The labeled packet traverses 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 another LSP. A more detailed
   description of an LSP can be found in [RFC3031].

   The MPLS-LSR-STD-MIB [RFC3813] describes the objects required 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
   (LERs). An ingress LER takes each incoming unlabeled or labeled
   packet and encapsulates it with the corresponding label of the LSP it
   represents, and then forwards it to the adjacent LSR of the LSP.
   Each FEC is mapped to a label-forwarding entry, so that a packet
   could be encapsulated with one or more label entries; this is
   referred to as a label stack.

   The packet traverses the LSP. Upon reaching the egress LER, further
   action will be taken to handle the packet, depending on the type of
   packet received. MPLS Architecture [RFC3031] details the
   functionality of ingress and egress LERs.

   The 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 that performs MPLS forwarding is known as an LSR. An LSR
   receives a labeled packet and performs forwarding action based on the
   label received.

   The LSR maintains a mapping of an incoming label and incoming
   interface to one or more outgoing labels and outgoing interfaces in
   its forwarding database. When a labeled packet is received, the LSR
   examines the topmost label in the label stack and then does a 'swap',
   'push', or 'pop' operation based on the contents.

   The MPLS-LSR-STD-MIB [RFC3813] describes the managed objects for
   modeling an MPLS [RFC3031] LSR. The MPLS-LSR-STD-MIB [RFC3813]
   contains the managed objects to maintain mapping of in-segments to
   out-segments.

4.2.6. Pseudowire Modules

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

   The emulated service layer, generic PW layer, and PSN Virtual Circuit
   (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.

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

   The 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 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
   the 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.

The PW-TDM-MIB [RFC5604] describes a model for managing TDM
pseudowires, i.e., TDM data encapsulated for transmission over a 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 Structure Aware Transport mode (E1, T1, and
NxDS0) as defined in the PWE3 TDM Requirements document [RFC4197].

- The generic PW module configures general parameters of the PW that
   are common to all types of emulated services and PSN types.

The PW-STD-MIB [RFC5601] defines a MIB module that can be used to
manage PW services for transmission over a 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.

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

The PW-MPLS-STD-MIB [RFC5602] describes a model for managing
pseudowire services for transmission over different flavors of MPLS
tunnels. The generic PW MIB module [RFC5601] defines the parameters
global to the PW, regardless of the underlying PSN and emulated
service. This document is applicable for PWs that use the 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 Traffic Engineering (MPLS-TE) PSNs, non-TE MPLS
PSNs (an outer tunnel created by the Label Distribution Protocol
(LDP) or manually), and MPLS PW labels 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 set up through a management plane or a control plane.

The MPLS-TE-STD-MIB [RFC3812] describes managed objects for modeling
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 a failure occurs within the system or network.

   Various components of MPLS resiliency solutions are as follows:

      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 MIB modules below only support MIB-based management for MPLS
   resiliency.

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

   The MPLS-FRR-GENERAL-STD-MIB [RFC6445] contains objects that apply to
   any MPLS LSR implementing MPLS TE fast-reroute functionality.

   The MPLS-FRR-ONE2ONE-STD-MIB [RFC6445] contains objects that apply to
   the one-to-one backup method.

   The MPLS-FRR-FACILITY-STD-MIB [RFC6445] contains objects that apply
   to the facility backup method.

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

4.2.9. Fault Management and Performance Management

   MPLS manages LSP and pseudowire faults through the use of LSP ping
   [RFC4379], Virtual Circuit Connectivity Verification (VCCV)
   [RFC5085], Bidirectional Forwarding Detection (BFD) for LSPs
   [RFC5884], and BFD for VCCV [RFC5885] tools.

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

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

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

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

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

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

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

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

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

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

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

The gmplsTunnelErrorTable [RFC4802] and gmplsTunnelReversePerfTable
[RFC4802] provide 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 MPLS MIB module interdependencies. This
   section also highlights GMPLS and PW MIB module interdependencies.

   The relationship "A --> B" means that 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 the MPLS-TC-STD-MIB.

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

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

   - The 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 the MPLS-LSR-STD-MIB.

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

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

   - The PW-MPLS-STD-MIB and PW-ENET-STD-MIB contain references to
      objects in the PW-STD-MIB.

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

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

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

   Note that there is a Textual Convention (MplsIndexType) defined in
   the MPLS-LSR-STD-MIB that is imported by the MPLS-LDP-STD-MIB.

4.2.11. Dependencies on External MIB Modules

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

   The 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 the
   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 the ifTable.

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

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

The MPLS MIB modules depend on the Constrained Shortest Path First
(CSPF) component to obtain the path required for an MPLS tunnel to
reach the end point of the tunnel, and on the BFD component to verify
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 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 document [RFC5950].

The MPLS MIB documents 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 OAM
function. MPLS-TP OAM is described in [RFC6371].

5.1. MPLS-TP Tunnel

5.1.1. Gap Analysis

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

   - IP-based environment

      i. The MPLS-TE-STD-MIB [RFC3812] does not support the tunnel
         Ingress/Egress identifier based on Global_ID and Node_ID
         [RFC6370].

      ii. The MPLS-TE-STD-MIB [RFC3812] does not support
          co-routed/associated bidirectional tunnel configurations.

   - ICC-based environment

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

5.1.2. Recommendations

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

   - The MPLS-LSR-STD-MIB [RFC3813] module may be enhanced to identify
      the next hop based on a Media Access Control (MAC) address for
      environments that do not use IP. The mplsOutSegmentTable may be
      extended to hold the MAC address.

   - The MPLS-TE-STD-MIB [RFC3812] and MPLS-LSR-STD-MIB may be enhanced
      to provide static and signaling 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.
   The points below capture the gaps in existing PW MIB modules for
   managing 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. The PW-STD-MIB [RFC5601] does not support the PW end point
            identifier based on Global_ID and Node_ID.

         ii. The PW-MPLS-STD-MIB [RFC5602] does not support operation over
             co-routed/associated bidirectional tunnels.

     - ICC-based environment

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

5.2.2. Recommendations

     - The PW-MPLS-STD-MIB [RFC5602] can be enhanced to operate over
        co-routed/associated bidirectional tunnels.

5.3. MPLS-TP Sections

5.3.1. Gap Analysis

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

5.3.2. Recommendations

   Link-specific and/or path/segment-specific sections can be supported
   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 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 following 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.

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 in the following three topologies: linear, ring, and
   mesh.

5.5.2. Recommendations

   New MIB modules can be created to address all the gaps mentioned in
   Section 5.5.1.

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
   Section 5.6.1.

6. An Introduction to the MPLS-TP MIB Modules

   This section highlights new MIB modules that have been identified as
   being required for MPLS-TP. This section also provides an overview
   of the purpose of each MIB module 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 functionality. 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. New MIB Modules for MPLS-TP

   Four new MIB modules are identified as follows:

   - Textual Conventions for MPLS-TP

   - Identifiers for MPLS-TP

   - LSR MIB Extensions for MPLS-TP

   - Tunnel Extensions for MPLS-TP

   Note that the MIB modules mentioned here are applicable for MPLS
   operations as well.

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 to provide a concept that is shared between the MIB modules.

   For example, a Maintenance Entity Group End Point (MEP) identifier is
   used to identify a 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

   The MPLS-LSR-STD-MIB describes managed objects for modeling an MPLS
   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
   MPLS-TP LSPs, which are co-routed or associated bidirectionally.
   This extended MIB is also applicable for modeling MPLS-TP tunnels.

6.1.5. Tunnel Extensions for MPLS-TP

   The MPLS-TE-STD-MIB describes managed objects that are used to model
   and manage MPLS-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
   used to meet MPLS-based transport network requirements.

6.2.1. New MIB Modules for MPLS-TP Pseudowires

   Three new MIB modules are identified as follows:

   - Pseudowire Textual Conventions for MPLS-TP

   - Pseudowire Extensions for MPLS-TP

   - Pseudowire MPLS Extensions for MPLS-TP

6.2.2. Pseudowire Textual Conventions for MPLS-TP

   The PW-TC-STD-MIB defines Textual Conventions used for PW technology
   and for 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

   The PW-STD-MIB describes managed objects for the modeling of
   pseudowire edge-to-edge services carried over a general PSN. This
   MIB module is extended to support MPLS-TP-specific attributes related
   to pseudowires.

6.2.4. Pseudowire MPLS Extensions for MPLS-TP

   The PW-MPLS-STD-MIB defines the managed objects for pseudowire
   operations over MPLS LSRs. This MIB module supports

   - manually and dynamically signaled PWs

   - point-to-point connections

   - the use of any emulated service

   - outer tunnels provisioned using MPLS-TE

   - PWs with no outer tunnel

   An extended MIB module would define additional objects, extending the
   PW-MPLS-STD-MIB by continuing to support configurations that operate
   with or without an 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. New MIB Modules for OAM for MPLS-TP

   Two new MIB modules are identified as follows:

   - BFD MIB module

   - OAM MIB module

6.3.2. BFD MIB Module

   The BFD-STD-MIB defines managed objects for performing BFD operations
   in IP networks. This MIB module is modeled to support the 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. OAM MIB Module

   A new MIB module needs to be written that will define managed objects
   for OAM maintenance identifiers, i.e., Maintenance Entity Group (MEG)
   identifiers, the MEP, and the 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. New MIB Modules for MPLS Protection Switching and Recovery

   Three new MIB modules are identified as follows:

   - Linear Protection Switching MIB module

   - Ring Protection Switching MIB module

   - Mesh Protection Switching MIB module

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 needs to be written that 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 the MIB module.
   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, RFC 3414 [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
   necessary 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.

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