

Internet Engineering Task Force (IETF)
Request for Comments: 6639
Category: Informational
ISSN: 2070-1721

D. King, Ed.
Old Dog Consulting
M. Venkatesan, Ed.
Aricent
June 2012

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

This document is not an Internet Standards Track specification; it is published for informational purposes.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Not all documents approved by the IESG are a candidate for any level of Internet Standard; see Section 2 of RFC 5741.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <http://www.rfc-editor.org/info/rfc6639>.

Copyright Notice

Copyright (c) 2012 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction	4
1.1. MPLS-TP Management Function	5
2. Terminology	5
3. The SNMP Management Framework	5
4. Overview of Existing Work	6
4.1. MPLS Management Overview and Requirements	6
4.2. An Introduction to the MPLS and Pseudowire MIB Modules	6
4.2.1. Structure of the MPLS MIB OID Tree	6
4.2.2. Textual Convention Modules	8
4.2.3. Label Switched Path (LSP) Modules	8
4.2.4. Label Edge Router (LER) Modules	8
4.2.5. Label Switching Router (LSR) Modules	9
4.2.6. Pseudowire Modules	9
4.2.7. Routing and Traffic Engineering	10
4.2.8. Resiliency	11
4.2.9. Fault Management and Performance Management	11
4.2.10. MIB Module Interdependencies	13
4.2.11. Dependencies on External MIB Modules	15
5. Applicability of MPLS MIB Modules to MPLS-TP	16
5.1. MPLS-TP Tunnel	17
5.1.1. Gap Analysis	17
5.1.2. Recommendations	17
5.2. MPLS-TP Pseudowire	17
5.2.1. Gap Analysis	17
5.2.2. Recommendations	18
5.3. MPLS-TP Sections	18
5.3.1. Gap Analysis	18
5.3.2. Recommendations	18
5.4. MPLS-TP OAM	18
5.4.1. Gap Analysis	18
5.4.2. Recommendations	19
5.5. MPLS-TP Protection Switching and Recovery	19
5.5.1. Gap Analysis	19
5.5.2. Recommendations	19
5.6. MPLS-TP Interfaces	19
5.6.1. Gap Analysis	19
5.6.2. Recommendations	19

6. An Introduction to the MPLS-TP MIB Modules	20
6.1. MPLS-TP MIB Modules	20
6.1.1. New MIB Modules for MPLS-TP	20
6.1.2. Textual Conventions for MPLS-TP	20
6.1.3. Identifiers for MPLS-TP	21
6.1.4. LSR MIB Extensions for MPLS-TP	21
6.1.5. Tunnel Extensions for MPLS-TP	21
6.2. PWE3 MIB Modules for MPLS-TP	21
6.2.1. New MIB Modules for MPLS-TP Pseudowires	21
6.2.2. Pseudowire Textual Conventions for MPLS-TP	21
6.2.3. Pseudowire Extensions for MPLS-TP	22
6.2.4. Pseudowire MPLS Extensions for MPLS-TP	22
6.3. OAM MIB Modules for MPLS-TP	22
6.3.1. New MIB Modules for OAM for MPLS-TP	22
6.3.2. BFD MIB Module	22
6.3.3. OAM MIB Module	23
6.4. Protection Switching and Recovery MIB Modules for MPLS-TP ..	23
6.4.1. New MIB Modules for MPLS Protection Switching and Recovery	23
6.4.2. Linear Protection Switching MIB Module	23
6.4.3. Ring Protection Switching MIB Module	23
6.4.4. Mesh Protection Switching MIB Module	23
7. Management Options	23
8. Security Considerations	24
9. IANA Considerations	24
10. Acknowledgements	24
11. Contributors' Addresses	25
12. References	26
12.1. Normative References	26
12.2. Informative References	27

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]
|
|-- pwTDMIB -- 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.

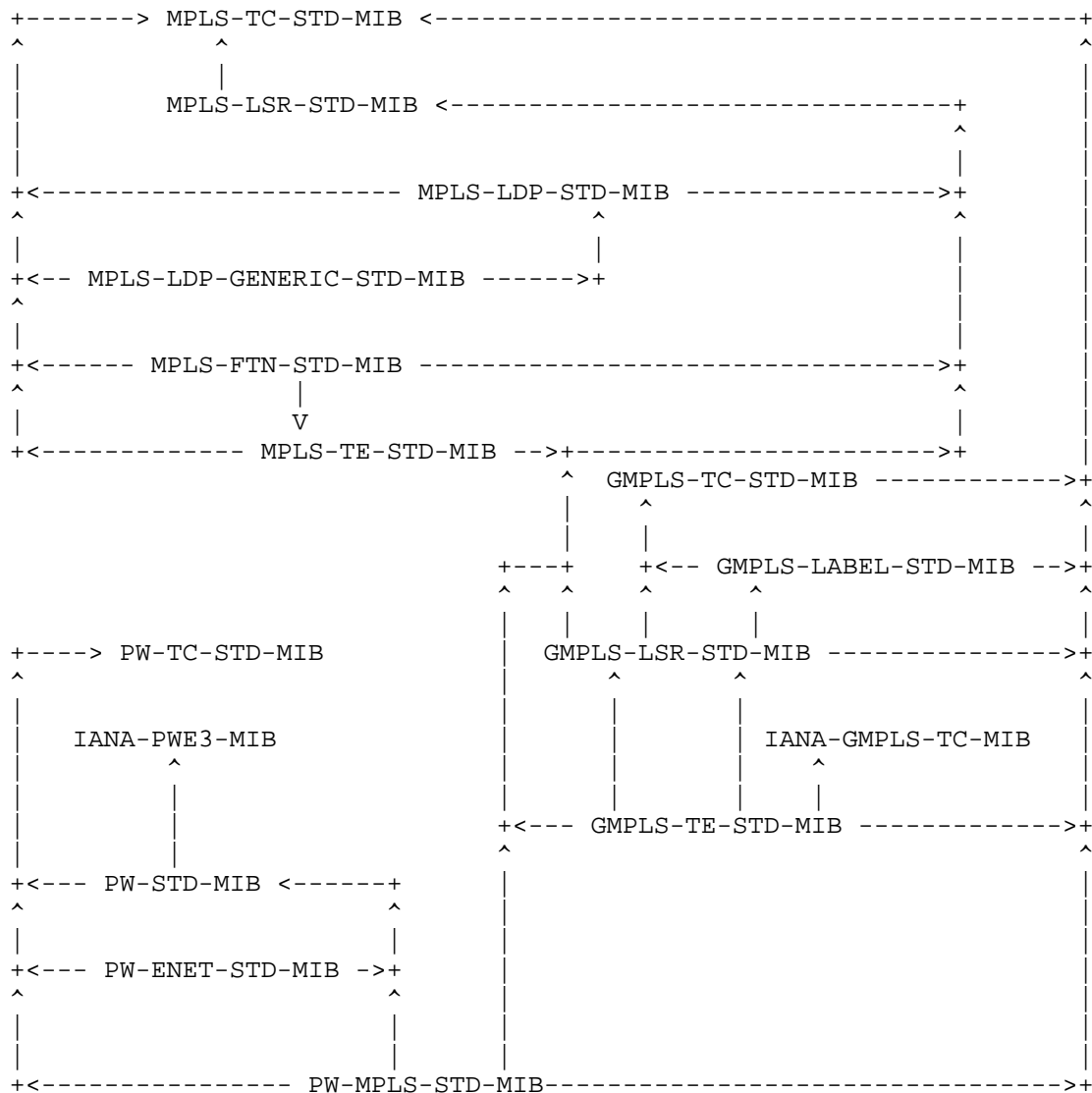
The `gmplsTunnelErrorTable` [RFC4802] and `gmplsTunnelReversePerfTable` [RFC4802] provide information about performance, errored packets, and in/out packet counters.

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.



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.

10. Acknowledgements

The authors would like to thank Eric Gray, Thomas Nadeau, Benjamin Niven-Jenkins, Saravanan Narasimhan, Joel Halpern, David Harrington, and Stephen Farrell for their valuable comments.

This document also benefited from review by participants in ITU-T Study Group 15.

11. Contributors' Addresses

Adrian Farrel
Old Dog Consulting
UK

EMail: adrian@olddog.co.uk

Scott Mansfield
Ericsson
300 Holger Way
San Jose, CA 95134
US

Phone: +1 724 931 9316
EMail: scott.mansfield@ericsson.com

Jeong-dong Ryoo
ETRI
161 Gajeong, Yuseong
Daejeon, 305-700
South Korea

Phone: +82 42 860 5384
EMail: ryoo@etri.re.kr

A S Kiran Koushik
Cisco Systems Inc.

EMail: kkoushik@cisco.com

A. Karmakar
Cisco Systems Inc.

EMail: akarmaka@cisco.com

Sam Aldrin
Huawei Technologies Co.
2330 Central Expressway
Santa Clara, CA 95051
USA

EMail: aldrin.ietf@gmail.com

12. References

12.1. Normative References

- [RFC2863] McCloghrie, K. and F. Kastenholz, "The Interfaces Group MIB", RFC 2863, June 2000.
- [RFC3811] Nadeau, T., Ed., and J. Cucchiara, Ed., "Definitions of Textual Conventions (TCs) for Multiprotocol Label Switching (MPLS) Management", RFC 3811, June 2004.
- [RFC3812] Srinivasan, C., Viswanathan, A., and T. Nadeau, "Multiprotocol Label Switching (MPLS) Traffic Engineering (TE) Management Information Base (MIB)", RFC 3812, June 2004.
- [RFC3813] Srinivasan, C., Viswanathan, A., and T. Nadeau, "Multiprotocol Label Switching (MPLS) Label Switching Router (LSR) Management Information Base (MIB)", RFC 3813, June 2004.
- [RFC3814] Nadeau, T., Srinivasan, C., and A. Viswanathan, "Multiprotocol Label Switching (MPLS) Forwarding Equivalence Class To Next Hop Label Forwarding Entry (FEC-To-NHLFE) Management Information Base (MIB)", RFC 3814, June 2004.
- [RFC3815] Cucchiara, J., Sjostrand, H., and J. Luciani, "Definitions of Managed Objects for the Multiprotocol Label Switching (MPLS), Label Distribution Protocol (LDP)", RFC 3815, June 2004.
- [RFC4220] Dubuc, M., Nadeau, T., and J. Lang, "Traffic Engineering Link Management Information Base", RFC 4220, November 2005.
- [RFC4221] Nadeau, T., Srinivasan, C., and A. Farrel, "Multiprotocol Label Switching (MPLS) Management Overview", RFC 4221, November 2005.
- [RFC4801] Nadeau, T., Ed., and A. Farrel, Ed., "Definitions of Textual Conventions for Generalized Multiprotocol Label Switching (GMPLS) Management", RFC 4801, February 2007.
- [RFC4802] Nadeau, T., Ed., and A. Farrel, Ed., "Generalized Multiprotocol Label Switching (GMPLS) Traffic Engineering Management Information Base", RFC 4802, February 2007.

- [RFC4803] Nadeau, T., Ed., and A. Farrel, Ed., "Generalized Multiprotocol Label Switching (GMPLS) Label Switching Router (LSR) Management Information Base", RFC 4803, February 2007.
- [RFC5542] Nadeau, T., Ed., Zelig, D., Ed., and O. Nicklass, Ed., "Definitions of Textual Conventions for Pseudowire (PW) Management", RFC 5542, May 2009.
- [RFC5601] Nadeau, T., Ed., and D. Zelig, Ed., "Pseudowire (PW) Management Information Base (MIB)", RFC 5601, July 2009.
- [RFC5602] Zelig, D., Ed., and T. Nadeau, Ed., "Pseudowire (PW) over MPLS PSN Management Information Base (MIB)", RFC 5602, July 2009.
- [RFC5603] Zelig, D., Ed., and T. Nadeau, Ed., "Ethernet Pseudowire (PW) Management Information Base (MIB)", RFC 5603, July 2009.
- [RFC5604] Nicklass, O., "Managed Objects for Time Division Multiplexing (TDM) over Packet Switched Networks (PSNs)", RFC 5604, July 2009.

12.2. Informative References

- [RFC2578] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.
- [RFC2579] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Textual Conventions for SMIv2", STD 58, RFC 2579, April 1999.
- [RFC2580] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Conformance Statements for SMIv2", STD 58, RFC 2580, April 1999.
- [RFC3031] Rosen, E., Viswanathan, A., and R. Callon, "Multiprotocol Label Switching Architecture", RFC 3031, January 2001.
- [RFC3410] Case, J., Mundy, R., Partain, D., and B. Stewart, "Introduction and Applicability Statements for Internet-Standard Management Framework", RFC 3410, December 2002.
- [RFC3414] Blumenthal, U. and B. Wijnen, "User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3)", STD 62, RFC 3414, December 2002.

- [RFC3415] Wijnen, B., Presuhn, R., and K. McCloghrie, "View-based Access Control Model (VACM) for the Simple Network Management Protocol (SNMP)", STD 62, RFC 3415, December 2002.
- [RFC3931] Lau, J., Ed., Townsley, M., Ed., and I. Goyret, Ed., "Layer Two Tunneling Protocol - Version 3 (L2TPv3)", RFC 3931, March 2005.
- [RFC3945] Mannie, E., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Architecture", RFC 3945, October 2004.
- [RFC3985] Bryant, S., Ed., and P. Pate, Ed., "Pseudo Wire Emulation Edge-to-Edge (PWE3) Architecture", RFC 3985, March 2005.
- [RFC4197] Riegel, M., Ed., "Requirements for Edge-to-Edge Emulation of Time Division Multiplexed (TDM) Circuits over Packet Switching Networks", RFC 4197, October 2005.
- [RFC4377] Nadeau, T., Morrow, M., Swallow, G., Allan, D., and S. Matsushima, "Operations and Management (OAM) Requirements for Multi-Protocol Label Switched (MPLS) Networks", RFC 4377, February 2006.
- [RFC4378] Allan, D., Ed., and T. Nadeau, Ed., "A Framework for Multi-Protocol Label Switching (MPLS) Operations and Management (OAM)", RFC 4378, February 2006.
- [RFC4379] Kompella, K. and G. Swallow, "Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures", RFC 4379, February 2006.
- [RFC4447] Martini, L., Ed., Rosen, E., El-Aawar, N., Smith, T., and G. Heron, "Pseudowire Setup and Maintenance Using the Label Distribution Protocol (LDP)", RFC 4447, April 2006.
- [RFC5085] Nadeau, T., Ed., and C. Pignataro, Ed., "Pseudowire Virtual Circuit Connectivity Verification (VCCV): A Control Channel for Pseudowires", RFC 5085, December 2007.
- [RFC5654] Niven-Jenkins, B., Ed., Brungard, D., Ed., Betts, M., Ed., Sprecher, N., and S. Ueno, "Requirements of an MPLS Transport Profile", RFC 5654, September 2009.
- [RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, June 2010.

- [RFC5884] Aggarwal, R., Kompella, K., Nadeau, T., and G. Swallow, "Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)", RFC 5884, June 2010.
- [RFC5885] Nadeau, T., Ed., and C. Pignataro, Ed., "Bidirectional Forwarding Detection (BFD) for the Pseudowire Virtual Circuit Connectivity Verification (VCCV)", RFC 5885, June 2010.
- [RFC5950] Mansfield, S., Ed., Gray, E., Ed., and K. Lam, Ed., "Network Management Framework for MPLS-based Transport Networks", RFC 5950, September 2010.
- [RFC5951] Lam, K., Mansfield, S., and E. Gray, "Network Management Requirements for MPLS-based Transport Networks", RFC 5951, September 2010.
- [RFC6370] Bocci, M., Swallow, G., and E. Gray, "MPLS Transport Profile (MPLS-TP) Identifiers", RFC 6370, September 2011.
- [RFC6371] Busi, I., Ed., and D. Allan, Ed., "Operations, Administration, and Maintenance Framework for MPLS-Based Transport Networks", RFC 6371, September 2011.
- [RFC6445] Nadeau, T., Ed., Koushik, A., Ed., and R. Cetin, Ed., "Multiprotocol Label Switching (MPLS) Traffic Engineering Management Information Base for Fast Reroute", RFC 6445, November 2011.

Authors' Addresses

Daniel King (editor)
Old Dog Consulting
UK

EMail: daniel@olddog.co.uk

Venkatesan Mahalingam (editor)
Aricent
India

EMail: venkat.mahalingams@gmail.com

