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A YANG Data Model for Traffic Engineering Tunnels, Label Switched Paths and Interfaces

Abstract

This document defines a YANG data model for the provisioning and management of Traffic Engineering (TE) tunnels, Label Switched Paths (LSPs), and interfaces. The model covers data that is independent of any technology or dataplane encapsulation and is divided into two YANG modules that cover device-specific, and device independent data.

This model covers data for configuration, operational state, remote procedural calls, and event notifications.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

YANG [RFC6020] and [RFC7950] is a data modeling language that was introduced to define the contents of a conceptual data store that allows networked devices to be managed using NETCONF [RFC6241]. YANG has proved relevant beyond its initial confines, as bindings to other interfaces (e.g. RESTCONF [RFC8040]) and encoding other than XML (e.g. JSON) are being defined. Furthermore, YANG data models can be used as the basis of implementation for other interfaces, such as CLI and programmatic APIs.

This document describes a YANG data model for Traffic Engineering (TE) tunnels, Label Switched Paths (LSPs), and interfaces. The data model is divided into two YANG modules. The module 'ietf-te.yang' includes data that is generic and device-independent, while the module 'ietf-te-device.yang' includes data that is device-specific.

The document describes a high-level relationship between the modules defined in this document, as well as other external protocol YANG modules. The TE generic YANG data model does not include any data specific to a signaling protocol. It is expected other data plane technology model(s) will augment the TE generic YANG data model.

Also, it is expected other YANG modules that model TE signaling protocols, such as RSVP-TE ([RFC3209], [RFC3473]), or Segment-Routing TE (SR-TE) [RFC9256] will augment the generic TE YANG module.

2. Terms and Conventions

2.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2.2. Terminology

The following terms are defined in [RFC6241] and are used in this specification:

*client

*configuration data

*state data

This document also makes use of the following terminology introduced in the YANG Data Modeling Language [RFC7950]:

*augment

*data model

*data node

2.3. Prefixes in Data Node Names

In this document, names of data nodes and other data model objects are prefixed using the standard prefix associated with the corresponding YANG imported modules, as shown in Table 1.

Prefix	YANG module	Reference
yang	ietf-yang-types	[RFC6991]
inet	ietf-inet-types	[RFC6991]
rt-types	ietf-routing-types	[RFC8294]
te-types	ietf-te-types	[RFC8776]
te-packet-types	ietf-te-packet-types	[RFC8776]
te	ietf-te	this document
te-dev	ietf-te-device	this document

Table 1: Prefixes and corresponding YANG modules

2.4. Model Tree Diagrams

The tree diagrams extracted from the module(s) defined in this document are given in subsequent sections as per the syntax defined in [RFC8340].

3. Design Considerations

This document describes a generic TE YANG data model that is independent of any dataplane technology. One of the design objectives is to allow specific data plane technology models to reuse the TE generic data model and possibly augment it with technology specific data.

The elements of the generic TE YANG data model, including TE Tunnels, LSPs, and interfaces have leaf(s) that identify the technology layer where they reside. For example, the LSP encoding type can identify the technology associated with a TE Tunnel or LSP.

Also, the generic TE YANG data model does not cover signaling protocol data. The signaling protocol used to instantiate TE LSPs are outside the scope of this document and expected to be covered by augmentations defined in other document(s).

The following other design considerations are taken into account with respect to data organization:

* The generic TE YANG data model 'ietf-te' contains device independent data and can be used to model data off a device (e.g. on a TE controller). When the model is used to manage a specific device, the model contains the TE Tunnels originating from the specific device. When the model is used to manage a TE controller, the 'tunnels' list contains all TE Tunnels and TE tunnel segments originating from device(s) that the TE controller manages.

* The device-specific TE data is defined in module 'ietf-te-device' as shown in Figure 1.

* In general, minimal elements in the model are designated as "mandatory" to allow freedom to vendors to adapt the data model to their specific product implementation.

* Suitable defaults are specified for all configurable elements.

* The model declares a number of TE functions as features that can be optionally supported.

3.1. State Data Organization

The Network Management Datastore Architecture (NMDA) [RFC8342] addresses modeling state data for ephemeral objects. This document adopts the NMDA model for configuration and state data representation as per IETF guidelines for new IETF YANG models.

4. Model Overview

The data models defined in this document cover the core TE features that are commonly supported by different vendor implementations. The support of extended or vendor specific TE feature(s) is expected to either be in augmentations, or deviations to this model that are defined in separate documents.

4.1. Module Relationship

The generic TE YANG data model that is defined in "ietf-te.yang" covers the building blocks that are device independent and agnostic of any specific technology or control plane instances. The TE device model defined in "ietf-te-device.yang" augments the generic TE YANG data model and covers data that is specific to a device -- for example, attributes of TE interfaces, or TE timers that are local to a TE node.

The TE data models for specific instances of data plane technology exist in separate YANG modules that augment the generic TE YANG data model. The TE data models for specific instances of signaling protocols are outside the scope of this document and are defined in other documents. For example, the RSVP-TE YANG model augmentation of the TE model is covered in a separate document.

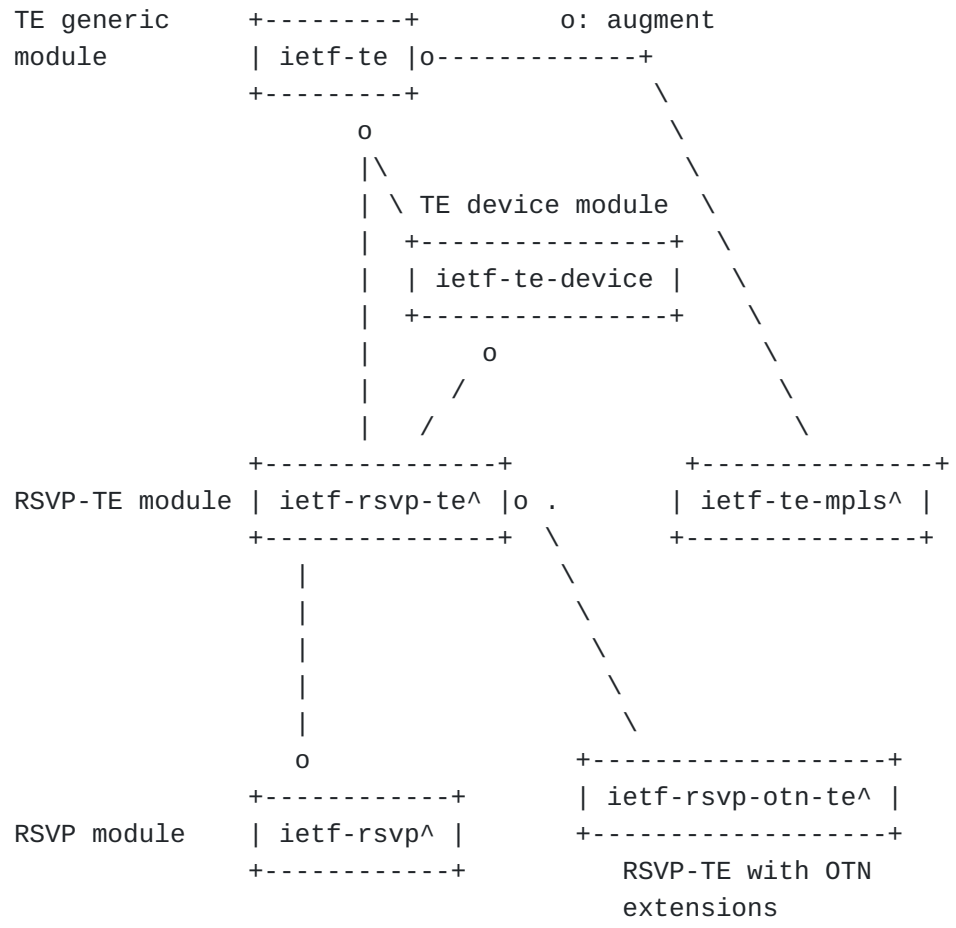

Figure 1: Relationship of TE module(s) with signaling protocol modules

5. TE YANG Model

The generic TE YANG module ('ietf-te') is meant for the management and operation of a TE network. This includes creating, modifying and retrieving information about TE Tunnels, LSPs, and interfaces and their associated attributes (e.g. Administrative-Groups, SRLGs, etc.).

A full tree diagram of the TE model is shown in the Appendix in Figure 13.

5.1. Module Structure

The 'te' container is the top level container in the 'ietf-te' module. The presence of the 'te' container enables TE function system wide. Below provides further descriptions of containers that exist under the 'te' top level container.

There are three further containers grouped under the 'te' container as shown in Figure 2 and described below.

globals:

The 'globals' container maintains the set of global TE attributes that can be applicable to TE Tunnels and interfaces.

tunnels:

The 'tunnels' container includes the list of TE Tunnels that are instantiated. Refer to Section 5.1.2 for further details on the properties of a TE Tunnel.

lsps:

The 'lsps' container includes the list of TE LSP(s) that are instantiated for TE Tunnels. Refer to Section 5.1.3 for further details on the properties of a TE LSP.

The model also contains two Remote Procedure Calls (RPCs) as shown in Figure 13 and described below.

tunnels-path-compute:

A RPC to request path computation for a specific TE Tunnel. The RPC allows requesting path computation using atomic and stateless operation. A tunnel may also be configured in 'compute-only' mode to provide stateful path updates - see Section 5.1.2 for further details.

tunnels-action:

An RPC to request a specific action (e.g. reoptimize, or tear-and-setup) to be taken on a specific tunnel or all tunnels.

Figure 13 shows the relationships of these containers and RPCs within the 'ietf-te' module.

```
module: ietf-te
  +--rw te!
     +--rw globals
     |     ...
     +--rw tunnels
     |     ...
     +--ro lsps
           ...

  rpcs:
    +---x tunnels-path-compute
    |  +---w input
    |  |     ...
    |  +--ro output
    |        ...
    +---x tunnels-actions
       +---w input
       |     ...
       +--ro output
             ...
```

Figure 2: TE Tunnel model high-level YANG tree view

5.1.1. TE Globals

The 'globals' container covers properties that control a TE feature's behavior system-wide, and its respective state as shown in Figure 3 and described in the text that follows.

```
  +--rw globals
  |  +--rw named-admin-groups
  |  |  +--rw named-admin-group* [name]
  |  |        ...
  |  +--rw named-srlgs
  |  |  +--rw named-srlg* [name]
  |  |        ...
  |  +--rw named-path-constraints
  |     +--rw named-path-constraint* [name]
```

Figure 3: TE globals YANG subtree high-level structure

named-admin-groups:

A YANG container for the list of named (extended) administrative groups that may be applied to TE links.

named-srlgs:

A YANG container for the list of named Shared Risk Link Groups (SRLGs) that may be applied to TE links.

named-path-constraints:

A YANG container for a list of named path constraints. Each named path constraint is composed of a set of constraints that can be applied during path computation. A named path constraint can be applied to multiple TE Tunnels. Path constraints may also be specified directly under the TE Tunnel. The path constraints specified under the TE Tunnel take precedence over the path constraints derived from the referenced named path constraint. A named path constraint entry can be formed of the path constraints shown in Figure 4:

```
|  +--rw named-path-constraints
|     +--rw named-path-constraint* [name]
|             {te-types:named-path-constraints}?
|        +--rw name                              string
|        +--rw te-bandwidth
|        |     ...
|        +--rw link-protection?                  identityref
|        +--rw setup-priority?                   uint8
|        +--rw hold-priority?                    uint8
|        +--rw signaling-type?                   identityref
|        +--rw path-metric-bounds
|        |     ...
|        +--rw path-affinities-values
|        |     ...
|        +--rw path-affinity-names
|        |     ...
|        +--rw path-srlgs-lists
|        |     ...
|        +--rw path-srlgs-names
|        |     ...
|        +--rw disjointness?
|        |       te-path-disjointness
|        +--rw explicit-route-objects-always
|        |     ...
|        +--rw path-in-segment!
|        |     ...
|        +--rw path-out-segment!
|              ...
```

Figure 4: Named path constraints YANG subtree

oname: A YANG leaf that holds the named path constraint entry. This is unique in the list and used as a key.

ote-bandwidth: A YANG container that holds the technology agnostic TE bandwidth constraint.

olink-protection: A YANG leaf that holds the link protection type constraint required for the links to be included in the computed path.

osetup/hold priority: YANG leafs that hold the LSP setup and hold admission priority as defined in [RFC3209].

osignaling-type: A YANG leaf that holds the LSP setup type, such as RSVP-TE or SR.

opath-metric-bounds: A YANG container that holds the set of metric bounds applicable on the computed TE tunnel path.

opath-affinities-values: A YANG container that holds the set of affinity values and mask to be used during path computation.

opath-affinity-names: A YANG container that holds the set of named affinity constraints and corresponding inclusion or exclusion instructions for each to be used during path computation.

opath-srlgs-lists: A YANG container that holds the set of SRLG values and corresponding inclusion or exclusion instructions to be used during path computation.

opath-srlgs-names: A YANG container that holds the set of named SRLG constraints and corresponding inclusion or exclusion instructions for each to be used during path computation.

odisjointness: The level of resource disjointness constraint that the secondary path of a TE tunnel has to adhere to.

oexplicit-route-objects-always: A YANG container that contains two route objects lists:

- o'route-object-exclude-always': a list of route entries to always exclude from the path computation.

o'route-object-include-exclude': a list of route entries to include or exclude in the path computation.

The 'route-object-include-exclude' is used to configure constraints on which route objects (e.g., nodes, links) are included or excluded in the path computation.

The interpretation of an empty 'route-object-include-exclude' list depends on the TE Tunnel (end-to-end or Tunnel Segment) and on the specific path, according to the following rules:

1. An empty 'route-object-include-exclude' list for the primary path of an end-to-end TE Tunnel indicates that there are no route objects to be included or excluded in the path computation.

2. An empty 'route-object-include-exclude' list for the primary path of a TE Tunnel Segment indicates that no primary LSP is required for that TE Tunnel.

3. An empty 'route-object-include-exclude' list for a reverse path means it always follows the forward path (i.e., the TE Tunnel is co-routed). When the 'route-object-include-exclude' list is not empty, the reverse path is routed independently of the forward path.

4. An empty 'route-object-include-exclude' list for the secondary (forward) path indicates that the secondary path has the same endpoints as the primary path.

opath-in-segment: A YANG container that contains a list of label restrictions that have to be taken into considerations when crossing domains. This TE tunnel segment in this case is being stitched to the upstream TE tunnel segment.

opath-out-segment: A YANG container that contains a list of label restrictions that have to be taken into considerations when crossing domains. The TE tunnel segment in this case is being stitched to the downstream TE tunnel segment.

5.1.2. TE Tunnels

The 'tunnels' container holds the list of TE Tunnels that are provisioned on ingress LER devices in the network as shown in Figure 5.

```
+--rw tunnels
|  +--rw tunnel* [name]
|     +--rw name                              string
|     +--rw alias?                            string
|     +--rw identifier?                       uint32
|     +--rw color?                            uint32
|     +--rw description?                      string
|     +--rw admin-state?                      identityref
|     +--ro operational-state?                identityref
|     +--rw encoding?                         identityref
|     +--rw switching-type?                   identityref
|     +--rw source?                           te-types:te-node-id
|     +--rw destination?                      te-types:te-node-id
|     +--rw src-tunnel-tp-id?                 binary
|     +--rw dst-tunnel-tp-id?                 binary
|     +--rw bidirectional?                    boolean
|     +--rw controller
|     |  +--rw protocol-origin?        identityref
|     |  +--rw controller-entity-id?   string
|     +--rw reoptimize-timer?                 uint16
|     +--rw association-objects
|     |  +--rw association-object* [association-key]
|     |  |     ...
|     |  +--rw association-object-extended* [association-key]
|     |        ...
|     +--rw protection
|     |  +--rw enable?                           boolean
|     |  +--rw protection-type?                  identityref
|     |  +--rw protection-reversion-disable?     boolean
|     |  +--rw hold-off-time?                    uint32
|     |  +--rw wait-to-revert?                   uint16
|     |  +--rw aps-signal-id?                    uint8
|     +--rw restoration
|     |  +--rw enable?                            boolean
|     |  +--rw restoration-type?                  identityref
|     |  +--rw restoration-scheme?                identityref
|     |  +--rw restoration-reversion-disable?     boolean
|     |  +--rw hold-off-time?                     uint32
|     |  +--rw wait-to-restore?                   uint16
|     |  +--rw wait-to-revert?                    uint16
|     +--rw te-topology-identifier
|     |  +--rw provider-id?   te-global-id
|     |  +--rw client-id?     te-global-id
|     |  +--rw topology-id?   te-topology-id
|     +--rw te-bandwidth
|     |  +--rw (technology)?
|     |        ...
|     +--rw link-protection?                  identityref
|     +--rw setup-priority?                   uint8
```

```
|     +--rw hold-priority?                  uint8
|     +--rw signaling-type?                 identityref
|     +--rw hierarchy
|     |  +--rw dependency-tunnels
|     |  |     ...
|     |  +--rw hierarchical-link
|     |        ...
|     +--rw primary-paths
|     |  +--rw primary-path* [name]
|     |        ...
|     +--rw secondary-paths
|     |  +--rw secondary-path* [name]
|     |        ...
|     +--rw secondary-reverse-paths
|     |  +--rw secondary-reverse-path* [name]
|     |        ...
|     +---x tunnel-action
|     |  +---w input
|     |  |     ...
|     |  +--ro output
|     |        ...
|     +---x protection-external-commands
|        +---w input
|              ...
```

Figure 5: TE Tunnel list YANG subtree structure

When the model is used to manage a specific device, the 'tunnels' list contains the TE Tunnels originating from the specific device. When the model is used to manage a TE controller, the 'tunnels' list contains all TE Tunnels and TE tunnel segments originating from device(s) that the TE controller manages.

The TE Tunnel model allows the configuration and management of the following TE tunnel objects:

TE Tunnel:

A YANG container of one or more TE LSPs established between the source and destination TE Tunnel termination points.

TE Path:

An engineered path that once instantiated in the forwarding plane can be used to forward traffic from the source to the destination TE Tunnel termination points.

TE LSP:

A TE LSP is a connection-oriented service established over a TE Path and that allows the delivery of traffic between the TE Tunnel source and destination termination points.

TE Tunnel Segment:

A part of a multi-domain TE Tunnel that is within a specific network domain.

The TE Tunnel has a number of attributes that are set directly under the tunnel (as shown in Figure 5). The main attributes of a TE Tunnel are described below:

operational-state:

A YANG leaf that holds the operational state of the tunnel.

name:

A YANG leaf that holds the name of a TE Tunnel. The name of the TE Tunnel uniquely identifies the tunnel within the TE tunnel list. The name of the TE Tunnel can be formatted as a Uniform Resource Indicator (URI) by including the namespace to ensure uniqueness of the name amongst all the TE Tunnels present on devices and controllers. The configured TE Tunnels can be reported with the name of the device embedded within the TE

Tunnel name. For initiated TE Tunnels from the controller, the controller is responsible to ensures that TE Tunnel names are unique.

alias:

A YANG leaf that holds an alternate name to the TE tunnel. Unlike the TE tunnel name, the alias can be modified at any time during the lifetime of the TE tunnel.

identifier:

A YANG leaf that holds an identifier of the tunnel. This identifier is unique amongst tunnels originated from the same ingress device.

color:

A YANG leaf that holds the color associated with the TE tunnel. The color is used to map or steer services that carry matching color on to the TE tunnel as described in [RFC9012].

admin-state:

A YANG leaf that holds the tunnel administrative state. The administrative status in state datastore transitions to 'tunnel-admin-up' when the tunnel used by the client layer, and to 'tunnel-admin-down' when it is not used by the client layer.

operational-state:

A YANG leaf that holds the tunnel operational state.

encoding/switching:

The 'encoding' and 'switching-type' are YANG leafs that define the specific technology in which the tunnel operates in as described in [RFC3945].

source/destination:

YANG containers that hold the tunnel source and destination node endpoints identities, including:

-te-node-id: A YANG leaf that holds the identifier of the source or destination of the TE Tunnel TE node identifiers as defined in [RFC8776].

-node-id: A YANG leaf that holds the identifier of the source or destination of the TE Tunnel node identifiers as defined in [RFC8345].

-tunnel-tp-id: A YANG leaf that holds the identifier of the source or destination of the TE Tunnel Termination Points (TTPs) as defined in [RFC8795]. The TTP identifiers are optional on nodes that have a single TTP per node. For example, TTP identifiers are optional for packet (IP/MPLS) routers.

bidirectional:

A YANG leaf that when present indicates the LSP of a TE Tunnel is bidirectional as defined in [rfc3473].

controller:

A YANG container that holds tunnel data relevant to an optional external TE controller that may initiate or control a tunnel. This target node may be augmented by external module(s), for example, to add data for PCEP initiated and/or delegated tunnels.

reoptimize-timer:

A YANG leaf to set the interval period for tunnel reoptimization.

association-objects:

A YANG container that holds the set of associations of the TE Tunnel to other TE Tunnels. Associations at the TE Tunnel level apply to all paths of the TE Tunnel. The TE tunnel associations can be overridden by associations configured directly under the TE Tunnel path.

protection:

A YANG container that holds the TE Tunnel protection properties.

restoration:

A YANG container that holds the TE Tunnel restoration properties.

te-topology-identifier:

A YANG container that holds the topology identifier associated with the topology where paths for the TE tunnel are computed as defined in [RFC8795].

network-id:

A YANG leaf that can optionally be used to identify the network topology where paths for the TE tunnel are computed as defined in [RFC8345].

hierarchy:

A YANG container that holds hierarchy related properties of the TE Tunnel. A TE LSP can be set up in MPLS or Generalized MPLS (GMPLS) networks to be used as a TE link to carry traffic in other (client) networks [RFC6107]. In this case, the model introduces the TE Tunnel hierarchical link endpoint parameters to identify the specific link in the client layer that the underlying TE Tunnel is associated with. The hierarchy container includes the following:

odependency-tunnels: A set of hierarchical TE Tunnels provisioned or to be provisioned in the immediate lower layer that this TE tunnel depends on for multi-layer path computation. A dependency TE Tunnel is provisioned if and only if it is used (selected by path computation) at least by one client layer TE Tunnel. The TE link in the client layer network topology supported by a dependent TE Tunnel is dynamically created only when the dependency TE Tunnel is actually provisioned.

ohierarchical-link: A YANG container that holds the identity of the hierarchical link (in the client layer) that is supported by this TE Tunnel. The endpoints of the hierarchical link are defined by TE tunnel source and destination node endpoints. The hierarchical link can be identified by its source and destination link termination point identifiers.

primary-paths:

A YANG container that holds the list of primary paths. A primary path is identified by 'name'. A primary path is selected from the list to instantiate a primary forwarding LSP for the tunnel. The list of primary paths is visited by order of preference. A primary path has the following attributes:

-primary-reverse-path: A YANG container that holds properties of the primary reverse path. The reverse path is applicable to bidirectional TE Tunnels.

-candidate-secondary-paths: A YANG container that holds a list of candidate secondary paths which may be used for the primary path to support path protection. The candidate secondary

path(s) reference path(s) from the tunnel secondary paths list. The preference of the secondary paths is specified within the list and dictates the order of visiting the secondary path from the list. The attributes of a secondary path can be defined separately from the primary path. The attributes of a secondary path will be inherited from the associated 'active' primary when not explicitly defined for the secondary path.

secondary-paths:

A YANG container that holds the set of secondary paths. A secondary path is identified by 'name'. A secondary path can be referenced from the TE Tunnel's 'candidate-secondary-path' list.

secondary-reverse-paths:

A YANG container that holds the set of secondary reverse paths. A secondary reverse path is identified by 'name'. A secondary reverse path can be referenced from the TE Tunnel's 'candidate-secondary-reverse-paths' list. A secondary reverse path contains attributes similar to a primary path.

The following set of common path attributes are shared for primary (forward and reverse) and secondary paths:

path-computation-method:

A YANG leaf that specifies the method used for computing the TE path.

path-computation-server:

A YANG container that holds the path computation server properties when the path is externally queried.

compute-only:

A path of a TE Tunnel is, by default, provisioned so that it can be instantiated in the forwarding plane so that it can carry traffic as soon as a valid path is computed. In some cases, a TE path may be configured only for the purpose of computing a path and reporting it without the need to instantiate the LSP or commit any resources. In such a case, the path is configured in 'compute-only' mode to distinguish it from the default behavior. A 'compute-only' path is configured as a usual with the associated per path constraint(s) and properties on a device or TE controller. The device or TE controller computes the feasible path(s) subject to configured constraints. A client may query the

'compute-only' computed path properties 'on-demand', or alternatively, can subscribe to be notified of computed path(s) and whenever the path properties change.

use-path-computation:

A YANG leaf that indicates whether or not path computation is to be used for a specified path.

lockdown:

A YANG leaf that when set indicates the existing path should not be reoptimized after a failure on any of its traversed links.

path-scope:

A YANG leaf that specifies the path scope if segment or an end-to-end path.

preference:

A YANG leaf that specifies the preference for the path. The lower the number higher the preference.

k-requested-paths:

A YANG leaf that specifies the number of k-shortest-paths requested from the path computation server and returned sorted by its optimization objective.

association-objects:

A YANG container that holds a list of tunnel association properties.

optimizations:

A YANG container that holds the optimization objectives that path computation will use to select a path.

named-path-constraint:

A YANG leafref that references an entry from the global list of named path constraints.

te-bandwidth:

A YANG container that holds the path bandwidth (see [RFC8776]).

link-protection:

A YANG leaf that specifies the link protection type required for the links to be included the computed path (see [RFC8776]).

setup/hold-priority:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

signaling-type:

see description provided in Section 5.1.1. This value overrides the provided one in the referenced named-path-constraint.

path-metric-bounds:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-affinities-values:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-affinity-names:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-srlgs-lists:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-srlgs-names:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

disjointness:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

explicit-route-objects-always:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-in-segment:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

path-out-segment:

see description provided in Section 5.1.1. These values override those provided in the referenced named-path-constraint.

computed-paths-properties:

A YANG container that holds properties for the list of computed paths.

computed-path-error-infos:

A YANG container that holds a list of errors related to the path.

lsp-provisioning-error-infos:

A YANG container that holds the list of LSP provisioning error information.

lsps:

A YANG container that holds a list of LSPs that have been instantiated for this specific path.

In addition to the path common attributes, the primary path has the following attributes that are not present in the secondary path:

* Only the primary path contains the list of 'candidate-secondary-paths' that can protect the primary path.

* Only the primary path can contain a primary-reverse-path associated with the primary path (and its associated list of 'candidate-secondary-reverse-path').

5.1.3. TE LSPs

The 'lsps' container includes the set of TE LSP(s) that have been instantiated. A TE LSP is identified by a 3-tuple ('tunnel-name', 'lsp-id', 'node').

When the model is used to manage a specific device, the 'lsps' list contains all TE LSP(s) that traverse the device (including ingressing, transiting and egressing the device).

When the model is used to manage a TE controller, the 'lsps' list contains the TE LSP(s) on devices managed by the controller that act as ingress, and may optionally include TE LSPs on devices managed by the controller that act as transit or egress role.

5.2. Tree Diagram

Figure 6 shows the tree diagram of depth=4 for the generic TE YANG model defined in modules 'ietf-te.yang'. The full tree diagram is shown in Section 13.

```
module: ietf-te
  +--rw te
     +--rw enable?    boolean
     +--rw globals
     |  +--rw named-admin-groups
     |  |  +--rw named-admin-group* [name]
     |  |          {te-types:extended-admin-groups,
     |  |           te-types:named-extended-admin-groups}?
     |  |        ...
     |  +--rw named-srlgs
     |  |  +--rw named-srlg* [name] {te-types:named-srlg-groups}?
     |  |        ...
     |  +--rw named-path-constraints
     |     +--rw named-path-constraint* [name]
     |             {te-types:named-path-constraints}?
     |           ...
     +--rw tunnels
     |  +--rw tunnel* [name]
     |     +--rw name                              string
     |     +--rw alias?                            string
     |     +--rw identifier?                       uint32
     |     +--rw color?                            uint32
     |     +--rw description?                      string
     |     +--rw admin-state?                      identityref
     |     +--ro operational-state?                identityref
     |     +--rw encoding?                         identityref
     |     +--rw switching-type?                   identityref
     |     +--rw source
     |     |     ...
     |     +--rw destination
     |     |     ...
     |     +--rw bidirectional?                    boolean
     |     +--rw controller
     |     |     ...
     |     +--rw reoptimize-timer?                 uint16
     |     +--rw association-objects
     |     |     ...
     |     +--rw protection
     |     |     ...
     |     +--rw restoration
     |     |     ...
     |     +--rw network-id?                       nw:network-id
     |     +--rw te-topology-identifier
     |     |     ...
     |     +--rw te-bandwidth
     |     |     ...
     |     +--rw link-protection?                  identityref
     |     +--rw setup-priority?                   uint8
     |     +--rw hold-priority?                    uint8
```

```
   |     +--rw signaling-type?                identityref
   |     +--rw hierarchy
   |     |     ...
   |     +--rw primary-paths
   |     |     ...
   |     +--rw secondary-paths
   |     |     ...
   |     +--rw secondary-reverse-paths
   |     |     ...
   |     +---x tunnel-action
   |     |     ...
   |     +---x protection-external-commands
   |           ...
   +--ro lsps
      +--ro lsp* [tunnel-name lsp-id node]
         +--ro tunnel-name                          string
         +--ro lsp-id                               uint16
         +--ro node
         |       te-types:te-node-id
         +--ro source?
         |       te-types:te-node-id
         +--ro destination?
         |       te-types:te-node-id
         +--ro tunnel-id?                           uint16
         +--ro extended-tunnel-id?
         |       yang:dotted-quad
         +--ro operational-state?                   identityref
         +--ro signaling-type?                      identityref
         +--ro origin-type?                         enumeration
         +--ro lsp-resource-status?                 enumeration
         +--ro lockout-of-normal?                   boolean
         +--ro freeze?                              boolean
         +--ro lsp-protection-role?                 enumeration
         +--ro lsp-protection-state?                identityref
         +--ro protection-group-ingress-node-id?
         |       te-types:te-node-id
         +--ro protection-group-egress-node-id?
         |       te-types:te-node-id
         +--ro lsp-actual-route-information
               ...

rpcs:
  +---x tunnels-path-compute
  |  +---w input
  |  |  +---w path-compute-info
  |  +--ro output
  |     +--ro path-compute-result
  +---x tunnels-actions
     +---w input
```

```
|  +---w tunnel-info
|  |  +---w (filter-type)
|  |        ...
|  +---w action-info
|     +---w action?       identityref
|     +---w disruptive?   empty
+--ro output
   +--ro action-result?   identityref
```

Figure 6: Tree diagram of depth-4 of TE Tunnel YANG data model

5.3. YANG Module

The generic TE YANG module 'ietf-te' imports the following modules:

*ietf-te-types defined in [RFC8776]

*ietf-yang-types and ietf-inet-types defined in [RFC6991]

*ietf-network and ietf-network-topology defined in [RFC8345]

This module references the following documents: [RFC4206], [RFC4427], [RFC4872], [RFC3209], [RFC6780], [RFC7471], [RFC9012], [RFC8570], [RFC8232], [RFC7271], [RFC8234], [RFC7308], and [ITU_G.808.1].

```
<CODE BEGINS> file "ietf-te@2023-06-16.yang"

module ietf-te {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-te";

  /* Replace with IANA when assigned */

  prefix te;

  /* Import TE generic types */

  import ietf-te-types {
    prefix te-types;
    reference
      "RFC8776: Common YANG Data Types for Traffic Engineering.";
  }
  import ietf-inet-types {
    prefix inet;
    reference
      "RFC6991: Common YANG Data Types.";
  }
  import ietf-yang-types {
    prefix yang;
    reference
      "RFC6991: Common YANG Data Types.";
  }

  import ietf-network {
    prefix "nw";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }

  import ietf-network-topology {
    prefix "nt";
    reference "RFC 8345: A YANG Data Model for Network Topologies";
  }

  organization
    "IETF Traffic Engineering Architecture and Signaling (TEAS)
     Working Group.";
  contact
    "WG Web:   <https://tools.ietf.org/wg/teas/>
     WG List:  <mailto:teas@ietf.org>

     Editor:   Tarek Saad
               <mailto:tsaad.net@gmail.com>

     Editor:   Rakesh Gandhi
               <mailto:rgandhi@cisco.com>
```

```
   Editor:   Vishnu Pavan Beeram
             <mailto:vbeeram@juniper.net>

   Editor:   Himanshu Shah
             <mailto:hshah@ciena.com>

   Editor:   Xufeng Liu
             <mailto: xufeng.liu.ietf@gmail.com>

   Editor:   Igor Bryskin
             <mailto:i_bryskin@yahoo.com>

   Editor:   Oscar Gonzalez de Dios
             <mailto: oscar.gonzalezdedios@telefonica.com>";

 description
   "YANG data module for TE configuration, state, and RPCs.
    The model fully conforms to the Network Management
    Datastore Architecture (NMDA).

    Copyright (c) 2023 IETF Trust and the persons identified as
    authors of the code.  All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject to
    the license terms contained in, the Revised BSD License set
    forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
    (https://trustee.ietf.org/license-info).

    This version of this YANG module is part of RFC XXXX
    (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
    for full legal notices.";

 // RFC Ed.: replace XXXX with actual RFC number and remove this
 // note.
 // RFC Ed.: update the date below with the date of RFC publication
 // and remove this note.

 revision 2023-06-16 {
   description
     "Initial revision for the TE generic YANG module.";
   reference
     "RFCXXXX: A YANG Data Model for Traffic Engineering Tunnels
      and Interfaces.";
 }

 typedef tunnel-ref {
   type leafref {
```

```
    path "/te:te/te:tunnels/te:tunnel/te:name";
  }
  description
    "This type is used by data models that need to reference
     configured TE tunnel.";
}

typedef te-gen-node-id {
  type union {
    type te-types:te-node-id;
    type inet:ip-address;
    type nw:node-id;
  }
  description
    "Generic type that identifies a node in a TE topology.";
}

/**
 * TE tunnel generic groupings
 */

grouping te-generic-node-id {
  description
    "A reusable grouping for a TE generic node identifier.";
  leaf id {
    type te-gen-node-id;
    description
      "The identifier of the node. Can be represented as IP
       address or dotted quad address or as an URI.";
  }
  leaf type {
    type enumeration {
      enum ip {
        description
          "IP address representation of the node identifier.";
      }
      enum dotted-quad {
        description
          "Dotted quad address representation of the node
           identifier.";
      }
      enum node-id {
        description
          "URI representation of the node identifier.";
      }
    }
    description
      "Type of node identifier representation.";
  }
```

```
}

grouping path-common-properties {
  description
    "Common path attributes.";
  leaf name {
    type string;
    description
      "TE path name.";
  }
  leaf path-computation-method {
    type identityref {
      base te-types:path-computation-method;
    }
    default "te-types:path-locally-computed";
    description
      "The method used for computing the path, either
       locally computed, queried from a server or not
       computed at all (explicitly configured).";
  }
  container path-computation-server {
    when "derived-from-or-self(../path-computation-method, "
       + "'te-types:path-externally-queried')" {
      description
        "The path-computation server when the path is
         externally queried.";
    }
    uses te-generic-node-id;
    description
      "Address of the external path computation
       server.";
  }
  leaf compute-only {
    type empty;
    description
      "When present, the path is computed and updated whenever
       the topology is updated. No resources are committed
       or reserved in the network.";
  }
  leaf use-path-computation {
    when "derived-from-or-self(../path-computation-method, "
       + "'te-types:path-locally-computed')";
    type boolean;
    default "true";
    description
      "When 'true' indicates the path is dynamically computed
       and/or validated against the Traffic-Engineering Database
       (TED), and when 'false' indicates no path expansion or
       validation against the TED is required.";
```

```
  }
  leaf lockdown {
    type empty;
    description
      "When present, indicates no reoptimization to be attempted
       for this path.";
  }
  leaf path-scope {
    type identityref {
      base te-types:path-scope-type;
    }
    default "te-types:path-scope-end-to-end";
    config false;
    description
      "Indicates whether the path is a segment or portion of
       of the full path., or is the an end-to-end path for
       the TE Tunnel.";
  }
}

/* This grouping is re-used in path-computation rpc */
grouping path-compute-info {
  description
    "Attributes used for path computation request.";
  uses tunnel-associations-properties;
  uses te-types:generic-path-optimization;
  leaf named-path-constraint {
    if-feature "te-types:named-path-constraints";
    type leafref {
      path "/te:te/te:globals/te:named-path-constraints/"
         + "te:named-path-constraint/te:name";
    }
    description
      "Reference to a globally defined named path constraint set.";
  }
  uses path-constraints-common;
}

/* This grouping is re-used in path-computation rpc */
grouping path-forward-properties {
  description
    "The path preference.";
  leaf preference {
    type uint8 {
      range "1..255";
    }
    default "1";
    description
      "Specifies a preference for this path. The lower the number
```

```
        higher the preference.";
    }
    leaf co-routed {
      when "/te:te/te:tunnels/te:tunnel/te:bidirectional = 'true'" {
        description
          "Applicable to bidirectional tunnels only.";
      }
      type boolean;
      default "false";
      description
        "Indicates whether the reverse path must to be co-routed
         with the primary.";
    }
  }

  /* This grouping is re-used in path-computation rpc */
  grouping k-requested-paths {
    description
      "The k-shortest paths requests.";
    leaf k-requested-paths {
      type uint8;
      default "1";
      description
        "The number of k-shortest-paths requested from the path
         computation server and returned sorted by its optimization
         objective.";
    }
  }

  grouping path-state {
    description
      "TE per path state parameters.";
    uses path-computation-response;
    container lsp-provisioning-error-infos {
      config false;
      description
        "LSP provisioning error information.";
      list lsp-provisioning-error-info {
        description
          "List of LSP provisioning error info entries.";
        leaf error-reason {
          type identityref {
            base te-types:lsp-provisioning-error-reason;
          }
          description
            "LSP provision error type.";
        }
        leaf error-description {
          type string;
```

```
      description
        "The textual representation of the error occurred during
         path computation.";
    }
    leaf error-timestamp {
      type yang:date-and-time;
      description
        "Timestamp of when the reported error occurred.";
    }
    leaf error-node-id {
      type te-types:te-node-id;
      description
        "Node identifier of node where error occurred.";
    }
    leaf error-link-id {
      type te-types:te-tp-id;
      description
        "Link ID where the error occurred.";
    }
    leaf lsp-id {
      type uint16;
      description
        "The LSP-ID for which path computation was performed.";
    }
  }
}
container lsps {
  config false;
  description
    "The TE LSPs container.";
  list lsp {
    key "node lsp-id";
    description
      "List of LSPs associated with the tunnel.";
    leaf tunnel-name {
      type leafref {
        path "/te:te/te:lsps/te:lsp/te:tunnel-name";
      }
      description "TE tunnel name.";
    }
    leaf node {
      type leafref {
        path "/te:te/te:lsps/te:lsp[tunnel-name="
           + "current()/../te:tunnel-name][lsp-id="
           + "current()/../te:lsp-id]/te:node";
      }
      description "The node where the LSP state resides on.";
    }
    leaf lsp-id {
```

```
        type leafref {
          path "/te:te/te:lsps/te:lsp[tunnel-name="
                         + "current()/../tunnel-name]/te:lsp-id";
        }
        description "The TE LSP identifier.";
      }
    }
  }
}

/* This grouping is re-used in path-computation rpc */
grouping path-computation-response {
  description
    "Attributes reported by path computation response.";
  container computed-paths-properties {
    config false;
    description
      "Computed path properties container.";
    list computed-path-properties {
      key "k-index";
      description
        "List of computed paths.";
      leaf k-index {
        type uint8;
        description
          "The k-th path returned from the computation server.
           A lower k value path is more optimal than higher k
           value path(s)";
      }
      uses te-types:generic-path-properties {
        augment "path-properties" {
          description
            "additional path properties returned by path
             computation.";
          uses te-types:te-bandwidth;
          leaf disjointness-type {
            type te-types:te-path-disjointness;
            config false;
            description
              "The type of resource disjointness.
               When reported for a primary path, it represents the
               minimum level of disjointness of all the secondary
               paths. When reported for a secondary path, it
               represents the disjointness of the secondary path.";
          }
        }
      }
    }
  }
```

```
  container computed-path-error-infos {
    config false;
    description
      "Path computation information container.";
    list computed-path-error-info {
      description
        "List of path computation info entries.";
      leaf error-description {
        type string;
        description
          "Textual representation of the error that occurred
           during path computation.";
      }
      leaf error-timestamp {
        type yang:date-and-time;
        description
          "Timestamp of last path computation attempt.";
      }
      leaf error-reason {
        type identityref {
          base te-types:path-computation-error-reason;
        }
        description
          "Reason for the path computation error.";
      }
    }
  }
}

grouping protection-restoration-properties {
  description
    "Protection and restoration parameters.";
  container protection {
    description
      "Protection parameters.";
    leaf protection-type {
      type identityref {
        base te-types:lsp-protection-type;
      }
      default "te-types:lsp-protection-unprotected";
      description
        "LSP protection type.";
    }
    leaf protection-reversion-disable {
      type boolean;
      default "false";
      description
        "Disable protection reversion to working path.";
    }
```

```
    leaf hold-off-time {
      type uint32;
      units "milli-seconds";
      description
        "The time between the declaration of an SF or SD condition
         and the initialization of the protection switching
         algorithm.";
      reference
        "RFC4427";
    }
    leaf wait-to-revert {
      type uint16;
      units "seconds";
      description
        "Time to wait before attempting LSP reversion.";
      reference
        "RFC4427";
    }
    leaf aps-signal-id {
      type uint8 {
        range "1..255";
      }
      default "1";
      description
        "The APS signal number used to reference the traffic of
         this tunnel. The default value for normal traffic is 1.
         The default value for extra-traffic is 255. If not
         specified, non-default values can be assigned by the
         server, if and only if, the server controls both
          endpoints.";
      reference
        "ITU_G.808.1";
    }
  }
  container restoration {
    description
      "Restoration parameters.";
    leaf restoration-type {
      type identityref {
        base te-types:lsp-restoration-type;
      }
      default "te-types:lsp-restoration-restore-none";
      description
        "LSP restoration type.";
    }
    leaf restoration-scheme {
      type identityref {
        base te-types:restoration-scheme-type;
      }
```

```
      default "te-types:restoration-scheme-preconfigured";
      description
        "LSP restoration scheme.";
    }
    leaf restoration-reversion-disable {
      type boolean;
      default "false";
      description
        "Disable restoration reversion to working path.";
    }
    leaf hold-off-time {
      type uint32;
      units "milli-seconds";
      description
        "The time between the declaration of an SF or SD condition
         and the initialization of the protection switching
         algorithm.";
      reference
        "RFC4427";
    }
    leaf wait-to-restore {
      type uint16;
      units "seconds";
      description
        "Time to wait before attempting LSP restoration.";
      reference
        "RFC4427";
    }
    leaf wait-to-revert {
      type uint16;
      units "seconds";
      description
        "Time to wait before attempting LSP reversion.";
      reference
        "RFC4427";
    }
  }
}

grouping tunnel-associations-properties {
  description
    "TE tunnel association grouping.";
  container association-objects {
    description
      "TE tunnel associations.";
    list association-object {
      key "association-key";
      unique "type id source/id source/type";
      description
```

```
    "List of association base objects.";
  reference
    "RFC4872";
  leaf association-key {
    type string;
    description
      "Association key used to identify a specific
       association in the list";
  }
  leaf type {
    type identityref {
      base te-types:association-type;
    }
    description
      "Association type.";
    reference
      "RFC4872";
  }
  leaf id {
    type uint16;
    description
      "Association identifier.";
    reference
      "RFC4872";
  }
  container source {
    uses te-generic-node-id;
    description
      "Association source.";
    reference
      "RFC4872";
  }
}
list association-object-extended {
  key "association-key";
  unique
    "type id source/id source/type global-source extended-id";
  description
    "List of extended association objects.";
  reference
    "RFC6780";
  leaf association-key {
    type string;
    description
      "Association key used to identify a specific
       association in the list";
  }
  leaf type {
    type identityref {
```

```
          base te-types:association-type;
        }
        description
          "Association type.";
        reference
          "RFC4872, RFC6780";
      }
      leaf id {
        type uint16;
        description
          "Association identifier.";
        reference
          "RFC4872, RFC6780";
      }
      container source {
        uses te-generic-node-id;
        description
          "Association source.";
        reference
          "RFC4872, RFC6780";
      }
      leaf global-source {
        type uint32;
        description
          "Association global source.";
        reference
          "RFC6780";
      }
      leaf extended-id {
        type yang:hex-string;
        description
          "Association extended identifier.";
        reference
          "RFC6780";
      }
    }
  }
}

grouping tunnel-end-point {
  description
    "Common grouping used to specify the tunnel source and
    destination end-points.";
  leaf node-id {
    type nw:node-id;
    description
      "The TE tunnel end-point node identifier";
  }
  leaf te-node-id {
```

```
    type te-types:te-node-id;
    description
      "The TE tunnel end-point TE node identifier";
  }
  leaf tunnel-tp-id {
    when "../node-id or ../te-node-id" {
      description
        "The TE tunnel termination point identifier is local to
        a node";
    }
    type binary;
    description
      "The TE tunnel end-point TE tunnel termination point
      identifier";
  }
}

/* This grouping is re-used in path-computation rpc */
grouping tunnel-common-attributes {
  description
    "Common grouping to define the TE tunnel parameters";
  container source {
    description
      "TE tunnel source end-point.";
    uses tunnel-end-point;
  }
  container destination {
    description
      "TE tunnel destination end-point.";
    uses tunnel-end-point;
  }
  leaf bidirectional {
    type boolean;
    default "false";
    description
      "Indicates a bidirectional tunnel";
  }
}

/* This grouping is re-used in path-computation rpc */
grouping tunnel-hierarchy-properties {
  description
    "A grouping for TE tunnel hierarchy information.";
  container hierarchy {
    description
      "Container for TE hierarchy related information.";
    container dependency-tunnels {
      description
        "List of tunnels that this tunnel can be potentially
```

```
     dependent on.";
  list dependency-tunnel {
    key "name";
    description
      "A tunnel entry that this tunnel can potentially depend
       on.";
    leaf name {
      type leafref {
        path "/te:te/te:tunnels/te:tunnel/te:name";
        require-instance false;
      }
      description
        "Dependency tunnel name. The tunnel may not have been
         instantiated yet.";
    }
    uses te-types:encoding-and-switching-type;
  }
}
container hierarchical-link {
  description
    "Identifies a hierarchical link (in client layer)
     that this tunnel is associated with. By default, the
     topology of the hierarchical link is the same topology of
     the tunnel;";
  reference
    "RFC4206";
  leaf enable {
    type boolean;
    default "false";
    description
      "Enables the hierarchical link properties supported by
       this tunnel";
  }
  leaf local-node-id {
    type nw:node-id;
    description
      "The local node identifier.";
  }
  leaf local-te-node-id {
    type te-types:te-node-id;
    description
      "The local TE node identifier.";
  }
  leaf local-link-tp-id {
    type nt:tp-id;
    description
      "The local link termination point identifier.";
  }
  leaf local-te-link-tp-id {
```

```
        type te-types:te-tp-id;
        description
          "The local TE link termination point identifier.";
      }
      leaf remote-link-tp-id {
        type nt:tp-id;
        description
          "The remote link termination point identifier.";
      }
      leaf remote-te-node-id {
        type te-types:te-node-id;
        description
          "Remote TE node identifier.";
      }
      leaf network-id {
        type nw:network-id;
        description
          "The network topology identifier where the hierarchical
          link supported by this TE tunnel is instantiated.";
      }
      uses te-types:te-topology-identifier {
        description
          "The TE topology identifier where the hierarchical link
           supported by this TE tunnel is instantiated.";
      }
    }
  }
}

grouping path-constraints-common {
  description
    "Global named path constraints configuration
     grouping.";
  uses te-types:common-path-constraints-attributes {
    description
      "The constraints applicable to the path. This includes:
       - The path bandwidth constraint
       - The path link protection type constraint
       - The path setup/hold priority constraint
       - path signaling type constraint
       - path metric bounds constraint. The unit of path metric
         bound is interpreted in the context of the metric-type.
         For example for metric-type 'path-metric-loss', the bound
         is multiples of the basic unit 0.000003% as described
         in RFC7471 for OSPF, and RFC8570 for ISIS.
       - path affinity constraints
       - path SRLG constraints";

  }
```

```
  uses te-types:generic-path-disjointness;
  uses te-types:path-constraints-route-objects;
  container path-in-segment {
    presence "The end-to-end tunnel starts in a previous domain;
              this tunnel is a segment in the current domain.";
    description
      "If an end-to-end tunnel crosses multiple domains using
       the same technology, some additional constraints have to be
       taken in consideration in each domain.
       This TE tunnel segment is stitched to the upstream TE tunnel
       segment.";
    uses te-types:label-set-info;
  }
  container path-out-segment {
    presence
      "The end-to-end tunnel is not terminated in this domain;
       this tunnel is a segment in the current domain.";
    description
      "If an end-to-end tunnel crosses multiple domains using
       the same technology, some additional constraints have to be
       taken in consideration in each domain.
       This TE tunnel segment is stitched to the downstream TE
       tunnel segment.";
    uses te-types:label-set-info;
  }
}

/**
 * TE container
 */

container te {
  description
    "TE global container.";
  leaf enable {
    type boolean;
    description
      "Enables the TE component features.";
  }

  /* TE Global Data */
  container globals {
    description
      "Globals TE system-wide configuration data container.";
    container named-admin-groups {
      description
        "TE named admin groups container.";
      list named-admin-group {
        if-feature "te-types:extended-admin-groups";
```

```
    if-feature "te-types:named-extended-admin-groups";
    key "name";
    description
      "List of named TE admin-groups.";
    leaf name {
      type string;
      description
        "A string name that uniquely identifies a TE
         interface named admin-group.";
    }
    leaf bit-position {
      type uint32;
      description
        "Bit position representing the administrative group.";
      reference
        "RFC3209 and RFC7308";
    }


  }
}
container named-srlgs {
  description
    "TE named SRLGs container.";
  list named-srlg {
    if-feature "te-types:named-srlg-groups";
    key "name";
    description
      "A list of named SRLG groups.";
    leaf name {
      type string;
      description
        "A string name that uniquely identifies a TE
         interface named SRLG.";
    }
    leaf value {
      type te-types:srlg;
      description
        "An SRLG value.";
    }
    leaf cost {
      type uint32;
      description
        "SRLG associated cost. Used during path to append
         the path cost when traversing a link with this SRLG.";
    }
  }
}
container named-path-constraints {
```

```
    description
      "TE named path constraints container.";
    list named-path-constraint {
      if-feature "te-types:named-path-constraints";
      key "name";
      leaf name {
        type string;
        description
          "A string name that uniquely identifies a
           path constraint set.";
      }
      uses path-constraints-common;
      description
        "A list of named path constraints.";
    }
  }
}

/* TE Tunnel Data */
container tunnels {
  description
    "Tunnels TE configuration data container.";
  list tunnel {
    key "name";
    description
      "The list of TE tunnels.";
    leaf name {
      type string;
      description
        "TE tunnel name.";
    }
    leaf alias {
      type string;
      description
        "An alternate name of the TE tunnel that can be modified
         anytime during its lifetime.";
    }
    leaf identifier {
      type uint32;
      description
        "TE tunnel Identifier.";
      reference
        "RFC3209";
    }
    leaf color {
      type uint32;
      description "The color associated with the TE tunnel.";
      reference "RFC9012";
    }
```

```
leaf description {
  type string;
  default "None";
  description
    "Textual description for this TE tunnel.";
}
leaf admin-state {
  type identityref {
    base te-types:tunnel-admin-state-type;
  }
  default "te-types:tunnel-admin-state-up";
  description
    "TE tunnel administrative state.";
}
leaf operational-state {
  type identityref {
    base te-types:tunnel-state-type;
  }
  config false;
  description
    "TE tunnel operational state.";
}
uses te-types:encoding-and-switching-type;
uses tunnel-common-attributes;
container controller {
  description
    "Contains tunnel data relevant to external controller(s).
     This target node may be augmented by external module(s),
     for example, to add data for PCEP initiated and/or
     delegated tunnels.";
  leaf protocol-origin {
    type identityref {
      base te-types:protocol-origin-type;
    }
    description
      "The protocol origin for instantiating the tunnel.";
  }
  leaf controller-entity-id {
    type string;
    description
      "An identifier unique within the scope of visibility
       that associated with the entity that controls the
       tunnel.";
    reference "RFC8232";
  }
}
leaf reoptimize-timer {
  type uint16;
  units "seconds";
```

```
  description
    "Frequency of reoptimization of a traffic engineered
     LSP.";
}
uses tunnel-associations-properties;
uses protection-restoration-properties;
uses te-types:tunnel-constraints;
uses tunnel-hierarchy-properties;
container primary-paths {
  description
    "The set of primary paths.";
  reference "RFC4872";
  list primary-path {
    key "name";
    description
      "List of primary paths for this tunnel.";
    leaf active {
      type boolean;
      config false;
      description
        "Indicates an active path that
         has been selected from the primary paths list.";
    }
    uses path-common-properties;
    uses path-forward-properties;
    uses k-requested-paths;
    uses path-compute-info;
    uses path-state;
    container primary-reverse-path {
      when "../../../te:bidirectional = 'true'";
      description
        "The reverse primary path properties.";
      uses path-common-properties;
      uses path-compute-info;
      uses path-state;
      container candidate-secondary-reverse-paths {
        description
          "The set of referenced candidate reverse secondary
           paths from the full set of secondary reverse paths
           which may be used for this primary path.";
        list candidate-secondary-reverse-path {
          key "secondary-reverse-path";
          ordered-by user;
          description
            "List of candidate secondary reverse path(s)";
          leaf secondary-reverse-path {
            type leafref {
              path "../../../../../../"
                 + "te:secondary-reverse-paths/"
```

```
            + "te:secondary-reverse-path/te:name";
        }
        description
          "A reference to the reverse secondary path when
           co-routed with the secondary path.";
      }
      leaf active {
        type boolean;
        config false;
        description
          "Indicates an active path that has been
           selected from the secondary reverse paths
           list.";
      }
    }
  }
}
container candidate-secondary-paths {
  description
    "The set of candidate secondary paths which may be
     used for this primary path. When secondary paths are
     specified in the list the path of the secondary LSP
     in use must be restricted to those paths
     referenced.
     The priority of the secondary paths is specified
     within the list. Higher priority values are less
     preferred - that is to say that a path with priority
     0 is the most preferred path. In the case that the
     list is empty, any secondary path may be
     utilised when the current primary path is in use.";
  list candidate-secondary-path {
    key "secondary-path";
    ordered-by user;
    description
      "List of candidate secondary paths for this
       tunnel.";
    leaf secondary-path {
      type leafref {
        path "../../../../../te:secondary-paths/"
           + "te:secondary-path/te:name";
      }
      description
        "A reference to the secondary path that may be
         utilised when the containing primary path is
         in use.";
    }
    leaf active {
      type boolean;
      config false;
```

```
          description
            "Indicates an active path that has been selected
             from the candidate secondary paths.";
        }
      }
    }
  }
}
container secondary-paths {
  description
    "The set of secondary paths.";
  reference "RFC4872";
  list secondary-path {
    key "name";
    description
      "List of secondary paths for this tunnel.";
    uses path-common-properties;
    leaf preference {
      type uint8 {
        range "1..255";
      }
      default "1";
      description
        "Specifies a preference for this path. The lower the
         number higher the preference.";
    }
    leaf secondary-reverse-path {
      type leafref {
        path "../../../"
           + "te:secondary-reverse-paths/"
           + "te:secondary-reverse-path/te:name";
      }
      description
        "A reference to the secondary reverse path that
         may be utilised when the secondary path is in use.";
    }
    uses path-compute-info;
    uses protection-restoration-properties;
    uses path-state;
  }
}
container secondary-reverse-paths {
  description
    "The set of secondary reverse paths.";
  list secondary-reverse-path {
    key "name";
    description
      "List of secondary paths for this tunnel.";
    uses path-common-properties;
```

```
    leaf preference {
      type uint8 {
        range "1..255";
      }
      default "1";
      description
        "Specifies a preference for this path. The lower the
         number higher the preference. Paths that have the
         same preference will be activated together.";
    }
    uses path-compute-info;
    uses protection-restoration-properties;
    uses path-state;
  }
}
action tunnel-action {
  description
    "Tunnel action.";
  input {
    leaf action-type {
      type identityref {
        base te-types:tunnel-action-type;
      }
      description
        "Tunnel action type.";
    }
  }
  output {
    leaf action-result {
      type identityref {
        base te-types:te-action-result;
      }
      description
        "The result of the tunnel action operation.";
    }
  }
}
action protection-external-commands {
  input {
    leaf protection-external-command {
      type identityref {
        base te-types:protection-external-commands;
      }
      description
        "Protection external command.";
    }
    leaf protection-group-ingress-node {
      type boolean;
      default "true";
```

```
  description
    "When 'true', indicates that the action is
     applied on ingress node.
     By default, the action applies to the ingress node
     only.";
}
leaf protection-group-egress-node {
  type boolean;
  default "false";
  description
    "When set to 'true', indicates that the action is
     applied on egress node.
     By default, the action applies to the ingress node
     only.";
}
leaf path-name {
  type string;
  description
    "The name of the path that the external command
    applies to.";
}
leaf path-type {
  type te-types:path-type;
  description
    "The type of the path that the external command
    applies to.";
}
leaf traffic-type {
  type enumeration {
    enum normal-traffic {
      description
        "The manual-switch or forced-switch command
         applies to the normal traffic (this Tunnel).";
    }
    enum null-traffic {
      description
        "The manual-switch or forced-switch command
         applies to the null traffic.";
    }
    enum extra-traffic {
      description
        "The manual-switch or forced-switch command
         applies to the extra traffic (the extra-traffic
         Tunnel sharing protection bandwidth with this
         Tunnel).";
    }
  }
  description
    "Indicates whether the manual-switch or forced-switch
```

```
            commands applies to the normal traffic, the null
            traffic or the extra-traffic.";
          reference
            "RFC4427";
        }
        leaf extra-traffic-tunnel-ref {
          type tunnel-ref;
          description
            "In case there are multiple extra-traffic tunnels
             sharing protection bandwidth with this Tunnel
             (m:n protection), represents which extra-traffic
             Tunnel the manual-switch or forced-switch to
             extra-traffic command applies to.";
        }
      }
    }
  }
}

/* TE LSPs Data */
container lsps {
  config false;
  description
    "TE LSPs state container.";
  list lsp {
    key "tunnel-name lsp-id node";
    unique "source destination tunnel-id lsp-id "
      + "extended-tunnel-id";
    description
      "List of LSPs associated with the tunnel.";
    leaf tunnel-name {
      type string;
      description "The TE tunnel name.";
    }
    leaf lsp-id {
      type uint16;
      description
        "Identifier used in the SENDER_TEMPLATE and the
         FILTER_SPEC that can be changed to allow a sender to
         share resources with itself.";
      reference
        "RFC3209";
    }
    leaf node {
      type te-types:te-node-id;
      description
        "The node where the TE LSP state resides on.";
    }
    leaf source {
```

```
  type te-types:te-node-id;
  description
    "Tunnel sender address extracted from
     SENDER_TEMPLATE  object.";
  reference
    "RFC3209";
}
leaf destination {
  type te-types:te-node-id;
  description
    "The tunnel endpoint address.";
  reference
    "RFC3209";
}
leaf tunnel-id {
  type uint16;
  description
    "The tunnel identifier that remains
     constant over the life of the tunnel.";
  reference
    "RFC3209";
}
leaf extended-tunnel-id {
  type yang:dotted-quad;
  description
    "The LSP Extended Tunnel ID.";
  reference
    "RFC3209";
}
leaf operational-state {
  type identityref {
    base te-types:lsp-state-type;
  }
  description
    "The LSP operational state.";
}
leaf signaling-type {
  type identityref {
    base te-types:path-signaling-type;
  }
  description
    "The signaling protocol used to set up this LSP.";
}
leaf origin-type {
  type enumeration {
    enum ingress {
      description
        "Origin ingress.";
    }
```

```
    enum egress {
      description
        "Origin egress.";
    }
    enum transit {
      description
        "Origin transit.";
    }
  }
  description
    "The origin of the LSP relative to the location of the
     local switch in the path.";
}
leaf lsp-resource-status {
  type enumeration {
    enum primary {
      description
        "A primary LSP is a fully established LSP for which
         the resource allocation has been committed at the
         data plane.";
    }
    enum secondary {
      description
        "A secondary LSP is an LSP that has been provisioned
         in the control plane only; e.g. resource allocation
         has not been committed at the data plane.";
    }
  }
  description
    "LSP resource allocation state.";
  reference
    "RFC4872, section 4.2.1";
}
leaf lockout-of-normal {
  type boolean;
  description
    "When set to 'true', it represents a lockout of normal
     traffic external command. When set to 'false', it
     represents a clear lockout of normal traffic external
     command. The lockout of normal traffic command applies
     to this Tunnel.";
  reference
    "RFC4427";
}
leaf freeze {
  type boolean;
  description
    "When set to 'true', it represents a freeze external
     command.  When set to 'false', it represents a clear
```

```
     freeze external command. The freeze command applies to
     all the Tunnels which are sharing the protection
     resources with this Tunnel.";
  reference
    "RFC4427";
}
leaf lsp-protection-role {
  type enumeration {
    enum working {
      description
        "A working LSP must be a primary LSP whilst a
         protecting LSP can be either a primary or a
         secondary LSP. Also, known as protected LSPs when
         working LSPs are associated with protecting LSPs.";
    }
    enum protecting {
      description
        "A secondary LSP is an LSP that has been provisioned
         in the control plane only; e.g. resource allocation
         has not been committed at the data plane.";
    }
  }
  description
    "LSP role type.";
  reference
    "RFC4872, section 4.2.1";
}
leaf lsp-protection-state {
  type identityref {
    base te-types:lsp-protection-state;
  }
  config false;
  description
    "The reported protection state controlling which
     tunnel is using the resources of the protecting LSP.";
}
leaf protection-group-ingress-node-id {
  type te-types:te-node-id;
  description
    "Indicates the te-node-id of the protection group
     ingress node when the APS state represents an external
     command (LoP, SF, MS) applied to it or a WTR timer
     running on it. If the external command is not applied to
     the ingress node or the WTR timer is not running on it,
     this attribute is not specified. A value 0.0.0.0 is used
     when the te-node-id of the protection group ingress node
     is unknown (e.g., because the ingress node is outside
     the scope of control of the server)";
}
```

```
      leaf protection-group-egress-node-id {
        type te-types:te-node-id;
        description
          "Indicates the te-node-id of the protection group egress
           node when the APS state represents an external command
           (LoP, SF, MS) applied to it or a WTR timer running on
           it. If the external command is not applied to the
           ingress node or the WTR timer is not running on it, this
           attribute is not specified. A value 0.0.0.0 is used when
           the te-node-id of the protection group ingress node is
           unknown (e.g., because the ingress node is outside the
           scope of control of the server)";
      }
      container lsp-actual-route-information {
        description
          "RSVP recorded route object information.";
        list lsp-actual-route-information {
          when "../../origin-type = 'ingress'" {
            description
              "Applicable on ingress LSPs only.";
          }
          key "index";
          description
            "Record route list entry.";
          uses te-types:record-route-state;
        }
      }
    }
  }
}

/* TE Tunnel RPCs/execution Data */

rpc tunnels-path-compute {
  description
    "TE tunnels RPC nodes.";
  input {
    container path-compute-info {
      /*
       * An external path compute module may augment this
       * target.
       */
      description
        "RPC input information.";
    }
  }
  output {
    container path-compute-result {
      /*
```

```
       * An external path compute module may augment this
       * target.
       */
      description
        "RPC output information.";
    }
  }
}

rpc tunnels-actions {
  description
    "TE tunnels actions RPC";
  input {
    container tunnel-info {
      description
        "TE tunnel information.";
      choice filter-type {
        mandatory true;
        description
          "Filter choice.";
        case all-tunnels {
          leaf all {
            type empty;
            mandatory true;
            description
              "When present, applies the action on all TE
               tunnels.";
          }
        }
        case one-tunnel {
          leaf tunnel {
            type tunnel-ref;
            description
              "Apply action on the specific TE tunnel.";
          }
        }
      }
    }
    container action-info {
      description
        "TE tunnel action information.";
      leaf action {
        type identityref {
          base te-types:tunnel-action-type;
        }
        description
          "The action type.";
      }
      leaf disruptive {
```

```
          when "derived-from-or-self(../action, "
             + "'te-types:tunnel-action-reoptimize')";
          type empty;
          description
            "When present, specifies whether or not the
             reoptimization
             action is allowed to be disruptive.";
        }
      }
    }
    output {
      leaf action-result {
        type identityref {
          base te-types:te-action-result;
        }
        description
          "The result of the tunnel action operation.";
      }
    }
  }
}
```

<CODE ENDS>

Figure 7: TE Tunnel data model YANG module

6. TE Device YANG Model

The device TE YANG module ('ietf-te-device') models data that is specific to managing a TE device. This module augments the generic TE YANG module.

6.1. Module Structure

6.1.1. TE Interfaces

This branch of the model manages TE interfaces that are present on a device. Examples of TE interface properties are:

- *Maximum reservable bandwidth, bandwidth constraints (BC)
- *Flooding parameters
  - -Flooding intervals and threshold values
- *Interface attributes
  - -(Extended) administrative groups
  - -SRLG values
  - -TE metric value
- *Fast reroute backup tunnel properties (such as static, auto-tunnel)

The derived state associated with interfaces is grouped under the interface "state" sub-container as shown in Figure 8. This covers state data such as:

- *Bandwidth information: maximum bandwidth, available bandwidth at different priorities and for each class-type (CT)
- *List of admitted LSPs
  - -Name, bandwidth value and pool, time, priority
- *Statistics: state counters, flooding counters, admission counters (accepted/rejected), preemption counters
- *Adjacency information
  - -Neighbor address
  - -Metric value

```
module: ietf-te-device
  augment /te:te:
      +--rw interfaces
         .
         +-- rw te-dev:te-attributes
                <<intended configuration>>
             .
             +-- ro state
                <<derived state associated with the TE interface>>
```

Figure 8: TE interface state YANG subtree

6.2. Tree Diagram

Figure 9 shows the tree diagram of the device TE YANG model defined in modules 'ietf-te-device.yang'.

```
module: ietf-te-device

  augment /te:te:
    +--rw interfaces
       +--rw threshold-type?            enumeration
       +--rw delta-percentage?          rt-types:percentage
       +--rw threshold-specification?   enumeration
       +--rw up-thresholds*             rt-types:percentage
       +--rw down-thresholds*           rt-types:percentage
       +--rw up-down-thresholds*        rt-types:percentage
       +--rw interface* [interface]
          +--rw interface                          if:interface-ref
          +--rw te-metric?
          |       te-types:te-metric
          +--rw (admin-group-type)?
          |  +--:(value-admin-groups)
          |  |  +--rw (value-admin-group-type)?
          |  |     +--:(admin-groups)
          |  |     |  +--rw admin-group?
          |  |     |          te-types:admin-group
          |  |     +--:(extended-admin-groups)
          |  |              {te-types:extended-admin-groups}?
          |  |        +--rw extended-admin-group?
          |  |                te-types:extended-admin-group
          |  +--:(named-admin-groups)
          |     +--rw named-admin-groups* [named-admin-group]
          |             {te-types:extended-admin-groups,
          |              te-types:named-extended-admin-groups}?
          |        +--rw named-admin-group    leafref
          +--rw (srlg-type)?
          |  +--:(value-srlgs)
          |  |  +--rw values* [value]
          |  |     +--rw value    uint32
          |  +--:(named-srlgs)
          |     +--rw named-srlgs* [named-srlg]
          |             {te-types:named-srlg-groups}?
          |        +--rw named-srlg    leafref
          +--rw threshold-type?                    enumeration
          +--rw delta-percentage?
          |       rt-types:percentage
          +--rw threshold-specification?           enumeration
          +--rw up-thresholds*
          |       rt-types:percentage
          +--rw down-thresholds*
          |       rt-types:percentage
          +--rw up-down-thresholds*
          |       rt-types:percentage
          +--rw switching-capabilities* [switching-capability]
          |  +--rw switching-capability    identityref
```

```
        |  +--rw encoding?               identityref
        +--ro te-advertisements-state
           +--ro flood-interval?           uint32
           +--ro last-flooded-time?        uint32
           +--ro next-flooded-time?        uint32
           +--ro last-flooded-trigger?     enumeration
           +--ro advertised-level-areas* [level-area]
              +--ro level-area    uint32
augment /te:te/te:globals:
  +--rw lsp-install-interval?        uint32
  +--rw lsp-cleanup-interval?        uint32
  +--rw lsp-invalidation-interval?   uint32
augment /te:te/te:tunnels/te:tunnel:
  +--rw path-invalidation-action?    identityref
  +--rw lsp-install-interval?        uint32
  +--rw lsp-cleanup-interval?        uint32
  +--rw lsp-invalidation-interval?   uint32
augment /te:te/te:lsps/te:lsp:
  +--ro lsp-timers
  |  +--ro uptime?            uint32
  |  +--ro time-to-install?   uint32
  |  +--ro time-to-destroy?   uint32
  +--ro downstream-info
  |  +--ro nhop?                 te-types:te-tp-id
  |  +--ro outgoing-interface?   if:interface-ref
  |  +--ro neighbor
  |  |  +--ro id?     te-gen-node-id
  |  |  +--ro type?   enumeration
  |  +--ro label?               rt-types:generalized-label
  +--ro upstream-info
     +--ro phop?       te-types:te-tp-id
     +--ro neighbor
     |  +--ro id?     te-gen-node-id
     |  +--ro type?   enumeration
     +--ro label?     rt-types:generalized-label

rpcs:
  +---x link-state-update
     +---w input
        +---w (filter-type)
           +--:(match-all)
           |  +---w all          empty
           +--:(match-one-interface)
              +---w interface?   if:interface-ref
```

Figure 9: TE Tunnel device model YANG tree diagram

6.3. YANG Module

The device TE YANG module 'ietf-te-device' imports the following module(s):

- *ietf-interfaces defined in [RFC8343]
- *ietf-routing-types defined in [RFC8294]
- *ietf-te-types defined in [RFC8776]
- *ietf-te defined in this document

```
<CODE BEGINS> file "ietf-te-device@2023-06-16.yang"

module ietf-te-device {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-te-device";

  /* Replace with IANA when assigned */

  prefix te-dev;

  /* Import TE module */

  import ietf-te {
    prefix te;
    reference
      "RFCXXXX: A YANG Data Model for Traffic Engineering
       Tunnels and Interfaces";
  }

  /* Import TE types */

  import ietf-te-types {
    prefix te-types;
    reference
      "RFC8776: Common YANG Data Types for Traffic Engineering.";
  }
  import ietf-interfaces {
    prefix if;
    reference
      "RFC8343: A YANG Data Model for Interface Management";
  }
  import ietf-routing-types {
    prefix rt-types;
    reference
      "RFC8294: Common YANG Data Types for the Routing Area";
  }

  organization
    "IETF Traffic Engineering Architecture and Signaling (TEAS)
     Working Group";
  contact
    "WG Web:   <https://tools.ietf.org/wg/teas/>
     WG List:  <mailto:teas@ietf.org>

     Editor:   Tarek Saad
               <mailto:tsaad.net@gmail.com>

     Editor:   Rakesh Gandhi
               <mailto:rgandhi@cisco.com>
```

```
   Editor:   Vishnu Pavan Beeram
             <mailto:vbeeram@juniper.net>

   Editor:   Himanshu Shah
             <mailto:hshah@ciena.com>

   Editor:   Xufeng Liu
             <mailto: xufeng.liu.ietf@gmail.com>

   Editor:   Igor Bryskin
             <mailto:i_bryskin@yahoo.com>

   Editor:   Oscar Gonzalez de Dios
             <mailto: oscar.gonzalezdedios@telefonica.com>";

 description
   "This module defines a data model for TE device configurations,
    state, and RPCs. The model fully conforms to the
    Network Management Datastore Architecture (NMDA).

    Copyright (c) 2023 IETF Trust and the persons identified as
    authors of the code.  All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject to
    the license terms contained in, the Revised BSD License set
    forth in Section 4.c of the IETF Trust's Legal Provisions
    Relating to IETF Documents
    (https://trustee.ietf.org/license-info).

    This version of this YANG module is part of RFC XXXX
    (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
    for full legal notices.";

 // RFC Ed.: replace XXXX with actual RFC number and remove this
 // note.
 // RFC Ed.: update the date below with the date of RFC publication
 // and remove this note.

 revision 2023-06-16 {
   description
     "Initial revision for the TE device YANG module.";
   reference
     "RFCXXXX: A YANG Data Model for Traffic Engineering Tunnels
      and Interfaces";
 }

 grouping lsp-device-timers {
   description
     "Device TE LSP timers configs.";
```

```
  leaf lsp-install-interval {
    type uint32;
    units "seconds";
    description
      "TE LSP installation delay time.";
  }
  leaf lsp-cleanup-interval {
    type uint32;
    units "seconds";
    description
      "TE LSP cleanup delay time.";
  }
  leaf lsp-invalidation-interval {
    type uint32;
    units "seconds";
    description
      "TE LSP path invalidation before taking action delay time.";
  }
}

grouping te-igp-flooding-bandwidth-config {
  description
    "Configurable items for igp flooding bandwidth
     threshold configuration.";
  leaf threshold-type {
    type enumeration {
      enum delta {
        description
          "'delta' indicates that the local
           system should flood IGP updates when a
           change in reserved bandwidth >= the specified
           delta occurs on the interface.";
      }
      enum threshold-crossed {
        description
          "THRESHOLD-CROSSED indicates that
           the local system should trigger an update (and
           hence flood) the reserved bandwidth when the
           reserved bandwidth changes such that it crosses,
           or becomes equal to one of the threshold values.";
      }
    }
    description
      "The type of threshold that should be used to specify the
       values at which bandwidth is flooded. 'delta' indicates that
       the local system should flood IGP updates when a change in
       reserved bandwidth >= the specified delta occurs on the
       interface. Where 'threshold-crossed' is specified, the local
       system should trigger an update (and hence flood) the
```

```
     reserved bandwidth when the reserved bandwidth changes such
     that it crosses, or becomes equal to one of the threshold
     values.";
  }
  leaf delta-percentage {
    when "../threshold-type = 'delta'" {
      description
        "The percentage delta can only be specified when the
         threshold type is specified to be a percentage delta of
         the reserved bandwidth.";
    }
    type rt-types:percentage;
    description
      "The percentage of the maximum-reservable-bandwidth
       considered as the delta that results in an IGP update
       being flooded.";
  }
  leaf threshold-specification {
    when "../threshold-type = 'threshold-crossed'" {
      description
        "The selection of whether mirrored or separate threshold
         values are to be used requires user specified thresholds
         to be set.";
    }
    type enumeration {
      enum mirrored-up-down {
        description
          "mirrored-up-down indicates that a single set of
           threshold values should be used for both increasing
           and decreasing bandwidth when determining whether
           to trigger updated bandwidth values to be flooded
           in the IGP TE extensions.";
      }
      enum separate-up-down {
        description
          "separate-up-down indicates that a separate
           threshold values should be used for the increasing
           and decreasing bandwidth when determining whether
           to trigger updated bandwidth values to be flooded
           in the IGP TE extensions.";
      }
    }
    description
      "This value specifies whether a single set of threshold
       values should be used for both increasing and decreasing
       bandwidth when determining whether to trigger updated
       bandwidth values to be flooded in the IGP TE extensions.
       'mirrored-up-down' indicates that a single value (or set of
       values) should be used for both increasing and decreasing
```

```
     values, where 'separate-up-down' specifies that the
     increasing and decreasing values will be separately
     specified.";
}
leaf-list up-thresholds {
  when "../threshold-type = 'threshold-crossed'"
     + "and ../threshold-specification = 'separate-up-down'" {
    description
      "A list of up-thresholds can only be specified when the
       bandwidth update is triggered based on crossing a
       threshold and separate up and down thresholds are
       required.";
  }
  type rt-types:percentage;
  description
    "The thresholds (expressed as a percentage of the maximum
     reservable bandwidth) at which bandwidth updates are to be
     triggered when the bandwidth is increasing.";
}
leaf-list down-thresholds {
  when "../threshold-type = 'threshold-crossed'"
     + "and ../threshold-specification = 'separate-up-down'" {
    description
      "A list of down-thresholds can only be specified when the
       bandwidth update is triggered based on crossing a
       threshold and separate up and down thresholds are
       required.";
  }
  type rt-types:percentage;
  description
    "The thresholds (expressed as a percentage of the maximum
     reservable bandwidth) at which bandwidth updates are to be
     triggered when the bandwidth is decreasing.";
}
leaf-list up-down-thresholds {
  when "../threshold-type = 'threshold-crossed'"
     + "and ../threshold-specification = 'mirrored-up-down'" {
    description
      "A list of thresholds corresponding to both increasing
       and decreasing bandwidths can be specified only when an
       update is triggered based on crossing a threshold, and
       the same up and down thresholds are required.";
  }
  type rt-types:percentage;
  description
    "The thresholds (expressed as a percentage of the maximum
     reservable bandwidth of the interface) at which bandwidth
     updates are flooded - used both when the bandwidth is
     increasing and decreasing.";
```

```
  }
}

/**
 * TE device augmentations
 */
augment "/te:te" {
  description
    "TE global container.";
  /* TE Interface Configuration Data */
  container interfaces {
    description
      "Configuration data model for TE interfaces.";
    uses te-igp-flooding-bandwidth-config;
    list interface {
      key "interface";
      description
        "TE interfaces.";
      leaf interface {
        type if:interface-ref;
        description
          "TE interface name.";
      }
      /* TE interface parameters */
      leaf te-metric {
        type te-types:te-metric;
        description
          "TE interface metric.";
      }
      choice admin-group-type {
        description
          "TE interface administrative groups
           representation type.";
        case value-admin-groups {
          choice value-admin-group-type {
            description
              "choice of admin-groups.";
            case admin-groups {
              description
                "Administrative group/Resource
                 class/Color.";
              leaf admin-group {
                type te-types:admin-group;
                description
                  "TE interface administrative group.";
              }
            }
            case extended-admin-groups {
              if-feature "te-types:extended-admin-groups";
```

```
        description
          "Extended administrative group/Resource
           class/Color.";
        leaf extended-admin-group {
          type te-types:extended-admin-group;
          description
            "TE interface extended administrative group.";
        }
      }
    }
  }
  case named-admin-groups {
    list named-admin-groups {
      if-feature "te-types:extended-admin-groups";
      if-feature "te-types:named-extended-admin-groups";
      key "named-admin-group";
      description
        "A list of named admin-group entries.";
      leaf named-admin-group {
        type leafref {
          path "../../../../te:globals/"
             + "te:named-admin-groups/te:named-admin-group/"
             + "te:name";
        }
        description
          "A named admin-group entry.";
      }
    }
  }
}
choice srlg-type {
  description
    "Choice of SRLG configuration.";
  case value-srlgs {
    list values {
      key "value";
      description
        "List of SRLG values that
         this link is part of.";
      leaf value {
        type uint32 {
          range "0..4294967295";
        }
        description
          "Value of the SRLG";
      }
    }
  }
  case named-srlgs {
```

```
    list named-srlgs {
      if-feature "te-types:named-srlg-groups";
      key "named-srlg";
      description
        "A list of named SRLG entries.";
      leaf named-srlg {
        type leafref {
          path "../../../../te:globals/"
             + "te:named-srlgs/te:named-srlg/te:name";
        }
        description
          "A named SRLG entry.";
      }
    }
  }
}
uses te-igp-flooding-bandwidth-config;
list switching-capabilities {
  key "switching-capability";
  description
    "List of interface capabilities for this interface.";
  leaf switching-capability {
    type identityref {
      base te-types:switching-capabilities;
    }
    description
      "Switching Capability for this interface.";
  }
  leaf encoding {
    type identityref {
      base te-types:lsp-encoding-types;
    }
    description
      "Encoding supported by this interface.";
  }
}
container te-advertisements-state {
  config false;
  description
    "TE interface advertisements state container.";
  leaf flood-interval {
    type uint32;
    description
      "The periodic flooding interval.";
  }
  leaf last-flooded-time {
    type uint32;
    units "seconds";
    description
```

```
    "Time elapsed since last flooding in seconds.";
}
leaf next-flooded-time {
  type uint32;
  units "seconds";
  description
    "Time remained for next flooding in seconds.";
}
leaf last-flooded-trigger {
  type enumeration {
    enum link-up {
      description
        "Link-up flooding trigger.";
    }
    enum link-down {
      description
        "Link-down flooding trigger.";
    }
    enum threshold-up {
      description
        "Bandwidth reservation up threshold.";
    }
    enum threshold-down {
      description
        "Bandwidth reservation down threshold.";
    }
    enum bandwidth-change {
      description
        "Bandwidth capacity change.";
    }
    enum user-initiated {
      description
        "Initiated by user.";
    }
    enum srlg-change {
      description
        "SRLG property change.";
    }
    enum periodic-timer {
      description
        "Periodic timer expired.";
    }
  }
  default "periodic-timer";
  description
    "Trigger for the last flood.";
}
list advertised-level-areas {
  key "level-area";
```

```
          description
            "List of level-areas that the TE interface is
             advertised in.";
          leaf level-area {
            type uint32;
            description
              "The IGP area or level where the TE interface link
               state is advertised in.";
          }
        }
      }
    }
  }
}

/* TE globals device augmentation */

augment "/te:te/te:globals" {
  description
    "Global TE device specific configuration parameters.";
  uses lsp-device-timers;
}

/* TE tunnels device configuration augmentation */

augment "/te:te/te:tunnels/te:tunnel" {
  description
    "Tunnel device dependent augmentation.";
  leaf path-invalidation-action {
    type identityref {
      base te-types:path-invalidation-action-type;
    }
    description
      "Tunnel path invalidation action.";
  }
  uses lsp-device-timers;
}

/* TE LSPs device state augmentation */

augment "/te:te/te:lsps/te:lsp" {
  description
    "TE LSP device dependent augmentation.";
  container lsp-timers {
    when "../te:origin-type = 'ingress'" {
      description
        "Applicable to ingress LSPs only.";
    }
    description
```

```
      "Ingress LSP timers.";
    leaf uptime {
      type uint32;
      units "seconds";
      description
        "The LSP uptime.";
    }
    leaf time-to-install {
      type uint32;
      units "seconds";
      description
        "The time remaining for a new LSP to be instantiated
         in forwarding to carry traffic.";
    }
    leaf time-to-destroy {
      type uint32;
      units "seconds";
      description
        "The time remaining for a existing LSP to be deleted
         from forwarding.";
    }
  }
  container downstream-info {
    when "../te:origin-type != 'egress'" {
      description
        "Downstream information of the LSP.";
    }
    description
      "downstream information.";
    leaf nhop {
      type te-types:te-tp-id;
      description
        "downstream next-hop address.";
    }
    leaf outgoing-interface {
      type if:interface-ref;
      description
        "downstream interface.";
    }
    container neighbor {
      uses te:te-generic-node-id;
      description
        "downstream neighbor address.";
    }
    leaf label {
      type rt-types:generalized-label;
      description
        "downstream label.";
    }
```

```
  }
  container upstream-info {
    when "../te:origin-type != 'ingress'" {
      description
        "Upstream information of the LSP.";
    }
    description
      "upstream information.";
    leaf phop {
      type te-types:te-tp-id;
      description
        "upstream next-hop or previous-hop address.";
    }
    container neighbor {
      uses te:te-generic-node-id;
      description
        "upstream neighbor address.";
    }
    leaf label {
      type rt-types:generalized-label;
      description
        "upstream label.";
    }
  }
}

/* TE interfaces RPCs/execution Data */

rpc link-state-update {
  description
    "Triggers a link state update for the specific interface.";
  input {
    choice filter-type {
      mandatory true;
      description
        "Filter choice.";
      case match-all {
        leaf all {
          type empty;
          mandatory true;
          description
            "Match all TE interfaces.";
        }
      }
      case match-one-interface {
        leaf interface {
          type if:interface-ref;
          description
            "Match a specific TE interface.";
```

```
            }
          }
        }
      }
    }
  }
}

<CODE ENDS>
```

Figure 10: TE device data model YANG module

7. Notifications

Notifications are a key component of any topology data model.

[RFC8639] and [RFC8641] define a subscription mechanism and a push mechanism for YANG datastores. These mechanisms currently allow the user to:

*Subscribe to notifications on a per-client basis.

*Specify subtree filters or XML Path Language (XPath) filters so that only contents of interest will be sent.

*Specify either periodic or on-demand notifications.

8. IANA Considerations

This document registers the following URIs in the IETF XML registry [RFC3688]. Following the format in [RFC3688], the following registrations are requested to be made.

URI: urn:ietf:params:xml:ns:yang:ietf-te
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-te-device
Registrant Contact: The IESG.
XML: N/A, the requested URI is an XML namespace.

This document registers two YANG modules in the YANG Module Names registry [RFC6020].

Name: ietf-te
Namespace: urn:ietf:params:xml:ns:yang:ietf-te
Prefix: te
Reference: RFCXXXX

Name: ietf-te-device
Namespace: urn:ietf:params:xml:ns:yang:ietf-te-device
Prefix: te-device
Reference: RFCXXXX

9. Security Considerations

The YANG module specified in this document defines a schema for data that is designed to be accessed via network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the mandatory-to-implement

secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the mandatory-to-implement secure transport is TLS [RFC8446].

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

"/te/globals": This module specifies the global TE configurations on a device. Unauthorized access to this container could cause the device to ignore packets it should receive and process.

"/te/tunnels": This list specifies the configuration and state of TE Tunnels present on the device or controller. Unauthorized access to this list could cause the device to ignore packets it should receive and process. An attacker may also use state to derive information about the network topology, and subsequently orchestrate further attacks.

"/te/interfaces": This list specifies the configuration and state TE interfaces on a device. Unauthorized access to this list could cause the device to ignore packets it should receive and process.

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

"/te/lsps": this list contains information state about established LSPs in the network. An attacker can use this information to derive information about the network topology, and subsequently orchestrate further attacks.

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

"/te/tunnels-actions": using this RPC, an attacker can modify existing paths that may be carrying live traffic, and hence result to interruption to services carried over the network.

"/te/tunnels-path-compute": using this RPC, an attacker can retrieve secured information about the network provider which can be used to orchestrate further attacks.

The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

10. Acknowledgement

The authors would like to thank the members of the multi-vendor YANG design team who are involved in the definition of this model.

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12. Appendix A: Data Tree Examples

This section contains examples of use of the model with RESTCONF [RFC8040] and JSON encoding.

For the example we will use a 4 node MPLS network were RSVP-TE MPLS Tunnels can be setup. The loopbacks of each router are shown. The network in Figure 11 will be used in the examples described in the following sections.

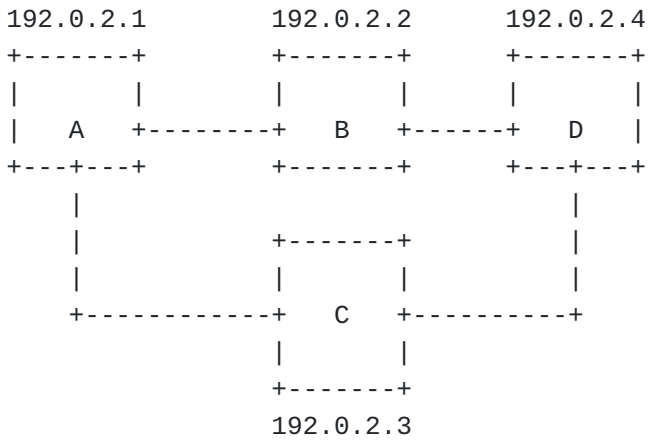

Figure 11: TE network used in data tree examples

12.1. Basic Tunnel Setup

This example uses the TE Tunnel YANG data model defined in this document to create an RSVP-TE signaled Tunnel of packet LSP encoding type. First, the TE Tunnel is created with no specific restrictions or constraints (e.g., protection or restoration). The TE Tunnel ingresses on router A and egresses on router D.

In this case, the TE Tunnel is created without specifying additional information about the primary paths.

```
POST /restconf/data/ietf-te:te/tunnels HTTP/1.1
    Host: example.com
    Accept: application/yang-data+json
    Content-Type: application/yang-data+json

{
  "ietf-te:tunnel": [
    {
      "name": "Example_LSP_Tunnel_A_2",
      "encoding": "te-types:lsp-encoding-packet",
      "admin-state": "te-types:tunnel-state-up",
      "source": "192.0.2.1",
      "destination": "192.0.2.4",
      "bidirectional": "false",
      "signaling-type": "te-types:path-setup-rsvp"
    }
  ]
}
```

12.2. Global Named Path Constraints

This example uses the YANG data model to create a 'named path constraint' that can be reference by TE Tunnels. The path constraint, in this case, limits the TE Tunnel hops for the computed path.

```
POST /restconf/data/ietf-te:te/globals/named-path-constraints
     HTTP/1.1
    Host: example.com
    Accept: application/yang-data+json
    Content-Type: application/yang-data+json


  "ietf-te:named-path-constraint": {
         "name": "max-hop-3",
         "path-metric-bounds": {
           "path-metric-bound": {
             "metric-type": "te-types:path-metric-hop",
             "upper-bound": "3"
    }
   }
  }
}
```

12.3. Tunnel with Global Path Constraint

In this example, the previously created 'named path constraint' is applied to the TE Tunnel created in Section 12.1.

```
POST /restconf/data/ietf-te:te/tunnels HTTP/1.1
    Host: example.com
    Accept: application/yang-data+json
    Content-Type: application/yang-data+json

{
  "ietf-te:ietf-tunnel": [
    {
      "name": "Example_LSP_Tunnel_A_4_1",
      "encoding": "te-types:lsp-encoding-packet",
      "description": "Simple_LSP_with_named_path",
      "admin-state": "te-types:tunnel-state-up",
      "source": "192.0.2.1",
      "destination": "192.0.2.4",
      "signaling-type": "path-setup-rsvp",
      "primary-paths": [
        {
          "primary-path": {
            "name": "Simple_LSP_1",
            "use-path-computation": "true",
            "named-path-constraint": "max-hop-3"
          }
        }
      ]
    }
  ]
}
```

12.4. Tunnel with Per-tunnel Path Constraint

In this example, the a per tunnel path constraint is explicitly indicated under the TE Tunnel created in Section 12.1 to constrain the computed path for the tunnel.

```
POST /restconf/data/ietf-te:te/tunnels HTTP/1.1
    Host: example.com
    Accept: application/yang-data+json
    Content-Type: application/yang-data+json

{
  "ietf-te:tunnel": [
    {
      "name": "Example_LSP_Tunnel_A_4_2",
      "encoding": "te-types:lsp-encoding-packet",
      "admin-state": "te-types:tunnel-state-up",
      "source": "192.0.2.1",
      "destination": "192.0.2.4",
      "signaling-type": "te-types:path-setup-rsvp",
      "primary-paths": {
        "primary-path": [
          {
            "name": "path1",
            "path-metric-bounds": {
              "path-metric-bound": [
                {
                  "metric-type": "te-types:path-metric-hop",
                  "upper-bound": "3"
                }
              ]
            }
          }
        ]
      }
    }
  ]
}
```

12.5. Tunnel State

In this example, the 'GET' query is sent to return the state stored about the tunnel.

```
GET  /restconf/data/ietf-te:te/tunnels +
     /tunnel="Example_LSP_Tunnel_A_4_1"
     /p2p-primary-paths/ HTTP/1.1
    Host: example.com
    Accept: application/yang-data+json
```

The request, with status code 200 would include, for example, the following json:

```
{
  "ietf-te:primary-paths": {
    "primary-path": [
      {
        "name": "path1",
        "path-computation-method": "te-types:path-locally-computed",
        "computed-paths-properties": {
          "computed-path-properties": [
            {
              "k-index": "1",
              "path-properties": {
                "path-route-objects": {
                  "path-route-object": [
                    {
                      "index": "1",
                      "numbered-node-hop": {
                        "node-id": "192.0.2.2"
                      }
                    },
                    {
                      "index": "2",
                      "numbered-node-hop": {
                        "node-id": "192.0.2.4"
                      }
                    }
                  ]
                }
              }
            }
          ]
        },
        "lsps": {
          "lsp": [
            {
              "tunnel-name": "Example_LSP_Tunnel_A_4_1",
              "node": "192.0.2.1 ",
              "lsp-id": "25356"
            }
          ]
        }
      }
    ]
  }
}
```


12.6. Example TE Tunnel with Primary and Secondary Paths

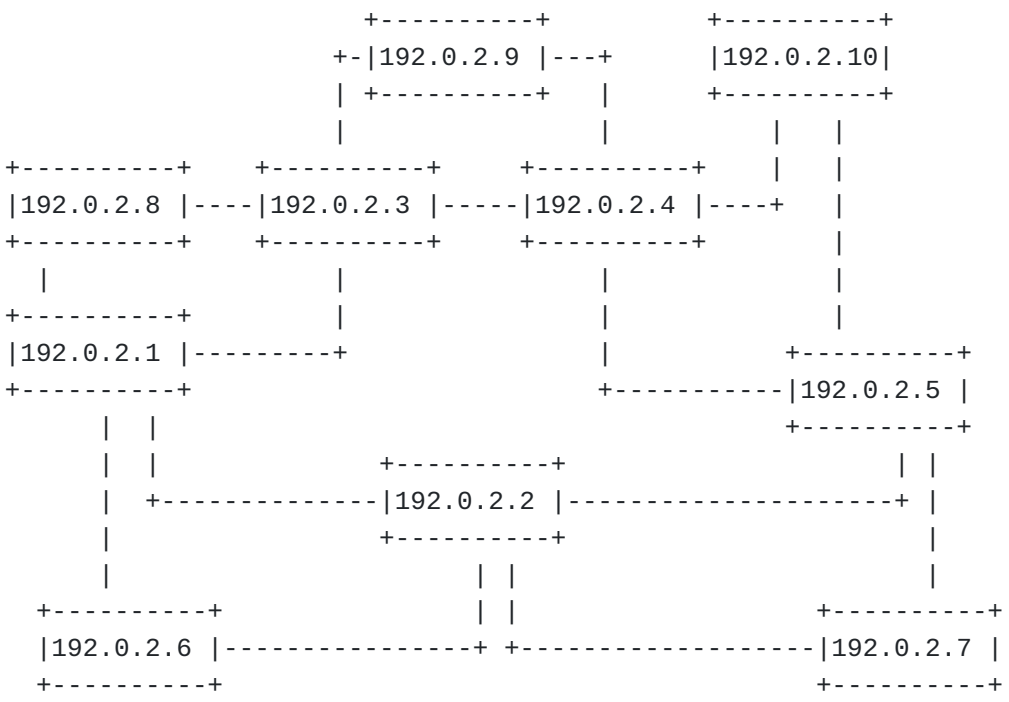

Figure 12: TE network used in data tree examples

Below is the state retrieved for a TE tunnel from source 192.0.2.1 to 192.0.2.5 with primary, secondary, reverse, and secondary reverse paths as shown in Figure 12.

```
{
  "ietf-te:te": {
    "tunnels": {
      "tunnel": [
        {
          "name": "example-1",
          "description": "Example in slide 1",
          "source": "192.0.2.1",
          "destination": "192.0.2.5",
          "bidirectional": false,
          "primary-paths": {
            "primary-path": [
              {
                "name": "primary-1 (fwd)",
                "explicit-route-objects-always": {
                  "route-object-include-exclude": [
                    {
                      "index": 1,
                      "numbered-node-hop": {
                        "node-id": "192.0.2.2",
                        "hop-type": "loose"
                      }
                    }
                  ]
                },
                "primary-reverse-path": {
                  "name": "primary-2 (rev)",
                  "explicit-route-objects-always": {
                    "route-object-include-exclude": [
                      {
                        "index": 1,
                        "numbered-node-hop": {
                          "node-id": "192.0.2.3",
                          "hop-type": "loose"
                        }
                      }
                    ]
                  },
                  "candidate-secondary-reverse-paths": {
                    "candidate-secondary-reverse-path": [
                      "secondary-3 (rev)",
                      "secondary-4 (rev)",
                      "secondary-5 (rev)"
                    ]
                  }
                },
                "candidate-secondary-paths": {
                  "candidate-secondary-path": [
                    "secondary-1 (fwd)",
```

```
          "secondary-2 (fwd)"
        ]
      }
    }
  ]
},
"secondary-paths": {
  "secondary-path": [
    {
      "name": "secondary-1 (fwd)",
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.1"
            }
          },
          {
            "index": 2,
            "numbered-node-hop": {
              "node-id": "192.0.2.2",
              "hop-type": "loose"
            }
          }
        ]
      }
    },
    {
      "name": "secondary-2 (fwd)",
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.2"
            }
          },
          {
            "index": 2,
            "numbered-node-hop": {
              "node-id": "192.0.2.5",
              "hop-type": "loose"
            }
          }
        ]
      }
    }
  ]
```

```
},
"secondary-reverse-paths": {
  "secondary-reverse-path": [
    {
      "name": "secondary-3 (rev)",
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.5"
            }
          },
          {
            "index": 2,
            "numbered-node-hop": {
              "node-id": "192.0.2.4",
              "hop-type": "loose"
            }
          }
        ]
      }
    },
    {
      "name": "secondary-4 (rev)",
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.4"
            }
          },
          {
            "index": 2,
            "numbered-node-hop": {
              "node-id": "192.0.2.3",
              "hop-type": "loose"
            }
          }
        ]
      }
    },
    {
      "name": "secondary-5 (rev)",
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
```

```
              "numbered-node-hop": {
                "node-id": "192.0.2.3"
              }
            },
            {
              "index": 2,
              "numbered-node-hop": {
                "node-id": "192.0.2.1",
                "hop-type":"loose"
              }
            }
          ]
        }
      }
    ]
  }
},
{
  "name": "example-3",
  "description": "Example in slide 3",
  "source": "192.0.2.1",
  "destination": "192.0.2.5",
  "bidirectional": true,
  "primary-paths": {
    "primary-path": [
      {
        "name": "primary-1 (bidir)",
        "explicit-route-objects-always": {
          "route-object-include-exclude": [
            {
              "index": 1,
              "numbered-node-hop": {
                "node-id": "192.0.2.2",
                "hop-type": "loose"
              }
            }
          ]
        },
        "candidate-secondary-paths": {
          "candidate-secondary-path": [
            "secondary-1 (bidir)",
            "secondary-2 (bidir)"
          ]
        }
      }
    ]
  },
  "secondary-paths": {
    "secondary-path": [
```

```
      {
        "name": "secondary-1 (bidir)",
        "explicit-route-objects-always": {
          "route-object-include-exclude": [
            {
              "index": 1,
              "numbered-node-hop": {
                "node-id": "192.0.2.1"
              }
            },
            {
              "index": 2,
              "numbered-node-hop": {
                "node-id": "192.0.2.2",
                "hop-type": "loose"
              }
            }
          ]
        }
      },
      {
        "name": "secondary-2 (bidir)",
        "explicit-route-objects-always": {
          "route-object-include-exclude": [
            {
              "index": 1,
              "numbered-node-hop": {
                "node-id": "192.0.2.2"
              }
            },
            {
              "index": 2,
              "numbered-node-hop": {
                "node-id": "192.0.2.5",
                "hop-type": "loose"
              }
            }
          ]
        }
      }
    ]
  }
},
{
  "name": "example-4",
  "description": "Example in slide 4",
  "source": "192.0.2.1",
  "destination": "192.0.2.5",
  "bidirectional": false,
```

```
"primary-paths": {
  "primary-path": [
    {
      "name": "primary-1 (fwd)",
      "co-routed": [null],
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.2",
              "hop-type": "loose"
            }
          }
        ]
      },
      "primary-reverse-path": {
        "name": "primary-2 (rev)",
        "candidate-secondary-reverse-paths": {
          "candidate-secondary-reverse-path": [
            "secondary-3 (rev)",
            "secondary-4 (rev)"
          ]
        }
      },
      "candidate-secondary-paths": {
        "candidate-secondary-path": [
          "secondary-1 (fwd)",
          "secondary-2 (fwd)"
        ]
      }
    }
  ]
},
"secondary-paths": {
  "secondary-path": [
    {
      "name": "secondary-1 (fwd)",
      "co-routed": [null],
      "explicit-route-objects-always": {
        "route-object-include-exclude": [
          {
            "index": 1,
            "numbered-node-hop": {
              "node-id": "192.0.2.1"
            }
          },
          {
            "index": 2,
```

```
                    "numbered-node-hop": {
                      "node-id": "192.0.2.2",
                      "hop-type": "loose"
                    }
                  }
                ]
              }
            },
            {
              "name": "secondary-2 (fwd)",
              "co-routed": [null],
              "explicit-route-objects-always": {
                "route-object-include-exclude": [
                  {
                    "index": 1,
                    "numbered-node-hop": {
                      "node-id": "192.0.2.2"
                    }
                  },
                  {
                    "index": 2,
                    "numbered-node-hop": {
                      "node-id": "192.0.2.5",
                      "hop-type": "loose"
                    }
                  }
                ]
              }
            }
          ]
        },
        "secondary-reverse-paths": {
          "secondary-reverse-path": [
            {
              "name": "secondary-3 (rev)"
            },
            {
              "name": "secondary-4 (rev)"
            }
          ]
        }
      }
    ]
  }
}
```

13. Appendix B: Full Model Tree Diagram

Figure 13 shows the full tree diagram of the TE YANG model defined in module 'ietf-te.yang'.

```
module: ietf-te
  +--rw te
     +--rw enable?    boolean
     +--rw globals
     |  +--rw named-admin-groups
     |  |  +--rw named-admin-group* [name]
     |  |          {te-types:extended-admin-groups,
     |  |           te-types:named-extended-admin-groups}?
     |  |     +--rw name            string
     |  |     +--rw bit-position?   uint32
     |  +--rw named-srlgs
     |  |  +--rw named-srlg* [name] {te-types:named-srlg-groups}?
     |  |     +--rw name     string
     |  |     +--rw value?   te-types:srlg
     |  |     +--rw cost?    uint32
     |  +--rw named-path-constraints
     |     +--rw named-path-constraint* [name]
     |             {te-types:named-path-constraints}?
     |        +--rw name                       string
     |        +---u path-constraints-common
     +--rw tunnels
     |  +--rw tunnel* [name]
     |     +--rw name                                  string
     |     +--rw alias?                                string
     |     +--rw identifier?                           uint32
     |     +--rw color?                                uint32
     |     +--rw description?                          string
     |     +--rw admin-state?                          identityref
     |     +--ro operational-state?                    identityref
     |     +---u te-types:encoding-and-switching-type
     |     +---u tunnel-common-attributes
     |     +--rw controller
     |     |  +--rw protocol-origin?        identityref
     |     |  +--rw controller-entity-id?   string
     |     +--rw reoptimize-timer?                     uint16
     |     +---u tunnel-associations-properties
     |     +---u protection-restoration-properties
     |     +---u te-types:tunnel-constraints
     |     +---u tunnel-hierarchy-properties
     |     +--rw primary-paths
     |     |  +--rw primary-path* [name]
     |     |     +--ro active?                     boolean
     |     |     +---u path-common-properties
     |     |     +---u path-forward-properties
     |     |     +---u k-requested-paths
     |     |     +---u path-compute-info
     |     |     +---u path-state
     |     |     +--rw primary-reverse-path
     |     |     |  +---u path-common-properties
```

```
|     |     |  +---u path-compute-info
|     |     |  +---u path-state
|     |     |  +--rw candidate-secondary-reverse-paths
|     |     |     +--rw candidate-secondary-reverse-path*
|     |     |             [secondary-reverse-path]
|     |     |        +--rw secondary-reverse-path    leafref
|     |     |        +--ro active?                   boolean
|     |     +--rw candidate-secondary-paths
|     |        +--rw candidate-secondary-path* [secondary-path]
|     |           +--rw secondary-path    leafref
|     |           +--ro active?           boolean
|     +--rw secondary-paths
|     |  +--rw secondary-path* [name]
|     |     +---u path-common-properties
|     |     +--rw preference?                          uint8
|     |     +--rw secondary-reverse-path?              leafref
|     |     +---u path-compute-info
|     |     +---u protection-restoration-properties
|     |     +---u path-state
|     +--rw secondary-reverse-paths
|     |  +--rw secondary-reverse-path* [name]
|     |     +---u path-common-properties
|     |     +--rw preference?                          uint8
|     |     +---u path-compute-info
|     |     +---u protection-restoration-properties
|     |     +---u path-state
|     +---x tunnel-action
|     |  +---w input
|     |  |  +---w action-type?   identityref
|     |  +--ro output
|     |     +--ro action-result?   identityref
|     +---x protection-external-commands
|        +---w input
|           +---w protection-external-command?     identityref
|           +---w protection-group-ingress-node?   boolean
|           +---w protection-group-egress-node?    boolean
|           +---w path-name?                       string
|           +---w path-type?
|           |       te-types:path-type
|           +---w traffic-type?                    enumeration
|           +---w extra-traffic-tunnel-ref?        tunnel-ref
+--ro lsps
   +--ro lsp* [tunnel-name lsp-id node]
      +--ro tunnel-name                          string
      +--ro lsp-id                               uint16
      +--ro node
      |       te-types:te-node-id
      +--ro source?
      |       te-types:te-node-id
```

```
         +--ro destination?
         |       te-types:te-node-id
         +--ro tunnel-id?                          uint16
         +--ro extended-tunnel-id?                 yang:dotted-quad
         +--ro operational-state?                  identityref
         +--ro signaling-type?                     identityref
         +--ro origin-type?                        enumeration
         +--ro lsp-resource-status?                enumeration
         +--ro lockout-of-normal?                  boolean
         +--ro freeze?                             boolean
         +--ro lsp-protection-role?                enumeration
         +--ro lsp-protection-state?               identityref
         +--ro protection-group-ingress-node-id?
         |       te-types:te-node-id
         +--ro protection-group-egress-node-id?
         |       te-types:te-node-id
         +--ro lsp-actual-route-information
            +--ro lsp-actual-route-information* [index]
               +---u te-types:record-route-state

rpcs:
  +---x tunnels-path-compute
  |  +---w input
  |  |  +---w path-compute-info
  |  +--ro output
  |     +--ro path-compute-result
  +---x tunnels-actions
     +---w input
     |  +---w tunnel-info
     |  |  +---w (filter-type)
     |  |     +--:(all-tunnels)
     |  |     |  +---w all       empty
     |  |     +--:(one-tunnel)
     |  |        +---w tunnel?   tunnel-ref
     |  +---w action-info
     |     +---w action?       identityref
     |     +---w disruptive?   empty
     +--ro output
        +--ro action-result?   identityref

grouping te-generic-node-id:
  +-- id?     te-gen-node-id
  +-- type?   enumeration
grouping path-common-properties:
  +-- name?                      string
  +-- path-computation-method?   identityref
  +-- path-computation-server
  |  +---u te-generic-node-id
  +-- compute-only?              empty
```

```
  +-- use-path-computation?      boolean
  +-- lockdown?                  empty
  +--ro path-scope?                identityref
grouping path-compute-info:
  +---u tunnel-associations-properties
  +---u te-types:generic-path-optimization
  +-- named-path-constraint?               leafref
  |       {te-types:named-path-constraints}?
  +---u path-constraints-common
grouping path-forward-properties:
  +-- preference?   uint8
  +-- co-routed?    boolean
grouping k-requested-paths:
  +-- k-requested-paths?   uint8
grouping path-state:
  +---u path-computation-response
  +--ro lsp-provisioning-error-infos
  |  +--ro lsp-provisioning-error-info* []
  |     +--ro error-reason?        identityref
  |     +--ro error-description?   string
  |     +--ro error-timestamp?     yang:date-and-time
  |     +--ro error-node-id?       te-types:te-node-id
  |     +--ro error-link-id?       te-types:te-tp-id
  |     +--ro lsp-id?              uint16
  +--ro lsps
     +--ro lsp* [node lsp-id]
        +--ro tunnel-name?   -> /te/lsps/lsp/tunnel-name
        +--ro node?          leafref
        +--ro lsp-id?        leafref
grouping path-computation-response:
  +--ro computed-paths-properties
  |  +--ro computed-path-properties* [k-index]
  |     +--ro k-index?                              uint8
  |     +---u te-types:generic-path-properties
  +--ro computed-path-error-infos
     +--ro computed-path-error-info* []
        +--ro error-description?   string
        +--ro error-timestamp?     yang:date-and-time
        +--ro error-reason?        identityref
grouping protection-restoration-properties:
  +-- protection
  |  +-- protection-type?                identityref
  |  +-- protection-reversion-disable?   boolean
  |  +-- hold-off-time?                  uint32
  |  +-- wait-to-revert?                 uint16
  |  +-- aps-signal-id?                  uint8
  +-- restoration
     +-- restoration-type?                identityref
     +-- restoration-scheme?              identityref
```

```
     +-- restoration-reversion-disable?   boolean
     +-- hold-off-time?                   uint32
     +-- wait-to-restore?                 uint16
     +-- wait-to-revert?                  uint16
grouping tunnel-associations-properties:
  +-- association-objects
     +-- association-object* [association-key]
     |  +-- association-key?   string
     |  +-- type?              identityref
     |  +-- id?                uint16
     |  +-- source
     |     +---u te-generic-node-id
     +-- association-object-extended* [association-key]
        +-- association-key?   string
        +-- type?              identityref
        +-- id?                uint16
        +-- source
        |  +---u te-generic-node-id
        +-- global-source?     uint32
        +-- extended-id?       yang:hex-string
grouping tunnel-end-point:
  +-- node-id?        nw:node-id
  +-- te-node-id?     te-types:te-node-id
  +-- tunnel-tp-id?   binary
grouping tunnel-common-attributes:
  +-- source
  |  +---u tunnel-end-point
  +-- destination
  |  +---u tunnel-end-point
  +-- bidirectional?   boolean
grouping tunnel-hierarchy-properties:
  +-- hierarchy
     +-- dependency-tunnels
     |  +-- dependency-tunnel* [name]
     |     +-- name?
     |     |       -> /te/tunnels/tunnel/name
     |     +---u te-types:encoding-and-switching-type
     +-- hierarchical-link
        +-- enable?                           boolean
        +-- local-node-id?                    nw:node-id
        +-- local-te-node-id?                 te-types:te-node-id
        +-- local-link-tp-id?                 nt:tp-id
        +-- local-te-link-tp-id?              te-types:te-tp-id
        +-- remote-link-tp-id?                nt:tp-id
        +-- remote-te-node-id?                te-types:te-node-id
        +-- network-id?                       nw:network-id
        +---u te-types:te-topology-identifier
grouping path-constraints-common:
  +---u te-types:common-path-constraints-attributes
```

```
+---u te-types:generic-path-disjointness
+---u te-types:path-constraints-route-objects
+-- path-in-segment!
|  +---u te-types:label-set-info
+-- path-out-segment!
   +---u te-types:label-set-info
```

Figure 13: Full tree diagram of TE Tunnel YANG data model

14. References

14.1. Normative References

[ITU_G.808.1] ITU-T Recommendation G.808.1, "Generic protection switching - Linear trail and subnetwork protection", ITU-T G.808.1 , May 2014.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V., and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC 3209, DOI 10.17487/RFC3209, December 2001, <https://www.rfc-editor.org/info/rfc3209>.

[RFC3473] Berger, L., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions", RFC 3473, DOI 10.17487/RFC3473, January 2003, <https://www.rfc-editor.org/info/rfc3473>.

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <https://www.rfc-editor.org/info/rfc3688>.

[RFC4206] Kompella, K. and Y. Rekhter, "Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)", RFC 4206, DOI 10.17487/RFC4206, October 2005, <https://www.rfc-editor.org/info/rfc4206>.

[RFC4427] Mannie, E., Ed. and D. Papadimitriou, Ed., "Recovery (Protection and Restoration) Terminology for Generalized Multi-Protocol Label Switching (GMPLS)", RFC 4427, DOI 10.17487/RFC4427, March 2006, <https://www.rfc-editor.org/info/rfc4427>.

[RFC4872] Lang, J.P., Ed., Rekhter, Y., Ed., and D. Papadimitriou, Ed., "RSVP-TE Extensions in Support of End-to-End Generalized Multi-Protocol Label Switching (GMPLS) Recovery", RFC 4872, DOI 10.17487/RFC4872, May 2007, <https://www.rfc-editor.org/info/rfc4872>.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020,

DOI 10.17487/RFC6020, October 2010, <https://www.rfc-editor.org/info/rfc6020>.

[RFC6107] Shiomoto, K., Ed. and A. Farrel, Ed., "Procedures for Dynamically Signaled Hierarchical Label Switched Paths", RFC 6107, DOI 10.17487/RFC6107, February 2011, <https://www.rfc-editor.org/info/rfc6107>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <https://www.rfc-editor.org/info/rfc6242>.

[RFC6780] Berger, L., Le Faucheur, F., and A. Narayanan, "RSVP ASSOCIATION Object Extensions", RFC 6780, DOI 10.17487/RFC6780, October 2012, <https://www.rfc-editor.org/info/rfc6780>.

[RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <https://www.rfc-editor.org/info/rfc6991>.

[RFC7271] Ryoo, J., Ed., Gray, E., Ed., van Helvoort, H., D'Alessandro, A., Cheung, T., and E. Osborne, "MPLS Transport Profile (MPLS-TP) Linear Protection to Match the Operational Expectations of Synchronous Digital Hierarchy, Optical Transport Network, and Ethernet Transport Network Operators", RFC 7271, DOI 10.17487/RFC7271, June 2014, <https://www.rfc-editor.org/info/rfc7271>.

[RFC7308] Osborne, E., "Extended Administrative Groups in MPLS Traffic Engineering (MPLS-TE)", RFC 7308, DOI 10.17487/RFC7308, July 2014, <https://www.rfc-editor.org/info/rfc7308>.

[RFC7471] Giacalone, S., Ward, D., Drake, J., Atlas, A., and S. Previdi, "OSPF Traffic Engineering (TE) Metric

Extensions", RFC 7471, DOI 10.17487/RFC7471, March 2015, <https://www.rfc-editor.org/info/rfc7471>.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <https://www.rfc-editor.org/info/rfc7950>.

[RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <https://www.rfc-editor.org/info/rfc8040>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8232] Crabbe, E., Minei, I., Medved, J., Varga, R., Zhang, X., and D. Dhody, "Optimizations of Label Switched Path State Synchronization Procedures for a Stateful PCE", RFC 8232, DOI 10.17487/RFC8232, September 2017, <https://www.rfc-editor.org/info/rfc8232>.

[RFC8234] Ryoo, J., Cheung, T., van Helvoort, H., Busi, I., and G. Wen, "Updates to MPLS Transport Profile (MPLS-TP) Linear Protection in Automatic Protection Switching (APS) Mode", RFC 8234, DOI 10.17487/RFC8234, August 2017, <https://www.rfc-editor.org/info/rfc8234>.

[RFC8294] Liu, X., Qu, Y., Lindem, A., Hopps, C., and L. Berger, "Common YANG Data Types for the Routing Area", RFC 8294, DOI 10.17487/RFC8294, December 2017, <https://www.rfc-editor.org/info/rfc8294>.

[RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <https://www.rfc-editor.org/info/rfc8340>.

[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <https://www.rfc-editor.org/info/rfc8341>.

[RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <https://www.rfc-editor.org/info/rfc8342>.

[RFC8343] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 8343, DOI 10.17487/RFC8343, March 2018, <https://www.rfc-editor.org/info/rfc8343>.

[RFC8345] Clemm, A., Medved, J., Varga, R., Bahadur, N., Ananthakrishnan, H., and X. Liu, "A YANG Data Model for Network Topologies", RFC 8345, DOI 10.17487/RFC8345, March 2018, <https://www.rfc-editor.org/info/rfc8345>.

[RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <https://www.rfc-editor.org/info/rfc8446>.

[RFC8570] Ginsberg, L., Ed., Previdi, S., Ed., Giacalone, S., Ward, D., Drake, J., and Q. Wu, "IS-IS Traffic Engineering (TE) Metric Extensions", RFC 8570, DOI 10.17487/RFC8570, March 2019, <https://www.rfc-editor.org/info/rfc8570>.

[RFC8639] Voit, E., Clemm, A., Gonzalez Prieto, A., Nilsen-Nygaard, E., and A. Tripathy, "Subscription to YANG Notifications", RFC 8639, DOI 10.17487/RFC8639, September 2019, <https://www.rfc-editor.org/info/rfc8639>.

[RFC8641] Clemm, A. and E. Voit, "Subscription to YANG Notifications for Datastore Updates", RFC 8641, DOI 10.17487/RFC8641, September 2019, <https://www.rfc-editor.org/info/rfc8641>.

[RFC8776] Saad, T., Gandhi, R., Liu, X., Beeram, V., and I. Bryskin, "Common YANG Data Types for Traffic Engineering", RFC 8776, DOI 10.17487/RFC8776, June 2020, <https://www.rfc-editor.org/info/rfc8776>.

[RFC8795] Liu, X., Bryskin, I., Beeram, V., Saad, T., Shah, H., and O. Gonzalez de Dios, "YANG Data Model for Traffic Engineering (TE) Topologies", RFC 8795, DOI 10.17487/RFC8795, August 2020, <https://www.rfc-editor.org/info/rfc8795>.

[RFC9012] Patel, K., Van de Velde, G., Sangli, S., and J. Scudder, "The BGP Tunnel Encapsulation Attribute", RFC 9012, DOI 10.17487/RFC9012, April 2021, <https://www.rfc-editor.org/info/rfc9012>.

14.2. Informative References

[rfc3473] Berger, L., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions", RFC

3473, DOI 10.17487/RFC3473, January 2003, <https://www.rfc-editor.org/info/rfc3473>.

[RFC3945] Mannie, E., Ed., "Generalized Multi-Protocol Label Switching (GMPLS) Architecture", RFC 3945, DOI 10.17487/RFC3945, October 2004, <https://www.rfc-editor.org/info/rfc3945>.

[RFC9256] Filsfils, C., Talaulikar, K., Ed., Voyer, D., Bogdanov, A., and P. Mattes, "Segment Routing Policy Architecture", RFC 9256, DOI 10.17487/RFC9256, July 2022, <https://www.rfc-editor.org/info/rfc9256>.

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