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Profiles for Traffic Engineering (TE) Topology Data Model and  
Applicability to non-TE-centric Use Cases  
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## Abstract

This document describes how profiles of the Topology YANG data model, defined in RFC8795, can be used to address applications in Traffic Engineering aware (TE-aware) deployments, irrespective of whether they are TE-centric or not.

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## 1. Introduction

Many network scenarios are being discussed in various IETF Working Groups (WGs) that are not classified as "Traffic Engineering" use cases but can be addressed by a profile (sub-set) of the Topology YANG data model, defined in [RFC8795].

Traffic Engineering (TE) is defined in [RFC9522] as aspects of Internet network engineering that deal with the issues of performance evaluation and performance optimization of operational IP networks. TE encompasses the application of technology and scientific principles to the measurement, characterization, modeling, and control of Internet traffic.

According to section 1.2 of [RFC9522]:

The key elements required in any TE solution are as follows:

1. Policy
2. Path steering
3. Resource management

Some TE solutions rely on these elements to a lesser or greater extent. Debate remains about whether a solution can truly be called "TE" if it does not include all of these elements. For the sake of this document, we assert that all TE solutions must include some aspects of all of these elements. Other solutions can be classed as "partial TE" and also fall in scope of this document.

As a consequence, the line between what is TE and what is not TE is quite blurred.

The Topology YANG data model, defined in [RFC8795], augments the Network Topology YANG data model, defined in [RFC8345], with generic and technology-agnostic features that are not only applicable to TE-centric deployments, but also applicable to non-TE-centric yet TE-aware deployments.

A TE-aware deployment is one where the topology carries information that can be used to influence how traffic can be engineered within the network. In some scenarios, this information can be leveraged even in use cases where traffic doesn't need to be engineered.

Examples of generic TE-aware features that can apply to both TE-centric and non-TE-centric use-cases are: inter-domain link discovery (plug-id), geo-localization, multi-layer topology representation, node-specific switching limitation, link reliability, and topology abstraction.

It is also worth noting that also the boundary between the TE-specific model constructs and the core network topology model constructs is also blurred since new applications may need to

leverage on constructs which was originally defined to support TE-centric scenarios but that are also needed to support these new applications.

An example of a concept that originated from TE-centric scenarios but can be considered a core network topology model construct is the SRLG. New applications such as what-if analysis need to be aware of the SRLG information also for non-TE-centric scenarios to provide reliable results.

It is also worth noting that the Topology YANG data model, defined in [RFC8795], is quite an extensive and comprehensive model in which most features are optional. Therefore, even though the full model appears to be complex, at the first glance, a profile (sub-set) of the model can be used to address specific scenarios irrespective of whether they are TE-centric or not.

The implementation of profiles can simplify and expedite adoption of the Topology YANG data model, defined [RFC8795], and allow for its reuse even for non-TE-centric use-cases. The key question is whether all or some of the attributes defined in the Topology YANG data model, defined in [RFC8795], are needed to address a given network scenario.

Section 2 provides examples where profiles of the Topology YANG data model, defined in [RFC8795], can be used to address some generic use cases applicable to both TE-centric and non-TE-centric deployments.

Understanding that these profiles are generic would be more straightforward if the profiled YANG data nodes were defined under a container with a different name than 'te' or directly under the parent YANG data node. However, the 'te' container in the context of [RFC8795], should be understood as the container of YANG data nodes providing TE-aware topology information.

## 2. Examples of generic profiles

### 2.1. Multi-domain Links Discovery

The following profile of the Topology YANG data model, defined in [RFC8795], can be used to support the UNI Topology Discovery, or in general, inter-domain link discovery:

```
module: ietf-te-topology
  augment /nw:networks/nw:network/nw:network-types:
    +--rw te-topology!
  augment /nw:networks/nw:network/nw:node/nt:termination-point:
    +--rw te-tp-id?   te-types:te-tp-id
    +--rw te!
      +--rw admin-status?
      |   te-types:te-admin-status
      +--rw inter-domain-plug-id?          binary
      +--ro oper-status?                   te-types:te-oper-status
```

Figure 1: UNI Topology

It is also worth noting that the UNI links can also be TE (e.g. an OTN UNI) or non-TE (e.g., an Ethernet UNI) as well as multi-function UNI links, supporting both TE and non-TE technologies, such as the UNI links, described in Section 4.4 of [I-D.ietf-ccamp-transport-nbi-app-statement], which can be configured either OTN UNI or Ethernet UNI or SDH UNI.

The UNI Topology profiled YANG data model shown in Figure 1 can also be used with technology-specific UNI augmentations, as described in Section 3. Technology-specific augmentations can for example describe the capability of the TP to be configured as a UNI for the types of services supported by the UNI (e.g., L2VPN/L3VPN).

For example, in [I-D.ietf-ccamp-eth-client-te-topo-yang], the eth-svc container is defined to represent the capabilities of the Termination Point (TP) to be configured as an Ethernet UNI, together with the Ethernet classification and VLAN operations supported by that TP.

The [I-D.ietf-ccamp-otn-topo-yang] provides another example, where:

- \* the client-svc container is defined to represent the capabilities of the TP to be configured as an transparent client UNI (e.g., STM-N, Fiber Channel or transparent Ethernet);
- \* the OTN technology-specific Link Termination Point (LTP) augmentations are defined to represent the capabilities of the TP to be configured as an OTN UNI, together with the information about OTN label and bandwidth availability at the OTN UNI.

Te UNI Topology profiled YANG data model shown in Figure 1 does not require the network to be a TE network and, therefore, it could be used as a core network topology model to discover UNIs (or in general any external link) for TE and non-TE networks as well as multi-layer networks encompassing both TE and non-TE layers.

The advantages of using the UNI Topology profiled YANG data model shown in Figure 1 as a core network topology model is to have a common solutions for:

- \* discovering UNIs as well as inter-domain NNI links, which is applicable to any technology (TE or non TE) used at the UNI or within the network;
- \* modelling non TE UNIs such as Ethernet, and TE UNIs such as OTN, as well as UNIs which can configured as TE or non-TE (e.g., being configured as either Ethernet or OTN UNI).

## 2.2. Administrative and Operational status management

The following profile of the Topology YANG data model, defined in [RFC8795], can be used to manage the administrative and operational for nodes, termination points and links as well as to associate some administrative names to network topologies, nodes, termination points and links:

```

module: ietf-te-topology
  augment /nw:networks/nw:network/nw:network-types:
    +--rw te-topology!
  augment /nw:networks/nw:network:
    +--rw te-topology-identifier
    |   +--rw provider-id?   te-global-id
    |   +--rw client-id?    te-global-id
    |   +--rw topology-id?   te-topology-id
    +--rw te!
    +--rw name?              string
  augment /nw:networks/nw:network/nw:node:
    +--rw te-node-id?        te-types:te-node-id
    +--rw te!
    +--rw te-node-attributes
    |   +--rw admin-status?   te-types:te-admin-status
    |   +--rw name?           string
    +--ro oper-status?        te-types:te-oper-status
  augment /nw:networks/nw:network/nt:link:
    +--rw te!
    +--rw te-link-attributes
    |   +--rw name?           string
    |   +--rw admin-status?   te-types:te-admin-status
    +--ro oper-status?        te-types:te-oper-status
  augment /nw:networks/nw:network/nw:node/nt:termination-point:
    +--rw te-tp-id?          te-types:te-tp-id
    +--rw te!
    +--rw admin-status?       te-types:te-admin-status
    +--rw name?               string
    +--ro oper-status?        te-types:te-oper-status

```

Figure 2: Generic Topology with admin and operational state

### 2.3. Overlay and Underlay Topologies

The following profile of the Topology YANG data model, defined in [RFC8795], can be used to manage the overlay/underlay relationships for nodes and links, as described in section 5.8 of [RFC8795]:

```

module: ietf-te-topology
augment /nw:networks/nw:network/nw:network-types:
  +--rw te-topology!
augment /nw:networks/nw:network/nw:node:
  +--rw te-node-id?   te-types:te-node-id
  +--rw te!
    +--rw te-node-attributes
      +--rw underlay-topology {te-topology-hierarchy}?
        +--rw network-ref? -> /nw:networks/network/network-id
augment /nw:networks/nw:network/nt:link:
  +--rw te!
    +--rw te-link-attributes
      +--rw underlay {te-topology-hierarchy}?
        +--rw enabled?                               boolean
        +--rw primary-path
          +--rw network-ref?
            | -> /nw:networks/network/network-id
          +--rw path-element* [path-element-id]
            +--rw path-element-id                     uint32
            +--rw (type)?
              +--:(numbered-link-hop)
                | +--rw numbered-link-hop
                |   +--rw link-tp-id      te-tp-id
                |   +--rw hop-type?      te-hop-type
                |   +--rw direction?     te-link-direction
              +--:(unnumbered-link-hop)
                +--rw unnumbered-link-hop
                  +--rw link-tp-id      te-tp-id
                  +--rw node-id         te-node-id
                  +--rw hop-type?      te-hop-type
                  +--rw direction?     te-link-direction

```

Figure 3: Generic Topology with overlay/underlay information

The advantages of using the underlay/overlay network profiled YANG data model shown in Figure 3 as a core network topology model is to have a common solutions for navigating between overlay/underlay network topologies where:

- \* both the underlay and overlay network topologies are TE networks;
- \* both the underlay and overlay network topologies are non-TE networks;
- \* the underlay and overlay network topologies are TE and non-TE networks;

- \* the underlay or the overlay network topology is a multi-layer network encompassing both TE and non-TE layers.

#### 2.3.1. Supporting relationships in RFC8345

[RFC8345] defines the modeling constructs for supporting relations, including supporting network (i.e. topology), supporting node, supporting link, and supporting termination point. These relation constructs facilitate network mappings and transformations. One use case is to map a customized topology to a native topology. The customized topology uses different name spaces from the native topology when naming nodes, links, or termination points. There is a supporting relationship between a modeling construct in the customized topography to its counterpart in the native topology. In such a relationship, the modeling constructs at both ends represent the same type of network objects, which can be network (i.e. topology), node, link, or termination point.

[RFC8795] defines the modeling constructs for network overlay and underlay relations. When the network overlay technology is used, some network objects (nodes or links) in the overlay network are built on top of network objects in the underlay network. As a result, the overlay-underlay relationship is created between network objects in the overlay networks and other network objects in the underlay network. Between the network object pairs in the overlay-underlay relationship, the types of the network objects are usually not the same. The network object can be a node in the overlay network, while the related underlay network object is a topology in the underlay network. A link in the overlay network can be related to a path that consists of a sequence of nodes and links in the underlay network.

#### 2.4. Nodes with switching limitations

It is worth noting that a node, as defined in [RFC8345], does not provide any information about the possible connectivity between its TPs.

A node can have some switching limitations where connectivity is not possible between all its TP pairs, for example when:

- \* the node represents a physical device with switching limitations;
- \* the node represents an abstraction of a network topology.

The following profile of the Topology YANG data model, defined in [RFC8795], can be used for the management of nodes with switching limitations by defining the node connectivity matrix to represent feasible connections between termination points across the nodes:

```

module: ietf-te-topology
  augment /nw:networks/nw:network/nw:network-types:
    +--rw te-topology!
  augment /nw:networks/nw:network/nw:node:
    +--rw te-node-id?    te-types:te-node-id
    +--rw te!
      +--rw te-node-attributes
        +--rw connectivity-matrices
          +--rw number-of-entries?    uint16
          +--rw is-allowed?           boolean
          +--rw connectivity-matrix* [id]
            +--rw id                  uint32
            +--rw from
              | +--rw tp-ref?         leafref
            +--rw to
              | +--rw tp-ref?         leafref
            +--rw is-allowed?         boolean

```

Figure 4: Generic Topology with connectivity constraints

## 2.5. Multipoint links

According to Section 4.4.4 of [RFC8345], multipoint links can be "represented through pseudonodes (similar to IS-IS, for example)".

Each access point can have different directionality with respect to the multipoint link, as shown in Figure 5: - an access point of a multipoint link can be able to both transmit and receive traffic: this access point can be modelled as a TP (e.g., TP A in Figure 5) terminating two links, one incoming link (e.g., Link 1 in Figure 5) and one outgoing link (e.g., Link 2 in Figure 5); - an access point of a multipoint link can be able only to receive traffic: this access point can be modelled as a TP (e.g., TP B in Figure 5) with only one incoming link (e.g., Link 3 in Figure 5); - an access point of a multipoint link can be able only to transmit traffic: this access point can be modelled as a TP (e.g., TP C in Figure 5) with only one outgoing link (e.g., Link 4 in Figure 5).

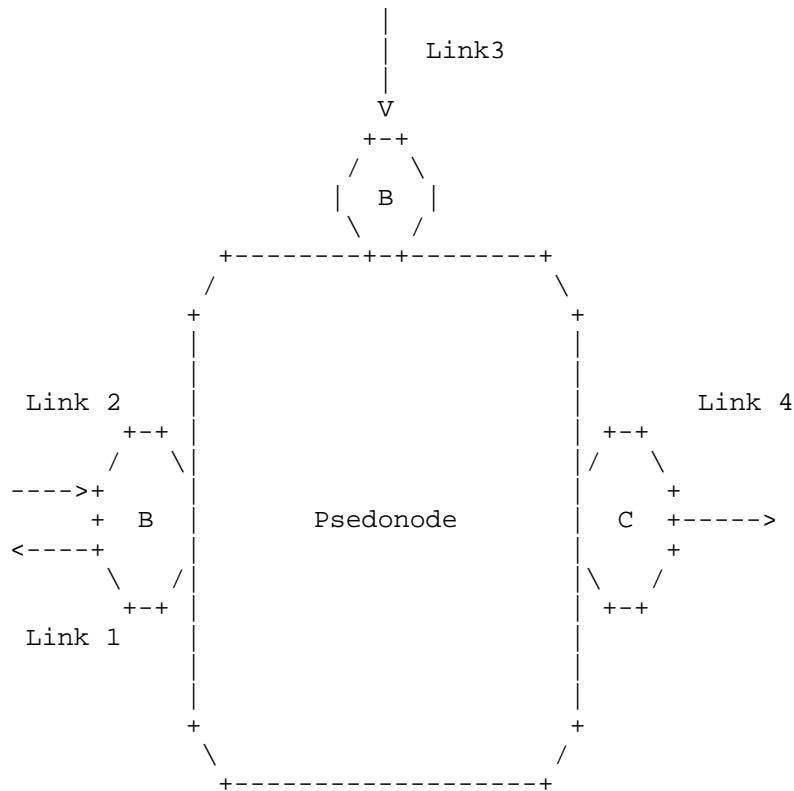


Figure 5: Example of a pseudonode modelling a multipoint link

The switching limitations of the pseudonode, as defined in Section 2.4, provides sufficient information to identify the type of multipoint link: - in case of multipoint links, the connectivity matrix of the pseudonode, reports that connectivity is enabled by default between all the TPs of the node; - in case of point-to-multipoint links, the connectivity matrix of the pseudonode, reports that connectivity is possible only between the root TP and the leaf TPs >> - if the point-to-multipoint link is bidirectional, the connectivity matrix of the pseudonodes reports that connectivity is possible from the root TP to the leaf TPs as well as from the leaf TPs to the root TP; >> - the connectivity matrix of the pseudonode can also describe point-to-multipoint links with more than one root (also known as rooted-multipoint links), indicating also whether connectivity between root TPs is allowed or not; - in case of hybrid multipoint links, as defined in [I-D.ietf-nmop-simap-concept], the connectivity matrix of the pseudonode reports the list of TP pairs for which connectivity is allowed or not allowed.

It is worth noting that the directionality of the access point of a multipoint link overrides the switching limitations of the pseudonode. For example, even if the connectivity matrix of the pseudonode in Figure 5 indicates that connectivity is possible between TP A and TP B, the traffic entering the pseudonode from TP A cannot be transmitted by TP B since there is no outgoing link from TP B.

Therefore, the connectivity matrix of a pseudonode modelling a point-to-multipoint unidirectional link, does not need to report that connectivity is only possible from the root TP to the leaf TPs but it can report that connectivity is possible by default between all the TPs of the node. The pseudonode represents a point-to-multipoint unidirectional link, as indicated by a single root TP that can only receive traffic and one or more leaf TPs that can only transmit traffic.

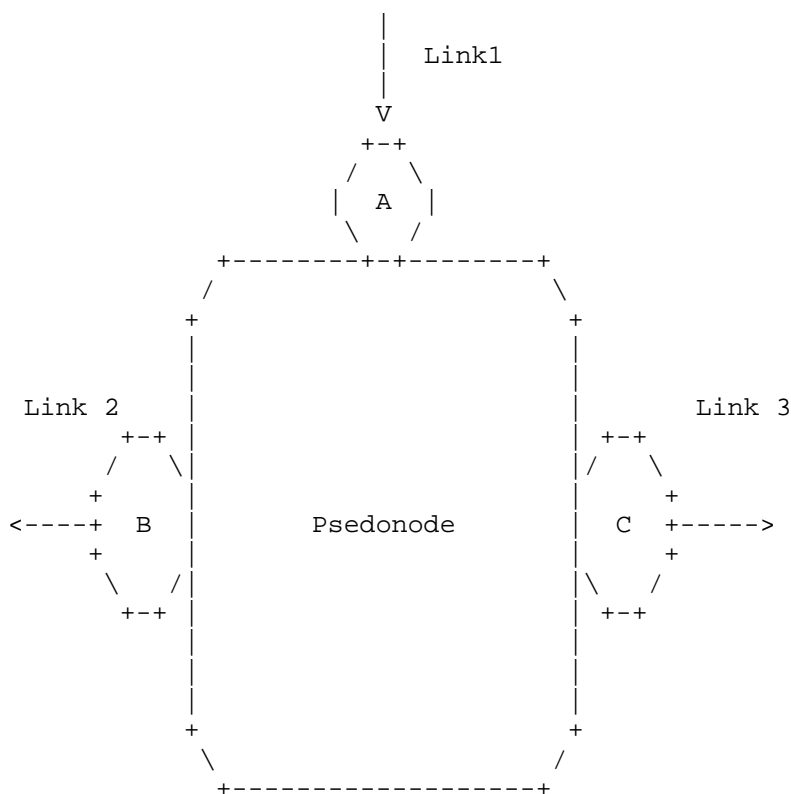


Figure 6: Example of a pseudonode modelling an unidirectional point-to-multipoint link

For example, Figure 6 shows an example of a pseudonode representing an unidirectional point-to-multipoint link where the TP A is the root TP and TPs B and C are the two leaf TPs.

### 3. Technology-specific augmentations

There are two main options to define technology-specific Topology Models which can use the attributes defined in the Topology YANG data model, defined in [RFC8795].

Both options are applicable to any possible profile of the TE Topology Model, such as those defined in Section 2.

The first option is to define a technology-specific TE Topology Model which augments the TE Topology Model, as shown in Figure 7:

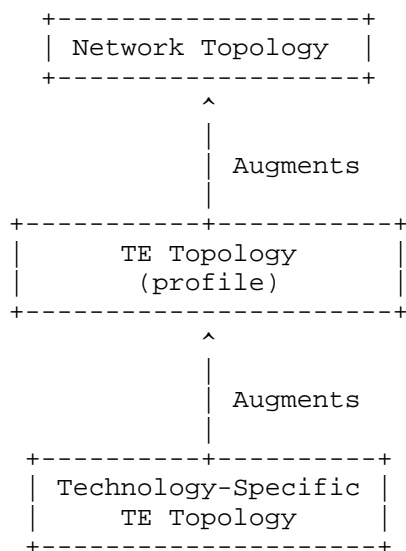


Figure 7: Augmenting the TE Topology Model

This approach is more suitable for cases when the technology-specific TE topology model provides augmentations to the TE Topology constructs, such as bandwidth information (e.g., link bandwidth), tunnel termination points (TTPs) or connectivity matrices. It also allows providing augmentations to the Network Topology constructs, such as nodes, links, and termination points (TPs).

This is the approach currently used in [I-D.ietf-ccamp-eth-client-te-topo-yang] and [I-D.ietf-ccamp-otn-topo-yang].

It is worth noting that a profile of the technology-specific TE Topology model not using any TE topology attribute or constructs can be used to address any use case that do not require these attributes. In this case, only the 'te-topology' presence container of the TE Topology Model needs to be implemented because it is the parent container for the 'network-type' representing the technology-specific topology model. Other data nodes defined in the TE Topology Model do not need to be implemented by this profile.

The second option is to define a technology-specific Network Topology Model which augments the Network Topology Model and to rely on the multiple inheritance capability, which is implicit in the network-types definition of [RFC8345], to allow using also the generic attributes defined in the TE Topology model:

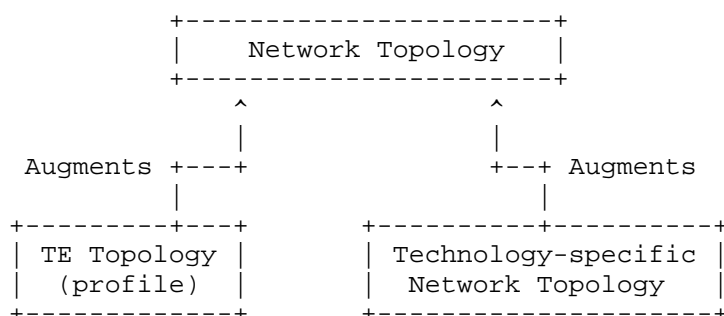


Figure 8: Augmenting the Network Topology Model with multi-inheritance

This approach is more suitable in cases where the technology-specific Network Topology Model provides augmentation only to the constructs defined in the Network Topology Model, such as nodes, links, and termination points (TPs). Therefore, with this approach, only the generic attributes defined in the TE Topology Model could be used.

It is also worth noting that in this case, technology-specific augmentations for the bandwidth information could not be defined.

In principle, it would be also possible to define both a technology specific TE Topology Model which augments the TE Topology Model, and a technology-specific Network Topology Model which augments the Network Topology Model and to rely on the multiple inheritance capability, as shown in Figure 9:

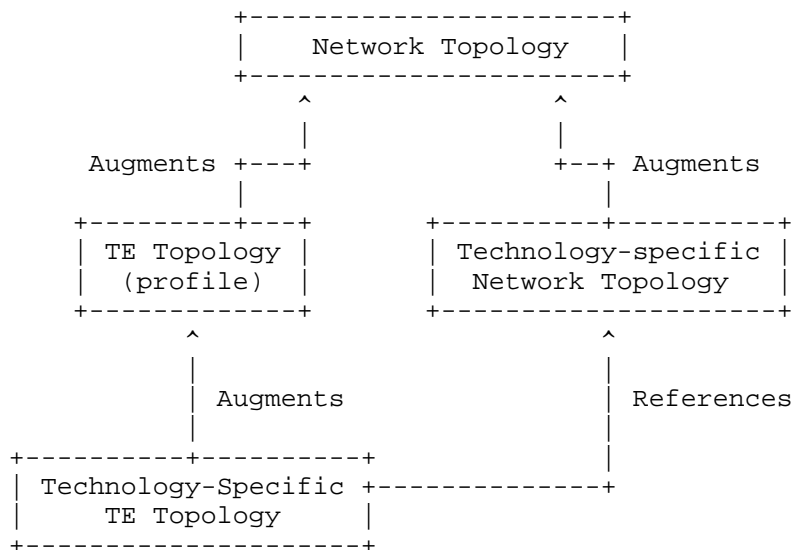


Figure 9: Augmenting both the Network and TE Topology Models

This option does not provide any technical advantage with respect to the first option, shown in Figure 7, but could be useful to add augmentations to the TE Topology constructs and to re-use an already existing technology-specific Network Topology Model.

It is worth noting that the technology-specific TE Topology model can reference constructs defined by the technology-specific Network Topology model but it could not augment constructs defined by the technology-specific Network Topology model.

### 3.1. Multi-inheritance

As described in section 4.1 of [RFC8345], the network types should be defined using presence containers to allow the representation of network subtypes.

The hierarchy of network subtypes can be single hierarchy, as shown in Figure 7. In this case, each presence container contains at most one child presence container, as shows in the JSON code below:

```
{
  "ietf-network:ietf-network": {
    "ietf-te-topology:te-topology": {
      "example-te-topology": {}
    }
  }
}
```

The hierarchy of network subtypes can also be multi-hierarchy, as shown in Figure 8 and Figure 9. In this case, one presence container can contain more than one child presence containers, as show in the JSON codes below:

```
{
  "ietf-network:ietf-network": {
    "ietf-te-topology:te-topology": {}
    "example-network-topology": {}
  }
}

{
  "ietf-network:ietf-network": {
    "ietf-te-topology:te-topology": {
      "example-te-topology": {}
    }
    "example-network-topology": {}
  }
}
```

Other examples of multi-hierarchy topologies are described in [I-D.ietf-teas-yang-sr-te-topo].

### 3.2. Example (Link augmentation)

This section provides an example on how technology-specific attributes can be added to the Link construct:

```

+--rw link* [link-id]
  +--rw link-id          link-id
  +--rw source
  |   +--rw source-node?  -> ../../../../nw:node/node-id
  |   +--rw source-tp?    leafref
  +--rw destination
  |   +--rw dest-node?    -> ../../../../nw:node/node-id
  |   +--rw dest-tp?      leafref
  +--rw supporting-link* [network-ref link-ref]
  |   +--rw network-ref
  |   |   -> ../../../../nw:supporting-network/network-ref
  |   +--rw link-ref      leafref
  +--rw example-link-attributes
  |   <...>
  +--rw te!
    +--rw te-link-attributes
      +--rw name?                                string
      +--rw example-te-link-attributes
      |   <...>
      +--rw max-link-bandwidth
        +--rw te-bandwidth
          +--rw (technology)?
            +--:(generic)
            |   +--rw generic?    te-bandwidth
            +--:(example)
            |   +--rw example?    example-bandwidth

```

Figure 10: Augmenting the Link with technology-specific attributes

The technology-specific attributes within the example-link-attributes container can be defined either in the technology-specific TE Topology Model (Option 1) or in the technology-specific Network Topology Model (Option 2 or Option 3). These attributes can only be non-TE and do not require the implementation of the te container.

The technology-specific attributes within the example-te-link-attributes container as well as the example max-link-bandwidth can only be defined in the technology-specific TE Topology Model (Option 1 or Option 3). These attributes can be TE or non-TE and require the implementation of the te container.

#### 4. Implementation Status

Different profiles of the TE topology model, defined in [RFC8795], has been implemented and publicly demonstrated.

#### 4.1. ACTN multi-vendor interoperability tests

A profile has been implemented and publicly demonstrated in the first multi-vendor interoperability test of the IETF-defined ACTN framework and YANG model standards performed in 2017 and involving Huawei and Nokia Shanghai Bell, organized by and conducted in the lab facility of China Mobile.

This interoperability test covered also multi-layer, multi-domain topology auto-discovery, based on a work-in-progress version of the Internet-Draft which was then finalized and published as [RFC8795].

The results of the results obtained in extensive ACTN interoperability tests are reported in [ACTN-TEST].

#### 4.2. ETSI Plugtests

ETSI has held two millimetre Wave Transmission (mWT) SDN to test the northbound interface exposed by microwave (MW) network controllers:

1. The first Plugtest has been held in Sophia Antipolis, France on 21 - 24 January 2019
2. The second and third Plugtest have been merged and held in Sophia Antipolis, France on November 2020

Both plugtests covered multi-layer and multi-domain topology discovery scenarios, based on a work-in-progress version of the Internet-Draft which was then finalized and published as [RFC8795].

Both plugtests have been attended by the majority of the MW vendors and proved a good level of multi-vendor support.

The results of these ETSI plugtests are reported in [ETSI\_MW-TEST-1] and [ETSI\_MW-TEST-2], which also describe the different profiles of the TE topology model used for the MW topology model and for the Ethernet topology model.

Based on the success of the plugtests, an ETSI Group Specification (GS) [ETSI\_MW-PROFILE] has been published to document a common profile to be implemented at the northbound of MW network controllers.

The use of the TE topology profile as the basis for MW technology-specific augmentations have been specified also in the MW topology model defined in [RFC9656].

It is worth noting that MW radio link technology is not a TE-centric technology and not even a switching technology: in MW networks, switching is performed at higher layers (e.g., Ethernet or IP) and modelled as overlay topologies on top of the MW radio link topology. The approach of profiling [RFC8795] worked well to model the bandwidth of microwave links as well as the overlay/underlay relationship between the overlay Ethernet topology and the supporting underlay MW topology.

## 5. Open Issues

### 5.1. Implemented profiles

When a server implements a profile of the TE topology model, there is no standardized mechanism for the server to report to the client the subset of the model being implemented.

This might not be an issue in case the TE topology profile is read by the the client because the server reports in the operational datastore only the leaves which have been implemented, as described in section 5.3 of [RFC8342].

More investigation is instead required in case the TE topology profile is configured by the client, to avoid that the client tries to write an attribute not used in the TE Topology profile implemented by the server.

It is also worth noting that the supported profile may also depend on other attributes (for example the network type), so the YANG deviation mechanism is not applicable to this scenario.

It is worth noting that existing implementations of [RFC8795], including those reported in Section 4, have described the implemented profiled by manually pruning the YANG tree generated from the YANG module defined in [RFC8795].

The pruned/profiled YANG trees were sufficient to the implementers to generate proper APIs.

However, it is possible to use the YANG deviation statements to programmatically generate a pruned/profiled YANG tree.

Some investigations are on-going to see whether it is sufficient to define YANG deviations to document the pruned/profiled YANG trees to be implemented for a specific application or whether other existing tools can be leveraged to generate proper APIs.

Note: that this issue is also tracked in github as issue #161.

## 6. Security Considerations

This document provides only information about how the Topology YANG data model, defined in [RFC8795], can be profiled to address some scenarios which are not considered as TE.

As such, this document does not introduce any additional security considerations besides those already defined in [RFC8795].

## 7. IANA Considerations

This document requires no IANA actions.

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