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IETF Network Slice YANG Data Model
draft-liu-teas-transport-network-slice-yang-04

Abstract

This document describes a YANG data model for managing and controlling IETF network slices, defined in [I-D.ietf-teas-ietf-network-slices].

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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This Internet-Draft will expire on January 10, 2022.

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1. Introduction

This document defines a YANG [RFC7950] data model for for representing, managing, and controlling IETF network slices, defined in [I-D.ietf-teas-ietf-network-slices]

The defined data model is an interface between clients and providers for configurations and state retrievals, so as to support network slicing as a service. Through this model, a client can learn the slicing capabilities and the available resources of the provider. A client can request or negotiate with a network slicing provider to create an instance. The client can incrementally update its requirements on individual topology elements in the slice instance,

and retrieve the operational states of these elements. With the help of other mechanisms and data models defined in IETF, the telemetry information can be published to the client.

The YANG data model in this document conforms to the Network Management Datastore Architecture (NMDA) [RFC8342].

1.1. Terminology

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.

The following terms are defined in [RFC7950] and are not redefined here:

- augment
- data model
- data node

1.2. Tree Diagrams

Tree diagrams used in this document follow the notation defined in [RFC8340].

2. Modeling Considerations

An IETF network slice is modeled as network topology defined in [RFC8345], with augmentations. A new network type "network-slice" is defined in this document. When a network topology data instance contains the network-slice network type, it represents an instance of an IETF network slice.

2.1. Relationships to Related Topology Models

There are several related YANG data models that have been defined in IETF. Some of these are:

Network Topology Model:
Defined in [RFC8345].

OTN Topology Model:
Defined in [I-D.ietf-ccamp-otn-topo-yang].

L2 Topology Model:
Defined in [I-D.ietf-i2rs-yang-l2-network-topology].

L3 Topology Model:
Defined in [RFC8346].

TE Topology Model:
Defined in [RFC8795].

Figure 1 shows the relationships among these models. The box of dotted lines denotes the model defined in this document.

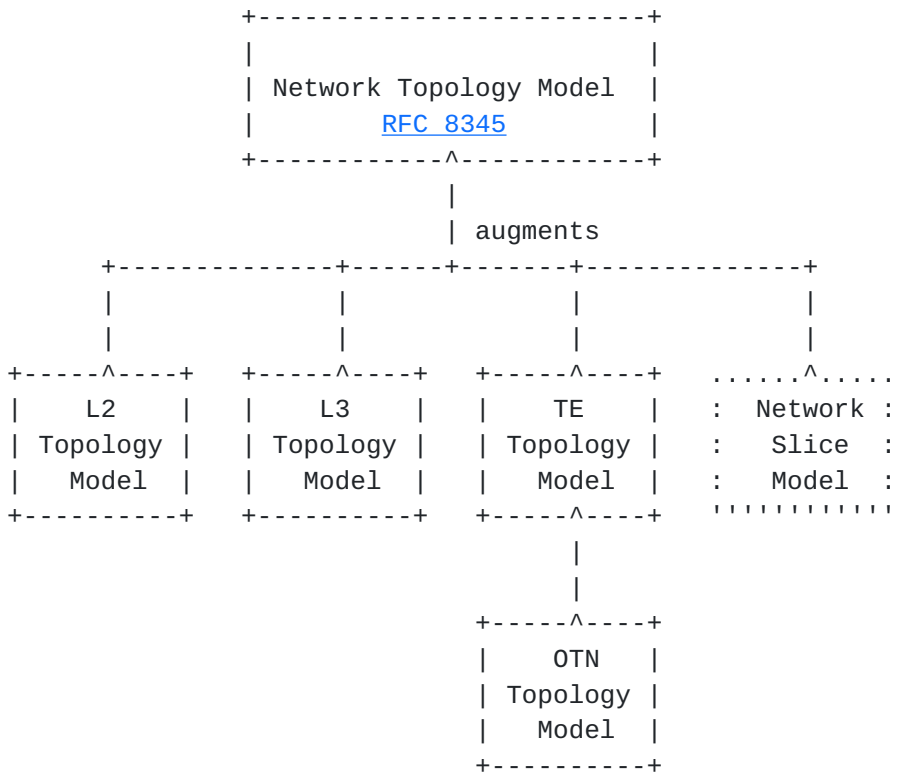

Figure 1: Model Relationships

2.2. Network Slice with TE

In many situations, an IETF network slide needs to have TE (Traffic Engineering) capabilities to achieve certain network characteristics. The TE Topology Model defined in [RFC8795] can be used to make an IETF network slice TE capable. To achieve this, an IETF network slice instance will be configured to have both "network-slice" and "te-topology" network types, taking advantage of the multiple

inheritance capability featured by the network topology model [RFC8345]. The following diagram shows their relations.

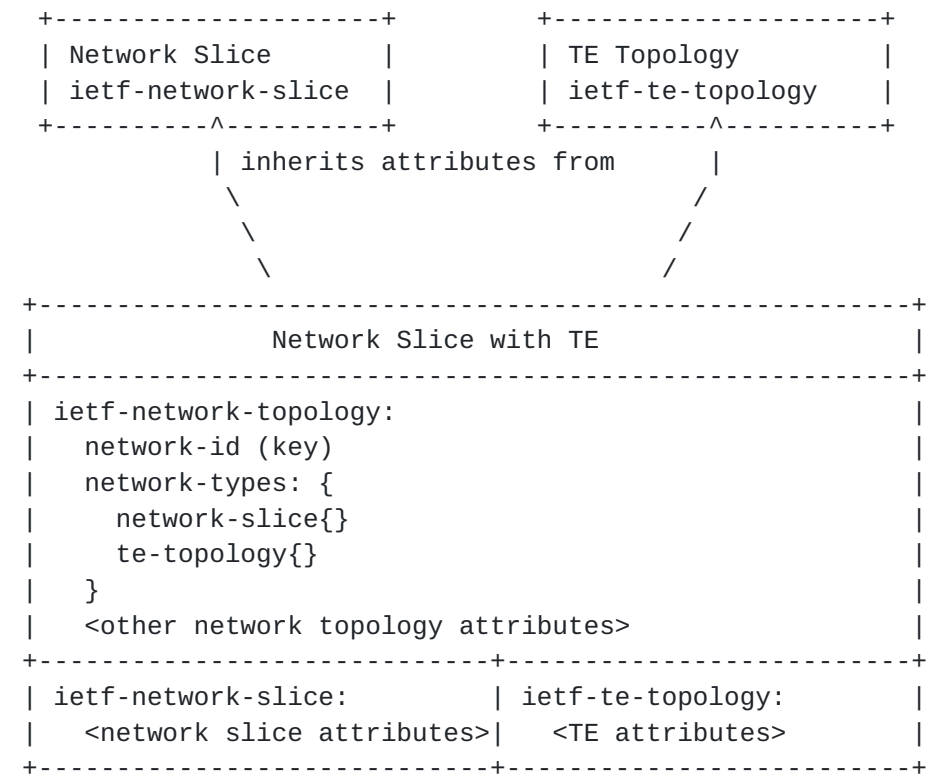

Figure 2: Network Slice with TE

This method can be applied to other types of network topology models too. For example, when a network topology instance is configured to have the types of "network-slice" defined in this document, "te-topology" defined in [RFC8795], and "l3-unicast-topology" defined in [RFC8346], this network topology instance becomes an IETF network slice instance that can perform layer 3 traffic engineering.

2.3. ACTN for Network Slicing

Since ACTN topology data models are based on the network topology model defined in [RFC8345], the augmentations defined in this document are effective augmentations to the ACTN topology data models, resulting in making the ACTN framework [RFC8453] and data models [I-D.ietf-teas-actn-yang] capable of slicing networks with the required network characteristics.

3. Model Applicability

There are many technologies to achieve network slicing. The data model defined in this document can be applied to a wide ranges of cases. This section describes how this data model is applied to a few cases.

3.1. Network Slicing by Virtualization

In the case shown in Figure 3, node virtualization is used to separate and allocate resources in physical devices. Two virtual routers VR1 and VR2 are created over physical router R1. Each of the virtual routers takes a portion of the resources such as ports and memory in the physical router. Depending on the requirements and the implementations, they may share certain resources such as processors, ASICs, and switch fabric.

As an example, Appendix A. shows the JSON encoded data instances of the native topology and the customized topology for Network Slice Blue.

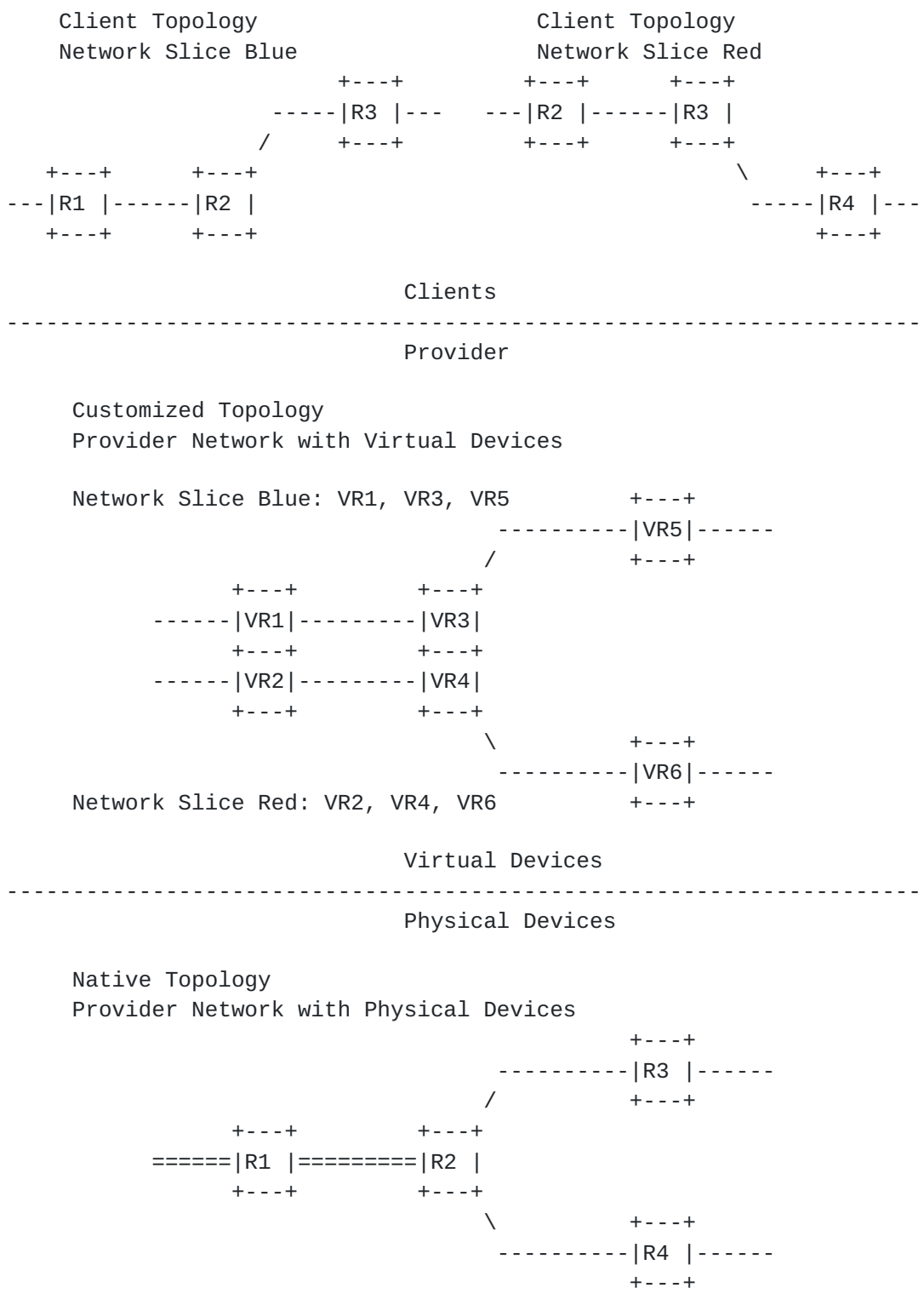

Figure 3: Network Slicing by Virtualization

3.2. Network Slicing by TE Overlay

Figure 4 shows a case where TE (Traffic Engineering) overlay is applied to achieve logically separated client IETF network slices. In the underlay TE capable network, TE tunnels are established to support the TE links in the overlay network. These links and tunnels maintain the characteristics required by the clients. The provider selects the proper logical nodes and links in the overlay network, assigns them to specific IETF network slices, and uses the data model defined in this document to send the results to the clients.

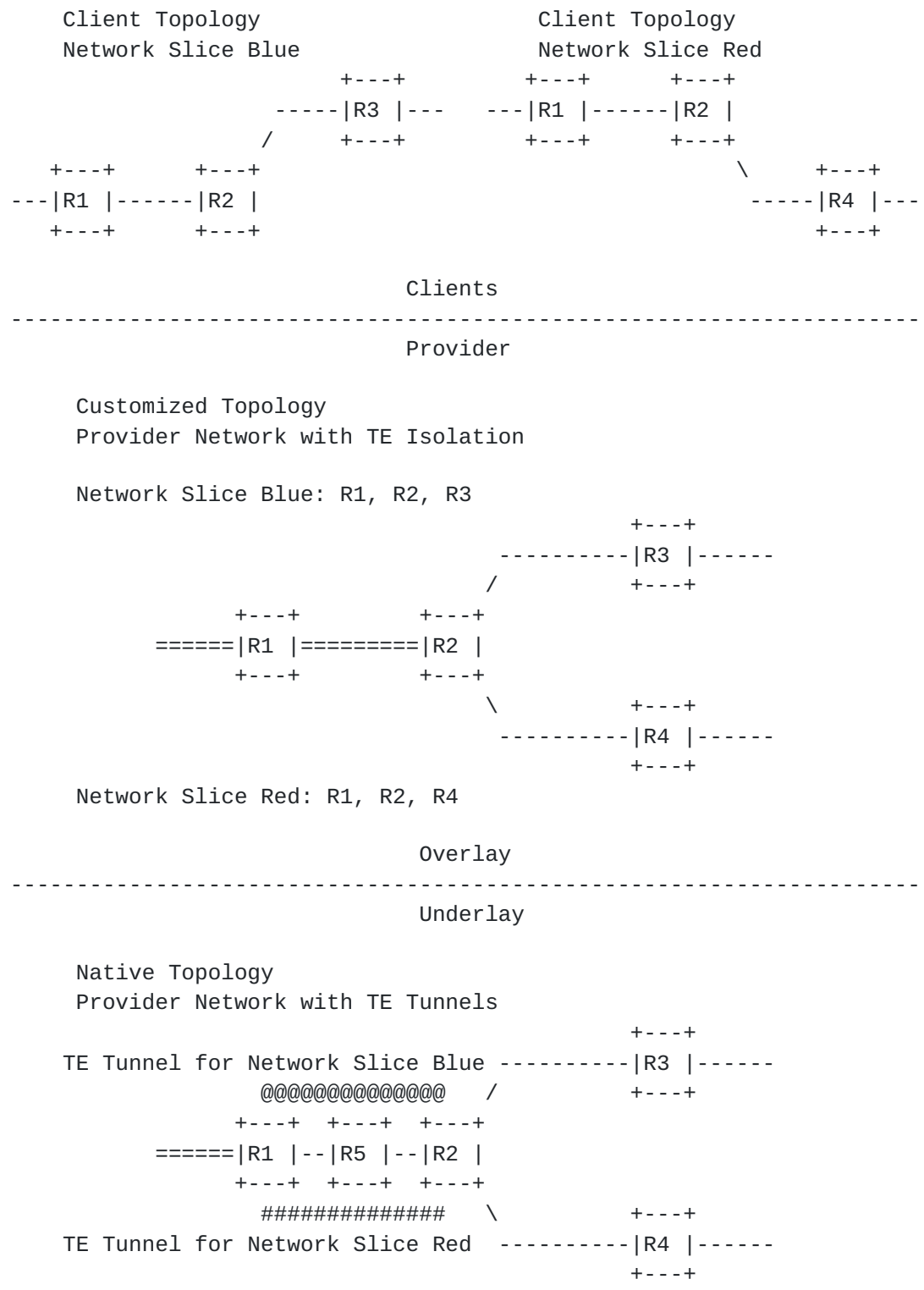

Figure 4: Network Slicing by TE Overlay

4. Model Tree Structure

TODO - Complete IETF network slice attributes that are technology-agnostic and common to all use cases.

```
module: ietf-network-slice
  augment /nw:networks/nw:network/nw:network-types:
    +--rw network-slice!
  augment /nw:networks/nw:network:
    +--rw network-slice
       +--rw optimization-criterion?   identityref
       +--rw delay-tolerance?          boolean
       +--rw periodicity*              uint64
       +--rw isolation-level?          identityref
  augment /nw:networks/nw:network/nw:node:
    +--rw network-slice
       +--rw isolation-level?   identityref
       +--rw compute-node-id?   string
       +--rw storage-id?        string
  augment /nw:networks/nw:network/nt:link:
    +--rw network-slice
       +--rw delay-tolerance?   boolean
       +--rw periodicity*       uint64
       +--rw isolation-level?   identityref
```

5. YANG Module

This module references [RFC8345], [RFC8776], and [GSMA-NS-Template]

```
<CODE BEGINS> file "ietf-network-slice@2020-11-01.yang"
module ietf-network-slice {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-network-slice";
  prefix "ns";

  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";
  }
```

```
    import ietf-te-types {
      prefix "te-types";
      reference
        "RFC 8776: Traffic Engineering Common YANG Types";
    }

    organization
      "IETF Traffic Engineering Architecture and Signaling (TEAS)
       Working Group";

    contact
      "WG Web:   <http://tools.ietf.org/wg/teas/>
       WG List:  <mailto:teas@ietf.org>

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

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       Editor:   Sergio Belotti
                 <mailto:sergio.belotti@nokia.com>

       Editor:   Reza Rokui
                 <mailto:reza.rokui@nokia.com>
      ";

    description
      "YANG data model for representing and managing network
       slices.

       Copyright (c) 2020 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 Simplified BSD License set
       forth in Section 4.c of the IETF Trust's Legal Provisions
       Relating to IETF Documents
```

```
      (http://trustee.ietf.org/license-info).

      This version of this YANG module is part of RFC XXXX; see the
      RFC itself for full legal notices.";

    revision 2020-11-01 {
      description "Initial revision";
      reference
        "RFC XXXX: YANG Data Model for Network Slices";
    }

    /*
     * Identities
     */
    identity isolation-level {
      description
        "Base identity for the isolation-level.";
      reference
        "GSMA-NS-Template: Generic Network Slice Template,
         Version 3.0.";
    }
    identity no-isolation {
      base isolation-level;
      description
        "Network slices are not separated.";
    }
    identity physical-isolation {
      base isolation-level;
      description
        "Network slices are physically separated (e.g. different rack,
         different hardware, different location, etc.).";
    }
    identity logical-isolation {
      base isolation-level;
      description
        "Network slices are logically separated.";
    }
    identity process-isolation {
      base physical-isolation;
      description
        "Process and threads isolation.";
    }
    identity physical-memory-isolation {
      base physical-isolation;
      description
        "Process and threads isolation.";
    }
    identity physical-network-isolation {
```

```
      base physical-isolation;
      description
        "Process and threads isolation.";
    }
    identity virtual-resource-isolation {
      base logical-isolation;
      description
        "A network slice has access to specific range of resources
         that do not overlap with other network slices
         (e.g. VM isolation).";
    }
    identity network-functions-isolation {
      base logical-isolation;
      description
        "NF (Network Function) is dedicated to the network slice, but
         virtual resources are shared.";
    }
    identity service-isolation {
      base logical-isolation;
      description
        "NSC data are isolated from other NSCs, but virtual
         resources and NFs are shared.";
    }

    /*
     * Groupiings
     */
    grouping network-slice-topology-attributes {
      description "Network Slice topology scope attributes.";
      container network-slice {
        description
          "Containing Network Slice attributes.";
        leaf optimization-criterion {
          type identityref {
            base te-types:objective-function-type;
          }
          description
            "Optimization criterion applied to this topology.";
        }
        leaf delay-tolerance {
          type boolean;
          description
            "'true' if is not too critical how long it takes to deliver
             the amount of data.";
          reference
            "GSMA-NS-Template: Generic Network Slice Template,
             Version 3.0.";
        }
```

```
        leaf-list periodicity {
          type uint64;
          units seconds;
          description
            "A list of periodicities supported by the network slice.";
          reference
            "GSMA-NS-Template: Generic Network Slice Template,
             Version 3.0.";
        }
        leaf isolation-level {
          type identityref {
            base isolation-level;
          }
          description
            "A network slice instance may be fully or partly, logically
             and/or physically, isolated from another network slice
             instance. This attribute describes different types of
             isolation:";
        }
      } // network-slice
    } // network-slice-topology-attributes

    grouping network-slice-node-attributes {
      description "Network Slice node scope attributes.";
      container network-slice {
        description
          "Containing Network Slice attributes.";
        leaf isolation-level {
          type identityref {
            base isolation-level;
          }
          description
            "A network slice instance may be fully or partly, logically
             and/or physically, isolated from another network slice
             instance. This attribute describes different types of
             isolation:";
        }
        leaf compute-node-id {
          type string;
          description
            "Reference to a compute node instance specified in
             a data model specifying the computing resources.";
        }
        leaf storage-id {
          type string;
          description
            "Reference to a storage instance specified in
             a data model specifying the storage resources.";
```

```
        }
      } // network-slice
    } // network-slice-node-attributes

    grouping network-slice-link-attributes {
      description "Network Slice link scope attributes";
      container network-slice {
        description
          "Containing Network Slice attributes.";
        leaf delay-tolerance {
          type boolean;
          description
            "'true' if is not too critical how long it takes to deliver
             the amount of data.";
          reference
            "GSMA-NS-Template: Generic Network Slice Template,
             Version 3.0.";
        }
        leaf-list periodicity {
          type uint64;
          units seconds;
          description
            "A list of periodicities supported by the network slice.";
          reference
            "GSMA-NS-Template: Generic Network Slice Template,
             Version 3.0.";
        }
        leaf isolation-level {
          type identityref {
            base isolation-level;
          }
          description
            "A network slice instance may be fully or partly, logically
             and/or physically, isolated from another network slice
             instance. This attribute describes different types of
             isolation:";
        }
      } // network-slice
    } // network-slice-link-attributes

    /*
     * Data nodes
     */
    augment "/nw:networks/nw:network/nw:network-types" {
      description
        "Defines the Network Slice topology type.";
      container network-slice {
        presence "Indicates Network Slice topology";
```

```
        description
          "Its presence identifies the Network Slice type.";
      }
    }

    augment "/nw:networks/nw:network" {
      when "nw:network-types/ns:network-slice" {
        description "Augment only for Network Slice topology.";
      }
      description "Augment topology configuration and state.";
      uses network-slice-topology-attributes;
    }

    augment "/nw:networks/nw:network/nw:node" {
      when "../nw:network-types/ns:network-slice" {
        description "Augment only for Network Slice topology.";
      }
      description "Augment node configuration and state.";
      uses network-slice-node-attributes;
    }

    augment "/nw:networks/nw:network/nt:link" {
      when "../nw:network-types/ns:network-slice" {
        description "Augment only for Network Slice topology.";
      }
      description "Augment link configuration and state.";
      uses network-slice-link-attributes;
    }

  }
  <CODE ENDS>
```

6. IANA Considerations

RFC Ed.: In this section, replace all occurrences of 'XXXX' with the actual RFC number (and remove this note).

This document registers the following namespace URIs in the IETF XML registry [RFC3688]:

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

This document registers the following YANG modules in the YANG Module Names registry [RFC6020]:

```
---------------------------------------------------------------------
name:         ietf-l3-te-topology
namespace:    urn:ietf:params:xml:ns:yang:ietf-network-slice
prefix:       ns
reference:    RFC XXXX
---------------------------------------------------------------------
```

7. 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:

/nw:networks/nw:network/nw:network-types/ns:network-slice
: This subtree specifies the network slice type. Modifying the configurations can make network slice type invalid and cause interruption to IETF network slices.

/nw:networks/nw:network/ns:network-slice
: This subtree specifies the topology-wide configurations. Modifying the configurations here can cause traffic characteristics changed in this IETF network slice and related networks.

/nw:networks/nw:network/nw:node/ns:network-slice
: This subtree specifies the configurations of the nodes in a IETF network slice. Modifying the configurations in this subtree can

change the traffic characteristics on this node and the related networks.

/nw:networks/nw:network/nt:link/ns:network-slice
This subtree specifies the configurations of the links in a IETF network slice. Modifying the configurations in this subtree can change the traffic characteristics on this link and the related networks.

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:

/nw:networks/nw:network/nw:network-types/ns:network-slice
Unauthorized access to this subtree can disclose the network slice type.

/nw:networks/nw:network/ns:network-slice
Unauthorized access to this subtree can disclose the topology-wide states.

/nw:networks/nw:network/nw:node/ns:network-slice
Unauthorized access to this subtree can disclose the operational state information of the nodes in a IETF network slice.

/nw:networks/nw:network/nt:link/ns:network-slic
Unauthorized access to this subtree can disclose the operational state information of the links in a IETF network slice.

8. Acknowledgements

The TEAS Network Slicing Design Team (NSDT) members included Aijun Wang, Dong Jie, Eric Gray, Jari Arkko, Jeff Tantsura, John E Drake, Luis M. Contreras, Rakesh Gandhi, Ran Chen, Reza Rokui, Ricard Vilalta, Ron Bonica, Sergio Belotti, Tomonobu Niwa, Xuesong Geng, and Xufeng Liu.

9. References

9.1. Normative References

[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>.

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

[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>.

[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>.

[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>.

[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>.

[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>.

[RFC8346] Clemm, A., Medved, J., Varga, R., Liu, X., Ananthakrishnan, H., and N. Bahadur, "A YANG Data Model for Layer 3 Topologies", RFC 8346, DOI 10.17487/RFC8346, March 2018, <https://www.rfc-editor.org/info/rfc8346>.

[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>.

[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>.

[GSMA-NS-Template] GSM Association, "Generic Network Slice Template, Version 3.0", NG.116, May 2020.

[I-D.ietf-teas-ietf-network-slices] Farrel, A., Gray, E., Drake, J., Rokui, R., Homma, S., Makhijani, K., Contreras, L. M., and J. Tantsura, "Framework for IETF Network Slices", draft-ietf-teas-ietf-network-slices-00 (work in progress), April 2021.

9.2. Informative References

[RFC7951] Lhotka, L., "JSON Encoding of Data Modeled with YANG", RFC 7951, DOI 10.17487/RFC7951, August 2016, <https://www.rfc-editor.org/info/rfc7951>.

[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>.

[RFC8453] Ceccarelli, D., Ed. and Y. Lee, Ed., "Framework for Abstraction and Control of TE Networks (ACTN)", RFC 8453, DOI 10.17487/RFC8453, August 2018, <https://www.rfc-editor.org/info/rfc8453>.

[I-D.ietf-ccamp-otn-topo-yang]
Zheng, H., Busi, I., Liu, X., Belotti, S., and O. G. D. Dios, "A YANG Data Model for Optical Transport Network Topology", draft-ietf-ccamp-otn-topo-yang-12 (work in progress), February 2021.

[I-D.ietf-i2rs-yang-l2-network-topology]
Dong, J., Wei, X., Wu, Q., Boucadair, M., and A. Liu, "A YANG Data Model for Layer 2 Network Topologies", draft-ietf-i2rs-yang-l2-network-topology-18 (work in progress), September 2020.

[I-D.ietf-teas-actn-yang]
Lee, Y., Zheng, H., Ceccarelli, D., Yoon, B. Y., and S. Belotti, "Applicability of YANG models for Abstraction and Control of Traffic Engineered Networks", draft-ietf-teas-actn-yang-07 (work in progress), February 2021.

Appendix A. Data Tree for the Example in Section 3.1.

A.1. Native Topology

This section contains an example of an instance data tree in the JSON encoding [RFC7951]. The example instantiates "ietf-network" for the native topology depicted in Figure 3.


```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-id":"example-native-topology",
        "network-types": {
        },
        "node": [
          {
            "node-id":"R1",
            "ietf-network-topology:termination-point": [
              {
                "tp-id":"1-0-1"
              },
              {
                "tp-id":"1-0-2"
              },
              {
                "tp-id":"1-2-1"
              },
              {
                "tp-id":"1-2-2"
              }
            ]
          },
          {
            "node-id":"R2",
            "ietf-network-topology:termination-point": [
              {
                "tp-id":"2-1-1"
              },
              {
                "tp-id":"2-1-2"
              },
              {
                "tp-id":"2-3-1"
              },
              {
                "tp-id":"2-4-1"
              }
```

```
            ]
          },
          {
            "node-id":"R3",
            "ietf-network-topology:termination-point": [
              {
                "tp-id":"3-0-1"
              },
              {
                "tp-id":"3-2-1"
              }
            ]
          },
          {
            "node-id":"R4",
            "ietf-network-topology:termination-point": [
              {
                "tp-id":"4-0-1"
              },
              {
                "tp-id":"4-2-1"
              }
            ]
          }
        ],
        "ietf-network-topology:link": [
          {
            "link-id":"R1,1-0-1,,",
            "source": {
              "source-node":"R1",
              "source-tp":"1-0-1"
            }
          },
          {
            "link-id":",,R1,1-0-1",
            "destination": {
              "dest-node":"R1",
              "dest-tp":"1-0-1"
            }
          },
          {
            "link-id":"R1,1-0-2,,",
            "source": {
              "source-node":"R1",
              "source-tp":"1-0-2"
            }
          },
          {
```

```
            "link-id":",,R1,1-0-2",
            "destination": {
              "dest-node":"R1",
              "dest-tp":"1-0-2"
            }
          },
          {
            "link-id":"R1,1-2-1,R2,2-1-1",
            "source": {
              "source-node":"R1",
              "source-tp":"1-2-1"
            },
            "destination": {
              "dest-node":"R2",
              "dest-tp":"2-1-1"
            }
          },
          {
            "link-id":"R2,2-1-1,R1,1-2-1",
            "source": {
              "source-node":"R2",
              "source-tp":"2-1-1"
            },
            "destination": {
              "dest-node":"R1",
              "dest-tp":"1-2-1"
            }
          },
          {
            "link-id":"R1,1-2-2,R2,2-1-2",
            "source": {
              "source-node":"R1",
              "source-tp":"1-2-2"
            },
            "destination": {
              "dest-node":"R2",
              "dest-tp":"2-1-2"
            }
          },
          {
            "link-id":"R2,2-1-2,R1,1-2-2",
            "source": {
              "source-node":"R2",
              "source-tp":"2-1-2"
            },
            "destination": {
              "dest-node":"R1",
              "dest-tp":"1-2-2"
```

```
        }
      },
      {
        "link-id":"R2,2-3-1,R3,3-2-1",
        "source": {
          "source-node":"R2",
          "source-tp":"2-3-1"
        },
        "destination": {
          "dest-node":"R3",
          "dest-tp":"3-2-1"
        }
      },
      {
        "link-id":"R3,3-2-1,R2,2-3-1",
        "source": {
          "source-node":"R3",
          "source-tp":"3-2-1"
        },
        "destination": {
          "dest-node":"R2",
          "dest-tp":"2-3-1"
        }
      },
      {
        "link-id":"R2,2-4-1,R4,4-2-1",
        "source": {
          "source-node":"R2",
          "source-tp":"2-4-1"
        },
        "destination": {
          "dest-node":"R4",
          "dest-tp":"4-2-1"
        }
      },
      {
        "link-id":"R4,4-2-1,R2,2-4-1",
        "source": {
          "source-node":"R4",
          "source-tp":"4-2-1"
        },
        "destination": {
          "dest-node":"R2",
          "dest-tp":"2-4-1"
        }
      },
      {
        "link-id":"R3,3-0-1,,",
```

```
              "source": {
                "source-node":"R3",
                "source-tp":"3-0-1"
              }
            },
            {
              "link-id":",,R3,3-0-1",
              "destination": {
                "dest-node":"R3",
                "dest-tp":"3-0-1"
              }
            },
            {
              "link-id":"R4,4-0-1,,",
              "source": {
                "source-node":"R4",
                "source-tp":"4-0-1"
              }
            },
            {
              "link-id":",,R4,4-0-1",
              "destination": {
                "dest-node":"R4",
                "dest-tp":"4-0-1"
              }
            }
          ]
        }
      ]
    }
  }
```

A.2. Network Slice Blue

This section contains an example of an instance data tree in the JSON encoding [RFC7951]. The example instantiates "ietf-network-slice" for the topology customized for Network Slice Blue depicted in Figure 3.

```
{
  "ietf-network:networks": {
    "network": [
      {
        "network-id":"example-customized-blue-topology",
        "network-types": {
          "ietf-network-slice:network-slice": {
```

```
            }
          },
          "supporting-network": [
            {
              "network-ref":"example-native-topology"
            }
          ],
          "node": [
            {
              "node-id":"VR1",
              "supporting-node": [
                {
                  "network-ref":"example-native-topology",
                  "node-ref":"R1"
                }
              ],
              "ietf-network-slice:network-slice": {
                "isolation-level":
                "ietf-network-slice:physical-memory-isolation"
              },
              "ietf-network-topology:termination-point": [
                {
                  "tp-id":"1-0-1"
                },
                {
                  "tp-id":"1-3-1"
                }
              ]
            },
            {
              "node-id":"VR3",
              "supporting-node": [
                {
                  "network-ref":"example-native-topology",
                  "node-ref":"R2"
                }
              ],
              "ietf-network-slice:network-slice": {
                "isolation-level":
                "ietf-network-slice:physical-memory-isolation"
              },
              "ietf-network-topology:termination-point": [
                {
                  "tp-id":"3-1-1"
                },
                {
                  "tp-id":"3-5-1"
                }
```

```
            ]
          },
          {
            "node-id":"VR5",
            "supporting-node": [
              {
                "network-ref":"example-native-topology",
                "node-ref":"R3"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-memory-isolation"
            },
            "ietf-network-topology:termination-point": [
              {
                "tp-id":"5-3-1"
              },
              {
                "tp-id":"5-0-1"
              }
            ]
          }
        ],
        "ietf-network-topology:link": [
          {
            "link-id":"VR1,1-0-1,,",
            "source": {
              "source-node":"VR1",
              "source-tp":"1-0-1"
            },
            "supporting-link": [
              {
                "network-ref":"example-native-topology",
                "link-ref":"R1,1-0-1,,"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          },
          {
            "link-id":",,VR1,1-0-1",
            "destination": {
              "dest-node":"VR1",
              "dest-tp":"1-0-1"
            },
```

```
        "supporting-link": [
          {
            "network-ref":"example-native-topology",
            "link-ref":",,R1,1-0-1"
          }
        ],
        "ietf-network-slice:network-slice": {
          "isolation-level":
          "ietf-network-slice:physical-network-isolation"
        }
      },
      {
        "link-id":"VR1,1-3-1,VR3,3-1-1",
        "source": {
          "source-node":"VR1",
          "source-tp":"1-3-1"
        },
        "destination": {
          "dest-node":"VR3",
          "dest-tp":"3-1-1"
        },
        "supporting-link": [
          {
            "network-ref":"example-native-topology",
            "link-ref":"R1,1-2-1,R2,2-1-1"
          }
        ],
        "ietf-network-slice:network-slice": {
          "isolation-level":
          "ietf-network-slice:physical-network-isolation"
        }
      },
      {
        "link-id":"VR3,3-1-1,VR1,1-3-1",
        "source": {
          "source-node":"VR3",
          "source-tp":"3-1-1"
        },
        "destination": {
          "dest-node":"R1",
          "dest-tp":"1-3-1"
        },
        "supporting-link": [
          {
            "network-ref":"example-native-topology",
            "link-ref":"R2,2-1-1,R1,1-2-1"
          }
        ],
```

```
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          },
          {
            "link-id":"VR3,3-5-1,VR5,5-3-1",
            "source": {
              "source-node":"VR3",
              "source-tp":"3-5-1"
            },
            "destination": {
              "dest-node":"VR5",
              "dest-tp":"5-3-1"
            },
            "supporting-link": [
              {
                "network-ref":"example-native-topology",
                "link-ref":"R2,2-3-1,R3,3-2-1"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          },
          {
            "link-id":"VR5,5-3-1,VR3,3-5-1",
            "source": {
              "source-node":"VR5",
              "source-tp":"5-3-1"
            },
            "destination": {
              "dest-node":"VR3",
              "dest-tp":"3-5-1"
            },
            "supporting-link": [
              {
                "network-ref":"example-native-topology",
                "link-ref":"R3,3-2-1,R2,2-3-1"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          },
          {
```

```
            "link-id":"VR5,5-0-1,,",
            "source": {
              "source-node":"VR5",
              "source-tp":"5-0-1"
            },
            "supporting-link": [
              {
                "network-ref":"example-native-topology",
                "link-ref":"R3,3-0-1,,"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          },
          {
            "link-id":",,VR5,5-0-1",
            "destination": {
              "dest-node":"VR5",
              "dest-tp":"5-0-1"
            },
            "supporting-link": [
              {
                "network-ref":"example-native-topology",
                "link-ref":",,R3,3-0-1"
              }
            ],
            "ietf-network-slice:network-slice": {
              "isolation-level":
              "ietf-network-slice:physical-network-isolation"
            }
          }
        ],
        "ietf-network-slice:network-slice": {
          "optimization-criterion":
          "ietf-te-types:of-minimize-cost-path",
          "isolation-level":
          "ietf-network-slice:physical-isolation"
        }
      }
    ]
  }
}
```

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