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Framework and Data Model for OTN Network Slicing

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Abstract

The requirement of slicing network resource with desired quality of

service is emerging at every network technology, including the

Optical Transport Networks (OTN). As a part of the transport

network, OTN can provide hard pipes with guaranteed data isolation

and deterministic low latency, which are highly demanded in the

Service Level Agreement (SLA).

This document describes a framework for OTN network slicing and a

YANG data model augmentation of the OTN topology model. Additional

YANG data model augmentations will be defined in a future version of

this draft.

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1. Introduction

The requirement of slicing network resource with desired quality of

service is emerging at every network technology, including the

Optical Transport Networks (OTN). As a part of the transport

network, OTN can provide hard pipes with guaranteed data isolation

and deterministic low latency, which are highly demanded in the

Service Level Agreement (SLA). This document describes a framework

for OTN network slicing and a YANG data model augmentation of the OTN

topology model. Additional YANG data model augmentations will be

defined in a future version of this draft.

1.1. Definition of OTN Slice

An OTN slice is an OTN virtual network topology connecting a number

of OTN endpoints using a set of shared or dedicated OTN network

resources to satisfy specific service level objectives (SLOs).

An OTN slice is a technology-specific realization of an IETF network

slice [I-D.ietf-teas-ietf-network-slices] in the OTN domain, with the

capability of configuring slice resources in the term of OTN

technologies. Therefore, all the terms and definitions with respect

to network slicing as defined in [I-D.ietf-teas-ietf-network-slices]

apply to OTN slicing.

An OTN slice can span multiple OTN administrative domains,

encompassing access links, intra-domain paths, and inter-domain

links. An OTN slice may include multiple endpoints, each associated

with a set of physical or logical resources, e.g. optical port or

time slots, at the termination point (TP) of an access link or inter-

domain link at an OTN provider edge (PE) equipment.

An end-to-end OTN slice may be composed from multiple OTN segment

slices in a hierarchical or sequential (or stitched) combination.

Figure 1 illustrates the scope of OTN slices in multi-domain

environment.

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<-------------------End-to-end OTN Slice----------------->

<-- OTN Segment Slice 1 ---> <-- OTN Segment Slice 2 --->

+-------------------------+ +-----------------------+

| +-----+ +-------+ | | +-------+ +-----+|

+----+ | | OTN | | OTN | | | | OTN | | OTN || +----+

| CE +-+-o PE +-...--+ Borde o--+--+-o Borde +-...--+ PE o+--+ CE |

+----+ |/| | | Node |\ | | | Node | | || +----+

| ||+-----+ +-------+ ||| | +-------+ +-----+| |

| || OTN Domain 1 ||| | OTN Domain 2 | |

| ++-----------------------++| +-----------------------+ |

| | | | |

| +-----+ +------------+ | |

| | | | |

V V V V V

Access OTN Slice Inter-domain Access

Link Endpoint Link Link

Figure 1: OTN Slice

OTN slices may be pre-configured by the management plane and

presented to the customer via the northbound interface (NBI), or they

may be dynamically provisioned by a higher layer slice controller,

e.g. an IETF network slice controller (IETF NSC) through the NBI.

The OTN slice is provided by a service provider to a customer to be

used as though it was part of the customer's own networks.

2. Use Cases for OTN Network Slicing

2.1. Leased Line Services with OTN

For end business customers (like OTT or enterprises), leased lines

have the advantage of providing high-speed connections with low

costs. On the other hand, the traffic control of leased lines is

very challenging due to rapid changes in service demands. Carriers

are recommended to provide network-level slicing capabilities to meet

this demand. Based on such capabilities, private network users have

full control over the sliced resources which have allocated to them

and which could be used to support their leased lines, when needed.

Users may formulate policies based on the demand for services and

time to schedule the resources from the entire network's perspective

flexibly. For example, the bandwidth between any two points may be

established or released based on the time or monitored traffic

characteristics. The routing and bandwidth may be adjusted at a

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specific time interval to maximize network resource utilization

efficiency.

2.2. Co-construction and Sharing

Co-construction and sharing of a network are becoming a popular means

among service providers to reduce networking building CAPEX. For Co-

construction and sharing case, there are typically multiple co-

founders for the same network. For example, one founder may provide

optical fibres and another founder may provide OTN equipment, while

each occupies a certain percentage of the usage rights of the network

resources. In this scenario, the network O&M is performed by a

certain founder in each region, where the same founder usually

deploys an independent management and control system. The other

founders of the network use each other's management and control

system to provision services remotely. In this scenario, different

founders' network resources need to be automatically (associated)

divided, isolated, and visualized. All founders may share or have

independent O&M capabilities, and should be able to perform service-

level provisioning in their respective slices.

2.3. Wholesale of optical resources

In the optical resource wholesale market, smaller, local carriers and

wireless carriers may rent resources from larger carriers, or

infrastructure carriers instead of building their networks.

Likewise, international carriers may rent resources from respective

local carriers and local carriers may lease their owned networks to

each other to achieve better network utilization efficiency. From

the perspective of a resource provider, it is crucial that a network

slice is timely configured to meet traffic matrix requirements

requested by its tenants. The support for multi-tenancy within the

resource provider's network demands that the network slices are

qualitatively isolated from each other to meet the requirements for

transparency, non-interference, and security. Typically, a resource

purchaser expects to use the leased network resources flexibly, just

like they are self-constructed. Therefore, the purchaser is not only

provided with a network slice, but also the full set of

functionalities for operating and maintaining the network slice. The

purchaser also expects to, in a flexible and independent manner,

schedule and maintain physical resources to support their own end-to-

end automation using both leased and self-constructed network

resources.

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2.4. Vertical dedicated network with OTN

Vertical industry slicing is an emerging category of network slicing

due to the high demand for private high-speed network interconnects

for industrial applications. In this scenario, the biggest challenge

is to implement differentiated optical network slices based on the

requirements from different industries. For example, in the

financial industry, to support high-frequency transactions, the slice

must ensure to provide the minimum latency along with the mechanism

for latency management. For the healthcare industry, online

diagnosis network and software capabilities to ensure the delivery of

HD video without frame loss. For bulk data migration in data

centers, the network needs to support on-demand, large-bandwidth

allocation. In each of the aforementioned vertical industry

scenarios, the bandwidth shall be adjusted as required to ensure

flexible and efficient network resource usage.

2.5. End-to-end network slicing

In an end-to-end network slicing scenario such as 5G network slicing

[TS.28.530-3GPP], an IETF network slice

[I-D.ietf-teas-ietf-network-slices] provides the required

connectivity between other different segments of an end-to-end

network slice, such as the Radio Access Network (RAN) and the Core

Network (CN) segments, with a specific performance commitment. An

IETF network slice could be composed of network slices from multiple

technological and administrative domains. An IETF network slice can

be realized by using or combining multiple underlying OTN slices with

OTN resources, e.g. ODU time slots or ODU containers,to achieve end-

to-end slicing across the transport domain.

3. Framework for OTN slicing

OTN slices may be abstracted differently depending on the requirement

contained in the configuration provided by the slice customer.

Whereas the customer requests an OTN slice to provide connectivities

between specified endpoints, an OTN slice can be abstracted as a set

of endpoint-to-endpoint links, with each link formed by an end-to-end

tunnel across the underlying OTN networks. The resources associated

with each link of the slice is reserved and commissioned in the

underlying physical network upon the completion of configuring the

OTN slice, and all the links are active.

An OTN slice can also be abstracted as an abstract topology when the

customer reqeuests the slice to share resources between multiple

endpoints and to use the resources on demand. The abstract topology

may consist of virtual nodes and virtual links, and their associated

resources are reserved but not comissioned across the underlying OTN

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networks. The customer can later commission resources within the

slice dynamically using the NBI provided by the service provider.

Those means to abstract an OTN slice is similar to the Virtual

Network (VN) concept defined for higher-level interfaces in

[I-D.ietf-teas-actn-vn-yang], where the connectivity-based slice

abstraction corresponds to VN Type 1 and the resource-based slice

abstraction corresponds to VN type 2.

A particular resource in an OTN network, such as a port or link, may

be sliced with one of the two granularity levels:

o Link-based slicing, where a link and its associated link

termination points (LTPs) are dedicatedly allocated to a

particular OTN slice.

o Tributary-slot based slicing, where multiple OTN slices share the

same link by allocating different OTN tributary slots in different

granularities.

Furthermore, an OTN switch is typically fully non-blockable switching

at the lowest ODU container granularity, it is desirable to specify

just the total number of tributary slots in the lowest granularity

(e.g. ODU0), when configuring tributary-slot based slicing on links

and ports internal to an OTN network. In multi-domain OTN network

scenarios where separate OTN slices are created on each of the OTN

networks and are stitched at inter-domain OTN links, it is necessary

to specify matching tributary slots at the endpoints of the inter-

domain links. In some real network scenarios, OTN network resources

including tributary slots are managed explicitly by network operators

for network maintenance considerations. Therefore an OTN slice

controller shall support configuring an OTN slice with both options.

An OTN slice controller (OTN-SC) is a logical function responsible

for the life-cycle management of OTN slices instantiated within the

corresponding OTN network domains. The OTN-SC provides technology-

specific interfaces at its north bound (OTN-SC NBI) to allow a

higher-layer slice controller, such as an IETF network slice

controller (NSC), or an orchestrator, to configure OTN slices with

OTN-specific network resources. The OTN-SC interfaces at the south

bound using the MDSC-to-PNC interface (MPI) with a Physical Network

Controller (PNC) or Multi-Domain Service Orchestrator (MDSC), as

defined in the ACTN control framework [RFC8453]. The logical

function within the OTN-SC is responsible for translating OTN slice

configurations received into concrete slice realization which can be

understood and provisioned at the south bound by the PNC or MDSC.

When realizing OTN slices, the OTN-SC may translate a connectivity-

based OTN slice into a set of end-to-end tunnels using the Traffic-

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engineering(TE) tunnel interface defined in [I-D.ietf-teas-yang-te].

For a resource-based OTN slices, the OTN-SC may transate the abstract

topology representing the slice into a colored graph on an abstract

TE topology using the TE topology interface defined in [RFC8795].

The OTN-SC NBI is technology-specific, while the IETF NSC-NBI is

technology- agnostic. An IETF NSC may translate its customer's

technology-agnostic slice request into an OTN slice request and

utilize the OTN-SC NBI to realize the IETF network slice.

Alternatively, the IETF NSC may translate the slicing request into

tunnel or topology configuration commands and communicate directly

with the underlying PNC or MDSC to provision the IETF network slice.

Figure 2 illustrates the OTN slicing control hierarchy and the

positioning of the OTN slicing interfaces.

+--------------------+

| Provider's User |

+--------|-----------+

| CMI

+-----------------------+----------------------------+

| Orchestrator / E2E Slice Controller |

+------------+-----------------------------+---------+

| | NSC-NBI

| +---------------------+---------+

| | IETF Network Slice Controller |

| +-----+---------------+---------+

| | |

| OTN-SC NBI |OTN-SC NBI |

+------------+-------------+--------+ |

| OTN-SC | |

+--------------------------+--------+ |

| MPI | MPI

+--------------------------+---------------+---------+

| PNC |

+--------------------------+-------------------------+

| SBI

+-----------+----------+

|OTN Physical Network |

+----------------------+

Figure 2: Positioning of OTN Slicing Interfaces

OTN-SC functionalities may be recursive such that a higher-level OTN-

SC may designate the creation of OTN slices to a lower-level OTN-SC

in a recursive manner. This scenario may apply to the creation of

OTN slices in multi-domain OTN networks, where multiple domain-wide

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OTN slices provisioned by lower-layer OTN-SCs are stitched to support

a multi-domain OTN slice provisioned by the higer-level OTN-SC.

Alternatively, the OTN-SC may interface with an MDSC, which in turn

interfaces with multiple PNCs through the MPI to realize OTN slices

in multi-domain without OTN-SC recursion. Figure 3 illustrates both

options for OTN slicing in multi-domain.

+-------------------+ +-------------------+

| OTN-SC | | OTN-SC |

+--------|----------+ +---|----------|----+

|MPI |OTN-SC NBI|

+--------|----------+ +---|----+ +---|----+

| MDSC | | OTN-SC | | OTN-SC |

+---|----------|----+ +---|----+ +---|----+

|MPI |MPI |MPI |MPI

+---|----+ +---|----+ +---|----+ +---|----+

| PNC | | PNC | | PNC | | PNC |

+--------+ +--------+ +--------+ +--------+

Multi-domain Option 1 Multi-domain Option 2

Figure 3: OTN-SC for multi-domain

OTN-SC functionalities are logically independent and may be deployed

in different means to cater to the realization needs. In reference

with the ACTN control framework [RFC8453], an OTN-SC may be deployed

- as an independent network function; - together with a Physical

Network Controller (PNC) for single domain or with a Multi-Domain

Service Orchestrator (MDSC)for multi domain; - together with a

higher-level network slice controller to support end-to-end network

slicing;

4. YANG Data Model for OTN Slicing Configuration

4.1. OTN Slicing YANG Model for MPI

4.1.1. MPI YANG Model Overview

When realizing OTN slices, the OTN-SC may translate a connectivity-

based OTN slice into a set of end-to-end tunnels using the Traffic-

engineering(TE) tunnel interface defined in [I-D.ietf-teas-yang-te].

For a resource-based OTN slices, the OTN-SC may transate the abstract

topology representing the slice into a colored graph on an abstract

TE topology using the TE topology interface defined in [RFC8795].

For the configuration of connectivity-based OTN slices, existing

models such as the TE tunnel interface [I-D.ietf-teas-yang-te] may be

used and no addition is needed. This model is addressing the case

for configuring resource-based OTN slices, where the model permits to

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reserve resources exploiting on the common knowledge of an underlying

virtual topology between the OTN-SC and the subtended network

controller (MDSC or PNC). The slice is configured by by marking

corresponding link resources on the TE topology received from the

underlying MDSC or PNC with a slice identifier and OTN-specific

resource requirements, e.g. the number of ODU time slots or type/

number of ODU container. The MDSC or PNC, based on the marked

resources by OTN-SC, will update the underlying TE topology with new

TE link for each of the colored links to keep booked the reserved OTN

resources e.g. time slots or ODU containers.

4.1.2. MPI YANG Model Tree

module: ietf-otn-slice

augment /nw:networks/nw:network/nt:link/tet:te/tet:te-link-

attributes:

+--rw (otn-slice-granularity)?

+--:(link)

| +--rw slice-id? uint32

+--:(link-resource)

+--rw slices\* [slice-id]

+--rw slice-id uint32

+--rw (technology)?

| +--:(otn)

| +--rw otn-ts-num? uint32

+--ro sliced-link-ref? ->

../../../../../nt:link/link-id

Figure 4: OTN network slicing tree diagram

4.1.3. MPI YANG Code

<CODE BEGINS>file "ietf-otn-slice@2021-02-22.yang"

module ietf-otn-slice {

yang-version 1.1;

namespace "urn:ietf:params:xml:ns:yang:ietf-otn-slice";

prefix "otnslice";

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";

}

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import ietf-te-topology {

prefix "tet";

reference

"RFC8795: YANG Data Model for Traffic Engineering

(TE) Topologies";

}

import ietf-otn-topology {

prefix "otntopo";

reference

"I-D.ietf-ccamp-otn-topo-yang: A YANG Data Model

for Optical Transport Network Topology";

}

organization

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description

"This module defines a YANG data model to configure an OTN

network slice realization.

The model fully conforms to the Network Management Datastore

Architecture (NMDA).

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This version of this YANG module is part of RFC XXXX; see

the RFC itself for full legal notices.";

revision "2021-02-22" {

description

"Initial Version";

reference

"draft-zheng-ccamp-yang-otn-slicing-01: Framework and Data

Model for OTN Network Slicing";

}

/\*

\* Groupings

\*/

grouping otn-link-slice-profile {

choice otn-slice-granularity {

default link;

case link {

leaf slice-id {

type uint32;

description

"Slice identifier";

}

}

case link-resource {

list slices {

key slice-id;

description

"List of slices.";

leaf slice-id {

type uint32;

description

"Slice identifier";

}

choice technology {

case otn {

leaf otn-ts-num {

type uint32;

description

"Number of OTN tributary slots allocated for the

slice.";

}

}

}

leaf sliced-link-ref {

config false;

type leafref {

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path "../../../../../nt:link/nt:link-id";

}

description

"Relative reference to virtual links generated from

this TE link.";

}

}

}

}

}

/\*

\* Augments

\*/

augment "/nw:networks/nw:network/nt:link/tet:te/"

+ "tet:te-link-attributes" {

when "../../../nw:network-types/tet:te-topology/"

+ "otntopo:otn-topology" {

description

"Augmentation parameters apply only for networks with

OTN topology type.";

}

description

"Augment OTN TE link attributes with slicing profile.";

uses otn-link-slice-profile;

}

}

<CODE ENDS>

Figure 5: OTN network slicing YANG model

4.2. OTN Slicing YANG Model for OTN-SC NBI

TBD.

5. Manageability Considerations

To ensure the security and controllability of physical resource

isolation, slice-based independent operation and management are

required to achieve management isolation. Each optical slice

typically requires dedicated accounts, permissions, and resources for

independent access and O&M. This mechanism is to guarantee the

information isolation among slice tenants and to avoid resource

conflicts. The access to slice management functions will only be

permitted after successful security checks.

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6. Security Considerations

<Add any security considerations>

7. IANA Considerations

<Add any IANA considerations>

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