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millimetre Wave Transmission (mWT); Definition of a Wireless Transport Profile for Standard SDN Northbound Interfaces

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Contents

Intellectual Property Rights 5
Foreword....................5
Modal verbs terminology....................5
Introduction 5
1 Scope 7
2 References 7
2.1 Normative references 7
2.2 Informative references....................8
3 Definition of terms, symbols and abbreviations....................8
3.1 Terms....................8
3.2 Symbols....................9
3.3 Abbreviations 9
4 Scope of the Profile 10
4.1 Network Architecture 10
4.2 Use Cases 10
4.2.1 Microwave and Ethernet Topology Discovery 10
4.2.1.1 Overview....................10
4.2.1.2 Microwave Topology 11
4.2.1.3 Ethernet TE Topology....................12
4.2.1.3.1 Introduction 12
4.2.1.3.2 External Ethernet Links and Inter-Domain Connectivity 12
4.2.2 Ethernet Service Configuration....................13
4.2.2.1 Ethernet Services....................13
4.2.2.2 Bandwidth Profiles....................14
4.2.2.2.1 BWPs in the Ethernet TE Topology 14
4.2.2.2.2 BWPs in the Service Model....................14
4.2.2.2.3 Full Example of Service, Ethernet TE Topology and MW Topology 15
4.3 Abstraction Levels....................16
4.3.1 Introduction....................16
4.3.2 AL1: Abstraction Level 1 - "Black-box" 16
4.3.2.1 Definition 16
4.3.2.2 AL1 Representation of Multi-Region Domains 16
4.3.2.2.1 Full connectivity, VLAN Isolation....................16
4.3.2.2.2 Partial connectivity, VLAN Isolation 16
4.3.2.2.3 VLAN Transparency 17
4.3.3 AL2: Abstraction Level 2 - "Partially Transparent" 17
4.3.3.1 Definition 17
4.3.3.2 AL2 Representation of Multi-Region Domains 17
4.3.3.2.1 Partial connectivity, VLAN Isolation 17
4.3.3.2.2 Partial connectivity, VLAN Transparency 18
4.3.3.2.3 Considerations about the Representation of Multi-Region Domains 18
5 MPI interface....................19
5.1 Reference SDN Architecture....................19
5.2 Specifications at the MPI 19
5.2.1 RESTCONF Protocol 19
5.2.2 YANG data models....................19
5.2.2.1 YANG Version 19
5.2.2.2 Common YANG data models 19
5.2.2.3 YANG Data Models at the Microwave MPI....................20
5.2.2.4 Hierarchical relationship among YANG data models....................20
5.3 Service Assurance and Exception handling....................21
5.3.1 Service Assurance....................21
5.3.2 Exception Handling 21

Annex A (normative): Detailed list of Models, Modules and Attributes 22

A.1 Data modules 22

A.2 Model trees 22
A.2.1 General Considerations 22
A.2.2 Microwave Topology (draft-ietf-ccamp-mw-topo-yang-02) 22
A.2.3 Ethernet TE topology (draft-ietf-ccamp-eth-client-te-topo-yang-01) 24
A.2.4 Ethernet service (draft-ietf-ccamp-client-signal-yang-05) 27

Annex B (normative): Use of LLDP for automatic external Ethernet link discovery 30

B.1 Introduction 30

B.2 Algorithm description... 30

B.3 Example Calculation of the `inter-domain-plug-id` Value 31
B.3.1 Domain A LLDP Packet TLV Values 31
B.3.2 Domain B LLDP Packet TLV Values 32
B.3.3 Sorting and Concatenation 32

Annex C (informative): Examples 34

C.1 Physical Network 34

C.2 Microwave and Ethernet TE Topologies 34
C.2.1 Topology Model of the Physical Network 34
C.2.2 Types of Ethernet LTPs 35
C.2.2.1 Edge Ethernet LTP, C-VLAN-Bridge Capable Network 35
C.2.2.2 Edge Ethernet LTP, Provider Bridge Capable Network 36
C.2.2.3 Edge Ethernet LTP, Customer Edge Port 36
C.2.2.4 Summary of Edge Ethernet LTP Types 37

C.3 Examples of Service Types 37
C.3.1 Relationship among Service Types and LTP Types 37
C.3.2 Selected Examples of Supported Service Configurations 39

Annex D (informative): AL1 Representation of Multi-Region Domains with VLAN Transparency 49

D.1 Introduction 49

D.2 AL1, Full connectivity, VLAN Transparency 49

D.3 AL1, Partial Connectivity, VLAN Transparency 50

Annex E (informative): Bibliography 51

History 52

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) millimetre Wave Transmission (mWT).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The rapid evolution of telecommunications networks towards ever higher complexity and agility requires increasing levels of automation in network and service management. The range of technologies and solutions grouped under the collective name of SDN is a fundamental component of such automation.

Automation through SDN applies to every segment and layer of the telecommunications networks, including the wireless transmission technology.

SDN adoption is still in the early phases, and there exists a multitude of standards from several SDOs, that are in principle applicable to wireless transmission. Often these standards are specified in a way covering a very wide spectrum of applications and transmission technologies. This creates potentially a very large number of standard-compliant but non-interoperable implementations of SDN even for a single technology or application.

The purpose of the present document is to describe a parsimonious subset ("Profile") of the relevant available standards, and a set of recommendations for best practices, suitable to support the functionalities described in the wireless transmission Use Cases in clause 4.2.

1 Scope

The present document defines a Profile for standard SDN northbound interfaces in Wireless transmission networks. Specifically, the NBI refers to the MPI interface as defined in IETF RFC 8453 [12].

The term Profile is used for the present document because it identifies the selection of standard Models and the selection Attributes therein from the IETF library as specified in Annex A, but does not define any additional standard models or attributes.

This Profile applies exclusively to a single MW or mmW domain. A domain may be composed by one or more homogeneous regions, all managed by a single PNC.

In addition, Annex B contains the description of the usage of the LLDP protocol [17] for the automatic detection of inter-domain Ethernet access links, and an algorithm to calculate the inter-domain-plug-id [16] value.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] IETF draft-ietf-ccamp-mw-topo-yang-02: "A YANG Data Model for Microwave Topology".

[2] IETF draft-ietf-ccamp-eth-client-te-topo-yang-01: "A YANG Data Model for Ethernet TE Topology".

[3] IETF draft-ietf-ccamp-client-signal-yang-06: "A YANG Data Model for Transport Network Client Signals".

[4] IETF draft-ietf-teas-yang-te-28: "A YANG Data Model for Traffic Engineering Tunnels, Label Switched Paths and Interfaces".

[5] IETF RFC 6991: "Common YANG Data Types".

[6] IETF RFC 7950: "The YANG 1.1 Data Modeling Language".

[7] IETF RFC 7951: "JSON Encoding of Data Modeled with YANG".

[8] IETF RFC 8040: "RESTCONF Protocol".

[9] IETF RFC 8294: "Common YANG Data Types for the Routing Area".

[10] IETF RFC 8342: "Network Management Datastore Architecture (NMDA)".

[11] IETF RFC 8345: "A YANG Data Model for Network Topologies".

[12] IETF RFC 8453: "Framework for Abstraction and Control of TE Networks (ACTN)".

[13] IETF RFC 8525: "YANG Library".

[14] IETF RFC 8527: "RESTCONF Extensions to Support the Network Management Datastore Architecture".

[15] IETF RFC 8528: "YANG Schema Mount".

[16] IETF RFC 8795: "YANG Data Model for Traffic Engineering (TE) Topologies".

[17] IEEE 802.1AB™: "IEEE Standard for Local and metropolitan area networks - Station and Media Access Control Connectivity Discovery".

[18] IEEE 802.1Q™-2018: "IEEE Standard for Local and Metropolitan Area Networks-Bridges and Bridged Networks".

[19] IETF RFC 8776: "Common YANG Data Types for Traffic Engineering".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] MEF 4 Technical Specification: "Metro Ethernet Network Architecture Framework - Part 1: Generic Framework".

[i.2] MEF 6.3 Technical Specification: "Subscriber Ethernet Services Definitions".

[i.3] MEF 10.3 Technical Specification: "Ethernet Services Attributes Phase 3".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

access ethernet link: external ethernet link that is connected to a final user (e.g. NodeB), usually of UNI-C type

NOTE: See MEF 4 [i.1].

domain: (by default) entirety of the domain controlled by the PNC implementing the MPI under consideration

edge ethernet LTP: ethernet LTP that is connected to an external ethernet link

ethernet connection: bi-directional construct comprising two uni-directional ethernet links connecting a couple of ethernet LTPs

external ethernet link: ethernet link that has one termination inside and the other one outside of the domain managed by the PNC

NOTE 1: It can be further classified as an inter-domain ethernet link, or an access ethernet link.

NOTE 2: The PNC has no information about the nature of such links, in particular if these are a UNI or an NNI and whether they are connected to a final client (e.g. NodeB) or to another transport domain (e.g. router, DWDM, etc.).

full ethernet connectivity: complete reachability of all ethernet edge LTPs with one another

homogeneous region: subset of microwave network elements within a domain, that have full ethernet connectivity, and provide the same VLAN functionality on all edge LTPs

inter-domain ethernet link: external ethernet link that is connected to a transport domain (e.g. router, DWDM, etc.) or to another MW domain, usually of NNI type

NOTE: See MEF 4 [i.1].

internal ethernet link: ethernet link connecting Ethernet LTPs belonging the TE Ethernet topology of the domain managed by the PNC

multi-region domain: microwave domain that is composed internally by more than one homogeneous region, lacking full ethernet connectivity amongst them

partial ethernet connectivity: incomplete reachability of some ethernet edge LTPs with one another

VLAN isolation: capability of a homogeneous region to isolate the internal VLAN addressing space for path selection from any external one

NOTE: The MDSC does not need to have any information about the VLAN operation capabilities, addressing space, available ranges inside a region that provides VLAN isolation, and does not need to coordinate the external VLAN ID addressing space with the internal domain one.

VLAN transparency: lack of VLAN isolation capability by a homogeneous region

NOTE 1: The MDSC may or may not have visibility of these information; in any case its ability to configure any of those parameters is regulated according to the chosen Abstraction Level (see clause 4.3).

NOTE 2: If MDSC does not take into account the VLAN ID usage inside the domain, and coordinate it with the external VLAN ID address space, the PNC may not be able to instantiate a requested service, resulting in a trial and error process by the MDSC.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACTN	Abstraction and Control of TE Networks
AL	Abstraction Level
AN	Abstract Node
B2B	Business to Business
BWP	Bandwidth Profile
CBS	Committed Burst Size
CIR	Committed Information Rate
CLTP	Carrier Link Termination Point
CM	Connectivity Matrix
C-VID	C-VLAN ID
C-VLAN	Client-Side VLAN
DWDM	Dense Wavelength Division Multiplexing
E2E	End to End
EBS	Excess Burst Size
eeLTP	Ethernet edge LTP
EIR	Excess Information Rate
eLTP	Ethernet LTP
ETH	Ethernet
GE	Gigabit Ethernet
ID	Identity
JSON	JavaScript Object Notation
LLDP	Link Layer Discovery Protocol
LTP	Link Termination Point
MDSC	Multi-Domain Service Coordinator
mmW	Millimetre Wave

MPI	MDSC-PNC Interface
MW	Microwave
NBI	Northbound Interface
NE	Network Element
NMDA	Network Management Datastore Architecture
NNI	Network Network Interface
PNC	Provisioning Network Controller
RFC	Request for Comments
RLTP	Radio Link Termination Point
ro	read-only
rw	read-write
SDN	Software Defined Networking
SDO	Standard Defining Organization
S-VLAN	Service-Side VLAN
TE	Traffic Engineering
TLV	Type-Length-Value
UNI	User Network Interface
UNI-C	User Network Interface - Customer Edge
VID	VLAN ID
VLAN	Virtual Local Area Network
WBH	Wireless Backhaul
WTN	Wireless Transmission Network

4 Scope of the Profile

4.1 Network Architecture

This Profile applies to a single domain of MW and mmW devices. The interactions with other domains are covered by the selection of the attributes necessary to identify the Ethernet access links from [2], and the Ethernet service characteristics from [3].

The Profile applies to physical WTN topologies that do not allow for multiple paths to connect two eeLTPs. Only wireless links of point-to-point type are considered, i.e. radio links comprising two radio NEs.

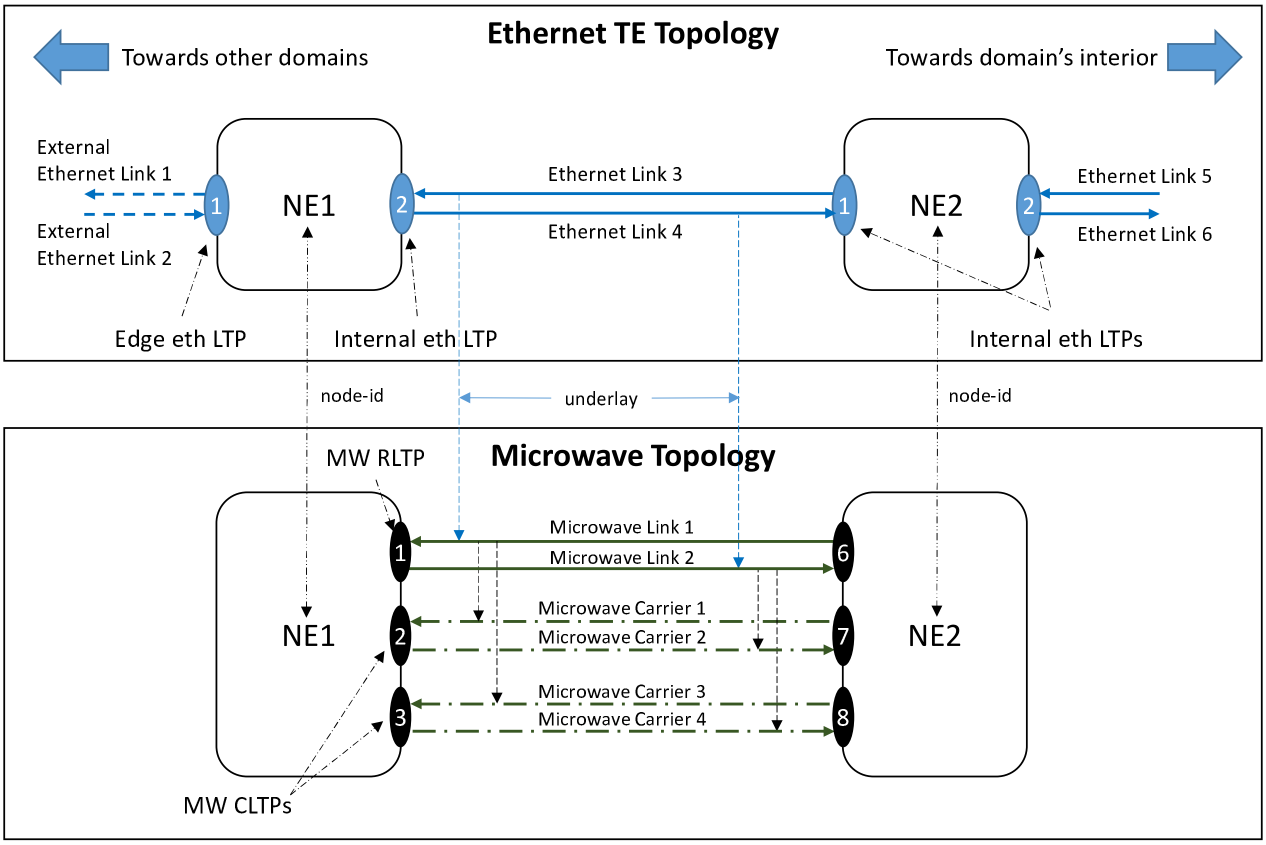
4.2 Use Cases

4.2.1 Microwave and Ethernet Topology Discovery

4.2.1.1 Overview

The network discovery Use Case is the basic functionality needed for network and service management automation, in that it shall provide the inventory of the microwave topology, the Ethernet topology and the Ethernet service information.

Figure 4.2.1.1.1 shows the relationships between the Microwave and the ethernet topologies for a microwave link with two bonded radio carriers.



NOTE 1: The external ethernet links are shown for clarity only, the PNC needs to keep information only about the eeLTPs.

NOTE 2: LTPs of a given node are part of the same list and have different names (ltp-id), which are local to that node. There is no relation among the name spaces of LTPs across different nodes.

Figure 4.2.1.1.1: Microwave and Ethernet Topologies

4.2.1.2 Microwave Topology

The microwave topology provides identification of the physical network by means of the microwave nodes, LTPs and radio links.

The following clarifications shall apply:

1) The two nodes are connected by two microwave radio links (one for each direction), each of which can consist of more than one radio carrier, attached to the respective radio LTPs. Microwave links and radio carriers are modelled as separate link entities, `microwave-radio-link` and `microwave-carrier`, and each of them is attached to specific LTP (`microwave-rltp` and `microwave-cltp`). It is assumed that the multiple carriers associated to the microwave link carry the data traffic associated to the Ethernet services as a bundle, with some form of load balancing among them, which is out of scope of the present document.

2) The MW radio links are associated to the corresponding Ethernet link in the Ethernet topology (one per direction), via the underlay attribute in the Ethernet TE topology model [2].
The `node-id` attribute of the microwave topology and the `node-id` attribute in the Ethernet topology shall be set to the same value, consisting of a dotted quad of numbers between 0 and 255. For ease of identification, this value should coincide with the IPv4 management plane address of the corresponding physical microwave NE.

4.2.1.3 Ethernet TE Topology

4.2.1.3.1 Introduction

The Ethernet TE topology model provides information about TE nodes (which correspond 1:1 to the MW nodes), eLTPs, Ethernet links connecting the NEs and providing the possible path(s) over which the Ethernet services can be provisioned:

a) The Ethernet links are associated to the corresponding Microwave link (one per direction), via the underlay attribute in the Ethernet TE topology model [2] and [1].

b) Internal (or intra-domain) Ethernet links connect the ethernet eLTPs belonging to one another.

c) External (or access or inter-domain) Ethernet links connect an eeLTP to an external equipment.

d) The `node-id` attribute of the microwave topology and the `node-id` attribute in the Ethernet topology shall be set to the same value, consisting of a dotted quad of numbers between 0 and 255. For ease of identification, this value should coincide with the IPv4 management plane address of the corresponding microwave NE.

The Ethernet TE topology contains information about all eLTPs available on the NEs, regardless if these are connected to another MW NE, to any other external device, or even are unconnected. The MDSC determines which eLTPs are relevant for its purposes, based on the existence of Ethernet links connected to them.

Clause 4.2.1.3.2 discusses how the MDSC can differentiate eeLTPs from eLTPs that are unconnected. eLTPs connected to a faulty Ethernet link appear as unconnected, regardless of the internal or external nature of the faulty link.

4.2.1.3.2 External Ethernet Links and Inter-Domain Connectivity

One of the main purposes of the MDSC is to coordinate and provision services across multiple domains. Since no PNC can know or manage the inter-domain links, these have to be modelled by the MDSC based on information about the eeLTPs from the corresponding domains.

Two attributes of an eLTP concur in defining it as an eeLTP:

1) The `inter-domain-plug-id` attribute shall be present, and shall have a network-wide-unique value:

    a) If the eLTP is not an eeLTP, the attribute shall be missing.

2) The `client-facing` attribute shall be present, and shall have the Boolean value "true":

    a) If the eLTP is not an eeLTP, the attribute shall be missing or, if present, it shall assume the Boolean value "false".

Both attributes may be configured either manually or automatically. Both attributes shall be managed in the same way, either both manually, or both automatically.

In case of automatic configuration:

1) The algorithm specified in Annex B shall be used to calculate the `inter-domain-plug-id` attribute, regardless of the presence and value of the `client-facing` attribute.

2) The PNC may be able to infer the edge nature of the eLTP independently from the `inter-domain-plug-id` attribute's successful configuration, but the `inter-domain-plug-id` attribute shall always have priority to determine if an eLTP is an eeLTP actually connected to an external domain.

It may happen that an eLTP is changed to eeLTP, or vice-versa, during the lifetime of the network, reflecting the changes in physical topology (e.g. addition or removal of links and/or equipment, delays in configuring external NEs, etc.). The MDSC shall update its picture of the network by regularly uploading it or by subscribing to the relevant attributes' notifications.

4.2.2 Ethernet Service Configuration

4.2.2.1 Ethernet Services

The service types specified in this Profile are VLAN-based Ethernet services as defined in [3]. The present document will refer to the point-to-point services as E-LINE and the multi-point-to-multi-point as E-LAN, following the terminology of [i.2]. This profile does not cover rooted-multipoint services ("E-TREE").

The type of service is determined by the value of the `etht-svc-type` attribute of the Service Model (see clause A.2.4):

- E-LINE services: "`p2p-svc`"
- E-LAN services: "`mp2mp-svc`"

Details about the domain-internal transport mechanism (which may not even be ethernet-based), or where which VLAN operations are performed within the MW domain may not be exposed over the MPI to the MDSC, depending on the adopted Abstraction Level (see clause 4.3).

Ethernet services can be established between any eLTPs described in the retrieved Ethernet TE topology.

Whereas the overall goal of the MDSC is to coordinate E2E services across multiple domains, i.e. between eeLTPs. It may be of practical value to create services between eLTPs, either for testing purposes, or in case of time delays in the coordination with other domains (e.g. delayed configuration of the LLDP protocol on the external domain's eLTP).

But in general, the objects of the present document are the data services between two or more eLTPs and/or eeLTPs, falling into one of the 6 Types defined in Table 4.2.2.1.1. In case of E-LINE, the service has two and only two eLTPs/eeLTPs, whereas in case of E-LAN the service has at least two eLTPs/eeLTP (see [i.2] for the difference between a point-to-point EVC and a multipoint to multipoint EVC associating two UNIs). In case of E-LAN, Table 4.2.2.1.1 defines the Type of Service to be implemented between each possible couple of eLTPs.

Table 4.2.2.1.1 Service Classification

Service Type	Classification @ LTP A	Classification @ LTP Z	Reference	Remarks
Type 1	Untagged	Untagged	C-VLAN bridge, Provider bridge as per [18]. MEF 10.3 [i.3].	Note 2.
Type 2	Untagged	C-VLAN	C-VLAN bridge, Provider bridge as per [18]. MEF 10.3 [i.3].	Note 2.
Type 3	Untagged	S-VLAN	Provider bridge as per [18].	Note 2.
Type 4	C-VLAN	C-VLAN	C-VLAN bridge, Provider bridge as per [18]. MEF 10.3 [i.3]	The C-VLAN values at the two edges can be the same (C-VLAN preservation) or different (no C-VLAN preservation).
Type 5	S-VLAN	S-VLAN	Provider bridge as per [18].	The S-VLAN values at the two edges can be the same (S-VLAN preservation) or different (no S-VLAN preservation). The C-VLAN is ignored but always preserved, if present.
Type 6	S-VLAN	C-VLAN	Provider bridge as per [18].	The C-VLAN is always preserved.

NOTE 1: A VLAN for internal path selection is used by the bridges within the network, but its configuration is performed autonomously by the PNC based on the equipment characteristics.

NOTE 2: When the Classification is Untagged, in the egress direction all the frames are transmitted as untagged. In the ingress direction, only untagged frames are expected to be received. However, if received, priority-tagged frames and frames tagged with the VLAN ID equal to the LTP's port VID also matches this classification, as specified in MEF 10.3 [i.3], and are forwarded as specified for the service configuration.

NOTE 3: In case of E-LAN, if the Service Type between at least one pair of the eLTPs/eeLTPs requires a Provider Bridge, then the whole service is considered to require support for the Provider Bridge capability.

Services shall not be accepted by the PNC if the network does not support them. See Annex C for examples and network capabilities as visible to the MDSC via the eeLTPs.

The untagged classification is configured by the MDSC by configuring the same VID value for both the port VLAN ID and the C-VLAN ID used by service classification at a given LTP. In case of tagged classification, the MDSC shall configure the port VLAN ID with a different value than the C-VLAN ID used by the service classification at a given LTP.

As a general approach, the Profile does not allow the MDSC to specify in detail if and where VLAN operations (VLAN tag push, pop, swap) are performed: this shall be left to the PNC to decide, based on the equipment characteristics and the planning guidelines used in the given network.

4.2.2.2 Bandwidth Profiles

4.2.2.2.1 BWPs in the Ethernet TE Topology

In the Ethernet TE topology the eLTPs may have an associated BWP. This may be a single BWP for both ingress and egress (symmetrical case), or a set of two BWPs, one for ingress and one for egress (asymmetrical case).

The asymmetrical case has an application in WBH networks, for example to set the traffic shaping parameters on the interconnection from a high-capacity MW link towards a lower capacity MW link. The physical ethernet interconnection between MW NEs has a usually fixed and symmetrical throughput (e.g. 100, 1 000 or 10 000 Mbps), whereas the modem capacity over the air depends on the given link configuration, and is usually smaller than the physical ethernet link throughput. Setting the egress capacity to a lower value, matching the speed of the slower link, translates in traffic shaping being applied.

Internal and external (access or inter-domain) eLTPs are managed differently:

1) The BWPs for internal eLTPs are managed by the PNC, and used by the MDSC as a reference to correctly dimension the BWP of the services it provisions across those eLTPs. There is no reason for the MDSC to change those BWPs, since they reflect the underlying network dimensioning that is based a.o. on the MW link engineering (MW throughput), which is not controlled by the MDSC. The MDSC may however use this information, if available, to improve the E2E service provisioning and the bandwidth utilization over the network.

2) The BWPs for eeLTPs (both access and inter-domain) are managed by the MDSC. This allows to coordinate parameters such as traffic shaping from one domain to the next.

NOTE: The BWPs associated to the eLTPs in the Ethernet TE Topology have no explicit relation to the service BWPs.

4.2.2.2.2 BWPs in the Service Model

The Service model in principle allows two ways to specify BWPs: either locally to each service, or globally. As per the present document, the global definition of BWPs shall be used exclusively:

1) The set of global BWPs to be used in the network shall be maintained independently from any service instance.

2) Each end point of a service instance shall refer to the global BWP(s).

This allows to easily standardize the types of BWPs and maintain consistency across the network.

Both symmetrical and asymmetrical BWP types are available (see also Figure 4.2.2.2.3.1):

1) Symmetrical BWP (example: B2B data services):
The `ingress-egress-bandwidth-profile` shall be configured by the MDSC, and shall be the same at both end points.

2) Asymmetrical BWP (example: Mobile Backhaul):
Both the `ingress-bandwidth-profile` and the `egress-bandwidth-profile` shall be configured by the MDSC, and shall correspond at both end points A and Z:

   a) The A-ingress and Z-egress BWP shall be the same.

   b) The Z-ingress and A-egress BWP shall be the same.

c) The BWPs at points 2.a and 2.b above are in general different.

The management of BWPs is restricted by the following rules:

1) Since a given BWP may be referenced to by a large and varying number of service instances, it shall be up to the MDSC to ensure that no BWP is deleted unless there is no service instance referring to it.

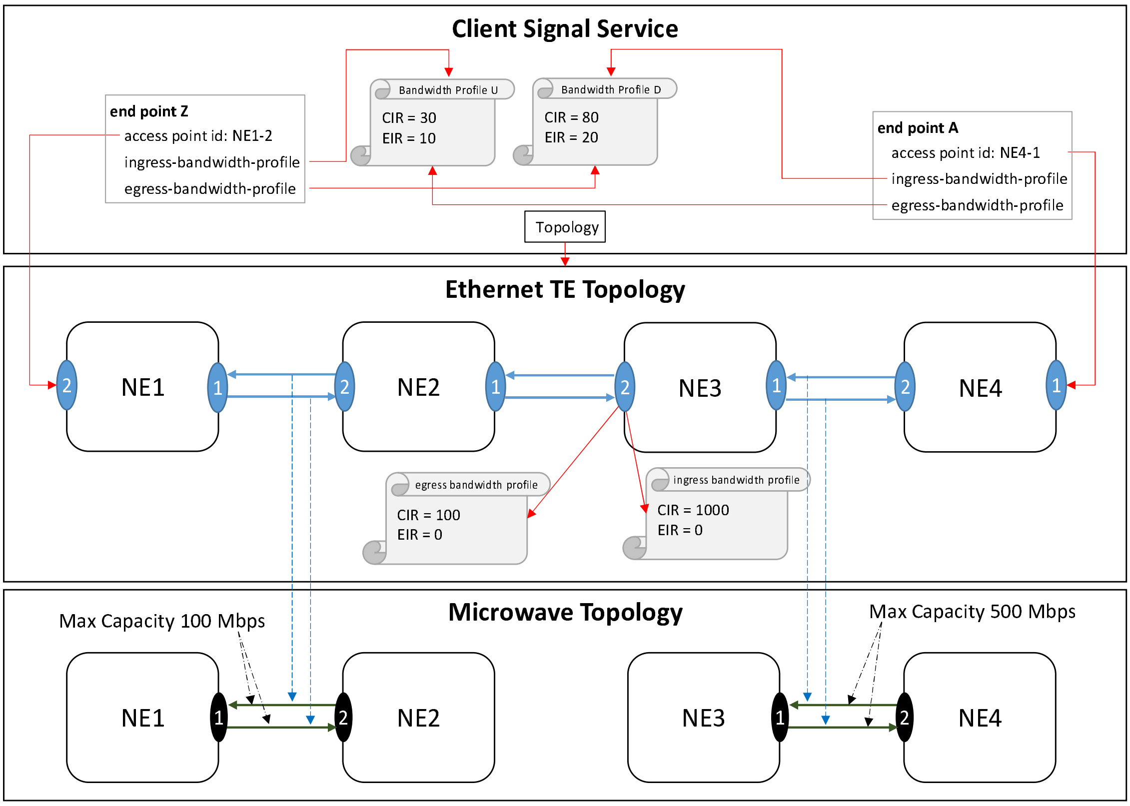
2) The BWP attributes are marked as "rw" in the model, since in general BWPs can be created, deleted and modified. However, if an existing BWP is modified, this will in general require the PNC to check a large number of existing service instances, and possibly modify many NE configurations accordingly. This may take a significant amount of time, and may not be successful for all services, potentially causing a transient, unpredictable and inconsistent state across the network. Therefore, BWPs can be created and deleted, but cannot be modified. In case an existing BWP needs to be modified, a new one shall be created, and all affected service instances shall be updated one by one, referring to the new BWP, before the old one can be deleted, thus ensuring that the MDSC is always in full control of the network.

4.2.2.2.3 Full Example of Service, Ethernet TE Topology and MW Topology

The relationships between the Ethernet service model and the MW and Ethernet TE topology models are exemplified in Figure 4.2.2.2.3.1.

This example shows an asymmetrical ethernet service provisioned over a network of two MW links, which have different radio throughputs, and being interconnected via an ethernet connection. The BWPs at eLTP 2 of NE3 are shown to exemplify a possible use of shaping in a hierarchical MW network, whilst no assumption is implied about any other eLTP.

Only the attributes and relationships most relevant to this clause are represented in the Figure, and the capacity values are chosen to be a reasonable example of a WBH case using typical MW capacity values and a GE physical interconnection between the two links.



NOTE: The topologies and values used in this example are just for illustration purposes.

Figure 4.2.2.2.3.1: Example of Full Topology and Usage of BWPs

4.3 Abstraction Levels

4.3.1 Introduction

This Profile defines two abstraction levels, which determine the level of detail of the information that is exchanged over the MPI.

Reference to these abstraction levels will determine exactly which subset of models and attributes shall be mandatory in the implementation of a specific MPI.

It is possible that an MDSC instance happens to control a very large and composite network (e.g. nation-wide), which can be composed by a collection of homogeneous regions, each of which may allow or require a different representation among those defined in the following clauses. In such a case, the MDSC shall support all required representations, respectively.

4.3.2 AL1: Abstraction Level 1 - "Black-box"

4.3.2.1 Definition

This is the most basic way to model a network, and it is defined by the following rules:

1) The microwave topology information shall **not** be available from the PNC nor requested over the MPI by the MDSC.

2) The whole domain shall be modelled by the top-level Ethernet TE Topology as a single Ethernet abstract node, showing only the eeLTPs. The external ethernet links may be modelled as well (single-ended on the eeLTP of the MW domain).

3) The Ethernet services shall be specified only based on the modelling listed above.

4.3.2.2 AL1 Representation of Multi-Region Domains

4.3.2.2.1 Full connectivity, VLAN Isolation

In this case, the PNC is controlling one or more homogeneous regions, but the MDSC only sees a single abstract node, to whom all the eeLTPs belong. There is no limitation in the connectivity among eeLTPs nor are there any constraints on the VLAN ID availability for service provisioning.

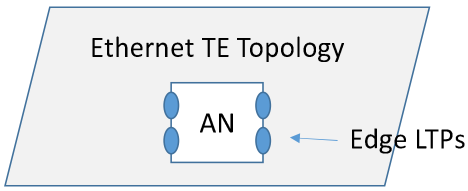


Figure 4.3.2.2.1.1: AL1 Ethernet Topology: Full Connectivity, VLAN Isolation

4.3.2.2.2 Partial connectivity, VLAN Isolation

In this case, the PNC is controlling more than one homogeneous region, that do not have full connectivity among them. In order for the MDSC to discern which services can be provisioned or not across any couple of eeLTPs, the underlay topology representation may be used to expose the connectivity limitations. Figure 4.3.2.2.2.1 depicts an example for a domain with two homogeneous regions, modelled as AN1 and AN2. In this example, there is no ethernet connectivity among LTPs belonging to AN1 with LTPs belonging to AN2.

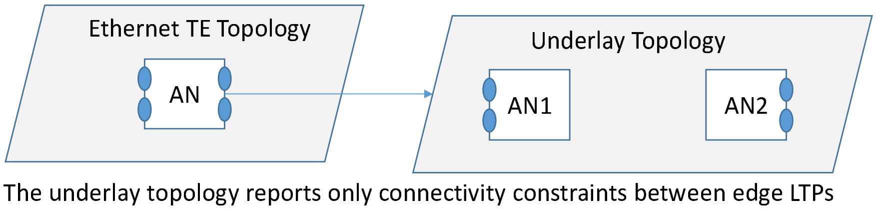


Figure 4.3.2.2.2.1: AL1 Ethernet Topology: Partial Connectivity, VLAN Isolation

The services shall be provisioned based on the top topology's eeLTPs. The underlay topology and its ANs provide the connectivity information to the MDSC in order to avoid requesting services between couples of eeLTPs that do not have a possible ethernet connection between them.

In alternative to the solution described above, the simple model of clause 4.3.2.2.1 may be used, but the MDSC will have to discover any lack of connectivity by trial and error.

4.3.2.2.3 VLAN Transparency

In the case of networks with VLAN transparency, the VIDs cannot be chosen arbitrarily by the MDSC.

Trying to manage such a network as a black box (AL1), in principle requires a trial-and-error approach, which can be very time-consuming and is potentially open to race conditions on a live network.

To avoid a trial-and-error approach, the Connectivity Matrix construct from the Ethernet TE Topology model (see clause A.2.3) may be used.

The Connectivity Matrix, however, has a complexity that grows exponentially with the number of eeLTPs. Moreover, the Connectivity Matrix is dynamically changing as services are created and deleted in the network. These two factors combined risk increasing the computational load on the PNC and the communication load on the MPI to unacceptable levels.

It seems therefore preferable to use the AL2 abstraction level approach in the case of networks requiring VLAN transparency, unless there is the certainty that the network size (in terms of number of eeLTPs) results in an acceptable computational and communications load on the PNC and MPI.

Annex D discusses these cases in more detail.

4.3.3 AL2: Abstraction Level 2 - "Partially Transparent"

4.3.3.1 Definition

This abstraction level publishes all the information specified by this Profile in Annex A at the MPI:

1) The microwave topology for the whole domain shall be available.

2) The Ethernet topology shall be available for the whole domain, including both internal and eeLTPs and internal and possibly the external ethernet links. For the internal links, the reference to the supporting microwave links shall be reported. The external Ethernet links may be modelled as well (single-ended on the eeLTP of the MW domain).

3) The information about the Ethernet service and the VLAN operations shall be available over the MPI, but, as mentioned before, neither the service path nor the VLAN operations shall be determined by the MDSC.

4.3.3.2 AL2 Representation of Multi-Region Domains

4.3.3.2.1 Partial connectivity, VLAN Isolation

In this case, the PNC is controlling more than one homogeneous region, that do not have full connectivity among them. The MDSC has visibility of the ethernet TE topology inside each homogeneous region, and knows the connectivity among regions. VLAN isolation allows the MDSC to ignore the actual VLAN ID space and operations capabilities available inside the domain. Figure 4.3.3.2.1.1 depicts an example for a domain with two homogeneous regions.

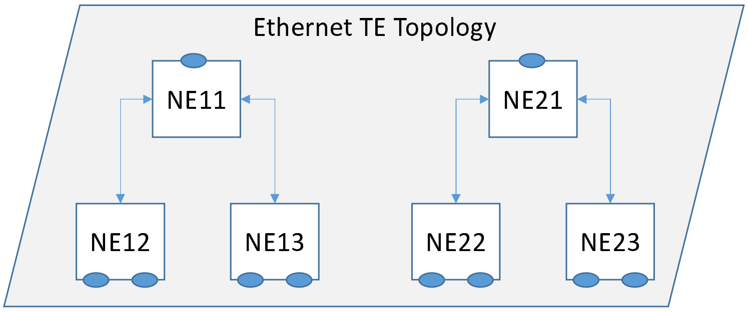


Figure 4.3.3.2.1.1: AL2 Ethernet Topology: Partial Connectivity, VLAN Isolation

4.3.3.2.2 Partial connectivity, VLAN Transparency

In this case, the PNC is controlling more than one homogeneous region, that do not have full connectivity among them. The MDSC has visibility of the ethernet TE topology inside each homogeneous region, and knows the connectivity among regions. VLAN transparency requires the MDSC to know VLAN ID space and operations capabilities available inside the domain, in order to coordinate VLAN usage across domains. Figure 4.3.3.2.2.1 depicts an example for a domain with two homogeneous regions.

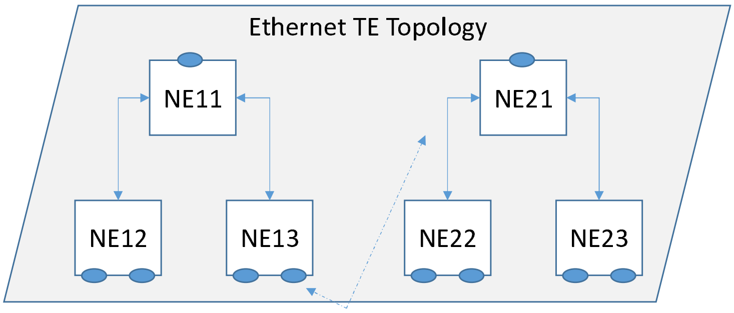


Figure 4.3.3.2.2.1: AL2 Ethernet Topology: Partial Connectivity, VLAN Transparency

In domains with a large number of NEs, keeping the VLAN availability/constraints information current can put a significant load both computationally and on the MPI bandwidth. Efficiency optimization is left to the actual implementations.

4.3.3.2.3 Considerations about the Representation of Multi-Region Domains

The MDSC in the AL2 abstraction level has all the necessary information to identify the homogeneous regions within the PNC's domain.

In case several homogeneous regions are required to represent the network, it is likely that the PNC is managing a high number of MW links distributed geographically over a wide area.

In such situations, it could be useful to use the underlay topology representation as exemplified in Figure 4.3.3.2.3.1, in order to minimize the impact on the MPI and the MDSC of topology changes and service provisioning activities that only affect one homogeneous region at a time.

Underlay topologies would be used in such a case to simplify the top-level topology representation and segregate the homogeneous regions.

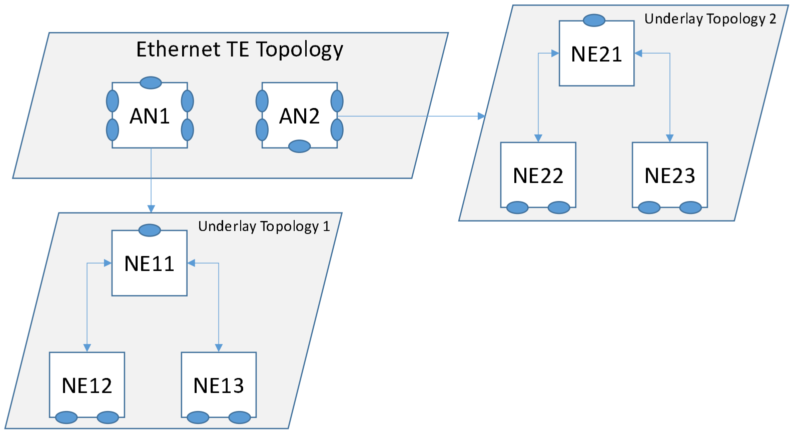


Figure 4.3.3.2.3.1: AL2 Ethernet Topology: Partial Connectivity, Use of Underlays

5 MPI interface

5.1 Reference SDN Architecture

The SDN reference architecture used in the present document is the ACTN framework defined in the IETF RFC 8453 [12].

In particular, the present document refers specifically to the MPI interface between the PNC and the MDSC.

5.2 Specifications at the MPI

5.2.1 RESTCONF Protocol

The RESTCONF protocol, as defined in IETF RFC 8040 [8], using the JSON representation, defined in IETF RFC 7951 [7], shall be used at the MPI. Extensions to RESTCONF, as defined in IETF RFC 8527 [14], to be compliant with Network Management Datastore Architecture (NMDA) defined in IETF RFC 8342 [10], shall be used as well at the MPI interface.

5.2.2 YANG data models

5.2.2.1 YANG Version

The data models used on these interfaces shall use the YANG 1.1 Data Modeling Language, as defined in IETF RFC 7950 [6].

5.2.2.2 Common YANG data models

As required in IETF RFC 8040 [8], the "ietf-yang-library" YANG module defined in IETF RFC 8525 [13] is used to allow the MDSC to discover the set of YANG modules supported by each PNC at its MPI.

The PNC shall use the following common topology YANG models at the MPI to report the abstract topologies:

a) The Base Network Model, defined in the "ietf-network" YANG module of IETF RFC 8345 [11].

b) The Base Network Topology Model, defined in the "ietf-network-topology" YANG module of IETF RFC 8345 [11] which augments the Base Network Model.

c) The TE Topology Model, defined in the "ietf-te-topology" YANG module of IETF RFC 8795 [16] which augments the Base Network Topology Model with TE specific information.

These common YANG models are generic and augmented by technology-specific YANG modules as described in the following clauses.

5.2.2.3 YANG Data Models at the Microwave MPI

The PNC shall use the following YANG models at the MPI to support the Use Cases specified in clause 4.2:

a) The Microwave Topology Model, defined in the "ietf-microwave-topology " YANG module of "draft-ietf-ccamp-mw-topo-yang" [1].

b) The Data Model for Ethernet TE Topology, defined in the "ietf-eth-te-topology" YANG module of "draft-ietf-ccamp-eth-client-te-topo-yang" [2].

c) The Transport Network Client Signals Model, defined in the "etht-svc" YANG module of "draft-ietf-ccamp-client-signal-yang" [3].

Annex A specifies the detailed list of attributes that are required at the MPI interface for Microwave Transmission applications, from the data models listed in the following clauses.

5.2.2.4 Hierarchical relationship among YANG data models

The augmentation relationships among the data models listed in the previous clauses can be visualized as in Figures 5.2.2.4.1, 5.2.2.4.2 and 5.2.2.4.3.

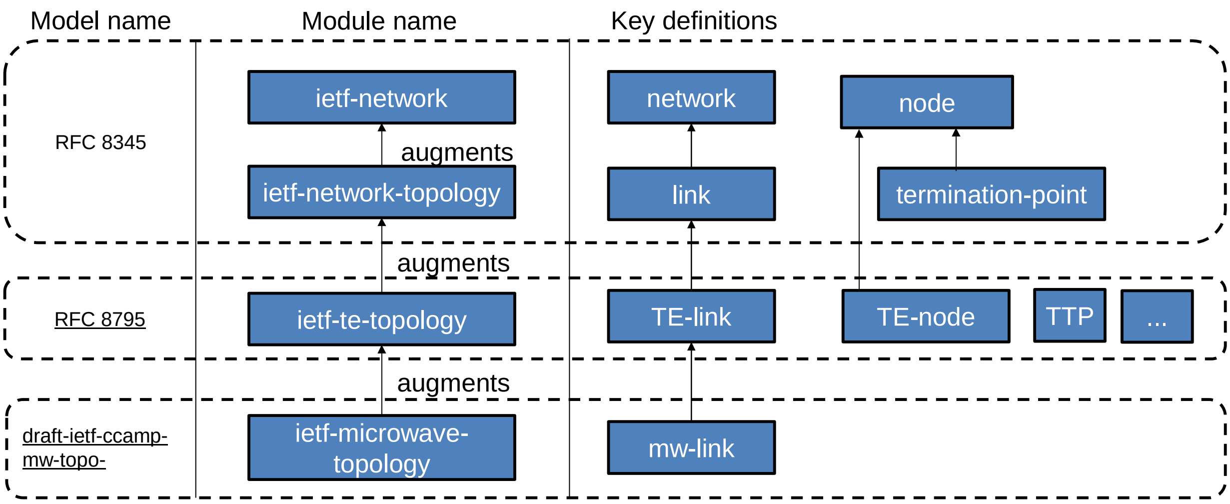


Figure 5.2.2.4.1: Microwave Topology Model Hierarchy

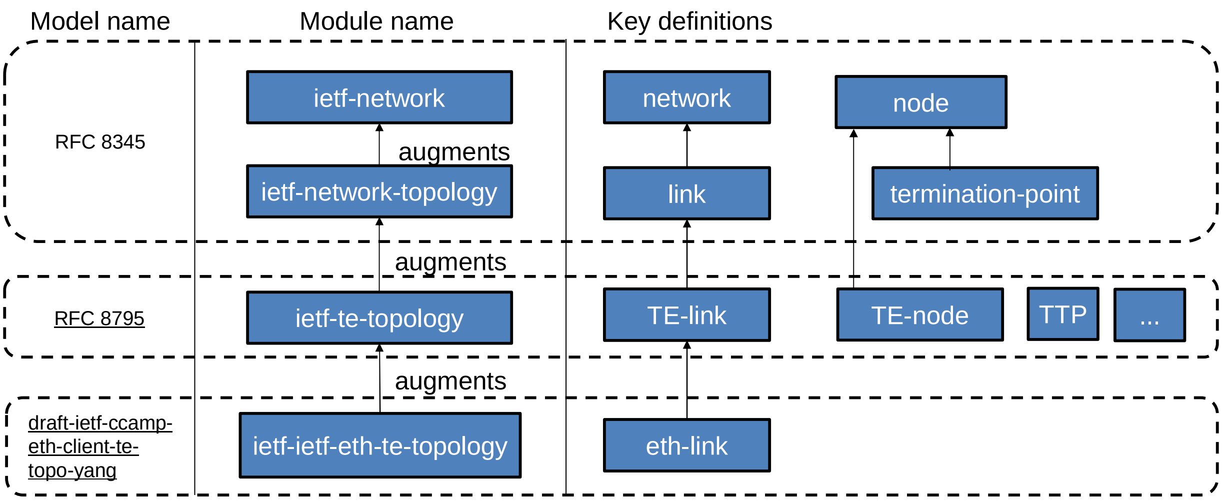


Figure 5.2.2.4.2: Ethernet Topology Model Hierarchy

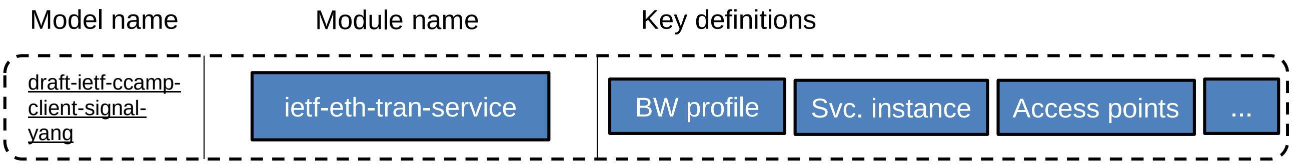


Figure 5.2.2.4.3: Ethernet Service Model

5.3 Service Assurance and Exception handling

5.3.1 Service Assurance

The role of MDSC as Service Coordinator means that, even if it can obtain information about the MW and ethernet topologies, the entities it is interested in directly managing are the service instances.

In order to monitor the status of the services it requests to the PNC, the MDSC shall monitor at a minimum the following attributes from [3]:

```
module: ietf-eth-tran-service
+--rw etht-svc
  +--rw etht-svc-instances* [etht-svc-name]
    +--rw admin-status?          identityref
    +--ro state
      +--ro operational-state?    identityref
      +--ro provisioning-state?   Identityref
```

5.3.2 Exception Handling

There are two main types of exceptions that can occur, when the PNC cannot perform an operation requested by the MDSC:

1) Synchronous exceptions: the PNC is immediately able to identify the exception, and provides an error indication as part of its response to the MDSC request.

2) Asynchronous exceptions: the PNC accepts the request as valid, returning a success code, but subsequently an exception occurs (e.g. during the path computation, or due to some dynamic event in the network):

   a) The occurrence of such an exception shall be determined by the MDSC by either polling or subscribing to the relevant attributes in the operational datastore.

   b) Clause 5.3.1 specifies the minimum level of information and recommend a notification mechanism that allow the MDSC to handle asynchronous exceptions.

Annex A (normative): Detailed list of Models, Modules and Attributes

A.1 Data modules

- ietf-microwave-topology@2021-10-22.yang (draft-ietf-ccamp-mw-topo-yang-02 [1])
- ietf-eth-te-topology@2019-11-18.yang (draft-ietf-ccamp-eth-client-te-topo-yang-01 [2])
- ietf-eth-tran-types@2021-07-07.yang (draft-ietf-ccamp-client-signal-yang-05 [3])
- ietf-eth-tran-service@2021-01-11.yang (draft-ietf-ccamp-client-signal-yang-05 [3])
- ietf-trans-client-svc-types@2019-11-03.yang (draft-ietf-ccamp-client-signal-yang-05 [3])
- ietf-te@2021-10-22.yang (draft-ietf-teas-yang-te-28 [4])
- ietf-te-types@2020-06-10.yang (IETF RFC 8776 [19])
- ietf-yang-types@2013-07-15.yang (IETF RFC 6991 [5])
- ietf-inet-types@2013-07-15.yang (IETF RFC 6991 [5])
- ietf-yang-schema-mount@2019-01-14.yang (IETF RFC 8528 [15])
- ietf-routing-types@2017-12-04.yang (IETF RFC 8294 [9])
- ietf-network@2018-02-26.yang (IETF RFC 8345 [11])
- ietf-network-topology@2018-02-26.yang (IETF RFC 8345 [11])
- ietf-te-topology@2020-08-06.yang (IETF RFC 8795 [16])

A.2 Model trees

A.2.1 General Considerations

The following clauses detail the attributes, the compliance requirement as per the present document, and any related notes, one by one.

The attribute trees have been merged with the relevant higher models/modules in the model hierarchy (see clause 5.2.2.4) for convenience.

NOTE: In general, an attribute specified as mandatory by the present document can still be optionally implemented, if it is defined as optional in the YANG model.

A.2.2 Microwave Topology (draft-ietf-ccamp-mw-topo-yang-02)

Table A.2.2.1: Microwave Topology Attributes

Compliance	Conf.	Model
Mandatory		module: ietf-network
Mandatory	ro	+--rw networks
Mandatory	ro	+--rw network* [network-id]
Mandatory	ro	+--rw network-id network-id
Mandatory	ro	+--rw network-types
Mandatory	ro	| +--rw tet:te-topology!

Compliance	Conf.	Model
Mandatory	ro	| +--rw mwtopo:mw-topology!
Mandatory	ro	+--rw node* [node-id]
Mandatory	ro	| +--rw node-id node-id
Mandatory	ro	| +--rw nt:termination-point* [tp-id]
Mandatory	ro	| +--rw nt:tp-id tp-id
Mandatory	ro	| +--rw nt:supporting-termination-point* [network-ref node-ref tp-ref]
Mandatory	ro	| | +--rw nt:network-ref
		| | | -> ../../../nw:supporting-node/network-ref
Mandatory	ro	| | +--rw nt:node-ref
		| | | -> ../../../nw:supporting-node/node-ref
Mandatory	ro	| | +--rw nt:tp-ref
Mandatory	ro	| | -> /nw:networks/network[nw:network-id=current()
		| | /../network-ref]/node[nw:node-id=current()
		| | /../node-ref]/termination-point/tp-id
Mandatory	ro	| +--rw tet:te!
Mandatory	ro	| +--rw tet:admin-status? te-types:te-admin-status
Mandatory	ro	| +--rw tet:name? string
Mandatory	ro	| +--ro tet:oper-status? te-types:te-oper-status
Optional	ro	| +--ro tet:geolocation
Optional	ro	| | +--ro tet:altitude? int64
Optional	ro	| | +--ro tet:latitude? geographic-coordinate-degree
Optional	ro	| | +--ro tet:longitude? geographic-coordinate-degree
Mandatory	ro	| +--rw mwtopo:mw-tp-choice
Mandatory	ro	| +--rw (mwtopo:mw-tp-option)?
Mandatory	ro	| +--:(mwtopo:microwave-rltp)
Mandatory	ro	| | +--rw mwtopo:microwave-rltp!
Mandatory	ro	| +--:(mwtopo:microwave-ctp)
Mandatory	ro	| +--rw mwtopo:microwave-ctp!
Mandatory	ro	+--rw nt:link* [link-id]
Mandatory	ro	+--rw nt:link-id link-id
Mandatory	ro	+--rw nt:source
Mandatory	ro	| +--rw nt:source-node? -> ../../../nw:node/node-id
Mandatory	ro	| +--rw nt:source-tp?
		| -> ../../../nw:node[nw:node-id=current()
		| /../source-node]/termination-point/tp-id
Mandatory	ro	+--rw nt:destination
Mandatory	ro	| +--rw nt:dest-node? -> ../../../nw:node/node-id
Mandatory	ro	| +--rw nt:dest-tp?
		| -> ../../../nw:node[nw:node-id=current()
		| /../dest-node]/termination-point/tp-id
Mandatory	ro	+--rw tet:te!
Mandatory	ro	+--rw (tet:bundle-stack-level)?
Mandatory	ro	| +--:(tet:bundle)
Mandatory	ro	| +--rw tet:bundled-links
Mandatory	ro	| +--rw tet:bundled-link* [sequence]
Mandatory	ro	| +--rw tet:sequence uint32
Mandatory	ro	| +--rw tet:src-tp-ref? -> ../../../../../
		| | nw:node[nw:node-id current()/../../..
		| | /../nt:source/source-node]/
Mandatory	ro	| | termination-point/tp-id
Mandatory	ro	| +--rw tet:des-tp-ref? -> ../../../../../
		| nw:node[nw:node-id = current()/../../
		| ../../nt:destination/dest-node]/
		| termination-point/tp-id
Mandatory	ro	+--rw tet:te-link-attributes
Mandatory	ro	| +--rw tet:name? string
Mandatory	ro	| +--rw tet:admin-status? te-types:te-admin-status
Mandatory	ro	| +--rw tet:max-link-bandwidth
Mandatory	ro	| | +--rw tet:te-bandwidth
Mandatory	ro	| | +--rw (tet:technology)?
Mandatory	ro	| | +--:(mwtopo:microwave)
Mandatory	ro	| | +--ro mwtopo:mw-bandwidth? uint64

Compliance	Conf.	Model
Mandatory	ro	| +--rw mwtopo:mw-link-choice
Mandatory	ro	| | +--rw (mwtopo:mw-link-option)?
Mandatory	ro	| | +--:(mwtopo:microwave-radio-link)
Mandatory	ro	| | | +--rw mwtopo:microwave-radio-link!
Mandatory	ro	| | | +--rw mwtopo:mode? identityref
Mandatory	ro	| | +--:(mwtopo:microwave-carrier)
Mandatory	ro	| | +--rw mwtopo:microwave-carrier!
Mandatory	ro	| | +--rw mwtopo:tx-frequency? uint32
Mandatory	ro	| | +--rw mwtopo:rx-frequency? uint32
Mandatory	ro	| | +--rw mwtopo:channel-separation? uint32
Mandatory	ro	| +--rw bwatopo:link-availability* [availability]
Mandatory	ro	| +--rw bwatopo:availability decimal64
Mandatory	ro	| +--rw bwatopo:link-bandwidth? uint64
Mandatory	ro	+--ro tet:oper-status? te-types:te-oper-status

A.2.3 Ethernet TE topology (draft-ietf-ccamp-eth-client-te-topo-yang-01)

Table A.2.3.1: Ethernet TE Topology Attributes

Compliance	Conf.	Model
Mandatory		module: ietf-network
Mandatory	rw	+--rw networks
Mandatory (see note 1)	rw	+--rw network* [network-id]
Mandatory (see note 1)	rw	| +--rw network-id network-id
Mandatory	ro	| +--rw network-types
Mandatory	ro	| | +--rw tet:te-topology!
Mandatory	ro	| | +--rw ethtetopo:eth-tran-topology!
Mandatory	ro	| +--rw node* [node-id]
Mandatory	ro	| | +--rw node-id node-id
Mandatory	ro	| | +--rw nt:termination-point* [tp-id]
Mandatory	ro	| | | +--rw nt:tp-id tp-id
Mandatory	ro	| | | +--rw tet:te-tp-id? te-types:te-tp-id
Mandatory	ro	| | | +--rw tet:te!
Optional	ro	| | | | +--rw tet:admin-status? te-types:te-admin-status
Optional	ro	| | | | +--rw tet:name? string
(See note 2)	ro	| | | | +--rw tet:inter-domain-plug-id? binary
Optional	ro	| | | | +--ro tet:oper-status? te-types:te-oper-status
Optional	ro	| | | | +--ro tet:geolocation
Optional	ro	| | | | +--ro tet:altitude? int64
Optional	ro	| | | | +--ro tet:latitude? geographic-coordinate-degree
Optional	ro	| | | | +--ro tet:longitude? geographic-coordinate-degree
Optional	ro	| | | +--rw ethtetopo:ltp-mac-address? yang:mac-address
(See note 10)		| | | +--rw ethtetopo:port-vlan-id? etht-types:vlanid
Optional	ro	| | | +--rw ethtetopo:maximum-frame-size? uint16
		| | | +--rw (ethtetopo:direction)?
(See note 12)		| | | | +--:(ethtetopo:symmetrical)
(See note 12)		| | | | | +--rw ethtetopo:ingress-egress-bandwidth-profile
(See note 12)		| | | | | +--rw ethtetopo:bandwidth-profile-type?
(See note 12)		| | | | | | etht-types:bandwidth-profile-type
(See note 12)		| | | | | +--rw ethtetopo:CIR? uint64
(See note 12)		| | | | | +--rw ethtetopo:CBS? uint64
(See note 12)		| | | | | +--rw ethtetopo:EIR? uint64
(See note 12)		| | | | | +--rw ethtetopo:EBS? uint64
(See note 12)		| | | | | +--rw ethtetopo:color-aware? boolean
(See note 12)		| | | | | +--rw ethtetopo:coupling-flag? boolean
(See note 12)		| | | | +--:(asymmetrical)
(See note 12)		| | | | | +--rw ingress-bandwidth-profile
(See note 12)		| | | | | | +--rw bandwidth-profile-type?
(See note 12)		| | | | | | | etht-types:bandwidth-profile-type

Compliance	Conf.	Model
(See note 12)		| | | | | | | +--rw CIR? uint64
(See note 12)		| | | | | | | +--rw CBS? uint64
(See note 12)		| | | | | | | +--rw EIR? uint64
(See note 12)		| | | | | | | +--rw EBS? uint64
(See note 12)		| | | | | | | +--rw color-aware? boolean
(See note 12)		| | | | | | | +--rw coupling-flag? boolean
(See note 12)		| | | | | | +--rw egress-bandwidth-profile
(See note 12)		| | | | | +--rw bandwidth-profile-type?
(See note 12)		| | | | | | etht-types:bandwidth-profile-type
(See note 12)		| | | | | | +--rw CIR? uint64
(See note 12)		| | | | | | +--rw CBS? uint64
(See note 12)		| | | | | | +--rw EIR? uint64
(See note 12)		| | | | | | +--rw EBS? uint64
(See note 12)		| | | | | | +--rw color-aware? boolean
(See note 12)		| | | | | | +--rw coupling-flag? boolean
(See note 3)	ro	| | | +--rw ethtetopo:eth-svc!
(See note 3)	ro	| | | +--rw ethtetopo:client-facing? boolean
(See note 3)	ro	| | | +--rw ethtetopo:supported-classification
(See note 3)	ro	| | | | +--rw ethtetopo:port-classification? boolean
(See note 3)	ro	| | | | +--rw ethtetopo:vlan-classification
(See note 3)	ro	| | | | +--rw ethtetopo:vlan-tag-classification? boolean
(See note 3)	ro	| | | | +--rw ethtetopo:outer-tag
(See note 3)	ro	| | | | | +--rw ethtetopo:supported-tag-types*
		| | | | | | etht-types:eth-tag-classify
(See note 3)	ro	| | | | | +--rw ethtetopo:vlan-bundling? boolean
(See note 3)	ro	| | | | | +--rw ethtetopo:vlan-range?
		| | | | | etht-types:vid-range-type
(See note 11)	ro	| | | +--rw ethtetopo:supported-vlan-operations
(See note 11)	ro	| | | +--rw ethtetopo:asymmetrical-operations? boolean
(See note 11)	ro	| | | +--rw ethtetopo:transparent-vlan-operations?
(See note 11)		| | | | boolean
(See note 11)	ro	| | | +--rw ethtetopo:vlan-pop
(See note 11)	ro	| | | | +--rw ethtetopo:vlan-pop-operations? boolean
(See note 11)	ro	| | | | +--rw ethtetopo:max-pop-tags? uint8
(See note 11)	ro	| | | +--rw ethtetopo:vlan-push
(See note 11)	ro	| | | +--rw ethtetopo:vlan-push-operation? boolean
(See note 11)	ro	| | | +--rw ethtetopo:outer-tag
(See note 11)	ro	| | | | +--rw ethtetopo:supported-tag-types*
(See note 11)		| | | | | etht-types:eth-tag-type
(See note 11)	ro	| | | | +--rw ethtetopo:vlan-range?
		| | | | etht-types:vid-range-type
Mandatory	ro	| | +--rw tet:te-node-id? te-types:te-node-id
Mandatory	ro	| | +--rw tet:te!
Optional	ro	| | +--rw tet:te-node-attributes
Optional	ro	| | | +--rw tet:admin-status? te-types:te-admin-status
Optional	ro	| | | +--rw tet:connectivity-matrices
Optional (see note 4)	ro	| | | | +--rw tet:number-of-entries? uint16
Optional (see note 4)	ro	| | | | +--rw tet:is-allowed? boolean
Optional (see note 4)	ro	| | | | +--rw tet:connectivity-matrix* [id]
Optional (see note 4)	ro	| | | | +--rw tet:id uint32
Optional (see note 4)	ro	| | | | +--rw tet:from
Optional (see note 4)	ro	| | | | | +--rw tet:tp-ref? leafref
Optional (see note 4)	ro	| | | | | +--rw tet:label-restrictions
Optional (see note 4)	ro	| | | | | +--rw tet:label-restriction* [index]
Optional (see note 4)	ro	| | | | | +--rw tet:restriction? enumeration
Optional (see note 4)	ro	| | | | | +--rw tet:index uint32
Optional (see note 4)	ro	| | | | | +--rw tet:label-start
Optional (see note 4)	ro	| | | | | | +--rw tet:te-label
		| | | | | | | +--:(ethtetopo:eth)
Optional (see note 4)	ro	| | | | | | | +--rw ethtetopo:vlanid?
		| | | | | | | etht-types:vlanid
Optional (see note 4)	ro	| | | | | +--rw tet:label-end
Optional (see note 4)	ro	| | | | | | +--rw tet:te-label

<table>
<tr><th>Compliance</th><th>Conf.</th><th>Model</th></tr>
<tr><td></td><td></td><td>| | | | | | | +--:(ethtetopo:eth)</td></tr>
<tr><td>Optional (see note 4)</td><td>ro</td><td>| | | | | | | +--rw ethtetopo:vlanid?</td></tr>
<tr><td></td><td></td><td>| | | | | | | etht-types:vlanid</td></tr>
<tr><td>Optional (see note 5)</td><td>ro</td><td>| | | | | +--rw tet:label-step</td></tr>
<tr><td></td><td></td><td>| | | | | | +--:(ethtetopo:eth)</td></tr>
<tr><td>Optional (see note 5)</td><td>ro</td><td>| | | | | | +--rw ethtetopo:eth-step? uint16</td></tr>
<tr><td>Optional (see note 5)</td><td>ro</td><td>| | | | | +--rw tet:range-bitmap?</td></tr>
<tr><td></td><td></td><td>| | | | | | yang:hex-string</td></tr>
<tr><td>Optional (see note 4)</td><td>ro</td><td>| | | | | +--rw ethtetopo:tag-type?</td></tr>
<tr><td></td><td></td><td>| | | | | | etht-types:eth-tag-type</td></tr>
<tr><td>Optional (see note 4)</td><td>ro</td><td>| | | | +--rw tet:to</td></tr>
<tr><td>Optional (see note 4)</td><td>ro</td><td>| | | | | +--rw tet:tp-ref? leafref</td></tr>
<tr><td>Optional (see note 4)</td><td>ro</td><td>| | | | +--rw tet:is-allowed? boolean</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--rw tet:domain-id? uint32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--rw tet:is-abstract? empty</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--rw tet:name? string</td></tr>
<tr><td>Optional (see note 6)</td><td>ro</td><td>| | | +--rw tet:underlay-topology {te-topology-hierarchy}?</td></tr>
<tr><td>Optional (see note 6)</td><td>ro</td><td>| | | +--rw tet:network-ref?</td></tr>
<tr><td></td><td></td><td>| | | -> /nw:networks/network/network-id</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:oper-status? te-types:te-oper-status</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:geolocation</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--ro tet:altitude? int64</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--ro tet:latitude? geographic-coordinate-degree</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--ro tet:longitude? geographic-coordinate-degree</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| +--rw nt:link* [link-id]</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | +--rw nt:link-id link-id</td></tr>
<tr><td>(See note 7)</td><td>ro</td><td>| | +--rw nt:source</td></tr>
<tr><td>(See note 7)</td><td>ro</td><td>| | | +--rw nt:source-node? -> ../../../nw:node/node-id</td></tr>
<tr><td>(See note 7)</td><td>ro</td><td>| | | +--rw nt:source-tp? leafref</td></tr>
<tr><td>(See note 8)</td><td>ro</td><td>| | +--rw nt:destination</td></tr>
<tr><td>(See note 8)</td><td>ro</td><td>| | | +--rw nt:dest-node? -> ../../../nw:node/node-id</td></tr>
<tr><td>(See note 8)</td><td>ro</td><td>| | | +--rw nt:dest-tp? leafref</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | +--rw tet:te!</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | +--rw tet:te-link-attributes</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | +--rw tet:name? string</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | +--rw tet:underlay {te-topology-hierarchy}?</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | +--rw tet:enabled? boolean</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | +--rw tet:primary-path</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | +--rw tet:network-ref?</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | | -> /nw:networks/network/network-id</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | +--rw tet:path-element* [path-element-id]</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | +--rw tet:path-element-id uint32</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | +--rw (tet:type)?</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | +--:(tet:unnumbered-link-hop)</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | | +--rw tet:unnumbered-link-hop</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | | +--rw tet:link-tp-id te-tp-id</td></tr>
<tr><td>(See note 9)</td><td>ro</td><td>| | | | | | +--rw tet:node-id te-node-id</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | | +--rw tet:admin-status? te-types:te-admin-status</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | | +--rw tet:max-link-bandwidth</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | | | +--rw tet:te-bandwidth</td></tr>
<tr><td></td><td></td><td>| | | | +--rw (tet:technology)?</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | | | +--:(ethtetopo:eth)</td></tr>
<tr><td>Mandatory</td><td>ro</td><td>| | | | +--rw ethtetopo:eth-bandwidth? uint64</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:oper-status? te-types:te-oper-status</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:statistics</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:discontinuity-time? yang:date-and-time</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:disables? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:enables? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:maintenance-clears? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:maintenance-sets? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:modifies? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:downs? yang:counter32</td></tr>
<tr><td>Optional</td><td>ro</td><td>| | +--ro tet:ups? yang:counter32</td></tr>
</table>

Compliance	Conf.	Model
Optional	ro	| | +--ro tet:fault-clears? yang:counter32
Optional	ro	| | +--ro tet:fault-detects? yang:counter32
Optional	ro	| | +--ro tet:protection-switches? yang:counter32
Optional	ro	| | +--ro tet:protection-reverts? yang:counter32
Optional	ro	| | +--ro tet:restoration-failures? yang:counter32
Optional	ro	| | +--ro tet:restoration-starts? yang:counter32
Optional	ro	| | +--ro tet:restoration-successes? yang:counter32
Optional	ro	| | +--ro tet:restoration-reversion-failures?
		| | | yang:counter32
Optional	ro	| | +--ro tet:restoration-reversion-starts? yang:counter32
Optional	ro	| | +--ro tet:restoration-reversion-successes?
		| | yang:counter32
Mandatory	ro	| +--rw tet:te-topology-identifier
Mandatory	ro	| | +--rw tet:provider-id? te-global-id
Mandatory	ro	| | +--rw tet:client-id? te-global-id
Mandatory	ro	| | +--rw tet:topology-id? te-topology-id
Optional	ro	| +--rw tet:te!
Optional	ro	| +--rw tet:name? string
Optional	ro	| +--ro tet:geolocation
Optional	ro	| +--ro tet:altitude? int64
Optional	ro	| +--ro tet:latitude? geographic-coordinate-degree
Optional	ro	| +--ro tet:longitude? geographic-coordinate-degree

NOTE 1: (applicable to the whole table) A container is marked rw if even only one of the lower level attributes is required to be marked rw.
NOTE 2: Mandatory on eeLTPs, not applicable to internal Ethernet LTPs.
NOTE 3: Mandatory on eeLTPs.
Optional on internal Ethernet LTPs.
NOTE 4: Optional. Only applicable to AL1 representations of networks with VLAN Transparency, as discussed in Annex D (informative). Only needed if the trial-and-error approach is to be avoided (see clause 4.3).
NOTE 5: Optional within the scope of note 6. May simplify the PNC implementation.
NOTE 6: Applicable only when the node has an underlay topology.
NOTE 7: Mandatory for internal links. Optional for outgoing external links, if external links are reported. Not applicable for external incoming links.
NOTE 8: Mandatory for internal links. Optional for external incoming links, if external links are reported. Not applicable for external outgoing links.
NOTE 9: Mandatory if ETH over MW links are reported.
NOTE 10: Mandatory rw on eeLTP. Optional ro on internal ethernet LTPs.
NOTE 11: Optional. Only applicable to networks with VLAN Transparency.
NOTE 12: Mandatory rw for eeLTPs, both symmetrical and asymmetrical (unless the physical network only supports one case).
Optional ro for internal LTPs (managed by the PNC). The MDSC may use the information related to internal LTPs' BWP, if present, to better allocate the available bandwidth and correctly provision the E2E services. See clause 4.2.2.2.1.

A.2.4 Ethernet service (draft-ietf-ccamp-client-signal-yang-05)

In the ietf models, the VLAN `tag-type` can assume one of the following values:

Table A.2.4.1: Vlan Tags

Type	Ethertype	etht-types:eth-tag-classify value
C-VLAN	0x8100	classify-c-vlan
S-VLAN	0x88a8	classify-s-vlan

Table A.2.4.2: Ethernet Service Attributes

Compliance	Conf.	Model
Mandatory		module: ietf-eth-tran-service
Mandatory	rw	+--rw etht-svc
Mandatory	rw	+--rw globals
Mandatory	rw		+--rw named-bandwidth-profiles* [bandwidth-profile-name]
Mandatory	rw		+--rw bandwidth-profile-name string
Optional	rw		+--rw bandwidth-profile-type? etht-types:bandwidth-profile-type
Mandatory	rw		+--rw CIR? uint64
Optional	rw		+--rw CBS? uint64
Mandatory	rw		+--rw EIR? uint64
Optional	rw		+--rw EBS? uint64
Optional	rw		+--rw color-aware? boolean
Optional	rw		+--rw coupling-flag? boolean
Mandatory	rw	+--rw etht-svc-instances* [etht-svc-name]
Mandatory	rw	+--rw etht-svc-name string
Optional	rw	+--rw etht-svc-title? string
Optional	rw	+--rw etht-svc-descr? string
Optional	rw	+--rw etht-svc-customer? string
Mandatory	rw	+--rw etht-svc-type? etht-types:service-type
Optional	rw	+--rw etht-svc-lifecycle? etht-types:lifecycle-status
Mandatory	rw	+--rw te-topology-identifier
Optional	rw		+--rw provider-id? te-global-id
Optional	rw		+--rw client-id? te-global-id
Mandatory	rw		+--rw topology-id? te-topology-id
Mandatory	rw	+--rw etht-svc-end-points* [etht-svc-end-point-name]
Mandatory	rw		+--rw etht-svc-end-point-name string
Optional	ro		+--rw etht-svc-end-point-id? string
Optional	ro		+--rw etht-svc-end-point-descr? string
Mandatory	rw		+--rw etht-svc-access-points* [access-point-id]
Mandatory	rw			+--rw access-point-id string
Mandatory	rw			+--rw access-node-id? te-types:te-node-id
Mandatory	rw			+--rw access-ltp-id? te-types:te-tp-id
Mandatory	ro			+--ro state
Optional	ro				+--ro operational-state? identityref
Optional	ro				+--ro provisioning-state? identityref
Mandatory	rw		+--rw service-classification-type? identityref
			+--rw (service-classification)?
				+--:(vlan-classification)
Mandatory	rw			+--rw outer-tag!
Mandatory	rw				+--rw tag-type? etht-types:eth-tag-classify
					+--rw (individual-bundling-vlan)?
					+--:(individual-vlan)
Mandatory	rw					+--rw vlan-value? etht-types:vlanid
					+--:(vlan-bundling)
Optional	rw				+--rw vlan-range? etht-types:vid-range-type
			+--rw (direction)?
				+--:(symmetrical)
(See note)	rw				+--rw ingress-egress-bandwidth-profile
					+--rw (style)?
					+--:(named)
(See note)	rw					+--rw bandwidth-profile-name? leafref
				+--:(asymmetrical)
(See note)	rw				+--rw ingress-bandwidth-profile
						+--rw (style)?
						+--:(named)
(See note)	rw						+--rw bandwidth-profile-name? leafref
(See note)	rw				+--rw egress-bandwidth-profile
				+--rw (style)?
				+--:(named)
(See note)	rw				+--rw bandwidth-profile-name? leafref
Mandatory	rw		+--rw vlan-operations
			+--rw (direction)?

Compliance	Conf.	Model
		| +--:(symmetrical)
Mandatory	rw	| +--rw symmetrical-operation
Mandatory	ro	| +--rw pop-tags? uint8
Mandatory	rw	| +--rw push-tags
Mandatory	rw	| +--rw outer-tag!
Mandatory	ro	| | +--rw tag-type? etht-types:eth-tag-type
Mandatory	ro	| | +--rw vlan-value? etht-types:vlanid
Mandatory	ro	| | +--rw default-pcp? uint8
Mandatory	rw	| +--rw second-tag!
Mandatory	rw	| +--rw tag-type?
Mandatory	rw	| | etht-types:eth-tag-type
Mandatory	rw	| +--rw vlan-value? etht-types:vlanid
Mandatory	rw	| +--rw default-pcp? uint8
Mandatory	rw	+--rw admin-status? identityref
Mandatory	ro	+--ro state
Mandatory	ro	+--ro operational-state? identityref
Mandatory	ro	+--ro provisioning-state? identityref
Optional	ro	+--ro creation-time? yang:date-and-time
Optional	ro	+--ro last-updated-time? yang:date-and-time
Optional	ro	+--ro created-by? string
Optional	ro	+--ro last-updated-by? string
Optional	ro	+--ro owned-by? string
NOTE: The BWP attributes are marked as "rw", since BWPs can be created and deleted by the MDSC. See clause 4.2.2.2 for details about usage or modifications of BWPs.		

Annex B (normative): Use of LLDP for automatic external Ethernet link discovery

B.1 Introduction

In order for the MDSC to orchestrate services across different domains, it needs to be able to identify the inter-domain links between couples of domains.

This is performed by assigning a conventional network-wide-unique value to the attribute `/nw:networks/nw:network/nw:node/nt:termination-point/tet:te/tet:inter-domain-plug-id` for the external access links of the MW domain.

In addition to the manual method, which is not suitable for automation on large networks, an algorithm has been devised to calculate such a value automatically, based on the content of the TLVs exchanged by the Ethernet interfaces on both sides of the inter-domain access link.

A PNC compliant to this Profile shall comply to the algorithm described in the present Annex.

B.2 Algorithm description

This algorithm for calculating a unique value for the inter-domain-plug-id attribute is based on the LLDP protocol [17].

This protocol shall be activated on both Ethernet interfaces to which the inter-domain link is connected.

The goals of the algorithm are:

- Enable the PNCs on both sides to automatically calculate the same unique value, without any information exchange between the PNCs:
    - The only prerequisite is that the protocol be available on both equipment and be activated beforehand in the bidirectional mode.
- Use only mandatory LLDP TLVs.

Referring to Figure B.2.1, each PNC:

a) Concatenates the character string values of the "Chassis ID", prefixed by the Chassis ID subtype code, and "Port ID", prefixed by the Port ID subtype code, in this order, that the LLDP protocol **sends** to the other domain, obtaining a token T1.

b) Concatenates the character string values of the "Chassis ID", prefixed by the Chassis ID subtype code, and "Port ID", prefixed by the Port ID subtype code, in this order, that the LLDP protocol **receives** from the other domain, obtaining a token T2.

c) Compares T1 and T2, and concatenates them in the order from bigger to smaller (i.e. if T1 > T2, the concatenation is [T1,T2]). In the very unlikely case that T1 = T2, the order is not relevant.

d) Prefixes a byte of value 0x01 (prefix for automatic inter-domain-plug-id calculation) to the concatenation obtaining [0x01,T1,T2] or [0x01,T2,T1] depending on the comparison in step c.

NOTE: The resulting binary concatenated string (inter-domain-plug-id value) is represented in JSON using Base64 coding.

This algorithm ensures that both sides calculate the same final value, even without any direct communication between PNC1 and PNC2. The MDSC is now able to correctly discover the inter-domain links.

The LLDP sends its packets periodically, allowing for dynamic updating of the topology information. The MDSC may subscribe to the inter-domain-plug-id attributes of the inter-domain links.

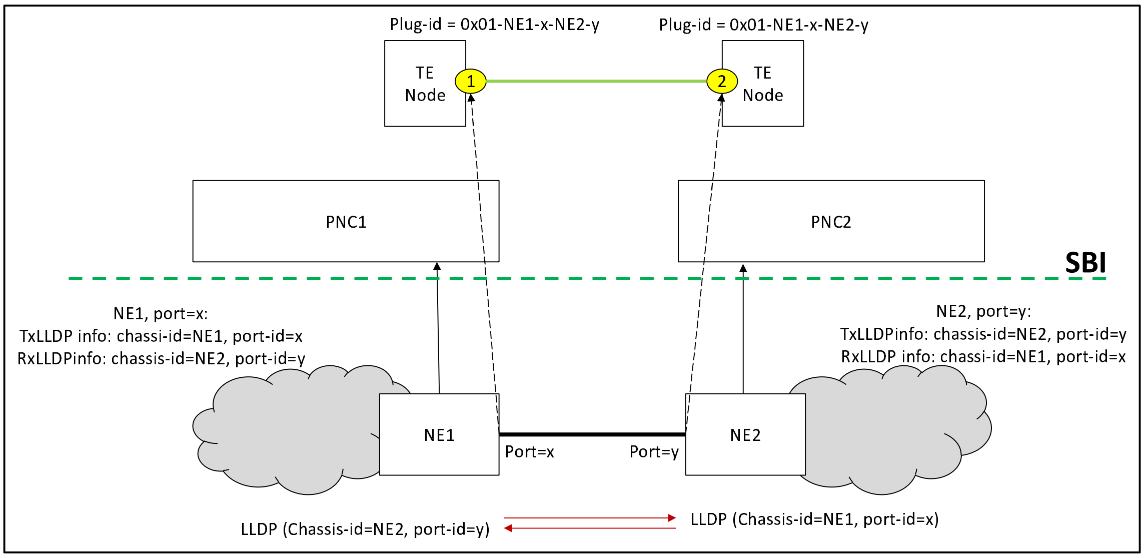


Figure B.2.1: Algorithm Block Diagram

B.3 Example Calculation of the `inter-domain-plug-id` Value

B.3.1 Domain A LLDP Packet TLV Values

Table B.3.1.1 shows the representation of the contents of the Chassis ID TLV in JSON pseudo-code.

Table B.3.1.1: Domain A Chassis ID TLV [JSON]

```
{
"lldp.tlv.type": "1",
"lldp.tlv.len": "7",
"lldp.chassis.subtype": "4",
"lldp.chassis.id.mac": "2c:97:b1:f6:f7:21"
}
```

Table B.3.1.2 shows the machine representation of the contents of the Chassis ID TLV in hexadecimal notation.

Table B.3.1.2: Domain A Chassis ID TLV [Hex]

Subtype	Chassis ID					
0x04	0x2C	0x97	0xB1	0xF6	0xF7	0x21

Table B.3.1.3 shows the representation of the contents of the Port ID TLV in JSON pseudo-code.

Table B.3.1.3: Domain A Port ID TLV [JSON]

```
{
"lldp.tlv.type": "2",
"lldp.tlv.len": "24",
"lldp.port.subtype": "5",
"lldp.port.id": "GigabitEthernet 2\/255\/2"
}
```

Table B.3.1.4 shows the machine representation of the contents of the Chassis ID TLV in hexadecimal notation.

Table B.3.1.4: Domain A Port ID TLV [Hex]

Subtype	Port ID						
0x05	0x47	0x69	0x67	0x61	0x62	0x69	0x74
(Continued)	0x45	0x74	0x68	0x65	0x72	0x6E	0x65
(Continued)	0x74	0x20	0x32	0x2F	0x32	0x35	0x35
(Continued)	0x2F	0x32					

B.3.2 Domain B LLDP Packet TLV Values

Table B.3.2.1 shows the representation of the contents of the Chassis ID TLV in JSON pseudo-code.

Table B.3.2.1: Domain B Chassis ID TLV [JSON]

```
{
"lldp.tlv.type": "1",
"lldp.tlv.len": "7",
"lldp.chassis.subtype": "4",
"lldp.chassis.id.mac": "00:b0:ac:06:78:01"
}
```

Table B.3.2.2 shows the machine representation of the contents of the Chassis ID TLV in hexadecimal notation.

Table B.3.2.2: Domain B Chassis ID TLV [Hex]

Subtype	Chassis ID					
0x04	0x00	0xB0	0xAC	0x06	0x78	0x01

Table B.3.2.3 shows the representation of the contents of the Port ID TLV in JSON pseudo-code.

Table B.3.2.3: Domain B Port ID TLV [JSON]

```
{
"lldp.tlv.type": "2",
"lldp.tlv.len": "6",
"lldp.port.subtype": "1",
"lldp.port.id": "Gi0/4"
}
```

Table B.3.2.4 shows the machine representation in hexadecimal notation of the contents of the Chassis ID TLV.

Table B.3.2.4: Domain B Port ID TLV [Hex]

Subtype	Port ID				
0x01	0x47	0x69	0x30	0x2F	0x34

B.3.3 Sorting and Concatenation

The values of the TLV subtype and content shall be concatenated as specified in clause B.2, creating Token T1 and T2 respectively.

Table B.3.3.1: Domain A Token: T1 [Hex]

T1	0x04	0x2C	0x97	0xB1	0xF6	0xF7	0x21
(Continued)	0x05	0x47	0x69	0x67	0x61	0x62	0x69
(Continued)	0x74	0x45	0x74	0x68	0x65	0x72	0x6E
(Continued)	0x65	0x74	0x20	0x32	0x2F	0x32	0x35
(Continued)	0x35	0x2F	0x32				

Table B.3.3.2: Domain B Token: T2 [Hex]

T2	0x04	0x00	0xB0	0xAC	0x06	0x78	0x01
(Continued)	0x01	0x47	0x69	0x30	0x2F	0x34	

The comparison between T1 and T2 results in T1 > T2, therefore the tokens are concatenated in the order [T1,T2], and the resulting string is be prefixed by the hexadecimal value 0x01 to signify the use of this specific automatic calculation algorithm.

Table B.3.3.3: Binary Value of `inter-domain-plug-id` [Hex]

[0x01,T1,T2]	0x01	0x04	0x2C	0x97	0xB1	0xF6	0xF7	0x21
(Continued)	0x05	0x47	0x69	0x67	0x61	0x62	0x69	0x74
(Continued)	0x45	0x74	0x68	0x65	0x72	0x6E	0x65	0x74
(Continued)	0x20	0x32	0x2F	0x32	0x35	0x35	0x2F	0x32
(Continued)	0x04	0x00	0xB0	0xAC	0x06	0x78	0x01	0x01
(Continued)	0x47	0x69	0x30	0x2F	0x34			

The textual representation of this binary string is then based on the Base64 coding, resulting in the value shown in Table B.3.3.4 in JSON pseudo-code.

Table B.3.3.4: Base64-Coded Value of `inter-domain-plug-id` [JSON]


```
{
"inter-domain-plug-id":
"AQQsl7H29yEFR2lnYWJpdEV0aGVybmV0IDIvMjU1LzIEALCsBngBAUdpMC80"
}
```

Annex C (informative): Examples

C.1 Physical Network

This is the physical network to be used in the following representations. It comprises 3 microwave links, with 5 NEs. NE2 is a so-called "hub", terminating two Radio links, and is connected to a third radio link by means of a local ethernet connection.

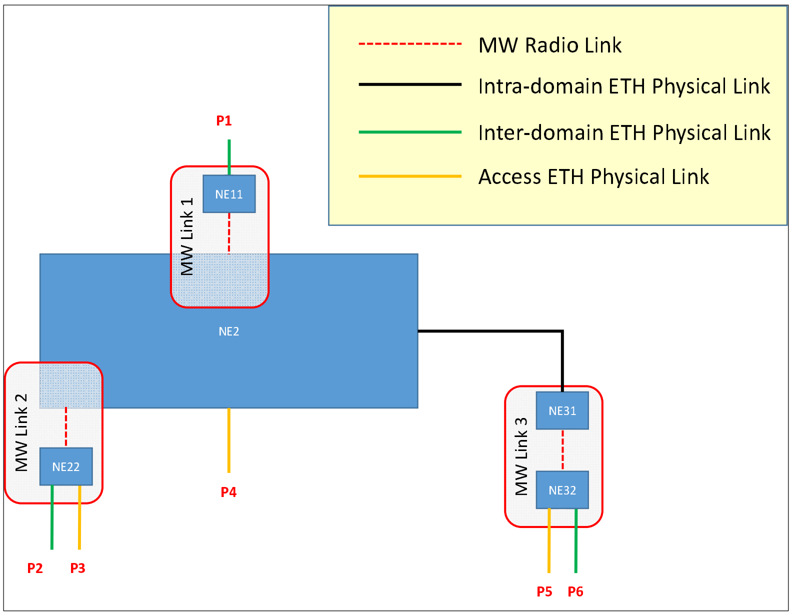
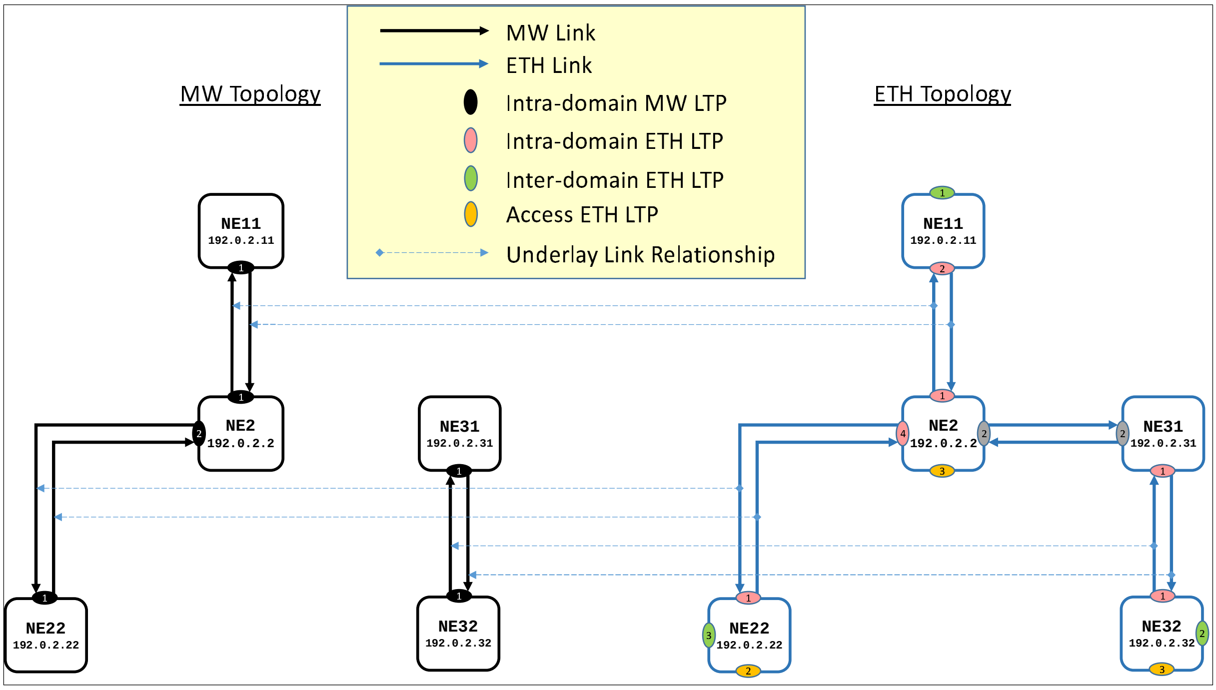


Figure C.1.1: Physical Representation of the Example Network

C.2 Microwave and Ethernet TE Topologies

C.2.1 Topology Model of the Physical Network

Figure C.2.1.1 shows the microwave and ethernet tolopogies modelling the physical network in clause C.1.



NOTE: The `ltp-id` values are local to the node, in this example they are (arbitrarily) numbered from 1 upwards, independently.

Figure C.2.1.1: Topology Representation of the Example Network

As required in clauses 4.2.1.2 and 4.2.1.3.1, in order to facilitate the correspondence between the Microwave and the Ethernet TE topologies, the `node-id` attribute of any given physical NE has the same value in both topologies.

C.2.2 Types of Ethernet LTPs

C.2.2.1 Edge Ethernet LTP, C-VLAN-Bridge Capable Network

This example shows LTPs providing connection to a network capable of VLAN bridging with a single level of tagging, with two possible subcases, depending on the capability to perform VLAN translation, or not.

```
{
  "tp-id": "c-vlan-bridge-port-no-c-vlan-translation",
  "te-tp-id": 1,
  "port-vlan-id": 10,
  "eth-svc": {
    "client-facing": true,
    "supported-classification": {
      "vlan-classification": {
        "vlan-tag-classification": true,
        "outer-tag": {
          "supported-tag-types": [
            "classify-c-vlan"
          ],
          "vlan-range": "1-4094"
        }
      }
    },
    "supported-vlan-operations": {
      "transparent-vlan-operations": true
    }
  }
},
```

```
{
  "tp-id": "c-vlan-bridge-port-with-c-vlan-translation",
  "te-tp-id": 3,
  "port-vlan-id": 10,
  "eth-svc": {
    "client-facing": true,
    "supported-classification": {
      "vlan-classification": {
        "vlan-tag-classification": true,
        "outer-tag": {
          "supported-tag-typ es": [
            "classify-c-vlan"
          ],
          "vlan-range": "1-4094"
        }
      }
    },
    "supported-vlan-operations": {
      "transparent-vlan-operations": true,
      "vlan-pop": {
        "vlan-pop-operations": true,
        "max-pop-tags": 1
      },
      "vlan-push": {
        "vlan-push-operation": true,
        "outer-tag": {
          "supported-tag-types": [
            "c-vlan-tag-type"
          ]
        }
      }
    }
  }
},
```


Figure C.2.2.1.1: Ethernet LTPs for C-VLAN Bridged Networks

C.2.2.2 Edge Ethernet LTP, Provider Bridge Capable Network

This example shows LTPs providing connection to a provider bridge capable network, with two possible subcases, depending on the capability to perform VLAN translation, or not.


```
{
  "tp-id": "provider-network-port-no-s-vlan-translation",
  "te-tp-id": 2,
  "port-vlan-id": 10,
  "eth-svc": {
    "client-facing": true,
    "supported-classification": {
      "vlan-classification": {
        "vlan-tag-classification": true,
        "outer-tag": {
          "supported-tag-types": [
            "classify-s-vlan"
          ],
          "vlan-range": "1-4094"
        }
      }
    },
    "supported-vlan-operations": {
      "transparent-vlan-operations": true
    }
  }
},
```

```
{
  "tp-id": "provider-network-port-with-s-vlan-translation",
  "te-tp-id": 4,
  "port-vlan-id": 10,
  "eth-svc": {
    "client-facing": true,
    "supported-classification": {
      "vlan-classification": {
        "vlan-tag-classification": true,
        "outer-tag": {
          "supported-tag-types": [
            "classify-s-vlan"
          ],
          "vlan-range": "1-4094"
        }
      }
    },
    "supported-vlan-operations": {
      "transparent-vlan-operations": true,
      "vlan-pop": {
        "vlan-pop-operations": true,
        "max-pop-tags": 1
      },
      "vlan-push": {
        "vlan-push-operation": true,
        "outer-tag": {
          "supported-tag-types": [
            "s-vlan-tag-type"
          ]
        }
      }
    }
  }
},
```


Figure C.2.2.2.1: Ethernet LTP Type s for S-VLAN Bridged Networks

C.2.2.3 Edge Ethernet LTP, Customer Edge Port

This example shows an LTP providing connection to a provider bridge capable network, accepting traffic from a customer providing packets untagged or tagged with a C-VLAN tag, upon which an S-VLAN tag (defined by the Service) is going to be added.

```json
{
  "tp-id": "customer-edge-port",
  "te-tp-id": 5,
  "port-vlan-id": 10,
  "eth-svc": {
    "client-facing": true,
    "supported-classification": {
      "vlan-classification": {
        "vlan-tag-classification": true,
        "outer-tag": {
          "supported-tag-types": [
            "classify-c-vlan"
          ],
          "vlan-range": "1-4094"
        }
      }
    },
    "supported-vlan-operations": {
      "transparent-vlan-operations": false,
      "vlan-pop": {
        "vlan-pop-operations": true,
        "max-pop-tags": 1
      },
      "vlan-push": {
        "vlan-push-operation": true,
        "outer-tag": {
          "supported-tag-types": [
            "s-vlan-tag-type"
          ]
        }
      }
    }
  }
}
```


Figure C.2.2.3.1: Ethernet LTPs for S-VLAN Bridged Networks

C.2.2.4 Summary of Edge Ethernet LTP Types

Table C.2.2.4.1 summarizes the types of LTP based on the examples shown in clauses C.2.2.1, C.2.2.2 and C.2.2.3.

Table C.2.2.4.1: LTP Types

LTP Type	Name in JSON Example	Remarks
Type 1	`c-vlan-bridge-port-no-c-vlan-translation`	Forces C-VLAN transparency
Type 2	`c-vlan-bridge-port-with-c-vlan-translation`	Allows C-VLAN isolation
Type 3	`provider-network-port-no-s-vlan-translation`	Forces S-VLAN transparency
Type 4	`provider-network-port-with-s-vlan-translation`	Allows S-VLAN isolation
Type 5	`customer-edge-port`	• Untagged traffic (eq. to C-VLAN with C-VLAN = Port VID) • C-VLAN to C-VLAN over provider bridge network • C-VLAN isolation

C.3 Examples of Service Types

C.3.1 Relationship among Service Types and LTP Types

In this clause a few examples are shown, of services that can be provisioned over the network in Figure C.2.1.1 according to the present document.

Based on the eeLTP capabilities (Type 1 to Type 5), the MDSC knows what kind of services can be provisioned between any couple of LTPs. The correlation between service Type and LTP Type is summarized in Table C.3.1.1.

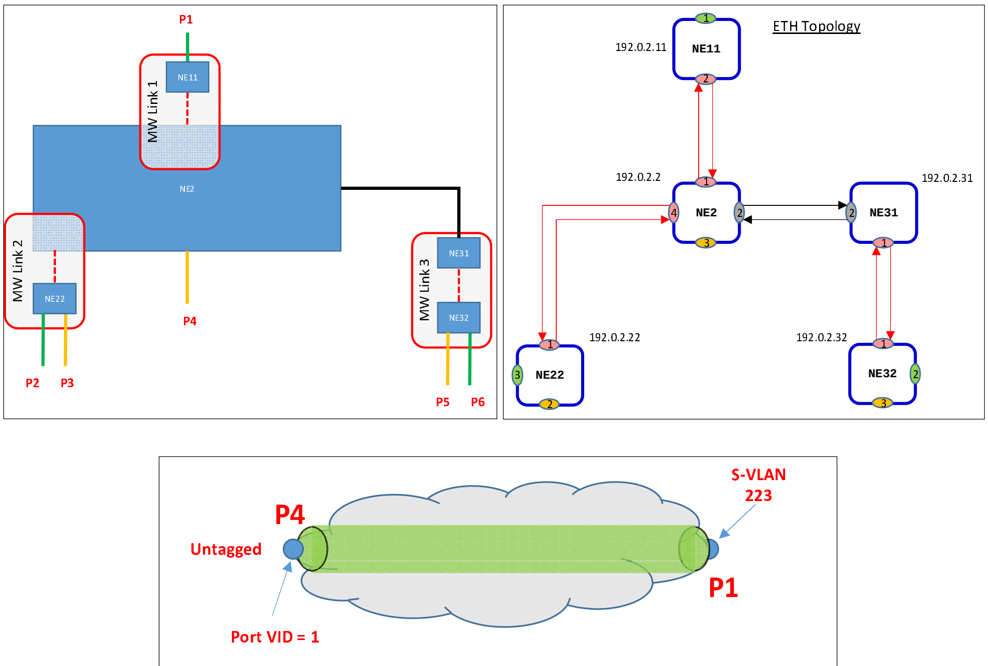
Table C.3.1.1: Service Types and LTP Types

Classification @ LTP A	Type of LTP @A based on network	Classification @ LTP Z	Type of LTP @Z based on network	Notes
Untagged	C-VLAN bridge: 1 or 2	Untagged	C-VLAN bridge: 1 or 2	
	Provider Bridge: 5		Provider Bridge: 5	
Untagged	C-VLAN bridge: 1 or 2	C-VLAN	C-VLAN bridge: 1 or 2	
	Provider Bridge: 5		Provider Bridge: 5	
Untagged	C-VLAN bridge: (1 or 2)	S-VLAN	C-VLAN bridge: N/A	NOTE 1
	Provider Bridge: 5		Provider Bridge: 3 or 4	
C-VLAN	C-VLAN bridge: (1 or) 2	C-VLAN	C-VLAN bridge: (1 or) 2	NOTE 2
	Provider Bridge: 5		Provider Bridge: 5	
S-VLAN	C-VLAN bridge: N/A	S-VLAN	C-VLAN bridge: N/A	
	Provider Bridge: 3 or 4		Provider Bridge: 3 or 4	
S-VLAN	C-VLAN bridge: N/A	C-VLAN	C-VLAN bridge: N/A	
	Provider Bridge: 3 or 4		Provider Bridge: 5	

NOTE 1: LTPs of Type 1 or Type 2 are possible if there is a provider bridge along the service path.

NOTE 2: It is impossible to have different C-VIDs if both eeLTPs are Type 1, unless there is a Type 2 port along the service path that is able to change the C-VID value.

C.3.2 Selected Examples of Supported Service Configurations



Service	Port	TE Node ID	LTP ID	Outer Tag
Untag_2_Tag	P4	192.0.2.2	3	C-VLAN*=1
	P1	192.0.2.11	1	S-VLAN=223

* This is actually the Port VID

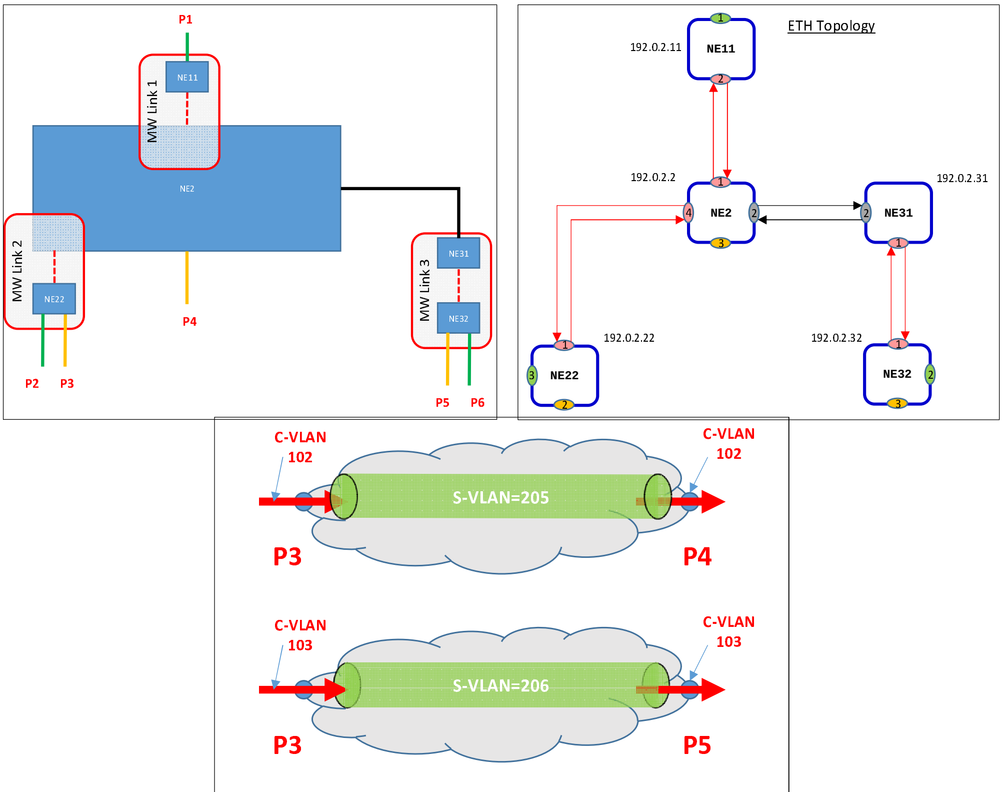
NOTE: The use of specific VID values may be restricted, depending on the network capabilities and the ethernet connectivity, see clause 4.3 for more details.

Figure C.3.2.1: Untagged to S-VLAN Service Example

```
"ietf-eth-tran-service:etht-svc": {
  "etht-svc-instances": [
    {
      "etht-svc-name" : "Untag_2_S-Tag",
      "etht-svc-end-points" : [
        {
          "etht-svc-end-point-name" : "P1",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P1",
              "access-node-id" : "190.0.2.11",
              "access-ltp-id" : "1"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-s-vlan",
            "vlan-value" : "223"
          }
        },
        {
          "etht-svc-end-point-name" : "P4",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P4",
              "access-node-id" : "190.0.2.2",
              "access-ltp-id" : "3"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "1"
          }
```

```
"ietf-network:networks": {
  "network": [
    {
      "network-id": "ETH Provider Bridge Topology",
      "network-types": {
        "ietf-te-topology:te-topology": {}
      },
      "node": [
        {
          "node-id": "NE11",
          "ietf-te-topology:te-node-id": "192.0.2.11",
          "ietf-network-topology:termination-point": [
            {
              "tp-id": "P1",
              "ietf-te-topology:te-tp-id": 1,
              "ietf-eth-te-topology:port-vlan-id": 1,
              "ietf-eth-te-topology:eth-svc": {
                "client-facing": true,
                "supported-classification": {
                  "vlan-classification": {
                    "vlan-tag-classification": true,
                    "outer-tag": {
                      "supported-tag-types": [
                        "classify-s-vlan"
                      ],
                      "vlan-range": "1-4094"
                    } } } } } ] },
        {
          "node-id": "NE2",
          "ietf-te-topology:te-node-id": "192.0.2.2",
          "ietf-network-topology:termination-point": [
            {
              "tp-id": "P4",
              "ietf-te-topology:te-tp-id": 3,
              "ietf-eth-te-topology:port-vlan-id": 223,
              "ietf-eth-te-topology:eth-svc": {
                "client-facing": true,
                "supported-classification": {
                  "vlan-classification": {
                    "vlan-tag-classification": true,
                    "outer-tag": {
                      "supported-tag-types": [
                        "classify-c-vlan"
                      ],
                      "vlan-range": "1-4094"
                    }
```

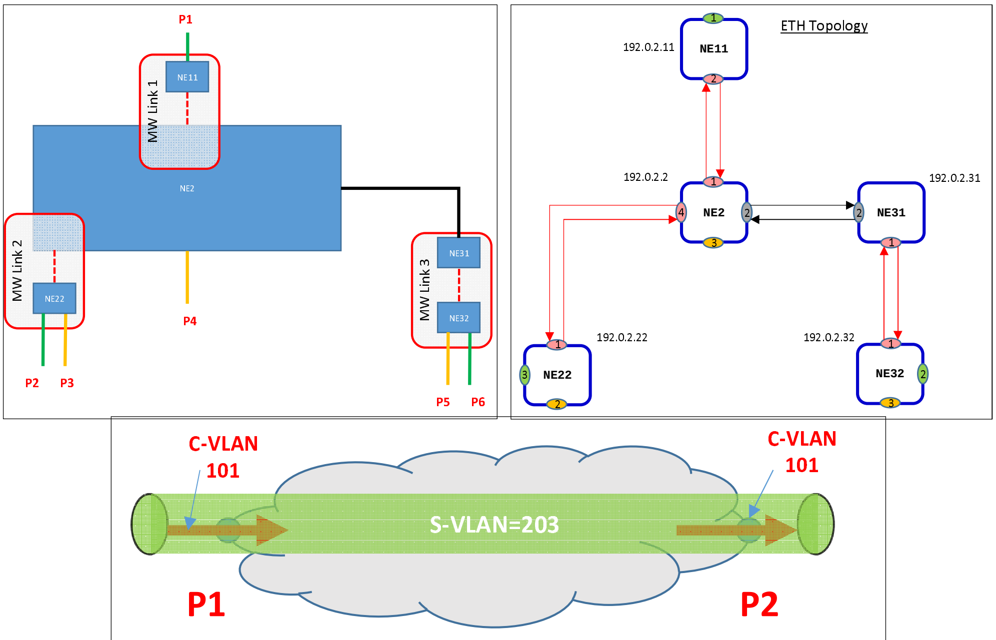
Figure C.3.2.2: Service and Topology JSON Code for Untagged to S-VLAN Service



Service Name	Port	TE Node ID	LTP ID	Outer Tag
X2_local_1	P3	192.0.2.22	2	C-VLAN=102
	P4	192.0.2.2	3	C-VLAN=102
X2_local_2	P3	192.0.2.22	2	C-VLAN=103
	P5	192.0.2.32	3	C-VLAN=103

NOTE: The information about the S-VLAN (shown in the Figure C.3.2.3) may or may not be available to the MDSC, see clause 4.3 for more details.

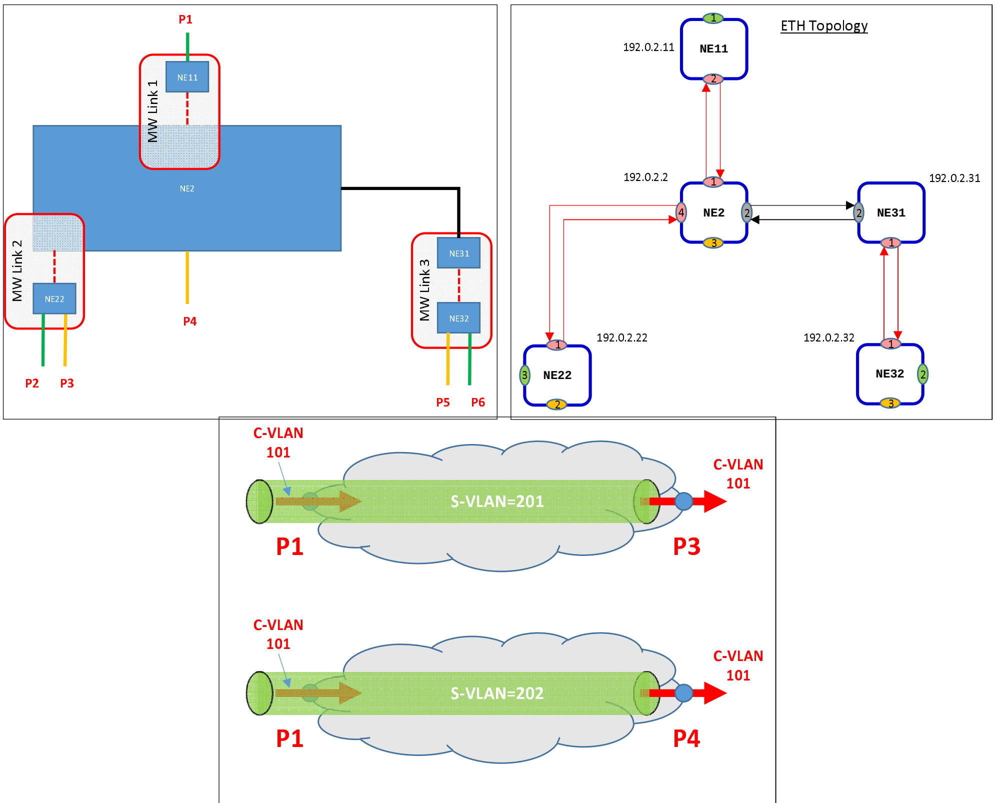
Figure C.3.2.3: C-VLAN to C-VLAN Service Example



Service Name	Port	TE Node ID	LTP ID	Outer Tag
S1_remote_1	P1	192.0.2.11	1	S-VLAN=203
	P2	192.0.2.22	3	S-VLAN=203

NOTE: The information about the C-VLAN (shown in the Figure C.3.2.4) may or may not be available to the MDSC, see clause 4.3 for more details.

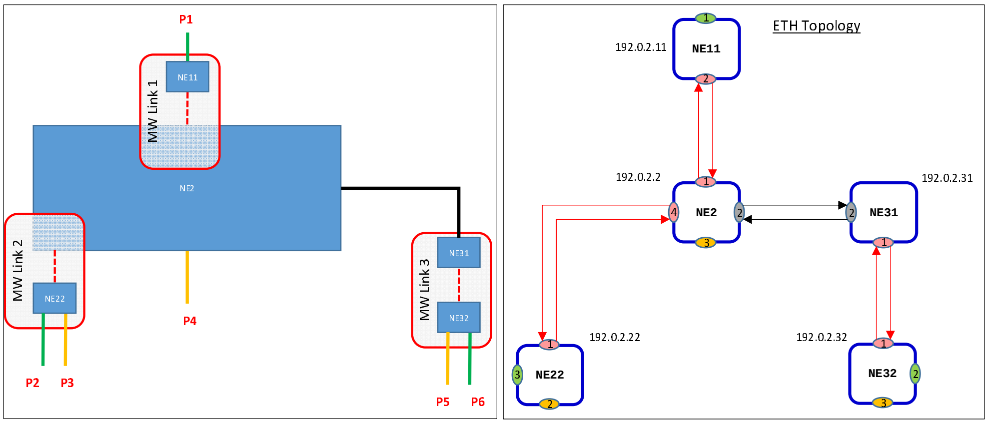
Figure C.3.2.4: S-VLAN to S-VLAN Service Example

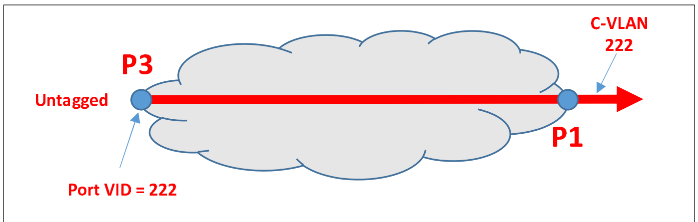


Service Name	Port	TE Node ID	LTP ID	Outer Tag
S1_local_1	P1	192.0.2.11	1	S-VLAN=201
	P3	192.0.2.22	2	C-VLAN=101
S1_local_2	P1	192.0.2.11	1	S-VLAN=202
	P4	192.0.2.2	3	C-VLAN=101

NOTE: The use of specific VID values may be restricted, depending on the network capabilities and the ethernet connectivity, see clause 4.3 for more details.

Figure C.3.2.5: S-VLAN to C-VLAN Service Example



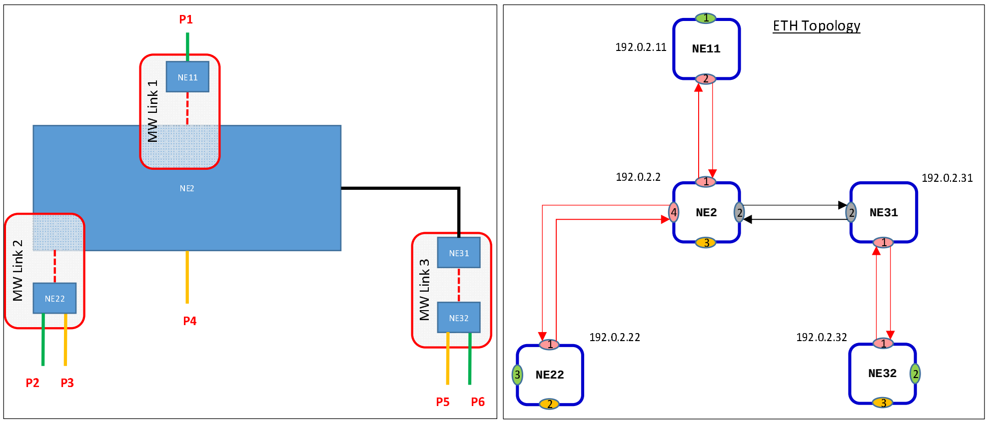


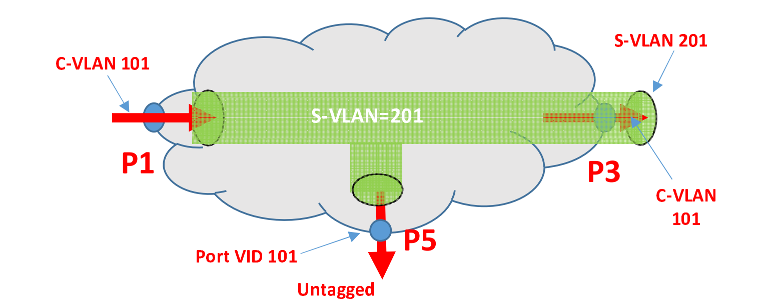
Service	Port	TE Node ID	LTP ID	Outer Tag
Untag_2_Tag	P3	192.0.2.22	2	C-VLAN*=222
	P1	192.0.2.11	1	C-VLAN=222

* Port VID

NOTE: The use of specific VID values may be restricted, depending on the network capabilities and the ethernet connectivity, see clause 4.3 for more details.

Figure C.3.2.6: Untagged to C-VLAN Service Example





Service	Port	TE Node ID	LTP ID	Outer Tag
X2_LAN_MIXED	P1	192.0.2.11	1	C-VLAN=101
	P3	192.0.2.22	2	S-VLAN=201
	P5	192.0.2.32	3	C-VLAN*=101

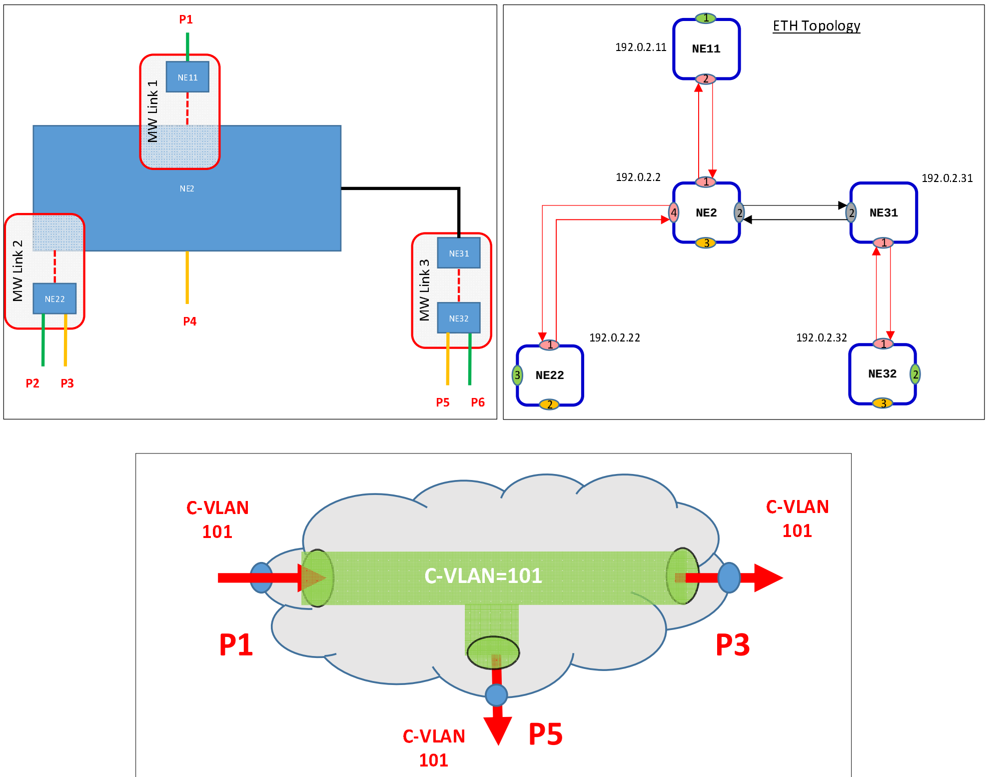
* Port VID

NOTE: Since P3 requires Provider Bridge capability, the network shall support Provider Bridging for the whole service.

Figure C.3.2.7: E-LAN Service Example with Mixed Tagging

```
"ietf-eth-tran-service:etht-svc": {
  "etht-svc-instances": [
    {
      "etht-svc-name" : "X2_LAN_Mixed",
      "etht-svc-type": "ietf-eth-tran-types:mp2mp-svc",
      "etht-svc-end-points" : [
        {
          "etht-svc-end-point-name" : "P1",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P1",
              "access-node-id" : "190.0.2.11",
              "access-ltp-id" : "1"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "101"
          }
        },
        {
          "etht-svc-end-point-name" : "P3",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P3",
              "access-node-id" : "190.0.2.22",
              "access-ltp-id" : "2"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-s-vlan",
            "vlan-value" : "201"
          }
        },
        {
          "etht-svc-end-point-name" : "P5",
          "etht-svc-access-points" : [
              {
              "access-point-id" : "P5",
              "access-node-id" : "190.0.2.32",
              "access-ltp-id" : "3"
              }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "Port VID"
          }
```

Figure C.3.2.8: Service JSON Code for E-LAN with Mixed Tagging



Service	Port	TE Node ID	LTP ID	Outer Tag
X2_LAN_C2C	P1	192.0.2.11	1	C-VLAN=101
	P3	192.0.2.22	2	C-VLAN=101
	P5	192.0.2.32	3	C-VLAN=101

NOTE: Since all ports of the service requie only Customer Bridge capabilities, the network can support only Customer Bridge functionality, Provide Bridge capabilities are not mandatory.

Figure C.3.2.9: E-LAN Service Example with C-VLAN Tagging

```
"ietf-eth-tran-service:etht-svc": {
  "etht-svc-instances": [
    {
      "etht-svc-name" : "X2_LAN_C2C",
      "etht-svc-type": "ietf-eth-tran-types:mp2mp-svc",
      "etht-svc-end-points" : [
        {
          "etht-svc-end-point-name" : "P1",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P1",
              "access-node-id" : "190.0.2.11",
              "access-ltp-id" : "1"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "101"
          }
        },
        {
          "etht-svc-end-point-name" : "P3",
          "etht-svc-access-points" : [
            {
              "access-point-id" : "P3",
              "access-node-id" : "190.0.2.22",
              "access-ltp-id" : "2"
            }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "101"
          }
        },
        {
          "etht-svc-end-point-name" : "P5",
          "etht-svc-access-points" : [
              {
              "access-point-id" : "P5",
              "access-node-id" : "190.0.2.32",
              "access-ltp-id" : "3"
              }
          ],
          "service-classification-type" : "vlan-classification",
          "outer-tag" : {
            "tag-type" : "classify-c-vlan",
            "vlan-value" : "101"
          }
```


Figure C.3.2.10: Service JSON Code for E-LAN with C-VLAN Tagging

Annex D (informative): AL1 Representation of Multi-Region Domains with VLAN Transparency

D.1 Introduction

As noted in clause 4.3.2.2.3, in the case of VLAN transparency the VIDs cannot be chosen arbitrarily by the MDSC.

Trying to manage such a network as a black box (AL1), in principle requires a trial-and-error approach, which can be very time-consuming and is potentially open to race conditions on a live network.

Nonetheless, the available Ethernet TE topology models allow the relevant information to be shared by the PNC to the MDSC by means of the Connectivity Matrix construct (see clause A.2.3).

The Connectivity Matrix, has a complexity that grows exponentially with the number of eeLTPs. Since the CM is not indexed based on the eeLTPs, it is not possible to retrieve just the relevant part of it via the MPI, which refers to the eeLTPs required by the given service under creation. Therefore, the whole CM is sent over the MPI at every request.

Moreover, the Connectivity Matrix is dynamically changing as services are created and deleted in the network. In principle, the PNC may have to update internally the CM each time a VID is provisioned in the network.

These two factors combined risk increasing the computational load on the PNC and the communication load on the MPI to unacceptable levels.

The following clauses describe how the CM may be used, in case the network complexity and the computational resources allow it for a given network, and for some reason the AL1 abstraction level is to be used in networks with VLAN Transparency.

Efficiency optimization measures are left to the actual implementations, and not discussed here.

D.2 AL1, Full connectivity, VLAN Transparency

In this case, the PNC is controlling one or more homogeneous regions, where the eeLTPs have full connectivity among them, and there is full VLAN transparency. The whole domain can be represented as a single abstract node, but in order for the MDSC to discern which services can be provisioned or not across any couple of eeLTPs, the CM may be provided for the AN. The MDSC has to coordinate the domain's internal VLAN ID addressing space with the external ones.

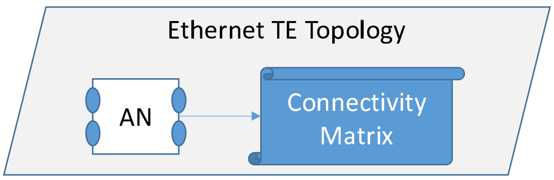


Figure D.2.1: AL1 Ethernet Topology: Full Connectivity, VLAN Transparency

The CM defined in [16] contains for each couple of LTPs the (uni-directional) connectivity (or lack thereof), and any label restrictions. If used, it is subject to the following conditions:

1) It contains at least one couple of entries (one entry per direction of the ethernet connection) for each couple of eeLTPs. These two entries together describe the ethernet connection identified as `id`.

2) The `id` parameter is usually the same for both directions in an ethernet connection.

3) The value of the `label-restrictions` attribute is usually the same for both LTPs and both directions constituting an ethernet connection.

In domains with a large number of eeLTPs, maintaining the full connectivity matrix can put a significant load both computationally and on the MPI bandwidth. Efficiency optimization is left to the actual implementations.

In alternative to the solution described above, the simple model of clause 4.3.2.2.1 may be used, but the MDSC may have to discover the connectivity issues and VLAN ID conflicts by trial and error.

D.3 AL1, Partial Connectivity, VLAN Transparency

In this case, the PNC is controlling more than one homogeneous region, that do not have full connectivity among them, and provide full VLAN transparency. In order for the MDSC to discern which services can be provisioned or not across any couple of eeLTPs, the individual CMs [16] is provided for each homogeneous region. The MDSC has to coordinate the domain's internal VLAN ID addressing space with the external ones.

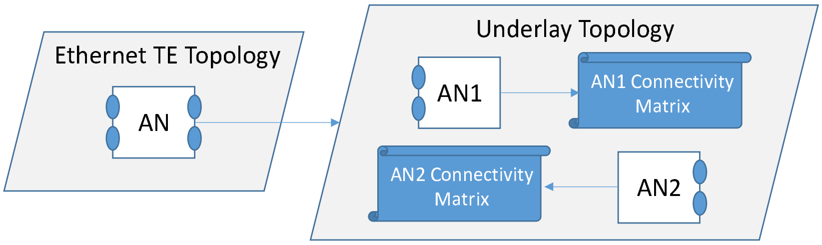


Figure D.1.2.1: AL1 Ethernet Topology: Partial Connectivity, VLAN Transparency

In the example of Figure D.1.2.1, there is no ethernet connectivity among LTPs belonging to AN1 and LTPs belonging to AN2.

If used, the connectivity matrices is usually calculated by the PNC for each ANs of the underlay topology, subject to the following conditions:

1) They contain at least one couple of entries (one entry per direction of the ethernet connection) for each couple of eeLTPs belonging to the underlay AN they refer to. These two entries together describe the ethernet connection identified as `id`.

2) The `id` parameter is usually the same for both directions in an ethernet connection.

3) The value of the `label-restrictions` attribute is usually the same for both LTPs and both directions constituting an ethernet connection.

In alternative to the solution described above, the simple model of clause 4.3.2.2.1 or 4.3.2.2.2 may be used, but the MDSC may have to discover the connectivity issues and VLAN ID conflicts by trial and error.

Annex E (informative): Bibliography

- IETF draft-ietf-teas-actn-yang-08: "Applicability of YANG models for Abstraction and Control of Traffic Engineered Networks".
- MEF 10.4 MEF Standard: "Subscriber Ethernet Service Attributes".
- MEF 11 Technical Specification: "User Network Interface (UNI) Requirements and Framework".
- MEF 10.2 Technical Specification: "Technical Specification MEF 10.2".

History

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