MEF SPECIFICATION
MEF 59

Network Resource Management Information Model: Connectivity

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1 List of Contributing Members

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2 Abstract

This specification describes the MEF Network Resource Management Information Model (NRM IM).

Lifecycle Service Orchestration Reference Architecture (LSO RA, MEF 55 [10]) extends the traditional MEF scope concerning Service Modeling, from a pure view "from outside the network" to cover a range of Operational, Orchestration, and Network Management behaviors, including SDN and NFV paradigms.

In support to MEF 55 [10], NRM IM is then defined to manage the Network Infrastructure, through SDN Controllers, WAN Controllers, OTN Subnetwork Managers, and other legacy Network Management Systems.

The NRM IM structure is based on current and developing best network management solutions by ITU-T, ONF, TM Forum, to allow wider and future proof interoperability across multi-vendor and multi-technology networks. Examples of reference network management solutions are ITU-T G.7711/Y.1702 [12], ONF TR-512 [15], ONF TR-527 [16], TM Forum MTNM [20] and MTOSI [21].

The NRM IM models the management features defined by MEF Service Information Model (MEF 7.3 [4]) in a resource-oriented view, at network level, i.e. potentially spanning more technology domains supporting the service. This model can be used as the basis for LSO RA PRESTO Interface Profiles defining APIs.

This document normatively includes the content of the following Papyrus [18] UML files as if they were contained within this document (pull request #**587,** GitHub Repository [11]):

- NRM_Connectivity.di
- NRM_Connectivity.notation
- NRM_Connectivity.uml

3 Terminology and Acronyms

This section defines the terms used in this document. In those cases where the normative definitions of terms are found in other documents the third column is used to provide the reference that is controlling.

Terms defined in MEF specifications MEF 6.2 [2], MEF 7.3 [4], MEF 10.3 [5], MEF 12.2 [6], MEF 26.2 [7], MEF 45 [8], MEF 55 [10], TMF GB922 [19] are included in this document by reference and, hence, not repeated in the table below, unless when mentioned in local definitions, e.g. ICM.

Term	Definition	Reference
ICM	Infrastructure Control and Management: The set of functionality providing domain specific network and topology view resource management capabilities including configuration, control and supervision of the network infrastructure.	MEF 55 [10]
Internal Network-to-Network Interface (INNI)	A reference point representing the boundary between two networks or network elements that are operated within the same administrative domain. Note: In this specification, the “networks or network elements” refers to those in a given ICM Domain, hence, between two ICM domains.	MEF 4 [1] MEF 55 [10]
NRM IM	Network Resource Management Information Model	This document
Product Instance	Specific implementation of a Product Offering dedicated to the benefit of a party.	TMF GB922 [19]
Product Offering	An externally facing representation of a Service and/or Resource procurable by the Customer.	TMF GB922 [19]

Term	Definition	Reference
Product Specification	The detailed description of product characteristics and behavior used in the definition of Product Offerings.	TMF GB922 [19]
Resource	A physical or non-physical component (or some combination of these) within a Service Provider's infrastructure or inventory.	TMF GB922 [19]
Service	Represents the Customer experience of a Product Instance that has been realized within the Service Provider's and / or Partners' infrastructure.	TMF GB922 [19]
Service Component	A segment or element of a Service that is managed independently by the Service Provider.	MEF 55 [10]
TAPI or T-API	Transport API Information Model	ONF TR-527 [16] ONF TAPI IM [17]
UML	Unified Modeling Language	OMG UML, Infrastructure, Version 2.5

Table 1 - Terminology and Acronyms

4 Scope

The scope of this specification is a protocol neutral definition of the information, i.e., the attributes (or properties), of the network resource management objects including

- Ethernet technology constructs,
- the adaptation of MEF 7.2[1] [3], Q.840.1 [14], G.8052 [13], MEF 12.2 [6] equivalent constructs, plus any additional construct necessary to map equivalent MEF 7.3 [4] Service constructs.

Functional references are MEF 6.2 [2], MEF 10.3 [5], MEF 26.2 [7], MEF 45 [8], MEF 51 [9].

The MEF NRM IM reuses and extends the definitions of the ONF Transport API Information Model (TAPI IM [16], [17]), which is derived from the ONF Core Information Model ([15]).

The ONF Core IM is a common information model for network/transport technologies, evolution of TMF and ITU-T models. It is extensible to new features/functions.

The TAPI model is derived from the ONF Core IM to make this more oriented to an implementation of transport network management interface. It standardizes a single core technology-agnostic model that abstracts common transport network functions.

The TAPI capabilities are extended through the *specification approach*. The essential concept is to associate an instance of a TAPI class with a set of extensions that account for the specific case (*specification class*). These *specification classes* are definitions of specific cases of usage of a class to be extended.

The modeling of capability necessarily involves the modeling of constraints and rules, as a specific capability is always restricted in some way with respect to the maximum possible capability. The ONF Specification approach focusses on model of constrained capability.

Clearly a UML class model provides a definition of capability in terms of things that can be created and values that can be set. However, the full ONF Core IM and TAPI go way beyond the capability of any real solution. It is therefore necessary for any particular solution to be able to state its specific capabilities. The term used by ONF for the modeling of capabilities is "Capability Specification" or "Specification" or "Spec" for short.

See TR-512.7 Specification Model [15], “2.2 Rationale for, and features of, the ONF Specification approach”.

[1] Note that MEF 7.2 has been superseded by MEF 7.3. It is referenced because it includes “resource oriented” management features.

The MEF NRM IM is designed around a set of *specification classes* which extends, or augments, TAPI classes. See Figure 1 below.

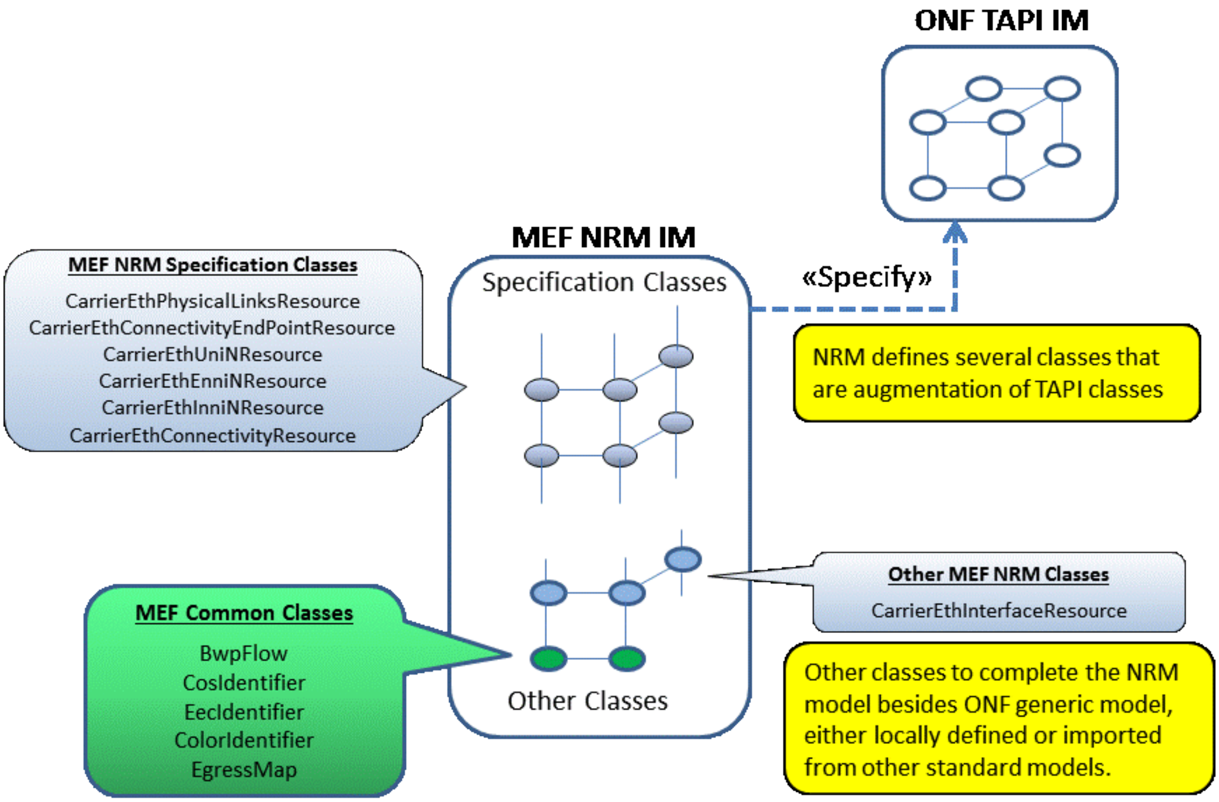


Figure 1 - MEF NRM extending ONF TAPI

While the NRM IM classes are designed to augment selected TAPI classes, the formal augmentation is specified in interface specific models, which are described by Interface Profile Specifications.

The MEF NRM IM classes are applicable to PRESTO Interface Reference Point (MEF 55 [10]), see Figure 2 below.

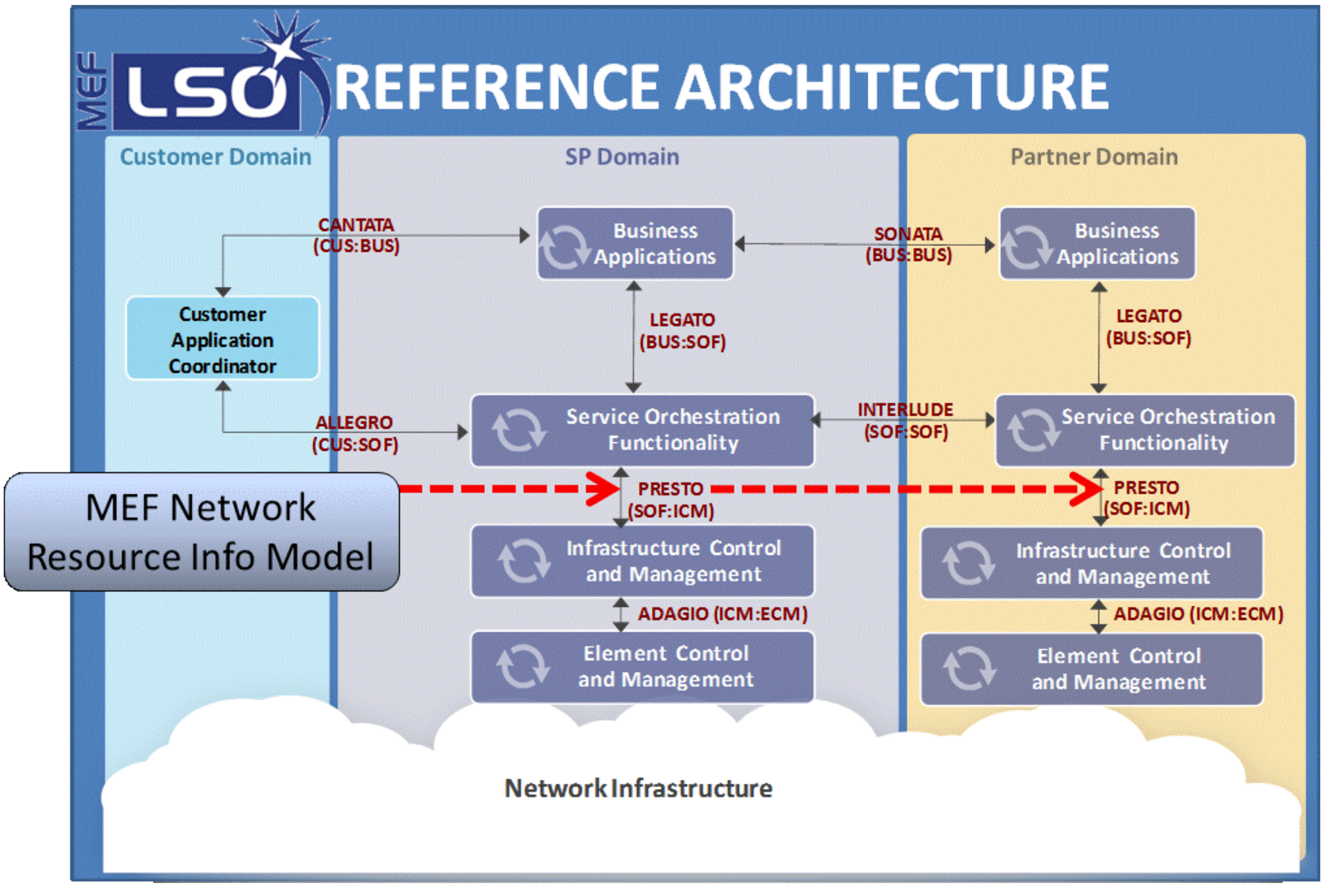


Figure 2 - MEF NRM positioning in LSO RA

The definition of MEF NRM IM is necessary to ensure both:

- LSO RA internal consistency. All MEF models will use applicable model elements from the NRM IM.
- LSO RA external consistency. This enables the LSO RA to interface with standard network management models, such as those from the ITU-T and the ONF.
  This will allow the LSO RA to be used with managed, multi-vendor, multi-technology network infrastructures.

This specification includes Carrier Ethernet connectivity resource management features, identified as the set of management features supported by MEF 7.3 ([4]) at service level.

MEF 7.3 features not included in this specification are:

- Virtual UNI model
- Performance Monitoring.

Some of the UML diagrams are very dense. To view them either zoom (sometimes to 400%) or open the corresponding UML diagram via Papyrus [18] (for each figure with a UML diagram the UML model diagram name is provided under the figure in *italic* font).

5 Introduction

The following sections of this document include:

- The description of the ONF Specification approach (6)
- The Papyrus [18] UML constructs used in this specification (7)
- The overview of NRM IM classes (8)
- The list of all defined object classes and their attributes for:
    - Carrier Ethernet External and Internal Interfaces (9.1)
    - Carrier Ethernet ConnectivityEnd Point (9.2)
    - Carrier Ethernet Connectivity (9.3)
- The definitions of types and enumerations (10)
- The imported classes (11) and types (12)
- References (13)
- Appendix A lists the relevant network scenarios
- Appendix B presents some mechanisms to extend the definition of a class
- Appendix C presents an overview of the MEF 7.3 [4] to NRM IM mapping choices
- Appendix D provides a mapping table of the NRM IM classes to analogous classes defined by other relevant SDOs

6 Specification Approach Overview

6.1 Motivation

Both Core IM [15] and TAPI [17] models are designed to be inherently invariant with respect to:

- networking technologies and their evolutions,
- vendor specific extensions (e.g. new features not yet standardized anywhere) and/or variations (e.g. specific optimized solutions).

To supply a usable management model, the technology specific models (e.g. Ethernet, OTN, MPLS-TP) and the possible vendor extensions must be “plugged into” TAPI model.

UML provides inheritance and composition associations to augment a class definition, but both mechanisms require that the entire schema is coded prior to compile. In other words, every time e.g. ITU-T defines a new attribute of ODU CTP, then the whole model (generic and specific parts) shall be necessarily modified and recompiled. This is costly, for the delivery time, the backward compatibility management, the massive update of software in the network, etc.

So far, a common solution was to replace UML inheritance and composition by the “additional info” or “name-value pairs” paradigm, i.e. untyped attributes where to model the specific standard items (e.g. IEEE Ethernet parameters) and the vendor specific extensions. This approach supplied a reasonable compromise between the conflicting requirements of flexibility and interoperability. For example, the new attribute of ODU CTP is simply documented in natural language as a name-value pair. See Appendix B for some examples of extension mechanisms.

This compromise is no longer sustainable given the increasing flexibility and softwarization that is required to modern networks. In fact, the limits of this approach are that:

- Relevant if not most part of the model is not machine interpretable (e.g. all the ODU or Ethernet specific attributes, together with all vendor extensions). These specific modeling items shall be (manually) added later in the software production stages.
- Manual work is necessary to create and maintain the natural language definitions of extensions, even if such extensions are originally defined in UML by reference SDOs. As technology specific models are developed by different SDOs, in different times and with different paces, the alignment effort is excessive.

The two items above cause additional costs specially in new product introduction, migration, etc. It is then necessary to increase the degree of modeling softwarization: ONF proposed solution is called “specification approach” [2].

The specification approach provides both the flexibility of “additional info” pattern and the rigors of UML definitions.

The essential approach is to define “specification classes” which are associated to the classes they refine. One key distinction with UML composition association is the class definition is never aware of any augmenting specification class. So the core model and the specific model can be decoupled till to run time stage, like using “additional info”, but with the “additional info” being described in UML. This is a basis for the realization of model federation.

Note that specification classes must be leaves of the inheritance hierarchy.

[2] “specification approach” or “specification pattern”, but this last expression can be confused with other existing specification patterns.

6.2 Definition

A specification class is a specialized construct, originally used in the ONF TAPI [17], to insert the attributes of one class into a second class. For example, this enables vendor-specific parameters to be added to standard data models in an interoperable way.

The following is a simple example, showing that the attributes of the CarrierEthConnectivityResource class are inserted into a ConnectivityService class.

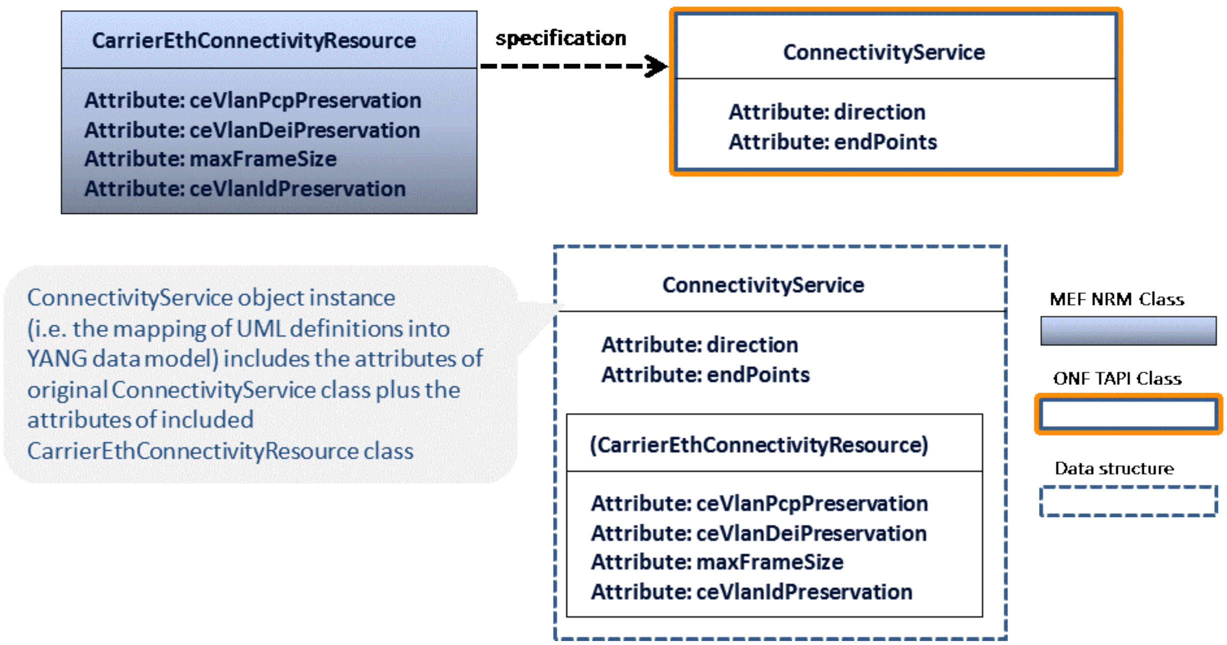


Figure 3 - Example of ONF *specification* extension

Note: the symbology used is that of a UML dependency. Indeed, in this example, CarrierEthConnectivityResource requires ConnectivityService to complete its definition. However, the motivation for using this construct is to more easily build YANG [22] data models. Hence, the resulting data structure desired is a YANG view, which means that the attributes of CarrierEthConnectivityResource are actually contained in the ConnectivityService class. (In UML, you would have CarrierEthConnectivityResource associated to a ConnectivityService).

7 Usage of Papyrus Modeling Environment

In the following subsections, object classes are represented in figures as a box with a name compartment and an attributes compartment (Figure 4). The name compartment also shows stereotype for the class «OpenModelClass».

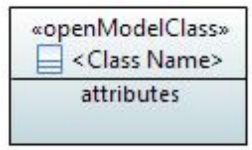


Figure 4 - Graphical Notations for Object Classes

Papyrus [18] defines the following object class properties:

- IsAbstract - Indicates if the object class can be instantiated or is just used for inheritance. This property is described for each class in this document.
- Is leaf - This property is not used in this document.
- Is active - This property is not used in this document.
- Visibility - This property is not used in this document
- In addition, the OpenModelClass stereotype [17] defines the following Open Model specific enhancements for data object classes, always fixed to specified default in this document:
    - support - This property qualifies the support of the object class at the management interface. Default is "MANDATORY"
    - condition - This attribute contains the condition for the condition-related support properties. Default is "empty".

Papyrus [18] defines the following attribute properties, used in this document:

- Is read only - If true, the attribute may only be read, and not changed by the client. The default value is false. It is listed in the object class attribute tables in this document.
- Type - This property provides the type definition of the attribute. It is listed in the object class attribute tables in this document.

- Multiplicity - This property defines the number of values the attribute can simultaneously have. * is a list attribute with 0, one or multiple values. It is listed in the object class attribute tables in this document.

- Default value - This property provides the value that the attribute has to start with in case the value is not provided during creation, or already defined because of a system state. In cases where a default value makes no sense, it is undefined. It is listed in the object class attribute tables in this document.

- Aggregation - This property specifies the type of the association when the attribute is from an association. It is shown in the associations in the class diagram figures.

- Is derived - fixed to default value “is false”.

- Is derived union - fixed to default value “is false”.

- Is leaf - fixed to default value “is false”.

- Is ordered - For a multi-valued multiplicity; this specifies whether the values in an instantiation of this attribute are sequentially ordered; fixed to default value “is false”.

- Is static - fixed to default value “is false”.

- In addition, the OpenModelAttribute stereotype [17] defines the following Open Model specific enhancements for attributes, always fixed to specified default in this document:

    - partOfObjectKey - This property indicates if the attribute is part of the object key or not. It is not listed in the object class tables in this document. Default is “0” (no part of object key). In this specification, there are no object key attributes because the defined classes augment the TAPI classes, which have their object key attributes. Similarly, for referenced MEF Common classes.

    - uniqueSet - This property defines if the attribute is part of a set of attributes which together (i.e., their values) have to be unique among all instances within a defined context. No value means no uniqueness constraint. Default is “no value”.

    - isInvariant - This property defines at which time the attribute can be set, true = attribute can only be set at creation time; false = attribute can be set at any time. Default is “false”.

    - valueRange - This property provides the restriction on the attribute values. Default is “empty”, i.e. no restrictions.

    - unsigned - This optional property indicates if the attribute type is unsigned (value = true) or signed (value = false); if applicable, otherwise ignored. Default is “false”.

- counter - This optional property defines the counter type of the attribute type; if applicable. Default is “NA” (Not Applicable).

- unit - This optional property contains a textual definition of the unit associated with the attribute value. The spelling of the unit (not only SI units) shall be in accordance to the NIST Publication 811 “Guide for the Use of the International System of Units (SI)” (http://www.nist.gov/pml/pubs/sp811/index.cfm), section 9 “Rules and Style Conventions for Spelling Unit Names”. Default is “empty”.

- support - This property qualifies the support of the attribute at the management interface. Default is “MANDATORY”.

- condition - This attribute contains the condition for the condition-related support properties. Default is “empty”.

- In addition, the Reference stereotype [17] defines the following Open Model specific enhancement for attributes:

    - reference - This attribute contains the reference upon which the UML artefact is based. A reference to a standard is preferred.

In the following sections, the attribute tables list all the attributes defined for that class, including the attributes generated from the associations (attribute names start with “_”). Note that some of these association attributes are not shown in the diagrams, while correctly listed in the tables. This is an anomaly of used version of Papyrus [18].

The inherited attributes are not listed, neither in tables nor in diagrams.

8 Network Resource Information Model Overview

Figure 5 shows how NRM IM classes augment the ONF TAPI classes:

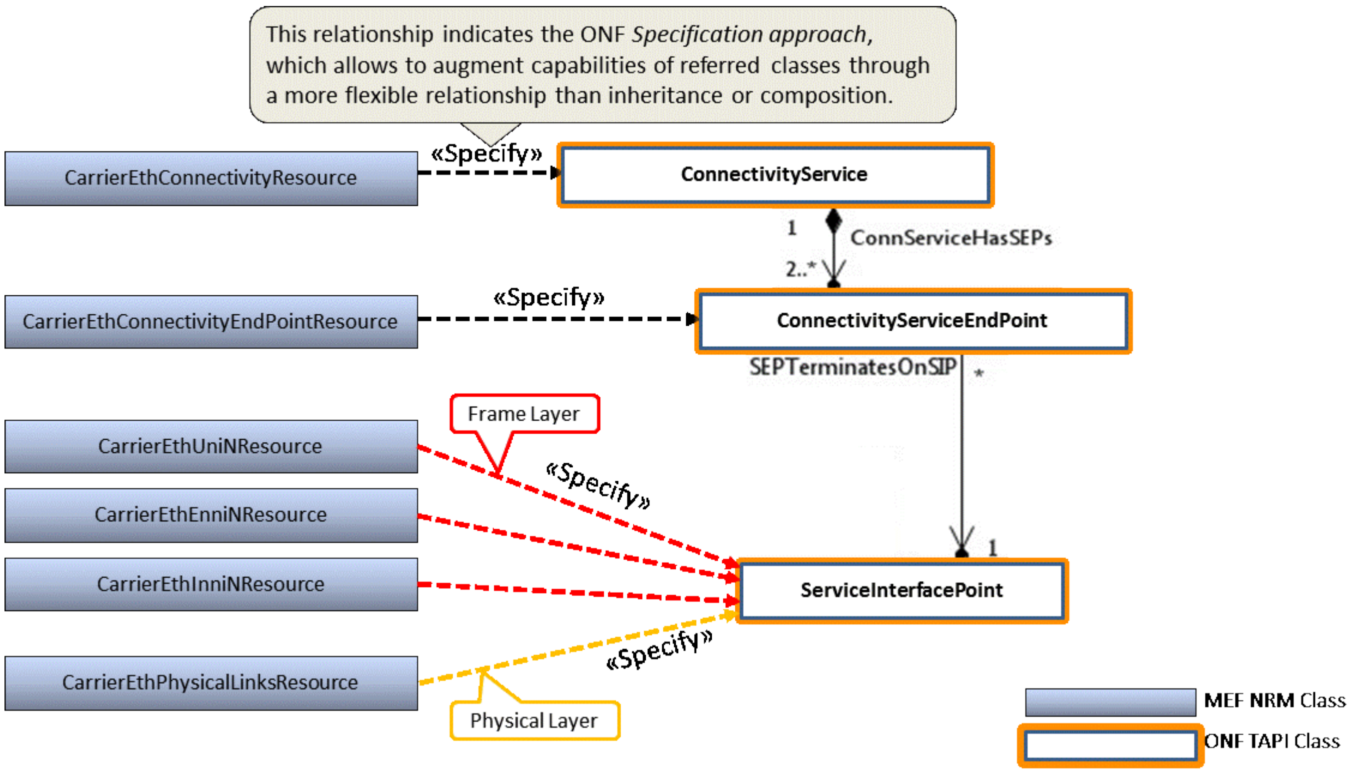


Figure 5 - Overall relationship between MEF NRM IM and ONF TAPI

- The **CarrierEthConnectivityResource** represents the Ethernet end to end connectivity at resource level. It may represent an original EVC, OVC, or Service Component. It augments the TAPI **ConnectivityService** class, which represents the request for connectivity between two or more TAPI **ConnectivityServiceEndPoint**. More detailed connection and routing information are modeled by different constructs of TAPI.

- The **CarrierEthConnectivityEndPointResource** class models the service end point. It augments the TAPI **ConnectivityServiceEndPoint**.

  The relationship between **CarrierEthConnectivityResource** and its **CarrierEthConnectivityEndPointResource** is modeled through the relationship between **ConnectivityService** and **ConnectivityServiceEndPoint** of TAPI model.

- The **CarrierEthUniNResource**, **CarrierEthEnniNResource** and **CarrierEthInniNResource** classes represent respectively UNI-N, ENNI-N and INNI-N management functions, related to the Ethernet frame layer, while the **CarrierEthPhysicalLinksResource** class represents the Network Interface management functions related to the Ethernet physical layer, i.e. the set of one or more physical links supporting the Ethernet interface.

- The TAPI **ServiceInterfacePoint** class represents the outward-facing aspect of the edge-port functions for accessing the forwarding capabilities provided by the network. It provides a limited, simplified view of interest to external clients (e.g. client addressing, capacity, resource availability, etc.), that enables the clients to make a connectivity service request without the need to understand the provider network internals.
  The TAPI **ServiceInterfacePoint** class can be augmented by the following couples:

  - UNI-N: **CarrierEthUniNResource** plus **CarrierEthPhysicalLinksResource**
  - ENNI-N: **CarrierEthEnniNResource** plus **CarrierEthPhysicalLinksResource**
  - INNI-N: **CarrierEthInniNResource** plus **CarrierEthPhysicalLinksResource**

- The **CarrierEthInterfaceResource** class, not shown in Figure 5 as it does not augment any TAPI class, contains common attributes for Carrier Ethernet External and Internal interfaces, and is the common parent class of **CarrierEthUniNResource**, **CarrierEthEnniNResource** and **CarrierEthInniNResource** classes.

  The relationship between **CarrierEthPhysicalLinksResource** plus **CarrierEthInterfaceResource** and the client(s) **CarrierEthConnectivityEndPointResource** is modeled through the relationship between **ServiceInterfacePoint** and **ConnectivityServiceEndPoint** of TAPI model.

The MEF modeling constructs eligible for common reuse have been copied from original MEF models in a centralized "MEF Common IM" [11]. This includes several MEF 7.3 [4] definitions, which have been reused in NRM model.

9 Network Resource Information Model Classes

9.1 Carrier Ethernet External and Internal Interfaces

The following diagram illustrates the NRM IM *specification classes* representing UNI-N, ENNI-N and INNI-N at resource level, with their attributes and associations with other object classes.

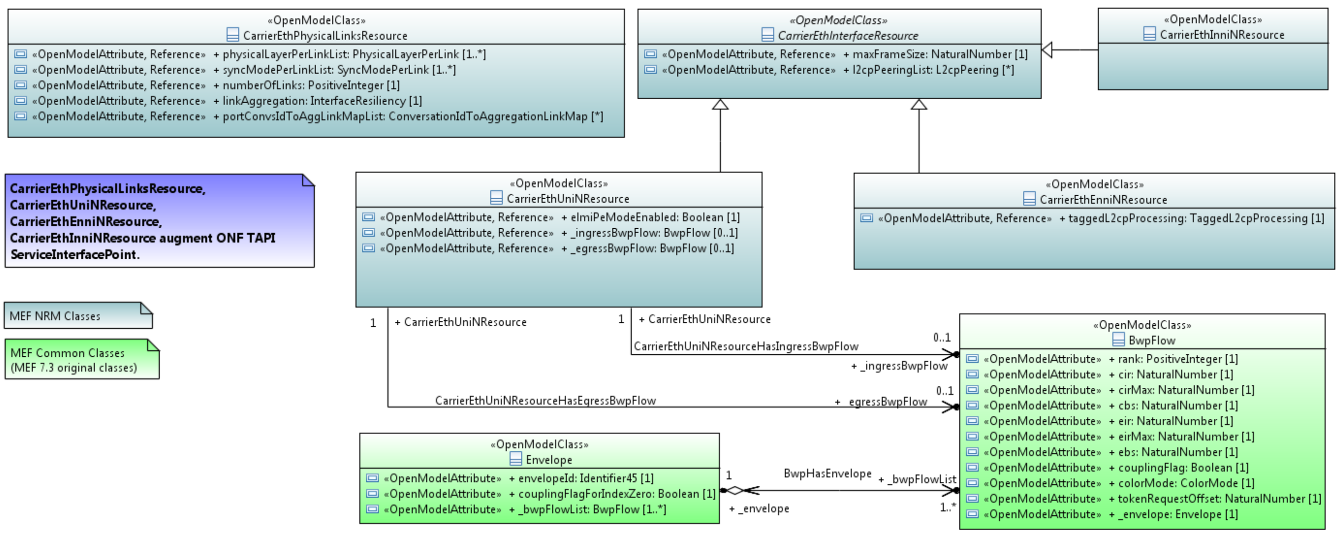


Figure 6 - *Service Interface Points* Diagram

9.1.1 CarrierEthPhysicalLinksResource attributes

This class represents the set of one or more physical links supporting the Ethernet interface. This allows a proper extension of TAPI Service Interface Point at Ethernet physical layer, while maintaining 7.3 features.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
physicalLayerPerLinkList	PhysicalLayerPerLink		1..*	R	Reference • MEF 10.3 section 9.2 and MEF 26.2 section 14.2	This attribute is a list of physical layers, one for each physical link implementing the UNI or ENNI or INNI. Different physical links can use different physical layers. The Physical Layer for each physical link implementing the UNI or ENNI or INNI MUST be one of the PHYs listed in IEEE Std 802.3 – 2012 but excluding 1000BASE-PX-D and 1000BASE-PX-U.
syncModePerLinkList	SyncModePerLink		1..*	RW	Reference • MEF 10.3 section 9.3 and MEF 26.2 section 14.3	This attribute is a list with one item for each of the physical links. When the value of an item is "Enabled," the bits transmitted from the CEN to the CE on the physical link corresponding to the item can be used by the CE as a bit clock reference.
numberOfLinks	PositiveInteger		1	R	Reference • MEF 10.3 section 9.4 and MEF 26.2 section 14.4	This attribute specifies the number of links at the Carrier Ethernet Interface (UNI or ENNI or INNI).
linkAggregation	InterfaceResiliency		1	RW	Reference • MEF 10.3.2 (UNI Resiliency) and MEF 26.2 section 14.5	This attribute represents the Link Aggregation for a UNI or an ENNI or an INNI.
portConvsIdToAggLinkMapList	ConversationIdToAggregationLinkMap		0..*	RW	Reference • MEF 10.3.2 and MEF 26.2 section 14.6	This attribute is applicable only when the UNI or ENNI or INNI resiliency attribute has the value of ALL_ACTIVE. Its value is a Port Conversation ID to Aggregation Link Map as defined in IEEE Std 802.1AX – 2014.

Table 2 - Attributes of CarrierEthPhysicalLinksResource Class

9.1.2 CarrierEthInterfaceResource attributes

This class contains common attributes for Carrier Ethernet External and Internal interfaces.

Is abstract: true

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
maxFrameSize	Natural-Number		1	R	Reference • MEF 10.3 section 9.7 and MEF 26.2 section 14.8, table 54	This value indicates the maximum length of frames supported by this Interface.
l2cpPeeringList	L2cpPeering		0..*	RW	Reference • MEF 26.2 section 10.1, 14.21 and MEF 45 section 8.2	This attribute represents the L2CP Peering Service defined in MEF 45 section 8.2 when applied to the UNI/ENNI/INNI.

Table 3 - Attributes of CarrierEthInterfaceResource Class

9.1.3 CarrierEthUniNResource attributes

This class represents UNI-N management function. It augments the TAPI ServiceInterfacePoint class at the Ethernet frame layer.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
elmiPeModeEnabled	Boolean		1	RW	Reference • MEF 10.3 section 9.18	This attribute denotes whether the ELMI is enabled or not. When the value is TRUE, the CEN MUST meet the mandatory requirements in MEF 16 that apply to the UNI-N. Note: Ethernel Local Management Interface protocol contents are defined which clearly identify MEF Service/Resource constructs like UNI and EVC, hence the attribute cannot be placed in an ethernet generic class.
_ingressBwpFlow	BwpFlow		0..1	RW	Reference • MEF 10.3 section 9.14 and MEF 26.2 section 14.12	This attribute represents the relationship between the UNI-N and the ingress BwpFlow.
_egressBwpFlow	BwpFlow		0..1	RW	Reference • MEF 10.3 section 9.15 and MEF 26.2 section 14.13	This attribute represents the relationship between the UNI-N and the egress BwpFlow.

Table 4 - Attributes of CarrierEthUniNResource Class

9.1.4 CarrierEthEnniNResource attributes

This class represents ENNI-N management function. It augments the TAPI ServiceInterfacePoint class at the Ethernet frame layer.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
taggedL2cpProcessing	TaggedL2cpProcessing		1	RW	Reference • MEF 26.2 section 10.2 and MEF 45 section 8.3	This attribute represents the Tagged L2CP Processing defined in MEF 45 section 8.3 (IEEE 802.1 compliant or 802.1 non-compliant. Desired to be 802.1 compliant). It is one of the ENNI Operator Multi-lateral attributes, which requires the CENs at the ENNI-N to agree on the values but may allow these values to be different.

Table 5 - Attributes of CarrierEthEnniNResource Class

9.1.5 CarrierEthInniNResource attributes

This class represents INNI-N management function. It augments the TAPI ServiceInterfacePoint class at the Ethernet frame layer.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

No attributes defined.

9.2 Carrier Ethernet Connectivity End Point Resource

The following diagram illustrates the NRM IM *specification class* representing EVC, OVC and Service Component end points at resource level, with its attributes and associations with other object classes.

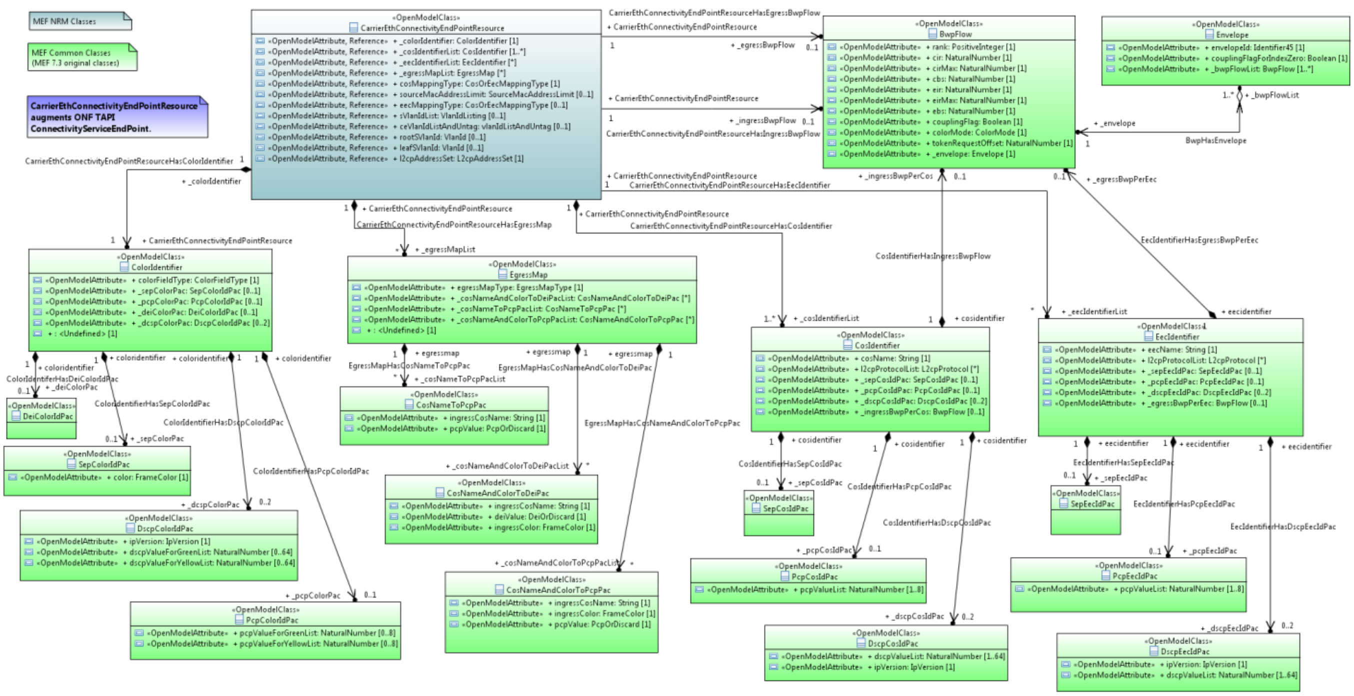


Figure 7 - *Connectivity Service End Point* Diagram

9.2.1 CarrierEthConnectivityEndPointResource attributes

This class models the Carrier Ethernet Connectivity Service End Point. It augments the TAPI ConnectivityServiceEndPoint.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
cosMappingType	CosOrEecMappingType		1	RW	Reference • MEF 10.3 section 10.2 and MEF 26.2 section 16.6	The Class of Service (CoS) is used to specify ingress Bandwidth Profiles. The CoS Mapping Type is one of SEP (Service End Point) based, PCP based or DSCP based.
sourceMacAddressLimit	SourceMacAddressLimit		0..1	RW	Reference • MEF 10.3 section 10.9 and MEF 26.2 section 16.15	This attribute limits the number of source MAC Addresses that can be used in ingress EI Frames mapped to the Connectivity Service End Point of all types over a time interval. When not present, the number of source MAC addresses is unlimited. Two independent parameters control the behavior of this attribute: N : A positive integer and t : A time interval. This attribute operates by maintaining a list of maximum length N of source MAC addresses which are aged-out of the list if not seen in a time interval t. If an ingress Service Frame arrives with a new source MAC address when the list is full, the Service Frame is discarded.
eecMappingType	CosOrEecMappingType		0..1	RW	Reference • MEF 10.3 section 10.4 and MEF 26.2 section 16.9	The Egress Equivalence Class (EEC) is used to specify Egress Bandwidth Profiles. The EEC Mapping Type is one of SEP (Service End Point) based, PCP based or DSCP based. When the list of EEC Identifier is empty, this attribute shall be unset. Otherwise it shall be set.
_colorIdentifier	ColorIdentifier		1	RW	Reference • MEF 10.3 section 10.3 and MEF 26.2 section 16.7	This attribute represents the relationship between the Connectivity Service End Point and a Color Identifier.

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
sVlanIdList	VlanIdListing		0..1	RW	Reference • MEF 26.2 section 16.5.1	List of one or more S-VLAN ID values. An S-Tagged Frame, whose S-VLAN ID value matches an entry in this attribute, maps to the Connectivity Service End Point. Type=LIST: all listed VLAN IDs. Type=EXCEPT: all VLAN IDs except the listed ones. Type=ALL, all VLAN IDs, hence vlanId list is not applicable.
ceVlanIdListAndUntag	vlanIdListAndUntag		0..1	RW	Reference • MEF 10.3 section 9.10 and MEF 26.2 section 16.5.4	List of one or more C-VLAN ID values. A C-Tagged Frame, whose C-VLAN ID value matches an entry in this attribute, maps to the Connectivity Service End Point. It is possible to specify whether untagged and priority tagged frames are included in the mapping. Type=LIST: all listed VLAN IDs. Type=EXCEPT: all VLAN IDs except the listed ones. Type=ALL, all VLAN IDs, hence vlanId list is not applicable.
rootSVlanId	VlanId		0..1	RW	Reference • MEF 26.2 section 16.5.2	This attribute applies only to End Points with Trunk End Point Role. It identifies the S-VLAN ID of frames mapped to either a Root End Point or a Trunk End Point (via the Root S-VLAN ID value) of the Connectivity Service.
leafSVlanId	VlanId		0..1	RW	Reference • MEF 26.2 section 16.5.2	This attribute applies only to End Points with Trunk End Point Role. It identifies the S-VLAN ID of frames mapped to either a Leaf End Point or a Trunk End Point (via the Leaf S-VLAN ID value) of the Connectivity Service.
_cosIdentifierList	CosIdentifier		1..*	RW	Reference • MEF 10.3 section 10.2 and MEF 26.2 section 16.6	This attribute represents the relationship between the Connectivity Service End Point and the Class of Service Identifier(s).
_eecIdentifierList	EecIdentifier		0..*	RW	Reference • MEF 10.3 section 10.4 and MEF 26.2 section 16.9	This attribute represents the relationship between the Connectivity Service End Point and the Egress Equivalence Class Identifier(s).

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
_egressMapList	EgressMap		0..*	RW	Reference • MEF 26.2 section 16.8	This attribute represents the relationship between the End Point and the Egress Map(s). This attribute is a set of mappings that determine the content of the S-Tag or C-Tag of an egress EI Frame.
l2cpAddressSet	L2cpAddressSet		1	RW	Reference • MEF 26.2 section 12.16 and MEF 45 section 8.1	This attribute specifies the subset of the Bridge Reserved Addresses that are filtered (i.e. L2CP Frames with this destination address are Peered or Discarded but not Passed) at a L2CP Decision Point.
_egressBwpFlow	BwpFlow		0..1	RW	Reference • MEF 10.3 section 12 and MEF 26.2 section 13	This attribute denotes the relationship between a Connectivity Service End Point and the bandwidth profile flow. It describes egress policing on all egress EI Frames mapped to a given End Point.
_ingressBwpFlow	BwpFlow		0..1	RW	Reference • MEF 10.3 section 12 and MEF 26.2 section 13	This attribute denotes the relationship between a Connectivity Service End Point and the bandwidth profile flow. It describes ingress policing on all ingress EI Frames mapped to a given End Point.

Table 6 - Attributes of CarrierEthConnectivityEndPointResource Class

9.3 Carrier Ethernet Connectivity Resource

The following diagram illustrates the NRM IM *specification class* representing EVC, OVC and Service Component at resource level, with its attributes and associations with other object classes.

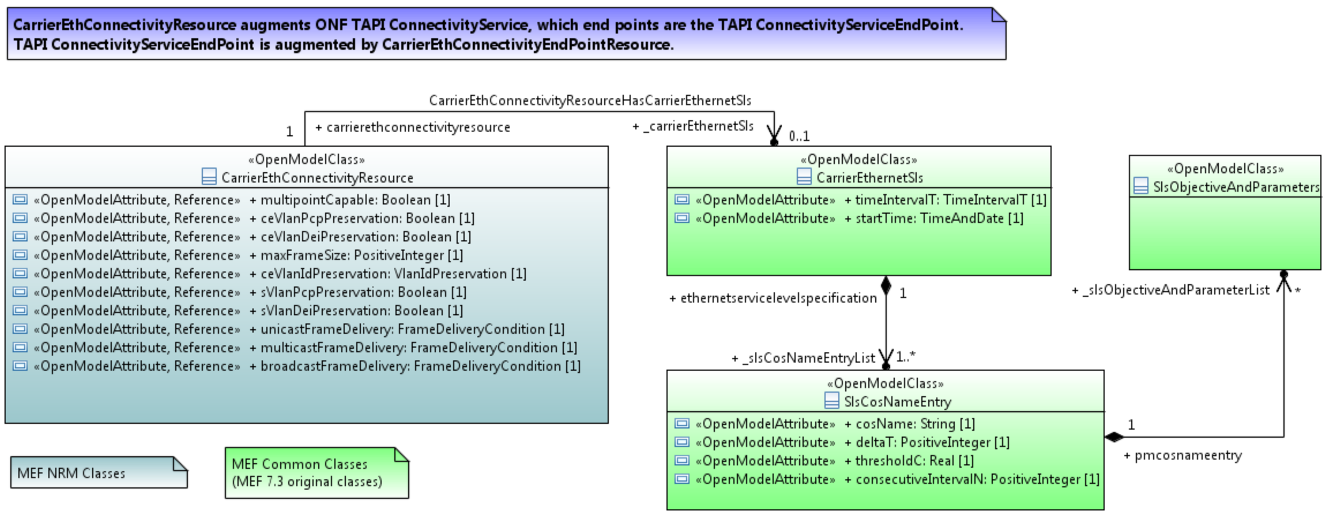


Figure 8 - *Connectivity Service* Diagram

9.3.1 CarrierEthConnectivityResource attributes

This class represents the Ethernet end to end connectivity at resource level. It may map an original EVC, OVC, or Service Component. It augments the TAPI ConnectivityService class, which represents the request for connectivity between two or more ConnectivityServiceEndPoint.

Is abstract: false

Applied stereotypes:

- OpenModelClass
  - support: MANDATORY

Attribute Name	Type	Default	Multiplicity	Access	Stereotypes	Description
multipointCapable	Boolean		1	RW	Reference • MEF NRM	A value of "true" indicates that the End Points can be added/removed during Connectivity Service lifecycle.
ceVlanPcpPreservation	Boolean		1	RW	Reference • MEF 10.3 section 8.6.2 and MEF 26.2 section 12.8	This attribute can be used to preserve the value of the CE-VLAN PCP field in VLAN Tagged Service Frames across a Connectivity Service.
ceVlanDeiPreservation	Boolean		1	RW	Reference • MEF 26.2 section 12.9	This attribute can be used to preserve the value of the CE-VLAN DEI field in VLAN Tagged Service Frames across a Connectivity Service.
maxFrameSize	PositiveInteger		1	RW	Reference • MEF 10.3 section 8.9 and MEF 26.2 section 12.6	This attribute denotes the maximum frame size in bytes requested for the connectivity service.
ceVlanIdPreservation	VlanIdPreservation		1	RW	Reference • MEF 10.3 section 8.6.1 and MEF 26.2 section 12.7	This attribute describes a relationship between the format of the VLAN ID and related fields values of the frame at one Interface and the format and VLAN ID and related fields values of the corresponding frame at another Interface. Used the MEF 7.3 OVC type (PRESERVE/STRIP/RETAIN) as it depends on EVC/OVC decomposition performed by SOFs.

Attribute Name	Type	Default	Multi-plicity	Ac-cess	Stereotypes	Description
sVlanPcpPreservation	Boolean		1	RW	Reference • MEF 26.2 section 12.10	This attribute describes a relationship between the S-VLAN PCP value of a frame at one ENNI and the S-VLAN PCP of the corresponding frame at another ENNI supported by the Operator CEN where each ENNI has a Connectivity Service End Point that is associated by the Connectivity Service.
sVlanDeiPreservation	Boolean		1	RW	Reference • MEF 26.2 section 12.11	This attribute describes a relationship between the S-VLAN DEI value of a frame at one ENNI and the S-VLAN DEI of the corresponding frame at another ENNI supported by the Operator CEN where each ENNI has a Connectivity Service End Point that is associated by the Connectivity Service.
unicastFrameDelivery	FrameDeliveryCondition	UNCONDITIONALLY	1	RW	Reference • MEF 10.3 section 8.5 and MEF 26.2 section 12.13	When the value is conditionally, the conditions that determine whether a Data Service Frame is delivered or discarded MUST be specified. Conditions can be described in the name-value pair list.
multicastFrameDelivery	FrameDeliveryCondition	UNCONDITIONALLY	1	RW	Reference • MEF 10.3 section 8.5 and MEF 26.2 section 12.13	When the value is conditionally, the conditions that determine whether a Data Service Frame is delivered or discarded MUST be specified. Conditions can be described in the name-value pair list.
broadcastFrameDelivery	FrameDeliveryCondition	UNCONDITIONALLY	1	RW	Reference • MEF 10.3 section 8.5 and MEF 26.2 section 12.13	When the value is conditionally, the conditions that determine whether a Data Service Frame is delivered or discarded MUST be specified. Conditions can be described in the name-value pair list.
_carrierEthernetSls	CarrierEthernetSls		0..1	RW	Reference • MEF10.3 section 8.8 and MEF 26.2 section 12.13	This attribute presents the relationship between a Connectivity Service and a service level specification.

Table 7 - Attributes of CarrierEthConnectivityResource Class

10 Network Resource Information Model Type Definitions

10.1 Data Types

The following data types are locally defined by NRM, i.e. are not imported from any other model.

10.1.1 FrameDeliveryCondition type

This type allows to specify conditions when the delivery type is conditionally.

Attribute Name	Type	Multiplicity	Properties	Description
action	DeliveryActionType	1		Data Service Frame disposition.
deliveryCondition	NameAndValue	0..*		When the value is conditionally, the conditions that determine whether a Data Service Frame is delivered or discarded MUST be specified. Conditions can be described in the name-value pair list, where name is used to represent the condition name or identifier, and value is used to represent the condition details associated to that name/identifier. Interoperability requires further standardization.

Table 8 - FrameDeliveryCondition Data Type

10.1.2 vlanIdListAndUntag type

This type allows to specify the list of one or more C-VLAN ID values, to be considered according to the mapping type. In addition, it is possible to specify whether untagged and priority tagged frames are included in the mapping.

Attribute Name	Type	Multiplicity	Properties	Description
vlanIdMappingType	VlanIdMappingType	1		Type=LIST: all listed VLAN IDs. Type=EXCEPT: all VLAN IDs except the listed ones. Type=ALL, all VLAN IDs, hence vlanId list is not applicable.
untaggedAndPrioTagged-Included	Boolean	1		If true, then untagged and priority tagged frames are included in the mapping, otherwise not.
vlanId	VlanId	0..*		This is for VLAN ID from 1 to 4094

Table 9 - vlanIdListAndUntag Data Type

10.2 Enumerations

The following enumeration is locally defined by NRM, i.e. is not imported from any other model.

10.2.1 DeliveryActionType type

- DISCARD
- CONDITIONALLY
- UNCONDITIONALLY

11 Imported Classes

The list of classes imported from MEF_Common model:

- BwpFlow
- CarrierEthernetSls
- ColorIdentifier
- CosIdentifier
- CosNameAndColorToDeiPac
- CosNameAndColorToPcpPac
- CosNameToPcpPac
- DeiColorIdPac
- DscpColorIdPac
- DscpCosIdPac
- DscpEecIdPac
- EecIdentifier
- EgressMap
- Envelope
- PcpColorIdPac
- PcpCosIdPac
- PcpEecIdPac
- SepColorIdPac
- SepCosIdPac
- SepEecIdPac
- SlsCosNameEntry

- SlsObjectiveAndParameters

12 Imported Type Definitions

The list of data types imported from MEF_Types model:

- ConversationIdToAggregationLinkMap
- L2cpPeering
- L2cpProtocol
- NaturalNumber
- PhysicalLayerPerLink
- PositiveInteger
- SourceMacAddressLimit
- SyncModePerLink
- VlanId
- VlanIdListing

Note: “NameAndValue” is imported from TAPI model.

The list of enumerations imported from MEF_Types model:

- CosOrEecMappingType
- FrameDelivery
- InterfaceResiliency
- L2cpAddressSet
- L2cpProtocolType
- PhysicalLayer
- TaggedL2cpProcessing
- VlanIdMappingType
- VlanIdPreservation

13 References

[1] MEF Technical Specification MEF 4, *Metro Ethernet Network Architecture Framework - Part 1: Generic Framework*, 2004

[2] MEF Technical Specification MEF 6.2, *Ethernet Services Definitions - Phase 3*, 2014

[3] MEF Technical Specification MEF 7.2, *Carrier Ethernet Management Information Model*, 2013

[4] MEF Technical Specification MEF 7.3, *Carrier Ethernet Services Management Information Model*, 2016

[5] MEF Technical Specification MEF 10.3, *Ethernet Services Attributes Phase 3*, 2013.

[6] MEF Technical Specification MEF 12.2, *Carrier Ethernet Network Architecture Framework Part 2: Ethernet Services Layer*, 2014.

[7] MEF Technical Specification MEF 26.2, *External Network Network Interfaces (ENNI) and Operator Service Attributes*, 2016

[8] MEF Technical Specification MEF 45, *Multi-CEN L2CP*, August 2014

[9] Technical Specification MEF 51, *OVC Services Definitions*, August 2015

[10] MEF Service Operation Specification MEF 55, *Lifecycle Service Orchestration Reference Architecture and Framework*, 2016

[11] MEF Info Model GitHub repository: "https://github.com/MEF-GIT/MEF-Common-Model"

[12] ITU-T G.7711/Y.1702 Generic protocol-neutral information model for transport resources, December 2016

[13] ITU-T G.8052/Y.1346 *Protocol-neutral management information model for the Ethernet transport capable network element*, November 2016

[14] ITU-T Q.840.1 *Requirements and analysis for NMS-EMS management interface of Ethernet over Transport and Metro Ethernet Network*, March 2007

[15] ONF TR-512 Core Information Model, Version 1.3, September 28, 2017

[16] ONF TR-527 Functional Requirements for Transport API, June 10, 2016

[17] ONF Transport API (TAPI) Information Model, RC2 version of SDK 2.0.0 - "http://opensourcesdn.org/projects/project-snowmass/github.com/OpenNetworking-Foundation/Snowmass-ONFOpenTransport", September 2017

[18] Papyrus UML Tool - Version Neon (4.6.0) “https://www.eclipse.org/papyrus/documentation.html” Copyright © 2015 The Eclipse Foundation. All Rights Reserved.

[19] TM Forum, Information Framework (SID), GB922, Release 17.0.0, June 2017.

[20] TM Forum MTNM 4.5, July 2015

[21] TM Forum MTOSI 4.0, July 2015

[22] IETF RFC 6020 - YANG - A data modeling language for NETCONF

Appendix A Examples of Network Scenarios (Informative)

In the following are depicted some network scenarios.

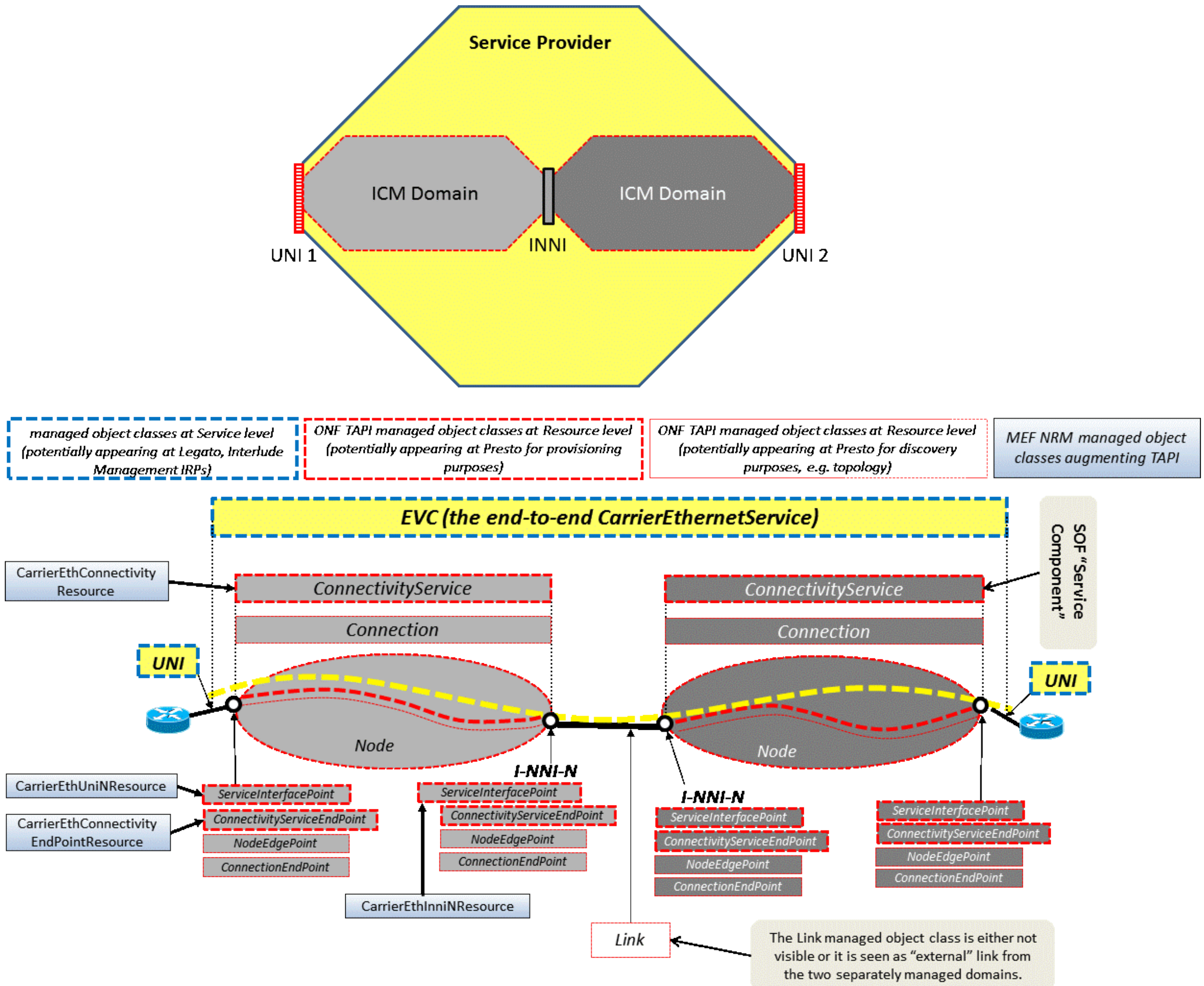
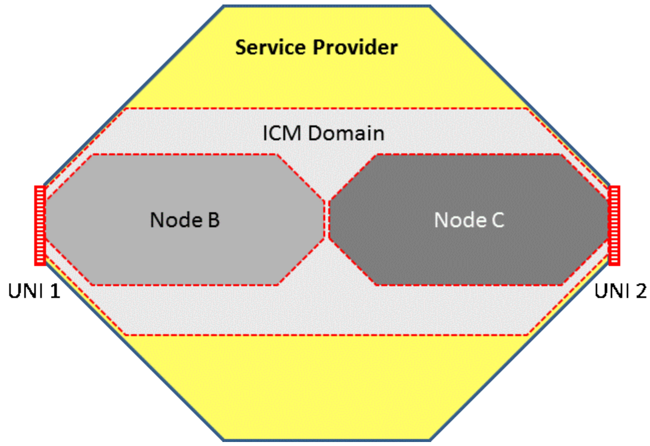


Figure 9 - Single Provider, separately managed domains



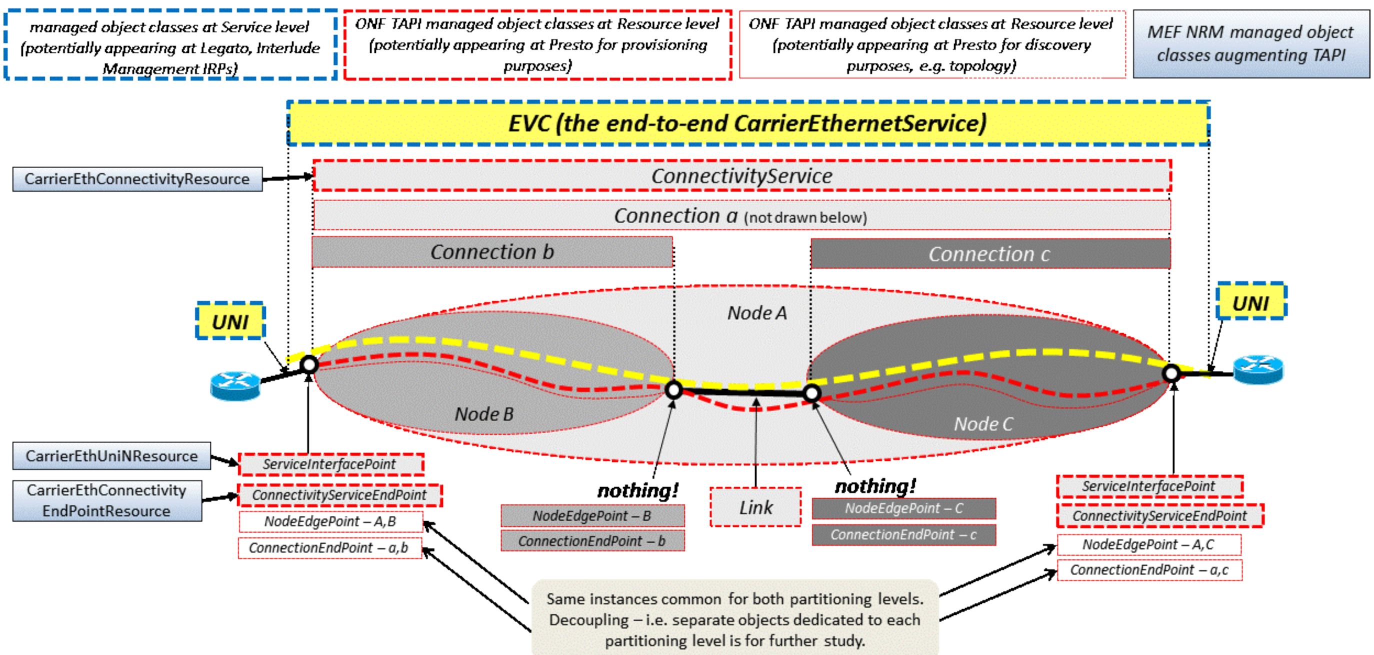


Figure 10 - Single Provider, single managed domain, partitioning

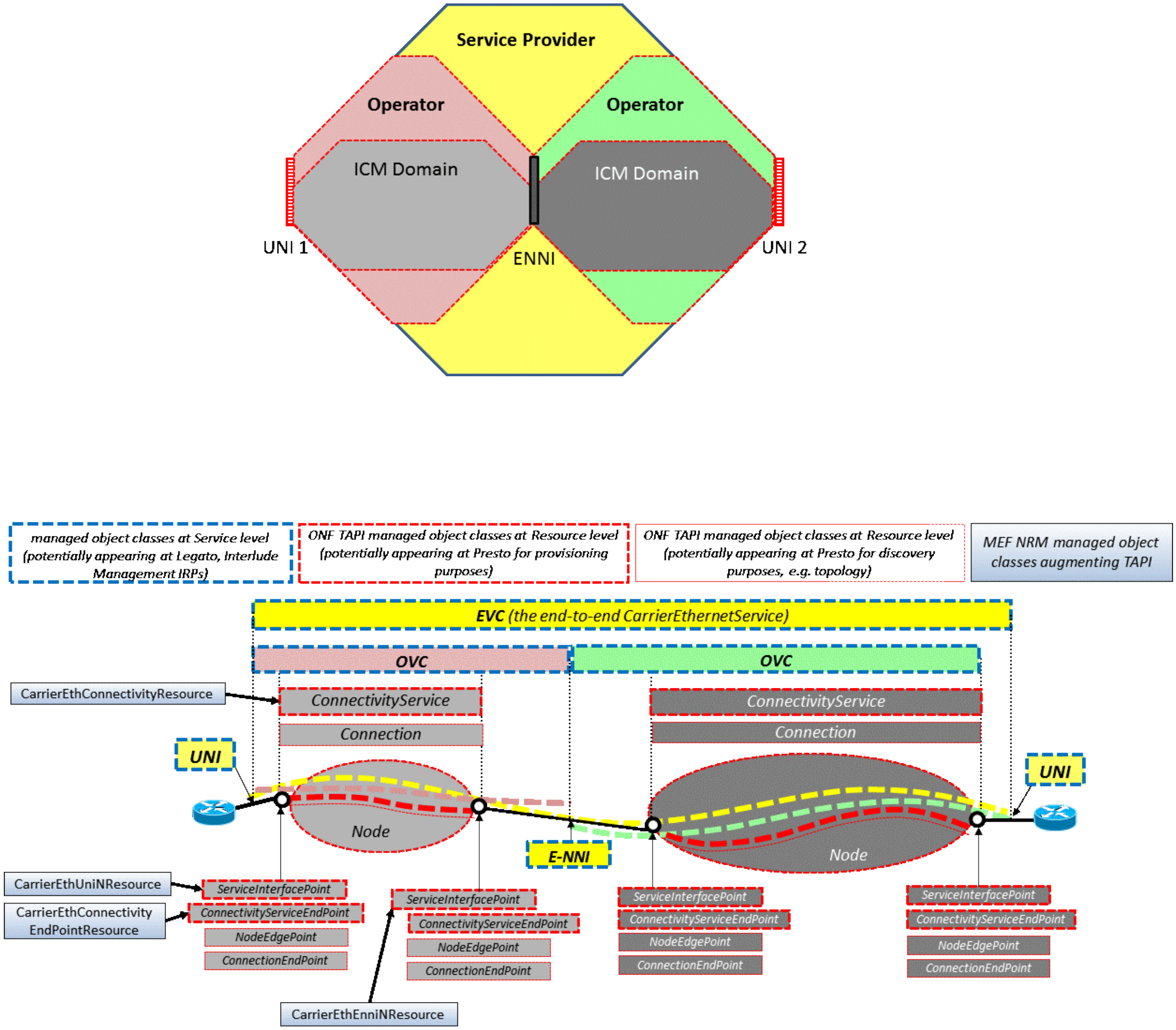


Figure 11 - Different Operators

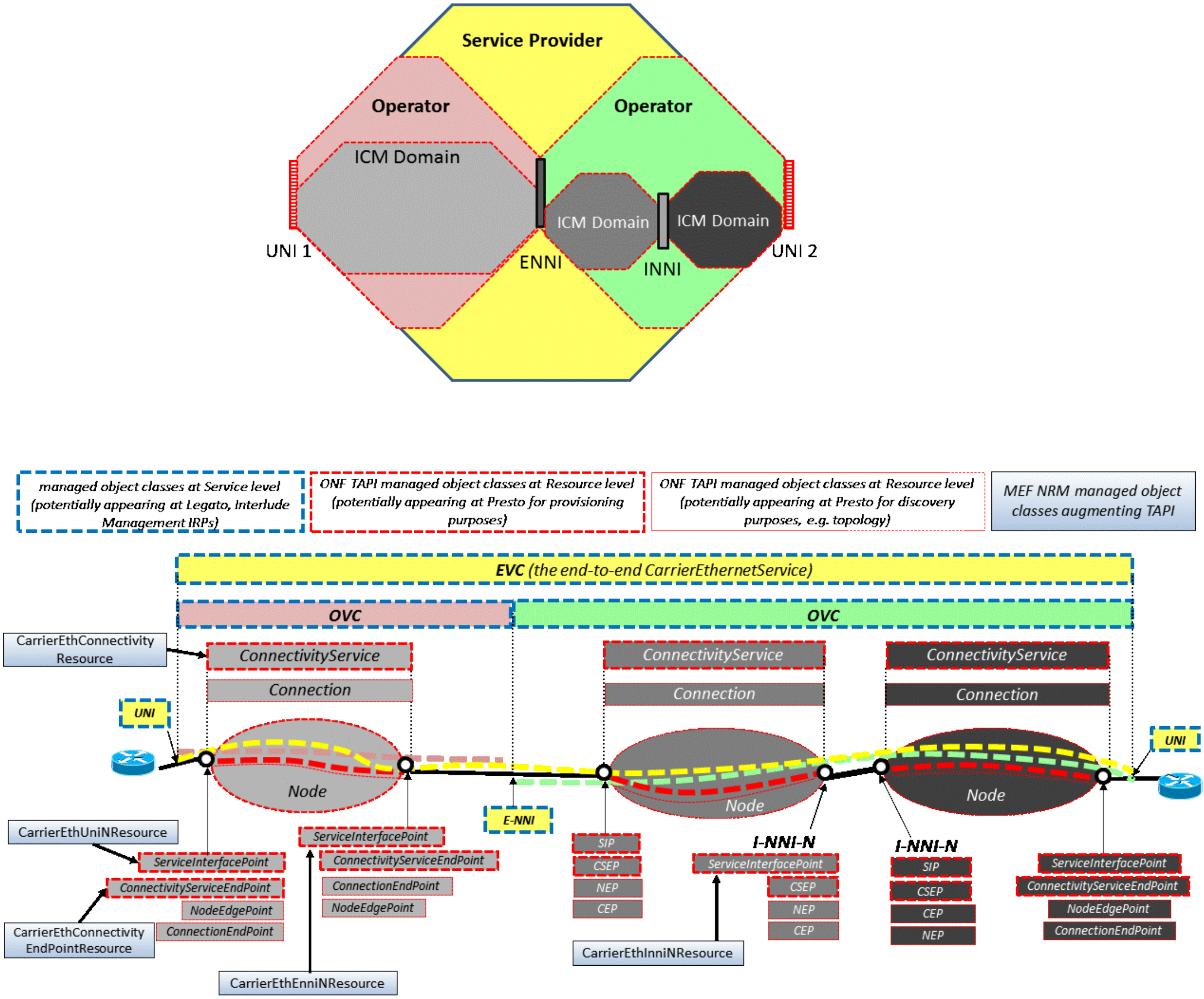


Figure 12 - Different Operators, separately managed domains

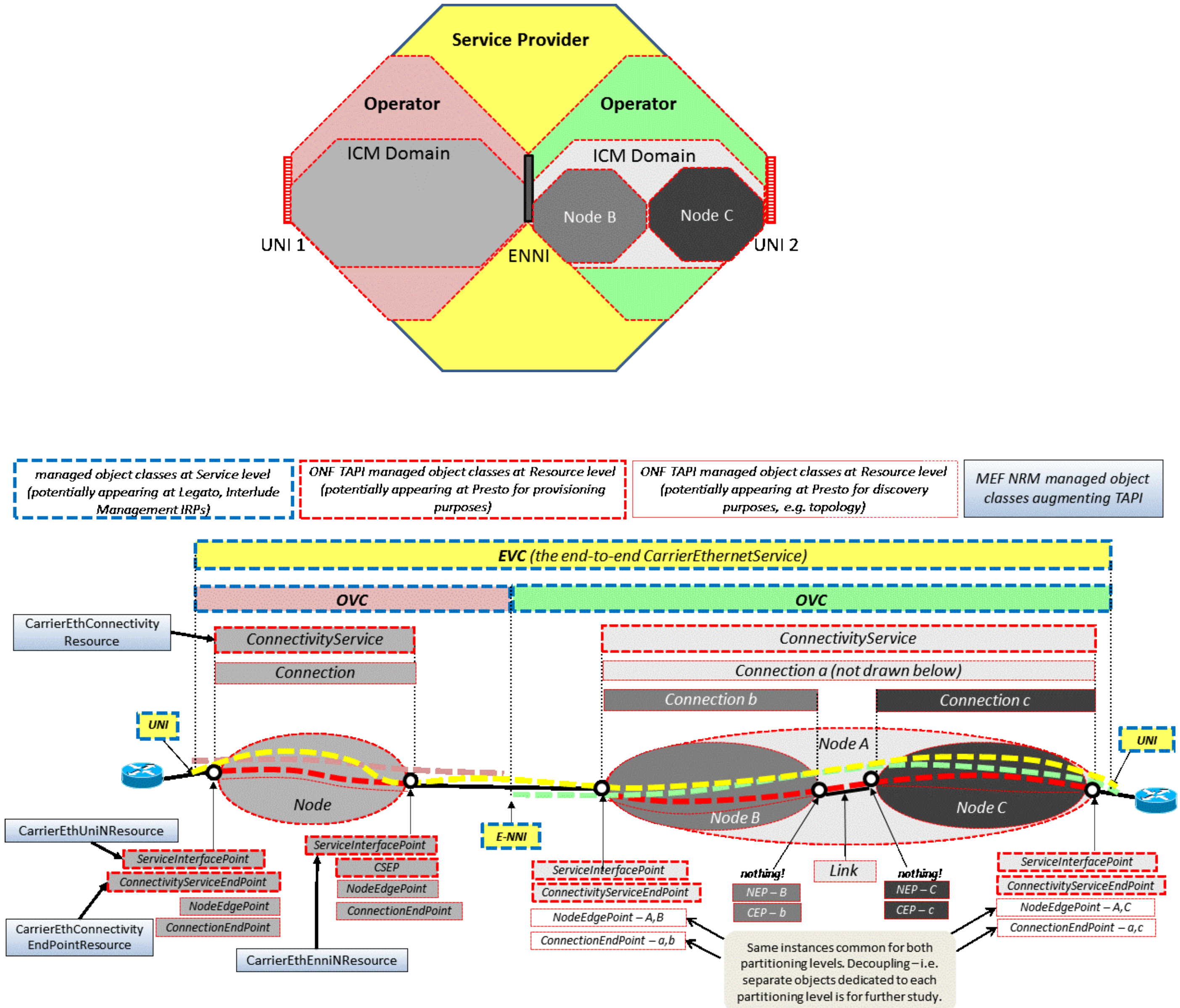


Figure 13 - Different Operators, Partitioning

Considering scenario of Figure 12, the Figure 14 describes a possible operation thread from SP EVC Provisioning down to Connectivity Service Provisioning to Network Infrastructure.

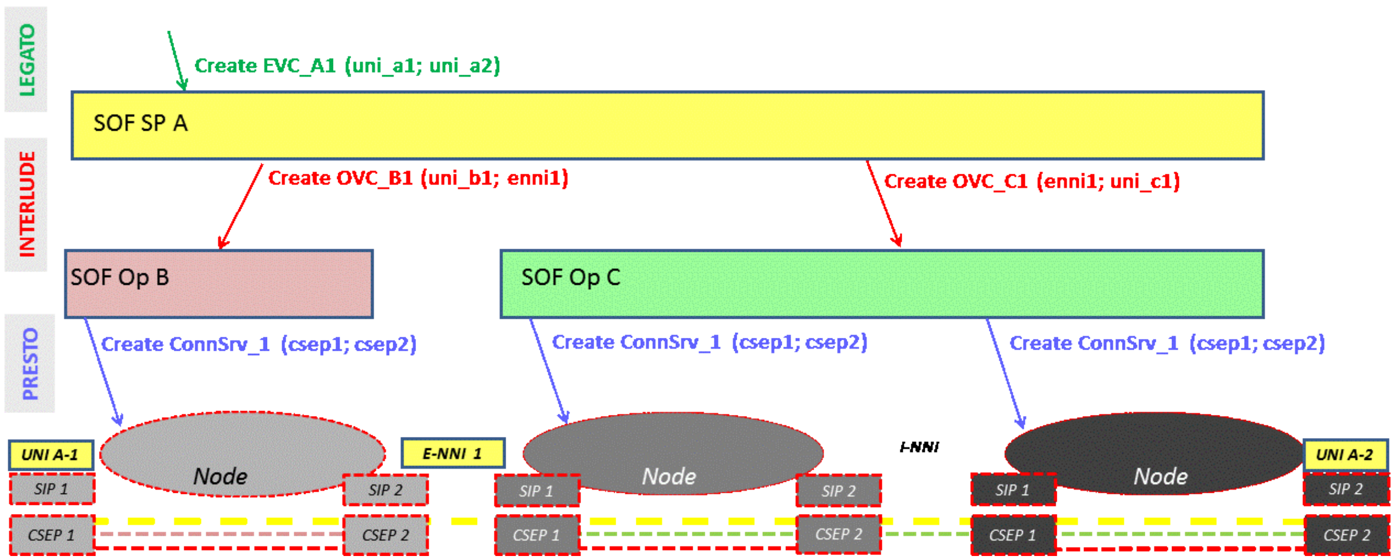


Figure 14 - SP and two Operators: provisioning flow

Figure 15 describes a possible operation thread in case the SP A is directly managing the ICM Domain.

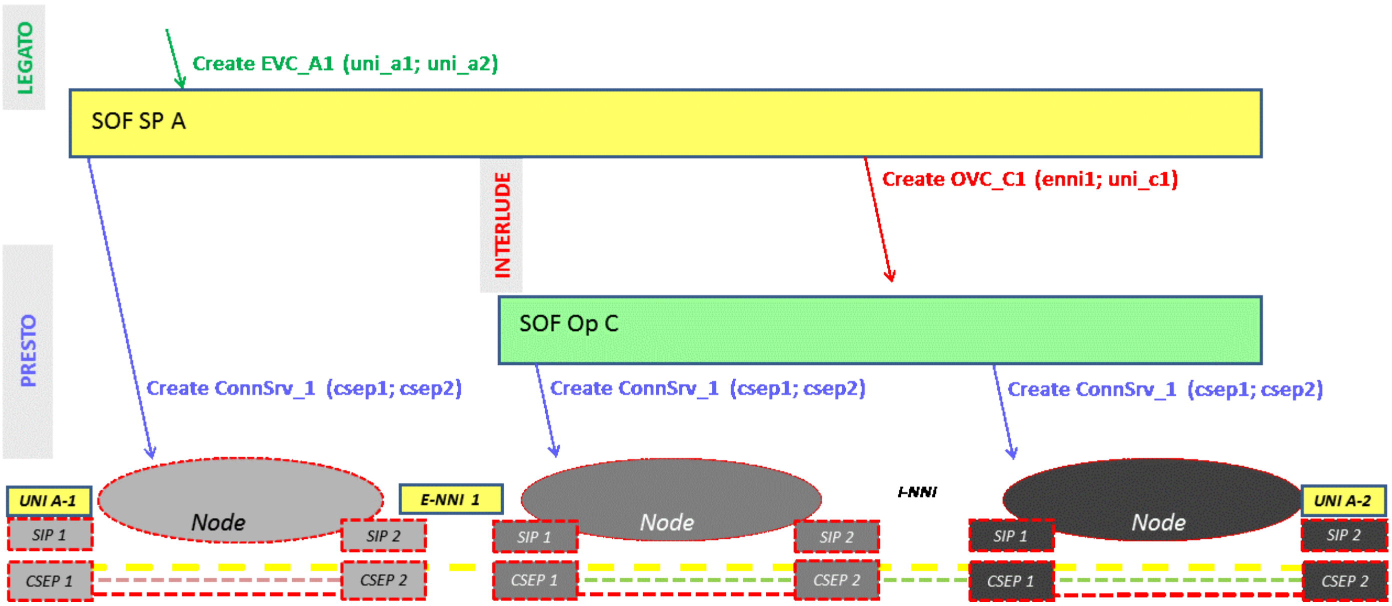


Figure 15 - SP and one Operator: provisioning flow

Same as above, now considering an example of Multiple Operator Scenario (MEF 26.2 [7]).

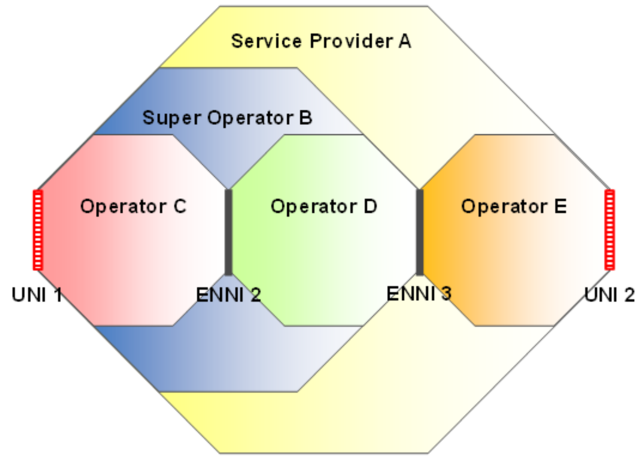


Figure 16 - Scenario with Multiple Operators (MEF 26.2 [7])

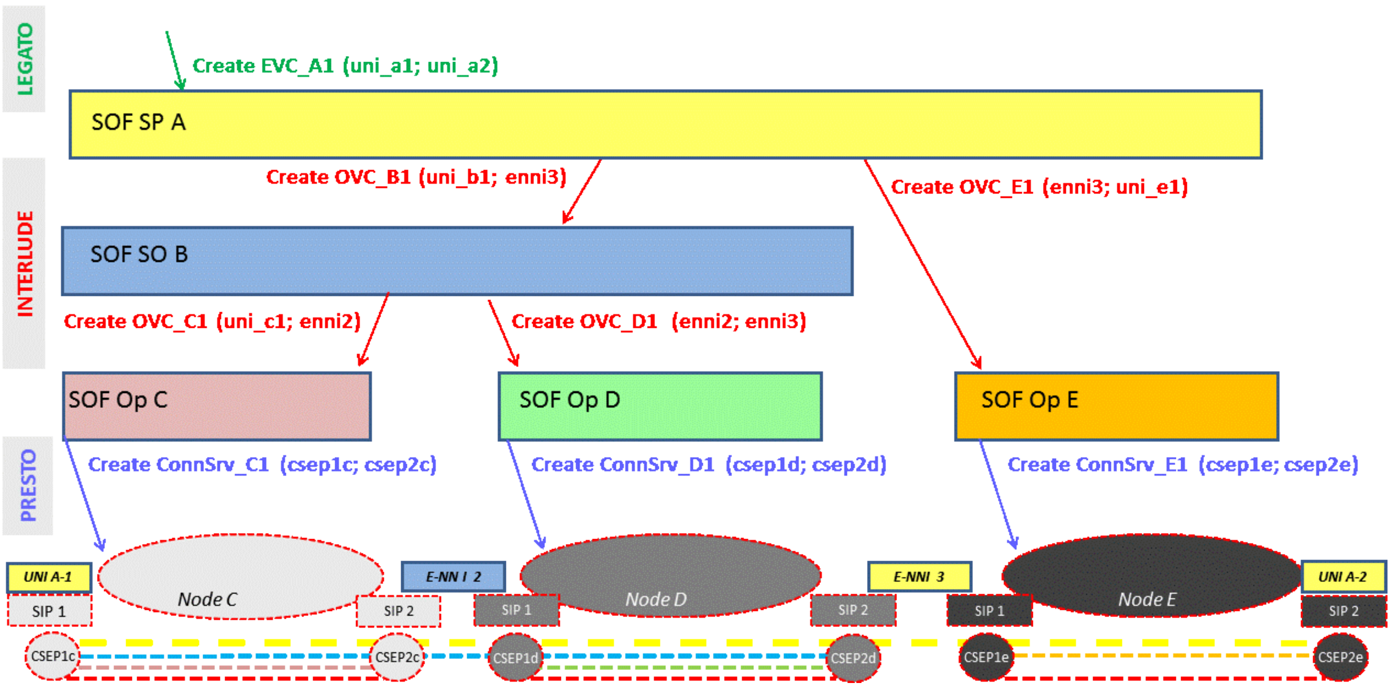


Figure 17 - EVC/OVC/Connectivity Service

Appendix B Examples of Extension Mechanisms (Informative)

The following figures show some methods for extending the definition of the ConnectivityService class of ONF TAPI model.

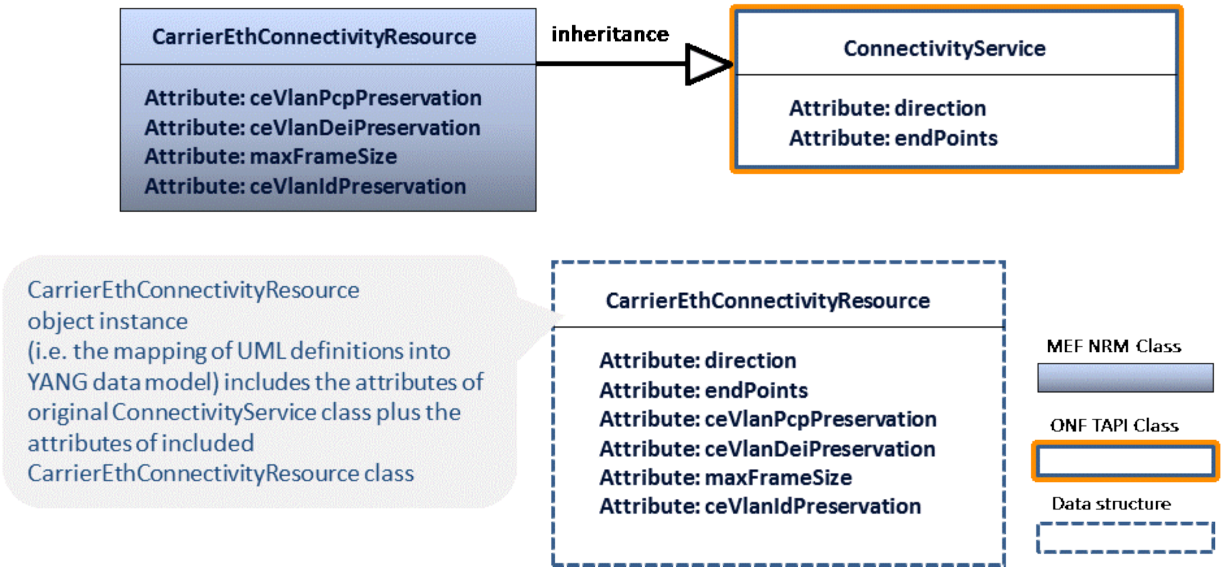


Figure 18 - Example of UML *generalization*

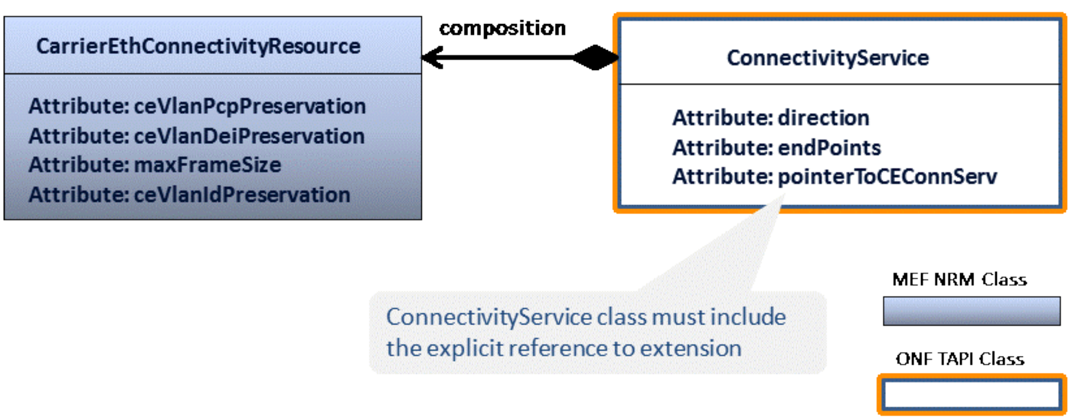
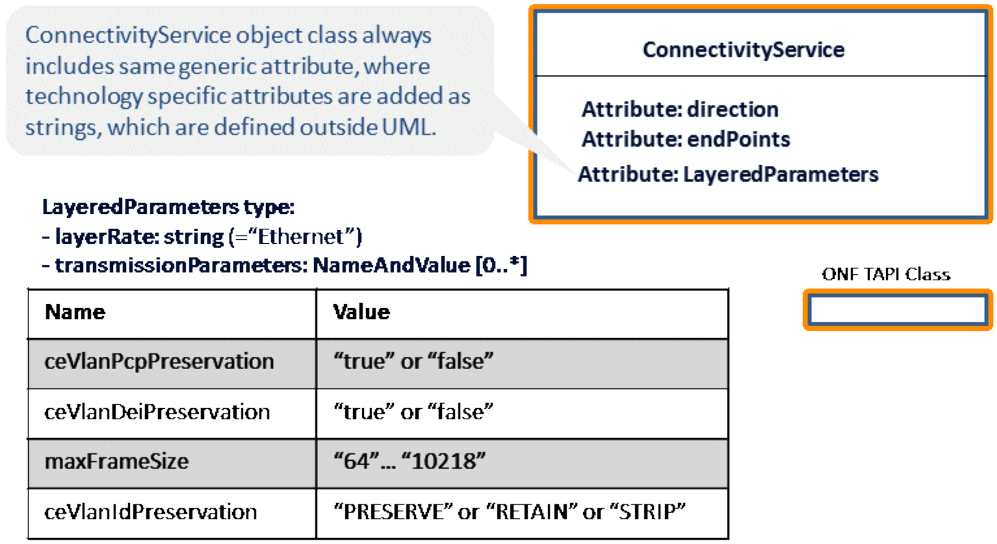


Figure 19 - Example of UML *composition*



Name	Value
ceVlanPcpPreservation	"true" or "false"
ceVlanDeiPreservation	"true" or "false"
maxFrameSize	"64"… "10218"
ceVlanIdPreservation	"PRESERVE" or "RETAIN" or "STRIP"

Figure 20 - Example of untyped extension

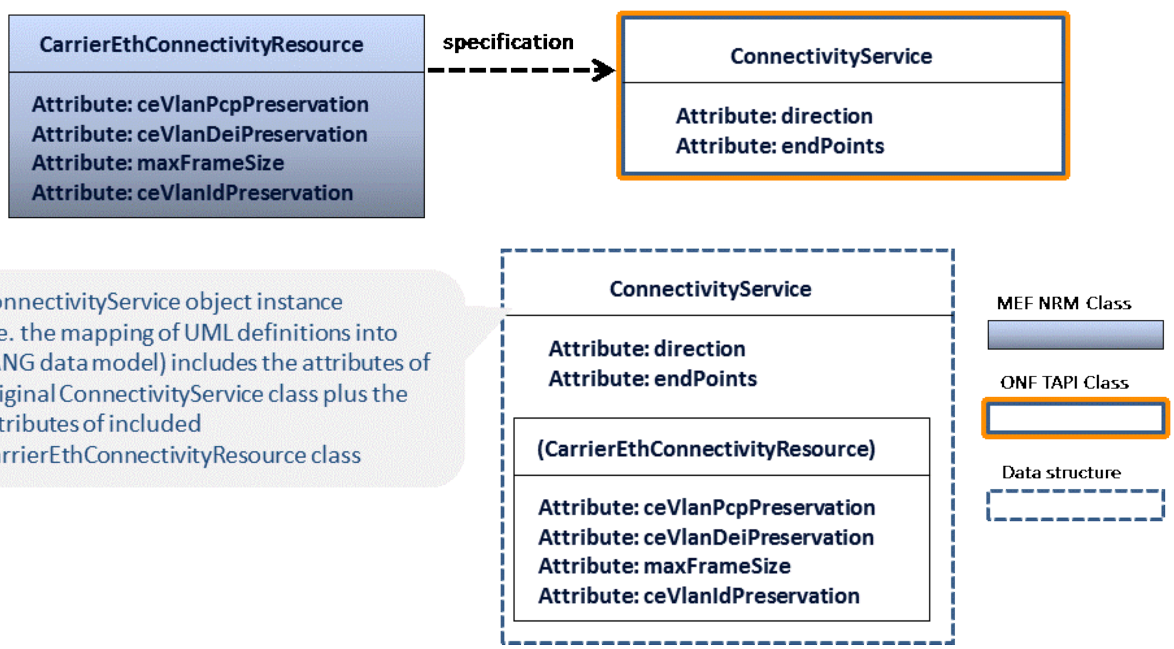


Figure 21 - Example of ONF *specification* extension

Appendix C Mappings from MEF 7.3 to NRM (Informative)

Below an overview of MEF 7.3 [4] to NRM mappings. On the left side of the figures the MEF 7.3 [4] classes and attributes, on the right part the MEF NRM classes. Note that a *yellow* attribute on the left side can be mapped either with the NRM class in same figure or with an NRM class in another figure.

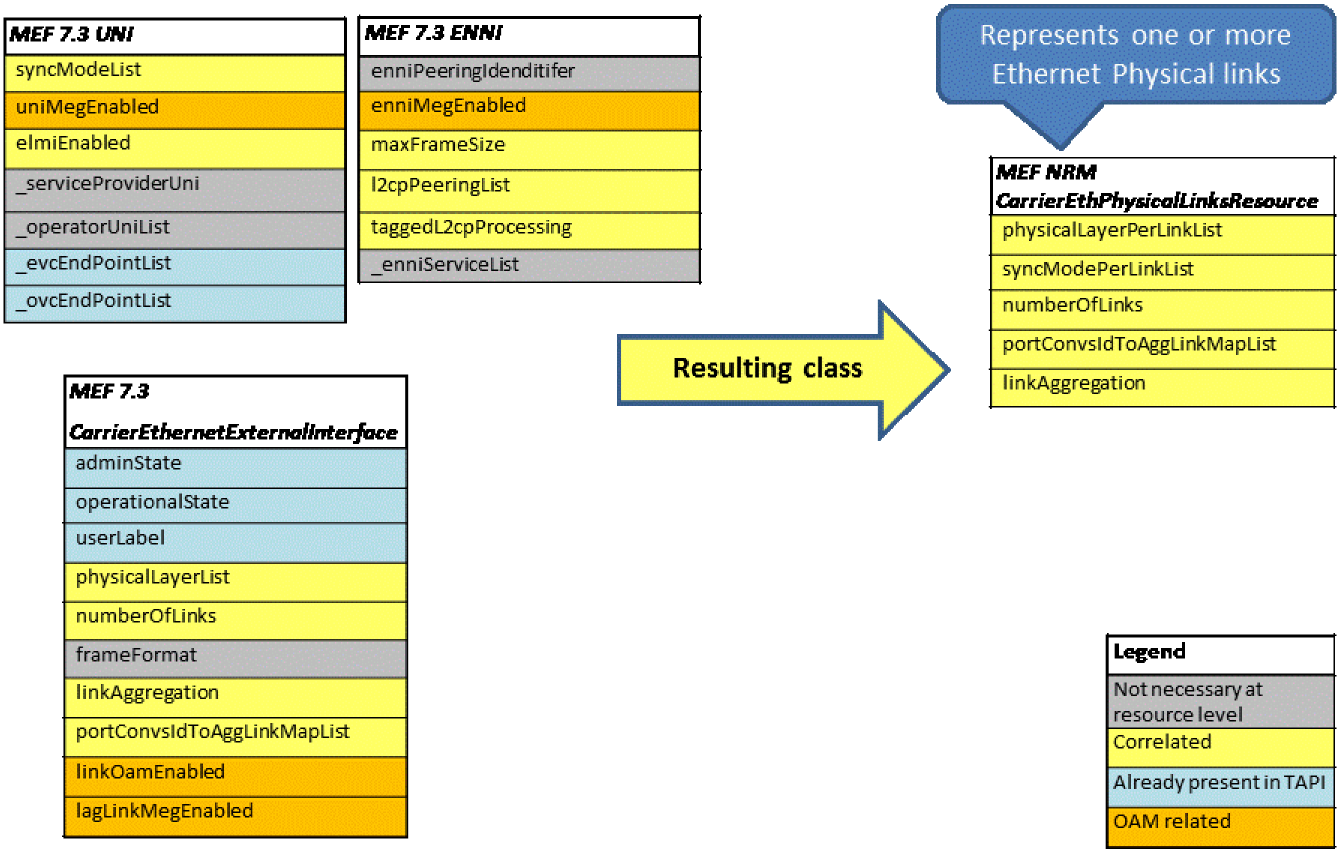


Figure 22 - UNI and ENNI at Physical Layer

elmiEnabled is defined at Ethernet UNI-N Interface level.

frameFormat: not included in resource model, as it is readonly and single-valued.

maxFrameSize, **l2cpPeeringList** are defined at Ethernet Interface level.

taggedL2cpProcessing is maintained at ENNI-N Interface level.

uniMegEnabled, **enniMegEnabled**, **linkOamEnabled**, **lagLinkMegEnabled** are not in the scope of NRM Connectivity model.

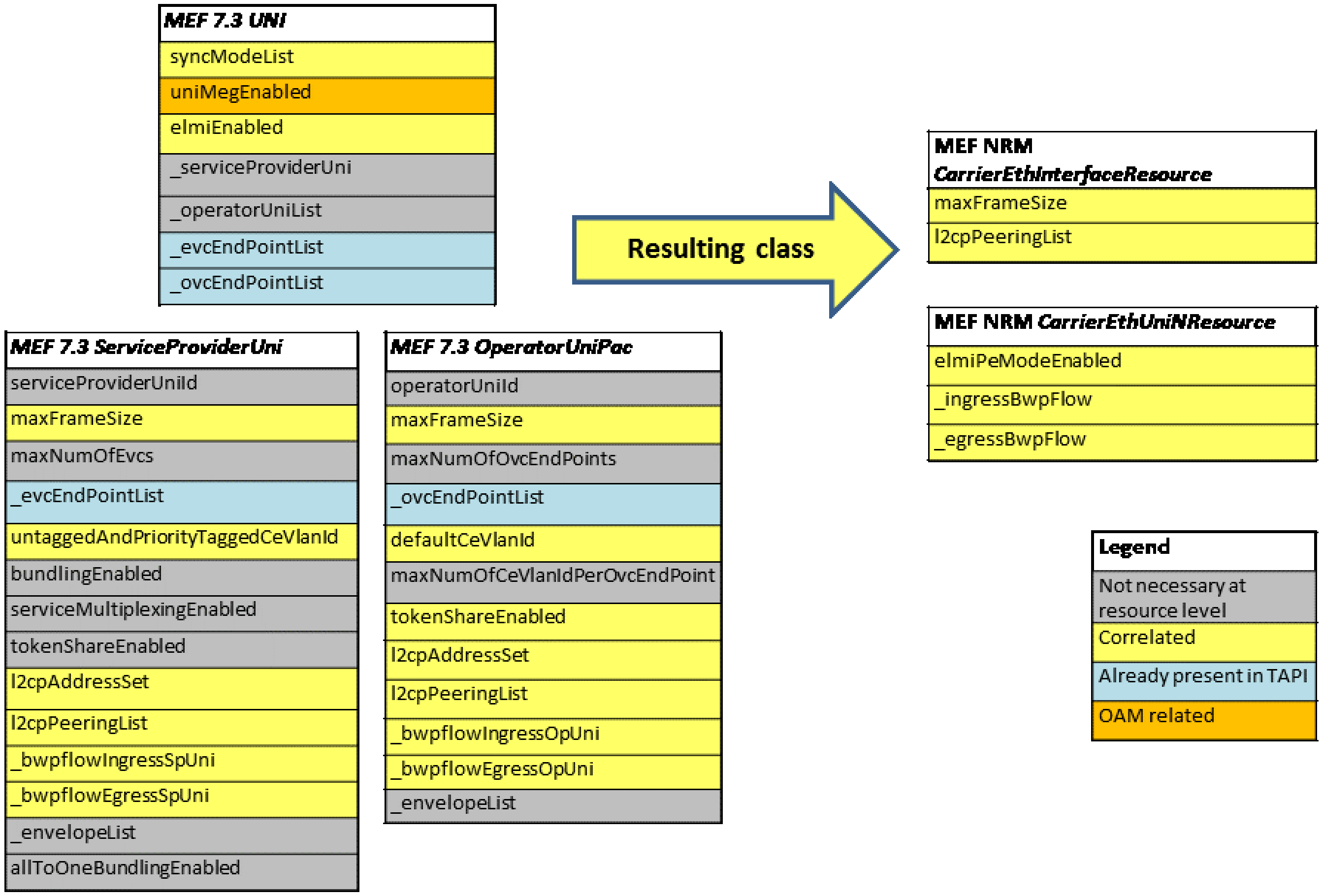


Figure 23 - UNI (Frame Aggregation Layer)

uniMegEnabled is not in the scope of NRM Connectivity model.

untaggedAndPriorityTaggedCeVlanId, **defaultCeVlanId** can be replaced by enhancing the **ceVlanIdList** of **CarrierEthConnectivityEndPointResource** to allow the indication that un-tagged and priority-tagged frames are mapped to this end point.

tokenShareEnabled is redundant, as it is “enabled” when more **CarrierEthConnectivityEndPointResource** point to same **Envelope** (through **BwpFlow**).

_envelopeList: Envelopes are already referenced by **BwpFlow**.

l2cpAddressSet is moved to **CarrierEthConnectivityEndPointResource**.

serviceProviderUniId: this attribute is an example of management information which likely does not need to be provisioned down to infrastructure. At most, it could help ICM, EML GUI users to map pure resource view with service view.

maxNumOfEvcs: not necessary at NRM level, SOF can enforce it.

bundlingEnabled, serviceMultiplexingEnabled, allToOneBundlingEnabled: not necessary at NRM level, SOF can enforce appropriate multiplicity of objects.

maxNumOfCeVlanIdPerOvcEndPoint: not necessary at NRM level, SOF can enforce it.

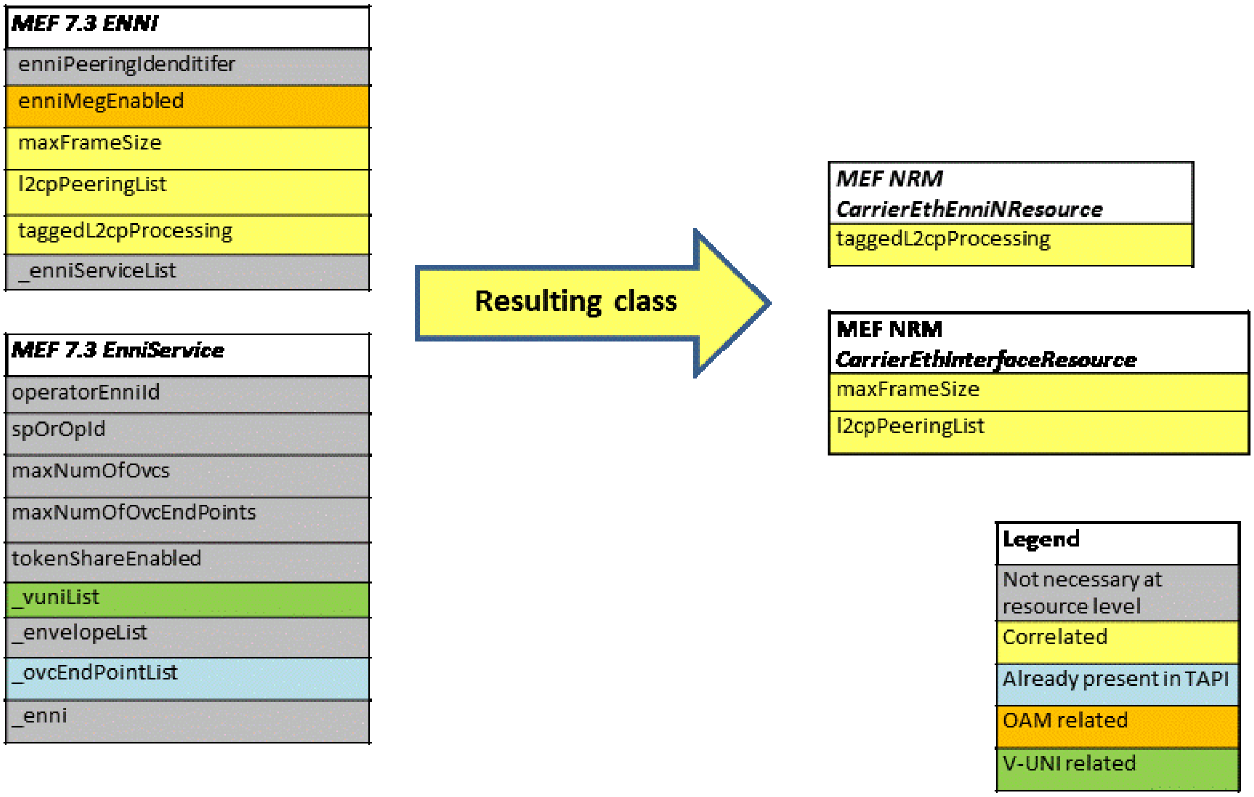


Figure 24 - ENNI (Frame Aggregation Layer)

enniPeeringIdenditifer is the topological information at Service level. It allows to identify the two linked ENNI-N.

enniMegEnabled is not in the scope of NRM Connectivity model.

EnniService class is not necessary at resource level, because it represents a grouping of OVC end points of a same ENNI. This grouping is on SP or SO base, and specifies common service attributes:

- **spOrOpId** is not applicable at resource level as grouping criteria
- **maxNumOfOvcs**, **maxNumOfOvcEndPoints** can be enforced by SOF
- **tokenShareEnabled** is redundant, as it is “enabled” when more **CarrierEthConnectivityEndPointResource** refers same **Envelope**, this reference being specified through **BwpFlow**.
- **_envelopeList** is already present in **BwpFlow**

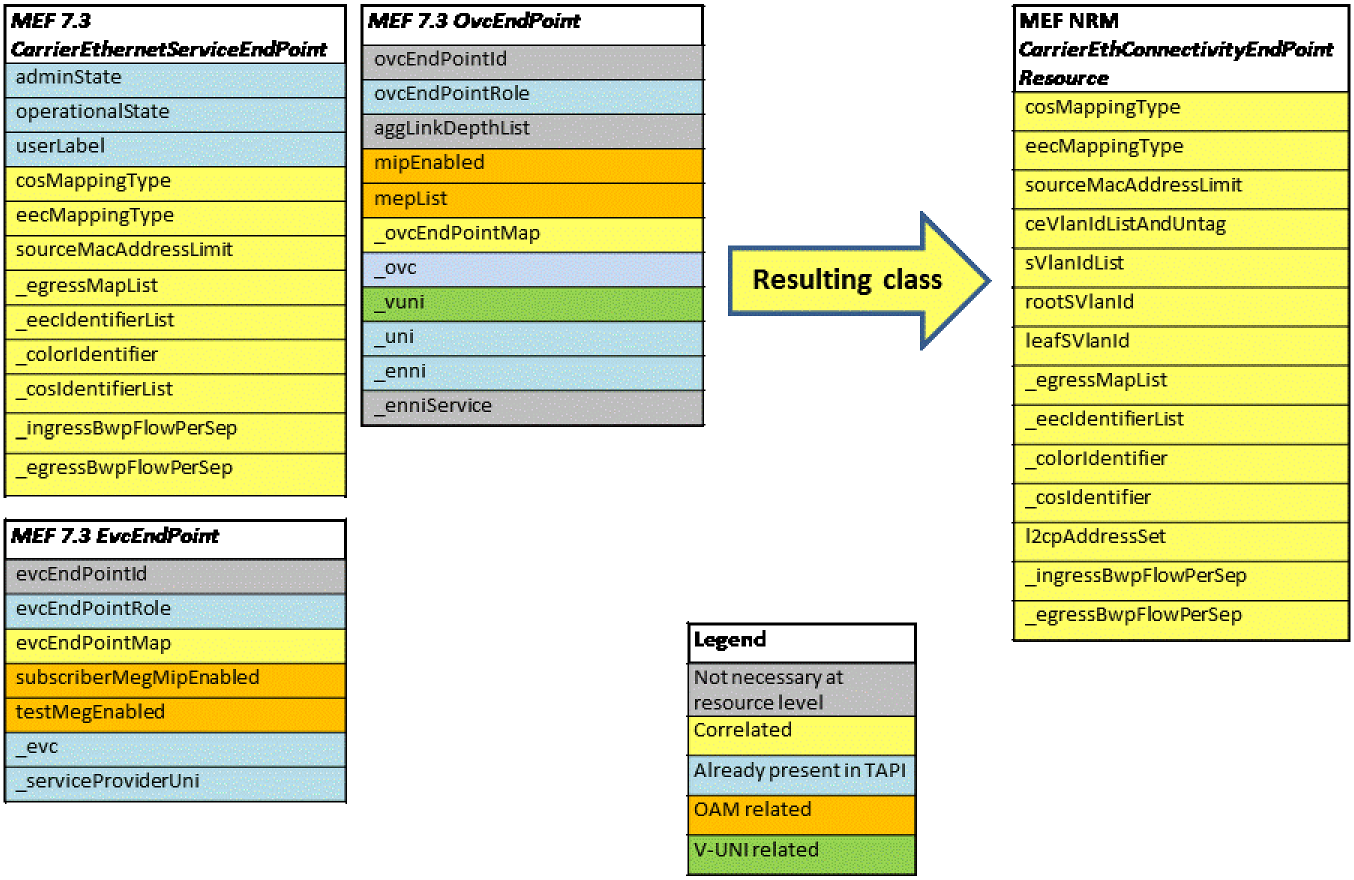


Figure 25 - EVC/OVC End Point

adminState, **operationalState**, **userLabel** already defined in TAPI.

evcEndPointMap is mapped by CE VLAN ID list.

_ovcEndPointMap is replaced by CE/S/root/leaf VLAN ID lists.

UNI **defaultCeVlanId** can be replaced by enhancing the **ceVlanIdList** to allow the indication that untagged and priority-tagged frames are mapped to this end point.

subscriberMegMipEnabled, **mipEnabled**, **mepList**, **testMegEnabled** are not in the scope of NRM Connectivity model.

aggLinkDepthList not applicable at resource management level because conversationID to Aggregation Link Map would always be known.

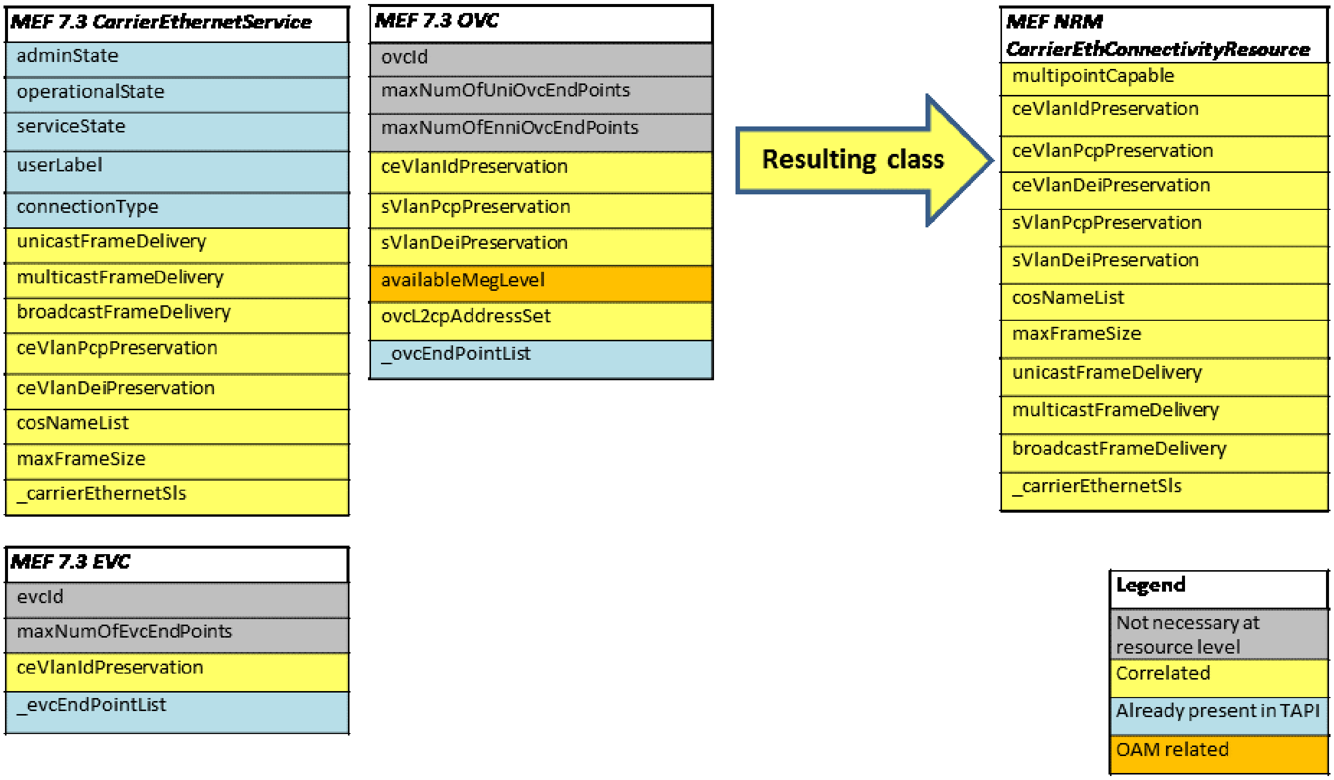


Figure 26 - EVC, OVC

adminState, **operationalState**, **serviceState**, **userLabel**, **connectionType** already defined in TAPI.

multipointCapable attribute is added to describe connectivity service capability to add/remove end points.

unicastFrameDelivery, **multicastFrameDelivery**, **broadcastFrameDelivery**: type enhanced with a name-value pair list, to allow specification of conditions.

ceVlanIdPreservation, **ceVlanPcpPreservation**, **ceVlanDeiPreservation**, **sVlanPcpPreservation**, **sVlanDeiPreservation** may be not applicable in case of not Ethernet INNIs – i.e. "transit" domains transparently supporting Ethernet. Note that in an Ethernet transit domain the information is necessary in case a new end point is added (hence domain moves from "transit" to "access").

availableMegLevel is not in the scope of NRM Connectivity model.

ovcL2cpAddressSet: centralized in **CarrierEthConnectivityEndPointResource**.

maxNumOfEvcEndPoint, maxNumOfUniOvcEndPoints, **maxNumOfEnniOvcEndPoints**: not necessary at NRM level, SOF can enforce them.

Appendix D Summary Table of Classes (Informative)

MEF 7.3	ONF Core IM	ONF TAPI	MEF NRM Specification Classes	MEF 7.2 / Q.840.1	G.8052
EVC	*Forwarding Construct*	*ConnectivityService*	*CarrierEthConnectivityResource*	*ETH_FDFr_EVC*	*ETH_CrossConnection*
OVC	*Forwarding Construct*	*ConnectivityService*	*CarrierEthConnectivityResource*	*ETH_ OVC*	*ETH_CrossConnection*
UNI	*LTP, LP*	*ServiceInterfacePoint, LP*	*CarrierEthInterfaceResource* *CarrierEthUniNResource* *CarrierEthPhysicalLinksResource*	*ETH_FPP_UNI* *(MAU)TransportPort*	*ETH_TrailTerminationPoint* *(ETY_)TrailTerminationPoint*
ENNI	*LTP, LP*	*ServiceInterfacePoint, LP*	*CarrierEthInterfaceResource* *CarrierEthEnniNResource* *CarrierEthPhysicalLinksResource*	*ETH_FPP_ENNI* *(MAU)TransportPort*	*ETH_TrailTerminationPoint* *(ETY_)TrailTerminationPoint*
INNI (Not defined)	*LTP, LP*	*ServiceInterfacePoint, LP*	*CarrierEthInterfaceResource* *CarrierEthInniNResource* *CarrierEthPhysicalLinksResource*	Not defined *(MAU)TransportPort*	*ETH_TrailTerminationPoint* *(ETY_)TrailTerminationPoint*
EvcEndPoint	*LTP, LP, FcPort*	*ConnectivityServiceEndPoint*	*CarrierEthConnectivityEndPoint Resource*	*ETH_Flow_Point*	*ETH_ConnectionTerminationPoint*
OvcEndPoint	*LTP, LP, FcPort*	*ConnectivityServiceEndPoint*	*CarrierEthConnectivityEndPoint Resource*	*ETH_OVC_End_Point*	*ETH_ConnectionTerminationPoint*
Link (Not defined)	*Link, LinkPort*	*Link*	Not yet defined	*ETH_FPP_Link*	Not defined

Table 10 - Summary Table of Managed Object Classes