Technical Specification
MEF 26.2

External Network Network Interfaces (ENNI) and Operator Service Attributes

August 2016

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1   List of Contributing Members

The following members of the MEF Forum participated in the development of this document and have requested to be included in this list.

ADVA Optical Networking SE	Hauwei Technologies
albis-elcon	HFR, Inc.
AT&T	PLDT Corp. Business Solutions
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2 Abstract

The *Metro Ethernet Network Architecture Framework – Part 1: Generic Framework* (MEF 4 [10]) specifies a reference point that is the interface between two Carrier Ethernet Networks (CENs), where each Operator CEN is under the control of a distinct administrative authority.[1] This reference point is termed the External Network Network Interface or ENNI.[2] The ENNI is intended to support the extension of Ethernet services across multiple Operator CENs. This Technical Specification specifies:

- The requirements at the ENNI reference point as well as the interface functionality in sufficient detail to ensure interoperability between two Operator CENs.

- The connectivity attributes UNI to UNI, UNI to ENNI, and ENNI to ENNI such that multiple Operator CENs can be interconnected and the Ethernet services and Service Attributes in MEF 6.2 [11], MEF 10.3 [12], and MEF 51 [25] can be realized.

- The concept of the Super Operator which allows an Operator, acting as a Super Operator, to combine multiple Operator CENs together and make them appear as a single Operator CEN to a Service Provider or another Super Operator.

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[1] MEF 4 uses the term MEN which is equivalent to CEN as used in this document.

[2] MEF 4 [10] hyphenates the acronym but this document does not.

3   Terminology

Terms defined in MEF 6.2 [11], MEF 10.3 [12], and MEF 10.3.2 [13] are included in this document by reference and, hence, not repeated in table below.

Term	Definition	Source
@ENNI	An OVC End Point that is located at an ENNI and that is not in a VUNI	This document
@UNI	An OVC End Point that is located at a UNI	This document
@VUNI	An OVC End Point that is located at an ENNI and that is in a VUNI	This document
Bandwidth Profile Flow	A set of EI Frames arriving at an EI that meet a specific criterion	This document
Broadcast Data EI Frame	A Data EI Frame with a Broadcast Destination MAC Address	This document
Bundled OVC	A Point-to-Point or Multipoint-to-Multipoint OVC that associates an OVC End Point that has more than one S-VLAN ID value that maps to it	This document
C-Tag	Subscriber VLAN Tag	IEEE Std 802.1Q™ – 2014 [3]
Data EI Frame	Either a Data ENNI Frame or a Data Service Frame	This document
Data ENNI Frame	An ENNI Frame that is neither a Layer 2 Control Protocol ENNI Frame nor a SOAM ENNI Frame	This document
Double Tagged ENNI Frame	A Tagged ENNI Frame whose 2 byte field beginning with the fifth byte after the Source Address field is a TPID with the value 0x8100	This document
DSCP	DiffServ Code Point	RFC 2474 [7]
EI	External Interface	This document
EI Frame	Either an ENNI Frame or a Service Frame	This document
End Point Map Bundling	The mapping of multiple S-VLAN ID values to a single OVC End Point in the OVC End Point Map, when the OVC associating that OVC End Point is not a Rooted-Multipoint OVC	This document
ENNI	A reference point representing the boundary between two Operator CENs that are operated as separate administrative domains	MEF 4 [10]

Term	Definition	Source
ENNI Common Attributes	Technical details that need to be agreed to by Operators in order for their CENs to be interconnected to form an ENNI	This document
ENNI Frame	The first bit of the Destination MAC Address through the last bit of the Frame Check Sequence of an IEEE 802.3 Packet transmitted across the ENNI	This document
ENNI-N	The functional element administered by the Operator of the Operator CEN that supports the protocols and procedures required at the ENNI in this document	This document
Envelope	A set of *n* Bandwidth Profile Flows in which each Bandwidth Profile Flow is assigned a unique rank between 1 (lowest) and *n* (highest)	This document
External Interface	Either a UNI or an ENNI[3]	MEF 4 [10]
Feeder OVC	An OVC in the connectivity between a VUNI and the paired RUNI	This document
Hairpin Switching	When an ingress VLAN Tagged ENNI Frame at a given ENNI results in an egress VLAN Tagged ENNI Frame with a different S-VLAN ID value at the given ENNI	This document
L2CP EI Frame	Either an L2CP ENNI Frame or an L2CP Service Frame	This document
L2CP ENNI Frame	Layer 2 Control Protocol ENNI Frame	This document
Layer 2 Control Protocol ENNI Frame	An ENNI Frame that could be used in a recognized Layer 2 Control Protocol	This document
Leaf OVC End Point	An OVC End Point that has the role of Leaf	This document
Maintenance Interval	A time interval agreed to by the SP/SO and Operator during which the OVC may not perform well or at all	This document
Multicast Data EI Frame	A Data EI Frame with a Multicast Destination MAC Address	This document
Multipoint-to-Multipoint OVC	An OVC that can associate two or more Root OVC End Points and cannot associate Leaf or Trunk OVC End Points	This document

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[3] MEF 4 considers several types of External Interfaces. This document is limited to consideration of the UNI and ENNI.

Term	Definition	Source
Operator	The Administrative Entity of a CEN	This document
Operator Service Attribute	An externally observable behavior of a single Operator CEN	This document
Operator Virtual Connection	An association of OVC End Points	This document
OVC	Operator Virtual Connection	This document
OVC End Point	A logical entity at a given External Interface that is associated with a distinct set of frames passing over that External Interface	This document
OVC End Point Role	A property of an OVC End Point that determines the forwarding behavior between it and other OVC End Points that are associated with the OVC End Point by an OVC	This document
Performance Metric	A quantitative characterization of EI Frame delivery quality experienced by the SP/SO	This document
Point-to-Point OVC	An OVC that can associate exactly two Root OVC End Points	This document
Priority Tagged ENNI Frame	An ENNI Frame with the 2 byte field following the Source Address field being a TPID with the value 0x88a8 and the corresponding VLAN ID value is 0x000	This document
Qualified Frame	An EI Frame that satisfies several criteria and has all of the Performance Metrics in the OVC SLS except One-way Availability apply to it	This document
Remote UNI	The UNI that is paired with a VUNI	This document
Resiliency Performance	The number of High Loss Intervals and Consecutive High Loss Intervals in a time interval T	This document
Root OVC End Point	An OVC End Point that has the role of Root	This document
Rooted-Multipoint OVC	An OVC that can associate at least one Leaf or Trunk OVC End Point	This document
RUNI	Remote UNI	This document
Single Tagged ENNI Frame	A Tagged ENNI Frame whose 2 byte field beginning with the fifth byte after the Source Address field of a Tagged ENNI Frame is not a TPID with the value equal to 0x8100	This document
SLS	OVC Service Level Specification	This document

Term	Definition	Source
SOAM EI Frame	Either a SOAM ENNI Frame or a SOAM Service Frame	This document
SOAM ENNI Frame	An ENNI Frame whose MAC Destination Address does not indicate the frame to be an L2CP ENNI Frame and whose Ethertype = 0x8902	This document
SP/SO	Service Provider or Super Operator	This document
S-Tag	Service VLAN Tag.	IEEE Std 802.1Q – 2014 [3]
Super Operator	An Operator that uses other Operators to provide connectivity to one or more OVC End Points of its OVC	This document
S-VLAN ID	The 12 bit VLAN ID field in the S-Tag of an ENNI Frame	This document
Tag	An optional field in a frame header. It is the 4-byte field that, when present in an Ethernet frame, appears immediately after the Source Address or another tag in an Ethernet frame header. It consists of the 2-byte Tag Protocol Identification Field (TPID) which indicates S-Tag or C-Tag, and the 2-byte Tag Control Information field (TCI) which contains the 1-bit DEI, the 3-bit Priority Code Point, and the 12-bit VLAN ID field	IEEE Std 802.1Q – 2014 [3]
Tagged ENNI Frame	An ENNI Frame that is either a VLAN Tagged ENNI Frame or a Priority Tagged ENNI Frame	This document
Trunk OVC End Point	An OVC End Point that has the role of Trunk	This document
Unicast Data EI Frame	A Data EI Frame with a Unicast Destination MAC Address	This document
Untagged ENNI Frame	An ENNI Frame whose two bytes following the Source Address field do not contain the value 0x88a8	This document
Virtual UNI	**The instantiation in one CEN of functions that effect a portion of the Service Attributes observable at a UNI supported by a different CEN**	**This document**
VLAN Tagged ENNI Frame	An ENNI Frame with the 2 byte field following the Source Address field being a TPID with the value 0x88a8 and the corresponding VLAN ID value is not 0x000	This document
VUNI	Virtual UNI	This document

Table 1 – Acronyms and Definitions

Note that throughout this specification, UNI means a demarcation point and ENNI means a demarcation point. Functionality associated with an interface at the ENNI is denoted by ENNI-N.

4 Scope

This document contains specifications for interconnecting Operator CENs in order to support MEF Forum Ethernet Services. It includes

- Support for Point-to-Point, Multipoint-to-Multipoint, and Rooted-Multipoint EVCs spanning an arbitrary number of Operator CENs and ENNIs,

- Ethernet frames at the ENNI with formats according to IEEE Std 802.1Q – 2014. [3],

- Up to 100-Gigabit Ethernet physical links according to IEEE Std 802.3 – 2012 [4],

- Hairpin switching, where ENNI Frames associated with an OVC may be sent back across an ENNI from which they were received by the Operator,

- Link protection based on IEEE Std 802.1AX – 2014 [2],

- Bandwidth Profiles using the token sharing algorithm of MEF 41 [23] at the ENNI and UNI,

- Performance Metrics for Operator Virtual Connections that correspond to the EVC Performance Metrics of MEF 10.3. [12],

- Virtual UNI and Feeder OVC concepts that generalize the material in MEF 28 [19], and

- The Super Operator concept that allows an Operator CEN to be constructed from multiple other Operator CENs.

This document supersedes External Network Network Interface (ENNI) – Phase 2 (MEF 26.1 [18]) and External Network Network Interface (ENNI) Support for UNI Tunnel Access and Virtual UNI (MEF 28 [19]). Appendix I details the key differences between this document and MEF 26.1 and MEF 28.

5 Compliance Levels

The keywords **MUST**, **MUST NOT**, **REQUIRED**, **SHALL**, **SHALL NOT**, **SHOULD**, **SHOULD NOT**, **RECOMMENDED**, **MAY**, and **OPTIONAL**, when they appear in this document, are to be interpreted as described in RFC 2119 [6]. All key words must be in upper case, bold text.

Items that are **REQUIRED** (contain the words **MUST** or **MUST NOT**) are labeled as **[Rx]** for required. Items that are **RECOMMENDED** (contain the words **SHOULD** or **SHOULD NOT**) are labeled as **[Dx]** for desirable. Items that are **OPTIONAL** (contain the words **MAY** or **OPTIONAL**) are labeled as **[Ox]** for optional.

Note that when the term "support"' is used in a normative context in this document, it means that the Operator (Section 8.2) is capable of enabling the functionality upon agreement between the Service Provider (Section 8.2) or the Super Operator (Section 8.10) and the Operator.

6   Numerical Prefix Conventions

This document uses the prefix notation to indicate multiplier values as shown in Table 2.

Decimal		Binary	
Symbol	**Value**	**Symbol**	**Value**
k	10^3	Ki	2^{10}
M	10^6	Mi	2^{20}
G	10^9	Gi	2^{30}
T	10^{12}	Ti	2^{40}
P	10^{15}	Pi	2^{50}
E	10^{18}	Ei	2^{60}
Z	10^{21}	Zi	2^{70}
Y	10^{24}	Yi	2^{80}

Table 2 – Numerical Prefix Conventions

7   Introduction

This document provides the models and framework for interconnecting multiple Carrier Ethernet Networks (CENs). The attributes defined in this document can be used to realize Ethernet-based behaviors including:

- Service Attributes in MEF 10.3 [12],

- Service Definitions in MEF 6.2 [11], and

- Service Definitions in MEF 51 [25].

The approach is to define attributes that apply to a CEN. Each attribute can take on one or more values where the value for an attribute dictates behavior for the CEN as seen by an external observer. How a behavior is implemented within a CEN is opaque to the external observer and beyond the scope of this document.

Three kinds of attributes are defined:

- ENNI Common Attributes control CEN behaviors that enable CENs to be interconnected and exchange Ethernet frames, called ENNI Frames. The interconnection is achieved by the Operators agreeing on the value for each ENNI Common Attribute.

- Operator Multilateral Attributes control the behaviors observable at the ENNI. The behaviors are the same for all clients of the Operator.

- Operator Service Attributes control the behavior observable at and between interfaces to a CEN. The behaviors are achieved by the Operator and the Operator's client agreeing on the value for each Operator Service Attribute.

This document is organized as follows:

- Section 8 presents the key concepts and definitions,

- Section 9 defines the ENNI Common Attributes,

- Section 10 contains the Operator Multilateral Attributes,

- Section 11 introduces the Operator Service Attributes which are defined in Section 12 through Section 16,

- Section 15 defines Operator Service Attributes that supersede the VUNI and RUNI concepts contained in MEF 28 [19],

- Section 17 specifies the Bandwidth Profile algorithm by reference to the Generic Token Bucket algorithm of MEF 41 [23], and

- The Appendices contain examples.

8   Key Concepts and Definitions

This section presents concepts and definitions that are the foundation for this document.

8.1   ENNI External Reference Model

Formally, the Metro Ethernet Network Architecture Framework (MEF 4 [10]) specifies a reference point that is the interface between two Carrier Ethernet Networks (CENs), where each CEN is under the control of a distinct administrative authority. This reference point is termed the External Network Network Interface or ENNI. The MEF Forum external reference point model is displayed in Figure 1 which is derived from Figure 3 in MEF 4 [10].[4] An Ethernet-aware Wide Area Network (E-WAN) is functionally equivalent to a CEN but is given a distinct name to suggest that an E-WAN may have a larger geographical extent than a typical CEN. In this specification, CEN includes E-WAN.
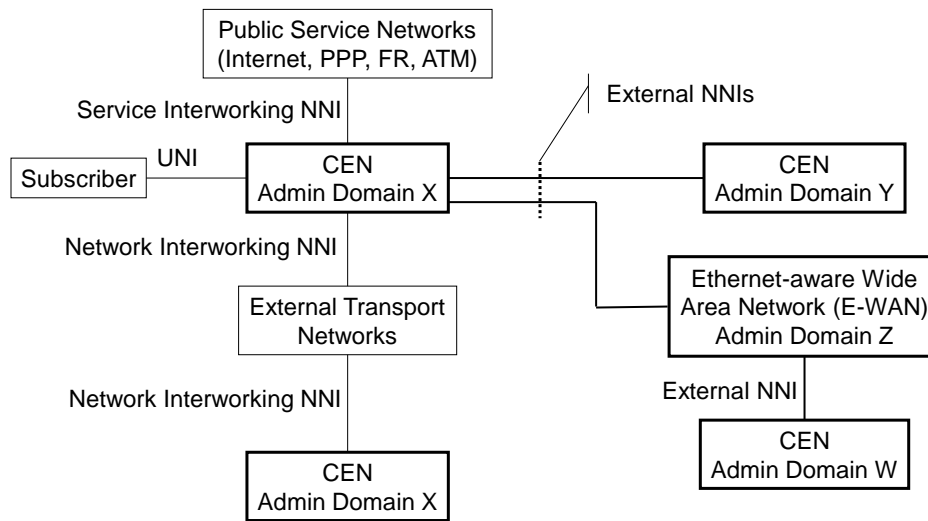
Figure 1 – MEF Forum External Reference Model

This document generalizes the definition of the ENNI to include interconnection of a CEN and another type of network as detailed in Section 8.2

8.2   Service Provider, Operator, and External Network Network Interface (ENNI)

It is likely that a potential Subscriber for Ethernet Services will have locations that are not all served by a single CEN Operator. Put another way, in order for such a Subscriber to obtain services, multiple CEN Operators will need to be used to support all of the Subscriber's User Network Interfaces (UNIs). A further potential complication is that the CEN Operators supporting the UNIs may not all interconnect with each other necessitating the use of transit CEN Operators. Figure 2 shows an example where there are four Subscriber UNIs supported by

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[4] MEF 4 uses the term MEN which is equivalent to CEN as used in this document.

three CEN Operators where Operator A does not directly connect with Operator C necessitating the use of Operator D as an intermediary.

The External Network Network Interface (ENNI) is the physical demarcation point between the responsibilities of a CEN Operator and the responsibilities of the administrative authority for another network that interconnects with the CEN. An example of such an arrangement can be found in MEF 33 [21] where the other network is an Internet Service Provider. However, this document is focused on the use of the ENNI to support Ethernet Virtual Connections (EVCs) where the ENNI is interconnecting two CENs as shown in Figure 2.

The goal of this Technical Specification is to enable configurations like that of Figure 2 to support the Service Attributes defined in MEF 10.3 [12], Service Definitions in MEF 6.2 [11] and Service Definitions in MEF 51 [25].
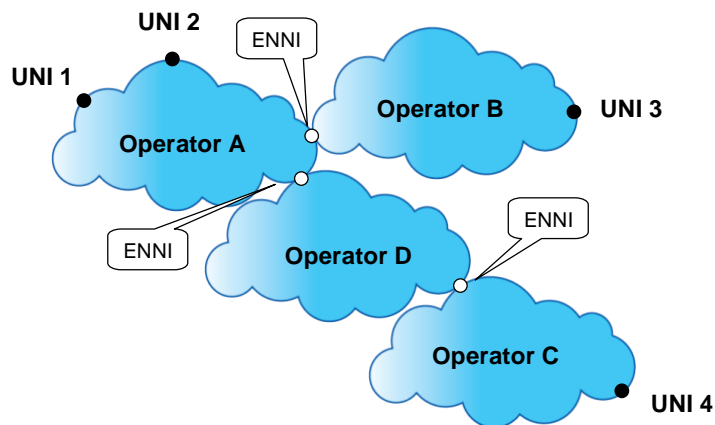
Figure 2 – Example of Multiple CEN Operators Supporting Ethernet Services

This document uses the following Service Model. For a given Ethernet Virtual Connection (EVC), the Subscriber contracts with a Service Provider to be responsible for delivering Ethernet Services among the UNIs associated by the EVC. The Service Provider, in turn, selects and contracts with various CEN Operators to deliver the UNI-to-UNI services. It is the responsibility of the Service Provider to ensure that the UNI to UNI service features purchased by the Subscriber are delivered. For example, the Service Provider is responsible for ensuring that there are no data loops traversing multiple Operator CENs and ensuring that the Service Level Specification agreed to by the Subscriber and the Service Provider is met.

There is no constraint on the type of organization that can act as the Service Provider. Examples include:

- One of the Operators involved in instantiating the Services, e.g., Operator D in Figure 2,

- A third party such as a systems integrator,

- An enterprise IT department (acting as both Service Provider and Subscriber), and

- A Mobile Operator (acting as both Service Provider and Subscriber).

Note that the role of an organization can be different for different EVC instances. For example, an organization can act as an Operator for one EVC and as Service Provider and an Operator for another EVC.

8.3   Operator Service Attributes

An Operator Service Attribute is an externally observable behavior of a single Operator CEN. Such a behavior can be observable at an interface or it can be observable between interfaces such as between a UNI and an ENNI. An Operator Service Attribute can take on one of several values where each value mandates a given behavior.

This document defines Operator Service Attributes and the possible values for each. In addition this document mandates requirements constraining the values of Operator Service Attributes. This document does not address how an Operator implements the CEN in order to achieve the Operator Service Attribute values and related requirements. Such considerations are beyond the scope of this document.

It is important to keep in mind that the Operator Service Attributes, values, and requirements apply to a single Operator CEN. Thus in Figure 2, the Service Provider deals with four sets of Operator Service Attributes and values, one set for each of Operator A, Operator B, Operator C, and Operator D. This means that the value for a given Operator Service Attribute in a given Operator CEN is determined by the Service Provider and the Operator of the CEN.[5] The Operator Service Attributes can be thought of as the menu from which the Service Provider purchases, from each Operator, what is needed to instantiate the UNI to UNI services purchased by the Subscriber.

8.4   ENNI Common Attributes

When Operators interconnect their CENs to form an ENNI, several technical details need to be agreed to. Examples include the physical layer of each of the links supporting the ENNI and the valid formats of the ENNI Frames. These technical details are called ENNI Common Attributes. Each ENNI Common Attribute takes on a single value and Operators supporting the ENNI have to agree on the value for each ENNI Common Attribute. The method by which agreement is reached is outside the scope of this document. Generally speaking, the Operators that need to agree are any Operator that is not a Super Operator (See Section 8.10) and any Super Operator that has arranged for unshared access to the ENNI. Section 13.2 provides the specific details.

Service Providers and Super Operators that are not party to the agreement of the ENNI Common Attribute values can be aware or unaware of the value for each ENNI Common Attribute. Such

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[5] In some cases the values are determined by an Operator and a Super Operator as described in Section 8.10.

organizations may want to be aware of the values since the values of the ENNI Common Attributes can influence the decision as to which ENNIs to use.

8.5 Operator Multilateral Attributes

An Operator Multilateral Attribute is a behavior of a single Operator CEN at an ENNI that is externally visible to a Service Provider or Super Operator using that CEN and ENNI and/or to peer Operators operating CENs on the other side of the ENNI. An Operator Multilateral Attribute has the same value for all Service Providers or Super Operators using that CEN and ENNI to whom the behavior is externally visible. It follows that several organizations may need to agree on the value: the Operator who operates the CEN, the Service Provider or Super Operators who are using the Operator's CEN, and certain Operator(s) who operate CENs on the other side of the ENNI (Section 13.2 spells out which ones). The procedures by which such agreements are reached are beyond the scope of this document.

Note that Operator Multilateral Attributes differ from ENNI Common Attributes in that the Operators on each side of the ENNI may have different values for the same Operator Multilateral Attribute. In addition, an Operator may need to agree to the value of an Operator Multilateral Attribute with the Service Providers and Super Operators that are purchasing services as well as with the peer Operator.

8.6 ENNI Frame

An ENNI Frame is an Ethernet frame transmitted or received by an Operator CEN across an ENNI. When an ENNI Frame is transmitted by an Operator CEN, from the perspective of this Operator CEN, it is called an egress ENNI Frame. When the ENNI Frame is received by an Operator CEN, from the perspective of this CEN, it is called an ingress ENNI Frame.

The ENNI Frame consists of the first bit of the Destination MAC Address through the last bit of the Frame Check Sequence.

There are three types of ENNI Frame as specified in Sections 8.6.1, 8.6.2, and 8.6.3.

8.6.1 Layer 2 Control Protocol ENNI Frame

A Layer 2 Control Protocol ENNI Frame (L2CP ENNI Frame) is an ENNI Frame that could be used in a recognized Layer 2 Control Protocol. Given that there are several Layer 2 protocols used for various control purposes, it is important that Carrier Ethernet Networks be able to process such information effectively.

> **[R1]** An ENNI Frame whose destination MAC address is one of the addresses listed in Table 2 of MEF 45 [24] **MUST** be treated as a Layer 2 Control Protocol ENNI Frame.

MEF 45 [24] contains requirements for the handling of specific Layer 2 Control Protocols.

8.6.2   SOAM ENNI Frame

An ENNI Frame whose MAC Destination Address does not indicate the frame to be an L2CP ENNI Frame and has an Ethertype = 0x8902 is defined to be a SOAM ENNI Frame. (See Table 21-1 of IEEE Std 802.1Q – 2014 [3].) Requirements for SOAM ENNI Frames can be found in MEF 17 [16], MEF 30.1 [20], and MEF 35.1 [22].

Note that an SOAM ENNI Frame can be an Untagged ENNI Frame, a Single Tagged ENNI Frame, or a Double Tagged ENNI Frame. See Section 9.3 for the definition of Untagged ENNI Frame, Single Tagged ENNI Frame and Double Tagged ENNI Frame.

8.6.3   Data ENNI Frame

An ENNI Frame that is not a Layer 2 Control Protocol ENNI Frame and not a SOAM ENNI Frame is defined to be a Data ENNI Frame. A Data ENNI Frame with a unicast Destination MAC Address is defined to be a Unicast Data ENNI Frame. A Data ENNI Frame with a multicast Destination MAC Address is defined to be a Multicast Data ENNI Frame. A Data ENNI Frame with a broadcast Destination MAC Address is defined to be a Broadcast Data ENNI Frame.

8.7   EI Frame

As can be seen in Section 8.8, Operator Service Attributes describe behaviors involving both ENNI Frames that, by definition, cross an ENNI and Service Frames that, by definition, cross a UNI. Because of this, the following terms are defined for ease of description:

- **EI Frame:** Either an ENNI Frame or a Service Frame

- **Data EI Frame:** Either a Data ENNI Frame or a Data Service Frame

- **Unicast Data EI Frame:** A Data EI Frame with a Unicast Destination MAC Address

- **Multicast Data EI Frame:** A Data EI Frame with a Multicast Destination MAC Address

- **Broadcast Data EI Frame:** A Data EI Frame with a Broadcast Destination MAC Address

- **L2CP EI Frame:** Either an L2CP ENNI Frame or an L2CP Service Frame[6]

- **SOAM EI Frame:** Either a SOAM ENNI Frame or a SOAM Service Frame

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[6] The method by which the type of Layer 2 Control Protocol is determined is beyond the scope of this document.

The terms Service Frame, Data Service Frame, L2CP Service Frame, and SOAM Service Frame
are defined in MEF 10.3 [12].

8.8   Operator Virtual Connection

The Operator Virtual Connection (OVC) is the building block for constructing an EVC spanning
multiple Operator CENs.

In the same way that an EVC defines an association of UNIs, an OVC is an association of OVC
End Points. An OVC End Point is a logical entity at a given External Interface that is associated
with a distinct set of frames passing over that External Interface. An OVC End Point represents
the logical attachment of an OVC to an External Interface (a UNI or ENNI in the context of this
document).

At each External Interface, there is a way to map each EI Frame to at most one OVC End Point.
Section 16.5 describes the mapping method.

In this document there are two types of External Interface; UNI and ENNI. In the future, the
OVC concept may be generalized by defining additional kinds of External Interfaces. Per [R36],
at least one OVC End Point associated by an OVC is at an ENNI.

Per [R34], an ingress EI Frame that maps to OVC End Point A can only result in an egress EI
Frame at an External Interface where there is an OVC End Point B and an OVC associates OVC
End Points A and B.

Figure 3 shows an example of two OVCs. OVC 1 connects UNI A, UNI B, and the ENNI by
associating the OVC End Points c, d, and f. OVC 2 connects UNI A and the ENNI by associating
OVC End Points a, b, and e. OVC 2 associates two OVC End Points at the ENNI. This allows
what is called Hairpin Switching (see Section 12.3.1) via OVC End Points a and b. An OVC is
mandated to associate at most one OVC End Point at a given UNI thus precluding Hairpin
Switching at a UNI.
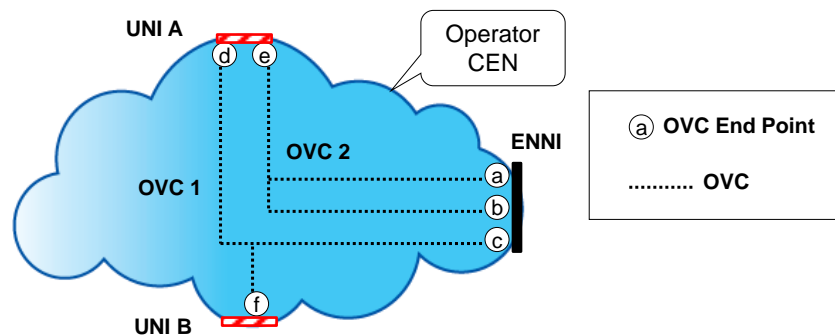
Figure 3 – Examples of OVCs

8.9 Relationship between OVCs and EVC

An Ethernet Virtual Connection (EVC) is defined in MEF 10.3 [12] as an association of two or more UNIs. When an EVC associates UNIs attached to more than one Operator CEN, the EVC is realized by concatenating OVCs. Figure 4 illustrates how this is done with an example.

In this example, there is an EVC associating UNI Q and UNI S and it is constructed by concatenating OVC A2 in CEN A with OVC B2 in CEN B. The concatenation is achieved by properly configuring the OVC End Point Map Service Attribute value for ENNI AB in CEN A and the OVC End Point Map Service Attribute value for ENNI AB in CEN B. (See Section 16.5 for the definitions and requirements for the OVC End Point Map Service Attribute.) These OVC End Point Map Service Attribute values are configured such that an ENNI Frame at ENNI AB that is mapped to OVC End Point x by CEN A is mapped to OVC End Point y by CEN B and vice versa. An ingress Service Frame at UNI Q that is destined for UNI S will result in an egress ENNI Frame at ENNI AB mapped to OVC End Point x in CEN A. When this frame is received by CEN B as an ingress ENNI Frame, it will be mapped to OVC End Point y and then result in an egress Service Frame at UNI S. The other EVCs in the example can be similarly instantiated by configuring the OVC End Point Map Service Attribute values as shown in the table. It is the responsibility of the Service Provider responsible for an EVC to insure that the OVCs are correctly concatenated for the corresponding EVC.

EVC	UNIs	OVCs
1 (red)	UNI P, UNI R, UNI T	A1, B1, C1
2 (blue)	UNI Q, UNI S	A2, B2
3 (black)	UNI P, UNI R	A3, B3
4 (green)	UNI S, UNI V	B4, C4
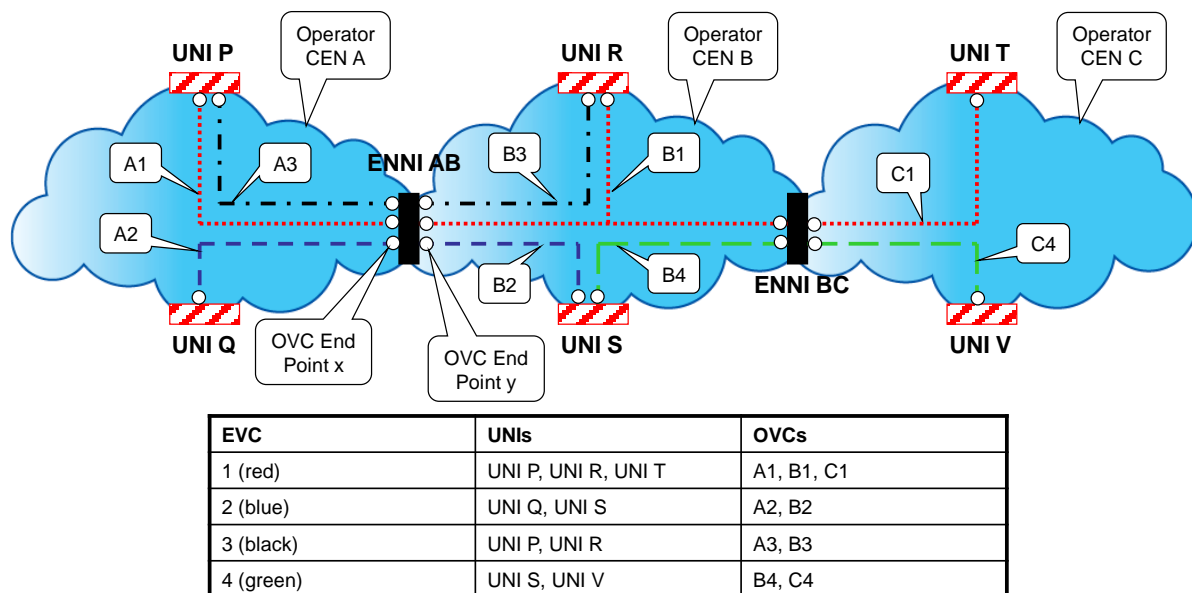
Figure 4 – Example Relationship of OVCs to EVCs

The example of Figure 4 illustrates one possible configuration. In this example, each Operator CEN has only one OVC for each EVC that it is supporting. However, it is possible to use multiple OVCs in a single Operator CEN to build an EVC. Appendix A.4 contains an example. It is also possible that a single OVC in an Operator CEN can support more than one EVC. One example of how this can occur is when an OVC End Point Map Service Attribute value has

Bundling as described in Appendix A.7. The Operator Service Attributes contained in this document are sufficient to support Point-to-Point, Multipoint-to-Multipoint, and Rooted-Multipoint EVCs.

8.10   Super Operator

In order to implement the Operator Service Attribute values that an Operator provides to a Service Provider, the Operator can contract with one or more other Operators. An Operator that contracts in this way is called a Super Operator. Furthermore, an Operator implementing Service Attribute values for a Super Operator may in turn contract with one or more other Operators. Consequently, an Operator can simultaneously be a Super Operator.

Figure 5 shows an example of multiple levels of Super Operators. In this example Operator A and Operator B appear to Service Provider Alpha to be ordinary Operators. However, Operator A contracts with Operator C and Operator D and thus appears as a Super Operator to Operator C and Operator D. Finally, Operator C contracts with Operator E thus appearing to Operator E as a Super Operator.
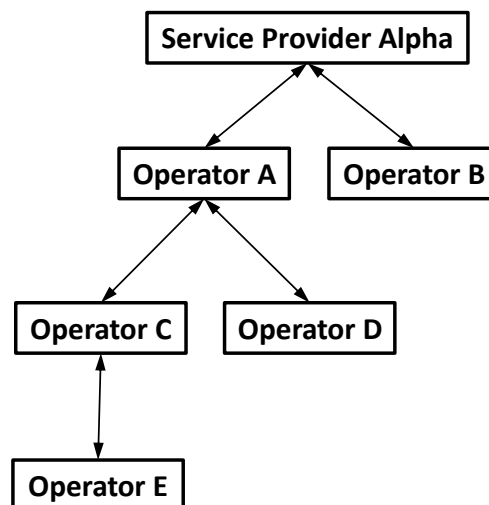
Figure 5 – Example of Two Levels of Super Operators

There is no restriction on the type of organization that can act as a Super Operator. One of the Operators may also act as the Super Operator. In particular, for a given instance of an EVC, the same organization could act as an Operator, a Super Operator and as the Service Provider. The Super Operator/Operator business relationship can be different for different OVC instances. For example, Operator A can be a Super Operator with respect to Operator B for one OVC; while, for another OVC, Operator B can be a Super Operator with respect to Operator A.

Each Super Operator operates its own CEN, and instantiates OVCs over it in support of the Service Provider or another Super Operator. A Super Operator's CEN encompasses the CENs of the underlying Operators it contracts with, and the Super Operators OVCs are constructed by

agreeing on Operator Service Attribute values with the underlying Operators, in a similar way to how a Service Provider may construct an EVC. Thus, both CENs and OVCs may be thought of as nested, when there is a Super Operator. Just as in the case of EVCs, a Super Operator's OVC may be carried by multiple OVCs in the underlying Operator, or the Operators OVC may bundle together several different Super Operator OVCs (from the same or different Super Operators).

As an example of a Super Operator, consider the Multipoint-to-Multipoint EVC instantiated by the Service Provider using Operator A and Operator B shown in Figure 6. From the point of view of the Service Provider, OVC Service Attribute values need to be established with Operator A and Operator B. In particular, the Service Provider and Operator B agree on the Operator Service Attribute values for the Multipoint-to-Multipoint OVC shown in Figure 6.
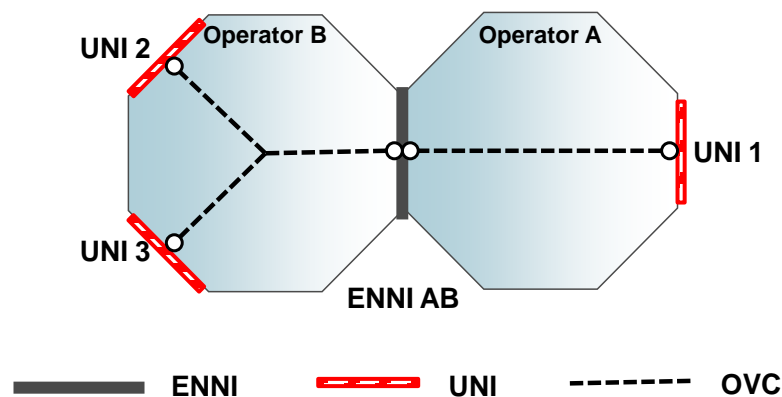
Figure 6 – Service Provider View

But in this example, Operator B's CEN does not reach UNI 2 and UNI 3. In this case Operator B, acting as a Super Operator, contracts with Operator C and Operator D as shown in Figure 7 to reach UNI 2 and UNI 3. In this case, Operator B, acting as the Super Operator, needs to establish Operator Service Attribute values with Operator C and Operator D. Note that there is a Multipoint-to-Multipoint OVC in CEN B in Figure 7. Operator B is responsible to establish the proper behaviors of this OVC so that the Multipoint-to-Multipoint OVC established by agreement with the Service Provider in Figure 6 has the proper Service Attribute values.
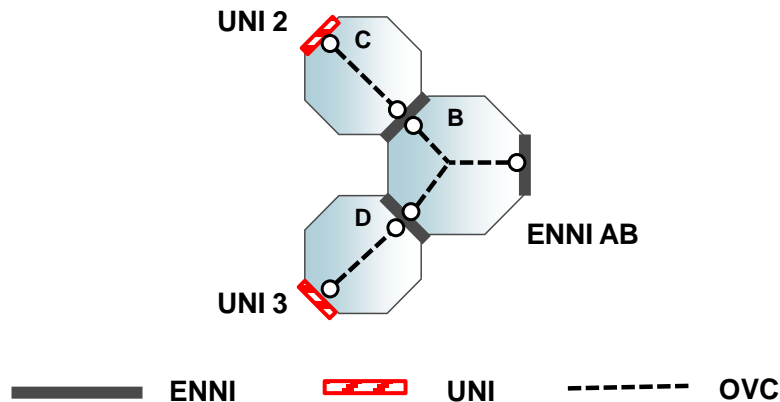
Figure 7 – Super Operator B View

In this example, the value for each Operator Service Attribute in the Operator C CEN is determined by Operator C and Operator B acting as a Super Operator. Similarly, the value for each Operator Service Attribute in the Operator D CEN is determined by Operator D and Operator B acting as a Super Operator. The details regarding these Operator Service Attribute values are not visible to the Service Provider who sees just a single Multipoint-to-Multipoint OVC as shown in Figure 6.

Operator B plays two roles in this example:

1. Super Operator in dealing with Operators C and D, and

2. Operator in dealing with the Service Provider.

Additional Super Operator examples are contained in Appendix E.

In general, the value of each Operator Service Attribute in an Operator CEN is determined by the Operator of the CEN and either a Service Provider (see Section 8.3) or an Operator acting as a Super Operator. For ease of description, SP/SO is used to mean Service Provider or Super Operator in this document.

The value of an Operator Service Attribute agreed to between a Super Operator and a contracted Operator can and might need to be different than the value for the corresponding Operator Service Attribute agreed to between the Super Operator and the Service Provider (or another Super Operator). As an example, consider the Operator UNI Identifiers in Figure 6 and Figure 7. It is possible that Operator C has assigned *West0001* as the value for the Operator UNI Identifier Service Attribute for UNI 2 in Figure 7 while Operator D has assigned the same value, *West0001*, for UNI 3 in Figure 7. See Section 14.1 for the details of the Operator UNI Identifier Service Attribute. But to meet the uniqueness requirement for the values of Operator UNI Identifier Service Attributes, [R86], Operator B, acting as a Super Operator, needs to use a different value for at least one of these Operator UNI Identifier Service Attributes in Figure 6.

Note that in the example of Figure 7, Operator C or Operator D could act as Super Operator by contracting with one or more Operators to establish connectivity between the ENNI with Operator B and the respective UNIs. Since an Operator can also act as a Super Operator, there can be an arbitrary number of Super Operator levels. However, practical considerations such as SOAM will probably limit the number of levels to a modest number.

Appendix D contains additional examples of Super Operator configurations. Appendix H contains information on the relationship between the values of each Service Attribute as seen by an Operator, Super Operator, Service Provider, and Subscriber.

8.11   Multiple Service Providers and/or Super Operators at an ENNI

An ENNI can be used by more than one SP/SO. For example, in Figure 4, suppose that EVC 1 is the responsibility of Service Provider Alpha and suppose that EVC 4 is the responsibility of Service Provider Beta. This means that ENNI BC is shared by the two Service Providers in the sense that:

- Service Provider Alpha and Operator B agree on the values of the ENNI Service Attributes for ENNI BC,

- Service Provider Beta and Operator B agree on the values of the ENNI Service Attributes for ENNI BC,

- Service Provider Alpha and Operator C agree on the values of the ENNI Service Attributes for ENNI BC, and

- Service Provider Beta and Operator C agree on the values of the ENNI Service Attributes for ENNI BC.

Each SP/SO can see a different value for an ENNI Service Attribute. For example each could see a different value for the Maximum Number of OVCs Service Attribute (Section 13.3). Another example is the value of Operator ENNI Identifier Service Attribute where each Operator agrees to a different value with each SP/SO resulting in a total of four values for this Service Attribute.

8.12   Single Service Provider at a UNI

Section 7 of MEF 10.3 [12] restricts the UNI to the use of a single Service Provider. This document aligns with this constraint. To this end, a UNI can only be associated with a single Operator that is not a Super Operator, and may be associated with multiple Super Operators only if they have a hierarchical contractual relationship between them relating to the UNI in question. In particular, if an Operator (including Super Operators) provides an OVC to a UNI to a given SP/SO, then all other OVCs provided by the Operator to the same UNI have to be provided to the same SP/SO. In other words, an Operator (including a Super Operator) cannot provide OVCs to the same UNI to multiple SP/SOs.

8.13   Virtual UNI (VUNI) and Remote UNI (RUNI)

A Virtual UNI (VUNI) is the instantiation in one Operator CEN of functions that perform a portion of the Service Attributes observable at a UNI supported by a different Operator CEN. Each VUNI is paired with a UNI, called a Remote UNI (RUNI) that is supported by an Operator CEN other than the Operator CEN containing the VUNI. The Operator CEN supporting the RUNI instantiates only a portion of the functions needed to perform the Service Attributes observable at the RUNI, and relies on the VUNI to instantiate the remaining necessary functions. In effect, functions and Service Attributes are divided between the Operator of the VUNI (called the VUNI Provider) and the Operator of the RUNI (called the RUNI Provider). This division gives the SP/SO more flexibility and may allow the SP/SO to compensate for limited capabilities in the Operator CEN supporting the RUNI. This division may also allow for centralization of functions in a single Operator CEN rather than spread out at many locations, because a single Operator CEN may have multiple VUNIs, each paired with a separate RUNI. Note that, while each VUNI is paired with a single RUNI, a single RUNI may be paired with multiple VUNIs, all in the same or different other Operator CENs. Like a UNI, there may be one or more OVC End Points at a VUNI. Note that these OVC End Points at the VUNI are at an ENNI. To reduce confusion, an OVC End Point that is at a VUNI is said to be in the VUNI.

9 ENNI Common Attributes

The ENNI is defined as a reference point representing the boundary between two or more Operator CENs that are operated as separate administrative domains. Section 13.2 describes how there can be more than two Operator CENs when Super Operators are involved.

Similar to the concept of the UNI-C and UNI-N functional components of the UNI described in MEF 11 [14], it is useful to identify ENNI-N_1 and ENNI-N_2 as the separately administered functional components that support the ENNI between CEN 1 and CEN 2. Figure 8 illustrates this concept. Each ENNI-N_i represents those functions necessary to implement the protocols and procedures specified in this document. Implementation of the ENNI-N_i is beyond the scope of this document.
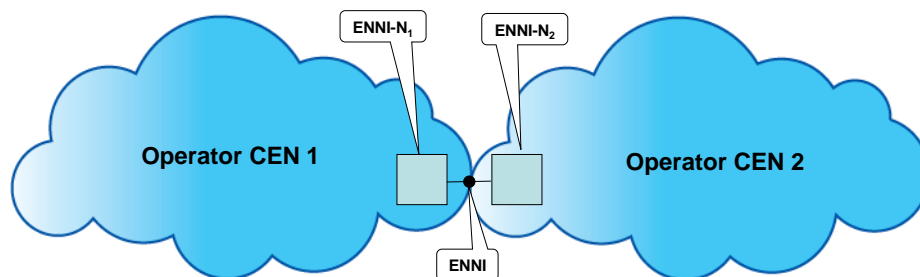
Figure 8 – Representation of ENNI-N_i

The ENNI Common Attributes are summarized in Table 3 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
ENNI Peering Identifier	An identifier for the ENNI intended for operations purposes by the interconnecting Operators at the ENNI	A string that is unique across all of the ENNIs between the Operator CENS
ENNI Physical Layer	The physical layer of each of the links supporting the ENNI	A subset of the PHYs listed in IEEE Std 802.3 – 2012 [4] for each physical link
ENNI Frame Format	The format of the PDUs at the ENNI	*Ethernet MAC Frame conforming to Clause 3 of IEEE 802.3-2012* [4]
ENNI Number of Links	The number of physical links in the ENNI	A strictly positive integer
ENNI Ling Aggregation	The method for protection, if any, against a physical link failure	*None*, *2-Link Active/Standby*, *All Active*, or *Other*
ENNI Port Conversation ID to Aggregation Link Map	The mapping of Port Conversation IDs to physical links	See IEEE Std 802.1AX – 2014 [2]
ENNI MEG	The indication of the instantiation of the ENNI MEG	*Enabled* or *Disabled*
ENNI LAG Link MEG	The indication of the instantiation of the LAG Link MEG on each physical link at the ENNI	*Enabled* or *Disabled*
ENNI Link OAM	The indication of the instantiation of Link OAM on each physical link at the ENNI	*Enabled* or *Disabled*

Table 3 – ENNI Common Attributes

9.1   ENNI Peering Identifier Common Attribute

The ENNI Peering Identifier Common Attribute value is a string used to allow the Operators at the ENNI to uniquely identify the ENNI for operations purposes.

> **[R2]**   The ENNI Peering Identifier Common Attribute value **MUST** be unique across all ENNIs for each of the Operator CENs.

If Operators A and B connect via an ENNI with the value of the ENNI Peering Identifier Common Attribute equal to "Chicago Hanover – Acme CE Services", then [R2] mandates that no other ENNI supported by Operator A have the same value for the ENNI Peering Identifier Common Attribute. The mandate also applies to Operator B.

[R3]   The ENNI Peering Identifier Common Attribute value **MUST** contain no more than 45 characters.[7]

[R4]   The ENNI Peering Identifier Common Attribute value **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

9.2   ENNI Physical Layer Common Attribute

An ENNI can be implemented with one or more physical links. The ENNI Physical Layer Common Attribute is a list of physical layers, one for each physical link implementing the ENNI. Different physical links can use different physical layers.

[R5]   The Physical Layer for each physical link implementing the ENNI **MUST** be one of the PHYs listed in IEEE Std 802.3 – 2012 [4] that can operate with a line rate of at least 1 Gbps but excluding 1000BASE-PX-D and 1000BASE-PX-U.

[R6]   The PHYs **MUST** operate with a line rate of at least 1 Gbps.

[R7]   The PHYs **MUST** operate in full duplex mode.

Note that a PHY that can operate at multiple bit rates, e.g., 1000Base-T, complies with [R5] but [R6] mandates that it operate at 1 Gbps or more when used for an ENNI.

9.3   ENNI Frame Format Common Attribute

The ENNI Frame Format Common Attribute has the value *Ethernet MAC Frame conforming to Clause 3 of IEEE 802.3-2012*. Additional potential values, e.g., MPLS-based formats, are beyond the scope of this document. The ENNI Frame is an Ethernet frame and is defined to consist of the first bit of the Destination MAC Address through the last bit of the Frame Check Sequence. ENNI Frames use Service VLAN tags (S-Tags), as defined in IEEE Std 802.1Q-2014 [3], to map frames to OVC End Points as described in Section 16.5. An ENNI Frame can have zero or more VLAN tags.

[R8]   Each ENNI-N **MUST** comply with the Ethernet Media Access Control standards specified in Clauses 3 and 4 of IEEE Std 802.3 – 2012 [4].

Note that [R8] means that ENNI Frames will be discarded by the receiving CEN if they are not properly constructed. For example, an ENNI Frame with an incorrect Frame Check Sequence will be discarded. However, this document provides for ENNI Frames that are longer than the maximum specified in IEEE Std 802.3–2012 [4]. See Section 10.3.

The frame names per the following list are used throughout this document:

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[7] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

- When the 2 byte field following the Source Address field is a TPID with the value 0x88a8 and the corresponding VLAN ID value is not 0x000, the ENNI Frame is said to be a VLAN Tagged ENNI Frame.

- When the 2 byte field following the Source Address field is a TPID with the value 0x88a8 and the corresponding VLAN ID value is 0x000, the ENNI Frame is said to be a Priority Tagged ENNI Frame.

- An ENNI Frame that is either a VLAN Tagged ENNI Frame or a Priority Tagged ENNI Frame is said to be a Tagged ENNI Frame.

- When the two bytes following the Source Address field do not contain the value 0x88a8, the ENNI Frame is said to be an Untagged ENNI Frame.

- When the 2 byte field beginning with the fifth byte after the Source Address field of a Tagged ENNI Frame is not a TPID with the value equal to 0x8100, the ENNI Frame is said to be a Single Tagged ENNI Frame.

- When the 2 byte field beginning with the fifth byte after the Source Address field of a Tagged ENNI Frame is a TPID with the value 0x8100, the ENNI Frame is said to be a Double Tagged ENNI Frame.

[R9] An S-Tag **MUST** have the format specified in Clauses 9.5 and 9.6 of IEEE Std 802.1Q–2014. [3]

[R10] A C-Tag **MUST** have the format specified in Clauses 9.5 and 9.6 of IEEE Std 802.1Q–2014. [3]

When an ENNI Frame contains an S-Tag, the value of the 12 bit VID field in the S-Tag is defined as the S-VLAN ID.

9.4   ENNI Number of Links Common Attribute

The value for the ENNI Number of Links Common Attribute is a strictly positive integer. This ENNI Common Attribute specifies the number of links that compose the ENNI.

Per Section 8.4, an SP/SO might or might not know the value of this Common Attribute. In any event, a SP/SO will know the value or values of the OVC End Point Aggregation Link Depth Service Attribute that is described in Section 16.14.

9.5   ENNI Link Aggregation Common Attribute

The ENNI Link Aggregation Common Attribute value is one of *None*, *2-Link Active/Standby*, *All Active*, or *Other*. The value of this Common Attribute is dependent on the value of the ENNI Number of Links Common Attribute.

[R11]   If the value of the ENNI Number of Links Common Attribute is 1, then the value of the ENNI Link Aggregation Common Attribute **MUST** be set to *None*.

[R12]   If the value of the ENNI Number of Links Common Attribute is 2 then the value of the ENNI Link Aggregation Common Attribute **MUST** be set to one of *2-Link Active/Standby*, *All Active*, or *Other*.

[R13]   If the value of the ENNI Number of Links Common Attribute is 3 or more then the value of the ENNI Link Aggregation Common Attribute **MUST** be set to either *All Active* or *Other*.

Table 4 summarizes the above requirements.

Number of Links	*None*	*2-Link Active/Standby*	*All Active*	*Other*
1	☑	☐	☐	☐
2	☐	☑	☑	☑
3 or more	☐	☐	☑	☑

Table 4 – Allowed Values of the ENNI Link Aggregation Common Attribute

The following requirements depend on the value of the ENNI Link Aggregation Common Attribute.

[R14]   When the value of the ENNI Link Aggregation Common Attribute is set to *2-Link Active/Standby*, each CEN **MUST** implement Link Aggregation as in either Clause 5.6.1 of IEEE Std 802.1AX – 2008 [1] or Clause 6.7.1 of IEEE Std 802.1AX – 2014 [2] with one Link Aggregation Group (LAG) across the links supporting the ENNI and with one link in active mode and the other in standby mode.

[R15]   When the value of the ENNI Link Aggregation Common Attribute is set to *All Active* each CEN **MUST** use Link Aggregation as specified in Clause 5.3 of IEEE Std 802.1AX-2014 [2], including the use of the version 2 LACPDUs as specified in Clause 5.3.1h of IEEE Std 802.1AX-2014 [2], with one Link Aggregation Group (LAG) across the links supporting the ENNI.

[R16]   When the value of the ENNI Link Aggregation Common Attribute is *All-Active*, each CEN **MUST** use "Per-service frame distribution" as specified in Clause 8.2 of IEEE Std 802.1AX-2014 [2], where the Port Conversation ID is equal to the S-VLAN ID for VLAN Tagged ENNI Frames and equal to 0 for Untagged and Priority Tagged ENNI Frames.

[R16] means that the Service ID for each ENNI Frame is the value of the VLAN ID in the S-Tag when present and is 0 when the ENNI Frame has no S-Tag. [R16] also means that the Port Conversation ID = Service ID in the Service ID to Port Conversation ID Map.

[R17] When the ENNI Link Aggregation Common Attribute is set to *All-Active*, each CEN **MUST** be configured such that there is only one aAggActorAdminKey that has the same value as the aAggPortActorAdminKey for the ports terminating the links at the ENNI.

The aAggActorAdminKey and aAggPortActorAdminKey are managed objects defined in IEEE Std 802.1AX-2014 [2]. Ensuring that there is only one aAggActorAdminKey with the same value as the aAggPortActorAdminKey for the ports at the ENNI assures that only a single Link Aggregation Group is formed at the ENNI. This eliminates that possibility of any loops potentially arising from multiple ENNI links coming up independently or forming separate Link Aggregation Groups.

[O1] When the value of the ENNI Link Aggregation Common Attribute is *Other*, the Operators **MAY** implement any other resiliency mechanism by mutual agreement.

The other resiliency mechanism referred to in [O1] is beyond the scope of this document.

9.6   ENNI Port Conversation ID to Aggregation Link Map Common Attribute

The ENNI Port Conversation ID to Aggregation Link Map Common Attribute is applicable only when the ENNI Link Aggregation Common 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 [2]. By the definition of Common Attribute, when the value of the ENNI Link Aggregation Common Attribute is *All Active*, each CEN needs to use the same Port Conversation ID to Aggregation Link Map.

[R18] When the ENNI Link Aggregation Common Attribute is set to *All Active*, the set of Link Number IDs as defined in IEEE Std 802.1AX – 2014 [2] for each CEN **MUST** be $\{1,2,\dots,m\}$ where m is the value of the ENNI Number of Links Common Attribute.

[R19] When the ENNI Link Aggregation Common Attribute is set to *All Active*, the number of links mapped to each Port Conversation ID **MUST** be equal to or greater than *n* where *n* is the value of the second element of the pair <Port Conversation ID, *n*> and <Port Conversation ID, *n*> is the value of the OVC End Point Aggregation Link Depth Service Attribute of Section 16.14.

[O2] When the ENNI Link Aggregation Common Attribute is set to *All Active* and an OVC End Point Map Service Attribute value (Section 16.5) in a CEN maps more than one S-VLAN ID value to an OVC End Point, the CEN **MAY** support a value of the ENNI Port Conversation ID to Aggregation Link Map Common Attribute such that ENNI Frames with different S-VLAN ID values mapped to the OVC End Point can be carried on different physical links.

The value of the ENNI Port Conversation ID to Aggregation Link Map Common Attribute described in [O2] is useful when the bandwidth needed for the OVC End Point exceeds the capacity of a single physical link at the ENNI. However, in certain configurations (for example when the links terminate on different devices in the CEN), supporting such map could require an Operator to make tradeoffs between the ENNI Frame distribution and the application of MEF Forum SOAM and Bandwidth Profiles.

> **[R20]** When Ingress Bandwidth Profiles (Sections 16.10, 16.12, 15.1.6) and/or Egress Bandwidth Profiles (Sections 16.11, 16.13, 15.1.7) are used at a given ENNI by a CEN, the Operator of the CEN **MUST** support a value in the ENNI Port Conversation ID to Aggregation Link Map Common Attribute such that all ENNI Frames that map to a given Envelope (Section 17) are carried on the same physical link.

It may difficult to implement the Bandwidth Profile Algorithm (Section 17.2) when ENNI Frames mapped to an Envelope are carried on multiple physical links. [R20] is intended to address the situation where the CENs have this implementation issue.

9.7 ENNI MEG Common Attribute

The value of ENNI MEG Common Attribute is either *Enabled* or *Disabled*.

> **[R21]** When the value of the ENNI MEG Common Attribute is *Enabled*, each CEN **MUST** meet the mandatory requirements of MEF 30.1 [20] that apply to the ENNI MEG.

> **[R22]** When the value of the ENNI MEG Common Attribute is *Enabled*, the direction of the ENNI MEG MEP in each CEN **MUST** be *Down*.

When the value is *Enabled*, a number of further parameters need to be agreed to as described in MEF 30.1 [20].

9.8 ENNI LAG Link MEG Common Attribute

The value of the ENNI LAG Link MEG Common Attribute is either *Enabled* or *Disabled*.

> **[R23]** When the value of the ENNI LAG Link MEG Common Attribute is *Enabled*, the Operator CENs **MUST** operate the LAG Link MEG on each link in the ENNI.

> **[R24]** When the value of the ENNI LAG Link MEG Common Attribute is *Enabled*, each CEN **MUST** meet the mandatory requirements and the conditional mandatory requirements of MEF 30.1 [20] that apply to the LAG Link MEG.

When the value is *Enabled*, a number of further parameters need to be agreed to as described in MEF 30.1 [20]. Some parameters will usually be the same across all links in the LAG (for example, the MEG Level) while others have to be different (for example, the MEG ID).

9.9 ENNI Link OAM Common Attribute

The value of the ENNI Link OAM Common Attribute is either *Enabled* or *Disabled*.

[R25] When the value of the ENNI Link OAM Common Attribute is *Enabled*, each CEN **MUST** run Link OAM on all physical links in the ENNI as specified in Clause 57 of IEEE Std 802.3-2012 [4].

[R26] When the value of the ENNI Link OAM Common Attribute is *Enabled*, each CEN **MUST** run Link OAM in Active DTE mode as specified in Clause 57.2.9 of IEEE Std 802.3 – 2012 [4].

In MEF 26.1 [18], only one side of the ENNI is mandated to be in Active DTE mode. Consequently, [R26] mandates more functionality than the corresponding requirement in MEF 26.1.

[D1] When the value of the ENNI Link OAM Common Attribute is *Enabled*, Link Events as specified in Clauses 57.2.10 and 57.4.3.2 of IEEE Std 802.3 – 2012 [4] **SHOULD** be enabled on each link in the ENNI.

Operators using Link OAM on the ENNI could receive unwanted loopback messages which could cause an interruption of traffic using the ENNI. The following recommendation is meant to prevent this situation:

[D2] When the value of the ENNI Link OAM Common Attribute is *Enabled*, each CEN **SHOULD** advertise the OAM Remote Loopback Support as "not capable", during the OAM discovery phase as specified in IEEE Std 802.3 – 2012 [4].

10   Operator Multilateral Attributes

The Operator Multilateral Attributes are summarized in Table 5 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
ENNI L2CP Peering	Specifies the Layer 2 Control Protocols that are peered by the CEN	See MEF 45 [24]
ENNI Tagged L2CP Frame Processing	Specifies the processing behavior for tagged Layer 2 Control Protocols	See MEF 45 [24]
ENNI Maximum Frame Size	The maximum length ENNI Frame in bytes that can be reliably processed	A strictly positive integer

Table 5 – Operator Multilateral Attributes

10.1   ENNI L2CP Peering Multilateral Attribute

The ENNI L2CP Peering Multilateral Attribute is the same as the L2CP Peering Service Attribute defined in MEF 45 [24] when applied to the ENNI. See Section 8.2 of MEF 45 [24] for the possible values and requirements for this Common Attribute.

10.2   ENNI Tagged L2CP Frame Processing Multilateral Attribute

The ENNI Tagged L2CP Processing Multilateral Attribute is defined in MEF 45 [24]. See Section 8.3 of MEF 45 [24] for the possible values and requirements for this Service Attribute.

10.3   ENNI Maximum Frame Size Multilateral Attribute

The value for the ENNI Maximum Frame Size Multilateral Attribute is a strictly positive integer number of bytes. This value limits the length of frames carried by an OVC that associates an OVC End Point at this ENNI per the requirements in Section 12.6.

[R27]   The value of the ENNI Maximum Frame Size Multilateral Attribute **MUST** be at least 1526 bytes.

11   Operator Service Attributes

The Service Model for the use of the ENNI involves the purchase of services from one or more Operators. These services are the exchange of traffic among ENNIs and UNIs that are supported by each Operator CEN. The purchaser of these services from the Operators is referred to as the SP/SO. The basic model is shown in Figure 9. Operator Service Attributes describe the possible behaviors seen by an observer (the SP/SO) external to the Operator CEN at and between the external interfaces (UNI and ENNI).
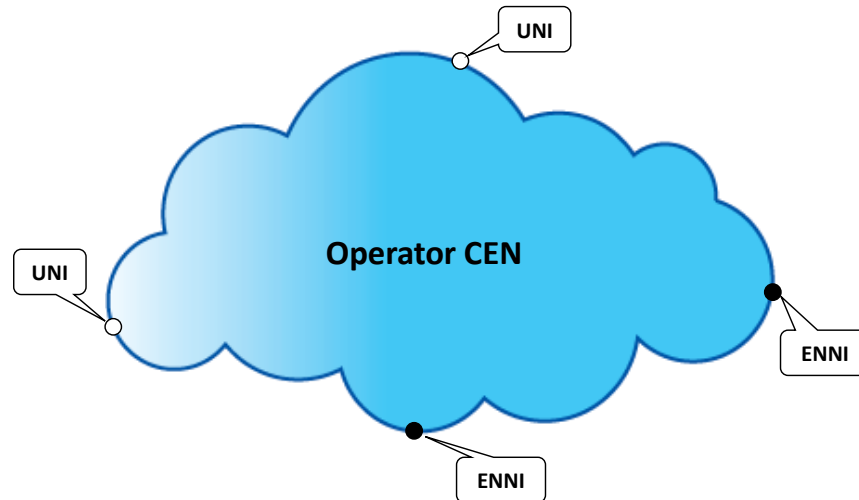
Figure 9 – ENNI Ethernet Services Model

The implementation of the Operator CEN is opaque to the SP/SO. What is important is the observed behavior at and among the UNIs and ENNIs in Figure 9. These behaviors can be described by the following sets of Operator Service Attributes:

- OVC Service Attributes are presented in Section 12.

- ENNI Service Attributes are presented in Section 13.

- Operator UNI Service Attributes are presented in Section 14.

- Virtual UNI Service Attributes are presented in Section 15.

- OVC End Point Service Attributes are presented in Section 16.

In the following sections, the term External Interface is used to denote either an ENNI or a UNI.

12 OVC Service Attributes

The OVC Service Attributes are summarized in Table 6 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
OVC Identifier	An identifier for the OVC intended for management purposes	A string that is unique across the Operator CEN
OVC Type	An indication of the number and roles of the OVC End Points associated by the OVC.	*Point-to-Point*, *Multipoint-to-Multipoint*, or *Rooted-Multipoint*
OVC End Point List	A list of OVC End Points associated by the OVC	A list of OVC End Point Identifiers
Maximum Number of UNI OVC End Points	The bound on the number of OVC End Points at different UNIs that can be associated by the OVC[8]	An integer greater than or equal to 0
Maximum Number ENNI OVC End Points	The bound on the number of OVC End Points at ENNIs that can be associated by the OVC[8]	A strictly positive integer
OVC Maximum Frame Size	The maximum length in bytes allowed in a frame mapped to an OVC End Point that is associated by the OVC	An integer number of bytes greater than or equal to 1526
OVC CE-VLAN ID Preservation	A relationship between the format and certain field values of the EI Frame at one External Interface and the format and certain field values of the corresponding EI Frame at another External Interface such that if an EVC is composed of OVCs that all have the value of this Service Attribute = *Preserve*, then the EVC behavior conforms to the requirements when the EVC CE-VLAN ID Preservation Service Attribute = *Enabled* as defined in MEF 10.3 [12]	*Preserve, Strip, or Retain*

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[8] Since at least 2 OVC endpoints are needed in order for an OVC to convey frames across the Operator CEN, the sum of Maximum Number of UNI Endpoints and Maximum Number of ENNI Endpoints needs to be greater than or equal to 2.

Attribute Name	Summary Description	Possible Values
OVC CE-VLAN PCP Preservation	A relationship between the format and certain field values of the EI Frame at one External Interface and the format and certain field values of the corresponding EI Frame at another External Interface such that if an EVC is composed of OVCs that all have the value of this Service Attribute = *Enabled*, then the value of the CE-VLAN ID CoS Service Attribute (as defined in MEF 10.3 [12]) for the EVC = *Enabled*.	*Enabled* or *Disabled*
OVC CE-VLAN DEI Preservation	A relationship between the format and certain field values of the EI Frame at one External Interface and the format and certain field values of the corresponding EI Frame at another External Interface such that if an EVC is composed of OVCs that all have the value of this Service Attribute = *Enabled*, then the value of the CE-VLAN DEI, if present, is unchanged from ingress UNI to egress UNI for the EVC	*Enabled* or *Disabled*
OVC S-VLAN PCP Preservation	A relationship between the S-VLAN PCP value of a frame at one ENNI and the S-VLAN PCP value of the corresponding frame at another ENNI	*Enabled* or *Disabled*
OVC S-VLAN DEI Preservation	A relationship between the S-VLAN DEI value of a frame at one ENNI and the S-VLAN DEI value of the corresponding frame at another ENNI	*Enabled* or *Disabled*
OVC List of Class of Service Names	The Class of Service Names supported by the OVC	A list of Class of Service Names
OVC Service Level Specification	Frame delivery performance definitions and objectives for frames between External Interfaces	See Section 12.13
OVC Frame Delivery	How ingress frames mapped to an OVC End Point are delivered to the other External Interfaces with OVC End Points associated by the OVC	A 3-tuple where each element equals one of *Discard*, *Deliver Unconditionally*, or *Deliver Conditionally*
OVC Available MEG Level	Specifies the lowest MEG Level available for the SP/SO	0,1,2,…,7 or *None*
OVC L2CP Address Set	The subset of the Bridge Reserved Addresses that are Peered or Discarded	See MEF 45 [24]

Table 6 – OVC Service Attributes

12.1   OVC Identifier Service Attribute

The value of the OVC Identifier Service Attribute is a string that is used to allow the SP/SO and Operator to uniquely identify an OVC for operations purposes.

> **[R28]**   The value of the OVC Identifier Service Attribute **MUST** be unique among all such identifiers for OVCs supported by the Operator CEN.

> **[R29]**   The value of the OVC Identifier Service Attribute **MUST** contain no more than 45 characters.[9]

> **[R30]**   The value of the OVC Identifier Service Attribute **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

Note that the EVC Identifier Service Attribute described in MEF 10.3 [12] is known to the Subscriber and Service Provider. Whether the EVC Identifier is made known to the Operators is up to the Service Provider.

12.2   OVC Type Service Attribute

There are three values for the OVC Type Service Attribute: *Point-to-Point*, *Multipoint-to-Multipoint*, and *Rooted-Multipoint*. The value of the OVC Type Service Attribute is dependent on the roles of the OVC End Points associated by the OVC. See Section 16.4 for the description of OVC End Point Role Service Attribute.

An OVC that cannot associate any Leaf or Trunk OVC End Points and is capable of associating more than two Root OVC End Points is defined to have OVC Type of *Multipoint-to-Multipoint* and is called a Multipoint-to-Multipoint OVC.

An OVC that can only associate exactly two Root OVC End Points is defined to have OVC Type of *Point-to-Point* and is called a Point-to-Point OVC. A Point-to-Point OVC can be considered a special case of Multipoint-to-Multipoint OVC.

Note that a Multipoint-to-Multipoint OVC that associates two Root OVC End Points differs from a Point-to-Point OVC in that additional Root OVC End Points can be added to the OVC.

An OVC that can associate at least one Leaf or Trunk OVC End Point is defined to have OVC Type of *Rooted-Multipoint* and is called a Rooted-Multipoint OVC. Note that an OVC that associates only Leaf OVC End Points is not useful since it cannot forward frames between External Interfaces. See Section 12.3.

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[9] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

The distinction between a Point-to-Point OVC or a Multipoint-to-Multipoint OVC and a Rooted-Multipoint OVC with only Root OVC End Points is that a Leaf or Trunk OVC End Point can be added to such a Rooted-Multipoint OVC.

12.3   OVC End Point List Service Attribute

The value of the OVC End Point List Service Attribute is a list of OVC End Point Identifiers. The list contains one OVC End Point Identifier value for each OVC End Point associated by the OVC. Section 16.1 describes OVC End Point Identifier Service Attribute.

> **[R31]**   An OVC **MUST** associate at most one OVC End Point at a given UNI.

> **[R32]**   An OVC **MUST** associate at most one OVC End Point in a given VUNI (Section 15).

If an OVC were to associate more than one OVC End Point in the same VUNI, then ingress frames at the RUNI could result in egress frames at the same RUNI, thus violating [R3] in MEF 10.3 [12].

> **[O3]**   A given OVC **MAY** associate more than one OVC End Point at a given ENNI.

> **[R33]**   An ingress EI Frame that does not map to an OVC End Point and does not map to an EVC (Section 16.5.4) at the ingress EI **MUST NOT** result in a corresponding egress frame at any EI.

> **[R34]**   If an egress EI Frame mapped to an OVC End Point results from an ingress EI Frame mapped to an OVC End Point, there **MUST** be an OVC that associates the two OVC End Points.

> **[R35]**   If an egress frame mapped to an OVC End Point results from an ingress frame mapped to an OVC End Point, the two OVC End Points **MUST** be different from each other.

[R35] means that, at a given ENNI, an ingress ENNI Frame mapped to an OVC End Point cannot result in an egress ENNI Frame at the given ENNI that is also mapped to that OVC End Point.

> **[R36]**   The value of the External Interface Type Service Attribute (Section 16.2) for at least one of the OVC End Points associated by an OVC **MUST** be *ENNI*.

The following requirements constrain the forwarding behavior among External Interfaces (EIs) of an OVC based on the roles of the OVC End Points (Section 16.4) associated by the OVC. (See Section 16.5.2 for the definition of Root S-VLAN ID value and Leaf S-VLAN ID value.)

> **[R37]**   If an egress EI Frame is mapped to a Leaf OVC End Point and is the result of an ingress EI Frame, then the ingress EI Frame **MUST** be mapped to a Root OVC

End Point or mapped to a Trunk OVC End Point via the Root S-VLAN ID value.

[R38]   If an egress EI Frame is mapped to a Trunk OVC End Point and is the result of an ingress EI Frame that was mapped to either a Root OVC End Point or mapped to a Trunk OVC End Point via the Root S-VLAN ID value, then the egress EI Frame **MUST** contain the Root S-VLAN ID value.

[R39]   If an egress EI Frame is mapped to a Trunk OVC End Point and is the result of an ingress EI Frame that was mapped to either a Leaf OVC End Point or mapped to a Trunk OVC End Point via the Leaf S-VLAN ID value, then the egress EI Frame **MUST** contain the Leaf S-VLAN ID value.

These forwarding requirements are summarized in Table 7. Note that an egress EI Frame that is mapped to a Root OVC End Point can be the result of an ingress frame at an EI that was mapped to a Root, Trunk, or Leaf OVC End Point.

		Ingress OVC End Point Role			
		Root	Leaf	Trunk (Leaf S-VLAN ID)	Trunk (Root S-VLAN ID)
Egress OVC End Point Role	Root	☑	☑	☑	☑
	Leaf	☑	☐	☐	☑
	Trunk (Leaf S-VLAN ID)	☐	☑	☑	☐
	Trunk (Root S-VLAN ID)	☑	☐	☐	☑

Table 7 – Allowed Connectivity Between OVC End Point Roles

By correct use of OVC End Point Roles and S-VLAN ID values, each Operator CEN can determine for each ingress frame that it receives whether the frame is the result of an ingress Service Frame at a Root UNI or a Leaf UNI. This information is necessary to implement a Rooted-Multipoint EVC that spans multiple Operator CENs. Appendix B contains examples of the support of Rooted-Multipoint EVCs.

12.3.1   Hairpin Switching

Hairpin Switching occurs when an ingress VLAN Tagged ENNI Frame at a given ENNI results in an egress VLAN Tagged ENNI Frame with a different S-VLAN ID value at the given ENNI. This behavior is possible when an OVC associates two or more OVC End Points at a given ENNI. Appendices A.4 and A.6 show examples of the use of Hairpin Switching.

Note that this configuration of OVC End Points is allowed by [O3]. Also note that [R31] precludes Hairpin Switching at a UNI.

Hairpin Switching can occur between any pair of OVC End Points at an ENNI that are associated by an OVC except that, as a consequence of [R32], Hairpin Switching cannot occur between a pair of OVC End Points that are both in the same VUNI at an ENNI. See Section 15.

Improper use of Hairpin Switching can result in a data loop between two Operator CENs at a single ENNI. Appendix A.5 shows an example of how this can happen. It is up to the SP/SO and Operators to ensure that such loops do not occur. Methods for detecting and/or preventing such loops are beyond the scope of this document.

12.4　Maximum Number of UNI OVC End Points Service Attribute

The value of the Maximum Number of UNI OVC End Points Service Attribute is a non-negative integer. The value is the upper bound on the number of OVC End Points that are at different UNIs that can be associated by the OVC.

12.5　Maximum Number of ENNI OVC End Points Service Attribute

The value of the Maximum Number of ENNI OVC End Points Service Attribute is a strictly positive integer. The value is the upper bound on the number of OVC End Points that can be associated by the OVC that are at ENNIs. Note that an OVC can associate more than one OVC End Point at a given ENNI as described in Section 12.3.1.

12.6　OVC Maximum Frame Size Service Attribute

The value for the OVC Maximum Frame Size Service Attribute is a strictly positive integer in bytes. An ingress frame mapped to an OVC End Point associated by the OVC whose length is too long compared to the value of the OVC Maximum Frame Size Service Attribute (adjusted to account for the frame format) is likely to be discarded per the following requirements. (Recall that the ENNI Frame consists of the first bit of the Destination MAC Address through the last bit of the Frame Check Sequence per Section 8.6.)

> **[R40]**　The value of the OVC Maximum Frame Size Service Attribute **MUST** be at least 1526 bytes.

> **[R41]**　The value of the OVC Maximum Frame Size Service Attribute **MUST** be less than or equal to

> - The smallest of the ENNI Maximum Frame Size Multilateral Attribute values (see Section 10.3) for all ENNIs at which there is an OVC End Point associated by the OVC, and

> - $M + 4$ where M is the smallest of the Operator UNI Maximum Service Frame Size Service Attribute values (see Section 14.8) for all UNIs at which there is an OVC End Point associated by the OVC.

[D3]   An ingress Double Tagged ENNI Frame that is mapped to an OVC End Point associated by the OVC and whose length exceeds the value of the OVC Maximum Frame Size Service Attribute **SHOULD** be discarded.

[D4]   An ingress Single Tagged ENNI Frame that is mapped to an OVC End Point associated by the OVC and whose length exceeds $N - 4$ where N is the value of the OVC Maximum Frame Size Service Attribute **SHOULD** be discarded.

[D5]   An ingress Service Frame with a C-Tag that is mapped to an OVC End Point associated by the OVC and whose length exceeds $N - 4$ where N is the value of the OVC Maximum Frame Size Service Attribute **SHOULD** be discarded.

[D6]   An ingress Service Frame without a C-Tag that is mapped to an OVC End Point associated by the OVC and whose length exceeds $N - 8$ where N is the value of the OVC Maximum Frame Size Service Attribute **SHOULD** be discarded.

The goal of the value of the OVC Maximum Frame Size Service Attribute and [D3], [D4], [D5], and [D6] is to provide upper bounds on the length of an ingress frame to ensure that the corresponding egress frame(s) will not be too large for the egress EI(s). Note that tags can be added from ingress EI to egress EI per Section 12.14.2.

12.7   OVC CE-VLAN ID Preservation Service Attribute

The value of OVC CE-VLAN ID Preservation Service Attribute can be one of *Preserve*, *Strip*, or *Retain*. The OVC CE-VLAN ID Preservation Service Attribute describes a relationship between the format and certain field values of the frame at one External Interface and the format and certain field values of the corresponding frame at another External Interface. OVC CE-VLAN ID Preservation Service Attribute set to *Preserve* is used to achieve EVC CE-VLAN ID Preservation that is a key property of the EPL, EP-LAN and EP-Tree Services specified in MEF 6.2 [11]. See Appendices A.3 and A.6 for examples of its use.

Behavior when the OVC CE-VLAN ID Preservation Service Attribute value is *Preserve* depends on where the OVC End Points that are associated by the OVC are located. For ease of description the following symbols are used:

- @UNI represents an OVC End Point that is located at a UNI,

- @ENNI represents an OVC End Point that is located at an ENNI and that is not in a VUNI, and

- @VUNI represents an OVC End Point that is located at an ENNI and that is in a VUNI.

See Section 15 for details regarding the VUNI.

[R42] When an OVC: 1) has the OVC CE-VLAN ID Preservation Service Attribute
value of *Preserve*, 2) associates at least one @UNI or @VUNI, 3) all CE-
VLAN IDs map to each @UNI (see Section 16.5.4), and 4) all ENNI CE-VLAN
IDs map to each @VUNI (see Section 16.5.3), then the relationship between the
format of the frame at the ingress External Interface and the corresponding
frame at the egress External Interface **MUST** be as specified in Table 8.

Ingress OVC End Point	Ingress Frame Format	Egress OVC End Point	Egress Frame Format
@UNI	Untagged	@UNI	Untagged
@UNI	Untagged	@ENNI or @VUNI	S-Tag only
@UNI	C-Tagged	@UNI	C-Tagged with VLAN ID value equal to that of ingress Service Frame at the ingress @UNI
@UNI	C-Tagged	@ENNI or @VUNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the @UNI
@ENNI or @VUNI	S-Tag and C-Tag	@UNI	C-Tagged with the VLAN ID value of the C-Tag equal to that of the VLAN ID value in the C-Tag of the ingress frame at the @ENNI or @VUNI
@ENNI or @VUNI	S-Tag only	@UNI	Untagged
@ENNI or @VUNI	S-Tag and C-Tag	@ENNI or @VUNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the ingress @ENNI or @VUNI.
@ENNI or @VUNI	S-Tag only	@ENNI or @VUNI	S-Tag only[10]

Table 8 – OVC CE-VLAN ID Preservation Service Attribute = *Preserve* **when All
CE-VLAN IDs Map to the @UNIs and @VUNIs**

[R43] When an OVC: 1) has the CE-VLAN ID Preservation Service Attribute value of
Preserve, 2) associates at least one @UNI or @VUNI, 3) not all CE-VLAN IDs
map to at least one @UNI (see Section 16.5.4), or not all ENNI CE-VLAN IDs
map to at least one @VUNI (see Section 16.5.3), then the relationships between
the format of the frame at the ingress External Interface and the corresponding
frame at the egress External Interface **MUST** be as specified in Table 9.

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[10] Note that this @ENNI to @ENNI behavior is mandated to always occur by [R75].

Ingress OVC End Point	Ingress Frame Format	Egress OVC End Point	Egress Frame Format
@UNI	C-Tagged with VLAN ID value in the range 1, … , 4094	@UNI	C-Tagged with VLAN ID value equal to that of the ingress Service Frame at the @UNI when the VLAN ID value of the ingress Service Frame C-Tag does not equal the value of the Operator UNI Default CE-VLAN ID Service Attribute at the egress UNI
@UNI	C-Tagged with VLAN ID value in the range 1, … , 4094	@ENNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the @UNI
@UNI	C-Tagged with VLAN ID value = 0	@ENNI	Either S-Tag only or S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the value of the Operator UNI Default CE-VLAN ID Service Attribute
@UNI	Untagged	@ENNI	S-Tag only
@UNI	C-Tagged with VLAN ID value in the range 1, … , 4094	@VUNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the @UNI when the VLAN ID does not equal the VUNI Default ENNI CE-VLAN ID Service Attribute value
@ENNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@UNI	Tagged with the VLAN ID value of the C-Tag equal to that of the C-Tag of the ingress frame at the @ENNI when the VLAN ID value of the C-Tag of the ingress ENNI Frame does not equal the value of the Operator UNI Default CE-VLAN ID Attribute at the egress UNI
@ENNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@ENNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the ingress @ENNI.
@ENNI	S-Tag only	@ENNI	S-Tag Only[11]
@ENNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@VUNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the ingress @ENNI when the VLAN ID does not equal the VUNI Default ENNI CE-VLAN ID Service Attribute value

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[11] Note that this @ENNI to @ENNI behavior is mandated to always occur by[R75].

Ingress OVC End Point	Ingress Frame Format	Egress OVC End Point	Egress Frame Format
@VUNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@UNI	Tagged with the VLAN ID value of the C-Tag equal to that of the C-Tag of the ingress frame at the @VUNI when the VLAN ID value of the C-Tag of the ingress ENNI Frame does not equal the value of the Operator UNI Default CE-VLAN ID Service Attribute at the egress UNI
@VUNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@ENNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the ingress @VUNI.
@VUNI	S-Tag and C-Tag with VLAN ID value in the C-Tag = 0	@ENNI	Either S-Tag only or S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the value of the VUNI Default ENNI CE-VLAN ID Service Attribute
@VUNI	S-Tag only	@ENNI	S-Tag only
@VUNI	S-Tag and C-Tag with VLAN ID value in the C-Tag in the range 1, … , 4094	@VUNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the ingress @VUNI when the VLAN ID value does not equal the egress VUNI Default ENNI CE-VLAN ID value

Table 9 – OVC CE-VLAN ID Preservation Service Attribute = *Preserve* **when not All CE-VLAN IDs Map to the @UNIs and @VUNIs**

Note that Table 9 does not cover all possible frame formats. For example, Table 9 does not cover the case when the ingress EI frame contains a C-Tag with a VLAN ID that is equal to the value of the Operator UNI Default CE-VLAN ID Service Attribute at the egress UNI. OVC CE-VLAN ID Preservation Service Attribute value = Preserve does not mandate a behavior for frame formats not covered in Table 9.This lack of specificity parallels that of MEF 10.3 [12] when the UNIs associated by the EVC do not have All to One Bundling. The reason for this lack of specificity, both here and in MEF 10.3, is to allow for behavior consistent with Provider Bridges (IEEE Std 802.1Q [3]) which does not support format preservation when there is not All to One Bundling and either the VUNI Default ENNI CE-VLAN ID Service Attribute value or the Operator UNI Default CE-VLAN ID Service Attribute value maps to the OVC End Point. When the default values do not map to OVC End Point, the behavior is well specified.

Note that when the OVC only associates @ENNIs, the relationship between the existence and value of C-Tags on an ingress frame and an egress frame is fully specified by [R75] and [R76].

Note that when a Service Frame is delivered from a UNI in one Operator CEN to a UNI in another Operator CEN via an EVC supported by two or more OVCs with all OVCs having the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*, then the Service Frame will have

CE-VLAN ID Preservation as defined in Section 8.6.1 in MEF 10.3 [12]. In other words, the value of the CE-VLAN ID Preservation Service Attribute for the EVC = *Enabled*. Also note that CE-VLAN ID Preservation as defined in Section 8.6.1 in MEF 10.3 [12] does not apply to untagged or priority-tagged Service Frames unless there is All to One Bundling at the UNI, and thus Table 9 does not include the cases for untagged or priority-tagged Service Frames at the UNI. See Table 4 and Table 5 in Section 8.6.1 of MEF 10.3 [12].

[R44] When an OVC has the OVC CE-VLAN ID Preservation Service Attribute value of either *Strip* or *Retain*, then the relationship between the format of the frame at the ingress External Interface and the corresponding frame at the egress External Interface **MUST** be as specified in Table 10.

Ingress OVC End Point	Ingress Frame Format	Egress OVC End Point	Egress Frame Format	
			Value = Retain	Value = Strip
@UNI	C-Tagged	@ENNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the @UNI	S-Tag only
@UNI	Untagged	@ENNI	S-Tag only	S-Tag only
@VUNI	S-Tag and C-Tag	@ENNI	S-Tag and C-Tag with the VLAN ID value in the C-Tag equal to the VLAN ID value in the C-Tag at the @VUNI	S-Tag only
@VUNI	S-Tag only	@ENNI	S-Tag only	S-Tag only

Table 10 OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*

When the value of the OVC CE-VLAN ID Preservation Service Attribute is not *Preserve*, Table 10 shows the two ways that an Operator CEN can handle ingress EI Frame at a UNI or at a VUNI with a C-Tag. The value *Retain* means that the C-Tag, if present, is encapsulated with the C-Tag VLAN ID value retained. The value *Strip* means that the C-Tag is discarded.

Note that Table 10 does not specify the behavior when the egress OVC End Point is not an @ENNI; this is because per [R148] and [R155], when the OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*, the OVC End Point Map Service Attribute (Section 16.5) at the @UNI or @VUNI can only contain a single CE-VLAN ID and hence the behavior is fully specified by the OVC End Point Map. This means that a C-Tag can be added or removed or the C-Tag VLAN ID can be changed. This differs from the behavior when the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*.

When multiple OVCs are stitched together that do not have their OVC CE-VLAN ID Preservation Service Attribute = *Preserve*, mixing OVCs with different values (*Strip* and *Retain*) for this Service Attribute can lead to unpredictable results. It is up to the Service Provider to establish consistency in the value of the OVC CE-VLAN ID Service Attribute when stitching together OVCs.

Appendix A shows some examples of the use of CE-VLAN ID Preservation in the construction of Ethernet Services.

Appendix D summarizes the various combinations of ingress frame formats, egress frame formats and the values of the CE-VLAN ID Preservation Service Attribute.

12.8 OVC CE-VLAN PCP Preservation Service Attribute[12]

The value of OVC CE-VLAN PCP Preservation Service Attribute can be either *Enabled* or *Disabled*. The OVC CE-VLAN PCP Preservation Service Attribute describes a relationship between the format and certain field values of the frame at one External Interface and the format and certain field values of the corresponding frame at another External Interface. The OVC CE-VLAN PCP Preservation Service Attribute is used to achieve CE-VLAN CoS Preservation for an EVC that is a key property of the EPL and EP-LAN Services specified in MEF 6.2 [11] See Appendices A.3 and A.6 for examples of its use.

> **[R45]** When an OVC has the OVC CE-VLAN PCP Preservation Service Attribute with a value of *Enabled*, the relationship between the format of the frame at the ingress External Interface and the corresponding frame at the egress External Interface **MUST** be as specified in Table 11.

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[12] The Service Attribute is called CE-VLAN CoS Preservation in MEF 26.1 [18].

Ingress Interface	Ingress Frame Format	Egress Interface	Egress Frame Format
@UNI	C-Tagged	@UNI	If C-Tagged, then PCP value is equal to that of the C-Tag PCP of the ingress Service Frame
@UNI	C-Tagged	@ENNI	S-Tag and C-Tag with the PCP value in the C-Tag equal to that of the C-Tag PCP of the ingress Service Frame
@UNI	C-Tagged	@VUNI	If Double Tagged, then the C-Tag PCP value is equal to that of the C-Tag PCP of the ingress Service Frame
@ENNI	S-Tag and C-Tag	@UNI	If C-Tagged, then PCP value is equal to that of the C-Tag PCP of the ingress ENNI Frame
@ENNI	S-Tag and C-Tag	@ENNI	S-Tag and C-Tag with the PCP value in the C-Tag equal to the PCP value in the C-Tag of the ingress ENNI Frame
@ENNI	S-Tag and C-Tag	@VUNI	If Double Tagged, then the C-Tag PCP value is equal to that of the C-Tag PCP of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@UNI	If C-Tagged, then PCP value is equal to that of the C-Tag PCP of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@ENNI	S-Tag and C-Tag with the PCP value in the C-Tag equal to the PCP value in the C-Tag of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@VUNI	If Double Tagged, then the C-Tag PCP value is equal to that of the C-Tag PCP of the ingress ENNI Frame

Note: See Section 12.7 for the definitions of @UNI, @ENNI, and @VUNI.

Table 11 – OVC CE-VLAN PCP Preservation Service Attribute = *Enabled*

Table 11 does not cover all possible frame formats. OVC CE-VLAN PCP Preservation Service Attribute value = *Enabled* does not mandate a behavior for frame formats not covered in Table 11.

When the egress interface is @ENNI, Table 11 specifies that the egress ENNI Frame have both an S-Tag and C-Tag. This is the case even when the value of the OVC CE-VLAN ID Service Attribute (Section 12.7) value is not *Preserve* and there is no need for a C-Tag in order to preserve the CE-VLAN ID value. The C-Tag with proper PCP value is needed so that when a Service Frame is delivered from a UNI in one Operator CEN to a UNI in another Operator CEN via two or more OVCs with the OVC CE-VLAN PCP Preservation Service Attribute = *Enabled*, then the EVC that associates these two UNIs will have the CE-VLAN CoS Preservation Service Attribute = *Enabled* as defined in Section 8.6.2 in MEF 10.3 [12].

[R46]   If the OVC CE-VLAN PCP Preservation Service Attribute has a value of *Enabled*, then the value of the OVC CE-VLAN ID Preservation Service attribute (Section 12.7) value **MUST NOT** be *Strip*.

12.9   OVC CE-VLAN DEI Preservation Service Attribute

The value of the OVC CE-VLAN DEI Preservation Service Attribute can be either *Enabled* or *Disabled*. The OVC CE-VLAN DEI Preservation Service Attribute can be used to preserve the value of the DEI field in VLAN Tagged Service Frames across an EVC.

[R47]   When an OVC has the OVC CE-VLAN DEI Preservation Service Attribute with a value of *Enabled*, the relationship between the format of the frame at the ingress External Interface and the corresponding frame at the egress External Interface **MUST** be as specified in Table 12.

Ingress Interface	Ingress Frame Format	Egress Interface	Egress Frame Format
@UNI	C-Tagged	@UNI	If C-Tagged, then DEI value is equal to that of the C-Tag DEI of the ingress Service Frame
@UNI	C-Tagged	@ENNI	S-Tag and C-Tag with the DEI value in the C-Tag equal to that of the C-Tag DEI of the ingress Service Frame
@UNI	C-Tagged	@VUNI	If Double Tagged, then the C-Tag DEI value is equal to that of the C-Tag DEI of the ingress Service Frame
@ENNI	S-Tag and C-Tag	@UNI	If C-Tagged , then DEI value is equal to that of the C-Tag DEI of the ingress ENNI Frame
@ENNI	S-Tag and C-Tag	@ENNI	S-Tag and C-Tag with the DEI value in the C-Tag equal to the DEI value in the C-Tag of the ingress ENNI Frame
@ENNI	S-Tag and C-Tag	@VUNI	If Double Tagged, then the C-Tag DEI value is equal to that of the C-Tag DEI of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@UNI	If C-Tagged, then DEI value is equal to that of the C-Tag DEI of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@ENNI	S-Tag and C-Tag with the DEI value in the C-Tag equal to the DEI value in the C-Tag of the ingress ENNI Frame
@VUNI	S-Tag and C-Tag	@VUNI	If Double Tagged, then the C-Tag DEI value is equal to that of the C-Tag DEI of the ingress ENNI Frame

Note: See Section 12.7 for the definitions of @UNI, @ENNI, and @VUNI.

Table 12 – OVC CE-VLAN DEI Preservation Service Attribute = *Enabled*

Table 12 does not cover all possible frame formats. OVC CE-VLAN DEI Preservation Service Attribute value = *Enabled* does not mandate a behavior for frame formats not covered in Table 12.

When the egress interface is @ENNI, Table 12 specifies that the egress ENNI Frame have both an S-Tag and C-Tag. This is the case even when the value of the OVC CE-VLAN ID Service Attribute (Section 12.7) value is not *Preserve* and there is no need for a C-Tag in order to preserve the CE-VLAN ID value. The C-Tag with proper DEI value is needed allow the preservation of the Service Frame DEI value for an EVC composed of OVCs that all have the value of the OVC CE-VLAN DEI Preservation Service Attribute = *Enabled*. Note that MEF 10.3 [12] does not contain an EVC Service Attribute for preserving the value of the C-Tag DEI in a Service Frame. The OVC CE-VLAN DEI Preservation Service Attribute is included in this document in anticipation of a revision of or amendment to MEF 10.3 including an EVC Service Attribute for preserving the value of the C-Tag DEI.

> **[R48]** If the OVC CE-VLAN DEI Preservation Service Attribute has a value of *Enabled*, then the value of the OVC CE-VLAN ID Preservation Service attribute (Section 12.7) value **MUST NOT** be *Strip*.

12.10 OVC S-VLAN PCP Preservation Service Attribute[13]

The value of the OVC S-VLAN PCP Preservation Service Attribute can be either *Enabled* or *Disabled*. The OVC S-VLAN PCP Preservation Service Attribute describes a relationship between the S-VLAN PCP value of a frame at one ENNI and the S-VLAN PCP value of the corresponding frame at another ENNI supported by the Operator CEN where each ENNI has an OVC End Point that is associated by the OVC.

> **[R49]** When an OVC has the OVC S-VLAN PCP Preservation Service Attribute with a value of *Enabled*, an egress ENNI Frame at an ENNI resulting from an ingress ENNI Frame **MUST** have an S-VLAN PCP value identical to the S-VLAN PCP value of the ingress ENNI Frame.

Note that when the S-VLAN PCP is used to indicate the color for an ENNI Frame (see Section 16.7), it could be undesirable to have OVC S-VLAN PCP Preservation = *Enabled* because to indicate the proper Color on an egress ENNI frame might require a change in the PCP value from that of the corresponding ingress ENNI frame.

12.11 OVC S-VLAN DEI Preservation Service Attribute

The value of the OVC S-VLAN DEI Preservation Service Attribute can be either *Enabled* or *Disabled*. The OVC S-VLAN DEI Preservation Service Attribute describes a relationship between the S-VLAN DEI value of a frame at one ENNI and the S-VLAN DEI value of the corresponding frame at another ENNI supported by the Operator CEN where each ENNI has an OVC End Point that is associated by the OVC.

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[13] The Service Attribute is called S-VLAN CoS Preservation in MEF 26.1 [18].

[R50] When an OVC has the OVC S-VLAN DEI Preservation Service Attribute with a value of *Enabled*, an egress ENNI Frame at an ENNI resulting from an ingress ENNI Frame **MUST** have the S-VLAN DEI value identical to the S-VLAN DEI value of the ingress ENNI Frame.

12.12 OVC List of Class of Service Names Service Attribute

The value of the OVC List of Class of Service Names Service Attribute is a list of Class of Service Names (which may include one or more of the CoS Labels defined in MEF 23.2 [17]). Each ingress ENNI Frame or ingress Service Frame is assigned a Class of Service Name via the OVC End Point Class of Service Identifier Service Attribute as described in Section 16.6. The Class of Service Name that is assigned to a frame indicates the performance objectives that apply to the frame under appropriate conditions as detailed in Section 12.13, and is used to determine how to set certain fields in an egress EI Frame that results from this ingress EI Frame, as described by the OVC End Point Egress Map Service Attribute (Section 16.8).

Table 13 shows an example of the value of the OVC List of Class of Service Names Service Attribute. Note that a frame assigned the Class of Service Name *Discard* is to be discarded per [R166].

Platinum
Gold
Silver
Discard

Table 13 – Example value for the OVC List of Class of Service Names Service Attribute

Note that the value of the OVC End Point Class of Service Identifier Service Attribute (Section 16.6) can be such that the Class of Service Names for EI Frames mapped to an OVC End Point does not include one or more of the entries in the value of the OVC List of Class of Service Names Service Attribute for the OVC that associates the OVC End Point. In other words, not all entries in the value of the OVC List of Class of Service Names Service Attribute for an OVC need to be supported at an OVC End Point associated by the OVC.

12.13 OVC Service Level Specification Service Attribute

The value of the OVC Service Level Specification Service Attribute is either *None* or a 4-tuple of the form $\langle t_s, T, CN, PM \rangle$ where:

- t_s is a time that represents the date and time for the start of the SLS.

- T is a time interval, e.g., 1 month, 2 weeks, that is used in conjunction with t_s to specify time intervals for determining when Performance Objectives are met. Note that the units for T are not constrained; in particular, 1 month is an allowable value for T, corresponding to a calendar month, e.g. from midnight on the 10th of one month up to but not including midnight the 10th of the following month.

- CN is a list of 4-tuples of the form $\langle CoS\_Name, \Delta t, C, n \rangle$ where

  - CoS_Name is a Class of Service Name contained in the value of the OVC List of Class of Service Names Service Attribute value (Section 12.12) and is not *Discard*.

  - Δt is a time interval much smaller than T, e.g., 10 seconds.

  - C is a real number in the range $[0,1]$[14], used as a threshold to determine whether a given time interval Δt_k has high loss.

  - n is a strictly positive integer, used to identify how many consecutive Δt intervals must have high loss to trigger a change in Availability.

- PM is a list where each element in the list consists of a Performance Metric Name, a list of parameter values specific to the definition of the Performance Metric, and Performance Metric Objective.

  [R51]   A Class of Service Name **MUST** appear at most once in the value of CN.

A Performance Metric is a quantitative characterization of EI Frame delivery quality experienced by the SP/SO. This section specifies the following Performance Metrics:

1. One-way Frame Delay Performance Metric (Section 12.13.2),

2. One-way Mean Frame Delay Performance Metric (Section 12.13.3),

3. One-way Frame Delay Range Performance Metric (Section 12.13.4),

4. One-way Inter-Frame Delay Variation Performance Metric (Section 12.13.5),

5. One-way Frame Loss Ratio Performance Metric (Section 12.13.6),

6. One-way Availability Performance Metric (Section 12.13.7),

7. One-way High Loss Intervals Performance Metric (Section 12.13.8),

8. One-way Consecutive High Loss Intervals Performance Metric (Section 12.13.9), and

9. One-way Group Availability Performance Metric (Section 12.13.10).

These are similar to the performance attributes for an EVC described in MEF 10.3 [12] but more general because both the UNI and ENNI are covered in this document.

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[14] Throughout this document, numeric ranges are denoted as follows: z in $[x, y]$ means $x \leq z \leq y$, z in $[x, y)$ means $x \leq z < y$, z in $(x, y]$ means $x < z \leq y$, and z in (x, y) means $x < z < y$.

The OVC Service Level Specification Service Attribute (SLS) is the technical specification of the service level agreed to by the Operator and the SP/SO. For any given SLS, a performance objective related to a given Performance Metric may or may not be specified.

> **[R52]**   If PM contains an entry with a given Performance Metric Name, then the entry **MUST** specify the related parameters and the Performance Objective for that Performance Metric.

These Performance Metrics describe the performance experienced by the SP/SO who is the user of the OVC. Methods for the Operator and the SP/SO to monitor the OVC performance to estimate this user experience are beyond the scope of this document.

PM can contain multiple entries with a given Performance Metric Name, but one or more of the parameter values associated with each objective for a given Performance Metric Name need to be different from each other. For example, *PM* could contain two objectives for One-way Frame Delay Performance Metric each corresponding to a different value of the percentile P_d (see Section 12.13.2).

12.13.1   Key SLS Definitions, Concepts, and Notation

This section describes definitions, concepts, and notation used throughout Section 12.13.

12.13.1.1 Common Parameters

The parameter S is used in most of the Performance Metric definitions. S is a non-empty set of ordered OVC End Point pairs taken from the value of the OVC End Point List Service Attribute (Section 12.3). Whenever S is used it is assumed that the OVC End Points in the value of the OVC End Point List Service Attribute are numbered 1 to m and thus $S \subseteq \{\langle i, j \rangle | i = 1, \dots, m, j = 1, \dots, m, i \neq j\}, S \neq \emptyset$.

> **[R53]**   Each ordered pair in S **MUST** be such that at least one OVC End Point in each pair has the value of the OVC End Point Role Service Attribute (Section 16.4) not equal to *Leaf*.

The parameter *CoS_Name* is used in all of the Performance Metric definitions. *CoS_Name* takes on a value of one of the entries in the value of the OVC List of Class of Service Names Service Attribute (Section 12.12) other than *Discard*.

> **[R54]**   A CoS_Name used in an item in the value of *PM* **MUST** also be in an item in the value of CN.

Figure 10 shows an example value for *PM* using S and *CoS_Name*.

$$PM = \begin{Bmatrix} \text{One-way Frame Loss Ratio, } \{\langle 1,2\rangle\}, \textit{Gold}, 0.01\% \\ \text{One-way Frame Loss Ratio, } \{\langle 2,1\rangle\}, \textit{Gold}, 0.01\% \\ \text{One-way Frame Loss Ratio, } \{\langle 1,2\rangle\}, \textit{Silver}, 0.05\% \\ \text{One-way Frame Loss Ratio, } \{\langle 2,1\rangle\}, \textit{Silver}, 0.05\% \\ \text{One-way Frame Loss Ratio, } \{\langle 1,2\rangle, \langle 2,1\rangle\}, \textit{Bronze}, 0.1\% \end{Bmatrix}$$

Figure 10 – Example of a Value for PM

In this example, the first item in each element is the Performance Metric Name, i.e., One-way Frame Loss Ratio (Section 12.13.6). The second item is S. The third item is the *CoS_Name*. The fourth item is the Performance Objective. In this example, S and *CoS_Name* vary from entry to entry.

12.13.1.2 Time Interval Sequences, Available Time, and Maintenance Interval

For each *CoS_Name* in CN, the time interval sequence $\{\Delta t_k, k = 0,1,2, \dots\}$ is used where

$$\Delta t_k = [t_0 + k\Delta t, t_0 + (k + 1)\Delta t)$$

Δt is from the item in CN with *CoS_Name*, and t_0 is the time at which the OVC is first turned up. Note that Δt can be different for different Class of Service Names.

For the SLS, the sequence $\{T_l, l = 0,1,2, \dots\}$ is used where

$$T_l = [t_s + lT, t_s + (l + 1)T)$$

Each element of $\{T_l\}$ is used for assessing the success of the OVC in meeting the Performance Objectives of the SLS.

For most of the Performance Metrics in the SLS, the Performance Metric Objective only applies to ingress EI Frames that arrive at the EI during Available Time. Available Time is defined for each *CoS_Name* in CN as follows.

For a given $\langle i, j\rangle \in S$ and a given *CoS_Name* in CN, each Δt_k is defined to be either Available or Unavailable and this is represented by $A_{\langle i,j\rangle}(\Delta t_k)$ where $A_{\langle i,j\rangle}(\Delta t_k) = 1$ means that Δt_k is Available and $A_{\langle i,j\rangle}(\Delta t_k) = 0$ means that Δt_k is Unavailable.

Informally, Available Time is based on frame loss during a sequence of consecutive small time intervals. When the previous sequence was defined as available, if the frame loss is high for each small time interval in the current sequence, then the small time interval at the beginning of the current sequence is defined as unavailable; otherwise it is defined as available. On the other hand, when the previous sequence was defined as unavailable, if frame loss is low for each small time interval in the current sequence, then the small time interval at the beginning of the current sequence is defined as available; otherwise, it is defined as unavailable. The formal definition follows. The definition of $A_{\langle i,j\rangle}(\Delta t_k)$ is based on the frame loss ratio function $flr_{\langle i,j\rangle}(\Delta t_k)$ which is defined as follows.

For a given $\langle i,j \rangle \in S$, a given *CoS_Name*, and a Δt_k, let $I_{\Delta t_k}^{\langle i,j \rangle}$ be the number of ingress EI Frames that meet the following conditions:

- The first bit of each EI Frame arrives at the EI where OVC End Point i is located within the time interval Δt_k,

- Each EI Frame maps to OVC End Point i via an OVC End Point Map. (See Section 16.5 for the descriptions of the OVC End Point.)

- Each EI Frame should be delivered to the OVC End Point j according to the OVC Frame Delivery Service Attribute (Section 12.14),

- Each EI Frame is not discarded per [R8], [R166], [R101], [D3], [D4], [D5], [D6], or [D14], or any of the conditions specified per [R37], [R38], and [R39],

- Each EI Frame has the given *CoS_Name*,

- Each EI Frame that is subject to an ingress Bandwidth Profile has an Ingress Bandwidth Profile Color Declaration equal to Green, and

- Each ingress EI Frame that is not subject to an ingress Bandwidth Profile has the Color Green per the OVC End Point Color Identifier Service Attribute (Section 16.7).

Let $E_{\Delta t_k}^{\langle i,j \rangle}$ be the number of unique (not duplicate) egress EI Frames where each EI Frame is the first, unerrored egress EI Frame that is mapped to the OVC End Point j at the EI where OVC End Point j is located that results from a frame counted in $I_{\Delta t_k}^{\langle i,j \rangle}$. Then

$$flr_{\langle i,j \rangle}(\Delta t_k) = \begin{cases} \left(\dfrac{I_{\Delta t_k}^{\langle i,j \rangle} - E_{\Delta t_k}^{\langle i,j \rangle}}{I_{\Delta t_k}^{\langle i,j \rangle}} \right) & if \ I_{\Delta t_k}^{\langle i,j \rangle} \geq 1 \\ 0 \ otherwise \end{cases}$$

In the case of a Multipoint-to-Multipoint OVC or a Rooted-Multipoint OVC, the SP/SO and the Operator can agree to define $flr_{\langle i,j \rangle}(\Delta t_k)$ as

$$flr_{\langle i,j \rangle}(\Delta t_k) = \begin{cases} \left(\dfrac{\tilde{I}_{\Delta t_k}^{\langle i,j \rangle} - E_{\Delta t_k}^{\langle i,j \rangle}}{\tilde{I}_{\Delta t_k}^{\langle i,j \rangle}} \right) & if \ \tilde{I}_{\Delta t_k}^{\langle i,j \rangle} \geq 1 \\ 0 \ otherwise \end{cases}$$

where $\tilde{I}_{\Delta t_k}^{\langle i,j \rangle} = I_{\Delta t_k}^{\langle i,j \rangle} - D$ and D is the number of frames discarded by the Operator, in order to conform to either the line rate of the EI where OVC End Point j is located or an egress Bandwidth Profile (if one is used) at the EI where OVC End Point j is located. Such frame drops may occur anywhere in the network, not just near the egress EI. One example of this could be

where an egress Bandwidth profile is implemented by applying a policer or shaper on a link within the network. Another example of this could be where Green frames for this OVC and Class of Service Name that should be delivered to the EI with OVC End Point j exceed the line rate on a link within the network, provided the line rate of that link is greater than or equal to the line rate of the EI. Good traffic engineering principles would suggest dropping such excessive frames as close to the ingress as possible. This adjustment is meant to account for a focused overload of traffic sent to the EI where OVC End Point j is located. The details of such an adjustment are beyond the scope of this document.

Let Δt_0 be the first short time interval agreed to by SP/SO and the Operator at or after turning up the association of OVC End Point i and OVC End Point j. $A_{\langle i,j \rangle}(\Delta t_k)$ is defined in Figure 11 for $k = 0,1,2,....$
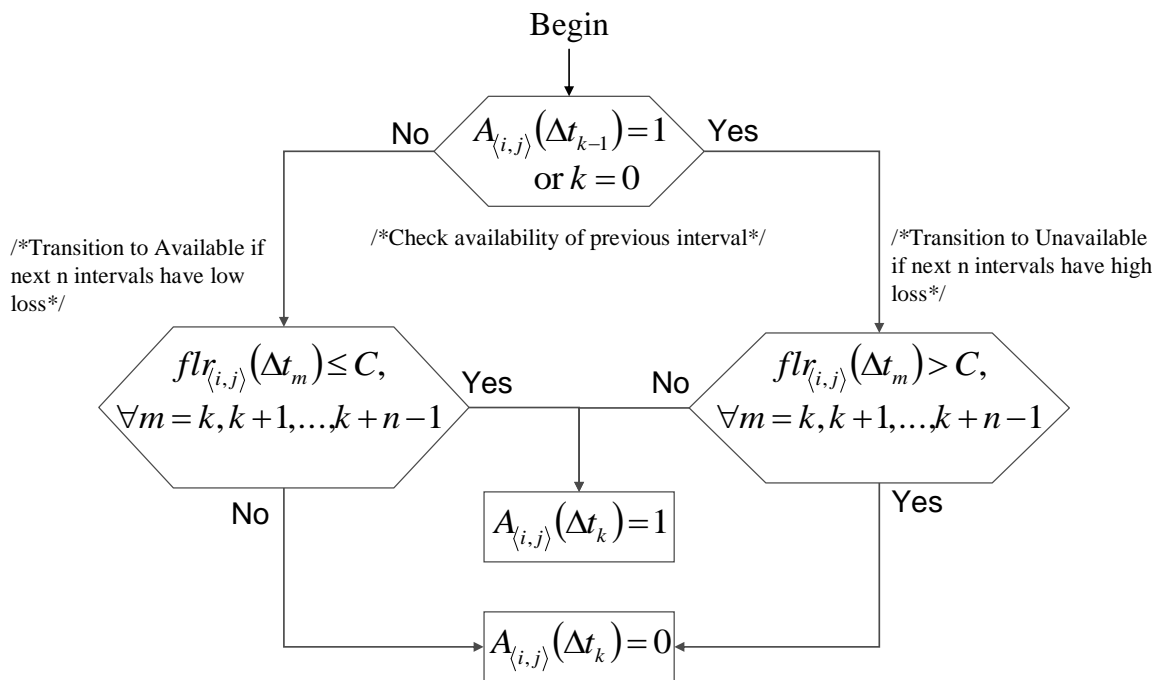
Figure 11 – Flowchart Definition of $A_{\langle i,j \rangle}(\Delta t_k)$ **for a Given Class of Service Name**

An alternative way of expressing $A_{\langle i,j \rangle}(\Delta t_k)$ for $k = 0$ is

$$A_{\langle i,j \rangle}(\Delta t_0) = \begin{cases} 0 \; if \; flr_{\langle i,j \rangle}(\Delta t_m) > C \; for \; all \; m = 0,1,...,n-1 \\ 1 \; otherwise \end{cases}$$

and for $k = 1,2,...$ is

$$A_{\langle i,j \rangle}(\Delta t_k) = \begin{cases} 0 \; if \; A_{\langle i,j \rangle}(\Delta t_{k-1}) = 1 \; and \; flr_{\langle i,j \rangle}(\Delta t_m) > C \; for \; all \; m = k, k+1, ..., k+n-1 \\ 1 \; if \; A_{\langle i,j \rangle}(\Delta t_{k-1}) = 0 \; and \; flr_{\langle i,j \rangle}(\Delta t_m) \le C \; for \; all \; m = k, k+1, ..., k+n-1 \\ A_{\langle i,j \rangle}(\Delta t_{k-1}) \; otherwise \end{cases}$$

In the event of a conflict between the above equations and Figure 11, the content of Figure 11 is controlling.

Recall that $\{\Delta t_k, k = 0,1,\dots\}, C$, and n can be different for different Class of Service Names.

The availability for Δt_k is based on the frame loss ratio during the short interval and each of the following $n - 1$ short intervals and the availability of the previous short time interval. In other words, a sliding window of width $n\Delta t$ is used to define availability. This use of a sliding window is similar to that of ITU-T Y.1563. [5]

Figure 12 presents an example of the determination of the availability for the small time intervals with a sliding window of $n = 10$ small time intervals.

$$n = 10$$

$$\blacksquare \quad flr_{\langle i,j \rangle}(\Delta t_m) > C$$

$$\square \quad flr_{\langle i,j \rangle}(\Delta t_m) \leq C$$
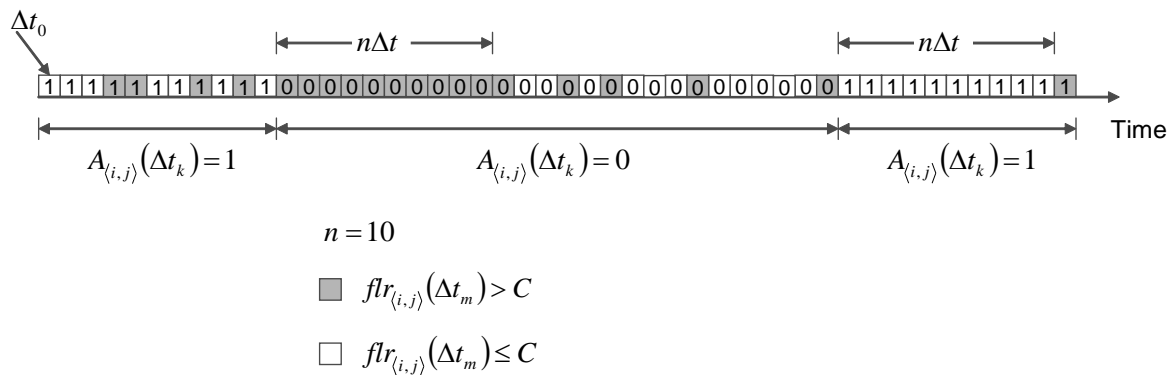
Figure 12 – Example of the Determination of $A_{\langle i,j \rangle}(\Delta t_k)$ for a Given Class of Service Name

As can be seen below, the definition of Available Time excludes small time intervals that intersect a Maintenance Interval. A Maintenance Interval is a time interval agreed to by the SP/SO and Operator during which the OVC may not perform well or at all. Examples of a Maintenance Interval include:

- A time interval during which the Operator may disable the OVC for network maintenance such as equipment replacement,

- A time interval during which the SP/SO and Operator may perform joint fault isolation testing, and

- A time interval during which the Operator may change service features and making the changes may disrupt the OVC.

Figure 13 shows an example of a Maintenance Interval.

Figure 13 – Example of a Maintenance Interval

Let W_{T_l} be the set of all Δt_k's contained in T_l that do not intersect a Maintenance Interval and let $|W_{T_l}|$ represent the number of elements in the set W_{T_l}.

Available Time for the ordered OVC End Point pair $\langle i,j \rangle$, *CoS_Name*, and T_l denoted by $AT_{T_l}^{\langle i,j \rangle}$, is defined as

$$AT_{T_l}^{\langle i,j \rangle} = \{\Delta t_k | \Delta t_k \in W_{T_l}, A_{\langle i,j \rangle}(\Delta t_k) = 1\}$$

Unavailable Time, denoted $UT_{T_l}^{\langle i,j \rangle}$, is defined as

$$UT_{T_l}^{\langle i,j \rangle} = \{\Delta t_k | \Delta t_k \in W_{T_l}, A_{\langle i,j \rangle}(\Delta t_k) = 0\}$$

Note that a Δt_k that intersects a Maintenance Interval is not included in Available Time and not included in Unavailable Time. Note that the definition of W_{T_l} means that the boundaries of T_l and the boundaries of a Maintenance Interval do not have to align with the boundary of a Δt_k.

12.13.1.3 Qualified Frames

The Performance metrics, with the exception of the One-way Availability Performance Metric, apply to Qualified Service Frames and Qualified ENNI Frames, called Qualified Frames.

Qualified Frames are defined as every EI Frame that satisfies the following criteria for a given $\langle i,j \rangle \in S$, a given *CoS_Name*, and a given T_l:

- Each EI Frame ingresses at the EI where OVC End Point i is located,

- Each EI Frame maps to OVC End Point i via an OVC End Point Map. (See Section 16.5 for the description of the OVC End Point Map.)

- Each EI Frame should be delivered to the OVC End Point j according to the OVC Frame Delivery Service Attribute (Section 12.14),

- Each EI Frame is not discarded per requirements [R8], [R166], [R101], [D3], [D4], [D5], [D6], or [D14], or any of the conditions specified per [R37], [R38], and [R39].

- The first bit of each EI Frame arrives at the ingress EI within the time interval T_l, and within a time interval $\Delta t_k \in AT_{T_l}^{\langle i,j \rangle}$ (see Section 12.13.1.2),

- Each EI Frame has the given *CoS_Name*,

- Each EI Frame that is subject to an ingress Bandwidth Profile has an Ingress Bandwidth Profile Color Declaration equal to Green, and

- Each EI Frame that is not subject to an ingress Bandwidth Profile has the Color Green per the OVC End Point Color Identifier Service Attribute (Section 16.7).

Recall that both OVC End Points in the ordered pair can be located at the same ENNI. See Section 12.3.1.

12.13.1.4 One-way Frame Delay

The One-way Frame Delay for a frame that ingresses at EI₁ and results in a frame that egresses at EI₂ is defined as the time elapsed from the reception of the first bit of the ingress frame at EI₁ until the transmission of the last bit of the first corresponding egress frame at EI₂. If the frame is erroneously duplicated in the Operator CEN and multiple copies delivered to EI₂, the delay is based on the first such copy delivered.

Note that this definition of One-way Frame Delay for a frame is the one-way[15] delay that includes the delays encountered as a result of transmission across the ingress and egress EIs as well as that introduced by the Operator CEN.

Note that when the path between two UNIs crosses one or more ENNIs, the UNI to UNI One-way Frame Delay, as defined in MEF 10.3 [12] does not equal the sum of the One-way Frame Delay between each pair of EIs. This is because the sum will double count the time to transmit a frame across each ENNI. To see this, note that the definition of delay, D_O, between a UNI and an ENNI on single Operator CEN can be expressed as $D_O = d_U + d_E + d_M$ were d_U is the time to transmit the frame across the UNI, d_E is the time to transmit the frame across the ENNI, and d_M is the queuing and transmission delay introduced by the Operator CEN. Now consider the case

---

[15] One-way delay is difficult to measure and therefore one way delay may be approximated from two way measurements. However these techniques are beyond the scope of this document.

where Operator CEN 1 and Operator CEN 2 are connected via an ENNI to create an EVC between two UNIs, one on each Operator CEN. The delay between the UNIs is $d_{U1} + d_E + d_{M1} + d_{U2} + d_{M2}$. But

$$D_{O1} + D_{O2} = d_{U1} + d_{M1} + d_{U2} + d_{M2} + 2d_E \neq d_{U1} + d_E + d_{M1} + d_{U2} + d_{M2}$$

Adding the two OVC delays overstates the UNI to UNI delay by d_E.

Note that this double counting of delays across an ENNI also means that the delay across a Super Operator OVC is not equal to the sum of the delays across the underlying Operator OVCs.

This effect will need to be taken into account when deriving the UNI to UNI delay performance from the delay performance of each Operator CEN in the path of the frame. This derivation is beyond the scope of this document.

12.13.2 One-way Frame Delay Performance Metric

This section defines the One-way Frame Delay Metric.

> **[R55]** For a given S, a given *CoS_Name*, and a given T_l, the SLS **MUST** define the One-way Frame Delay Performance Metric as follows:
>
> - Let $\bar{d}_{T_l d}^{\langle i,j \rangle}$ represent the P_d-Percentile of One-way Frame Delay for all Qualified Frames mapped to the OVC End Point j delivered to the egress EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i at the EI where OVC End Point i is located. If there are no such egress frames, then $\bar{d}_{T_l d}^{\langle i,j \rangle} = 0$.
>
> - Then the One-way Frame Delay Performance Metric **MUST** be defined as the maximum value of all of the values $\bar{d}_{T_l d}^{\langle i,j \rangle}$ for $\langle i,j \rangle \in S$.

To restate the definition mathematically, let $D_{T_l}^{\langle i,j \rangle}$ be the set of one-way Frame Delay values for all Qualified Frames mapped to the OVC End Point j at the EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i at the EI where OVC End Point i is located. $D_{T_l}^{\langle i,j \rangle}$ can be expressed as $D_{T_l}^{\langle i,j \rangle} = \left\{ d_1^{\langle i,j \rangle}, d_2^{\langle i,j \rangle}, \dots, d_{N_{T_l}^{\langle i,j \rangle}}^{\langle i,j \rangle} \right\}$ where $d_k^{\langle i,j \rangle}$ is the one-way Frame Delay of the kth frame and where $N_{T_l}^{\langle i,j \rangle}$ is the number of elements in $D_{T_l}^{\langle i,j \rangle}$. Define $\bar{d}_{T_l d}^{\langle i,j \rangle}$ for $P_d > 0$ as

$$\bar{d}_{T_l d}^{\langle i,j\rangle} = \begin{cases} min\left\{ d \in D_{T_l}^{\langle i,j\rangle} | P_d \le \dfrac{100}{N_{T_l}^{\langle i,j\rangle}} \displaystyle\sum_{k=1}^{N_T^{\langle i,j\rangle}} I\left(d, d_k^{\langle i,j\rangle}\right) \right\} & if\ N_{T_l}^{\langle i,j\rangle} \ge 1 \\ 0\ otherwise \end{cases}$$

where $I(d, d_k)$ is an indicator function defined by

$$I(d, d_k) = \begin{cases} 1\ if\ d \ge d_k \\ 0\ otherwise \end{cases}$$

$\bar{d}_{T_l d}^{\langle i,j\rangle}$ is the minimal delay during the time internal T_l that P_d percent of the frames do not exceed.

Then the One-way Frame Delay Performance Metric for an OVC can be expressed as

$$\bar{d}_{T_l,S} = max\left\{ \bar{d}_{T_l d}^{\langle i,j\rangle} | \langle i,j\rangle \in S \right\}$$

Table 14 shows what is contained in a PM entry for the One-way Frame Delay Performance Metric.

Item	Value
Performance Metric Name	One-Way Frame Delay Performance Metric
S	Non-empty subset of the ordered pairs of OVC End Points
CoS_Name	Class of Service Name
P_d	A percentile > 0
$\hat{d}$	Performance Metric Objective in time units > 0

Table 14 – *PM* Entry for the One-way Frame Delay Performance Metric

[R56] The SLS **MUST** define the One-way Frame Delay Performance Metric Objective as met over T_l for a PM entry of the form in Table 14 if and only if $\bar{d}_{T_l,S} \le \hat{d}$.

12.13.3   One-way Mean Frame Delay Performance Metric

This Section defines the One-way Mean Frame Delay Performance Metric.

[R57] For a given S, a given CoS_Name, and a given T_l, the SLS **MUST** define the One-way Mean Frame Delay Performance Metric as follows:

- Let $\bar{\mu}_{T_l}^{\langle i,j\rangle}$ represent the arithmetic mean of One-way Frame Delay for all Qualified Frames mapped to the OVC End Point j delivered to the EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i

at the EI where OVC End Point i is located. If there are no such egress frames, then $\bar{\mu}_{T_l}^{\langle i,j \rangle} = 0$.

- Then the One-way Mean Frame Delay Performance Metric **MUST** be defined as the maximum value of all of the values $\bar{\mu}_{T_l}^{\langle i,j \rangle}$ for $\langle i,j \rangle \in S$.

To restate the definition mathematically, let $D_{T_l}^{\langle i,j \rangle}$ be the set of one-way Frame Delay values for all Qualified Frames mapped to the OVC End Point j at the EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i at the EI where OVC End Point i is located. $D_{T_l}^{\langle i,j \rangle}$ can be expressed as $D_{T_l}^{\langle i,j \rangle} = \left\{ d_1^{\langle i,j \rangle}, d_2^{\langle i,j \rangle}, \ldots, d_{N_{T_l}^{\langle i,j \rangle}}^{\langle i,j \rangle} \right\}$ where $d_k^{\langle i,j \rangle}$ is the one-way Frame Delay of the kth frame and where $N_{T_l}^{\langle i,j \rangle}$ is the number of elements in $D_{T_l}^{\langle i,j \rangle}$. Define $\bar{\mu}_{T_l}^{\langle i,j \rangle}$ as

$$\bar{\mu}_{T_l}^{\langle i,j \rangle} = \begin{cases} \dfrac{1}{N_{T_l}^{\langle i,j \rangle}} \displaystyle\sum_{k=1}^{N_{T_l}^{\langle i,j \rangle}} d_k^{\langle i,j \rangle} \; if \; N_{T_l}^{\langle i,j \rangle} > 0 \\ 0 \; if \; N_{T_l}^{\langle i,j \rangle} = 0 \end{cases}$$

Then the One-way Mean Frame Delay Performance Metric for an OVC can be expressed as

$$\bar{\mu}_{T_l,S} = max \left\{ \bar{\mu}_{T_l}^{\langle i,j \rangle} | \langle i,j \rangle \in S \right\}$$

Table 15 shows what is contained in a PM entry for the One-way Mean Frame Delay Performance Metric.

Item	Value
Performance Metric Name	One-way Mean Frame Delay Performance Metric
S	Non-empty subset of the ordered pairs of OVC End Points
CoS_Name	The Class of Service Name
$\hat{\mu}$	Performance Metric Objective in time units > 0

Table 15 – *PM* Entry for the One-way Mean Frame Delay Performance Metric

[R58] The SLS **MUST** define the One-way Mean Frame Delay Performance Metric Objective as met over T_l for a PM entry of the form in Table 15 if and only if $\bar{\mu}_{T_l,S} \leq \hat{\mu}$.

12.13.4 One-way Frame Delay Range Performance Metric

This Section defines the One-way Frame Delay Range Performance Metric.

[R59]   For a given S, a given *CoS_Name*, and a given T_l, the SLS **MUST** define the One-way Frame Delay Range Performance Metric as follows:

- Let $\bar{d}_{T_l R}^{\langle i,j \rangle} = \bar{d}_{T_l r}^{\langle i,j \rangle} - \bar{d}_{min}^{\langle i,j \rangle}$. The term $\bar{d}_{T_l r}^{\langle i,j \rangle}$ represents the P_r-Percentile of the One-way Frame Delay for all Qualified Frames mapped to the OVC End Point j delivered to the egress EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i at the EI where OVC End Point i is located. $\bar{d}_{min}^{\langle i,j \rangle}$ is the minimum of the One-way Frame Delays for all Qualified Frames delivered to the EI where OVC End Point j is located resulting from an ingress frame at the EI where OVC End Point i is located. If there are no such egress frames, then $\bar{d}_{T_l R}^{\langle i,j \rangle} = 0$.

- Then the One-way Frame Delay Range Performance Metric **MUST** be defined as the maximum value of all of the values of $\bar{d}_{T_l R}^{\langle i,j \rangle}$ for $\langle i,j \rangle \in S$.

To restate the definition mathematically, let $D_{T_l}^{\langle i,j \rangle}$ be the set of one-way Frame Delay values for all Qualified Frames mapped to the OVC End Point j at the EI where OVC End Point j is located resulting from an ingress frame mapped to the OVC End Point i at the EI where OVC End Point i is located. $D_{T_l}^{\langle i,j \rangle}$ can be expressed as $D_{T_l}^{\langle i,j \rangle} = \left\{ d_1^{\langle i,j \rangle}, d_2^{\langle i,j \rangle}, ..., d_{N_{T_l}^{\langle i,j \rangle}}^{\langle i,j \rangle} \right\}$ where $d_k^{\langle i,j \rangle}$ is the one-way Frame Delay of the kth frame and where $N_{T_l}^{\langle i,j \rangle}$ is the number of elements in $D_{T_l}^{\langle i,j \rangle}$. With $d_{min}^{\langle i,j \rangle} = \min \left\{ d \in D_{T_l}^{\langle i,j \rangle} \right\}$, define $\bar{d}_{T_l R}^{\langle i,j \rangle}$ as

$$\bar{d}_{T_l R}^{\langle i,j \rangle} = \begin{cases} \left(\bar{d}_{T_l r}^{\langle i,j \rangle} - d_{min}^{\langle i,j \rangle} \right) if \ N_{T_l}^{\langle i,j \rangle} > 0 \\ 0 \ if \ N_{T_l}^{\langle i,j \rangle} = 0 \end{cases}$$

where

$$\bar{d}_{T_l r}^{\langle i,j \rangle} = \begin{cases} min \left\{ d \in D_{T_l}^{\langle i,j \rangle} | P_r \leq \frac{100}{N_{T_l}^{\langle i,j \rangle}} \sum_{k=1}^{N_{T_l}^{\langle i,j \rangle}} I\left(d, d_k^{\langle i,j \rangle} \right) \right\} if \ N_{T_l}^{\langle i,j \rangle} \geq 1 \\ 0 \ otherwise \end{cases}$$

and where $I(d, d_k)$ is an indicator function defined by

$$I(d, d_k) = \begin{cases} 1 \ if \ d \geq d_k \\ 0 \ otherwise \end{cases}$$

Then the One-way Frame Delay Range Performance Metric for an OVC can be expressed as

$$\bar{d}_{T_lR,S} = max\left\{ \bar{d}_{T_lR}^{\langle i,j \rangle} | \langle i,j \rangle \in S \right\}$$

Table 16 shows what is contained in a PM entry for the One-way Frame Delay Range Performance Metric.

Item	Value
Performance Metric Name	One-way Frame Delay Range Performance Metric
S	Non-empty subset of the ordered pairs of OVC End Points
CoS_Name	The Class of Service Name
P_r	A percentile > 0
$\hat{d}_R$	Performance Metric Objective in time units > 0

Table 16 – *PM* Entry for the One-way Frame Delay Range Performance Metric

[R60] The SLS **MUST** define the One-way Frame Delay Range Performance Metric Objective as met over T_l for a PM entry of the form in Table 16 if and only if $\bar{d}_{T_lR,S} \leq \hat{d}_R$.

12.13.5 One-way Inter-Frame Delay Variation Performance Metric

The One-way Inter-Frame Delay Variation Performance Metric (IFDV) characterizes the difference between the One-way Frame Delays of a pair of selected EI Frames. This definition is borrowed from RFC3393 [9] where IP packet delay variation is defined.

Let a_q be the time of the arrival of the first bit of the qth EI Frame at the ingress EI, then the two EI Frames *k* and *l* are selected according to the selection criterion:

$$|a_k - a_l| = \Delta\tau$$

Let r_q be the time EI Frame *q* is successfully received (last bit of the frame) at the egress EI and let d_q be the delay for EI Frame *q*, then the difference in the delays encountered by EI Frame *k* and EI Frame *l* is given by $d_k - d_l$. Define

$$\Delta d_{kl} = |d_k - d_l| = |(r_k - a_k) - (r_l - a_l)| = |(a_l - a_k) - (r_l - r_k)|$$

For $k < l$, a strictly positive value for $d_k - d_l$ implies that the two EI Frames are closer together at the egress EI while a negative value implies that the two EI Frames are further apart at the egress EI. If either or both frames are lost or not delivered due to, for example, FCS violation, then the value Δd_{kl} is not defined and does not contribute to the evaluation of the One-way Inter-Frame Delay Variation Performance Metric.

Figure 14 shows a depiction of the different times that are related to One-way Inter-Frame Delay Variation Performance Metric.
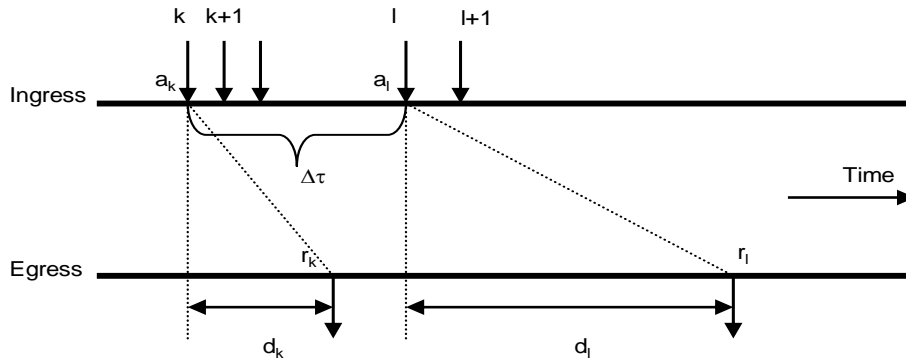
Figure 14 – One-way Inter-Frame Delay Variation Definition

[R61] For a given S, a given CoS_Name, and a given T_l, the SLS **MUST** define the One-way Inter-Frame Delay Variation Performance Metric as follows:

- Let $\Delta\tilde{d}_{T_l}^{\langle i,j\rangle}$ be the P_v-percentile of the Δd_{kl}'s of all Qualified Frame pairs where each Qualified Frame ingresses at OVC End Point i and results in an egress frame at OVC End Point j and whose difference in arrival times of the first bit of each frame in the pair at OVC End Point i was $\Delta\tau$.

- If there are no such pairs of frames for OVC End Point i and OVC End Point j, then $\Delta\tilde{d}_{T_l}^{\langle i,j\rangle} = 0$.

- Then the One-way Inter-Frame Delay Variation Performance Metric **MUST** be the maximum of the values $\Delta\tilde{d}_{T_l}^{\langle i,j\rangle}$ for $\langle i,j\rangle \in S$.

This definition is in agreement with the IP packet delay variation definition given in RFC3393 [9] where the delay variation is defined as the difference between the one-way delay of two packets selected according to some selection function and are within a given interval $[t_1, t_2]$.

The choice of the value for $\Delta\tau$ can be related to the application timing information. As an example for voice applications where voice frames are generated at regular intervals, $\Delta\tau$ may be chosen to be few multiples of the inter-frame time.

To restate the definition mathematically, let

$$V_{T_l}^{\langle i,j\rangle} = \left\{ \Delta d_1^{\langle i,j\rangle}, \Delta d_2^{\langle i,j\rangle}, \dots, \Delta d_{N_{T_l}^{\langle i,j\rangle}}^{\langle i,j\rangle} \right\}$$

be the set of the absolute value of delay variations for all eligible pairs of Qualified Frames mapped to the OVC End Point i from the EI where OVC End Point i is located to the EI where OVC End Point j is located where the difference in the arrival times of the first bit of each frame at the ingress EI was exactly $\Delta\tau$. Define

$$\Delta \tilde{d}_{T_l}^{\langle i,j \rangle} = \begin{cases} min \left\{ d \in V_{T_l}^{\langle i,j \rangle} | P_v \leq \frac{100}{N_{T_l}^{\langle i,j \rangle}} \sum_{k=1}^{N_{T_l}^{\langle i,j \rangle}} I\left(d, \Delta d_k^{\langle i,j \rangle}\right) \right\} if\ N_{T_l}^{\langle i,j \rangle} \geq 1 \\ 0\ otherwise \end{cases}$$

where $I(d, d_k)$ is an indicator function defined by

$$I(d, d_k) = \begin{cases} 1\ if\ d \geq d_k \\ 0\ otherwise \end{cases}$$

Then a One-way Inter-Frame Delay Variation Performance Metric for an OVC can be expressed as

$$\Delta \tilde{d}_{T_l,S} = max \left\{ \Delta \tilde{d}_{T_l}^{\langle i,j \rangle} | \langle i,j \rangle \in S \right\}$$

Table 17 shows what is contained in a PM entry for the One-way Inter-Frame Delay Variation Performance Metric.

Item	Value
Performance Metric Name	One-way Inter-Frame Delay Variation Performance Metric
S	Non-empty subset of the ordered pairs of OVC End Points
CoS_Name	The Class of Service Name
P_v	A percentile > 0
$\Delta\tau$	A time interval in time units
$\check{d}$	Performance Metric Objective in time units

Table 17 – *PM* Entry for the One-way Inter-Frame Delay Variation Performance Metric

[R62] The SLS **MUST** define the One-way Inter-Frame Delay Variation Performance Metric Objective as met over T_l for a PM entry of the form in Table 17 if and only if $\Delta \tilde{d}_{T_l,S} \leq \check{d}$.

12.13.6 One-way Frame Loss Ratio Performance for an OVC

The One-way Frame Loss Ratio Performance Metric characterizes frame loss as a percentage.

[R63] The SLS **MUST** define the One-way Frame Loss Ratio Performance Metric as follows:

- Let $I_{T_l}^{\langle i,j \rangle}$ denote the number of ingress Qualified Frames mapped to the OVC End Point i at the EI where OVC End Point i is located that should have been delivered to the EI where OVC End Point j is located according to the value of the OVC Frame Delivery Service Attribute (see Section 12.14).

- Let $E_{T_l}^{\langle i,j\rangle}$ be the number of unique (not duplicate) egress EI Frames where each EI Frame is the first egress EI Frame mapped to the OVC End Point j at the EI where OVC End Point j is located that results from a frame counted in $I_{T_l}^{\langle i,j\rangle}$.

- Define $FLR_{T_l}^{\langle i,j\rangle} = \begin{cases} \left(\dfrac{I_{T_l}^{\langle i,j\rangle} - E_{T_l}^{\langle i,j\rangle}}{I_{T_l}^{\langle i,j\rangle}}\right) \times 100 \ if \ I_{T_l}^{\langle i,j\rangle} \geq 1 \\ 0 \ otherwise \end{cases}$.

- Then the One-way Frame Loss Ratio Performance Metric **MUST** be defined as

$$FLR_{T_l,S} = \ max\left\{FLR_{T_l}^{\langle i,j\rangle} | \langle i,j\rangle \in S\right\}$$

In the case of a Multipoint-to-Multipoint OVC or a Rooted-Multipoint OVC, the SP/SO and the Operator can agree to define $FLR_{T_l}^{\langle i,j\rangle}$ as

$$FLR_{T_l}^{\langle i,j\rangle} = \begin{cases} \left(\dfrac{\tilde{I}_{T_l}^{\langle i,j\rangle} - E_{T_l}^{\langle i,j\rangle}}{\tilde{I}_{T_l}^{\langle i,j\rangle}}\right) \times 100 \ if \ \tilde{I}_{T_l}^{\langle i,j\rangle} \geq 1 \\ 0 \ otherwise \end{cases}$$

where $\tilde{I}_{T_l}^{\langle i,j\rangle} = I_{T_l}^{\langle i,j\rangle} - D$ and D is the number of frames discarded by the Operator, in order to conform to either the line rate of the EI where OVC End Point j is located or an egress Bandwidth Profile (if one is used) at the EI where OVC End Point j is located. Such frame drops may occur anywhere in the network, not just near the egress EI. One example of this could be where an egress Bandwidth profile is implemented by applying a policer or shaper on a link within the network. Another example of this could be where Green frames for this OVC and Class of Service Name that should be delivered to the EI with OVC End Point j exceed the line rate on a link within the network, provided the line rate of that link is greater than or equal to the line rate of the EI. Good traffic engineering principles would suggest dropping such excessive frames as close to the ingress as possible. This adjustment is meant to account for a focused overload of traffic sent to the EI where OVC End Point j is located. The details of such an adjustment are beyond the scope of this document.

Table 18 shows what is contained in a PM entry for the One-way Frame Loss Ratio Performance Metric.

Item	Value
Performance Metric Name	One-way Frame Loss Ratio Performance Metric
S	Non-empty subset of the ordered pairs of OVC End Points
CoS_Name	The Class of Service Name
$\hat{L}$	Performance Metric Objective expressed as a percentage

Table 18 – PM Entry for the One-way Frame Loss Ratio Performance Metric

[R64] The SLS **MUST** define the One-way Frame Loss Performance Metric Objective as met over T_l for a PM entry of the form in Table 18 if and only if $FLR_{T_l,S} \leq \hat{L}$.

12.13.7 One-way Availability Performance Metric

The One-way Availability Performance Metric is the percentage of time which is Available Time (Section 12.13.1.2). (The precise definition is presented in the following paragraphs.) As an example, an Operator can define the Performance Metric Objective for the One-way Availability Performance Metric to be 99.9% when the duration of $T_l = 30$ days. If there is no Maintenance Interval (Section 12.13.1.2) this objective will allow the service to be unavailable for approximately 43 minutes out of the 30 days.

For a given $\langle i,j \rangle \in S$, a given *CoS_Name*, and a given T_l, define

$$A_{T_l}^{\langle i,j \rangle} = 100 \times \frac{\left| AT_{T_l}^{\langle i,j \rangle} \right|}{\left| W_{T_l} \right|}$$

where the sets $AT_{T_l}^{\langle i,j \rangle}$ and W_{T_l} are defined in Section 12.13.1.2 and $|\ \ |$ represents the number of elements in a set. Note that by the definitions in Section 12.13.1.2, Δt_k's that intersect a Maintenance Interval are not included in the calculation of $A_{T_l}^{\langle i,j \rangle}$.

[R65] For a given S, a given *CoS_Name*, and a given T_l, the SLS **MUST** define the One-way Availability Performance Metric as:

$$A_{T_l}^S = min\left\{ A_{T_l}^{\langle i,j \rangle} | \langle i,j \rangle \in S \right\}$$

Table 19 shows what is contained in a PM entry for the One-way Availability Performance Metric.

Item	Value
Performance Metric Name	One-way Availability Performance Metric
S	Non-empty subset of the ordered OVC End Point pairs
CoS_Name	The Class of Service Name
$\hat{A}$	Performance Metric Objective expressed as a percentage

Table 19 – *PM* Entry for the One-way Availability Performance Metric

[R66] The SLS **MUST** define the One-way Availability Performance Metric Objective as met over T_l for a PM entry of the form in Table 19 if and only if $A_{T_l}^S \geq \hat{A}$.

12.13.8 One-way High Loss Intervals Performance Metric

The One-way High Loss Intervals Performance Metric is a count of the number of Δt_k's that are in Available Time (Section 12.13.1.2) for a given T_l and that have a high frame Loss. When $\Delta t = 1$ second, it is analogous to the definition of Severely Errored Seconds (SES) defined in Section 9 of ITU Recommendation Y.1563 [5].

Section 12.13.9 defines a related Performance Metric called the One-Way Consecutive High Loss Intervals Performance Metric. Figure 15 illustrates how the One-way High Loss Intervals Performance Metric and the One-way Consecutive High Loss Intervals Performance Metric fit into the hierarchy of time and other attributes.
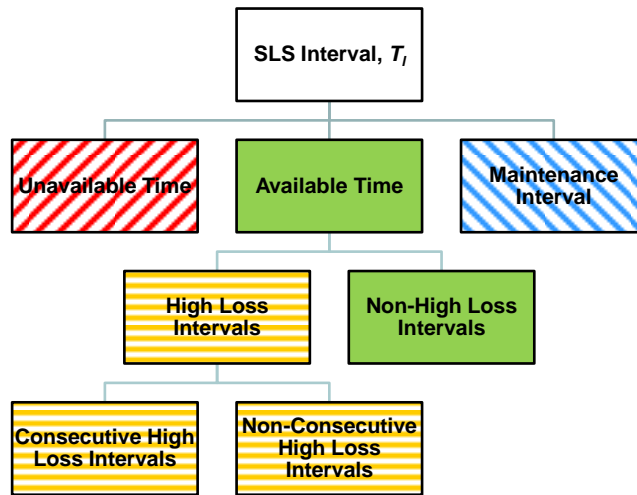
Figure 15 – Hierarchy of Time Showing the One-way Resiliency Attributes

For a given $\langle i,j \rangle \in S$ and a given *CoS_Name*, the high loss state of $\Delta t_k \subseteq T_l$ is represented by $H_{T_l}^{\langle i,j \rangle}(\Delta t_k)$ that is defined as

$$H_{T_l}^{\langle i,j \rangle}(\Delta t_k) = \begin{cases} 1 \text{ if } \Delta t_k \in AT_{T_l}^{\langle i,j \rangle} \text{ and } flr_{\langle i,j \rangle}(\Delta t_k) > C \\ 0 \text{ otherwise} \end{cases}$$

where $AT_{T_l}^{\langle i,j \rangle}$ and $flr_{\langle i,j \rangle}(\Delta t_k)$ are defined in Section 12.13.1.2. Recall that $\{\Delta t_k, k = 0,1, \dots \}$ and C can be different for different Class of Service Names.

For a given $\langle i,j \rangle \in S$ and a given *CoS_Name*, the count of High Loss Intervals, $HL_{T_l}^{\langle i,j \rangle}$, is defined as

$$HL_{T_l}^{\langle i,j \rangle} = \sum_{\Delta t_k \subseteq T_l} H_{T_l}^{\langle i,j \rangle}(\Delta t_k)$$

[R67] The SLS **MUST** define the One-way High Loss Intervals Performance Metric as:

$$HL^S_{T_l} = max\left\{HL^{\langle i,j\rangle}_{T_l}|\langle i,j\rangle \in S\right\}$$

Table 20 shows what is contained in a *PM* entry for the One-way High Loss Intervals Performance Metric.

Item	Value
Performance Metric Name	One-way High Loss Intervals Performance Metric
S	Non-empty subset of the ordered OVC End Point pairs
CoS_Name	The Class of Service Name
$\widehat{HL}$	Performance Metric Objective expressed as a non-negative integer

Table 20 – *PM* Entry for the One-way High Loss Intervals Performance Metric

[R68] The SLS **MUST** define the One-way High Loss Intervals Performance Metric Objective as met over T_l for a *PM* entry of the form in Table 20 if and only if $HL^S_{T_l} \leq \widehat{HL}$.

12.13.9 One-way Consecutive High Loss Intervals Performance Metric

The One-way Consecutive High Loss Intervals Performance Metric is a count of the number of runs of consecutive Δt_k's that are in Available Time (Section 12.13.1.2) and that have a high frame Loss. When $\Delta t = 1$ second, it is analogous to the definition of Consecutive Severely Errored Seconds defined in Annex B of ITU Recommendation Y.1563 [5].

For a given $\langle i,j\rangle \in S$, a given *CoS_Name*, a given T_l, and a strictly positive integer $p < n$ the count of Consecutive High Loss Intervals is denoted by $B^{\langle i,j\rangle}_{T_l}$ and defined by the flow chart in Figure 16. Note that $H^{\langle i,j\rangle}_{T_l}(\Delta t_k)$ is defined in Section 12.13.8.

Begin

$$B_{T_l}^{\langle i,j \rangle} = 0$$
$$k = \max\left(p, \min\{i \mid \Delta t_i \subseteq T_l\}\right)$$

/*Counter = 0 at start of T_l*/

No ← $H_{T_l}^{\langle i,j \rangle}(\Delta t_q) = 1, q = k - p + 1, ..., k$

/*p consecutive High Loss intervals?*/

Yes

$H_{T_l}^{\langle i,j \rangle}(\Delta t_{k-p}) = 1,$ **Yes**

/*Existing consecutive run?*/

No

$$B_{T_l}^{\langle i,j \rangle} = B_{T_l}^{\langle i,j \rangle} + 1$$

/*Increment counter*/

$$k = k + 1$$

No ← **End** $\Delta t_k \subseteq T_l$ **Yes**
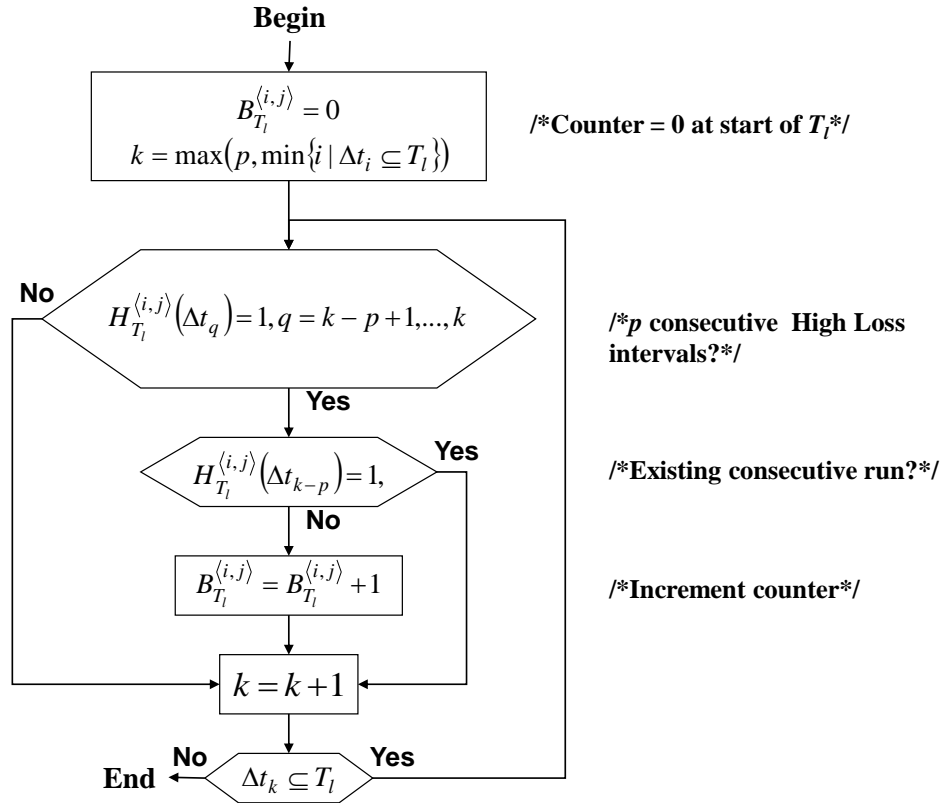
Figure 16 – Determining and Counting Consecutive High Loss Intervals for a Given Class of Service Name

Recall that $\{\Delta t_k, k = 0, 1, ...\}$, C, and n can be different for different Class of Service Names.

Figure 17 shows an example that depicts the Consecutive High Loss Intervals counting processes when there is no Maintenance Interval. Note that $A_{\langle i,j \rangle}(\Delta t_k)$ is defined in Section 12.13.1.2 and $H_{T_l}^{\langle i,j \rangle}(\Delta t_k)$ is defined in Section 12.13.8.

Δt_0 $\longleftarrow n\Delta t \longrightarrow$ $\longleftarrow n\Delta t \longrightarrow$

$A_{\langle i,j \rangle}(\Delta t_k)$ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

$H_{T_l}^{\langle i,j \rangle}(\Delta t_k)$ 0 0 0 1 1 1 1 1 0 1 1 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0   Time

$B_T^{\langle i,j \rangle}$ 0 0 0 0 0 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

$n = 10, p = 3$

▨ $flr_{\langle i,j \rangle}(\Delta t_m) > C$

☐ $flr_{\langle i,j \rangle}(\Delta t_m) \leq C$
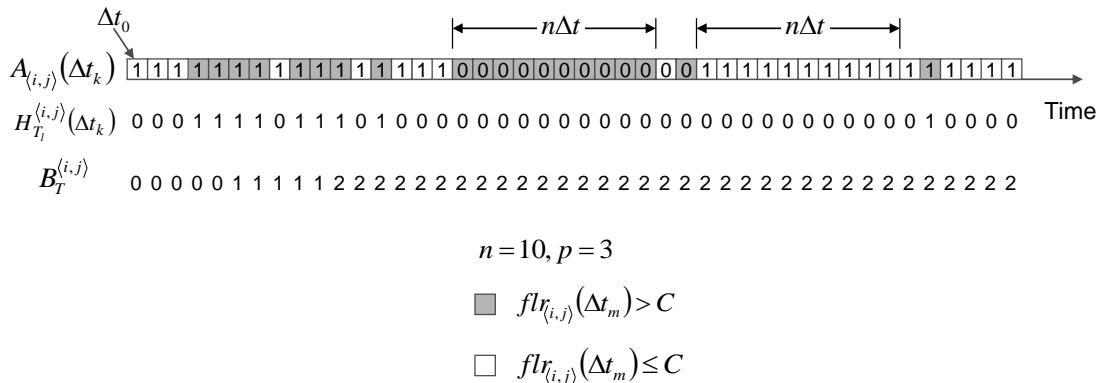
Figure 17 – Example of Counting Consecutive High Loss Intervals

[R69] The SLS **MUST** define the One-way Consecutive High Loss Intervals Performance Metric as:

$$B_{T_l}^S = max\left\{B_{T_l}^{\langle i,j\rangle}|\langle i,j\rangle \in S\right\}$$

Table 21 shows what is contained in a PM entry for the One-way Consecutive High Loss Intervals Performance Metric.

Item	Value
Performance Metric Name	One-way Consecutive High Loss Intervals Performance Metric
S	Non-empty subset of the ordered OVC End Point pairs
CoS_Name	The Class of Service Name
p	A strictly positive integer $< n$
$\hat{B}$	Performance Metric Objective expressed as a non-negative integer

Table 21 – *PM* Entry for the One-way Consecutive High Loss Intervals Performance Metric

[R70] The SLS **MUST** define the One-way Consecutive High Loss Intervals Performance Metric Objective as met over T_l for a PM entry of the form in Table 21 if and only if $B_{T_l}^S \leq \hat{B}$.

12.13.10 One-way Group Availability Performance Metric

The One-way Group Availability Performance Metric characterizes the percentage of time that at least a specified number of sets of ordered OVC End Point Pairs are available. It is defined for a collection of two or more non-empty sets of ordered pairs of OVC End Points that are associated by the OVC denoted by $G = \{S_1, \ldots, S_m\}$.

The following parameters are specific to the definition of the One-way Group Availability Performance Metric:

- $G = \{S_1, \ldots, S_m\}$, where each element in G is a set of ordered pairs of OVC End Points, and

- K, a strictly positive integer.

For a given CoS_Name and a given G, define $A^g(\Delta t_k, S)$ for $S \in G$ as

$$A^g(\Delta t_k, S) = min\{A_{\langle i,j\rangle}(\Delta t_k)|\langle i,j\rangle \in S\}$$

where $A_{\langle i,j\rangle}(\Delta t_k)$ is defined in Section 12.13.1.2. Note that $A^g(\Delta t_k, S) = 1$ when all ordered OVC End Point pairs in S have been experiencing low loss. Otherwise, $A^g(\Delta t_k, S) = 0$.

The One-way Group Availability for the time interval Δt_k is defined as

$$A_G(\Delta t_k) = \begin{cases} 1 \; if \; \sum_{S \in G} A^g(\Delta t_k, S) \geq K \\ 0 \; otherwise \end{cases}$$

[R71] For a given *CoS_Name*, a given G, and a given T_l, the SLS **MUST** define the One-way Group Availability Performance Metric as

$$A_{T_l}^G = \begin{cases} \dfrac{100}{|W_{T_l}|} \sum_{\Delta t_k \in W_{T_l}} A_G(\Delta t_k) \; if \; |W_{T_l}| > 0 \\ 100 \; otherwise \end{cases}$$

Note that W_{T_l} is defined in Section 12.13.1.2.

The One-way Group Availability Performance Metric can be viewed as the percentage of time that at least K S_k's in G are Available.

Table 22 shows what is contained in a PM entry for the One-way Group Availability Performance Metric.

Item	Value
Performance Metric Name	One-way Group Availability Performance Metric
$G = \{S_1, \ldots, S_m\}$	Non-empty subsets of ordered OVC End Point pairs
CoS_Name	The Class of Service Name
K	A strictly positive integer
$\hat{A}_G$	Performance Metric Objective expressed as percentage

Table 22 – *PM* Entry for the One-way Group Availability Performance Metric

[R72] The SLS **MUST** define the One-way Group Availability Performance Metric Objective as met over T_l for a PM entry of the form in Table 22 if and only if $A_{T_l}^G \geq \hat{A}_G$.

12.14 OVC Frame Delivery Service Attribute

The OVC Frame Delivery Service Attribute describes which frames are delivered to which EIs and the fields in a frame that are carried transparently.

12.14.1 OVC Frame Disposition

The value of the OVC Frame Delivery Service Attribute is a 3-tuple where each element equals one of *Discard*, *Deliver Unconditionally*, or *Deliver Conditionally*. This attribute applies to any ingress Data EI Frame that is not discarded per [R8], [R166], [R101], [R252], [R253], [D3], [D4], [D5], [D6], or [D14]. The dispositions corresponding to each element value are:

- *Discard*: The ingress Data EI Frame that is mapped to an OVC End Point associated by the OVC is discarded.

- *Deliver Unconditionally*: The ingress Data EI Frame that is mapped to an OVC End Point associated by the OVC is delivered across the other (egress) External Interface(s) provided [R37], [R38], and [R39] are satisfied.

- *Deliver Conditionally*: The ingress Data EI Frame that is mapped to an OVC End Point associated by the OVC is delivered across an egress External Interface if certain conditions are met, provided [R37], [R38], and [R39] are satisfied. An example of such a condition is that the destination MAC address is known by the Carrier Ethernet Network to be at the destination External Interface. Another example is broadcast throttling where some frames are dropped to limit the amount of such traffic.

The value of the first element of the 3-tuple applies to ingress Unicast Data EI Frames. The value of the second element of the 3-tuple applies to ingress Multicast Data EI Frames. The third element of the 3-tuple applies to ingress Broadcast Data EI Frames.

[R73]   When an element in the 3-tuple = *Deliver Conditionally*, the conditions that determine whether an ingress Data EI Frame is delivered or discarded **MUST** be agreed to by the SP/SO and Operator.

Note that the disposition of ingress Unicast Data EI Frames can be different than the disposition of ingress Multicast Data EI Frames which in turn can be different than the disposition of ingress Broadcast Data EI Frames.

Note that this is a description of the ideal service. Data EI Frames that should be delivered might be discarded due to network failure or congestion conditions. See the OVC Related Performance Service Attributes in Section 12.13.

12.14.2   OVC Frame Transparency

OVC Frame Transparency describes which fields in an egress EI Frame must be present and identical to the fields in the corresponding ingress EI Frame. The requirements on the format for an ENNI Frame are in Section 9.3. The requirements on the format for a Service Frame are in Section 9.6 of MEF 10.3 [12].

Figure 18 through Figure 33 show the possible combinations of egress EI Frame format and corresponding ingress EI Frame format.

[R74]   When the combination of the format of the egress EI Frame and the format of the corresponding ingress EI Frame match one of the figures in Figure 18 through Figure 33, the egress Data EI Frame **MUST** have unchanged fields compared to the corresponding ingress Data EI Frame as indicated in the matching figure.

Note that the definition of Untagged Service Frame in MEF 10.3 [12] includes tagged frames with TPID immediately following the Source Address other than 0x8100. In such Service Frames, the TPID corresponds to the Length/Type field shown in Figure 18 through Figure 33.

Note that additional fields beyond those covered by [R74] can be mandated to be unchanged when certain Service Attributes have certain values. For example, when the OVC S-VLAN PCP Preservation Service Attribute = *Enabled*, (Section 12.10) then the S-VLAN PCP in the TCI shown in Figure 30 is mandated to be unchanged.

Table 23 can be used to find the figure that applies to a given combination of ingress frame format and egress frame format.

		Egress Format			
		Tagged Service Frame	**Untagged Service Frame**	**Single Tagged ENNI Frame**	**Double Tagged ENNI Frame**
Ingress Format	**Tagged Service Frame**	Figure 18	Figure 19	Figure 22	Figure 23
	Untagged Service Frame	Figure 20	Figure 21	Figure 24	Figure 25
	Single Tagged ENNI Frame	Figure 26	Figure 28	Figure 30	Figure 31
	Double Tagged ENNI Frame	Figure 27	Figure 29	Figure 32	Figure 33

Table 23 – Key to Transparency Figures

Figure 18 – Tagged Service Frame to Tagged Service Frame Transparency

Ingress Data Service Frame   Egress Data Service Frame

| Destination Address |
| Source Address |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⬚ If present, length unchanged
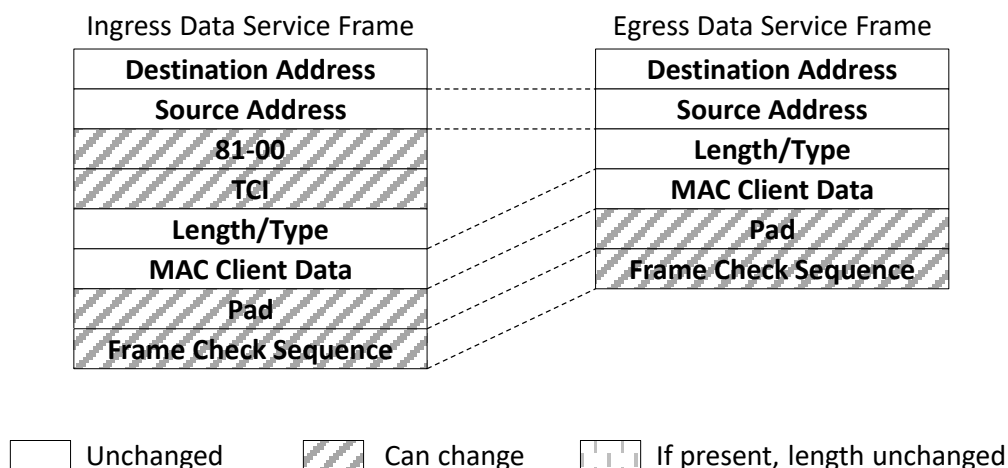
Figure 19 – Tagged Service Frame to Untagged Service Frame Transparency

Ingress Data Service Frame   Egress Data Service Frame

| Destination Address |
| Source Address |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⬚ If present, length unchanged

Figure 20 – Untagged Service Frame to Tagged Service Frame Transparency

Ingress Data Service Frame   Egress Data Service Frame

| Destination Address |
| Source Address |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⬚ If present, length unchanged

Figure 21 – Untagged Service Frame to Untagged Service Frame Transparency

Ingress Data Service Frame   Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⊞ If present, length unchanged
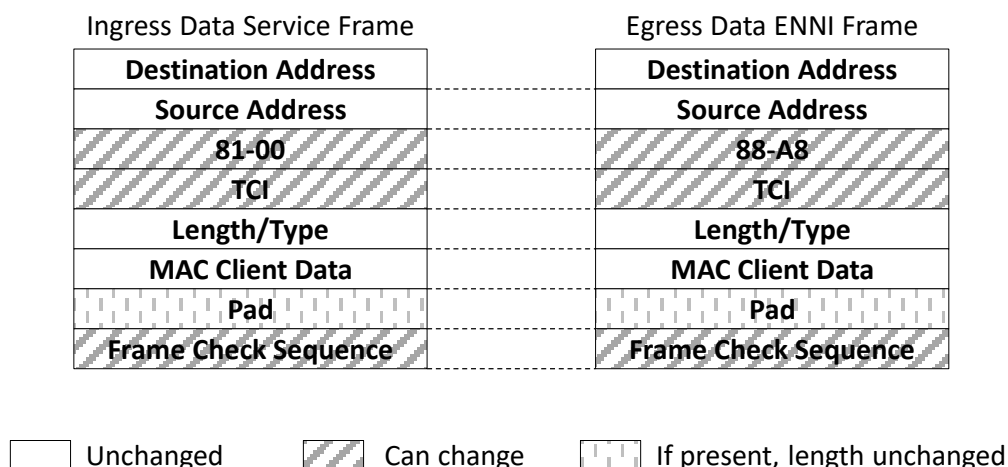
Figure 22 – Tagged Service Frame to Single Tagged ENNI Frame Transparency

Ingress Data Service Frame   Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⊞ If present, length unchanged
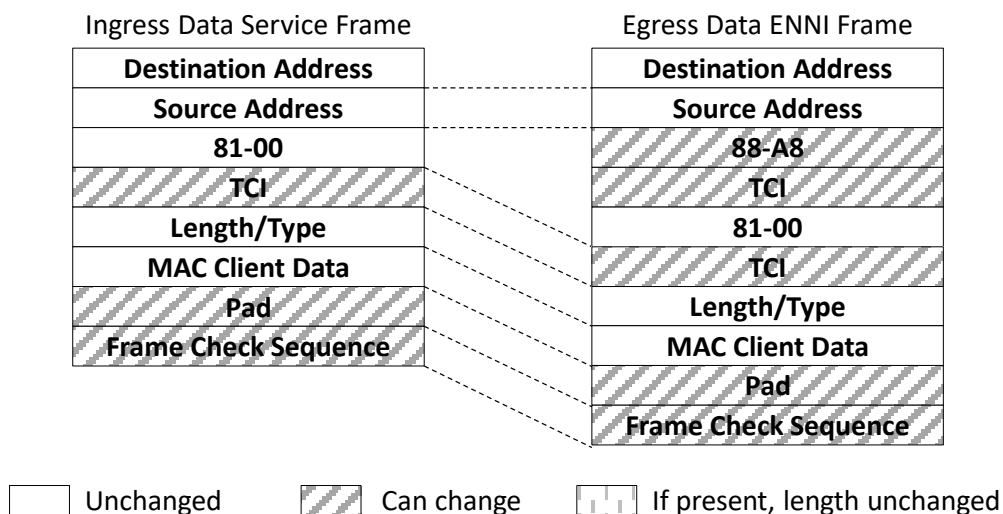
Figure 23 – Tagged Service Frame to Double Tagged ENNI Frame Transparency

Ingress Data Service Frame

Destination Address
Source Address
Length/Type
MAC Client Data
Pad
Frame Check Sequence

Egress Data ENNI Frame

Destination Address
Source Address
88-A8
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

☐ Unchanged   ▨ Can change   ⊡ If present, length unchanged
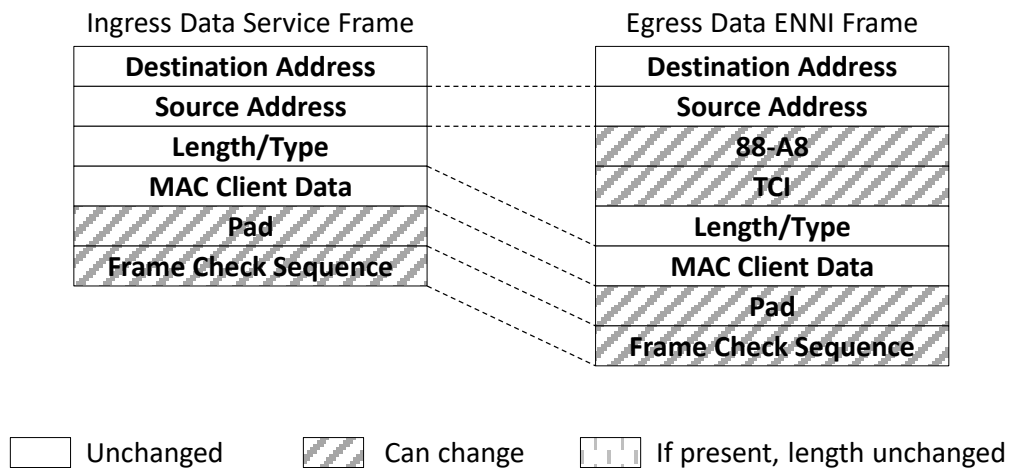
Figure 24 – Untagged Service Frame to Single Tagged ENNI Frame Transparency

Ingress Data Service Frame

Destination Address
Source Address
Length/Type
MAC Client Data
Pad
Frame Check Sequence

Egress Data ENNI Frame

Destination Address
Source Address
88-A8
TCI
81-00
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

☐ Unchanged   ▨ Can change   ⊡ If present, length unchanged

Figure 25 – Untagged Service Frame to Double Tagged ENNI Frame Transparency

Ingress Data ENNI Frame

Egress Data Service Frame

Destination Address
Source Address
88-A8
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

Destination Address
Source Address
81-00
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

☐ Unchanged   ▨ Can change   ☐ If present, length unchanged

Figure 26 – Single Tagged ENNI Frame to Tagged Service Frame Transparency

Ingress Data ENNI Frame

Egress Data Service Frame

Destination Address
Source Address
88-A8
TCI
81-00
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

Destination Address
Source Address
81-00
TCI
Length/Type
MAC Client Data
Pad
Frame Check Sequence

☐ Unchanged   ▨ Can change   ☐ If present, length unchanged

Figure 27 – Double Tagged ENNI Frame to Tagged Service Frame Transparency

Figure 28 – Single Tagged ENNI Frame to Untagged Service Frame Transparency
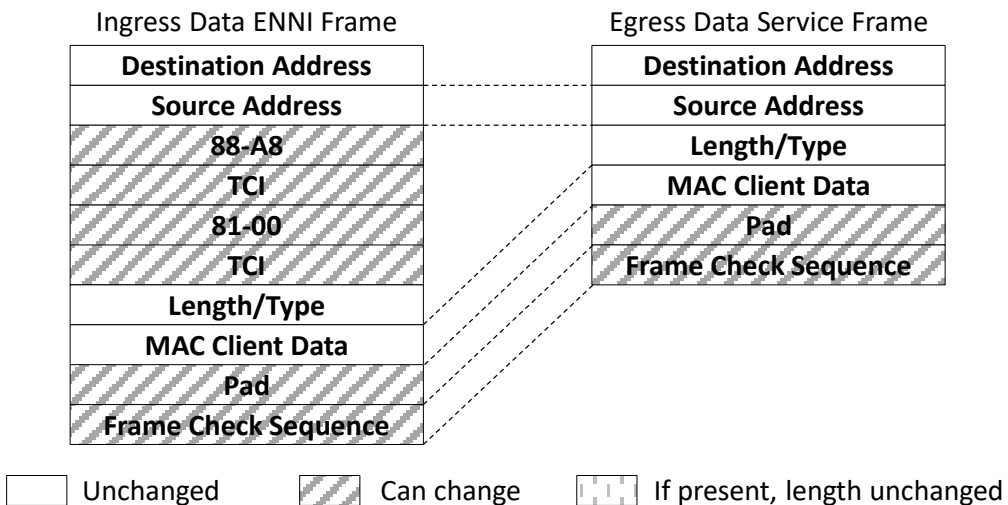
Figure 29 – Double Tagged ENNI Frame to Untagged Service Frame Transparency

Ingress Data ENNI Frame   Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |
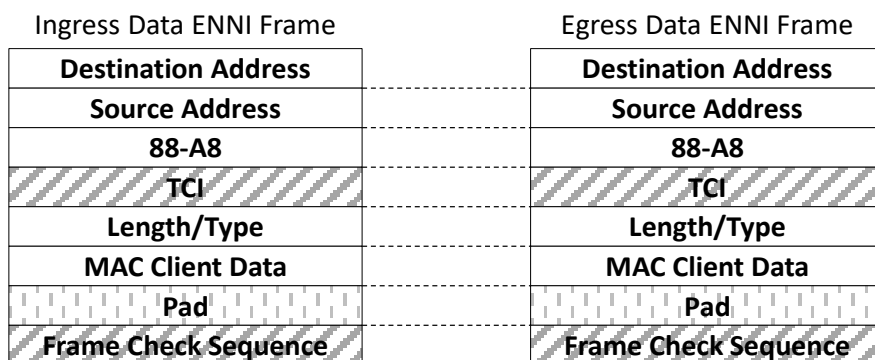
[ ] Unchanged   [//] Can change   [·|·] If present, length unchanged

Figure 30 – Single Tagged ENNI Frame to Single Tagged ENNI Frame Transparency

[R75]   If an egress ENNI Frame that is mapped to an OVC End Point that is not in a VUNI is the result of an ingress Single Tagged ENNI Frame that was mapped to an OVC End Point that is not in a VUNI, then the egress ENNI Frame **MUST** be Single Tagged.

Ingress Data ENNI Frame   Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |
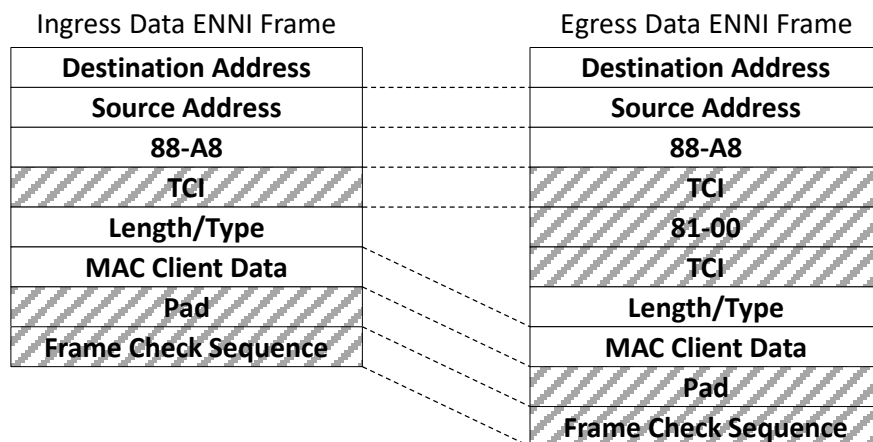
[ ] Unchanged   [//] Can change   [·|·] If present, length unchanged

Figure 31 – Single Tagged ENNI Frame to Double Tagged ENNI Frame Transparency

Ingress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⬚ If present, length unchanged
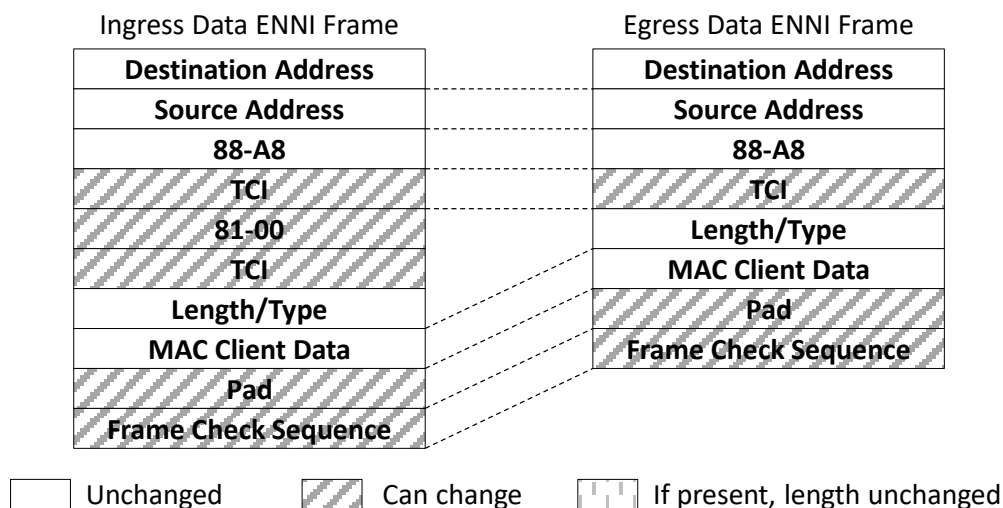
Figure 32 – Double Tagged ENNI Frame to Single Tagged ENNI Frame Transparency

Ingress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

Egress Data ENNI Frame

| Destination Address |
| Source Address |
| 88-A8 |
| TCI |
| 81-00 |
| TCI |
| Length/Type |
| MAC Client Data |
| Pad |
| Frame Check Sequence |

☐ Unchanged   ▨ Can change   ⬚ If present, length unchanged
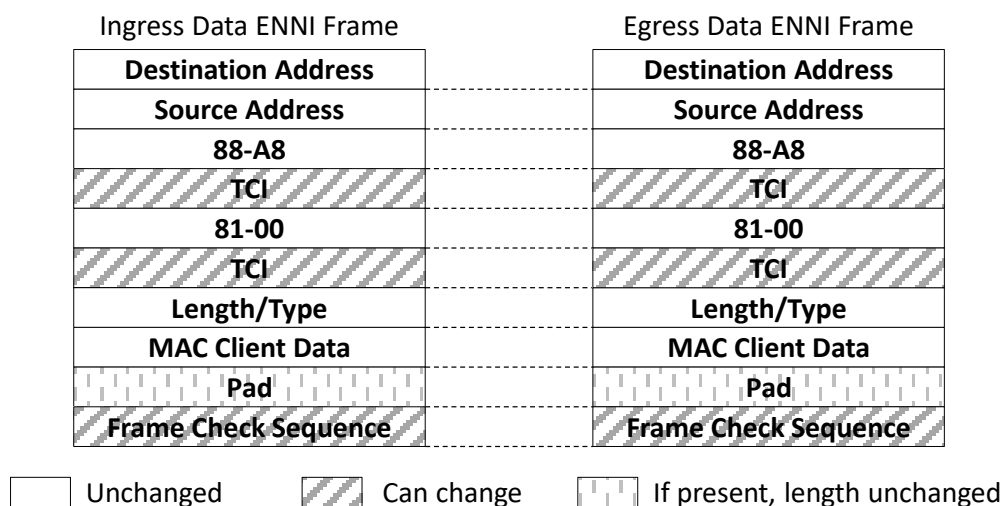
Figure 33 – Double Tagged ENNI Frame to Double Tagged ENNI Frame Transparency

[R76] If an egress ENNI Frame that is mapped to an OVC End Point that is not in a VUNI is the result of an ingress Double Tagged ENNI Frame that was mapped to an OVC End Point that is not in a VUNI, then the egress ENNI Frame **MUST** be Double Tagged with the C-Tag of the egress ENNI frame unchanged from the C-Tag of the ingress ENNI Frame.

A consequence of [R74] is that the values in the Destination Address, Source Address, Length/Type and MAC Client Data fields are never changed.

12.15 OVC Available MEG Level Service Attribute

The value of the OVC Available MEG Level Service Attribute is an integer from 0 to 7 or *None*. The value of OVC Available MEG Level Service Attribute is the MEG Level that is one MEG Level higher than any MEG level reserved by the Operator for MEGs whose MEPs are contained entirely within the Operator's CEN. The value *None* indicates that SOAM EI Frames are not guaranteed to pass over this OVC at any MEG Level. If an integer value is specified, then SOAM EI Frames at or above that MEG Level are guaranteed to pass over the OVC. Note that the Operator can instantiate MEPs or MIPs at or above the value of the OVC Available MEG Level on EIs that bound the OVC, if requested by the SP/SO.

The OVC Available MEG Level Service Attribute can be used by the SP/SO to determine which MEG levels are available that do not conflict with any SOAM used by the Operator within the CEN. When SOAM is used across a chain of OVCs, the OVC with the greatest OVC Available MEG Level Service Attribute value determines the lowest MEG level that can be used by the SP/SO.

Appendix D of MEF 51 [25] describes the use of the OVC Available MEG Level Service Attribute for concatenated OVCs.

12.16 OVC L2CP Address Set Service Attribute

The OVC L2CP Address Set Service Attribute is the L2CP Address Set Service Attribute that is defined in Section 8.1 of MEF 45 [24] when applied to the OVC. See Section 8.1 MEF 45 [24] for the possible values and requirements for this Service Attribute.

13   ENNI Service Attributes

For each instance of an ENNI, there are multiple sets of ENNI Service Attributes. The value for each ENNI Service Attribute in a set for an Operator CEN is specific to a SP/SO that is using the ENNI per Section 8.11. Each such value is agreed to by the SP/SO and the Operator. The methods and procedures for reaching agreement are beyond the scope of this document.

For a given SP/SO that is using the ENNI, a given ENNI Service Attribute can have an identical value for each Operator while another ENNI Service Attribute can have a different value for each Operator. For example, if Operator A and Operator B interconnect at the ENNI, a SP/SO can agree with Operator A that the ENNI Token Share Service Attribute (Section 13.5) value equals *Enabled* while at the same time the SP/SO can agree with Operator B that the ENNI Token Share Service Attribute value equals *Disabled*. All of the ENNI Service Attribute values for each Operator will be known to the SP/SO. It also possible that the value for an ENNI Service Attribute can be different for different SP/SOs using the ENNI.

The value of an ENNI Service Attribute that one Operator agrees to with a SP/SO might not be known by the other Operator, and vice versa.

The ENNI Service Attributes are summarized in Table 24 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
Operator ENNI Identifier	An identifier for the ENNI intended for management purposes	A string that is unique across the ENNIs of the Operator CEN.
S-VLAN ID Control	The degree to which a SP/SO can use S-VLAN IDs to map to OVC End Points	*Full* or *Partial*
Maximum Number of OVCs	The maximum number of OVCs that the Operator CEN can support at the ENNI	A strictly positive integer
Maximum Number of OVC End Points per OVC	The maximum number of OVC End Points that the Operator CEN can support at the ENNI for an OVC.	A strictly positive integer
ENNI Token Share	An indication of the support of mapping more than one Bandwidth Profile Flow to an Envelope at the ENNI	*Enabled* or *Disabled*
ENNI Envelopes	The Envelopes and corresponding Envelope Coupling Flag value to which Bandwidth Profile Flows can be mapped	A list entries of the form <Envelope ID value, Envelope Coupling Flag value>

Table 24 – ENNI Service Attributes

13.1 Operator ENNI Identifier Service Attribute

The Operator ENNI Identifier Service Attribute value is a string used to allow the SP/SO and Operator to uniquely identify the ENNI for operations purposes.

[R77] The Operator ENNI Identifier Service Attribute value **MUST** be unique across all ENNIs supported by the Operator CEN.

[R78] The Operator ENNI Identifier Service Attribute value **MUST** contain no more than 45 characters.[16]

[R79] The Operator ENNI Identifier Service Attribute value **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

13.2 S-VLAN ID Control Service Attribute

The value of the S-VLAN ID Control Service Attribute is *Full* or *Partial*. When the value is *Full*, the Operator can support only a single SP/SO at the ENNI (the Operator might support other SP/SOs at other EIs). In other words, S-VLAN IDs at the ENNI can only be mapped to OVC End Points for a single SP/SO. When the value is *Partial*, there can be multiple SP/SOs using the ENNI and different S-VLAN IDs can be mapped to OVC End Points for different SP/SOs.

When there are multiple Super Operators using an ENNI, it is possible for more than one Super Operator to have the value of the S-VLAN Control Service Attribute equal *Full*. Figure 34 shows an example. In this example Operator 2, acting as a Super Operator, has contracted with Operator 1 to have the S-VLAN Control Service Attribute equal *Full*. Operator 3, acting as a Super Operator, has contracted with Operator 2 to have the S-VLAN Control Service Attribute equal *Full.* In this example, Operator 3 is free to agree with a SP/SO to have the S-VLAN Control Service Attribute value equal *Full* or *Partial*.

---

[16] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

S-VLAN ID Control Service Attribute = *Full*
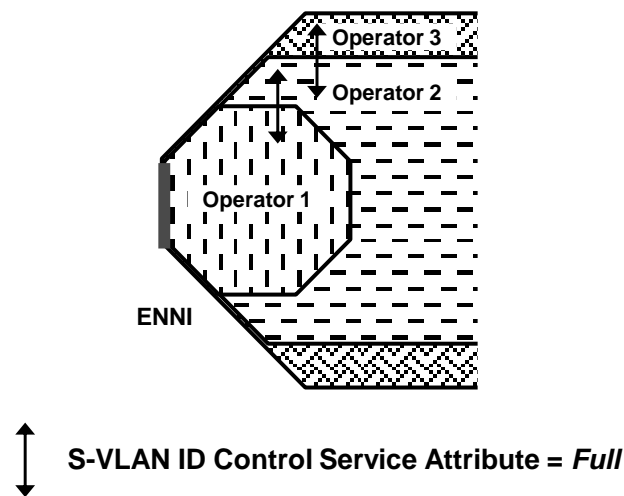
Figure 34 – Example of Multiple Super Operators with the Value of S-VLAN ID Control Service Attribute =
Full

[R80]   When a Super Operator has agreed with an Operator that the S-VLAN Control
Service Attribute value equals *Partial*, this Super Operator, acting as an
Operator, **MUST** agree to the value *Partial*, with all of its SP/SO clients at the
ENNI.

Figure 35 shows an example of [R80]. In this example, Operator 3, acting as a Super Operator,
has agreed with Operator 2 to set the value of the S-VLAN Control Service Attribute to *Partial*.
Consequently, per [R80], all SP/SOs contracting with Operator 3 will have the value of the S-
VLAN Control Service Attribute equal to *Partial*.

S-VLAN ID Control Service Attribute = *Full*

S-VLAN ID Control Service Attribute = *Partial*
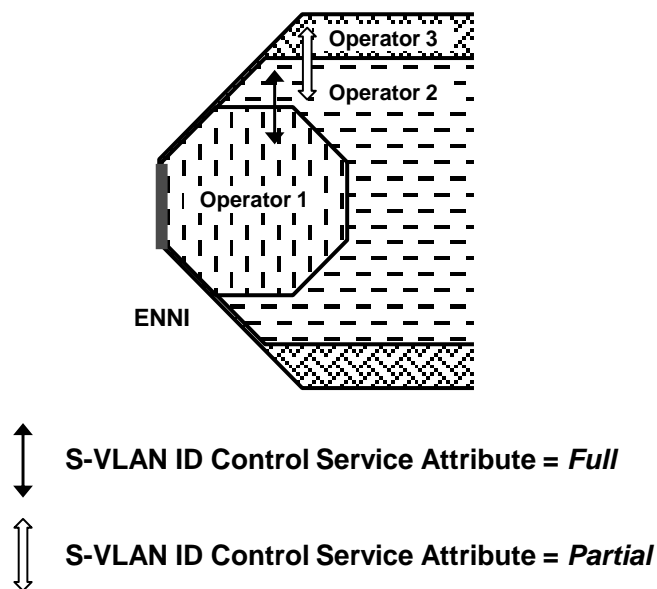
Figure 35 – Example of a Super Operator with the Value of S-VLAN ID Control Equal *Partial*

[R81]   When an Operator has more than one SP/SO client at the ENNI, the value of S-VLAN ID Control **MUST** be *Partial* for every SP/SO client at the ENNI.

[R81] ensures that each SP/SO client of a given Operator can map at least one S-VLAN ID to an OVC End Point at the ENNI.

The value of the S-VLAN Control Service Attribute determines which Super Operators supporting an ENNI need to agree to the value of each ENNI Common Attribute (Section 8.4) and each Operator Multilateral Attribute (Section 8.5). For an ENNI, there is always one non-Super Operator on each side of the ENNI that needs to agree to the value of each ENNI Common Attribute and each Operator Multilateral Attribute. In addition, any SP/SO involved with the ENNI that has contracted with an Operator for the value of the S-VLAN Control Service Attribute to equal *Full* needs to agree to the value of each ENNI Common Attribute and each Operator Multilateral Attribute. It follows that for each ENNI, two or more organizations need to agree to the value of each ENNI Common Attribute and each Operator Multilateral Attribute. The procedures by which such agreements are reached are beyond the scope of this document.

As an example, Operators 1, 2, 3, A, and B in Figure 36 need to agree to the value of each ENNI Common Attribute. Operators 1 and A need to be party to the agreements because they are not Super Operators. Operators 2, 3, and B need to be party to the agreements because, acting as Super Operators, they have agreed to the value of the S-VLAN ID Control Service Attribute = *Full*.
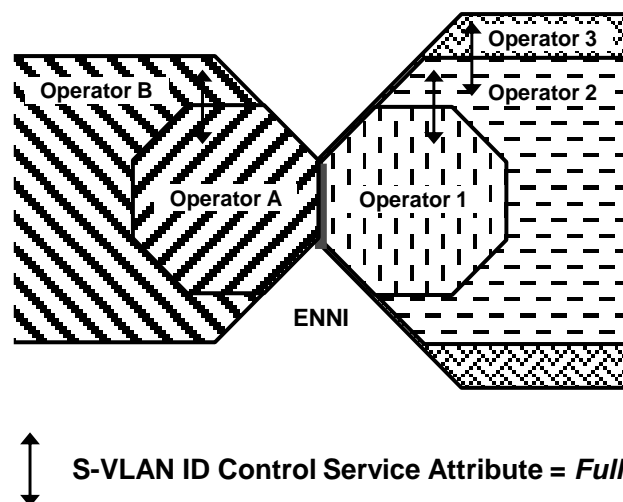
Figure 36 – Example of Organizations that Need to Agree on the Values of the ENNI Common Attributes

13.3   Maximum Number of OVCs Service Attribute

The value of the Maximum Number of OVCs Service Attribute is a strictly positive integer. It provides an upper bound on the number of OVCs that the Operator will support at the ENNI for the SP/SO.

13.4 Maximum Number of OVC End Points per OVC Service Attribute

The value of the Maximum Number of OVC End Points per OVC Service Attribute is a strictly positive integer. It provides an upper bound on the number of OVC End Points that are associated by each OVC that the Operator can support at the ENNI. This upper bound applies to the sum of the number OVC End Points that are not in a VUNI and the number of OVC End Points that are in a VUNI. See Section 15 for details regarding the VUNI.

Note that if the Maximum Number of OVC End Points per OVC Service Attribute is one, then hairpin switching cannot be supported at the ENNI. See Section 12.3.1.

13.5 ENNI Token Share Service Attribute

The value of the ENNI Token Share Service Attribute is either *Enabled* or *Disabled*.

[R82] When the value of the ENNI Token Share Service Attribute is *Enabled*, at least one Envelope at the ENNI **MUST** be able to have two or more Bandwidth Profile Flows mapped to it by.

[D7] When the value of the ENNI Token Share Service Attribute is *Enabled*, every Envelope at the ENNI **SHOULD** be able to have two or more Bandwidth Profile Flows mapped to it.

[R83] When the value of the ENNI Token Share Service Attribute is *Disabled*, every Envelope at the ENNI **MUST** have exactly one Bandwidth Profile Flow mapped to it.

See Section 17 for the details regarding Bandwidth Profile Flow and Envelope at an ENNI.

The requirements in this document are sufficient to allow a single SP/SO to use Token Sharing. Additional requirements are needed to enable multiple SP/SOs to share tokens with each other. Such requirements are beyond the scope of this document.

13.6 ENNI Envelopes Service Attribute

The value of the ENNI Envelopes Service Attribute is a list of pairs of the form $\langle x, y \rangle$ where x is an Envelope ID value and y is the Envelope Coupling Flag value. The possible values for Envelope ID and Envelope Coupling Flag are detailed in Section 17.1.

[R84] The ENNI Envelopes Service Attribute value **MUST** contain at most one entry with a given Envelope ID value.

[R85] The Envelope ID value in the Envelope and Rank Parameter (ER_i) for each Bandwidth Profile Flow specified at the ENNI **MUST** match the Envelope ID value in exactly one of the ENNI Envelopes Service Attribute list entries.

See Section 17.1 for the details regarding the Envelope and Rank Parameter.

14 Operator UNI Service Attributes

The Operator UNI Service Attributes values are agreed to by the SP/SO and the Operator. The Operator UNI Service Attributes are summarized in Table 25 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
Operator UNI Identifier	An identifier for the UNI intended for management purposes	A string that is unique across the Operator CEN
Operator UNI Physical Layer	The physical layer of each of the links supporting the UNI	A subset of the PHYs listed in IEEE Std 802.3 – 2012 [4] for each physical link
Operator UNI Synchronous Mode	The specification of which physical links can be used as a frequency synchronization reference	A list of items, one for each physical link, where each item can equal either *Enabled* or *Disabled*
Operator UNI Number of Links	The number of physical links at the UNI	A strictly positive integer
Operator UNI Link Aggregation	The method for protection, if any, against a physical link failure	*None*, *2-Link Active/Standby*, *All Active*, or *Other*
Operator UNI Port Conversation ID to Aggregation Link Map	The mapping of Port Conversation IDs to physical links	See IEEE Std 802.1AX – 2014 [2]
Operator UNI Service Frame Format	The format of the PDUs at the UNI	*Ethernet MAC Frame conforming to Clause 3 of IEEE 802.3-2012 [4]*
Operator UNI Maximum Service Frame Size	The maximum length Service Frame in bytes that can be reliably processed	An integer number of bytes greater than or equal to 1522
Operator UNI Default CE-VLAN ID	The CE-VLAN ID value for untagged and priority tagged Service Frames	An integer in the range $1, 2, ..., 4094$
Operator UNI Maximum Number of OVC End Points	The maximum number of OVC End Points that the Operator CEN can support at the UNI	A strictly positive integer
Operator UNI Maximum Number of CE-VLAN IDs per OVC End Point	The maximum number of CE-VLAN ID values that can be mapped to an OVC End Point by the Operator CEN at the UNI	A strictly positive integer
Operator UNI Ingress Bandwidth Profile	A single Bandwidth Profile Flow based on criterion 7 of [R230]	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
Operator UNI Egress Bandwidth Profile	A single Bandwidth Profile Flow based on criterion 8 of [R230]	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.

Attribute Name	Summary Description	Possible Values
Operator UNI Link OAM	The indication of the instantiation of Link OAM on the physical links at the UNI	*Enabled* or *Disabled*
Operator UNI MEG	The indication of the instantiation of the UNI MEG	*Enabled* or *Disabled*
Operator UNI LAG Link MEG	The indication of the instantiation of the LAG Link MEG	*Enabled* or *Disabled*
Operator UNI E-LMI	The indication of support of E-LMI per MEF 16 [15]	*Enabled* or *Disabled*
Operator UNI Token Share	An indication of the support of mapping more than one Bandwidth Profile Flow to an Envelope at the UNI	*Enabled* or *Disabled*
Operator UNI Envelopes	The Envelopes and Envelope Coupling Flag values to which Bandwidth Profile Flows can be mapped	A list entries of the form <Envelope ID value, Envelope Coupling Flag value>

Table 25 – Operator UNI Service Attributes

It is important to note that the Operator UNI Service Attributes are different from the UNI Service Attributes detailed in MEF 10.3 [12]. They are different because the value of each Operator UNI Service Attribute is agreed to by the SP/SO and the Operator while the value of each UNI Service Attribute described MEF 10.3 is agreed to by the Subscriber and the Service Provider. In some cases these attributes may have the same value (e.g., Operator UNI Physical Layer Service Attribute and UNI Physical Layer Service Attribute will have the same values), but nonetheless they are separate attributes. A comparison of the attributes can be found in Appendix H.

14.1   Operator UNI Identifier Service Attribute

The value of the Operator UNI Identifier Service Attribute is a string that is used to allow the SP/SO and Operator to uniquely identify the UNI for operations purposes.

>   **[R86]**   The value of the Operator UNI Identifier Service Attribute **MUST** be unique among all UNIs for the Operator's CEN.

>   **[R87]**   The value of the Operator UNI Identifier Service Attribute **MUST** contain no more than 45 characters.[17]

>   **[R88]**   The value of the Operator UNI Identifier Service Attribute **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

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[17] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

14.2 Operator UNI Physical Layer Service Attribute

The value of the Operator UNI Physical Layer Service Attribute is a list of physical layers, one for each physical link implementing the UNI. Different physical links can use different physical layers.

[R89] The Physical Layer for each physical link implementing the UNI **MUST** be one of the PHYs listed in IEEE Std 802.3 – 2012 [4] but excluding 1000BASE-PX-D and 1000BASE-PX-U.

[R90] Each Physical Layer **MUST** operate in full duplex mode.

14.3 Operator UNI Synchronous Mode Service Attribute

The value of the Operator UNI Synchronous Mode Service Attribute is a list with one item for each of the physical links implementing the UNI. Each item in the list takes on one of two values: *Enabled* or *Disabled*. When the value of an item is *Enabled*, the bits transmitted from the Operator CEN to the Customer Edge on the physical link corresponding to the item can be used by the Customer Edge as a bit clock reference.

[R91] When the value of an item in the Synchronous Mode Service Attribute is *Enabled*, the CEN Operator **MUST** specify the quality of the clock reference that is being provided on the physical link corresponding to the list item.

14.4 Operator UNI Number of Links Service Attribute

The value of the Operator UNI Number of Links Service Attribute is the number of physical links at the UNI.

14.5 Operator UNI Link Aggregation Service Attribute

The Operator UNI Link Aggregation Service Attribute value is one of *None*, *2-Link Active/Standby*, *All Active*, or *Other*. The value of this Service Attribute is dependent on the value of the Operator UNI Number of Links Service Attribute.

[R92] If the value of the Operator UNI Number of Links Service Attribute is one, then the value of the Operator UNI Link Aggregation Service Attribute **MUST** be set to *None*.

[R93] If the value of the Operator UNI Number of Links Service Attribute is 2 then the value of the Operator UNI Link Aggregation Service Attribute **MUST** be set to one of *2-Link Active/Standby*, *All Active*, or *Other*.

[R94] If the value of the Operator UNI Number of Links Service Attribute is 3 or more then the value of the Operator UNI Link Aggregation Service Attribute **MUST** be set to either *All Active* or *Other*.

Table 26 summarizes the above requirements.

Number of Links	*None*	*Active/Standby*	*All Active*	*Other*
1	☑	☐	☐	☐
2	☐	☑	☑	☑
3 or more	☐	☐	☑	☑

Table 26 – Allowed Values of the Operator UNI Link Aggregation Service Attribute

The following requirements depend on the value of the Operator UNI Link Aggregation Service Attribute.

[R95] When the value of the Operator UNI Link Aggregation Service Attribute is set to *2-Link Active/Standby*, the Operator CEN **MUST** implement Link Aggregation as in either Clause 5.6.1 of IEEE Std 802.1AX – 2008 [1] or Clause 6.7.1 of IEEE Std 802.1AX – 2014 [2] with one Link Aggregation Group (LAG) across the links supporting the UNI and with one link in active mode and the other in standby mode.

[R96] When the value of the Operator UNI Link Aggregation Service Attribute is set to *All Active* the Operator CEN **MUST** use Link Aggregation as specified in Clause 5.3 of IEEE Std 802.1AX-2014 [2], including the use of the version 2 LACPDUs as specified in Clause 5.3.1h of IEEE Std 802.1AX-2014 [2], with one Link Aggregation Group (LAG) across the links supporting the UNI.

[R97] When the Operator UNI Link Aggregation Service Attribute is set to *All-Active*, the Operator CEN **MUST** use "Per-service frame distribution" as specified in Clause 8.2 of IEEE Std 802.1AX-2014 [2], where the Port Conversation ID is equal to the VLAN ID for VLAN Tagged Service Frames and equal to 0 for Untagged and Priority Tagged Service Frames.

[R97] means that the Service ID for each Service Frame is the value of the VLAN ID in the C-Tag when present and is 0 when the Service Fame has no C-Tag. [R97] also means that the Port Conversation ID = Service ID in the Service ID to Port Conversation ID Map.

[R98] When the Operator UNI Link Aggregation Service Attribute is set to *All-Active*, the Operator CEN **MUST** be configured such that there is only one aAggActorAdminKey that has the same value as the aAggPortActorAdminKey for the ports terminating the links at the UNI.

The aAggActorAdminKey and aAggPortActorAdminKey are managed objects defined in IEEE Std 802.1AX-2014 [2]. Ensuring that there is only one aAggActorAdminKey with the same value as the aAggPortActorAdminKey for the ports terminating the links at the UNI assures that only a single Link Aggregation Group is formed at the UNI. This eliminates that possibility of any loops potentially arising from multiple UNI links coming up independently or forming separate Link Aggregation Groups.

[O4]   When the value of the Operator UNI Link Aggregation Service Attribute is
Other, the SP/SO and the Operator **MAY** implement any other resiliency
mechanism by mutual agreement.

The other resiliency mechanism referred to in [O4] is beyond the scope of this document.

14.6   Operator UNI Port Conversation ID to Aggregation Link Map Service Attribute

The Operator UNI Port Conversation ID to Aggregation Link Map Service Attribute is
applicable only when the Operator UNI Resiliency Mechanism Service 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 [2].

[R99]   When the Operator UNI Link Aggregation Service Attribute is set to *All Active*,
the set of Link Number IDs as defined in IEEE Std 802.1AX – 2014 [2] for the
Operator CEN **MUST** be $\{1, 2, ..., m\}$ where m is the value of the Operator UNI
Number of Links Service Attribute.

[O5]   When the Operator UNI Link Aggregation Service Attribute is set to *All Active*
and a OVC End Point Map (Section 16.5) maps more than one CE-VLAN ID
value to an OVC End Point, the Operator CEN **MAY** support a value of the
Operator UNI Port Conversation ID to Aggregation Link Map Service Attribute
such that Service Frames with different CE-VLAN ID values mapped to the
OVC End Point can be carried on different physical links.

The value of the Operator UNI Port Conversation ID to Aggregation Link Map Service Attribute
described in [O5] is useful when the bandwidth needed for the OVC End Point exceeds the
capacity of a single physical link at the UNI. However, in certain configurations (for example
when the links terminate on different devices in the Operator CEN), supporting such map could
require an Operator to make tradeoffs between the Service Frame distribution and the application
of MEF SOAM and Bandwidth Profiles.

[R100]   When Ingress Bandwidth Profiles (Sections 14.12, 16.10, 16.12) and/or Egress
Bandwidth Profiles (Sections 14.13, 16.11, 16.13) are used at the UNI, the
Operator of the CEN **MUST** support a value in the Operator UNI Port
Conversation ID to Aggregation Link Map Service Attribute such that all
Service Frames that map to a given Envelope (Section 17) are carried on the
same physical link.

It may be difficult to implement the Bandwidth Profile Algorithm (Section 17.2) when Service
Frames mapped to an Envelope are carried on multiple physical links. [R100] is intended to
address the situation where the Operator CEN and/or the CE have this implementation issue.

14.7   Operator UNI Service Frame Format Service Attribute

The Operator UNI Service Frame Format Service Attribute has the value *Ethernet MAC Frame conforming to Clause 3 of IEEE 802.3-2012*. Additional potential values are beyond the scope of this document.

> **[R101]**   The Operator CEN **MUST** comply with the Ethernet Media Access Control standards specified in Clauses 3 and 4 of IEEE Std 802.3 – 2012 [4].

Note that [R101] means that Service Frames will be discarded by the receiving Operator CEN if they are not properly constructed. For example, a Service Frame with an incorrect Frame Check Sequence will be discarded. However, this document provides for Service Frames that are longer than the maximum specified in IEEE Std 802.3–2012 [4]. See Section 14.8.

14.8   Operator UNI Maximum Service Frame Size Service Attribute

The value for the Operator UNI Maximum Service Frame Size is a strictly positive integer in bytes.

> **[R102]**   The value of the Operator UNI Maximum Service Frame Size **MUST** be at least 1522 bytes.

Note that per [R40] and [R41], if the value of the Operator UNI Maximum Service Frame Size Service Attribute is 1522, then the value of the OVC Maximum Frame Size Service Attribute for an OVC associating an OVC End Point at the UNI is 1526. Then per [D5], an ingress Service Frame with a C-Tag that is mapped to an OVC End Point associated by this OVC and whose length exceeds 1522 is recommended to be discarded. Also per [D6], an ingress Service Frame without a C-Tag that is mapped to an OVC End Point associated by this OVC and whose length exceeds 1518 is recommended to be discarded.

14.9   Operator UNI Default CE-VLAN ID Service Attribute

The value of the Operator UNI Default CE-VLAN ID is an integer that is the CE-VLAN ID value assigned to Untagged Service Frames and Priority Tagged Service Frames. See Section 7 of MEF 10.3 [12] for the definition of Untagged Service Frame and Priority Tagged Service Frame.

> **[R103]**   The value of the Operator UNI Default CE-VLAN ID Service Attribute **MUST** be a integer in the range 1,2,...,4094.

The value of the Operator UNI Default CE-VLAN ID can impact the behavior of the OVC End Point Map Service Attribute as described in Section 16.5.4. For example, if the value of the Operator UNI Default CE-VLAN ID Service Attribute is not contained in any OVC End Point Map Service Attribute value (see Section 16.5.4) for the OVC End Points at the UNI, then ingress untagged and priority tagged Data Service Frames will be discarded and all egress Data Service Frames will be tagged.

When the OVC End Point Map for an OVC End Point at the UNI (Section 16.5.4) contains all CE-VLAN ID values, the value of the Operator UNI Default CE-VLAN ID Service Attribute does not affect the behavior of the mapping of Service Frames to OVC End Points at the UNI. In such a situation, there is no need for the SP/SO and Operator to agree on a value for the Operator UNI Default CE-VLAN ID Service Attribute.

14.10 Operator UNI Maximum Number of OVC End Points Service Attribute

The value of the Operator UNI Maximum Number of OVC End Points Service Attribute is a strictly positive integer that specifies the maximum number of OVC End Points that the UNI can support.

Note that since Hairpin Switching is not allowed at a UNI, the value of the Operator UNI Maximum Number of OVC End Points Service Attribute is the same as the maximum number of OVCs that the UNI can support.

14.11 Operator UNI Maximum Number of CE-VLAN IDs per OVC End Point Service Attribute

The value of the Operator UNI Maximum Number of CE-VLAN IDs per OVC End Point Service Attribute is a strictly positive integer that specifies the largest number of CE-VLAN ID values that can map to an OVC End Point in a OVC End Point Map Service Attribute at the UNI.

14.12 Operator UNI Ingress Bandwidth Profile per UNI Service Attribute

The value of the Operator UNI Ingress Bandwidth Profile per UNI Service Attribute is *Parameters* or *Disabled*.

> **[R104]** When the value of the Operator UNI Ingress Bandwidth Profile per UNI Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 7 of [R230] **MUST** be contained in an Envelope that contains only this Bandwidth Profile Flow.

> **[R105]** When the value of the Operator UNI Ingress Bandwidth Profile per UNI Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.

14.13 Operator UNI Egress Bandwidth Profile per UNI Service Attribute

The value of the Operator UNI Egress Bandwidth Profile per UNI Service Attribute is *Parameters* or *Disabled*. An Operator UNI Egress Bandwidth Profile per UNI Service Attribute applies to all egress Service Frames at the UNI.

[R106] When the value of the Operator UNI Egress Bandwidth Profile per UNI Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 8 of [R230] **MUST** be contained in an Envelope that contains only this Bandwidth Profile Flow.

[R107] When the value of the Operator UNI Egress Bandwidth Profile per UNI Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.

14.14 Operator UNI Link OAM Service Attribute

The value of the Operator UNI Link OAM Service Attribute is either *Enabled* or *Disabled*.

[R108] When the value of the Operator UNI Link OAM Service Attribute is *Enabled*, the Operator **MUST** run Link OAM on all physical links in the UNI as specified in Clause 57 of IEEE Std 802.3-2012 [4].

[R109] When the value of the Operator UNI Link OAM Service Attribute is *Enabled*, the Operator **MUST** run Link OAM in Active DTE Mode as specified in Clause 57.2.9 of IEEE Std 802.3-2012 [4].

[D8] When the value of the Operator UNI Link OAM Service Attribute is *Enabled*, Link Events as specified in Clauses 57.2.10 and 57.4.3.2 of IEEE Std 802.3 – 2012 [4] **SHOULD** be enabled on each link in the UNI.

14.15 Operator UNI MEG Service Attribute

The value of the Operator UNI MEG Service Attribute is either *Enabled* or *Disabled*.

[R110] When the value of the Operator UNI MEG Service Attribute is *Enabled*, the Operator CEN **MUST** meet the mandatory requirements of MEF 30.1 [20] that apply to the UNI MEG.

[R111] When the value of the Operator UNI MEG Service Attribute is *Enabled*, the direction of the UNI MEG MEP **MUST** be *Down*.

When the value of the Operator UNI MEG Service Attribute is *Enabled*, several parameter values need to be determined as described in MEF 30.1 [20].

14.16 Operator UNI LAG Link MEG Service Attribute

The value of the Operator UNI LAG Link MEG Service Attribute is either *Enabled* or *Disabled*.

[R112] When the value of the Operator UNI LAG Link MEG Service Attribute is *Enabled*, the Operator CEN **MUST** operate the LAG Link MEG on each link in the UNI.

[R113] When the value of the Operator UNI LAG Link MEG Service Attribute is *Enabled*, the Operator CEN **MUST** meet the mandatory requirements of MEF 30.1 [20] that apply to the UNI LAG Link MEG.

When the value is *Enabled*, a number of further parameters need to be agreed to as described in MEF 30.1 [20]. Some parameters will commonly be the same across all links in the LAG (for example, the MEG Level) while others have to be different (for example, the MEG ID).

14.17 Operator UNI E-LMI Service Attribute

The value of the Operator UNI E-LMI Service Attribute is either *Enabled* or *Disabled*.

[R114] When the value of the Operator UNI E-LMI Service Attribute is *Enabled*, the Operator CEN **MUST** meet the mandatory requirements in MEF 16 [15] that apply to the UNI-N.

14.18 Operator UNI Token Share Service Attribute

The value of the Operator UNI Token Share Service Attribute is either *Enabled* or *Disabled*.

[R115] When the value of the Operator UNI Token Share Service Attribute is *Enabled*, at least one Envelope at the UNI **MUST** be able to have two or more Bandwidth Profile Flows mapped to it.

[D9] When the value of the Operator UNI Token Share Service Attribute is *Enabled*, every Envelope at the UNI **SHOULD** be able to have two or more Bandwidth Profiles mapped to it.

[R116] When the value of the Operator UNI Token Share Service Attribute is *Disabled*, every Envelope at the UNI **MUST** have exactly one Bandwidth Profile Flow mapped to it..

14.19 Operator UNI Envelopes Service Attribute

The value of the Operator UNI Envelopes Service Attribute is a list of pairs of the form $<x,y>$ where x is an Envelope ID value and y is the Envelope Coupling Flag value.

[R117] The Operator UNI Envelopes Service Attribute value **MUST** contain at most one entry with a given Envelope ID value.

[R118] The Envelope ID value in the Envelope and Rank Parameter (ER^i) for each Bandwidth Profile Flow specified at the UNI **MUST** match the Envelope ID value in exactly one of the Operator UNI Envelopes Service Attribute value entries.

See Section 17.1.1 for the details regarding the Envelope and Rank Parameter.

14.20 Operator UNI L2CP Address Set Service Attribute

The Operator UNI L2CP Address Set Service Attribute is the L2CP Address Set Service Attribute defined in MEF 45 [24] when applied to the UNI. See MEF 45 [24] for the possible values and requirements for this Service Attribute.

14.21 Operator UNI L2CP Peering Service Attribute

The Operator UNI L2CP Peering Service Attribute is the L2CP Peering Service Attribute defined in MEF 45 [24] when applied to the UNI. See MEF 45 [24] for the possible values and requirements for this Service Attribute.

15 Virtual UNI (VUNI), Feeder OVC, and Remote UNI (RUNI)

The underlying concepts for the VUNI and RUNI are introduced in Section 8.13.

Connectivity between a VUNI and the paired RUNI is accomplished by a chain of one or more OVCs that are called Feeder OVCs.[18] Figure 37 shows an example of a VUNI, its paired RUNI, and two Feeder OVCs. It is the responsibility of the SP/SO to configure the Feeder OVCs such that the VUNI is correctly paired with the RUNI.
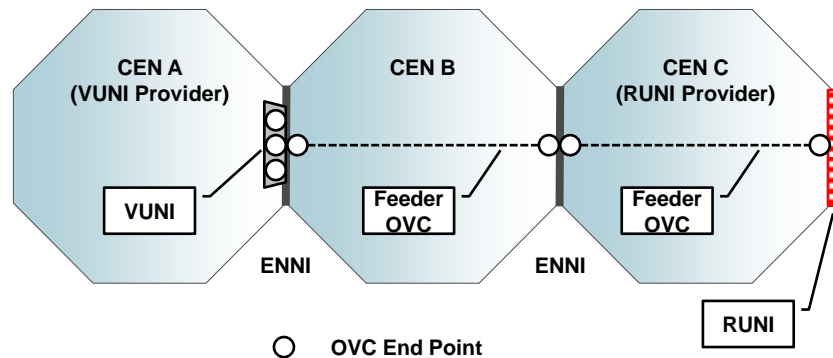
Figure 37 – Example of VUNI, RUNI, and Feeder OVCs

There are two ways to pair an RUNI with multiple VUNIs. One way is to have multiple OVC End Points at the RUNI with each associated by a different Feeder OVC. Figure 39 shows an example of this approach. A second way is to pair the RUNI with multiple cascaded VUNIs. Appendix C.5 shows an example of this approach.
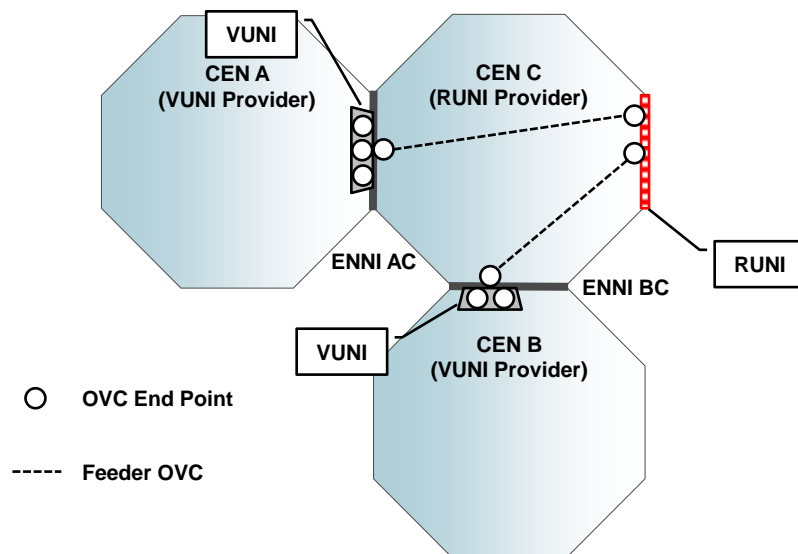
Figure 38 – Example of Multiple OVC End Points at the RUNI

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[18] The Feeder OVC is a generalization of the UNI Tunnel Access specified in MEF 28 [19]. For example, UTA can only connect an RUNI to an ENNI while a Feeder OVC can also connect two ENNIs.

The goal of the VUNI is to give the SP/SO flexibility in implementing EVCs. For example, the RUNI Provider may not have the ability to recognize individual CE-VLAN ID values at the RUNI. In such a case, this multiplexing functionality can be performed by the VUNI Provider.

Appendix C contains other examples of the use of the VUNI.

15.1 VUNI Service Attributes and Requirements

The VUNI Service Attributes are summarized in Table 27 and described in detail in the following sub-sections. In addition, a sub-section presents requirements related to the VUNI.

Attribute Name	Summary Description	Possible Values
VUNI Identifier	An identifier for the instance of the VUNI intended for operations purposes	A string that is unique among all VUNI Identifiers for the Operator CEN
VUNI S-VLAN ID	A value that allows mapping ENNI Frames to OVC End Points in the VUNI	An integer in the range $1, 2, ..., 4094$
VUNI Default ENNI CE-VLAN ID	The ENNI CE-VLAN ID value for ENNI Frames with no C-Tag or a C-Tag whose VLAN ID value is 0	An integer in the range $1, 2, ..., 4094$
VUNI Maximum Number of OVC End Points	The maximum number of OVC End Points that can be in the VUNI	A strictly positive integer
VUNI Maximum Number of ENNI CE-VLAN IDs per OVC End Point	The maximum number of ENNI CE-VLAN ID values that can be mapped to an OVC End Point that is in the VUNI	A strictly positive integer
VUNI Ingress Bandwidth Profile	A single Bandwidth Profile Flow based on criterion 3 of [R230]	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
VUNI Egress Bandwidth Profile	A single Bandwidth Profile Flow based on criterion 6 of [R230]	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
VUNI Maintenance End Point List	The indication of the instantiation of a MEG MEP	A list with each item specifying the MEG Level

Table 27 – VUNI Service Attributes

15.1.1 VUNI Identifier Service Attribute

The value of the VUNI Identifier Service Attribute is a string that is used to allow the SP/SO and the Operator to uniquely identify a VUNI for operations purposes.

> **[R119]** The VUNI Identifier Service Attribute value **MUST** be unique among all VUNI Identifier values for the Operator CEN.

> **[R120]** The VUNI Identifier Service Attribute value **MUST** contain no more than 45 characters.[19]

> **[R121]** The VUNI Identifier Service Attribute value **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

15.1.2 VUNI S-VLAN ID Service Attribute

The value of the VUNI S-VLAN ID Service Attribute is an integer in the range $1, 2, \dots, 4094$ that uniquely identifies the VUNI at the ENNI.

> **[R122]** The VUNI S-VLAN ID Service Attribute value **MUST** appear in the value of the OVC End Point Map Form V (Section 16.5.3) for each OVC End Point at an ENNI that is in the VUNI.

Note that a list of the OVC End Points that are in a VUNI can be constructed by collecting all of the OVC End Point Identifiers for OVC End Points whose OVC End Point Map Service Attribute value is Form V (see Section 16.5.3) and the value of the S-VLAN ID in the map equals the value of the VUNI S-VLAN ID Service Attribute.

15.1.3 VUNI Default ENNI CE-VLAN ID Service Attribute

The value of the VUNI Default ENNI CE-VLAN ID Service Attribute is an integer in the range $1, \dots, 4094$. The VUNI Default ENNI CE-VLAN ID Service Attribute is needed for the definition of the ENNI CE-VLAN ID for an ENNI Frame. The ENNI CE-VLAN ID is used in Form V of the OVC End Point Map Service Attribute at an ENNI (see Section 16.5.3).

If an ENNI Frame has an S-Tag whose VLAN ID value equals the value of the VUNI S-VLAN ID Service Attribute for a VUNI at the ENNI, then the value of the ENNI CE-VLAN ID for the ENNI Frame is defined as follows:

- If an ENNI Frame has a C-Tag whose VLAN ID value is not zero, then the ENNI CE-VLAN ID value for the ENNI Frame is the value of VLAN ID in the C-Tag,

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[19] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

- If the ENNI Frame either has no C-Tag or has a C-Tag whose VLAN ID value is zero, then the ENNI CE-VLAN ID value is equal to the value of the VUNI Default CE-VLAN ID Service Attribute.

The ENNI CE-VLAN ID is not defined for an ENNI Frame without an S-Tag and for an ENNI Frame with an S-Tag with a VLAN ID value that does not match the value of a VUNI S-VLAN ID Service Attribute.

Figure 39 shows an example of OVC End Point Map Service Attributes. Per [R144], the OVC End Point Map Service Attribute values for OVC End Points a, b, c, e, and f are of Form V. For example, <10: 12> signifies S-VLAN ID value = 10 and ENNI CE-VLAN ID value = 12. The OVC End Point Map Service Attribute value for OVC End Point d is of Form E (see Section 16.5.1) with <83> signifying S-VLAN ID value = 83.
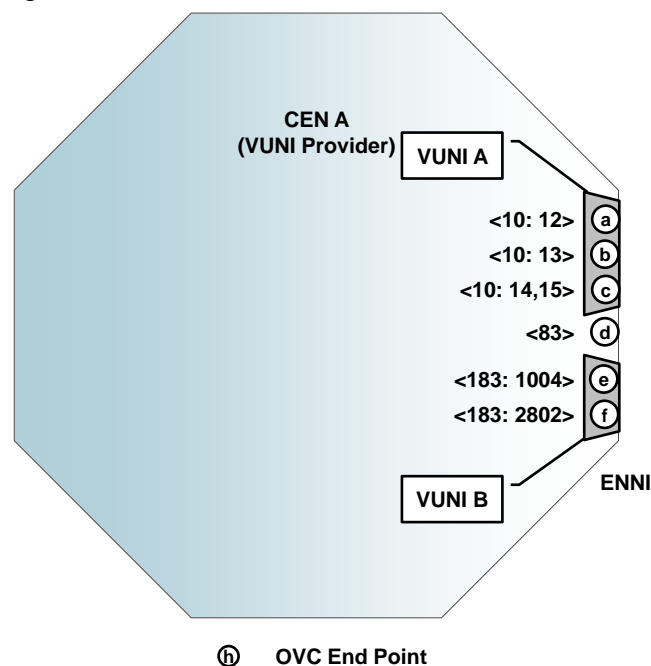
Figure 39 – Example OVC End Point Map Service Attributes

Table 28 shows example mappings of ENNI Frames to OVC End Points for the OVC End Point Map Service Attributes in Figure 39 where the VUNI Default ENNI CE-VLAN ID Service Attribute value for VUNI A equals 15 and the VUNI Default ENNI CE-VLAN ID Service Attribute value for VUNI B equals 17.

	S-VLAN ID Value	C-VLAN ID Value	OVC End Point
Example 1	83	Any or No C-Tag	d
Example 2	10	12	a
Example 3	10	No C-Tag	c
Example 4	10	0	c
Example 5	10	14	c
Example 6	10	15	c
Example 7	10	87	none
Example 8	183	27	none
Example 9	183	No C-Tag	none
Example 10	183	0	none
Example 11	183	2802	f

Table 28 – Example Mappings of ENNI Frames

Examples 9 and 10 in Table 28 do not map to an OVC End Point because the ENNI CE-VLAN ID value for these ENNI Frames is 17 while 17 does not appear in the OVC End Point Map Service Attribute values for OVC End Points e or f.

15.1.4 VUNI Maximum Number of OVC End Points Service Attribute

The value of the VUNI Maximum Number of OVC End Points Service Attribute is a strictly positive integer. The VUNI Maximum Number of OVC End Points Service Attribute value is the largest number of OVC End Points that can be in the VUNI. At any given time, the number of OVC End Points in the VUNI can be less than this value.

Note that per [R32], the value of the VUNI Maximum Number of OVC End Points Service Attribute is also the maximum number of OVCs that a VUNI can support.

15.1.5 VUNI Maximum Number of ENNI CE-VLAN IDs per OVC End Point Service Attribute

The value of the VUNI Maximum Number of ENNI CE-VLAN IDs per OVC End Point Service Attribute is a strictly positive integer that specifies the largest number of ENNI CE-VLAN ID values that can map to an OVC End Point in a value of the OVC End Point Map Service Attribute for an OVC End Point that is in the VUNI.

15.1.6 VUNI Ingress Bandwidth Profile Service Attribute

The value of the VUNI Ingress Bandwidth Profile Service Attribute is either *Parameters* or *Disabled*.

> **[R123]** When the value of the VUNI Ingress Bandwidth Profile Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 3 of [R230] for the VUNI **MUST** be contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 3 of [R230].

[R124] When the value of the VUNI Ingress Bandwidth Profile Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.

Note that because of [R232] and [R233], if the value of the VUNI Ingress Bandwidth Profile Service Attribute is *Enabled*, then all other ingress Bandwidth Profiles related to the OVC End Points in the VUNI will have to be *Disabled*. This means that an ingress ENNI Frame mapped to an OVC End Point that is in the VUNI will have a single Bandwidth Profile Color Declaration.

15.1.7 VUNI Egress Bandwidth Profile Service Attribute

The value of the VUNI Egress Bandwidth Profile Service Attribute is either *Parameters* or *Disabled*.

[R125] When the value of the VUNI Egress Bandwidth Profile Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 6 of [R230] for the VUNI **MUST** be contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 6 of [R230].

[R126] When the value of the VUNI Egress Bandwidth Profile Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.

15.1.8 VUNI L2CP Address Set Service Attribute

The VUNI L2CP Address Set Service Attribute is the L2CP Address Set Service Attribute defined in MEF 45 [24] when applied to the VUNI. See MEF 45 [24] for the possible values and requirements for this Service Attribute.

15.1.9 VUNI L2CP Peering Service Attribute

The VUNI L2CP Peering Service Attribute is the L2CP Peering Service Attribute defined in MEF 45 [24] when applied to the VUNI. See MEF 45 [24] for the possible values and requirements for this Service Attribute.

15.1.10 VUNI Maintenance End Point List Service Attribute

The value of the VUNI Maintenance End Point List Service Attribute is a list MEG Levels, one for each MEP that is instantiated. When the list is not empty, several parameter values need to be determined for each MEP as described in MEF 30.1 [20].

[R127] The direction for all MEPs in the value of the VUNI Maintenance End Point List **MUST** be *Down*.

15.2 Feeder OVC Requirements

The following requirements apply to a Feeder OVC.

[R128] A Feeder OVC **MUST** be a Point-to-Point OVC.

[R129] A Feeder OVC **MUST** have the values of the OVC CE-VLAN ID Preservation
Service Attribute (Section 12.7), the OVC CE-VLAN PCP Preservation Service
Attribute (Section 12.8), and the OVC CE-VLAN DEI Preservation Service
Attribute (Section 12.9) set as specified in Table 29.

OVC Service Attribute	Value
OVC CE-VLAN ID Preservation	*Preserve*
OVC CE-VLAN PCP Preservation	*Enabled*
OVC CE-VLAN DEI Preservation	*Enabled*

Table 29 – Required Feeder OVC Preservation Attribute Values

[R128] and [R129] significantly constrain the Feeder OVC but they are less stringent than the
requirements applied to the UNI Tunnel Access OVC (UTA OVC) in MEF 28 [19].
Consequently the Feeder OVC is a generalization of the UTA OVC. Generalizations include:

1. The UTA OVC is mandated to associate one OVC End Point at a UNI with one OVC
End Point at an ENNI while a Feeder OVC can associate OVC End Points that are each
at an ENNI,

2. The UTA OVC is mandated to have Color Forwarding = *Disabled* (Section 7.2.15 in
MEF 26.1 [18]) while the Feeder OVC has no corresponding Service Attribute and hence
no corresponding constraint,

3. The UTA OVC is mandated to have a OVC End Point Map Service Attribute value that
maps all CE-VLAN IDs to the OVC End Point while the value for the OVC End Point
Map Service Attribute for a Feeder OVC is unconstrained,

4. The UTA OVC is mandated to support a single Class of Service Name while the Feeder
OVC can support multiple Class of Service Names,

5. The UTA OVC is mandated to have at most an Ingress Bandwidth Profile at the UNI that
is per OVC End Point with CM = *color-blind* and one of CIR and EIR equal to zero
while there are no such constraints on the Feeder OVC regarding Ingress Bandwidth
Profile and Egress Bandwidth Profile, and

6. The UTA OVC is limited to a per OVC End Point Ingress Bandwidth Profile with one of
CIR and EIR equal to zero at the ENNI while there are no such constraints on the Feeder
OVC regarding Ingress Bandwidth Profile and Egress Bandwidth Profile.

7. The UTA OVC is mandated to have OVC Frame Disposition = *Deliver Unconditionally*
for all types of EI Frames while there is no such constraint on the Feeder OVC.

An important implication of item 3 is illustrated in Figure 40. Three OVC End Points can exist at
the RUNI. In this example, two are associated by Feeder OVCs thus allowing two VUNIs to pair

with the RUNI. This type of configuration gives the SP/SO more options in selecting paths for EVCs than is allowed by MEF 28 [19]. The configuration in Figure 40 is not allowed by MEF 28 [19] because it mandates that the OVC End Point Map contain all CE-VLAN ID values.
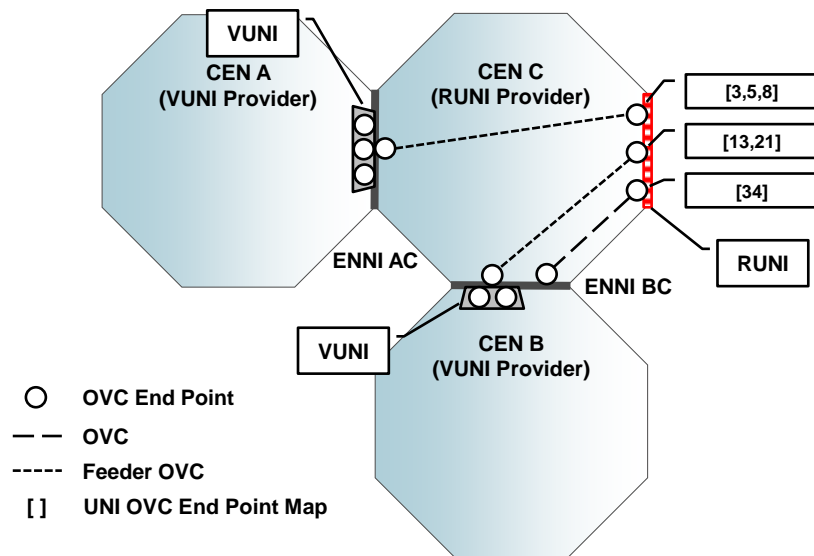
Figure 40 – Example of Multiple OVC End Points at the RUNI

16 OVC End Point Service Attributes

This section describes Operator Service Attributes that apply to an OVC End Point.

An OVC End Point is a logical entity at a given External Interface that is associated with a distinct set of frames passing over that External Interface. Per Section 8.8 an OVC is an association of OVC End Points. An OVC End Point represents the logical attachment of an OVC to an External Interface (a UNI or ENNI in the context of this document).

The combination of the External Interface Type value (Section 16.2) and the External Interface Identifier value (Section 16.3) serve to specify a specific External Interface. The OVC End Point is said to be at this External Interface. Frames that ingress or egress an External Interface are generically called EI Frames. See Section 8.7 for the formal definition of EI Frame.

There are Service Attributes for each instance of an OVC End Point. These are summarized in Table 30 and described in detail in the following sub-sections.

Attribute Name	Summary Description	Possible Values
OVC End Point Identifier	An identifier for the OVC End Point intended for operations purposes	A string that is unique among all OVC End Point Identifier values across the Operator CEN
OVC End Point External Interface Type	Identifies the type of External Interface at which the OVC End Point is located	*UNI* or *ENNI*
OVC End Point External Interface Identifier	The identifier value for the External Interface at which the OVC End Point is located.	An Operator ENNI Identifier Service Attribute value per Section 13.1 or an Operator UNI Identifier Service Attribute value per Section 14.1
OVC End Point Role	Indicates how EI Frames mapped to the OVC End Point can be forwarded	*Root*, *Leaf*, or *Trunk*
OVC End Point Map	The information that determines which EI Frames are mapped to the OVC End Point	One of four possible forms as mandated in Section 16.5.
OVC End Point Class of Service Identifier	The mechanism that allows a Class of Service Name to be determined for an ingress EI Frame	A triple of the form $<F, M, P>$ where the value of F is a field in the ingress EI Frame, M is a mapping between each possible value of the field F and a Class of Service Name, and P is map between L2CP types and Class of Service Names
OVC End Point Color Identifier	The mechanism by which the Color of an EI Frame is determined from content of the EI Frame for an OVC End Point	A pair of the form $<F, M>$ where F is a field in the ingress EI Frame and M is a mapping between each possible value of the field F and a Color
OVC End Point Egress Map	The specification of the content of the S-Tag and/or C-Tag PCP value and DEI value for egress EI Frames	Six forms of map, $CN{\rightarrow}S\text{-}Tag\ PCP$, $CC{\rightarrow}S\text{-}Tag\ DEI$, $CC{\rightarrow}S\text{-}Tag\ PCP$, $CN{\rightarrow}C\text{-}Tag\ PCP$, $CC{\rightarrow}C\text{-}Tag\ DEI$, and $CC{\rightarrow}C\text{-}Tag\ PCP$, as described in Section 16.8
OVC End Point Egress Equivalence Class Identifier	The mechanism that allows an Egress Equivalence Class Name to be determined for an egress EI Frame	A triple of the form $<F, M, P>$ where the value of F is a field in the egress EI Frame, M is a mapping between each possible value of the field F and an Egress Equivalence Class Name, and P is map between L2CP types and Egress Equivalence Class Names

Attribute Name	Summary Description	Possible Values
Ingress Bandwidth Profile Per OVC End Point	Ingress policing on all ingress EI Frames mapped to the OVC End Point	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
Egress Bandwidth Profile Per End Point	Egress policing and shaping on all egress EI Frames mapped to the OVC End Point	*Parameters* or *Disabled* When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
Ingress Bandwidth Profile Per Class of Service Name	Ingress policing on all ingress EI Frames with a given Class of Service Name for the receiving Operator CEN	A list of pairs of the form $\langle x, y \rangle$ where x is a Class of Service Name that is supported by the OVC that associates the OVC End Point and y has the value *Parameters* or *Disabled*. When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
Egress Bandwidth Profile Per Egress Equivalence Class Name	Egress policing and shaping on all egress EI Frames with a given Egress Equivalence Class Name	A list of pairs of the form $\langle x, y \rangle$ where x is an Egress Equivalence Class Name and y has the value *Parameters* or *Disabled*. When *Parameters*, several parameter values need to be agreed to by the SP/SO and Operator.
OVC End Point Aggregation Link Depth	The number of ENNI links that can carry ENNI Frames mapped to the OVC End Point	A list of pairs of the form <S-VLAN ID value, strictly positive integer>. Only applicable to OVC End Points at a ENNI
OVC End Point Source MAC Address Limit	A limit on the number of different source MAC addresses that can be used	*Disabled* or the pair $\langle N, \tau \rangle$ where N is a strictly positive integer and τ is a time interval
OVC End Point MIP	The indication of the instantiation of a MIP	*Enabled or Disabled*
OVC End Point Maintenance End Point List	The MEPs enabled for the OVC End Point	A list with each item specifying the MEG Level and direction for a MEP

Table 30 – OVC End Point Service Attributes

MEF 10.3 [15] has an EVC per UNI Service Attribute called Test MEG. An analogous Service Attribute is not included in this document. The Test MEG is recommended to be reserved for the SP and Subscriber by MEF 30.1. It is generally used on an on-demand basis. Attributes like the MEG ID and MEP ID are coordinated between the SP and Subscriber. Adding additional parties to this, such as an Operator or Super Operator, significantly increases the complexity of implementing the Test MEG. It is likely that without significant extra coordination among the involved parties the Test MEG cannot be successfully implemented. Therefore a Test MEG Service Attribute is not included in this document. Although not included, the agreement by multiple parties to use a Test MEG is not forbidden by this document.

16.1   OVC End Point Identifier Service Attribute

The value of the OVC End Point Identifier Service Attribute is a string that is used to allow the SP/SO and Operator to uniquely identify the OVC End Point for operations purposes.

> **[R130]**   The value of the OVC End Point Identifier **MUST** be unique among all such identifiers for OVC End Points supported by the Operator CEN.

> **[R131]**   The value of the OVC End Point Identifier **MUST** contain no more than 45 characters.[20]

> **[R132]**   The value of the Operator OVC End Point Identifier **MUST** be a non-null RFC 2579 [8] Display String but not contain the characters 0x00 through 0x1f.

16.2   OVC End Point External Interface Type Service Attribute

The value of the OVC End Point External Interface Type Service Attribute is either *UNI* or *ENNI*.

16.3   OVC End Point External Interface Identifier Service Attribute

The value of the OVC End Point External Interface Identifier Service Attribute is either an Operator ENNI Identifier Service Attribute value per Section 13.1 or an Operator UNI Identifier per Service Attribute value per Section 14.1.

> **[R133]**   If the value of the OVC End Point External Interface Type Service Attribute is *ENNI*, then the value of the End Point External Interface Identifier Service Attribute **MUST** be an Operator ENNI Identifier Service Attribute value per Section 13.1.

> **[R134]**   If the value of the OVC End Point External Interface Type Service Attribute is *UNI*, then the value of the End Point External Interface Identifier Service Attribute **MUST** be an Operator UNI Identifier Service Attribute value per Section 14.1.

The combination of the External Interface Type value and the External Interface Identifier value serves to specify a specific External Interface. The OVC End Point is said to be at this External Interface.

16.4   OVC End Point Role Service Attribute

The value of the OVC End Point Role Service Attribute is one of *Root*, *Leaf*, or *Trunk*.[21]

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[20] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

[21] Note that the use of "Trunk" in this document refers to a different concept than the use of "trunk" in IEEE 802.1Q-2014 [3].

[R135] The value of the OVC End Point Role Service Attribute for an OVC End Point at a UNI **MUST** have the value of either *Root* or *Leaf*.

Note that the value of the OVC End Point Role Service Attribute for an OVC End Point at a UNI can be different than the role of the UNI (described in MEF 10.3 [12]) as seen by the Subscriber. Appendix B.2 contains an example of such a difference.

[R136] The value of the OVC End Point Role Service Attribute for an OVC End Point in a VUNI (Section 15) **MUST** have the value of either *Root* or *Leaf*.

[R137] The value of the OVC End Point Role Service Attribute for an OVC End Point at an ENNI that is not in a VUNI **MUST** have the value of one of *Root*, *Trunk*, or *Leaf*.

Note that the OVC End Point Role will always have the value *Root* when the associating OVC is not of the type *Rooted-Multipoint*. See Section 12.2 for the definition of OVC Type.

For ease of exposition:

- An OVC End Point whose OVC End Point Role Service Attribute equals *Root* is called a Root OVC End Point,

- An OVC End Point whose OVC End Point Role Service Attribute equals *Leaf* is called a Leaf OVC End Point, and

- An OVC End Point whose OVC End Point Role Service Attribute equals *Trunk* is called a Trunk OVC End Point.

16.5 OVC End Point Map Service Attribute[22]

The value of the OVC End Point Map Service Attribute specifies which EI Frames are mapped to the OVC End Point within an Operator CEN. The value of the OVC End Point Map Service Attribute is used by a receiving Operator CEN to determine which OVC is to be used to handle the incoming EI Frame by identifying the OVC End Point. The value of the OVC End Point Map Service Attribute is used by a sending Operator to populate S-VLAN ID and/or C-VLAN ID fields for an egress EI frame that is mapped to the OVC End Point.

The value of the OVC End Point Map Service Attribute for a given OVC End Point takes on one of the forms described Sections 16.5.1, 16.5.2, 16.5.3, and 16.5.4.

See Section 16.5.6 for examples.

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[22] The OVC End Point Map Service Attribute replaces the End Point Map Service Attribute described in Section 7.1.7 of MEF 26.1 [18].

16.5.1   OVC End Point Map Form E

The value of an End Point Map of Form E (E for ENNI) consists of a list of one or more S-VLAN ID values. An S-Tagged ENNI Frame whose S-VLAN ID value matches an entry in the list maps to the OVC End Point.

> **[R138]**   When the OVC End Point External Interface Type Service Attribute = *ENNI*, the OVC End Point Role Service Attribute ≠ *Trunk*, and the OVC End Point is not in a VUNI (Section 15), the OVC End Point Map Service Attribute **MUST** be of Form E.

> **[R139]**   When the OVC End Point Map Service Attribute is Form E for an OVC End Point, all ingress EI Frames at the ENNI with an S-VLAN ID value matching an entry in the value of the OVC End Point Map Service Attribute **MUST** map to the OVC End Point.

> **[R140]**   When the OVC End Point Map Service Attribute is Form E for an OVC End Point, all egress EI Frames at the ENNI that map to the OVC End Point **MUST** have an S-VLAN ID value that matches an entry in the value of the OVC End Point Map Service Attribute.

Note that additional requirements in Section 16.5.7 apply when the value of the OVC End Point Map Service Attribute Form E contains more than one entry. In particular, these requirements specify which S-VLAN ID value to use in an egress ENNI Frame.

16.5.2   OVC End Point Map Form T

The value of an OVC End Point Map of Form T (T for Trunk) consists of a pair of S-VLAN ID values, $\langle r, l \rangle$. r is called the Root S-VLAN ID value and l is called the Leaf S-VLAN ID value. An S-Tagged ENNI Frame whose S-VLAN ID value matches one of the two S-VLAN ID values in the OVC End Point Map Form T maps to the OVC End Point. Note that Form T differs from Form E because it distinguishes the role of each S-VLAN ID value.

> **[R141]**   When the OVC End Point has the role of Trunk (Section 16.4), the OVC End Point Map Service Attribute **MUST** be of Form T.

Note that because of [R135] and [R136], OVC End Point Map Form T only applies to OVC End Points that are at an ENNI and not in a VUNI.

> **[R142]**   When the OVC End Point Map Service Attribute is Form T for an OVC End Point, all ingress EI Frames at the ENNI with an S-VLAN ID value matching one of S-VLAN ID values in $\langle r, l \rangle$ **MUST** map to the OVC End Point.

> **[R143]**   When the OVC End Point Map Service Attribute is Form T for an OVC End Point, all egress EI Frames at the ENNI that map to the OVC End Point **MUST** have an S-VLAN ID value that matches one of the values in $\langle r, l \rangle$.

Note that [R38] and [R39] specify which value in $\langle r, l \rangle$ to use in the egress EI Frames referred to in [R143].

16.5.3   OVC End Point Map Form V

The value of an OVC End Point Map of Form V (V for VUNI) consists of one S-VLAN ID value and a list of one or more ENNI CE-VLAN ID values (Section 15.1.3). An S-Tagged ENNI Frame whose S-VLAN ID value matches the S-VLAN ID value in the map and whose ENNI CE-VLAN ID value matches one of the ENNI CE-VLAN ID values in the map, maps to the OVC End Point.

> **[R144]**   When the OVC End Point is in a VUNI (Section 15), the OVC End Point Map Service Attribute **MUST** be of Form V.

> **[R145]**   When the OVC End Point Map Service Attribute is Form V for an OVC End Point, all ingress EI Frames at the ENNI whose S-VLAN ID value and whose ENNI CE-VLAN ID value (Section 15.1.3) both match entries in the value of the OVC End Point Map Service Attribute **MUST** map to the OVC End Point.

> **[R146]**   When the OVC End Point Map Service Attribute is Form V for an OVC End Point, all egress EI Frames at the ENNI that map to the OVC End Point **MUST** have an S-VLAN ID value that matches the S-VLAN ID in the value of the OVC End Point Map Service Attribute.

> **[R147]**   When the OVC End Point Map Service Attribute is Form V for an OVC End Point, all egress ENNI Frames at the ENNI that map to the OVC End Point **MUST** have an ENNI CE-VLAN ID value (Section 15.1.3) that matches an entry in the value of the OVC End Point Map Service Attribute.

> **[R148]**   An OVC associating an OVC End Point at an ENNI with an OVC End Point Map Service Attribute of Form V that contains multiple ENNI CE-VLAN ID values (Section 15.1.3) **MUST** have the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*.

> **[R149]**   When the OVC End Point is in a VUNI, the OVC associating the OVC End Point has the value of the OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*, and OVC End Point of Form V has a single ENNI CE-VLAN ID value that equals the value of the VUNI Default ENNI CE-VLAN ID Service Attribute (Section 15.1.3), any egress ENNI Frame mapped to this OVC End Point **MUST** be a Single Tagged ENNI Frame.

When the OVC End Point is in a VUNI, the OVC Associating the OVC End Point has the value of the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*, and the OVC End Point Map of Form V has a single ENNI CE-VLAN ID value that equals the value of the VUNI Default ENNI CE-VLAN ID Service Attribute (Section 14.9), an egress ENNI Frame mapped to this OVC End Point can be a Single Tagged ENNI Frame or a Double Tagged ENNI Frame.

[R150] When the OVC End Point is in a VUNI and OVC End Point of Form V has a single ENNI CE-VLAN ID value that does not equal the value of the VUNI Default ENNI CE-VLAN ID Service Attribute (Section 15.1.3), any egress ENNI Frame mapped to this OVC End Point **MUST** be a Double Tagged ENNI Frame.

16.5.4 OVC End Point Map Form U

The value of the OVC End Point Map of Form U (U for UNI) is a list of one or more CE-VLAN ID values. A Service Frame is mapped to the OVC End Point if the CE-VLAN ID value of the Service Frame is in the list. The CE-VLAN ID value of a Service Frame is defined in Section 9.9 of MEF 10.3 [12].

[R151] When the OVC End Point External Interface Type Service Attribute = *UNI*, the OVC End Point Map Service Attribute **MUST** be of Form U.

[R152] When the OVC End Point Map Service Attribute is Form U for an OVC End Point, all ingress EI Frames at the UNI with a CE-VLAN ID value matching an entry in the value of the OVC End Point Map Service Attribute **MUST** map to the OVC End Point.

[R153] For a given UNI, the values of all of the OVC End Point Map Service Attribute **MUST** be such that each possible CE-VLAN ID value maps to at most one OVC End Point.

Note that because of requirement [R78] in MEF 10.3 [12] and [R33], an ingress Service Frame that is not mapped to an existing OVC End Point or an EVC at the UNI cannot be delivered to an EI.

When an Operator is not the Service Provider at a UNI, each CE-VLAN ID at the UNI is either mapped to an OVC End Point or it is discarded at the UNI. When an Operator is also the Service Provider at a UNI, then there is a third possibility. In this case, a CE-VLAN ID could be mapped to an EVC without being mapped to an OVC End Point. Such an EVC would associate only UNIs within the Operator CEN, since otherwise an OVC would be needed to reach another CEN. Note that the converse is also possible, namely, a CE-VLAN ID that is not mapped to any EVC could be mapped to an OVC End Point. For example, a Feeder OVC could have all CE-VLAN IDs mapped to it at the RUNI, with EVC mapping being performed at the VUNI. Any such CE-VLAN ID that is not mapped to an EVC will be carried by the OVC, but will be discarded at some point (e.g., at the VUNI) without reaching an egress UNI.

Note that this document is describing the attributes as agreed to by the SP/SO and Operator and therefore there is awareness of an OVC End Point at a UNI. MEF 10.3 [12] describes attributes as agreed to by the Subscriber and Service Provider for which OVC End Points are invisible. From the Subscriber's viewpoint, at a UNI, each CE-VLAN ID value either maps to an EVC or it does not map to an EVC.

[R154] When the OVC End Point Map Service Attribute is Form U for an OVC End Point, all egress VLAN Tagged Service Frames at the UNI that map to the OVC End Point **MUST** have a CE-VLAN ID value that matches an entry in the value of the OVC End Point Map Service Attribute.

[R155] An OVC associating an OVC End Point at a UNI whose value of the OVC End Point Map Service Attribute contains multiple CE-VLAN ID values **MUST** have the value of the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*.

[R156] When the OVC End Point is at a UNI, the OVC associating the OVC End Point has the value of the OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*, and OVC End Point of Form U has a single CE-VLAN ID value that equals the value of the Operator UNI Default CE-VLAN ID Service Attribute (Section 14.9), any egress Service Frame mapped to this OVC End Point **MUST** be an Untagged Service Frame.

When the OVC End Point is at a UNI, the OVC Associating the OVC End Point has the value of the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*, and the OVC End Point of Form U has a single CE-VLAN ID value that equals the value of the Operator UNI Default CE-VLAN ID Service Attribute (Section 14.9), there are no constraints on the format an egress Service Frame mapped to this OVC End Point. Such a frame could be an Untagged Service Frame, a Priority Tagged Service Frame, or a VLAN Tagged Service Frame.

[R157] When the OVC End Point is at a UNI and OVC End Point of Form U has a single CE-VLAN ID value that does not equal the value of the Operator UNI Default CE-VLAN ID Service Attribute (Section 14.9), any egress Service Frame mapped to this OVC End Point **MUST** be a VLAN Tagged Service Frame.

16.5.5   OVC End Point Map Service Attribute Requirements

[R158] For a given ENNI, the values of all of the OVC End Point Map Service Attributes for all SP/SOs using the ENNI **MUST** be such that a Tagged ENNI Frame maps to at most one OVC End Point.

[R158] means that:

- An S-VLAN ID value in a given map of Form E or Form T cannot appear in the value of any other OVC End Point Map Service Attribute among the maps for all SP/SOs using the ENNI,

- An S-VLAN value in a given map of Form V cannot appear in the value of any other OVC End Point Map Service Attribute of Form E or Form T among the maps for all SP/SOs using the ENNI,

- An S-VLAN value in a given map of Form V can appear in another value of another OVC End Point Map Service Attribute of Form V only if there is no overlap in the values of the ENNI CE-VLAN ID values (Section 15) in the two maps.

[R159] All instances of a value of the OVC End Point Map Service Attribute that is of Form V and contains a given S-VLAN ID value **MUST** map to OVC End Points for a single SP/SO.

It is the responsibility of the Operator to meet [R158] and [R159] in negotiating OVC End Point Map Service Attribute values with each SP/SO that is using the ENNI. The methods used to accomplish this are beyond the scope of this document.

[R33] mandates that an ingress EI Frame that is not mapped to an OVC End Point or an EVC will not result in an egress EI Frame. Note that this does not preclude the receiving Operator CEN from acting as a peer for a protocol carried in an S-Tagged ENNI Frame. For example, S-Tagged ENNI Frames could be used for the ENNI MEG Service OAM protocol.

[R160] An ENNI Frame without an S-Tag **MUST NOT** be mapped to an OVC End Point.

[R160] does not necessarily mean that an untagged ENNI Frame is to be discarded by the receiving Operator CEN. For example, an untagged ENNI Frame carrying a Layer 2 Control Protocol might be processed.

[O6] The OVC End Point Map Service Attributes for the OVC End Points associated by an OVC **MAY** have different forms.

Note that [O6] applies to OVC End Points at different EIs and, in the case of Hairpin Switching per Section 12.3.1, OVC End Points at the same ENNI.

[R161] Consider all OVC End Points that are associated by an OVC. If the value of the OVC End Point Map Service Attribute for one of these OVC End Points satisfies either of the following conditions:

- It is of Form U and contains more than one CE-VLAN ID value, or

- It is of Form V and contains more than one ENNI CE-VLAN ID value,

with λ being the list of CE-VLAN ID values if of Form U and λ being the list of ENNI CE-VLAN ID values if of Form V, then:

- The value of the OVC End Point Map Service Attribute for all OVC End Points associated by the OVC that have an OVC End Point Map Service Attribute of Form U **MUST** have the list of CE-VLAN IDs = λ, and

- The value of the OVC End Point Map Service Attribute for all OVC
  End Points associated by the OVC that have an OVC End Point Map
  Service Attribute of Form V **MUST** have the list of ENNI CE-VLAN
  IDs = λ.

Appendix C.4 shows an example of meeting [R161] to implement an EVC with Bundling at the
UNI such that [R81] of MEF 10.3 [12] is met.

16.5.6   OVC End Point Map Examples

Figure 41 illustrates some examples of OVC End Point Map Service Attribute values. In this
figure, ENNI Frames that map to either OVC End Point B1 or OVC End Point B2 in CEN B,
map to OVC End Point A1 in CEN A. This is an example of OVC End Point Map Bundling as
detailed in Section 16.5.7. OVC End Point A2 is in a VUNI (see Section 15) instance and thus,
per [R144], its OVC End Point Map is of Form V. Consequently, an ENNI Frame that maps to
OVC End Point A2 in CEN A always maps to OVC End B3 in CEN B but it is possible for an
ENNI Frame that maps to OVC End Point B3 in CEN B to not map to OVC End Point A2 in
CEN A.
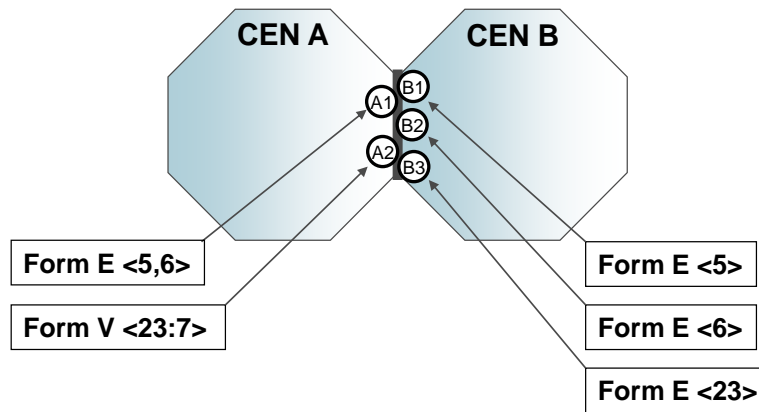
Figure 41 – Examples of OVC End Point Maps

More examples of OVC End Point Maps are in Appendix A.

16.5.7   OVC End Point Map Bundling

When an OVC End Point Map Service Attribute is of Form E and its value contains more than
one S-VLAN ID value, the OVC End Point Map is said to have OVC End Point Map Bundling.

[R162] If one of the OVC End Points associated by an OVC that is not a Rooted-
Multipoint OVC (Section 12.2) has OVC End Point Map Bundling, then all of
the OVC End Points associated by the OVC **MUST** have OVC End Point
Bundling with identical lists of S-VLAN ID values in the value of the OVC End
Point Map Service Attribute.

An OVC that is not a Rooted Multipoint OVC and that associates OVC End Points that all have OVC End Point Map Bundling is said to be a Bundled OVC. Because a Bundled OVC only associates OVC End Points that have an OVC End Map Service Attribute of Form E, a Bundled OVC can only associate OVC End Points that are at an ENNI but not in a VUNI.

> **[R163]** If an egress ENNI Frame mapped to an OVC End Point that is associated by a Bundled OVC is the result of a corresponding ingress ENNI Frame, then the egress ENNI Frame **MUST** have the same S-VLAN ID value as the corresponding ingress ENNI Frame.

Note that [R163] means that a Bundled OVC cannot have Hairpin Switching (Section 12.3.1).

Since a Bundled OVC can only associate OVC End Points that are at an ENNI but not in a VUNI, [R75] and [R76] apply which means:

- If a C-Tag is present in the ingress ENNI Frame, an identical C-Tag is present in any corresponding egress ENNI Frame, and

- If a C-Tag is not present in the ingress ENNI Frame, no C-Tag is present in any corresponding egress ENNI Frame.

This means that a Bundled OVC always exhibits the behavior that is required of an OVC that has the OVC CE-VLAN ID Preservation Service Attribute = *Preserve* (Section 12.7), the OVC CE-VLAN PCP Service Attribute = *Enabled* (Section 12.8), and the OVC CE-VLAN DEI Service Attribute = *Enabled* (Section 12.9).

With a Bundled OVC, it is possible that frames originated by more than one Subscriber will be carried by the OVC and thus there may be duplicate MAC addresses being used by multiple Subscribers. The methods to avoid problems in the Operator CEN that can result from this duplication are beyond the scope of this document.

An example of a Bundled OVC can easily be constructed from Figure 41 as shown in Figure 42. The OVC associating OVC End Point A1 with OVC End Point A3 in CEN A is Bundled and thus these two OVC End Points have identical OVC End Point Map Service Attribute values.
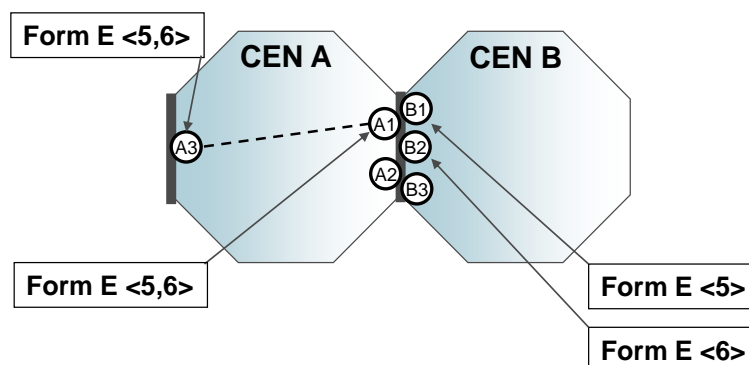
Figure 42 – Example of a Bundled OVC

Mapping of multiple S-VLAN ID values to an OVC End Point associated by a Rooted-Multipoint OVC is prohibited per the following requirement.

> **[R164]** If an OVC End Point is associated by a Rooted-Multipoint OVC and the OVC End Point Map Service Attribute for the OVC End Point is of Form E, then the value of the OVC End Point Map Service Attribute **MUST** contain only one S-VLAN ID value.

16.6 OVC End Point Class of Service Identifier Service Attribute

The value of the OVC End Point Class of Service Identifier Service Attribute is a triple of the form <*F*, *M*, *P*> where *F* is a protocol field in the ingress EI Frame, *M* is a map that maps each possible value of the field *F* and the absence of the field *F* to a Class of Service Name and *P* is a map of Layer 2 Control Protocol types as determined by the Protocol Identifier (see Section 6.2 of MEF 45 [24]) to Class of Service Names. The value of *F* is one of *OVC End Point*, *S-Tag PCP*, *C-Tag PCP*, or *DSCP*. When the value of *F* is *DSCP*, *M* can map a DSCP value to two different Class of Service Names, one Class of Service Name for ingress EI Frames carrying an IPv4 packet and a different Class of Service Name for ingress EI Frames carrying an IPv6 packet. The map *P* can map just a subset of all possible L2CP types and is allowed to be null.

Each ingress EI Frame mapped to the given OVC End Point has a single Class of Service Name. The Class of Service Name can be determined from inspection of the content of the ingress EI Frame.

As described in MEF 23.2 [17], the Class of Service Name is used to identify the performance objectives and associated parameters that apply to the ingress EI Frame as described in Section 12.13 of this document. It is also used to determine the value to set in certain protocol fields when the frame egresses the CEN, as described by the OVC End Point Egress Map Service Attribute (Section 16.8). Note that the Class of Service Name could be one of the Class of Service Labels standardized in MEF 23.2 [17].

> **[R165]** The maps *M* and *P*, when *P* is not null, **MUST** map to Class of Service Names contained in the value of the OVC List of Class of Service Names Service Attribute (see Section 12.12).

> **[O7]** The maps *M* and *P* **MAY** map to a Class of Service Name that calls for discard.

> **[R166]** An ingress EI Frame that has the Class of Service Name *Discard* **MUST** be discarded.

The values of *F*, *M*, and *P* can be different for each OVC End Point that is associated by an OVC.

The requirements regarding the OVC End Point Class of Service Identifier Service Attribute for Data EI Frames and SOAM EI Frames are different than they are for Layer 2 Control Protocol EI Frames. And the requirements regarding the OVC End Point Class of Service Identifier Service

Attribute for a given OVC End Point depend on the value of the External Interface Type Service Attribute for the OVC End Point, and on whether the OVC End Point is in a VUNI (Section 15).

16.6.1 OVC End Point Class of Service Identifier for an OVC End Point at an ENNI and not in a VUNI

This section describes the OVC End Point Class of Service Identifier Service Attribute for EI Frames mapped to an OVC End Point that is at an ENNI and not in a VUNI.

16.6.1.1 OVC End Point Class of Service Identifier Service Attribute for Ingress Data ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

For an OVC End Point at an ENNI that is not in a VUNI, the OVC End Point Class of Service Identifier Service Attribute for ingress Data ENNI Frames is based on the Priority Code Point Field in the S-Tag. Note that [R160] mandates that an ENNI Frame that does not have an S-Tag cannot be mapped to an OVC End Point at an ENNI.

> **[R167]** When the OVC End Point is at an ENNI and is not in a VUNI, the value of F **MUST** be *S-Tag PCP*.

For example, the S-Tag PCP values 0, 1, 2, and 3 could indicate the Class of Service Name *silver* while the S-Tag PCP values 4, 5, 6, and 7 could indicate the Class of Service Name *gold*.

In general, at a given ENNI, each OVC End Point not in a VUNI can have a different OVC End Point Class of Service Identifier Service Attribute value but the following requirements apply.

> **[R168]** For an OVC End Point at an ENNI that is not in a VUNI, M **MUST** be such that each possible S-Tag PCP value maps to exactly one Class of Service Name.

[R168] means that the sets of S-Tag PCP values that each map to a different Class of Service Name are disjoint and their union equals the set of all S-Tag PCP values. [R168] also means that each ingress Data ENNI Frame has a single Class of Service Name that applies to it.

> **[D10]** At a given ENNI, an Operator CEN **SHOULD** support the use of different mappings, M, of S-Tag Priority Code Point value to Class of Service Name for different OVC End Points at an ENNI that are not in a VUNI and that are associated by different OVCs.

16.6.1.2 OVC End Point Class of Service Identifier Service Attribute for Ingress L2CP ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

The map P is null for an OVC End Point that is at an ENNI and is not in a VUNI.

> **[R169]** If an ingress Layer 2 Control Protocol ENNI Frame is mapped to an OVC End Point that is not in a VUNI, then the Class of Service Name for this ingress

L2CP ENNI Frame **MUST** be the same as if it were an ingress Data ENNI Frame.

16.6.1.3 OVC End Point Class of Service Identifier Service Attribute for Ingress SOAM ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

[R170] If an ingress SOAM ENNI Frame is mapped to an OVC End Point at an ENNI that is not in a VUNI, then the Class of Service Name for this ingress SOAM ENNI Frame **MUST** be the same as if it were an ingress Data ENNI Frame.

16.6.2 OVC End Point Class of Service Identifier Service Attribute for an OVC End Point in a VUNI or at a UNI

This section describes the OVC End Class of Service Identifier Service Attribute for ENNI Frames mapped to an OVC End Point that is in a VUNI. It also describes the OVC End Point Class of Service Identifier Service Attribute for Service Frames mapped to an OVC End Point that is at a UNI.

16.6.2.1 OVC End Point Class of Service Identifier for Ingress Data EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

[R171] For an OVC End Point at an ENNI that is in a VUNI or is at a UNI, the value of F **MUST** be *OVC End Point*, *C-Tag PCP*, or *DSCP*.

16.6.2.1.1 *OVC End Point Class of Service Identifier Service Attribute for Ingress Data EI Frames Based on OVC End Point*

When the OVC End Point Class of Service Identifier Service Attribute is based on OVC End Point, the value of F is *OVC End Point*. This means that the field(s) used to determine the OVC End Point that the ingress EI Frame is mapped to via the value of the OVC End Point Map Service Attribute (Section 16.5) are also used to determine Class of Service name.

[R172] When the value of F is *OVC End Point* for an OVC End Point, M **MUST** contain a single Class of Service Name that is not *Discard*.

[R172] means that a single Class of Service Name applies to all ingress EI Frames mapped to the OVC End Point.

16.6.2.1.2 *OVC End Point Class of Service Identifier Service Attribute for Ingress Data EI Frames Based on C-Tag Priority Code Point*

When the OVC End Point Class of Service Identifier is based on C-Tag Priority Code Point, the value of F is *C-Tag PCP*.

[R173]   When the value of *F* is *C-Tag PCP* for an OVC End Point, *M* **MUST** be used to determine the Class of Service Name for each ingress Data EI Frame that is mapped to the OVC End Point.

[R174]   When the value of *F* is *C-Tag PCP* for an OVC End Point, *M* **MUST** map each possible C-Tag PCP value to exactly one Class of Service Name and each ingress EI Frame without a C-Tag to exactly one Class of Service Name.

[R174] means that the sets of C-Tag Priority Code Point values that each map to a different Class of Service Name are disjoint sets and the union of all such sets is the set of all possible C-Tag Priority Code Point values. [R174] also means that each ingress Data EI Frame mapped to the OVC End Point has a single Class of Service Name that applies to it.

[D11]   When the value of *F* is *C-Tag PCP* for an OVC End Point, the Class of Service Name for all ingress Data EI Frames mapped to the OVC End Point without a C-Tag **SHOULD** be the same Class of Service Name as that for ingress Data EI Frames mapped to the OVC End Point with a C-Tag that has the Priority Code Point value = 0.

Table 31 shows examples of the mapping of PCP value to Class of Service Name for two different OVC End Points at an EI.

OVC End Point A		OVC End Point B	
PCP Value	**Class of Service Name**	**PCP Value**	**Class of Service Name**
0	Silver	0	Gold
1	Discard	1	Gold
2	Discard	2	Gold
3	Silver	3	Gold
4	Gold	4	Gold
5	Gold	5	Gold
6	Gold	6	Gold
7	Gold	7	Platinum
Untagged	Silver	Untagged	Gold

Table 31 – Examples of Mapping PCP Value to Class of Service Name

Note that a single Class of Service Name for all ingress EI Frames mapped to an OVC End Point, i.e., *F = OVC End Point*, can be achieved by mapping all possible PCP values and Untagged to the same Class of Service Name.

16.6.2.1.3   OVC End Point Class of Service Identifier Service Attribute for Ingress Data EI Frames Based on Internet Protocol

When the OVC End Point Class of Service Identifier Service Attribute is based on Internet Protocol, the value of *F* is *DSCP*. This means that the Class of Service Name is determined from the value of the DSCP for an ingress Data EI Frame carrying an IPv4 or an IPv6 packet.

[R175]   When the value of *F* is *DSCP* for an OVC End Point, *M* **MUST** be used to determine the Class of Service Name for each ingress Data EI Frame that is mapped to the OVC End Point.

[O8]   When the value of *F* is *DSCP*, *M* **MAY** be such that a value of DSCP maps to one Class of Service Name for an ingress Data EI Frame carrying an IPv4 packet and maps to a different Class of Service Name for an ingress Data EI Frame carrying an IPv6 packet.

[R176]   When the value of *F* is *DSCP* for an OVC End Point, *M* **MUST** be such that each possible DSCP value maps to exactly one Class of Service Name for ingress Data EI Frames carrying an IPv4 packet that are mapped to the OVC End Point.

[R177]   When the value of *F* is *DSCP* for an OVC End Point, *M* **MUST** be such that each possible DSCP value maps to exactly one Class of Service Name for ingress Data EI Frames carrying an IPv6 packet that are mapped to the OVC End Point.

[R178]   When the value of *F* is *DSCP* for an OVC End Point, *M* **MUST** map each ingress EI Frame that is not carrying either an IPv4 or IP6 packet and that is mapped to the OVC End Point to exactly one Class of Service Name.

[R176] and [R177] mean that each possible <IP version, DSCP value> pair maps to exactly one Class of Service Name.

Table 32 shows an example of using OVC End Point Class of Service Identifier Service Attribute based on Internet Protocol. In this example an ingress Data EI Frame carrying an IPv4 packet with DSCP = 37 would be subject to the Class of Service Name *Platinum*. Similarly, an ingress Data EI Frame carrying an IPv6 packet with DSCP = 37 would be subject to the performance objectives for Class of Service Name *Platinum*. In this example *Diamond* can only apply to ingress Data EI Frames carrying an IPv4 packet and *Ruby* can only apply to ingress Data EI Frames carrying an IPv6 packet. This example illustrates [O8] that allows a mapping of DSCP value to Class of Service name for IPv4 that is different than the mapping of DSCP value to Class of Service Name for IPv6.

IPv4 DSCP Values	IPv6 DSCP Values	Class of Service Name
11,37,45	11,37,45	*Platinum*
8,10,12		*Diamond*
	38,213	*Ruby*
No IP Packet	No IP Packet	*Quartz*
All other values	All other values	*Discard*

Table 32 – Example of *M* when *F* Equals *DSCP*

Table 33 shows an example where only IPv4 is supported. In this example, the Class of Service Name for ingress Data EI Frames not carrying an IP packet is *Good Enough*. This fact and the last row in Table 33 means that *Good Enough* applies to any ingress Data EI Frame not carrying an IPv4 packet. Consequently, IPv6 is not recognized but instead is treated as non-IP. A similar approach can be used to support only IPv6.

IPv4 DSCP Values	IPv6 DSCP Values	Class of Service Name
11,37,45		*Superior*
8,10,12		*Near Superior*
All other values		*Discard*
No IP Packet	No IP Packet	*Good Enough*
	All values	*Good Enough*

Table 33 – Example of *M* that Only Supports IPv4 when *F* Equals *DSCP*

16.6.2.2 OVC End Point Class of Service Identifier Service Attribute for Ingress L2CP EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

For an OVC End Point that is in a VUNI or at a UNI, the Layer 2 Control Protocol types mapped to a Class of Service Name by *P* are referred to as the L2CP OVC End Point Class of Service Identifier.

[R179] If an ingress Layer 2 Control Protocol EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI and the Layer 2 Control Protocol carried by this ingress Layer 2 Control Protocol EI Frame is contained in the OVC End Point L2CP Class of Service Identifier, then the Class of Service Name for this frame **MUST** be the Class of Service Name mapped to by *P*.

[R180] If an ingress Layer 2 Control Protocol EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI and the Layer 2 Control Protocol carried by this ingress Layer 2 Control Protocol EI Frame is not contained in the L2CP OVC End Point Class of Service Identifier, then the Class of Service Name for this frame **MUST** be determined as if it is an ingress Data EI Frame.

16.6.2.3 OVC End Point Class of Service Identifier for Ingress SOAM EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

[R181] If an ingress SOAM EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI, then the Class of Service Name for this ingress SOAM EI Frame **MUST** be the same as if it were an ingress Data EI Frame.

16.7 OVC End Point Color Identifier Service Attribute

The value of the OVC End Point Color Identifier Service Attribute is a pair of the form <*F*, *M*> where *F* is a field in the ingress EI Frame and *M* is a mapping between each possible value of the

field *F* and a Color. The value of *F* is one of *S-Tag DEI*, *S-Tag PCP*, *OVC End Point*, *C-Tag DEI*, *C-Tag PCP*, or *DSCP*. The OVC End Point Color Identifier Service Attribute is the mechanism by which the Color for an ingress EI Frame that is mapped to an OVC End Point is indicated by the content in the EI Frame header.

> **[R182]**   The Color for an ingress EI Frame **MUST** be either Green or Yellow.

> **[R183]**   When the OVC End Point is at an ENNI but not in a VUNI (Section 15), the value of *F* **MUST** be either *S-Tag DEI* or *S-Tag PCP*.

> **[R184]**   When the OVC End Point is in a VUNI or at a UNI, the value of *F* **MUST** be one of *OVC End Point*, *C-Tag DEI*, *C-Tag PCP* or *DSCP*.

Sections 16.7.1, through 16.7.6 contain requirements for each of the above values of *F*.

16.7.1   OVC End Point Color Identifier Service Attribute with *F = S-Tag DEI*

> **[R185]**   When the value of *F* is *S-Tag DEI*, *M* **MUST** be such that the S-Tag DEI = 0 maps to Green and S-Tag DEI = 1 maps to Yellow.

16.7.2   OVC End Point Color Identifier Service Attribute with *F = S-Tag PCP*

> **[R186]**   When the value of *F* is *S-Tag PCP*, *M* **MUST** be such that each possible value of the S-Tag PCP maps to a Color.

[R186] means that the sets of S-Tag PCP values that map to each Color are disjoint sets and the union of these sets is the set of all possible S-Tag PCP values.

Note that MEF 23.2 [17] contains requirements for the coding of Color in the S-Tag PCP field.

16.7.3   OVC End Point Color Identifier Service Attribute with *F = OVC End Point*

The value of *F* equals *OVC End Point* means that the field(s) used to determine the OVC End Point that the ingress EI Frame is mapped to via the value of the OVC End Point Map Service Attribute (Section 16.5) are also used to determine the Class of Service Name.

> **[R187]**   When the value of *F* is *OVC End Point* for an OVC End Point, *M* **MUST** contain either Green or Yellow.

[R187] means that a single Color applies to all ingress EI Frames mapped to the OVC End Point.

16.7.4   OVC End Point Color Identifier Service Attribute with *F = C-Tag DEI*

> **[R188]**   When the value of *F* is *C-Tag DEI*, *M* **MUST** be such that the C-Tag DEI = 0 maps to Green and C-Tag DEI = 1 maps to Yellow.

[R189] When the value of *F* is *C-Tag DEI*, the Color of an ingress EI Frame without a C-Tag **MUST** be Green.

16.7.5   OVC End Point Color Identifier Service Attribute with *F = C-Tag PCP*

[R190] When the value of *F* is *C-Tag PCP*, *M* **MUST** be such that each possible value of the C-Tag PCP maps to a Color.

[R191] When the value of *F* is *C-Tag PCP*, the Color of an ingress EI Frame without a C-Tag **MUST** be Green.

[R190] means that the sets of C-Tag PCP values that map to each Color are disjoint sets and the union of these sets is the set of all possible C-Tag PCP values.

16.7.6   OVC End Point Color Identifier Service Attribute with *F = DSCP*

[O9] When the value of *F* is *DSCP*, *M* **MAY** be such that a value of DSCP maps to one Color for an ingress EI Frame carrying an IPv4 packet and maps to a different Color for an ingress EI Frame carrying an IPv6 packet.

[R192] When the value of *F* is *DSCP*, *M* **MUST** be such that each possible DSCP value maps to exactly one Color for ingress EI Frames carrying an IPv4 packet.

[R193] When the value of *F* is *DSCP*, *M* **MUST** be such that each possible DSCP value maps to exactly one Color for ingress EI Frames carrying an IPv6 packet.

[R194] When the value of *F* is *DSCP*, the Color of an ingress EI Frame that does not contain either an IPv4 or an IPv6 packet **MUST** be Green.

Note that the mapping of DSCP values to Color can be different for IPv4 and IPv6. Table 34 shows an example of the use of different mappings for IPv4 and IPv6.

IPv4 DSCP Values	IPv6 DSCP Values	Color
1,2,3,5,7,11,13,17	1,2,3,5,8,13,21,34	Yellow
All other values	All other values	Green

Table 34 – Example of DSCP to Color Mapping

16.8   OVC End Point Egress Map Service Attribute

The value of the OVC End Point Egress Map Service Attribute is a set of mappings that determine the content of the S-Tag or C-Tag of an egress EI Frame. There are six forms of the OVC End Point Egress Map Service Attribute value: *CN→S-Tag PCP*, *CC→S-Tag DEI*, *CC→S-Tag PCP*, *CN→C-Tag PCP*, *CC→C-Tag DEI*, and *CC→C-Tag PCP*. The first three forms are used in populating the S-Tag in an egress ENNI Frame based on the Class of Service Name and Color of the corresponding ingress EI Frame. The last three forms are used in populating the C-Tag in an egress EI Frame based on the Class of Service Name and Color of the

corresponding ingress EI Frame. Section 16.6 details the determination of the Class of Service Name for ingress EI Frames. The Color of an ingress EI Frame is determined by the Ingress Bandwidth Profile that is applied to it or according to the OVC End Point Color Identifier Service Attribute described in Section 16.7 if no Ingress Bandwidth Profile is applied.

Per Section 16.8.7, under some conditions, no value is needed for the OVC End Point Egress Map while under other conditions values for more than one form of OVC End Point Egress Map Service Attribute are needed.

Note that the OVC End Point Egress Map Service Attribute does not apply to egress SOAM EI Frames and egress Layer 2 Control Protocol EI Frames that are a result of frames generated inside the Operator CEN.

The six forms of the value of the OVC End Point Egress Map Service Attribute are described in Sections 16.8.1 through 16.8.6. Requirements on the use of the OVC End Point Egress Map Service Attribute are contained in Section 16.8.7.

An example of the use of the OVC End Point Egress Map is presented in Appendix F.

16.8.1   OVC End Point Egress Map Service Attribute Form *CN→S-Tag PCP*

The OVC End Point Egress Map Service Attribute Form *CN→S-Tag PCP* is a set of mappings of the form <Corresponding ingress EI Frame Class of Service Name> to either <Egress EI Frame S-Tag PCP value> or <*Discard*>.

> **[R195]**   The OVC End Point Egress Map Service Attribute Form *CN->S-Tag PCP* value **MUST** contain exactly one entry for each Class of Service Name in the value of the OVC List of Class of Service Names Service Attribute other than *Discard*.

Table 35 contains an example for the OVC List Class of Service Names Service Attribute value in Table 13.

Ingress Class of Service Name	Egress S-Tag PCP Value
Platinum	7
Gold	5
Silver	*Discard*

Table 35 – Example of the OVC End Point Egress Map Service Attribute Form *CN→S-Tag PCP*

As shown in Appendix F, multiple Class of Service Names can map to a given PCP value.

16.8.2   OVC End Point Egress Map Service Attribute Form *CC→S-Tag DEI*

The OVC End Point Egress Map Service Attribute Form *CC→S-Tag DEI* is a set of mappings of the form <Corresponding ingress EI Frame Class of Service Name, Corresponding ingress EI Frame Color> to either <Egress EI Frame S-Tag DEI value> or <*Discard*>.

[R196] The OVC End Point Egress Map Service Attribute Form *CC→S-Tag DEI*
MUST have two entries for each Class of Service Name in the value of the
OVC List of Class of Service Names Service Attribute (Section 12.12) that is
not *Discard*, one entry with the Color *Green* and one entry with the Color
Yellow.

Table 36 contains an example for the OVC List Class of Service Names Service Attribute value
in Table 13.

Ingress Class of Service Name	Ingress Color	Egress S-Tag DEI Value
Platinum	*Green*	0
Platinum	*Yellow*	1
Gold	*Green*	0
Gold	*Yellow*	*Discard*
Silver	*Green*	1
Silver	*Yellow*	1

Table 36 – Example of the OVC End Point Egress Map Service Attribute Form *CC→S-Tag DEI*

When this example map is used, ingress EI Frames with Class of Service Name *Silver* and Color
Green are demoted to *Yellow* egress ENNI Frames if *F* is DEI for the value of the OVC End
Point Color Identifier Service Attribute (Section 16.7) for the receiving CEN.

16.8.3 OVC End Point Egress Map Service Attribute Form *CC→S-Tag PCP*

The OVC End Point Egress Map Service Attribute Form *CC→S-Tag PCP* is a set of mappings
of the form <Corresponding ingress EI Frame Class of Service Name, Corresponding ingress EI
Frame Color> to either <Egress EI Frame S-Tag PCP value> or *<Discard>*.

[R197] The OVC End Point Egress Map Service Attribute Form *CC→S-Tag PCP*
MUST have two entries for each Class of Service Name in the value of the
OVC List of Class of Service Names Service Attribute (Section 12.12) that is
not *Discard*, one entry with the Color *Green* and one entry with the Color
Yellow.

Table 37 contains an example for the OVC List Class of Service Names Service Attribute value
in Table 13.

Ingress Class of Service Name	Ingress Color	Egress S-Tag PCP Value
Platinum	*Green*	7
Platinum	*Yellow*	6
Gold	*Green*	5
Gold	*Yellow*	*Discard*
Silver	*Green*	3
Silver	*Yellow*	2

Table 37 – Example of the OVC End Point Egress Map Service Attribute Form *CC→S-Tag PCP*

16.8.4   OVC End Point Egress Map Form *CN→C-Tag PCP*

The OVC End Point Egress Map Service Attribute Form *CN→C-Tag PCP* is a set of mappings of the form <Corresponding ingress EI Frame Class of Service Name> to either <Egress EI Frame C-Tag PCP value> or <*Discard*>.

> **[R198]**   The OVC End Point Egress Map Service Attribute Form *CN->C-Tag PCP* value **MUST** contain exactly one entry for each Class of Service Name in the value of the OVC List of Class of Service Names Service Attribute value other than *Discard*.

Table 38 contains an example for the OVC List Class of Service Names Service Attribute value in Table 13.

Ingress Class of Service Name	Egress C-Tag PCP Value
Platinum	7
Gold	5
Silver	*Discard*

Table 38 – Example of the OVC End Point Egress Map Service Attribute Form *CN→C-Tag PCP*

16.8.5   OVC End Point Egress Map Form *CC→C-Tag DEI*

The OVC End Point Egress Map Service Attribute Form *CC→C-Tag DEI* is a set of mappings of the form <Corresponding ingress EI Frame Class of Service Name, Corresponding ingress EI Frame Color> to either <Egress EI Frame C-Tag DEI value> or <*Discard*>.

> **[R199]**   The OVC End Point Egress Map Service Attribute Form *CC→C-Tag DEI* **MUST** have two entries for each Class of Service Name in the value of the OVC List of Class of Service Names Service Attribute (Section 12.12) that is not *Discard*, one entry with the Color *Green* and one entry with the Color *Yellow*.

Table 39 contains an example for the OVC List Class of Service Names value in Table 13.

Ingress Class of Service Name	Ingress Color	Egress C-Tag DEI Value
Platinum	*Green*	0
Platinum	*Yellow*	1
Gold	*Green*	0
Gold	*Yellow*	*Discard*
Silver	*Green*	1
Silver	*Yellow*	1

Table 39 – Example of the OVC End Point Egress Map Service Attribute Form *C-Tag DEI*

16.8.6 OVC End Point Egress Map Form *CC→C-Tag PCP*

The OVC End Point Egress Map Service Attribute Form *CC→C-Tag PCP* is a set of mappings of the form <Corresponding ingress EI Frame Class of Service Name, Corresponding ingress EI Frame Color> to either <Egress EI Frame C-Tag PCP value> or <*Discard*>.

[R200] The OVC End Point Egress Map Service Attribute Form *CC→C-Tag PCP* **MUST** have two entries for each Class of Service Name in the value of the OVC List of Class of Service Names Service Attribute (Section 12.12) that is not *Discard*, one entry with the Color *Green* and one entry with the Color *Yellow*.

Table 40 contains an example for the OVC List Class of Service Names Service Attribute value in Table 13.

Ingress Class of Service Name	Ingress Color	Egress C-Tag PCP Value
Platinum	*Green*	7
Platinum	*Yellow*	6
Gold	*Green*	5
Gold	*Yellow*	*Discard*
Silver	*Green*	3
Silver	*Yellow*	2

Table 40 – Example of the OVC End Point Egress Map Service Attribute Form *CC→C-Tag PCP*

16.8.7 OVC End Point Egress Map Service Attribute Requirements

The following requirement applies when the OVC End Point is at an ENNI and mandates how the value of the S-Tag PCP and DEI in each egress ENNI Frame is set. Note that these requirements apply to both when the OVC End Point is in and not in a VUNI.

[R201] If 1) the OVC End Point External Interface Type Service Attribute = ENNI and 2) the OVC End Points in the receiving CEN to which the egress ENNI Frames map via each OVC End Point Map (Section 16.5) all have the same value of *F* for the OVC End Point Color Identifier Service Attribute (Section 16.7), then

the OVC End Point Egress Map Forms used to populate the S-Tag PCP and S-Tag DEI of an egress ENNI Frame **MUST** be as shown in Table 41.

Note that the condition 2) of [R201] is met if every egress ENNI Frame maps to a single OVC End Point in the receiving CEN.

OVC S-VLAN PCP Preservation Value	OVC S-VLAN DEI Preservation Value	OVC End Point Color Identifier *F* Value in the Receiving CEN	OVC End Point Egress Map Form	
			Ingress EI Type = UNI	Ingress EI Type = ENNI
Enabled	*Enabled*	*S-Tag DEI*	*CN→S-Tag PCP* and *CC→S-Tag DEI*	None
Enabled	*Disabled*	*S-Tag DEI*	*CN→S-Tag PCP* and *CC→S-Tag DEI*	*CC→S-Tag DEI*
Enabled	*Enabled*	*S-Tag PCP*	*CC→S-Tag PCP*	None
Enabled	*Disabled*	*S-Tag PCP*	*CC→S-Tag PCP*	None
Enabled	*Enabled*	Other	*CN→S-Tag PCP*	None
Enabled	*Disabled*	Other	*CN→S-Tag PCP*	None
Disabled	*Enabled*	*S-Tag DEI*	*CN→S-Tag PCP* and *CC→S-Tag DEI*	*CN→S-Tag PCP*
Disabled	*Disabled*	*S-Tag DEI*	*CN→S-Tag PCP* and *CC→S-Tag DEI*	*CN→S-Tag PCP* and *CC→S-Tag DEI*
Disabled	*Enabled*	*S-Tag PCP*	*CC→S-Tag PCP*	*CC→S-Tag PCP*
Disabled	*Disabled*	*S-Tag PCP*	*CC→S-Tag PCP*	*CC→S-Tag PCP*
Disabled	*Enabled*	Other	*CN→S-Tag PCP*	*CN→S-Tag PCP*
Disabled	*Disabled*	Other	*CN→S-Tag PCP*	*CN→S-Tag PCP*

Table 41 – OVC End Point Map Egress Map Form Usage when the OVC End Point External Interface Type Service Attribute = ENNI

In Table 41 when the specified OVC End Point Egress Map forms mandated do not provide a value for the S-Tag PCP, the required value is mandated by the OVC S-VLAN PCP Preservation Service Attribute value.

In Table 41 when the specified OVC End Point Egress Map forms mandated do not provide a value for the S-Tag DEI, the S-Tag DEI can have an arbitrary value.

An entry of "None" in Table 41 means that no OVC End Point Egress Map needs to be used to properly specify the S-Tag PCP and S-Tag DEI values.

An example of when "Other" in the third column of Table 41 applies is when the receiving OVC End Point in the receiving CEN is in a VUNI. In this case, per Section 16.7, the OVC End Point Color Identifier *F* Value is one of *C-Tag DEI*, *C-Tag PCP* or *DSCP*.

It might not be necessary to specify all of the OVC End Point Egress Map forms. For example, if the conditions of the third row from the bottom of Table 41 are always met for an OVC End Point, only the *CC→S-Tag PCP* form needs to be specified.

When condition 2) of [R201] is not met, the form of the OVC End Point Egress Map might have to depend on which OVC End Point in the receiving CEN will receive the ENNI Frame in order to ensure that the proper Color is assigned to the ENN Frame by the receiving CEN. The OVC End Point Egress Map Service Attribute does not provide for this behavior. When condition 2) of [R201] is not met, the form of OVC End Point Egress Map to use is out of scope for this document.

When condition 2) of [R201] is met but the receiving OVC End Points have different values of *M* (Section 16.7), it might not be possible for the SP/SO to identify a single value of the OVC End Point Egress Map that achieves the desired behavior for all of the receiving OVC End Points. For example, if the SP/SO wishes to map Green frames in the transmitting OVC to Green in the receiving OVCs, but only S-Tag PCP = 2 maps to Green at one receiving OVC End Point and only S-Tag PCP 3 maps to Green at a different OVC End Point, then it is not possible to define a value of the OVC End Point Egress Map Service Attribute that achieves the desired behavior – frames identified as Green in the transmitting OVC can either all be sent with S-Tag PCP = 2 or all sent with S-Tag PCP = 3, but the Egress Map does not support sending some frames with S-Tag PCP = 2 and some with S-Tag PCP = 3 depending on which OVC End Point they will map to in the receiving CEN. The SP/SO can avoid this situation either by ensuring that all of the receiving OVC End Points that correspond with a given transmitting OVC End Point have the same (or at least sufficiently similar) values of *M* for the OVC End Point Color Identifier Service Attribute, or by using multiple OVCs in the transmitting CEN that each correspond with a single OVC in the receiving CEN.

When condition 2) of [R201] is not met and/or the receiving OVC End Points have different values of *M* for the OVC End Point Color Identifier Service Attribute, it still might be possible to achieve the desired behavior. For example, if the receiving OVC End Points have $CM^i = color\text{-}blind$, for all ingress Bandwidth Profile Flows for the receiving OVC End Point, then the OVC End Point Color Identifier Service Attribute is irrelevant.

When the receiving OVC End Points have different values of *M* for the OVC End Point Class of Service Identifier Service Attribute (Section 16.6), it might not be possible for SP/SO to identify a single value of the OVC End Point Egress Map that achieves the mapping of Class of Service

Name in the sending CEN to the desired Class of Service Name in the receiving CEN. For example, suppose only S-Tag PCP = 4 maps to the Class of Service Name *Diamond* for one receiving OVC End Point and only S-Tag PCP = 5 maps to the Class of Service Name *Diamond* for a different receiving OVC End Point. Further suppose that the SP/SO wants frames given the Class of Service Name *Caviar* in the sending CEN to be given the Class of Service Name *Diamond* in the receiving CEN. In order to achieve this behavior, egress ENNI Frames to be received by one OVC End Point will need to have the S-Tag PCP = 4 while egress ENNI Frames to be received by the other OVC End Point will need to have the S-Tag PCP = 5. But the OVC End Point Egress Map Service Attribute does not support sending some frames with S-Tag PCP = 4 and some with S-Tag PCP = 5 depending on which OVC End Point they will map to in the receiving CEN. The SP/SO can avoid this situation either by ensuring that all of the receiving OVC End Points that correspond with a given transmitting OVC End Point have the same (or at least sufficiently similar) values of *M* for the OVC End Point Class of Service Identifier Service Attribute, or by using multiple OVCs in the transmitting CEN that each correspond with a single OVC in the receiving CEN.

The following requirement mandates how to set the C-Tag PCP and DEI in an egress EI Frame, if present and apply to an OVC End Point that is in a VUNI or at a UNI. Note that the form of the value of the OVC End Point Egress Equivalence Class Identifier Service Attribute (Section 16.9.2) needs to be considered for such an OVC End Point.

> **[R202]** If 1) the OVC End Point is at a UNI and 2) the EVCs at the UNI to which the egress Service Frames map all have the same basis for the EVC per UNI Color Identifier Service Attribute (Section 10.3 of MEF 10.3 [12]), then the OVC End Point Egress Map Forms used to populate the C-Tag PCP and C-Tag DEI of an egress EI Frame, if present, **MUST** be as shown in Table 42.

> **[R203]** If 1) the OVC End Point is in a VUNI and 2) the EVCs at the RUNI to which the egress ENNI Frames map all have the same basis for the EVC per UNI Color Identifier Service Attribute (Section 10.3 of MEF 10.3 [12]), then the OVC End Point Egress Map Forms used to populate the C-Tag PCP and C-Tag DEI of an egress EI Frame, if present, **MUST** be as shown in Table 42.

Note that condition 2) of [R202] is met if every egress Service Frame maps to a single EVC at the UNI. Similarly, condition 2) of [R203] is met if every egress ENNI Frame maps to a single EVC at the RUNI.

The forms of OVC End Point Egress Map that are required as specified in Table 42 depend on the Basis for the EVC per UNI Color Identifier (Section 10.3 of MEF 10.3 [12]) for EVCs at the UNI or RUNI. This value may not be known to the Operator of the transmitting CEN, with whom the SP/SO is agreeing regarding the form of OVC End Point Egress Map. It is therefore the responsibility of the SP/SO to ensure the correct forms of map are agreed upon.

OVC CE-VLAN PCP Preservation Value	OVC CE-VLAN DEI Preservation Value	OVC End Point Egress Equivalence Class Identifier *F* Value	Basis for the EVC per UNI Color Identifier	OVC End Point Egress Map Form	
				C-Tag in Corresponding ingress EI Frame	No C-Tag in Corresponding ingress EI Frame*
Enabled	*Enabled*	*C-Tag PCP*	*C-Tag DEI*	None	*CN→C-Tag PCP and CC→C-Tag DEI*
Enabled	*Enabled*	*C-Tag PCP*	*C-Tag PCP*	None	*CC→C-Tag PCP*
Enabled	*Enabled*	*C-Tag PCP*	*DSCP*	None	*CN→C-Tag PCP*
Enabled	*Enabled*	*DSCP*	*C-Tag DEI*	None	*CC→C-Tag DEI*
Enabled	*Enabled*	*DSCP*	*C-Tag PCP*	None	*CC→C-Tag PCP*
Enabled	*Enabled*	*DSCP*	*DSCP*	None	None
Enabled	*Disabled*	*C-Tag PCP*	*C-Tag DEI*	*CC→C-Tag DEI*	*CN→C-Tag PCP and CC→C-Tag DEI*
Enabled	*Disabled*	*C-Tag PCP*	*C-Tag PCP*	None	*CC→C-Tag PCP*
Enabled	*Disabled*	*C-Tag PCP*	*DSCP*	None	*CN→C-Tag PCP*
Enabled	*Disabled*	*DSCP*	*C-Tag DEI*	*CC→C-Tag DEI*	*CC→C-Tag DEI*
Enabled	*Disabled*	*DSCP*	*C-Tag PCP*	None	*CC→C-Tag PCP*
Enabled	*Disabled*	*DSCP*	*DSCP*	None	None
Disabled	*Enabled*	*C-Tag PCP*	*C-Tag DEI*	*CN→C-Tag PCP*	*CN→C-Tag PCP and CC→C-Tag DEI*
Disabled	*Enabled*	*C-Tag PCP*	*C-Tag PCP*	*CC→C-Tag PCP*	*CC→C-Tag PCP*
Disabled	*Enabled*	*C-Tag PCP*	*DSCP*	*CN→C-Tag PCP*	*CN→C-Tag PCP*
Disabled	*Enabled*	*DSCP*	*C-Tag DEI*	None	*CC→C-Tag DEI*
Disabled	*Enabled*	*DSCP*	*C-Tag PCP*	*CC→C-Tag PCP*	*CC→C-Tag PCP*
Disabled	*Enabled*	*DSCP*	*DSCP*	None	None
Disabled	*Disabled*	*C-Tag PCP*	*C-Tag DEI*	*CN→C-Tag PCP and CC→C-Tag DEI*	*CN→C-Tag PCP and CC→C-Tag DEI*
Disabled	*Disabled*	*C-Tag PCP*	*C-Tag PCP*	*CC→C-Tag PCP*	*CC→C-Tag PCP*
Disabled	*Disabled*	*C-Tag PCP*	*DSCP*	*CN→C-Tag PCP*	*CN→C-Tag PCP*
Disabled	*Disabled*	*DSCP*	*C-Tag DEI*	*CC→C-Tag DEI*	*CC→C-Tag DEI*
Disabled	*Disabled*	*DSCP*	*C-Tag PCP*	*CC→C-Tag PCP*	*CC→C-Tag PCP*
Disabled	*Disabled*	*DSCP*	*DSCP*	None	None

*This column applies when the egress EI Frame needs to have a C-Tag. See Table 8 for some situations where there is not a C-Tag in the egress EI Frame. When there is not a C-Tag in the egress EI Frame, then no egress map is needed.

Table 42 – OVC End Point Map Form Usage for an OVC End Point in a VUNI or at a UNI and the Egress EI Frame Has a C-Tag

Note that Table 42 takes into account when the content of a C-Tag in an ingress EI Frame is mandated to be preserved via the OVC CE-VAN PCP Preservation Service Attribute value and/or the OVC CE-VLAN DEI Preservation Service Attribute value.

In Table 42 when the specified OVC End Point Egress Map forms mandated do not provide a value for the C-Tag PCP, the required value is mandated by the OVC CE-VLAN PCP Preservation Service Attribute value or can be arbitrary.

In Table 42 when the specified OVC End Point Egress Map forms mandated do not provide a value for the C-Tag DEI, the C-Tag DEI can have an arbitrary value.

An entry of "None" in Table 42 means that no OVC End Point Egress Map needs to be used to properly specify the C-Tag PCP and C-Tag DEI values.

It might not be necessary to specify all of the OVC End Point Egress Map forms. For example, if the conditions of the last row of Table 42 are always met for an OVC End Point, no OVC End Point Egress Map form needs to be specified.

When condition 2) of [R202] or [R203] is not met, the form of the OVC End Point Egress Map might have to depend on which EVC will receive the frame in order to ensure that the proper Color is assigned to the Service Frame by the Customer Edge. The OVC End Point Egress Map Service Attribute does not provide for this behavior. When condition 2) of [R202] or [R203] is not met, the form of OVC End Point Egress Map to use is out of scope for this document

When condition 2) of [R202] is met but the mapping of the values of the relevant Service Frame field to Color is different for different EVCs at the UNI, it might not be possible for the Service Provider to identify a single value of the OVC End Point Egress Map that achieves the desired behavior for all of the receiving EVCs at the UNI. Similarly when condition 2) of [R203] is met but the mapping of the values of the relevant Service Frame field to Color is different for different EVCs at the RUNI, it might not be possible for the SP/SO to identify a single value of the OVC End Point Egress Map that achieves the desired behavior for all of the receiving EVCs at the RUNI.

> **[D12]** When the OVC End Point is in a VUNI or at a UNI, the OVC End Point Equivalence Class *F* value is *C-Tag DSCP*, the basis for the EVC per UNI Color Identifier Service Attribute (Section 10.3 of MEF 10.3 [12]) is *C-Tag PCP*, and the OVC End Point Egress Map form used is *CC→C-Tag PCP*, the value of the OVC End Point Egress Map Service Attribute **SHOULD** be such that only two values of C-Tag PCP result from applying the map.

Note that an OVC End Point Egress Map Service Attribute value can be configured such that frames that were Yellow in the sending CEN are promoted to Green when passed to the receiving CEN. This will likely increase the number of Qualified ENNI Frames handled by the receiving CEN even though such frames were not qualified in the sending CEN. The result is that the receiving CEN will need more resources to meet the SLS. The resulting economic penalties may well be shared with the SP/SO.

16.9 OVC End Point Egress Equivalence Class Identifier Service Attribute

The value of the OVC End Point Egress Equivalence Class Identifier Service Attribute is a triple of the form $<F, M, P>$ where F is a protocol field in the egress EI Frame, M is a map that maps each possible value of the field F and the absence of the field F to an Egress Equivalence Class Name and P is a map of L2CP type to Egress Equivalence Class Name. The value of F is one of *S-Tag PCP*, *C-Tag PCP*, or *DSCP*. When the value of F is *DSCP*, M can map a DSCP value to two different Egress Equivalence Class Names, one for egress EI Frames carrying an IPv4 packet and a different one for egress EI Frames carrying an IPv6 packet. The map P can map just a subset of all possible L2CP types and is allowed to be null.

Each egress EI Frame mapped to the given OVC End Point has a single Egress Equivalence Class Name. The Egress Equivalence Class Name can be determined from inspection of the content of the egress EI Frame.

The Egress Equivalence Class Name is used to specify Egress Bandwidth Profiles as described in Section 17.4. When there is no Egress Bandwidth Profile per Egress Equivalence Class Name (see section 16.13) at an OVC End Point, i.e., there are no Bandwidth Profile Flows based on criterion 5 of [R230], the value of the OVC End Point Egress Equivalence Class Identifier Service Attribute has no effect.

It is possible to have only a single Egress Equivalence Class Name. For an OVC End Point at an ENNI that is not in a VUNI, all S-Tag PCP values can map to a single Egress Equivalence Class Name (Section 16.9.1). For an OVC End Point at a UNI or in a VUNI, the value of F can be set to C-Tag PCP and M can be set to map all EI Frames to a single Egress Equivalence Class Name (Section 16.9.2). In such cases, an Egress Bandwidth Profile per Egress Equivalence Class Name (see section 16.13) based on criterion 5 of [R230] is indistinguishable from an Egress Bandwidth Profile per OVC End Point (see section 16.11) based on criterion 4 of [R230].

The values of F, M, and P can be different for each OVC End Point that is associated by an OVC.

The requirements regarding the OVC End Point Egress Equivalence Class Identifier Service Attribute for Data EI Frames and SOAM EI Frames are different than they are for Layer 2 Control Protocol EI Frames. And the requirements regarding the OVC End Point Egress Equivalence Class Identifier Service Attribute for an OVC End Point depend on whether the OVC End Point is in a VUNI (see Section 15).

16.9.1 OVC End Point Egress Equivalence Class Identifier Service Attribute for an OVC End Point at an ENNI and not in a VUNI

This section describes the OVC End Point Egress Equivalence Class Identifier Service Attribute for frames mapped to an OVC End Point that is at an ENNI and that is not in a VUNI.

16.9.1.1 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress Data ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

For an OVC End Point at an ENNI that is not in a VUNI, the OVC End Point Egress Equivalence Class Identifier Service Attribute for egress Data ENNI Frames is based on the Priority Code Point Field in the S-Tag. Note that [R160] mandates that an ENNI Frame that does not have an S-Tag cannot be mapped to an OVC End Point at an ENNI.

> **[R204]** When the OVC End Point at an ENNI is not in a VUNI, the value of *F* **MUST** be *S-Tag PCP*.

In general, at a given ENNI, each OVC End Point not in a VUNI can have a different OVC End Point Egress Equivalence Class Identifier Service Attribute value but the following requirements apply.

> **[R205]** For an OVC End Point at an ENNI that is not in a VUNI, *M* **MUST** be such that each possible S-Tag PCP value maps to exactly one Egress Equivalence Class Name.

[R205] means that the sets of S-Tag PCP values that each map to a different Egress Equivalence Class Name are disjoint and their union equals the set of all S-Tag PCP values. [R205] also means that each egress Data ENNI Frame has a single Egress Equivalence Class Name that applies to it.

> **[D13]** At a given ENNI, an Operator CEN **SHOULD** support the use of different mappings, *M*, of S-Tag Priority Code Point value to Egress Equivalence Class Name for different OVC End Points at an ENNI that are not in a VUNI and that are associated by different OVCs.

16.9.1.2 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress L2CP ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

The map *P* is null for an OVC End Point that is at an ENNI and is not in a VUNI.

> **[R206]** If an egress Layer 2 Control Protocol ENNI Frame is mapped to an OVC End Point at an ENNI that is not in a VUNI, then the Egress Equivalence Class Name for this egress L2CP ENNI Frame **MUST** be the same as if it were an egress Data ENNI Frame per Section 16.9.1.1.

16.9.1.3 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress SOAM ENNI Frames Mapped to an OVC End Point at an ENNI that is not in a VUNI

[**R207**] If an egress SOAM ENNI Frame is mapped to an OVC End Point that is not in a VUNI, then the Egress Equivalence Class Name for this egress SOAM ENNI Frame **MUST** be the same as if it were an egress Data ENNI Frame per Section 16.9.1.1.

16.9.2 OVC End Point Egress Equivalence Class Identifier Service Attribute for an OVC End Point in a VUNI or at a UNI

This section describes the Egress Equivalence Class Identifier Service Attribute for frames mapped to an OVC End Point that is in a VUNI or at a UNI.

16.9.2.1 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress Data EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

[**R208**] For an OVC End Point that is in a VUNI or at a UNI, the value of F **MUST** be *C-Tag PCP*, or *DSCP*.

16.9.2.1.1 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress Data EI Frames Based on C-Tag Priority Code Point

When the OVC End Point Equivalence Class Identifier Service Attribute is based on C-Tag priority Code Point, the value of F is *C-Tag PCP*.

[**R209**] When the value of F is *C-Tag PCP* for an OVC End Point that is in a VUNI or at a UNI, M **MUST** be used to determine the Egress Equivalence Class Name for each egress Data EI Frame that has is mapped to the OVC End Point.

[**R210**] When the value of F is *C-Tag PCP* for an OVC End Point that is in a VUNI or at a UNI, M **MUST** map each possible C-Tag PCP value and each egress EI Frame without a C-Tag to exactly one Egress Equivalence Class Name.

[R210] means that the sets of C-Tag Priority Code Point values that each map to an Egress Equivalence Class Name are disjoint sets and the union of all such sets is the set of all possible C-Tag Priority Code Point values. [R210] also means that each egress Data EI Frame mapped to the OVC End Point has a single Egress Equivalence Class Name that applies to it.

Table 43 shows examples of the mapping of PCP value to Egress Equivalence Class Name for two different OVC End Points at an EI.

OVC End Point A		OVC End Point B	
PCP Value	Egress Equivalence Class Name	PCP Value	Egress Equivalence Class Name
0	mycetes	0	mycetes
1	opsida	1	mycetes
2	opsida	2	mycetes
3	opsida	3	mycetes
4	phyceae	4	mycetes
5	phyceae	5	opsida
6	phyceae	6	opsida
7	phyceae	7	opsida
Untagged	opsida	Untagged	opsida

Table 43 – Examples of Mapping PCP Value to Egress Equivalence Class Name

16.9.2.1.2 *OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress Data EI Frames Based on Internet Protocol*

When the OVC End Point Egress Equivalence Class Identifier is based on Internet Protocol for an OVC End Point that is in a VUNI or at a UNI, the value of *F* is *DSCP*. This means that the Egress Equivalence Class Name is determined from value of the DSCP for an egress Data EI Frame carrying an IPv4 or an IPv6 packet.

[R211] When the value of *F* is *DSCP* for an OVC End Point that is in a VUNI or at a UNI, *M* **MUST** be used to determine the Egress Equivalence Class Name for an egress Data EI Frame that is carrying an IPv4 or IPv6 packet and that is mapped to the OVC End Point.

[O10] When the value of *F* is *DSCP*, *M* **MAY** be such that a value of DSCP maps to one Egress Equivalence Class Name for an egress Data EI Frame carrying an IPv4 packet and maps to a different Egress Equivalence Class Name for an egress Data EI Frame carrying an IPv6 packet.

[R212] When the value of *F* is *DSCP* for an OVC End Point that is in a VUNI or at a UNI, *M* **MUST** be such that each possible DSCP value maps to exactly one Egress Equivalence Class Name for egress Data EI Frames carrying an IPv4 packet that are mapped to the OVC End Point.

[R213] When the value of *F* is *DSCP* for an OVC End Point that is in a VUNI or at a UNI, *M* **MUST** be such that each possible DSCP value maps to exactly one Egress Equivalence Class Name for egress Data EI Frames carrying an IPv6 packet that are mapped to the OVC End Point.

[R214] When the value of *F* is *DSCP* for an OVC End Point that is in a VUNI or at a UNI, *M* **MUST** map each egress EI Frame that is not carrying either an IPv4 or

IP6 packet and that is mapped to the OVC End Point to exactly one Egress Equivalence Class Name.

Table 44 shows an example of using the OVC End Point Egress Equivalence Class Identifier Service Attribute based on Internet Protocol. In this example an egress Data EI Frame carrying an IPv4 packet with DSCP = 37 would be in the Egress Equivalence Class Name *Sophomore*. Similarly, an egress Data EI Frame carrying an IPv6 packet with DSCP = 37 would be in the Egress Equivalence Class Name *Sophomore*. In this example *Senior* can only apply to egress Data EI Frames carrying an IPv4 packet and *Junior* can only apply to egress Data EI Frames carrying an IPv6 packet.

IPv4 DSCP Values	IPv6 DSCP Values	Egress Equivalence Class Name
11,37,45	11,37,45	*Sophomore*
8,10,12		*Senior*
	38,213	*Junior*
No IP Packet	No IP Packet	*Freshman*
All other values	All other values	*Freshman*

Table 44 – Example of *M* when *F* equals DSCP for an OVC End Point in a VUNI or at a UNI

Table 45 shows an example where only IPv4 is supported. In this example, the Egress Equivalence Class Name for egress Data EI Frames not carrying an IP packet is *Baggage*. This fact and the last row of Table 45 means that *Baggage* applies to any egress Data EI Frame not carrying an IPv4 packet. An analogous approach can be used for the case where only IPv6 is supported.

IPv4 DSCP Values	IPv6 DSCP Values	Egress Equivalence Class Name
11,37,45		*First*
8,10,12		*Business*
No IP Packet	No IP Packet	*Baggage*
All other values		*Economy*
	All values	*Baggage*

Table 45 – Example of *M* that Only Supports IPv4 when *F* Equals *DSCP* for an OVC End Point in a VUNI or at a UNI

16.9.2.2 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress L2CP EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

For an OVC End Point that is in a VUNI or at a UNI, *P*, a list of Layer 2 Control Protocols can be specified with each entry in the list mapping to a single Egress Equivalence Class Name. The entries in this list are referred to as the L2CP OVC End Point Equivalence Class Identifiers.

> **[R215]** If an egress Layer 2 Control Protocol EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI and the Layer 2 Control Protocol carried by this egress Layer 2 Control Protocol ENNI Frame is contained in the L2CP OVC

End Point Egress Equivalence Class Identifiers, then the Egress Equivalence Class Name for this frame **MUST** be the Egress Equivalence Class Name mapped to by the Layer 2 Control Protocol.

[R216] If an egress Layer 2 Control Protocol EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI and the Layer 2 Control Protocol carried by this egress Layer 2 Control Protocol EI Frame is not contained in the L2CP OVC End Point Egress Equivalence Class Identifiers, then the Egress Equivalence Class Name for this frame **MUST** be determined as if it is an egress Data ENNI Frame.

16.9.2.3 OVC End Point Egress Equivalence Class Identifier Service Attribute for Egress SOAM EI Frames Mapped to an OVC End Point that is in a VUNI or at a UNI

[R217] If an egress SOAM EI Frame is mapped to an OVC End Point that is in a VUNI or at a UNI, then the Egress Equivalence Class Name for this egress SOAM EI Frame **MUST** be the same as if it were an egress Data EI Frame.

16.10 Ingress Bandwidth Profile per OVC End Point Service Attribute

The value of the Ingress Bandwidth Profile per OVC End Point is *Parameters* or *Disabled*. The Ingress Bandwidth Profile per OVC End Point Service Attribute describes ingress policing by the Operator CEN on all ingress EI Frames mapped to a given OVC End Point.

[R218] When the value of the Ingress Bandwidth Profile per OVC End Point Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 1 of [R230] for this OVC End Point **MUST** be contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 1 of [R230].

[R219] When the value of the Ingress Bandwidth Profile per OVC End Point Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.[23]

Figure 43 illustrates an example of the application of Ingress Bandwidth Profiles per OVC End Point Service Attribute. In this example, OVC End Point₁ corresponds to Bandwidth Profile Flow 1 with $CIR^1 = CIR^1_{max} = 15 Mbps$, OVC End Point₂ corresponds to Bandwidth Profile Flow 2 with $CIR^2 = CIR^2_{max} = 10 Mbps$, and OVC End Point₃ corresponds to Bandwidth Profile Flow 3 with $CIR^3 = CIR^3_{max} = 20 Mbps$.

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[23] In MEF 26.1 [18] CM^i is mandated to equal *color-aware*. This mandate is removed in this document.
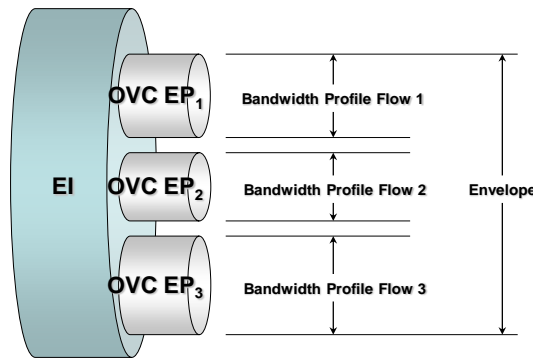
Figure 43 – Ingress Bandwidth Profile per OVC End Point Service Attribute Example

16.11 Egress Bandwidth Profile per OVC End Point Service Attribute

The value of the Egress Bandwidth Profile per OVC End Point Service Attribute is *Parameters* or *Disabled*. The Egress Bandwidth Profile per OVC End Point Service Attribute describes the length and arrival time characteristics of all egress EI Frames that are mapped to a given OVC End Point.

> **[R220]**   When the value of the Egress Bandwidth Profile per OVC End Point Service Attribute is *Parameters*, a single Bandwidth Profile Flow based on criterion 4 of [R230] for this OVC End Point **MUST** be contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 4 of [R230].

> **[R221]**   When the value of the Egress Bandwidth Profile per OVC End Point Service Attribute is *Parameters*, the Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator.[24]

16.12 Ingress Bandwidth Profile per Class of Service Name Service Attribute[25]

The value of the Ingress Bandwidth Profile per Class of Service Name is a list of pairs of the form $\langle x, y \rangle$ where x is a Class of Service Name that is in the value of the OVC List of Class of Service Names Service Attribute (Section 12.12) for the OVC that associates the OVC End Point and y has the value *Parameters* or *Disabled*. There is at most one pair in the list for each Class of Service Name that is in the value of the OVC List of Class of Service Names Service Attribute for the OVC that associates the OVC End Point except for the Class of Service Name for *Discard*.

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[24] In MEF 26.1 [18] CM^i is mandated to equal *color-aware*. This mandate is removed in this document.

[25] This Service Attribute was named Ingress Bandwidth Profile per Class of Service Identifier in MEF 26.1 [18].

[R222] When the value of y is *Parameters* in the pair $\langle x, y \rangle$, a single Bandwidth Profile Flow based on criterion 2 of [R230] for the Class of Service Name x **MUST** be specified and contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 2 of [R230].

[R223] The Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator for each Bandwidth Profile Flow specified per [R222].[26]

Note that if x in $\langle x, y \rangle$ is not configured for a given OVC End Point, then y can be set to Disabled thus obviating the need to specify parameter values for a Bandwidth Profile Flow that will never be used.

16.13 Egress Bandwidth Profile per Egress Equivalence Class Name Service Attribute[27]

The value of the Egress Bandwidth Profile per Egress Equivalence Class Name Service Attribute is a list of pairs of the form $\langle x, y \rangle$ where x is an Egress Equivalence Class Name and y has the value *Parameters* or *Disabled*. There is at most one pair in the list for each Egress Equivalence Class Name.

[R224] When the value of y is *Parameters* in the pair $\langle x, y \rangle$, a single Bandwidth Profile Flow based on criterion 5 of [R230] for the Egress Equivalence Class Name x **MUST** be specified and contained in an Envelope that contains only Bandwidth Profile Flows based on criterion 5 of [R230].

[R225] The Bandwidth Profile Flow parameters described in Section 17.1 **MUST** be agreed to by the SP/SO and the Operator for each Bandwidth Profile Flow specified per [R224].[28]

16.14 OVC End Point Aggregation Link Depth Service Attribute

The OVC End Point Aggregation Link Depth Service Attribute only applies to OVC End Points at an ENNI and only when the ENNI Link Aggregation Common Attribute of Section 9.5 has the value *All Active*. The OVC End Point Aggregation Link Depth Service Attribute value is a list of pairs of the form $\langle s, n \rangle$ where s is an S-VLAN ID value that is contained in the value of the OVC End Point Map Service Attribute and n is an integer in the range 1 to the value of the ENNI Number of Links Common Attribute of Section 9.4. n specifies the number of links in the value of the ENNI Port Conversation ID to Aggregation Link Map Common Attribute (Section 9.6) for the S-VLAN ID value s.

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[26] In MEF 26.1 [18] CM^i is mandated to equal *color-aware*. This mandate is removed in this document.

[27] This Service Attribute was named Egress Bandwidth Profile per Class of Service Identifier in MEF 26.1 [18].

[28] In MEF 26.1 [18] CM^i is mandated to equal *color-aware*. This mandate is removed in this document.

Note that the list of $\langle s, n \rangle$ pairs can only contain more than one item when the value of the OVC End Point End Point Map Service Attribute is of Form E (Section 16.5.1) or Form T (Section 16.5.2). Also note that, because of the nature of the ENNI Port Conversation ID to Aggregation Link Map Common Attribute (Section 9.6) and the OVC End Point Map Service Attribute *Form V* (Section 16.5.3), the value of n needs to be the same for all OVC End Points in a given VUNI (Section 15).

> **[R226]** All OVC End Points in a given VUNI **MUST** have the same value for the OVC End Point Aggregation Link Depth Service Attribute.

The larger the OVC End Point Aggregation Link Depth Service Attribute value, the more robust the exchange of ENNI Frames across the ENNI is with respect to link failure.

Since the SP/SO might not know the value of the ENNI Number of Links Common Attribute (Section 9.4) and/or the value of the ENNI Link Aggregation Common Attribute (Section 9.5), it is the responsibility of the Operator to ensure that the value of the OVC End Point Aggregation Link Depth Service Attribute agreed to with the SP/SO is consistent with the values of these Common Attributes.

Note that it is not necessary for the SP/SO to know which links protect a given S-VLAN ID. Also note that an analogous Service Attribute for an OVC End Point at a UNI is not necessary since the SP/SO has full knowledge of the value of the Operator UNI Port Conversation to ID to Aggregation Link Map Service Attribute (Section 14.6).

16.15 OVC End Point Source MAC Address Limit Service Attribute

The value of the OVC End Point Source MAC Address Limit Service Attribute can be either the pair $\langle N, \tau \rangle$ where N is a strictly positive integer and τ is a time interval or *Disabled*.

This attribute limits the number of source MAC Addresses that can be used in ingress EI Frames mapped to the OVC End Point of all types over a time interval.

When the value of this attribute is $\langle N, \tau \rangle$, the CEN maintains a list of maximum length N of source MAC addresses which are aged-out of the list if not seen in a time interval τ. If an ingress EI Frame arrives with a new source MAC address when the list is full, it is recommended that the ENNI Frame be discarded.

In algorithmic terms, this can be stated as maintaining a list L where

$$L = \{\langle A_i, t_i \rangle | i = 1, 2, \ldots, q \leq N, A_i = \text{unicast MAC Address}, t_i = \text{a time}\}$$

The t_i in each $\langle A_i, t_i \rangle$ is the most recent time that an ingress EI Frame arrived at the EI that was mapped to the OVC End Point and contained the source MAC address A_i.

> **[D14]** If the OVC End Point Source MAC Address Limit Service Attribute = *Enabled*, then for a sequence of ingress EI Frames mapped to the OVC End Point with

source MAC Addresses A_j and arrival times at the EI t_j for $j = 0,1,2,\ldots$ the frames **SHOULD** be discarded per the logic of Figure 44 where $L = \emptyset$ at time t_0.

EI Frame with Source MAC Address A_j arrives at time t_j $(j \geq 0)$

Remove all $\langle A_i, t_i \rangle$ from L with $t_i \leq t_j - \tau$

There exists $\langle A_i, t_i \rangle \in L$ such that $A_j = A_i$ — Yes → Replace $\langle A_i, t_i \rangle \in L$ with $\langle A_j, t_j \rangle$

No

$|L| < N$ — Yes → Add $\langle A_j, t_j \rangle$ to L

No → Discard the EI Frame
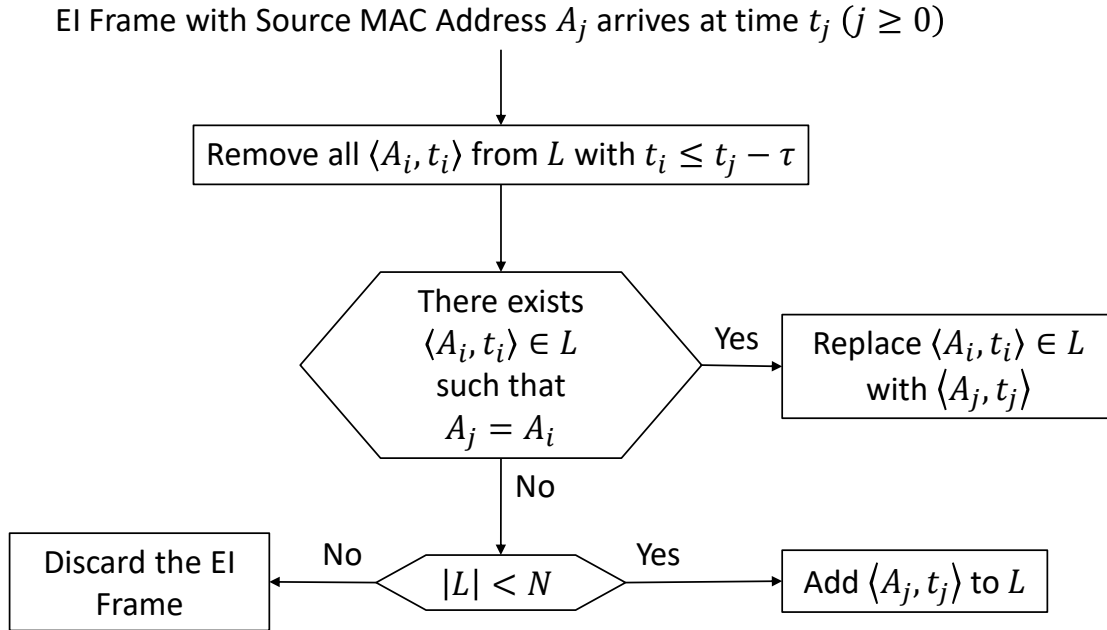
Figure 44 – EI Frame Discard for the OVC End Point Source MAC Address Limit Service Attribute

Note that [D14] does not mandate a specific implementation in the CEN. Any implementation that yields the same behavior as that of Figure 44 meets the requirement. For example, an implementation that removes a the pair $\langle A_i, t_i \rangle$ from the list at time $t = t_i + \tau$ yields the same ENNI Frame discard behavior as that of Figure 44.

Note that to implement the EVC per UNI Source MAC Address Limit Service Attribute described in MEF 10.3 [12], it might not be necessary to have the value of the OVC End Point Source MAC Address Limit Service Attribute = *Enabled* for all OVC End Points implementing the EVC. For example, in the case of a Multipoint-to-Multipoint EVC implemented with one Multipoint-to-Multipoint OVC and several Point-to-Point OVCs, having the value of the OVC End Point Source MAC Address Limit Service Attribute = *Enabled* for just the OVC End Points associated by the Multipoint-to-Multipoint OVC is sufficient to have the value of EVC per UNI Source MAC Address Limit Service Attribute = *Enabled* for all of the UNIs in the EVC.

16.16 OVC End Point MIP Service Attribute

The value of the OVC End Point MIP Service Attribute is either *Enabled* or *Disabled*. When the value is *Enabled*, several parameter values, including the MEG Level, need to be determined as described in MEF 30.1 [20].

When the OVC End Point is at a UNI or a VUNI, the MIP will be a Subscriber MEG MIP:

[R227] When the OVC End Point is at a UNI or in a VUNI and the value of the OVC End Point MIP Service Attribute is *Enabled*, the Operator CEN **MUST** instantiate a Subscriber Level MIP as described in MEF 30.1 [20] for each of the EVCs supported by the OVC that associates the OVC End Point.

[R228] When the OVC End Point is at an ENNI and not in a VUNI, and the value of the OVC End Point MIP Service Attribute is *Enabled*, the Operator CEN **MUST** instantiate a MIP as described in MEF 30.1 [20].

Note that the Operator CEN needs to have visibility of the EVCs in order to meet [R227] when the OVC End Point MIP Service Attribute value is *Enabled*. As an example, CEN B in Appendix C.4 might not have EVC visibility at the ENNI with CEN C in the sense that CEN B might not know that ENNI CE-VLAN ID 11 maps to EVC a-b and that ENNI CE-VLAN ID 15 maps to EVC a-c. Consequently, there can be situations where an Operator will only agree to have the value be *Disabled*.

16.17 OVC End Point Maintenance End Point List Service Attribute

The value of the OVC End Point Maintenance End Point List Service Attribute is a list of pairs, one for each MEP that is instantiated. Each pair is of the form $<l,d>$ where l equals the MEG Level, and d is the direction for the MEP, either *Up* or *Down*. When the list is not empty, several parameter values need to be determined for each MEP as described in MEF 30.1 [20].

[R229] The value of the OVC End Point Maintenance End Point List Service Attribute **MUST NOT** include MEPs that monitor a MEG that is completely contained within the Operator's CEN.

17   Bandwidth Profiles

A Bandwidth Profile defines the set of traffic parameters applicable to a sequence of EI Frames. Associated with the Bandwidth Profile is an algorithm to determine frame compliance with the specified parameters. In the case of an Ingress Bandwidth Profile, rate enforcement is accomplished via the disposition of non-compliant frames.

A Bandwidth Profile is specified using the concepts of Bandwidth Profile Flow and Envelope. A Bandwidth Profile Flow is defined as a set of EI Frames arriving at an EI that meet a specific criterion.

> **[R230]**   A Bandwidth Profile Flow **MUST** be specified using one of the following criteria:
>
> 1. All ingress EI Frames at the EI that are mapped to a given OVC End Point and that are not discarded per requirement [R8] or [R101],
>
> 2. All ingress EI Frames that have a given Class of Service Name, that map to a given OVC End Point, and that are not discarded per requirement [R8] or [R101],
>
> 3. All ingress ENNI Frames that are mapped to any of the OVC End Points that are in a given VUNI, and that are not discarded per requirement [R8],
>
> 4. All egress EI Frames that are mapped to a given OVC End Point,
>
> 5. All egress EI Frames that have a given Egress Equivalence Class Name and that map to a given OVC End Point,
>
> 6. All egress ENNI Frames that are mapped to any of the OVC End Points that are in a given VUNI,
>
> 7. All ingress Service Frames at the UNI that are not discarded per requirement [R101],
>
> 8. All egress Service Frames at the UNI.

Note that ingress EI Frames discarded due to [R8] or [R101] cannot be in a Bandwidth Profile Flow and thus they will not consume tokens in the Bandwidth Profile Algorithm described in Section 17.2.

Note that when a frame is discarded due to [R166], [D3], [D4], [D5], [D6], or [D14], or any of the conditions specified by [R37], [R38], and [R39], whether tokens are consumed or not is not specified.

An Envelope is a set of n Bandwidth Profile Flows in which each Bandwidth Profile Flow is assigned a unique rank between 1 (lowest) and n (highest). n can be any strictly positive integer.

[R231] All Bandwidth Profile Flows in an Envelope **MUST** satisfy the same criterion in [R230].

One implication of [R230] and [R231] is that the Bandwidth Profile Flows in an Envelope are either all Ingress Bandwidth Profile Flows or all Egress Bandwidth Profile Flows.

At most a single Envelope containing a single Bandwidth Profile Flow based on criterion 7 or criterion 8 of [R230] can exist at a UNI. For each of the remaining criteria of [R230], multiple Envelopes containing Bandwidth Profile Flows based on the criterion can exist at an EI.

Note that all of the criteria of [R230] except for criteria 7 and 8 are on an OVC End Point basis, so different OVC End Points at the same ENNI or UNI may use different criteria to specify their Bandwidth Profile Flows.

[R232] Each Bandwidth Profile Flow **MUST** belong to exactly one Envelope.

[R233] An ENNI Frame **MUST** be mapped to at most one Bandwidth Profile Flow.

[R234] A Service Frame **MUST** be mapped to at most one Bandwidth Profile Flow.

Note that a given EI Frame does not need to be mapped to a Bandwidth Profile Flow. When this is the case, it is said that the frame is not subject to a Bandwidth Profile. When an EI Frame is mapped to a Bandwidth Profile Flow, [R232], [R233], and [R234] mean that this EI Frame is subject to exactly one Envelope and thus the Bandwidth Profile Algorithm (see Section 17.2) is applied to this EI Frame exactly once. When the Bandwidth Profile Algorithm is applied to an EI Frame, the result is one of three colors, Green, Yellow, or Red. This color result is said to be the Color Declaration for the EI Frame. As a consequence, each EI Frame that is mapped to a Bandwidth Profile Flow has exactly one Color Declaration.

17.1 Bandwidth Profile Parameters

The following subsections detail the parameters and related requirements for the parameters used in the Bandwidth Profile Algorithm (see Section 17.2).

17.1.1 Envelope Parameters

Each Envelope has two parameters. The first parameter is the Envelope ID which is a string that identifies the Envelope. The second parameter is the Envelope Coupling Flag, (CF^0) which controls conversion of unused Green tokens into Yellow tokens in the Bandwidth Profile Algorithm.

[R235] The Envelope ID value **MUST** contain no more than 45 characters.[29]

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[29] The limit of 45 characters is intended to establish limits on field lengths in existing or future protocols that will carry the identifier.

[R236] The Envelope ID value **MUST** be unique among all Envelope IDs at an External Interface for the SP/SO.

[R237] The Envelope ID value **MUST** be a non-null RFC 2579 [8] DisplayString but not contain the characters 0x00 through 0x1f.

[R238] CF^0 **MUST** have a value of 0 or 1.

[R239] When only one Bandwidth Profile Flow is mapped to an Envelope, CF^0 **MUST** equal 0.

17.1.2   Bandwidth Profile Flow Parameters

Table 46 shows the parameters for each Bandwidth Profile Flow. The superscript $i = 1,2,\ldots,n$ is used to index the Bandwidth Profile Flow among all Bandwidth Profile Flows that are mapped to a given Envelope. Note that the descriptions in the table are informal. The precise role played by a given parameter is determined by the Bandwidth Profile Algorithm (see Section 17.2).

Parameter Name	Symbol	Units	Informal Description
Committed Information Rate per Bandwidth Profile Flow	CIR^i	bits per second	Limits the average rate of EI Frames that will be declared Green
Maximum Committed Information Rate per Bandwidth Profile Flow	CIR_{max}^i	bits per second	Limits the rate of tokens added to the committed token bucket
Committed Burst Size per Bandwidth Profile Flow	CBS^i	bytes	Limits the maximum number of bytes available for a burst of EI Frames that will be declared Green
Excess Information Rate per Bandwidth Profile Flow	EIR^i	bits per second	Limits the average rate of EI Frames that will be declared Yellow
Maximum Excess Information Rate per Bandwidth Profile Flow	EIR_{max}^i	bits per second	Limits the rate of tokens added to the excess token bucket
Excess Burst Size per Bandwidth Profile Flow	EBS^i	bytes	Limits the maximum number of bytes available for a burst of EI Frames that will be declared Yellow
Coupling Flag per Bandwidth Profile Flow	CF^i	integer	Determines if overflow Green tokens can be used as Yellow tokens
Color Mode per Bandwidth Profile Flow	CM^i	string	Indicates whether the Color Identifier of the EI Frame is considered by the Bandwidth Profile Algorithm
Envelope and Rank	ER^i	<Envelope ID, strictly positive integer>	Indicates the Envelope that the Bandwidth Profile Flow belongs to and the rank within the Envelope
Token Request Offset	F^i	integer	Adjusts the number of tokens requested for each EI Frame

Table 46 – Bandwidth Profile Flow Parameters

[R240] CIR^i **MUST** be ≥ 0.

[R241] CIR_{max}^i **MUST** be ≥ 0.

[R242] If $CIR^i > 0$, then CBS^i **MUST** be greater than or equal to the lower bound for the Bandwidth Profile Flow in Table 47.

Basis of the Bandwidth Profile	Lower Bound on CBS^i and EBS^i
Criterion 1, 2, 4, or 5 of [R230]	OVC Maximum Frame Size Service Attribute value of the OVC that associates the OVC End Point
Criterion 3 or 6 of [R230]	ENNI Maximum Frame Size Multilateral Attribute value
Criterion 7 or 8 of [R230]	Operator UNI Maximum Frame Size Service Attribute value

Table 47 – Required Lower Bounds on *CBS^i* and *EBS^i*

Note that, per [R102], if the Bandwidth Profile Flow consists of EI Frames at a UNI, then the lower bounds in Table 47 are ≥ 1522 bytes. Similarly, per [R27], if the Bandwidth Profile consists of EI Frames at an ENNI, then the lower bounds in Table 47 are ≥ 1526 bytes.

[R243] EIR^i **MUST** be ≥ 0.

[R244] EIR^i_{max} **MUST** be ≥ 0.

[R245] If $EIR^i > 0$, then EBS^i **MUST** be greater than or equal to the lower bound for the Bandwidth Profile Flow in Table 47.

[R246] CF^i **MUST** have a value of 0 or 1.

[R247] If $CF^0 = 1$ then CF^i **MUST** equal 0 for all Bandwidth Profile Flows mapped to the Envelope.

[R248] CM^i **MUST** have a value of *color-blind* or *color-aware*.

[R249] The value of the rank in ER^i **MUST** be in the range $1, 2, …, n$ where n is the number of Bandwidth Profile Flows with the same Envelope ID value.

[R250] The value of the rank in ER^i **MUST NOT** equal the rank of any of the other Bandwidth Profile Flows with the same Envelope ID value.

17.2   Bandwidth Profile Algorithm

The Bandwidth Profile Algorithm is specified by reference to the Generic Token Sharing Algorithm of MEF 41 [23]. Two things are needed to do this:

- The relationship of the parameter values in this document to the values of the parameters in MEF 41 [23], and

- The specification of the Token Requests used in MEF 41.

A Generic Token Sharing Algorithm is used for each Envelope. Let n be the number of Bandwidth Profile Flows in the Envelope. Each Generic Token Sharing Algorithm parameter takes on the value of a corresponding parameter from this document as shown in Table 48.

Generic Token Sharing Parameter	Value of Bandwidth Profile Parameter
GTR^i	$\dfrac{CIR^i}{8}$
GTR_{max}^i	$\dfrac{CIR_{max}^i}{8}$
GTV^i	CBS^i
YTR^i	$\dfrac{EIR^i}{8}$
YTR_{max}^i	$\dfrac{EIR_{max}^i}{8}$
YTV^i	EBS^i
CF^i	CF^i
CF^0	CF^0

Table 48 – Values of Generic Token Sharing Algorithm Parameters for $i = 1,2,...,n$

A Token Request, as defined in MEF 41 [23], corresponds to each frame that arrives at the External Interface and that is contained in Bandwidth Profile Flow i per Table 49.

Token Request Parameter	Value
l	$L - F^i$ where L is the length in bytes of the EI Frame
t	Arrival time of the ENNI Frame or Service Frame at the External Interface
c	If $CM^i = color\text{-}aware$ the color of the EI Frame (see Section 16.7); else Green
r	Value of rank in ER^i

Table 49 – Values for Token Requests for Bandwidth Profile Flow $i, i = 1,2,...,n$

Appendix G describes examples of the use of the Token Request Offset, F^i.

[R251] Let $\langle l_k, t_k, c_k, r_k \rangle, k = 0,1,...$ be the sequence of Token Requests constructed per Table 49 for all Bandwidth Profile Flows in the Envelope such that $t_k < t_{k+1}, k = 0,1,...$. Then the color declaration for each ENNI Frame or Service Frame **MUST** equal the Color Determination for the corresponding Token Request using the algorithm of Section 10.2 in MEF 41 [23] with parameter values set as in Table 48.

17.3   Ingress Bandwidth Profile Service Attributes

When a Bandwidth Profile Flow is based on criterion 1, 2, 3, or 7 of [R230], the EI Frames contained in this Bandwidth Profile Flow are said to be subject to an Ingress Bandwidth Profile. The Ingress Bandwidth Profile is used to regulate the amount of ingress traffic at a particular External Interface.

The disposition of a given EI Frame with respect to delivery to an egress External Interface is dependent on the frame's Color Declaration per [R252].

> **[R252]**   An ingress EI Frame that is declared Red by Ingress Bandwidth Profile **MUST** be discarded.

Note that if an ingress EI Frame is declared Green by an Ingress Bandwidth Profile and it meets other conditions per the definition of Qualified Frame per Section 12.13.1.3, then the SLS applies to this frame. In addition, per the definition of Qualified Frame in Section 12.13.1.3, an ingress EI Frame that is declared Yellow by an Ingress Bandwidth Profile is not subject to the performance objectives of the SLS.

Note that the color declaration for an ingress EI Frame is used as input to the OVC End Point Egress Map Service Attribute (Section 16.8).

17.4   Egress Bandwidth Profile Service Attributes

When a Bandwidth Profile Flow is based on criterion 4, 5, 6, or 8, of [R230], the EI Frames contained in this Bandwidth Profile Flow are said to be subject to an Egress Bandwidth Profile. An Egress Bandwidth Profile is used to regulate the amount of egress traffic at a particular External Interface.

The reference point for an Egress Bandwidth Profile is the External Interface. An Egress Bandwidth Profile describes arrival times and lengths of ENNI Frames or Service Frames that will be observed at the External Interface when an Egress Bandwidth Profile is in operation in the Operator CEN. This description is given in terms of what would happen if an observer at the External Interface applied the algorithm of Section 17.2 to egress EI Frames. This observer would see traffic after it had been subject to rate limiting and/or shaping in the Operator network and thus would have certain characteristics.

> **[R253]**   When an Envelope consists of Bandwidth Profile Flows based on one of criteria 4, 5, 6, or 8 of [R230], the result of an external observer applying the algorithm of Section 17.2 with the same Envelope and Bandwidth Profile Flow parameter values as those used by the Egress Bandwidth Profile **MUST** be to declare each ENNI Frame or Service Frame either Green or Yellow.

The implication is that the regulation of the EI Frames in the Operator CEN is such that all frames that would be determined to be Red by the external observer are discarded before reaching the egress External Interface. It is important to reiterate that this description of Egress

Bandwidth Profile does not mandate or constrain in any way the implementation in the Operator CEN.

Note that the color declaration by the external observer does not impact the handling of the EI Frame by the receiving Operator CEN or Subscriber.

> **[R254]** When a Bandwidth Profile Flow is based on one of criteria 4, 5, 6, or 8 of [R230], CM^i for the Bandwidth Profile Flow **MUST** equal *color-blind*.

[R254] simplifies the implementation of the Egress Bandwidth Profile for the Operator CEN because it reduces the amount of information needed. For example, [R254] means that the Operator CEN does not need to know how the external observer assigns a Color to each egress EI Frame based on inspection of the EI Frame content when applying the algorithm of Section 17.2. Note that [R254] does not impact, in any way, the OVC End Point Color Identifier Service Attribute of the receiving Operator CEN.

CM^i = *color-aware* for a Bandwidth Profile Flow based on one of criteria 4, 5, 6, or 8 of [R230] is beyond the scope of this document.

18 References

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[2] IEEE Std 802.1AX – 2014, *IEEE Standard for Local and metropolitan area networks – Link Aggregation*, December 2014.

[3] IEEE Std 802.1Q – 2014, *IEEE Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks*, 3 November 2014.

[4] IEEE Std 802.3 – 2012, *IEEE Standard for Ethernet*, 30 August 2012.

[5] International Telecommunication Union, Recommendation Y.1563, *Global information infrastructure, internet protocol aspects and next-generation networks, Internet protocol aspects – Quality of service and network performance, Ethernet frame transfer and availability performance*, 2009.

[6] Internet Engineering Task Force RFC 2119, *Key words for use in RFCs to Indicate Requirement Levels*, March 1997.

[7] Internet Engineering Task Force RFC 2474, *Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers*, December 1998.

[8] Internet Engineering Task Force RFC 2579. *Textual Conventions for SMIv2*, April 1999.

[9] Internet Engineering Task Force RFC 3393, *IP Packet Delay Variation Metric for IP Performance Metric (IPPM)*, November 2002.

[10] MEF Forum, MEF 4, *Metro Ethernet Network Architecture Framework – Part 1: Generic Framework*, May 2004.

[11] MEF Forum, MEF 6.2, *Ethernet Services Definitions - Phase 3*, July 2014.

[12] MEF Forum, MEF 10.3, *Ethernet Services Attributes Phase 3*, October 2013.

[13] MEF Forum, MEF 10.3.2, *Amendment to MEF 10.3 - UNI Resiliency Enhancement*, November 2015.

[14] MEF Forum, MEF 11, *User Network Interface (UNI) Requirements and Framework*, November 2004.

[15] MEF Forum, MEF 16, *Ethernet Local Management Interface (E-LMI)*, January 2006.

[16]   MEF Forum, MEF 17, *Service OAM Requirements & Framework – Phase 1*,
April 2007.

[17]   MEF Forum, MEF 23.2, *Carrier Ethernet Class of Service – Phase 3*, ????.

[18]   MEF Forum, MEF 26.1, *External Network Network Interface (ENNI) – Phase 2*,
January 2012.

[19]   MEF Forum, MEF 28, *External Network Network Interface (ENNI) Support for
UNI Tunnel Access and Virtual UNI*, October 2010.

[20]   MEF Forum, MEF 30.1, *Service OAM Fault Management Implementation
Agreement: Phase 2*, April 2013.

[21]   MEF Forum, MEF 33, *Ethernet Access Services Definition*, January 2012.

[22]   MEF Forum, MEF 35.1, *Service OAM Performance Monitoring Implementation
Agreement*, May 2015.

[23]   MEF Forum, MEF 41, *Generic Token Bucket Algorithm*, October 2013.

[24]   MEF Forum, MEF 45, *Multi-CEN L2CP*, July 2014.

[25]   MEF Forum, MEF 51, *OVC Services Definitions*, July 2015.

Appendix A   Selected OVC Examples (Informative)

This section presents several examples of the use of the Operator Service Attributes to achieve EVCs. The first sub-section establishes the conventions and notation used in the examples. The remaining sub-sections present the examples.

A.1   Notation and Conventions

The figures accompanying the examples use the icons as shown in Figure 45.

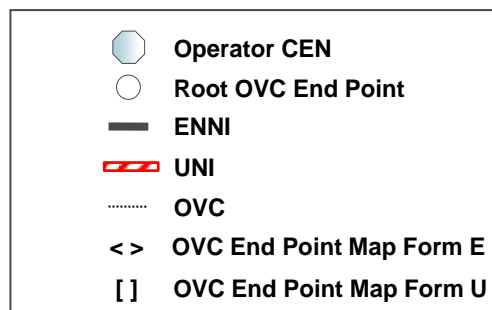|	
⬡	**Operator CEN**
○	**Root OVC End Point**
▬	**ENNI**
▱	**UNI**
··········	**OVC**
< >	**OVC End Point Map Form E**
[ ]	**OVC End Point Map Form U**

Figure 45 – Key to the Icons Used in the Appendix A Examples

In the examples, the Service Provider is not explicitly shown. The Service Provider could be any of the Operators or some other organization. The examples are valid no matter who is the Service Provider.

A.2   Example 1: Ethernet Virtual Private Lines to a Hub Location

In this example, four Operator CENs are used by the Service Provider to provide three EVCs, each from a branch location to a hub location. Figure 46 shows the EVCs for this example as perceived by the Subscriber. UNI a is the hub location and the other UNIs are the branch locations. The CE-VLAN ID/EVC Maps as agreed to by the Subscriber and the Service Provider for each UNI are included in the figure. From these maps it can be seen that none of the EVCs have CE-VLAN ID Preservation = *Enabled* as defined in MEF 10.3 [12].
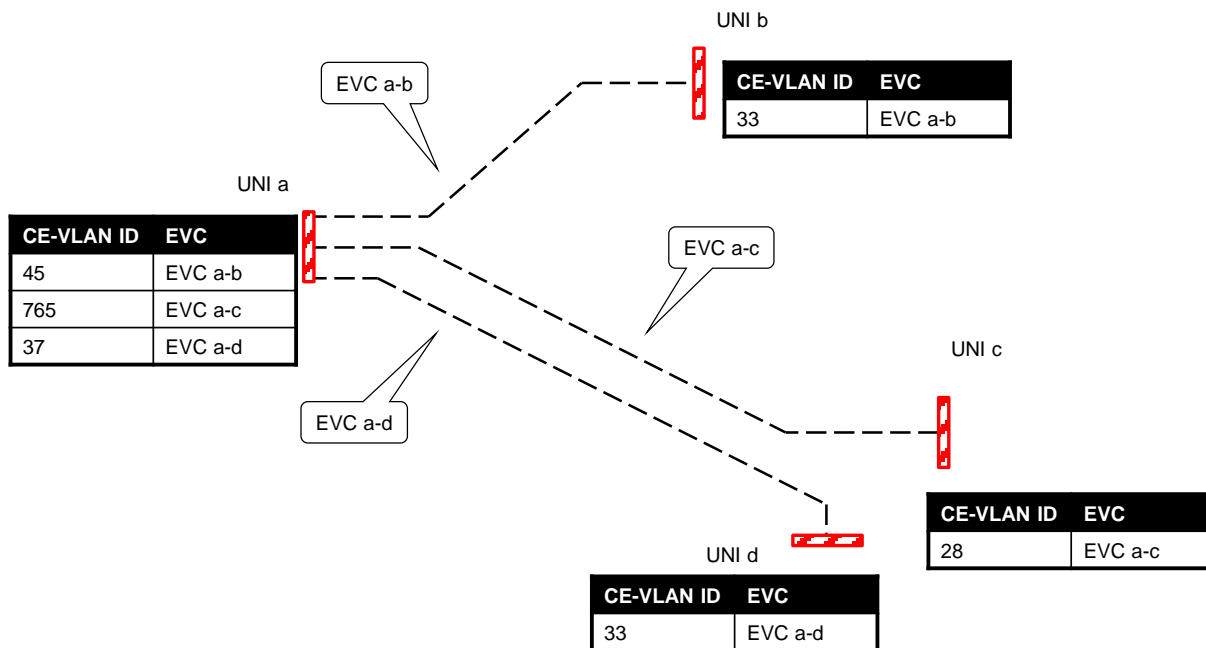
Figure 46 – EVCs to the Hub Location

Figure 47 shows Operator Service Attributes values that instantiate the EVPLs for this example using four Operator CENs. The values of the OVC End Point Map Service Attributes are shown in the figure. To see how this configuration works, consider a Service Frame that ingresses at UNI a and is destined for UNI d via EVC a-d. Such a Service Frame will have a CE-VLAN ID value = 37. Operator A maps this frame to the OVC End Point at UNI a and thus transmits a corresponding ENNI Frame with S-VLAN ID value = 1024 across the ENNI with Operator D. Operator D maps this ENNI Frame to the proper OVC End Point and thus transmits a corresponding ENNI Frame with S-VLAN ID value = 2024 across the ENNI with Operator C. Operator C maps this ENNI Frame to the proper OVC End Point and thus transmits a corresponding Service Frame with CE-VLAN ID value = 33 across UNI d. A similar sequence of events ensues for the other direction for EVC a-d and for the other EVCs in this example.
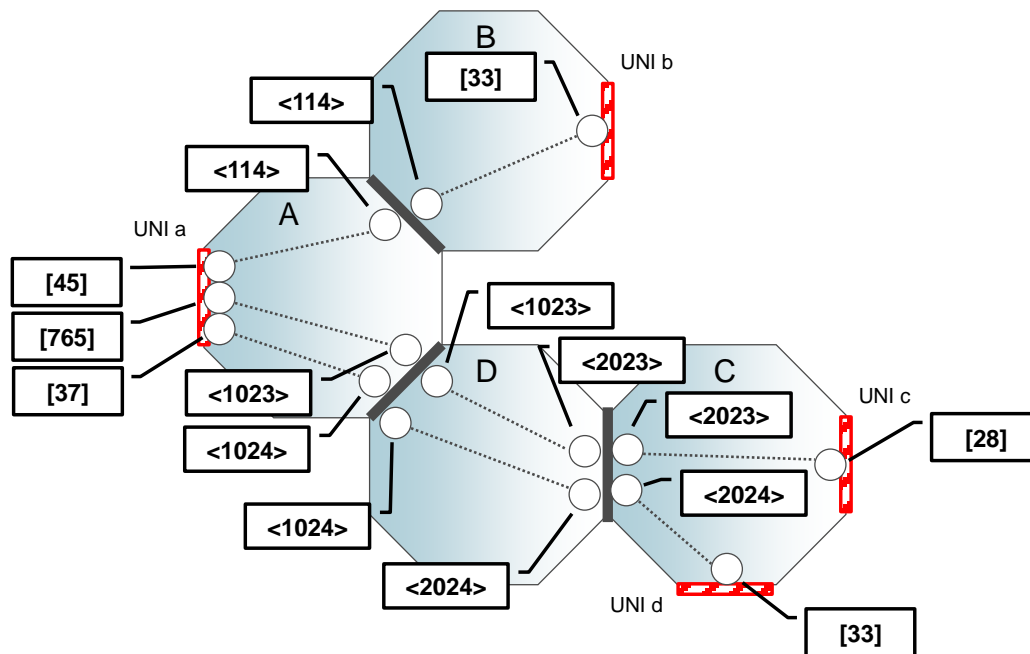
Figure 47 – Details of the Operator Service Attributes for Example 1

This example shows that EVC a-d is supported by three OVCs, one in each Operator CEN. The way that these OVCs are connected at each ENNI is via the OVC End Point Map Service Attribute values on each side of the ENNI.

A.3   Example 2: Ethernet Private LAN

In this example, the Service Provider provides a single Ethernet Private LAN connecting four UNIs. Figure 48 shows the EVC for this example as perceived by the Subscriber. Note that EPLAN requires that the EVC have CE-VLAN ID Preservation and CE-VLAN CoS Preservation both equal *Enabled* as per MEF 6.2 [11]. Note also that the CE-VLAN ID/EVC Map at each UNI is All to One as prescribed by MEF 6.2 [11].
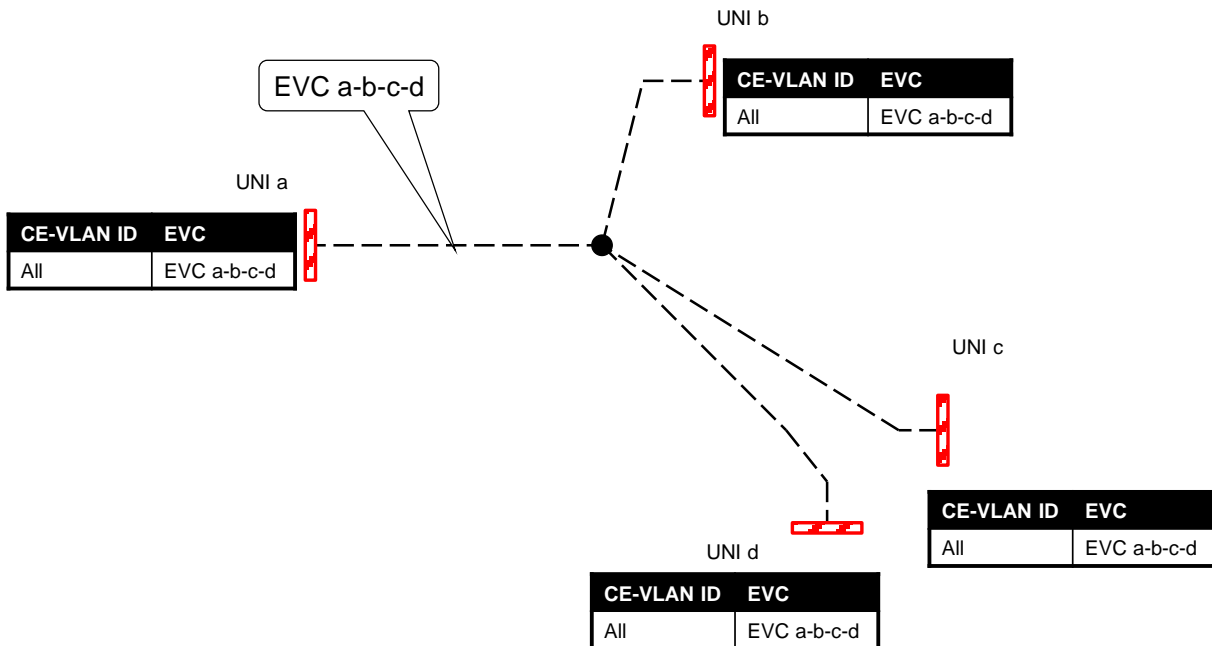
Figure 48 – EPLAN Connecting Four UNIs

Figure 49 shows Operator Service Attributes values that instantiate the EPLAN for this example using four Operator CENs. In order to support All to One Bundling, the value of the OVC End Point Map Service Attribute at each UNI maps all Service Frames to the OVC End Point. The value of each OVC End Point Map Service Attribute maps to the OVC End Point with one S-VLAN ID value as was the case with Example 1.

Figure 49 – Details of the Operator Service Attributes for Example 2

The OVC in the Operator CEN A associates three OVC End Points as does the OVC in the Operator CEN C. Consequently, if MAC address learning is done in the Operator CEN A, a unicast Service Frame between UNI a and UNI b need not enter the Operator D and Operator C CENs. Similarly, if MAC address learning is done in Operator CEN C, a unicast Service Frame between UNI c and UNI d need not leave the Operator C CEN.

Each OVC has the OVC CE-VLAN ID Preservation Service Attribute = *Preserve* and the OVC CE-VLAN PCP Preservation Service Attribute = *Enabled* as specified in Section 12.7 and Section 12.8. As an example to see how this works, consider an ingress Service Frame at UNI a that has a C-Tag and is destined for UNI d.

- The resulting ENNI Frame at the ENNI between Operator CENs A and D will have both an S-Tag (with S-VLAN ID value = 1023) and a C-Tag and that C-Tag will have the same C-VLAN ID value and the same C-Tag PCP value as the original C-Tag of the Service Frame.

- The corresponding ENNI Frame at the ENNI between Operator CENs D and C will have both an S-Tag (with S-VLAN ID value = 2023) and a C-Tag and that C-Tag will have the same C-VLAN ID value and the same C-Tag PCP value as the original C-Tag of the ENNI Frame at the ENNI between Operator CENs A and D.

- Finally, the corresponding egress Service Frame at UNI d will have just a C-Tag and that C-Tag will have the same C-VLAN ID value and the same C-Tag PCP value as the original C-Tag of the ENNI Frame at the ENNI between Operator CENs C and D.

The result is that the C-VLAN ID value and C-Tag PCP value are the same for both the ingress and the egress Service Frame. Using the tables in Section 12.7, it can be seen that an untagged ingress Service Frame results in an untagged egress Service Frame. (Note that MEF 10.3 [12] specifies that CE-CoS Preservation does not apply to untagged Service Frames.) Consequently, the EVC has CE-VLAN ID Preservation and CE-VLAN CoS Preservation both equal *Enabled*.

A.4 Example 3: Hairpin Switching

Figure 50 shows an example of the use of OVC End Points for Hairpin Switching. In this example, there is one multipoint EVC that associates UNI Aa, UNI Ab, and UNI B. Operator A has two OVCs. One associates the OVC End Point at UNI Aa and the top OVC End Point at the ENNI. The other OVC associates the OVC End Point at UNI Ab and the bottom OVC End Point at the ENNI. Operator B has one OVC that associates the two OVC End Points at the ENNI and the OVC End Point at UNI B. With this configuration, a Service Frame sent from UNI Aa to UNI Ab will pass through the Operator B CEN where it will be hairpin switched. And a similar path will be followed by a Service Frame sent from UNI Ab to UNI Aa.
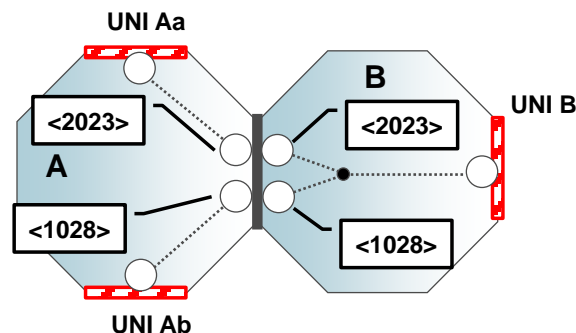

Figure 50 – Example of Hairpin Switching

Note that in this example, two OVCs are used in Operator CEN A to implement the single EVC.

A.5 Example 4: Data Loop at an ENNI with Hairpin Switching

The improper use of Hairpin Switching can lead to data loops at an ENNI. An example of such an improper configuration is shown in Figure 51. In this example, a broadcast frame will pass back and forth across the ENNI following the loop formed by the OVC End Points and Hairpin Switching.
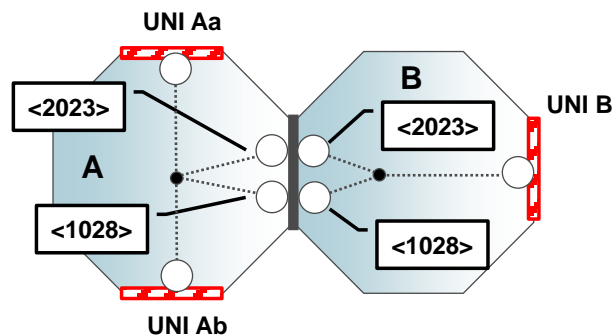
Figure 51 – Example of a Data Loop with Hairpin Switching

A.6 Example 5: Ethernet Private LAN with Hairpin Switching

In this example, the Service Provider provides a single Ethernet Private LAN connecting four UNIs just as was done in the example of Section A.3. Figure 48 shows the EVC for this example as perceived by the Subscriber.

Figure 52 shows Operator Service Attributes values that instantiate the EPLAN for this example using four Operator CENs. As in the example of Appendix A.3, the value of the OVC End Point Map Service Attribute at each UNI maps all Service Frames to the OVC End Point and each OVC has the OVC CE-VLAN ID Preservation Service Attribute = *Preserve* and the OVC CE-VLAN PCP Preservation Service Attribute = *Enabled* as specified in Section 12.7 and Section 12.8.
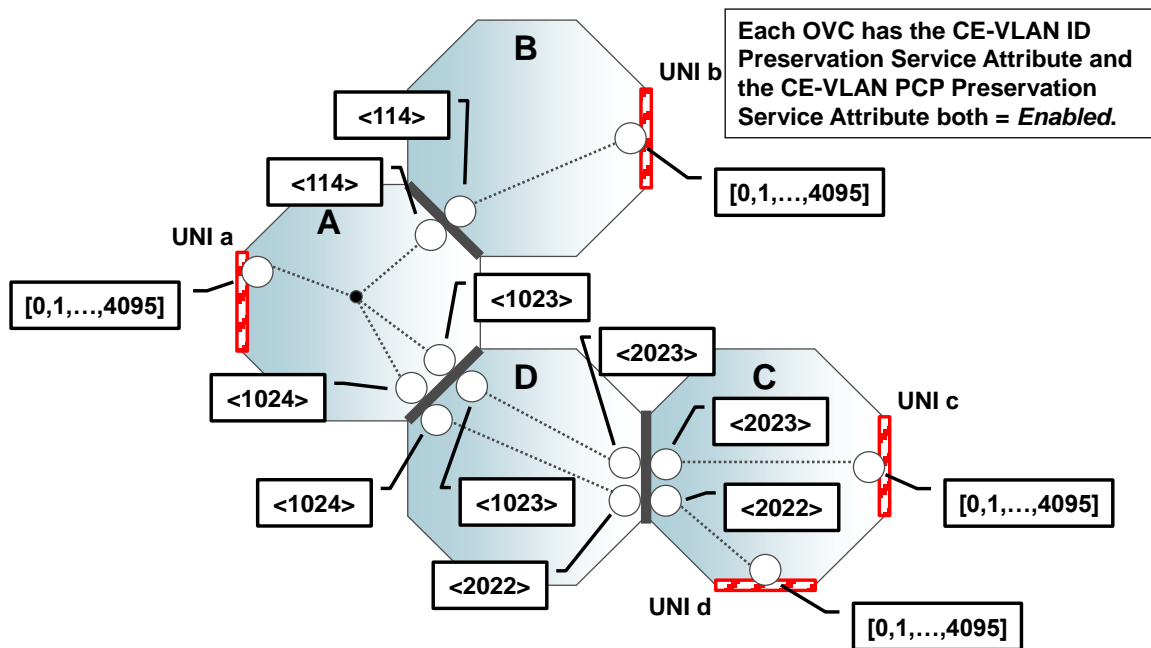
Figure 52 – Details of the Operator Service Attributes for Example 5

The key difference between this example and the example of Section A.3 is the use of Hairpin Switching in Operator CEN A. The OVC in Operator CEN A associates two OVC End Points at the ENNI between Operator CENs A and D. In addition, Operator CENs C and D each have two OVCs in support of the EPLAN. As a result, traffic from UNI c to UNI d will pass through Operator CENs A, C, and D.

A.7   Example 6: OVC End Point Map Bundling

Consider the EVCs to a hub location in Figure 46. Figure 53 shows the details of the Operator Service Attributes when Bundling is used in Operator CEN D.
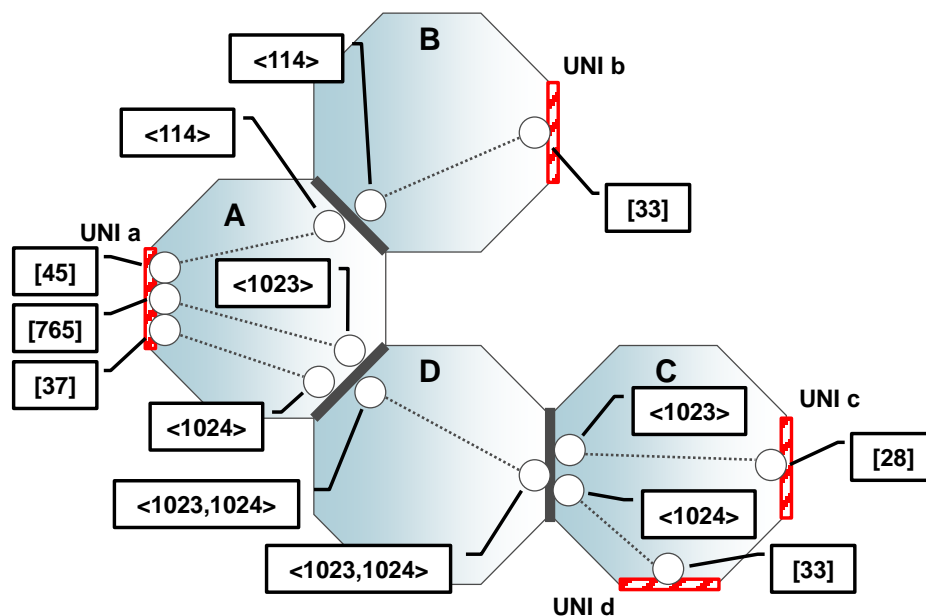
Figure 53 – Example of Using OVC End Point Map Bundling

Figure 53 differs from Figure 47 as follows:

- There is only one OVC in Operator CEN D. Thus, this is a case where more than one EVC is supported by an OVC.

- The OVC End Point Maps in the Operator CEN D have bundling with S-VLAN ID values 1023 and 1024 both mapped to a single OVC End Point at each ENNI.

Appendix B   Rooted-Multipoint Examples (Informative)

The forwarding behavior of a Rooted-Multipoint EVC is specified in MEF 10.3 [12] as any ingress Service Frames at a Root UNI may be forwarded to any other Root UNIs or Leaf UNIs in the same EVC, and any ingress Service Frames at a Leaf UNI may only be forwarded to any Root UNIs in the same EVC. This forwarding behavior can be extended to a Rooted-Multipoint EVC that spans one or more ENNIs by introducing a Rooted-Multipoint OVC and OVC End Point Role designations of *Root*, *Leaf*, and *Trunk*.

The forwarding behavior of a Rooted-Multipoint EVC requires being able to determine whether any given frame originated as an ingress Service Frame at a Root UNI or as an ingress Service Frame at a Leaf UNI. The method of preserving this information for each frame within an Operator CEN depends upon the technology used within the CEN and is beyond the scope of this document. Preserving this information at an ENNI can require using two S-VLAN ID values: the Root S-VLAN ID value identifies frames that originated at a Root UNI, and the Leaf S-VLAN ID value identifies frames that originated at a Leaf UNI. When a Rooted-Multipoint OVC associates a Trunk OVC End Point at an ENNI, both S-VLAN IDs are mapped to the Trunk OVC End Point by the value of the OVC End Point Map Service Attribute. (See Section 16.5.2.)

The examples in this section illustrate the use of these concepts to instantiate a Rooted-Multipoint EVC across multiple Operator CENs.

B.1   Example Using Trunk OVC End Points

Figure 54 shows a Rooted-Multipoint EVC connecting 6 UNIs as seen by the Subscriber.
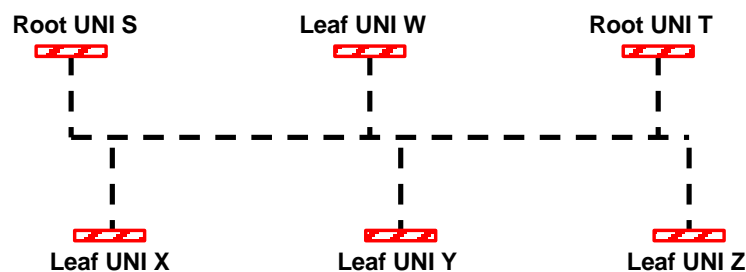
Figure 54 – Subscriber View of the Rooted-Multipoint EVC

Figure 55 shows an example of supporting this Rooted-Multipoint EVC using Trunk OVC End Points at the ENNIs that connect three Operator CENs. Note that each Operator CEN can receive ENNI Frames that originated at a Root UNI or a Leaf UNI. The use of Trunk OVC End Points at the ENNIs allows the Operator CEN to determine the type of ingress UNI and thus properly forward each ENNI Frame. Table 50 shows example mappings using Root and Leaf S-VLAN ID values.

Figure 55 – Rooted-Multipoint EVC using Trunk OVC End Points

CEN A		
OVC End Point Identifier	**Root S-VLAN ID value**	**Leaf S-VLAN ID value**
PAIX A32	1065	1066

CEN B		
OVC End Point Identifier	**Root S-VLAN ID value**	**Leaf S-VLAN ID value**
PAIX B12	1065	1066

CEN B		
OVC End Point Identifier	**Root S-VLAN ID value**	**Leaf S-VLAN ID value**
China Basin B123	56	57

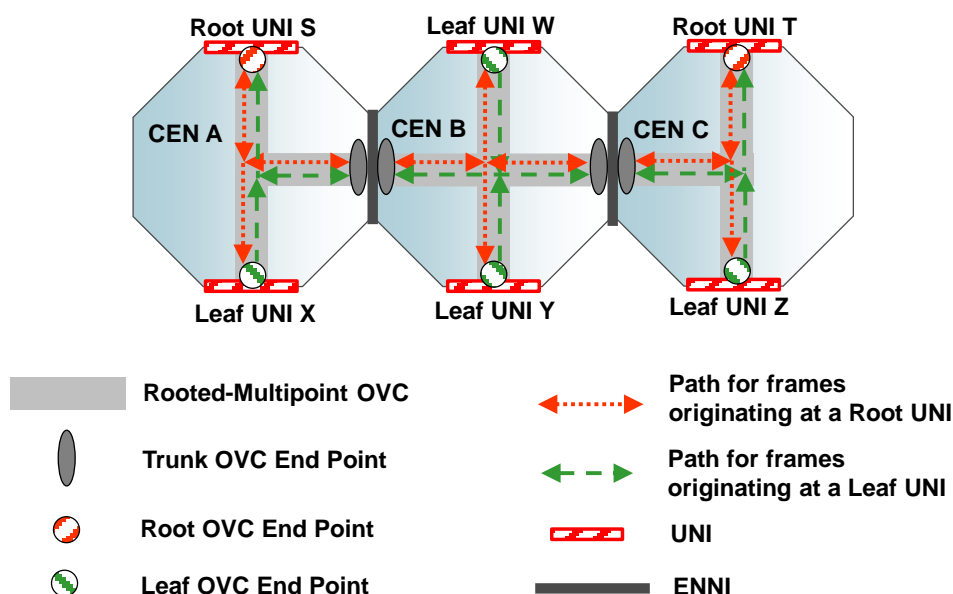| CEN C		
OVC End Point Identifier	**Root S-VLAN ID value**	**Leaf S-VLAN ID value**
China Basin C19	56	57

Table 50 – Example OVC End Point Map Service Attribute Values

B.2   Example Using a Rooted-Multipoint OVC in One Operator CEN

Figure 56 shows an example of supporting the Rooted-Multipoint EVC in Figure 54 using a Rooted-Multipoint OVC in just Operator CEN A along with Hairpin Switching in Operator CEN A. The Hairpin Switching has the effect of including the UNIs in Operator CEN B and Operator CEN C in the Rooted-Multipoint EVC. Note that Operator B and Operator C see only Point-to-Point OVCs with Root OVC End Points at the UNIs and ENNIs. However, the Subscriber and Service Provider recognize the role of each UNI in Operator CEN B and Operator CEN C as either a Root UNI or a Leaf UNI.
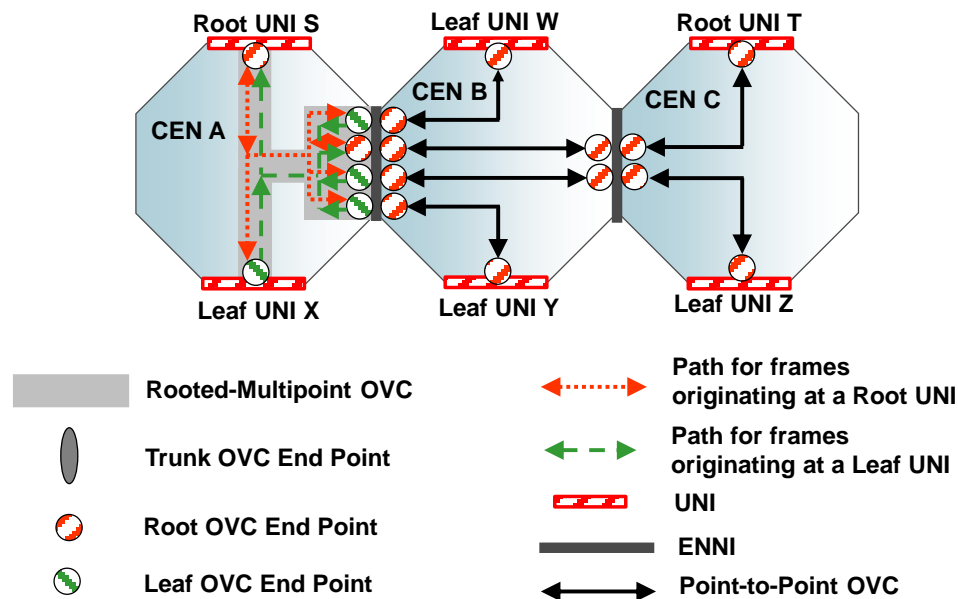
Figure 56 – Rooted-Multipoint EVC with a Rooted-Multipoint OVC in One Operator CEN

B.3   Example with All Root UNIs in One Operator CEN

Trunk OVC End Points are not always necessary to implement a Rooted-Multipoint EVC. Consider the Rooted-Multipoint EVC shown in Figure 57. In this example, Root UNI S and Root UNI T happen to be in Operator CEN A.
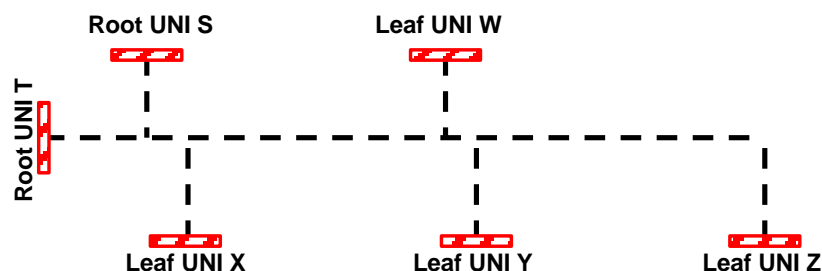
Figure 57 – Subscriber View of the Rooted-Multipoint EVC with all Root UNIs in one Operator CEN

Figure 58 shows an example of supporting the Rooted-Multipoint EVC of Figure 57 using just Root and Leaf OVC End Points. All Root UNIs are in the Operator CEN A, and the other Operator CENs have only Leaf UNIs. At each ENNI, all ENNI Frames going left to right originated at a Root UNI and all ENNI Frames going right to left originated at a Leaf UNI. This allows the use of Root and Leaf OVC End Points at the ENNIs, and a single S-VLAN ID value at the ENNIs. For example at ENNI AB, CEN A maps this single S-VLAN ID value to its Leaf OVC End Point while CEN B maps this same S-VLAN ID value to its Root OVC End Point.

In this figure, CEN A has a Leaf OVC End Point at ENNI AB because any ingress ENNI Frame mapped to this OVC End Point is the result of an ingress Service Frame at a Leaf UNI. For the same reason, CEN B has a Leaf OVC End Point at ENNI BC. CEN B has a Root OVC End Point at ENNI AB because any ingress ENNI Frame mapped to this OVC End Point is the result of an ingress Service Frame at a Root UNI. For the same reason, CEN C has Root OVC End Point at ENNI BC. Note that making the OVC End Point at UNI Z a Root OVC End Point, thus making the OVC in CEN C a Point-to-Point OVC, would also work for this example.
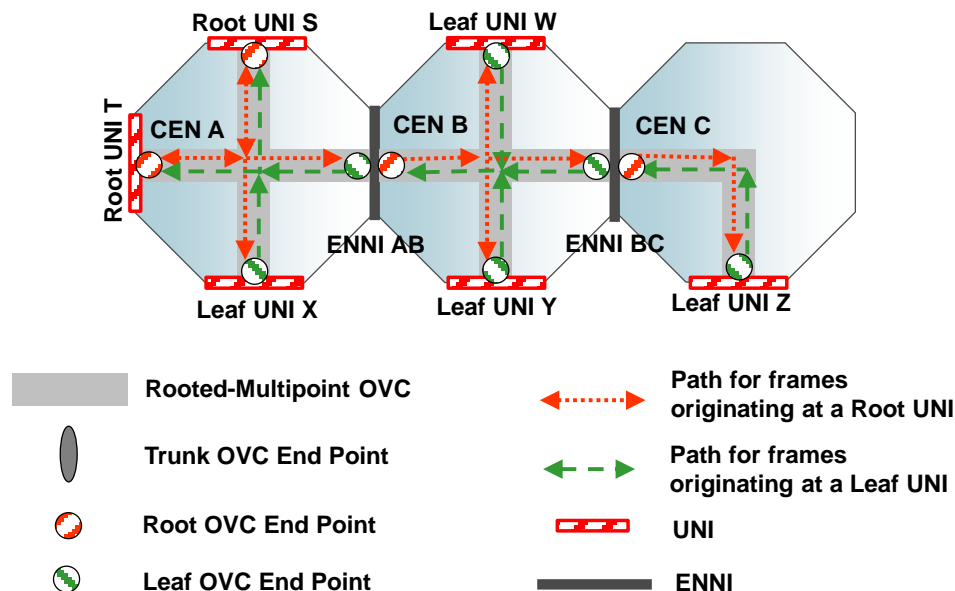
Figure 58 – Rooted-Multipoint EVC with all Root UNIs in one Operator CEN

B.4   Example Using a Bundled OVC

Figure 59 shows a Rooted-Multipoint EVC connecting 4 UNIs as seen by the Subscriber.

Figure 59 – Subscriber View of the Rooted-Multipoint EVC

Figure 60 shows an example of supporting this Rooted-Multipoint EVC using Trunk OVC End Points at the ENNIs in Operator CEN A and Operator CEN C. Operator CEN B uses a Point-to-Point Bundled OVC in this example. At each ENNI, CEN B maps the Root S-VLAN ID value

and the Leaf S-VLAN ID value to the OVC End Point. In this case, Operator CEN B need not be aware of which S-VLAN ID value represents frames that originated at a Root UNI and which S-VLAN ID value represents frame that originated at a Leaf UNI. Instead, CEN B simply passes the S-VLAN ID values unchanged between the two ENNIs as manda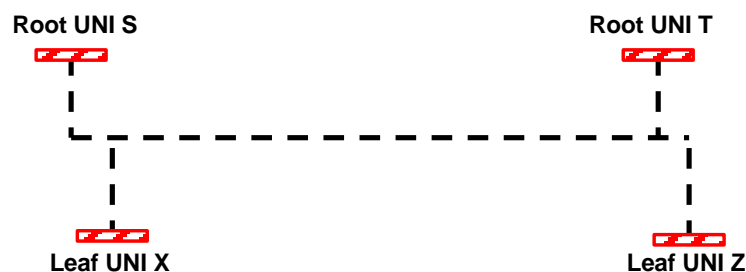ted by [R163]. CEN A and CEN C need to understand the significance of the Root S-VLAN ID value and the Leaf S-VLAN ID value.
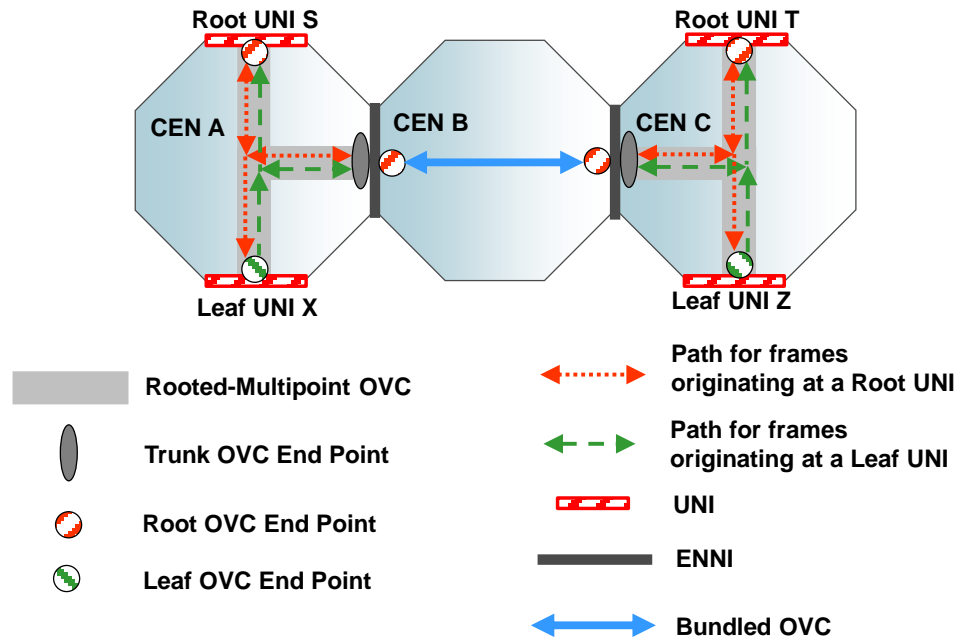
Figure 60 – Rooted-Multipoint EVC using a Bundled OVC

B.5 Example Using Hairpin Switching with Trunk OVC End Points

Figure 61 shows a Rooted-Multipoint EVC with 6 UNIs as seen by the Subscriber.
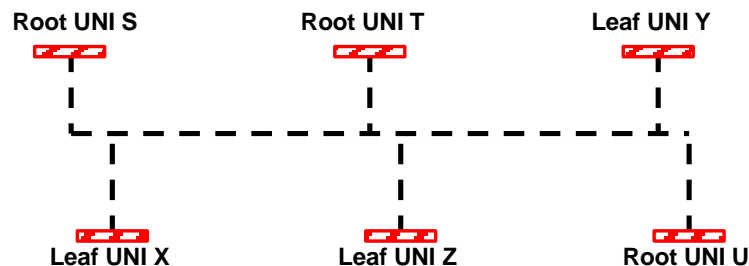
Figure 61 – Subscriber View of the Rooted-Multipoint EVC

Figure 62 shows an example of supporting this Rooted-Multipoint EVC using Hairpin Switching among the Trunk OVC End Points in CEN A. The configuration of this example would be useful

if CEN B could only support Point-to-Point OVCs. The Hairpin Switching in CEN A provides the connectivity between the UNIs in CEN C and CEN D that CEN B is unable to provide.
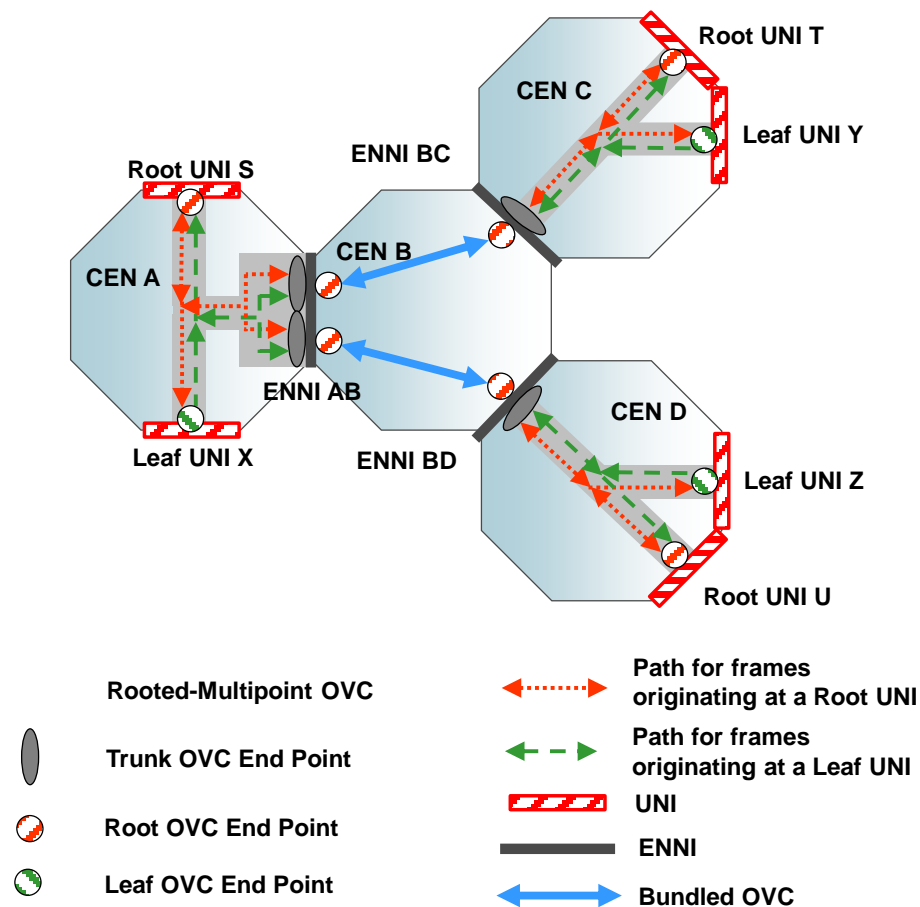
Figure 62 – Hairpin Switching with Trunk OVC End Points

Appendix C   Virtual UNI Examples (Informative)

This appendix presents examples of the use of the VUNI. The first sub-section establishes the conventions and notation used in the examples. The remaining sub-sections present the examples.

C.1   Notation and Conventions for VUNI Examples

Figure 63 shows the key to the icons used in the VUNI examples in this Appendix.
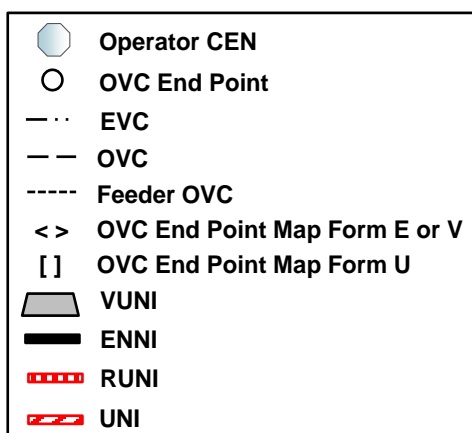
Figure 63 – Key to the Icons Used in the VUNI Examples

C.2   Example of Two EVCs to a Hub Location

Figure 64 shows the Subscriber view of the EVCs. UNI a is at the Subscriber's hub location while UNI b and UNI c are at the Subscriber's branch locations. The CE-VLAN ID/EVC Map for each UNI is shown in the figure.
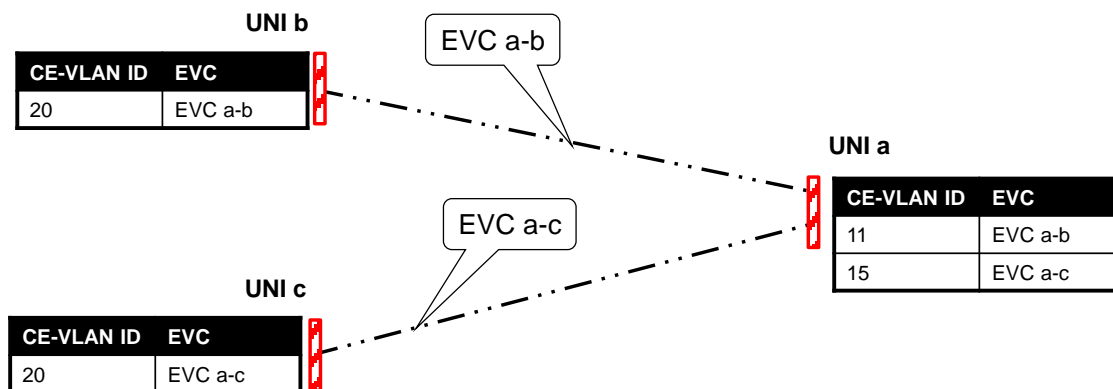
Figure 64 – Two EVCs to the Hub Location

Figure 65 shows an example of implementing the two the EVCs using a VUNI. In order to accomplish the CE-VLAN ID/EVC Map at UNI b, the OVC between UNI b and ENNI AB needs to have the OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*. Similarly, in order to accomplish the CE-VLAN ID/EVC Map at UNI c, one or both of the OVCs connecting UNI c with ENNI AB need to have the OVC CE-VLAN ID Preservation = *Strip* or *Retain*. Note that CENs B and C need not be aware of the contents of the CE-VLAN ID/EVC Map at UNI a.
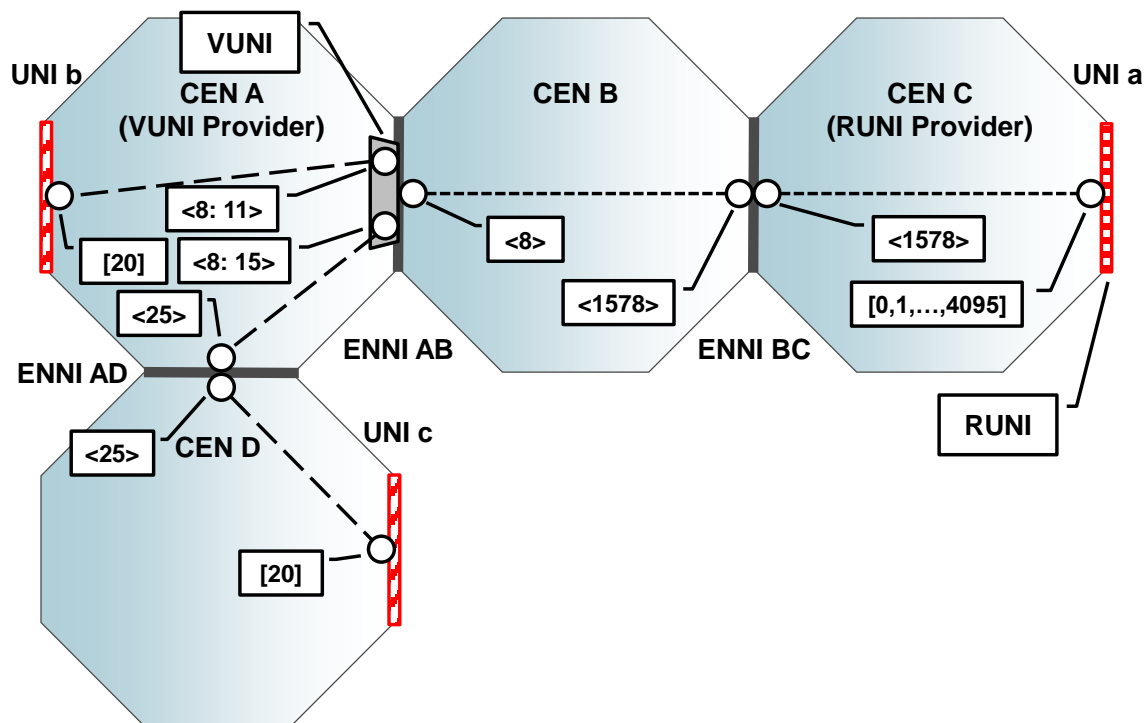
Figure 65 – Example of Implementing Two EVCs to the Hub Location with a VUNI

The EVCs in Figure 64 can also be implemented by replacing $[0,1,…,4095]$ with $[11,15]$ in Figure 65. This would allow CEN C to discard frames that would otherwise be discarded by CEN A but at the cost of having CEN C be aware of the CE-VLAN ID value of each ingress Service Frame at UNI a, e.g., the Operator of CEN C needs to configure equipment to properly process each CE-VLAN ID value.

C.3   Example of Back to Back VUNIs

Figure 66 shows the Subscriber view of three EVCs fully connecting three UNIs. The CE-VLAN ID/EVC Map for each UNI is shown in the figure.
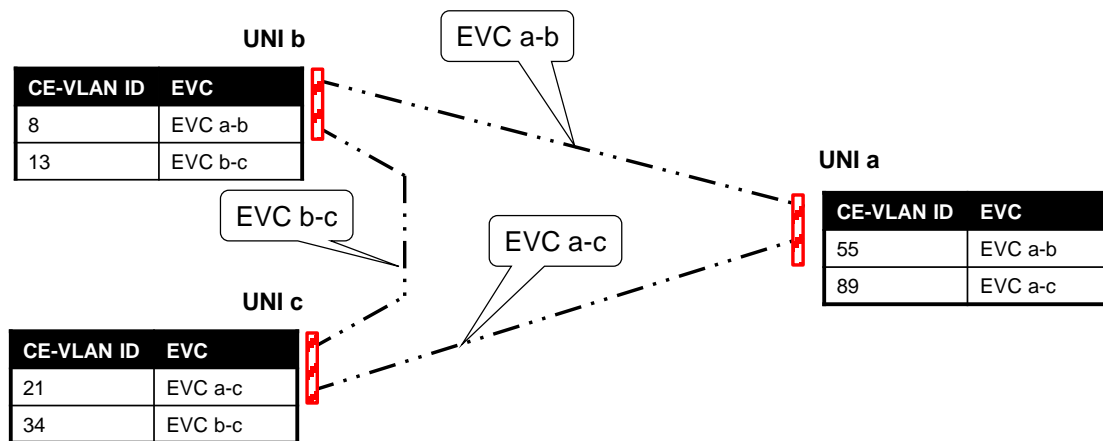
Figure 66 – Three EVCs Fully Connecting Three UNIs

Figure 67 shows the implementation of the three EVCs using back to back VUNIs in CEN B. In order to accomplish the CE-VLAN ID/EVC Maps at the UNIs, the OVCs in CEN B need to have the OVC CE-VLAN ID Preservation Service Attribute = *Strip* or *Retain*.
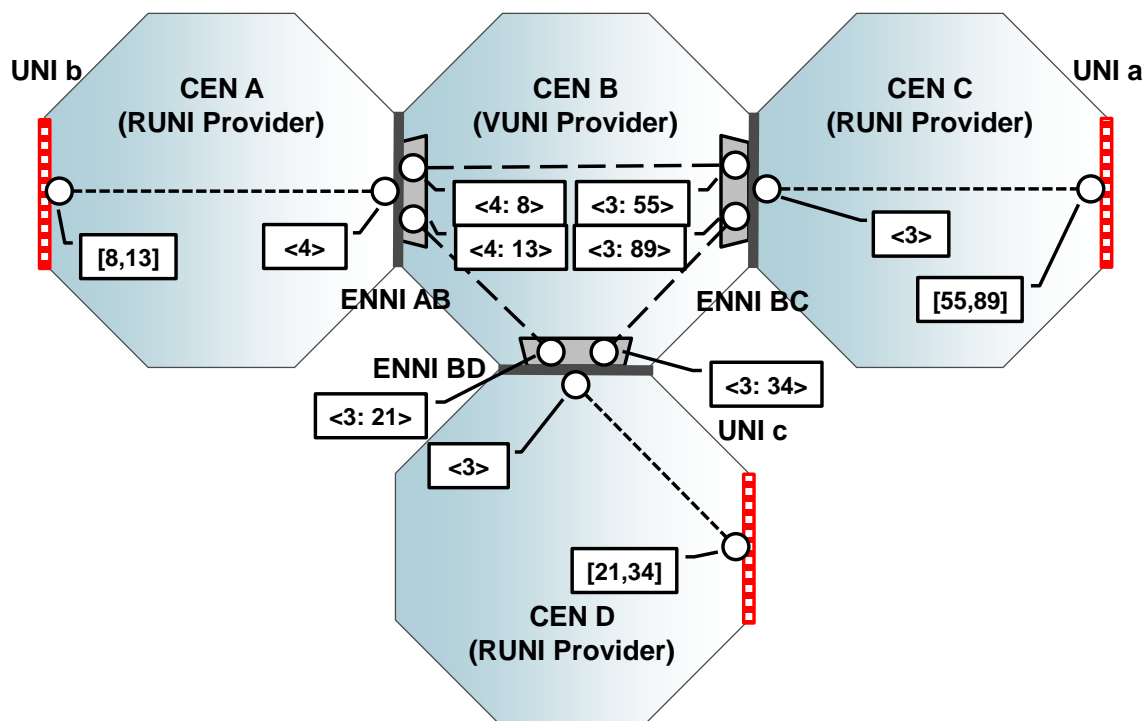
Figure 67 – Example of Implementing Three EVCs Using Back to Back VUNIs

In this example, the back to back VUNIs are in the same CEN. This is not required in general.

C.4   Example of an EVC with Bundling

Figure 68 shows the Subscriber view of a Multipoint-to-Multipoint EVC with Bundling as describe in MEF 10.3 [12]. The CE-VLAN ID/EVC Map for each UNI is shown in the figure
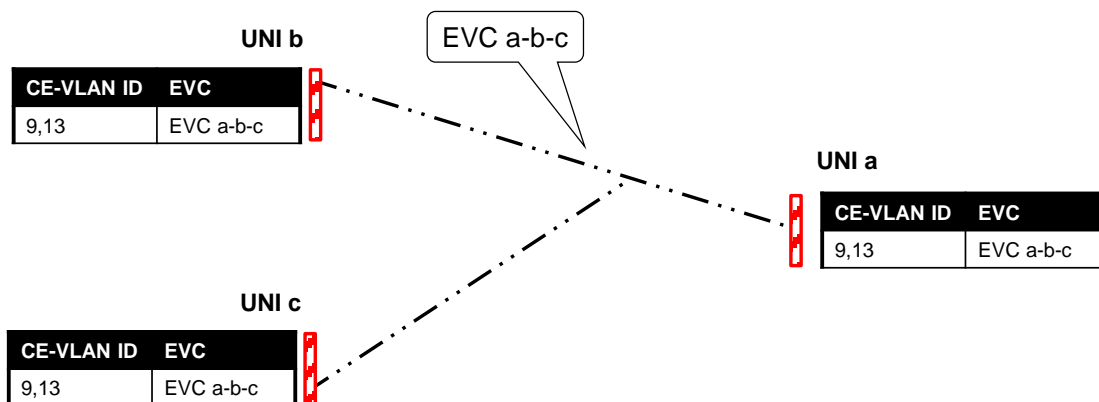
Figure 68 – Multipoint-to-Multipoint EVC with Bundling at the UNIs

Figure 69 shows the implementation of the Multipoint-to-Multipoint EVC. Note that the OVC End Points in CEN C meet [R161]. Also note that the EVC meets [R81] of MEF 10.3 [12].
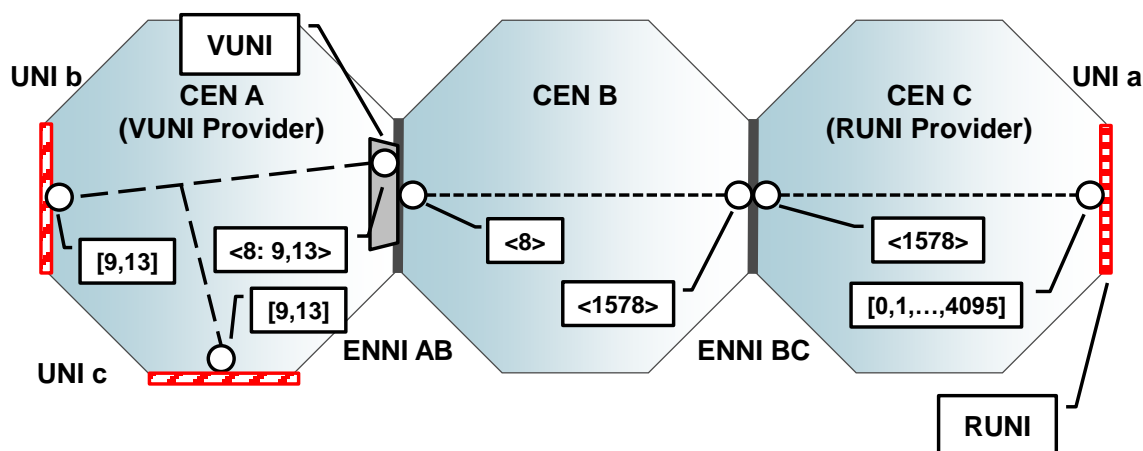
Figure 69 – Example of Implementing an EVC with Bundling at the UNIs

C.5   Example of Four EVCs to a HUB Location Using Cascaded VUNIs

Figure 70 shows the Subscriber view of the EVCs. UNI a is at the Subscriber's hub location while UNI b, UNI c, UNI d, and UNI e are at the Subscriber's branch locations. The CE-VLAN ID/EVC Map for each UNI is shown in the figure.

UNI b

CE-VLAN ID	EVC
20	EVC a-b

UNI c

CE-VLAN ID	EVC
30	EVC a-c

UNI d

CE-VLAN ID	EVC
35	EVC a-d

UNI e

CE-VLAN ID	EVC
25	EVC a-e

EVC a-b

EVC a-c

EVC a-d

EVC a-e

UNI a

CE-VLAN ID	EVC
11	EVC a-b
15	EVC a-c
35	EVC a-d
41	EVC a-e
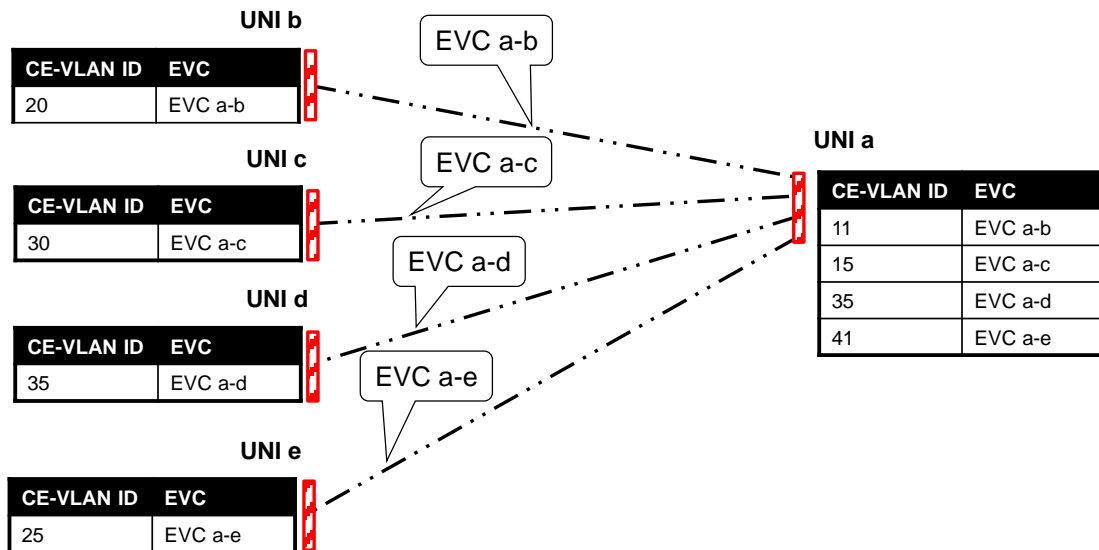
Figure 70 – Four EVCs to the Hub Location

Figure 71 shows the implementation of the four EVCs using cascaded VUNIs. With this implementation, two OVCs are used in CEN B. An advantage of this approach is that it reduces the number of OVCs in CEN B at the cost of having VUNIs in CEN A and CEN D. Note that one way to achieve the CE-VLAN ID/EVC Map at UNI d is to have the OVC connecting UNI d to the ENNI in CEN D have the OVC CE-VLAN ID Preservation Service Attribute = *Preserve*.
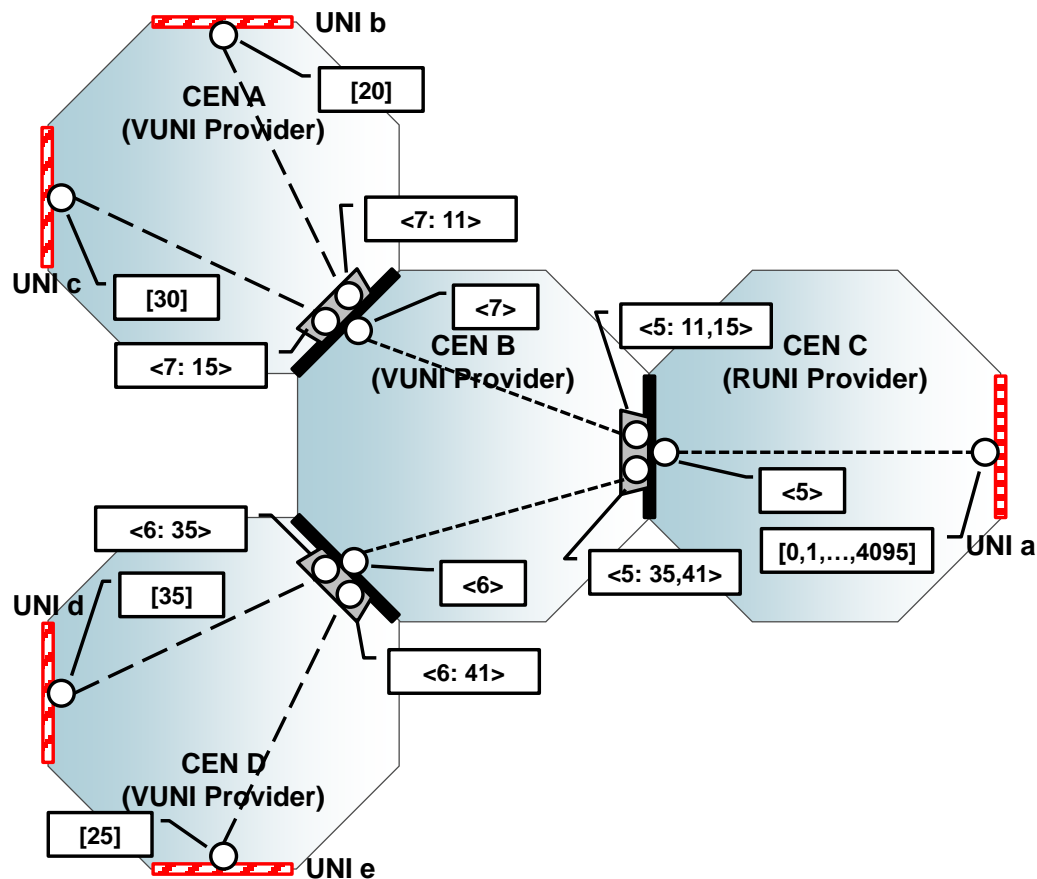
Figure 71 – Example of Implementing Four EVCs Using Cascaded VUNIs

Because of the requirements on the UTA in MEF 28 [19], cascading of VUNIs was not allowed by MEF 28. Such cascading is allowed by this document by using Feeder OVCs.

C.6   Example of a Rooted-Multipoint EVC with a VUNI

Figure 72 shows the Subscriber view of the EVCs. There are two EVCs associating UNI a. UNI a is a Root for EVC a-b-c and UNI a is a Leaf for EVC a-d-e-f. The role for each of the other UNIs and the CE-VLAN ID/EVC Map for each UNI are shown in the figure.
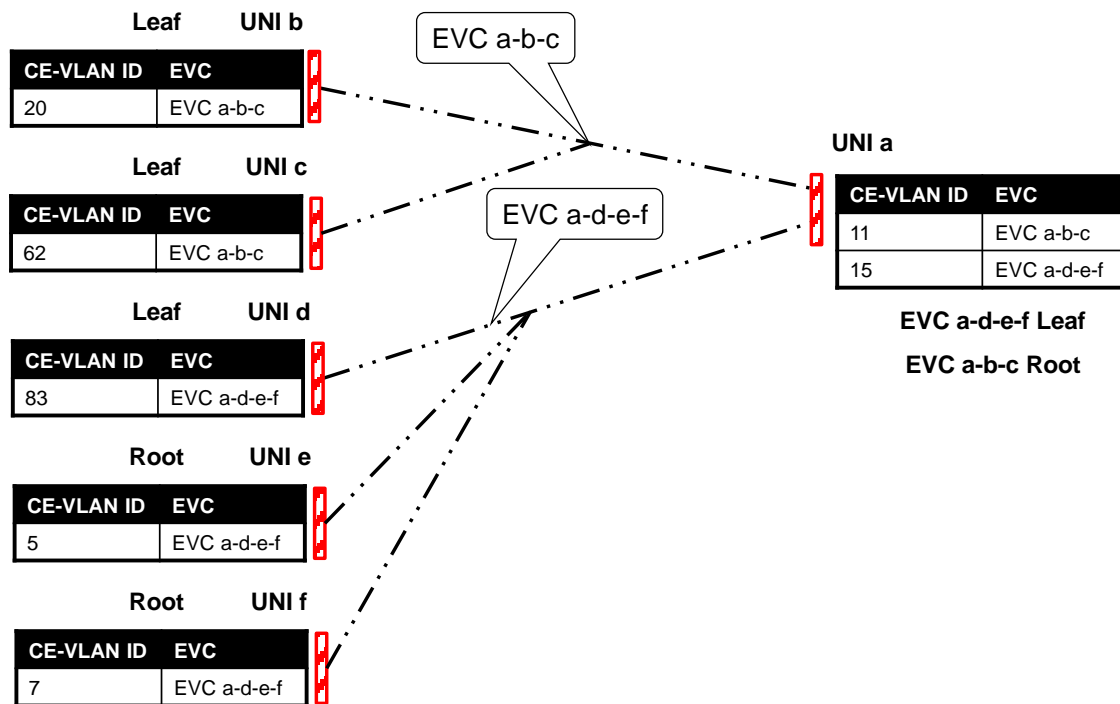
Figure 72 – Two Rooted-Multipoint EVCs

Figure 73 shows an example of implementing the two Rooted-Multipoint EVCs with a VUNI for which UNI a is the Remote UNI. The Role value for the OVC End Point in the VUNI that is supporting EVC a-b-c is the same as the role of the RUNI for EVC a-b-c. The Role value for the OVC End Point in the VUNI that is supporting EVC a-d-e-f is the same as the role of the RUNI for EVC a-d-e-f. This mirroring of the RUNI Role by the OVC End Point in a VUNI occurs when the OVC End Point in the VUNI supports a single EVC and is consistent with [R136].

®   OVC End Point with Role = *Root*

Ⓛ   OVC End Point with Role = *Leaf*   {R, L} OVC End Point Map Form T

Ⓣ   OVC End Point with Role = *Trunk*

Figure 73 – Example of Implementing Rooted-Multipoint EVCs with a VUNI
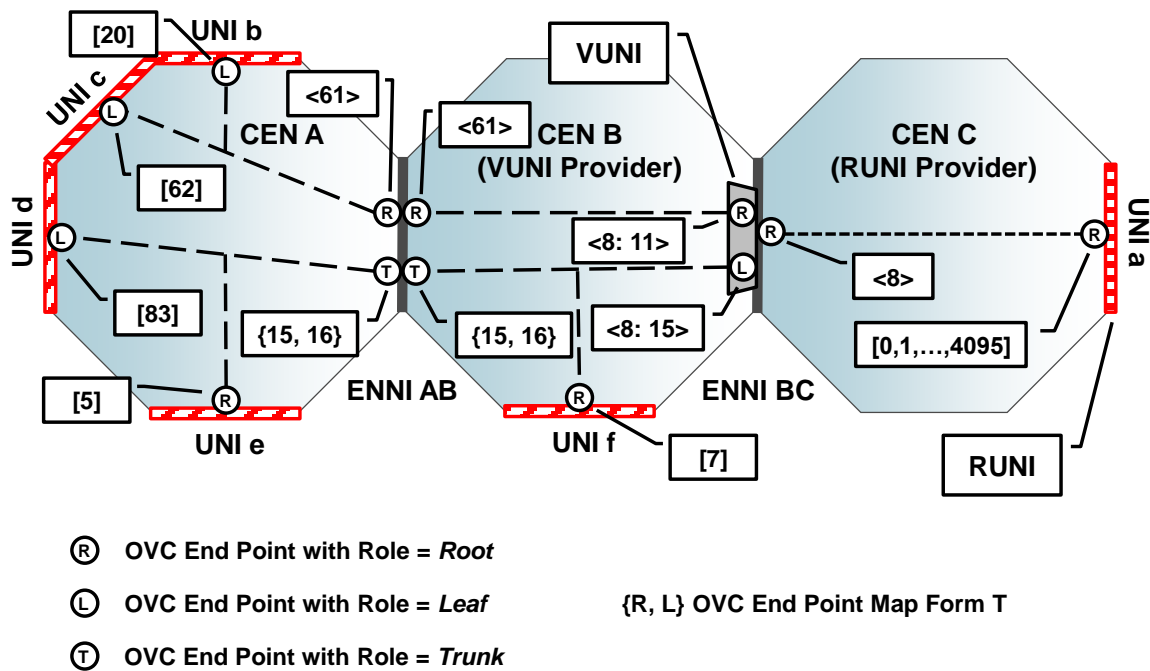
Appendix D   VLAN Tags in Delivered Egress Frames (Informative)

There are a number of requirements throughout the document that relate to the content of delivered egress EI frames – that is, frames transmitted by an operator over a UNI or ENNI that are a result of a corresponding ingress EI Frame. In particular, it is important that the number and content of VLAN tags is agreed between the Operator and the SP/SO, as this enables the SP/SO to link together multiple OVCs at an ENNI in order to create a higher-layer OVC or EVC.

Throughout this Appendix, "egress frame" is used as shorthand for "delivered egress frame".

There are several factors that can affect the way VLAN tags are used in an egress frame:

- The VLAN tags that were present in the corresponding ingress frame

- The location of the OVC End Point where the corresponding ingress frame was received; i.e. at a UNI, a VUNI, or an ENNI but not in a VUNI

- Whether the OVC is a Bundled OVC (see Section 16.5.7)

- The value of the OVC CE-VLAN Preservation Service Attributes for CE-VLAN ID, CE-VLAN PCP and CE-VLAN DEI (see Sections 12.7, 12.8 and 12.9)

- The OVC End Point Map (see Section 16.5) at the OVC End Point where the egress frame is being transmitted

This appendix summarizes the requirements that dictate the VLAN tags that are present in egress EI Frames, and the VLAN IDs used in those VLAN tags. Appendix D.1 describes whether the egress frame contains an S-VLAN tag, and the requirements on the S-VLAN ID used. Appendix D.2 describes whether the egress frame contains a C-VLAN tag, and the requirements on the C-VLAN ID used. Note that an egress frame may contain neither, one or both tags; so both sections need to be consulted.

Note that when a VLAN tag is present, it contains not only the VLAN ID, but also the PCP and DEI fields. There are various requirements governing how these are set – notably the preservation attributes (see Sections 12.8, 12.9 and 12.10) and the Egress Map attribute (see Section 16.8); however, these are not discussed further in this appendix.

To convey the information succinctly, the abbreviations introduced in Section 12.7 are reused in this appendix:

- @UNI: OVC End Point that is located at a UNI

- @VUNI: OVC End Point that is located at an ENNI and that is in a VUNI

- @ENNI: OVC End Point that is located at an ENNI and that is not in a VUNI

D.1   S-VLAN Tags

It is relatively straightforward to determine whether an egress frame should have an S-Tag, and if so, the S-VLAN ID it should contain:

- Egress frames being transmitted over a UNI (that is, at an @UNI) never include an S-Tag

- Egress frames being transmitted over an ENNI that are mapped to an OVC End (that is, at an @VUNI or @ENNI) always include an S-Tag.

In the latter case, the S-VLAN ID to include in the S-Tag is determined as follows:

- If the OVC is a bundled OVC, then every OVC End Point is at an ENNI and all have OVC End Point Map Service Attribute values of Form E, with the same set of S-VLAN IDs (see Section 16.5.7). In this case, the S-VLAN ID used in an egress frame is the same as the S-VLAN ID present in the corresponding ingress frame (see [R163]). Since all of the OVC End Point Map Service Attribute values contain the same set of S-VLAN IDs, this also conforms to [R140].

- For OVC End Points with Trunk role, the OVC End Point Map Service Attribute is of Form T (see [R141]) and the S-VLAN ID to use in egress frames is determined by the role of the corresponding ingress OVC End Point (see [R38], [R39] and [R143]).

- For other OVC End Points, the OVC End Point Map Service Attribute value contains only a single S-VLAN ID and therefore this is the one that is used (see [R140] and [R146]).

D.2   C-VLAN Tags

The requirements that describe whether an egress frame contains a C-Tag, and if so, the C-VLAN ID to use, are much more complex than in the case of S-VLAN tags. Primarily this is because Service Frames can be Untagged or C-Tagged, whereas delivered ENNI Frames are always S-Tagged.

The requirements are summarized in Table 51. Each row describes the requirements for egress frames that meet certain criteria: the first two columns describe the location of the OVC End Point where the corresponding ingress frame was received, and the tags that were present on that frame; the third column describes the location of the OVC End Point where the egress frame is being transmitted; and the fourth column describes the value of the OVC CE-VLAN ID Preservation Service Attribute for the OVC.

For brevity, frames are described in the table as "C-Tagged" or "Un-C-Tagged":

- C-Tagged: A Tagged Service Frame (see MEF 10.3 [12]) or a Double Tagged ENNI Frame (see Section 9.3)

- Un-C-Tagged: An Untagged Service Frame (see MEF 10.3 [12]) or a Single Tagged ENNI Frame (see Section 9.3)

Note that in all cases where OVC CE-VLAN ID Preservation Service Attribute is set to *Strip* or *Retain*, the OVC End Point Map Service Attribute value at an @UNI or @VUNI can only contain a single C-VLAN ID (see [R148] and [R155]); and therefore in these cases, the requirements in the table can refer unambiguously to "the CE-VLAN ID in the End Point Map".

Location of Ingress OVC End Point	Tags on Ingress Frame	Location of Egress OVC End Point	OVC CE-VLAN ID Preservation	Requirements on C-Tag in Egress Frames
Any	Any	@UNI	*Strip* or *Retain*	Un-C-Tagged if the CE-VLAN ID in the OVC End Point Map Service Attribute value at the egress OVC End Point matches the Operator UNI Default CE-VLAN ID Service Attribute value at the egress OVC End Point ([R156]); otherwise C-Tagged with the CE-VLAN ID in the OVC End Point Map Service Attribute value ([R157], [R154])
Any	Any	@VUNI	*Strip* or *Retain*	Un-C-Tagged if the CE-VLAN ID in the OVC End Point Map Service Attribute value at the egress OVC End Point matches the VUNI Default ENNI CE-VLAN ID Service Attribute value at the egress OVC End Point ([R149]); otherwise C-Tagged with the ENNI CE-VLAN ID in the OVC End Point Map Service Attribute value ([R150], [R147])
@UNI or @VUNI	Un-C-Tagged	@ENNI	*Strip* or *Retain*	Un-C-Tagged ([R44])
@ENNI	Un-C-Tagged	@ENNI	*Strip* or *Retain*	Un-C-Tagged ([R75])
@UNI or @VUNI	C-Tagged	@ENNI	*Strip*	Un-C-Tagged ([R44]). Note that if OVC CE-VLAN PCP Preservation Service Attribute value or OVC CE-VLAN DEI Preservation Service Attribute value is *Enabled*, then the OVC CE-VLAN ID Preservation Service Attribute value cannot be *Strip* ([R46], [R48])
@UNI or @VUNI	C-Tagged	@ENNI	*Retain*	C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame ([R44], [R45], [R47]). Note that the OVC End Point Map Service Attribute value at an egress @ENNI does not list any ENNI CE-VLAN IDs.
@ENNI	C-Tagged	@ENNI	*Strip* or *Retain*	C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame ([R76], [R45], [R47])

Location of Ingress OVC End Point	Tags on Ingress Frame	Location of Egress OVC End Point	OVC CE-VLAN ID Preservation	Requirements on C-Tag in Egress Frames
Any	Un-C-Tagged	@UNI	*Preserve*	* Un-C-Tagged if all CE-VLAN IDs map to the @UNI (see Section 16.5.4) ([R42], [R161]); otherwise either un-C-Tagged, or C-tagged with a C-VLAN ID equal to any CE-VLAN ID in the End Point Map or equal to 0 if the End Point Map includes the Operator UNI Default CE-VLAN ID at the egress OVC End Point ([R150])
Any	C-Tagged	@UNI	*Preserve*	* C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame, if all CE-VLAN IDs map to the @UNI (see Section 16.5.4) ([R42], [R161]) or if the C-VLAN ID in the corresponding ingress frame was in the range 1,…,4094 and is not equal to the Operator UNI Default CE-VLAN ID Service Attribute value at the egress OVC End Point ([R43]); otherwise either un-C-Tagged, or C-tagged with a C-VLAN ID equal to any CE-VLAN ID in the End Point Map or equal to 0 if the End Point Map includes the Operator UNI Default CE-VLAN ID at the egress OVC End Point ([R150])
Any	Un-C-Tagged	@VUNI	*Preserve*	* Un-C-Tagged if all ENNI CE-VLAN IDs map to the @VUNI (see Section 16.5.3) ([R42], [R161]); otherwise either un-C-Tagged, or C-tagged with a C-VLAN ID equal to any CE-VLAN ID in the End Point Map or equal to 0 if the End Point Map includes the VUNI Default ENNI CE-VLAN ID at the egress OVC End Point ([R144])

Location of Ingress OVC End Point	Tags on Ingress Frame	Location of Egress OVC End Point	OVC CE-VLAN ID Preservation	Requirements on C-Tag in Egress Frames
Any	C-Tagged	@VUNI	*Preserve*	* C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame, if all ENNI CE-VLAN IDs map to the @VUNI (see Section 16.5.3) ([R42], [R161]) or if the C-VLAN ID in the corresponding ingress frame was in the range 1,…,4094 and is not equal to the VUNI Default ENNI CE-VLAN ID at the egress OVC End Point ([R43]); otherwise either un-C-Tagged, or C-tagged with a C-VLAN ID equal to any CE-VLAN ID in the End Point Map or equal to 0 if the End Point Map includes the VUNI Default ENNI CE-VLAN ID at the egress OVC End Point ([R144])
@UNI or @VUNI	Un-C-Tagged	@ENNI	*Preserve*	Un-C-Tagged ([R42], [R43])
@ENNI	Un-C-Tagged	@ENNI	*Preserve*	Un-C-Tagged ([R75], [R42], [R43])
@UNI	C-Tagged	@ENNI	*Preserve*	* C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame, if all CE-VLAN IDs map to the @UNI (see section 16.5.4) ([R42], [R161]), or if the C-VLAN ID in the corresponding ingress frame was in the range 1,…,4094 ([R43]); otherwise C-tagged with the C-VLAN ID equal to the value of the Operator Default UNI CE-VLAN ID Service Attribute at the ingress UNI, if either the OVC CE-VLAN PCP Preservation Service Attribute value or the OVC CE-VLAN DEI Preservation Service Attribute value is *Enabled* ([R43], [R45], [R47]); otherwise, either un-C-Tagged or C-tagged with the C-VLAN ID equal to the value of the Operator Default UNI CE-VLAN ID Service Attribute at the ingress UNI ([R43]).

Location of Ingress OVC End Point	Tags on Ingress Frame	Location of Egress OVC End Point	OVC CE-VLAN ID Preservation	Requirements on C-Tag in Egress Frames
@VUNI	C-Tagged	@ENNI	*Preserve*	* C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame, if all CE-VLAN IDs map to the @VUNI (see section 16.5.3) ([R42], [R161]), or if the C-VLAN ID in the corresponding ingress frame was in the range 1,…,4094 ([R43]); otherwise C-tagged with the C-VLAN ID equal to the value of the Operator Default UNI CE-VLAN ID Service Attribute at the ingress UNI, if either the OVC CE-VLAN PCP Preservation Service Attribute value or the OVC CE-VLAN DEI Preservation Service Attribute value is *Enabled* ([R43], [R45], [R47]); otherwise, either un-C-Tagged or C-tagged with the C-VLAN ID equal to the value of the VUNI Default ENNI CE-VLAN ID Service Attribute at the ingress VUNI ([R43]).
@ENNI	C-Tagged	@ENNI	*Preserve*	C-Tagged with the C-VLAN ID equal to the C-VLAN ID in the corresponding ingress frame ([R76], [R42], [R43], [R45], [R47])

Note that when OVC CE-VLAN ID Preservation Service Attribute value is set to *Preserve*, the requirements do not fully specify in all cases whether the egress frame contains a C-Tag, and if so what the C-VLAN ID value is. These cases are marked with a "*" in the table.

Table 51 – Requirements for C-Tags in Delivered Egress EI Frames

Appendix E   Super Operator Examples (Informative)

E.1   Super Operator Roles and ENNI Use Example

This example illustrates the how an Operator can have multiple roles and how an ENNI use can vary with OVC.

Figure 74 shows the Subscriber view of the Multipoint-to-Multipoint EVC for this example.
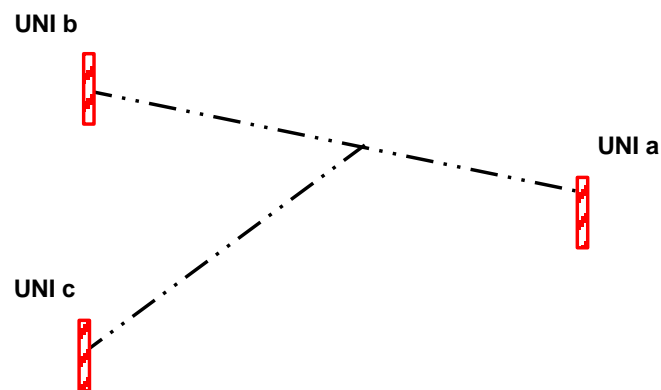
Figure 74 – Subscriber View of the Multipoint-to-Multipoint EVC

For this example the Service Provider uses Operator A and Operator B as shown in Figure 75. From the point of view of the Service Provider, OVC Service Attribute values need to be established with Operator A and Operator B. In particular, the Service Provider and Operator B agree on the Operator Service Attribute values for the Multipoint-to-Multipoint OVC shown in Figure 75.
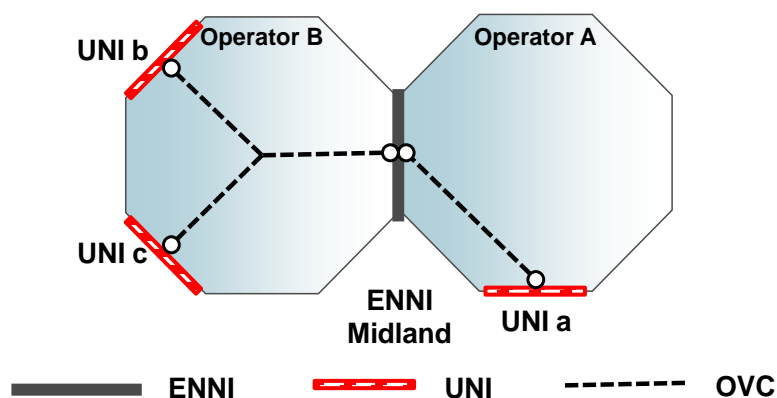
Figure 75 – Service Provider View

But in this example, Operator B's CEN does not reach UNI b or ENNI Midland. In this case Operator B, acting as a Super Operator, contracts with Operator C and Operator D as shown in

Figure 76 to reach UNI b and ENNI Midland. In this case, Operator B, acting as the Super Operator, needs to establish Operator Service Attribute values with Operator C and Operator D. Note that there is a Multipoint-to-Multipoint OVC in CEN B in Figure 76. Operator B is responsible to establish the proper behaviors of this OVC so that the Multipoint-to-Multipoint OVC established with the Service provider in Figure 75 has the proper Service Attribute values.
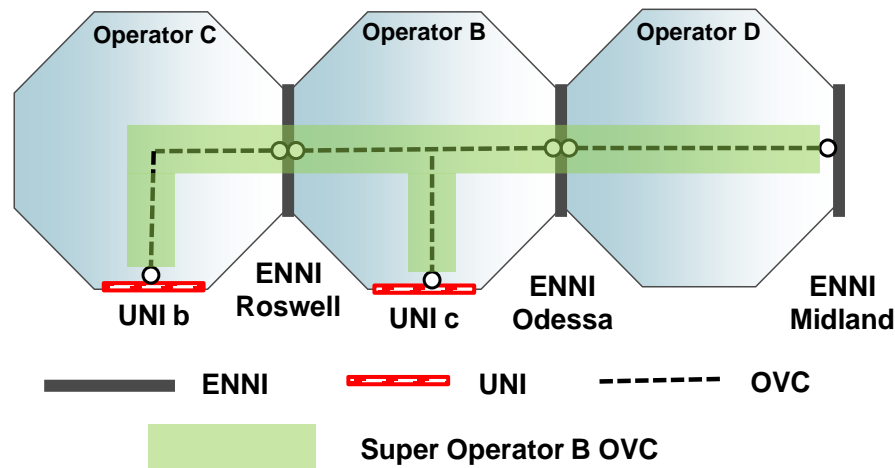
Figure 76 – Super Operator B View

Note that Operator B plays two roles in the above example: Operator B is both the Super Operator and is one of the Operators with whom the Super Operator has contracted. Note also that Operator B has different ENNIs for each of its roles. As Super Operator, B has an ENNI at Midland, and UNIs at UNI b and UNI c. As an Operator contracting to the Super Operator, B has ENNIs at Roswell and Odessa and a UNI at UNI c.

In general, the ENNI for a Super Operator can vary on an OVC by OVC basis. For the same Super Operator, the exact same physical point can be an ENNI for some of the Super Operator's OVCs and an interior point to other OVCs of the same Super Operator. For example, suppose a second Service Provider contracts with Operator B and Operator E for a point-to-point EVC between UNI d and UNI e, with an Operator boundary at ENNI Paris. In order to reach ENNI Paris, Operator B, acting as a Super Operator, contracts with Operator A, and in order to reach Operator A, Super Operator B also contracts with Operator D. The result is shown in Figure 77. Note in particular that Midland is an ENNI for the OVC provided by Super Operator B to Service Provider 1, but it is an interior point for the OVC provided by the same Super Operator B to Service Provider 2 (the ENNI is at Paris for that OVC.)
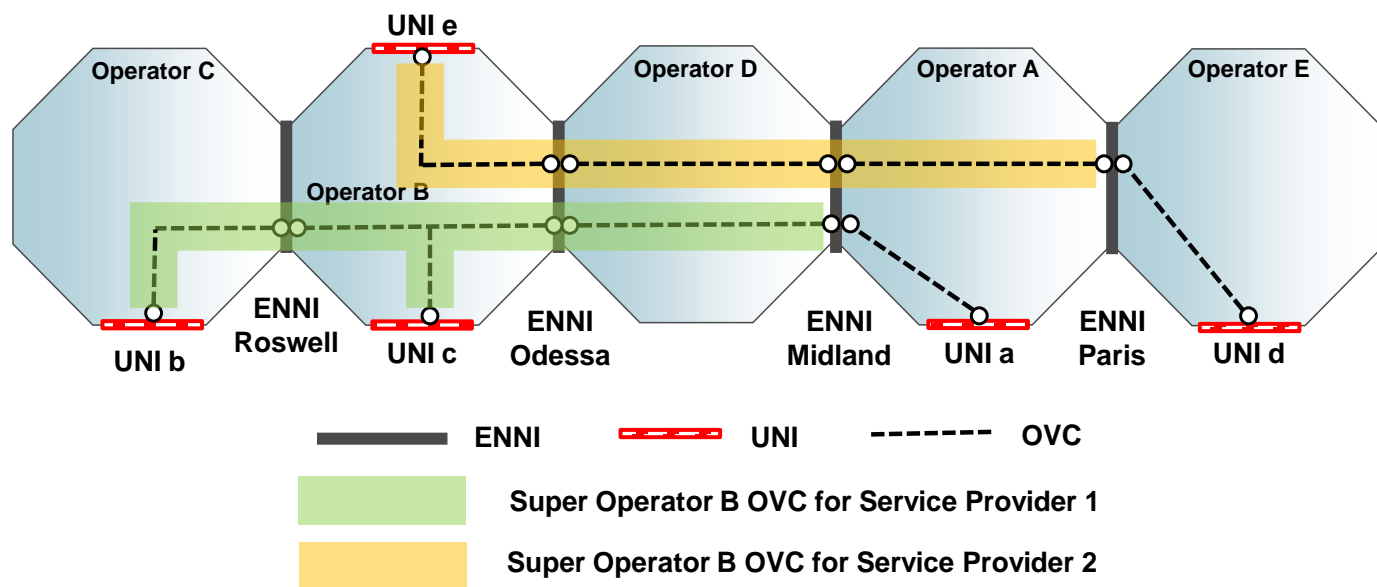
Figure 77 – Super Operator B View with Different ENNIs

The relationship between a Super Operator and an underlying Operator can result in an ENNI which the Super Operator shares with other SP/SOs that are clients of the underlying Operator. For example, suppose that Service Provider 1 contracts with Operators A and B as per Figure 75, and that Operator B, acting as a Super Operator, subcontracts with Operators C and D as per Figure 76. Suppose further that Service Provider 3 contracts with Operators A and D for an EVC running from UNI f to UNI g, with an Operator boundary at ENNI Midland. The result is shown in Figure 78.
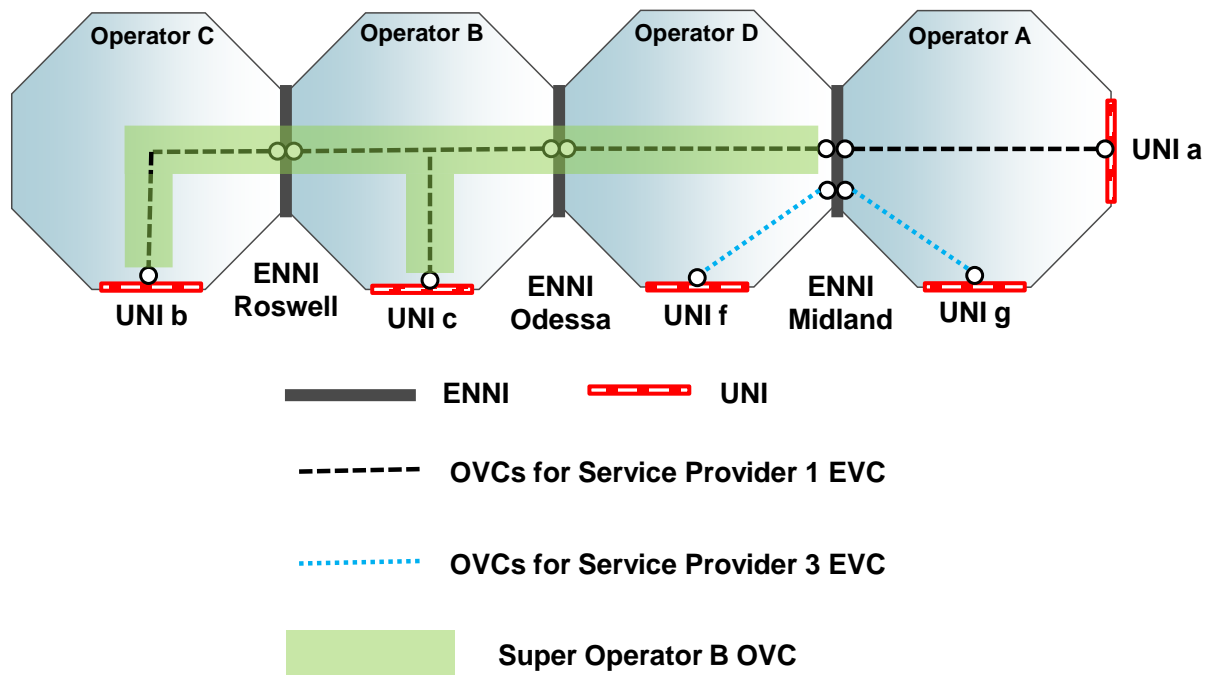
Figure 78 – Shared ENNI

As seen in Figure 78, Operator D has provided one OVC with an OVC End Point at ENNI Midland to Super Operator B, and has provided another OVC with an OVC End Point at the same ENNI Midland to a different client, namely Service Provider 3. Super Operator B is thus sharing its side of ENNI Midland with other SP/SOs, since there exist OVCs to the same side of the ENNI that are outside of Super Operator B's responsibility (the OVC from UNI f to ENNI Midland in Figure 78).

An alternative relationship between a Super Operator and an underlying Operator could be arranged, in which the underlying Operator agrees to provide OVCs to the ENNI exclusively to the Super Operator. In such a case the Super Operator would not share its side of the ENNI with any other SP/SO, in the sense that every OVC to the Super Operator's side of the ENNI will result in at least some piece that is the Super Operator's responsibility. As an example, suppose the Super Operator B and Operator D had such an agreement with regard to ENNI Midland, so that Operator D would provide OVCs to ENNI Midland exclusively to Super Operator B. In this case, Service Provider 3 sees ENNI Midland as a boundary between Operators B and A, and so Service Provider 3 would contract with Operators A and B for its EVC. Operator B, acting as a Super Operator, would subcontract with Operator D and the result is in Figure 79.
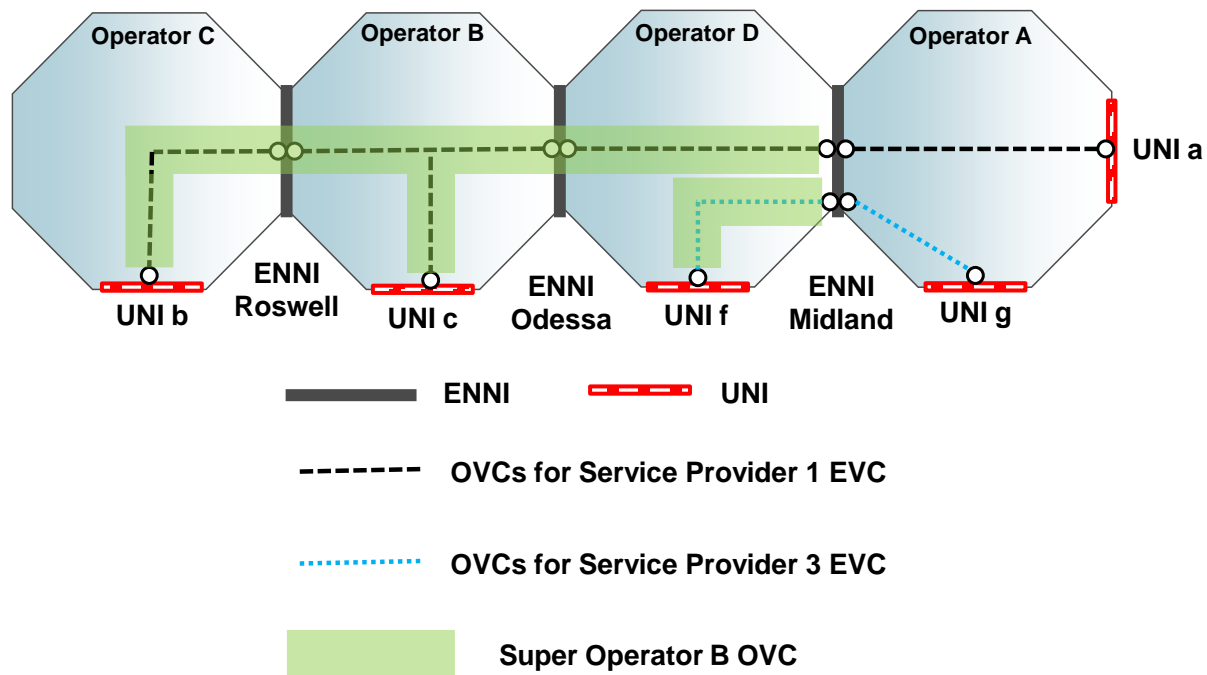
Figure 79 – Unshared ENNI

When a Super Operator arranges for an unshared ENNI with an underlying Operator, then the Super Operator will generally have a greater stake in the underlying physical characteristics of the ENNI. See Section 8.4 for details. In a sense, the Super Operator is acting to the Super Operator's clients as if the ENNI is its own physical ENNI, just as a Service Provider acts to its Subscriber as if the UNI is its own physical UNI, regardless of whether the UNI is actually provided by the Service Provider itself or through a contracted Operator. Also note that while an ENNI could be shared or unshared in the sense described above, a UNI must always be unshared. See Section 8.12 for details.

E.2 Super Operator with a VUNI Example

This example shows multiple levels of Super Operator including a VUNI. Figure 80 shows the Subscriber view of two EVCs to a hub location that are provided by the Service Provider.
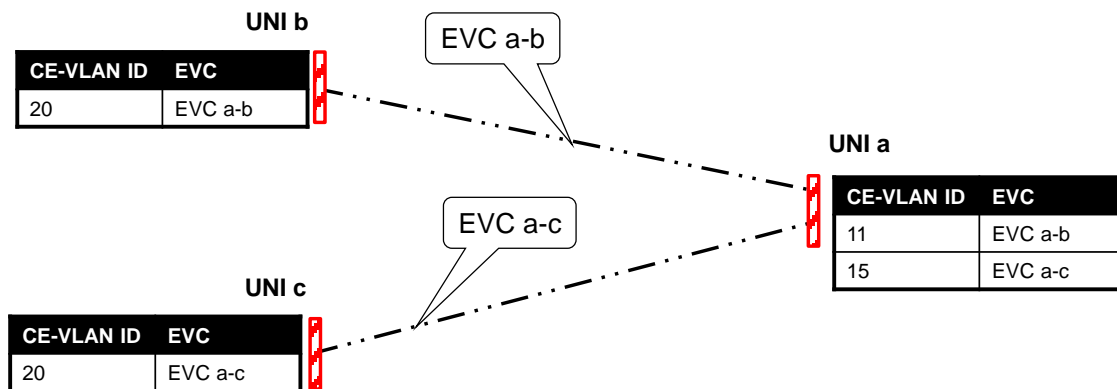
Figure 80 – Two EVCs to the Hub Location for a Super Operator Example

The Service Provider contracts with Operator A and Operator B to instantiate the EVCs via four OVCs as shown in Figure 81.
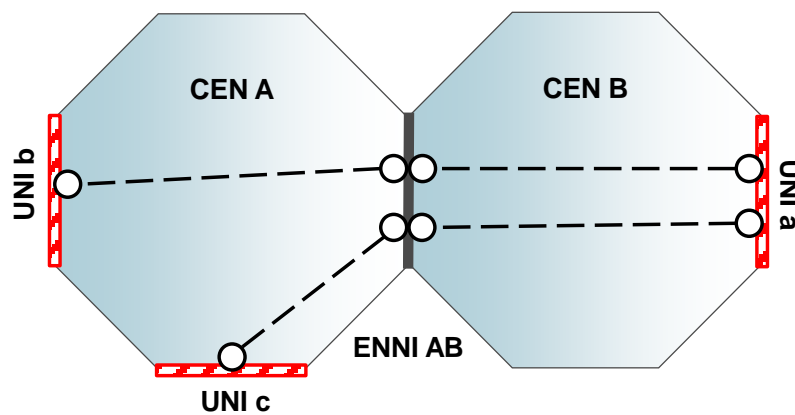
Figure 81 – Service Provider View

But it turns out that CEN owned by Operator B, CEN B, cannot reach UNI a. Thus Operator B, acting as Super Operator, contracts with Operator C to reach UNI a. Furthermore, in order to retain functionality, Operator B negotiates with Operator C to provide UNI a as an RUNI and Operator B implements a VUNI (see Section 15). The view of Operator B acting as a Super Operator is shown in Figure 82.
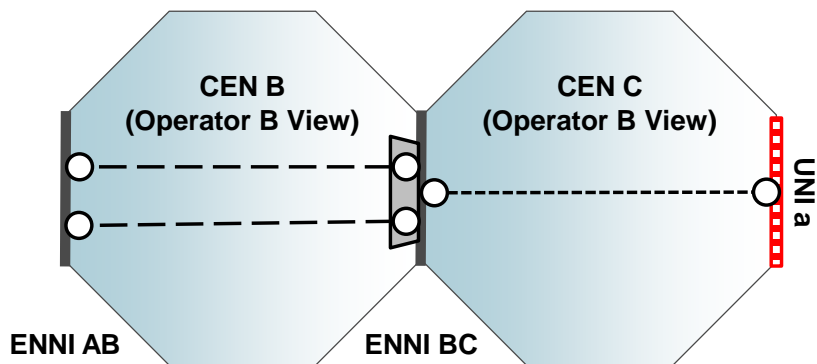
Figure 82 – View of Operator B Acting as a Super Operator

Finally, it turns out that the CEN owned by Operator C, CEN C, can only get close to UNI a. Consequently, acting as a Super Operator, Operator C contracts with Operator D to finally reach UNI a with Operator D providing UNI a as an RUNI. The view of Operator C acting as a Super Operator is shown in Figure 83.
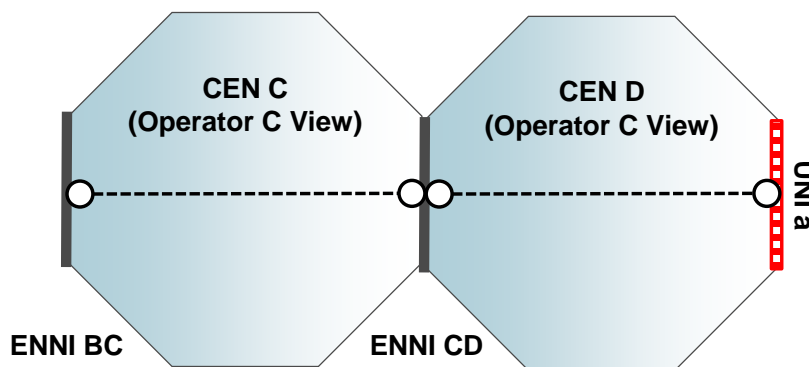
Figure 83 – View of Operator C Acting as a Super Operator

Figure 84 shows all of the CENs involved in supporting the two EVCs and the responsibilities of Super Operator B and Super Operator C.
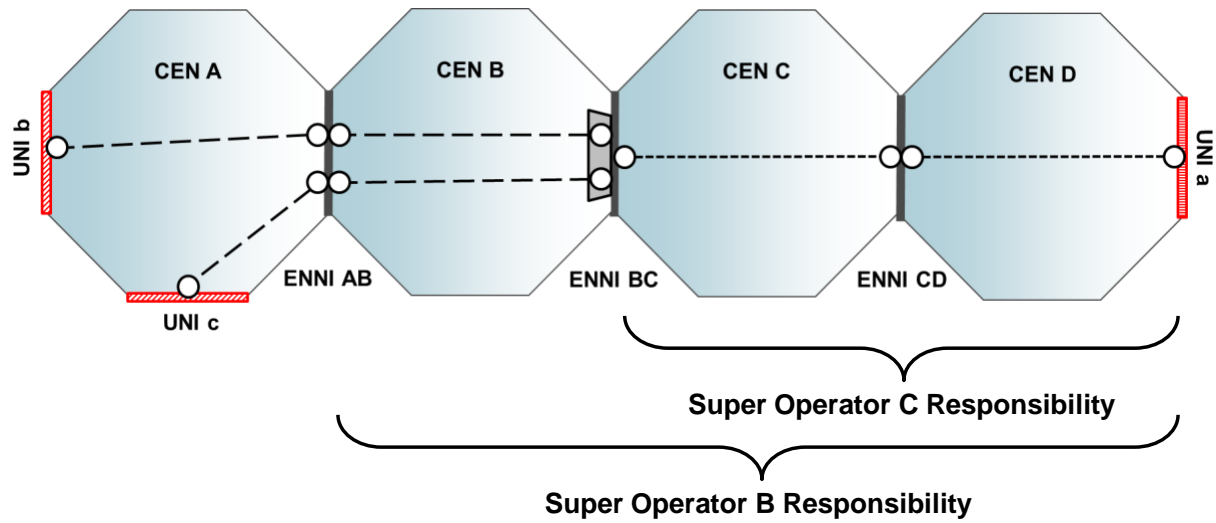
Figure 84 – All of the CENs Supporting the Two EVCs

Appendix F OVC End Point Egress Map Example (Informative)

In this example, the Service Provider is implementing the EVC shown in Figure 85 with Class of Service Names *Good*, *Super*, and *Best*.
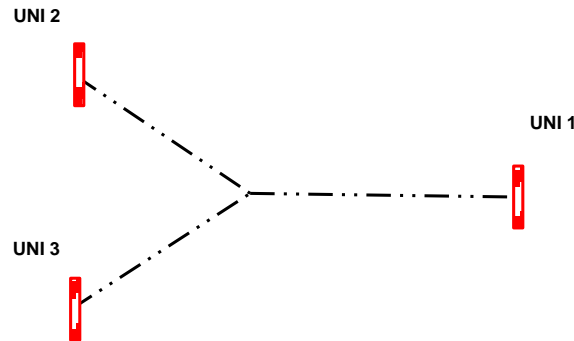
Figure 85 – EVC for the OVC End Point Egress Map Example

Figure 86 shows the three Operator CENs needed to achieve connectivity among the three UNIs along with the Class of Service Identifier value to Class of Service Name mappings for each CEN.

C-Tag PCP Value	Class of Service Name
1	Rock
3	Paper
5	Scissors
other	Discard

S-Tag PCP Value	Class of Service Name
1	Rock
3	Paper
5	Scissors
other	Discard

S-Tag PCP Value	Class of Service Name
4	Great
7	Wonderful
other	Discard

S-Tag PCP Value	Class of Service Name
1	Straw
3	Gold
5	Platinum
other	Discard

C-Tag PCP Value	Class of Service Name
1	Straw
3	Gold
5	Platinum
other	Discard

Figure 86 – CENs and Class of Service Names

Based on the various SLSs among other considerations, the Service Provider elects to map the Class of Service Names between CENs as shown in Figure 87. From this figure it can be seen that the Subscriber at UNI 2 and UNI 3 agrees with the Service Provider that C-Tag PCP values map to the EVC Class of Service Names as follows:

- $1 \rightarrow$ *Good*,

- 3 → *Super*, and

- 5 → *Best*.

Consequently, an ingress Service Frame at UNI 2 assigned the Class of Service Name *Super* would be given the Class of Service Names in each CEN as follows:

- CEN A: *Paper*,

- CEN B: *Great*, and

- CEN C: *Straw*.
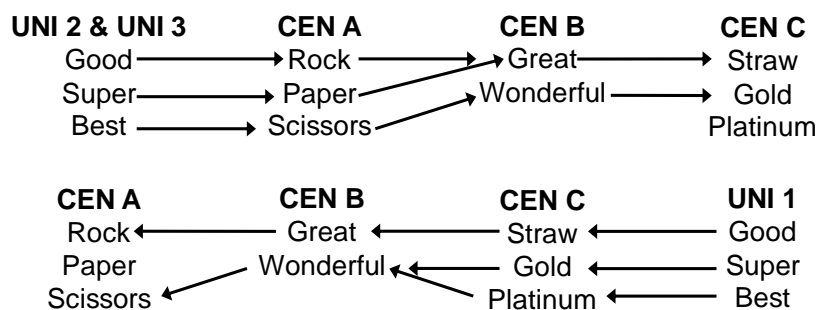
Figure 87 – Mapping of Class of Service Names between CENs

In order to accomplish the mapping of Class of Service Names between CENs shown in Figure 87, each egress ENNI Frame needs to have the proper S-Tag PCP value. This is accomplished by the values of the OVC End Point Egress Map Service Attribute shown in Figure 88

In this example, it is assumed that the OVCs have the OVC S-VLAN PCP Preservation Service Attribute = *Disabled*. Note that different forms of the OVC End Point Egress Map are used at the two ENNIs because the OVC End Point Color Identifier Service Attribute has different values for the OVC End Points that are at the different ENNIs.

Legend:
- Class of Service Identifier to Class of Service Name Maps
- OVC List of Class of Service Names
- OVC End Point Egress Maps

- ◐ *F = S-Tag DEI* for OVC End Point Color Identifier
- ⊖ *F = S-Tag PCP* for OVC End Point Color Identifier
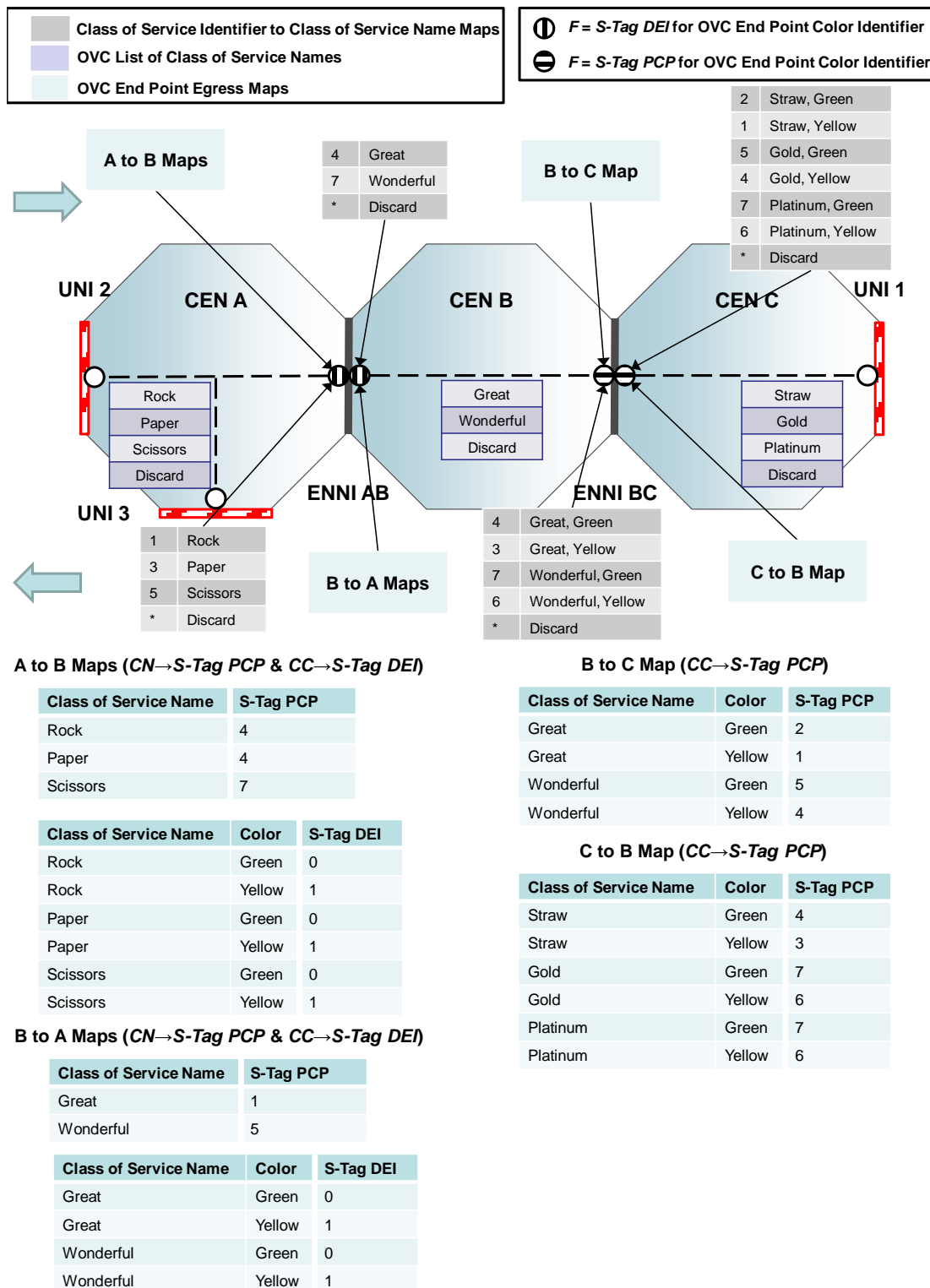
Figure 88 – Example OVC End Point Egress Map Service Attribute Values

A to B Maps (*CN→S-Tag PCP* & *CC→S-Tag DEI*)

Class of Service Name	S-Tag PCP
Rock	4
Paper	4
Scissors	7

Class of Service Name	Color	S-Tag DEI
Rock	Green	0
Rock	Yellow	1
Paper	Green	0
Paper	Yellow	1
Scissors	Green	0
Scissors	Yellow	1

B to A Maps (*CN→S-Tag PCP* & *CC→S-Tag DEI*)

Class of Service Name	S-Tag PCP
Great	1
Wonderful	5

Class of Service Name	Color	S-Tag DEI
Great	Green	0
Great	Yellow	1
Wonderful	Green	0
Wonderful	Yellow	1

B to C Map (*CC→S-Tag PCP*)

Class of Service Name	Color	S-Tag PCP
Great	Green	2
Great	Yellow	1
Wonderful	Green	5
Wonderful	Yellow	4

C to B Map (*CC→S-Tag PCP*)

Class of Service Name	Color	S-Tag PCP
Straw	Green	4
Straw	Yellow	3
Gold	Green	7
Gold	Yellow	6
Platinum	Green	7
Platinum	Yellow	6

Appendix G   Token Request Offset Examples (Informative)

An offset in the token request for a Bandwidth Profile Flow can help to compensate for lost Subscriber bandwidth due to the additional tagging overhead at an ENNI (e.g., due to a 4-byte S-Tag added by the Operator).

In this example, an EPL service is used between UNIs a & b, as shown in Figure 89, below.

UNI a   **UNI b**

CIR = 10 Mbps
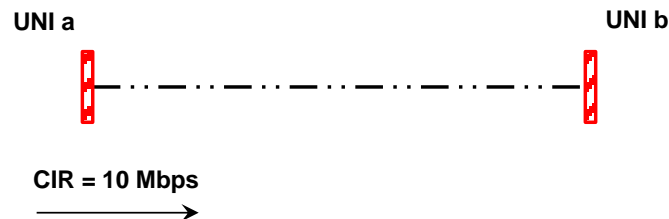
Figure 89 – EVC for the Token Request Offset example

There is a single Class of Service Name *Gold* associated with the EVC. The Subscriber expects to send / receive up to 10 Mbps through the service. The associated Ingress Bandwidth Profile Flow for *Gold* at UNI a has a CIR value of 10 Mbps and this Bandwidth Profile Flow is in an Envelope by itself.

The Service Provider contracts with four Operators to provide the end-to-end service. Figure 90 below shows the chain of OVCs needed to achieve the connectivity between the two UNIs. For simplicity, it also shows the CIR values for each ingress Bandwidth Profile Flow configured at each OVC End Point, going from left to right. Furthermore, the implementation in CEN A is such that an S-Tag is added to each ingress Service Frame at UNI a when sent out of ENNI AB, e.g., the value of the OVC CE-VLAN ID Preservation Service Attribute in CEN A is either *Preserve* or *Retain*.

ENNI AB   **ENNI BC**   **ENNI CD**

CEN A   **CEN B**   **CEN C**   **CEN D**

10   10   10   10

UNI a   **UNI b**

10   Ingress Bandwidth Profile Flow CIR in Mbps

Figure 90 – The chain of OVCs supporting the EPL service

In this scenario, each CEN Operator configures the same ingress Bandwidth Profile Flow CIR value for the OVC End Points at each ENNI. Now, let's consider that the Subscriber sends a string of 80-byte Service Frames into UNI a, expecting 10 Mbps to be delivered to UNI b.

Without a Token Request Offset ($F^i = 0$), the token request would be set at 84 for each ENNI frame, corresponding to the ENNI frame len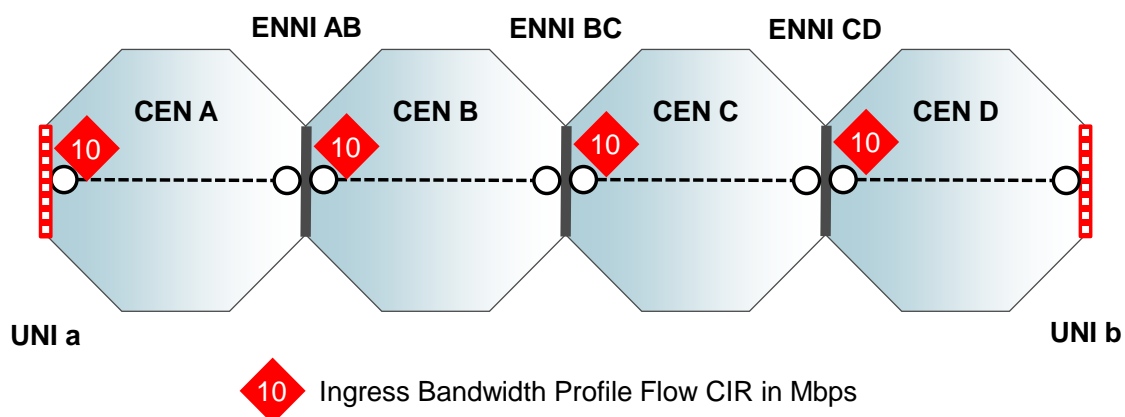gth. The maximum amount of bits per second in EI Frames declared Green carried through the chain of OVCs would be 9.5 Mbps (the extra 4 bytes on a base of 80 bytes, reduces end-to-end bandwidth by 5%).

In a token request offset scenario, the Service Provider reaches agreement with each Operator in the chain to implement a 4-byte offset ($F^i = 4$). The token request would result in 80 tokens (84 - 4) being consumed by the ENNI Bandwidth Profile algorithms, corresponding to the Service Frame length. The resulting maximum amount of bits per second in EI Frames declared Green carried through the chain of OVCs would be at best 10 Mbps (the effect of the extra 4 bytes of added S-Tag is cancelled by the token offset).

Basically, whenever C-Tag is encapsulated with an S-Tag for an E-Access Service defined in MEF 51 [25], an extra 4 bytes of overhead is required at the ENNI. In these scenarios, an ingress Bandwidth Profile Flow associated with an OVC End Point in the neighboring CEN, can use the Token Request Offset to ensure end-to-end bandwidth is preserved for the Service Provider.

A VUNI is an example of a use case with possibly two additional tags (8 bytes) at the ENNI, e.g., untagged ingress Service Frames at UNI a in CEN A connect to the VUNI, which, in turn, is required to add C-Tags and then an S-Tag to connect across the ENNI towards the RUNI.

An alternative to using Token Request Offset could be to increase the CIR at ENNIs to a value that would accommodate the added S-Tag for any frame. The maximum value needed to accommodate any frame would be based on a 64 byte Service Frame, which could require 68 or 72 bytes at an ENNI. Assume it requires 68 bytes, then the additional CIR required at an ENNI without token offset would be 68/64 = 1.0625 * UNI CIR. So without Token Request Offset, a 10 Mbps UNI CIR in Figure 1 would require 10.625 Mbps ENNI CIR to ensure that all 64 byte frames are passed. While setting 10.625 Mbps at ENNI CIR would result in 10 Mbps at egress UNI if 64 byte frames were received, it could result in higher egress CIR if larger frames are received. For example, if an ENNI were to receive 10.625 Mbps of 1522 byte frames, then the resulting egress flow at the egress UNI (assuming single S-Tag is stripped) would be 1518/1522 * 10.625 = 10.597 Mbps. This alternative could be acceptable for a point-to-point service, where a single UNI polices traffic for the entire service, and thus would limit larger frames to 10 Mbps at egress UNI. In a multipoint service, however, one egress UNI could be fed by multiple ingress UNIs. Figure 91 below shows an example of an E-LAN type service, with a Multipoint-to-Multipoint EVC connecting four different UNIs.
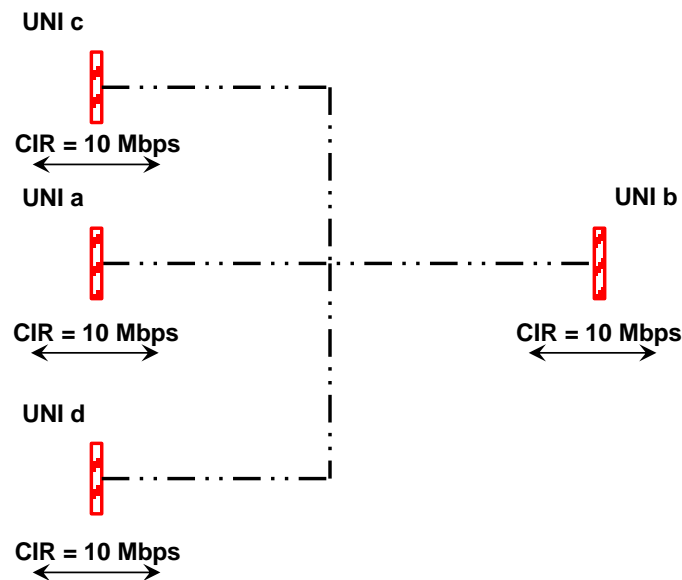
Figure 91 – Multipoint EVC for the bandwidth compensation example

In this example, the Subscriber's service allows him to send and receive 10 Mbps at each UNI in the Premium Class of Service, by using ingress and egress bandwidth profiles at each UNI, with CIR set at 10 Mbps.

Let's assume that the Service Provider contracts with the same four Operators to provide the end-to-end service, as shown in Figure 92 below.
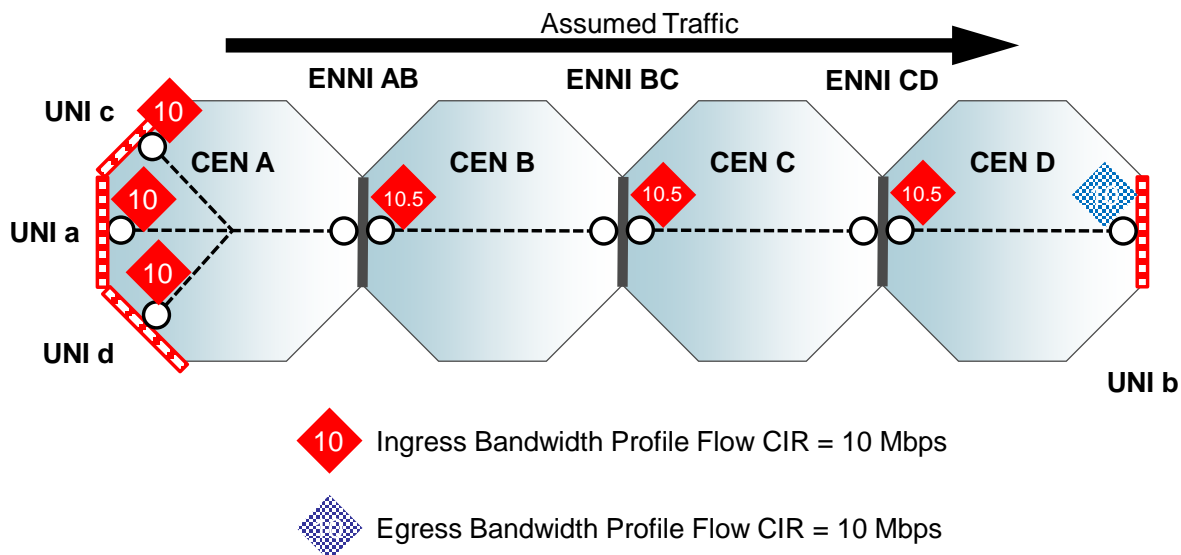
Figure 92 – The chain of OVCs Supporting the E-LAN Service

The end-to-end EVC is made up of an Access E-LAN Service[30] with three UNIs in CEN A, a Transit E-Line Service[30] in CEN B and another Transit E-Line Service[30] in CEN C, and finally an Access E-Line Service[30] in CEN D. Since in this example traffic flow is assumed to be from left to right, the bandwidth profiles are shown only for that direction. The CIR values for the ingress Bandwidth Profile Flows are shown in the red diamonds, and the CIR value for the egress Bandwidth Profile Flow at UNI b is shown in the blue diamond.

For example in Figure 92, without Token Request Offset ($F^i = 0$), if the ENNI CIR is adjusted to 10.625 Mb/s to accommodate 64 byte frames, but UNIs c and d are sending 1518 byte Service Frames to UNI b, then .597 Mbps of these frames would be transported across CENs B, C, and D before finally being dropped by the egress policer at UNI b. In contrast, if Token Request Offset is used, then the excess frames would be dropped at ENNI AB, rather than being transported to be dropped at the egress UNI. If a frame is going to be dropped due to overload, then it is better to be dropped sooner rather than later to avoid wasting network resources.

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[30] Defined in MEF 51 [25].

Appendix H   Comparison of Service Attribute Values (Informative)

In a moderately complex environment, where a Service Provider provides an EVC to a Subscriber, and implements the EVC using a number of OVCs purchased from underlying Operators, there may be a number of sets of Service Attributes in use to describe the EVC and the various OVCs. This Appendix examines the relationship between the values of the corresponding or analogous Service Attributes in the different sets.

Consider the situation shown in Figure 93 below:
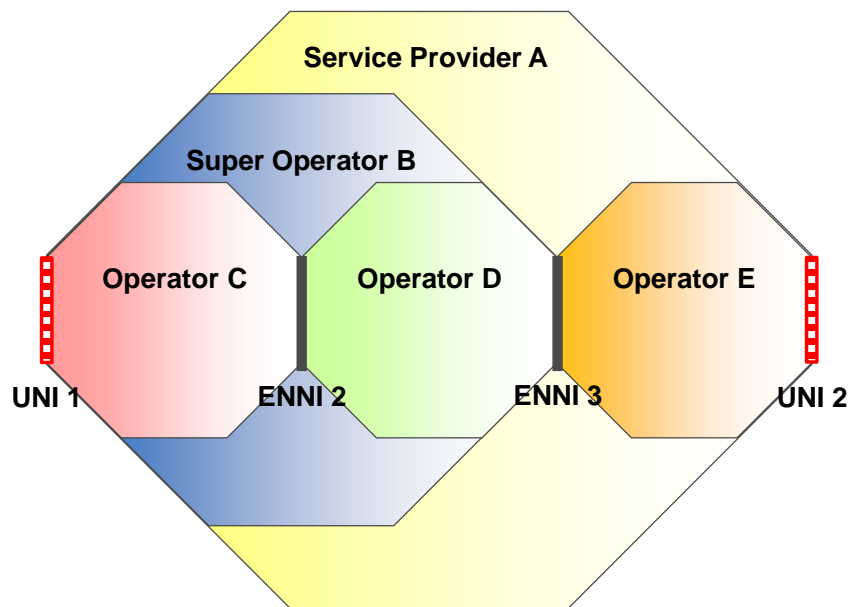
Figure 93 – Scenario with Multiple Operators

In this scenario, there are 5 sets of Service Attributes:

- EVC and UNI Service Attributes (per MEF 10.3 [12]) agreed between Service Provider A and the Subscriber

- Operator Service Attributes (per this document) agreed between Service Provider A and Super Operator B

- Operator Service Attributes (per this document) agreed between Service Provider A and Operator E

- Operator Service Attributes (per this document) agreed between Super Operator B and Operator C

- Operator Service Attributes (per this document) agreed between Super Operator B and Operator D

Note that there are also ENNI Common Attributes (per Section 9) agreed at ENNI 2 between Operator C and Operator D, and at ENNI 3 between Operator D and Operator E. ENNI Common Attributes are not discussed further in this Appendix.

It can be seen from the figure that there are some EIs where more than one set of Service Attributes is applicable; for example:

- At UNI 1, there are three sets of applicable Service Attributes:

    o EVC and UNI Service Attributes agreed between Service Provider A and the Subscriber

    o Operator Service Attributes agreed between Service Provider A and Super Operator B

    o Operator Service Attributes agreed between Super Operator B and Operator C

- On the left-hand side of ENNI 3, there are two sets of applicable Service Attributes:

    o Operator Service Attributes agreed between Service Provider A and Super Operator B

    o Operator Service Attributes agreed between Super Operator B and Operator D

In such cases, it is interesting to examine the relationship between the values of the attributes in the different sets. These are summarized in the subsections below.

When comparing different sets of Operator Service Attributes, the value of each Service Attribute can be compared directly between the two sets. When comparing Operator Service Attributes with EVC and UNI Service Attributes (as defined in MEF 10.3 [12]), each Operator Service Attribute is compared with the closest equivalent EVC or UNI Service Attribute.

The subsections below consider each of the types of Service Attributes in turn:

- OVC/EVC Service Attributes

- ENNI Service Attributes

- UNI/Operator UNI Service Attributes

- VUNI Service Attributes

- OVC End Point/EVC per UNI Service Attributes

Note that the comparison of different sets of Operator Service Attributes is described using only two levels of hierarchy (SP to SO, SO to Operator); however the same analysis applies if there are more than 2 levels (e.g. if the SP were instead another SO).

H.1 OVC/EVC Service Attributes

Table 52 below summarizes the relationship between different sets of OVC Service Attribute values, and between a set of OVC Service Attribute values and the analogous EVC Service Attribute values. The first two columns identify the Service Attributes. The third column describes the relationship between different sets of OVC Service Attribute values, for example the relationship between the values agreed between Service Provider A and Super Operator B and the values agreed between Super Operator B and Operator C in the example shown in Figure 93. The fourth column describes the relationship between a set of OVC Service Attribute values and a set of EVC Service Attribute values, for example the relationship between the values agreed between Service Provider A and the Subscriber and the values agreed between Service Provider A and Super Operator B in the example shown in Figure 93.

OVC Service Attribute (this document)	Closest EVC Service Attribute (MEF 10.3)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
OVC Identifier	EVC Identifier	Not related.	Not related.
OVC Type	EVC Type	Can be different.	Can be different (see Appendix A).
OVC End Point List	UNI List	Can be different.	Can be different – if an OVC End Point in the OVC End Point List is at a UNI, then the identifier for that UNI ID will appear in a UNI List for at least one EVC.
Max Num UNI OVC End Points	Max Num UNIs	Can be different – the number of UNIs in use between the SP and SO is at least as many as between the SO and the Operator, but there are no constraints on the relationship between the maximum values.	Can be different – the number of UNIs in use between the SP and Subscriber is at least as many as between the SP and the Operator, but there are no constraints on the relationship between the maximum values.
Max Num ENNI OVC End Points	N/A	Can be different – the number of ENNIs in use between the SP and SO is at least as many as between the SO and the Operator, but there are no constraints on the relationship between the maximum values.	N/A
OVC Max Frame Size	EVC Max Service Frame Size	The value agreed between the SP and the SO is less than or equal to the value agreed between the SO and the Operator.	The value agreed between the SP and the Subscriber is less than or equal to the value agreed between the SP and the Operator minus 4.
OVC CE-VLAN ID Preservation	CE-VLAN ID Preservation	Can be different. If every underlying OVC has value *Preserve*, the SO's OVC will meet the requirements for *Preserve*.	Can be different. If every OVC has value *Preserve*, the EVC will meet the requirements for *Enabled*.
OVC CE-VLAN PCP Preservation	CE-VLAN CoS Preservation	Can be different. If every underlying OVC has value *Enabled*, the SO's OVC will meet the requirements for *Enabled*.	Can be different. If every OVC has value *Enabled*, the EVC will meet the requirements for *Enabled*.

OVC Service Attribute (this document)	Closest EVC Service Attribute (MEF 10.3)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
OVC CE-VLAN DEI Preservation	N/A	Can be different. If every underlying OVC has value *Enabled*, the SO's OVC will meet the requirements for *Enabled*.	N/A
OVC S-VLAN PCP Preservation	N/A	Can be different. If every underlying OVC has value *Enabled*, the SO's OVC will meet the requirements for *Enabled*.	N/A
OVC S-VLAN DEI Preservation	N/A	Can be different. If every underlying OVC has value *Enabled*, the SO's OVC will meet the requirements for *Enabled*.	N/A
OVC List of CoS Names	N/A	Not related.	N/A
OVC SLS	EVC Related Performance	Can be different.	Can be different.
OVC Frame Delivery	Service Frame Delivery	For each frame type (unicast, multicast and broadcast), the value agreed between the SP and the SO requires the same or more frames to be discarded than the value agreed between the SO and the Operator. Note *Discard* requires more frames to be discarded than *Conditional*, which requires more frames to be discarded than *Unconditional*.	For each frame type (unicast, multicast and broadcast), the value agreed between the SP and the Subscriber requires the same or more frames to be discarded than the value agreed between the SP and the Operator. Note *Discard* requires more frames to be discarded than *Conditional*, which requires more frames to be discarded than *Unconditional*.
OVC Available MEG Level	N/A	The value agreed between the SP and the SO is greater than or equal to the value agreed between the SO and the Operator (where *None* is considered greater than any numeric value).	N/A
OVC L2CP Address Set	N/A	The value agreed between the SP and the SO is equal to or a superset of the value agreed between the SO and the Operator. Note *CTA* is a superset of *CTB*, which is a superset of *CTB-2*.	N/A

Table 52 – Comparison of OVC/EVC Service Attributes

In general, the values between different OVCs, or between an EVC and an underlying OVC, can be different; however, an underlying Operator's OVC cannot discard frames that an EVC or Super Operator OVC that is carried over it is required to deliver. This principle gives rise to the relationships for Maximum Frame Size, Frame Delivery, Available MEG Level and L2CP Address Set.

H.2   ENNI Service Attributes

Table 53 below summarizes the relationship between different sets of ENNI Service Attribute values, at a given ENNI. The first column identifies the Service Attribute. The second column describes the relationship between different sets of ENNI Service Attribute values, for example the relationship between the values agreed for ENNI 3 between Service Provider A and Super Operator B and the values agreed for ENNI 3 between Super Operator B and Operator D in the example shown in Figure 93. Note there are no EVC-based equivalents of ENNI Service Attributes.

ENNI Service Attribute (this document)	Relationship between SP-SO value and SO-Operator value
Operator ENNI Identifier	Not related.
S-VLAN ID Control	If the SO-Operator value is *partial*, then the SP-SO value has to be *partial*
Max Num OVCs	Can be different.
Max Num OVC End Points per OVC	Can be different.
ENNI Token Share	Can be different.
ENNI Envelopes	Can be different.

Table 53 – Comparison of ENNI Service Attributes

In general, the values of the ENNI Service Attributes at a given ENNI can be different because a Super Operator can implement features – such as hairpin switching and complex bandwidth profiles – further into their network than the ENNI in question. For example, with reference to Figure 93, Super Operator B might agree to values for ENNI 3 with Service Provider A, but then purchase a single bundled P2P OVC from Operator D and split this out into multiple OVCs with different bandwidth profiles at ENNI 2 in Operator C. Thus, the values agreed with Service Provider A for the Max Number of OVCs, the Max Number of OVC End Points per OVC, and the ENNI Token Share could be different than the values agreed with Operator D.

H.3   UNI/Operator UNI Service Attributes

Table 54 below summarizes the relationship between different sets of Operator UNI Service Attribute values, and between a set of Operator UNI Service Attribute values and the analogous UNI Service Attribute values (from MEF 10.3), for a given UNI. The first two columns identify the Service Attributes. The third column describes the relationship between different sets of Operator UNI Service Attribute values, for example the relationship between the values agreed for UNI 1 between Service Provider A and Super Operator B and the values agreed for UNI 1 between Super Operator B and Operator C in the example shown in Figure 93. The fourth column describes the relationship between a set of Operator UNI Service Attribute values and a set of UNI Service Attribute values, for example the relationship between the values agreed for UNI 1 between Service Provider A and the Subscriber and the values agreed for UNI 1 between Service Provider A and Super Operator B in the example shown in Figure 93.

If L2CP address set *CTB-2* is in use (see MEF 45 [24]), it is possible for certain L2 protocols to be "tunneled" across an OVC, in which case values for Service Attributes such as Link Aggregation, Link OAM and E-LMI could differ. The table below assumes *CTB-2* is not used.

Operator UNI Service Attribute (this document)	Closest UNI Service Attribute (MEF 10.3 unless otherwise stated)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
Operator UNI Identifier	UNI ID	Not related	Not related.
Operator UNI Physical Layer	Physical Layer	Values are the same.	Values are the same.
Operator UNI Sync Mode	Sync Mode	Values are the same.	Values are the same.
Operator UNI Num Links	Num Links	Values are the same.	Values are the same.
Operator UNI Link Aggregation	UNI Resiliency (MEF 10.3.2 [13])	Values are the same.	Values are the same.
Operator UNI Port Conversation ID to Aggregation Link Map	Port Conversation ID to Aggregation Link Map (MEF 10.3.2 [13])	Values are the same.	Values are the same.
Operator UNI Service Frame Format	Service Frame Format	Values are the same (only a single value is possible).	Values are the same (only a single value is possible).
Operator UNI Max Service Frame Size	UNI Max Service Frame Size	The value agreed between the SP and the SO is less than or equal to the value agreed between the SO and the Operator.	The value agreed between the SP and the Subscriber is less than or equal to the value agreed between the SP and the Operator.
Operator UNI Default CE-VLAN ID	CE-VLAN ID for Untagged and Priority-Tagged Service Frames	Values are usually the same (see below).	Values are usually the same (see below).
Operator UNI Max Num OVC End Points	Max Num EVCs / Service Multiplexing	Can be different.	Can be different / Not related.
Operator UNI Max Num CE-VLAN IDs per OVC End Point	Bundling / All-to-one Bundling	Can be different – the highest number of CE-VLAN IDs in use for an OVC agreed between the SP and SO is less than or equal to the number of CE-VLAN IDs used for the corresponding OVC agreed between the SO and the Operator, but there are no constraints on the relationship between the maximum values.	Can be different / Not related.
Operator UNI Ingress BWP	Ingress BWP per UNI	Can be different.	Can be different.
Operator UNI Egress BWP	Egress BWP per UNI	Can be different.	Can be different.

Operator UNI Service Attribute (this document)	Closest UNI Service Attribute (MEF 10.3 unless otherwise stated)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
Operator UNI Link OAM	Link OAM	Values are the same.	Values are the same.
Operator UNI MEG	UNI MEG	Values are the same.	Values are the same.
Operator UNI LAG Link MEG	N/A	Values are the same.	N/A
Operator UNI E-LMI	E-LMI	Values are the same.	Values are the same.
Operator UNI Token Share	Token Share (MEF 6.2 [11])	Can be different.	Can be different.
Operator UNI Envelopes	Envelopes[31]	Can be different.	Can be different.
Operator UNI L2CP Address Set	UNI L2CP Address Set (MEF 45 [24])	The value agreed between the SP and the SO is equal to or a superset of the value agreed between the SO and the Operator. Note *CTA* is a superset of *CTB*, which is a superset of *CTB-2*.	The value agreed between the SP and the Subscriber is equal to or a superset of the value agreed between the SP and the Operator. Note *CTA* is a superset of *CTB*, which is a superset of *CTB-2*.
Operator UNI L2CP Peering	UNI L2CP Peering (MEF 45 [24])	The value agreed between the SP and the SO is equal to or a superset of the value agreed between the SO and the Operator.	The value agreed between the SP and the Subscriber is equal to or a superset of the value agreed between the SP and the Operator.

Table 54 – Comparison of UNI Service Attributes

Note that the CE-VLAN ID/EVC Map Service Attribute from MEF 10.3 does not appear in the table because this attribute corresponds most closely with the OVC End Point Map Service Attribute, which is covered in Appendix H.5 below.

In general, values of the UNI / Operator UNI Service Attributes at a given UNI that relate to the physical interfaces or to OAM at the UNI are the same, while those that relate to the EVCs/OVCs at the UNI can be different because a SP/SO can implement features – such as service multiplexing and complex bandwidth profiles – further into their network than the UNI in question (for instance by using a VUNI). For example, with reference to Figure 93, Super Operator B might agree values for UNI 1 with Service Provider A, but then purchase a simple P2P OVC from Operator C that has all CE-VLAN ID values mapped to it and split this out into multiple OVCs with different bandwidth profiles by purchasing a VUNI at ENNI 2 from Operator D. Thus, the values agreed with Service Provider A for the Max Number of OVC End Points, the Max Number of CE-VLAN IDs per OVC End Point, and the BWP-related attributes could be different than the values agreed with Operator C.

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[31] Envelopes are not described as a UNI Service Attribute in MEF 10.3, but the concept is described in Section 12 of MEF 10.3 and the list of Envelopes and corresponding CF^0 flags is treated as a UNI Service Attribute in MEF 6.2.

The Operator UNI Default CE-VLAN ID Service Attribute (and correspondingly the CE-VLAN ID for Untagged and Priority-Tagged Service Frames) is a special case. In the table it is indicated that the values are usually the same, and this is always sufficient to obtain correct behavior. However there are corner cases where the value could be different, for example, if the value agreed between the Service Provider and the Super Operator is a CE-VLAN that does not map to any OVC in the Super Operator, then the Super Operator could agree a different value with the Operator that likewise doesn't map to any OVC in the Operator. A more obscure example is if OVC CE-VLAN ID Preservation is set to *Preserve* for the Operator's OVC, and for each UNI and VUNI in that OVC, all CE-VLANs map to it (i.e. every UNI and VUNI has All to One Bundling). In this case, the Super Operator can agree an arbitrary value with the Operator regardless of the value they have agreed with the Service Provider.

H.4 VUNI Service Attributes

A Service Provider may purchase a VUNI from an Operator, in order to implement the UNI-related Service Attributes they have agreed with a Subscriber; for example, with reference to Figure 93, Service Provider A may request a VUNI at ENNI 3 from Super Operator B, in order to implement UNI-related functionality for UNI 4 (the RUNI, in this example).

The Operator providing the VUNI (Super Operator B in this example) needs to implement the VUNI functionality somewhere in their network – that could be at the ENNI where the VUNI is being provided (ENNI 3 in this example), or further into their network – for example, Super Operator B could request a VUNI at ENNI 2 from Operator C, and purchase a Feeder OVC from Operator D. In either case, the VUNI agreed between the SP and the SO and the VUNI agreed between the SO and the underlying Operator both pertain to the same RUNI (UNI 4 in this example).

Table 55 below summarizes the relationship between different sets of VUNI Service Attribute values, for a given RUNI (whether or not the VUNI is at the same ENNI), and between a set of VUNI Service Attributes and the closest equivalent UNI Service Attributes for the RUNI. The first two columns identify the Service Attributes. The third column describes the relationship between different sets of VUNI Service Attribute values. The fourth column describes the relationship between a set of VUNI Service Attribute values and a set of UNI Service Attribute values for the corresponding RUNI.

VUNI Service Attribute (this document)	Closest UNI Service Attribute (MEF 10.3 unless otherwise stated)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
VUNI ID	N/A	Not related	N/A
VUNI S-VLAN ID	N/A	Values are the same if the VUNI is at the same ENNI; otherwise can be different.	N/A

VUNI Service Attribute (this document)	Closest UNI Service Attribute (MEF 10.3 unless otherwise stated)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
VUNI Default ENNI CE-VLAN ID	CE-VLAN ID for Untagged and Priority-Tagged Service Frames	Values are usually the same (see below).	Values are usually the same (see below).
VUNI Max Num OVC End Points	Max Num EVCs / Service Multiplexing	Can be different.	Can be different / Not related.
VUNI Max Num ENNI CE-VLAN IDs per OVC End Point	Bundling / All-to-one Bundling	Can be different.	Can be different / Not related.
VUNI Ingress BWP	Ingress BWP per UNI	Can be different.	Can be different.
VUNI Egress BWP	Egress BWP per UNI	Can be different.	Can be different.
VUNI L2CP Address Set	UNI L2CP Address Set (MEF 45 [24])	The value agreed between the SP and the SO is equal to or a superset of the value agreed between the SO and the Operator. Note *CTA* is a superset of *CTB*, which is a superset of *CTB-2*.	The value agreed between the SP and the Subscriber is equal to or a superset of the value agreed between the SP and the Operator. Note *CTA* is a superset of *CTB*, which is a superset of *CTB-2*.
VUNI L2CP Peering	UNI L2CP Peering (MEF 45 [24])	The value agreed between the SP and the SO is equal to or a superset of the value agreed between the SO and the Operator.	The value agreed between the SP and the Subscriber is equal to or a superset of the value agreed between the SP and the Operator.
VUNI MEP List	N/A	Values are the same if the VUNI is at the same ENNI; otherwise can be different.	N/A

Table 55 – Comparison of VUNI Service Attributes

The considerations for VUNI Service Attributes are similar to those for UNI / Operator UNI Service Attributes, given that there is much flexibility in how VUNIs are arranged (see examples in Appendix C). Again, the Default CE-VLAN ID is a special case, as described in Appendix H.3 above.

Another interesting case for VUNIs is the VUNI MEP List, if the Super Operator implements the VUNI further into their network than their ENNI that is agreed with the Service Provider. An example of this, with reference to Figure 93, is if Service Provider A agrees a VUNI with Super Operator B at ENNI 3, but Super Operator B implements this by agreeing a VUNI with Operator C at ENNI 2, and uses a Feeder OVC from Operator D. In this case, the VUNI MEPs that Super Operator B has agreed with Service Provider A could be implemented on the VUNI at ENNI 2 or on the OVC End Point for the Feeder OVC at ENNI 3, or they could be spread across the two (provided the MEG levels were respected). In addition, Super Operator B could implement their own MEGs (not visible to Service Provider A) between the VUNI at ENNI 2 and the OVC End

Point for the Feeder OVC at ENNI 3. Thus, the VUNI MEP List agreed with Operator C could have more or fewer MEPs than the list agreed with the Service Provider.

H.5 OVC End Point/EVC per UNI Service Attributes

Table 56 below summarizes the relationship between different sets of OVC End Point Service Attribute values, and between a set of OVC End Point Service Attribute values and the analogous EVC per UNI Service Attribute values, at a given EI. The first two columns identify the Service Attributes. The third column describes the relationship between different sets of OVC End Point Service Attribute values, for example the relationship between the values agreed between Service Provider A and Super Operator B and the values agreed between Super Operator B and Operator C for an OVC End Point at ENNI 3 in the example shown in Figure 93. The fourth column describes the relationship between a set of OVC End Point Service Attribute values and a set of EVC per UNI Service Attribute values, for example the relationship between the values agreed between Service Provider A and the Subscriber for an EVC per UNI at UNI 1 and the values agreed between Service Provider A and Super Operator B for the corresponding OVC End Point at UNI 1 in the example shown in Figure 93.

OVC End Point Service Attribute (this document)	Closest EVC per UNI Service Attribute (MEF 10.3)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
OVC End Point Identifier	UNI EVC ID	Not Related.	Not Related.
OVC End Point EI Type	N/A	Value is the same.	N/A
OVC End Point EI Identifier	N/A	Not Related.	N/A
OVC End Point Role	UNI Role (in EVC UNI List Service Attribute)	Can be different.	Can be different (see Appendix A)
OVC End Point Map	CE-VLAN ID/EVC Map (UNI Service Attribute)	Can be different.	Can be different.
OVC End Point CoS IDs	CoS ID	Can be different.	Can be different.
OVC End Point Color ID	Color ID	Can be different. If the OVC End Points are at a UNI, the value of F (i.e. the field in the frame) is the same.	Can be different, but based on the same field in the frame.
OVC End Point Egress Map	N/A	Can be different.	N/A
OVC End Point EEC ID	EEC ID	Can be different. If the OVC End Points are at a UNI, the value of F (i.e. the field in the frame) is the same.	Can be different, but based on the same field in the frame.

OVC End Point Service Attribute (this document)	Closest EVC per UNI Service Attribute (MEF 10.3)	Relationship between SP-SO value and SO-Operator value	Relationship between SP-Subscriber (EVC) value and SP-Operator (OVC) value
Ingress BWP per OVC End Point	Ingress BWP per EVC	Can be different.	Can be different.
Egress BWP per OVC End Point	Egress BWP per EVC	Can be different.	Can be different.
Ingress BWP per CoS Name	Ingress BWP per CoS ID	Can be different.	Can be different.
Egress BWP per EEC	Egress BWP per EEC ID	Can be different.	Can be different.
OVC End Point Aggregation Link Depth (N/A at a UNI)	N/A	Value is the same.	N/A
OVC End Point Source MAC Address Limit	Source MAC Address Limit	Values are related, but not in a straightforward way. If the values of τ are the same, the value of N agreed between the SP and the SO is less than or equal to the value of N agreed between the SO and the Operator.	Values are related, but not in a straightforward way. If the values of τ are the same, the value of N agreed between the SP and the Subscriber is less than or equal to the value of N agreed between the SP and the Operator.
OVC End Point MIP	Subscriber MEG MIP	If the value agreed between the SP and the SO is *Disabled*, then the value agreed between the SO and the Operator is *Disabled*; otherwise the values can be different.	If the value agreed between the SP and the Subscriber is *Disabled*, then the value agreed between the SP and the Operator is *Disabled*; otherwise the values can be different.
OVC End Point MEP List	N/A	Can be different.	N/A

Table 56 – Comparison of OVC End Point/EVC per UNI Service Attributes

As there is no strong alignment between the OVCs in the Super Operator's domain and the underlying OVCs in the Operator's domain, most of the values of the OVC End Point Service Attributes can be different; and similarly, the values of the EVC per UNI Service Attributes can be different than the values of the OVC End Point Service Attribute values in most cases.

Appendix I   Changes from MEF 26.1 and MEF 28 (Informative)

New material compared to MEF 26.1 [18] includes:

- ENNI Common Attributes (Sections 8.4 and 9),

- Super Operator (Section 8.10),

- Specification of multiple links based on IEEE Std 802.1AX – 2014 [2] at the UNI
  and the ENNI with traffic flowing on more than one link simultaneously (Sections
  9.5, 9.6, 14.5, and 14.6),

- ENNI MEG Common Attribute (Section 9.7),

- ENNI LAG Link MEG Common Attribute (Section 9.8),

- ENNI Link OAM Common Attribute (Section 9.9),

- Operator Multilateral Attributes (Section 10),

- ENNI Maximum Frame Size Multilateral Attribute (Section 10.3),

- OVC Maximum ENNI Frame Size Service Attribute (Section 12.6),

- OVC S-VLAN DEI Preservation Service Attribute (Section 12.11),

- OVC Available MEG Level Service Attribute (Section 12.15),

- ENNI Token Share Service Attribute (Section 13.5),

- ENNI Envelopes Service Attribute (Section 13.6),

- Operator UNI Service Attributes (Section 14),

- ENNI OVC End Point Map Service Attribute, (Section 16.5),

- OVC End Point Color Identifier Service Attribute (Section 16.7),

- OVC End Point Egress Map Service Attribute (Section 16.8),

- OVC End Point Egress Equivalence Class Identifier Service Attribute (Section
  16.9),

- OVC End Point Source MAC Address Limit Service Attribute (Section 16.15),

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- Introduction of token sharing in the Bandwidth Profile Algorithm by referring to MEF 41 [23] (Section 17), and

- Layer 2 Control Protocol Service Attributes by reference to Multi-CEN L2CP (MEF 45 [24]).

Changes compared to MEF 26.1 [18] include:

- Elimination of the ENNI Maximum Transmission Size ENNI Service Attribute (Section 7.1.6 in MEF 26.1 [18]),

- The OVC End Point Map Service Attribute (Section 16.5) replaces the End Point Map ENNI Service Attribute (Section 7.1.7 in MEF 26.1 [18]) and the OVC End Point Map OVC per UNI Service Attribute (Section 7.5.2 in MEF 26.1 [18]),

- Elimination of the OVC Maximum Transmission Size OVC Service Attribute (Section 7.2.10 in MEF 26.1 [18]),

- Elimination of the S-VLAN ID Preservation Service Attribute (Section 7.2.13 in MEF 26.1 [18]),

- The Color Forwarding OVC Service Attribute (Section 7.2.15 in MEF 26.1 [18]) is replaced by the OVC End Point Egress Map Service Attribute (Section 16.8),

- The time interval T in the OVC Service Level Specification Service Attribute (Section 7.2.16 in MEF 26.1 [18]) is generalized to a sequence of time intervals T_l (Section 12.13.1.2),

- Elimination of the material related to Layer 2 Control Protocol tunneling (Section 7.2.20 in MEF 26.1 [18]).

- OVC End Point per ENNI Service Attributes (Section 7.3 in MEF 26.1 [18]) and OVC per UNI Service Attributes (Section 7.5 in MEF 26.1 [18]) are replaced by OVC End Point Service Attributes (Section 16),

- The behavior of CE-VLAN ID Preservation (Section 7.11 in MEF 26.1 [18]) is updated to align with changes in MEF 10.3 [12] and to include the VUNI (Section 12.7),

- Link OAM requirements (Section 8 in MEF 26.1 [18]) are incorporated into the new ENNI Link OAM Common Attribute and changed to mandate that Link OAM be run on all or none of the physical links in the ENNI (Section 9.9), and

- Elimination of the requirement that a Bandwidth Profile algorithm at an ENNI be *color-aware* ([R89], [R91], [R93], and [R95] of MEF 26.1 [18],

Changes compared to MEF 28 [19] include:

- The UNI Tunnel Access OVC (Section 15) is replaced by the Feeder OVC enabling more configurations including:

  - Multiple CENs between the RUNI and the VUNI,

  - Flexible handling of Color,

  - A given UNI can be the RUNI for more than one VUNI,

  - Multiple Class of Service Names between the RUNI and VUNI,

  - Ingress Bandwidth Profiles at the RUNI and ENNI can be configured to be *color-aware* and declare an ingress EI Frame Green/Yellow/Red instead of just Green/Red or Yellow/Red, and

  - The Feeder OVC is not mandated to have OVC Frame Disposition equal to *Deliver Unconditionally*.

- New VUNI Service Attributes are introduced including (Section 15.1):

  - VUNI Maximum Number of ENNI CE-VLAN IDs per OVC End Point Service Attribute,

  - VUNI L2CP Address Set Service Attribute,

  - VUNI L2CP Peering Service Attribute, and

  - VUNI End Point Maintenance End Point List Service Attribute.