Implementation Agreement

MEF 23

Carrier Ethernet Class of Service – Phase 1

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1. Abstract

This Implementation Agreement (IA) specifies a small common set of Classes of Service (CoS) that can be used by Operators, Service Providers and their Subscribers to indicate the performance expectations to be associated with a given set of frames. This common set of CoS is envisioned as a subset of the CoS an Operator may provide. The MEF CoS IA will facilitate: Ethernet service interoperability and consistency between Operators, a common CoS set for Subscribers to utilize and support of key applications.

2. Terminology

This section defines the terms used in this document. In many cases, the normative definitions to terms are found in other documents. In these cases, the third column is used to provide the reference that is controlling. In cases of conflict with other documents, the controlling document is shown in the reference column.

Terminology, parameters, algorithms and attributes for the UNI are assumed to apply to the E-NNI in CoS IA Phase 1 except where stated otherwise.

Term	Definition	Reference
Bandwidth Profile	A characterization of Service Frame arrival times and lengths at a reference point and a specification of the disposition of each Service Frame based on its level of compliance with the Bandwidth Profile.	[2]
Bandwidth profile per CoS ID	A bandwidth profile applied on a per-Class of Service basis.	[2]
Bandwidth profile per EVC	A bandwidth profile applied on a per-EVC basis.	[2]
Bandwidth profile per ingress UNI	A bandwidth profile applied on a per-UNI basis.	[2]
BWP	Bandwidth Profile	
CBS	Committed Burst Size	[2]
CE	Customer Edge	[2]
CE-VLAN CoS	Customer Edge VLAN CoS	[2]
CE-VLAN CoS Preservation	An EVC attribute in which the CE-VLAN CoS of an egress Service Frame is identical in value to the CE-VLAN CoS of the corresponding ingress Service Frame.	[2]
CE-VLAN ID	Customer Edge VLAN ID	[2]
CE-VLAN Tag	Customer Edge VLAN Tag	[2]
CF	Coupling Flag	[2]
CIR	Committed Information Rate	[2]

Term	Definition	Reference
Class of Service	A set of Service Frames that have a commitment from the Service Provider to receive a particular level of performance.	[2]
Class of Service Identifier	An indicator for a particular CoS instance. Information derivable from a) the EVC to which the Service Frame is mapped, b) the combination of the EVC to which the Service Frame is mapped and a set of one or more than one CE-VLAN CoS values, c) the combination of the EVC to which the Service Frame is mapped and a set of one or more than one DSCP values, or d) the combination of the EVC to which the Service Frame is mapped and a set of one or more than one tunneled Layer 2 Control Protocols.	[2]
Class of Service Instance	A set of service frames treated as a single entity for the Service Provider commitment of performance objectives.	
Class of Service Label	A name for each CoS that is specified in the CoS Implementation Agreement.	
CM	Color Mode	[2]
Color Mode	CM is a Bandwidth Profile parameter. The Color Mode parameter indicates whether the color-aware or color-blind property is employed by the Bandwidth Profile. It takes a value of “color-blind” or “color-aware” only.	[2]
Color-aware	A Bandwidth Profile property where a pre-determined level of Bandwidth Profile compliance for each Service Frame is taken into account when determining the level of compliance for each Service Frame.	[2]
Color-blind	A Bandwidth Profile property where a pre-determined level of Bandwidth Profile compliance for each Service Frame, if present, is ignored when determining the level of compliance for each Service Frame.	[2]
Color Identifier	An indicator for a particular Bandwidth Profile Color instance of Green or Yellow for a Service Frame. Color Identifier is derived from PCP, DSCP or DEI. PCP and DSCP may indicate both CoS Identifier and Color Identifier.	
Committed Burst Size	CBS is a Bandwidth Profile parameter. It limits the maximum number of bytes available for a burst of Service Frames sent at the UNI speed to remain CIR-conformant.	[2]
Committed Information Rate	CIR is a Bandwidth Profile parameter. It defines the average rate in bits/s of Service Frames up to which the network delivers Service Frames and meets the performance objectives defined by the CoS Service Attribute.	[2]

Term	Definition	Reference
CoS	Class of Service or Classes of Service	[2]
Coupling Flag	CF is a Bandwidth Profile parameter. The Coupling Flag allows the choice between two modes of operation of the rate enforcement algorithm. It takes a value of 0 or 1 only.	[2]
Customer Edge	Equipment on the Subscriber side of the UNI.	[2]
Customer Edge VLAN CoS	The Priority Code Point bits in the IEEE 802.1Q Customer VLAN Tag in a Service Frame that is either tagged or priority tagged.	[2]
Customer Edge VLAN ID	The identifier derivable from the content of a Service Frame that allows the Service Frame to be associated with an EVC at the UNI.	[2]
Customer Edge VLAN Tag	The IEEE 802.1Q Customer VLAN Tag in a tagged Service Frame.	[2]
DEI	Discard Eligible Indicator	[5]
EBS	Excess Burst Size	[2]
Egress Bandwidth Profile	A service attribute that specifies the length and arrival time characteristics of egress Service Frames at the egress UNI.	[2]
Egress Service Frame	A Service Frame sent from the Service Provider network to the CE.	[2]
EI	External Interface	[6]
EIR	Excess Information Rate	[2]
E-LAN Service	An Ethernet service type that is based on a Multipoint-to-Multipoint EVC.	[1]
E-Line Service	An Ethernet service type that is based on a Point-to-Point EVC.	[1]
E-NNI	External Network-to-Network Interface. An interface used to interconnect two MEN service providers or operators	[6]
EPL	Ethernet Private Line	[1]
E-Tree Service	An Ethernet service type that is based on a Rooted-Multipoint EVC.	[1]
Ethernet Virtual Connection	An association of two or more UNIs that limits the exchange of Service Frames to UNIs in the Ethernet Virtual Connection.	[2]
EVC	Ethernet Virtual Connection	[2]
EVPL	Ethernet Virtual Private Line	[1]
EVP-LAN	Ethernet Virtual Private LAN	[1]
Excess Burst Size	EBS is a Bandwidth Profile parameter. It limits the maximum number of bytes available for a burst of Service Frames sent at the UNI speed to remain EIR-conformant.	[2]

Term	Definition	Reference
Excess Information Rate	EIR is a Bandwidth Profile parameter. It defines the average rate in bits/s of Service Frames up to which the network may deliver Service Frames but without any performance objectives.	[2]
External Interface	Defined physical demarcation point between the MEN and outside, across which Ethernet Service Frames are presented.	Derived from [6] and [2]
FD	Frame Delay	[2]
FDV	Frame Delay Variation	[2]
FLR	Frame Loss Ratio	[2]
Frame	Short for Ethernet Frame	[2]
Frame Delay	The time required to transmit a Service Frame from ingress UNI to egress UNI.	[2]
Frame Delay Performance	A measure of the delays experienced by different Service Frames belonging to the same CoS instance.	[2]
Frame Delay Variation	The difference in delay of two Service Frames.	[2]
Frame Delay Variation Performance	A measure of the variation in the delays experienced by different Service Frames belonging to the same CoS instance.	[2]
Frame Loss Ratio Performance	Frame Loss Ratio is a measure of the number of lost frames between the ingress UNI and the egress UNI. Frame Loss Ratio is expressed as a percentage.	[2]
Ingress Bandwidth Profile	A characterization of ingress Service Frame arrival times and lengths at the ingress UNI and a specification of disposition of each Service Frame based on its level of compliance with the characterization.	[2]
Ingress Service Frame	A Service Frame sent from the CE into the Service Provider network.	[2]
Layer 2 Control Protocol Service Frame	A Service Frame that is used for Layer 2 control, e.g., Spanning Tree Protocol.	[2]
Layer 2 Control Protocol Tunneling	The process by which a Layer 2 Control Protocol Service Frame is passed through the Service Provider network without being processed and is delivered unchanged to the proper UNI(s).	[2]
MEN	Metro Ethernet Network	[6]
Metro Ethernet Network	The Service Provider's network providing Ethernet services.	[6]

Term	Definition	Reference
Multipoint-to-Multipoint EVC	An EVC with two or more UNIs. A Multipoint-to-Multipoint EVC with two UNIs is different from a Point-to-Point EVC because one or more additional UNIs can be added to it.	[2]
Operator	A carrier that administers a particular MEN or domain. If the Operator also provides the service to the Subscriber they are also the Service Provider	
N/A	Not Applicable	
N/S	Not Specified	
Point-to-Point EVC	An EVC with exactly 2 UNIs.	[2]
Rooted-Multipoint EVC	A multipoint EVC in which each UNI is designated as either a Root or a Leaf. Ingress Service Frames at a Root UNI can be delivered to one or more of any of the other UNIs in the EVC. Ingress Service Frames at a Leaf UNI can only be delivered to one or more Root UNIs in the EVC.	[2]
Service Frame	An Ethernet frame transmitted across the UNI toward the Service Provider or an Ethernet frame transmitted across the UNI toward the Subscriber.	[2]
Service Level Agreement	The contract between the Subscriber and Service Provider specifying the agreed to service level commitments and related business agreements.	[2]
Service Level Specification	The technical specification of the service level being offered by the Service Provider to the Subscriber.	[2]
Service Provider	The organization providing Ethernet Service(s).	[2]
S-Tag	Service VLAN Tag.	[5]
SLA	Service Level Agreement	[2]
SLS	Service Level Specification	[2]
Subscriber	The organization purchasing and/or using Ethernet Services.	[2]
UNI	User Network Interface	[2]
User Network Interface	The physical demarcation point between the responsibility of the Service Provider and the responsibility of the Subscriber.	[2]
VLAN	Virtual LAN	[3]

Table 1: Terminology and Definitions Table

3. Scope

In Phase 1 this IA defines a minimal set of CoS for UNI-to-UNI services for both single MEN and multiple interconnected MENs administered by different Operators. A CoS model is defined that can be applied to the CoS Instances of an EVC. This IA is applicable at External Interfaces (EIs) which can be either UNI or E-NNI and includes placeholders for the performance objectives between the EIs. The internal mechanisms for implementing the CoS are out of scope and left up to implementation.

Specification of all possible or likely CoS is also out of scope. This IA will specify a minimal set of CoS (i.e., a Three CoS Model) that provides support for key applications while leaving some values associated with PCP and DSCP (component of EVC+PCP or EVC+DSCP CoS Identifiers) available for Operator use. The Operator may use these additional values to map to MEF CoS, internal CoS or additional Subscriber CoS (e.g., an Operator offers 2 CoS, in addition to the MEF CoS, at a UNI where the additional CoS are subclasses of the MEF CoS or are Operator specific). Operator specific CoS is outside the scope of the MEF CoS IA. An Operator may implement any number (e.g., 3, 2, or 1) of the MEF CoS across a given EI or for a given CoS Instance of an EVC. Future Phases may specify additional MEF CoS but should not modify the Three CoS defined in Phase 1. Any additional CoS Identifiers beyond what is specified in [2] are out of scope for CoS IA Phase 1.

Phase 1 will specify the CoS model structure including: number of specified CoS, associated Performance Attributes, applicability of Bandwidth Profile options, and PCP and DSCP components of the CoS Identifier. Place holders for Frame Delay, Frame Delay Variation and Frame Loss Ratio Performance Attribute Objectives are also provided. This phase does not include Availability Objectives. Later phases will elaborate on the relationship between CoS and Bandwidth Profile and add quantitative specification of Performance Attribute Objectives and associated parameters (e.g., Percentile (P), Reporting Interval (T)). L2CP specific methods of indicating CoS are also for a later phase.

Later phases will also consider the need for objectives that are allocated to typical Operator domains (i.e., segmentation internally or at E-NNIs) and concatenation methods appropriate for multiple MENs. Though the scope does not include certification, this IA is written to allow a follow-on specification of CoS test requirements and cases that could lead to CoS certification.

Any CoS-related control/signaling, operations and security aspects are out of scope. Internal CoS used by an Operator is also out of scope.

Where possible this IA will rely on CoS and performance monitoring related service attributes already defined in other MEF specifications. To ensure end-to-end CoS, this IA identifies, and where necessary constrains or extends, current MEF specifications to provide more specific frame CoS Identification and performance than current specifications. The IA also builds upon previous work in IEEE, ITU and IETF for consistency, fast development and facilitation of end-to-end CoS. This previous standards work includes IP, thus facilitating synergies between Ethernet and IP services and networks.

The figures below represent scope and applicability of the CoS IA to both UNI and E-NNI, to both Multipoint and Point-Point EVCs and to both single and multiple MENs.

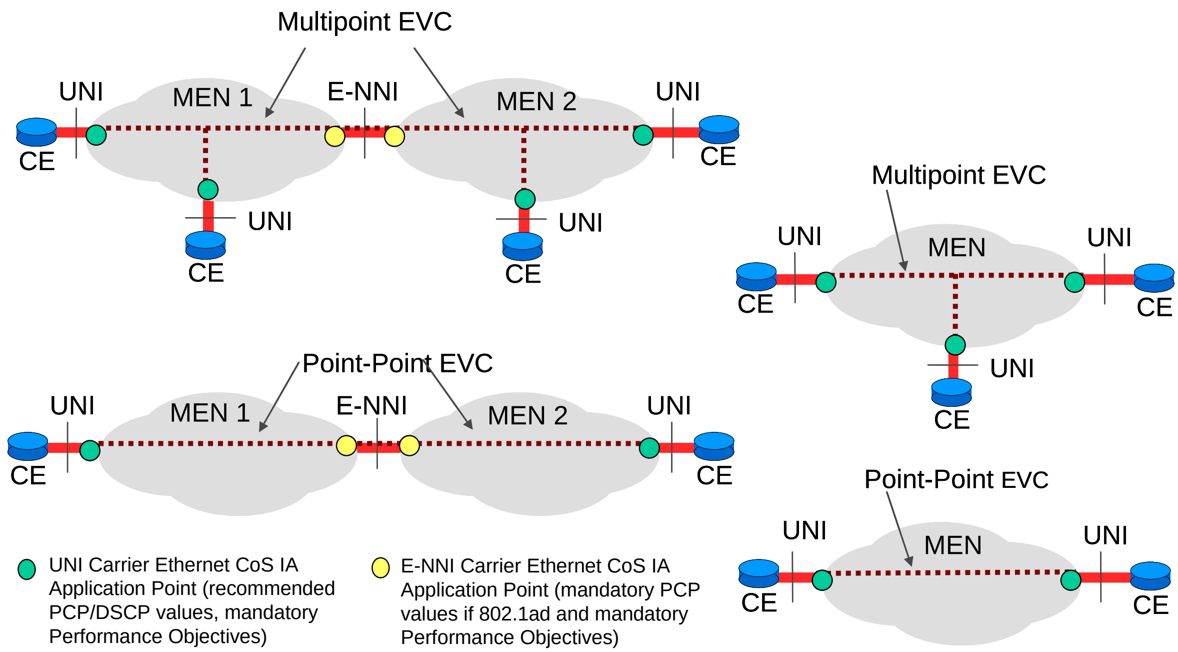

Figure 1 – CoS IA Scope and Applicability

With respect to the set of interfaces that are described as MEN External Interfaces in [6], the CoS IA will use the term External Interface (EI) to only include the UNI and E-NNI for instances where UNI and E-NNI share common characteristics.

The normative content of the CoS IA is in Section 6, Class of Service Model. This section provides motivation and background followed by specification of how CoS Identifiers and Color are used. This includes the introduction of the term CoS Label to represent CoS IA "classes" (i.e., CoS) and Color indication at the UNI and E-NNI. Next are description and requirements of how Frame Delay, Frame Delay Variation and Frame Loss Ratio Performance Attribute objectives are represented as placeholders in Phase 1. Next a short section provides the necessary Bandwidth Profile requirements in order to specify a CoS Model. Additional Bandwidth Profile specification work will be required in future phases and/or other MEF specifications. After a description of CoS Model applicability to EVC and Service Types, the CoS Model and associated Table is described and specified. The CoS Model table represents the primary thrust of the CoS IA as it provides the number of "classes" (i.e., CoS), PCP and DSCP component of CoS Identification values and overall structure. The Table is followed by a section on EI mapping. Finally there are several Appendices that provide background information, use cases and preliminary direction for future phase work.

4. Compliance Levels

The requirements that apply to the MEF CoS are specified in the following sections. Items that are **REQUIRED** (contain the words **MUST** or **MUST NOT**) will be labeled as **[Rx]**. Items that are **RECOMMENDED** or Desired (contain the words **SHOULD** or **SHOULD NOT**) will be labeled as **[Dx]**. Items that are **OPTIONAL** (contain the words **MAY** or **OPTIONAL**) will be labeled as **[Ox].**

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in RFC 2119 [4]. All key words use upper case, bold text to distinguish them from other uses of the words.

5. Introduction

Ethernet has its origins in providing local network connectivity and was not originally used to provide public services to Subscribers through Operators and Service Providers. With the introduction of Metro and Carrier Ethernet services, Service Providers and Operators started using this Ethernet "connectivity" technology to provide Ethernet "services". Various MEF specifications have added to IEEE 802 series standards in order to create a framework to define Ethernet services. This IA is motivated by the need to introduce and define specific "classes" or CoS that will receive a commitment for a particular level of performance for a set of Service Frames (e.g., those belonging to a particular application) from the Service Provider. This is to further develop Carrier Ethernet services that are interoperable and predictably support Subscriber applications. For example, Operators and Service Providers that connect MENs will be able to do so with a set of commonly understood CoS in addition to any bilateral CoS they want to support.

CoS IA normative language is primarily applicable to Service Providers and Operators. The requirements are developed based on the needs of Subscribers and their applications. Compliance with the CoS in this IA does not limit an Operator from providing additional CoS using CoS Identifier values (e.g., EVC, EVC+PCP or EVC+DSCP) that are left unused in this IA. Examples of additional CoS could include sub-classes within the MEF CoS or some Operator defined CoS in addition to the specific MEF CoS defined in this IA.

6. Class of Service Model (Normative)

6.1 Motivation and Background on CoS Model

The figure below illustrates the need for a standard CoS Model for mapping at E-NNI which is a key motivation for CoS IA. The problem addressed is that the Operators of MEN 1 and MEN 2 may have different CoS and different methods and values to indicate the CoS. The figure illustrates how the use of the CoS IA can provide a common set of CoS that the Operators can map frames into to facilitate interworking. For example for a frame going from MEN 1 to MEN

2 whereby CoS Heart maps to MEF CoS Label Medium which then maps to CoS Paper in MEN 2. Similarly, for a frame going from MEN 1 to MEN 2 whereby CoS Square also maps to MEF CoS Label Medium and thus maps to CoS Paper in MEN 2. Finally, for a frame going from MEN 2 to MEN 1 whereby CoS Paper maps to MEF CoS Label Medium and thus maps to CoS Square in MEN 1.

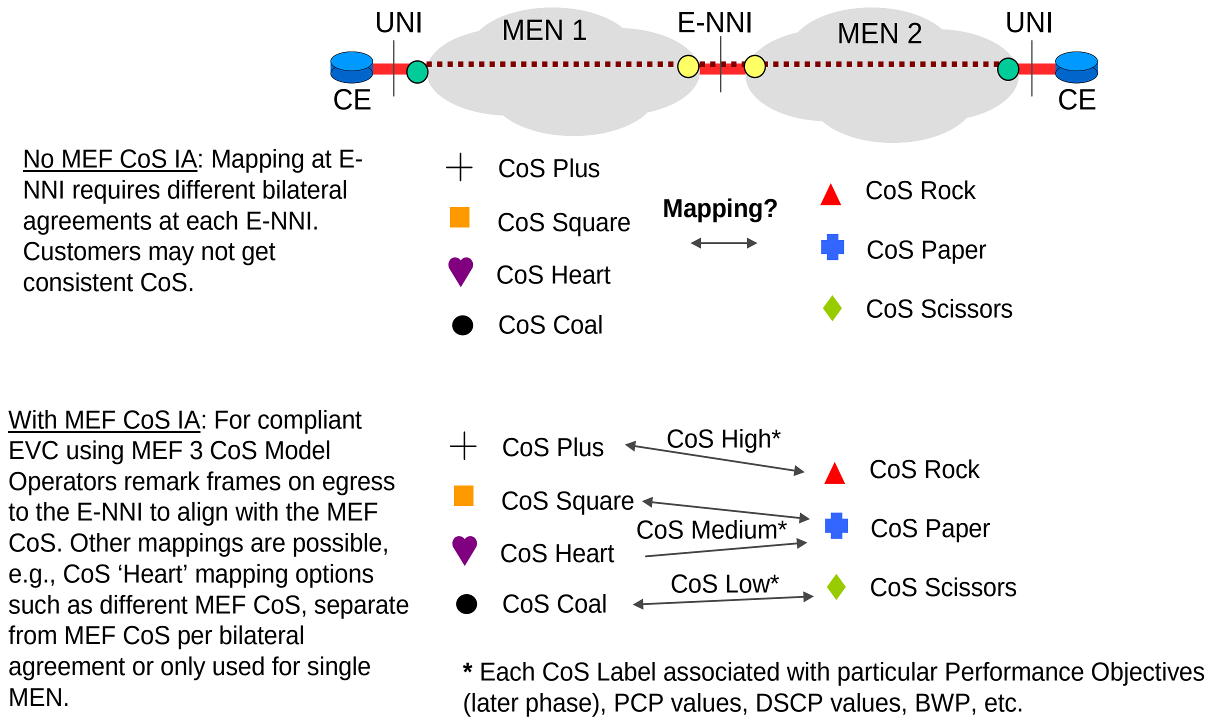

Figure 2 – CoS IA Motivation Example – E-NNI Mapping

Note that in the figure above the 3 CoS names used by the Operator (Rock, Paper, Scissors) may align with the CoS IA Three CoS Model. A case could be constructed where neither MEN complies with the CoS IA internally but both map to the CoS IA Model at the E-NNI. A Three CoS Model is specified in order to satisfy the competing needs of a diversity of applications, finding common needs among Operators, limited CoS Identifier and Color field value space (e.g., 8 possible PCP values) and ensuring sufficiently simple interoperability. CoS IA Phase 1 allows any combination of subsets of the 3 CoS specified.

The CoS Model Performance Attribute Objectives for Phase 1 are placeholders that will be replaced by appropriate values or expressions in later phases. The expressions may include optional variables or factors that can variably impact the Performance Objectives of each CoS. Examples may include consideration for distance (i.e., propagation delay) and low speed links that can create significant frame delay or delay variation in certain situations. In addition "unspecified" is a possible expression.

6.2 CoS Label

CoS Label is a term introduced in the CoS IA to provide a naming convention intended to be independent of all Service Provider, Operator and other standards' CoS "names". It is simply a label used in MEF CoS IA to provide a name or tag for referring to a MEF specified "class" or CoS. CoS Labels do not infer any specific implementation of network priority mechanisms (e.g., strict priority queuing, weighted fair queuing, etc.) in handling a Service Frame. Final CoS Labels are planned concurrent with a later CoS IA phase that includes specification of Performance Attribute Objectives. For Phase 1 placeholder CoS Labels used are H, M and L. These informally refer to High, Medium and Low. The order of the CoS Labels is based on the traffic classes in [5] and their associated PCP values. Later phases will determine the quantitative objectives associated with each CoS and any relationship between these performance objectives.

[R1] A CoS Instance that complies with this CoS IA **MUST** map to only one of the CoS Labels in Table 2.

The CoS IA does not allow multiple CoS (i.e., CoS Labels) for a single CoS Instance. Each CoS Instance must therefore map to a single CoS Label.

Users of this IA, such as Service Providers, may assign any names desired to the MEF CoS for their own services.

6.3 CoS and Color Identifiers

6.3.1 CoS Indication

At the UNI and the E-NNI the CoS for a given frame is indicated by a CoS Identifier. As specified in [2] there are multiple types of CoS Identifiers at the UNI including EVC, EVC + PCP (using CE-VLAN CoS), EVC + DSCP or EVC+L2CP. At the E-NNI, only PCP plus the connection across the MEN[1] (using S-tag PCP) is in-scope for Phase 1. When CoS ID is EVC, the CoS in this IA still apply but the means to convey CoS is based on mutual agreement between Service Provider and Subscriber at the UNI. *In the CoS IA when the terms PCP or DSCP are used in conjunction with UNI CoS Identification (i.e., CoS Identifier or CoS ID) it is short for EVC+PCP or EVC+DSCP CoS Identifiers (i.e., PCP or DSCP based CoS Identifier).*

The specific values for PCP in Table 2 were derived from [5] using Tables 6-4 and G-5 Priority Code Point Decoding. The table row used is "5P3D" scheme (5 traffic classes of which 3 also have drop eligibility PCP values). See Section 8.6 for table excerpts. The specific values of DSCP and Per Hop Behavior (PHB) for each CoS Label are also specified in this IA. Per [2], untagged Service Frames, whose CoS is not determined using the EVC (i.e., single CoS per EVC) or DSCP, have the same CoS Identifier as an ingress Data Service Frame with PCP = 0. Alternatively untagged frames based on EVC-only or EVC+DSCP CoS Identifiers can be used to indicate other CoS.

[1] The connection across the MEN is the means by which the MEN supports its portion of one or more EVCs.

L2CP frames, whose CoS is not determined using the EVC, may have a CoS Label determined by their MAC DA, Ethertype (Protocol type) or other method (e.g., mutual agreement with the Subscriber or between Operators). For untagged L2CP a default CoS Label mapping may be determined in a later CoS IA phase when Performance Objectives are quantified. The CoS Label for specific L2CP types is for later phases as well.

6.3.2 Color Indication

Color is a part of the Bandwidth Profile specification in [2]. The Color Mode parameter can be either Color Aware or Color Blind. The method of Color indication, for Color Aware, is not specified in [2]. At the EIs the Color for a given frame is indicated by a Color Identifier. Color Identifier is a term/attribute introduced in this IA that describes how the UNI Service Frame or E-NNI frame indicates Color (e.g., Color Identifier can indicate a Yellow frame at an E-NNI via the S-tag PCP or DEI).

In CoS IA Phase 1 Color Identification is accomplished via the PCP (i.e., CE-VLAN CoS in [2]) or DSCP at the UNI and via the PCP (i.e., S-tag PCP) or DEI at the E-NNI. Thus the PCP or DSCP may convey both CoS and Color. Also note that when frames are untagged at the UNI only DSCP can be used to indicate Yellow.

Use of DEI for Color Indication may free up additional values of the S-tag PCP but may not be feasible in the near term unless the networking equipment supports it (e.g., older Ethernet equipment and MPLS do not support DEI or an equivalent). DEI use is not shown explicitly in Table 2 but is specified in Requirement [R9] below. Its use at an E-NNI for Color Identifer will free up the PCP values shown for Color Yellow in Table 2 to be used by the Operator as needed.

6.3.3 CoS and Color Indication Requirements

The following requirements address the specific CoS and Color Identification requirements and associated Bandwidth Profile Color Modes for EIs.

The E-NNI, as defined in [6], is assumed to meet the following specific CoS and Color indication requirements.

With respect to IEEE 802.1ad-2005 ([5]) and the E-NNI:

[R2] If the frame format defined in 802.1ad is used at the E-NNI: The PCP field of the S-Tag **MUST** be used as the CoS Identifier.

[R3] At an E-NNI, when a per frame Color Identifier is used, the Color MUST be indicated using either the PCP field of the S-Tag, or indicated separately using the optional S-Tag DEI field.

[R4] If IEEE DEI field is used to indicate Color it **MUST** be implemented as described in [5].

With respect to the Color Mode of Bandwidth Profile at the UNI:

[R5] At the Ingress UNI Bandwidth Profile, Color Mode parameter value of Color Blind **MUST** be supported and Color Aware **MAY** be supported.

[D1] For a given CoS Instance all Ingress Bandwidth Profile Color Mode parameter settings at the UNIs **SHOULD** be the same.

With respect to the CoS at the EI when in Color Blind mode of Bandwidth Profile:

[D2] When Color Blind mode is used with a PCP or DSCP CoS Identifier at the Ingress UNI, the PCP or DSCP value **SHOULD** map to a CoS Label as per Table 2 column labeled *PCP / PHB (DSCP) CoS-only Identifiers* for a given Service Frame.

[R6] When Color Blind mode is used with a PCP CoS Identifier at the ENNI, the PCP value **MUST** map to a CoS Label as per Table 2 column labeled *PCP / PHB (DSCP) CoS-only Identifiers* for a given frame

With respect to the E-NNI Color Mode for a given CoS Instance:

[R7] The Color Mode parameter of each Bandwidth Profile at the E-NNI(s) associated with a CoS Instance **MUST** be set to Color Aware mode when Yellow frames can be present.

When an E-NNI interface specification document is available, a later phase of CoS IA will synchronize with it. For example if "tunneling" functionality and attributes are included, [R7] may be amended or appended. In addition, to the extent a future E-NNI specification includes Bandwidth Profile and associated Color Mode and Color preservation requirements, CoS IA Phase 1 requirements may be amended or appended.

With respect to the Egress UNI Color Mode for a given CoS Instance:

[D3] The Color Mode parameter of each Egress Bandwidth Profile at the UNIs associated with the CoS Instance **SHOULD** be set to Color Aware when Yellow frames can be present.

Motivation for requirements [R7] and [D3] is to prevent changing of Yellow frames (i.e., frame disposition in terms of Color at an Ingress UNI Bandwidth Profile) to Green frames at any downstream E-NNI or Egress UNI Bandwidth Profile. Note that the applicability of these requirements can vary per CoS Instance and per interface. [R7] and [D3] will not apply if the particular CoS Label and options selected (see Table 2) will not result in any Yellow frames from the Ingress UNI Bandwidth Profile. For example in the case of CoS Label H with EIR=0 and Coupling Flag set to 0, [R7] and [D3] are not applicable since there can be no Yellow frames after an initial startup period determined by EBS.

With respect to the CoS and Color at the EI when in Color Aware mode of Bandwidth Profile or there is no Bandwidth Profile:

[D4] When Color Aware mode is used at the Ingress UNI, the PCP or DSCP value **SHOULD** map to a CoS Label and Color as per Table 2 column labeled *Color Green* or *Color Yellow* for a given Service Frame.

[R8] When either Color Aware mode or no Bandwidth Profile is used with a PCP CoS Identifier at an E-NNI without DEI support, the PCP value **MUST** map to a CoS Label and Color as per the Table 2 column labeled *Color Green* or *Color Yellow* for a given frame.

[R9] When either Color Aware mode or no Bandwidth Profile is used with a PCP CoS Identifier at an E-NNI with DEI support enabled, the S-Tag PCP value **MUST** map to a CoS Label as per the Table 2 column labeled *CoS w/DEI* and the DEI **MUST** be used to identify the Color for a given frame.

As far as this IA is concerned PCP and DSCP values not in Table 2 can be used in any way the Operator desires. This IA only specifies a subset of CoS Identifier values at EIs and is not applicable to what is internal to a MEN. In the full Three CoS Model, 3 PCP values are left open for Operator use. If a subset is used additional values are available. It is possible for an Operator to reuse the PCP CoS Identifier values in Table 2, inside the MEN but is not constrained to do so. The intent for Phase 1 is for the associated CoS Label Performance Attribute Objectives to apply consistent with [2] and for the PCP and DSCP values specified to apply at the EIs.

The Per Hop Behavior (PHB) column in Table 2 provides the DSCP values used as part of the CoS Identifier at the UNI. The table includes Expedited Forwarding (EF), Assured Forwarding (AF) and Default PHBs.

6.4 Performance

Consistent with [2], Performance Attributes are defined such that they apply only to a Service Frame when the applicable Ingress Bandwidth Profile level of compliance at the UNI is determined to be Green. In this IA such frames are described as simply Green or Color Green Service Frames. The preceding can be applied to both single and multiple-MEN EVCs as per the Color Mode attribute requirements in section 6.3. Bandwidth Profile compliance is defined further in section 6.5. Examples of considerations for determining objectives are found in the Appendix section 8.1.5. The remainder of this section describes the Performance Attributes included in the CoS IA Phase 1. Future phases of the CoS IA will align with future revisions of [2] and E-NNI specifications.

6.4.1 Frame Delay Performance Attribute

Frame Delay (FD) Performance Attribute is defined in [2].

Frame Delay for a Green Service Frame is the one-way delay that includes the delays encountered as a result of transmission across the ingress and egress UNIs and E-NNIs (if present) as well as that introduced by the MEN. Note that the FD performance attribute in [2] is denoted by the objective $\hat{d}$ and is defined using a Percentile (P) over a Time interval (T). For Multipoint EVCs there is an additional parameter (S) indicating a subset of the ordered UNI pairs. While [2] does not specify values for parameters $\hat{d}$, P or T, future phases of CoS IA will specify them for each CoS Label. For Phase 1, there is no quantification and so specific normative language for FD is deferred to later phases when quantitative requirements will be included. These FD Performance Objective requirements will apply UNI-to-UNI consistent with [2] in Phase 1. Later phases may also look at UNI to E-NNI, E-NNI to E-NNI or other segment performance.

> **[R10]** A CoS instance utilizing MEF compliant CoS **MUST** provide FD Performance Attribute Objective between the associated UNIs per the associated *CoS Label* and *EVC Type* row in Table 2.

6.4.2 Frame Delay Variation Performance Attribute

The Frame Delay Variation (FDV) Performance Attribute is defined in [2].

The Frame Delay Variation performance attribute is denoted by the objective $\breve{d}$ and is defined in [2] as the P-percentile of the absolute values of the difference between the Frame delays of all Green Service Frame pairs under a list of specified conditions that includes parameters Δt and T as well. For Multipoint EVCs there is an additional parameter (S) indicating a subset of the ordered UNI pairs. While [2] does not specify values for the parameters $\breve{d}$, Δt, P or T, future phases of CoS IA will specify them for each CoS Label. For Phase 1, there is no quantification and so specific normative language for FDV is deferred to later phases when quantitative requirements will be included. FDV performance objective requirements will apply UNI-to-UNI consistent with [2] in Phase 1. Later phases may also look at UNI to E-NNI, E-NNI to E-NNI or other segment performance.

> **[R11]** A CoS instance utilizing MEF compliant CoS **MUST** provide FDV Performance Attribute Objective between the associated UNIs per the associated *CoS Label* and *EVC Type* row in Table 2.

6.4.3 Frame Loss Ratio Performance Attribute

The Frame Loss Ratio (FLR) Performance Attribute is defined in [2] as the ratio ($\hat{L}$), expressed as a percentage, over a specified time interval (T), of the number of Green Service Frames not delivered divided by the total number of Green Service Frames that should have been delivered. For Multipoint EVCs there is an additional parameter (S) indicating a subset of the ordered UNI pairs.

While [2] does not specify values for $\hat{L}$ or T, future phases of CoS IA will specify them for each CoS Label. For Phase 1, there is no quantification and so specific normative language for FLR is deferred to later phases when quantitative requirements will be included. FLR performance objective requirements will apply UNI-to-UNI consistent with [2] in Phase 1. Later phases may also look at UNI to E-NNI, E-NNI to E-NNI or other segment performance.

> **[R12]** A CoS instance utilizing MEF compliant CoS **MUST** provide FLR Performance Attribute Objective between the associated UNIs per the associated *CoS Label* and *EVC Type* row in Table 2.

6.5 BANDWIDTH PROFILE AND COLOR

6.5.1 Bandwidth Profile Compliance

CoS IA Phase 1 provides limited specification of Bandwidth Profile (BWP) and CoS interactions and concentrates on providing the CoS Model and structure. Future phases will provide more detailed specifications of BWP and which frames count toward SLSs for the scenarios of single and multiple MEN and various EVC types.

Bandwidth Profile is important to this IA because it determines which Service Frames ingress to a MEN or egress from a MEN at each EI and the Service Frame's compliance with the Bandwidth Profile determines Color and applicability of SLS. Ingress Bandwidth Profiles apply to frames entering a MEN at an EI and Egress Bandwidth Profiles apply to frames exiting a MEN at an EI.

In the CoS IA Phase 1 Bandwidth Profile and Color are used consistent with [2] for the UNI and are assumed equivalent for the E-NNI in CoS IA Phase 1. Identification of Color can be used to indicate which Service Frames are deemed to be within or outside of the SLS contract according to the contracted Bandwidth Profile. Levels of compliance are Green when fully compliant (compliant with CIR, CBS), Yellow when sufficient compliance for transmission but without SLS Performance Objectives (compliant with EIR, EBS) and Red or discarded when not compliant with either. Green and Yellow frames will be identified as such in this IA. Note that the ITU terminology in [8] for Green is Discard Ineligible frames and for Yellow/Red it is Discard Eligible frames.

Note that Table 2 provides CIR, EIR and CF constraints. CBS and EBS are specified across all MEF CoS in [2].

As stated in section 6.4 all performance attributes are defined such that they only apply to a Service Frame when the Ingress UNI Bandwidth Profile compliance is Green in terms of Color.

[R13] A CoS Instance utilizing MEF compliant CoS **MUST** use the Bandwidth Profiles defined in [2] at the Ingress UNI with the parameters and value constraints in the *Bandwidth Profile Constraint* column per the associated *CoS Label* row in Table 2.

Note that implicit rate limiting can be provided by the bandwidth limits of the EI Ethernet link. While this is not a Bandwidth Profile that is explicitly defined in [2], this case can result in behavior equivalent to a Color Blind mode Bandwidth Profile with CIR set to 'link rate' and EIR set to 0, and this may be the approach that a Service Provider elects to create this bandwidth profile. For this reason, this case is considered for the purposes of this IA to be an implementation of an implicit Bandwidth Profile as defined in [2].

The constraints for the Bandwidth Profile parameters shown in this IA are expressed as "equal to", "greater than" or "greater than or equal to" zero (e.g., CIR = 0, CIR >0, CIR ^{3} 0). Bandwidth Profile parameters and values that are not specified are not constrained by this IA in Phase 1.

The correct operation of the Bandwidth Profile at an External Interface (e.g., UNI) is independent of traffic conditions at the interface or in the MEN.

6.6 EVC and Service Type Applicability

Any of the MEF CoS can be used with any type of EVC that is described in [2] or any Service Type that is described in [1]. In particular, Point-to-Point EVCs could use the same CoS as some Multipoint-to-Multipoint EVCs. Still, at the E-NNI a specific implementation might serve these different service types using separate treatment (e.g., queues). MEF CoS IA is intended to be applicable to Point-to-Point, Multipoint-to-Multipoint and Rooted-Multipoint EVCs including the case where some or all are present simultaneously on a given EI.

For example, serving an EVP-LAN EVC might be more complex than an EVPL. A given pair of EIs on a Multipoint-to-multipoint EVC may communicate Service Frames using different paths within a MEN and among different Operator's MENs compared to the paths and network traversed by Service Frames from another pair of EIs on the same EVC. This and the variability of traffic between UNI pairs within compliance of the Bandwidth Profile can complicate meeting CoS Performance Attribute Objectives for Multipoint EVCs.

In future phases of this IA, Performance Attribute Objectives for a given MEF CoS will be provided separately for Point-to-Point and Multipoint EVC types (i.e., Multipoint-to-Multipoint and Rooted-Multipoint) as shown in Table 2. Therefore, Point–to-Point EVCs (e.g., EVPL service) could have stricter Performance Attribute Objectives when these Objectives are quantified in later phases. Separate placeholders for Performance Objectives are shown in Table 2 for this purpose.

Consistent with [2], for Multipoint-to-Multipoint and Rooted-Multipoint EVCs, the MEF CoS Performance Attribute Objectives apply between sets of ordered pairs of UNIs on the EVC that are allowed to exchange traffic. When the MEF CoS Performance Attribute Objectives are applied to a set of two or more pairs of UNIs the performance is based on the worst pair's performance as described in [2].

6.7 CoS Model

The CoS Model Table provides normative information for each MEF CoS in a Three CoS Model. The Table provides: CoS Label, placeholders for Performance Objectives for FD, FDV and FLR; Bandwidth Profile CIR and EIR constraints; and CoS Identifier and Color Identifier using PCP and DSCP. All Performance Objective requirements refer to UNI-to-UNI performance in Phase 1.

In later phases of MEF CoS IA, FD, FDV and FLR will be specified as one of the following:

1. *Numeric values* expressed in milliseconds (ms) for FD and FDV. FLR will be expressed as a decimal number representing a percentage.
2. *Expressions* that are evaluated for a given CoS instance to provide an numeric value for a given Performance Objective. The expression may include aspects such as distance for FD.
3. *Unspecified* performance for a particular objective for a given CoS Label

In Phase 1, Performance Objectives are expressed in relative terms using A, B, C where generally A is "better" than B, A is "better" than C, and B is "better" than C. A, B and C represent placeholders for future values, expressions or unspecified Performance Objectives. The term "better' is qualitative and informative in a general manner for Phase 1 and does not mean every Performance Objective will always be better, though in general they will. The differences between A and A´, B and B´ and C and C´ is informative to indicate the possible differing Performance Objectives between Point-to-Point and Multipoint EVC types. Performance Objectives (i.e., numeric values, expressions or unspecified designation) in later phases of this IA will be normative.

Since this CoS IA supports a Three CoS model and its subsets, there is a need for interworking or mapping between the subsets. For example, Operator of MEN 1 adopts all CoS in the Three CoS Model and Operator of MEN 2 adopts a subset of 2 CoS including CoS Label H and L. If MEN 1 and MEN 2 are connected via an E-NNI there is a need for mapping between the two models. This mapping will be determined coincident with a later phase when Performance Objectives are quantified.

6.7.1 Three CoS Model

This model, as shown in Table 2, specifies three MEF CoS Labels denoted by CoS Labels H, M and L. There is no restriction on how Operators may use the PCP (i.e., 4, 6, 7) and DSCP values not specified. However, there are additional restrictions on use of PCP values in [2] that are further defined in Section 6.7.2. The model provides for potentially different Performance Objectives for each CoS / EVC Type pair. In future phases other columns may similarly provide variation for EVC Type (e.g., Bandwidth Profile Constraints).

While there are not columns shown in Table 2 for EVC, the EVC may be used alone or in combination with the CoS Identifier components shown (PCP and DSCP) to determines the CoS Label for a Service Frame. EVC part of the CoS Identifier is not shown because it is not constrained in the CoS IA beyond the requirements in [2].

Note that the DSCP and associated Per Hop Behavior (PHB) are provided. However, DSCP is what is actually used in the Service Frame. Additional CoS Identifiers may be specified if future phases of CoS IA.

In [5] (Table 6-4 "5p3d" row) there is a traffic class called "Best Effort" which is associated with PCP=1 when not drop eligible and PCP=0 when drop eligible. In this IA CoS Label L is aligned with this traffic class in [5]. In terms of Bandwidth Profile note that CoS Label L allows CIR or EIR = 0. The special case of CIR = 0 effectively results in no MEF Performance Objectives for FD, FDV and FLR (i.e., Unspecified performance) while the case of CIR > 0 will require conformance with Performance Attribute Objectives. From a DSCP perspective CoS Label L is a combination of AF1 (for CIR>0) and Default (for CIR=0) classes.

CoS Label	EVC Type	FD	FDV	FLR	Ingress UNI Band-width Profile Con-straints[3]	PCP / PHB (DSCP) CoS and Color Identifiers[1]		PCP / PHB (DSCP) CoS-only Identifiers[1]	Example Applica-tions
						Color Green CoS w/DEI	Color Yellow[2]		
H	Pt-Pt	A_{FD}	A_{FDV}	A_{FLR}	CIR>0 EIR^3 0 [4] CF=0	5 / EF (46)	N/S in Phase 1	5 / EF (46)	VoIP and Mobile Backhaul Control
	Multipt	A_{FD}'	A_{FDV}'	A_{FLR}'					
M	Pt-Pt	B_{FD}	B_{FDV}	B_{FLR}	CIR>0 EIR^3 0	3 / AF31 (26)	2 / AF32 (28) or AF33 (30)	2-3 / AF31-33 (26, 28, 30)	Near-Real-Time or Critical Data Apps
	Multipt	B_{FD}'	B_{FDV}'	B_{FLR}'					
L	Pt-Pt	C_{FD}	C_{FDV}	C_{FLR}	CIR^3 0 EIR^3 0 [5]	1 / AF11 (10)	0 / AF12 (12), AF13 (14) or Default (0)	0-1 / AF11-13 (10, 12, 14) or Default (0)	TBD in future Phase
	Multipt	C_{FD}'	C_{FDV}'	C_{FLR}'					

[1] Full CoS Identifier includes EVC. Table specifies only the PCP or DSCP values to be used with EVC. EVC indication is not constrained by CoS IA.

[2] The Color Yellow column values are N/A when DEI is used to represent Color at the E-NNI.

[3] CBS, EBS, and Color Mode Bandwidth Profile parameters are not addressed in this table.

[4] EIR is not constrained though EIR=0 assumed since not specifying Color Yellow PCP and DSCP for CoS Label H. Relaxation of EIR constraint is for applications such as Mobile Backhaul (see Mobile Backhaul example use case in Appendix).

[5] Both CIR and EIR = 0 is not allowed as this would result in no conformant Service Frames under steady state operation.

Note: Separate rows for Point-to-Point and Multipoint for each CoS Label to allow for different Performance Objectives for each as denoted by the prime (′). Multipoint also includes Rooted Multipoint as per [2].

Table 2: Three CoS Model Table

6.7.2 PCP and DSCP Mapping

6.7.2.1 UNI

Full mapping of PCP or DSCP values at a UNI is required to ensure that customer frames are not inadvertently discarded and to simplify configuration of customer equipment. Note that per [2], a valid Service Frame delivery performance may be to discard the Service Frame. Thus a Class of Service Identifier may be specified for Service Frame discard in addition to those in this IA.

[R14] For a single-CoS EVC, all ingress Data Service Frames mapped to the EVC, regardless of PCP or DSCP value, **MUST** have the same CoS Identifier, as specified in [2].

[R15] For an EVC supporting any mix of MEF CoS and Operator specific CoS where EVC+PCP is used for CoS Identification, all possible PCP values **MUST** be fully mapped to the CoS supported on a given EVC at the UNI, i.e., each of the PCP values from 0 to 7 must be mapped to a CoS.

[R16] For an EVC supporting any mix of MEF CoS and Operator specific CoS where EVC+DSCP is used for CoS identification, all possible DSCP values **MUST** be fully mapped to the CoS supported on a given EVC at the UNI, i.e., each of the DSCP values from 0 to 63 must be mapped to a CoS.

For a multi-CoS EVC that supports only the standard MEF CoS as defined in this document, tables providing examples of full PCP and DSCP mapping at a UNI are located in Appendix Section 8.5. Providing the same CoS mapping on all UNIs for a given EVC will minimize customer confusion. The intent is to normatively define this full mapping in later phases of this specification as the actual Performance Objectives for each CoS are quantified, as described in Section 8.1.

For a multi-CoS EVC that supports the standard MEF CoS in addition to one or more non-standard CoS at a UNI, full PCP or DSCP mapping is still required at a UNI. See Section 6.3 for specific requirements.

Note that per [2], a Service Frame delivery performance may be to discard the Service Frame. Thus a Class of Service Identifier may be specified for Service Frame discard in addition to those in this IA.

6.7.2.2 E-NNI

For future study.

7. References

[1] MEF Technical Specification MEF 6.1, “Ethernet Services Definitions - Phase 2”

[2] MEF Technical Specification, MEF 10.1, “Ethernet Services Attributes - Phase 2”

[3] IEEE 802.1Q – 2005, “Virtual Bridged Local Area Networks”

[4] RFC 2119, “Key words for use in RFCs to Indicate Requirement Levels”, S. Bradner

[5] IEEE 802.1ad-2005, “Virtual Bridged Local Area Networks – Amendment 4: Provider Bridges”

[6] MEF Technical Specification MEF 4, “Metro Ethernet Network Architecture Framework - Part 1: Generic Framework”

[7] Inter-provider Quality of Service, MIT Communications Futures Program, 2006

[8] ITU-T Recommendation Y.1541, “Network performance objectives for IP-based services”

[9] MEF Technical Specification MEF 3, “Circuit Emulation Service Definitions, Framework and Requirements in Metro Ethernet Networks”

[10] RFC 2597, “Assured Forwarding PHB Group”, Heinanen

[11] RFC 3246, “An Expedited Forwarding PHB”, Davie

[12] RFC 4594, “Configuration Guidelines for DiffServ Service Classes”, Babiarz

8. Appendices (informative)

8.1 Potential Work Areas for Later Phases of MEF CoS IA

8.1.1 Performance Attribute Objective Derivation

Key applications (e.g., VoIP and Mobile Backhaul) and existing standards (e.g., Y.1541) will be used to derive the performance parameter values for each CoS in later phases. The applications that were identified and will be used to build the performance requirements are described in Appendix 8.2. An example of an Ethernet application that drives performance is Mobile Backhaul for metro networks.

8.1.2 Bandwidth Profile Extensions

As stated in Sections 6.4 and 6.5 Bandwidth Profile is a key element of Ethernet CoS. Some extensions of the BWP specification in [2] are contained in sections 6.3, 6.4 and 6.5. In later phases both Performance Objectives and Bandwidth Profile specifications are needed. Whether a Service Frame is applicable for SLS is complicated when frames traverse E-NNIs and Egress

BWPs that provide the opportunity for the frames UNI Ingress BWP disposition (i.e., Color) to be modified. For example, a requirement could be considered in which SLS is applicable for E-LAN and E-Tree Service Frames for which the Ingress Bandwidth Profile at the UNI compliance is Green and the applicable Egress Bandwidth Profile (if any) result at the egress UNI is Green or Yellow. In addition there is an open issue with Frame Loss SLS with whether SLS compliance is calculated only for Green frames (i.e., frame by frame) or an equivalent number of frames to the count of Green frames (i.e., count could include some delivered Yellow frames). A requirement may be constructed which allows Frame Loss SLS to be met with an equivalent number of Green + Yellow frames delivered at egress to the count of Green frames at Ingress.

Another potential area is addition of a "Multiple-BWP option". This would allow a hierarchy of BWPs for a single frame. This type of change would also impact [2]. Examples include current implementations of hierarchical policers/shapers and shared EIR policers and shapers.

BWP behavior must be clearly understood in order to state Performance Objectives that are precise and practical. Additional areas of BWP extension will also be considered in later phases.

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8.1.3 Specification of LSF

A Low Speed Factor is probably needed due to the following situation in MENs. While the UNI may still be standard 10Mb/s or greater the access transport links in the MEN will often be significantly slower thus impacting FD. Given the small base of fiber access and rate of fiber deployment to many sites, the use of lower speed copper, wireless and other transport technologies will be common as Carrier Ethernet expands. In addition multiple access links are sometimes bonded with associated fragmentation and reassembly impacts on performance. Examples of low speed access include 2BaseTL in 802.3ah or DS1/E1 transport of Ethernet using Generic Framing Procedure (GFP) or similar. For example, the FD Low Speed access Factor for CoS Label H could be derived using fragmentation delay of 1 ms and serialization delay of 1 ms based on 2 Mb/s effective link speed and 300 Byte frame size. ITU Y.1541 used 160-200 Byte voice packets for the short frame cases. Given the likely small impact, the LSF_S may be considered for elimination. The FD Low Speed Access factor for CoS Label M/L could be derived using fragmentation delay of 1 ms and serialization delay of 6 ms based on 2 Mb/s effective link speed and 1500 Byte frame size.

Later phases may add requirements such as the following. When utilizing the LSF the compliant MEF CoS for CoS Label H must provide FD that is equal to or less than the base FD plus a Low Speed Factor for short length frames (LSF_S). When utilizing the LSF the compliant MEF CoS for CoS Label M and L must provide FD that is equal to or less than the FD plus a FD Low Speed Factor for long length frames (LSF_L). The preceding requirements are to be used when the MEN has access or other low speed links that are limited to less than 10 Mb/s.

8.1.4 Segmentation Approach for Performance Parameters

Segmentation will be considered as a possible addition to the MEF CoS IA in later phases. Division of an EVC into network sections or segments and the ability to concatenate their performance is motivated by several factors. These include:

- typical administrative and network boundaries that exist between MENs at E-NNIs
- applications with the most challenging performance objectives that may bound network diameter (e.g., hops), access speed and require limited path distance
- the need to specify and report performance objectives against each segment in an EVC that traverses multiple MENs. This establishes clear responsibilities for an appropriate budgeted part of the end-to-end (UNI-to-UNI) CoS Performance Objective for each segment.

The segmentation and concatenation must be simple enough to make the CoS specifications workable for interprovider situations where trust and data sharing opportunities are limited. Segmentation facilitates establishing CoS performance budgets for each Operator or domain and then measuring actual performance against the segment objectives. An example of interprovider is interconnection of a metro access Operator, WAN Ethernet Operator and another metro access Operator to connect 2 UNIs. Some practical limit on the number of WAN segments will need to be imposed to bound performance.

8.1.4.1 2 Segment Model

A two segment model may be adapted for MEF CoS that includes Metro/Access and WAN segment types. One or more Metro/Access segments will always be present. A WAN segment or segments may be present for services that traverse several Operators.

MEF CoS segment performance objectives can be built on defined distance boundaries for each segment that makes up the service offered but the Operator is not obligated to strictly use these distance boundaries for actual MEF CoS implementations. The Metro segment is modeled on access, aggregation and switching within an area less than 150km diameter. A WAN segment is modeled as the long distance network that will have a Metro segment at both ends and provide connectivity over arbitrary distances greater than 150km.

Segment Name	**Abbreviation**	**Path Distance**	**FD (ms)**	**FDV (ms)**	**FLR**
Metro/Access	M	=<150km	M_FD	M_FDV	M_FLR
WAN	W	>150km	Fixed W_FD + (.005 x d)	W_FDV	W_FLR

d = Path Distance in km

Table 3: Two Segment Model

For concatenation of multiple segments FLR can be calculated by multiplication by (1-FLR) for each segment.

Values for each CoS Performance Objective for Metro and WAN segments can be built on previous standards and application needs. Some applications such as Mobile Backhaul may be specifically excluded from WAN due to performance requirements and application needs. The FD for WAN is built on distance plus a minimal queuing and processing fixed W_FD (e.g., 4ms derived from [7] for Real Time class). FD for Metro will need to be quantified (e.g., 25ms in [7], 100 ms in [8], 15ms for non-IP access in [8], 5.68ms in MEF14 test cases that assume 100Mb/s UNI). FDV for metro will need to be quantified (e.g., MEF 14 test cases 1 ms).

8.1.4.1 Concatenation of Segments

Combining or concatenating segments is a useful concept for providing both per segment and UNI-to-UNI objectives and performance reporting. When independence can be assumed, measurements that are based on the mean may be added or averaged to achieve concatenation. If mean is available for FD as specified in [8], concatenation may be achieved by simple addition, but [2] specifies use of a percentile FD and FDV measurement. Percentile measurement concatenation is more complex requiring convolution or estimation techniques (see examples found in [8] and [7]). Addition of percentile measurements tends to yield worst case maximums. Concatenation techniques and calculations are therefore areas of work for later phases of MEF CoS IA.

Also note that there is a probable need to limit the number of segments to have a firm constraint on UNI-to-UNI CoS performance. [7] suggests a limit of 3 WAN-like segments. To derive maximum IPDV for concatenated segments, Y.1541 example added maximum IPDV for each segment which results in overstatement. [7] recommends a fairly complex probability based ‘two point promise’ method. Adding FDV segments will overstate actual multi-segment FDV. Various standards and approaches have used probability distribution characteristics, convolution, moments and associated ranges of FDV objectives to provide more accurate methods for combining segments.

8.1.5 CoS Subset Mapping

There is a need to develop an E-NNI mapping table with the 7 possible subsets of CoS Labels supported by an Operator (i.e., H/M/L, H/L, H/M, M/L, H, M, L) in later phases coincident with when performance objectives are quantified.

8.1.6 Performance Attribute Objectives Considerations

Future phases will specify Performance Objectives and associated parameters. The following is an illustrative future phase requirement: MEF compliant CoS MUST provide FDV that is equal to or less than <the FDV objective> for the specified P and T for that CoS Label.

Future versions of [2] are expected to provide additional Frame Delay attributes. These may include Frame Delay Range attributes that may be candidates for addition to FDV or FD in later CoS IA phases for consistency and benefit in terms of concatenation of segments and consistency with ITU.

8.1.6.1 FD and FDV Low Speed MEN Considerations

Delay can be significantly impacted by low speed access or links in a MEN. This is accounted for by an added Low Speed Factor (LSF) that is defined for CoS Label H and a separate LSF defined for CoS Label M/L. In later phases the LSF for CoS Label H will be quantified based on relatively short frames and the LSF for CoS Label M/L will be based on long frames. Similar low speed link performance considerations are contained in [8] and [7].

Sample requirement: FD for a MEF compliant CoS may utilize the LSF when the MEN has access or other low speed links that are limited to less than 10 Mb/s.

Sample requirement: When utilizing the LSF the compliant MEF CoS Label must be described with the suffix -LSF (e.g., CoS Label H - LSF) to indicate that additional delay is added to the objective.

ITU uses mean delay and combines means for each segment to derive end–to-end to account for each domain's performance (as found in [8] and [7]]). Note that mean is simple to measure and calculate but can mask some poor performance. Any addition of mean FD will be in future drafts or phases of the MEF CoS IA and will depend on future additions or amendments to [2].

8.1.6.2 Frame Delay Distance Considerations

The performance objectives for FD in this IA consider distance via a propagation delay add-on.

In future phases of the CoS IA FD performance objectives will be stated as constants with an add-on term that is primarily driven by the physics of propagation. Propagation is estimated as 5 microseconds (µs) or .005 milliseconds (ms) delay per kilometer (km) from [8]. Therefore FD performance objectives are stated in the form of: (FD Constant in ms) + [(distance in km) * (.005 ms/km)] or FD+.005d.

Note that distance (d) is the distance in kilometers between External Interface terminations that are the subject of the CoS. If the path (i.e., circuit) distance is unknown or may vary due to routing or other path changes (e.g., dynamic control protocols) the terrestrial path distance is estimated from the straight line or air-distance (d_a) as follows: $d = 1.25 \times d_a$. This estimation method is from [8]. Estimates of actual path distance are highly preferred since the actual path may be considerably greater distance than this estimate provides.

8.2 Key Applications to Derive Performance Requirements

Intent of the CoS IA is to provide sufficient CoS and Performance Objectives to efficiently support the vast majority of well-known applications. There is an emphasis on applications likely to appear at E-NNIs. Identification of the applications supported, quantification of performance attributes, specification of associated parameters (e.g., P, T, etc.) and mapping to CoS Labels is for a later phase.

Application mapping is for the purpose of determining the quantitive Performance Objectives for each CoS. It is not intended to mandate how a Operator, Service Provider or Subscriber maps a particular instance of an application. For example, a Subscriber could map some VoIP for certain types of communication to CoS Label L and other VoIP to CoS Label H if desired. This IA will be constructed such that VoIP (of the high-quality type defined in this appendix) will be supported in the CoS it is mapped to if the Operator conforms with this IA for that CoS. The mapping that will be developed is for showing how the CoS performance objectives are derived and not meant to imply a requirement for application mapping in actual implementations.

Similar to Application mapping, L2CP needs to be mapped to CoS Labels. There may be different CoS Labels for differenent L2CP types. At a minimum, there is a need to specify a CoS that meets the L2CP application requirements.

The application performance is generally available end-to-end. Since the MEN of interest may only be a portion of the end-to-end network, allocation or budgeting of the objective may be required as the application Performance Objectives are quantified.

Application Set Name	Application Examples	Notes
Mobile Backhaul Synchronization	IEEE 1588	Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
Mobile Backhaul Control & Management	Mobile Service Provider Network Element management and control	Traffic internal to Mobile Service Provider network but Subscriber traffic to MEN. Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
Mobile Backhaul Conversational class	Voice	Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
Mobile Backhaul Streaming class	Streaming video	Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
Mobile Backhaul Interactive class	Web browsing	Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
Mobile Backhaul Background	Background download of emails	Traffic Classes and CoS mapping being defined in Mobile Backhaul IA
VoIP (high/toll/wireline quality)	Various VoIP codecs including G.729	
Circuit Emulation Service	DS1/E1 emulation	[9] 99.9999%tile FD
Interactive Video	Video Chat, Video Conferencing	
Streaming Video/Audio	Centrally provided multicast & unicast TV service over IP	
Internet/Web Streaming Video/Audio	Buffer and Play Internet video	
Interactive/ transaction Data	Subscriber VoIP signaling,	

Application Set Name	Application Examples	Notes
L2CP	Subscriber STP BPDU, etc.	May need further granularity. [2] mentions determining CoS Identifier from type of L2CP but does not go further.
Critical Data	Subscriber mgmt traps, crypto data, SNA, etc. over IP	
Default/ Best Effort	General web, many TCP apps such as email	

Table 4: Applications Types and Examples

8.3 Illustrative description of Mechanisms

A device implementing UNI-N functionality servicing multiple CoS usually features the capability to queue ingress traffic received from UNI-Cs. Traffic belonging to different CoS would likely be put into separate queues. It should be noted that multiple queues could serve a specific CoS. However, in doing so it is recommended to design the system in such a way that re-sequencing is avoided. Therefore, traffic belonging to a specific flow should be put into a single queue. This should include both Color Yellow (i.e., Drop/discard Eligible) and Color Green (non-Drop/discard Eligible) marked frames of this specific flow.

When multiple queues compete for being sent through an interface (towards the MEN internal), a scheduling decision is to be made. Scheduling can take many shapes and forms and can combine different methods like priority queuing (i.e., strict priority), WFQ, etc.

Specific queues might have rate guarantees (minimum rates) and a rate limit. This could be useful to avoid starvation by higher precedence queues. Note that Mobile backhaul application may require avoidance of multiple strict priority mechanisms (strict priority queuing/servicing mechanisms) at least beyond the Real Time classes to avoid starvation of lower classes.

In conjunction to the queuing system, some active queue management (e.g. WRED) should be used to allow congestion mitigation.

The delay and delay variation objectives should be considered when deciding how much buffering a specific queue could consume. As buffering increases so does the observed delay increases.

8.4 Example Use Cases

Below sections describe use cases for applications that may use this Implementation Agreement, starting with the trivial case in which the number of classes required to support the application(s) is less than the number of classes directly supported by a service based on this Implementation Agreement, and working through how a service might be offered based on this Implementation Agreement to support applications requiring more service classes than may be directly supported by this Implementation Agreement.

8.4.1 The Trivial (Direct Support) Use Cases

Many applications and services exist that require 1, 2 or 3 classes associated with some service guarantees. These applications may be directly supported using the 3 class model as defined in this Implementation Agreement.

8.4.2 Use Cases Requiring 4 (or more) Service Classes

The subsections below describe approaches to use this Implementation Agreement in supporting applications or services requiring 4 or more CoS. An instance of such an application is a mobile backhaul deployment requiring – for example – support for timing and synchronization, control and signaling, 2+ data classes and voice. An example is shown in Figure 3.

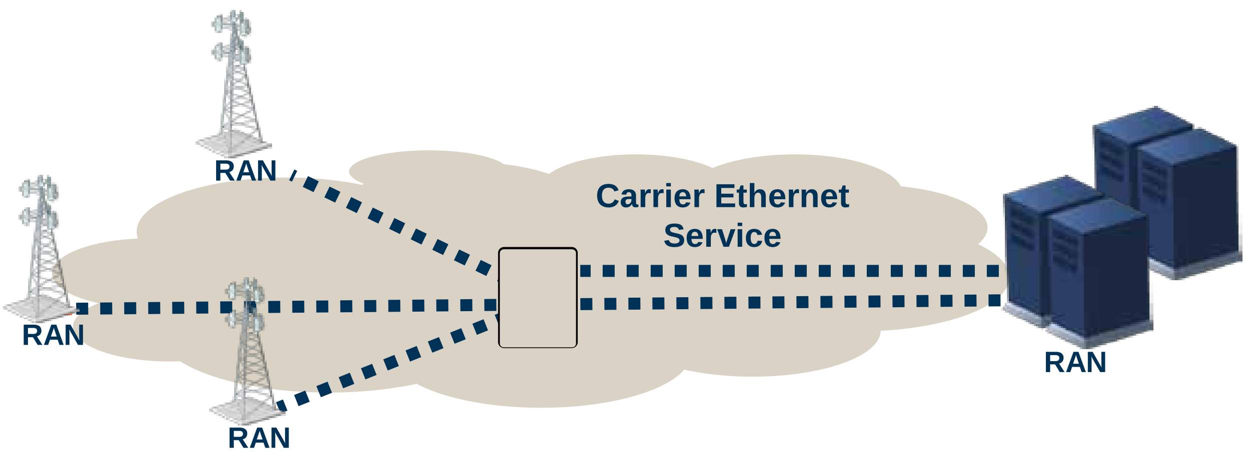

Figure 3 - Example Application: Mobile Backhaul

8.4.2.1 Mapping/Grouping Service Classes

Given the following (example) classes:

- Synchronization (Sync),
- Voice,
- Near Real Time (Near-RT),
- Control/Signaling (C/S),

- Data Class 1 (D-1),
- Data Class 2 (D-2),
- Background (B – e.g. – OAM bulk data, using TCP)

These could be mapped (as one possibility) using the 3-class model as follows:

- CoS Label H – Sync, Voice, Near-RT
- CoS Label M – C/S, D-1
- CoS Label L – D-2, B

An advantage of this approach is that this Implementation Agreement can be used to support the mapped classes of service, as it is defined in this Agreement.

Disadvantages to this approach include the following:

- CoS requirements are determined by the traffic with the most stringent handling requirements for all traffic classes in the CoS grouping
  - For instance, given the mapping/grouping example proposed previously, CoS Label H objectives for FD, FDV, FL, etc. is determined across all mobile backhaul classes (sync, voice, near-RT) mapped to CoS Label H.
- Contractual commitment from the carrier is likely to be determined by the CoS requirement for the entire class – irrespective of the actual requirement as distributed across multiple traffic classes.
- The resources allocated by the Service Provider may be out of line with actual use and demand from the network since the Ethernet Service provider will have to engineer more resources for the additional traffic in this class (e.g., inefficient network resource utilization).
- It is unclear what the best mapping should be:
  - By the application,
  - By the application platform/device, or
  - By the service

To illustrate the above points, using the above example, grouping synchronization, voice and near-real-time data using CoS Label H, results in the following:

- CoS requirements for CoS Label H is determined by the most stringent handling requirements – for example, those required for synchronization;

- The carrier's contracted delivery commitment is based on the aggregate of all traffic in the group – i.e. – synchronization, voice and near-real-time data (resources must be available to meet these commitments, even when not all in use);

- The Service Provider's allocated network resources are based on the delivery commitment for the worst case, but across all traffic types delivered;

- At some point in the network, some entity is required to perform the actual grouping – for example, the service access devices may need to recognize all of the types (synchronization, voice, near-real-time data) as being part of the CoS H, or the application/platform may need to associate all of these traffic types with a common CoS Label (corresponding to the label defined in the SLA for CoS H).

8.4.2.2 Client Side Adaptation – Using Multiple EVCs

There are many ways that an application might be adapted to use multiple EVCs to support more classes of service than are defined (on a per-EVC basis) by this Implementation Agreement. Two – probably representative – approaches are:

1) Application software or platform adaptation – (see Figure 4, below) – client side application platforms are connected to multiple VLANs (in order to allow connection to distinct EVCs as shown by the dashed lines in Figure 4) For IP applications running over an Ethernet service, multiple IP subnetworks are used, with each application platform multi-homed using multiple IP addresses and corresponding interfaces.

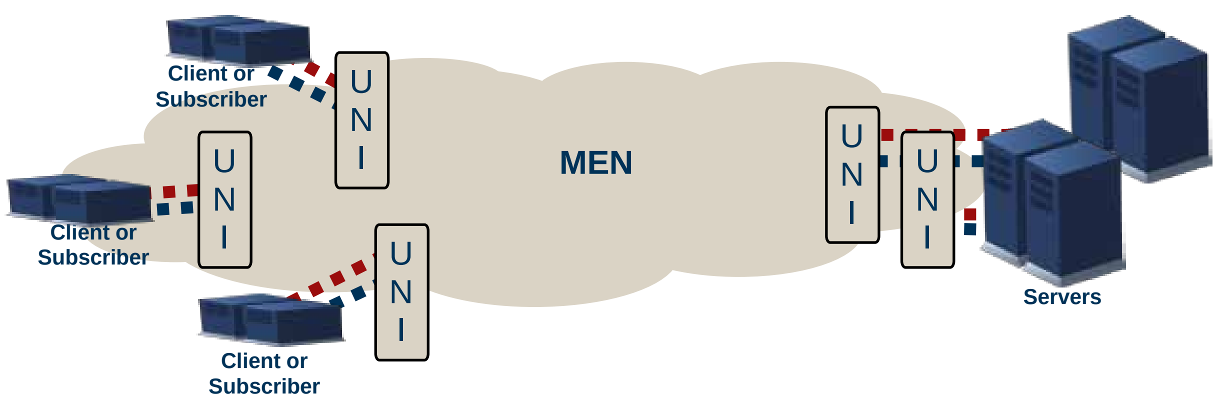

Figure 4 - Application Platform Client-side Adaptation

2) A local adaptation appliance is used, external to the client application platform(s) – (see Figure 5 below) – one or more appliances perform an adaptation between the application platforms and the UNI, bi-directionally (and symmetrically) mapping service classes to

fit within the supported classes defined in this Implementation Agreement, over multiple VLANs (allowing for mapping of subsets of CoS Identifiers to separate EVCs on the UNI side of the appliance). This adaptation function is external to the MEN.

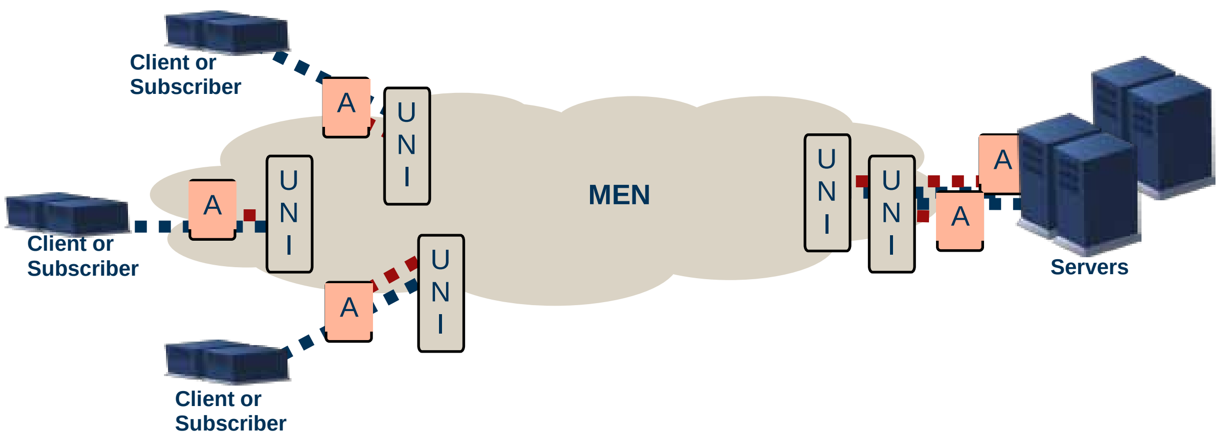

Figure 5 - In-Line Appliance, Client-Side Adaptation

In both approaches, CE-VLAN IDs are then mapped to distinct EVCs each supporting one or more CoS as defined in this Implementation Agreement. An issue with the first approach is that it requires additional complexities associated with configuring the application platform for multiple EVCs (and potentially IP subnetworks). Similarly, an issue with the second approach is that it requires one or more additional network devices in the client-side local network.

8.4.2.3 Service Side Adaptation

The CoS Implementation Agreement acknowledges that additional CoS can and will be used but cannot be readily standardized due to the large range of applications, existing Carrier Ethernet Services and scarcity of CoS Identifier address space for PCP. Using mechanisms that are out of scope for this Implementation Agreement, a Carrier or Ethernet Service Provider may choose to offer one or more additional CoS – over and beyond those defined by this Implementation Agreement. When a service is provided in this way, application platforms may use some set of CoS Labels – determined by their service level agreement – where some subset of the required service classes are mapped to CoS as defined by this Implementation Agreement and one or more other classes are mapped to additional classes as defined by the service level agreement. Under these circumstances, it is possible for an application to use more service classes than are defined by this Implementation Agreement while each application platform uses only a single VLAN (to access an EVC) supporting a single IP subnetwork.

This use case is further sub-divided into the single service-provider and multiple service-provider subcases. In the first case (illustrated in Figure 6, below), the service is completely bound – from the application's perspective by the service level agreement with that service provider. This provides the simplest service interface to the application, and this is a common case.

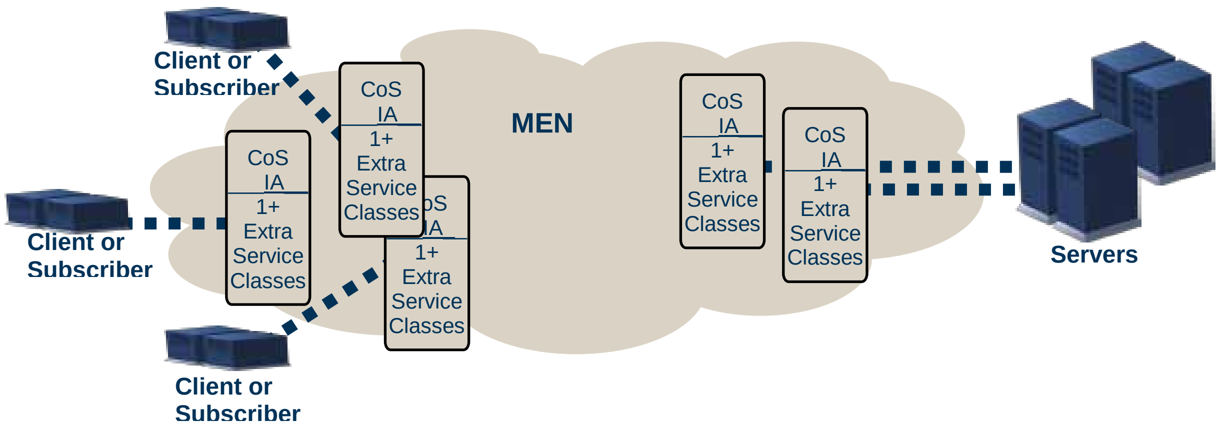

Figure 6 - Single Service Provider, Service Side Adaptation

In the second case (depicted in Figure 7, below), one or more additional Operators are also involved in providing the service. In this case, multiple distinct service agreements may be involved, and additional adaptations may have to be made (using bi-lateral agreements, for example) at the E-NNI.

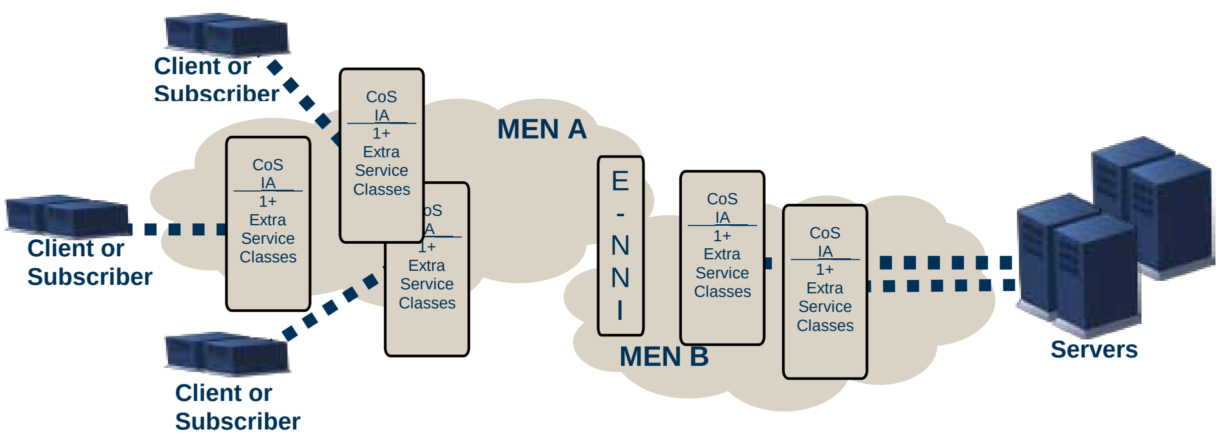

Figure 7 - Multiple Service Provider, Service Side Adaptation

8.5 Example PCP and DSCP Mapping at UNI for Multi-CoS EVCs Supporting Only Standard MEF Classes of Service

The CoS IA requires that all PCP (or DSCP) values that may occur in any service deployment are to be supported in some way by the service. Several alternatives exist. For example, any specific MEN service may support additional classes of service beyond those defined in this IA, and PCP (or DSCP) values not specified as CoS identifiers in the CoS IA may be mapped to a class of service provided as an enhancement of the CoS IA defined service classes.

Alternatively, a service may include at least one additional service class intended specifically to handle frames not associated (by PCP/DSCP value) with a defined CoS Identifier. If a specific MEN service supports ***only*** the service classes defined by this IA, there needs to be a mapping of all possible PCP (or DSCP) values to one of the service classes defined in the CoS IA or to a CoS defined in [2] called "Discard" which simply discards all frames that are classified as such.

This section provides example mappings for this case assuming no "Discard" CoS.

8.5.1 Example PCP Mappings

The following tables provide examples of full mappings of PCP at a UNI for multi-CoS EVCs that support only standard MEF CoS.

Table 5 shows an example mapping in which PCP value 5 is assumed to be handled by CE routers as "EF" traffic. This may be a common approach in handling low latency traffic based on a PCP marking – particularly when using (for instance) IP Routers.

MEF CoS Combination Supported on EVC	PCP Mapping per Class of Service - Color Blind Mode		
	H	M	L
{H + M + L}	5	2-4, 6, 7	0, 1
{H + M}	5	0-4, 6, 7	N/A
{H + L}	5	N/A	0-4, 6, 7
{M + L}	N/A	2-7	0, 1

Table 5: Example PCP Mapping for Multi-CoS EVC Supporting Only Standard Classes of Service at UNI – "Router-Application-Friendly" mapping

Table 6 shows a similar mapping that may apply in an application that bases choices of PCP values on the assumption of Ethernet CE bridges forwarding based on strict priority. In this case, higher PCP values would be handled at a higher priority. This mapping works in an application where very-high priority traffic is (by nature) very low volume (possibly less than 1 percent of the total traffic volume). This mapping is needed, for instance, if the application is not necessarily able to distinguish traffic that is carried natively in Ethernet over the local LAN from traffic that may be carried by a MEN service.

MEF CoS Combination Supported on EVC	PCP Mapping per Class of Service - Color Blind Mode		
	H	M	L
{H + M + L}	4-7	2,3	0, 1
{H + M}	4-7	0-3	N/A
{H + L}	4-7	N/A	0-3
{M + L}	N/A	2-7	0, 1

Table 6: Example PCP Mapping for Multi-CoS EVC Supporting Only Standard Classes of Service at UNI – "Bridging-Application-Friendly" mapping

8.5.2 Example DSCP Mappings

The following table provides an example of a full mapping of DSCP values at a UNI for multi-CoS EVCs that support only standard MEF CoS.

MEF CoS Combination Supported on EVC	DSCP Mapping per Class of Service – Color Blind Mode		
	H	M	L
{H + M + L}	40-47	16-39, 48-63	0-15
{H + M}	40-47	0-39, 48-63	N/A
{H + L}	40-47	N/A	0-39, 48-63
{M + L}	N/A	16-63	0-15

Table 7: Example DSCP Mapping for Multi-CoS EVC Supporting Only Standard Classes of Service at UNI

8.6 OTHER RELEVANT STANDARDS AND INDUSTRY MODELS

This section excerpts information from relevant standards that may be helpful in reading this document.

Below are excerpted tables from Section 6 and Annex G (informative) of [5]. Specifically this IA used the 5P3D row PCP values (bottom row on the excerpt below) for the CoS Identifier PCP values in Table 2 because 5 Priorities (i.e., classes) is the closest match to the 3 CoS Model. There is no row in the table for a smaller number of Priorities than 5P3D. Note that in Table G-2 of [3] the VO (voice) class specifies 10ms FD and FDV.

PCP Allocation		**PCP Values and Traffic Classes**							
# PCP Priorities	**# PCP Drop Eligible**	**PCP = 7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
8	0	IEEE Traffic Class = 7	6	5	4	3	2	1	0
5	**3**	IEEE Traffic Class = 7	6	4	4 DE	2	2 DE	0	0 DE

Table 8: PCP Decoding (Adapted from [5])

In the table below selected reference information is captured from [7] and [8] to guide future phase quantification of objectives and segmentation/concatenation.

Segment/Class	Source	IPTD (ms)	IPDV (ms)	IPLR	Notes
Access	[7]	25	16 p=.99 16-20 p=.00999 >20 $p<10^{-5}$	4×10^{-4}	IPDV uses "2 point promise" with these thresholds
Core/Metro	[7]	10 + .005 x (d-1200)	2 p=.99 2-6 p=.00999 >6 $p<10^{-5}$	10^{-5}	IPDV uses "2 point promise" with these thresholds
National/Class 0	[8]	100	50	10^{-3}	IPTD is mean. IPDV is 10^{-3} quartile – minimum
Global/Class 1	[8]	400	50	10^{-3}	IPTD is mean. IPDV is 10^{-3} quartile – minimum. IPDV is 10^{-5} in Provisional Class 6.
National/Class 2	[8]	100	Unspeci-fied	10^{-3}	IPTD is mean. IPDV is 10^{-3} quartile – minimum. IPDV is 10^{-5} in Provisional Class 7.

Segment/Class	Source	IPTD (ms)	IPDV (ms)	IPLR	Notes
Global/Class 3	[8]	400	Unspeci-fied	10^{-3}	IPTD is mean. IPDV is 10^{-3} quartile – minimum
Class 4	[8]	1000	Unspeci-fied	10^{-3}	IPTD is mean. IPDV is 10^{-3} quartile – minimum
Non-IP Net (access)	[8]	15	Unspeci-fied	Unspe-cified	IPTD is mean.

Table 9: Network Performance Objectives for IP-based Services