Contribution Number

MEF W105 Request for Draft 2

Performance Monitoring and Service Readiness Testing for SD-WAN

February 2022

This draft represents MEF work in progress and is subject to change.

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1 List of Contributing Members

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

Editor Note 1: *This list will be finalized before Letter Ballot. Any member that comments in at least one CfC is eligible to be included by opting in before the Letter Ballot is initiated. Note it is the MEF member that is listed here (typically a company or organization), not their individual representatives.*

- ABC Networks
- XYZ Communications

2 Abstract

An SD-WAN Service, as defined in MEF 70.1 [11], uses Performance Monitoring metrics to identify degradations or failures The metrics that are shared with SD-WAN Subscribers are described in this standard. SD-WAN Performance Monitoring also uses IP Packets to make performance measurements and uses these measurements to calculate Performance Metrics that can be reported. The requirements for Performance Monitoring of SD-WAN Service and the related information that the SD-WAN Service Provider provides to the SD-WAN Subscriber are detailed within this standard.

In addition, Service Readiness Testing requirements for SD-WAN services are defined within this standard. The Service Readiness Testing requirements are focused on the IP level because MEF 70.1 [11] defines an SD-WAN Service as an IP service where ‘the basic unit of transport at the SD-WAN UNI is an IP Packet’. Service Readiness Testing topics cover SD-WAN Service Readiness Measurement Point (SRMP), SD-WAN Test Methodologies, and the Service Readiness Testing report for an SD-WAN Service.

3 Release Notes

This document is still undergoing revision and at least one Call for Comments Ballot is planned. The contents may change subject to comments received during future Call for Comments Ballots.

4 Terminology and Abbreviations

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 other MEF or external documents.

In addition, terms defined in MEF 48.1 [7], MEF 61.1 [8], MEF 66 [10], and MEF 70.1 [12] are included in this document by reference and are not repeated in the table below.

Term	Definition	Reference
AFMP	Application Flow Measurement Point	This document
AF Specification	Application Flow Specification	This Document
Application Flow Measurement Point	A point where measurements of IP Packet performance are performed for Application Flows	This document
Application Flow Specification	A named set of Application Flow Criteria	MEF 70.1 [12]
CLEAR-TCA Window Threshold	The number of PM Metric Calculation Intervals, within the TCA Window Size, for which the PM Metric Value must be below the TCA Performance Threshold to generate a CLEAR-TCA, when using Stateful TCA Reporting.	This document
Collector Test Function	A logical function for counting and discarding received IP Packets, which can include test packets.	MEF 67 [10]
CTF	Collector Test Function	MEF 67 [11]
Damping Factor	A parameter with a numeric value that indicates the length of time to suppress new TCAs. Applicable to Stateless TCA Reporting only.	This document
Generator Test Function	A logical function for generating and transmitting IP Packets which can include test packets.	MEF 67 [11]
GTF	Generator Test Function	MEF 67 [11]
Layer 2	The second layer in the OSI seven-layer stack.	ISO 7498 [3]
Layer 3	The third layer in the OSI seven-layer stack.	ISO 7498 [3]
L2	Layer 2	This document
L3	Layer 3	This document
Measured Information Rate	The Information Rate expressed in bits per second measured during a single PM Metric Calculation Interval for each Monitored Entity.	This document

Term	Definition	Reference
Measurement IP Packet	Synthetic or Subscriber IP Packets that are used to measure performance.	This document
Monitored Entity	The entity, SWVC End Point ordered pair, or TVC End Point ordered pair, that is being monitored.	This document
Monitored Entity Identifier	The identifier of a Monitored Entity. For TVCs it is the three-tuple (Ingress UCS EP, Egress UCS EP, UCS CoS Name) or, if the SP uses TVC IDs, (TVC ID, ???) where ??? represents some way of indicating which direction of the TVC is being monitored. For AFs it is the 4-tuple (AF Spec, Zone, Ingress UNI, Egress UNI).	This document
Passive Monitoring	The monitoring of performance that does not use synthetic IP Packets or modify Subscriber IP Packets to perform measurements.	This document
Performance Monitoring	The collection of data concerning the performance of the Service. In this document, SD-WAN is the service for which Performance Monitoring is defined.	This document (derived from MEF 35.1 [6])
PM	Performance Monitoring	This document (derived from MEF 35.1 [6])
PM Counter Value	The value of a PM Counter.	This document
PM Metric	A metric that is measured or calculated as a part of Performance Monitoring.	This document
PM Metric Value	The value of a PM Metric.	This document
PM Metric Calculation Data Set	A set of PM Metric Calculation Values for a given PM Metric Calculation Interval.	This document
PM Metric Calculation Interval	The time interval over which one or more PM Metrics are calculated.	This document
PM Metric Calculation Profile	A profile that defines the PM Metrics that are calculated and the PM Metric Calculation Interval	This document
PM Metric Report Interval	The time interval over which one or more PM Metrics are reported to the Subscriber by the Service Provider. In this document, the Service Provider is the SD-WAN Service Provider.	This document
SD-WAN Controller/Orchestrator	The entity that is responsible for managing/orchestrating the SD-WAN Service.	This document
SD-WAN PM	Performance Monitoring of the Application Flows and TVCs in an SD-WAN Service.	This document
SD-WAN PM Implementation	An implementation that meets the requirements specified within this document for SD-WAN Performance Monitoring	This document
SD-WAN Test Function	An application for testing SD-WAN service that resides on a SD-WAN Edge.	This document

Term	Definition	Reference
SD-WAN Virtual Connection End Point	A logical construct at an SD-WAN UNI where Policies are associated with Ingress and Egress Application Flows.	MEF 70.1 [12]
Service Readiness Measurement Point	A reference point in the SD-WAN Service where events can be observed and measured during Service Readiness Testing. A Service Readiness Measurement Point contains both a Generator Test Function and a Collector Test Function.	This document derived from MEF 48.1 [7]
Service Readiness Testing	The testing that validates that the SD-WAN service is ready to be configured with specific customer policies. Testing verifies continuity of ordered pair of UCS End Points.	This document
Service Readiness Testing Parameters	The parameters that are defined for SRT. The parameters for SRT tests that are agreed between the SP and the Subscriber.	This document
Service Readiness Testing Results	The results, which are included in the SRT Report, of the SRT performed on each ordered pair of UCS End Points .	This document
SET-TCA Window Threshold	The number of PM Metric Calculation Intervals, within the TCA Window Size, for which the PM Metric Value must be at or above the TCA Performance Threshold to generate a SET TCA, when using Stateful TCA Reporting.	This document
SRMP	Service Readiness Measurement Point	This document
SRT	Service Readiness Testing	This document
SRT Parameters	Service Readiness Testing Parameters	This document
SRT Results	Service Readiness Testing Results	This document
Stateful TCA Reporting	A TCA reporting mechanism whereby a SET-TCA is generated when an alertable condition begins and a CLEAR-TCA is generated when it ends.	This document derived from MEF 35.1 [5]
Stateless TCA Reporting	A TCA reporting mechanism whereby TCAs are generated whenever an alertable condition is detected.	This document derived from MEF 35.1 [5]
SWVC End Point	SD-WAN Virtual Connection End Point	MEF 70.1 [12]
TCA	Threshold Crossing Alert	This document derived from MEF 35.1 [5]
TCA Function	An implementation of Threshold Crossing Alerts	This document
TCA Function Parameters	The variables that are agreed to and configured to describe when a TCA is generated.	This document
TCA Reporting	The TCA type, either Stateful or Stateless.	This document
TCA Performance Threshold	The PM Metric Value that is compared against, for each PM Metric Calculation Interval, when determining whether to generate a TCA.	This document

Term	Definition	Reference
TCA Window Size	The sliding window of the number of consecutive PM Metric Calculation Intervals that are used to evaluate whether to generate a SET-TCA or CLEAR-TCA, when using Stateful TCA reporting.	This document
Threshold Crossing Alert	A notification message that is specific to a particular PM Metric and is generated when the PM Metric Value exceeds, equals, or falls below the threshold.	This document derived from MEF 35.1 [5]
Tunnel Virtual Connection End Point	The logical location between the SWVC EP and UCS UNI where the TVC begins and ends within an SD-WAN Edge.	This document
TVC EP	Tunnel Virtual Connection End Point	This document
Tunnel Virtual Connection Measurement Point	The logical location between the SWVC EP and the UCS UNI where measurements of TVC performance are performed.	This document
TVC MP	Tunnel Virtual Connection Measurement Point	This document
UTC	Coordinated Universal Time	This document
Zone Name	The name used to identify a specific Zone.	This document

167 **Table 1 – Terminology and Abbreviations**

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5 Compliance Levels

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 (RFC 2119 [1], RFC 8174 [2]) when, and only when, they appear in all capitals, as shown here. All key words must be in 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**.**

A paragraph preceded by **[CRa]<** specifies a conditional mandatory requirement that **MUST** be followed if the condition(s) following the "<" have been met. For example, "**[CR1]<**[D38]" indicates that Conditional Mandatory Requirement 1 must be followed if Desirable Requirement 38 has been met. A paragraph preceded by **[CDb]<** specifies a Conditional Desirable Requirement that **SHOULD** be followed if the condition(s) following the "<" have been met. A paragraph preceded by **[COc]<** specifies a Conditional Optional Requirement that **MAY** be followed if the condition(s) following the "<" have been met.

6 Numerical Prefix Conventions

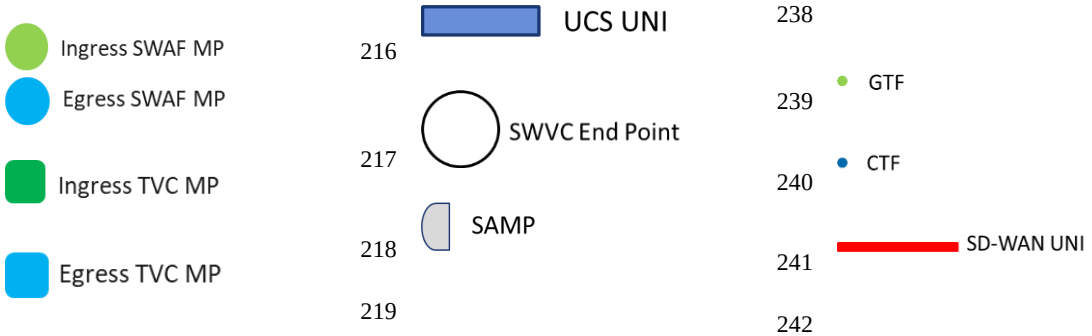
This document uses the prefix notation to indicate multiplier values as shown in Table 2.

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

6.1 Diagram Conventions

The diagrams in this document have a number of components that appear frequently. These components are represented in a standard way as described in the following:



7 Introduction

As SD-WAN Service is standardized, there is a need from both Service Providers and Subscribers to have a consistent method defined to monitor and report the performance of the service. Additionally, there is a need to standardize the testing performed to verify that the SD-WAN Service is ready for Application Flows and associated policies to be added. SD-WAN Performance Monitoring (SD-WAN PM) provides a standardized method for monitoring the performance of the service. SD-WAN Service Readiness Testing (SD-WAN SRT) provides a standardized method for ensuring that the SD-WAN Service is ready for Application Flows and associated polices to be added.

A naming convention used throughout this document uses the term Application Flow to indicate a flow where IP Packets enter at the ingress to an Application Flow and egress at a SD-WAN UNI.

This document describes the necessary requirements for the SD-WAN PM and SD-WAN SRT pertinent to an SD-WAN Service as described and defined in MEF 70.1 [12]. SD-WAN PM is described in Section 7 of this document, and it addresses the following topics:

- The SD-WAN PM statistics and information the SD-WAN SP provides to the SD-WAN Subscriber including:
    - Performance Monitoring Metric Values per Application Flow per ingress Application Flow and egress SD-WAN UNI ordered pair
    - Performance Monitoring Metric Values per Tunnel Virtual Connection (TVC)
    - Threshold Crossing Alerts (TCA)

Note: the term SD-WAN Performance Monitoring (PM) is limited to the functions and metrics defined within this document.

Note: SD-WAN PM includes monitoring TVCs but does not include monitoring UCS EP pairs. This is because a TVC represent a forwarding relationship between two SD-WAN Edges. If a forwarding relationship does not exist between two SD-WAN Edges, then SD-WAN PM is not used between them.

PM metrics collected for SD-WAN services are used by the SD-WAN SP and the Subscriber to manage the service in real time. As an example, statistics on the number of packets transmitted and received on an SD-WAN UNI might be particularly important to a Subscriber who is trying to resolve an issue with communication to the location served by the UNI. If no packets are received from that location on the SD-WAN UNI at the SD-WAN Edge, the Subscriber may be able to quickly determine that the problem is with their equipment at that location. Similar metrics are

collected for Application Flows and TVCs. The SD-WAN Service Provider can use these to determine if an Application Flow is passing packets and pass this information to the Subscriber via the Subscriber Portal.

Some PM Metrics can be used to make forwarding decisions within the SD-WAN Service. PM Metrics such as One-way Mean Packet Delay or One-way Packet Loss could be used to determine if a TVC is meeting the performance criteria specified for an Application Flow. Forwarding of IP Packets of a given Application Flow over the TVC can be stopped if the TVC is not meeting the performance criteria

The SD-WAN SRT is described in Section 9 of this document and addresses the following topics:

- SD-WAN Service Readiness Measurement Point (SRMP) functions and locations within the SD-WAN framework, as defined in MEF 70.1 [11]
- The test methodologies used for bringing SD-WAN Service into service including verifying continuity of agreed to UCS End Point pairs included in an SWVC
- Definition of the SD-WAN SRT report including the attributes and metrics included in the report

Note: SRT is performed on UCS End Point pairs because there is no standard method for implementing TVCs. Since TVCs may be implemented before or after the SWVC is turned over to the Subscriber, UCS End Point pairs are tested as a part of SRT. In this way, continuity of the UCS between UCS End Point pairs is verified so that if one or more TVCs is instantiated between the SD-WAN Edges, continuity is known to have existed at the time of SRT.

Service Readiness Testing verifies that the SD-WAN Service is ready for the SD-WAN SP or Subscriber to implement the appropriate policies and begin forwarding packets. It does not verify the operation of the policies or SD-WAN Service Attributes. Instead, it is focused on verifying that the UCSs providing continuity between the appropriate SD-WAN Edges are working correctly.

Areas that are not addressed within this document include the specific tools or implementations used to perform SD-WAN PM or SD-WAN SRT.

7.1 Use of Tunnel Virtual Connection or Underlay Connectivity Service UNI Pair

Within this document, an association between two SD-WAN Edges within an SWVC is identified in two ways, either by TVC Identifier or by a pair of UCS End Point Identifiers and a Class of Service. MEF 70.1 [12] defines the following terms.

A UCS is defined as a network service that provides connectivity between Subscriber locations or between a Subscriber location and the Internet. The UCS End Point is the logical construct that associates a specific UCS with the UCS UNI.

A TVC is defined in MEF 70.1 [12] as a point-to-point forwarding relationship between two SD-WAN Edges across either:

- a given single Private non-Internet Underlay Connectivity Service, or
- two Internet Access Underlay Connectivity Services

A TVC Identifier is an identifier that is unique within an SWVC. Each TVC is assigned an identifier.

Within this document TVC is used to describe the forwarding relationship between two SD-WAN Edges that is monitored via PM. Within this document UCS End Point ordered pair is used to describe what is verified via Service Readiness Testing.

8 SD-WAN Performance Monitoring

An SD-WAN SP may measure and report a variety of PM Metrics describing the performance of the various components of the SD-WAN Service. The tools used to calculate the SD-WAN PM Metrics are not defined within this document.

This document specifies the following aspects of SD-WAN PM:

- Performance Monitoring per Application Flow per SWVC End Point ordered pair
- Performance Monitoring per TVC
- PM Metrics defined in section 8.3
- Threshold Crossing Alerts (TCAs)

The Application Flows that are monitored are agreed on by the SD-WAN Service Provider and the Subscriber. This may be a subset of all Application Flows or SWVC EP ordered pairs. Every TVC is monitored since each TVC represents a forwarding relationship between SD-WAN Edges and it is assumed that SD-WAN PM is needed on all of these.

SD-WAN PM Metric Values are the results of PM measurements and calculations performed using IP PM Packets or other methods.

Note: "Ingress" is used to describe packets received from the Subscriber at the SD-WAN UNI. "Egress" is used to describe packets that are transmitted towards the Subscriber at the SD-WAN UNI.

SD-WAN PM Metrics are not defined to include the performance of the Subscriber Network.

8.1 Performance Monitoring Framework

Performance Monitoring of SD-WAN service uses a different framework than more traditional Service OAM (SOAM) Performance Monitoring. SD-WAN PM starts with PM Metric Calculation Intervals (PMCIs) that are significantly shorter (10 seconds or less) than the traditional Measurement Intervals used in SOAM PM. PM measurements are made during the PMCI and the PMCI metric value is calculated from the measurements. PMCI metric values are used not only to measure the performance of Application Flows or TVCs but can also be used to make IP Packet forwarding decisions when performance criteria are included in policies.

The results of each PMCI are reported based on the definition of the PM Metric Report (PMR). The interval in which PM Metric Reports are generated and the PM Metrics included in the report are included in the PMR definition. PM Reports can be used by the SD-WAN SP, or they may be shared with the Subscriber.

In addition to PMRs, Threshold Crossing Alerts (TCAs) may also be included. TCAs are alerts or alarms that are generated by the SD-WAN PM Implementation when a defined threshold is either met, exceeded, or not exceeded. TCAs are useful for quickly identifying a service impacting degradation or fault. They may even be used to make IP Packet forwarding decisions.

An implementation of the requirements for SD-WAN PM in this standard is known as a PM Implementation.

The PM Metrics, calculation, reporting, and the use of the PM metric values for Threshold Crossing Alerts are defined in the following sections of this document.

8.2 Performance Monitoring Metrics

This section describes the measurement methods and PM Metrics that are defined for SD-WAN Service. One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, and One-way Packet Loss Ratio are specified per agreed to Application Flow per SWVC EP ordered pair and for each TVC per CoS Name. Measured Information Rate (Measured Information Rate) is specified for Ingress and Egress Application Flows per SWVC EP ordered pair located at different SD-WAN Edges.

Measured Information Rate, One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, and One-way Packet Loss Ratio are defined in MEF 70.1 [11] section 15. These definitions are for an SD-WAN Service and not directly applicable to monitored entities, as defined in section 8.3, described in this document. The definitions for the PM Metrics are below for both Application Flows, see section 8.2.1, and TVCs, see section 8.2.2.

8.2.1 Application Flow PM Metrics

The definitions and requirements for measurements, calculation of PM Metrics, and the PM Metrics for Application Flows are contained in this section. The definitions used in support of these requirements are as follows:

- An Application Flow is defined as a sequence of IP Packets that Ingress at an SD-WAN UNI or are directed towards an SD-WAN UNI from a UCS that:
    - Match the same Application Flow Specification, and
    - Have source IP Addresses in the same Zone or are all in the Zone *Internet*
- An Application Flow is monitored at an Application Flow Measurement Point (AFMP).
- An Ingress AFMP is located between where any policies are applied and before the UCS UNIs (see Figure 1).

- The Egress AFMP is located between the UCS UNIs and before where any Policies are applied (see Figure 1).

- For One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation , and One-way Packet Loss Ratio PM Metrics, measurements are performed between the ordered pair of Ingress AFMP located on one SD-WAN Edge and Egress AFMP located on another SD-WAN Edge.

- For Measured Information Rate PM Metrics, measurements are performed before Ingress Policy is applied or after Egress Policy is applied (see Figure 2).

Note: Measured Information Rate is calculated based on byte counts collected by the Measured Information Rate byte counters.

The location of Ingress and Egress AFMPs is shown in Figure 1.

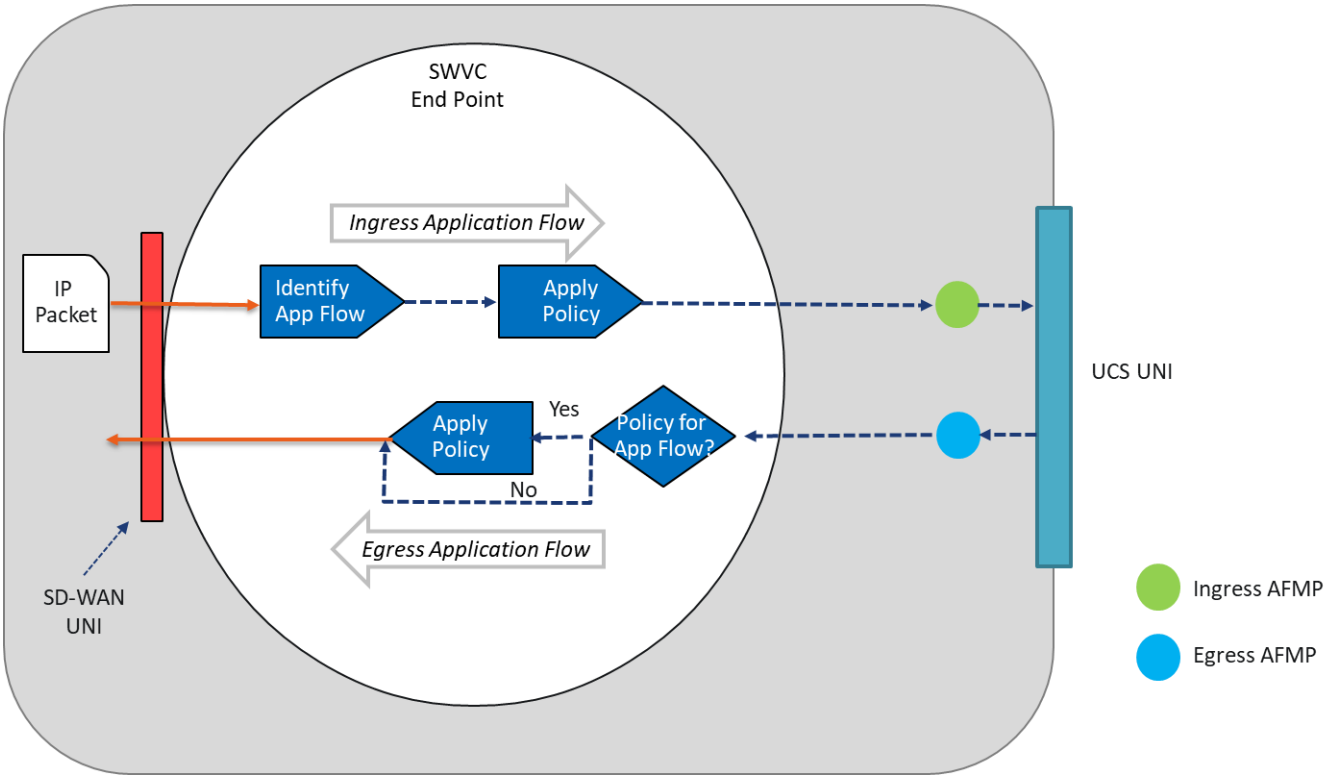


Figure 1 – AFMP Locations

The flow of Measurement IP Packets is from the Ingress AFMP at one SD-WAN Edge to the Egress AFMP at another SD-WAN making an ordered pair. Measurement IP Packets are defined as synthetic or Subscriber IP Packets that are used to measure performance. This document does not specify the method or tool used to perform these measurements.

The location within the SWVC EP of the Application Flow Ingress and Egress Measured Information Rate Byte Counters are shown in Figure 2.

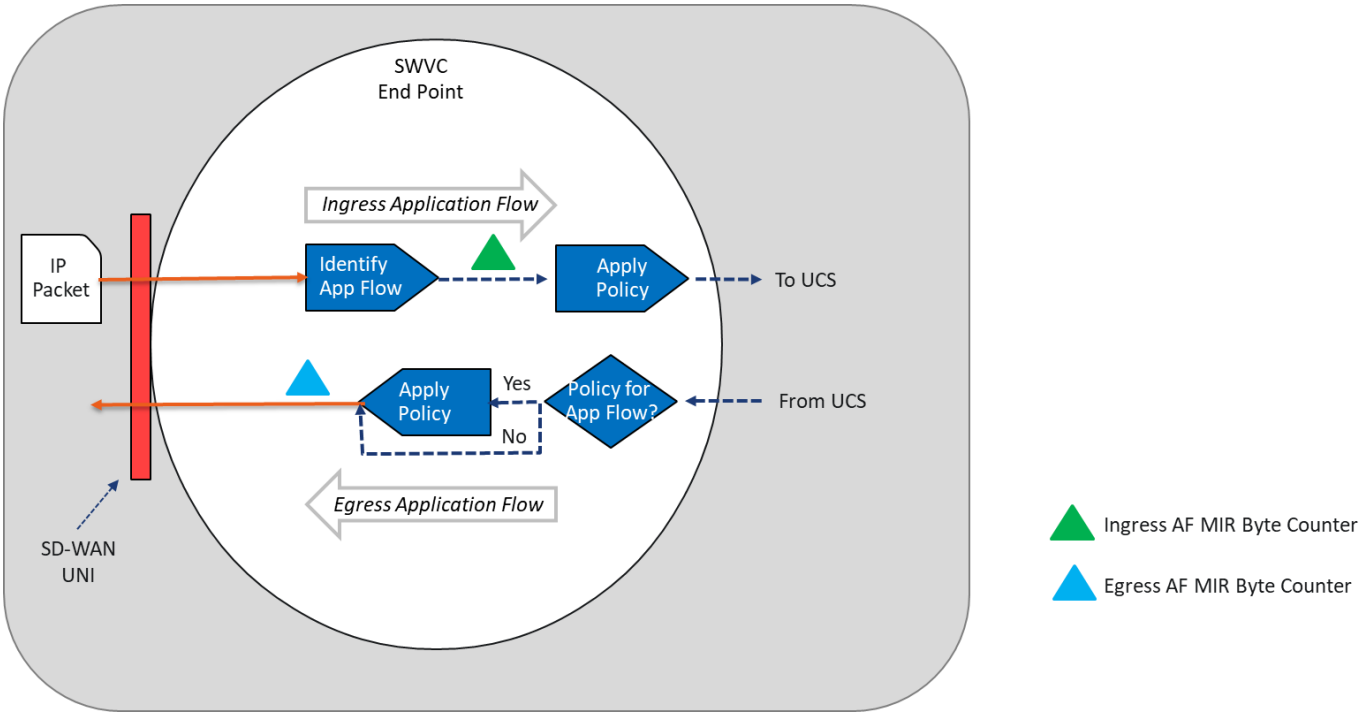


Figure 2 – Measured Information Rate Byte Counter Locations

The flow of Measurement IP Packets is from the Ingress AFMP to the Egress AFMP

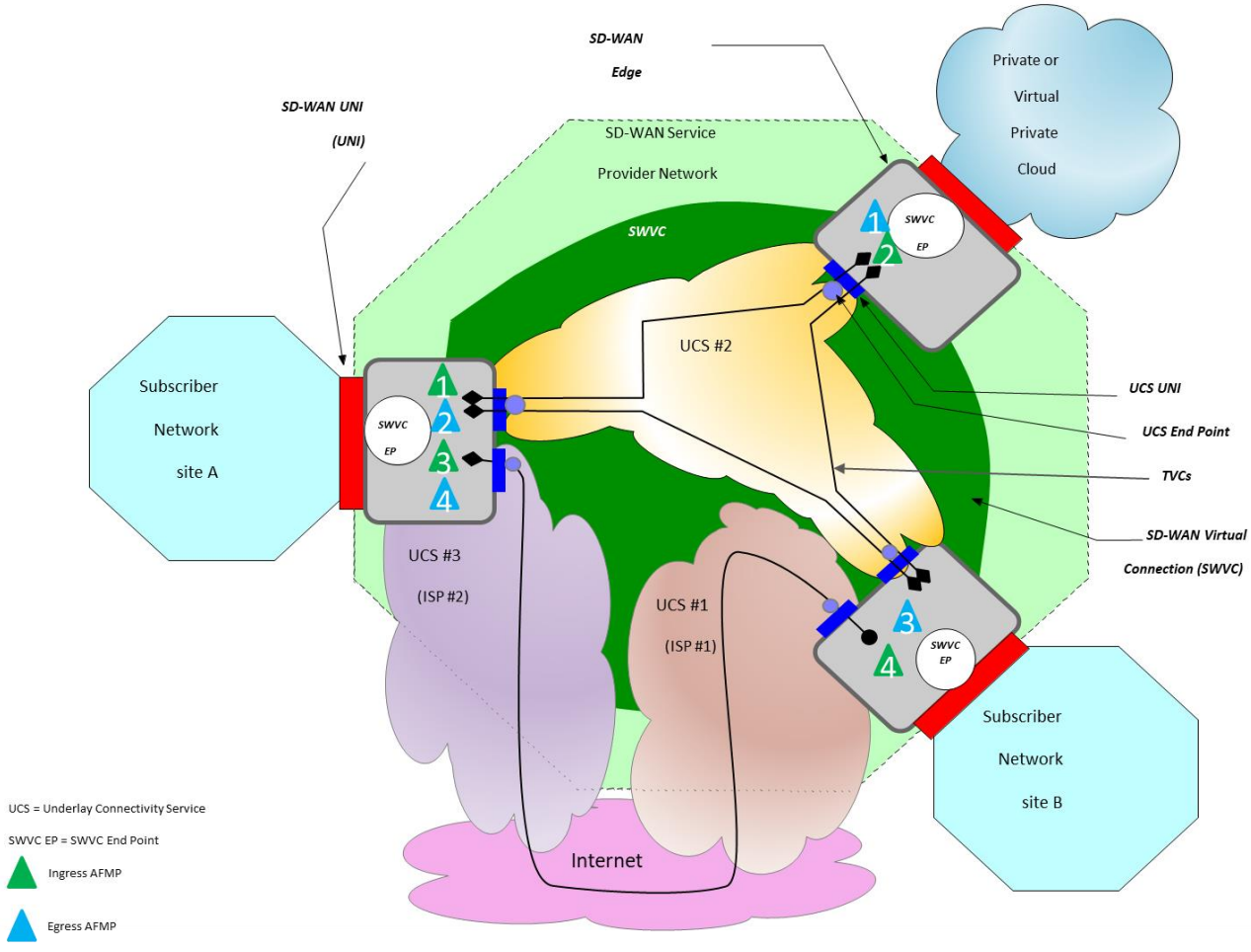


Figure 3 – Ingress AFMP to Egress AFMP ordered pair

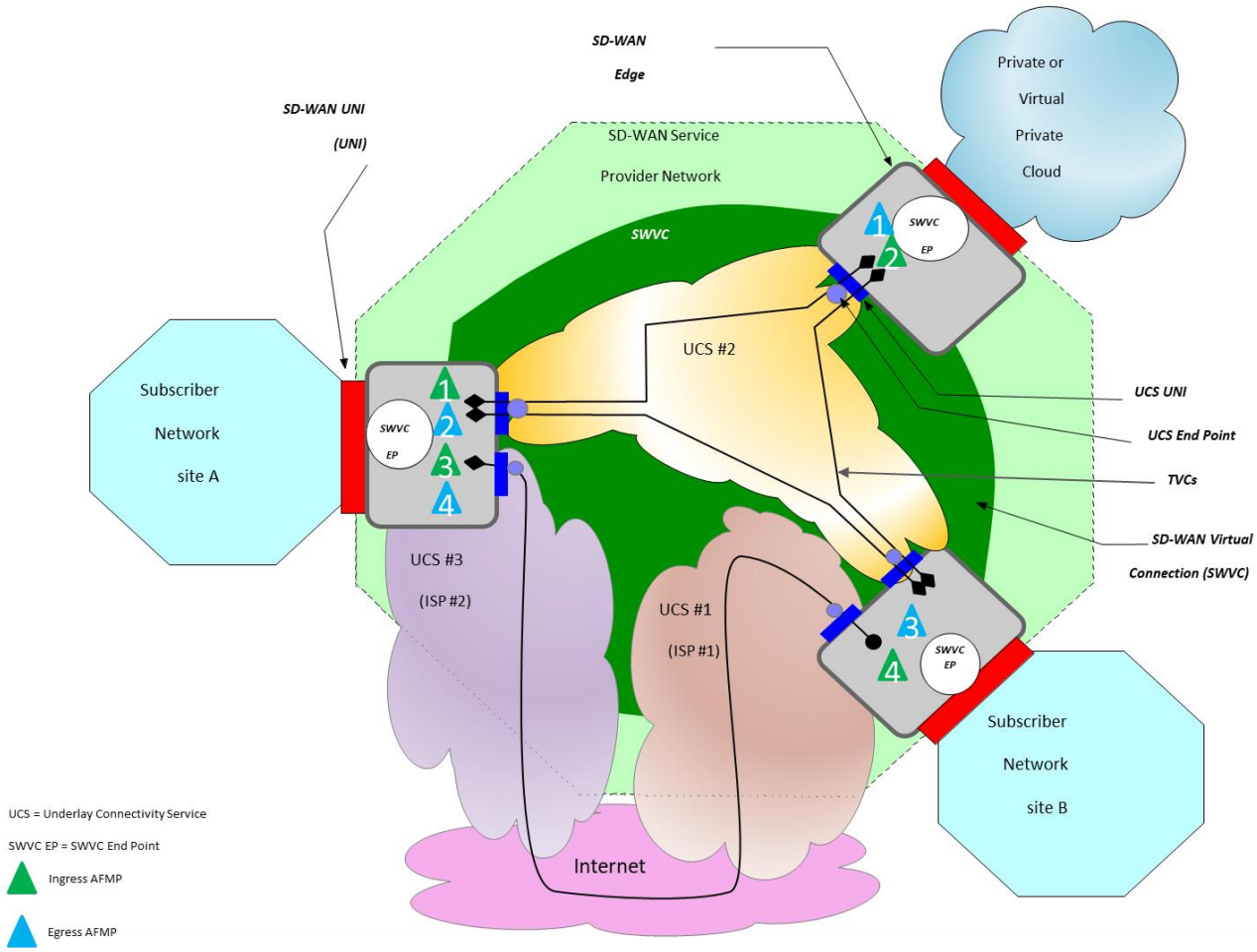


Figure 3 shows four ordered pairs of AFMPs, identified as pair 1, pair 2, pair 3, and pair 4 that are monitoring four Application Flows (1, 2, 3, and 4). The performance of IP Packets from the Ingress AFMP to the Egress AFMP is measured and PM Metric Values are calculated from the measurements. In the example, AFMP ordered pair 1 monitors Application Flow 1, AFMP ordered pair 2 monitors Application Flow 2, AFMP ordered pair 3 monitors Application Flow 3, and AFMP ordered pair 4 monitor Application Flow 4.

The following requirements apply to Application Flows.

[R1] The Subscriber and SP **MUST** agree on the set of AF Specification, Zone Name pairs to be monitored.

[R2] For each AF Specification, Zone Name pair agreed on in [R1], the Subscriber and SP **MUST** agree to the set of PM Metrics to be monitored.

An example of the agreed PM Metrics is shown in Table 1.

AF Specification, Zone Name	PM Metrics
Voice, Corporate	PD IPDV PL IMIR EMIR
Email, Corporate	IMIR
Video Streaming, Corporate	PD IMIR EMIR

Table 1 – AF Specification, Zone Name and PM Metric Agreement Example

[R3] The Subscriber and SP **MUST** agree on a single set of SD-WAN UNI ordered pairs for which PD, IPVD and PLR will be monitored for all AF Specification, Zone Name pairs for which those metrics have been agreed to be monitored per [R2].

An example is shown in Table 2.

SD-WAN UNI Identifier ordered pairs	
UNI 1	UNI 2
A	B
B	A
A	D
E	A
F	A
A	F

Table 2 – Monitored SD-WAN UNI ordered pair Agreement Example

[R4] The Subscriber and SP **MUST** agree on a single set of SD-WAN UNIs for which Ingress Measured Information Rate and Egress Measured Information Rate will be monitored for all AF Specification, Zone Name pairs for which those metrics have been agreed to be monitored per [R2].

An example is shown in Table 3.

SD-WAN UNI Identifiers
A
B
C
D
E
F
G

Table 3 – Monitored SD-WAN UNI Agreement Example

[R5] The SP **MUST** instantiate an Ingress AFMP and Egress AFMP for each SD-WAN UNI ordered pair included in the set of SD-WAN UNI ordered pairs.

[R6] The SP **MUST** instantiate an Ingress AF Measured Information Rate Byte Counter for each SD-WAN UNI and for each AF Spec, Zone pair for which Ingress AF Measured Information Rate is being monitored.

[R7] The SP **MUST** instantiate an Egress AF Measured Information Rate Byte Counter for each SD-WAN UNI and for each AF Spec, Zone pair for which Egress AF Measured Information Rate is being monitored.

Given the examples above Table 4 shows the PM Metrics that will be monitored for each AF Specification, Zone Name and SD-WAN UNI ordered pair.

AF Specification, Zone Name	**SD-WAN UNI ordered pair**	**PM Metric**
Voice, Corporate	A-B	PD IPDV PL
Voice, Corporate	B-C	PD IPDV PL
Voice, Corporate	D-A	PD IPDV PL
Voice, Corporate	F-A	PD IPDV PL
Video Streaming, Corporate	A-B	PD
Video Streaming, Corporate	B-C	PD
Video Streaming, Corporate	D-A	PD

AF Specification, Zone Name	SD-WAN UNI ordered pair	PM Metric
Video Streaming, Corporate	F-A	PD

Table 4 – AF Specification, Zone Name, ordered pair, and PM Metric Example

Given the examples above Table 5 shows the PM Metrics that will be monitored for each AF Specification, Zone Name and SD-WAN UNI.

AF Specification, Zone Name	SD-WAN UNI	PM Metric
Voice, Corporate	A	IMIR EMIR
Voice, Corporate	B	IMIR EMIR
Voice, Corporate	C	IMIR EMIR
Voice, Corporate	D	IMIR EMIR
Voice, Corporate	E	IMIR EMIR
Voice, Corporate	F	IMIR EMIR
Voice, Corporate	G	IMIR EMIR
Email, Corporate	A	IMIR
Video Streaming, Corporate	A	IMIR EMIR
Video Streaming, Corporate	B	IMIR EMIR
Video Streaming, Corporate	C	IMIR EMIR
Video Streaming, Corporate	D	IMIR EMIR

Table 5 – AF Specification Zone Name, UNI ID, and PM Metric Overview

[D1] For each AF Specification, Zone pair that is agreed to be monitored, One-way Mean Packet Delay and One-way Packet Loss Ratio **SHOULD** be included in the list of agreed PM Metrics.

[R8] For a given pair of Application Flow Specification and Zone, <*afs*, *z*>, agreed per [R1], and a given ordered pair of UNIs <*u1*, *u2*> agreed per [R3], the SP **MUST** monitor and report performance for the pair <*iaf*, *u2*>, where *iaf* is the Ingress Application Flow identified by the 3-tuple <*afs*, *z*, *u1*>, for each of the following Performance Metrics that were agreed for the pair <*afs*, *z*> per [R2]:

- One-way Mean Packet Delay
- One-way Mean Inter-Packet Delay Variation
- One-way Packet Loss Ratio

[R9] For a given pair of Application Flow Specification and Zone, <*afs*, *z*>, agreed per [R1], and a given UNI *u1* agreed per [R4], the SP **MUST** monitor and report performance for the Ingress and Egress Application Flows identified by the 3-tuple <*afs*, *z*, *u1*>, for each of the following Performance Metrics that were agreed for the pair <*afs*, *z*> per [R2]:

- AF Ingress Measured Information Rate (for the Ingress Application Flow)
- AF Egress Measured Information Rate (for the Egress Application Flow)

The definitions for the PM Metrics for Application Flows are detailed below.

The One-way Mean Packet Delay for an IP Packet belonging to a given Application Flow, is defined as:

- The time elapsed from the transmission of the first bit of the IP Packet at the Ingress AFMP until the reception of the last bit of the first corresponding IP Packet at the Egress AFMP. If the IP Packet is erroneously duplicated as it traverses the network, the delay is based on the first copy that is delivered.

One-way Mean Packet Delay for Application Flows is defined as:

- Let $\Delta=\{\delta 1, \delta 2, \delta 3, \ldots \delta n\}$ represent the One-way Packet Delay of the *n* IP Packets associated with Application Flow *a* from Ingress AFMP to Egress AFMP during a time interval whose duration is the value of the PM Metric Calculation Interval (see section 8.3). Then the One-way Mean Packet Delay for Application Flow *an* over that interval is the arithmetic mean of the values $\delta 1 \ldots \delta n$.

- If Δ' is *null* (no measurement values) then the One-Way Packet Delay for the PM Metric Calculation Interval is reported as *Undefined*.

One-way Mean Inter-Packet Delay Variation for Application Flows is defined as:

- Let $\Delta=\{\delta_1, \delta_2, \delta_3, \ldots \delta_n\}$ represent the One-way Packet Delay of the *n* IP Packets associated with Application Flow *a* from the Ingress AFMP to the Egress AFMP during a time interval whose duration is the value of the PM Metric Calculation Interval (see section 8.3).

- Let Δ'= the set of all pairs of elements $\{\delta_m, \delta_n\}$ in Δ such that $n>m$ and the difference in the time of transmission at the Ingress AFMP of packets *n* and *m* equals the IPDV Separation Time.

- If Δ' is *null* (no measurement values) then the One-Way Mean Inter-Packet Delay Variation for the PM Metric Calculation Interval is reported as *Undefined*. Otherwise, let v_{mn} be the absolute value of the difference in One-Way Packet Delay for each pair, $\{\delta_m, \delta_n\}$ in Δ', i.e., $v_{mn}=|\delta_m-\delta_n|$. Then the One-Way Mean Inter-Packet Delay Variation for *an* over that interval is the arithmetic mean of the values v_{mn} for each element in Δ'.

Packet Loss Ratio for Application Flows is defined as:

- Let *s* represent the total number of IP Packets associated with Application Flow *a* from the Ingress AFMP to the Egress AFMP during a time interval whose duration is the value of the PM Metric Calculation Interval (see section 8.3).

- Let *r* represent the total number of IP Packets received from the Ingress AFMP to the Egress AFMP for Application Flow *a* that were sent during the same period. Then the One-Way Packet Loss Ratio over that interval for *a* is defined as follows:

    - If *s=0* then the One-Way Packet Loss Ratio is 0.[1]

    - If *s>0* then the One-Way Packet Loss Ratio is *(s-r)/s*

- If Δ' is *null* (no measurement values) then the One-Way Packet Loss Ratio for the PM Metric Calculation Interval is reported as *Undefined*.

The One-Way Packet Loss Ratio is usually represented as a percentage.

AF Ingress Measured Information Rate is defined as:

- The Measured Information Rate in bits per second for IP Packets associated with an Ingress Application Flow for a given Application Flow Specification and Zone that ingress at an SD-WAN UNI. In this document this is abbreviated as AF Ingress Measured Information Rate.

AF Egress Measured Information Rate is defined as:

- The Measured Information Rate in bits per second for packets associated with an Egress Application Flow for a given Application Flow Specification and Zone, that egress at an

[1] In theory, this can only happen if Performance is measured on user-data. If Performance is measured on synthetic traffic, then there should be at least period*synthetic-rate qualified packets.

SD-WAN UNI. In this document this is abbreviated as AF Egress Measured Information Rate.

Measured Information Rate is used throughout this document and is calculated from byte counts as shown below:

$$Measured\ Information\ Rate\ = \frac{count\ of\ bytes\ during\ PMCI\ x\ 8}{PMCI\ Duration}$$

[R10] An SD-WAN PM Implementation **MUST** provide an AF Ingress Measured Information Rate value and AF Egress Measured Information Rate value for each Application Flow Specification, Zone pair for each SWVC EP that has been agreed on by the Subscriber and Service Provider for each PMCI.

[R11] An SD-WAN PM Implementation **MUST** count the bytes of all ingress IP Packets associated with the (Application Flow Specification, Zone) pair at the SD-WAN UNI before any Ingress Policy, as specified in MEF 70.1 [11] and shown in Figure 2, is applied when calculating AF Ingress Measured Information Rate.

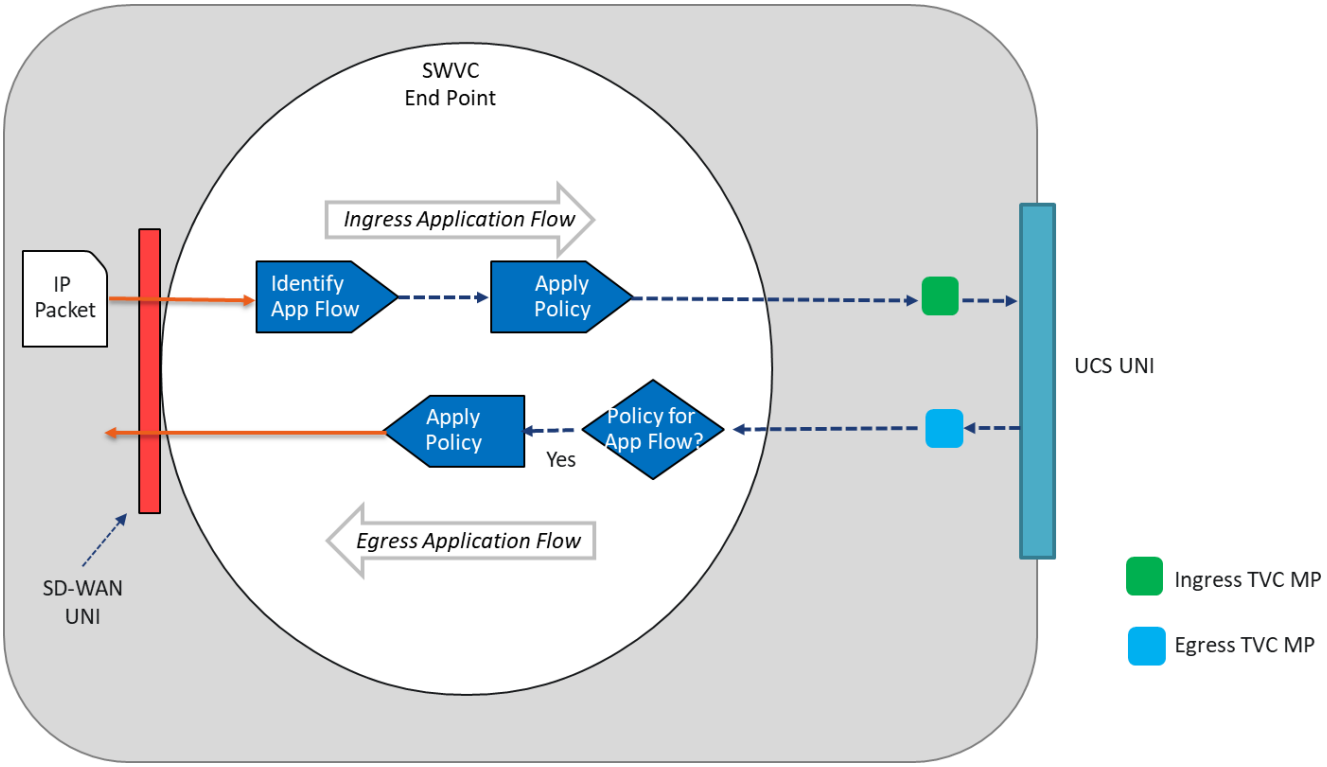
[R12] An SD-WAN PM Implementation **MUST** count the bytes of all egress IP Packets associated with the (Application Flow Specification, Zone) pair at the SD-WAN UNI after any Egress Policy, as specified in MEF 70.1 [11] and shown in Figure 2, is applied when calculating AF Egress Measured Information Rate.

8.2.2 TVC PM Metrics

The definitions and requirements for measurements, calculation of PM Metrics, and the PM Metrics for TVCs are contained in this section. The definitions used in support of these requirements are as follows:

- A TVC is defined as a forwarding relationship between two SD-WAN Edges. PM is performed unidirectionally on a TVC.
- A TVC is monitored at a TVC Measurement Point (TVC MP).
- An Ingress TVC MP is located after where the ingress Policy is enforced and before the corresponding UCS UNI.
- An Egress TVC MP is located after the corresponding UCS UNI and before where the egress Policy is enforced.
- For One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, and One-way Packet Loss Ratio PM Metrics, measurements are performed between the ordered pair

565 of Ingress TVC MP located on one SD-WAN Edge and Egress TVC MP located on another
566 SD-WAN Edge.



567

568 **Figure 4 – TVC MP Locations**

569 The flow of Measurement IP Packets is from the Ingress TVC MP to the Egress TVC MP

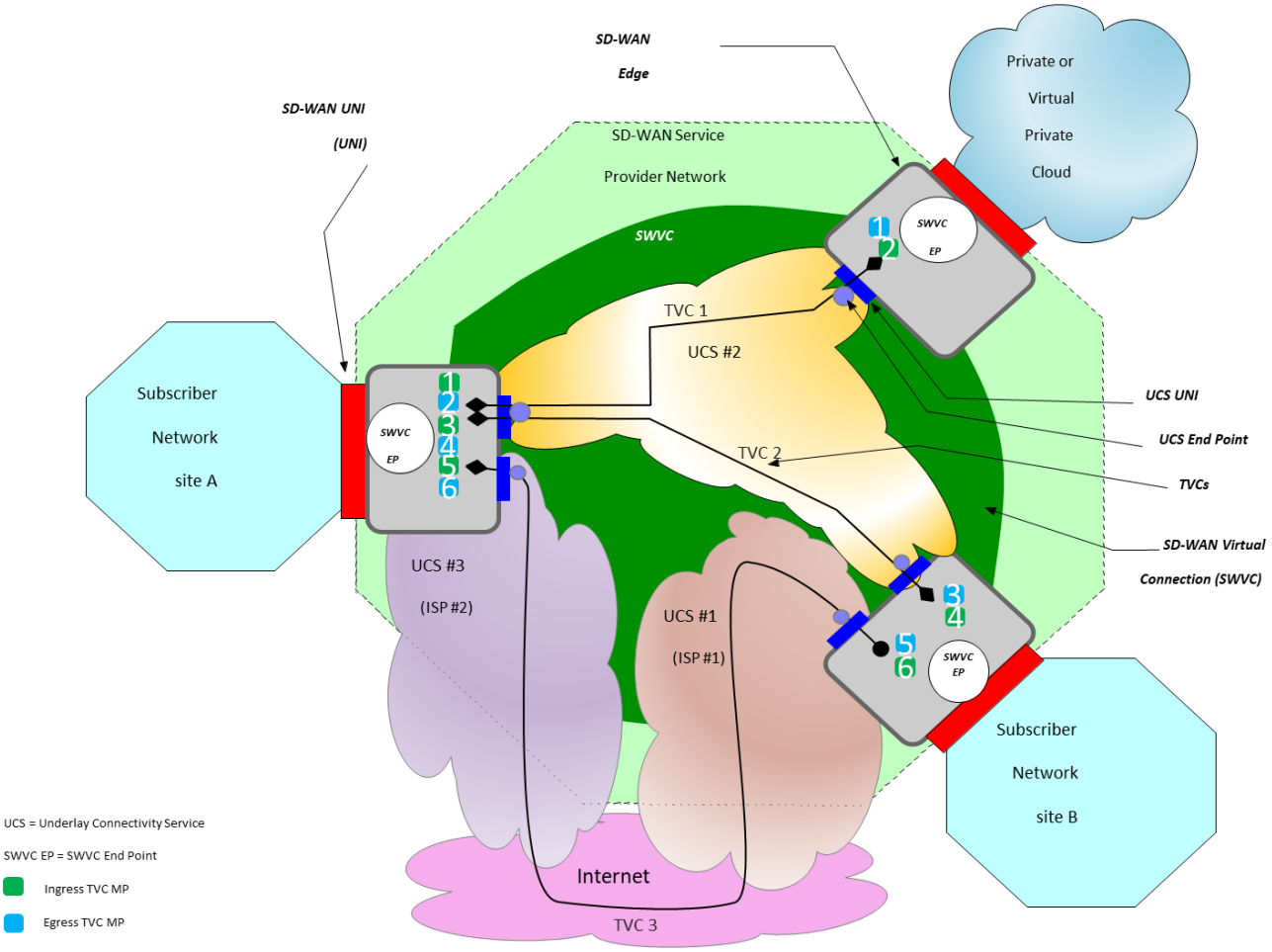


Figure 5 – Ingress TVC MP to Egress TVC MP ordered pair

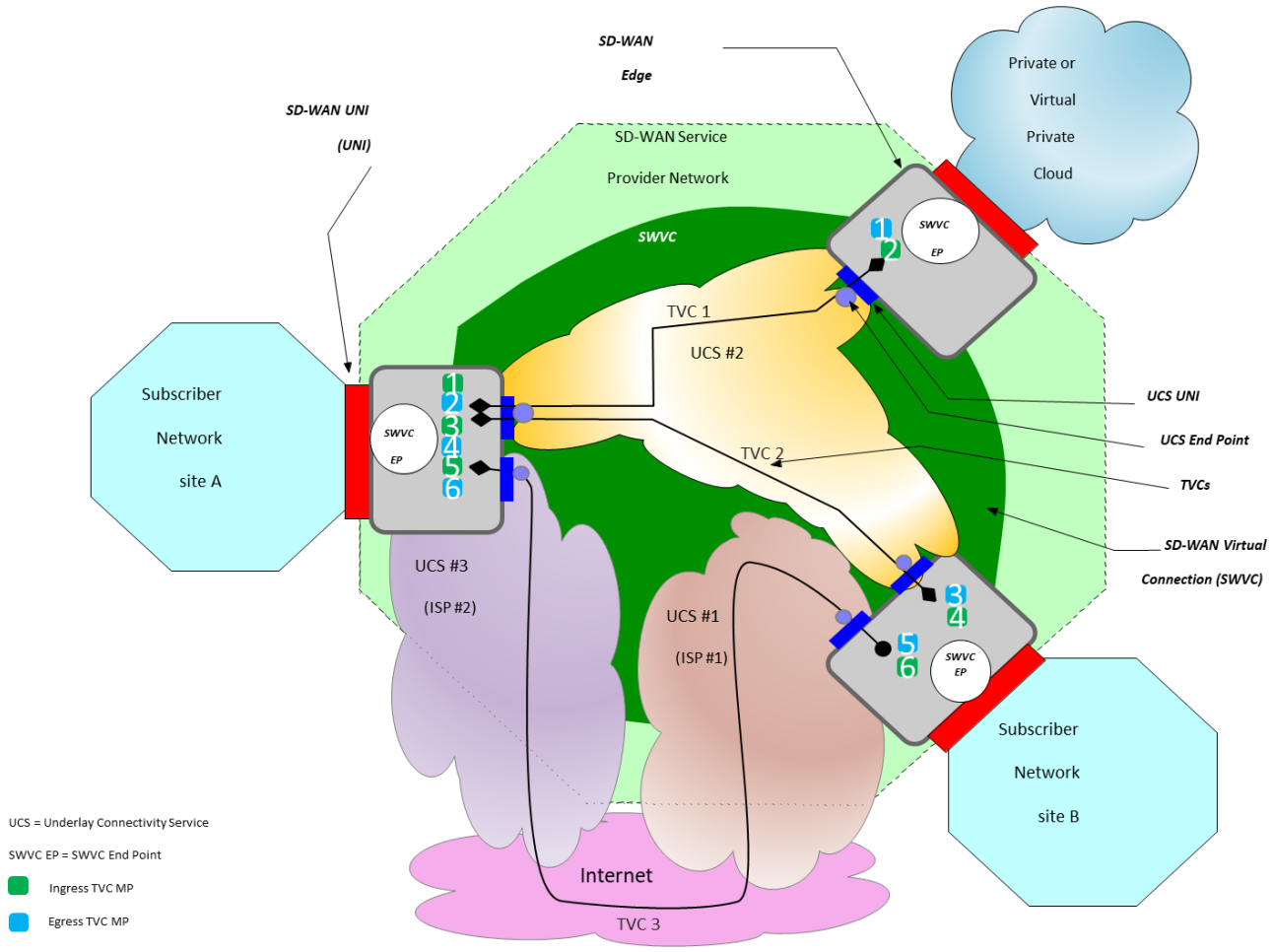


Figure 5 shows six TVC MP ordered pairs, identified as 1, 2, 3, 4, 5, and 6, that are monitoring three TVCs. Each ordered pair is made up of an Ingress TVC MP and an Egress TVC MP with the same number. IP Packets are exchanged between the Ingress and Egress TVC MPs, PM Metric measurements are performed using these packets, and PM Metric Values are calculated from the measurements. Two ordered pairs of TVC MPs are used to monitor the performance of each TVC. In the example, TVC MP ordered pairs 1 and 2 monitor TVC 1, TVC MP ordered pairs 3 and 4 monitor TVC 2, and TVC MP ordered pairs 5 and 6 monitor TVC 3.

One-Way Mean Packet Delay for TVCs is defined as:

- Let $\Delta=\{\delta 1, \delta 2, \delta 3, \ldots \delta n\}$ represent the One-Way Packet Delay of the n IP Packets sent over TVC t from Ingress TVC MP to Egress TVC MP during a time interval whose duration is the value of the PM Metric Calculation Interval (as defined in section 8.3) for TVCs. Then the One-Way Mean Packet Delay for TVC t over that interval is the arithmetic mean of the values $\delta 1 \ldots \delta n$.

- If Δ' is *null* (no measurement values) then the One-Way Mean Packet Delay for the PM Metric Calculation Interval is reported as *Undefined*.

One-Way Mean Inter-Packet Delay Variation for TVCs is defined as:

- Let $\Delta=\{\delta_1, \delta_2, \delta_3, \ldots \delta_n\}$ represent the One-Way Packet Delay of the *n* IP Packets sent over TVC *t* from Ingress TVC MP to Egress TVC MP during a time interval whose duration is the value of the PM Metric Calculation Interval.

- Let Δ'= the set of all pairs of elements $\{\delta_o, \delta_p\}$ in Δ such that $p>o$ and the difference in the arrival time at the Ingress TVC MP of packets *p* and *o* equals the duration of the IPDV Separation Time.

- If Δ' is *null*, then the One-Way Mean Packet Delay Variation for the PM Metric Calculation Interval is *Undefined*. Otherwise, let v_{op} be the absolute value of the difference in One-Way Packet Delay for each pair, $\{\delta_o, \delta_p\}$ in Δ', i.e., $v_{op}=|\delta_o-\delta p|$. Then the One-Way Mean Packet Delay Variation for *t* over that interval is the arithmetic mean of the values v_{op} for each element in Δ'.

One-Way Packet Loss Ratio for TVCs is defined as:

- Let *s* represent the total number of IP Packets sent over TVC *t* from Ingress TVC MP to Egress TVC MP during a time interval whose duration is the value of the PM Metric Calculation Interval.

- Let *r* represent the total number of IP Packets received from Ingress TVC MP at Egress TVC MP on TVC *t* that were sent during the same period. Then the One-Way Packet Loss Ratio over that interval for *t* is defined as follows:

    - If $s=0$ then the One-Way Packet Loss Ratio is 0.[2]

    - If $s>0$ then the One-Way Packet Loss Ratio is $(s-r)/s$

- If Δ' is *null* (no measurement values) then the One-Way Packet Loss Ratio for the PM Metric Calculation Interval is reported as *Undefined*.

The One-Way Packet Loss Ratio is usually represented as a percentage.

Note: the PM tool used to perform PM measurements may result in no IP Packets being forwarded over the TVC during the PM Metric Calculation Interval in which case the PM Metric Value can be reported as *Undefined*.

[2] In theory, this can only happen if Performance is measured on user-data. If Performance is measured on synthetic traffic, then there should be at least period*synthetic-rate qualified packets.

The impact of this PM Metric Value on forwarding decisions is beyond the scope of this document.

[R13] The SD-WAN SP **MUST** monitor all TVCs in an SWVC for the following PM Metrics:

- One-way Mean Packet Delay
- One-way Mean Inter-Packet Delay Variation
- One-way Packet Loss Ratio

All TVCs within a given SWVC are monitored using the same duration. This allows forwarding decisions based on performance and cost to be made. As an example, if the performance of two TVCs is the same and the cost is greater for one than the other, the lower cost TVC can be selected. If different durations were used, a forwarding decision could not be made based on performance over the same period of time.

Note: TVCs are monitored to inform the Subscriber of the performance of the overlay and to allow Application Flow forwarding decisions based on performance criteria to be made.

8.3 PM Metric Configuration

The configuration of PM Metrics is discussed in this section. The objects discussed here are not mandated for an implementation of SD-WAN PM, instead, this section is provided to assist in understanding the requirements in the calculation and reporting section of the document.

The parameters discussed in section 8.2 describe what must be supported so that PM works correctly. For PM reporting to work as described in section 8.4 there are several recommendations on how a given Application Flow Specification, Zone pair or TVC are configured for PM.

8.3.1 PM Metric Calculation Profile

In our example of PM configuration, we start with a PM Metric Calculation Profile. This profile contains the following:

- List of PM Metrics (at least one of)
  - One-way Mean Packet Delay
  - One-way Mean Inter-Packet Delay Variation
  - One-way Packet Loss Ratio
  - AF Ingress Measured Information Rate
  - AF Egress Measured Information Rate

- PM Metric Calculation Interval Duration

A PM Metric Calculation Profile can be defined for all TVCs, all Application Flow Specification, Zone pairs, or some sub-set of them. As an example, one PM Metric Calculation Profile could be defined for all TVCs to calculate One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, and One-way Packet Loss Ratio with a PM Metric Calculation Interval of 100ms. This profile would then be applied to all TVC ordered pairs. Another PM Metric Calculation Profile could be defined for the Voice, Corporate Application Flow Specification, Zone pair that calculates One-way Mean Packet Delay and One-way Mean Inter-Packet Delay Variation and applied to all flows which use that pair.

The attributes of a PM Metric Calculation Profile are defined within this section.

Parameter Name	Definition	Values	Comments
PM Metric Calculation Profile Identifier	A unique identifier for the PM Metric Profile Identifier		
List of PM Metrics	One or more PM Metrics	•One-way Mean Packet Delay •One-Way Mean Inter-Packet Delay Variation •One-way Packet Loss Ratio •AF Ingress Measured Information Rate •AF Egress Measured Information Rate	
PM Metric Calculation Interval Duration	The length of time in milliseconds for each PM Metric Calculation.	Duration Time	Duration must be ≤ 10000 ms.

Table 6 – PM Metric Calculation Profile Parameters

[R14] An SD-WAN PM Implementation **MUST** use the attributes specified in Table 6 for PM Metric Calculation Profile.

[R15] The SD-WAN SP and the Subscriber **MUST** agree on the PM Metric Calculation Interval Duration to be used.

[R16] A PM Metric **MUST** use the same PM Metric Calculation Interval Duration for all Application Flow/SWVC End Point ordered pairs within the same SWVC.

[R17] Different PM Metrics for Application Flow Specification, Zone pairs **MUST** be able to use different PM Metric Calculation Interval Durations.

[R18] All three PM Metrics specified in [R13] that are calculated for TVCs **MUST** use the same PM Metric Calculation Interval Duration for all TVC MP ordered pairs within the same SWVC.

An SD-WAN PM Implementation may use additional attributes for the PM Metric Calculation Profile. These attributes are outside the scope of this document.

[R19] An SD-WAN PM Implementation **MUST** have the ability to Create a PM Metric Calculation Profile.

The method used to Create a PM Metric Calculation Profile is outside the scope of this document.

[R20] An SD-WAN PM Implementation **MUST** have the ability to Delete a PM Metric Calculation Profile.

The method used to Delete a PM Metric Calculation Profile is outside the scope of this document.

8.3.2 PM Metric Monitored Entity

A PM Metric Monitored Entity is defined as one set of ordered pairs where PM Metrics that are calculated between MPs are monitored or a single point where Measured Information Rate is monitored. The PM Metric Monitored Entity contains the following:

- Monitoring Point #1

If the PM Metric Monitored Entity is a set of ordered pairs it contains the following:

- Monitoring Point #2

The parameters of the PM Metric Monitored Entity are defined in this section.

685

Parameter	Definition	Comments
PM Metric Monitored Entity Identifier	The identifier of a monitored Application Flow/SWVC End Point ordered pair or TVC MP ordered pair.	The format of the identifier is not defined in this standard and is left to the implementation to define.
Monitoring Point #1	The first Monitoring Point in the entity.	
Monitoring Point #2	The second Monitoring Point in the entity.	This is only used when One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, and One-way Packet Loss Ratio PM Metrics are being monitored.

686 **Table 7 – PM Metric Monitored Entity Parameters**

687 **[R21]** An SD-WAN PM Implementation **MUST** use the attributes specified in Table
688 7 for the PM Metric Monitored Entity.

689 An SD-WAN PM Implementation may use additional attributes for the PM Metric Monitored En-
690 tity. These attributes are outside the scope of this document.

691 **[R22]** An SD-WAN PM Implementation **MUST** have the ability to Create a PM
692 Metric Monitored Entity.

693 The method used to create a PM Metric Monitored Entity is outside the scope of this document.

694 **[R23]** An SD-WAN PM Implementation **MUST** have the ability to Delete a PM
695 Metric Monitored Entity.

696 The method used to delete an instance is beyond the scope of this document.

697 ### 8.3.3 PM Metric Calculation Instance

698 A PM Metric Calculation Instance is defined to specify the PM Metric Calculation Profile that is
699 used for a specific Monitored Entity. The PM Metric Calculation Instance defines the following:

700 - Monitored Entity Identifier

701 - Referenced PM Metric Calculation Profile

702 A Monitored Entity is defined as one set of ordered pairs or a single point where Measured Infor-
703 mation Rate is monitored. An example of a Monitored Entity Identifier for a TVC is the three-
704 tuple (Ingress UCS EP, Egress UCS EP, UCS CoS Name). An example of a Monitored Entity

Identifier for an Application Flow is the four-tuple (AF Specification, Zone, Ingress UNI, Egress UNI).

An example of a PM Metric Calculation Instance would include a Monitored Entity of TVC MP 1 and TVC MP 2 referencing PM Metric Calculation Profile Identifier 1.

The attributes of a PM Metric Calculation Instance are defined within this section.

Attribute	Definition	Comments
PM Metric Calculation Instance Identifier	A unique identifier for the PM Metric Calculation Instance	
Monitored Entity Identifier	The identifier of a monitored Application Flow/SWVC End Point ordered pair or TVC MP ordered pair.	The format of the identifier is not defined in this standard and is left to the implementation to define.
PM Metric Calculation Profile	The identifier of the PM Metric Calculation Profile to be used for this PM Metric Calculation Instance	The format of the identifier is not defined in this standard and is left to the implementation.

Table 8 – PM Metric Calculation Instance Attributes

[R24] An SD-WAN PM Implementation **MUST** use the attributes specified in Table 8 for the PM Metric Calculation Instance.

An SD-WAN PM Implementation may use additional attributes for the PM Metric Calculation Instance. These attributes are outside the scope of this document.

[R25] An SD-WAN PM Implementation **MUST** have the ability to Create a PM Metric Calculation Instance.

The method used to create a PM Metric Calculation Instance is outside the scope of this document. Once the instance is created, PM measurements begin. The method used to start these measurements is beyond the scope of this document.

[R26] An SD-WAN PM Implementation **MUST** have the ability to Delete a PM Metric Calculation Instance.

The method used to delete an instance is beyond the scope of this document. Whether the PM Metric Values can be retrieved after a PM Metric Calculation Instance is deleted is left to the implementation.

8.3.4 PM Metric Calculation Profile to PM Metric Calculation Instance Relationship

This section of the document discusses the relationship between the PM Metric Calculation Profile and the PM Metric Calculation Instance.

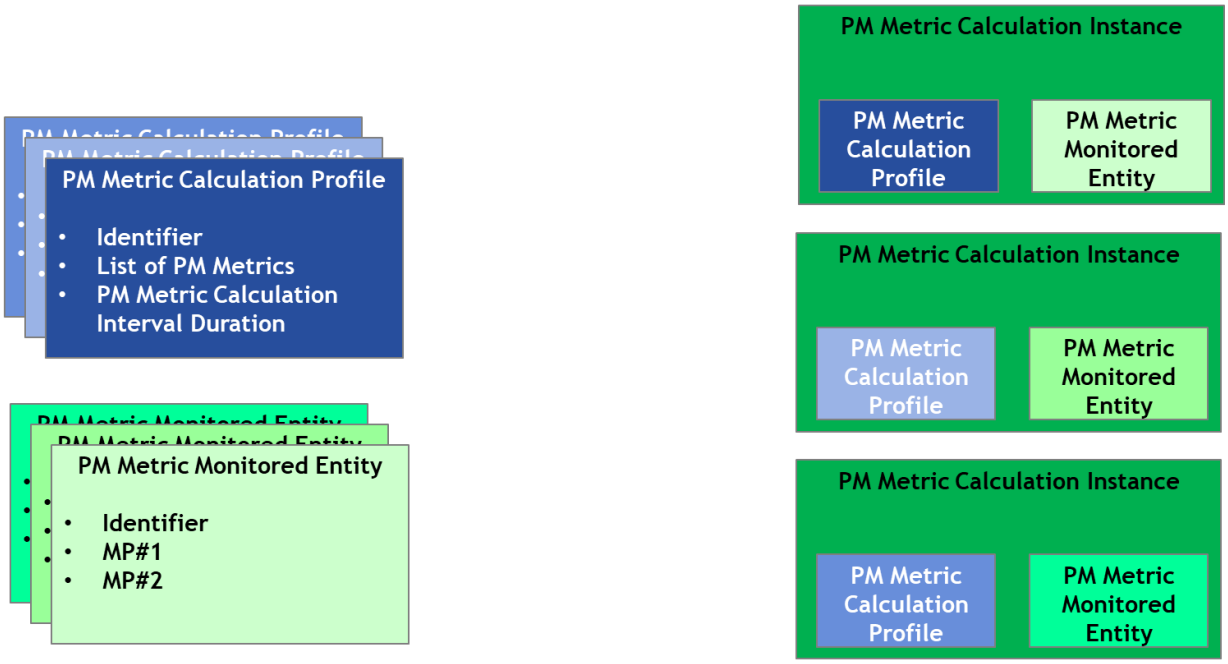


Figure 6 – PM Metric Calculation Profile to PM Metric Calculation Instance Relationship

Figure 6 shows the relationship between the PM Metric Calculation Profile and the PM Metric Calculation Instance. In this example, there are three PM Metric Calculation Profiles defined, each reflected by a different shade of blue. There are three PM Metric Monitored Entities defined, each reflected by a different shade of green. Finally, there are three PM Metric Calculation Instances shown, each with different profiles and entities.

8.4 PM Metric Calculation and Reporting

This section describes the configuration, calculation, and reporting of PM Metrics by the SD-WAN SP. Figure 7 illustrates the high-level sub-processes that are included in PM Metric Calculation and Reporting.

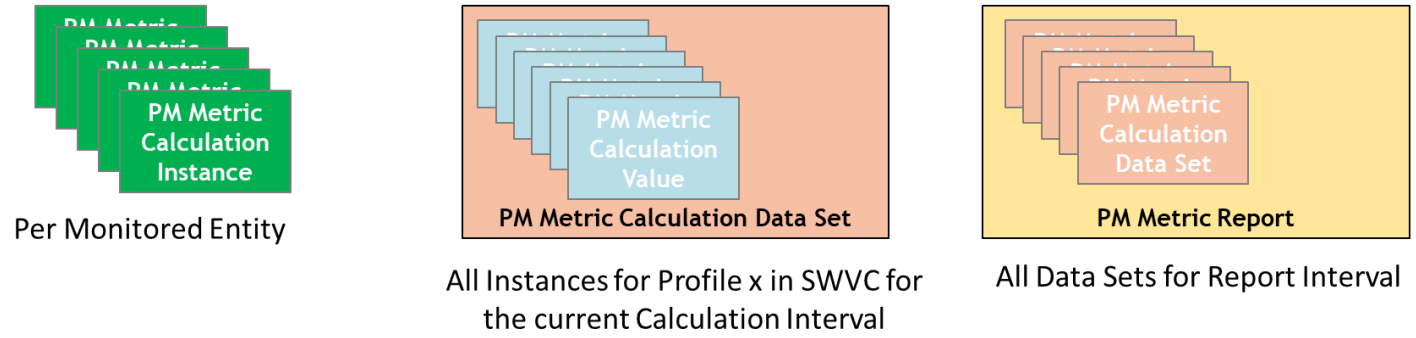


Figure 7 – PM Metric Calculation and Reporting

Once a PM Metric Calculation Instance is created, PM measurements for the Monitored Entity can begin. For each PM Metric enabled for the Monitored Entity (according to the profile), a PM Metric Value is calculated for each of the corresponding PM Metric Calculation Intervals. How the value is calculated is specified in section 8.2.

This PM Metric Value is included in a PM Metric Calculation Data Set that contains the PM Metric Values for all PM Metric Calculation Instances that are using the same PM Metric Calculation Interval Duration. The PM Metric Calculation Data Set is defined as a set or list of PM Metric Calculation Values for a given PM Metric Calculation Interval. The PM Metric Calculation Data Set contains the following attributes:

- PM Metric
- PM Metric Calculation Data Set Start Time
- PM Metric Calculation Data Set End Time
- PM Metric Calculation Instance Identifier
- List of PM Metric Calculation Values

These attributes are defined in section 8.4.1.

One or more PM Metric Calculation Data Sets are reported in a PM Metric Report. The PM Metric Report contains the following attributes:

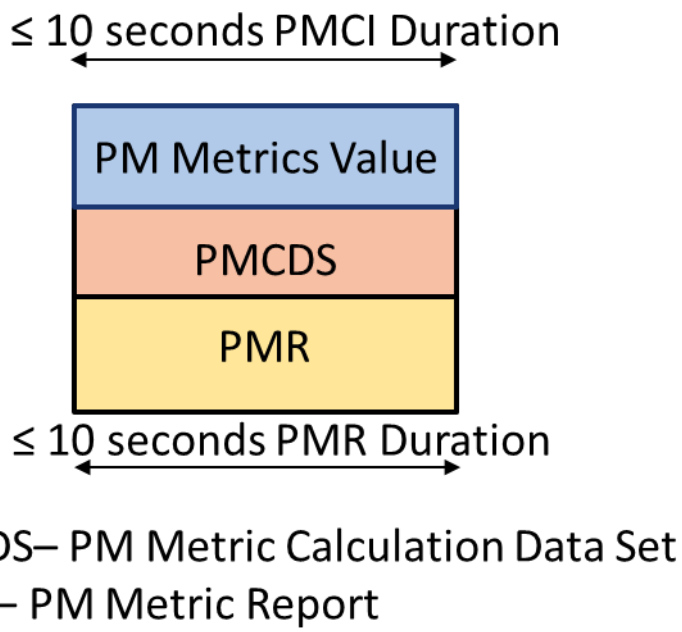
- PM Metric Report Interval Start Time
- PM Metric Report Interval End Time (or Duration)
- List of PM Metric Calculation Data Sets whose start and end time are within the PM Metric Report Interval.

763 The PM Metric Report Interval included in the PM Metric Report is defined as the interval, in ms,
764 of the interval of the PM Metric Report.

765 The above attributes are defined in section 8.4.2.

766 The relationship between PM Metric Calculation Data Sets and PM Metric Reports are shown
767 below.

768



769

770 **Figure 8 – PM Metric Calculation Data Set Duration Equals the PM Metric Report Dura-**
771 **tion**

772 Figure 8 shows the PM Metric Calculation Interval Duration and the PM Metric Report Interval
773 duration are equal. All PM Metric Calculation Instances that use that duration are included in the
774 report.

775 The PM Metric Calculation Interval Duration and the PM Metric Report Duration do not have to
776 be equal. Figure 9 shows an example of this.

777

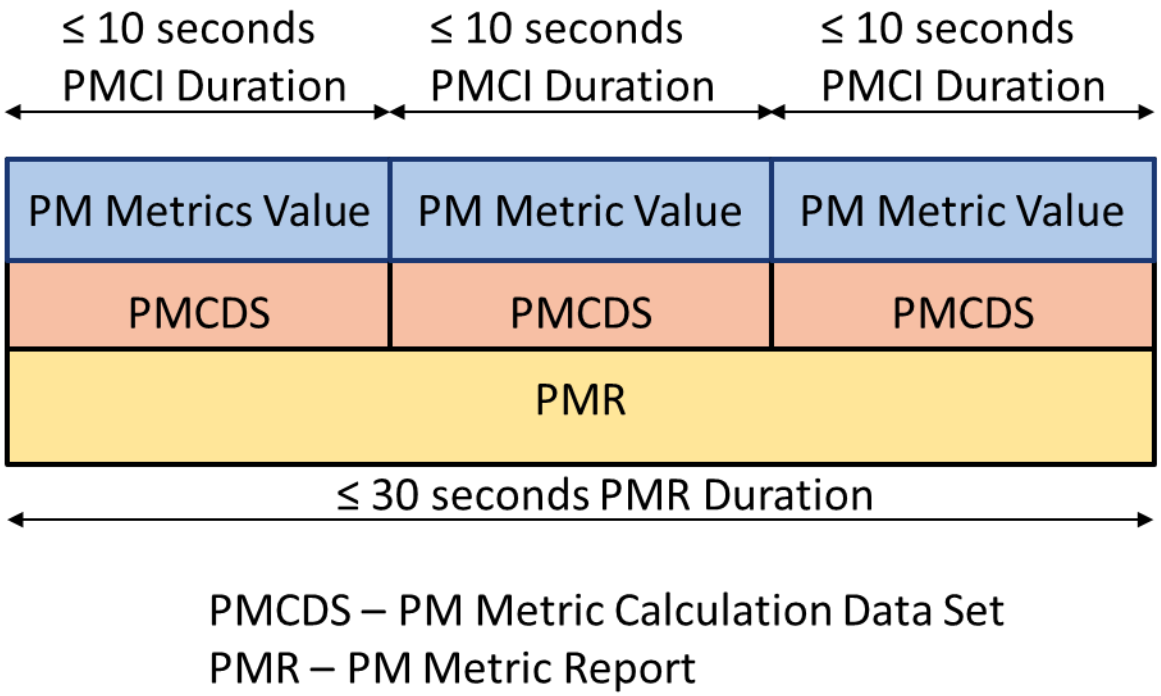


Figure 9 – PM Metric Reporting Duration > PM Metric Calculation Data Set Duration

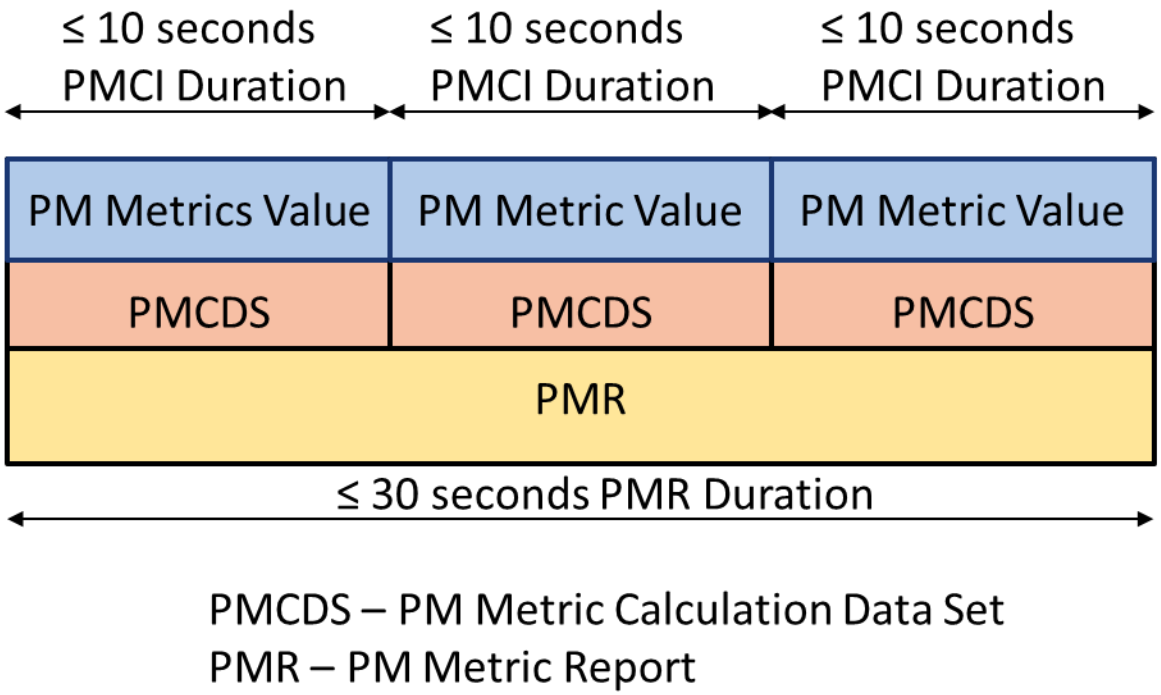


Figure 9 shows an example where the PM Metric Calculation Interval Duration is not equal to the PM Metric Report Duration. In this example, there are three PM Metric Calculation Data Sets in each PM Metric Report.

[R27] The PM Metric Report Duration **MUST** be a multiple of the PM Metric Calculation Interval Duration.

Note: [R27] avoids a PM Metric Report that contains a portion of a PM Metric Calculation Interval.

8.4.1 Ordered Pair PM Metric Calculation Data Set

The attributes of a PM Metric Calculation Data Set are defined within this section.

Attribute	Definition	Comments
PM Metric Calculation Data Set Start Time	The Date and Time that the PM Metric Calculation Data Set started measurement and calculation for the PM Metric Calculation Instances in the data set	
PM Metric Calculation Data Set End Time	Time that the PM Metric Calculation Data Set ended measurement and calculation for the PM Metric Calculation Instances in the data set	
PM Metric Calculation Instance Identifier	The identifier of the PM Metric Calculation Instance	The format of the PM Metric Calculation Instance Identifier is beyond the scope of this document and is left to the implementation to define.

Attribute	Definition	Comments
PM Metric Value List	A list of PM Metric Values for each PM Metric Calculation Instance contained within the data set.	This list contains values for PM Metric as specified in the PM Metric Calculation Profile.

Table 9 – PM Metric Calculation Data Set Attributes

[R28] An SD-WAN PM Implementation **MUST** use the attributes defined in Table 9.

[R29] An SD-WAN PM implementation of a PM Metric Calculation Data Set **MUST** include a PM Metric Value for each PM Metric included in the PM Metric Calculation Profile in the PM Metric Calculation Data Set for each PM Metric Calculation Instance included in each PM Metric Calculation Data Set.

[R30] An SD-WAN PM implementation **MUST** include one and only one PM Metric Value for each PM Metric being monitored for a given PM Metric Calculation Instance in each PM Metric Calculation Data Set.

[R31] If during a PM Metric Calculation Instance, the PM Metric Value cannot be calculated, the reported PM Metric Value **MUST** be NULL.

Note: A Measured Information Rate of 0 Mbps is considered a valid PM Metric Value. Implementations of Passive monitoring might result in PM Metrics that cannot be calculated.

8.4.2 PM Metric Report

The attributes of a PM Metric Report are defined in Table 10.

Attribute	Definition	Values	Comments
PM Metric Report Interval Start Time	Time that the oldest PM Metric Calculation Data Set contained in the PM Metric Report starts.	Time	
PM Metric Report Interval Duration	The interval, in ms, of the PM Metric Report.	Time	
List of PM Metric Calculation Data Sets	One or more PM Metric Calculation Data Sets including		The method used to define the data sets and the PM Metric

Attribute	Definition	Values	Comments
	all PM Metric Values per PM Metric Calculation Instance		Values is beyond the scope of this document.

Table 10 – PM Metric Report Attributes

[R32] The SD-WAN SP **MUST** provide a PM Metric Report that contains the attributes specified in Table 10.

[R33] If an aggregated value of a PM Metric over the PM Report Interval is reported, the aggregated value of the PM Metric **MUST** be provided in addition to the per PM Metric Calculation Data Set values.

[R34] The SD-WAN SP **MUST** start the PM Metric Report Start Time equal to the oldest PM Metric Calculation Data Set Start Time contained in the report.

Note: there may be some difference in time between the PM Metric Report Interval End Time and the time that the report is generated. This is due to the time it takes the SD-WAN PM implementation to collect the results for the last PM Metric Calculation Data Set included in the PM Metric Report Interval.

[D2] The SD-WAN SP **SHOULD** support the ability to store the PM Metric Values for a period of time as agreed to by the SD-WAN SP and Subscriber and for the PM Metric Values to be available for the Subscriber to retrieve.

The period of time agreed to by the SD-WAN SP and the Subscriber needs to conform to any legal requirements. Those requirements and the duration of the period of time are outside the scope of this document.

There are several mechanisms that can be used by the SD-WAN SP to report these PM Metric Values to the Subscriber. These mechanisms can range from refreshing PM Metric Values at some interval greater than or equal to the PM Metric Calculation Interval to informing the Subscriber of a performance degradation using Threshold Crossing Alerts (TCAs) as defined in section 8.5. This document does not mandate how the PM Metric Values are reported to the Subscriber.

8.5 Threshold Crossing Alerts

Threshold Crossing Alerts (TCAs) can be configured for certain PM Metrics and used to detect when performance is degraded beyond a given pre-configured level. From an SD-WAN perspective, TCAs can be used by the SD-WAN SP, or the SD-WAN SP can convey TCAs to the Subscriber.

Within this document the term TCA Function describes the implementation of Threshold Crossing Alerts. The TCA Function parameters are agreed to by the Subscriber and the Provider.

This agreement may be different than what is agreed to by the two parties for PM. Reporting of TCAs is described in section 8.5.3.

The TCA Function parameters that are agreed to by the Subscriber and the SP are shown below

- The TCA Performance Threshold Value is configured for a particular PM Metric. A TCA can be generated when the PM Metric Value for a set of PM Metric Calculation Intervals falls below, or reaches, or exceeds, the configured TCA Performance Threshold Value.

- The TCA Window Threshold defines the number of PM Metric Calculation Intervals where the PM Metric Value is either below, or meets or exceeds, the TCA Performance Threshold Value.

- The TCA Window Size defines the sliding window of the number of consecutive PM Metric Calculation Intervals that are used as the value of SET-TCA Window Threshold or TCA Window Threshold as defined in section 8.5.3.

There are two types of TCA reporting, Stateful and Stateless. Stateful TCA reporting is used to possibly reduce the total number of TCAs that are generated. The intent is to provide a notification when a degradation is first encountered, followed by another when the degradation is resolved. A Stateful TCA Function uses the following TCA Function Parameters to determine if a TCA should be set or cleared:

- TCA Performance Threshold Value
- TCA Window Threshold
- TCA Window Size

This contrasts with Stateless TCA reporting, in which TCAs are generated when a degradation is first encountered, for each PM Metric Calculation Interval that meets or exceeds the TCA Performance Threshold Value for as long as the degradation lasts subject to the Damping Factor. A TCA Function that uses Stateless TCA reporting uses the following TCA criteria to determine if a TCA should be set:

- TCA Performance Threshold Value
- PM Metric Calculation Interval
- PM Metric Value
- Damping Factor (desirable not mandatory)

An issue that can exist when using a Stateless TCA function is that a degradation that exists for more than one PM Metric Calculation Interval results in multiple TCAs being declared. A degradation that exists for several PM Metric Calculation Intervals can result in a flood of TCAs being generated possibly overwhelming SD-WAN SP alarm management systems. To avoid this, an optional attribute for Stateless TCA functions is defined. This is known as the Damping Factor. The Damping Factor is a method used to suppress new TCAs. The Damping Factor Value defines a

number of consecutive PM Metric Calculation Intervals where the PM Metric Value is equal to or greater than the TCA Performance Threshold Value and the new TCAs are suppressed for that number of PM Metric Calculation Intervals.

Within this document the term TCA Function is used to describe a single iteration of a TCA (Stateful or Stateless). The TCA Function parameters defined for a given TCA Function are unique and are defined for a given Monitored Entity (i.e., Ingress AF, Egress UNI) ordered pair or a (TVC, direction) pair. A Monitored Entity can have multiple TCA Functions associated with it, for the same or different PM Metrics.

Note: the use of TCAs to make forwarding decisions is beyond the scope of this document.

Stateful and Stateless TCA Reporting are explained in the following sections.

8.5.1 Stateful TCA Reporting

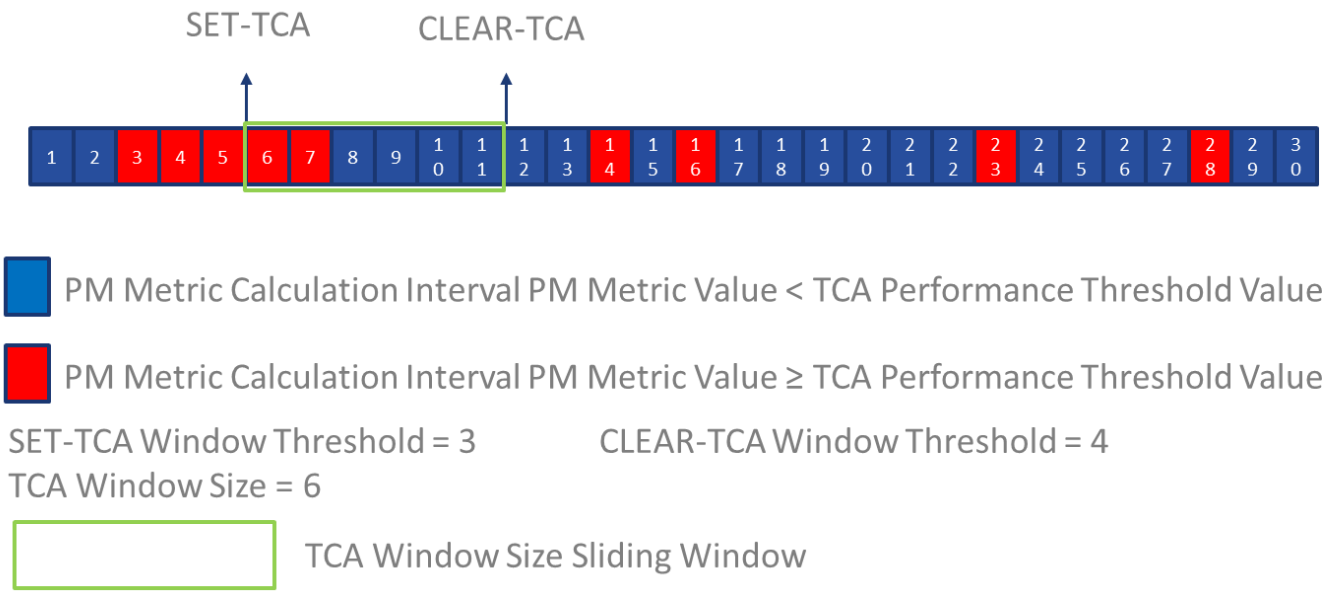
When using Stateful TCA reporting, each TCA Function can have two configured TCA Window Threshold Values: a SET threshold and a CLEAR threshold.

The TCA Function also has an internal state, which may be ‘set’ or ‘clear’.

The TCA Function begins in the 'clear' state. A SET-TCA is generated when the PM Metric Value equal to or greater than the TCA Performance Threshold Value for the number of PM Metric Calculation Intervals defined by the SET-TCA Window Threshold for the number of PM Metric Calculation Intervals defined by TCA Window Size. The Stateful TCA Function does not need to wait for the number of PM Metric Calculation Intervals defined by TCA Window Size to complete before generating a SET-TCA if the number of PM Metric Calculation Intervals defined by SET-TCA Window Threshold is exceeded. The TCA Function is then considered to be in a 'set' state, and no further SET-TCAs are generated in this state if the condition that triggered the TCA continues.

The TCA Function moves from the ‘set’ state to the ‘clear’ state when the PM Metric Value is less than the TCA Performance Threshold Value for the number of PM Metric Calculation Intervals defined by CLEAR-TCA Window Threshold out of the number of PM Metric Calculation Intervals defined by TCA Window Size. A CLEAR-TCA is generated, and the Stateful TCA Function returns to the 'clear' state. Thus, each SET-TCA is followed by a single CLEAR-TCA.

Figure 10 shows an example of Stateful TCA reporting. The sum of the SET-TCA Window Threshold and the CLEAR-TCA Window Threshold must be greater than the TCA Window Size (as required per [CR12]< in section 8.5.3). This is mandated within this document to avoid a condition where the SET-TCA and CLEAR-TCA criteria are met at the same time.



907

908 **Figure 10 – Stateful TCA**

909 Figure 10 shows an example of a Stateful TCA Function SET-TCA and CLEAR-TCA. In this
910 example, the TCA Window Size is set to 6. The SET-TCA Window Threshold is set to 3 and the
911 CLEAR-TCA Window Threshold is set to 4.

912 A Stateful SET-TCA is generated when the PM Metric Value is equal to or greater than TCA
913 Performance Threshold Value for SET in PM Metric Calculation Intervals 3, 4, and 5 (i.e., 3 out
914 of 6 SET-TCA Window Threshold out of TCA Window Size criterion met).

915 The Stateful CLEAR-TCA is generated when the PM Metric Value is less than TCA Performance
916 Threshold Value for CLEAR in PM Metric Calculation Intervals 8, 9, 10, and 11 (i.e., 4 out of 6
917 CLEAR-TCA Window Threshold out of TCA Window Size criterion met).

918 While the PM Metric Value is equal to or greater than the TCA Performance Threshold Value in
919 PM Metric Calculation Intervals 14, 16, 23, and 28, the SET-TCA Window Threshold and TCA
920 Window Size criterion is not met so another SET-TCA is not generated.

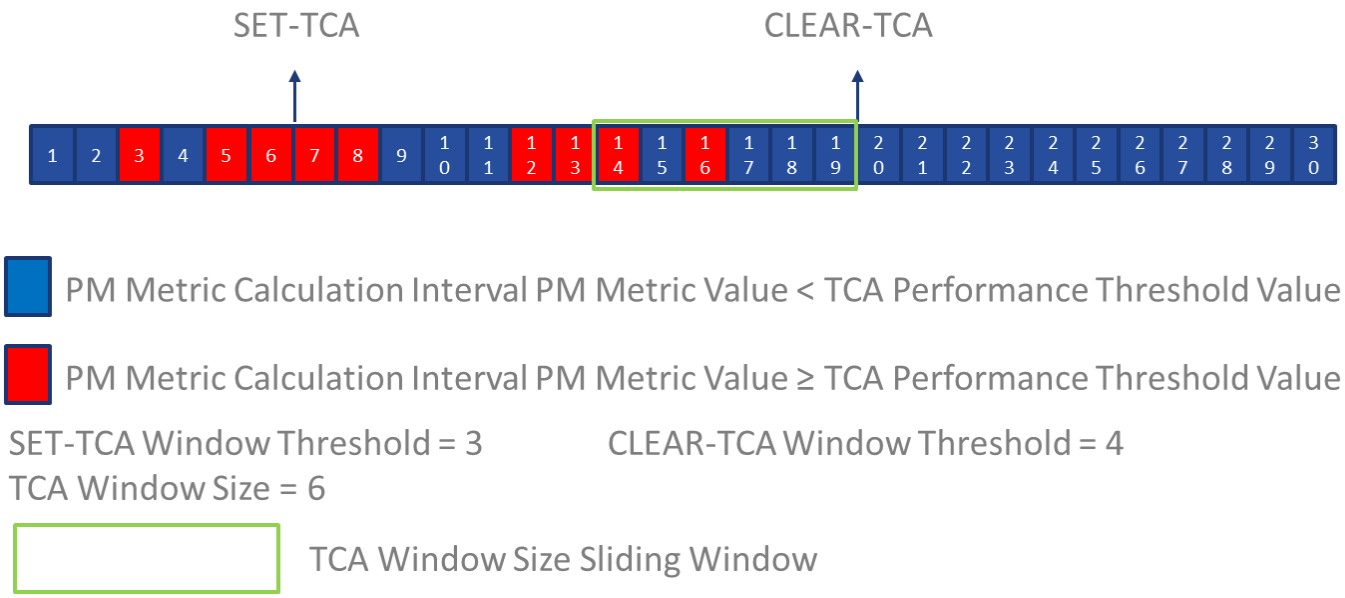


Figure 11 – Stateful TCA without Consecutive PM Metric Calculation Intervals ≥ TCA Performance Threshold Value

Figure 11 shows an example of a SET-TCA and CLEAR-TCA being generated even if consecutive PM Metric Calculation Intervals do not meet the criteria for SET-TCA or CLEAR-TCA. The PM Metric Value is equal to or greater than the TCA Performance Threshold Value in PM Metric Calculation Intervals 3, 5, and 6 meeting the SET-TCA Window Threshold and TCA Window Size criteria and a SET TCA is generated at the end of PMCI 6. A CLEAR-TCA is generated after the completion of PM Metric Calculation Interval 19 because the CLEAR-TCA Window Threshold and TCA Window Size criteria have been met, even though the PM Metric Value in PM Metric Calculation Interval 16 exceeded the TCA Performance Threshold Value.

8.5.2 Stateless Threshold Alert Reporting

The Stateless TCA Function treats each PM Metric Calculation Interval separately. The TCA Window Threshold and TCA Window Size are not used. When using Stateless TCA reporting, each TCA Function has a single configured TCA Performance Threshold Value. When a PM Metric Value in a PM Metric Calculation Interval is equal to or greater than the TCA Performance Threshold Value for a PM Metric Calculation Interval, a TCA is generated. There is no corresponding CLEAR. Figure 12 shows this.

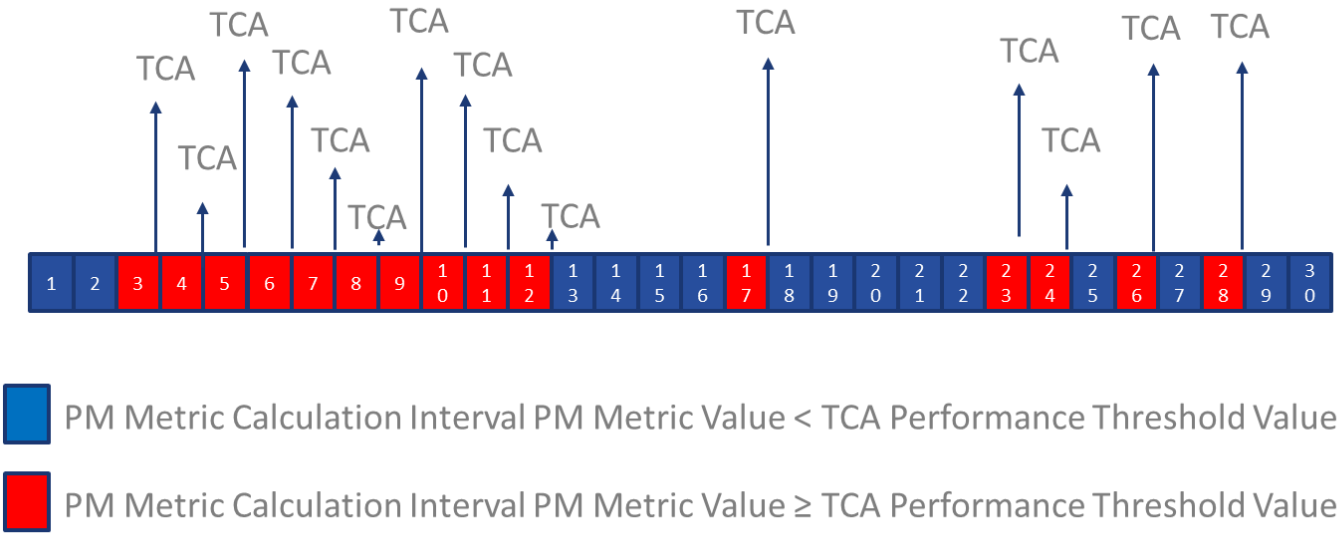


Figure 12 – Stateless TCA

As shown in Figure 12, multiple TCAs are generated when a degraded condition exists for more than one PM Metric Calculation Interval, one per PM Metric Calculation Interval that meets the TCA Function Parameters, when Stateless TCAs Reporting is used. In this example, the TCA criterion is met in PM Metric Calculation Interval 3-12, 17, 23, 24, 26, and 28. TCAs are generated in each of these PM Metric Calculation Intervals.

To avoid generating a TCA per PM Metric Calculation Interval when the TCA Function Parameters is met for multiple PM Metric Calculation Intervals, the Damping Factor is used. The impact of the Damping Factor is shown in Figure 13.

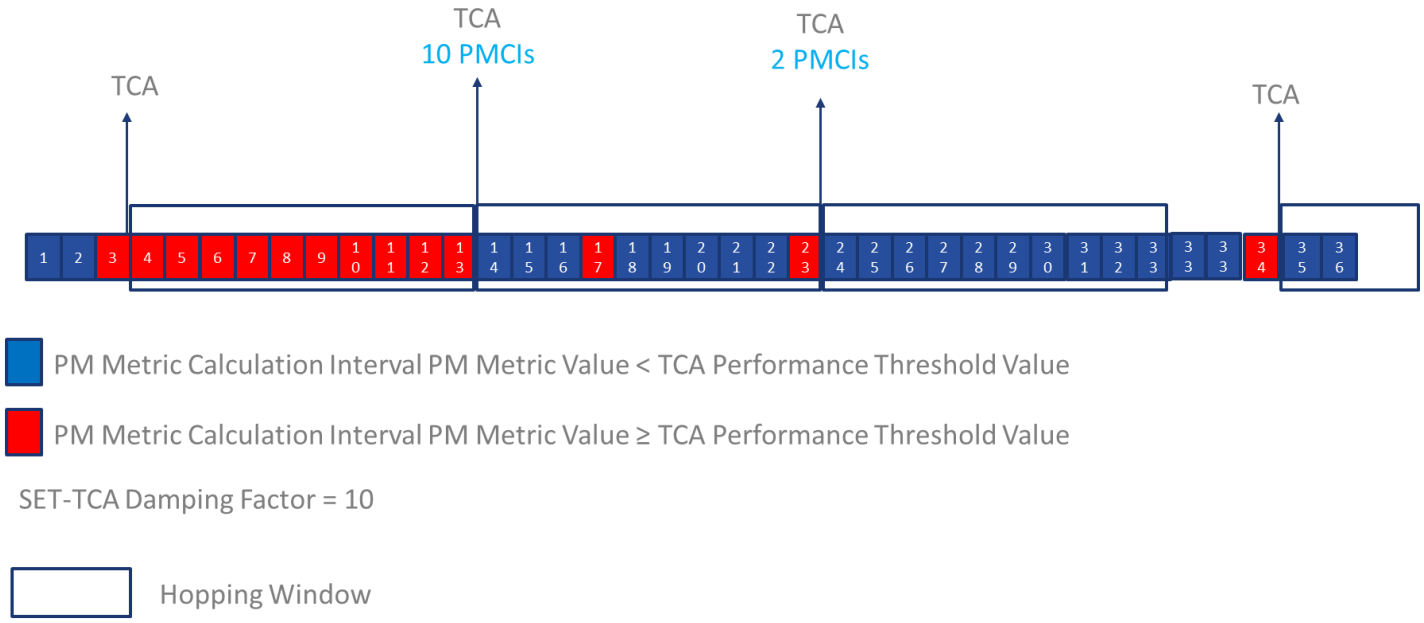


Figure 13 – Stateless TCA with Damping Factor

As shown in Figure 13, rather than multiple TCAs being generated, the TCAs are suppressed for the number of consecutive PM Metric Calculation Intervals defined by the SET-TCA Damping Factor. In the example, the PM Metric Value is equal to or greater than the TCA Performance Threshold Value in PM Metric Calculation Interval 3. An initial TCA is generated at the end of the PM Metric Calculation Interval, and the Damping algorithm is activated. A hopping window that is equal to the number of PM Metric Calculation Intervals specified by the Damping Factor starts at the completion of PM Metric Calculation Interval 3. Moving forward 10 PM Metric Calculation Intervals (SET-TCA Damping Factor value) another TCA is generated at the completion of PM Metric Calculation Interval 13 since at least one PM Metric Calculation Interval within the hopping window had a PM Metric Value equal to or greater than the TCA Performance Threshold Value. This TCA might include the count of PM Metric Calculation Intervals in the hopping window that had a PM Metric Value equal to or greater than the TCA Performance Threshold Value (shown as 10 PMCIs in blue text in Figure 13). Moving forward another 10 PM Metric Calculation Intervals to PM Metric Calculation Interval 23, a TCA is generated since at least one PM Metric Calculation Interval within the hopping window had a PM Metric Value equal to or greater than the TCA Performance Threshold Value. This TCA might include the count of PM Metric Calculation Intervals in the hopping window that had a PM Metric Value is equal to or greater than the TCA Performance Threshold Value (shown as 2 PMCIs in blue text in Figure 13). Moving forward 10 more PM Metric Calculation Intervals to interval 33, a TCA is not generated since zero of the PM Metric Calculation Intervals in the hopping window had a PM Metric Value is equal to or greater than the TCA Performance Threshold Value. At the completion of a hopping window without the occurrence of any TCAs, the damping algorithm resets to the start of the algorithm. If a future PM Metric Calculation Interval has a PM Metric Value equal to or greater than the TCA Performance Threshold Value, a TCA is generated at the completion of the PM

Metric Calculation Interval, and the Damping Factor is activated. This behavior repeats as long as the Stateless TCA is enabled which is shown by the TCA at the completion of PM Metric Calculation Interval 34 which activates the Damping Factor again.

8.5.3 Threshold Crossing Alert Requirements

This section defines the requirements for the use of TCAs.

8.5.3.1 Common TCA Requirements

The requirements in this section apply to Stateful and Stateless TCA Reporting implementations.

[D3] An SD-WAN PM Implementation **SHOULD** provide the ability to generate TCAs based on the TCA Function Parameters used.

[CR1]<[D3] An implementation supporting TCAs **MUST** support at least one of Stateful or Stateless TCA Reporting.

[CR2]<[D3] An implementation supporting TCAs **MUST** support TCA Functions with different TCA Function Parameter values for each Monitored Entity and each PM Metric.

[CD1]<[D3] An implementation supporting TCAs **SHOULD** support multiple TCA Functions with different TCA Function Parameter values for a given Monitored Entity and PM Metric.

[CR3]<[D3] An implementation supporting Stateful, and Stateless TCAs **MUST** SET the TCA at the completion of a PM Metric Calculation Interval in which the PM Metric Value is equal to or greater than the TCA Performance Threshold Value.

The SD-WAN SP can report the occurrence of a TCA to the Subscriber via the SD-WAN Service Dashboard or other mechanisms.

[CR4]<[D3] If TCAs are reported to the Subscriber by the SD-WAN SP, they **MUST** include the information contained in either Table 13 or Table 15, and if applicable Table 16.

Note: the method used to display TCAs within the SD-WAN Service Dashboard is beyond the scope of this document.

8.5.3.2 Stateful TCA Requirements

The requirements in this section apply to Stateful TCA implementations.

[CR5]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support SET-TCA functionality defined in section 8.5.1.

[CR6]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support CLEAR-TCA functionality defined in section 8.5.1.

[CR7]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support the value of the SET-TCA Window Thresholds being any value within a range of 1-300.

[CR8]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support the value of the CLEAR-TCA Window Thresholds being any value within a range of 1-300.

[CR9]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support the value of the TCA Window Size being any value with a range of 1-300.

[CR10]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support TCAs for the PM Metric shown in Table 11.

PM Metric	**SET-TCA Performance Threshold Value**	**SET-TCA Window Threshold Value**	**CLEAR-TCA Window Threshold Value**	**TCA Window Size Value**
One-way Mean Packet Delay	PT_{MPD}	SWT_{MPD}	CWT_{MPD}	TWS_{MPD}
One-way Mean Inter-Packet Delay Variation	PT_{IPDV}	SWT_{IPDV}	CWT_{IPDV}	TWS_{IPDV}
One-way Packet Loss Ratio	PT_{PLR}	SWT_{PLR}	CWT_{PLR}	TWS_{PLR}

Table 11 – Stateful TCA Reporting PM Metric Parameters

[CR11]<[D3] An implementation supporting Stateful TCA Reporting **MUST** support SET-TCA and CLEAR-TCAs when the conditions occur as shown in Table 12.

PM Metric	TCA SET Criteria	TCA CLEAR Criteria
One-way Mean Packet Delay	*When* $PMV_{MPD} \geq PT_{MPD}$ for SWT_{MPD} out of TWS_{MPD}	*When* $PMV_{MPD} \leq PT_{MPD}$ for CWT_{MPD} out of TWS_{MPD}
One-way Mean Inter-Packet Delay Variation	*When* $PMV_{IPDV} \geq PT_{IPDV}$ for SWT_{IPDV} out of TWS_{IPDV}	*When* $PMV_{IPDV} \leq PT_{IPDV}$ for CWT_{IPDV} out of TWS_{IPDV}
Packet Loss Ratio	*When* $PMV_{PLR} \geq PT_{PLR}$ for SWT_{PLR} out of TWS_{PLR}	*When* $PMV_{PLR} \leq PT_{PLR}$ for CWT_{PLR} out of TWS_{PLR}

Table 12 – Stateful TCA Reporting SET & CLEAR Criteria

[CR12]<[D3] For an implementation supporting Stateful TCA Reporting, for each TCA Function, the sum of the values of the SET-TCA Window Threshold (SWT_{MPD}, SWT_{IPDV}, or SWT_{PLR}) and the CLEAR-TCA Window Threshold (CWT_{MPD}, CWT_{IPDV}, or CWT_{PLR}) **MUST** be greater than the value of the TCA Window Size (TWS_{MPD}, TWS_{IPDV}, or TWS_{PLR}).

[CR13]<[D3] An implementation supporting Stateful TCA Reporting **MUST** generate a SET-TCA notification message and set the internal state of the TCA Function to ‘set’ when the TCA Function is in the ‘clear’ state and the criteria for SET-TCA defined in Table 12 are met.

[CR14]<[D3] An implementation supporting Stateful TCA Reporting **MUST** generate a CLEAR-TCA notification message and set the internal state of the TCA Function to ‘clear’ when the TCA Function is in the ‘set’ state and the criteria for CLEAR-TCA defined in Table 12 are met.

[CR15]<[D3] An implementation supporting Stateful TCA Reporting **MUST** include the attributes shown in Table 13 in the SET-TCA or CLEAR-TCA notification message.

Field Name	Field Value	Field Format	Field Description
Date and Time	Date/time in UTC	dateTime i.e.ddm-myyyyhhmmss	Time of the event, in UTC. For Stateful SET-TCA and CLEAR-TCA this is the time of the completion of the PM Metric Calculation Interval for which the PM Metric Value triggered the TCA to be generated.
Performance Metric Name	One of One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, or One-way Packet Loss Ratio	String	Human readable text for the Performance Metric for which the TCA Function was configured, i.e., one of those listed in Table 11.
TCA Performance Threshold Value	Numeric value	Integer	The TCA Performance Threshold Value for the Performance Metric.
SET-TCA Window Threshold Value	Numeric value	Integer	The value of the SET-TCA Window Threshold. Only used for SET-TCA notification messages.
CLEAR-TCA Window Threshold Value	Numeric value	Integer	The value of the CLEAR-TCA Window Threshold. Only used for CLEAR-TCA notification messages.
TCA Window Size Value	Numeric value	Integer	The number of PM Metric Calculation Intervals included in the sliding window for the SET-TCA or CLEAR-TCA process.

Field Name	Field Value	Field Format	Field Description
PM Metric Value	List of Numeric value for each PM Metric Calculation Interval	Integer	
TCA Type	STATEFUL-SET, or STATEFUL-CLEAR	String	The type of TCA, i.e., STATEFUL-SET or STATEFUL-CLEAR
Severity Level	CRITICAL, MAJOR, MINOR, WARNING, or CLEARED	String	CRITICAL, MAJOR, MINOR, or WARNING apply to STATEFUL-SET, CLEARED applies to STATEFUL-CLEAR.

Table 13 – Stateful TCA Notification Message Fields

Note: CLEARED is included in the Severity Level to align with TCA implementations where the STATEFUL-SET is a WARNING and the STATEFUL-CLEAR is shown as CLEARED.

8.5.3.3 Stateless TCA Reporting Requirements

The requirements in this section apply to Stateless TCA implementations.

[CR16]<[D3] An implementation supporting Stateless TCA Reporting **MUST** support the TCA functionality defined in section 8.5.

[CR17]<[D3] An implementation supporting Stateless TCA Reporting **MUST** support TCAs for the PM Metrics shown in Table 14.

Note: PMV shown in Table 14 is the acronym for PM Metric Value.

PM Metric	TCA Performance Threshold Value	TCA
One-way Mean Packet Delay	PT_{MPD}	*When* $PMV_{MPD} \geq PT_{MPD}$
One-way Mean Inter-Packet Delay Variation	PT_{IPDV}	*When* $PMV_{IPDV} \geq PT_{IPDV}$
One-way Packet Loss Ratio	PT_{PLR}	*When* $PMV_{PLR} \geq PT_{PLR}$

Table 14 – Stateless TCA Reporting PM Metric Calculations

[CD2]<[D3] An implementation supporting Stateless TCA Reporting **SHOULD** support the Damping Factor.

[CR18]<[D3] An implementation supporting Stateless TCA Reporting with the Damping Factor **MUST** support the Damping Factor values between 1-300 PM Metric Calculation Intervals.

[CR19]<[D3] An implementation of Stateless TCA Reporting that includes the Damping Factor **MUST** generate a TCA at the end of a PM Metric Calculation Interval if the PM Metric Value for that PM Metric Calculation Interval is greater than or equal to the TCA Performance Threshold and no TCA has been generated after any of the *d-1* preceding PM Metric Calculation Intervals, where *d* is the value of the Damping Factor.

[CD3]<[D3] For an implementation of Stateless TCAs that includes the Damping Factor, when a TCA is generated at the end of a PM Metric Calculation Interval, it **SHOULD** include the number of PM Metric Calculation Intervals, within the sequence of *d* PM Metric Calculation Intervals ending with the one at the end of which the TCA was generated, in which the PM Metric Value was greater than or equal to the TCA Performance Threshold, where *d* is the value of the Damping Factor.

[CR20]<[D3] An implementation of Stateless TCA Reporting **MUST** contain the information shown in Table 15 in the TCA.

Field Name	Field Value	Field Format	Field Description
Date and Time	Date/time in UTC	dateTime i.e., ddmmyyyyhhmmss	Time of the event, in UTC. This is the time of the end of the PM Metric Calculation Interval for which the TCA is generated.
Performance Metric Name	One of One-way Mean Packet Delay, One-way Mean Inter-Packet Delay Variation, or One-way Packet Loss Ratio	String	Human readable text for Performance Metric for which the TCA Function was configured, i.e., one of those listed in Table 14.
TCA Performance Threshold Value	Numeric value	Integer	The TCA Performance Threshold Value
Performance Metric Value	Numeric value	Integer	The PM Metric Value for the PM Metric Calculation
TCA Type	STATELESS	String	The type of TCA
Severity Level	One of CRITICAL, MAJOR, MINOR, WARNING	String	CRITICAL, MAJOR, MINOR, or WARNING.

Table 15 – Stateless TCA Reporting Notification Message Fields

[CR21]<[D3] If an implementation of Stateless TCA Reporting includes the Damping Factor, the Damping Factor shown in Table 16 **MUST** be appended to the TCA notification message.

[CR22]<[D3] If an implementation of Stateless TCA Reporting includes reporting the number of PM Metric Calculation Intervals within the hopping window that had a PM Metric Value that is equal to or greater than the TCA Threshold Value, the Number of PM Metric Calculation Intervals shown in Table 16 **MUST** be appended to the TCA Notification.

As discussed in section 8.5, the Damping Factor can be used to reduce the number of TCAs generated by an implementation supporting a Stateless TCA Reporting. The relatively short duration of the PM Metric Calculation Interval can cause many TCAs to be generated over a short time period. The use of the Damping Factor mitigates this issue. There may be questions about how many of the PM Metric Calculation Intervals within the hopping window actually met the criteria to generate a TCA to understand the severity of the degradation or fault. For this reason, the optional Number of PM Metric Calculation Intervals attribute identifies the number of PM Metric Calculation Intervals that met the criteria for a TCA. An implementation of the Damping Factor

without this optional capability may cause an SD-WAN SP to perform additional research to determine whether the number of PM Metric Calculation Intervals within the hopping window that met the criteria to generate a TCA.

Field Name	Field Value	Field Format	Field Description
Damping Factor	Numeric value	Integer	The value that identifies the number of PM Metric Calculation Intervals included in the Damping Factor process.
Number of PM Metric Calculation Intervals	Numeric value	Integer	The number of PM Metric Calculation Intervals in the hopping window in which the PM Metric Value ≥ the TCA Performance Threshold Value

Table 16 – Damping Factor TCA Notification Message Field

9 Service Readiness Testing for an SD-WAN Service

Service Readiness Testing (SRT) is the process of testing SD-WAN service to ensure it is ready for the Subscriber to begin using. It is performed to ensure that continuity across UCSs exists between SD-WAN Edges and that the service is ready for the Subscriber to begin using. SRT for SD-WAN service includes reporting UCS Service Attributes, SRT Parameters (defined in section 9.6), and SRT Results (defined in section 9.6). SRT verifies the continuity of each ordered pair of UCS End Points within the service agreed to be tested by the Subscriber and SD-WAN SP.

SRT cannot begin until the SD-WAN Edges that are a part of the Subscriber's SD-WAN Service are installed, have continuity to the SD-WAN SP's SD-WAN Controller/Orchestrator, are configured with the basic SD-WAN Edge configuration used by the SD-WAN SP, and UCSs are connected to the SD-WAN Edges via UCS UNIs as appropriate for the SD-WAN Service.

A test methodology is defined for SRT for ordered pairs of UCS End Point within this document. This methodology provides a step-by-step process for performing a specific test or measurement. It also includes the SRT Parameters used for the test methodology.

The remainder of this section contains the following:

- A discussion of SRT terms and components (section 8.1)
- A description of Service Readiness Measurement Points (SRMPs) (section 8.1)
- A description of where SRMPs are located (section 8.2)
- A discussion of SRT use cases (section 8.3)
- Tables that define which UCS attributes are tested, and which are reported (section 9.4)
- SRT for verifying continuity of ordered pairs of UCS End Points (section 8.7)
- Test result reporting (section 8.8)
- Requirements for devices and applications including SRMPs (section 8.4)

9.1 Service Readiness Testing Use Case

This section of the document details the SRT for SD-WAN use case example. The use case does not represent all possible use cases or configurations. It is provided to assist the reader in understanding how and when the continuity is verified.

9.1.1 Verifying Ordered Pair of UCS End Points Continuity

This use case describes the verification of ordered pair of UCS End Points continuity. SRT Parameters and SRT Results are defined in section 9.6. As a new SD-WAN Service is being installed and before it is activated for the Subscriber to use, the SD-WAN SP verifies that there is continuity between the agreed to pairs of SD-WAN Edges used to implement the SD-WAN Service. This is accomplished by performing SRT on the agreed to ordered pairs of UCS End Points.

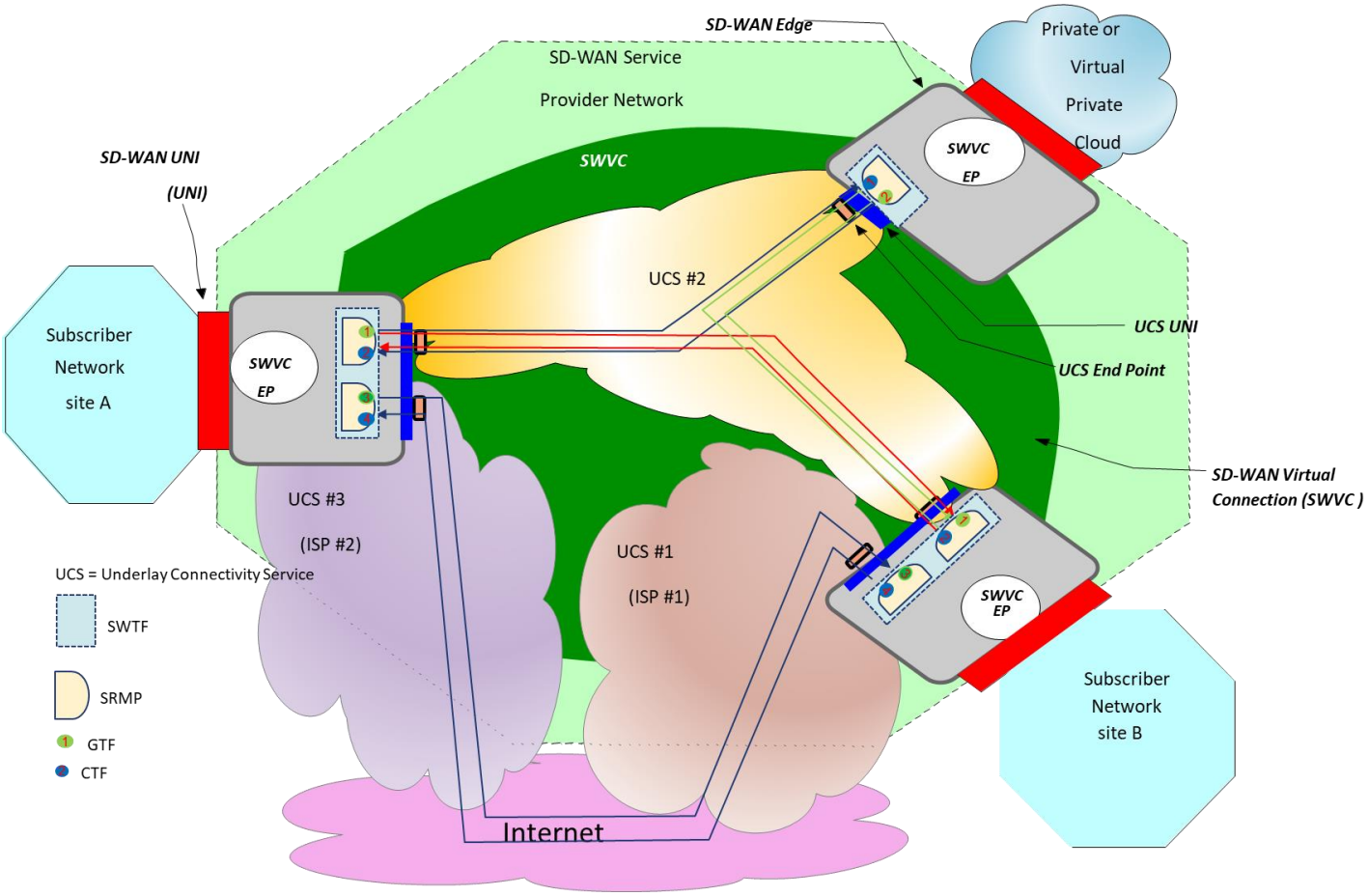


Figure 14 – SRT Order Pairs of UCS End Points Continuity Verification Use Case

Figure 14**Error! Reference source not found.** shows the use case for the verification of continuity between SD-WAN Edges. SRMPs are used at each of the UCS End Points in the ordered pair and tests are performed on each ordered pair of UCS End Points. When a new SD-WAN service is being activated, tests are performed on all agreed to ordered pairs of UCS End Points.

When a new SD-WAN Edge is added to an existing SWVC, the ordered pairs of UCS End Points between that SD-WAN Edge and existing SD-WAN Edges it is connected to may be verified. It is suggested that if this testing is performed, downtime with the Subscriber be arranged to avoid disrupting any Subscriber traffic that is sharing the same UCS.

9.2 Service Readiness Testing Terms and Components

This section describes terms and components used to perform SRT. SRT is performed using a least two Service Readiness Measurement Points (SRMPs). The SRMP is a logical point inside an SD-WAN Edge. The SRMP also contains both a Generator Test Function (GTF) and a Collector Test Function (CTF). A GTF generates IP Test Packets used for test measurements. A CTF either counts and discards IP Test Packets coming from a GTF or counts and processes IP Test Packets from a GTF. When testing with Unicast IP Test Packets, a GTF is paired with a CTF so that the IP Test Packets generated by the GTF are collected by a particular CTF.

An SRT Methodology is defined for continuity verification of ordered pairs of UCS End Points . The SRT Methodology identifies the test name, test objective, test procedure, variables used in the methodology, results, and remarks. SRT Methodologies are specified in section 9.7. SRT is performed from one SRMP to another SRMP (GTF-CTF).

9.3 Service Readiness Measurement Point Locations

The logical location of SRMPs within the network is shown in this section. The following figures show the location of SRMPs in relationship to processing functions within the SD-WAN Edge. The SRMPs are located so that IP Test Packets pass over the UCS which connects the ordered pair of UCS End Points between two SD-WAN Edges but are not processed by functions associated with the SWVC EP. How and where these functions are implemented is outside the scope of this document; however,

[R35] An SRT implementation **MUST** ensure that IP Test Packets generated or received by an SRMP have passed through the ordered pair of UCS End Points under test as shown.

The tool used to generate and receive packets is beyond the scope of this document.

[R36] The SRMP **MUST** be located so that IP Test Packets generated by the GTF are inserted at the UCS UNI which terminates the UCS under test.

The SRMP used for SRT connects to a UCS UNI. It is located so that IP Test Packets generated by the GTF are inserted on an UCS UNI without being processed by the functions associated with the SWVC EP. IP Test Packets collected by the CTF are received directly from the UCS UNI and are not processed by the functions associated with the SWVC EP. This is shown in Figure 15.

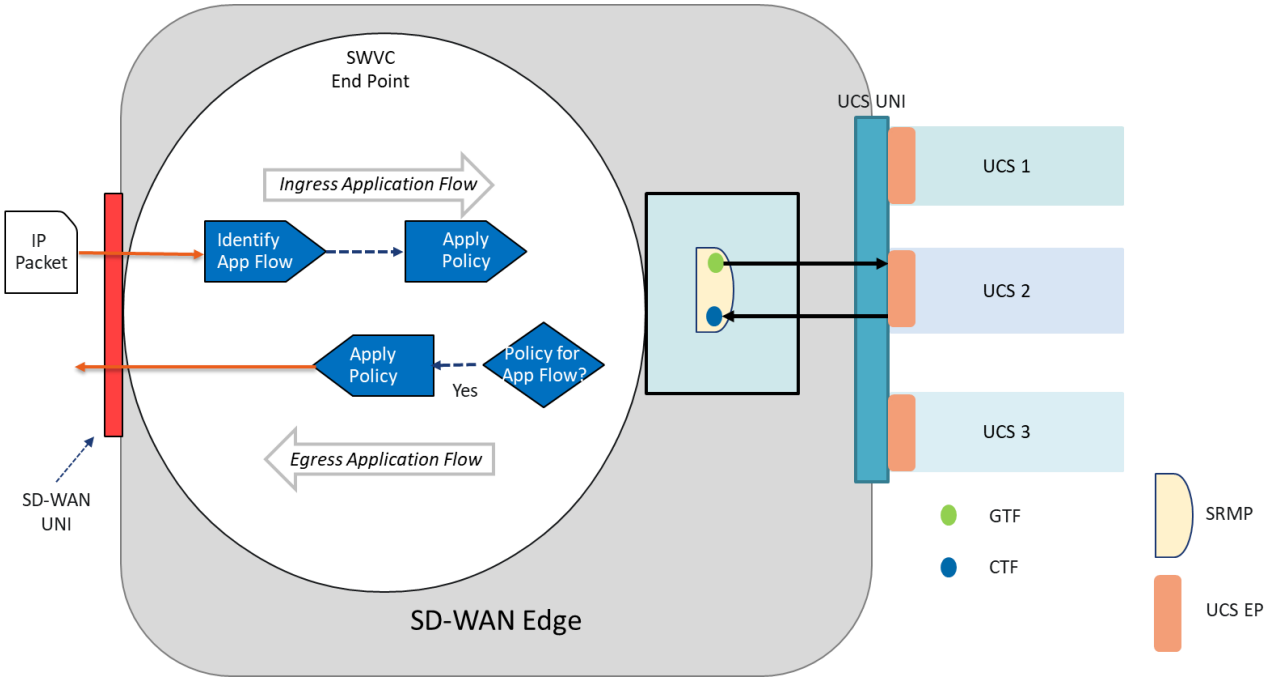


Figure 15 – SRMP Location for Ordered Pair of UCS End Points Continuity Testing

9.4 Service Readiness Measurement Point Requirements

This section defines the requirements for SRMPs. These requirements are expected to be useful for SD-WAN Technology Providers and SD-WAN SPs.

[R37] An SRMP **MUST** contain a Generator Test Function (GTF) and a Collector Test Function (CTF).

9.5 UCS Service Attribute Reporting

This section of the document details the UCS, UCS UNI, and UCS End Point Service Attributes that are included in the SRT Report as a part of the SRT Process.

[R38] The value of all UCS Service Attributes, UCS UNI Service Attributes and UCS End Point Service Attributes defined in MEF 70.1 [11] **MUST** be reported as part of the SRT process, for a new SD-WAN Service or when a new SD-WAN UNI or a new UCS UNI is added to an existing SD-WAN Service.

9.6 Service Readiness Testing Parameters and Results

SRT verifies and reports the results of the UCS End Point ordered pair Connectivity tests. A prerequisite to this testing is verifying that the SD-WAN Controller/Orchestrator can communicate with SD-WAN Edges that are a part of the SWVC.

9.6.1 SD-WAN Edge to SD-WAN Controller/Orchestrator Communication

As a prerequisite to SRT, the verification of communication between the SD-WAN Controller/Orchestrator and SD-WAN Edges is performed. The steps used to verify this communication are beyond the scope of this document. The SRT Report does not indicate if this verification was performed or if it passed or failed.

9.6.2 Ordered Pairs of UCS End Point SRT Parameters and SRT Results

As discussed previously in section 9, the SD-WAN SP and Subscriber agree to the ordered pairs of UCS End Points that are included in SRT. Verifying continuity of the ordered pairs between SD-WAN Edges for a given SWVC is required for SRT. The ordered pairs of UCS End Points are either part of two different Internet Access UCSs or a non-Internet UCS . SRT verifies that IP Test Packets can be sent from the first UCS End Point in the ordered pair to the second UCS End Point. The Pass/Fail result of each tested ordered pair of UCS End Points is reported. It should be noted that the Pass/Fail result of SD-WAN Edge to SD-WAN Controller/Orchestrator SRT does not have any impact on the result of the UCS End Point Order Pair SRT result.

[R39] When a new SWVC is being activated, the SD-WAN SP **MUST** verify continuity between the agreed upon ordered pairs of UCS End Points.

[R40] When a new SD-WAN Edge is added to an existing SWVC, the SD-WAN SP **MUST** verify continuity between the agreed upon ordered pairs of UCS End Points.

[R41] When the SD-WAN SP is verifying continuity, they **MUST** use the Test Process defined in Table 22.

9.7 Test Processes

This section contains the Test Processes for the verification of the service readiness. Testing is performed as shown in section 8.6. The process for continuity verification of ordered pairs of UCS End Points is included in this section as well.

Figure 16 shows the high level UCS End Point Ordered Pair Continuity SRT Process.

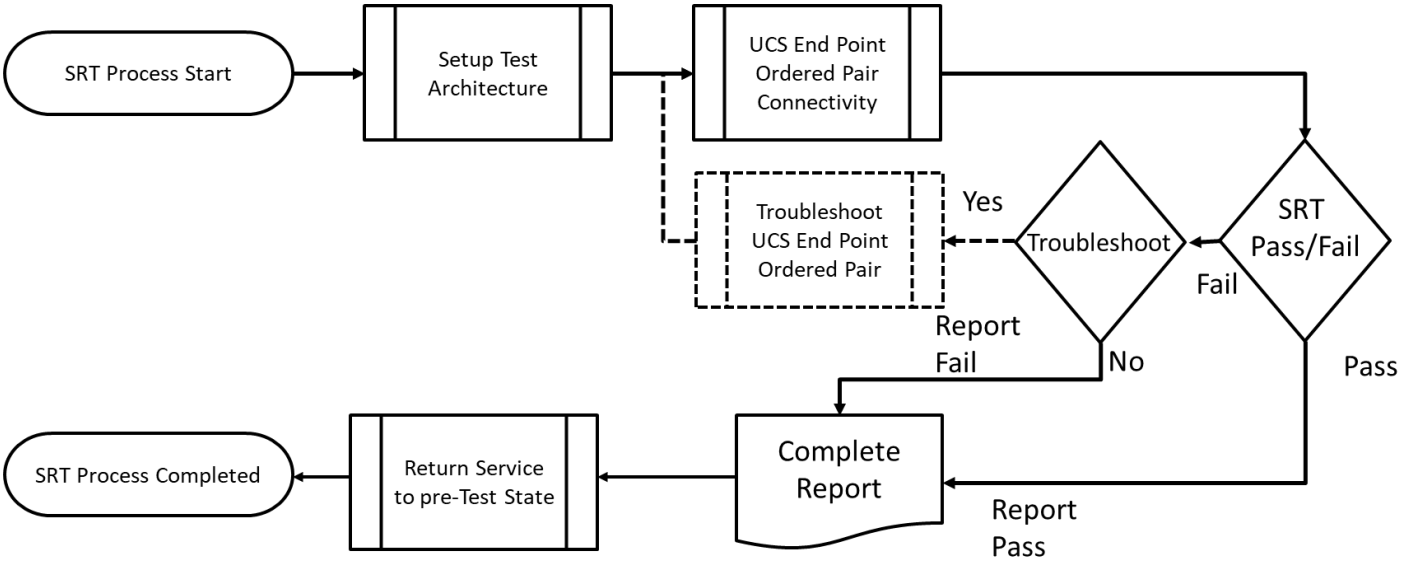


Figure 16 – UCS End Point Ordered Pair Continuity SRT Process

SRT is repeated for each ordered pair that is agreed to be included in SRT by the Subscriber and SD-WAN SP.

The first step of the process is to create the required SRMPs at the appropriate SD-WAN Edges and to connect the SRMP to the correct UCS End Point.

The second step in the process is to verify continuity between the end point pair as described in Table 17.

The third step in the process is to report the UCS Service Attributes, and SRT Results.

The fourth and final step in the process is to disconnect the SRMP from the UCS End Point and to restore the UCS End Point to its normal configuration.

Troubleshooting of a test failure is optional and depends on factors such as who provided the UCS and who is responsible for UCS management. If troubleshooting of the failure is performed, the UCS End Point Ordered Pair test is repeated when the trouble has been resolved. If troubleshooting is not performed, the failure is reported.

9.7.1 UCS End Point Ordered Pair Testing

Continuity between ordered pairs of UCS End Points is tested for the ordered pairs that are agreed to be tested by the SD-WAN SP and the Subscriber. The verification of continuity uses the methodology defined in Table 17.

[R42] Results for each ordered pair of UCS End Points tested in the SRT Test Methodology **MUST** be reported as pass or fail.

1236

Service Readiness Test Methodology	
Test Name	UCS End Point Ordered Pair Continuity
Test Objective	Verify that there is continuity between SD-WAN Edges per ordered pair of UCS End Points
Test Procedure	•For this Test Methodology $SRMP_1$ and $SRMP_2$ are placed as shown in Figure 15 and Figure 16. •SRMP $_1$ offers a number of IP Test Packets with the DA for reaching SRMP $_2$ so that the IP Test Packets are injected into the UCS End Point at location 1 at an interval where the IP Test Packets are equally distributed over time T_{SC}. The number of IP Test Packets offered and the value of time T_{SC} are agreed to by the SP and Subscriber. •SRMP $_2$ counts the IP Test Packets received from SRMP $_1$ and either provides the count of received packets or subtracts the number of received packets from the number of offered packets and provides the number of lost packets. Note: If SRMP $_2$ does not know the number of offered IP Test Packets, then the calculation of lost packets is performed at some point that is aware of both the number of offered IP Test Packets and the number of received IP Test Packets. •The above is repeated for each ordered pair of UCS End Points agreed to be tested by the Subscriber and SD-WAN SP.
Parameters	Set of order pairs of UCS End Points, $T_{SC,}$ number of IP Test Packets Offered, number of lost packets allowed per ordered pair of UCS End Points
Results	Pass = The number of lost packets is less than or equal to the allowed value Fail = The number of lost packets is greater than the allowed value
Remarks	

1237 **Table 17 – UCS End Point Ordered Pair Continuity Methodology**

1238 Note: to test the UCS EP ordered pair in each direction as shown in Figure 16, this methodology
1239 is repeated for the other direction between the SD-WAN Edges over the same UCS.

1240 When the agreed to set of order pairs of UCS End Points have been verified, the Subscriber can
1241 begin to use the service.

1242 9.8 Test Record

1243 After all tests have been completed an SRT record is created. The SRT record contains the attrib-
1244 ute and test result information described in sections 8.5, 8.6, and 8.7. The results from the different
1245 tests are mapped into one SRT record for that service. The SRT record can be shared with the
1246 Subscriber and can be stored within SD-WAN SP management systems. The format of the SRT
1247 record is not mandated by this document.

10 References

[1] IETF RFC 2119, *Key words for use in RFCs to Indicate Requirement Levels*, March 1997

[2] IETF RFC 8174, *Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words*, May 2017

[3] ISO/IEC 7498-1:1994, *Information technology – Open System Interconnection – Basic Reference Model: Basic Model*, June 1996

[4] ITU-T Recommendation X.733, *Information Technology – Open Systems Interconnection, System Management – Alarm Reporting Function*, 1992

[5] MEF 35.1, *Service OAM Performance Monitoring Implementation Agreement*, May 2015

[6] MEF 48.1, *Carrier Ethernet Service Activation Testing*, November 2019

[7] MEF 55.1, *Lifecycle Service Orchestration (LSO): Reference Architecture and Framework*, January 2021

[8] MEF 61.1, *IP Service Attributes*, May 2019

[9] MEF 66, *Service OAM for IP Services*, July 2020

[10] MEF 67, *Service Activation Testing for IP Services*, December 2020

[11] MEF 70.1, *SD-WAN Service Attributes and Service Framework*, November 2021

Appendix A Service Readiness Testing vs Service Activation Testing

This document introduces the concept of Service Readiness Testing for SD-WAN Services. This is different from Service Activation Testing that is defined for other MEF services. Service Activation Testing is performed on the service and verifies that the service is operating as described by the agreed to Service Attributes. The Service Attributes that are reported and/or tested are included in the definition of Service Activation Testing.

SD-WAN Service is built to run on top of one or more UCSs and uses policies to determine how an IP Packet received from a Subscriber is forwarded or discarded. A SD-WAN SP might maintain many policies. Some might be default policies used for all Subscribers and others might be developed to address a specific Subscriber's application. Verifying the correct operation of each policy may be done in a lab environment or in conjunction with a specific Subscriber's applications.

Rather than performing Service Activation Testing on SD-WAN Service, Service Readiness Testing is performed. Service Readiness Testing verifies that the SD-WAN Service is ready for the Subscriber to use or the SD-WAN SP or Subscriber to implement the Subscriber-specified policies. SRT does not verify the operation of the policies or SD-WAN Service Attributes. Instead, it is focused on determining that each ordered pair of UCS End Points provides continuity between the appropriate SD-WAN Edges.

The results of the SRT may be presented to the Subscriber as an SRT Report. The contents of the SRT Report are defined in this document. The format of the SRT Report is beyond the scope of this document.

The scope of testing within this document is limited to Service Readiness Testing. Any additional testing that the SD-WAN SP and Subscriber agree to perform is beyond the scope of this document.