Testing for SLA Compliance of business services over DOCSIS 3.1

A Technical Paper prepared for SCTE/ISBE by

Robert J. Flask
Sr. Product Line Manager
Viavi Solutions
5808 Churchman Byp.
Indianapolis, IN 46203
317-614-8125
robert.flask@viavisolutions.com

Table of Contents

List of Figures

List of Tables

Introduction

Communications and data service growth is driving the demand for Ethernet services. Many Ethernet services, such as cellular backhaul have stringent Service Level Agreement (SLA) requirements. SLA requirements are verified at time of turn-up and can be monitored in the background. With the extensive reach and coverage of the Hybrid Fiber Coax (HFC) networks, cable operators are well positioned to utilize DOCSIS as a delivery method for Ethernet services. Legacy DOCSIS systems including DOCSIS 3.0 have limitations that prevent it from being used for timing critical Ethernet services. DOCSIS 3.1 has added additional mechanisms that if designed and implemented can provide capability to provide Ethernet services to stringent services such as Advanced LTE backhaul. Best practices for Ethernet service SLA compliance can be implemented that include turn up and automation to simplify the process. There are various testing standards used for validating business service SLA's including RFC-6349, RFC-2544, Y.1564, Y.1731. Many of these standards weren't very relevant with DOCSIS 3.0 but now are likely to become part of the repertoire of DOCSIS 3.1 Ethernet service deployments.

Content

1. DOCSIS and Ethernet SLA Testing

DOCSIS is by nature a shared environment. When providing Ethernet services over DOCSIS, only a portion of the DOCSIS network capacity is being utilized for the customer. The DOCSIS network can be viewed as the User Network Interface (UNI). Multiple customers will use the DOCSIS network simultaneously, including residential data services and voice service. Providing a dedicated Ethernet service to a business entails the creation of an Ethernet Virtual Circuit (EVC) that utilizes a portion of the overall UNI. The most typical way of supporting Business Services Over DOCSIS (BSOD) today is via Layer 2 VPN support. CableLabs specifies guidelines for operators to offer MEF compliant Layer 2 Transparent LAN services (TLS) to commercial enterprises.

Note that the sum of all of the EVC's for guaranteed SLA service must be less than the overall UNI speed. This creates challenges for sharing a portion of a DOCSIS network with SLA business services and high capacity best-effort services.

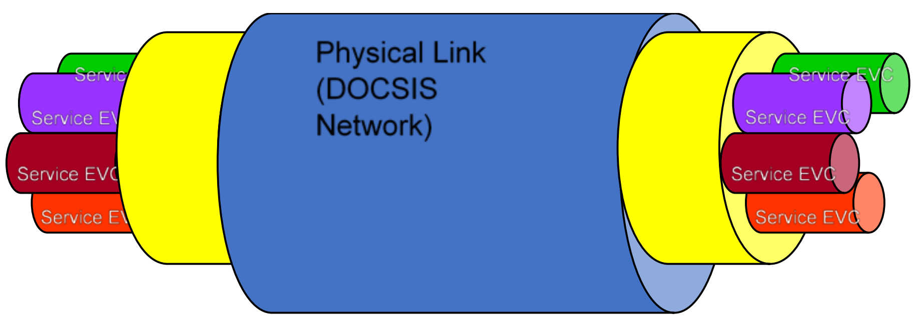

Figure 1 - Multiple EVC's over the DOCSIS network

The DOCSIS network is only a portion of what the Ethernet service resides in. Rarely does a customer only need Ethernet service within the DOCSIS portion of the network. As shown in Figure 2 the DOCSIS portion is typically just the last mile.

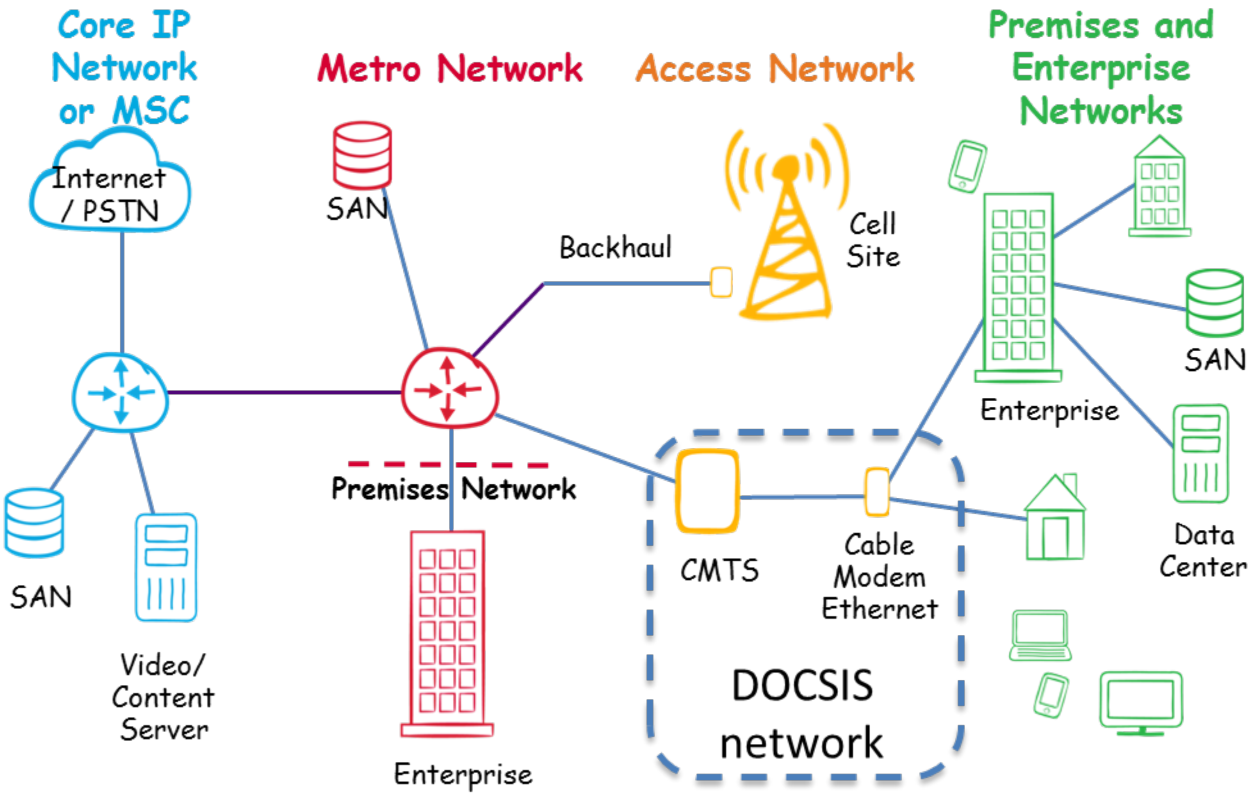

Figure 2 - DOCSIS Network is Last Mile Portion of the Ethernet Service

1.1. Legacy DOCSIS

Existing DOCSIS services up through DOCSIS 3.0 had capacity, architecture, and design limitations that limited the opportunities where DOCSIS could be effectively used for SLA based Ethernet business services. Asymmetric capacity limitations limited the speed of service that could be offered and performance metrics regarding latency (frame delay), and jitter (frame delay variation). The timing accuracy for DOCSIS 3.0 systems prevented the use of DOCSIS for cellular backhaul, LTE, and Advanced LTE.

1.1.1. Best Effort Services – SMB

DOCSIS fits well into the Small to Medium Business that mostly requires solid and consistent Internet services. Throughput tests with capability to validate best effort pipe speeds is critical to make sure impairments aren't impacting the capacity. Typically, operators will provision with about 10 % Excess Information Rate above the stated service level to ensure Speedtest throughputs meet or exceed the advertised upload/download speeds.

But with best effort services there typically aren't any penalty clauses regarding speeds. More typically, the SLA's for best effort service surround availability and Mean Time To Repair (MTTR).

To ensure real life customer experience for a best effort service, RFC-6349 testing is recommended. This will identify the customers actual layer 4 TCP throughput and also identify any configuration or TCP efficiency issues. RFC 6349 testing can show the effects of traffic shaping that may be occurring.

1.2. Metro Ethernet service

1.2.1. Key Components of Ethernet service activation SLA testing

Ethernet business services can vary from being a basic best effort internet service, like a traditional home cable modem, to a high-performance Ethernet service with guaranteed performance with SLA requirements for availability, MTTR, Latency/Frame Delay (FD), Jitter/Frame Delay Variation (FDV), Throughput (Committed Information Rate (CIR)/ Excess Information Rate (EIR), and frame loss. Ethernet business services typically require some level of SLA. A typical SLA for a local Metro Ethernet service is show in Table 1 for Ethernet services and standard mobile backhaul service.

Table 1 - Example of typical local Metro Ethernet service requirements

KPI	Ethernet Services	Mobile Backhaul services
Frame Delay	typical 5 ms - best effort up to 30 ms	< 8 ms typical 5 ms
Frame Delay Variation	< 2 ms	
Frame Loss	6.25 x 10-6	
Throughput	99.99%	
Availability	99.995%	
Mean-time to repair	2 hours (max 4 hours)	

Comparatively, with legacy DOCSIS 3.0 the SLA levels are much relaxed. Particularly the Frame Delay and the Frame delay variation. Table 2 shows a typical example of an SLA over an existing DOCSIS 3.0 network. Note that the Frame Delay allowance is even higher than typical best effort Ethernet services.

Table 2 - Example of typical local Ethernet SLA over DOCSIS 3.0

KPI	DOCSIS Ethernet Services
Frame Delay	<60ms
Frame Delay Variation	< 12 ms
Frame Loss	< 0.1%
Throughput	95%
Availability	99.9%
Mean-time to repair	4 hours

1.2.2. Ethernet KPI verification

Validation of SLA requirements require testing and monitoring. Common practice is for initial testing via a field meter at install and service turn up. Often the field testing is combined with automated or centralized test through remote test heads or software agents to make a faster and more consistent test practice.

1.2.3. What are the key tests

To verify and test to the SLA, various tests are used for Metro Ethernet services depending on the service type and SLA. Table 3 shows a list of common tests that are used for validating the varying SLA requirements.

Table 3 - Service Tests for validating Ethernet SLA's

Service Activation Test	Description	Comment
Connectivity, Throughput and Auto-Negotiation	Verify basic connectivity Verify best effort throughput Validate auto negotiation settings to identify half/full duplex limitations	Pre-Check prior to complete SLA testing.
RFC-2544 – Single Stream Pipe test	Industry-standard service activation test for single-service Ethernet and IP (i.e. "pipe" test) Measures key performance indicators and bandwidth profile such as: throughput, latency, packet Jitter, frame loss, and committed burst size (CBS)	Commonly done at service activation with loop-back of remote device. This is an out of service test Testing in both directions, both independently and concurrently (independent transmissions from both ends) for bi-directional testing is critical to determine which direction is not meeting the SLA. Single ended loopback modes cannot isolate which direction.
Y.1564	The industry standard service activation test for multi-service Ethernet and IP ("Triple Play") Measures KPIs and bandwidth profile such as: • CIR, EIR (Throughput) • Frame Delay (FD), Latency • Frame Delay Variation (FDV), Jitter • Frame Loss Rate (FLR) • Committed Burst Size (CBS), Policing	Commonly done at service activation with loop-back of remote device. Testing in both directions both independently and concurrently (independent transmissions from both ends) for bi-directional testing is critical to determine which direction is not meeting the SLA. Single ended loopback modes cannot isolate which direction. This is an out of service test
Layer 2 Control Plane	Confirm transparent forwarding of Ethernet traffic through the providers network	Done at field turn-up. Typically instrument turn up with loopback from remote device
RFC-6349	Automated and repeatable TCP-throughput test per IETF RFC 6349 standards, including key performance metrics of TCP efficiency and Buffer delay	Can be virtualized with centralized reporting. This can be done in-service but utilizes full bandwidth
Y.1731	Performance monitoring and PM protocol. Can be used for service testing including loopback, frame delay, frame delay variation, frame loss	Useful in remote automation

1.2.4. Operation Administration and Monitoring (OAM)

802.11ag Connectivity Fault Management which is part of the Operational Administration and Maintenance (OAM) protocol allows maintenance and management of each EVC regardless of the transport layer. This allows operators to partition the network across the different boundaries and third-party operators.

Y.1731 Performance Monitoring OAM protocols allow for devices to have some continuous remote monitoring activities. Y.1731 provides in-service performance monitoring to measure KPI's like frame delay, frame delay variation, frame loss. Y.1731 can also provide fault management capabilities including remote loopback. Y.1731 can be an important part of automated turn-up testing as well.

1.3. How DOCSIS 3.1 enables improved Ethernet services

Gigabit services offerings are now available with DOCSIS 3.1 systems. A system that utilizes two 192 MHz wide OFDM downstream channels as well as two 96MHz wide OFDM-A upstream channels is capable of supplying over 2.5 Gbps downstream and 1Gbps upstream of shared capacity.

The CableLabs specification for DOCSIS 3.1 devices and services took into consideration the desire to deploy business services over DOCSIS. The new modulation schemes provide improved data efficiency and signaling, and the addition of the DOCSIS Timing protocol provides steady and consistent point to point timing and clock accuracy at the CM egress point.

1.3.1. DTP – DOCSIS Timing Protocol

The DOCSIS timing protocol provides the ability for the CMTS to reference a timing protocol source and provide the clock on the output of the CM to the end device. DTP is based on the Precision Timing Protocol (PTP) of IEEE-1588-2008 with a few modifications

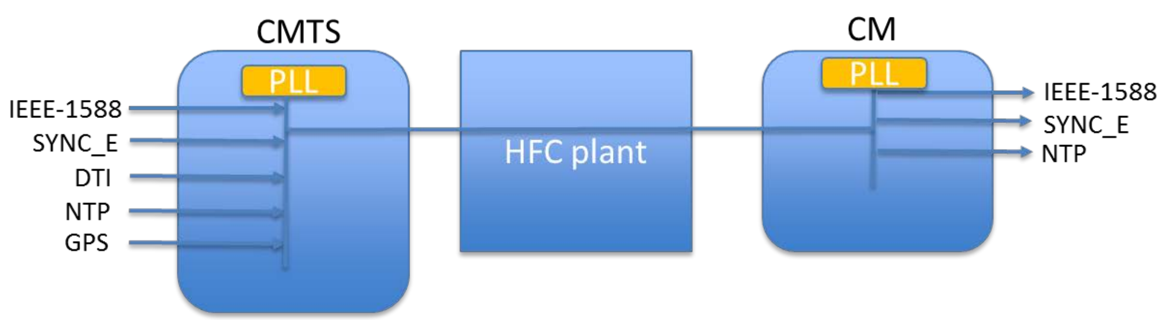

Figure 3 - DTP Clock System

When implemented, DTP allow the CMTS and CM to appear as a single DOCSIS system to the outside world. This allows the DOCSIS system to appear as a Boundary clock. This allows the Ethernet system to compensate and minimize the effects of any system delays or frame delay variances. The system delays that are calculated are added to the timestamp, which effectively negates the delays. Delays and variances are issues that made legacy DOCSIS inoperable for most business class services.

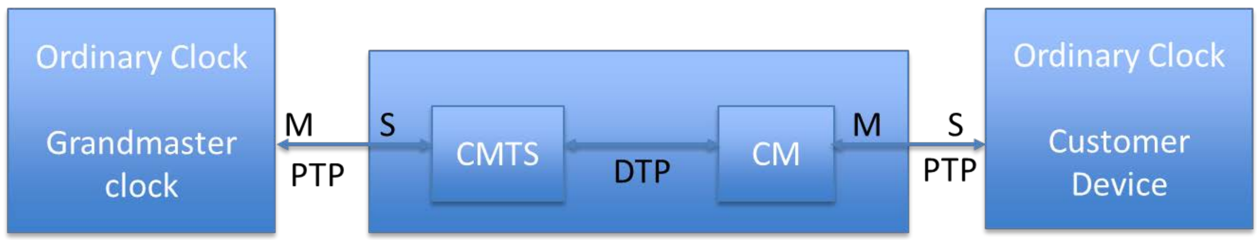

Figure 4 - DOCSIS System Works Like Boundary Clock

DTP provides the capabilities and facilities for service providers to design and implement a system. Operators will need to do the DTP tuning and system optimization to meet their desired needs.

One consideration is the modem to modem/system to system skew. This variance in modem behavior can be one of the largest sources of timing error in the error budget.

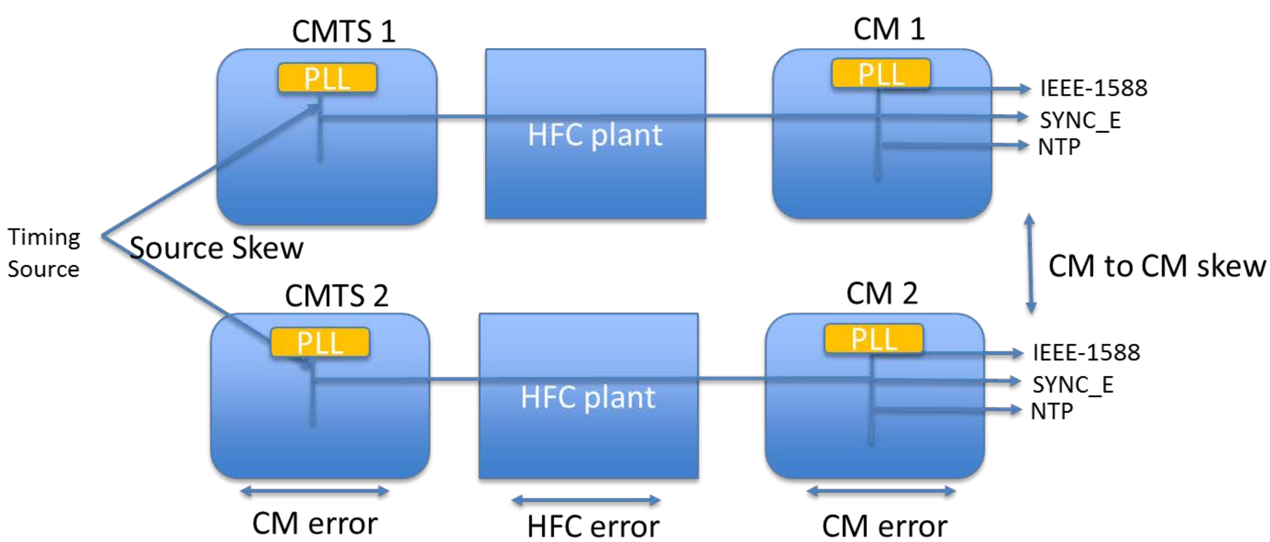

Figure 5 - DTP System Skew And Error Budgets

CableLabs has provided error budgets for the DTP systems to meet different levels of systems to support deployments such as LTE advanced. Table 4 shows system error budget for the different portions of where errors come in the DOCSIS network.

Table 4 - DTP System Timing Error Budget (table 10-9 CM-SP-MULPIv3.1-I11-170510

Parameter	Level I System (GPS location requirements)	Level II System (Relaxed positioning)	Level III System (LTE Advanced Macro Cell + addnl.	Level IV System (LTE Advanced macro cells and small cells	Level V System – Current DOCSIS implementation
T-cmts-error	+/- 20 ns	+/- 40 ns	+/- 150 ns	+/- 200 ns	+/- 500 ns
T-cm-error	+/- 20 ns	+/- 40 ns	+/- 200 ns	+/- 300 ns	+/- 500 ns
T-docsis-error	+/- 40 ns	+/- 80 ns	+/- 350 ns	+/- 500 ns	+/- 1000 ns
T-source-skew	5 ns	10 ns	100 ns	200 ns	500 ns
T-hfc-error	+/- 7.5 ns	+/- 15 ns	+/- 50 ns	+/- 150 ns	+/- 250 ns
T-cm-cm-skew	100 ns	200 ns	900 ns	1500 ns	3000 ns

1.3.1.1. HFC error portion

Looking at Table 4 on error budget it can be seen that the HFC error is one of the smaller components. This is due to the consistent nature of HFC propagation delay. DTP/PTP account for the delays and variations from CMTS to CM due to fiber propagation delay, coax delay and remote node data conversion delays.

2. Best Practices for SLA testing

Best practices for SLA compliant Ethernet Service activation include physical layer through application layer testing. Full KPI testing including RFC-2544 or Y.1564 is recommended to validate proper EVC functionality. It is recommended to do testing of the Layer 2 Control Plane to validate that the control plane traffic flows transparently from end to end and ensure that the control plane traffic flows. As a test to validate the actual end user customer experience and optimize any customer equipment, RFC-6349 tests are recommended. The RFC-6349 tests throughput at layer 4 TCP traffic which is what actual client users will be experiencing.

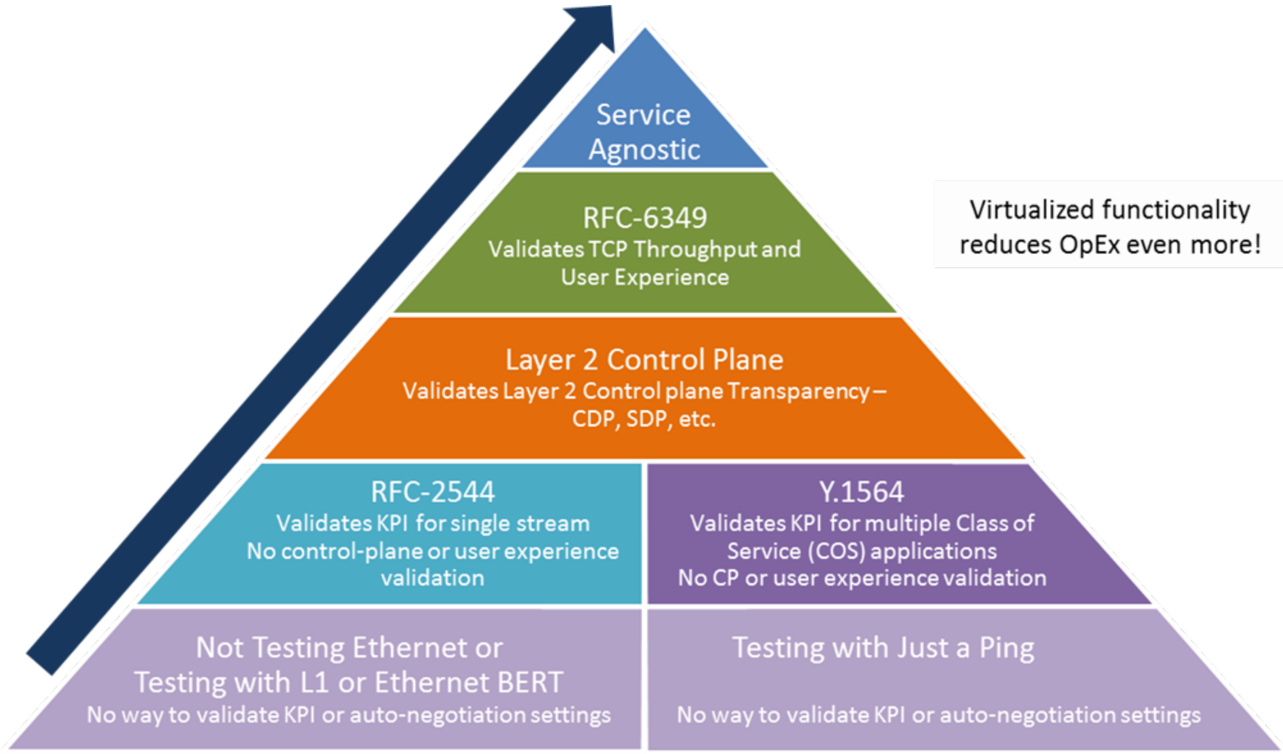

Figure 6 - Best practices for complete service activation

2.1. PTP/DTP timing

For technicians and engineers who must install Carrier Ethernet, Ethernet Backhaul, and PTP (IEEE 1588v2) circuits (like the DOCSIS DTP), testing the OWD, and 1588v2 performance referenced to CDMA and/or GPS receivers can save hours of troubleshooting by detecting asymmetric traffic ensuring proper handoffs for time-sensitive service-critical (mobile) applications. This solution can attain accuracies 10 times greater than most common SLAs, permitting service providers and operators to differentiate their offering and allowing network planners better understand delay tolerances affecting their applications.

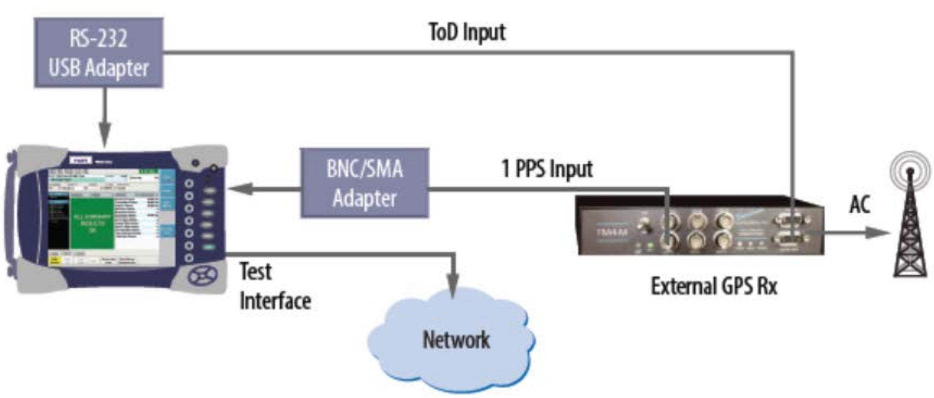

Figure 7 - OWD and 1588V2 testing connection using GPS source

2.2. OWD measurements for Mobile Backhaul SLA's and Carrier Ethernet

Measuring highly accurate one-way metrics, including OWD and packet jitter, in an Ethernet/IP backhaul scenario improves application troubleshooting and ensures thorough testing and verification of SLAs. Devices at the very edge of the network still can experience asymmetric delays. For example, in a mobile-voice application, increased delay may cause edge devices to buffer the information, thus smoothing out the speech. Unfortunately, unequal or asymmetrical delay can cause one side of the conversation to sound perfectly clear, while the other side appears to constantly talk over the speaker. Avoiding this requires verifying the OWD metric during installation and recording the measurement for future monitoring and troubleshooting as necessary. OWD measurements are important in validating the DOCSIS DTP system design supports the proper type of service and for example support an LTE advanced backhaul situation.

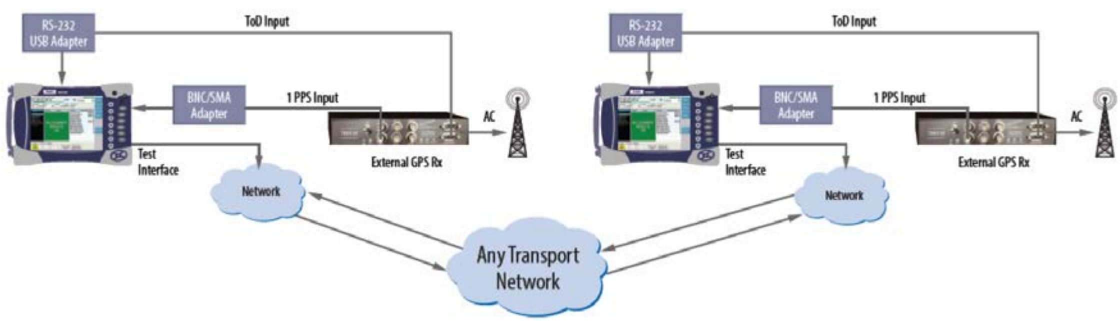

Figure 8 - PTP/DTP One Way Delay Testing with External GPS reference

2.3. Using automation with remote probe to speed up service activation

Service turn up normally involves sending a technician to the site to do the initial connection and activation. It is recommended to have the technician do an initial abbreviated connectivity and brief service test to ensure all EVC configurations and switch configurations are working properly. Lengthy testing can then be kicked off using virtual probes or physical hardware probes that can automate the RFC testing and be running multiple tests in parallel.

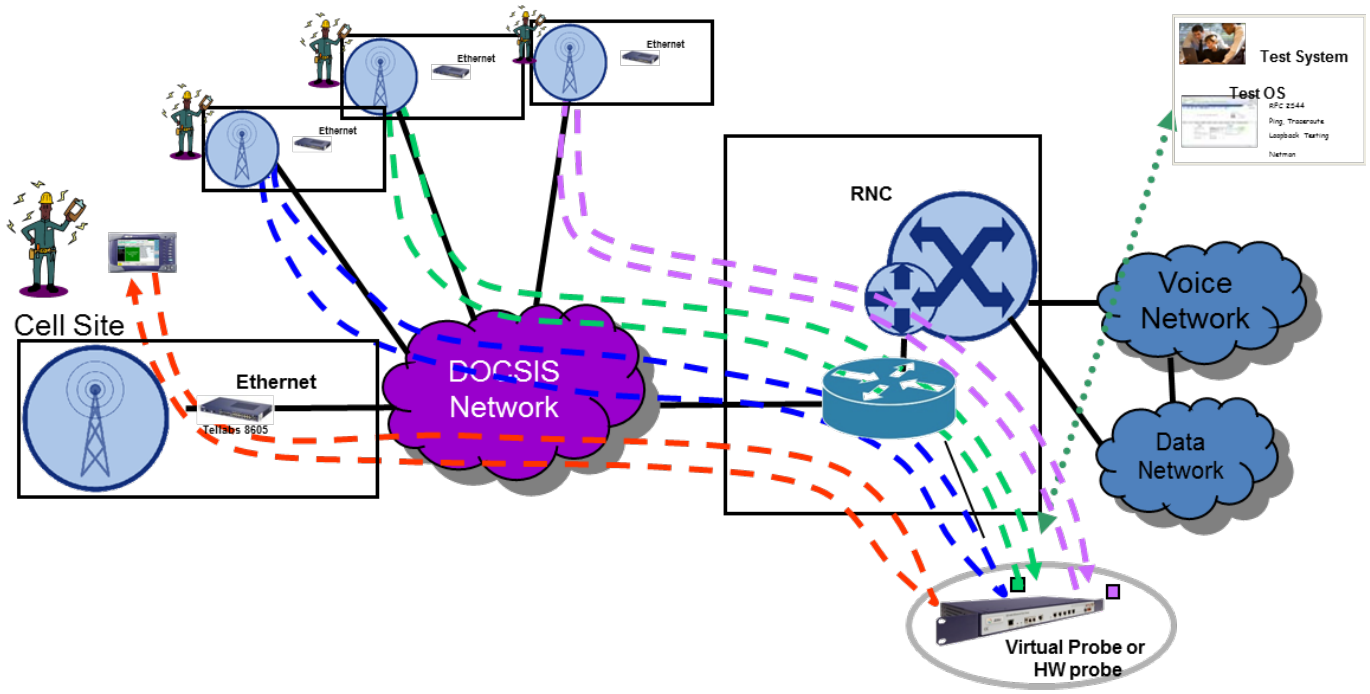

Figure 9 - Example of SLA Testing with Automation for Efficient Turn Up and Activation

Example of best practice for a typical workflow on cell site activation:

- Tech goes to a cell site
- Tech tests RF and DOCSIS network for proper operation and Throughput
- Tech install DOCSIS 3.1 Modem/Gateway
- Virtual Probe or HW probe is placed in wait for loopback mode
- Tech run's an abbreviated RFC-2544 test with a couple of frame sizes and only throughput testing to check for connectivity – 15minute timeframe
- Tech installs NID (if separate from D3.1 modem) & Cell Site Gateway
- Tech notifies the SYSTEM that there is connectivity and initiates test from Virtual Probe or HW probe.
- Full RFC-2544 test is run to NID/Customer equipment
  - NOTE 1: *This could be run from both directions: Portable to Virtual probe or Virtual Probe to Portable*
  - NOTE 2: *A quick test should be run on each configured VLAN*

Value of the workflow:

- Keeps Techs moving and working – Sites turned up faster
- Allows for full testing of EVC configuration (QOS, CIR, CBS, EIR, EBS, PIR, Frame Delay, Frame Delay Variation, and Frame Loss)

Conclusion

Legacy DOCSIS prior to DOCSIS 3.1 had limitations that prevented it from being a serious contender as a delivery mechanism for high performance SLA compliant Ethernet services. DOCSIS 3.1 provided additional signaling and timing mechanisms into the standard that equipment vendors and operators can leverage to create DOCSIS 3.1 systems capable of supporting key Ethernet services such as Advanced LTE. In particular, the DTP adoption of Ethernet PTP timing eliminates the problems associated with the delays and delay variations in legacy DOCSIS by making the entire DOCSIS system look like a border clock. When enabling SLA services, there are a set of best practices to validate the KPI's associated with the Ethernet circuit. Traditional tools, including RFC-2544 and Y.1564 are the cornerstone of EVC validation. Higher level Layer 2 control plane and RFC-6349 user experience validation should also be included. Service Activation for the EVC's can be optimized with automation using a testing solution that leverages virtual test probes and/or hardware test probes so technicians can rapidly progress from activation to activation.

Abbreviations

AP	access point
bps	bits per second
BERT	Bit Error Rate Test
BSOD	Business Service Over DOCSIS
CBS	Committed Burst Size
CIR	Committed Information Rate
CM	Cable Modem
CMTS	Cable Modem Terminating System
CPE	Customer Premise Equipment
DTP	DOCSIS Timing Protocol
EVC	Ethernet Virtual Circuit
EIR	Excess Information Rate
FD	Frame Delay
FDV	Frame Delay Variation
FEC	forward error correction
FLR	Frame Loss Rate
HFC	hybrid fiber-coax
Hz	hertz
ISBE	International Society of Broadband Experts
KPI	Key Performance Indicator
L2VPN	Layer 2 Virtual Private Network
LTE	Long Term Evolution (wireless service)
MEF	Metro Ethernet Forum
MTTR	Mean Time To Repair
NID	Network Interface Device
OAM	Operational Administration and Maintenance
OWD	One Way Delay

RFC	Request For Comment
SCTE	Society of Cable Telecommunications Engineers
SLA	Service Level Agreement
TLS	Transparent LAN service
UNI	User Network Interface
VLAN	Virtual Local Area Network

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