LTE-FDD and APTS support over Existing Cable Networks

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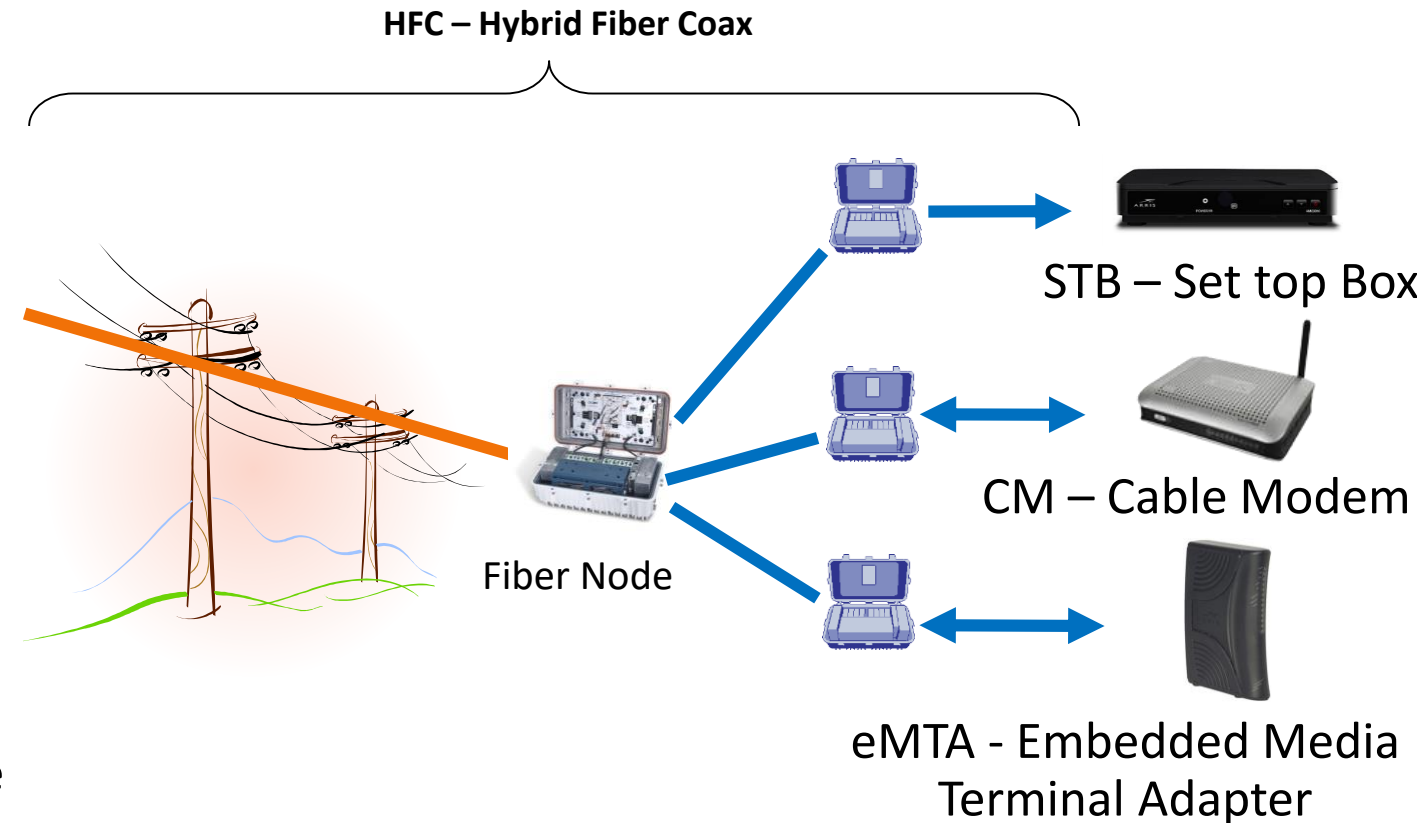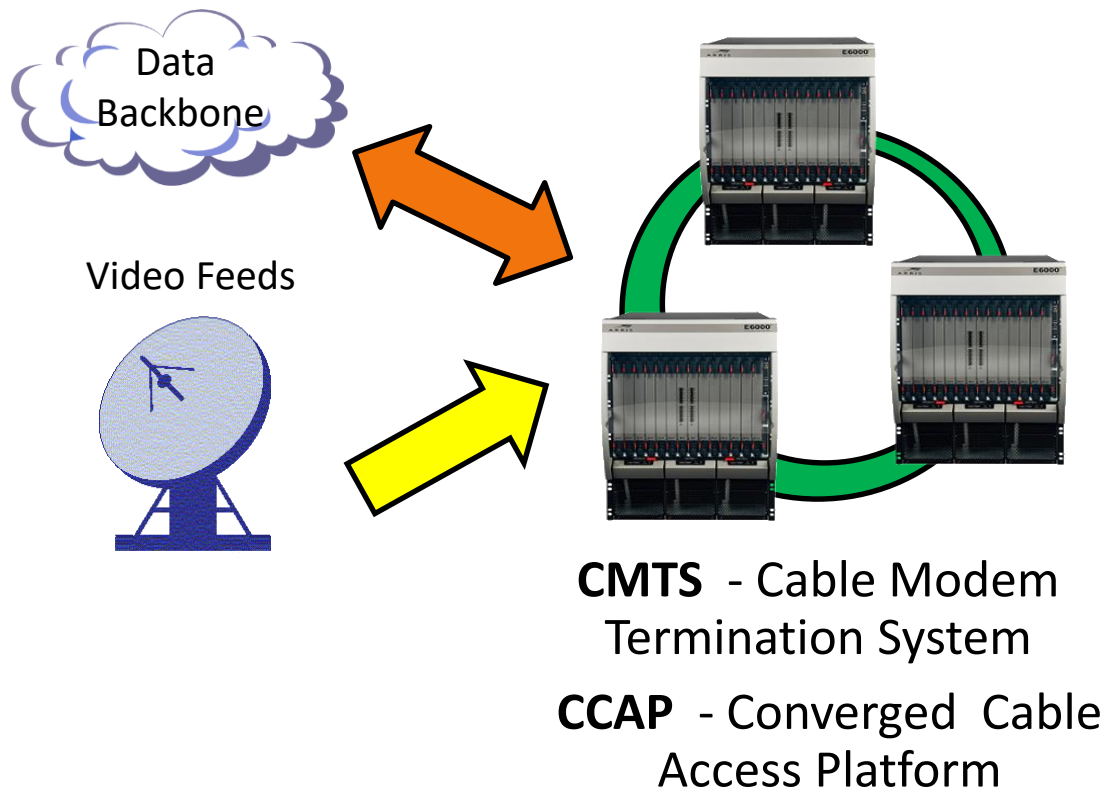Nir Laufer – Senior Director PLM , Oscilloquartz

ITSF 2018

Outline

- Mobile Backhaul Support through Cable Networks

- LTE-FDD /APTS frequency requirements

- Lab results for Frequency delivery

- Summary

Cable Network Topology

➢ The HFC network provides the communications link between the CMTS/CCAP and the stations, STBs, CMs and eMTAs.

➢ HFC plant consists of up to ~160 km of optical fiber, few hundred meters of coaxial cable, RF distributions and Amplifiers.

HFC – Hybrid Fiber Coax

Data Backbone

Video Feeds

CMTS - Cable Modem Termination System
CCAP - Converged Cable Access Platform

Fiber Node

STB – Set top Box

CM – Cable Modem

eMTA - Embedded Media Terminal Adapter

Cellular Backhaul and DOCSIS

➤ Cellular Backhaul support through DOCSIS network is an opportunity for supporting femtocell, picocell, microcell and macrocells

➤ DOCSIS presents many challenges in order to support precise Timing delivery:

  ➤ Asymmetry due the nature of DOCSIS upstream scheduling and HFC plant

  ➤ Jitter (PDV) due to the Upstream Scheduling

  ➤ Unknown delays and asymmetries in the CMTS and CM PHYs

➤ DOCSIS typical round trip latency of 5-10 ms poses challenge on eNodeB communication (might be reduced with special service flow implementations)

➤ New CableLabs WG has been established (Aug 2017) to work on the needed requirements for DOCSIS to support precise timing delivery for MBH.

Potential Use Cases

- 3G/4G LTE FDD - Frequency delivery

- 4G TDD/LTE-A - APTS (Assisted Partial Timing Support) backup to local GNSS – use of frequency/calibrated phase recovered from PTP in case of local GNSS outage
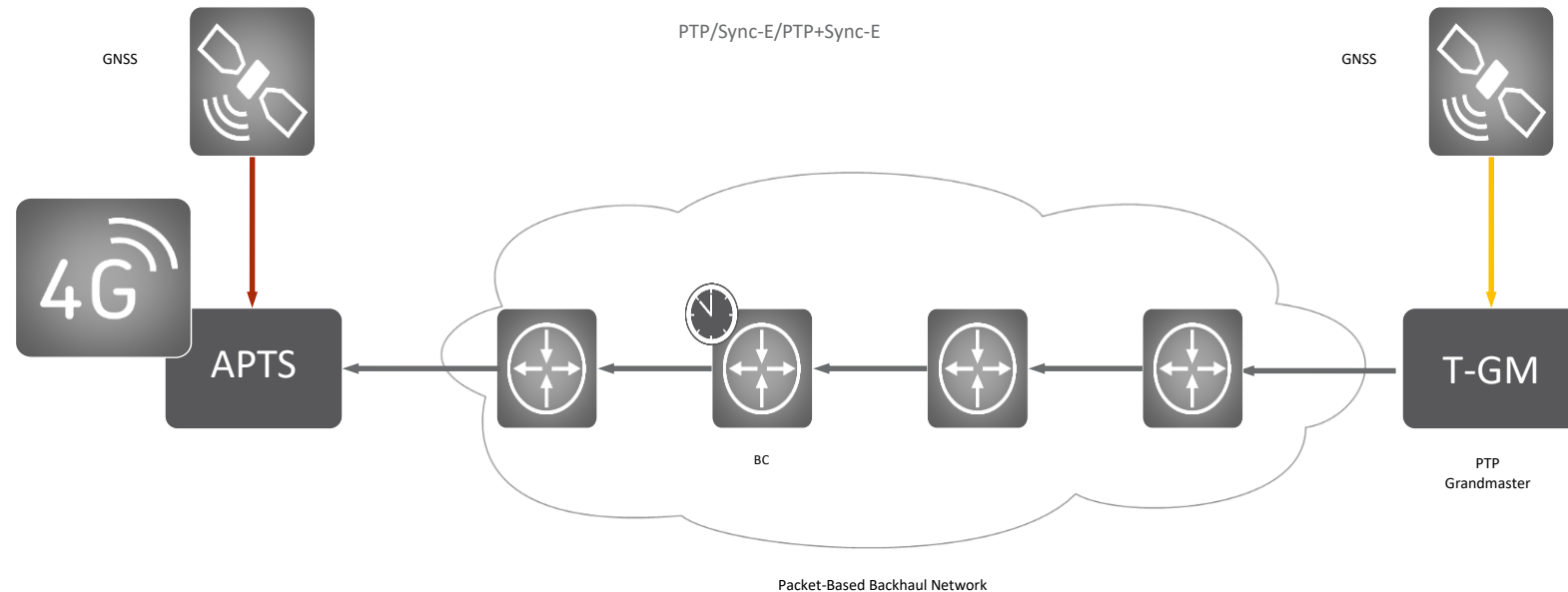
Cellular Backhaul and DOCSIS – Frequency

➢ While phase delivery over DOCSIS is a big challenge due to high asymmetry , the ability of supporting Frequency delivery should be considered.

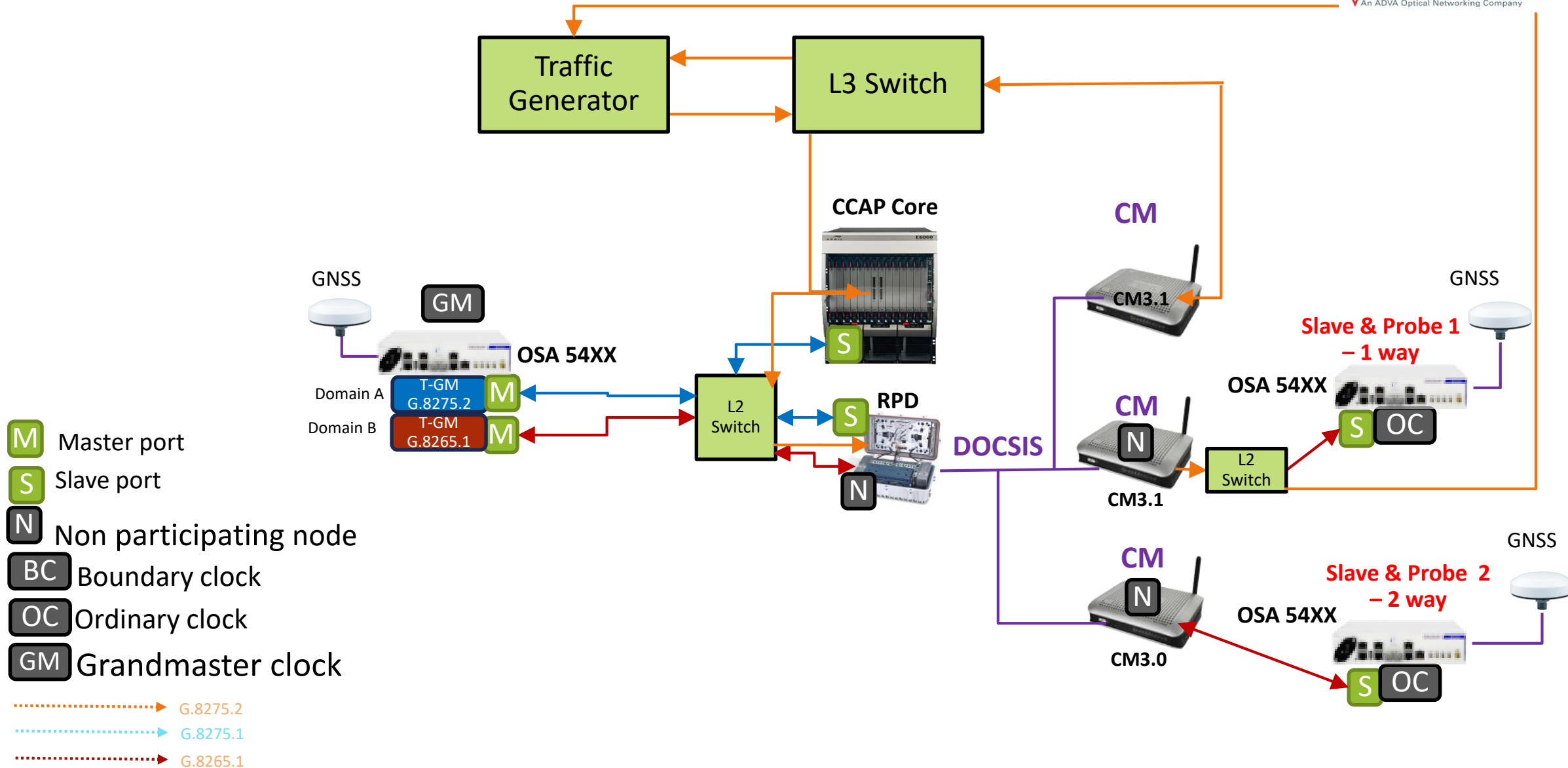Performance subject to PDV

Performance subject to PDV and Asymmetry

Application	Radio Interface		Backhaul	
	Frequency	Phase	Frequency	Phase
CDMA 2000	±50ppb	±3 to 10µs	GPS	GPS
GSM/WCDMA	±50ppb	n/a	±16ppb	n/a
LTE (FDD)	±50ppb	n/a	±16ppb	n/a
LTE (TDD) (large cell)	±50ppb	±5µs	±16ppb	±1.1µs
LTE (TDD) (small cell)	±50ppb	±1.5µs	±16ppb	±1.1µs
LTE-A MBSFN	±50ppb	±1 to 5µs	±16ppb	±1.1µs
LTE-A CoMP*	±50ppb	±500nsec to 5µs	±16ppb	500ns - ±1.1µs
LTE-A eICIC*	±50ppb	±1 to 5µs	±16ppb	±1.1µs

Lab setup- PTP (G.8265.1) - ICCAP

Lab setup- PTP (G.8265.1) - RemotePhy

Legend:
- **M** Master port
- **S** Slave port
- **N** Non participating node
- **BC** Boundary clock
- **OC** Ordinary clock
- **GM** Grandmaster clock

- ······► G.8275.2
- ······► G.8275.1
- ······► G.8265.1

Diagram labels:
- Traffic Generator
- L3 Switch
- ARRIS
- OSCILLOQUARTZ — An ADVA Optical Networking Company
- CCAP Core
- CM — CM3.1
- GNSS
- GM
- OSA 54XX
- Domain A — T-GM G.8275.2 — M
- Domain B — T-GM G.8265.1 — M
- L2 Switch
- RPD — S / N
- DOCSIS
- Slave & Probe 1 – 1 way
- OSA 54XX — S OC
- GNSS
- CM — N — CM3.1
- L2 Switch
- CM — N — CM3.0
- OSA 54XX
- Slave & Probe 2 – 2 way
- GNSS
- S OC

Setup/test description

- PTP setup:
  - G.8265.1/G.8275.2 GM (GPS synced) was connected directly to the CMTS.
  - 64 sync/delay msg/sec.
  - 2 slaves were connected to two different CMs.
  - One slave was configured as a 1-way slave (frequency lock oriented using only sync messages from GM). No 1588 timing messages are sent on the US (except negotiation).
  - One slave was configured as a 2-way slave (Both DS and US are used for 1588 timing messages) – recover both frequency and phase .
  - 1588 packets were configured with DSCP value of 46
  - Tested in none assisted mode – GNSS was only used for measurement not for asymmetry calibration

- DOCSIS Setup:
  - 8x4 channel bonding was used for 3.0 CM (~250 Mbps DS & 125 Mbps US)
  - OFDM DS for 3.1 CM.
  - Traffic generator was used to load DS and US channels via a separate CM connected to the same US/DS channels (UDP traffic with various packet lengths).
  - Different load scenarios on US and DS (0% → over subscription scenarios).
 - A high priority DOCSIS service flow was configured for UDP ports 319 (1588 event packets).

Setup/test description

- Both slaves were connected to a GPS and were comparing PTP slave lock to GPS for frequency and phase.

- Results were compared to ITU-T G.8261.1 network limits for frequency delivery (+/-16 ppb)
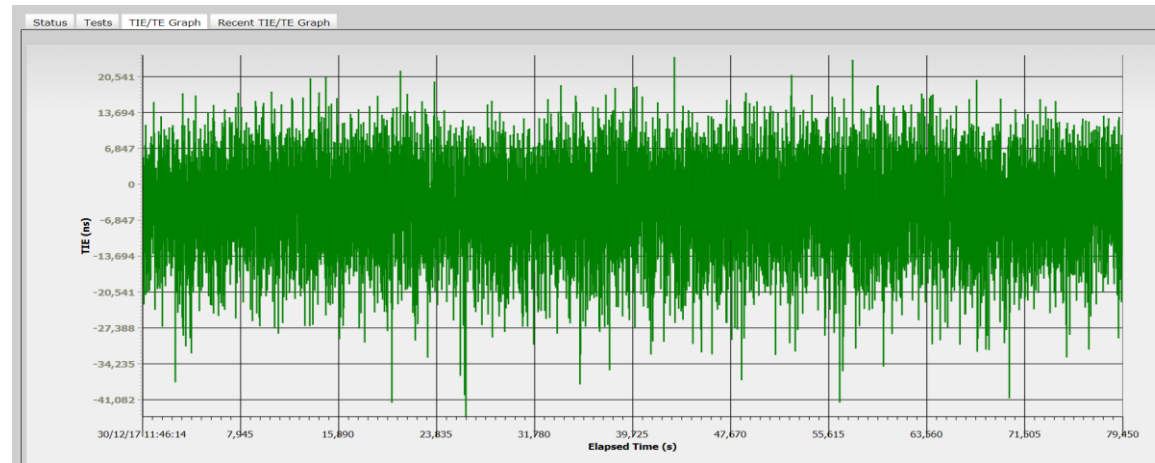
- Tests were run for 24H at least.

G.8261.1-Y.1361.1(12)_F04
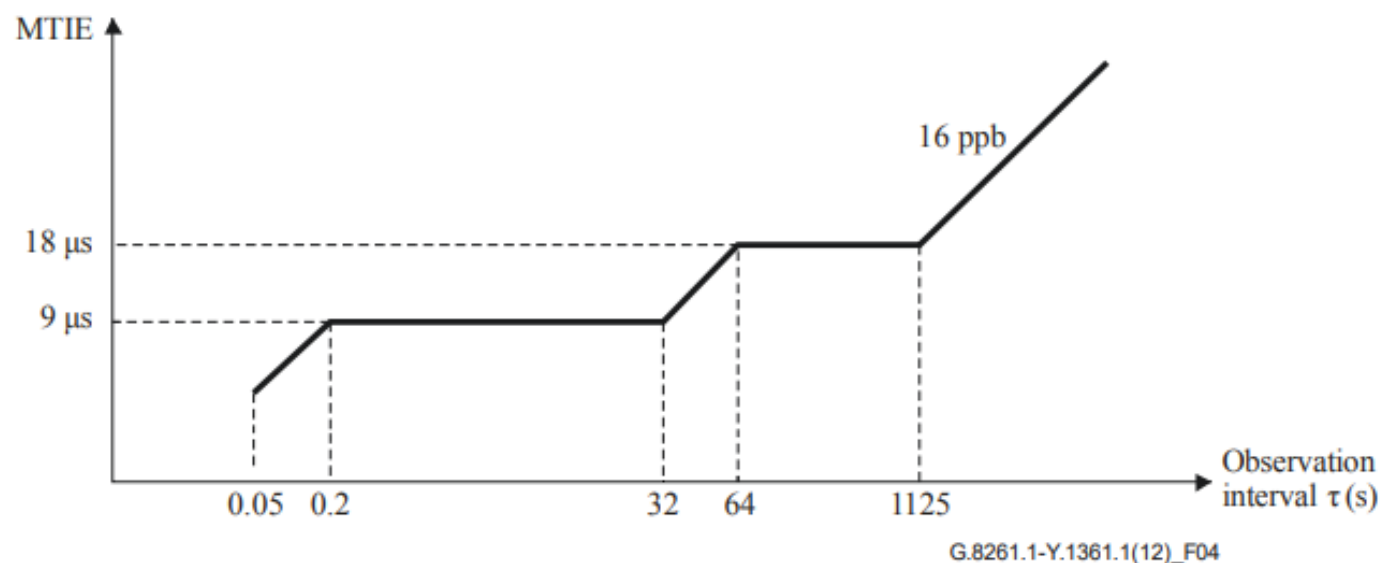
Test results: 1-way Clock (8x4 SC-QAM)
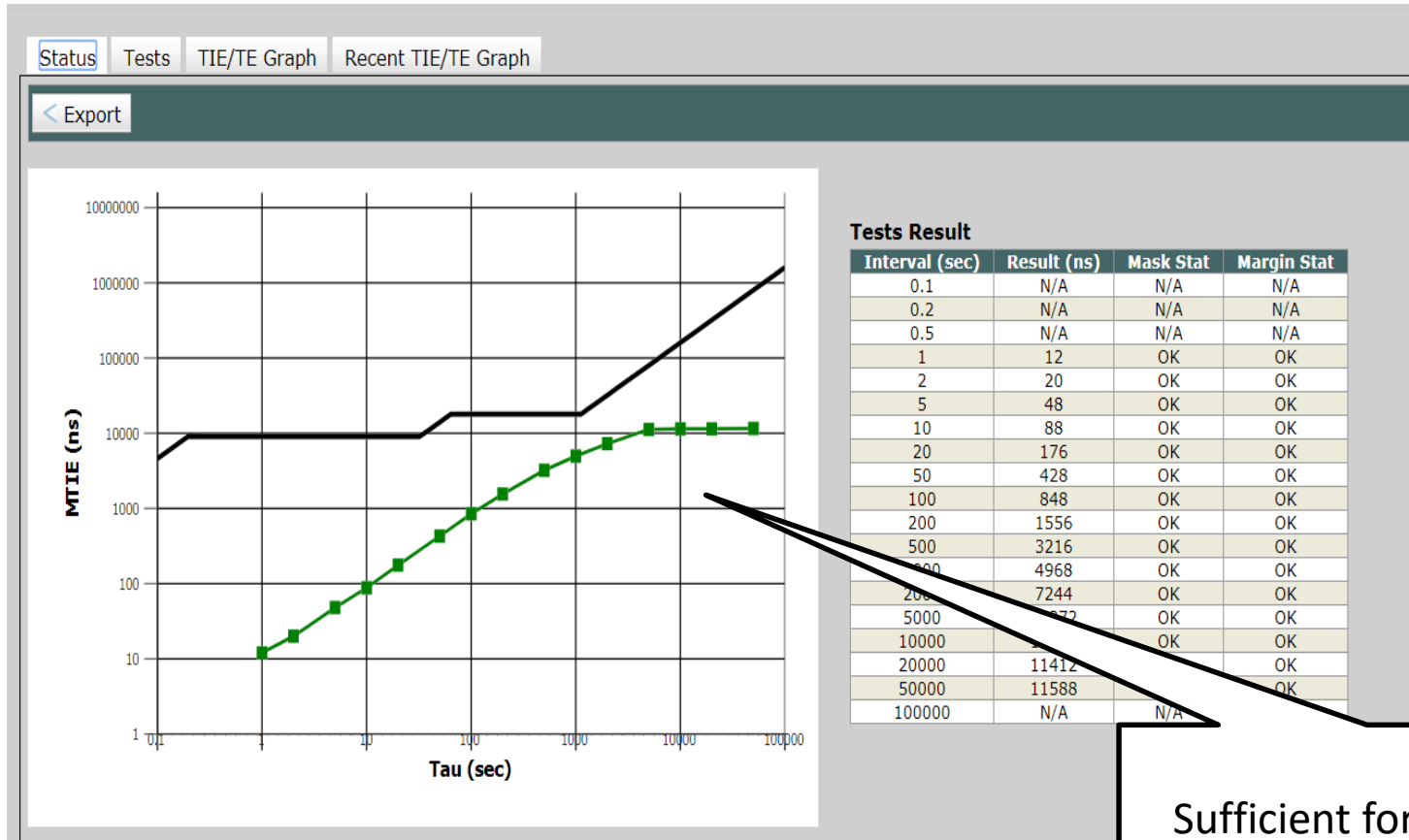
Output Clock TIE and derived FFO
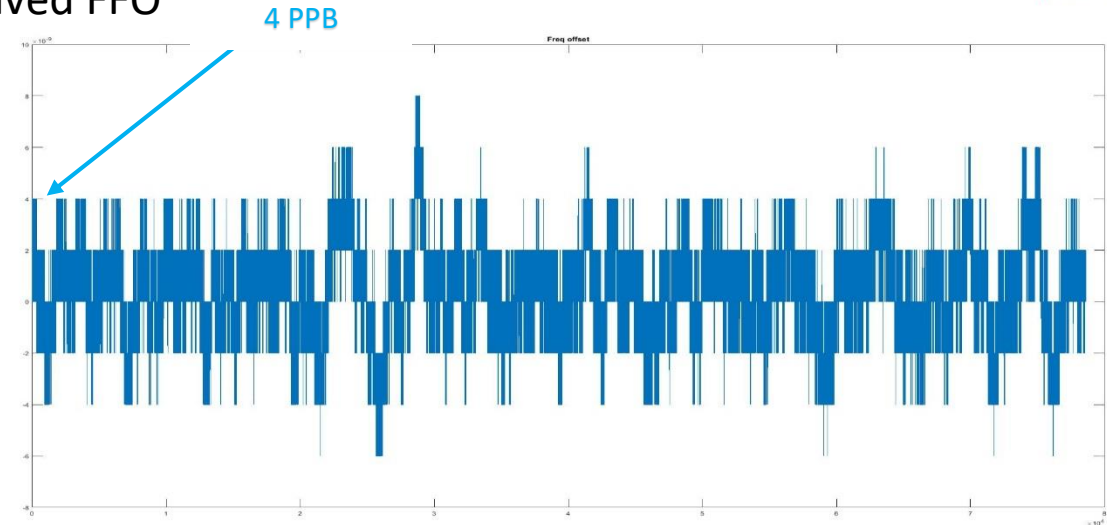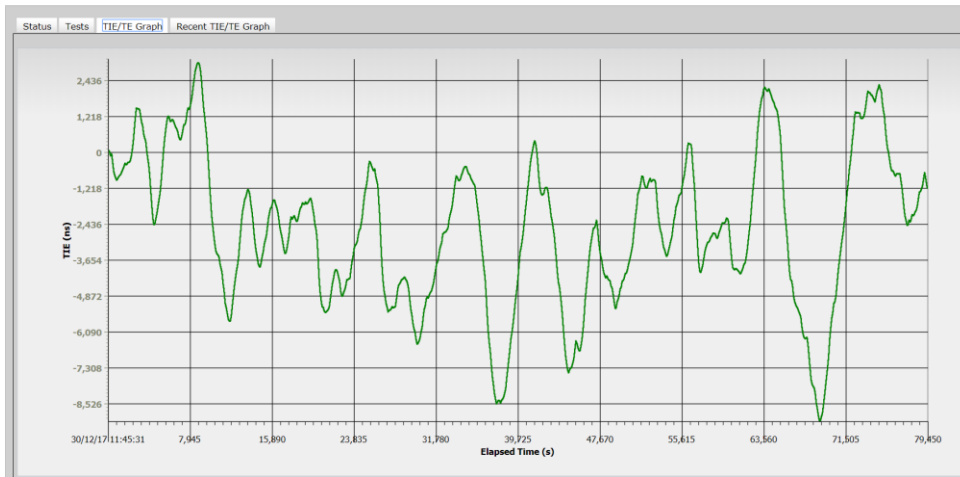
PTP PDV (20-50 usec peak to peak)

Note: " lucky packets" in each 4 sec window are displayed
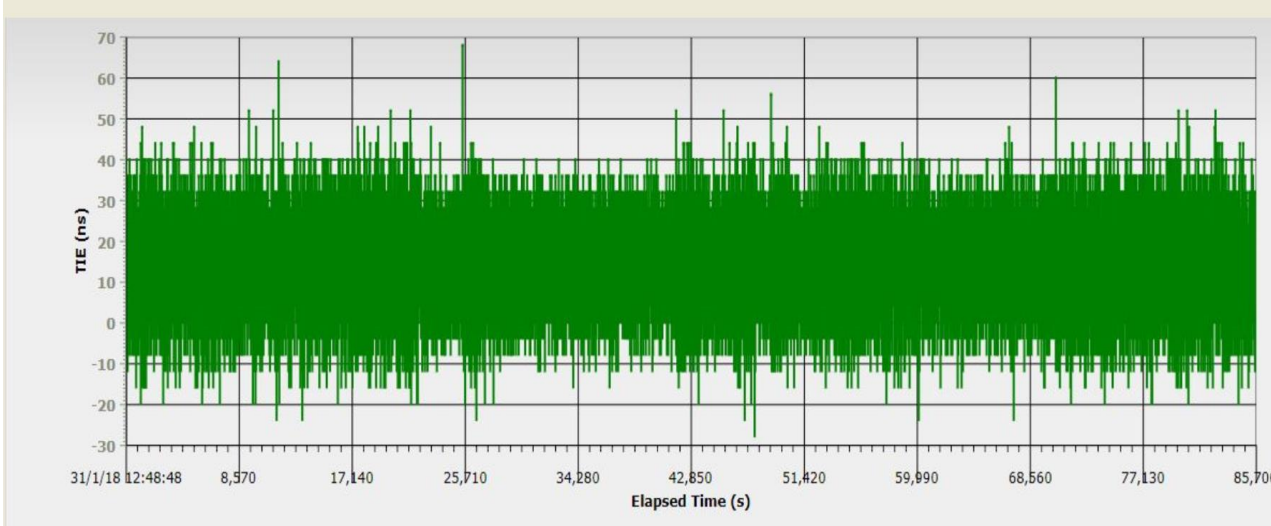
Test results: 1-way Clock (8x4 SC-QAM)

- G.8261.1 MTIE mask

Tests Result

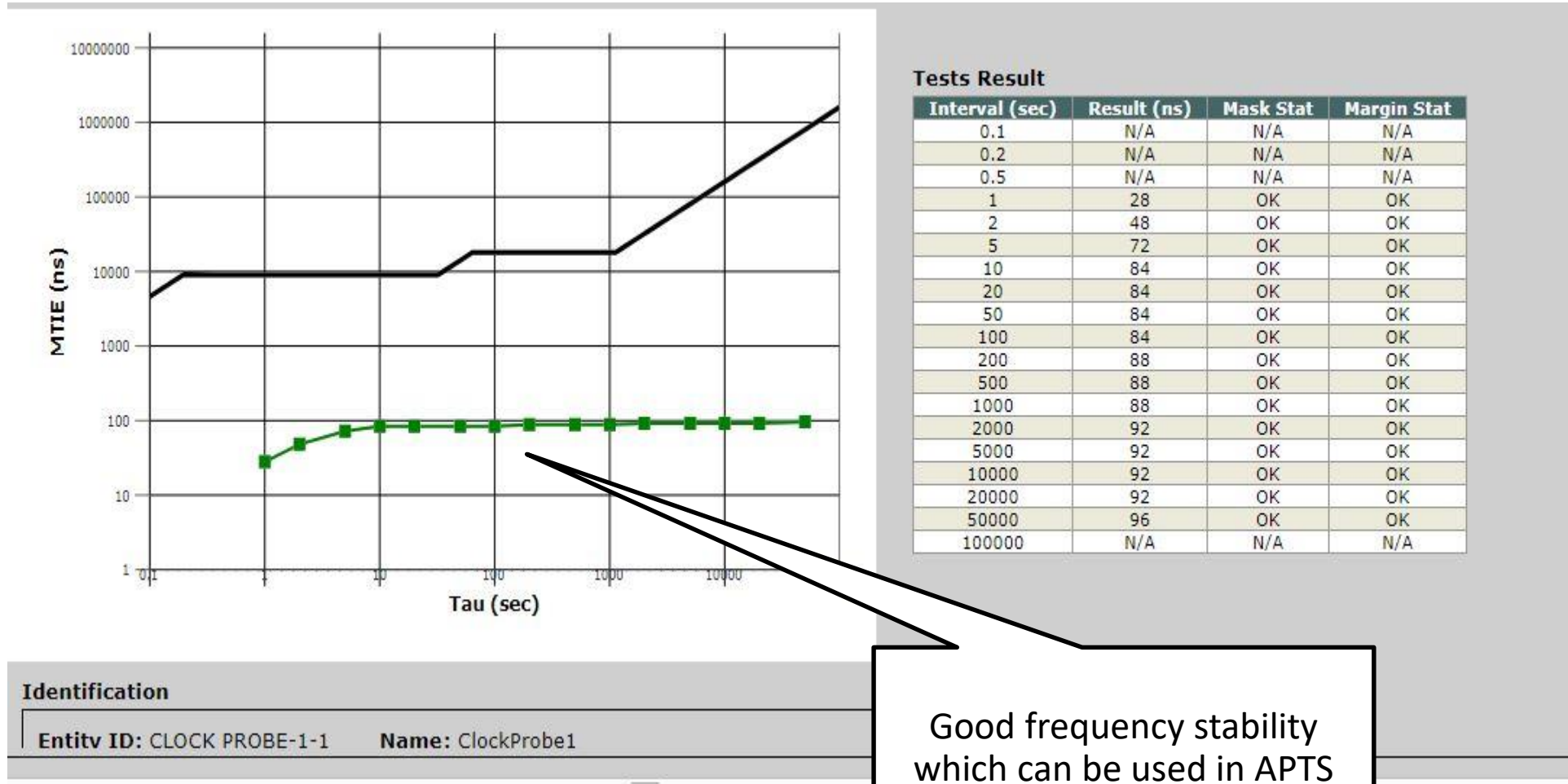| Interval (sec)	Result (ns)	Mask Stat	Margin Stat
0.1	N/A	N/A	N/A
0.2	N/A	N/A	N/A
0.5	N/A	N/A	N/A
1	12	OK	OK
2	20	OK	OK
5	48	OK	OK
10	88	OK	OK
20	176	OK	OK
50	428	OK	OK
100	848	OK	OK
200	1556	OK	OK
500	3216	OK	OK
	4968	OK	OK
200	7244	OK	OK
5000		OK	OK
10000		OK	OK
20000	11412		OK
50000	11588		OK
100000	N/A	N/A	

Sufficient for FDD BS , but not for APTS

Test results: 1-way Clock (OFDM)

Output Clock TIE

PTP PDV (5-10 usec peak to peak)
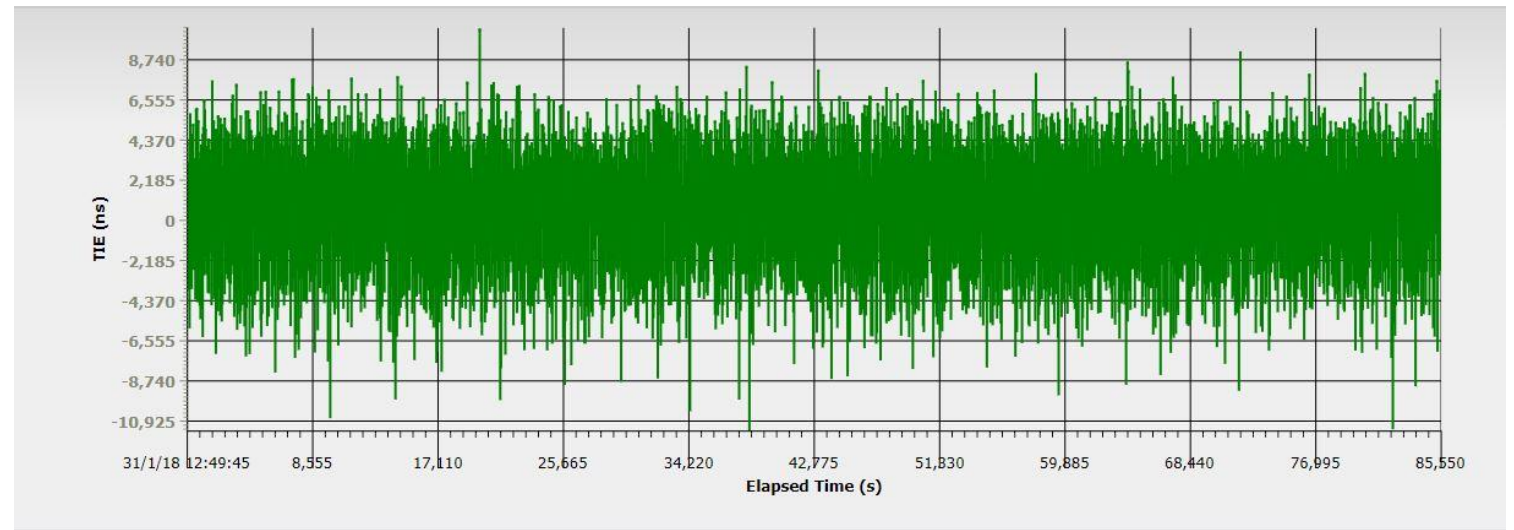
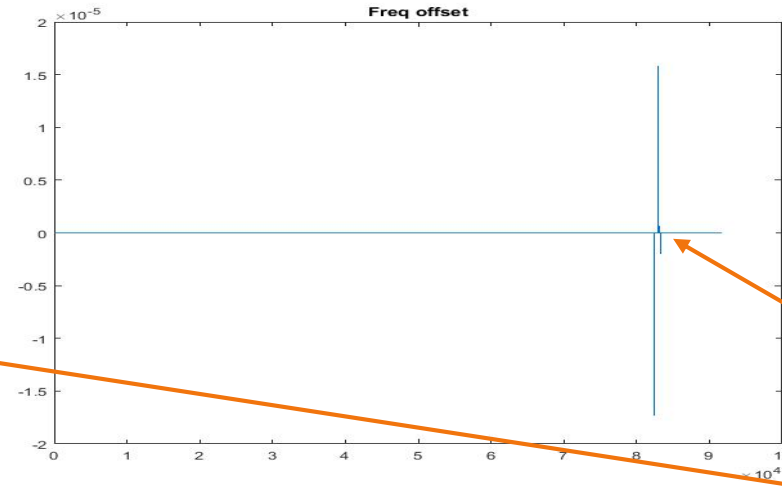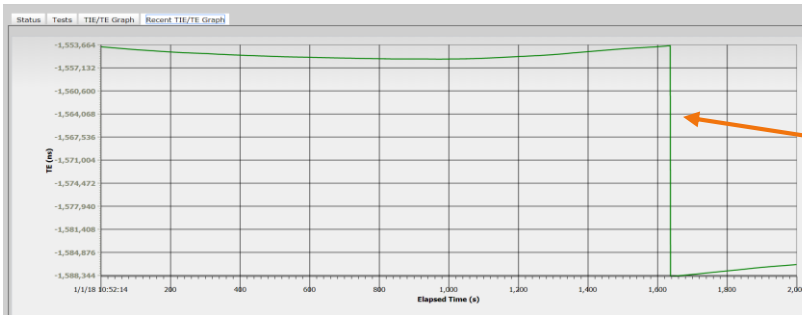

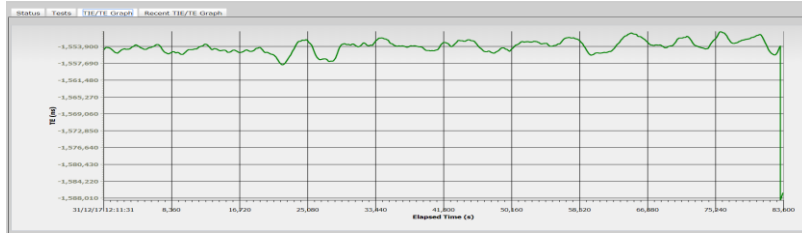Note: " lucky packets" in each 4 sec window are displayed
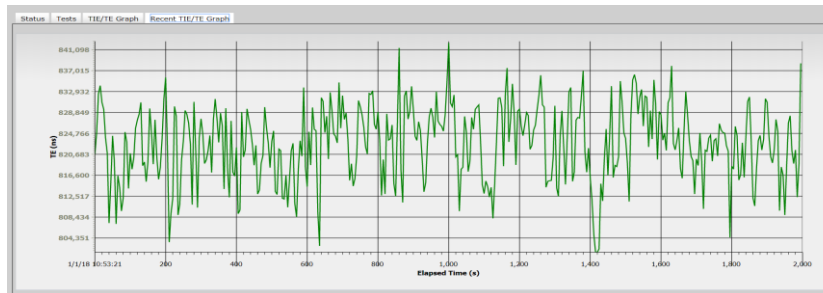
Test results: 1-way Clock (OFDM)

- G.8261.1 MTIE mask

Tests Result

Interval (sec)	Result (ns)	Mask Stat	Margin Stat
0.1	N/A	N/A	N/A
0.2	N/A	N/A	N/A
0.5	N/A	N/A	N/A
1	28	OK	OK
2	48	OK	OK
5	72	OK	OK
10	84	OK	OK
20	84	OK	OK
50	84	OK	OK
100	84	OK	OK
200	88	OK	OK
500	88	OK	OK
1000	88	OK	OK
2000	92	OK	OK
5000	92	OK	OK
10000	92	OK	OK
20000	92	OK	OK
50000	96	OK	OK
100000	N/A	N/A	N/A

Identification

Entity ID: CLOCK PROBE-1-1   **Name:** ClockProbe1

Good frequency stability which can be used in APTS

Test results: 2-way Clock

Output Clock TE and derived FFO
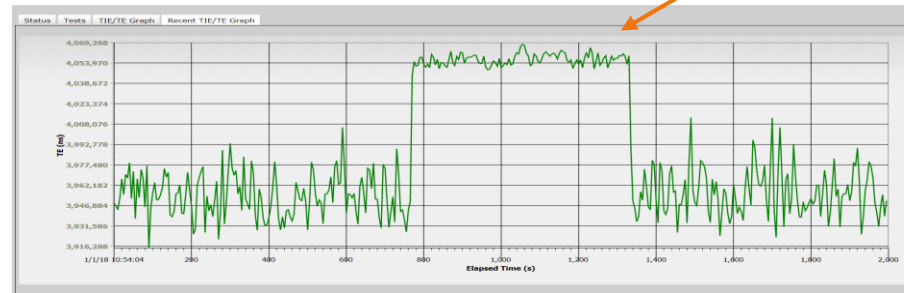

PTP packet delays DS

PTP packet delays US

US BR Change
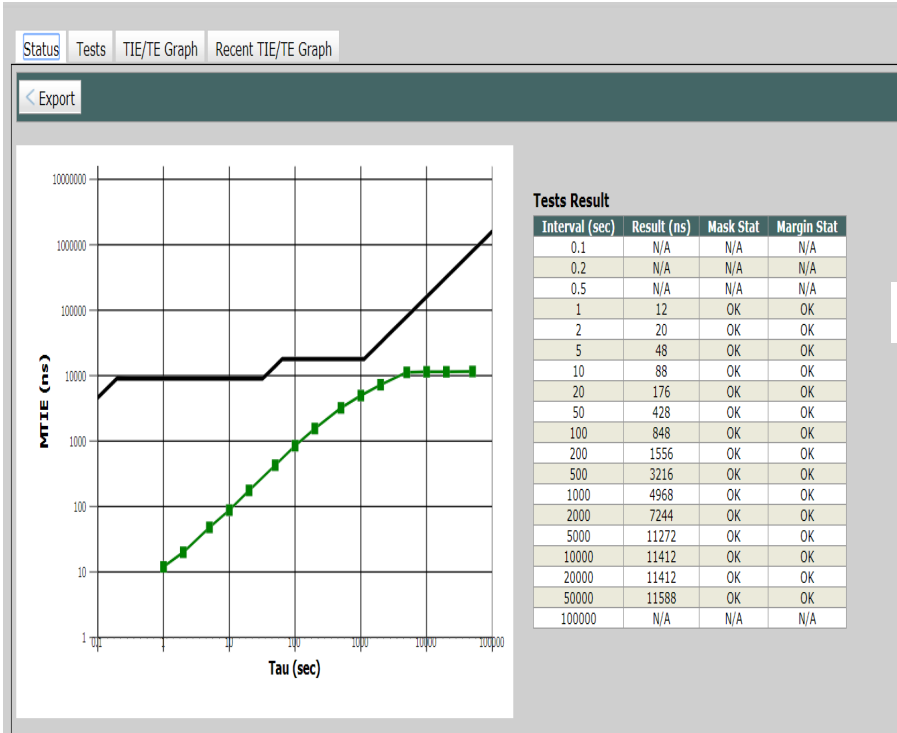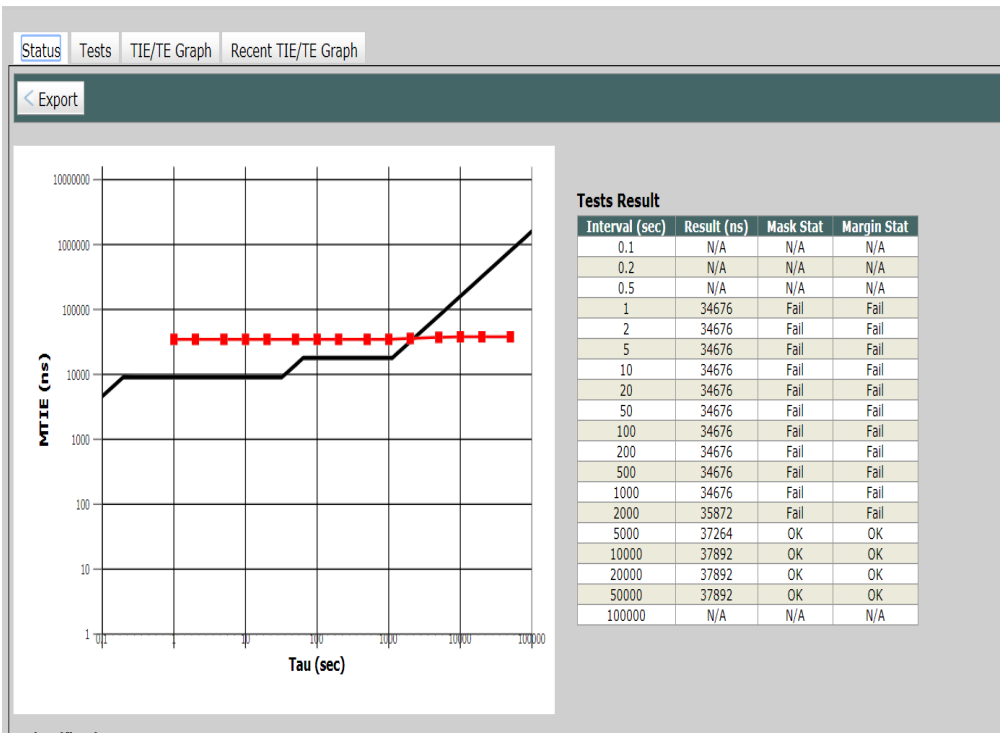
Note: " lucky packets" in each 4 sec window are displayed

Test results: 2-way Clock
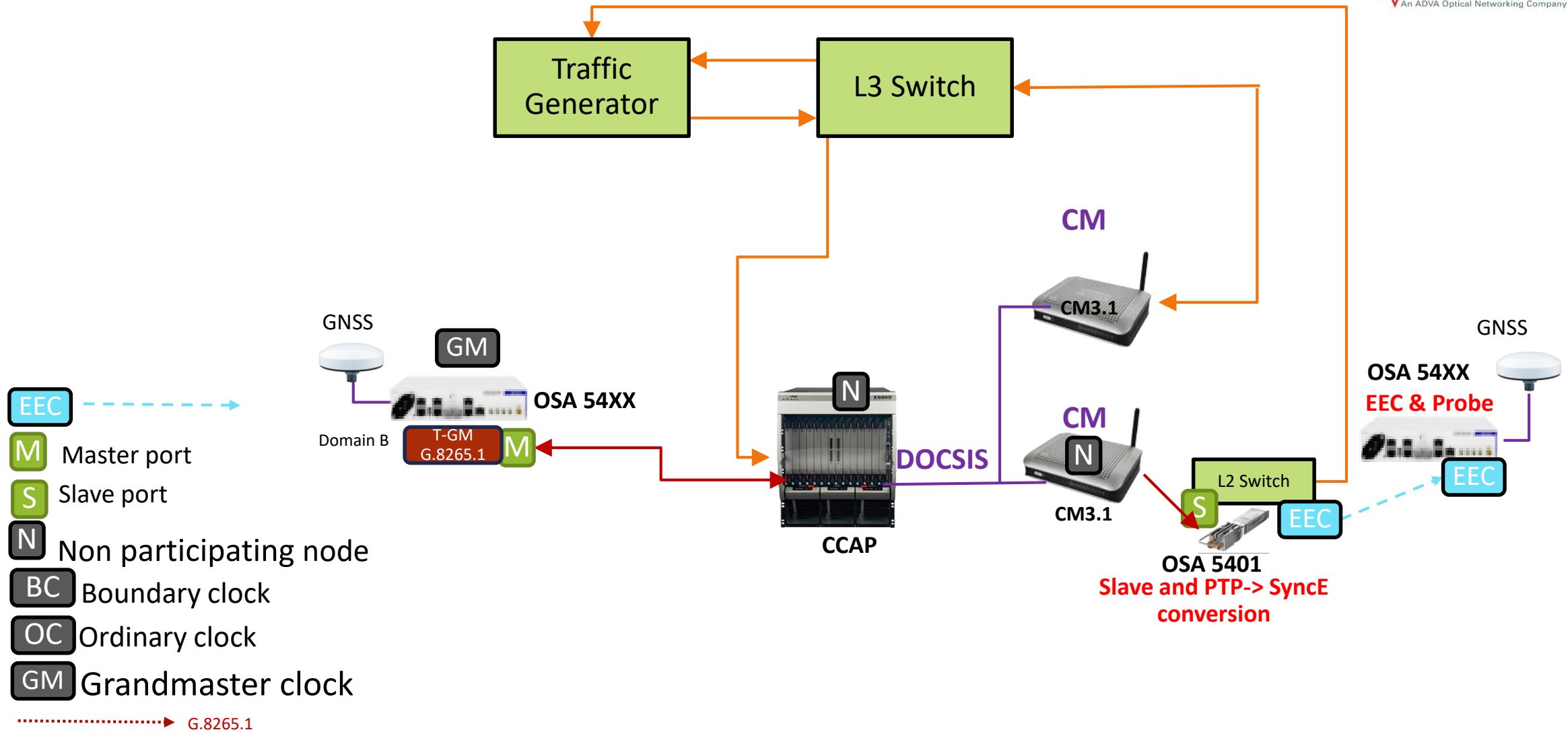
- G.8261.1 MTIE mask

US BR Change

Test results

- Both slaves manage to lock properly on frequency within 30-45 minutes.

- 2-way slave locks on frequency faster than the 1-way slave (probably due to the use of both sync and delay timestamps).

- Both slaves pass the MTIE (Max time Interval Error) mask defined in ITU-T G.8261.1

- The 2-way slave manages to lock on phase after a long time... as expected the phase error is > 1.5 ms. Mostly due to US/DS Asymmetry with > 100 microsec of PDV.

- The 2-way slave is sensitive to phase changes caused by dynamic changes in DOCSIS asymmetry. Changes in US load causes changes in US delays (and overall asymmetry) and thus will cause the slave to adjust phase and frequency and as a result fail the G.8261.1 MTIE mask.

- 1-way slave is not affected by changes to US/DS loads (when high priority service flows are configured for 1588 packets).

- 1-way slave can be supported over DOCSIS 3.0 (bonded SC-QAM) and DOCSIS 3.1 (OFDM). DOCSIS 3.1 OFDM provides better results

Lab setup- PTP (G.8265.1 → SyncE)

Traffic Generator

L3 Switch

CM
CM3.1

GNSS

GM

OSA 54XX

Domain B

T-GM
G.8265.1 M

EEC

M Master port

S Slave port

N Non participating node

BC Boundary clock

OC Ordinary clock

GM Grandmaster clock

G.8265.1

N

CCAP

DOCSIS

CM
N

CM3.1

L2 Switch

S

OSA 5401
Slave and PTP-> SyncE conversion

EEC

GNSS

OSA 54XX
EEC & Probe

EEC

Summary

- With required optimization , delivery of frequency over DOCSIS 3.0 (bonded SC-QAM) and DOCSIS 3.1 (OFDM) using PTP was able to meet G.8261 network limits.

- DOCSIS modulation , PTP mode of operation and slave clock recovery algorithm quality are key factors.

- The use DOCSIS 3.1 OFDM significantly improves the results and provide safe margins and can be used for both use cases (frequency only and APTS)

- Future work is planed towards testing and quality of phase which can be delivered over DOCSIS 3.1 in GNSS assisted and none assisted modes

Thank You!