5G Sync support over Cable Networks

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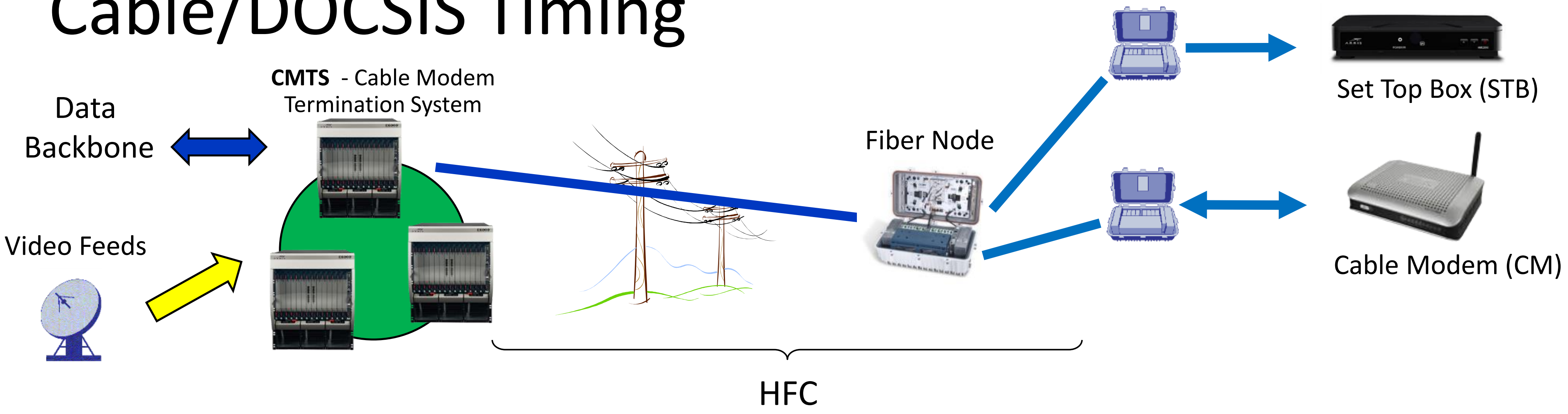
Agenda

- **Cable Timing introduction**
- Cable and Mobile - why even bother?
- Sync solutions over Cable
- Preliminary results

Cable/DOCSIS Timing



- DOCSIS transport is Synchronous in nature and uses a common clock derived by the CMTS
- The CMTS delivers Timestamps on the downstream (for DOCSIS 3.1):
  - A 64 bit timestamp derived from a 204.8 MHz clock carried by the OFDM signal
  - MAP messages: assigns upstream transmit opportunities for each CM. The request and grant cycle between the CM and CMTS use MAP messages
- The CM derives its frequency from the OFDM symbol clock and the “time reference” from the repeated timestamps
- +/-5 ppm on Clock accuracy (usually free running).
- Clock drift rate <= 10-8 per second
- **The DOCSIS path delay is inherently asymmetrical (at the ms level…) and can contain a moderate to high amount of jitter (10s of µs…)**

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Why do Mobile over DOCSIS?

- HFC infrastructure provides many advantages for wireless backhaul when compared to pure fiber backhaul or microwave/wireless backhaul approaches. These include:

  - **Ubiquity** – HFC networks run down every street and to every building in the city. This gives significant flexibility to wireless teams to design optimal small cell deployments.
  - **Power** – One of the most notable advantages of HFC over fiber and wireless backhaul is its ability to transport power to small cells.
  - **Deployment Speed & Simplicity** – HFC aerial architecture provides an ideal medium for fast small cell backhaul deployments.

Why do Mobile over DOCSIS – case study

- A North American operator wanted to further quantify the real-world benefits of using coax versus extending their fiber to feed their small cell deployments.
  - A highly dense location that was a likely candidate for upcoming small cell deployments was chosen.
  - The operator's wireless team provided ideal small cell deployment locations. These locations were designed for their RF characteristics only and did not take into consideration proximity to HFC plant, power or fiber

Why do Mobile over DOCSIS – case study

- The fiber wireline design team designed a build to connect each of the ideal small cell locations to the nearest fiber location (typically the nearest fiber node).
- as comparison the design team completed a design that connected the small cells to existing coaxial infrastructure (connection to coax through a simple cut-in coupler).
- They found that all the ideal small cell locations were within **10 meters of coax**….

Small Cell Count	Backhaul Option	Backbone Fibers	Estimated Civil Build Cost	Estimated Build Time
15	DWDM	1	$183k	4-6 months
	Coax w/ couplers	0	$1.5k	1 week

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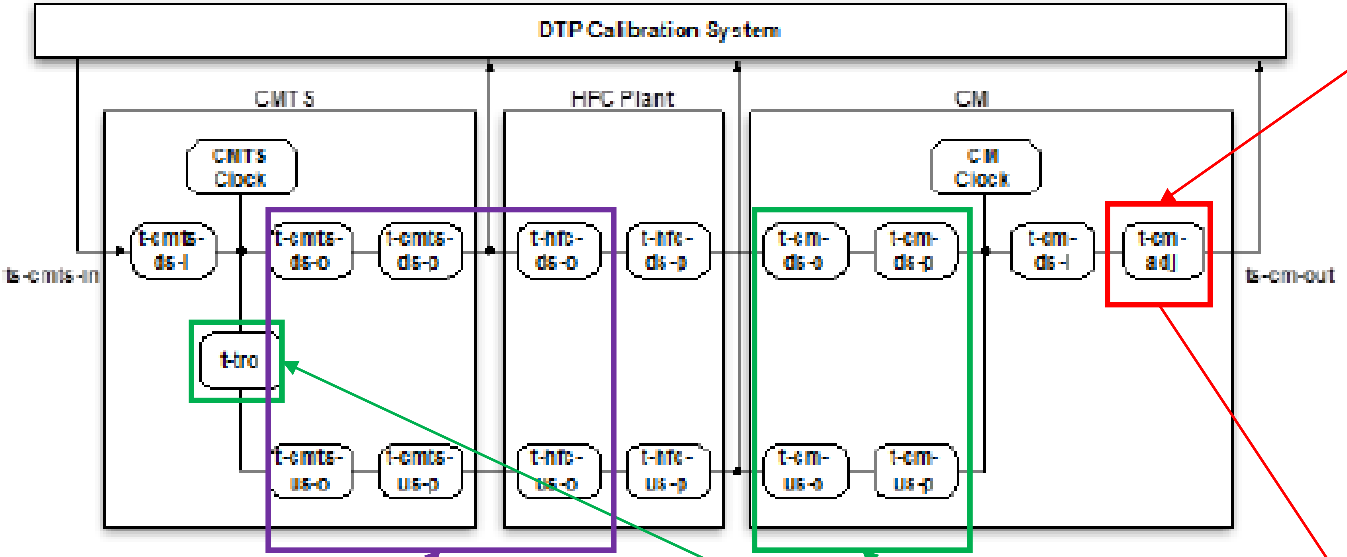
DTP – DOCSIS Timing Protocol

- Introduced in DOCSIS 3.1
- Defines a mechanism to measure and model the asymmetries in the HFC network and to provide an adjustment factor to the DOCSIS timestamp



Parameters sent by the CMTS

Parameters sent by the CM

Calculated by the DTP Master

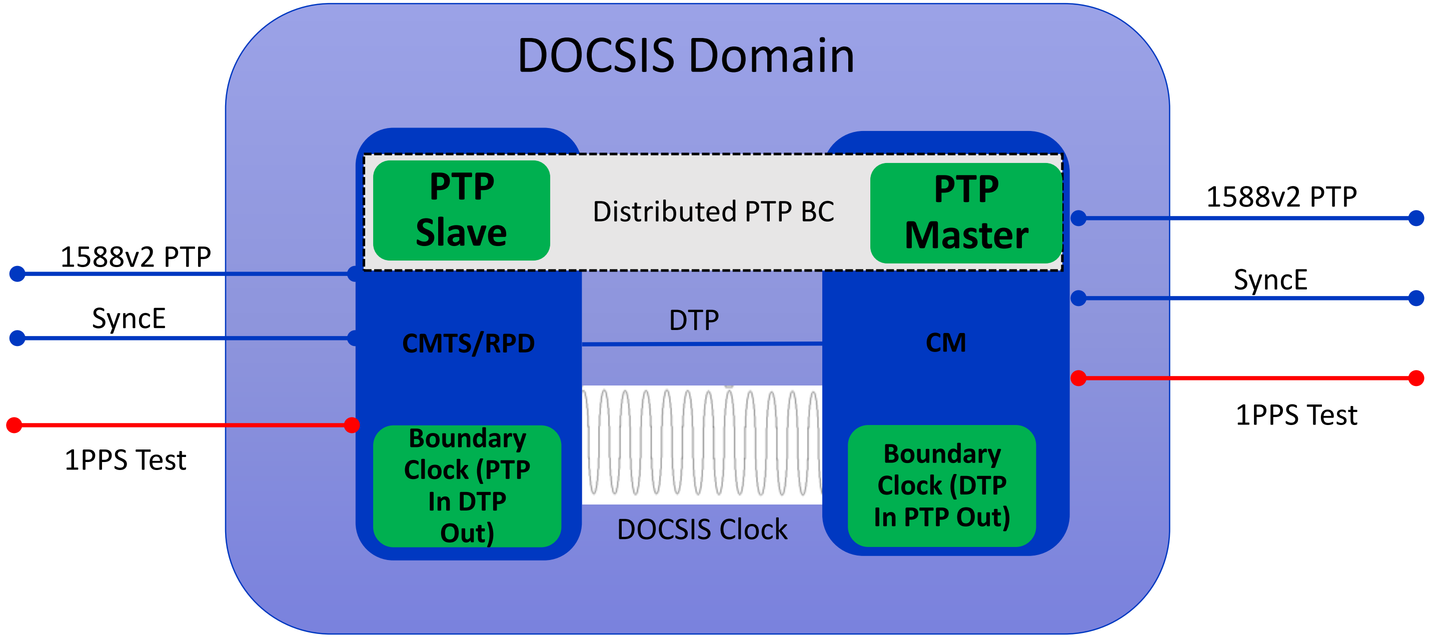
t-cm-adj = *t-cmts-ds-i* + *t-cmts-ds-o* + *t-cmts-ds-p* + *t-hfc-ds-o* + *t-hfc-ds-p* + *t-cm-d-o* + *t-cm-ds-p* + *t-cm-ds-i*

t-hfc-ds-p = (*t-tro* – *t-cmts-ds-o* – *t-cmts-ds-p* – *t-hfc-ds-o* – *t-cm-d-o* – *t-cm-ds-p* – *t-cm-us-o* – *t-cm-us-p* – *t-hfc-us-o* – *t-cmts-us-o* – *t-cmts-us-p*) / 2

t-cm-adj = *t-cmts-ds-i* + *t-cmts-ds-o* + *t-cmts-ds-p* + *t-hfc-ds-o* + (*t-tro* – *t-cmts-ds-o* – *t-cmts-ds-p* – *t-hfc-ds-o* – *t-cm-d-o* – *t-cm-ds-p* – *t-cm-us-o* – *t-cm-us-p* – *t-hfc-us-o* – *t-cmts-us-o* – *t-cmts-us-p*) / 2 + *t-cm-d-o* + *t-cm-ds-p* + *t-cm-ds-i*

t-cm-adj = *t-cmts-ds-i* + *t-cm-ds-i* + (*t-tro* + *t-cmts-ds-o* + *t-cmts-ds-p* + *t-hfc-ds-o* + *t-cm-d-o* + *t-cm-ds-p* – *t-cm-us-o* – *t-cm-us-p* – *t-hfc-us-o* – *t-cmts-us-o* – *t-cmts-us-p*) / 2

DOCSIS Domain Time Distribution

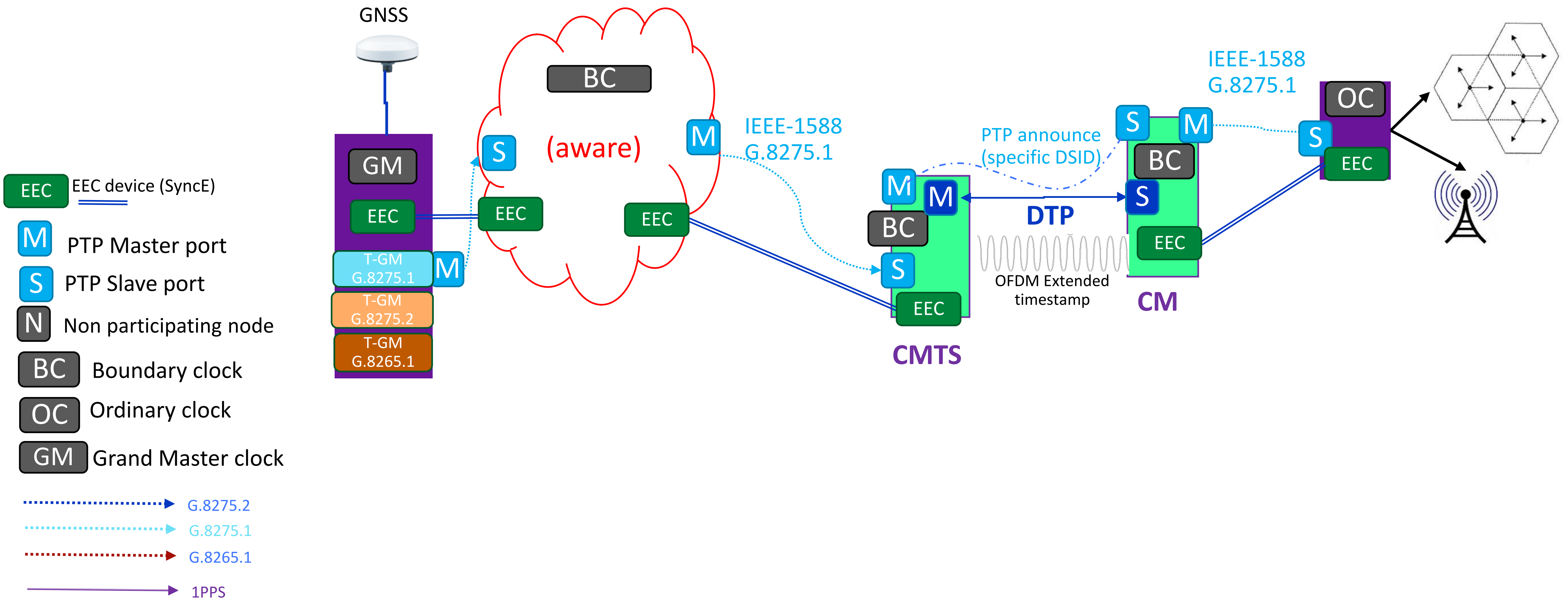


- CMTS synchronizes DOCSIS domain to network source
  - With IEEE1588v2, CMTS fulfills PTP Slave Port functions while syncing the DOCSIS Domain to its clock.
  - SyncE EEC may reside in CMTS, can be used to assist clock holdover and Locking time if SyncE primary reference clock is the same as PTP GM
- CM clock is tightly locked to CMTS (and ultimately PRTC) using DOCSIS Symbol clock.
- DOCSIS latency and asymmetry are measured and compensated for by DTP
- Using DOCSIS Time Protocol, the CM generates precision timing for subtending network (PTP Master and SyncE output functions reside in the CM)

MBH over DOCSIS “SYNC” spec

- There is a Cable labs working group dedicated for specifying the requirements needed for the DOCSIS network (CMTS/RMD/RPD and CM) to support MBH
- WG started to work in 2018.
- I01 was released:
  - Requirements of supporting phase over DOCSIS with full network support of 1588 (all the NE are 1588 BC using the G.8275.1 profile and based on ITU-T G.8273.2 performance requirements)
  - Requirements of supporting frequency over DOCSIS with full network support of SyncE
  - I-CMTS / DAA use cases
  - Testing concepts and requirements (e.g. 1 PPS, probing points etc.)
- I02 will include (planned for Q4/20):
  - New DOCSIS TLVs and MIBs (for CM configuration)
  - Fixes and updates to I01
- I03 will include (Planned for 2021):
  - Requirements of supporting phase over DOCSIS with partial network support of 1588 (some of the NE are 1588 BC using the G.8275.2 profile and based on ITU-T G.8273.4 performance requirements)

MBH Sync over ICMTS – fully aware network (G.8275.1)



MBH over DOCSIS "SYNC" spec – Phase Budget (fully aware network)

Budget Component	ITU-T	I-CMTS			DAA		
	Reference	n	@	TE	n	@	TE
PRTC *(Class A is 100 ns, Class B is 40 ns, ePRTC is 30 ns)*	100	Class A		100	Class A		100
Network Holdover and PTP rearrangements	NA or 400			200			200
Network Dynamic TE and SyncE rearrangements	200 for 10 BC			200			200
T-BC *(Class A is 50 ns, Class B is 20 ns)*	500 for 10 BC	2	50	100	4	50	200
Link Asymmetry	250 for 10 BC			50			50
Ethernet & Dynamic Aspects of Ethernet TE Budget	**1050**			**650**			**750**
CMTS *(Class A is 200 ns, Class B is 100 ns)*		Class A		200	Class A		200
DTP				50			50
HFC path				50			10
HFC node				50			10
HFC amp/LE		N+5	10	50	N+3	10	30
CM *(Class A is 250 ns, Class B is 100 ns)*		Class A		250	Class A		250
DOCSIS Network TE Budget				**650**			**550**
Rearrangements and short Holdover in the End Application	250 or 0			0			0
Base Station Slave or Intra-Site distribution	50	Class A		50	Class A		50
Base Station RF Interface	150			150			150
Base Station Network TE Budget	**450**			**200**			**200**
Total TE Budget	**1500**			**1500**			**1500**

DOCSIS "steals" 1/3 of the budget…

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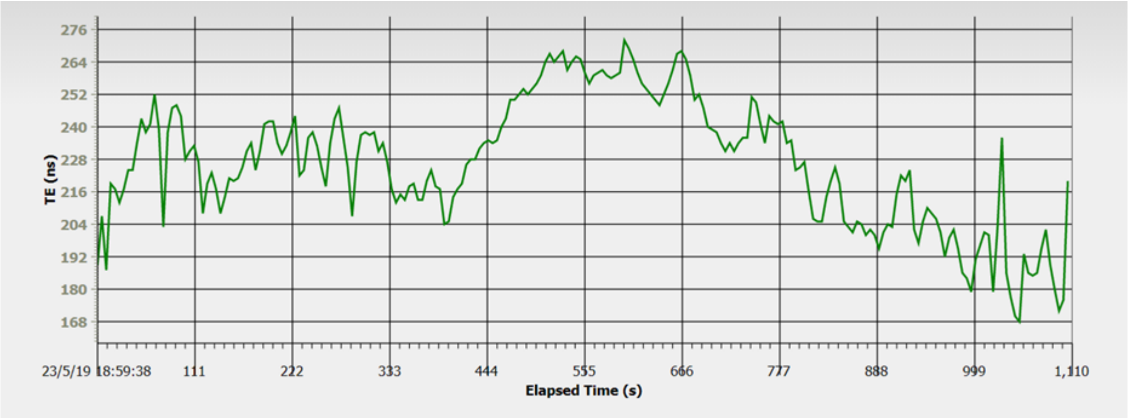
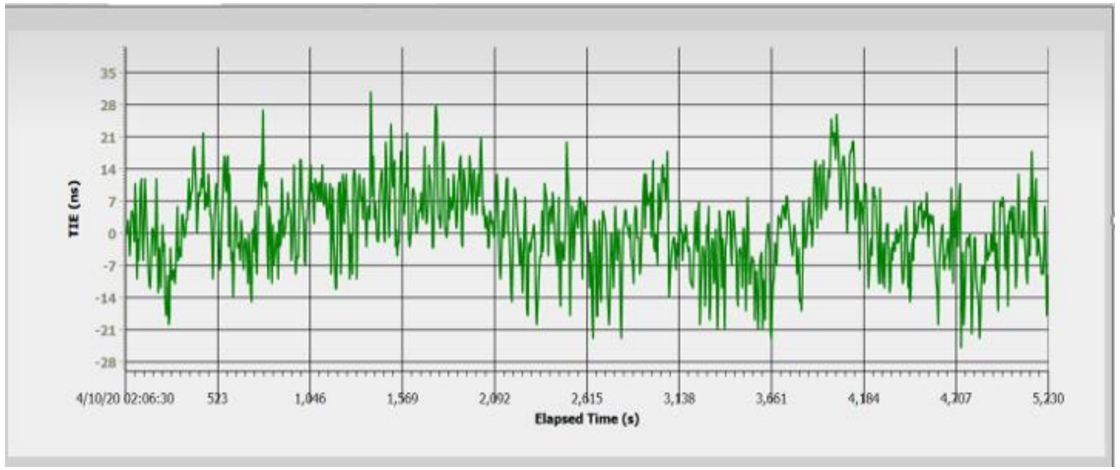
Slave Clock Time Error Performance with 3’ of Coax (zero length plant)

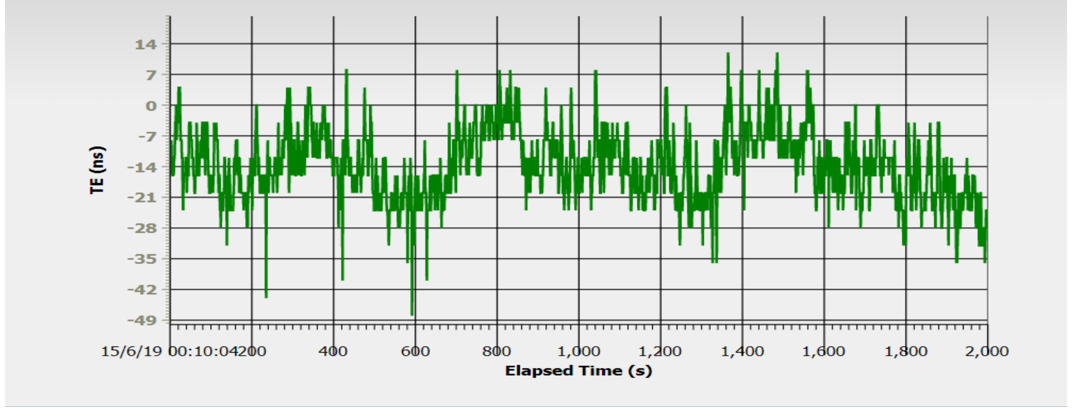
- TE of the recovered phase at the slave probe is compared to GPS time
- Measurement is performed with a 3-foot coax to approximate the zero-length plant for calibration
- Upper diagram shows the recovered phase has a TE of 220 ns with a variation of 100 ns peak-to-peak
- Results meet the ~500 ns TE budget for a Class A DOCSIS system defined in the Cable Labs SYNC specification
- Lower diagram shows recovered phase after further adjusting DTP parameters to reduce the cTE

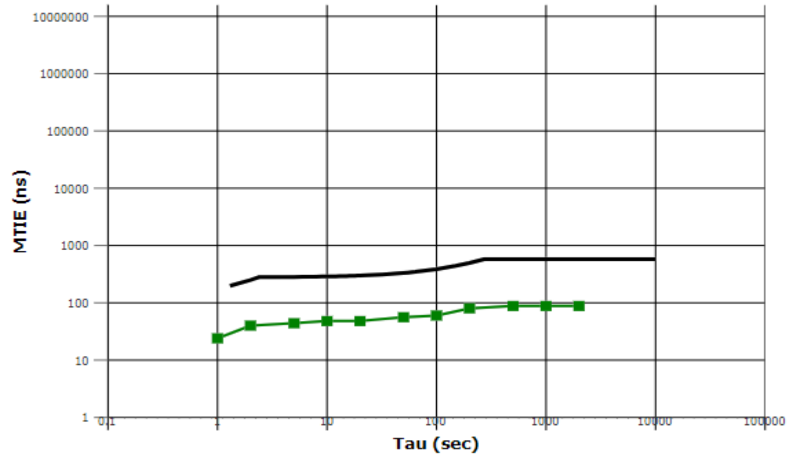




Slave Clock Time Error Performance with 400’ of Coax

- Plant cable length was increased to 400’
- DTP parameters were unchanged from calibrated values with 3’ coax
- The measured TE at the output of the CM is roughly
  -10 ns with a variation of 50 ns peak-to-peak
- MTIE is below 100 ns, which meets the requirement for phase delivery in G.8271.1
- Consistent results with 3’ coax





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	24	N/A	N/A
2	40	OK	OK
5	44	OK	OK
10	48	OK	OK
20	48	OK	OK
50	56	OK	OK
100	60	OK	OK
200	80	OK	OK
500	88	OK	OK
1000	88	OK	OK
2000	88	OK	OK
5000	N/A	N/A	N/A
10000	N/A	N/A	N/A
20000	N/A	N/A	N/A
50000	N/A	N/A	N/A
100000	N/A	N/A	N/A

POC Results Summary

- Similar results were seen when using Remote PHY or traditional CMTS (DAA vs. CAA).
- Time transfer stability (Jitter) between the E6000/RPD and CM (DTP) was < ±30 ns.
- Time transfer stability after RPD/CM reset was < 50 ns.
- After DTP calibration between RPD/CMTS - CM and network Asymmetry compensation at the RPD/CMTS, the end to end |TE| over DOCSIS was < 100 ns and MTIE < 100 ns.
- Results are within the MBH Sync Spec requirements (300-650 ns depending on DAA vs. CAA & class A vs. Class B devices).

Conclusion

- The HFC network is a good candidate for backhauling (or even fronthauling) 5G
- Sync delivery can meet the 100-200 ns TE
- Lab trials and field trials are in discussion for 2021 with multiple operators

THANK YOU

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