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Advanced Cable System Services and Synchronization Requirements

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Network Architecture and Strategy

Advanced Cable System

HISTORY OF TIME SYNCHRONIZATION

Prague Orloj - Prague, Czech Republic, 2011

ATIS Work

April 17, 2

(A brief) Timing History

1999 - Current	Time of Day (RFC 868)	Used for DOCSIS (1.0-3.0) cable modem time synchronization.
???? - Current	SONET Synchronization	Once used for SONET, SONET+ATM core network. Still used for legacy TDM transport over transport
???? - Current	Network Time Protocol	Used for IP device (servers, PC, phone, badge reader, etc) time of day.
2005 – Current	DOCSIS Timing Interface (DTI)	Used for modular cable modem termination systems (M-CMTS) deployments.

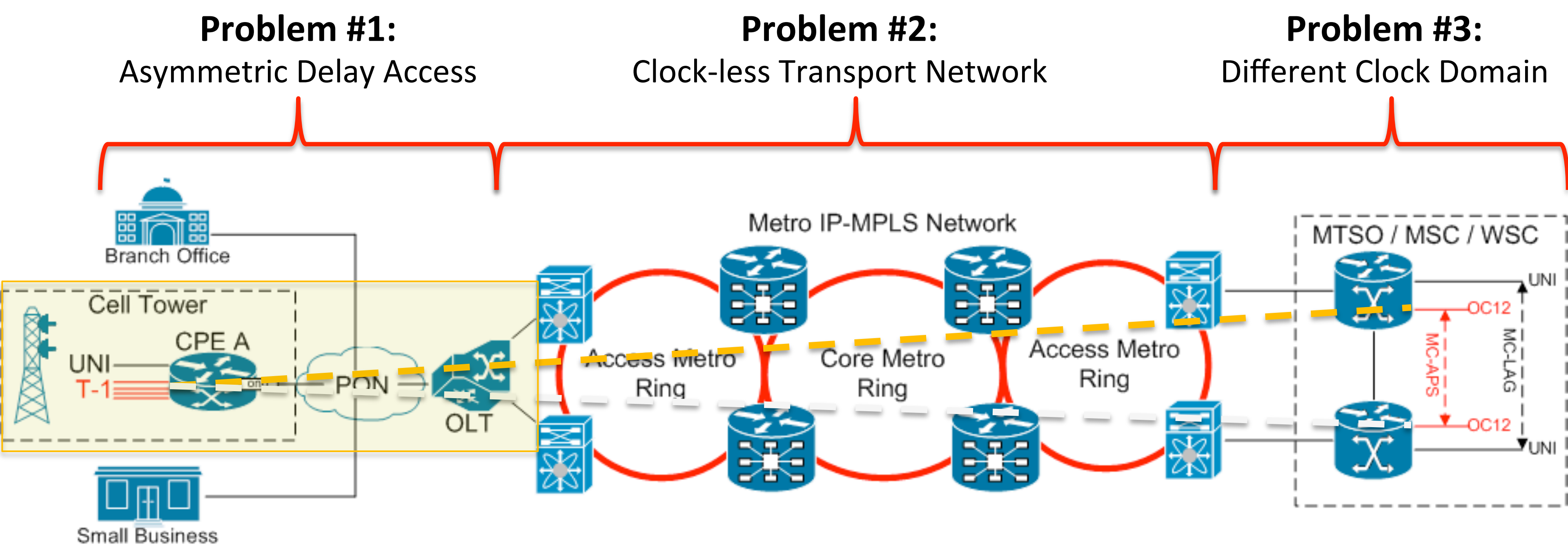
- Early days of high speed transport (OC-12, OC-48) we used SONET and SONET+ATM transport for our network core.
- With the advent of low-cost, high speed Ethernet (1GbE) we began shifting away from synchronous links.
- Timing protocols (such as ToD and NTP) exist solely for the purpose of distributing semi-accurate time of day to end stations (e.g. to drive clock displays.)
- DTI is very important to us and will be discussed in a future slide.

Timing Evolution

- A couple things happened to change the landscape of time synchronization at Bright House Networks.
- Mobile network operators (MNOs) needs for TDM transport.
  - This drives creative solutions to provide loop clocking over a "clock-less" network core.
- Performance monitoring of MEF services (Y.1731) with one-way delay and delay variation statistics.
  - This drives more accurate deployments of NTP, PTP.
- Modular CMTS deployments arrived to drive down CMTS access costs.
  - M-CMTS Deployments required a high accuracy (<5ns) and high stability (<1ns jitter budget) time source.

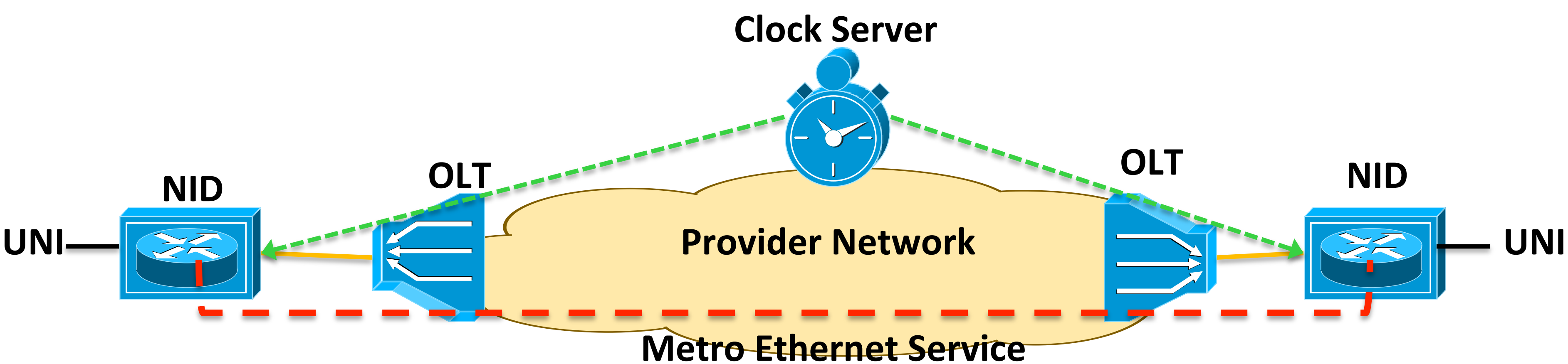
Enter: Adaptive Clock Recovery

- Providing clock for TDM services was one of our largest challenges. The specific challenge points are divided below:
  - Our EPON access has asymmetric delay.
  - We have no (or very little) clock capability within our network.
  - There's the additional (operational) challenge of supporting multiple clock domains.
- Circuit Emulation Service over PSN (CESoPSN) coupled with adaptive clock recovery (and low jitter) allowed us to use the network we have.



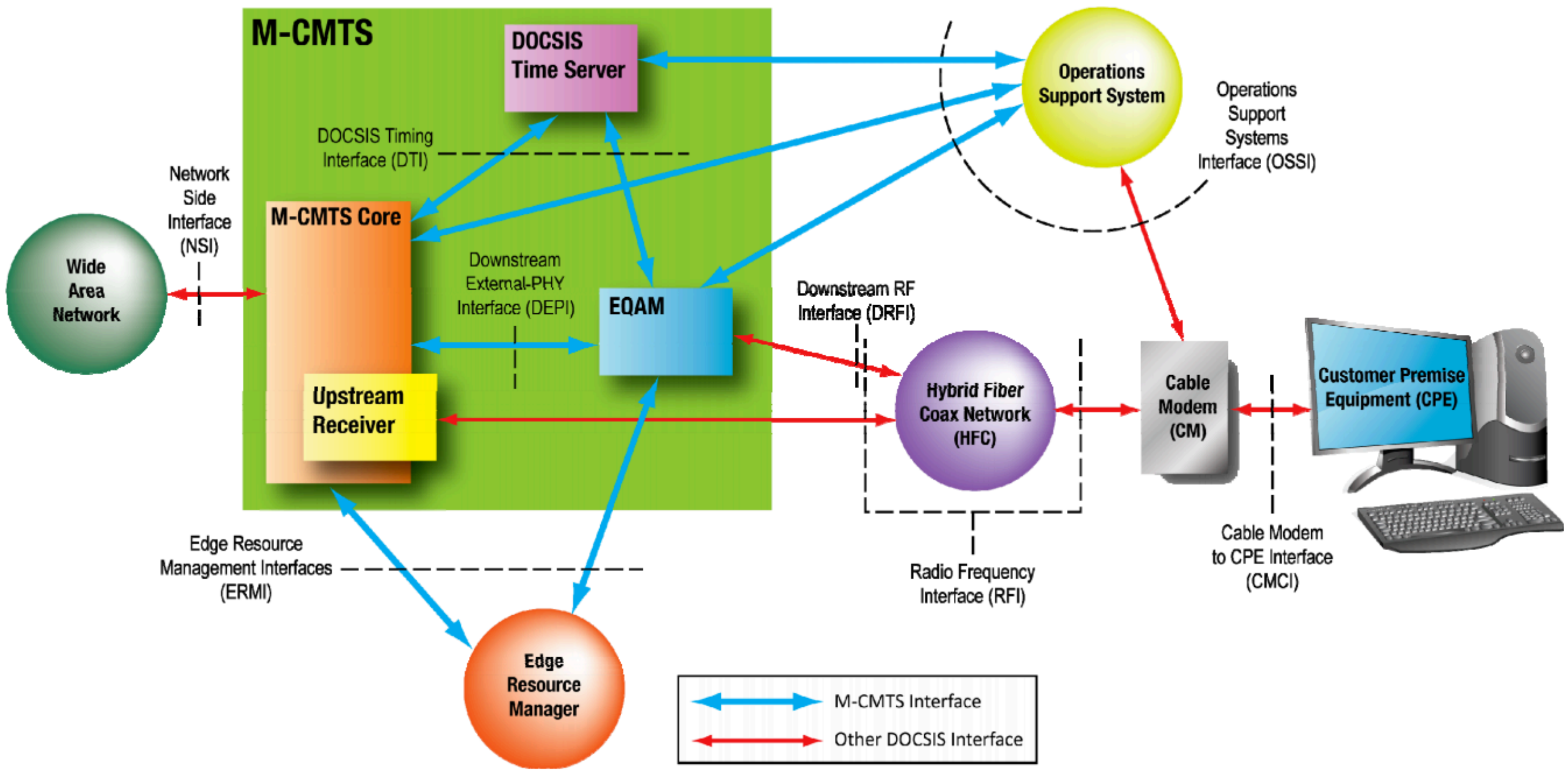
Followed by: One-Way Delay

- For accurate one-way delay and delay variation measurement the endpoints must be synchronized.
  - With SLAs dictating one millisecond delay variation and five millisecond delay values, the endpoints must be synchronized to microseconds of each other.
- It's very easy to tell when the endpoints are too far out of sync…
  - Negative delay values begin showing up in the performance reports.
- Both the provider network core and access can be sources of asymmetric delay…
  - Asymmetry across the provider network can be solved by distributing clock sources.
  - The asymmetry in the cost effective access has been the greater challenge.



And the … DOCSIS Timing Interface

- Originally a CMTS was an integrated device – all the coaxial QAM PHYs were in the same physical device.
- The M-CMTS architecture enabled the coaxial PHYs to be separated from the M-CMTS "core".
- This introduced the reliance on a DTI Server to maintain a consistent timing reference between the M-CMTS Core and E-QAM.



Advanced Cable System

TIME SYNC REQUIREMENTS

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Time Sync Observations

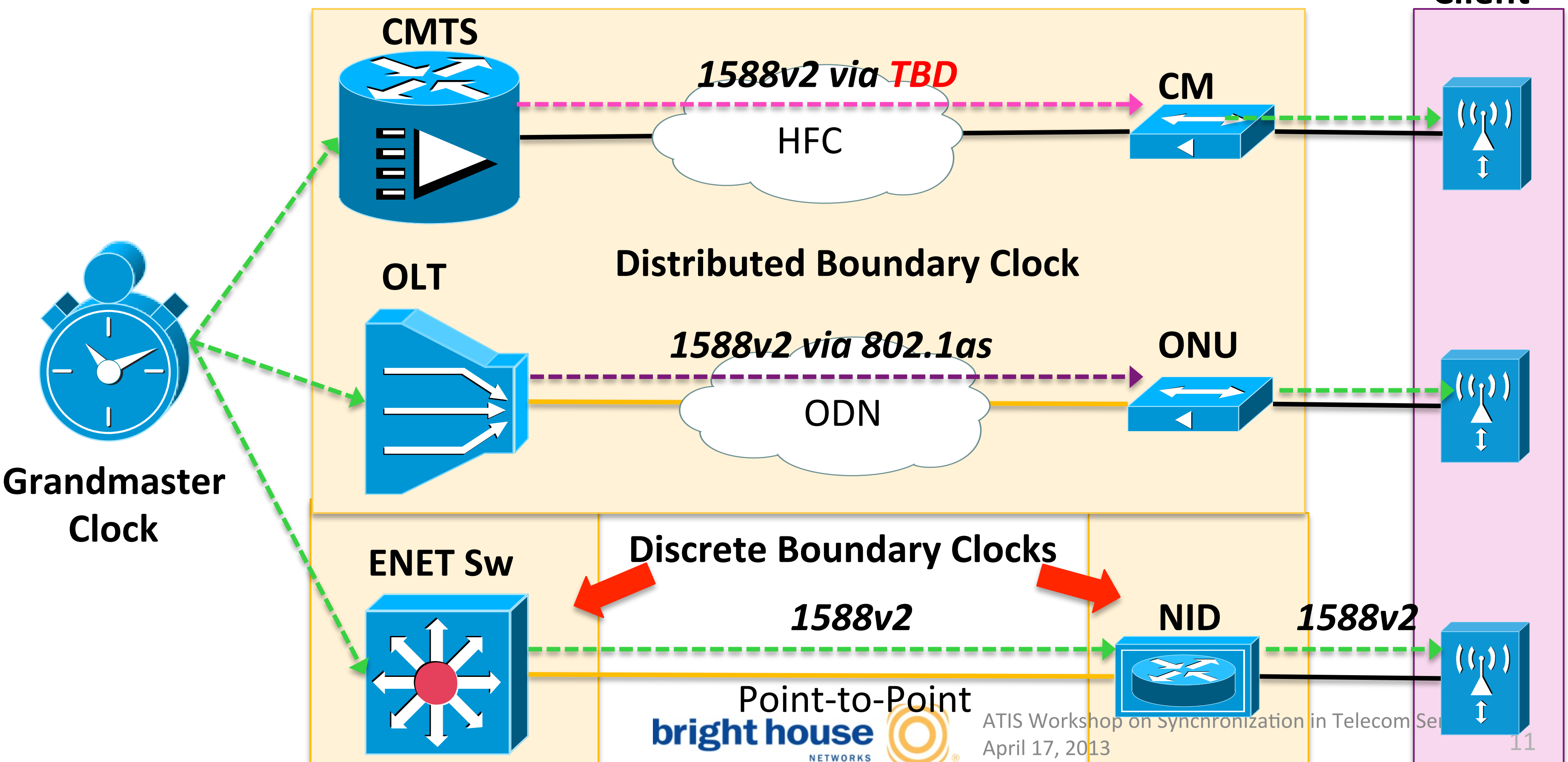
- Observation 1: Our customer MNOs are no longer growing their T-1 footprint (capping pre-4G services.)
  - New CESoPSN services using Adaptive Clock Recovery are no longer needed.
  - We continue to support existing deployments, but our deployed numbers of serviced T-1s are shrinking.
- Observation 2: Our customer MNOs are primarily using local GPS clocks for macro Cells.
  - For existing Macro Cells, no MNO has asked for us to provide frequency and/or time of day over a packet network service.
  - Of course we provide T-1 clock via ACR.
- Observation 3: Small cells are coming.
  - Radio distribution is required to provide more bandwidth per cubic meter.
  - But these small cells going to need to be very cost effective.

Clock Distribution at Scale

- We are looking at providing clock (frequency and ToD) over our existing access solutions.
  - Today our customers rely on stand-alone GPS clocks in many cases and we need to replicate this capability.
- Our access solution portfolio includes:
  - DOCSIS (coaxial medium)
  - EPON and 10G-EPON Access
  - Ethernet (Point-to-Point)
- Thus we desire to provide accurate packet-based time synchronization ubiquitously across all our broadly deployed access solutions.

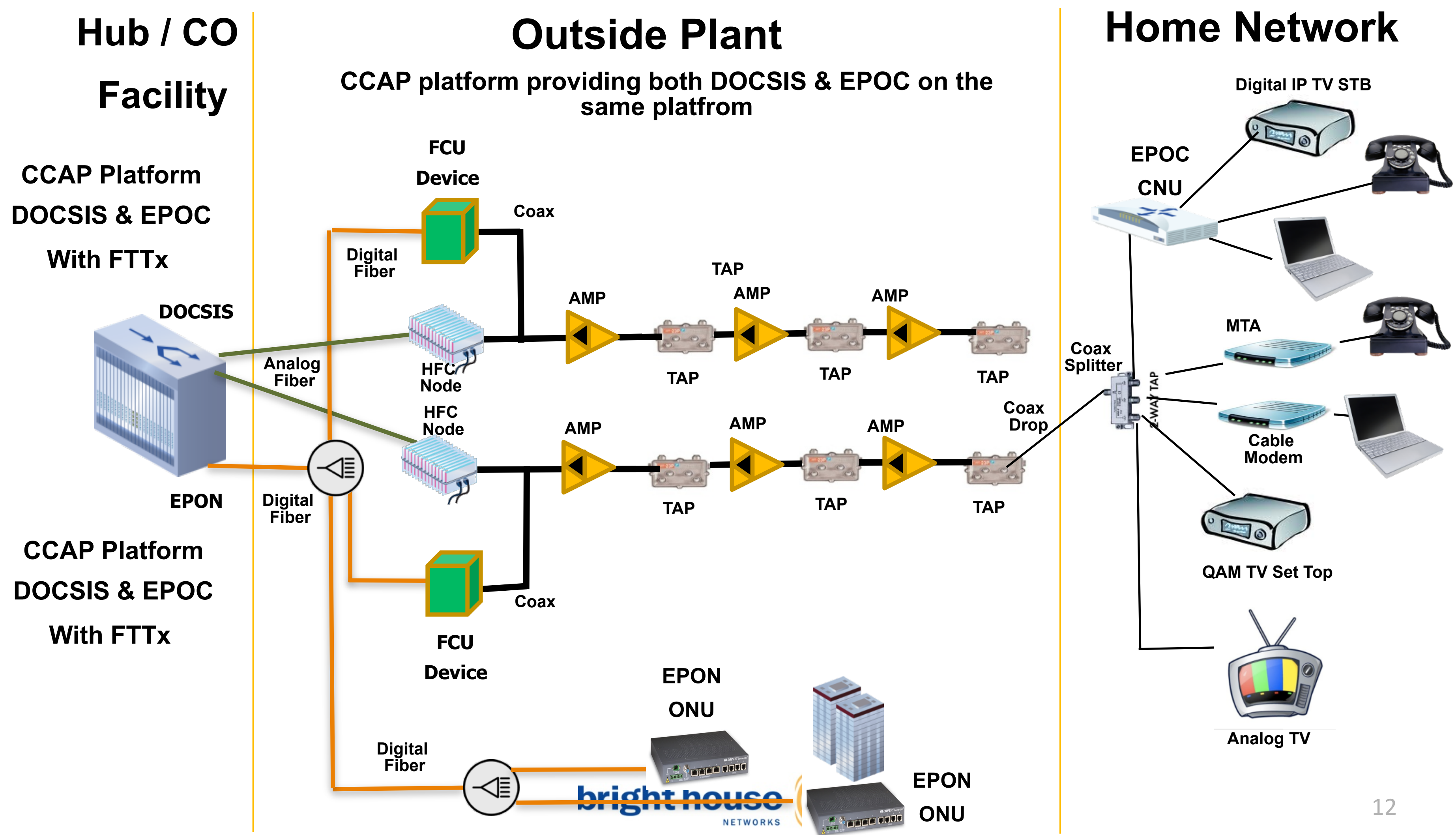
Different Access: Same Model

- No matter the access solution, clock distribution remains the same.
- 1588v2 distributes both Frequency and ToD.
  - CMTS+CM and OLT+ONU operate as a distributed boundary clock.
  - Ethernet switch and NID operate as discrete boundary clocks.



And Converged Access

- A Converged Cable Access Platform (CCAP) provides a single logical access platform that can support legacy services over coax, DOCSIS, EPON and EPoC.



CCAP Continued

- Whether the CCAP is a single box or multiple pieces of sheet metal, it is intended to be managed as a single entity.
- As such, clock distribution in the hub/CO doesn't necessarily change.
  - Some might argue it gets easier, particularly if the CCAP is a single integrated platform for both coax access and fiber access.

WARNING: We view CCAP differently than some of our cable operator colleagues. For us, CCAP is about providing a cost effective, big-fat, commonly-provisioned IP pipe to the access.

Whether this pipe happens to traverse coax medium with DOCSIS frames or Ethernet frames or traverse fiber with Ethernet frames is of less importance.

Clock Distribution in Multipoint Networks

- Both DOCSIS and EPON access technologies provide asymmetric delay and delay variation characteristics.
- Downstream
  - Delay: typically very low, sub millisecond.
  - Delay Variation: Also very low, subject to normal factors that increase jitter such as high link utilization, queue occupancy.
- Upstream
  - Delay: Variable. In both EPON and DOCSIS this value can be multiple milliseconds, often at least one order of magnitude larger than the downstream delay.
  - Delay Variation: High. Also can be multiple milliseconds.
- The difference in upstream delay is largely attributed to the upstream grant process as seen in the next slide.
- In both EPON and DOCSIS tuning can be performed to reduce upstream delay and jitter but obtaining delay and jitter far below 1ms is not reasonable.
  - If the requirement is to have the upstream access segment's delay and jitter <1ms, we would deploy point-to-point.

Simplifed EPON Scheduling

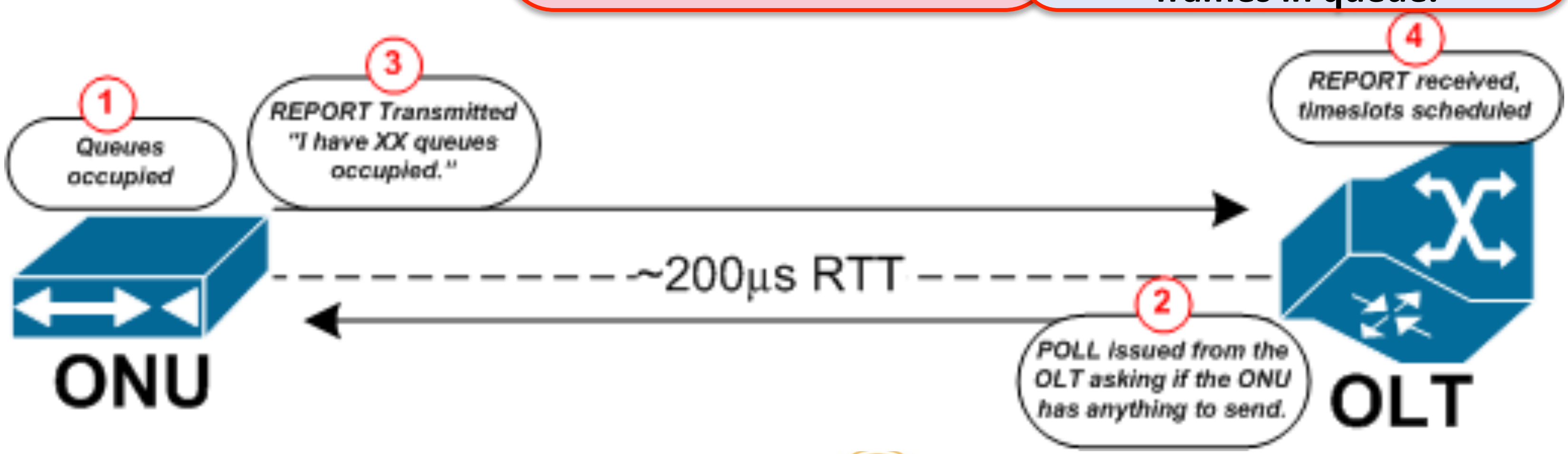
EPON is a point-to-multipoint access medium.

- **As a result EPON utilizes a shared scheduler inside of the OLT to manage upstream transmissions via a request-grant mechanism.**
- **Before an ONU can transmit the OLT must provide a grant.**
- **This results in upstream delay and *upstream delay* variability.**

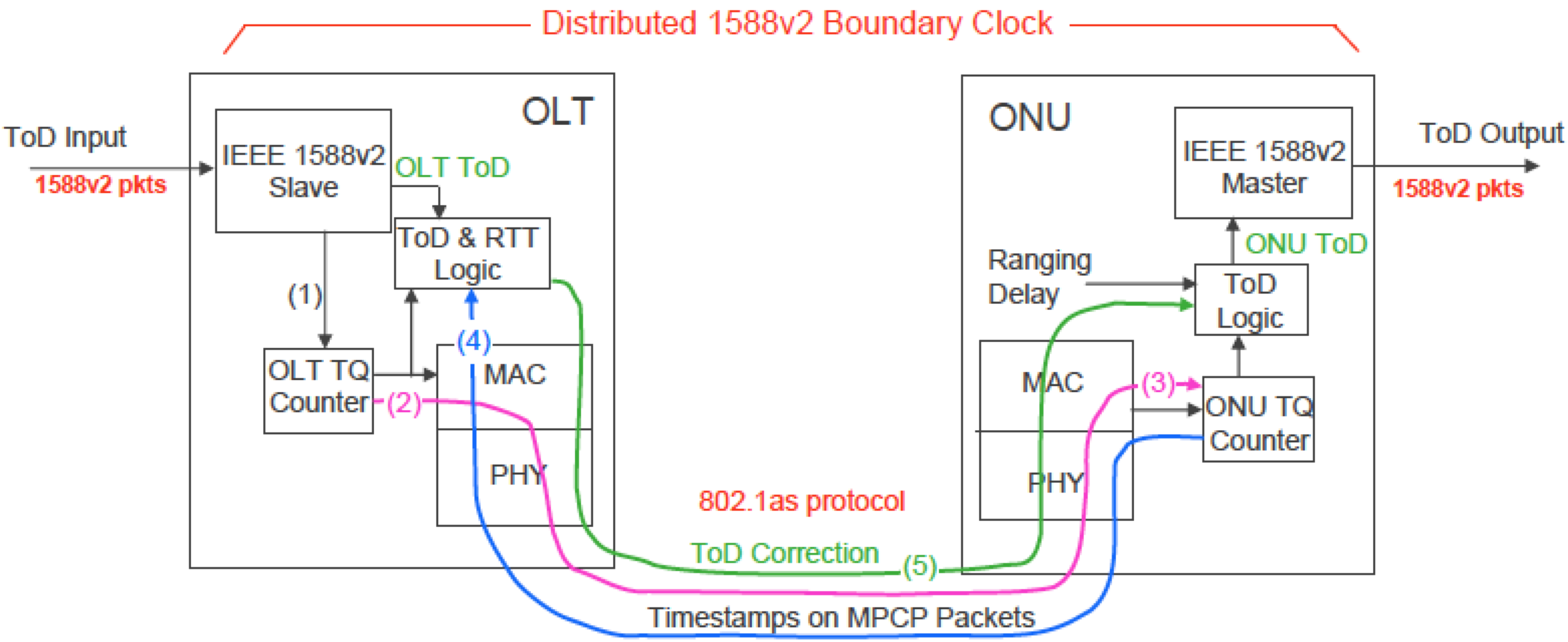
Before an ONU can request a transmission time, it must wait for a POLL from the OLT.

Once ONU receives a POLL providing a timeslot to report its need, the OLT schedules timeslots and sends the grant to the ONU.

At the end of its grant window, an ONU can send another report IF it has frames in queue.



802.1as Model

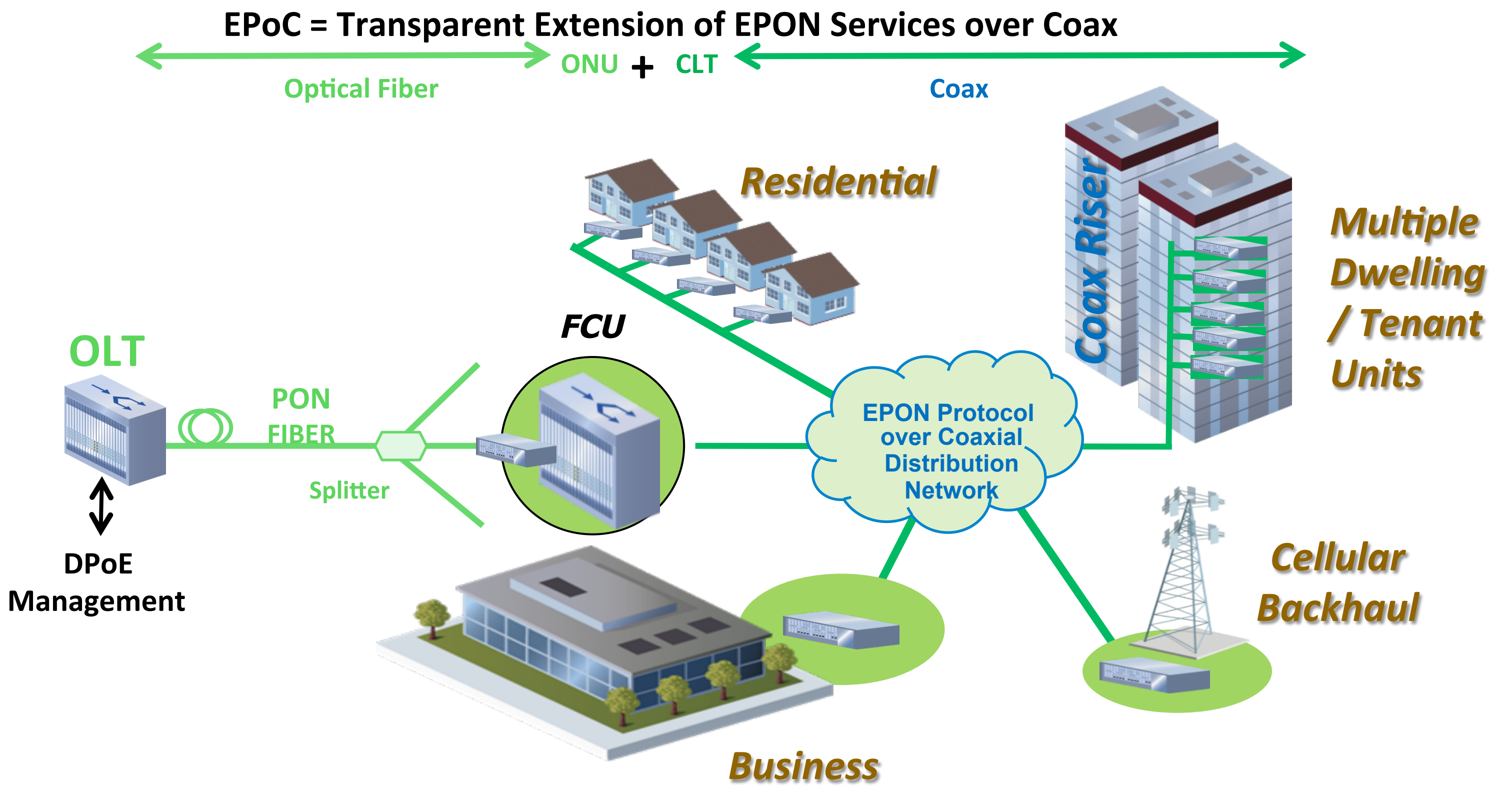


- EPON time transport method is defined in 802.1as clause 13.
  - Multipoint control protocol (MPCP) is used to communicate between OLT and ONU for purposes of scheduling.
  - The ONU and the OLT use MPCP to provide both the timestamp and a timestamp correction field in time quanta – 1TQ = 16ns.
- Range of current time error: OLT-to-ONU is ~120ns[1]
  - [local ctr - 8ns, ½ RTT drift - 96ns, DS/US fiber -17ns]

[1] Time Synchronization over Ethernet Passive Optical Networks, Yuanqiu Luo, Frank Effenberger, Huawei, Nirwan Ansari, NJIT, IEEE Communications Magazine, Oct, 2012.

Future Protocol: EPoC (IEEE 802.3bn)

- Some North American cable operators that are looking to extend the EPON protocol to operate over coaxial cable.
- One of the reasons is to provide an incremental path to FTTx.
- And this new protocol is also expected to support transport of packet timing.



Timing Accuracy Concerns

- Moving forward, particularly with multipoint access technologies (DOCSIS, EPON, 10G-EPON, future-EPoC) there are timing distribution concerns in the access space…
  - Emerging standard requirements for the CoMP air interface: ~500ns accuracy.
  - FCC E911 emergency services time sync requirements: ~100ns accuracy.
- As previously discussed, EPON (currently) is challenged with guaranteeing the ~100ns accuracy.
  - Our desire is that work in this area continues to progress.
  - Clearly additional work will be required to ensure EPoC and DOCSIS provide similar capabilities.