Timing Needs in Cable Networks

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Outline

- What is a Cable Network?
- Timing Aspects in Cable
- Distributed Architecture and Timing Requirements
- Mobile Backhaul Support through Cable Networks

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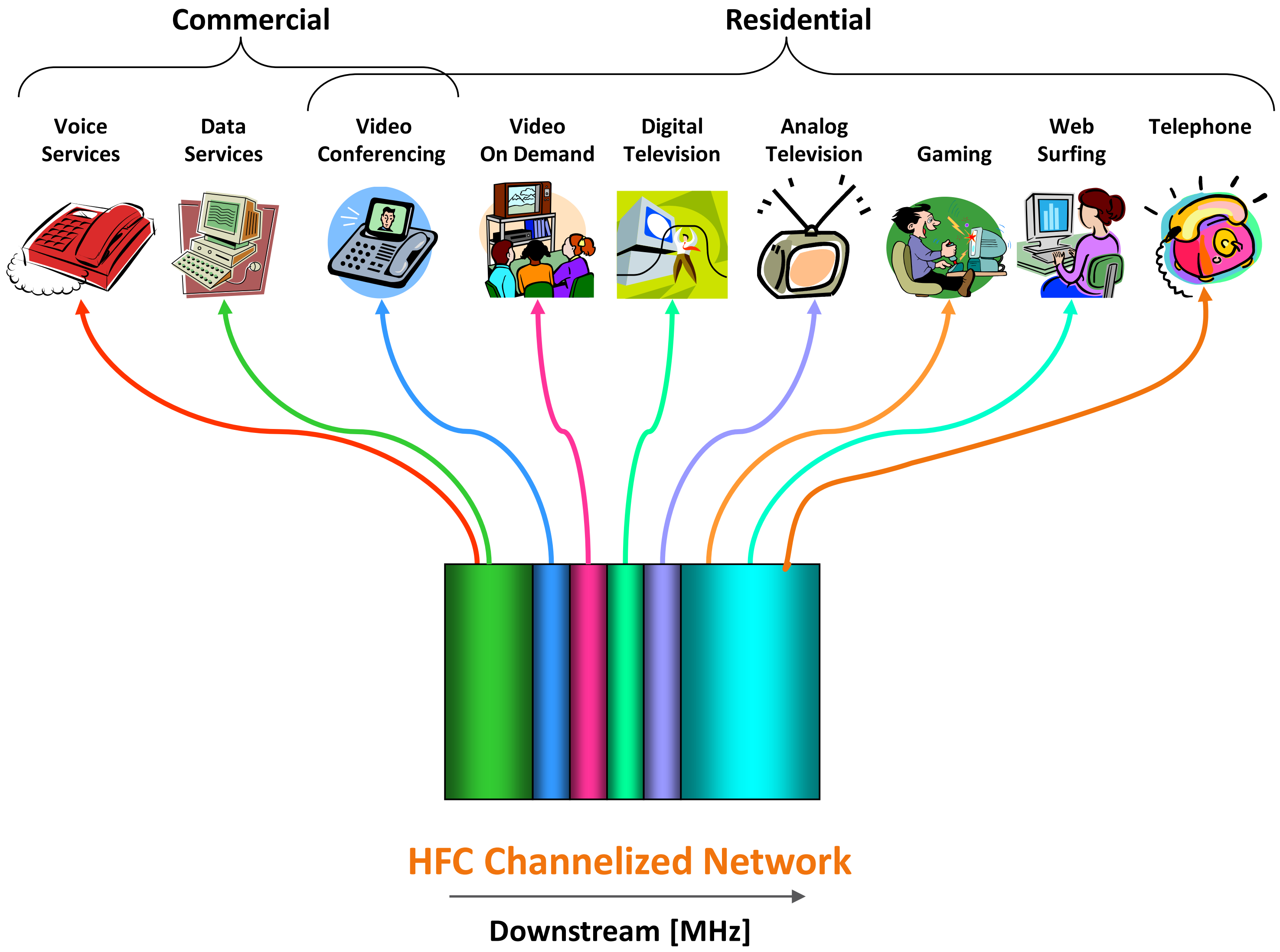
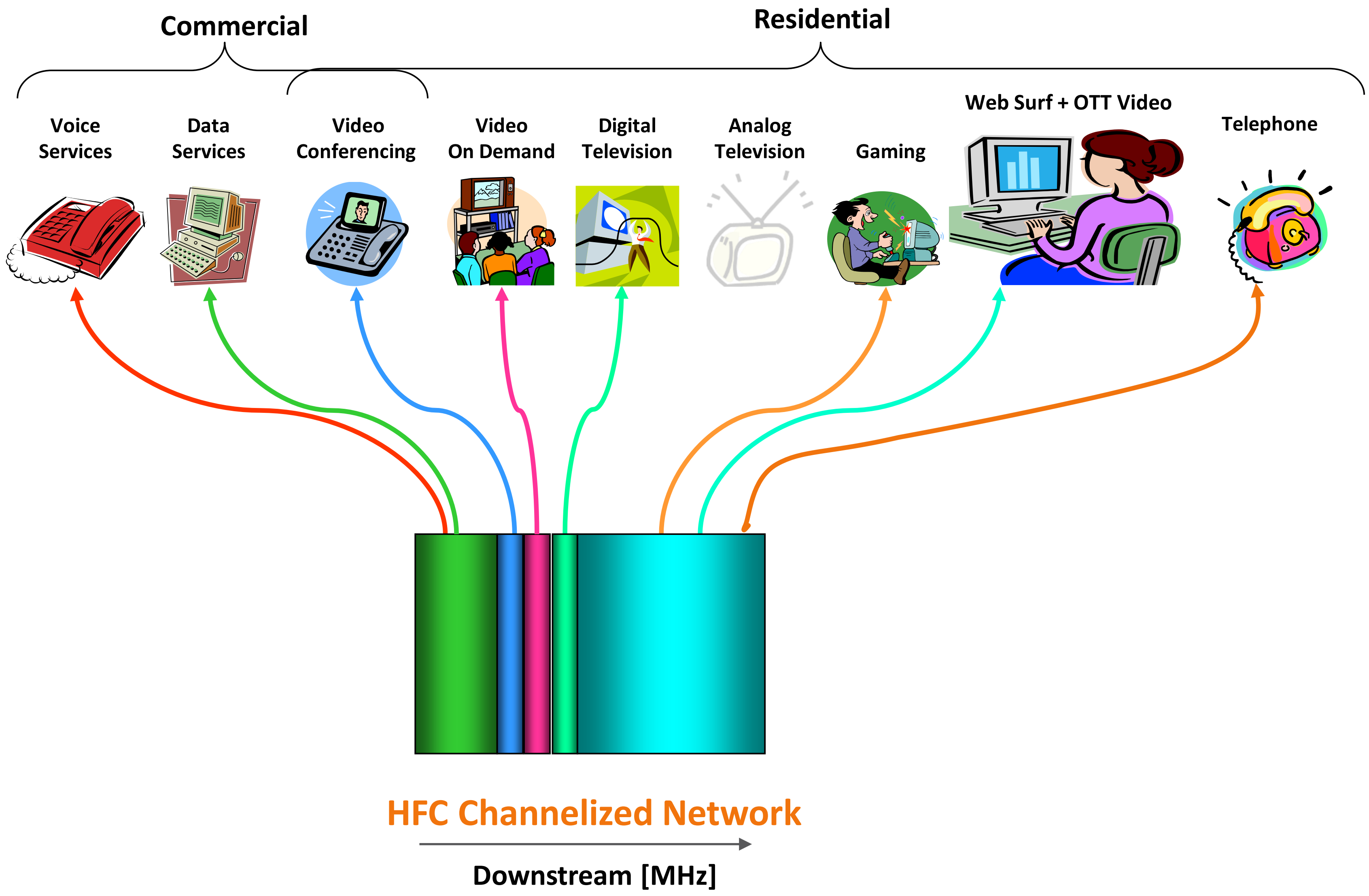
Cable Services Delivery



Cable Services Delivery - Today

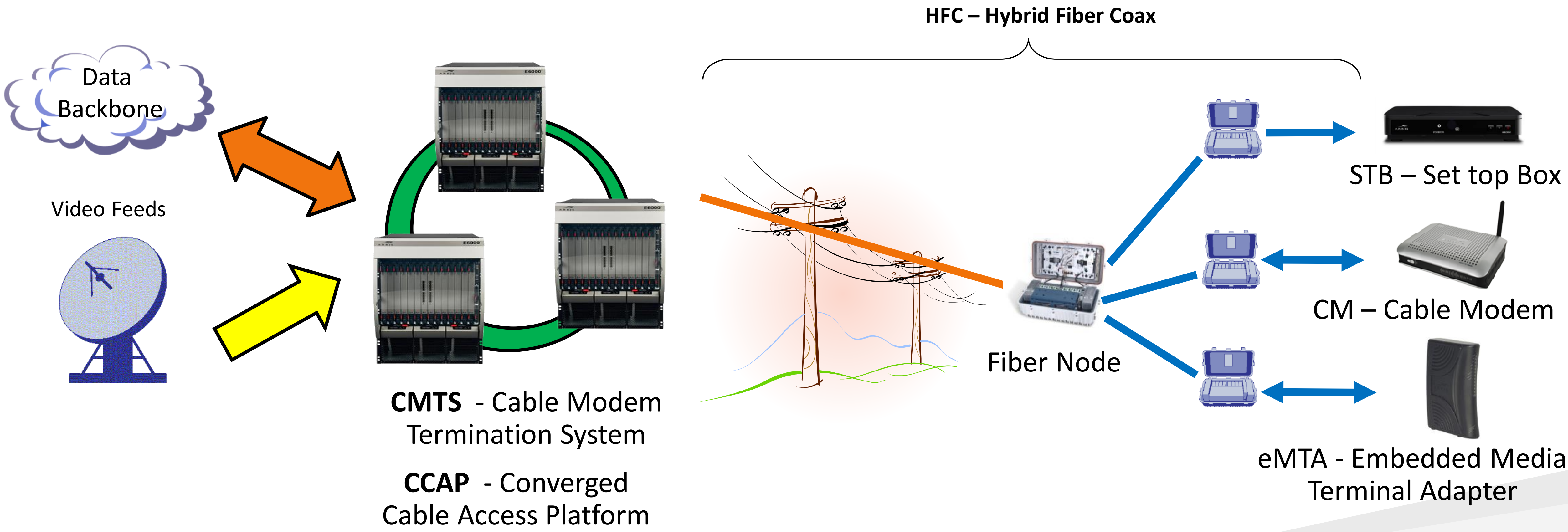


What is DOCSIS?

- The cable TV industry came together in the late 90's and set up a group called CableLabs
- They created a set of specifications called Data Over Cable Service Interface Specifications, or DOCSIS for short
- DOCSIS defines the electrical and logical interfaces specification for network and RF elements in a cable network
- DOCSIS is a Point to Multipoint Protocol
- Downstream is continuous "One to Many"
- Upstream is dynamically scheduled BW allocation
- DOCSIS versions are 1.0, 1.1, 2.0, 3.0 and 3.1

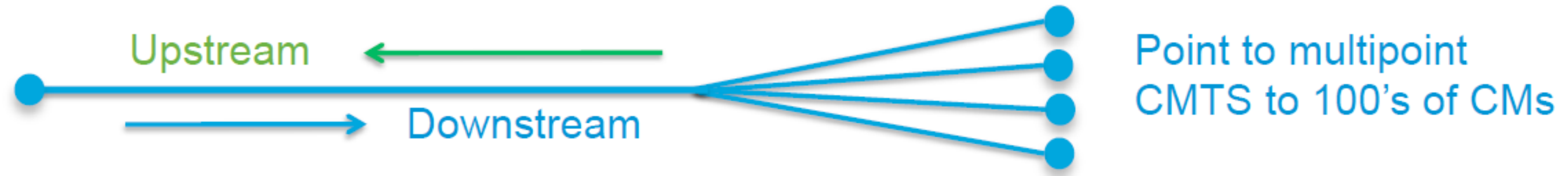
Cable Network Topology

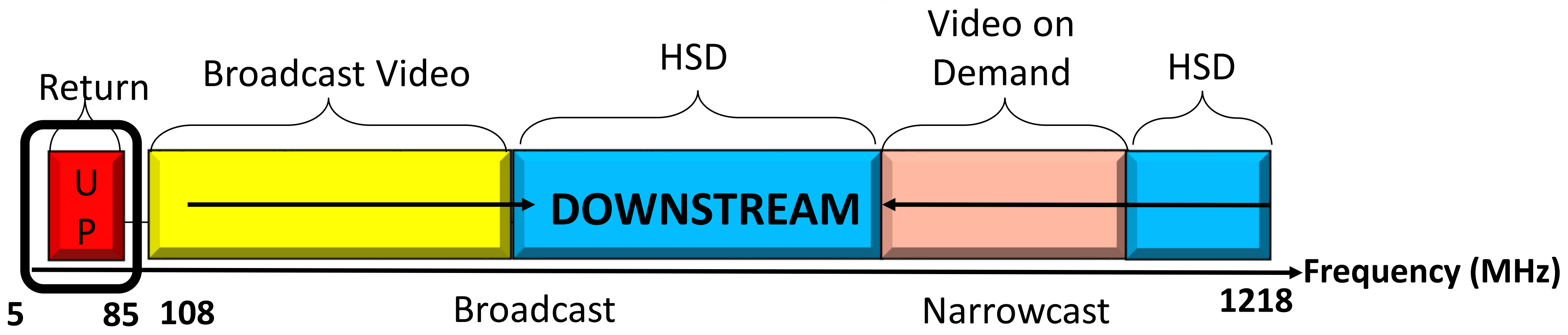
- The HFC network provides the communications link between the CMTS/CCAP and the stations, STBs, CMs and eMTAs.
- HFC plant consists of up to ~160 km of optical fiber, few hundred meters of coaxial cable, RF distributions and Amplifiers.



Communication over the HFC Network

➢ The HFC consists of both Downstream (DS) and Upstream (US) links that are very different in behavior.





Upstream:

- In DOCSIS 3.1 channel width can vary from 6.4 MHz up to 96 MHz
- Located at the lower end of the spectrum
- Channels shared among all CMs on the link via TDMA bursts

Downstream:

- In DOCSIS 3.1 channel width can vary from 6 MHz to 192 MHz
- Located at the center and higher end of the spectrum
- TDM continuous broadcast transmission

Communication Behavior

- All Simultaneous users contend for the US and DS access.
- The CMTS transmits data to the cable modems on a first come, first served basis.
- CM must time-share upstream channels.
- Request and Grant reservation scheme.
- Only one modem can be active in the US at any given instant in time.
- The DOCSIS path delay is inherently asymmetrical and can contain a moderate to high amount of jitter

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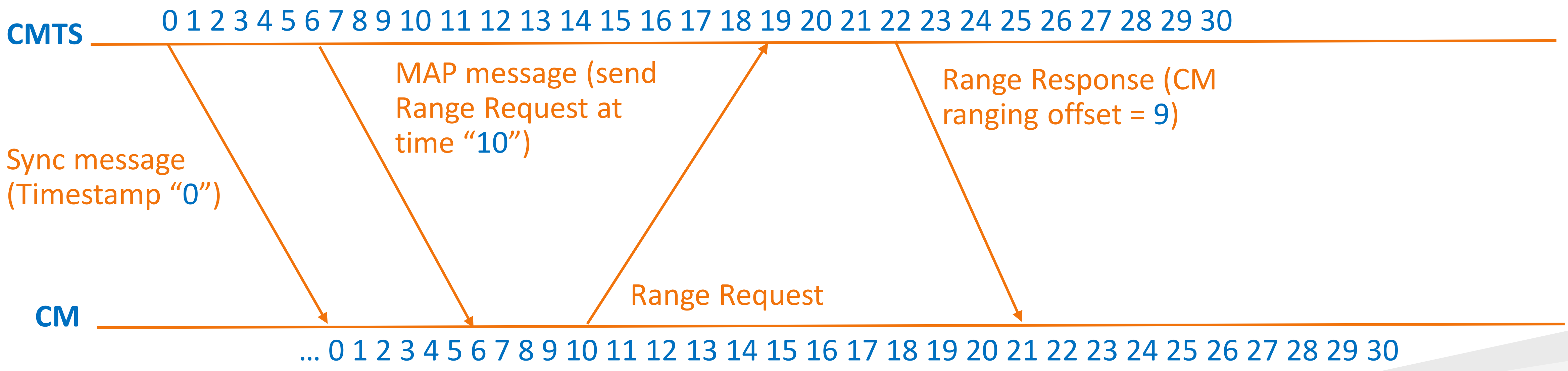
DOCSIS Timing

- DOCSIS transport is Synchronous in nature and uses a common clock derived by the CMTS
- The CMTS delivers MAC management messages on the downstream:
  - Sync Messages: a 32 bit timestamp derived from a 10.24 MHz clock. The timestamp is sent between 5-500 times per second
  - 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 QAM symbol clock and “time reference” from the Sync messages
- Up to 500ns Jitter on downstream timestamp
- +/-5 ppm on Clock accuracy.
- Clock drift rate <= 10-8 per second

Cable Modem Ranging

- The CM needs to know how far off their clock is from the master reference, or their transmissions will be distorted at the CMTS
- Time offset is determined for each CM to allow its transmissions to be received at the correct time at the CMTS
- The determination process of this offset is called Ranging
- Ranging offset is a value indicating the upstream delay between a CMTS and a specific CM
- Ranging is done when a CM is booting up and every ~30 seconds thereafter



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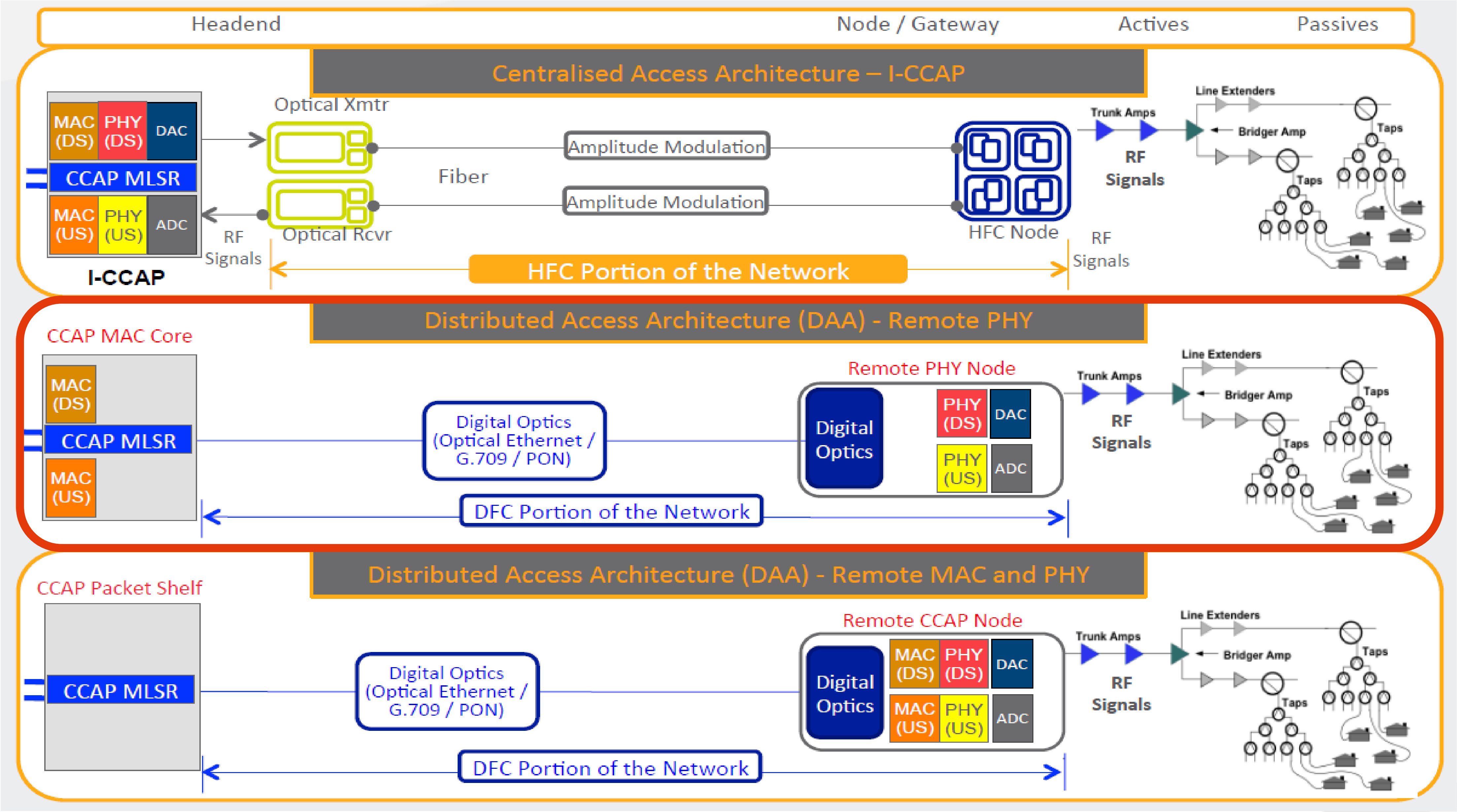
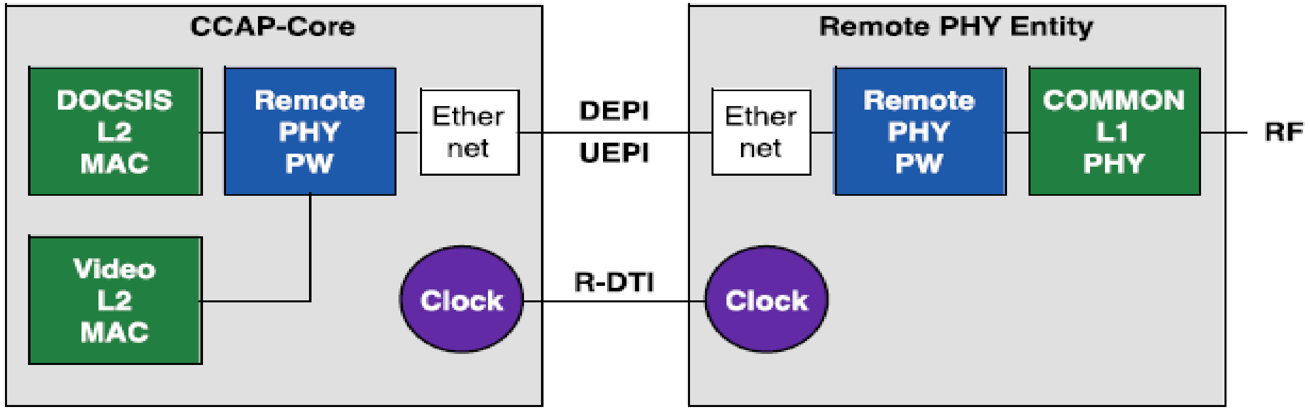
Distributed Access Architectures



Remote PHY and Timing

- Separating the MAC and the PHY into 2 boxes with 160 km distance between them poses challenges on timing synchronization
- The CCAP Core maintains the MAC functionality and produces the MAP messages
- The R-PHY Entity timestamps the sync packets
- **The Core and R-PHY must be synced in clock and phase!**
- CableLabs Remote DTI spec (R-DTI) specifies the timing requirements for R-PHY architecture:



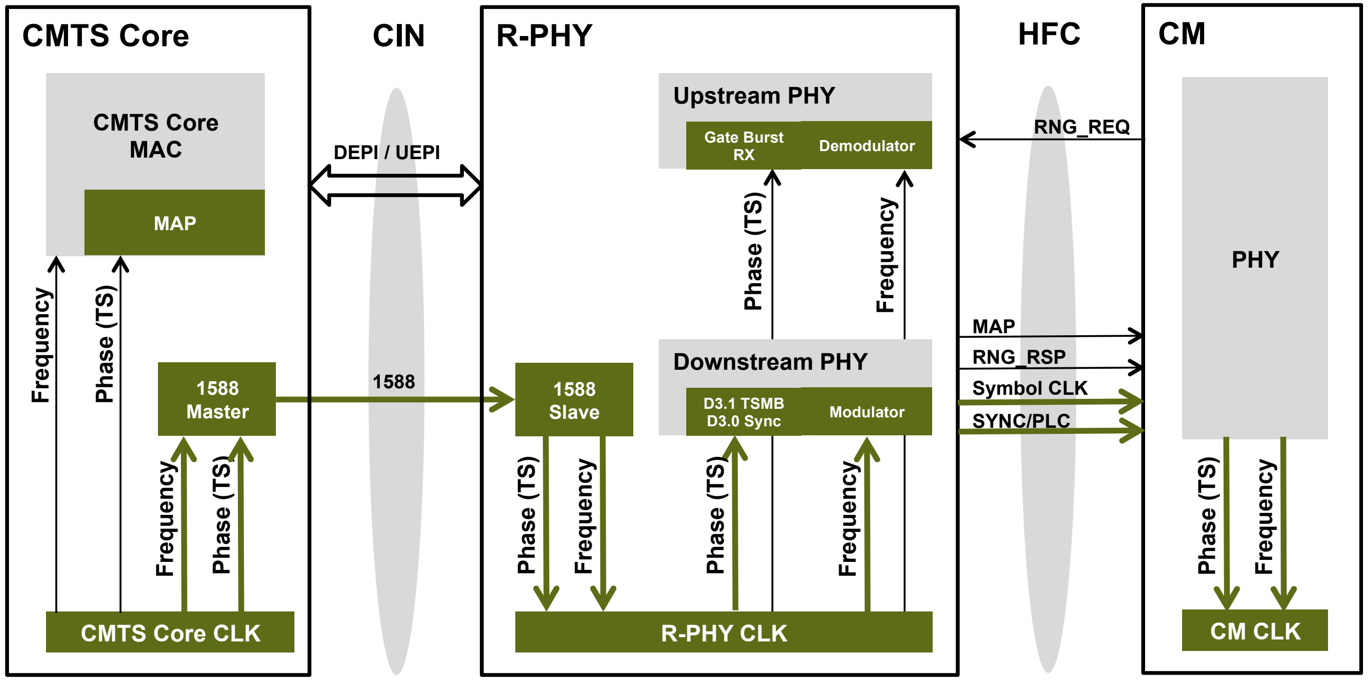
R-PHY Timing Requirements and Challenges

- The Presicion Time Protocol (PTP) was chosen for Core and R-PHY synchronization
- G.8275.2 PTP profile selected
- SyncE is optional
- Frequency accuracy of <= 5ppm (or 500 ppb for some advanced applications)
- Phase error <= (0.5ms - 1ms) depends on timing topology
- Fast convergence from boot-up till phase lock (few minutes)
- 1588 unaware or partially aware networks
- Frequency drift (slew rate when CM are locked) is <= 10 ppb/sec
- No phase steps are allowed when CMs are locked
- Scale (each Core could have hundreds of Remote PHY devices that should be synced)

Remote PHY Deployment Scenarios – Node Slave

- Will probably be the most common scenario.
  Two main use cases:

  A. CMTS Core is the Grand Master (GM) and the Remote Phy Device (RPD) is the Slave:

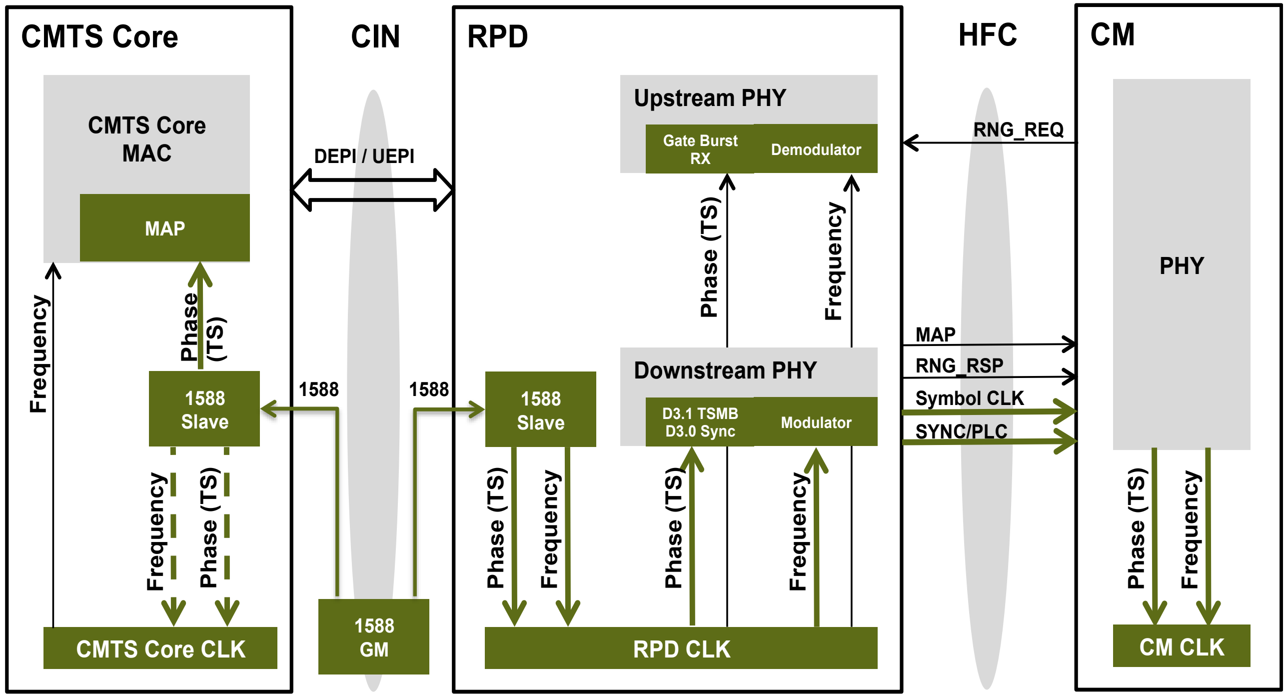


– <u>Main Advantage:</u>
  - No need for an external Grand Master

– <u>Main Disadvantage:</u>
  - The CMTS Core will need to distribute timing information via PTP to hundreds or thousands of RPDs

Remote PHY Deployment Scenarios – Node Slave

B. CMTS Core and the RPD are Slaves to an external Grand Master:

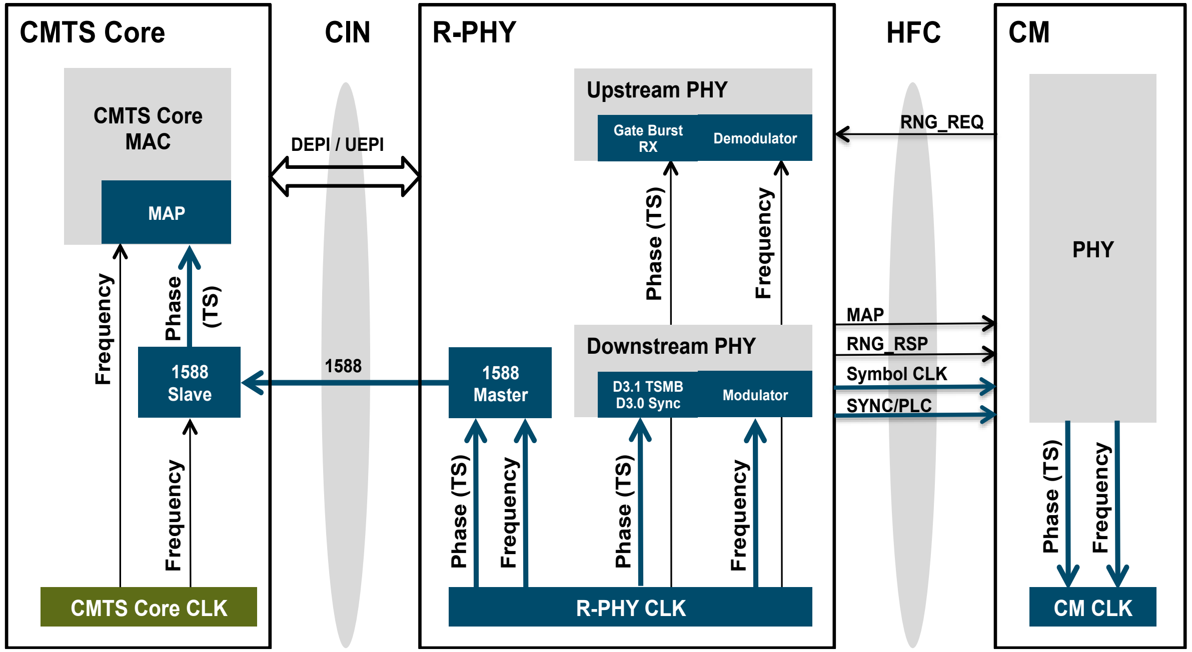


– Main Advantages:
  - CMTS Core is only a slave. PTP performance requirements are on the Grand Master
  - Accurate ToD

– Main Disadvantage:
  - A need for external GM (costly, Interop required)

Remote PHY Deployment Scenarios – Node Master

- **Remote PHY is the Master and the CMTS Core is the Slave**
- The CMTS Core tracks each RPD time without achieving frequency sync
- CMTS Core MAC module obtains the frequency and phase information from the timestamp messages and runs a phase calibration process to track the RPD time without achieving frequency synchronization

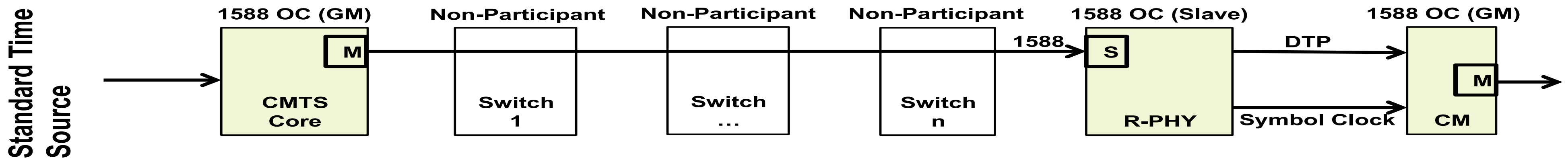


– <u>Main Advantage :</u>
  - No need for frequency sync between the CMTS Core and RPD

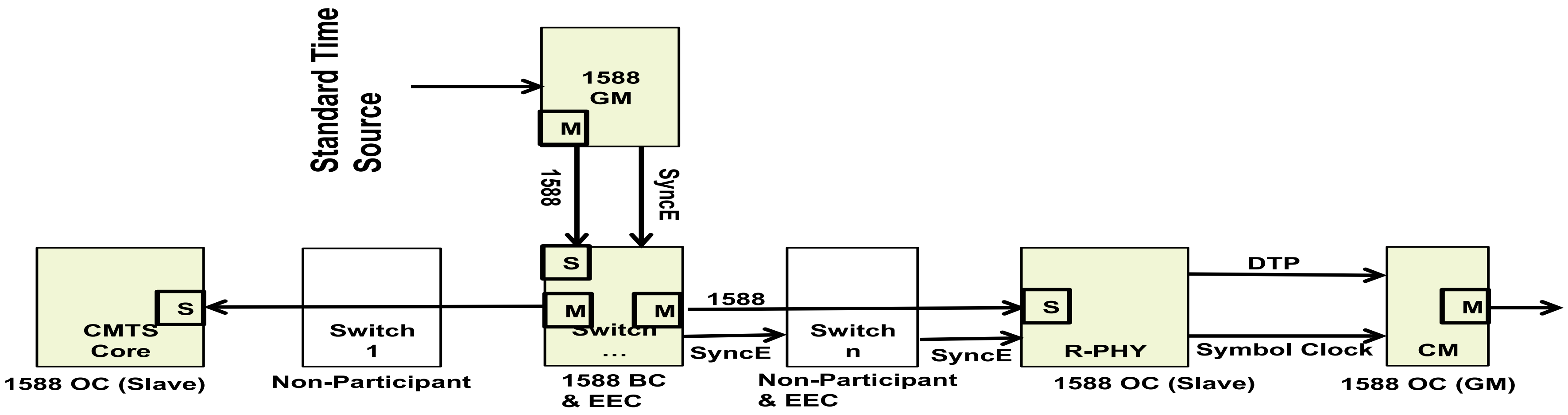
– <u>Main Disadvantage :</u>
  - The CMTS Core will need to handle each RPD timing separately, at possible scale of thousand of RPDs

R-PHY Deployment Scenarios – Network Scenarios

- **Scenario 1:**
  - Core is master, node is slave, network is timing unaware



- **Scenario 3:**
  - Core is slave, node is slave, network is timing Aware (Boundary Clock (BC) or Transparent Clock (TC))



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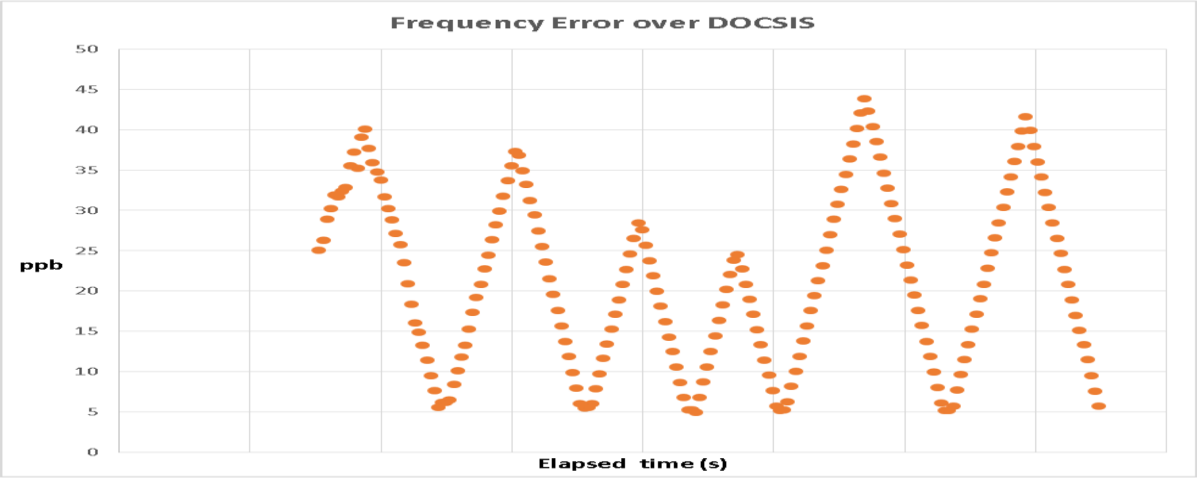
Cellular Backhaul and DOCSIS

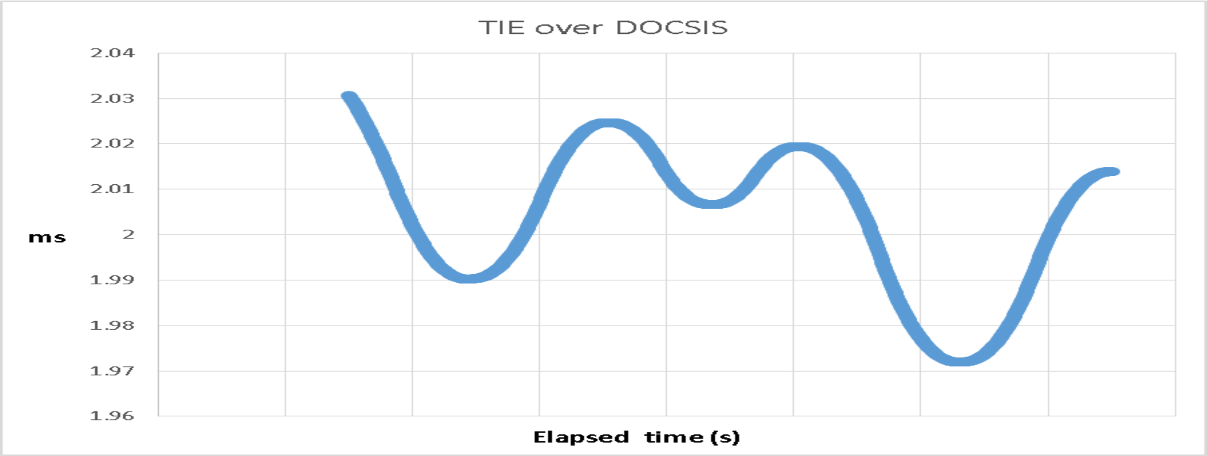
- Cellular Backhaul support through DOCSIS network is an opportunity for supporting femtocell, picocell, microcell and macrocells
- DOCSIS presents many challenges in order to support precise Timing delivery:
  - Asymmetry due the nature of DOCSIS upstream scheduling and HFC plant
  - Jitter (PDV) due 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)

Cellular Backhaul and DOCSIS

- For LTE-FDD deployments, the current DOCSIS network may be sufficient (with some improvements)



- For LTE-TDD deployments, major changes are required



DTP – DOCSIS Timing Protocol

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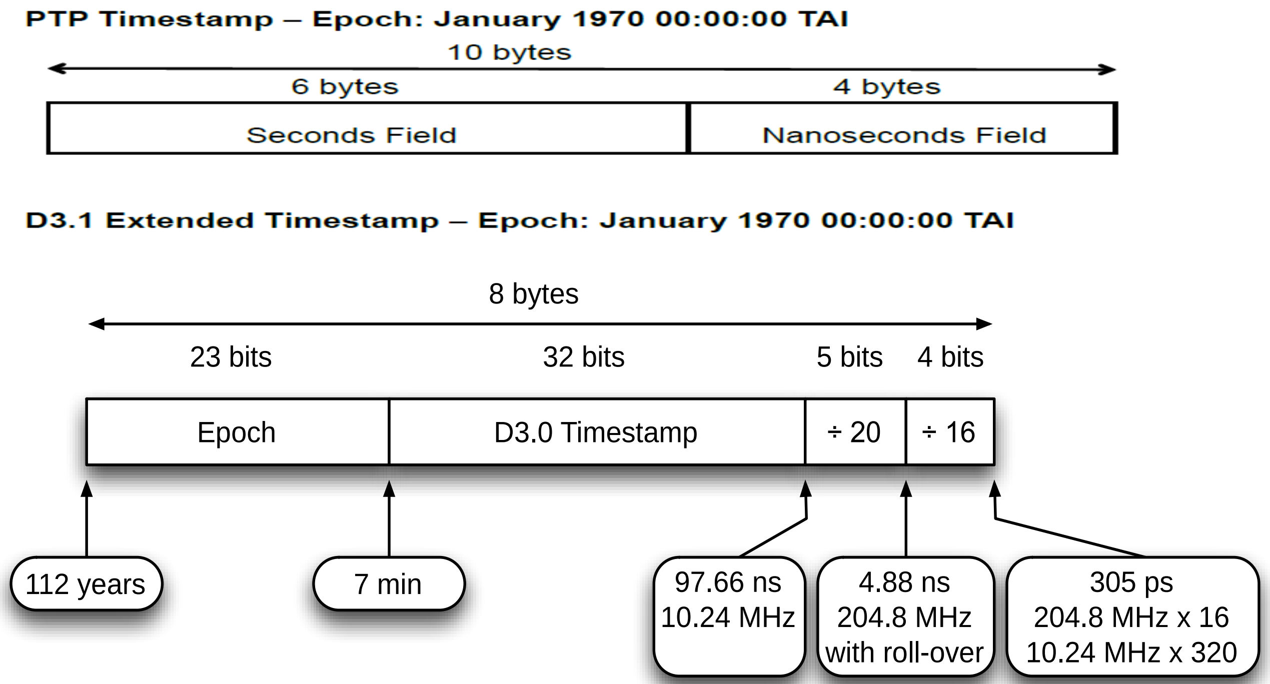
- DTP has been created to solve Timing issues and create a consistent time synchronization mechanism through the DOCSIS domain between the CMTS and CM
  - Frequency is addressed by coupling the cable modem (CM) Ethernet timing to the DOCSIS downstream Symbol clock
  - Time is addressed by:
    - Coupling the CMTS SYNC message timestamp to the PTP timestamp received from a GM
    - Coupling the CM PTP timestamp message to the DOCSIS SYNC message timestamp
  - Time offset and asymmetry will be addressed through new measurement, signaling, and ranging
- The CM would have an Ethernet output that support SyncE and PTP
- Introduced in DOCSIS 3.1

DTP Overview

DOCSIS 3.1 Extended Timesta



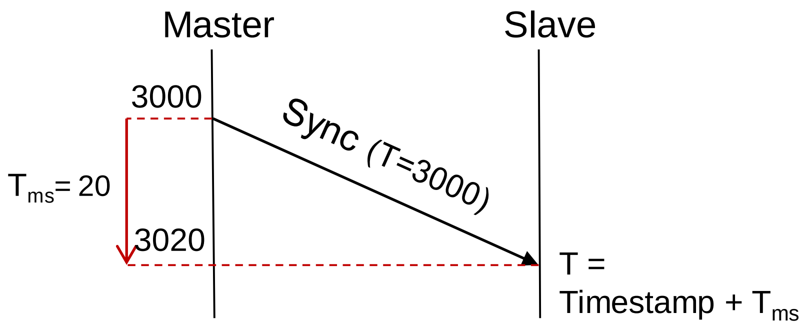
Epoch: A reference point in time (e.g., January 1970 00:00:00)

Timescale: A standard measure of time (e.g., a counter that increments at a known frequency)

Changes from DOCSIS 3.0

- Provides an absolute timestamp rather than a relative timestamp
  - Epoch: January 1970 00:00:00 (midnight)
  - Timescale: International Atomic Time (TAI), does not account for leap seconds
- Includes more bits for a higher degree of precision (305 ps versus 97.6562 ns)
- Extended time stamp is carried in the Timestamp Message Block

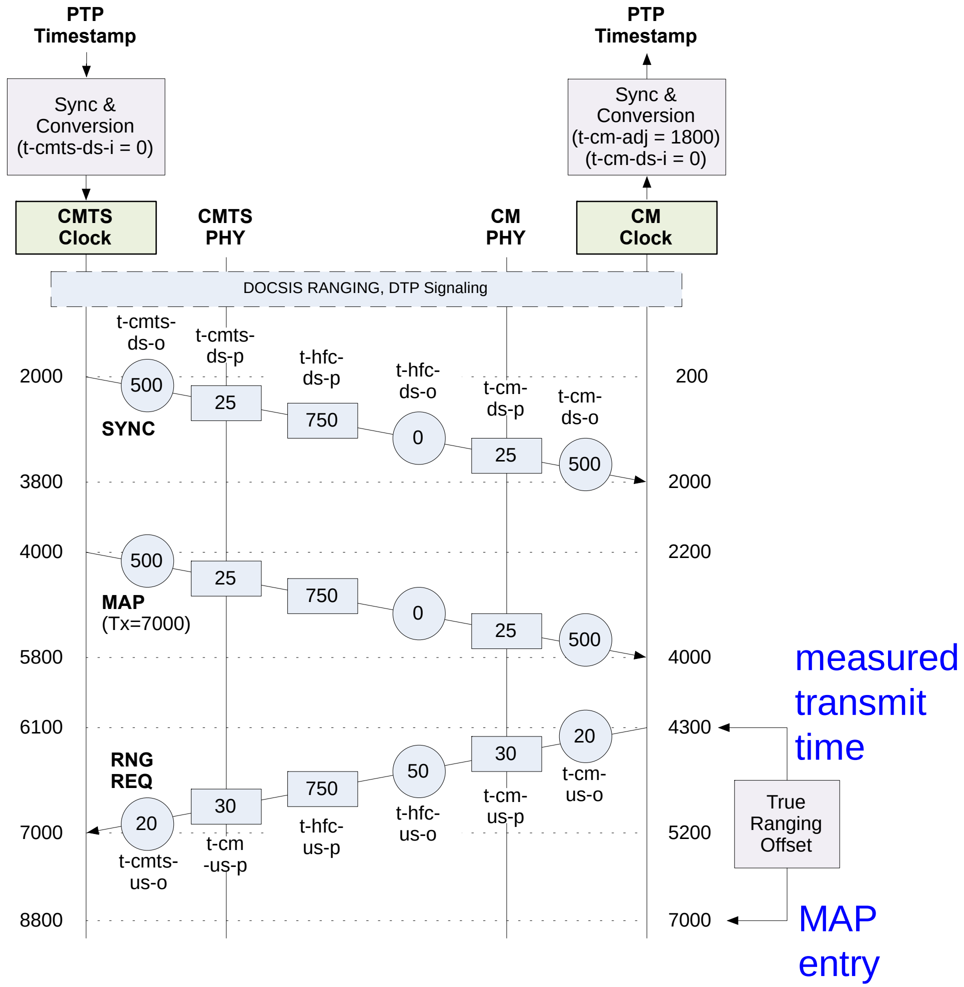
DTP - True Ranging Offset (TRO)



To synchronize its time with the master clock, the slave clock must account for the received Timestamp and the network delay.

- Much of the information needed to calculate this delay in a DOCSIS network is built into the ranging process.
- Upstream delay = Calculated primarily during the CM ranging process.
- Round trip delay (True Ranging Offset) = Calculated by the CM.
- Downstream delay = round trip delay - upstream delay.

TRO Example



TRO Measured	Round Trip Delay Between Reference Points	
	500	✓ known
	+ 25	✓ characterized
	+ 750	? to be measured
	+ 25	✓ characterized
	+ 500	✓ known
	+ 50	✓ characterized
7000	+ 800	? to be measured
- 4300	+ 50	✓ characterized
======	====	
2700	2700	

Clock offset needed =
2700(TRO) – 900(aggregated us delay)=1800

DTP Error Budget

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Table 10–9 - DTP System Timing Error Budget

Parameter		Level II System	Level III System	
T-cmts-error		± 40 ns	± 100 ns	
T-cm-error		± 40 ns	± 100 ns	
T-docsis-error		± 80 ns	± 200 ns	
T-source-skew		10 ns	25 ns	
T-hfc-error		30 ns	75 ns	
T-cm-cm-skew		200 ns	500 ns	

T-cmts-error The variance in delay that the CMTS causes as measured from the clocking ingress port (NSI or DTI) to the CMTS DOCSIS egress.

T-cm-error The variation in delay that the CM introduces as measured from the CM DOCSIS ingress port to the CM CMCI egress port.

T-docsis-error The timing error introduced by the combination of the CMTS and CM. This value is tested with a zero length HFC plant.

T-docsis-error = T-cmts-error + T-cm-error

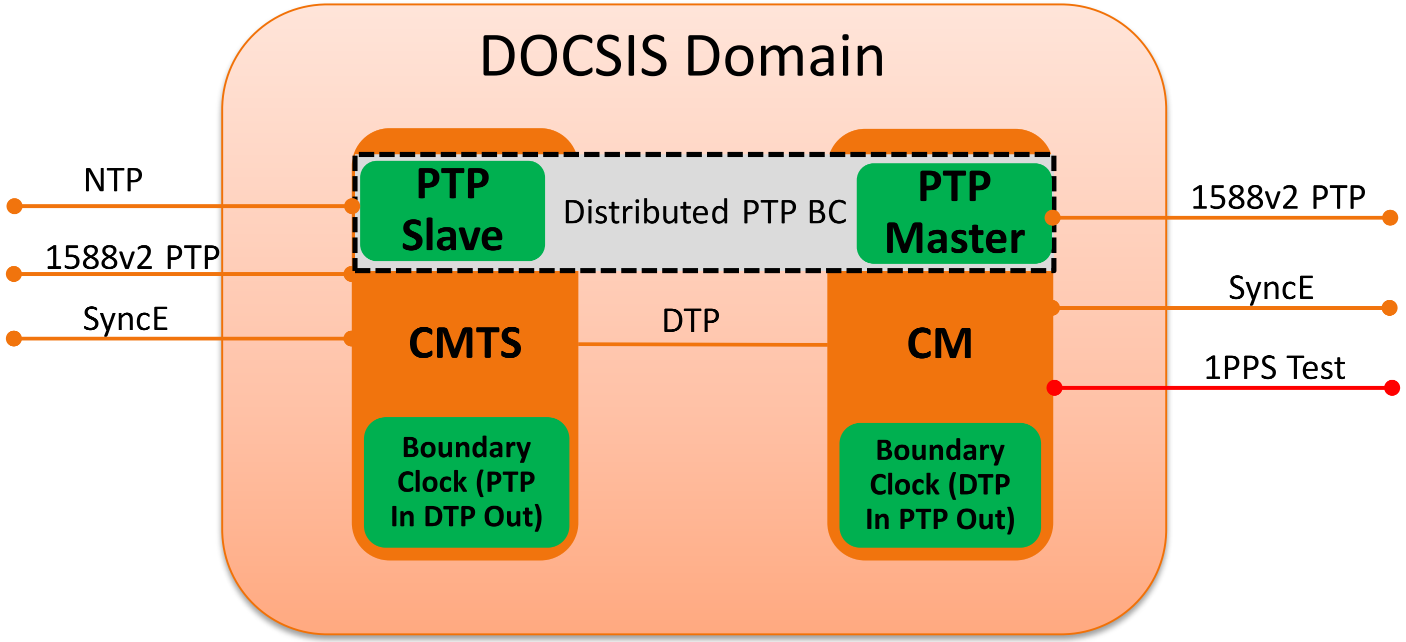
T-source-skew This is the max allowable difference in arrival time of a reference timing source at the NSI ports of two CMTSs that exist within the same timing system.

T-hfc-error This is the latency error introduced by the modeling of the HFC plant.

T-cm-cm-skew The is the skew that can occur between two similar reference points at the timing egress points on the two CMs.

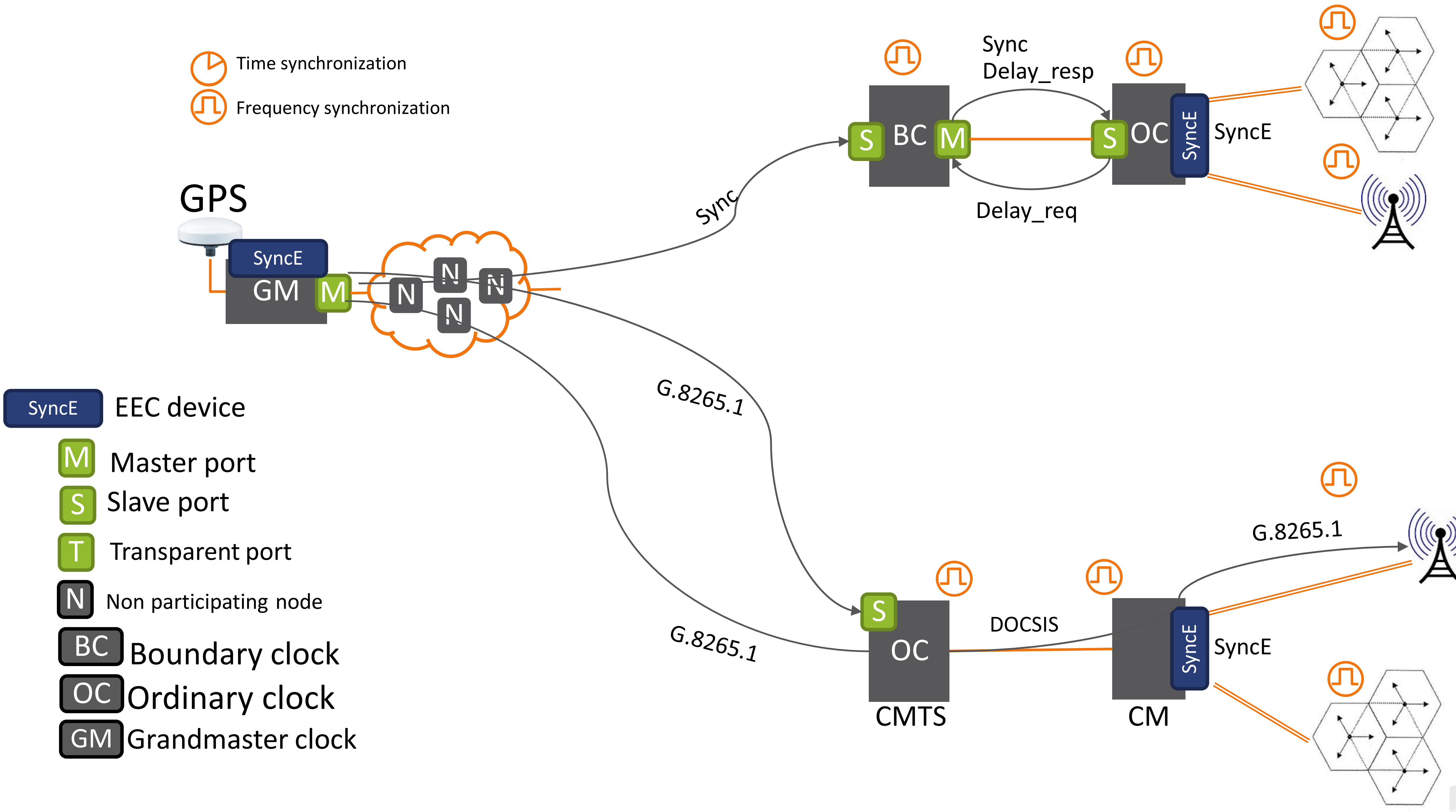
T-cm-cm-skew = 2 * T-docsis-error + T-source-skew + T-hfc-error

DOCSIS Domain Time Distribution

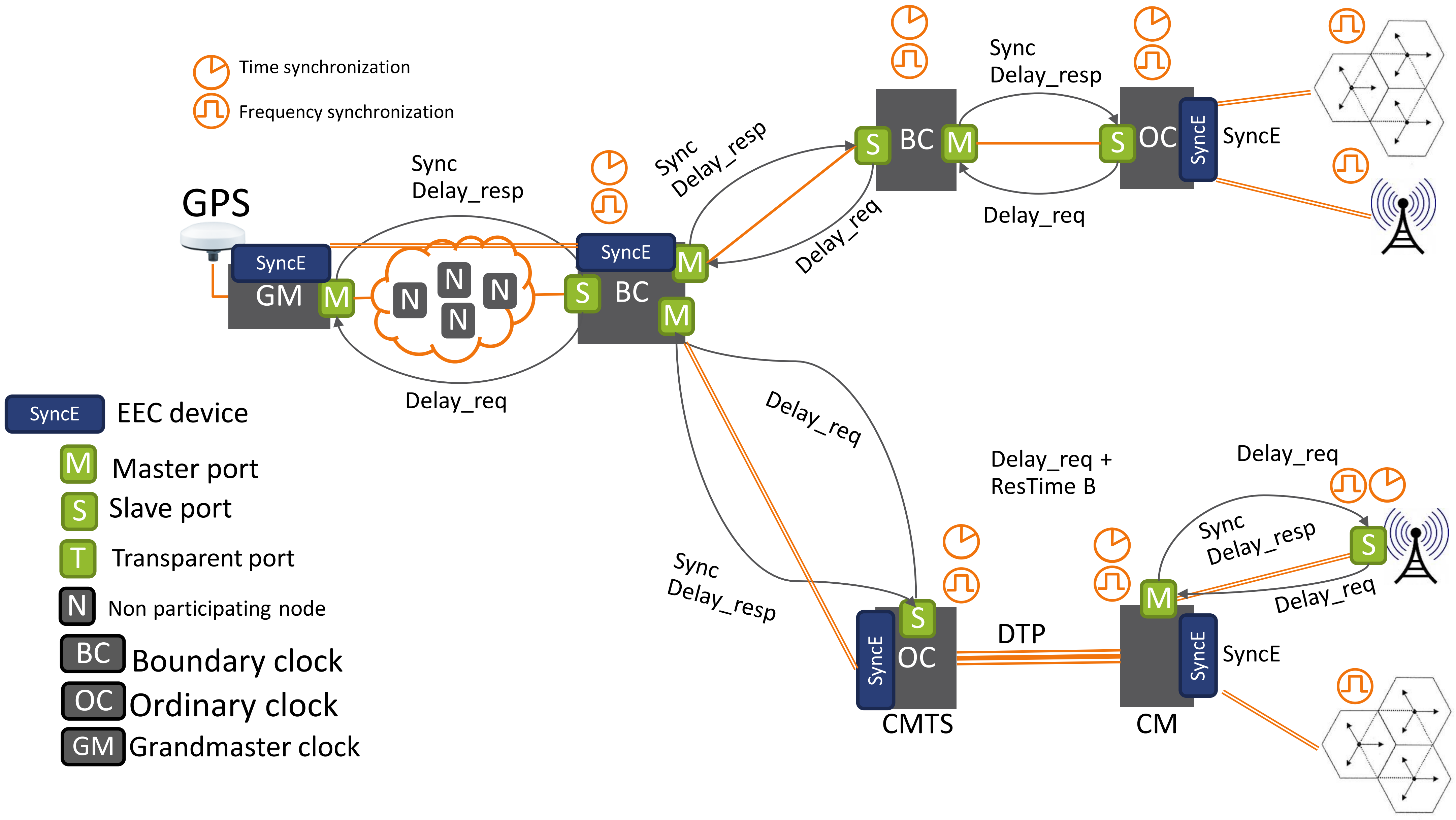


- CMTS synchronizes DOCSIS domain to network source
  - With IEEE1588v2, CMTS fulfills PTP Slave Port functions while syncing the DOCSIS Domain to its clock
  - SyncE Slave port also resides in CMTS, can be used to assist clock holdover and Locking time if SyncE primary reference clock is the same as PTP GM
- DOCSIS latency and asymmetry are measured and compensated for by DTP
- CM generates precision timing for subtending network (PTP Master and SyncE output functions reside in the CM)
- The PTP “Boundary Clock” function mainly resides in CMTS (higher quality clock), and can support tight Holdover requirements.

Frequency Delivery- PTP/SyncE (G.8265.1)



Phase Delivery- Hybrid 1588v2+SyncE (G.8275.1/2)



Thank You!