EPoC System Level Synchronization Transport
802.3bn Interim meeting - Phoenix

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Agenda

- Mobile BackHaul (MBH) & Circuit Emulation Services (CES) sync requirements
- EPON & EPoC network architecture
- IEEE 1588v2 and EPON / EPoC
- Distributed 1588v2 boundary clock concept
- EPON frequency & time sync distribution method
- EPON + EPoC distributed boundary clock
- ITU sync distribution work, standards, and budget allocations
- Potential time/frequency error budgets for EPON & EPoC
- Summary

Mobile BackHaul synchronization requirements

Wireless Technology	Frequency Accuracy	Time Accuracy
GSM	50 ppb	-
UMTS FDD	50 ppb	-
UMTS TDD	50 ppb	2.5 us
LTE FDD	50 ppb	-
LTE TDD	50 ppb	2.5 us
TD-SCDMA	50 ppb	3 us
CDMA 2000	50 ppb	3 us
WiMAX FDD	2 ppm	-
WiMAX TDD	2 ppm	3 us

[source: 3GPP, 3GPP2, IEEE 802.16e, ITU G987.1 specifications]

- Newer wireless technologies aiming for 500 ns accuracy at air interface (CoMP - Coordinated Multi-Point Transmission and Reception [1])
- FCC E911 emergency location services require ~100 ns/UTC accuracy

MEF-8 CES Synchronization requirements

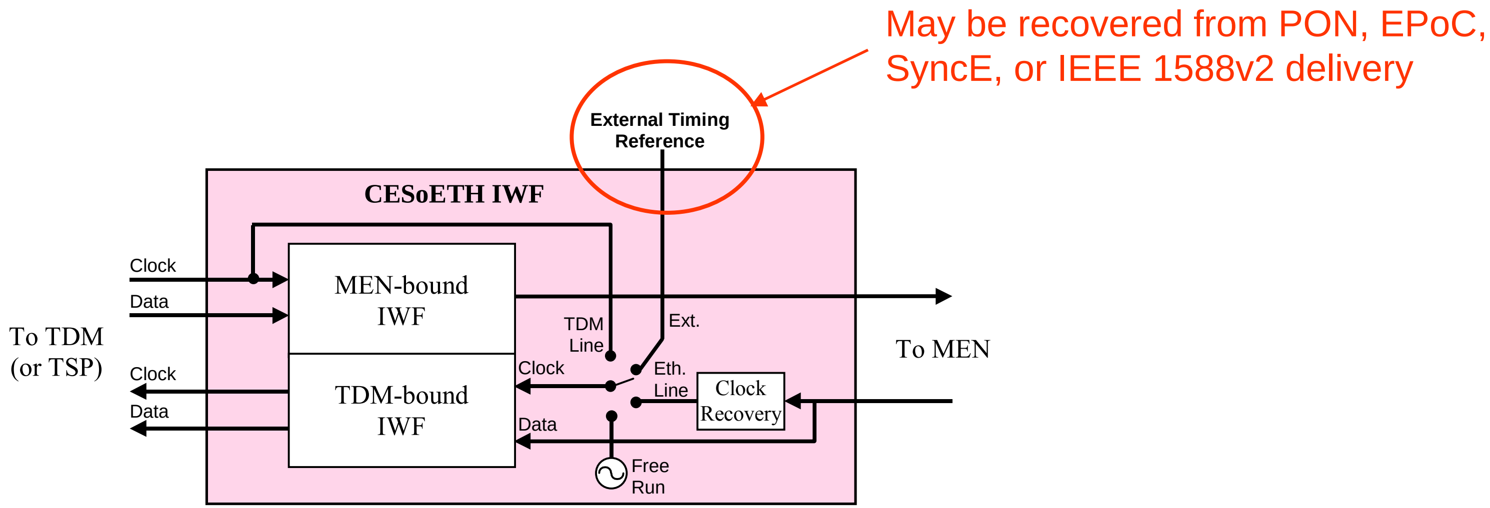


Figure 6-7/MEF-8 - Synchronization Options for the TDM bound IWF

- The External Timing Reference interface is required for Differential-mode or "network" CES timing
- MEF-8 TDM synchronization interface requirements

R47 The method of synchronization MUST be such that the TDM-bound IWF meets the traffic interface requirements specified in ITU-T recommendations [G.823] for E1 and E3 circuits, and [G.824] for DS1 and DS3 circuits

G.8261 CES Synchronization requirements

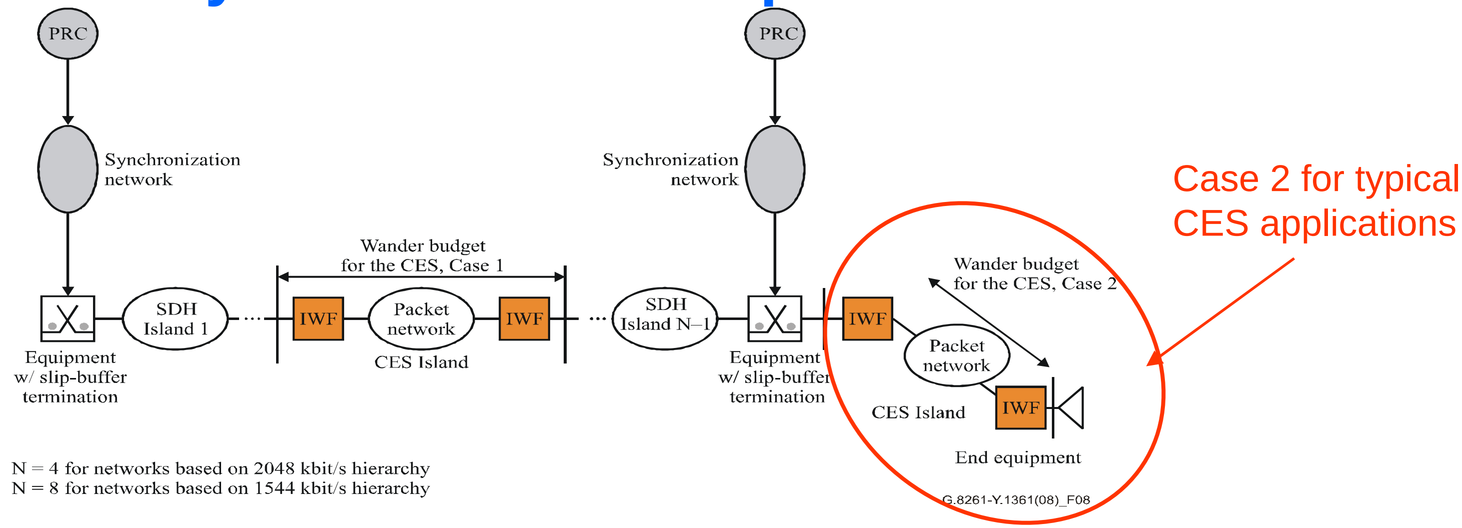


Figure 8/G.8261 - Network models for traffic and clock wander accumulation, Deployment Case 1 and Case 2

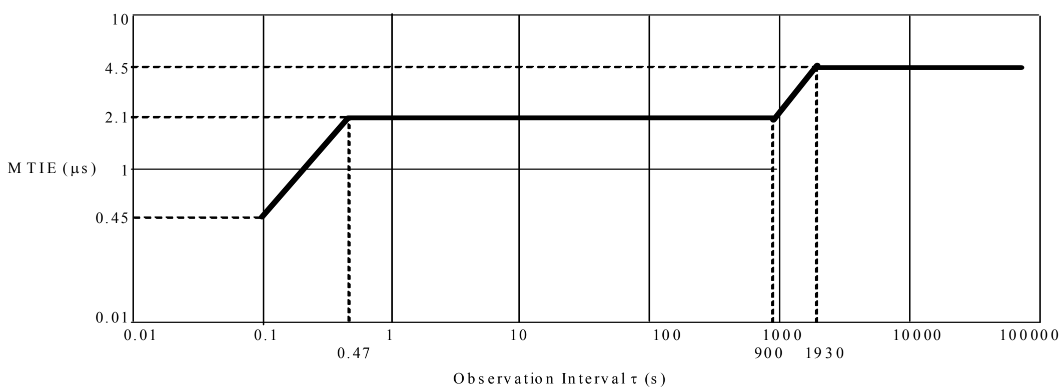
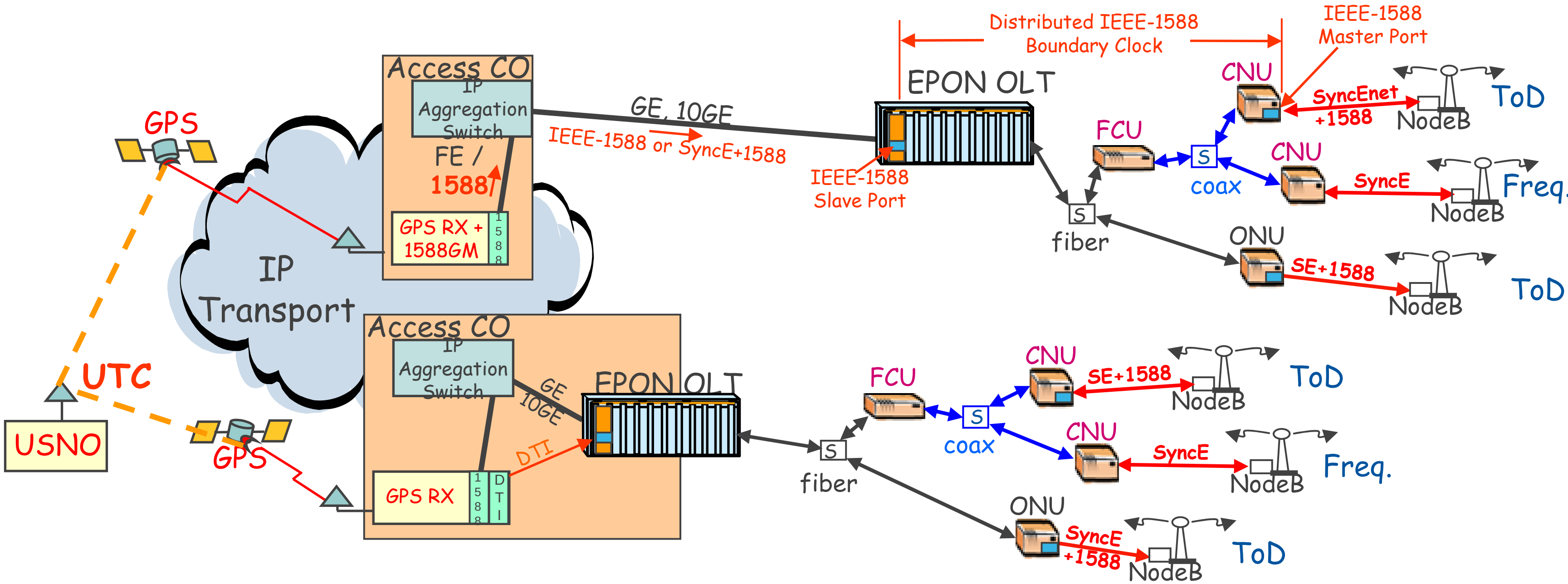


Figure 10/G.8261 - Deployment Case 1: wander budget for 1544 kbit/s interface (also applies to Case 2)

- Synchronization requirements from G.8261 are more stringent than MEF-8
  - Lower wander generation requirement
  - PDV tolerance test patterns

Synchronization delivery for Mobile BackHaul

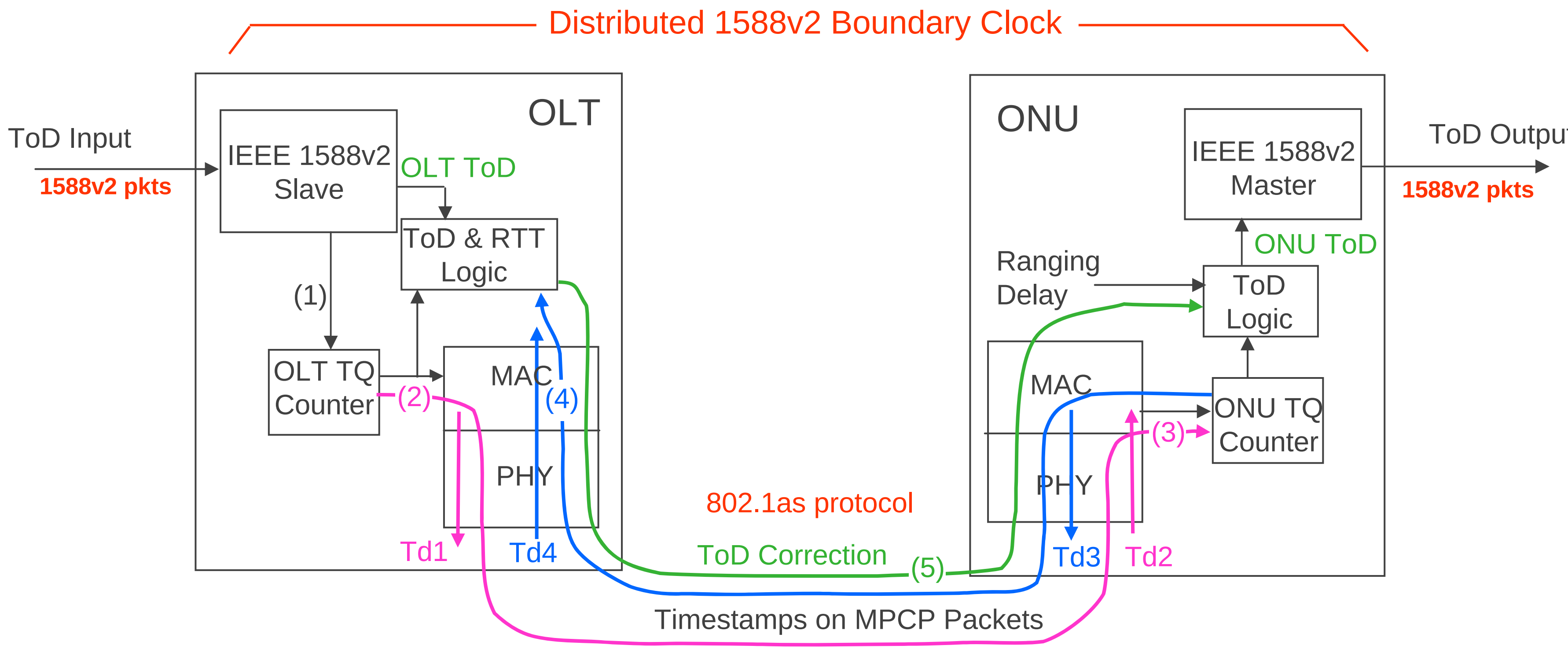


- EPoC core architecture & MBH NEs must meet FDD and TDD MBH requirements (15 ppb for Freq. & 1-1.5 usec/UTC for ToD delivery), in both FDD/TDD EPoC modes
- Should meet ITU SG15/Q13 error budget requirements for frequency (G.8261.1) and time/phase delivery (work in progress in Q13)
- Combination of EPON OLT + FCU + MBH CNU to look like a distributed IEEE 1588v2 BC (boundary clock)
- CNUs for MBH time delivery to support SyncE + IEEE 1588v2 time delivery to MBH IEEE 1588v2 slave

IEEE 1588v2 & EPON / EPoC

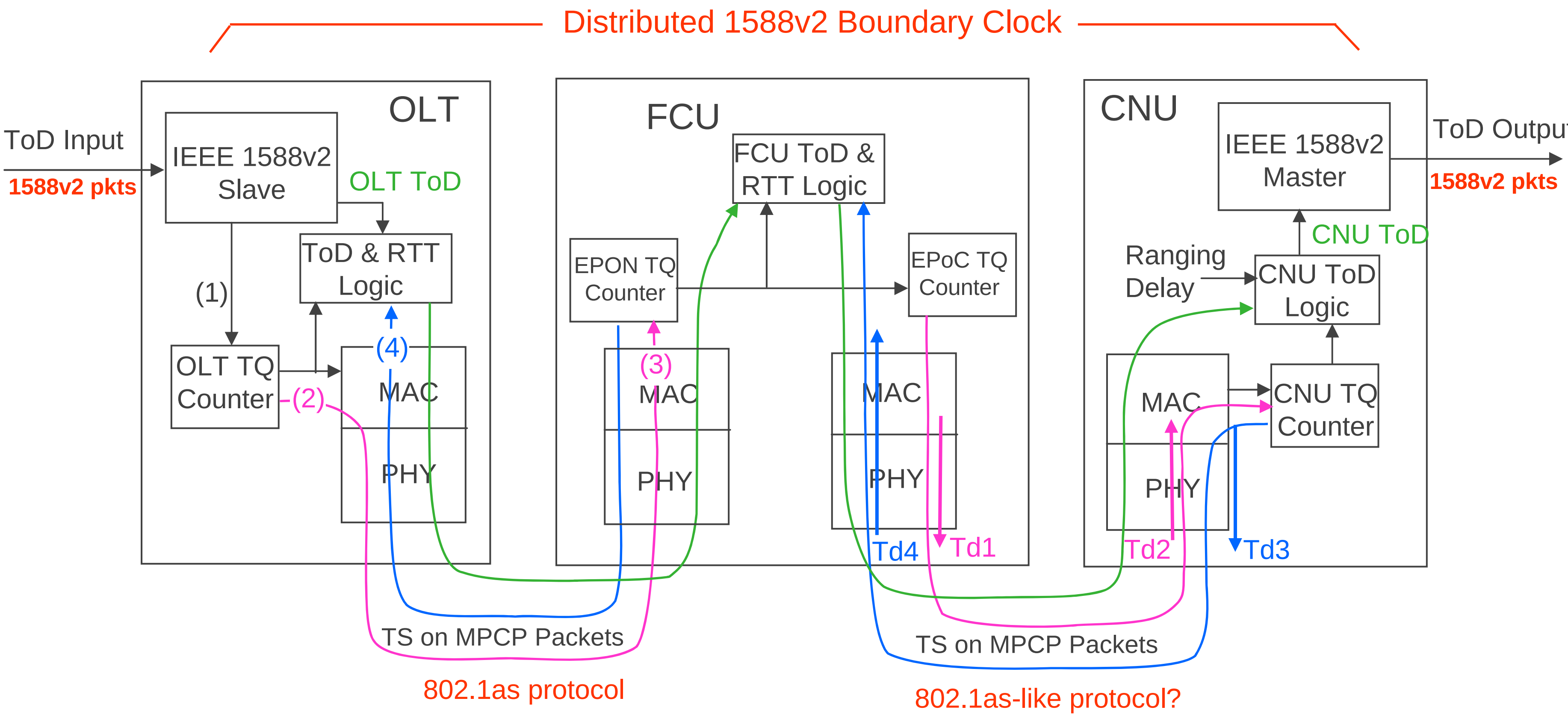
- Why can't native IEEE 1588v2 packets be transported through EPON?
  - They can, but the result is unusable for MBH time synchronization
  - IEEE 1588v2 assumes DS / US delay symmetry for time transport
  - EPON downstream TDM delay is minimal (typ. 10's of usec)
  - EPON upstream TDMA delay is much larger - polling, gate delays (typ msec)
  - Native 1588v2 packets also experience extra congestion-dependent delays (PDV, or packet delay variation) due to competing EPON traffic
  - IEEE 1588v2 assumes the 1-way link delay is ½ of the DS + US delays
    => msec-level time transfer errors through OLT/ONU for native 1588
  - Similar issues would be encountered for EPoC for native 1588 packet transport through PON and/or coax
- Solution?
  - Implement IEEE 802.1as protocol between OLT and ONU
  - OLT & ONU function as a distributed IEEE 1588v2 boundary clock

EPON Frequency and Time Distribution Method



- EPON time transport method defined in IEEE 802.1as, clause 13
- The local 32b TQ counter in the OLT (1 TQ = 16ns) is timed from an external time source (1)
- MPCP messages sent to ONUs have OLT TQ counter value loaded into timestamp (TS) field at the OLT EPON MAC (2)
- At the ONU, the timestamp is recovered from RX MPCP messages and used to reset the local ONU TQ counter (3)
- OLT calculates RTT for a particular ONU from local TQ counter vs. return timestamps from the ONU (4)
- Important that (Td1 + Td2) = (Td3 + Td4) [Td1 & Td3 - MAC(TS)->PHYout; Td2, Td4 - PHYin-> TS extracted]
- ToD at ONU calculated from local TQ counter, ranging delay, & slow ToD correction (5)
- Range of current time error: OLT-to-ONU ~120 ns [6] [local ctr - 8ns, ½ RTT drift - 96ns, DS/US fiber -17ns]

EPON + EPoC Distributed Boundary Clock



- A similar method to 802.1as can be used to transfer synchronization and ToD corrections between the EPoC FCU and CNU
- Again important for EPoC time transport (and RTT calc) that (Td1 + Td2) = (Td3 + Td4)
- Question: what level of performance is needed so the combination of EPON and EPoC meets current and emerging MBH time-sync requirements?

ITU-T G.8261.1 Sync Distribution Model - Frequency

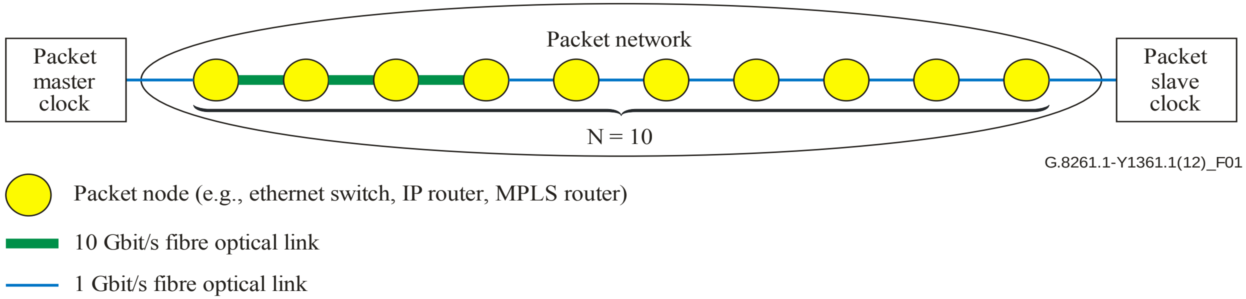


Figure 1/G.8261.1 - HRM-1 for Packet Delay Variation network limits

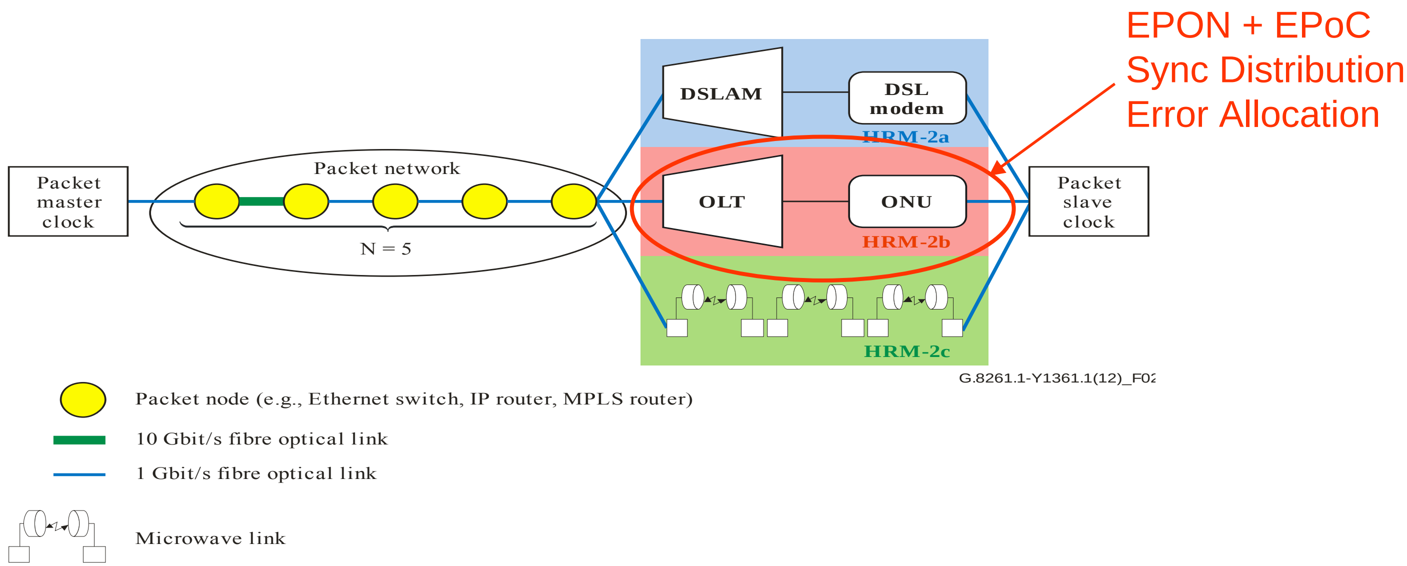


Figure 2/G.8261.1 - HRM-2 for Packet Delay Variation network limits

- ITU-T requirements on frequency synchronization of MBH are contained in G.8261 [2] & G.8261.1 [7], both - consented & active
- ITU-T synchronization studies in performed in Q13/15

G.8261.1 Sync Distribution Model - Frequency

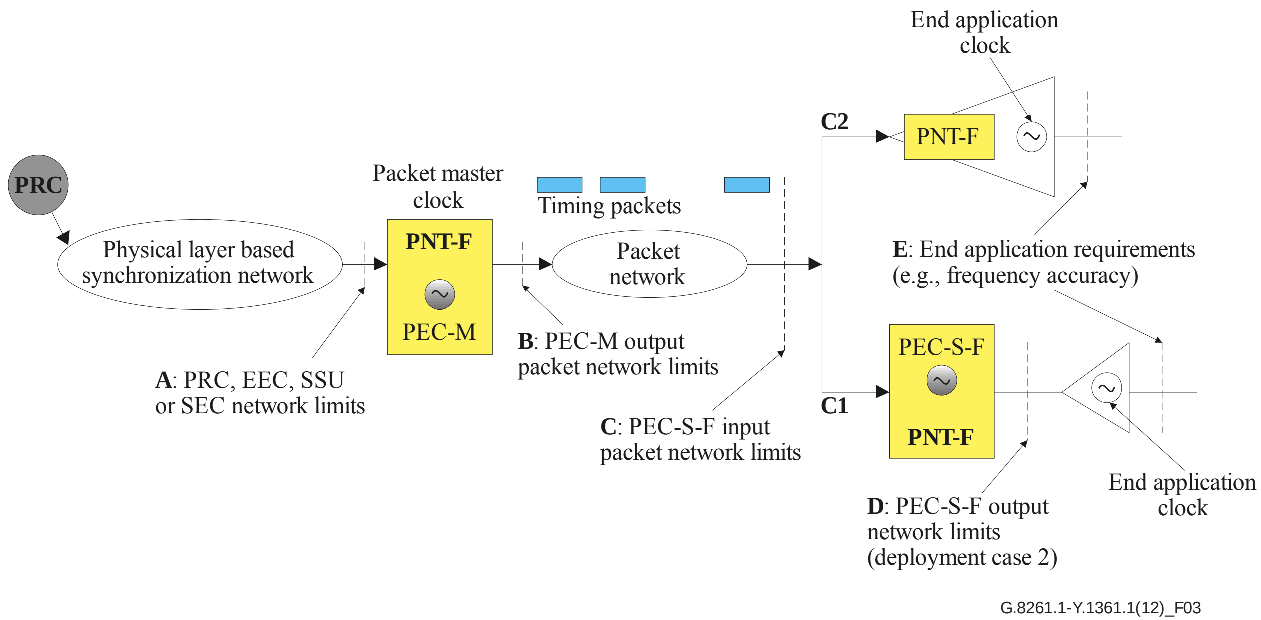


Figure 3/G.8261.1 -Reference Points for network limits

- Network PDV limits that a 1588v2 slave clock has to tolerate are defined in G.8261.1
  at the "C" interface for the PEC-S-F (packet equipment clock slave - frequency)
- MTIE and frequency accuracy requirements for the PEC-S-F are defined in G.8261.1 at the "D" interface

G.8261.1 Sync Distribution Model - Frequency

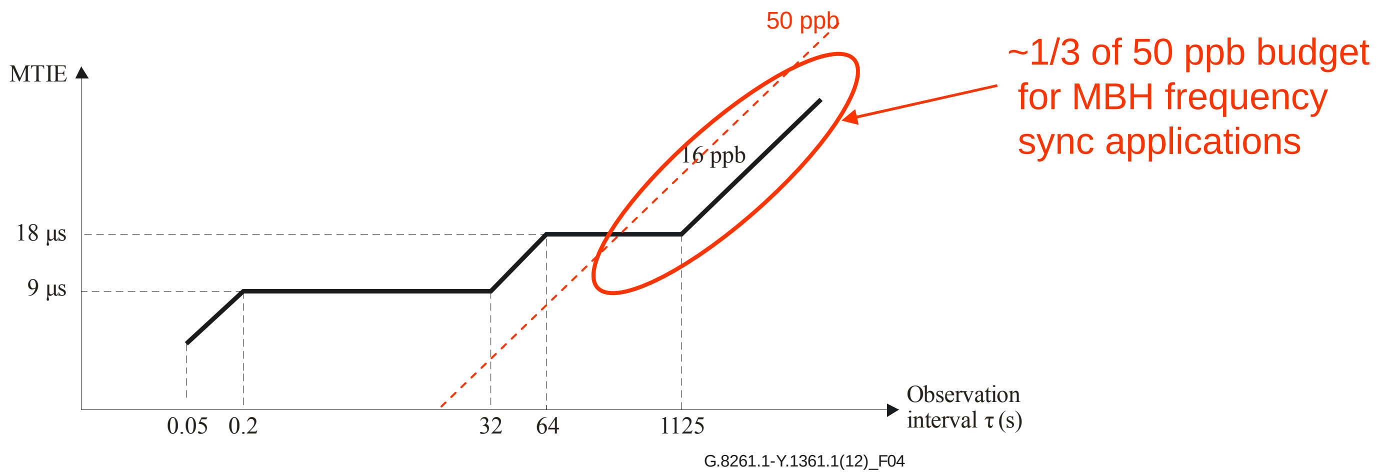


Figure 4/G.8261.1 -Output wander network limit for case 3 based on G.823

- The above MTIE interface specification has been consented in G.8261.1 [7] for MBH frequency synchronization applications
- It is recommended that both EPON ONUs and EPoC CNUs used for MBH frequency sync applications also meet the above MTIE requirement

G.8271 Sync Distribution Model - Time

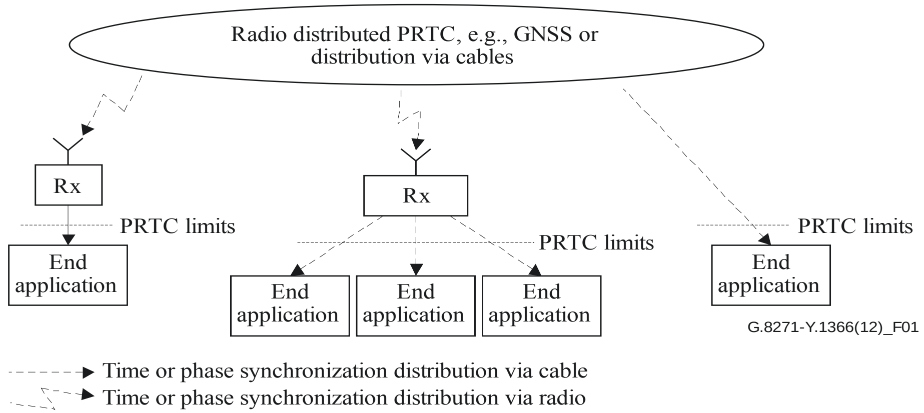


Figure 1/G.8271 -Example of a distributed PRTC synchronization network

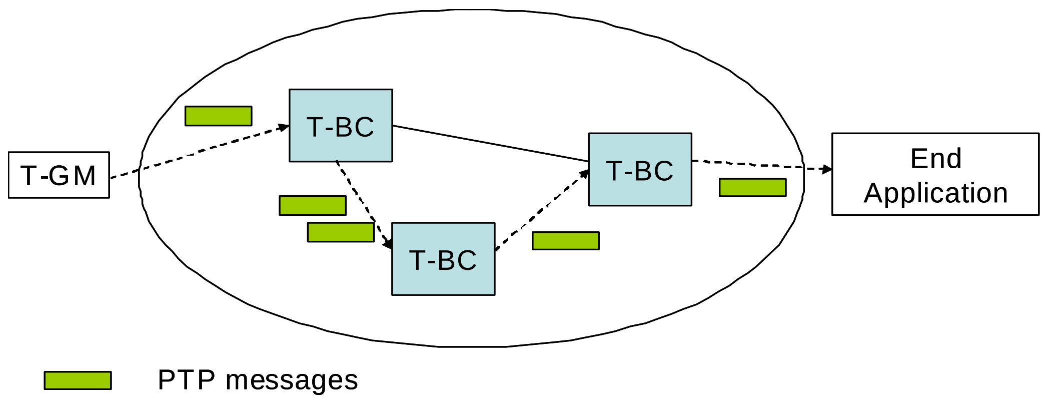


Figure 2/G.8271 -Example of packet-based method with support from network nodes

- The initial Q13/15 network models are contained in G.8271
- Q13/15 is still working on defining network topologies, PDV, and wander (MTIE) limits

G.8271 Sync Distribution Model - Time

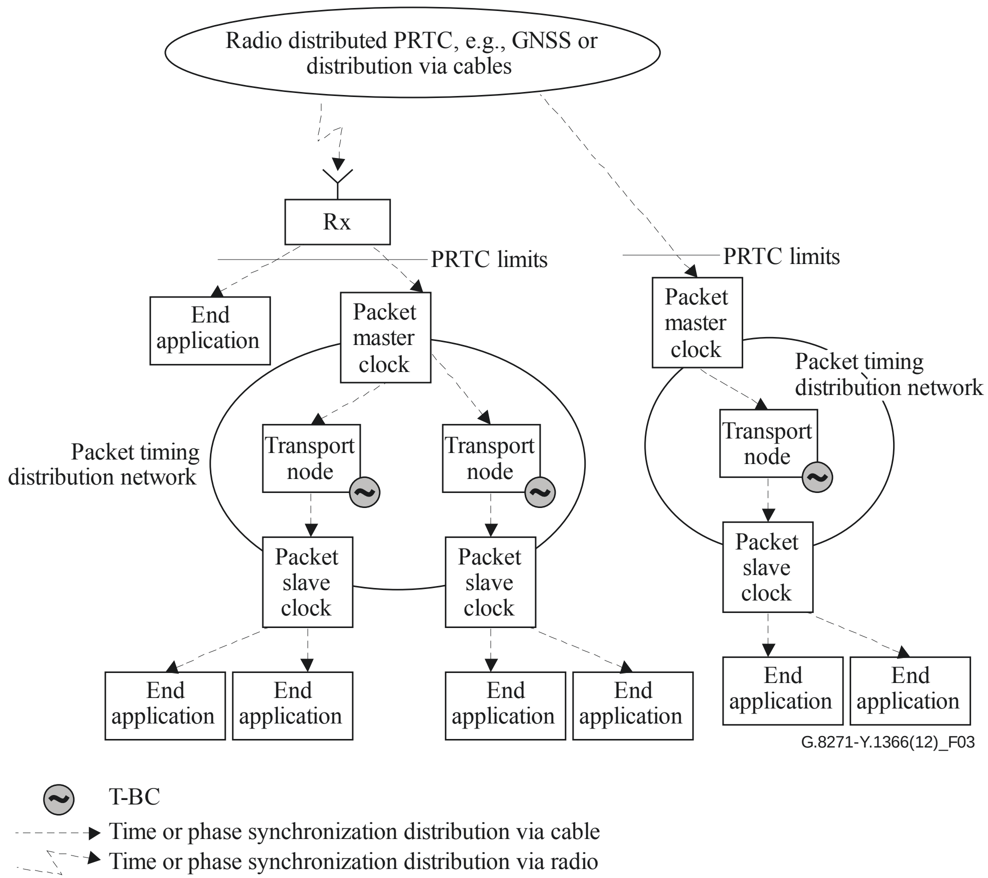


Figure 3/G.8271 - Example of time synchronization distributed via packet based methods

- Another view of the G.8271 time distribution model currently being studied in Q13/15

G.8271 Sync Distribution Model - Time

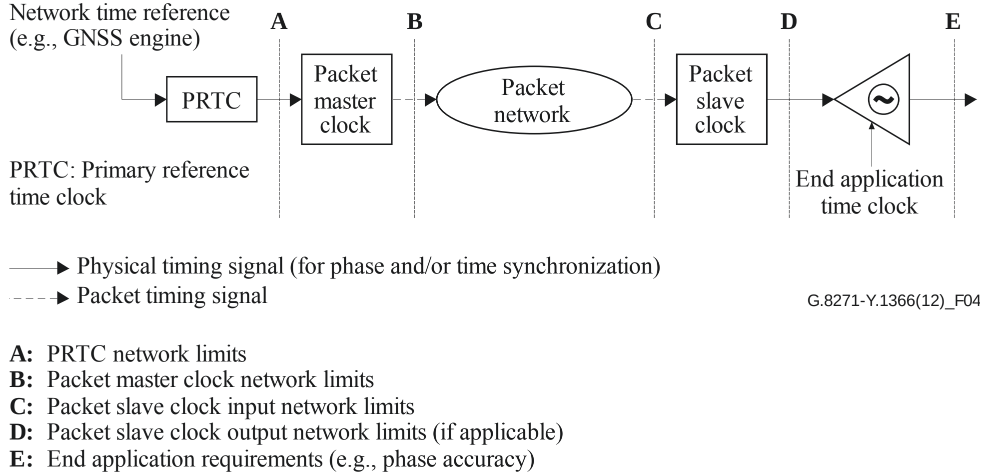


Figure 4/G.8271 -Network Reference Model

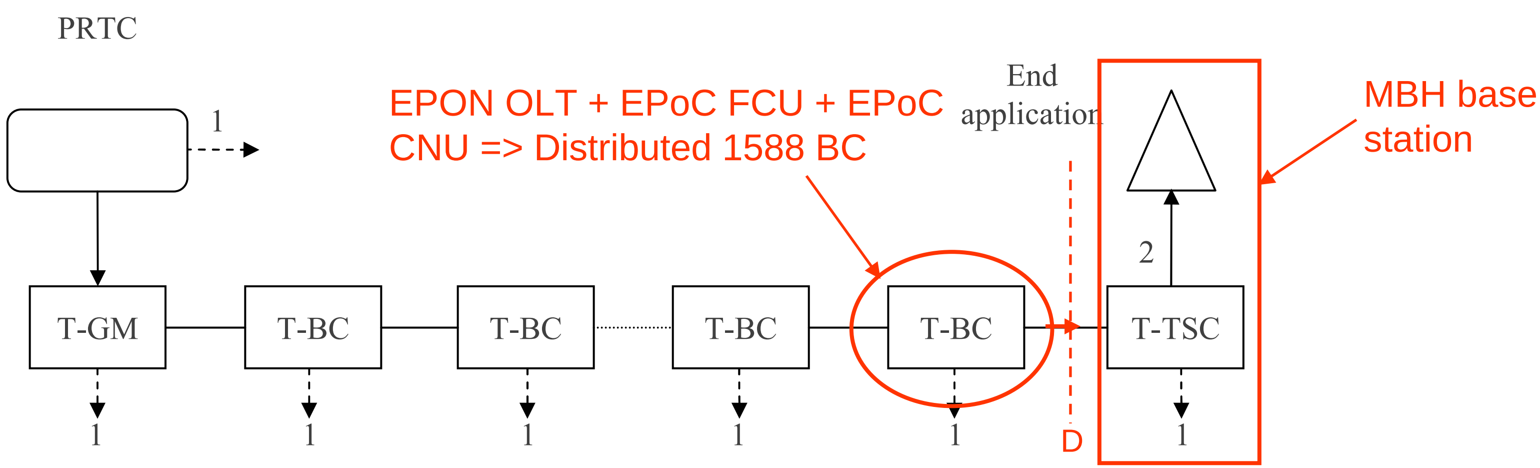


Figure 5/G.8271 -Possible locations of external phase/time interfaces in a chain of Telecom Boundary Clocks

- Current goal of Q13/15 is to meet **1.0 us** time accuracy at point D relative to UTC

Example Error budgets for Time/Frequency distribution for EPON & EPoC

- For MBH FDD applications, EPoC CNU & EPON ONU should meet MTIE requirements in Fig. 4, G.8261.1 (slide 12)
- For MBH TDD applications, it is recommended that EPON and EPoC only consume a fraction of the current 1.0 us error allocation
  Possible error allocations
  - EPON: ~125-150ns
  - EPON + EPoC: ~250 ns
- Emerging MBH time sync requirements are getting tighter: CoMP air interface ~500ns
  => Would require access segment to drop to ~150ns error budget
- FCC E911 emergency services time sync requirements ~100ns
  (limit of GPS + time receiver)
  => Likely not possible to meet with added EPON/EPoC access segment

Proposed EPoC Synchronization Evaluation Criteria

- Reference Connection

  CLT -> CNU

- Error Criteria
  - Frequency transfer Error

    </= 15 ppb

  - Time-transfer (ToD) Error
    - EPoC Link: </= +/-120ns [Tentative]

      [Goal: EPON + EPoC combined (OLT->FCU->CNU): +/-250 ns or less]

Summary

- Current and emerging wireless standards require precise frequency and time synchronization to UTC
- Combination of EPON OLT and EPON ONU, or EPON OLT + EPoC FCU + EPoC CNU can be built to function like a single distributed IEEE 1588v2 boundary clock
- ToD time transfer at OCU/FCU (EPON to coax) should be done with digital methods relative to local OCU/FCU TQ counters
- Time transfer mechanism on EPoC should function similar to method described in 802.1as, clause 13
- System level frequency and time transfer error budgets should guide choice of time transport protocol on the coax
- Proposed Eval criteria frequency/time error budget for EPoC link on previous slide

References

[1] Impact of Synchronization Impairments on CoMP Joint Transmission Performance, Helmut Imlau, Heinz Droste, Samip Malla, Deutsche Telecom, presentation at ITSF 2012 http://www.itsf-conference.com/agenda_outline/s2627/

[2] ITU-T G.8261/Y.1361, Timing and synchronization aspects in packet networks, April, 2008, http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.8261-200804-I!!PDF-E&type=items

[3] MEF-8, Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks, October, 2004.

[4] G.823, The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy, March, 2000 http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.823-200003-I!!PDF-E&type=items

[5] G.824, The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy, March, 2000 http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.824-200003-I!!PDF-E&type=items

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

[7] ITU-T G.8261.1/Y.1361.1, Packet delay variation network limits applicable to packet-based methods (frequency synchronization), February, 2012 http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.8261.1-201202-I!!PDF-E&type=items

[8] ITU-T G.8271/Y.1366, Time and phase synchronization aspects of packet networks, February, 2012, http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.8271-201202-I!!PDF-E&type=items

[9] ITU-T Q13/15, WD8271, Helsinki, 4-8 June, 2012, Draft G.8271.1 - Network limits for time synchronization in Packet Networks, Stefano Ruffini, Ericsson (editor).

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