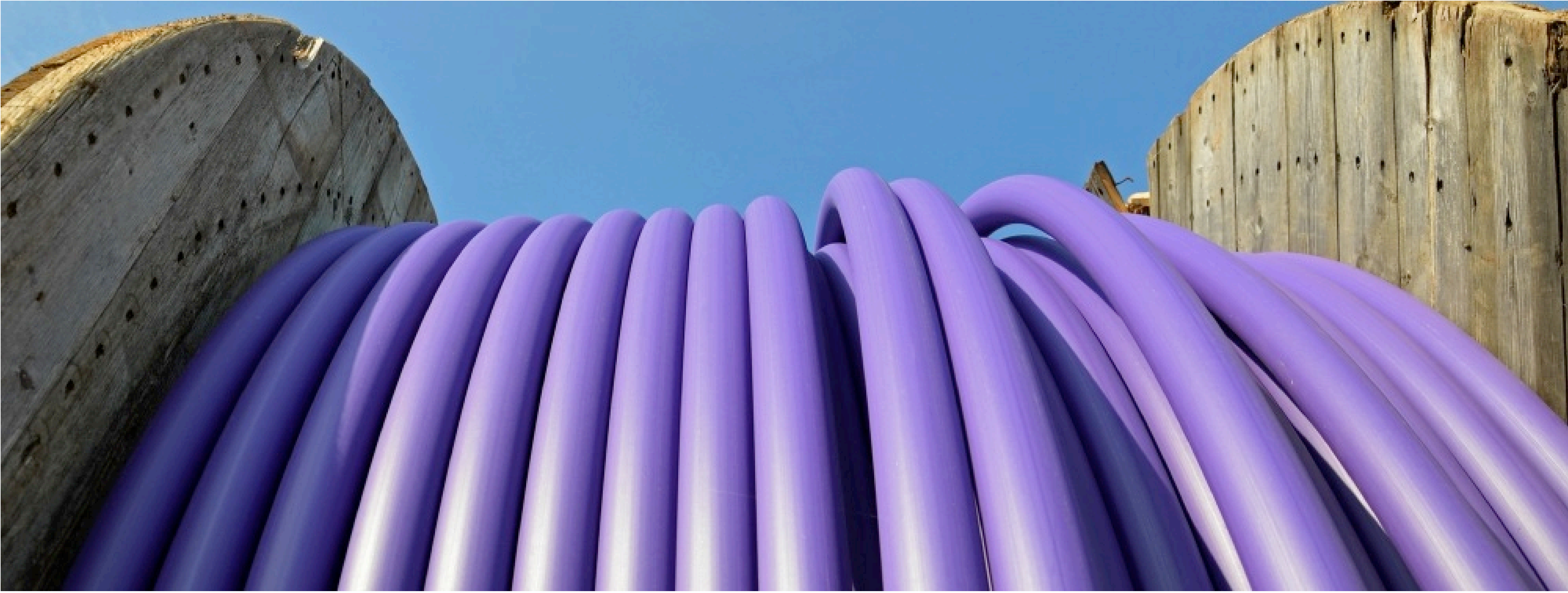

EPoC Time Transport

IEEE 802.3bn Task Force / Pittsburgh meeting

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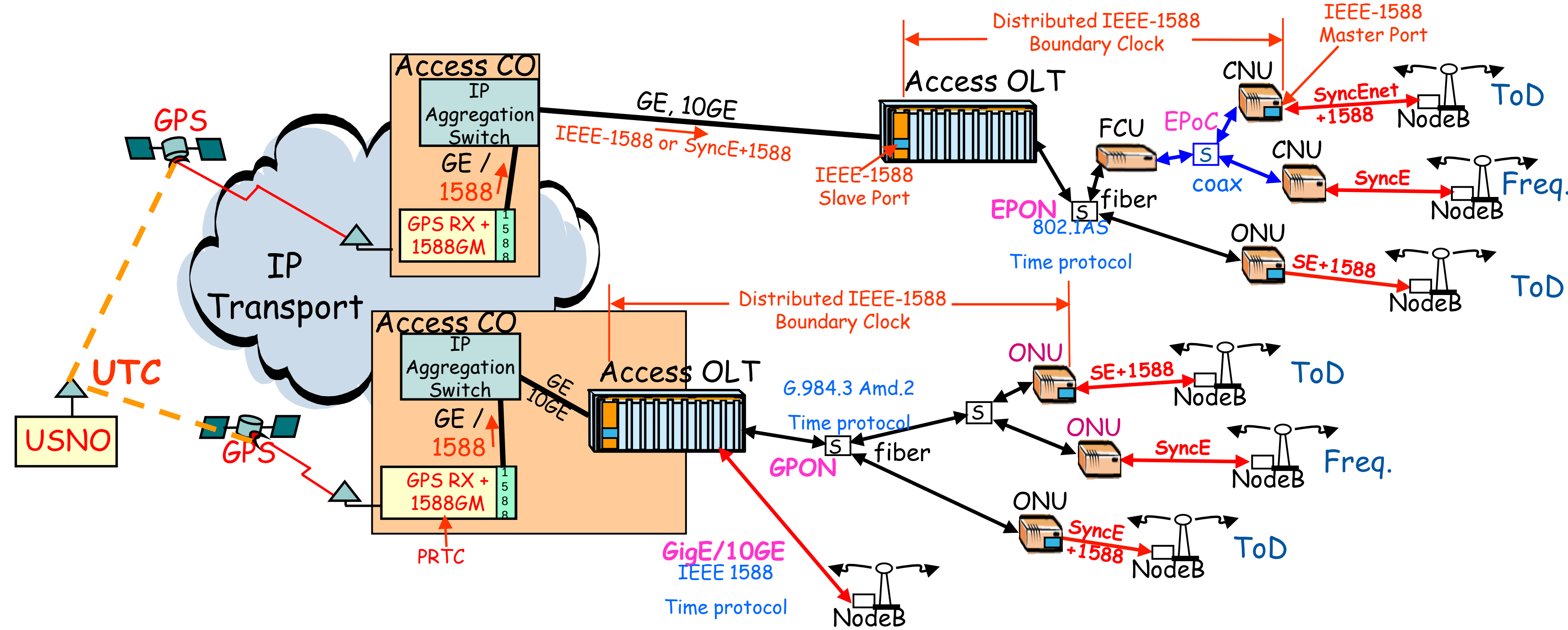
May 18, 2015

Agenda

- Review of synchronization delivery methods in access networks
- EPON time transport method
- Cascaded EPON & EPoC links
- EPoC OFDM ranging mechanism
- Improved EPoC time transport method
- Clause 90 (aka 802.3bf) Timesync parameters
- PHY TX/RX path asymmetry
- Conclusions

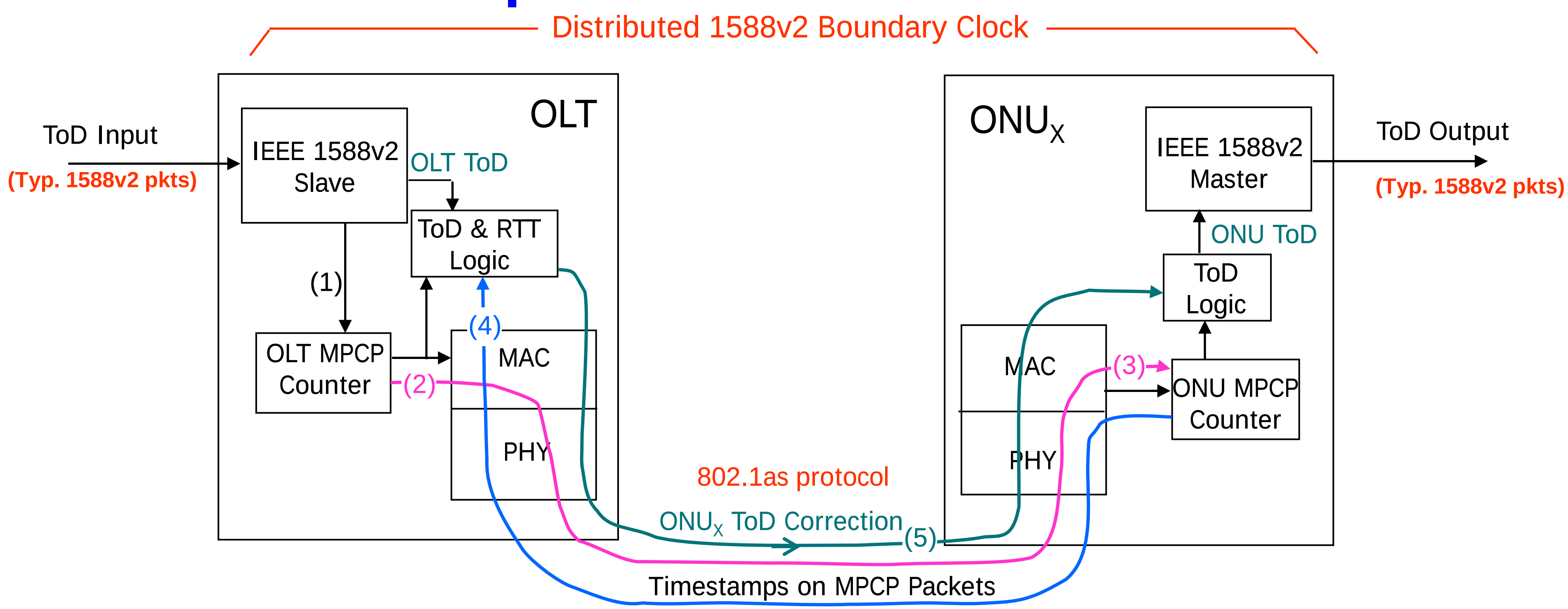
Synchronization delivery methods for Mobile BackHaul



- Mobile BackHaul (MBH) networks should meet ITU SG15/Q13 FDD and TDD MBH error budgets (15 ppb for Freq. & 1-1.5 usec/UTC for ToD delivery
- Should meet ITU SG15/Q13 error budget requirements for frequency (G.8261.1) and time/phase delivery (G.827x series in progress in Q13)
- Combination of xPON OLT & ONU (with added FCU/CNU for EPoC) should function like a “distributed” IEEE 1588v2 BC (boundary clock)
- ONUs/CNUs for MBH time delivery should support SyncE + IEEE 1588v2 time delivery to wireless base station IEEE 1588v2 slaves

From – “Mobile backhaul synchronization requirements for broadband networks,” OFC/NFOEC 2014, Bill Powell, Alcatel-Lucent, March, 2014

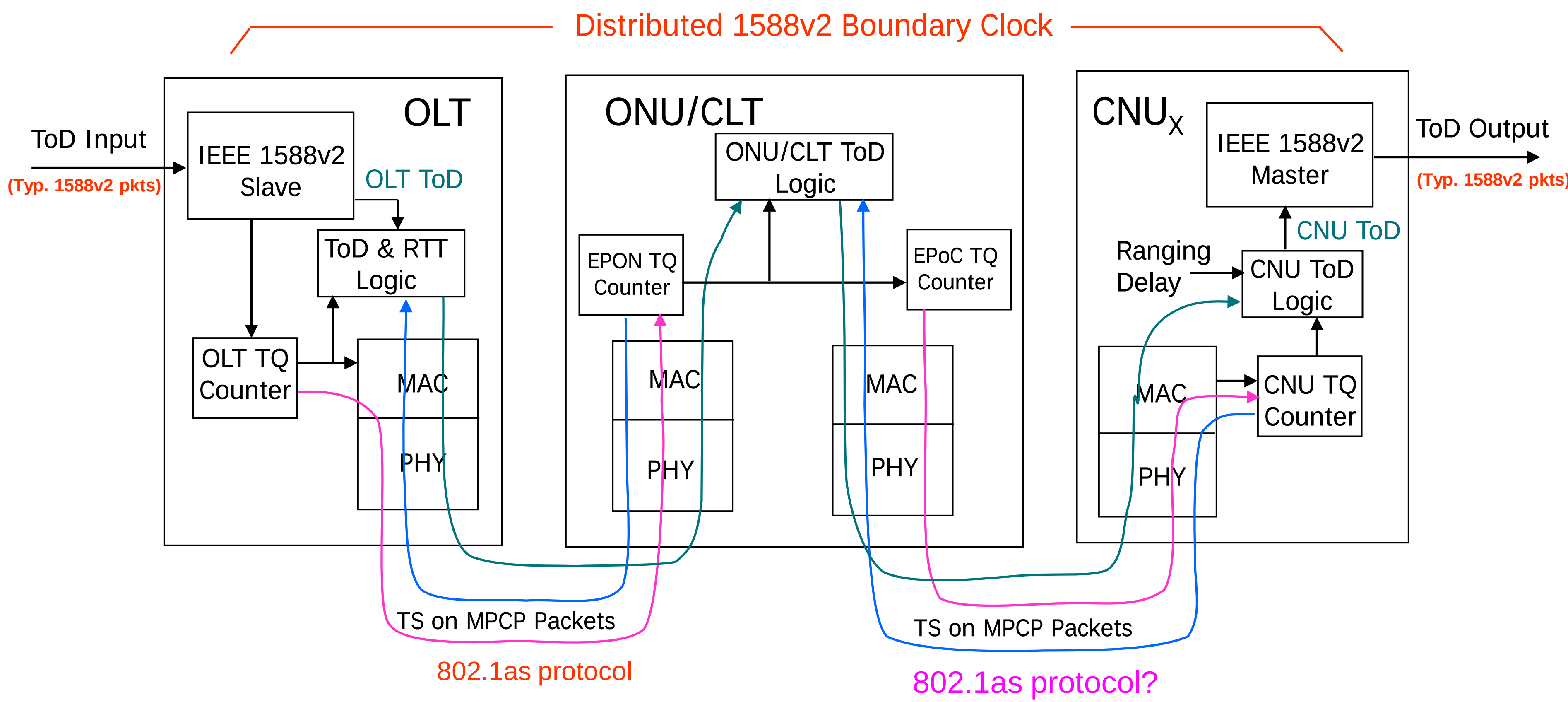
1G/10G EPON time transport mechanism



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

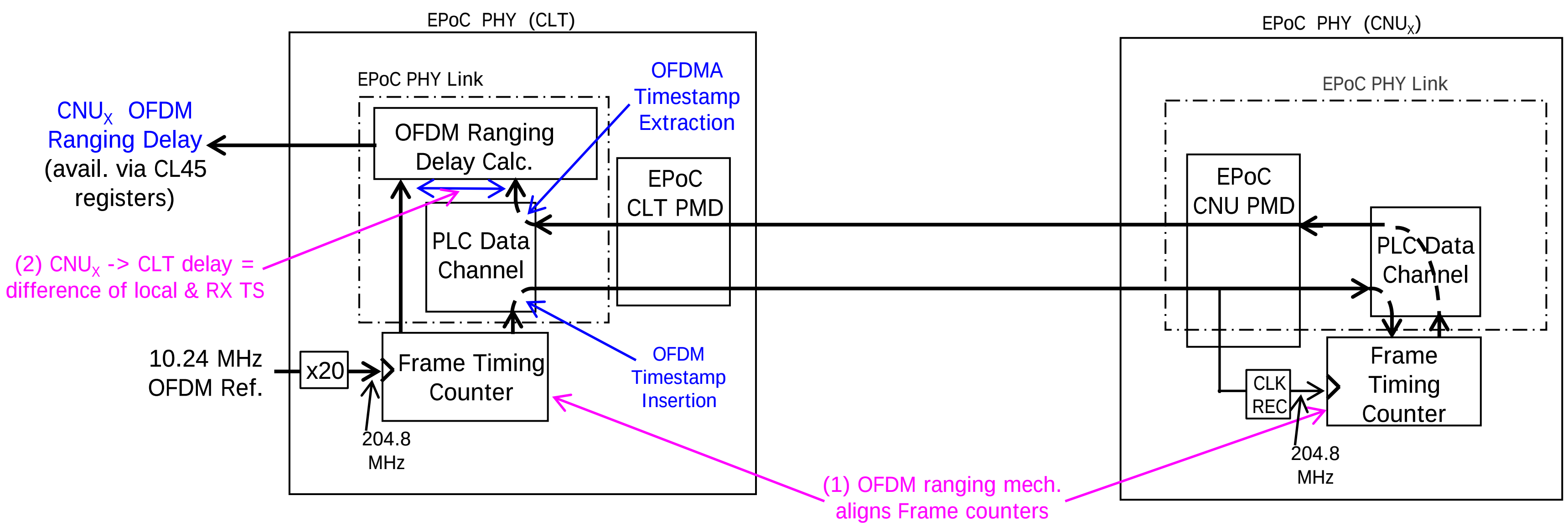
[1] Time Synchronization over Ethernet Passive Optical Networks, Yuanqiu Luo, Frank Effenberger- Huawei, Nirwan Ansari-NJIT, IEEE Communications Magazine, Oct, 2012.

Time transport errors to a CNU typically include both EPON and EPoC links



- Simply re-using the 802.1as protocol from the EPoC MPCP layer will likely more than double the OLT->CNU time transport errors of EPON (may get additional delay error through the EPoC OFDM/OFDMA PHYs)
- Since time transport errors through the EPoC CLT->CNU link are in addition to EPON time transport errors from the OLT->ONU/CLT, it is recommended to minimize EPoC time transport errors far below the inaccuracy of EPoC MPCP ranging

EPoC OFDM Ranging delay calculation



- EPoC OFDM ranging delay for each CNU_X is computed in units of the PHY 204.8 MHz OFDM clock
- Although the OFDM ranging delay only needs to be computed to a fraction of the smallest OFDMA CP (Cyclic Prefix), or a few hundred ns, it should be possible to compute the OFDM ranging delay to ~25 ns or less using OFDM fine ranging
- Since time transport errors through the EPoC CLT->CNU link are in addition to EPON time transport errors from the OLT->ONU/CLT, it is recommended to minimize EPoC time transport errors far below the inaccuracy of MPCP ranging

Improved EPoC time transport method

EPON ranging & Time Transport

- 802.1as Clause 13 species a methodology to calculate ToD_EPON_X for each ONU_X at a future MPCP frame & sends this value to each ONU_X

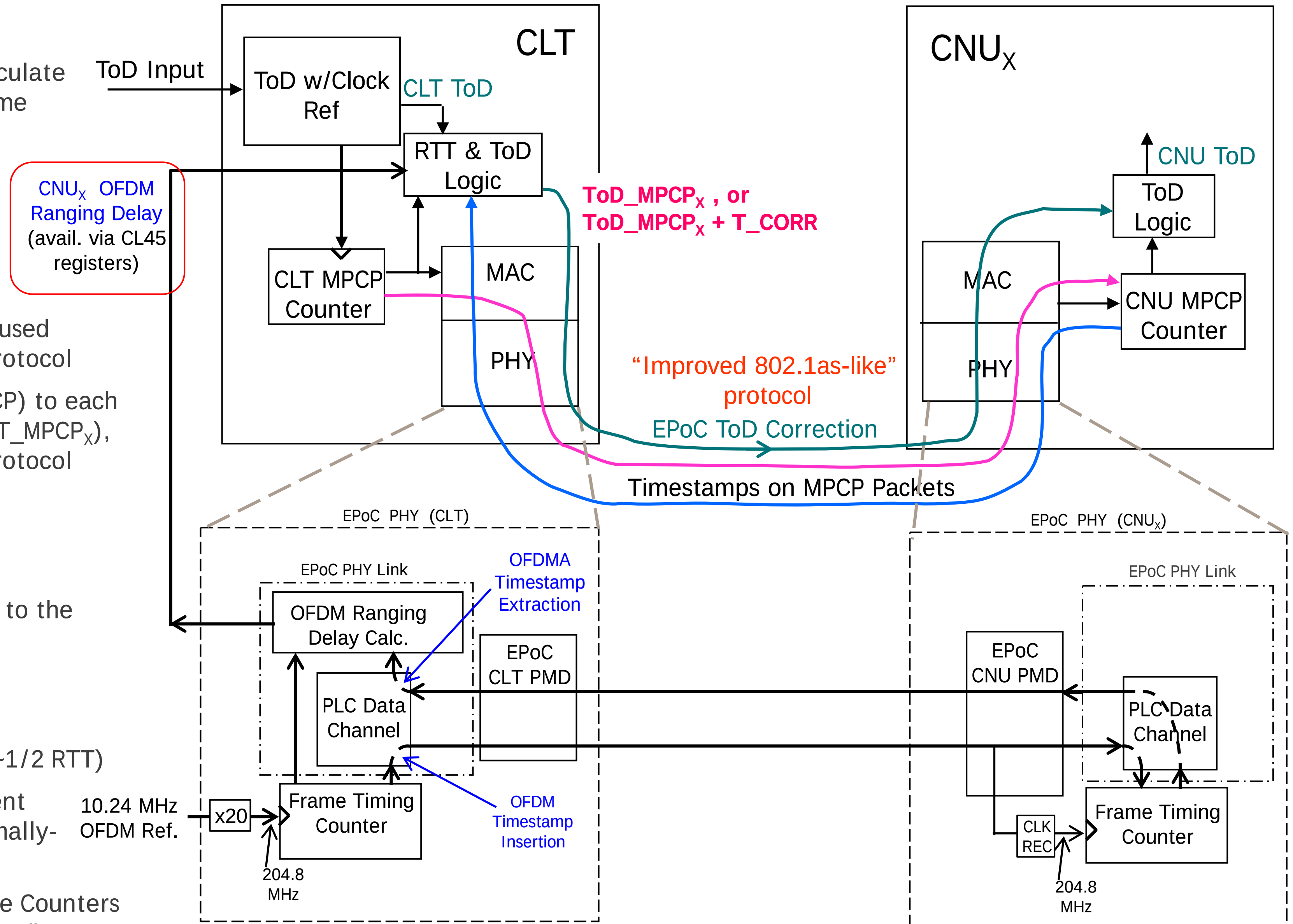
EPoC ranging & Time Transport

- EPoC PHY ranging can be much more precise in computing OFDM ranging delay (<25 ns error should be possible)
- The improved EPoC OFDM ranging delay can be used with an improved 802.1as-like time transport protocol
- Instead of sending a future ToD value (ToD_MPCP) to each CNU_X calculated using the MPCP ranging delay (T_MPCP_X), an improved version of the 802.1as Clause 13 protocol could send:

  $ToD\_MPCP_X + T\_CORR_X$

  to each CNU_X at a future MPCP frame N (similar to the current 802.1as CL13 protocol), where:

  $T\_CORR_X = T\_OFDM_X - T\_MPCP_X$
  T_OFDM_X = EPoC OFDM ranging delay for CNU_X
  T_MPCP_X = EPoC MPCP ranging delay for CNU_X (~1/2 RTT)
- The future ToD value to each CNU_X should be sent periodically to compensate for slow often thermally-induced changes in CNU ranging delay
- The CLT MPCP counter and EPOC CLT PHY Frame Counters should be locked to a common clock (phase locked)



802.3bf (802.3 Clause 90) Ethernet PHY Timesync parameters

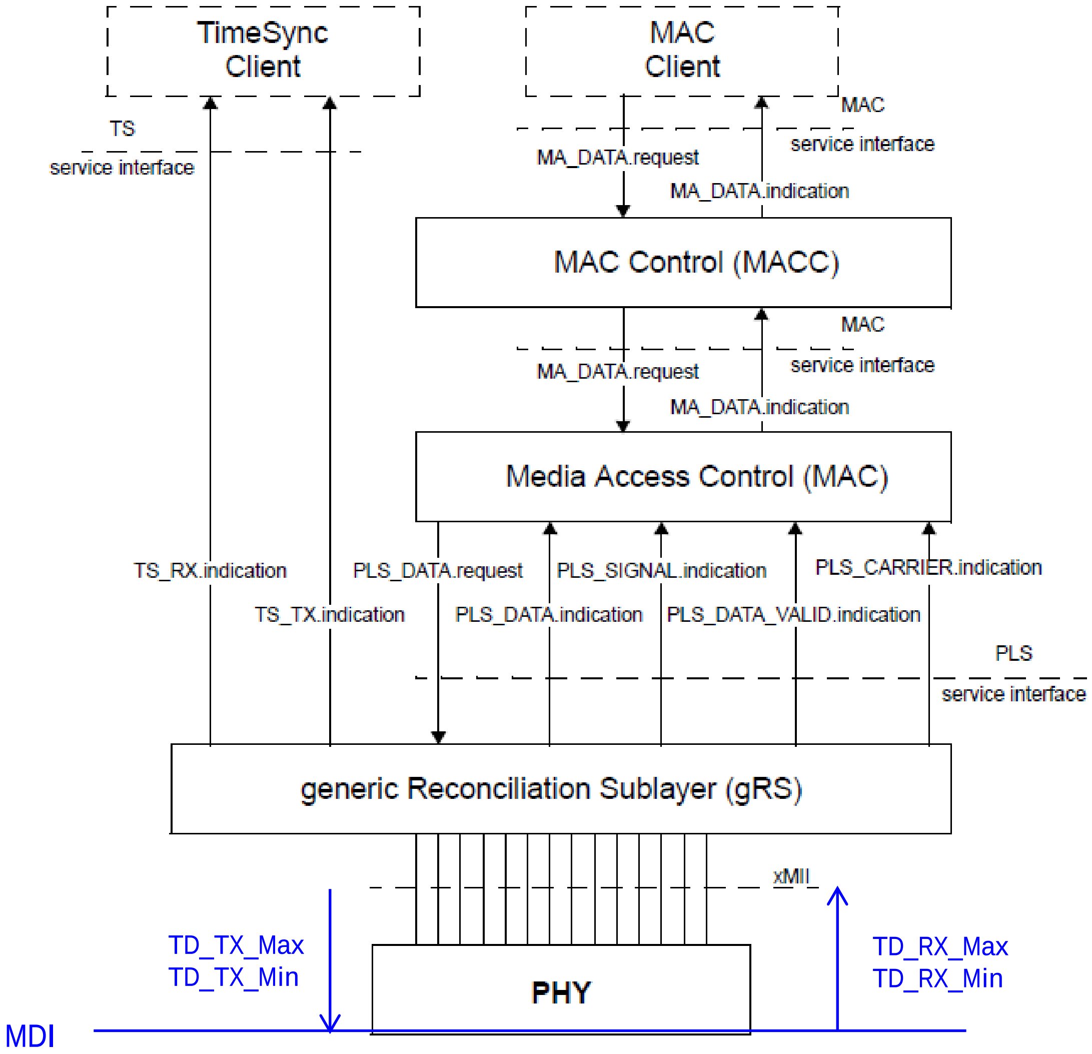


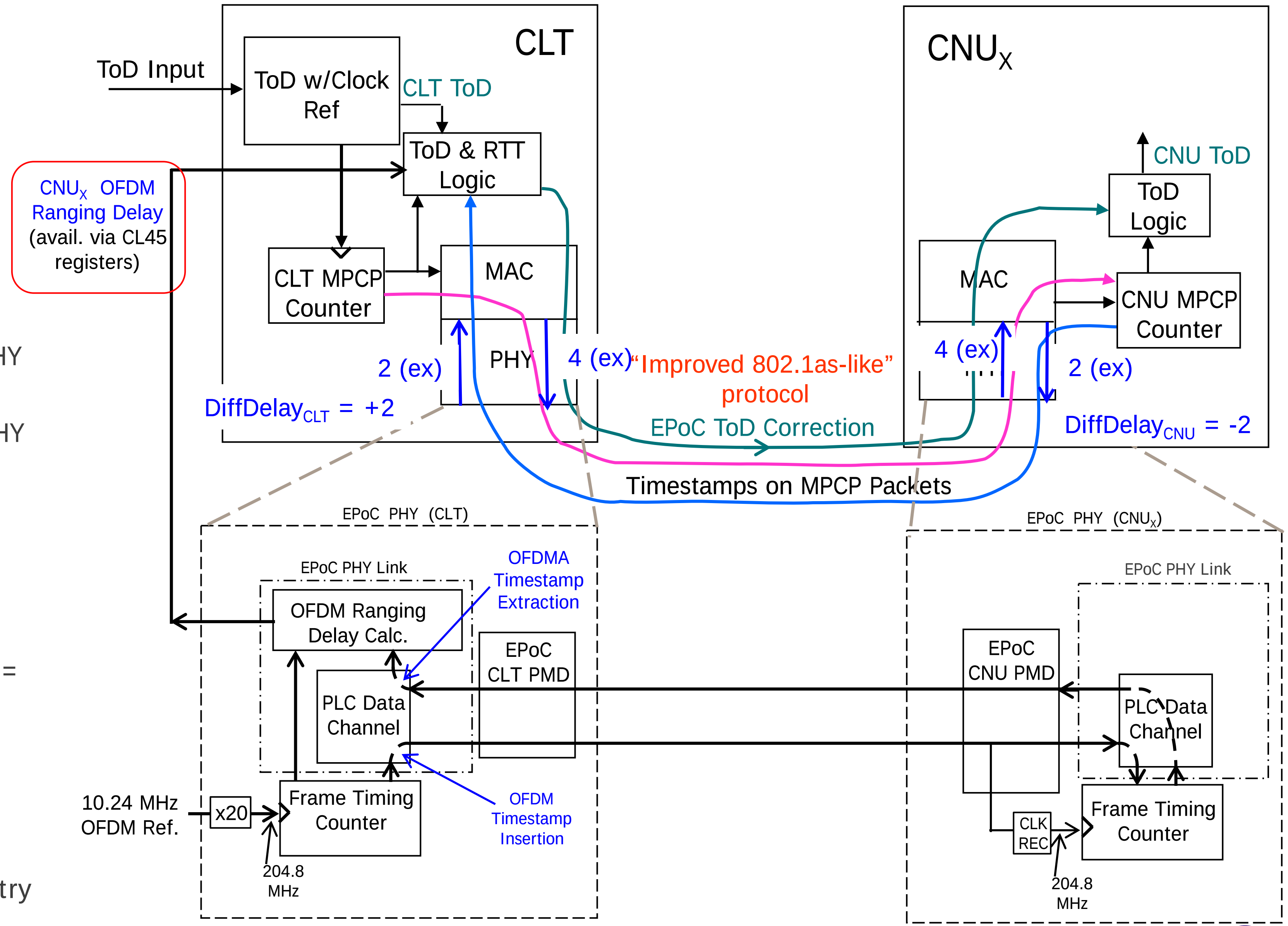
Figure 90–1—Relationship of the TimeSync Client, TSSI and gRS sublayer relative to MAC and MAC Client and associated interfaces

- Goal for minimizing time transport errors:
  TD_TX = TD_RX
- Clause 90 parameters
  - PHY TX delay – max
  - PHY TX delay – min
  - PHY RX delay – max
  - PHY RX delay – min
- Issue - No required bound on min/max or TX/RX PHY delay symmetry
- Ideal PHY behavior for time transport:
  TD_TX – TD_RX = 0 (symmetric delay)
- We really only care about the magnitude of the asymmetry, not min, max or even nominal delays

PHY transmit/receive path asymmetry

New Clause 45 PHY delay parameters

- DiffDelay
  difference in delay between the XGMII interface to the MDI interface path and the MDI interface to the XGMII interface path in units of 1/204.8 MHz
- DiffDelayTol
  the tolerance (max error) of the DiffDelay variable in units of 1/204.8 MHz
- Above variables defined for both the CLT PHY and the CNU PHY
- $DiffDelay_{CLT} - DiffDelay_{CNU}$ = total TX / RX PHY path asymmetry
- Example shown:
  $DiffDelay_{CLT} - DiffDelay_{CNU}$ = +2 – (-2) - +4
  Check:
  DS PHY Delays ($CLT_{TX} + CNU_{RX}$) = 4 + 4 = 8
  US PHY Delays ($CNU_{TX} + CLT_{RX}$) = 2 + 2 = 4
  PhyDelay(CLT->CNU) – PhyDelay(CNU->CLT) = 8 – 4 = +4
- Possible different manufacturers for CLT & CNU silicon so we cannot expect DS PHY delays to equal US PHY delays
- This method does not require DS/US delay symmetry, but can compensate for asymmetry if Diff params specified for each end



Summary

- MPCP ranging algorithm only estimates 1-way time delay (1/2 RTT) to ~100ns accuracy
- EPoC PLC OFDM ranging method should provide ~10-25 ns OFDM ranging accuracy
- Use of OFDM ranging delays for individual CNUs can be used with an improved (future) 802.1as Clause 13 algorithm to significantly improve EPoC CLT->CNU time transport accuracy
- Clause 90 (aka 802.3bf) PHY time delay parameters specify registers for min/max values with no guarantee of TX/RX symmetry
- Use of newly proposed EPoC DiffDelay and DiffDelayTol parameters to specify PHY delay asymmetry & max error can additionally enhance a future 802.1as Clause 13 time transport algorithm improvement