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

<table>
<thead>
<tr>
<th>Wireless Technology</th>
<th>Frequency Accuracy</th>
<th>Time Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>50 ppb</td>
<td>-</td>
</tr>
<tr>
<td>UMTS FDD</td>
<td>50 ppb</td>
<td>-</td>
</tr>
<tr>
<td>UMTS TDD</td>
<td>50 ppb</td>
<td>2.5 us</td>
</tr>
<tr>
<td>LTE FDD</td>
<td>50 ppb</td>
<td>-</td>
</tr>
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<td>50 ppb</td>
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<tr>
<td>TD-SCDMA</td>
<td>50 ppb</td>
<td>3 us</td>
</tr>
<tr>
<td>CDMA 2000</td>
<td>50 ppb</td>
<td>3 us</td>
</tr>
<tr>
<td>WiMAX FDD</td>
<td>2 ppm</td>
<td>-</td>
</tr>
<tr>
<td>WiMAX TDD</td>
<td>2 ppm</td>
<td>3 us</td>
</tr>
</tbody>
</table>

[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

- 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

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

May be recovered from PON, EPoC, SyncE, or IEEE 1588v2 delivery
G.8261 CES Synchronization requirements

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

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 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)
- CNUss 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 \( \frac{1}{2} \) of the DS + US delays
    \[ \Rightarrow \text{msec-level time transfer errors through OLT/ONU for native 1588} \]
  - 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 \((Td1 + Td2) = (Td3 + Td4)\) \([Td1 & Td3 - MAC(TS)\rightarrow PHYout; Td2, Td4 - PHYin\rightarrow TS extracted]\)
- ToD at ONU calculated from local TQ counter, ranging delay, & slow ToD correction (5)
- Range of current time error: OLT-to-ONU \(\sim 120\) ns \([6] \) \([\text{local ctr - 8ns, } \frac{1}{2} \text{ RTT drift - 96ns, DS/US fiber -17ns}]\)
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

- Packet master clock
- Packet network
- Packet slave clock
- Packet node (e.g., ethernet switch, IP router, MPLS router)
- 10 Gbit/s fibre optical link
- 1 Gbit/s fibre optical link

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

- Packet master clock
- Packet network
- Packet slave clock
- Packet node (e.g., Ethernet switch, IP router, MPLS router)
- 10 Gbit/s fibre optical link
- 1 Gbit/s fibre optical link
- Microwave link

- EPON + EPoC
- Sync Distribution Error Allocation

- 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
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.
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 CNUUs used for MBH frequency sync applications also meet the above MTIE requirement.
G.8271 Sync Distribution Model - Time

- 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

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

- Time or phase synchronization distribution via cable
- Time or phase synchronization distribution via radio

PTP messages
G.8271 Sync Distribution Model - Time

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

Figure 3/G.8271 - Example of time synchronization distributed via packet based methods
• 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
    \(\leq 15\) ppb
  - Time-transfer (ToD) Error
    - EPoC Link: \(\leq \pm 120\)ns [Tentative]
    [Goal: EPON + EPoC combined (OLT->FCU->CNU): \(\pm 250\) 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


