Accurate Synchronization in 100G-EPON

Xiang Liu and Frank Effenberger
Futurewei Technologies, Huawei R&D USA

www.huawei.com

HUAWEI

Motivation

In the IEEE 802.3ca 100G-EPON Task Force Meeting in January 2017, it was suggested to examine how low latency requirements for future services, such as 5G mobile backhaul/fronthaul and virtual reality/augmented reality videos, would impact NG-EPON standards (wey_3ca_1_0117).

For future optical access networks, highly accurate time synchronization between OLT and its connected ONUs is also desired for time-sensitive applications, such as those described in IEEE 802.1CM - Time-Sensitive Networking for Fronthaul, http://www.ieee802.org/1/pages/802.1cm.html.

In this presentation, we describe the time synchronization requirements and its impact on the wavelength planning of 100G-EPON.

Desired Synchronization Accuracy

Synchronization timing error

$|TE_{RE}|$ = 20 ns — Budget for internal RE timing error

$|TE_{PRTC/GM}|$ — Budget for PRTC/GM accuracy (Not specified by CPRI)

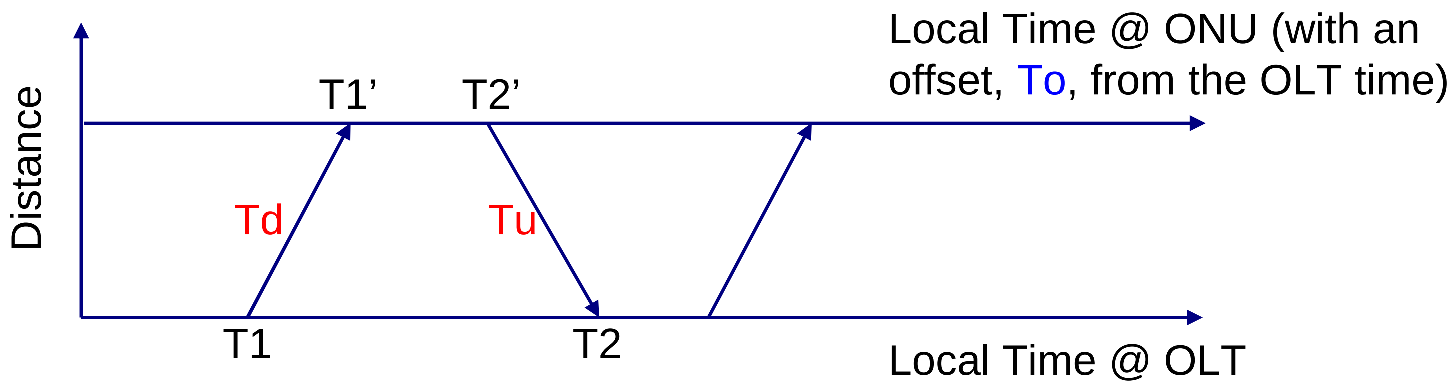
- Class A+: $|TE| < 32.5$ ns - $|TE_{RE}|$ = 12.5 ns
  - **MIMO, Tx-diversity**
- Class A: $|TE| < 65$ ns - $|TE_{RE}|$ = 45 ns
  - **CA Intra Contiguous.**
- Class B: $|TE| < 130$ ns - $|TE_{RE}|$ = 110 ns
  - **CA Intra Non-Contiguous, CA Inter**
- Class C: $|TE| < 1.5$ µs - $|TE_{RE}|$ - $\max|TE_{PRTC/GM}|$
  = 1.48 µs - $\max|TE_{PRTC/GM}|$
  = (1.38 µs if $\max|TE_{PRTC/GM}|$ = 100 ns)
  = (1.45 µs if $\max|TE_{PRTC/GM}|$ = 30 ns)
  - **LTE TDD**

11-Oct-2016 CPRI Common Public Radio Interface 4

Reference: IEEE 802.1CM: cm-CPRI-synchronization-requirements-update-1016-v01.pdf

Time Synchronization Method

The key is to accurately find the time offset, To, between the OLT clock and the ONU clock.



We have

T1'-T1=Td+To (1)

T2-T2'=Tu-To (2)

where Td (Tu) is the fiber propagation induced time delay for the downstream (upstream) signal. We then have

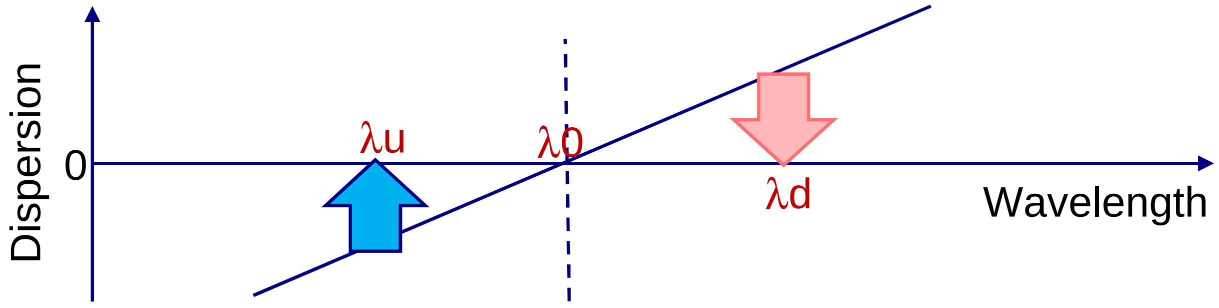
To=[(T1'-T1-T2+T2') – (Tu-Td)]/2.

So, the error of determining To is (Tu-Td)/2.

This means that we need to minimize the difference between Td and Tu.

A Practical Solution

Judiciously choose the Downstream (DS) wavelength and the Upstream (US) wavelength such that the transmission latency difference between DS and US is minimized, with the consideration of the uncertainties of the laser wavelengths, the fiber zero-dispersion wavelength (ZDW), dispersion slope.



Assuming

Downstream wavelength (λd), Upstream wavelength (λu),

Zero-dispersion Wavelength (λ0): 1302 nm ≤ λ0 ≤ 1322 nm,

Zero *Dispersion Slope* (S0): ≤ 0.09 ps/(nm²•km).

We have:

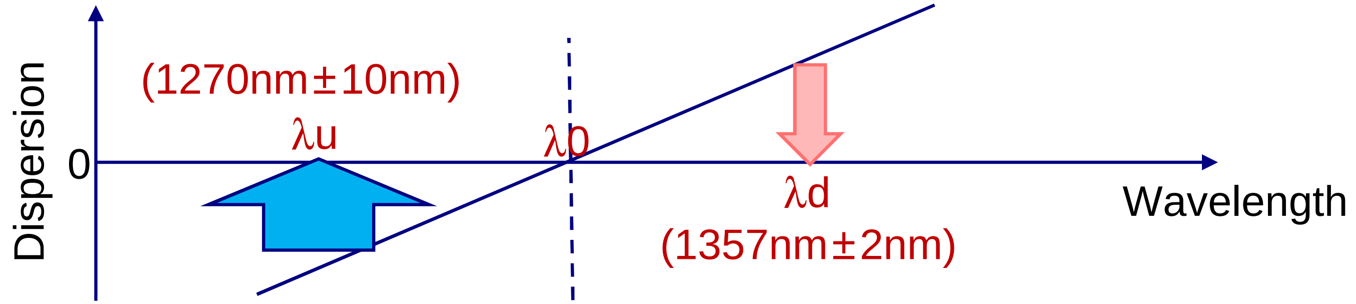
(Td-Tu) = L(km)*S0*[(λd-λ0)^2 - (λu-λ0)^2]/2

So, we can let λd and λu to be symmetric about λ0 to minimize (Td-Tu), which will in turn minimize the measurement error of To.

HUAWEI

Relevance to 100G-EPON Wavelengths (1)

For Wavelength Plan B, the first US signal is at 1270±10nm for TDMA coexistence with 10G-EPON. To minimize the time synchronization error, it is preferred that we set the first DS wavelength symmetric to 1270nm w.r.t. the ZDW, as shown below.



Upstream wavelength (λu): 1270±10nm; (TDMA w/ 10G-EPON and 10G-GPON)

Downstream wavelength (λd): 1357nm±2nm;

We have the worst-case DS/US latency differences:

(i) $20km*0.09ps/(nm^2 \bullet km) *[(1359-1302)^2 - (1280-1302)^2]/2\ nm^2 \approx +2.5ns$

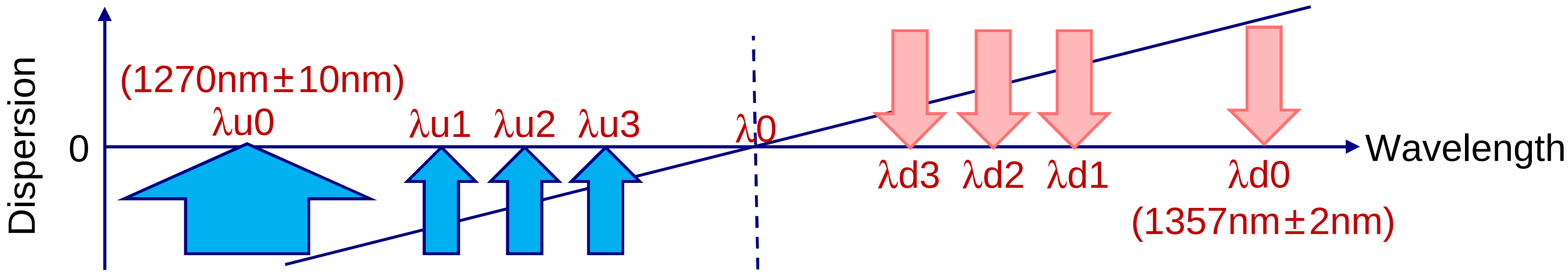
(ii) $20km*0.09ps/(nm^2 \bullet km) *[(1355-1322)^2 - (1260-1322)^2]/2\ nm^2 \approx -2.5ns$

So, the measurement error of To is about ±1.25 ns, which is a small fraction (10%) of the desired overall synchronization error (±12.5 ns).

Thus, this choice of the first pair of 100G-EPON wavelengths can meet the stringent synchronization requirement of future mobile fronthaul applications.

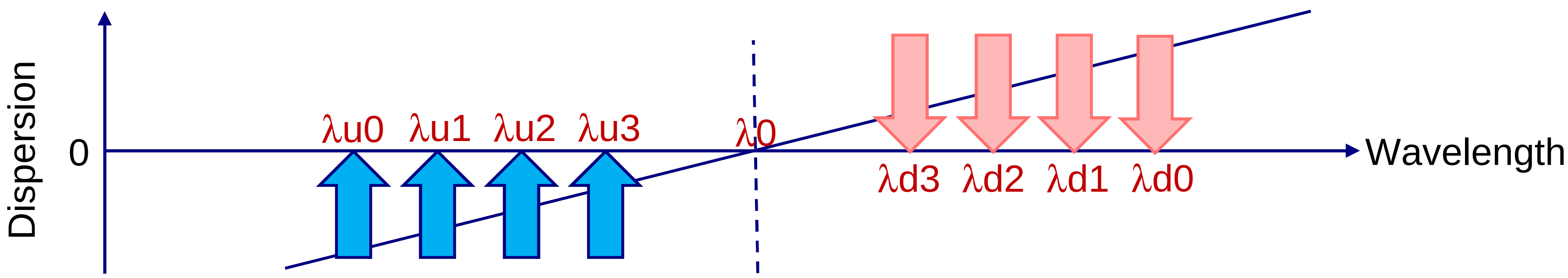
Relevance to 100G-EPON Wavelengths (2)

For Wavelength **Plan B**, the last three pairs of DS and US wavelengths are added via wavelength-division multiplexing (WDM). To minimize the time synchronization error, it is preferred that we set each pair of DS and US wavelengths to be symmetric about the ZDW, as shown below.



Relevance to 100G-EPON Wavelengths (3)

For Wavelength **Plan A**, all the four pairs of DS and US wavelengths are aggregated via wavelength-division multiplexing (WDM). To minimize the time synchronization error, it is preferred that we set each pair of DS and US wavelengths to be symmetric about the ZDW, as shown below.



Summary

- When defining the wavelength plan of 100G-EPON, it is needed to consider the accurate time synchronization requirements for future time-sensitive networking applications.
- Based on the analysis presented in this contribution, it is beneficial to arrange each pair of DS and US wavelengths in such a way that they are approximately symmetric about the ZDW of the fiber.
  - This can be applied to both Wavelength Plan A and Wavelength Plan B that are under active consideration.
  - The needed changes are relatively easy to implement in the O-band, which has been chosen for 100G-EPON.
- The task force is thus recommended to consider the benefit of the symmetric wavelength pairing scheme when deciding the wavelength plan for 100G-EPON.

Thank you

www.huawei.com