Security Level:

Skew sources in 100G-EPON

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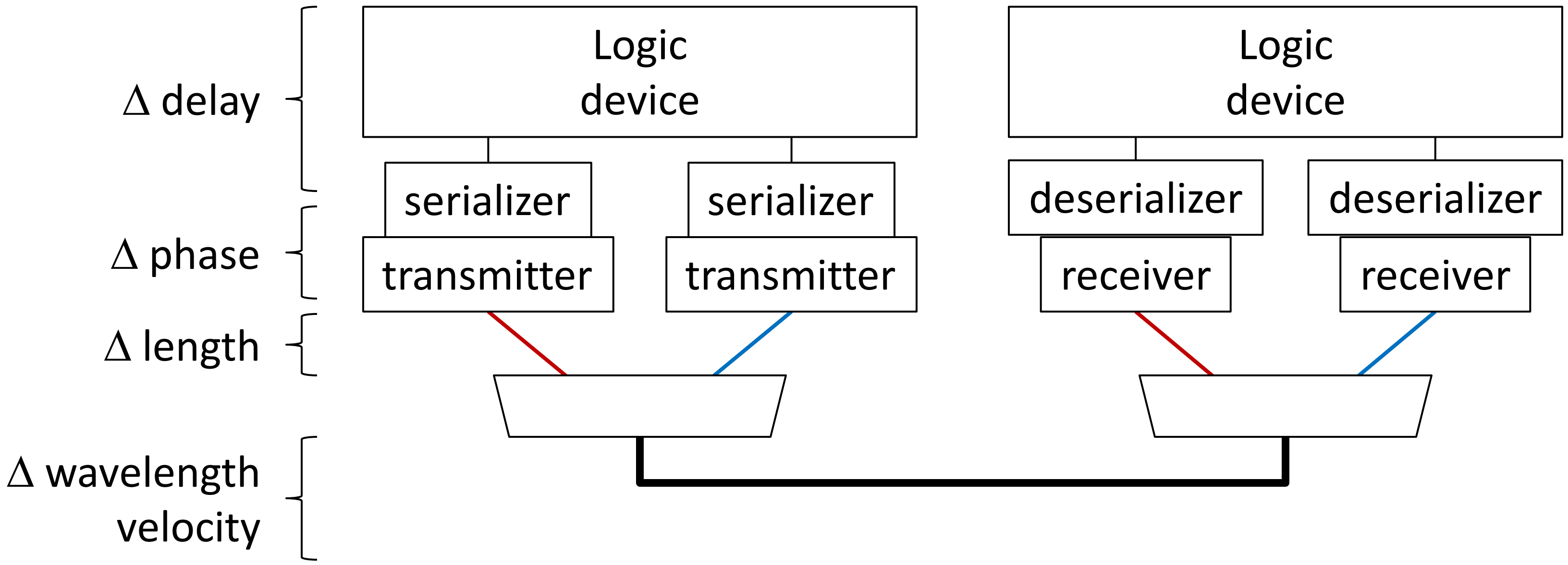
Motivation

- If frame play out is a multi-channel system is based on 1st bit frame arrival (see kramer_3ca_2_0316)
- Then any skew or jitter in frame arrival time could potential have an adverse impact on the frame play out algorithm resulting in misordered frames.
- Therefore we must have a good understanding of what will cause skew and jitter in the system.
- Given that the play out algorithm resides in the MPCP+ layer and skew and jitter below that must be understood.

Potential sources of skew / jitter

- **Terms used in this presentation**
  - Skew – a fixed difference in transmission time
  - Jitter – a dynamic difference in transmission time



In MPCP

- **GATE times between Channels will not be aligned**
  - Frame boundary Grants for different lanes of the same ONU will not align in time
  - Random data demands from ONUs with differing needs will force grant times in various lanes to start at different times.
  - “later” frames could be granted before “earlier” frames
  - This is dynamic (changes burst to burst)
  - Magnitude will vary depending on traffic and on DBA but likely 100’s of byte times (i.e., 1000’s UI)
  - However grant times are known by the OLT so this source of jitter can and must be mitigated in the OLT receiver

In RS

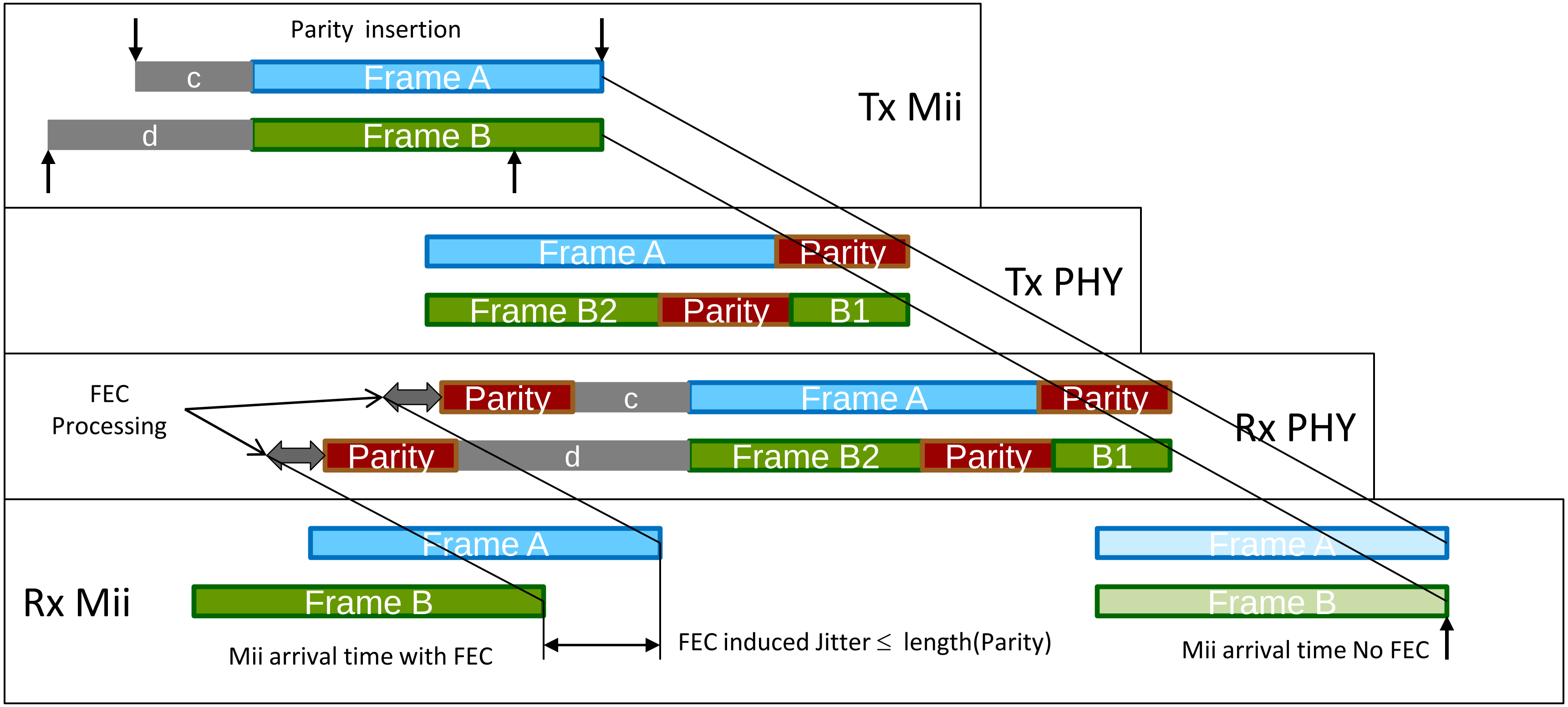
- **We can assume (or require) that the RS layers are:**
  - Synchronous and Phase aligned
    - **This is deterministic (constant frame to frame)**
  - However frames delivered to the RS layer from the 100G MAC can arrive at any time during the 4 byte transmit time creating a 32 UI jitter (relative to 25G clock) at the MII interface

In PCS

- **We should require that individual channels within a multi-channel PCS are frequency synchronized.**
  - Do we need an inter-channel jitter specification?
- **Depending on arrival a frame may have n or n+1 Sync bit headers**
  - This is dynamic
  - But this is very small 1 UI
- **Depending on arrival a frame may create m or m+1 FEC Code Words**
  - This could induce a jitter of 1 FEC code word
    - **For RS(223,255) = 255*8 = 2040 UI (81 ns @ 25G)**
- **Could require the PCS to mitigate these**

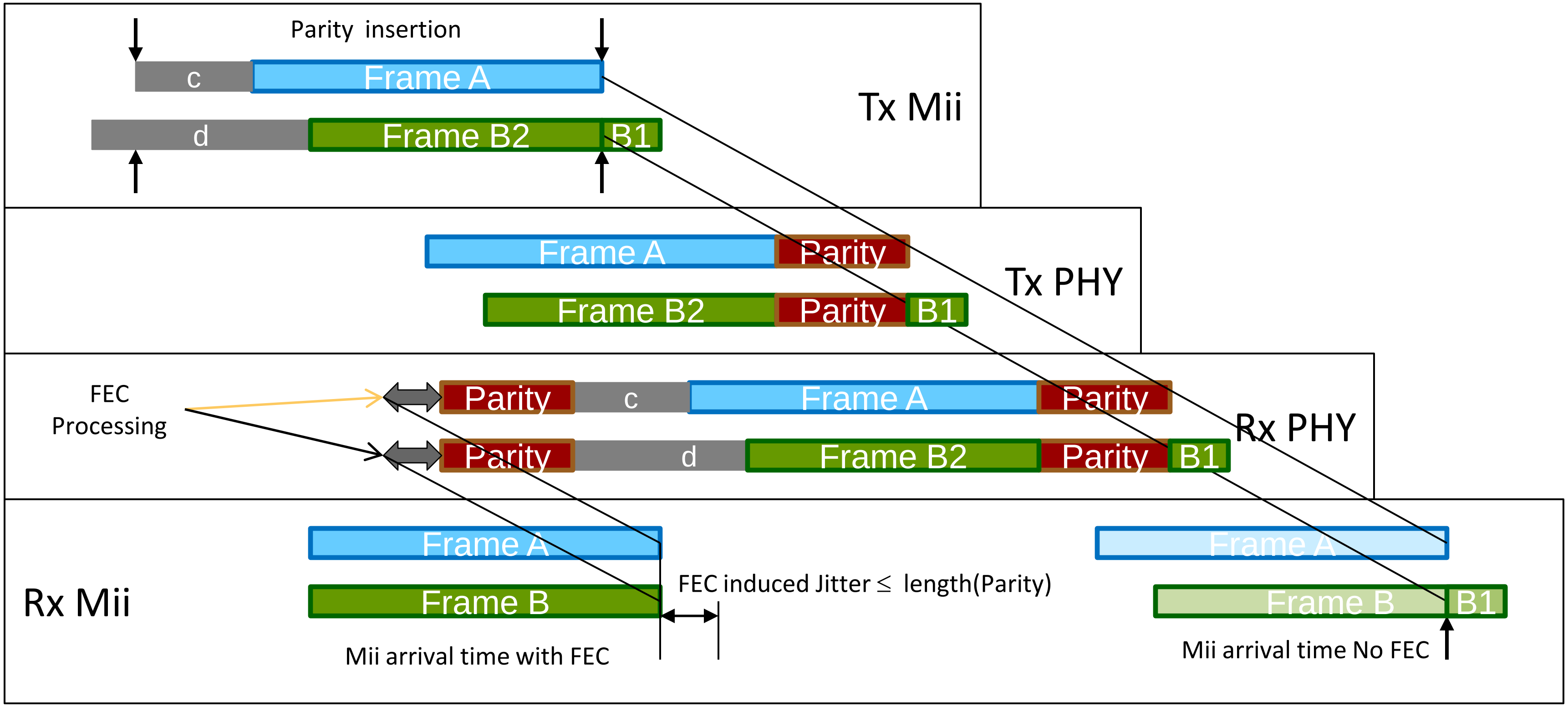
FEC induced jitter

- **FEC codeword not aligned between channels**



FEC induced jitter

- **FEC codewords aligned between channels**



Due to WDM

- **Different wavelengths travel at different velocities in fiber**
  - Will produce a skew of known magnitude which depends on wavelengths chosen and length of fiber
  - If we can measure this then it could be mitigated

$$Delay_{max} = A + \frac{0.093\lambda^2}{8}\left[1 + \left(\frac{1300}{\lambda}\right)^4\right]$$

$$Delay_{min} = A + \frac{0.093\lambda^2}{8}\left[1 + \left(\frac{1324}{\lambda}\right)^4\right]$$

Where:

λ – wavelength of interest
1300 – minimum zero dispersion wavelength
1324 – maximum zero dispersion wavelength

Ref: anslow_01_0907.pdf
remein_3ca_2_0516.xlsx

Skew due to WDM (examples)

Type	DWDM	DWDM	NGPON2	LR4	CWDM	Custom
Spacing	800 GHz	800 GHz	100 GHz	20 nm	20 nm	10 nm
Ch0 λ_c (nm)	~1295	~1342	~1596	1271	1291	1295
Ch 4 λ_c (nm)	~1308	~1357	~1599	1331	1351	1342.5
Ch width	20 %	20 %	20 %	± 6.4 nm	± 6.5 nm	10/5 nm[1]
Skew (UI)	<< 2	~10	8 UI	± 8	-2, + 19	-1, +12

1) Ch 1 is 10 nm wide, Ch 2, 3, & 4 are 5 nm wide

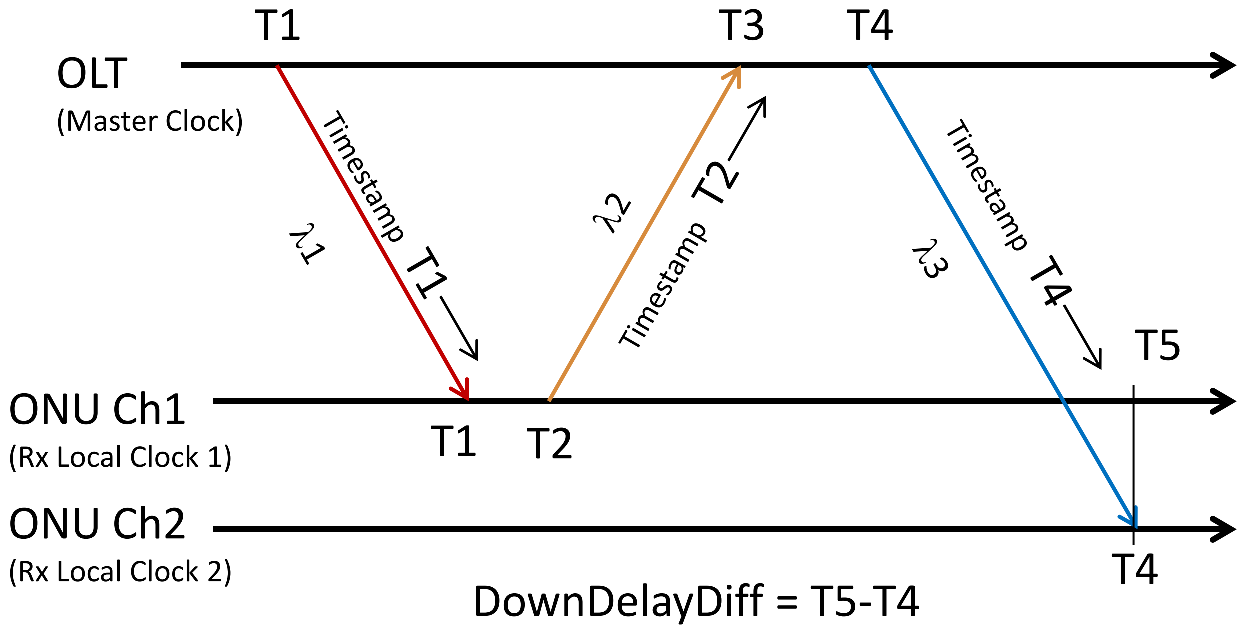
- **Question is where and how do we measure this?**

Where to measure skew?

- **PMD – no good reference point**
- **PMA**
  - no good reference point in DS
  - might be able to use burst start in US but this might include a jitter component of it’s own (declaration of “burst start” my differ ONU to ONU)
  - Incomplete (doesn’t measure all components)
- **PCS**
  - should measure / mitigate Line Code & FEC induced jitter
  - But no good way to measure WDM skew, especially in US
  - Incomplete and no mechanism to communicate to MPCP
- **RS – no good reference point**
- **MPCP – possible mechanism to measure total skew given in next slides.**

DS skew measurement

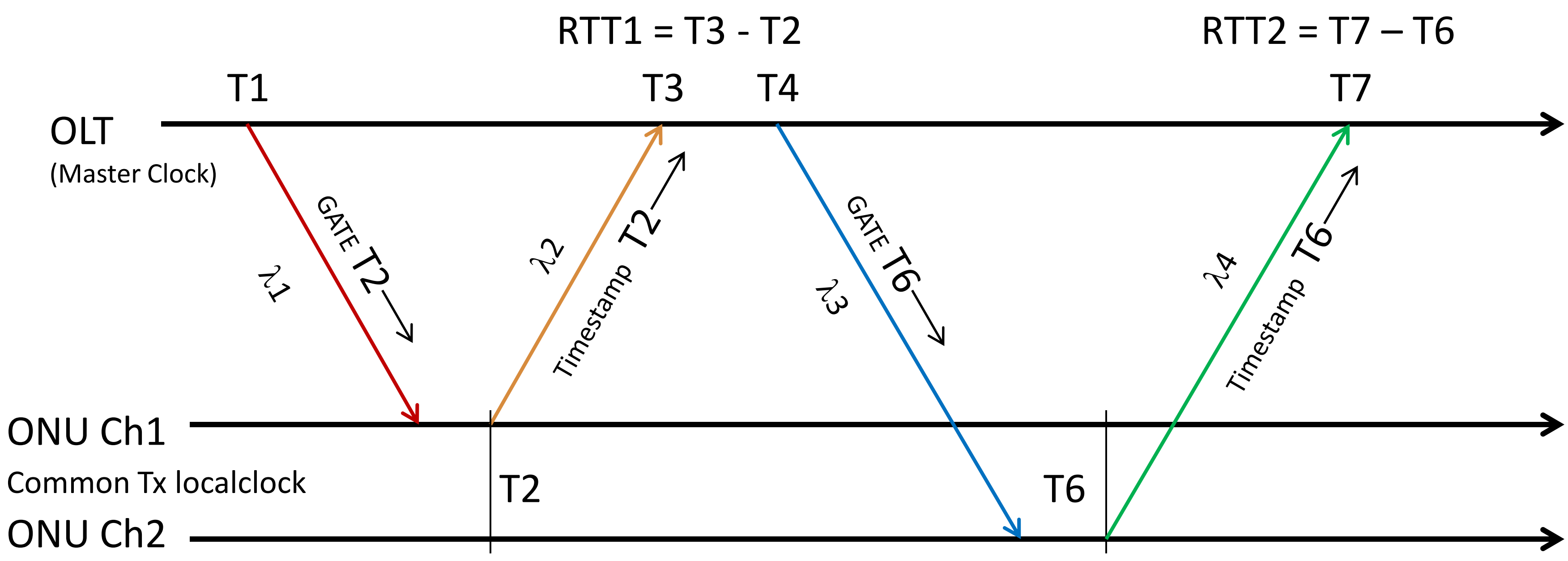
- OLT uses a single master clock for all channels
- ONU maintains a local clock for each channel
- MPCP messages sent on each channel
- Difference between any two local clocks is skew



US skew measurement

- **ONU maintains single Transmit Clock**
- **OLT compares RTT between two channels to determine skew**

UpDelayDiff = RTT2 - RTT1
Because:
RTT1 = Down1 + Up1
RTT2 = Down1 + Up2



Summary

- **Skew will exist between 100G-EPON channels**
- **Skew will need to be measured and compensated for in order for frame reordering scheme to work properly**

Source	Fixed / Dynamic	Size (UI)	Mitigate	Where	How
MPCP	D	1000's	Y	MPCP	Grant time tracking
RS	D	32	Y	MPCP	Measure
Line Code	D	1	N	MPCP	-
FEC	D	2040[1]	Y	PCS	PCS Compensation
WDM	F	TBD	Y	MPCP	Measure

Note 1: assuming RS(223,255)

Thank you

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