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Engineering Time at the Edge

ITSF Lisbon 2013

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LTE-A Services Phase Alignment Requirements

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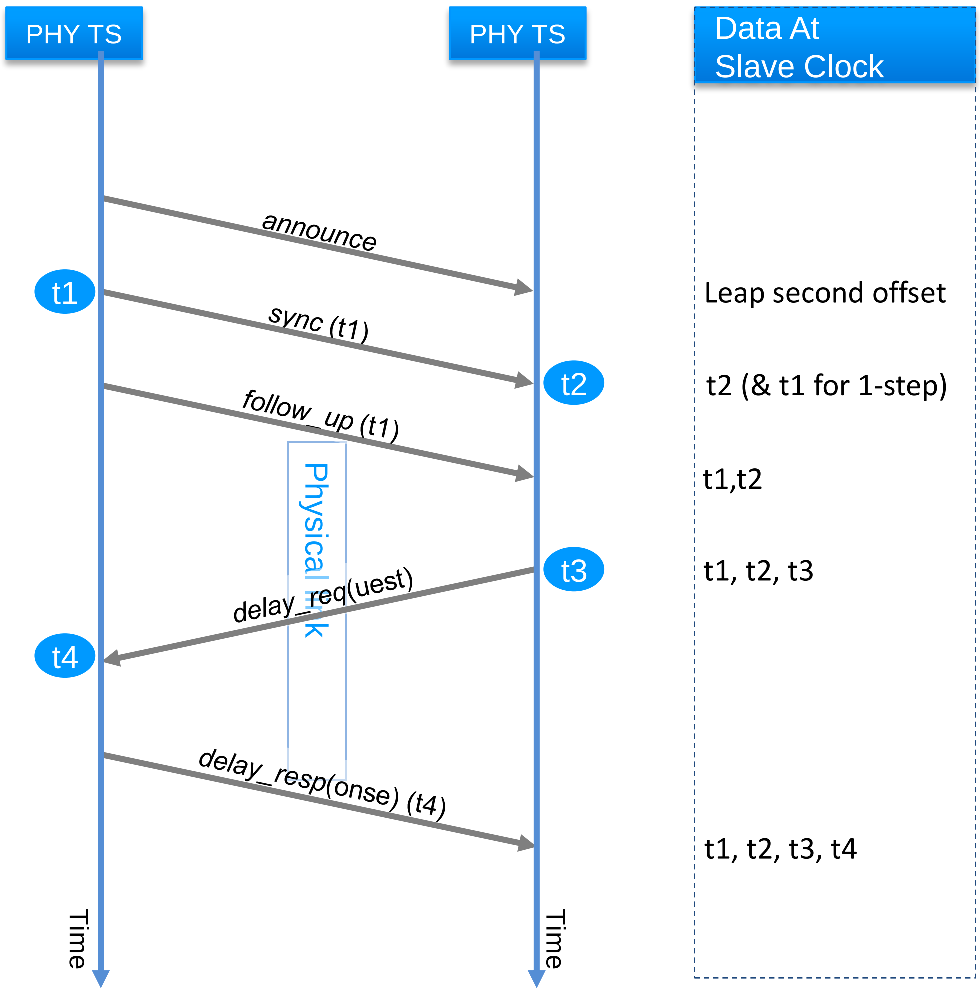
Assuming a budget of ±1.5µs time error at the eNB antenna, how the network has to be (or not to be) engineered ?

Network Service		Inter Cell Phase Alignment
eICIC (feICIC)		± 1.5µs
CoMP		± 1.5µs
MiMo		± 1.5µs
MBSFN/eMBMS		± 1 - 32µs
Positioning OTDOA/UTDOA ACEID (US Centric)	Country wide	± 0.4µs - ± 1.5µs
	County wide	*± 1.5µs - ± 5µs*

How Time is Transferred using Packet Time



Round Trip Delay

$RTD = (t2 - t1) + (t4 - t3)$

Offset:

(slave clock error and one-way path delay)

$Offset_{SYNC} = t2 – t1$

$Offset_{DELAY\_REQ} = t4 – t3$

1588 PTP assumes path symmetry, therefore

One-Way Path Delay = RTD ÷ 2

Slave Clock Error = (t2 - t1) - (RTD ÷ 2)

Performance degraded by delay asymmetry in forward and reverse direction of paths

Typical Budget Allocation for Network Asymmetry

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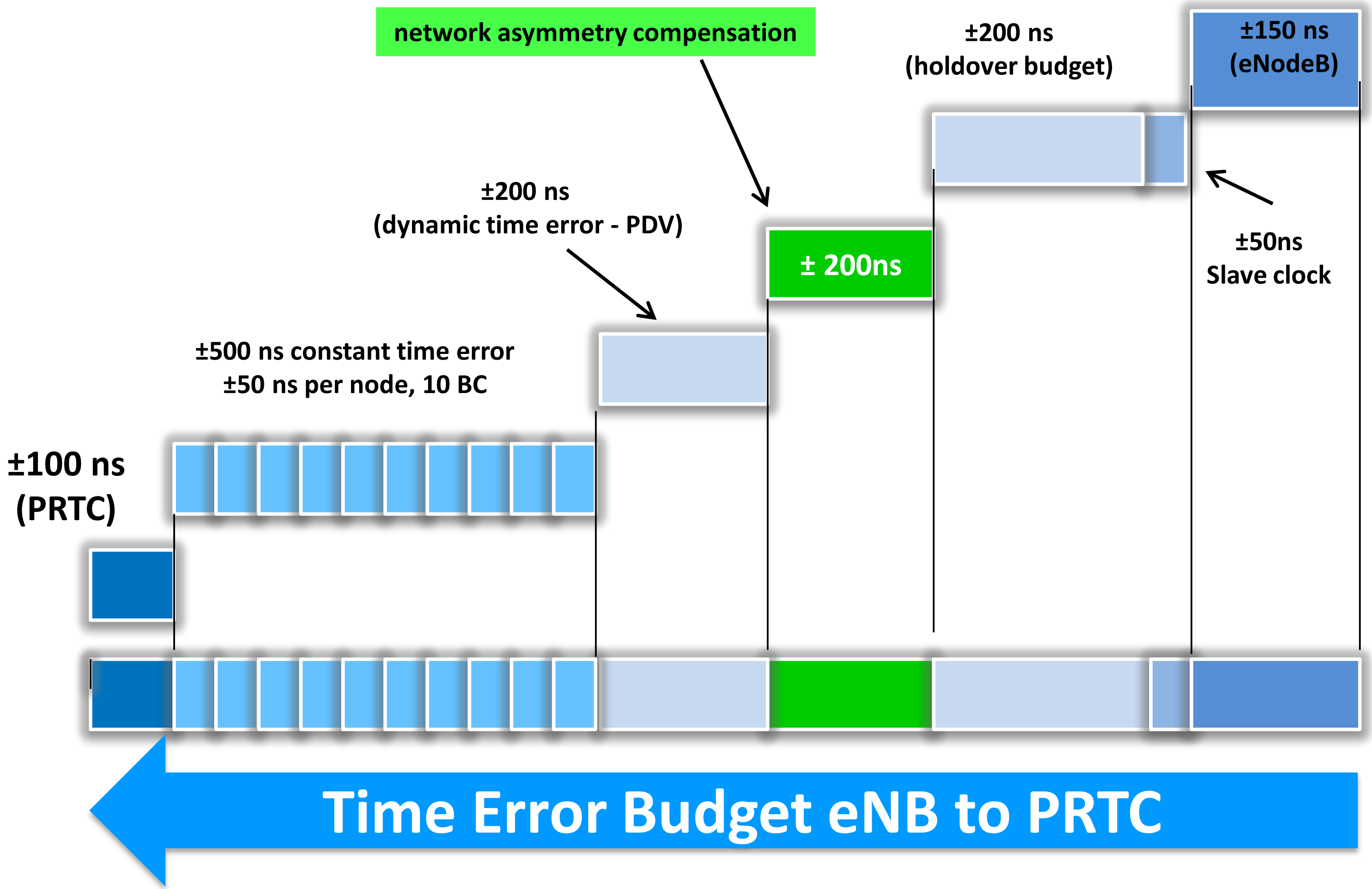

Based on G.8271.1

Potential Sources of Asymmetry

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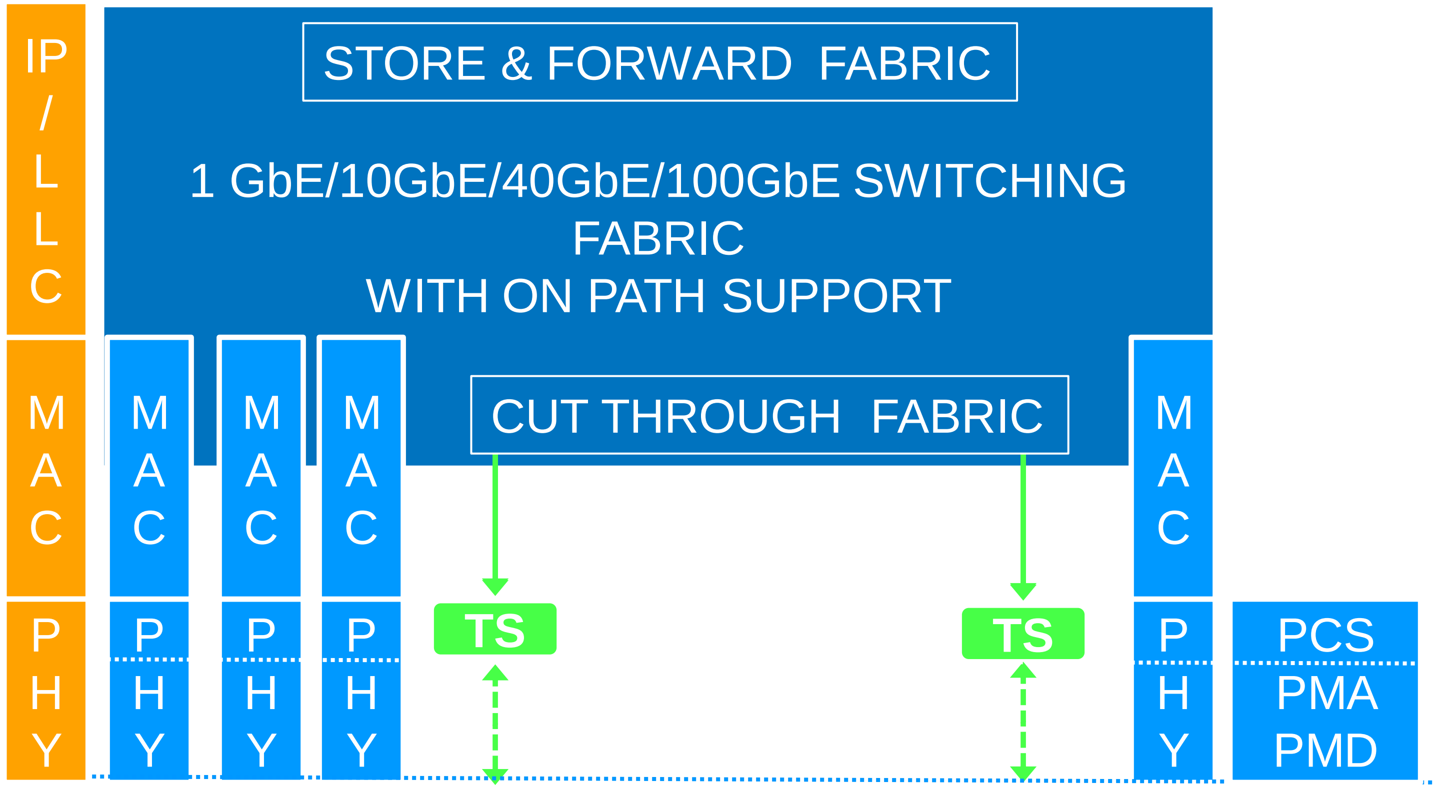
- BC/TC with PHY based Timestamps eliminate "most" asymmetries
  - "load" asymmetries are due to the behavior of a switch when dealing with different dynamic load conditions in the reverse and forward path
  - "other" asymmetries coming from the "fabric", queuing mechanisms with or without congestion,…

± 50ns budget/ hop

- But
  - What about SFP/SFP+/CFP asymmetries (PHY is not MDI) ?
  - What about physical link/path asymmetries ?

± 200ns budget end to end

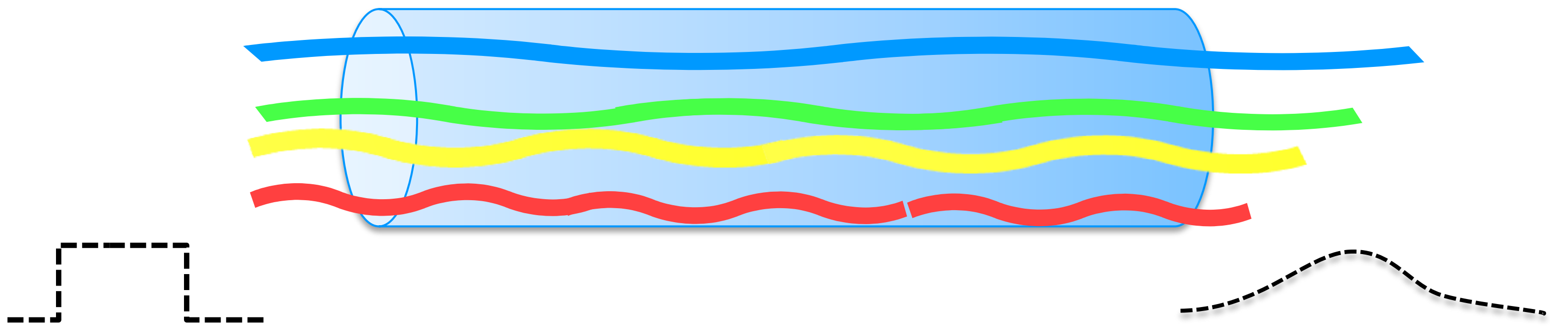
A switch at 10,000 Feet



Typical delay dispersion range observed from TS to the MDI ~ 15ns to +150ns : ~67ns

- Usually uncompensated , implementation dependent
- Range depends on how SFPs/XFP/CFP are integrated within the switch (PCS/ PMA/ PMD layers are sometimes distributed/stacked)
- Integrated PHY/MDI usually provides the smallest dispersion range

Transmission over Fiber at 10,000 feet



- Chromatic dispersion causes the shorter λ to travel faster than the longer λ

Transmission over Fiber/D-CWDM

Main Sources of Dispersions

- Wavelengths (λ) are travelling at different phase velocity within a fiber (index of refraction) – this is due to chromatic dispersion
  - Phase velocity $v_{\lambda}=n/c$
- Group-velocity dispersion causes a short pulse of light to spread in time as a result of different frequency components of the pulse travelling at different velocities
  - Group velocity $v_g=c(n-\lambda*dn/d\lambda)$
- Sources of asymmetries in D-CWDM
  - Difference in Fiber length between the upstream and the downstream
  - Differences in Phase velocity – require DCM (Dispersion Compensation Module)
  - Group velocity – require Line Amplifiers (usually combined with DCM)
  - Differences in index of refraction between wavelengths used for the upstream and the downstream

Transmission Asymmetries

- Impact of DCMs
  - Dispersion Compensation Fiber (DCF) based DCM ~ adds asymmetry that are proportional to the length of fiber ~ 8 to 10%
  - Fiber Bragg Grating (FBG) based DCM ~ a few nanoseconds

- Impact of Fiber length discrepancies
  - Most OTDR accuracy ~ 0.0022 % of the length of fiber
  - Difference in phase velocity between 2 λ in the same band (upstream/downstream)

Some exercise ….

Phase velocity of a wavelength λ : ν = n/c – n index of refraction of λ

For λ=1490 nm, n= 1.4682 over an SM-28 fiber type (G.652/O-Band) ~ 204,190,476.77 m/s or 4,897.39 ns / km

For λ=1310 nm, n= 1.4677 over an SM-28 fiber type (G.652/O-Band) ~ 204,260,038.15 m/s or 4,895.72 ns / km

Speed of light c= 299,792,458 m/s

Is 200 ns enough ?

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200ns may be very short unless……

G.652/SM-28 fiber type, λ: 1490nm and 1310nm – 2 hops – 100km of fiber

DCF based DCM	• 39,179.10 ns
FBG based DCM	• ~ 3, 4 ns
Fiber length difference	• @ 0.010% – 10 m ~ 48.99ns
Difference in index of refraction	
Uncompensated SFPs	• 400 ns (end to end, worst case) – assuming ~ 67ns/SFP – 2 hops=6 SFPs

Time error : worst case 19.815 µs (39,179.10+48.99+400)/2

Time error : best case 226.5 ns (4+48.99+400)/2

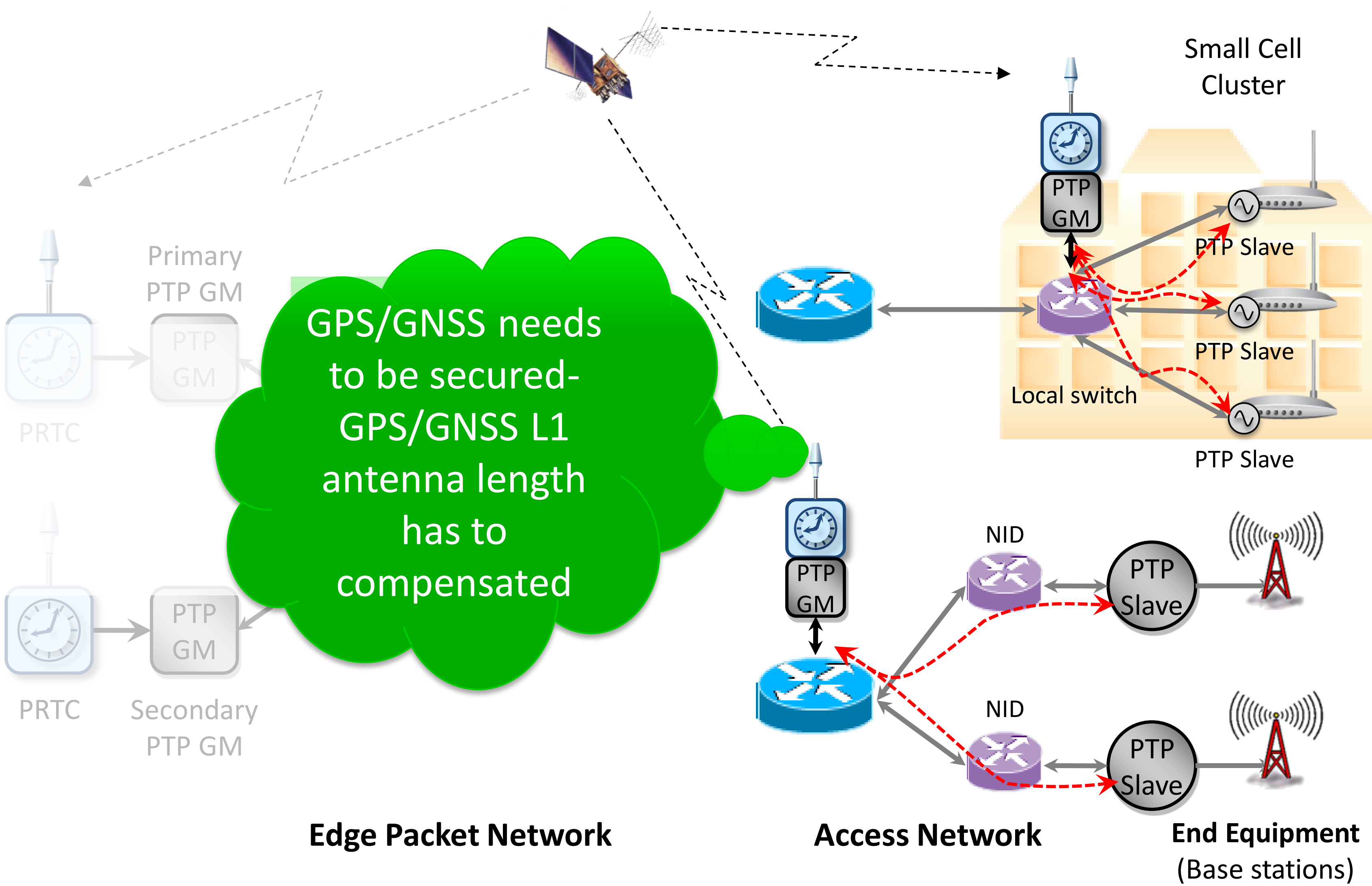
Solutions

- Plan A (Assumes no 3rd party backhaul)
  - Limit the distance (no DCMs, no Optical Amplifiers)
  - Limit the # of hops (SFPs!) or select SFPs or do both
  - Calibrate each fiber length down to 0.01% or better
  - Don't use DCF based DCM or use NZ-DSF fiber, but G.652 is 70% of the installed base
- Plan B (Assumes no 3rd party backhaul)
  - Do asymmetry compensation hop/hop
- Plan C (Assumes no 3rd party backhaul)
  - Don't use C-DWDM, use EFM technologies or GPON with automatic delay compensation (see ITU G.984.3 Amendment 2)
- Plan D (works whatever is being deployed in the backhaul)
  - Move the PRTC closer to the edge …. *Or review the budget allocation*

What about re-arrangement?

Moving the PRTC to The Edge

A solution that fits all deployment scenarii



Any questions ?

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Back-up slides

- ITU-T wavelength bands

	Wavelength(nm)	Pf(mW)
O-band	1260-1360	O: Original
E-band	1360-1460	E: Extended
S-band	1460-1530	S: Short
C-band	1530-1565	C: Conventional
L-band	1565-1625	L: Long
U-band	1625-1675	U: Ultra-long