PON for Network Aggregation & Transport

- 100G EPON Network Backhaul Applications and impacts on the choice of wavelength plan

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Outline

- Traditional applications for PON
- Emerging applications for “HIGH-SPEED” PON
- Network backhaul and fronthaul requirements for 100G EPON
- Impacts on WDM wavelength plan and QOS

Traditional Applications for PON

- As of today, PONs have been viewed as last mile access technologies
- PON is the main technology for FTTH
- The driving forces behind seeking higher-speed PON are often assuming as various IP video related applications – HD, 4K,8k, DVR, and recently VR…
- The justifications for 100Gbps rate PON in the traditional PON application areas are not clear – "speed tests" are often mentioned at 100G EPON discussions…

When PON MAC rate approaches a certain level, for example 100Gbps, the killer application may not be in the last mile anymore…

Emerging Applications for high-speed PON

- GPON mobile backhaul applications have been developed for years
- Recently, 10G PON (XGS-PON, 10G EPON) mobile front-haul application start to appear
- Mobile front-haul is thought to be an important application for NG-PON2

At 10 Gbps MAC rate, PON is not limited in the last mile anymore

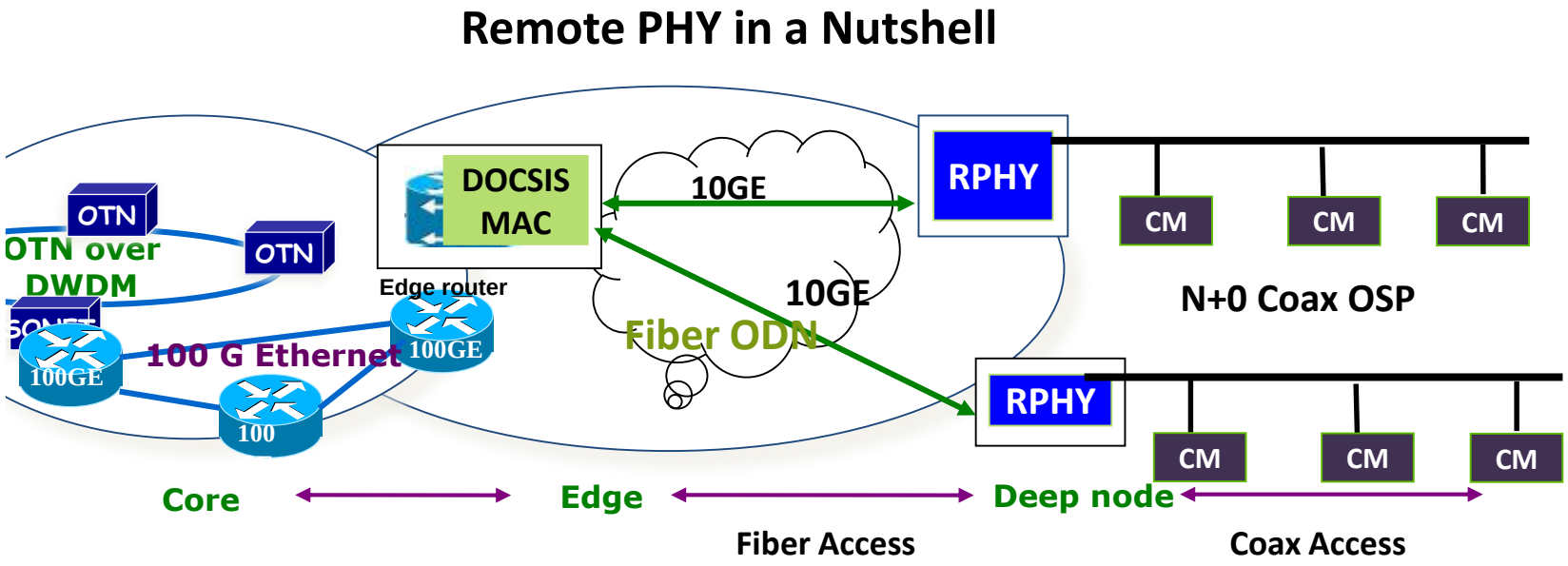
PON for Network Transport

- When PON MAC rates are beyond 10Gbps or 25Gbps for example, the PON may move to the upper section in the network
- At 100Gbps MAC rate, the killer application for PON may be in the aggregation and transport sections of network
- PON Mobile backhaul and front-haul applications are already moving towards this direction…
- 100G EPON may be used for small data center interconnect
- RPHY (remote PHY) backhaul may be a killer application of the 100G EPON for MSOs

PON for Network Aggregation and Transport will pose new requirements and therefore impacts the standards

100G EPON for RPHY Backhaul

PON RPHY backhaul is used as a network transport application for 100G EPON to illustrate the requirements and impacts on wavelength plan, etc.

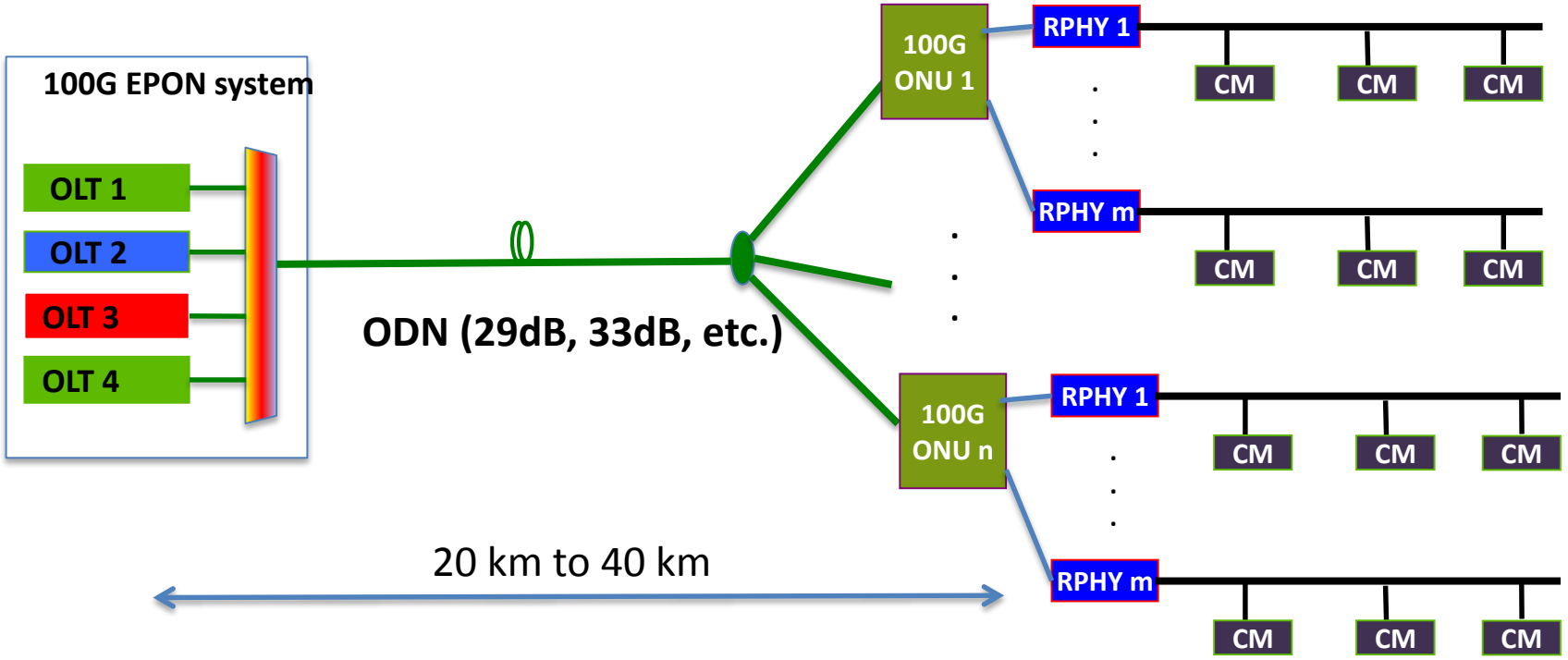


- RPHY technology brings RF modulation deep in the field to N+0 coax OSP
- Higher order modulations are possible for RPHY to increase efficiency
- 10G Ethernet interfaces are between RPHY and DOCSIS MAC
- RPHY and MAC are synchronized via SyncE

Backhaul RPHY Traffic

- Backhauling large amounts of Remote PHY traffics at 10Gbps rate is a challenge
- HFC cannot be used to backhaul RPHY traffic
- AON (Ethernet with or without DWDM) may be used to backhaul RPHY; however AON has very limited deployment and managing a large number of colored DWDM in the access network is difficult
- PON is growing in MSO's network, NG-PON2 or 25G/100G EPON may be used to backhaul RPHY traffic.
- The backhaul networks are in the section before last mile; ie. in edge to metro portions of networks
- The distances of this backhaul network are in the edge to metro scale, in our case it could reach 40km

100G EPON for RPHY Backhaul Architecture



- Each 100G ONU has multiple 10G or 25G UNI
- One or more RPHYs connect to a 10G or 25G UNI
- Assuming maximum reach is 40km

Can 100G EPON meet the reach requirement?

100G EPON for RPHY Backhaul Requirements

- Reach requirement: 40km maximum reach
- Synchronization: Support SyncE
  - Multi-channel scheduling, framing, FEC, etc.
- QOS: Low delay and jitter
  - This not may not be independent from the 2nd requirement

Assuming QOS is not a major problem, then, Can 100G EPON meet the reach requirement?

- IEEE 802.3 PON standards specify ODN loss rather than ODN distance
- For network transport and aggregation applications, the splitting ratio of 100G EPON could be reduced to, for example, 1:16, or 1:8,…
- Therefore, in principle with 29dB or 33dB ODN loss, 40km reach is possible with reduced splitting ratios

Can the wavelength plans support 40km reach?

100G EPON O-band Wavelength Plans A&B

- The 800GHz O-band Plan A & B has two upstream channels in the zero dispersion distribution region of G.652 SMF
- Plan A&B uses wide channel spacing to suppress FWM
  - Besides a corner case when FWM + SBS (dai_3ca_01a_0117) could cause optical noises in channel 4, conventional FWM is suppressed for 20km reach
- When the ODN reach is extended beyond 20km under the same power budget, FWM could be an issue

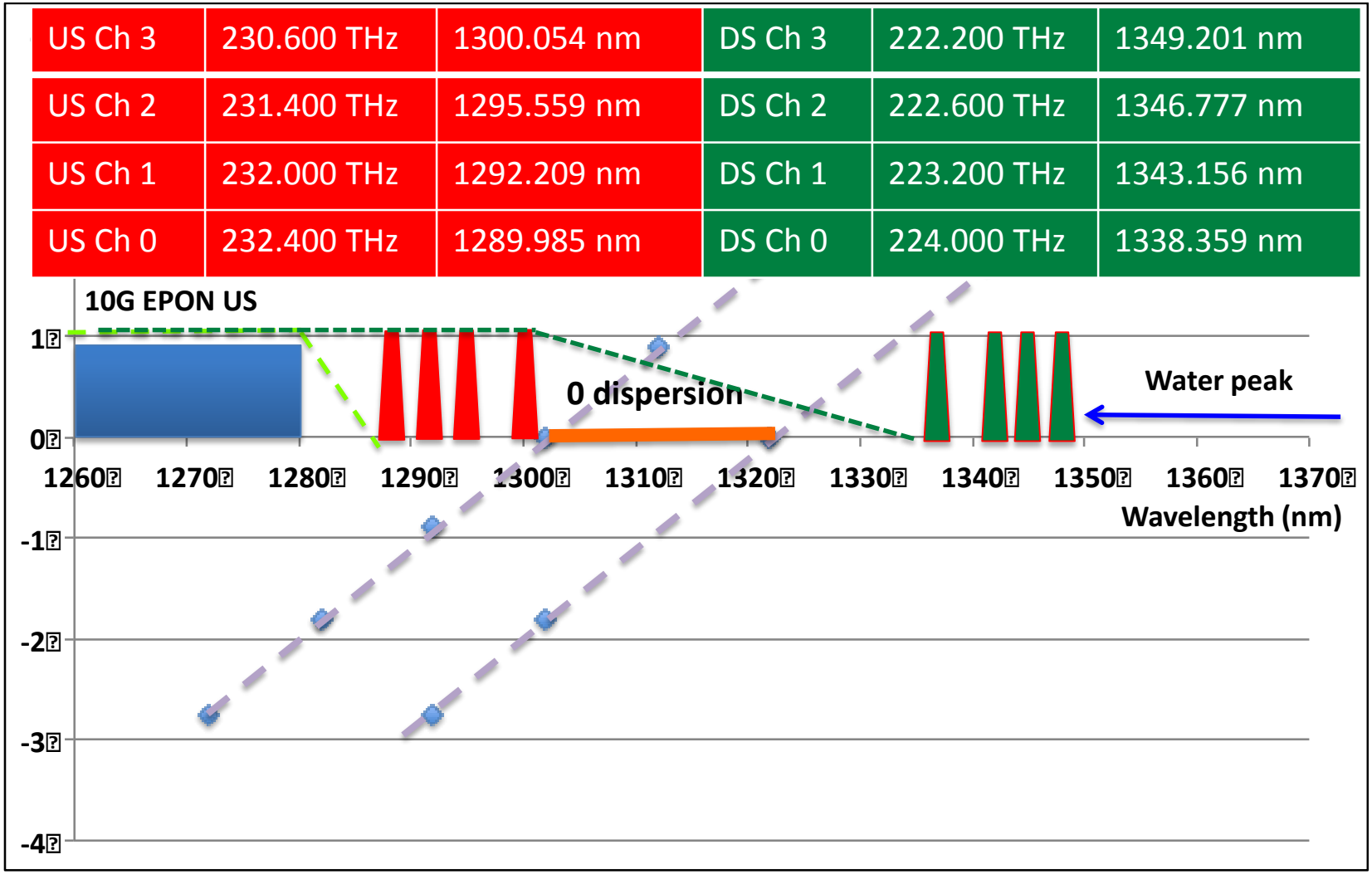
Extending ODN reach beyond 20km could make FWM a problem again!

Solution

- 400GHz O-band uneven spacing wavelength plan (dai_3ca_02a_0116) or its even spacing version solves both problems
- With 400GHz spacing, all channels are out of the zero dispersion of G.652 with moderate dispersion
  - Expending reach beyond 20km is feasible (under the constrain of total ODN loss)
- Channel 4 is not in the zero dispersion region, FWM induced SBS optical noise will not occur
- The cost difference of 400GHz and 800GHz WDM optical may not be that big

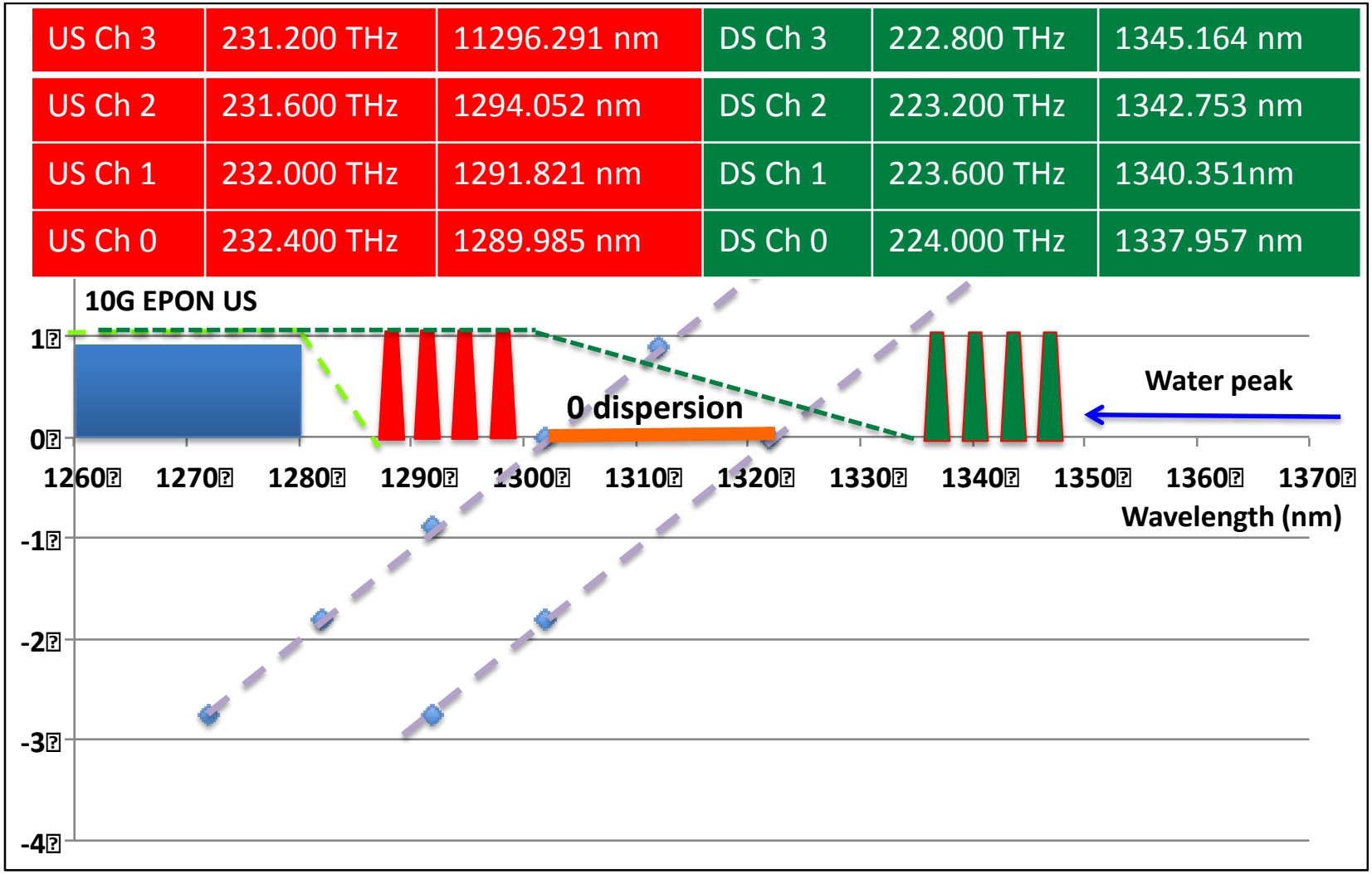
100G EPON 400HGz Uneven Spacing Wavelength Plan

US Ch 3	230.600 THz	1300.054 nm	DS Ch 3	222.200 THz	1349.201 nm
US Ch 2	231.400 THz	1295.559 nm	DS Ch 2	222.600 THz	1346.777 nm
US Ch 1	232.000 THz	1292.209 nm	DS Ch 1	223.200 THz	1343.156 nm
US Ch 0	232.400 THz	1289.985 nm	DS Ch 0	224.000 THz	1338.359 nm



100G EPON 400HGz Even Spacing Wavelength Plan

US Ch 3	231.200 THz	11296.291 nm	DS Ch 3	222.800 THz	1345.164 nm
US Ch 2	231.600 THz	1294.052 nm	DS Ch 2	223.200 THz	1342.753 nm
US Ch 1	232.000 THz	1291.821 nm	DS Ch 1	223.600 THz	1340.351nm
US Ch 0	232.400 THz	1289.985 nm	DS Ch 0	224.000 THz	1337.957 nm



Conclusions

- **The killer application of 100G EPON will be in the aggregation and transport sections of network**
- **100G EPON should be scalable to >20km to meet the network aggregation and transport requirements (under the ODN loss constrain)**
- **FWM may be a problem when the 800GHz spacing O-band wavelength scales to >20km**
- **The 400HGz spacing O-band wavelength plan can scale beyond 20km**

Thanks

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