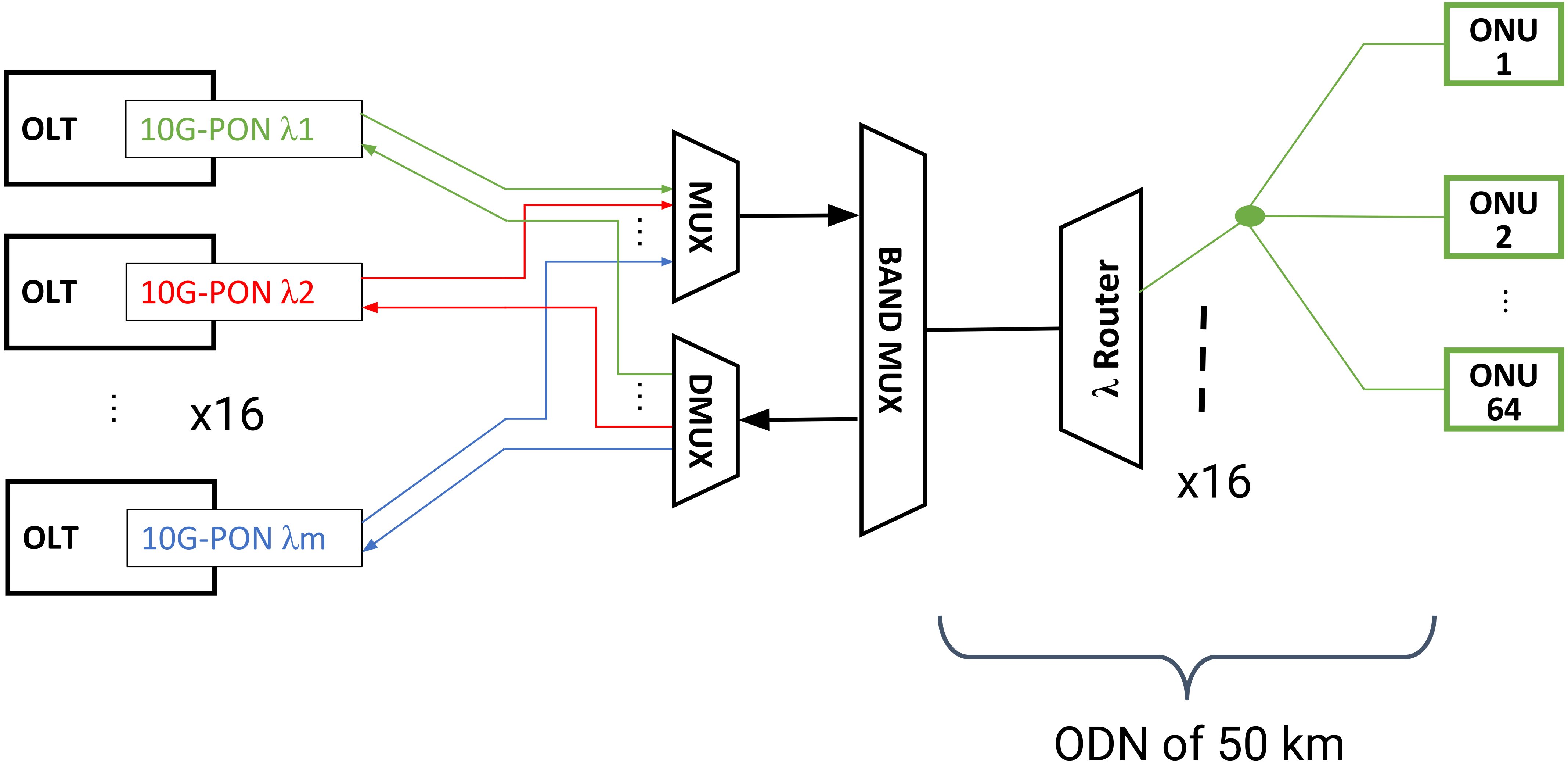
Super-PON
Wavelength Considerations

Liang Du, Google

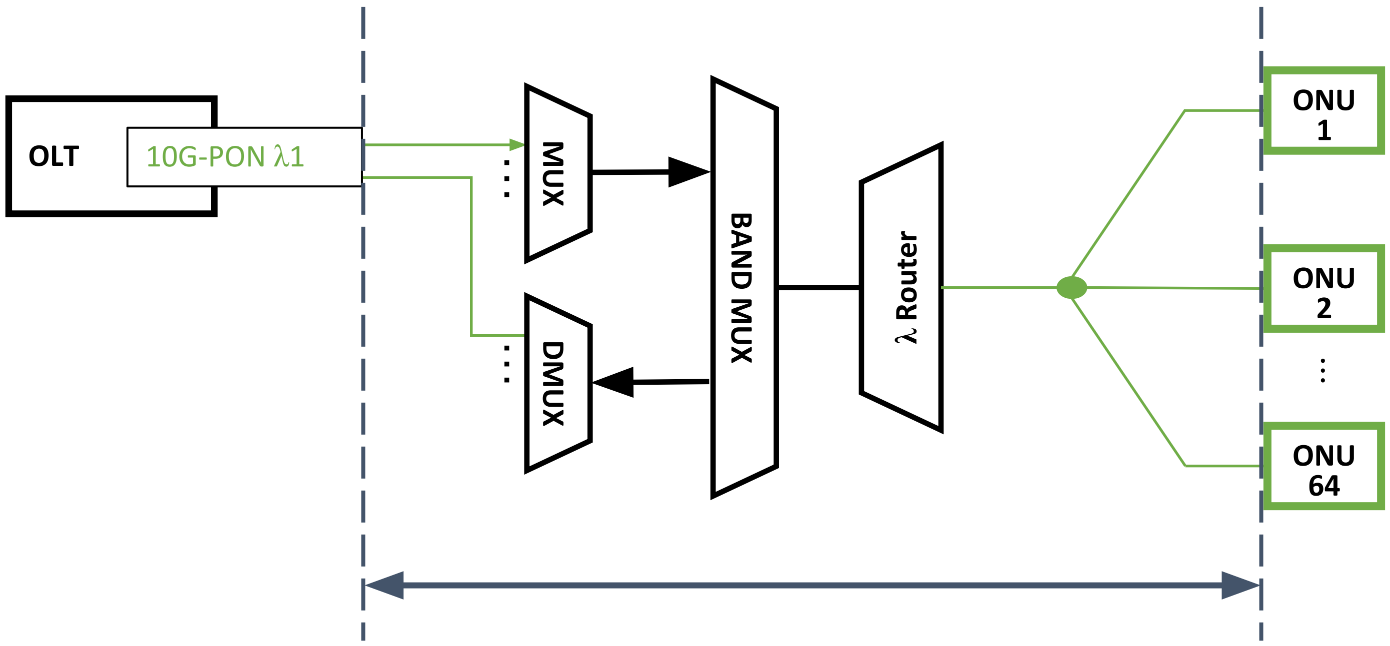
IEEE P802.3cs - March 12, 2019

Google Fiber

P802.3cs Super-PON requirements



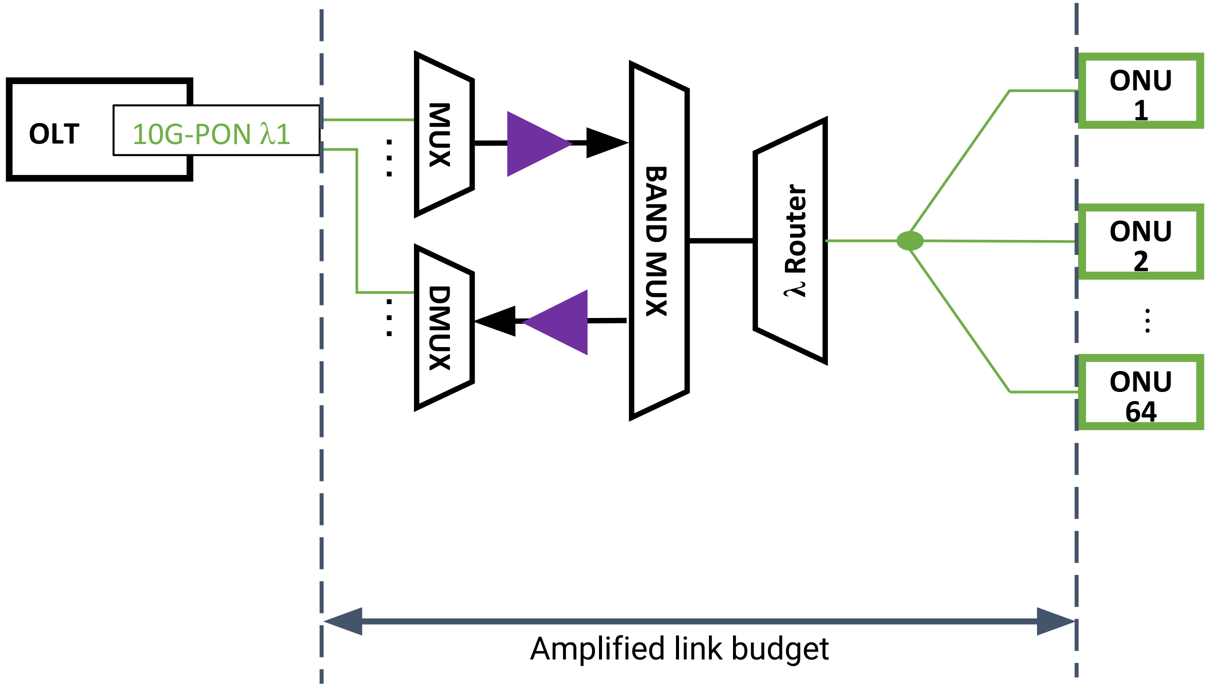
Link budget with no amplifiers



Components	Loss Max (dB)	Comment
50km Fiber	12/17.5	C/O bands
λ Router	6.6	4 to 6.6
1x64	21.5	
mux/demux	5.5	
band mux	2	
Total	**47.6/53.1**	**Too large!**

- Link budget from Transmitter to Receiver
- Requires high-power lasers and sensitive receivers at both ends

Link budget with amplifiers



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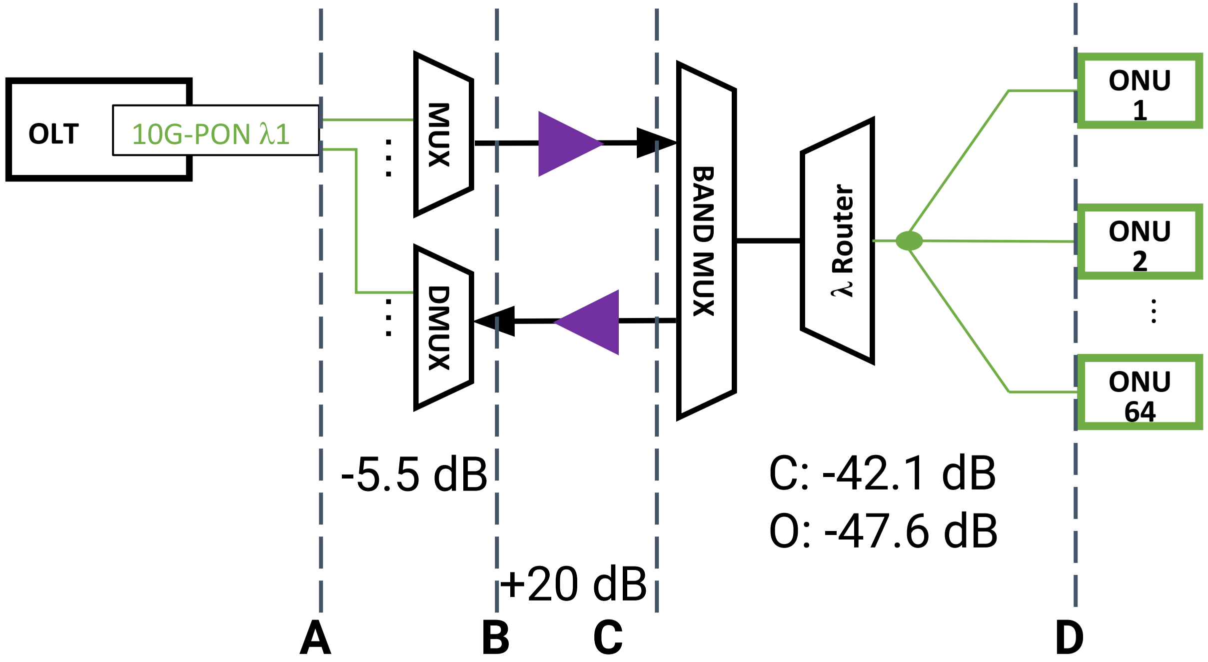
Total	**47.6/53.1**	**Too large!**
Amplifier gain	20	more complex
Total with amp	**27.6/33.1**	**Doable**

- Assuming a 20-dB amplifier gain, the link budget becomes much more reasonable
- However, the system is not that simple

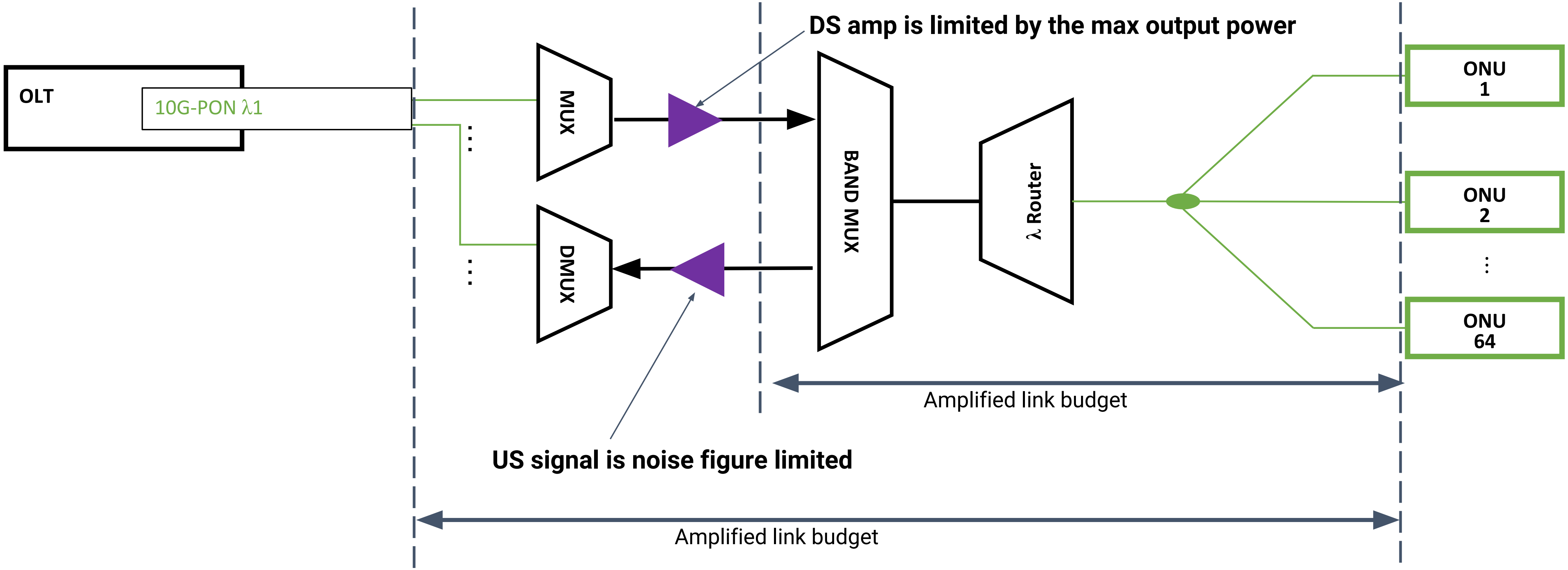
Power levels at amplifier inputs/outputs



- For DS direction, power out of amplifiers is extremely high
  - limited by amplifier output power
- For US direction, power into amplifier is extremely low
  - limited by noise from amplifiers

Location	Power [dBm] DS C-band	Power [dBm] US C-band	Power [dBm] DS O-band	Power [dBm] US O-band
A	+2 (PR30)	-23.6	+5 (PR40)	-27.1
B	-3.5	-18.1	-0.5	-21.6
C	+16.5	-38.1	+19.5	-41.6
D	-25.6	+4 (PR30)	-28.1	+6 (PR40)

Link budget with amplifiers



- Using amplifiers allows the link budget to *mostly* ignore the CO mux/demux
- The link budget that really matters is between the amplifiers and ONUs
- Loss between the amplifiers and OLT has little effect on the system

Downstream Power levels

ONU sensitivity required	DS amplifier output C-band 1 WL	DS amplifier output C-band 16 WL	DS amplifier output O-band 1 WL	DS amplifier output O-band 16 WL
-25.6 (from slide 5)	+16.5	+29.5		
-28.1 (from slide 5)			+19.5	+31.5
-28.5 (PR30)	+13.6	+25.6	+19.1	+31.1
-29.5 (PR40)	+12.6	+24.6	+18.1	+30.1

- The higher loss in the O-band for the 50 km link causes the required multiplexed output power to be >30 dBm, even for PR40 ONU sensitivity
  - Using O-band for DS is not feasible
- Lower link losses in C/L bands requires a multiplexed power of ~25 dBm
  - EDFAs are capable of the combined output power.
  - Fault detection and auto shut-off for eye safety will be required

Upstream OSNR levels

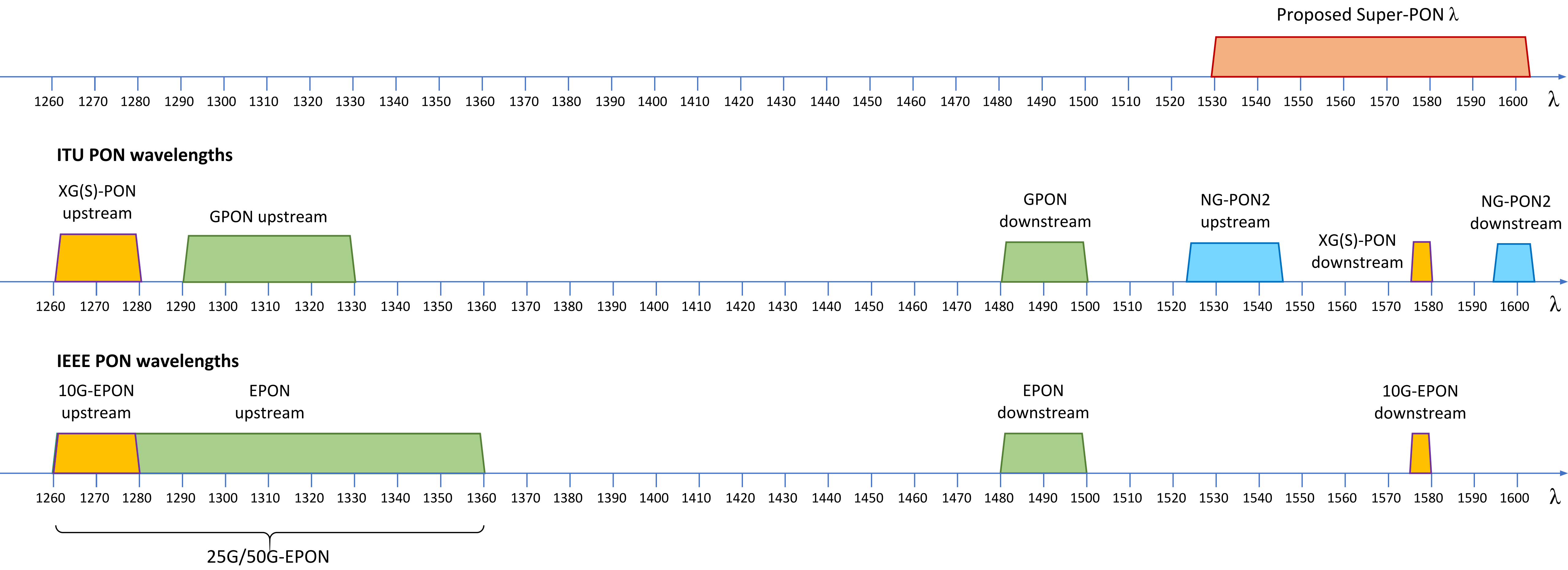
ONU output power	Power at amp C-band (location C)	Theoretical OSNR NF=5.5 dB	Power at amp O-band (location C)	Theoretical OSNR
-1 (PR20)	-43.1	9.4	-48.6	3.9
+4 (PR30)	-38.1	14.4	-43.6	8.9
+6 (PR40)	-36.1	16.4	-41.6	10.9
+9 (very high)	-33.1	19.4	-38.6	13.9

- The higher loss in the O-band for the 50 km link causes very low input power levels at the optical amplifier input
  - At PR40 ONU output powers, there is insufficient OSNR to support 10 Gbps
  - An unreasonable +9 dBm is required to obtain sufficient OSNR
- Lower link losses in C/L bands allows for PR30 and PR40 power levels to obtain sufficient OSNR to support 10 Gbps

Using the C/L bands for Super-PON

- Previous slides suggest the lower attenuation of the C/L bands is needed to close the very aggressive link requirements
- WDM compatible transmitters are most available in the C/L bands, especially for large link budget applications

Super-PON Wavelength Plan



Motion

Super-PON upstream and downstream wavelengths shall belong to the C- and L-bands.

EDFAs

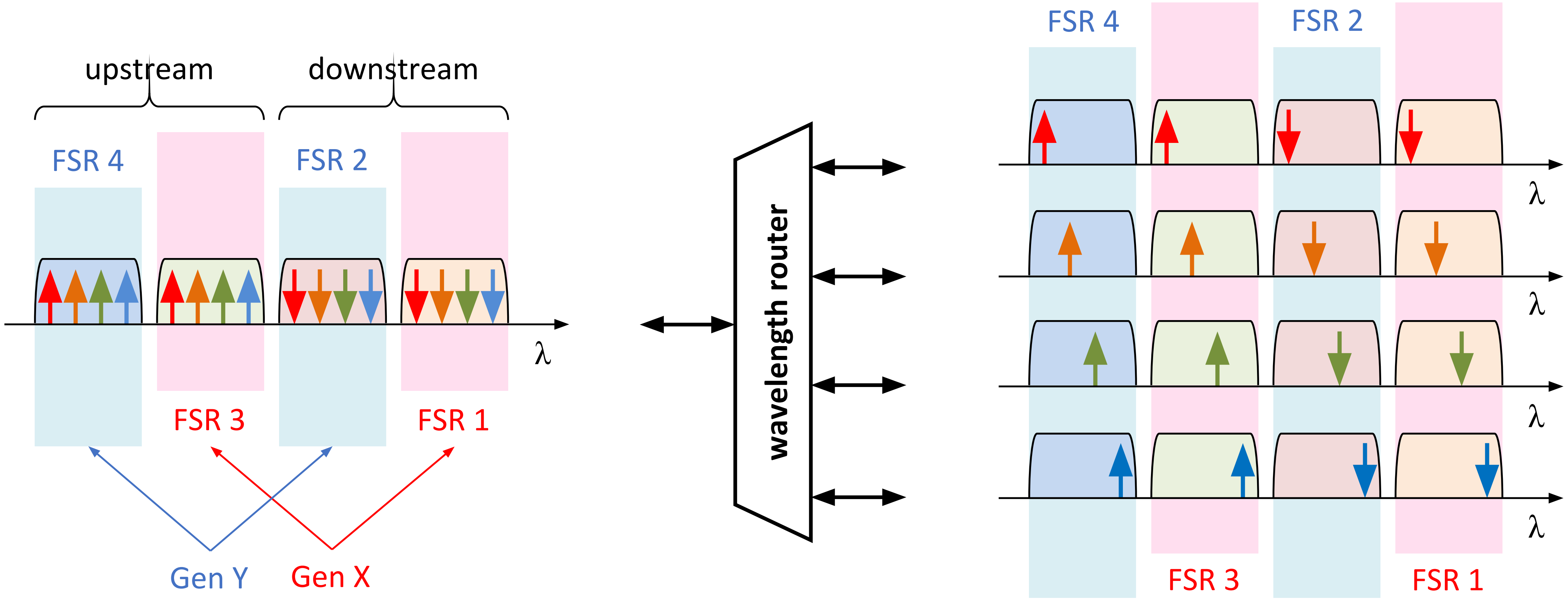
- EDFAs are the most mature optical amplifiers and have the following benefits:
  - Lower noise figure than SOAs
  - A long time constant that makes them less susceptible than SOAs to inter-channel crosstalk and burst mode induced gain fluctuations
    - Burst mode operation is required for upstream preamplifier function
    - WDM operation at near or above saturation input power is required for downstream booster function
  - Gain-clamping for burst mode operation is well researched and understood to further increase the stability of burst mode operation
  - Work in C/L bands

Motion

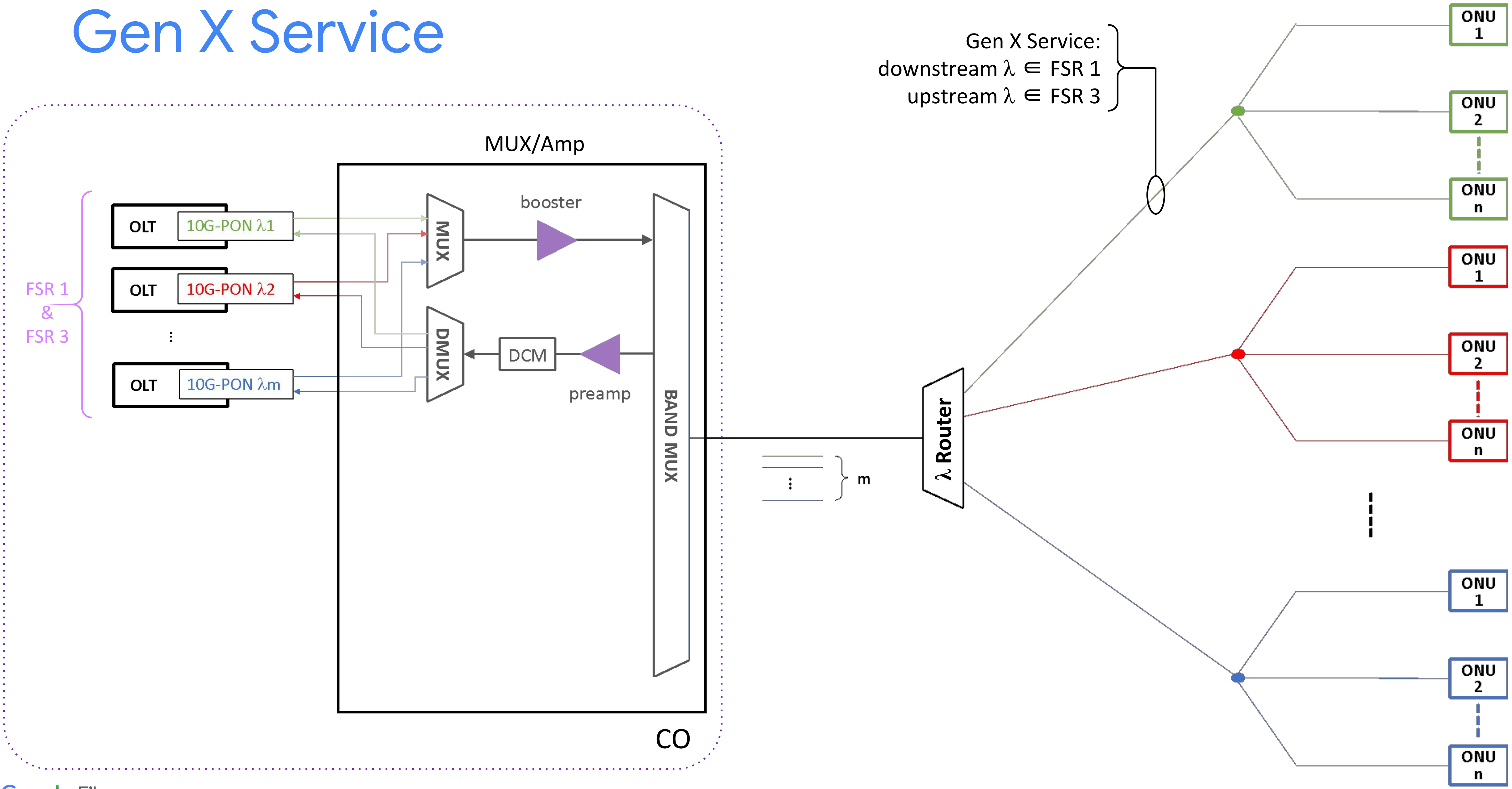
Super-PON wavelength and link budget planning shall assume that EDFAs are used for both the downstream booster amplifier function and the upstream preamplifier function.

4 sub-bands for seamless upgradeability

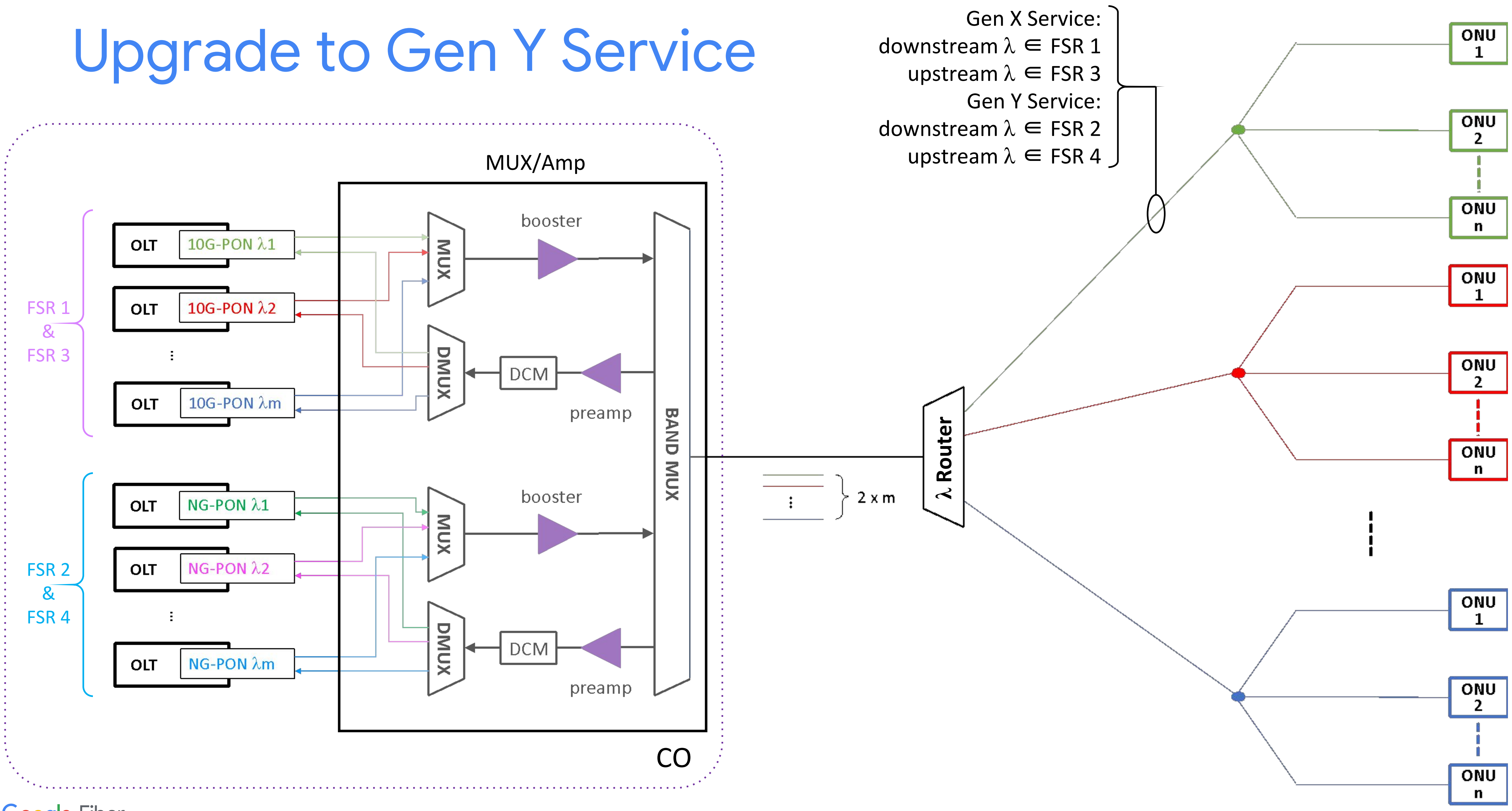
- Each channel inside any sub-band is mapped to a specific physical port
- Each wavelength router output passes 4 wavelength



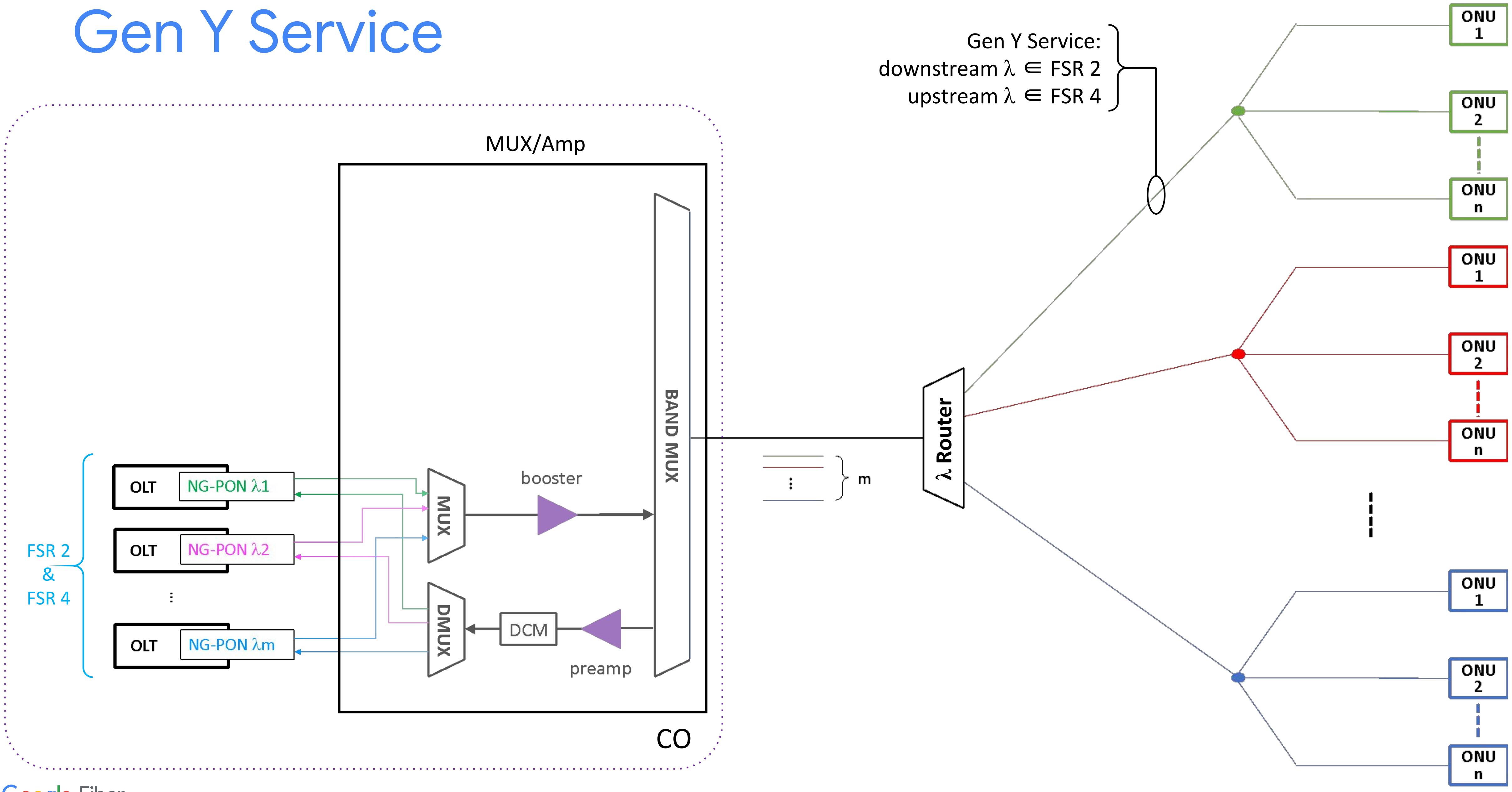
Gen X Service



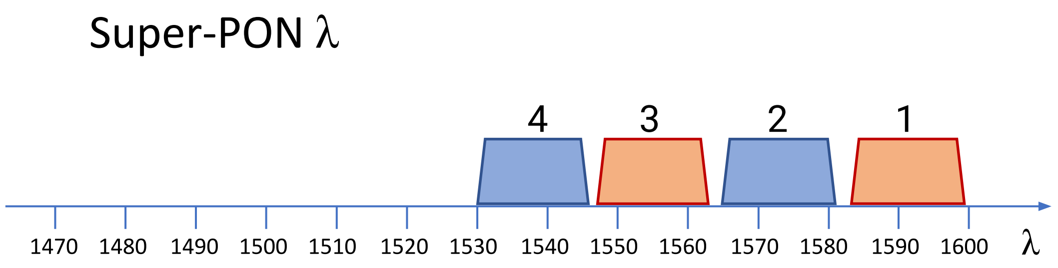
Upgrade to Gen Y Service

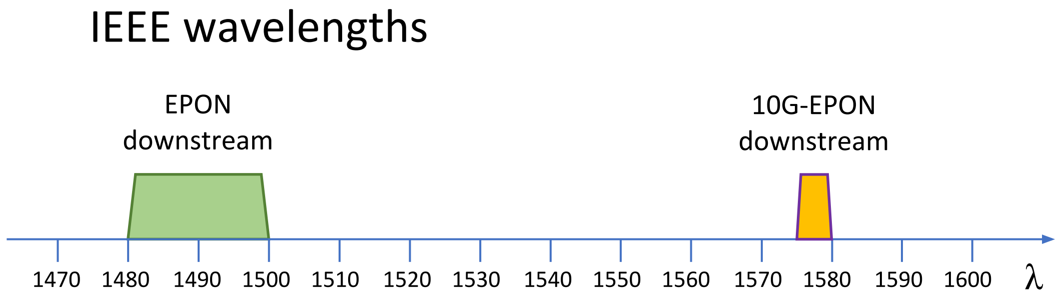


Gen Y Service



Super-PON Wavelength Plan





- Propose 4 sub-bands within C/L-bands
- EDFAs have good performance between 1530 nm and 1600 nm
- To make the bidi-element easier to build, alternate bands should be used for each generation
- To enable wavelength coexistence with 10G EPON, the “RED” bands should be used for the 10G generation of Super-PON

Motion

The Super-PON wavelength plan shall be based on four sub-bands to be used to enable concurrent operation of two technology generations for seamless upgradeability. Alternate bands shall be used for each generation.

Thank you