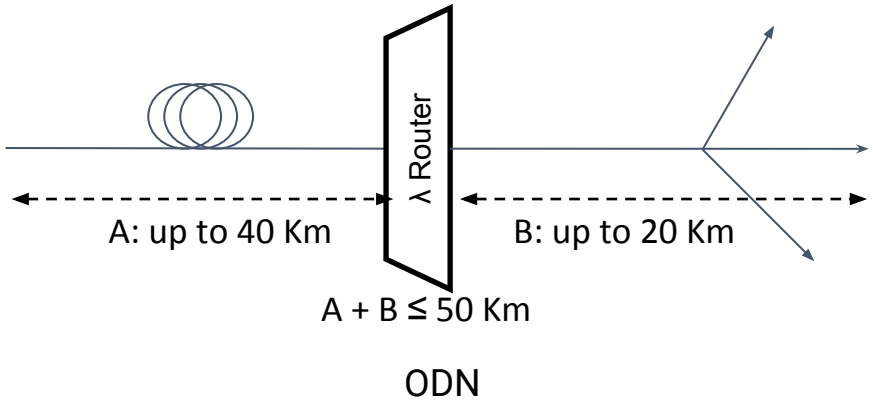
Super-PON Link Budget Analysis Revised Fiber loss

IEEE P802.3cs, July 2019

Liang Du, Google

Google Fiber

Loss of ODN Components



Loss budget		
Components	Loss Max (dB)	Comment
50km Fiber	12	0.24 dB/km
λ Router	6.6	4 to 6.6
1x64	21.5	
splice/connector	1	arbitrary
Total	41.1	

- Worst case numbers are used for the splitters and the CAWG
- Typical numbers are used for the fiber and splice/connector
- Could assume the use of MZI-AWG for a loss of 3.3 dB
  - Could add 1.5 dB to this to account for the initial lower volume optimization phase
  - Total link budget of 39.3

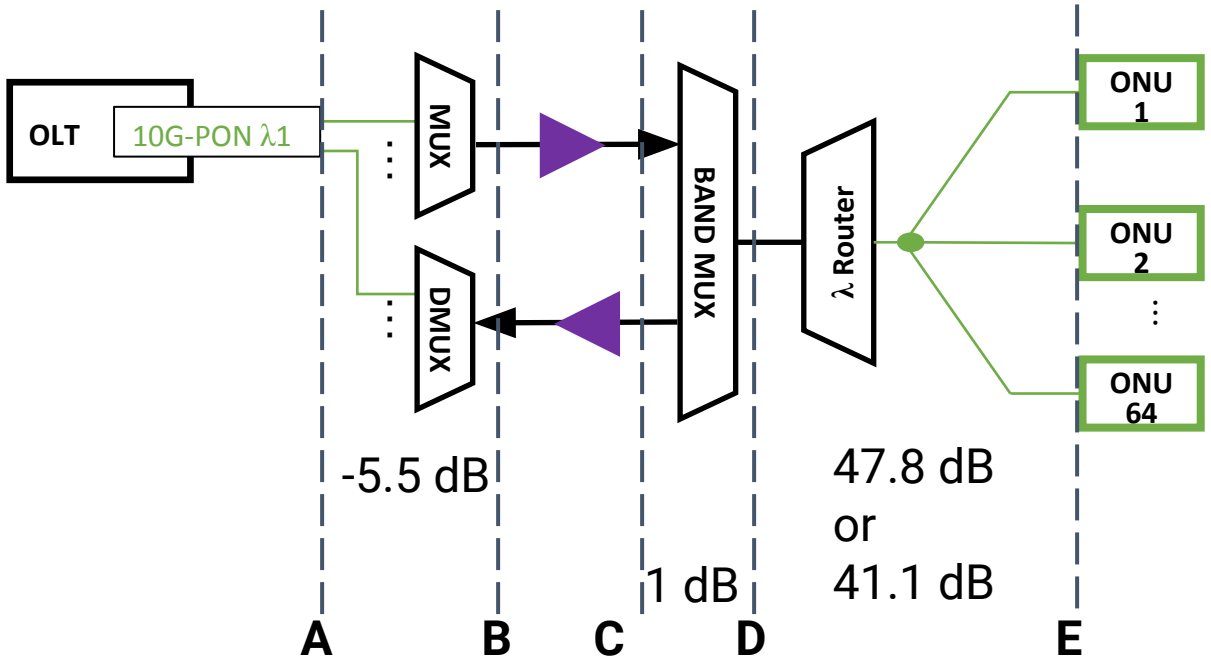
Loss of ODN Components worst case

Loss budget L-band		
Components	Loss Max (dB)	Comment
50km Fiber	17.5	0.35 dB/km
λ Router	6.6	4 to 6.6
1x64	21.5	
splice/connector	2.2	2*0.5+6*0.2
Total	47.8	

Loss budget C-band		
Components	Loss Max (dB)	Comment
50km Fiber	13.75	0.275 dB/km
λ Router	6.6	4 to 6.6
1x64	21.5	
splice/connector	2.2	2*0.5+6*0.2
Total	44.05	

- Worst case numbers are used for the splitters, CAWG, fiber, and splices
- The increase in link length/complexity magnifies the margin left for components

Downstream power levels



- High output power of amplifier is a big problem for worst case
  - A class 4 laser will be needed
  - Likely to have many NL effects
- Using typical values still requires a challenging booster amplifier
  - Still a class 3 laser

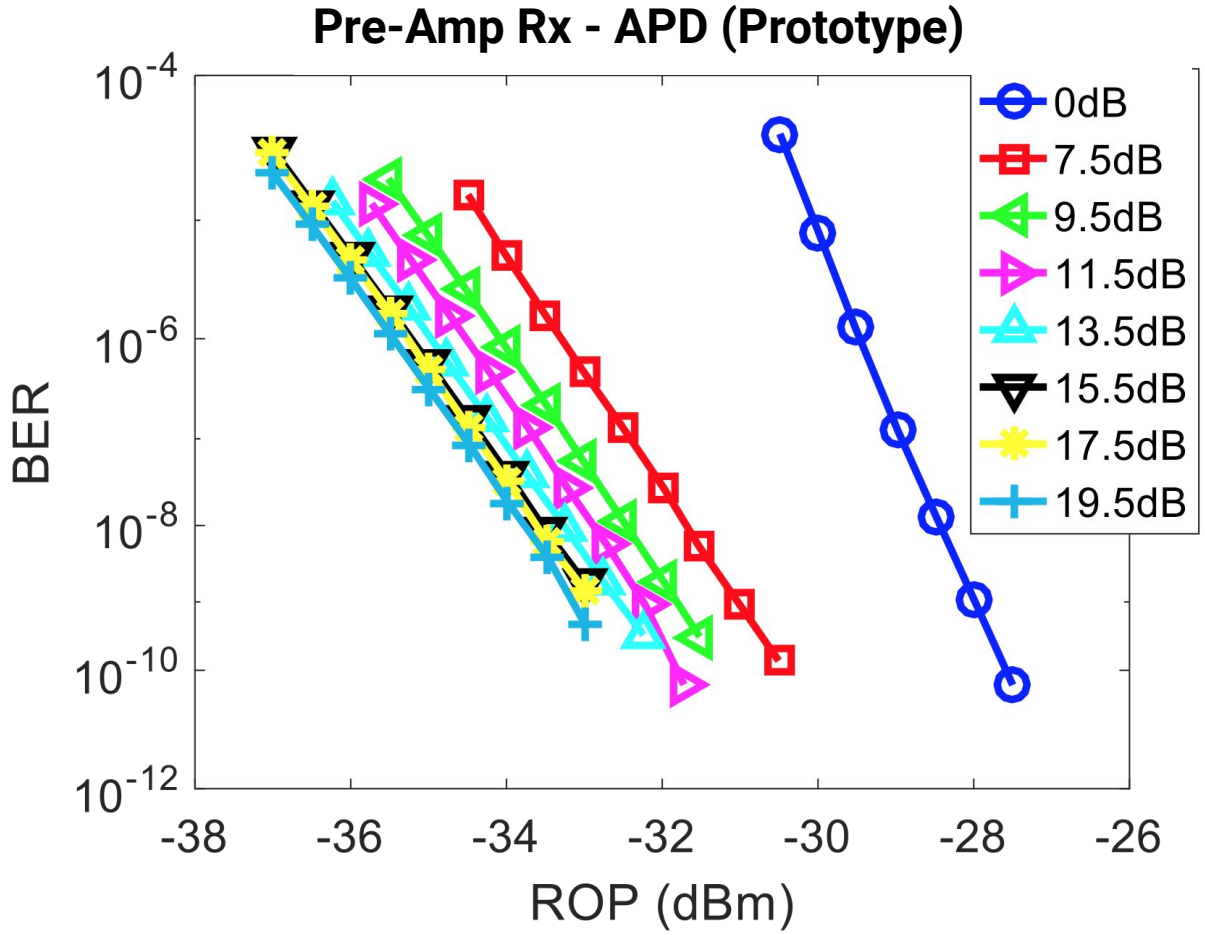
Location	DS/WL [dBm]	DS total [dBm]
A	-1.9	
B	-7.4	4.6
C	12.6	24.6
D	11.6	23.6
E	-29.5 PR40	

Location	DS/WL [dBm]	DS total [dBm]
A	4.8	
B	-0.7	11.3
C	19.3	31.3
D	18.3	30.3
E	-29.5 PR40	

Performance: EML + pre-amp (10G)

Early samples shows we can achieve RX sensitivity -38dBm at BER=1e-4

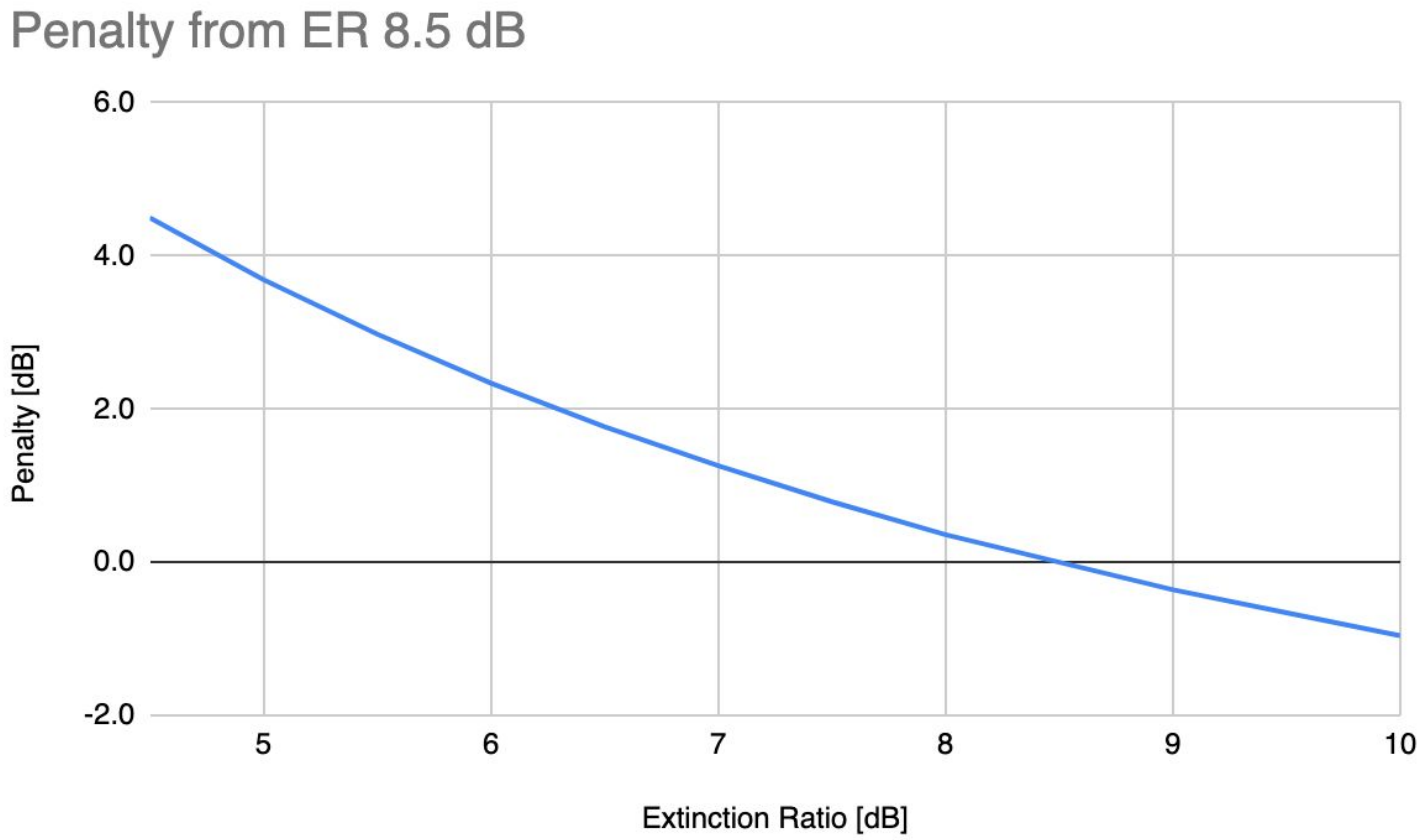
- measured at the input of pre-amp
- ER=8.5dB



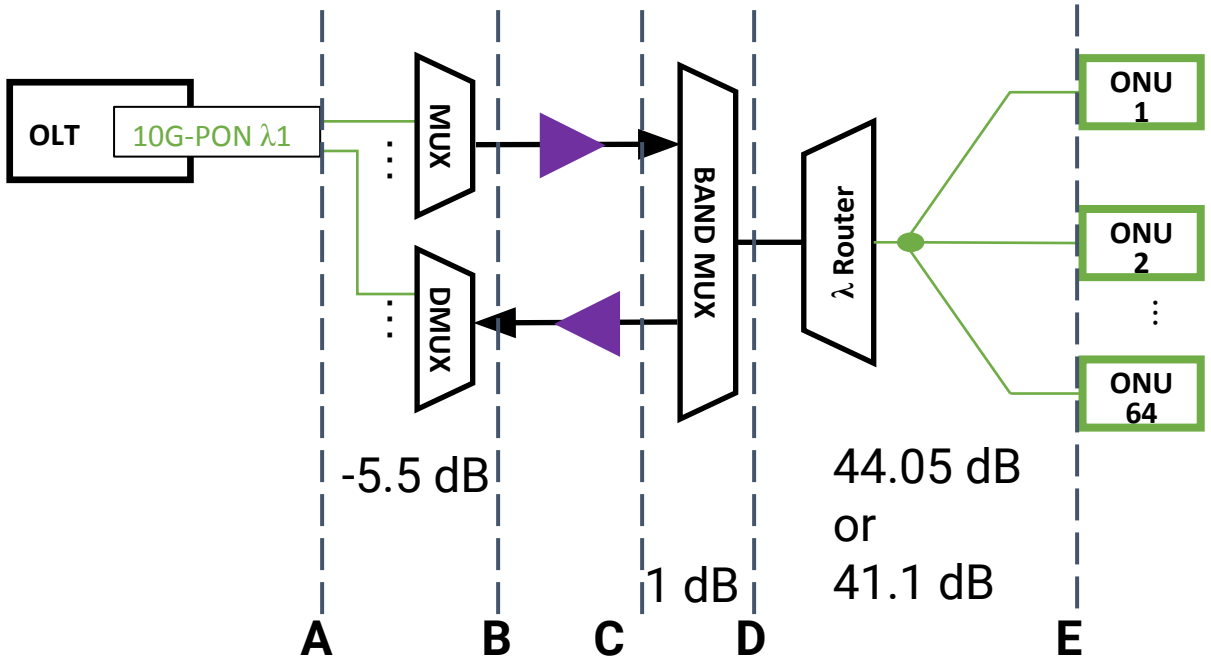
Penalty from ER

- 2.3 dB penalty for 6 dB ER
- 4.5 dB penalty for 4.5 dB ER
- These are larger than values previously seen in PON because the US is signal-ASE limited, rather than Rx power limited
- Formula is described:

$$Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0} \propto \frac{P_1 - P_0}{\sqrt{P_1} + \sqrt{P_0}} \propto \sqrt{2P_{ave}} \frac{\sqrt{ER} - 1}{\sqrt{ER + 1}}$$



Upstream power levels



- High required ONT launch powers will drive up ONT costs
- For worst case, the power required (@8.5 dB ER) is very unrealistic
- For typical, it is possible but still higher than NG-PON2's requirements

Location	US/WL [dBm]	US total [dBm]
A	-17.5	
B	-12	0
C	-37	-25
D	-38	-26
E	3.1	

Location	DS/WL [dBm]	DS total [dBm]
A	-17.5	
B	-12	0
C	-37	-25
D	-38	-26
E	6.05	

Comfortable link budgets

Downstream

Location	DS/WL [dBm]	DS total [dBm]
A	-1.5	
B	-7	11.05
C	13	25
D	12	24
E	-29.5 PR40	

41.5 dB link budget

Upstream

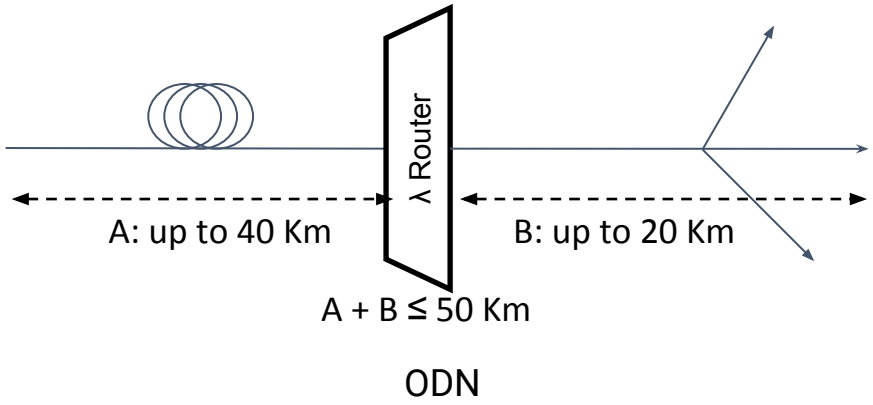
Location	US/WL [dBm]	US total [dBm]
A	-17.5	
B	-12	0
C	-37	-25
D	-38	-26
E	1.7	

39.7 dB link budget

1.7 dB @ 8.5 dB ER gives equivalent performance to 4.0 dBm @ 6 dB ER.

This aligns the required ONT to that of NG-PON2

Loss of ODN Components



ODN

DS: 41.5 dB link budget

US: 39.7 dB link budget

Loss budget		
Components	Loss Max (dB)	Comment
50km Fiber	12	0.24 dB/km
λ Router	4.8	3.3 + 1.5
1x64	21.5	
splice/connector	1	2*0.2+6*0.1
Total	39.3	

- 2.2 dB margin in DS link budget
- 0.4 dB margin on US link budget
- Can achieve our objectives

Summary

- Using worst case values for all optical components results in a very large required link budget, making the optical components difficult/expensive
- Assuming worst case loss values, we can reduce the maximum link length or the power splitting ratio to close the budget in a reasonable way
- Other specifications suffer of similar issues and use a “better link”
  - e.g., 10GBASE-ER
- The increased number of elements in Super-PON (WDM components) magnifies the worst case
- It is desirable to find a balance between worst case scenarios and reasonable specifications

Thank you