Super-PON
Wavelength Considerations

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P802.3cs Super-PON requirements

OLT 10G-PON $\lambda_1$
OLT 10G-PON $\lambda_2$
OLT 10G-PON $\lambda_m$

MUX
DMUX
BAND MUX
$\lambda$ Router

ONU 1
ONU 2
ONU 64

$x_{16}$

ODN of 50 km
Link budget with no amplifiers

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

<table>
<thead>
<tr>
<th>Components</th>
<th>Loss Max (dB)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>50km Fiber</td>
<td>12/17.5</td>
<td>C/O bands</td>
</tr>
<tr>
<td>λ Router</td>
<td>6.6</td>
<td>4 to 6.6</td>
</tr>
<tr>
<td>1x64</td>
<td>21.5</td>
<td></td>
</tr>
<tr>
<td>mux/demux</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>band mux</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>47.6/53.1</strong></td>
<td><strong>Too large!</strong></td>
</tr>
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Link budget with amplifiers

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

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<td><strong>Total</strong></td>
<td><strong>47.6/53.1</strong></td>
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</tr>
<tr>
<td>Amplifier gain</td>
<td>20</td>
<td>more complex</td>
</tr>
<tr>
<td><strong>Total with amp</strong></td>
<td><strong>27.6/33.1</strong></td>
<td><strong>Doable</strong></td>
</tr>
</tbody>
</table>
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

<table>
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<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+2 (PR30)</td>
<td>-23.6</td>
<td>+5 (PR40)</td>
<td>-27.1</td>
</tr>
<tr>
<td>B</td>
<td>-3.5</td>
<td>-18.1</td>
<td>-0.5</td>
<td>-21.6</td>
</tr>
<tr>
<td>C</td>
<td>+16.5</td>
<td>-38.1</td>
<td>+19.5</td>
<td>-41.6</td>
</tr>
<tr>
<td>D</td>
<td>-25.6</td>
<td>+4 (PR30)</td>
<td>-28.1</td>
<td>+6 (PR40)</td>
</tr>
</tbody>
</table>
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 ONU
● Loss between the amplifiers and OLT has little effect on the system
**Downstream Power levels**

<table>
<thead>
<tr>
<th>ONU sensitivity required</th>
<th>DS amplifier output C-band 1 WL</th>
<th>DS amplifier output C-band 16 WL</th>
<th>DS amplifier output O-band 1 WL</th>
<th>DS amplifier output O-band 16 WL</th>
</tr>
</thead>
<tbody>
<tr>
<td>-25.6 (from slide 5)</td>
<td>+16.5</td>
<td>+29.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-28.1 (from slide 5)</td>
<td></td>
<td></td>
<td>+19.5</td>
<td>+31.5</td>
</tr>
<tr>
<td>-28.5 (PR30)</td>
<td>+13.6</td>
<td>+25.6</td>
<td>+19.1</td>
<td>+31.1</td>
</tr>
<tr>
<td>-29.5 (PR40)</td>
<td>+12.6</td>
<td>+24.6</td>
<td>+18.1</td>
<td>+30.1</td>
</tr>
</tbody>
</table>

- 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

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

- 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

ITU PON Wavelengths
- XG(S)-PON upstream
- GPON upstream
- GPON downstream
- NG-PON2 upstream
- XG(S)-PON downstream
- NG-PON2 downstream

IEEE PON Wavelengths
- 10G-EPON upstream
- EPON upstream
- EPON downstream
- 10G-EPON downstream

25G/50G-EPON
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

Gen X Service:
downstream $\lambda \in$ FSR 1
upstream $\lambda \in$ FSR 3
Upgrade to Gen Y Service

Gen X Service: downstream $\lambda \in$ FSR 1
upstream $\lambda \in$ FSR 3

Gen Y Service:
downstream $\lambda \in$ FSR 2
upstream $\lambda \in$ FSR 4
Gen Y Service

Gen Y Service: downstream $\lambda \in$ FSR 2
upstream $\lambda \in$ FSR 4
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
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