50G single wavelength PON analysis and comparison

Dekun Liu
Minghui Tao
Background

- In 2017 July Berlin meeting, it was agreed that the task force should analyze and compare different solutions for 50G PON.

| Motion #6 |
The Task Force should analyze and compare the following solutions for 50G PON and choose the best one for 50G EPON: 1) Single wavelength TDM-PON with 50Gb/s line rate, 2) Two-wavelength TDM/WDM-PON with 25Gb/s line rate per lane.
The Task Force calls for contributions on these topics.
Moved: Dekun Liu Second: Liquan Yuan
For: 22 Against: 0 Abstain: 4
Procedural (> 50%) Motion Passed

- This contribution analyzes the different solutions to 50G PON and proposes the specs for 50G single wavelength PON.
2*25G PON

- 2*25G PON system’s power budget is 2-dB less than 25G-PON’s:
  -MUX/DEMUX’s IL is 1-dB respectively.

- Pros:
  - 25G photoelectric devices are available.
  - Based on NRZ modulation, modulation penalty and technical complexity are relatively low.

- Cons:
  - 50G ONUs need to be cooled
  - More wavelength source is need which increase both 25G and 50G cost
  - Two lasers and APDs are needed in each side, package cost will be high.
  - Cost per Gbit is higher than 25G PON, application scenario is vague
## 50G PON NRZ

### 40G~50G Laser provider

<table>
<thead>
<tr>
<th>Vendor</th>
<th>N</th>
<th>H</th>
<th>P</th>
<th>I</th>
<th>M</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-dB bandwidth</td>
<td>32GHz(43G EML)</td>
<td>50GHz(56G EML)</td>
<td>31~36GHz(50G EML)</td>
<td>20GHz(25G EML)</td>
<td>20GHz(25G EML)</td>
<td>TBD(43G EML)</td>
</tr>
<tr>
<td>Extinction Ratio</td>
<td>10dB</td>
<td>--</td>
<td>&gt;7dB</td>
<td>--</td>
<td>--</td>
<td>&gt;8.5dB</td>
</tr>
<tr>
<td>Output Power</td>
<td>&gt;5dBm</td>
<td>--</td>
<td>8dBm(with SOA)</td>
<td>--</td>
<td>6dBm</td>
<td>1.5dBm</td>
</tr>
</tbody>
</table>

### 40G~50G electrical devices provider

<table>
<thead>
<tr>
<th>Limiting Amplifier</th>
<th>CDR</th>
<th>TIA</th>
<th>SERDES</th>
<th>Laser Driver</th>
<th>FPC interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigpeak</td>
<td>Semtech, Mindspeed</td>
<td>TriQuint</td>
<td>Credo</td>
<td>TriQuint</td>
<td>Mitsubishi Electric</td>
</tr>
<tr>
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</tbody>
</table>
1310nm and O-band transmission are supported using 50G optics, \(-25.3\text{dBm}@\text{BER}=1\times10^{-3}\) can be obtained according to the simulation.

O+ band transmission is very hard as 50G-NRZ is very sensitive to dispersion.

At 1310nm, the 3-dB bandwidth of EML and APD should be \(\sim25\text{GHz}\) based on simulation.

- **Cons**
  - 50G optics are needed, cost is high
  - 50G-APD is not available so far
50G PON based on 25G optics with assistant of DSP

- DSP Compensation
  - Clock and data recovery
  - Digital compensation
    - FFE: Feed forward equalizer
    - DFE: Decision Feedback Equalizer
    - MLSE: Maximum likelihood sequence estimation

Diagram:

- 50G NRZ
- 25G APD
- 25G Laser
- LD Driver
- ADC+ DSP
- 20km
- 50G NRZ
50G PON based on DSP: Simulation

- **Simulation setup**

<table>
<thead>
<tr>
<th>50G-NRZ transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>25G-EML</strong></td>
</tr>
<tr>
<td>3-dB bandwidth</td>
</tr>
<tr>
<td>ER</td>
</tr>
<tr>
<td>Output Power</td>
</tr>
<tr>
<td><strong>25G-APD</strong></td>
</tr>
<tr>
<td>3-dB bandwidth</td>
</tr>
</tbody>
</table>

- **DSP compensation**

- **-25dBm@BER=1e-3** after 20-km transmission can be got just using FFE when EML chirp factor is -0.5
- **-24.4dBm@BER=1e-3** after 20-km transmission can be got just using FFE when EML chirp factor is 0.5

![Graph showing BER vs. Receive Sensitivity for different EML conditions](image)
50G PON based on DSP: Experiment

-27.5dBm@BER=1.4e-2 after 20-km with FFE only
-24.5dBm@BER=1e-3 after 20-km with FFE only
Advantage of 50G PON based on DSP

- O+ band is supported by DSP-EQ of 50G-NRZ transmission.
- Dispersion penalty is about 1-dB in 1350nm
50G PON NRZ power budget and wavelength plan

25G EML+SOA+DSP

- Tx_min
  +6.5dBm

- ER=8
  Ch.loss_max
  29dB

- Rx_sen_stress
  TDP (~1.5dB)

- Rx_sen
  -24 dBm @1E-2
  25G APD+DSP

- 50G NRZ: -24dBm@1E-2

- Enhanced FEC: -2dB

- 50G NRZ: -22dBm@1E-3

- 25G to 50G penalty: 3dB

- 25G NRZ: -25dBm@1E-3

- Note: assume some base line improvement on 25G APD sensitivity. More details see liu_3ca_1_1117 and guo_3ca_1_0917

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50G UP option 1

1260

50G UP option 2

1280

50G DN

1300

1320

1340

1360
50G PON based on PAM4

Diagram showing the components of a 50G PON system based on PAM4 technology.
50G PON PAM4 based on 25G optics

50G PAM4: -21.5dBm @1E-2

50G PAM4: -19.5dBm @1E-3

PAM4 penalty: 5.5dB

25G NRZ: -25dBm @1E-3

Note: assume some base line improvement on 25G APD
more details see liu_3ca_1_1117 and guo_3ca_1_0917
50G PON based on PAM4 with 10G optics

- Power
  - AWG
  - Driver
  - 10G DML

- Software Interface
  - Oscilloscope
  - 10G ROSA
  - Optical Attenuator

- Computer

Measured BER performance of 50-Gb/s PAM4 based on 10G

Measured BER performances of 50-Gb/s PAM4 for different

50G PAM4 based on 10G optics with FFE+MLSE after 20km
- -20.7dBm@BER=1e-3, ~-23dBm@BER=1E-2
50G PON based on PAM4 power budget and wavelength plan

25G EML+SOA

Tx_min

+9dBm

Ch.loss_max

29dB

Rx_sen_stress

TDP (~1.5dB)

Rx_sen

-21.5 dBm @1E-2

25G APD

50G UP option 1

50G UP option 2

50G DN

harstead_3ca_3_0917

<table>
<thead>
<tr>
<th>AVPmin (dBm)</th>
<th>number</th>
<th>mean</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>EML</td>
<td>6</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>EML+SOA</td>
<td>3</td>
<td>8.7</td>
<td>2.0</td>
</tr>
<tr>
<td>cooled DML</td>
<td>6</td>
<td>6.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ER (dB)</th>
<th>number</th>
<th>mean</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>EML</td>
<td>6</td>
<td>7.5</td>
<td>0.8</td>
</tr>
<tr>
<td>EML+SOA</td>
<td>3</td>
<td>7.3</td>
<td>1.2</td>
</tr>
</tbody>
</table>
## Cost comparison

<table>
<thead>
<tr>
<th>solution</th>
<th>Key cost components</th>
<th>Total cost by weigh*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLT</td>
<td>ONUs</td>
</tr>
<tr>
<td>1 *25G NRZ</td>
<td>one 25G EML+SOA* one 25G APD 25G EML driver+25G BTIA&amp;BCDR</td>
<td>one 25G uncooled DML one 25G APD 25G LDD+25G TIA&amp;CDR</td>
</tr>
<tr>
<td>1*50G NRZ based on DSP</td>
<td>one 25G EML+SOA one 25G APD+pre-SOA 25G EML driver+25G TIA oDSP chip*</td>
<td>one uncooled 25G DML one 25G APD 25G LDD+25G TIA oDSP chip</td>
</tr>
<tr>
<td>1*50G based on PAM4</td>
<td>one 25G EML+enhanced SOA* one 25G APD+pre-SOA PAM4 driver+25G linear TIA PAM4 encoder and Decoder</td>
<td>one uncooled 25G DML one 25G APD PAM4 driver+25G linear TIA PAM4 encoder and Decoder</td>
</tr>
</tbody>
</table>

* Note:
- 25G OLT is assumed to need a common EML+SOA, while 50G based on PAM needs a special designed EML+SOA
- the total cost by weigh assume the volume ratio of OLT : ONU = 1 : 20
- The cost of oDSP is estimated based on the experiments in page 8, including FEC, ~3.5*3.5mm² die size, 16nm ASIC technology (more reference in liu_3ca_4_1116)
Summary

- Several solutions of 50G PON are analyzed:
  - both 50G PON single wavelength based on NRZ+DSP and PAM4 are feasible to meet the 29dB power budget, with the assistance of DSP and/or booster amplifier.
- 1*50G has the following potential benefits over 2*25G:
  - Saving in wavelength resource
  - Simplicity in hardware and management
  - Cost-effectiveness
- Spec and wavelength plan shown in page 10 and page 14 are recommended as the starting point for 50G single wavelength PON analysis.
Thank you

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