Experimental Results of Single Wavelength 50G PON

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Junwen Zhang, Jun Shan Wey, and Xingang Huang
Introduction

This contribution presents the test results of three candidate technologies for 50-Gb/s/λ TDM-PON

• Options and Requirements
• Sensitivity Analysis and Test Results
• Wavelength Options
• Challenges
Background

- In July 2017 Berlin meeting, the Task Force decided to analyze and study the solutions for single wavelength 50G PON, and compare it with two-wavelength 25G solution (wangbo_3ca_2_0717).
- In last meeting, there are two contributions on 50-Gb/s/λ TDM-PON (liu_3ca_2_0917, and houtsma_3ca_0917). Both presented analysis on modulation formats, power budget, challenges and potential solutions.
- In this contribution, we present experimental results and analysis on single wavelength 50G PON.
Four Modulation Format Options for 50-Gbps/λ

- NRZ at 50GBaud:
  - best performance with 50G optics, clock frequency at 50GHz
  - becomes Duobinary-like signal with 25G optics
- PAM-4 at 25GBaud:
  - requires 25G optics, clock frequency at 25GHz
- EDB at 50GBaud:
  - requires 25G optics, clock frequency at 50GHz
- DMT:
  - requires 10-20G optics, ~20GHz sampling rate
  - high PAPR penalty and computation complexity
Required Optics and Electronics

Optical Bandwidth
- 50G optics: can support 50G NRZ; however, very high cost and no commercial 50G APD available
- 25G optics: is a mature technology for 50Gbps in DCI
- 10G optics: low-cost, but with additional ISI penalty

Receiver
- APD: 25G APD is available now
- SOA+PIN: pre-amplifier becomes significant to improve the sensitivity

TIA
- PAM-4 and DMT require linear TIA
- DMT is much more sensitive to linearity impairments compared with PAM-4

DSP
- Either pre- or post-equalization is required to improve performance
Transceiver Setup

- **EML**: O-band, BW ~20GHz, Output Power ~2.5dBm
- **APD**: O-band, BW~18GHz
- **SOA**: 25dB small signal gain
- **PIN**: BW ~12GHz
- **DAC**: BW <20GHz, **ADC**: BW ~30GHz
25GBaud PAM-4 test results

- 17-tap FFE is used at the Rx-side;
- The Rx Sensitivity of 50Gbps PAM-4 (25GBaud):

<table>
<thead>
<tr>
<th>BER\Rx</th>
<th>APD</th>
<th>SOA+PIN</th>
<th>SOA w/ LAN-WDM +PIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1E-3</td>
<td>~-20dBm</td>
<td>~-21.5dBm</td>
<td>~-22dBm</td>
</tr>
<tr>
<td>1E-2</td>
<td>~-23dBm</td>
<td>~-23.5dBm</td>
<td>~-26.5dBm</td>
</tr>
</tbody>
</table>

- Compared with 25G NRZ by APD, PAM-4 has 7dB penalty @1e-3, and 5.5dB penalty @1E-2
- PIN using SOA with LAN-WDM filter can compensate 3.5dB @ 1E-2
- Otherwise, Tx with optical power >6dBm is required to achieve 29dB power budget @1E-2
50GBaud NRZ/EDB based on 25G Optics

To transmit the 50GBaud signals of OOK, there are two methods:

- **Method 1**
  - Tx: NRZ signal, suffering narrow-bandwidth filtering, with large ISI
  - Rx: Advanced ISI processing, i.e., MLSD for multi-symbols optimization;

- **Method 2**
  - Tx: Pre-coded EDB signals, signal bandwidth within 25GHz
  - Rx: EDB detection and regular signal equalization (FFE or FFE+DFE)

Both methods can work well to mitigate bandwidth limitation.
50GBaud NRZ test results

- 17-tap FFE is used
- The Rx sensitivity of 50G NRZ achieved:

<table>
<thead>
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<th>SOA+PIN</th>
<th>SOA w/ LAN-WDM+PIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1E-3</td>
<td>~-23dBm</td>
<td>~-25.2dBm</td>
<td>~-27dBm</td>
</tr>
<tr>
<td>1E-2</td>
<td>~-24.5dBm</td>
<td>~-26.8dBm</td>
<td>~-29dBm</td>
</tr>
</tbody>
</table>

- Compared with the reference 25G NRZ by APD, 50G NRZ has 4dB power penalty
- PIN using SOA without filter can compensate >2dB, SOA with filter can compensate >4dB
- Otherwise, Tx with power >4.5dBm is required to achieve 29-dB power budget @1E-2
50GBaud EDB (pre-coded) test results

- 17-tap FFE is used
- The Rx sensitivity of 50G EDB achieved:

<table>
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<tr>
<th>BER\Rx</th>
<th>APD</th>
<th>SOA+PIN</th>
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<td>~-24dBm</td>
<td>~-25.5dBm</td>
<td>~-28.2dBm</td>
</tr>
</tbody>
</table>

- Compared with the reference 25G NRZ by APD, 50G EDB has 4.5~5dB power penalty
- PIN using SOA without filter can compensate 1.5dB, and SOA with filter can compensate 3.5-4dB
- Otherwise, Tx with power > 5dBm is required to achieve 29-dB power budget @1E-2
Wavelength Options

1. O-band wavelength is preferred, due to large chromatic dispersion penalty in C-band, especially for NRZ signals.

   Simulation Results: Power Penalty (dB) @1 E-3 in C-band

<table>
<thead>
<tr>
<th>CD (ps/nm)</th>
<th>0</th>
<th>16</th>
<th>80</th>
<th>160</th>
<th>240</th>
<th>320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber length (km)</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>PAM-4</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>0.7</td>
<td>1.8</td>
<td>8.5</td>
</tr>
<tr>
<td>NRZ (w/ MLSD)</td>
<td>0</td>
<td>0</td>
<td>2.2</td>
<td>6.8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

2. If advanced DSP is enabled, C-band is also possible with CD pre-compensation and nonlinearity compensation (J. Zhang, et al., ECOC 2017, Paper P2.SC8.53)
Challenges of 50-Gb/s/λ

1. Insufficient link power budget
   - Compared with 25G NRZ, 50Gbps/λ has high power penalty: 5.5dB (PAM-4), 4dB(NRZ), and 5dB (EDB) at 1E-2

2. Cost and complexity
   - Due to large power budget gap, optical amplifier is required
   - Equalization is required
   - ADC/DAC resolution is increased compared with 25G NRZ
   - Higher linearity requirement

3. Upstream burst receiver
   - No Burst linear TIA
   - No BCDR and burst equalization

4. Technology maturity
   - Key technologies may be available after 2020
Summary

1. Test results of single-wavelength 50G PON are presented:
   • Compared with 25G NRZ by APD, PAM-4 has 7dB penalty @1e-3, and 5.5dB penalty @1E-2
   • Compared with 25G NRZ by APD, 50G NRZ has 4dB penalty
   • Compared with 25G NRZ by APD, 50G EDB has 4.5~5dB penalty

2. Due to the large power budget gap, optical amplifier is required in the system, in either Tx or Rx side;

3. Challenges exist for single wavelength 50Gbps, including insufficient link power budget, cost and availability of burst receiver.
Thank You!

Leading 5G Innovations
• At the OLT, LD at 1550 nm is used as the light-source.
• A dual-drive MZM biased at quadrature point for complex signal modulations
• The 25- and 32-Gbaud PAM-4 signals are generated by a DAC at 80 and 81.92 Gsa/s, respectively.
• The 3 dB analog bandwidth of the DAC is 16 GHz The PAM-4 symbols, followed by the LN Pre-EQ and LUT-based Pre-DT algorithm to mitigate channel impairments.
• CD pre-compensation is used for fiber transmission

J. Zhang, et al., ECOC 2017, Paper P2.SC8.53