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Duobinary for 25G-PON

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Agenda

- 25G TDM-PON and 25G TWDM PON
- 25G Optical Duobinary (ODB) / Electrical Duobinary (EDB) Architecture
- Experimental Results
- ODB/EDB Advantages
- Summary
25G TDM-PON and 4*25G TWDM-PON based on ODB modulation for downstream and EDB for upstream

25G TDM-PON based on ODB and EDB modulation

4*25G symmetrical TWDM-PON structure
25G ODB/EDB Architecture – Downstream (DS)

Downstream format: ODB

- **25 Gb/s ODB Transmitter** [1]
  - Differential precoding ensures recovered bits are same as original signal bits
  - The continuous wave output 1550 nm DFB laser is modulated by precoded signal
  - Mach-Zehnder modulator (MZM) with 3 dB bandwidth of 10 GHz biased at intensity null. Encoder uses low-pass filtering instead of 1-bit delay-and-add
  - EDFA at OLT achieves +10 dBm launch power

- **25 Gb/s ODB Receiver**
  - High-bandwidth APD with 3 dB RF bandwidth of 10 GHz, plus 25 GHz TIA
  - The electrical signal is reshaped by a 25 Gb/s linear amplifier followed by clock and data recovery
25G ODB/EDB Architecture – Upstream (US)

Upstream format: EDB

**◆ 25 Gb/s EDB Transmitter** [2]
- Differential precoding ensures recovered bits are same as original signal bits
- 10 GHz EML TOSA generates 3-level EDB signal due to bandwidth limitation

**◆ 25 Gb/s EDB Receiver**
- 10 Gb/s linear APD ROSA with EDB decoder
  - EDB decoder consists of two threshold slicers and an exclusive-or
  - 7-tap feed-forward equalizer (FFE) for post-equalization (EQ), to improve the performance of EDB signal
- EDFA pre-amplifier at OLT increases the power budget to 32.5 dB
25G ODB Experimental Results

- Fiber transmission results in a negative power penalty,
  - fiber dispersion acts like a low pass filter consistent with ODB characteristics
- At $10^{-3}$ BER ($10^{-12}$ BER after standard FEC), the sensitivity is $-24.2$ dBm after transmission over 20 km in the C-band (around 1550 nm)
- EQ can further improve performance by 2 dB [3]
- With +10 dBm launch power, a loss budget of 34.2 dB after 20 km has been achieved
After EQ, $10^{-3}$ BER receiver sensitivity are: -19.0, -21.2 and -22.5 dBm for B2B, 20 and 30 km, respectively in the C-band (around 1550 nm).

Performance may be improved further, e.g., by better post EQ

With +2 dBm launch power and an EDFA preamplifier at the OLT, a loss budget of 32.5 dB after 20 km has been achieved.
Experimentally measured eye diagrams of (a) 25 Gb/s ODB signals and, (b) 25 Gb/s EDB signals

Receiver sensitivities at $10^{-3}$ BER for 25 Gb/s ODB and EDB signals at different reaches:

<table>
<thead>
<tr>
<th>Distance</th>
<th>ODB receiver sensitivity @$10^{-3}$</th>
<th>EDB receiver sensitivity @$10^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 km (B2B)</td>
<td>-20.5 dBm</td>
<td>-22.5 dBm</td>
</tr>
<tr>
<td>20 km</td>
<td>-24.2 dBm</td>
<td>-21.2 dBm</td>
</tr>
<tr>
<td>30 km</td>
<td>-23.0 dBm</td>
<td>-19.0 dBm</td>
</tr>
</tbody>
</table>
Advantages of the ODB/EDB Architecture

- **General PON requirements (P2MP)**
  - ONU simple: ODB receiver and EDB transmitter are as simple as NRZ
  - OLT enhancements: ODB transmitter and EDB receiver with post-EQ

- **Low cost; ODB/EDB realized with commercially available components**
  - ODB Downstream: 10 Gb/s MZM and 10 GHz APD/TIA receiver
  - EDB US: 10 Gb/s EML and 10 Gb/s linear APD ROSA
  - Potential for additional cost reduction
    - 10G InP or silicon photonics MZM vs 10G LiNbO₃ DDMZ
    - 10GHz APD ROSA replacing 25G APD ROSA

- **High performance**
  - ODB/EDB high dispersion tolerance; 25G transmission up to 30km at C/L band
  - ODB/EDB offer high receiver sensitivity
  - Even higher ODB performance possible using 16 GHz APD ROSA and post-EQ[3]
Summary

- 25 Gb/s/λ TDM-PON system based on 25 Gb/s ODB modulation for DS and 25 Gb/s EDB for US transmission

- Provides high-performance solution with low cost
  - ONU: low-cost, similar to NRZ transceiver without optical amplification
  - ODB DS: about -24.2dBm sensitivity at 10^{-3} BER=1e-3 w/o EQ after 20km SSMF transmission in the C-band
  - EDB U/S: -21.2dBm sensitivity at BER w/ EQ after 20km in the C-band
  - Loss budget ≥ 32.5 dB at 1550 nm over 20-km w/o dispersion compensation for both DS and US

- This solution may provide an attractive evolutionary path for NG-EPON.
Thank you

www.huawei.com
Bibliography

[1] D. van Veen et al., “40-Gb/s TDM-PON over 42 km with 64-way power split using a binary direct detection receiver,” ECOC’14, PD.1.4
