The Case for O-Band

John Johnson

IEEE 802.3 Interim, Huntington Beach
January 10, 2017

BROADCOM

O-band is the incumbent choice

- The combination of low dispersion, high-performance O-band lasers and simple 25Gb/s NRZ modulation lead to a solution with inherently low power penalty and low cost. These factors make O-band the incumbent solution for Nx25G optical transmission.
- O-band is already the incumbent solution for low-cost 2.5 and 10G ONUs and Nx25G datacom applications for these reasons.
- Outside of O-band, additional, more costly dispersion management techniques must be used <u>just to be on par</u> with the low-penalty transmission performance attainable in O-band.
- For the 802.3ca task force to choose a wavelength plan outside of O-band, there must be shown to be <u>significant advantages</u> over an O-band solution in terms of performance and cost that outweigh the additional techniques that must be used. Parity is not sufficient.
- In this contribution, we argue that this <u>burden of proof</u> has not been met, so the task force should agree on a wavelength plan with all channels in O-band in order to move the standard forward.

BROADCOM

Transmitter technology

- Low fiber chromatic dispersion in O-band enables low-TDP 25Gb/s NRZ transmission using low-cost, high-power DMLs.
  - Low cost DML sources are crucial to minimize ONU cost.
  - TDM coexistence enables use of uncooled DMLs for potentially lower cost.
  - Low TDP is critical in loss-limited PON applications. Expected 25G DML TDP < 1.5dB for λ < 1310nm (Tanaka_3ca_1_0716).
  - Cooled DMLs have by far the highest output power of any transmitters under consideration, minimizing the need for optical amplification (Harstead_3ca_1_0716).
- Transmission outside O-band requires more expensive low-chirp transmitters in order to keep TDP in a manageable range.
  - Extra TDP must be made up elsewhere in the power budget, adding cost.
  - Cooled EMLs are the best alternative, but are expected to cost 2X more (He_3ca_1_0716) and have 2.5dB lower output power than cooled DMLs (Harstead_3ca_1_0716).
  - Chirp managed lasers (CML) use DMLs precisely tuned to a filter to reduce chirp. The filter and high frequency accuracy increase insertion loss and cost (Yi_3ca_1_0316).
  - Electronic duobinary (without DSP) can be low cost, but the required pre-coding results in error twinning penalties. (Houtsma_3ca_1_0916)
  - More complex modulation formats such as optical duobinary (ODB) may require Mach-Zehnder modulators which are significantly more expensive than EMLs.

Dispersion compensation

- The low fiber chromatic dispersion in O-band makes dispersion compensation unnecessary.
  - Low-cost DMLs are sufficient to provide TDP < 1.5dB in the upstream direction for λ < 1310nm (Tanaka_3ca_1_0716).
  - Low chirp EMLs are sufficient to provide TDP < 1.5dB in the downstream direction for λ > 1310nm (Umeda_3ca_3_0316).
- Outside of O-band, some form of dispersion compensation is required for spans more than ~10km.
  - All DC methods add cost and operational complexity to manage dispersion over the wide range of fiber lengths in PON systems.
  - For spans < 10km, DC may not be strictly required but TDP will be higher than 20km transmission in O-band (Umeda_3ca_3_0316).
  - Dispersion compensating fiber (DCF) is passive and broadband, but requires extra cost, rack space and introduces up to ~1.2dB insertion loss (Harstead_3ca_3b_0916).
  - Etalon and grating based dispersion compensating modules (DCM) are smaller but narrowband and require power for temperature control (Umnov_3ca_1b_1116). Not suitable for upstream TDM traffic.
  - Electronic dispersion compensation (DSP) has high power dissipation and won't be practical for several CMOS generations (Liu_3ca_4_1116).

BROADCOM

Other considerations

- Other minor advantages of S/C/L-band exist but are not compelling enough to offset the losses and costs of higher dispersion:
- Splitting bands (Plan D) frees up more optical spectrum to relax laser and filter tolerances, but the issues of tight spectrum in O-band have been shown to be manageable.
  - The cost of OLT optics is not as important to overall system cost (Harstead_3ca_3a_1116)
  - Multiple contributions have shown that FWM can be avoided by allowing at most one lane in the zero-dispersion window. (Liu_3ca_1_1116)
  - US-DS diplexer gap can be > 40nm for 25G upstream ONUs, enabling low-cost focused-beam BOSA construction with minimal excess loss. (Funada_3ca_1_0117)
  - For 50/100G symmetric ONUs diplexer gap is <30nm so collimated beam diplexer must be used, but these are considered premium upstream services.
  - The use of TDM coexistence enables ±1.5nm laser accuracy for ONU cooled DMLs further reducing laser cost. (Harstead_3ca_2_0117, Johnson_3ca_2_0117)
- Having both US and DS in C-band (Plan C) doesn't add any benefit since the available spectrum is the nearly same as in O-band.
- EDFAs in C-band have great performance, but so far have not been shown to be essential vs. SOAs which have adequate performance and better size/cost/power.

BROADCOM

Summary

- The low dispersion in O-band makes it the natural solution for Nx25G optical transmission, especially for loss-limited PON where every fraction of a dB counts.
- Members of the task force have put considerable effort into demonstrating that all of the issues associated with the tight spectrum in O-band will be manageable.
- All the dispersion mitigation methods that enable operation outside of O-band add some power penalty, insertion loss, cost and/or complexity just to be on par with 25Gb/s DML performance in O-band.
- To date, none of these methods have been shown to offer any <u>significant</u> advantages for operation outside of O-band.
- Since there is no overwhelming reason to do otherwise, the task force should agree on a wavelength plan with all channels in O-band in order to move the standard forward.

BROADCOM

Proposed motion

- Motion #1: The P802.3ca standard shall specify a wavelength plan in which all upstream and downstream wavelengths are located in O-band.

BROADCOM®

Thank You!