10 Gb/s PMD considerations

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Large Optical Budget

- PON requires a large optical budget
  - Splitters are intrinsically lossy
  - Deployment practices are less than ideal
    - Mechanical splices
    - More connectors than you think
  - System margin to avoid troubles
- Bottom line, class “B+” is a must
  - 28 dB of budget, plus optical path penalty

Wavelength Co-existence

- There has been some interest in co-existence between 10GEPON and EPON
  - This seems very costly and difficult to implement reliably
  - Furthermore, previous system upgrades (B-PON to EPON, B-PON to G-PON) have not provided this compatibility
- We believe that co-existence is possible only in limited circumstances

Wavelength plan

- The current E and G-PONs use
  - 1260-1360 nm upstream
  - 1480-1500 nm downstream
  - 1550-1560 nm video overlays
  - Forget about using the water-band (most fiber is black there)
- The upstream window is ‘lucrative real-estate’ because of low dispersion
  - Unfortunately, the existing systems have built a ‘trailer park’ full of FP lasers on this resource, and we can’t just evict them…
- A cost effective 10G system could use 1530 nm CWDM window for downstream, but needs to use 1310 window for upstream
  - System could co-exist if they could ‘share’ the 1310 band, somehow… but that’s complicated

10 Gb/s components

- If we use the ~1550 nm window, external modulated DFB seems likely
  - OLT transmitter will be costly, but that's manageable because of sharing
- In the 1310 nm window, a directly modulated DFB should be possible
  - Cost effective for the ONT
- 10 Gb/s receiver
  - PIN-based (ONT) sensitivity around -18 dBm
  - APD-based (OLT) sensitivity around -24 dBm

Hypothetical Link Budgets

- Downstream
  - PIN receiver: -18 dBm
  - Budget: +28 dB
  - Transmitter: +10 dBm minimum!
- Upstream
  - APD receiver: -24 dBm
  - Budget: +28 dB
  - Transmitter: + 4 dBm minimum!
- Without FEC, both links are difficult

FEC makes budgets practical

- Ordinary RS(255,239) will give us 4 dB (conservatively) at 10 Gb/s
- This lowers transmitters into their ‘comfort zone’
  - OLT range could be +6 to +10 dBm
  - ONT range could be 0 to +5 dBm
- Unlike 1G systems, it seems that FEC is a mandatory part of the budget here

Using FEC

- The EPON FEC used lots of 8b10b tricks to make itself backward compatible
  - This matched the non-committal demand of the market for FEC at that data rate
  - Mass deployment has not used FEC, favoring to keep the 7% overhead for data
- At 10G, we need the FEC all the time
- We could also address the bandwidth impact positively by super-rating the optics
- The simplest way to do this is to use streaming FEC, as in G.975

Bits, bytes, and words

- Assuming we stay with 64b66b code, it is good to make the FEC fit the codewords
- 28 66b codewords = 231 bytes
- RS(248,231) gives 7.36% redundancy
- RS(252,231) gives 7.9% redundancy
- Data rates
  - MAC rate of 10 Gb/s
  - 64b66b rate of 10.03125 Gb/s
  - 231/248 rate of 11.071429_ Gb/s
  - 231/252 rate of 11.25 Gb/s (somewhat rounder)

Upstream with FEC

- Simplest scheme is to always arrange to transmit whole FEC codewords
  - 224 MAC byte units
  - On average, 112 bytes are wasted…
- Enhancement is to support shortened codewords
  - Not clear if this is worth the effort, particularly considering the physical layer overhead

10G burst mode

- The key variable is the overhead time, composed of three major parts
  - Transmitter on-off
  - Receiver PMD
  - Receiver clock phase recovery (PMA)
- Transmitter and phase recovery times are inversely proportional to clock rate
- Over ~1 Gb/s, the Rx PMD layer time is mostly constant in time

Upstream efficiency

- In previous systems, Rx PMD time was perhaps half of the overall upstream overhead time
- So, in going up in rate 10x, we might expect to see a 40% reduction in overhead time
- Bursting period can remain constant (from a service perspective), so efficiency can actually increase

Conclusions

- Wavelength coexistence is doubtful
- Link budget is challenging
- FEC looks mandatory
- 10G upstream doesn’t hurt efficiency