IEEE 802.3ah

FEC Cost Effectiveness for EFM

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Thanks for assistance to:

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Scope

- FEC as the cost effective method to meet reach/split targets using low-cost optics:
  - Split-limited case: improves link budget
  - Reach-limited case: mitigates MPN effects
- Parameters to evaluate cost effectiveness of FEC

Cost Effectiveness Evaluation

- Split limited:
  - FEC improves link budget to enable high split ratios
  - FEC ↔ High power Tx.
  - FEC ↔ APD at ONUs (High sensitivity Rx.)
  - FEC ↔ Adding a split to the net
- Reach limited:
  - FEC extends MPN-limited uplink reach to the 20km target and improve link budget
  - FP laser + FEC ↔ DFB laser

Mechanism

- Parameters are vendor specific, numbers are merely estimations
- Shows typical cost estimation for 1 code – RS(255,239) code
- Cost is relative – [REL] as cost tag
- Assuming a revenue model which is not affected by small BW loss or gain

Coding Gain

- RS(255,239,8)
  - BER improvement of 10^{-4} to 10^{-12}
  - Coding gain (@ 10^{-12}) – **5.6dB** for AWGN

For some commercial PIN and APD receivers:

- **4.5dB for APD**, **3.5-4dB for PIN** -Sufficient for adding a two-way splitter
- FEC improves MPN penalty

FEC Cost - Gate Count

- FEC gate count per coding gain

For the RS (255,239,8) the gate count is ~300KG @ 31.25MHz

- Silicon cost per gate count
  - 0.18µ @ 100KG ≡ 1.0 [REL]
  - 0.25µ @ 100KG ≈ 3.0[REL]
- FEC Cost:
  - 0.18µ ≈ 3.0[REL]
  - 0.25µ ≈ 9.0[REL]

Power Dissipation

- FEC gate count is at 31.25M
- $P=\rho\eta G\, f_{max}$ = 0.03[μW/(MHz*G)]* *0.5*300[KG]*31.25[MHz]=0.15W
- Aggregating ports for P2P OLT:
- P_{total}=NP = 0.15N[W]
- High FEC gate count might limit port number in a card.

Optical Component Cost

- Fundamental optical component based on 1000LX FP lasers ≈ **70 [REL]**
- DFB cost > **120 [REL]**
- Hi-power FP laser
  - Additional cost for –7dBm to –2dBm > **5 [REL]**
  - Additional gain **? [REL]**
- APD receiver cost > **25[REL]**

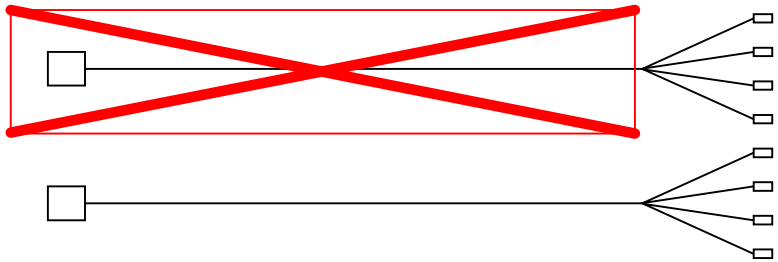
Passive Optical Splits

- Split No per dB – $\left\lfloor \frac{\mathbf{C\_gain}}{3.7} \right\rfloor$ [split/dB] = 1

- New_ONU_no = 2*ONU_no_{last}
- The benefit from FEC increases with the increase in the number of ONUs

Facility Cost for P2MP

- Facility cost is divided by ONU_no
- Facility cost goes down when there are more ONUs per PON since there are less OLTs and fibers to the split point. The reduction is up to a limit of negligible OLT cost:



Saving = port_cost +Fiber_cost ≈
≈ (500+ 0.06*15000)/ONU_no |64| ≈ 22 [REL/ONU]

- Increasing the number of ONU to a PON may also affect revenues of BW distribution in some deployment scenarios.

Rate Loss

- Rate loss of code - (255,239,8) RS code - 6%.
- Rate loss due to increasing sync. time in P2MP uplink receiver

- Assuming reasonable BW loss, the effect of the BW loss on most deployment scenarios is negligible since the system is not deployed in full BW capacity.

Hi-Split/Short-Reach Comparison

- FEC improves link budget to enable high split ratios
- **FEC ↔ Extended power FP**
  - **3 ↔ 5[REL]**
- **FEC ↔ APD at ONUs**
  - **3 ↔ 25 [REL]**
- **FEC ↔ Adding a split to the net**
  - **3 ↔ 22 [REL]**

- FEC is cost effective for Hi-split/short-reach

Long-Reach Comparison

- FEC extends MPN-limited uplink reach and improves link budget
- **FP laser + FEC $\leftrightarrow$ DFB laser**
  - **3 $\leftrightarrow$ 51 [REL]**
- FEC is cost effective for long-reach
- Possibilities:
  - Dividing APD cost by ONU number – can be considered to extend splits in uplink

Conclusion

- FEC is a cost effective method to meet reach/split targets using low-cost optics:
  - Improves link budget
  - Extends MPN-limited reach