Comments on ‘10Gb/s PHY for EPON’

Tatsuya Kubota
Hirotaka Wada

802.3 10G EPON study group
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Summary

I agree with the promotion of standardization of 10G EPON.

- We should consider migration from EPON.

- We should not discuss only the existing devices but also consider the new technology which will appear in the near future.

- We should consider a symmetric rates (10G/10G) optical network as the main subject.

- We should consider a reasonable cost system.

- We will focus on 10G PHY for EPON. However, we suggest to discuss topics other than PHY if necessary.

Overview

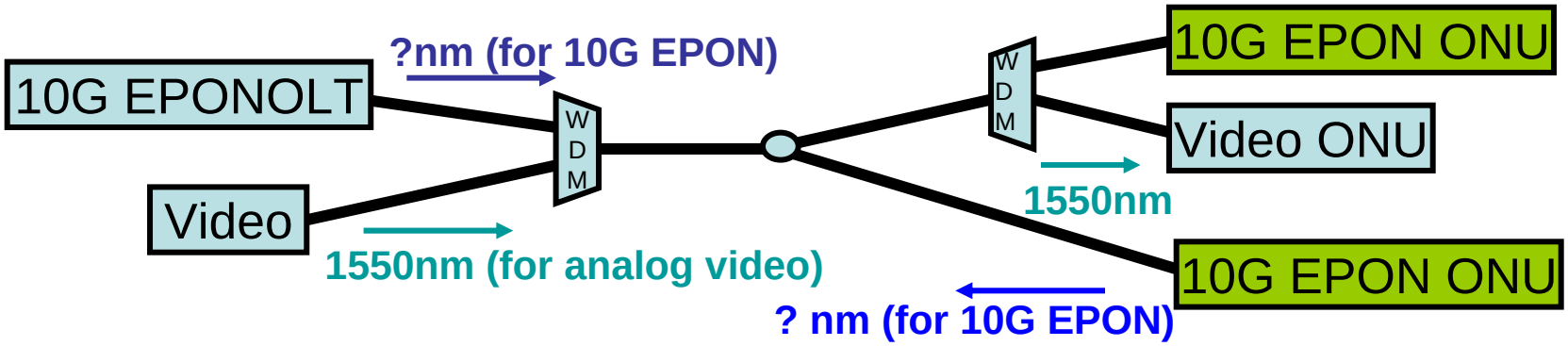
- 10G EPON System Compatibility
- Technical Considerations
- Conclusions

10G EPON System Compatibility

We should consider compatibility with EPON.

1. Optical budgets and distance are the same as those of EPON.
   - Optical budgets： >26dB
   - Maximum distance： >20km
   - Support ONUs： >32

2. To be able to coexist with overlay service on the same ODN.
   - It is necessary to consider the wavelength(1550-1560nm) for Analog video broadcast.

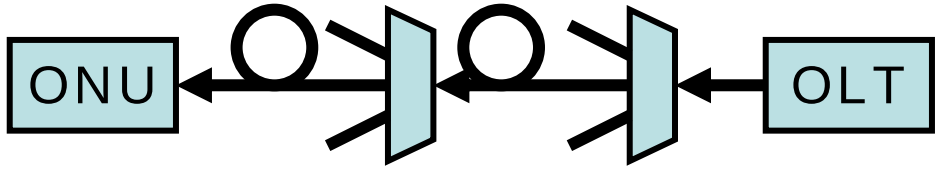


Technical Considerations

- Power Budget Expansion
  - High power Laser source
  - High sensitivity Photo Diode
- Improvement on dispersion tolerance
  - External modulation method
  - EDC (Electronic Dispersion Compensation)
  - DCF (Dispersion Compensation Fiber)
- Upstream burst multiple technology
  - Burst bit synchronization (10Gbps CDR)
  - High speed AGC amplifier
  - PMD parameter

Power Budget Expansion (1/8)

- Downstream Power Budget



Pin-PD Sensitivity (10G)
Max: -1 dBm (IR2)
Min : -17 dBm

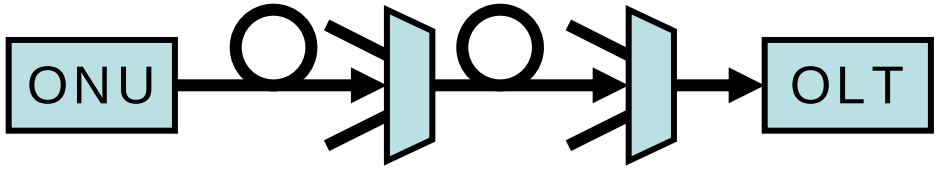
Input Power
Max: -3 dBm
Min : -25 dBm

26 dB (@ PX20 power budget)

Launch Power
Max: +7 dBm (PX20D)
Min : +1 dBm (EML)

Lack of 8 dB

- Upstream Power Budget



Launch Power (@ PX20U)
Max: +4 dBm
Min : -1 dBm (DFB)

26 dB (@ PX20 power budget)

Input Power
Max: -6 dBm
Min : -27 dBm

APD Sensitivity
(10G estimate)
Max: -6 dBm
Min : -24 dBm

Lack of 3 dB

Power Budget Expansion (2/8)

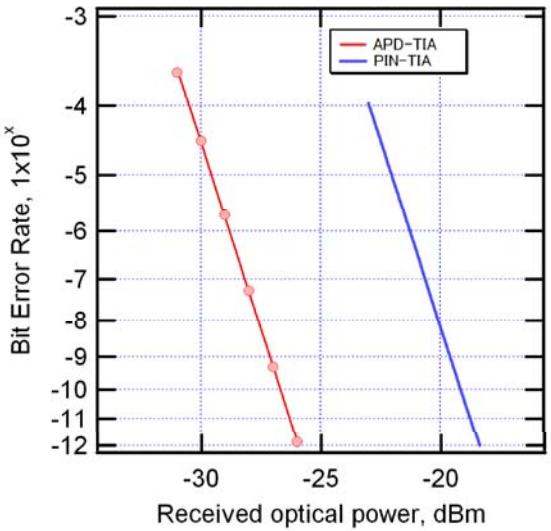
- High power optical source

	Output power	High speed responsibility	Extinction ratio	Cost	Size	Total
Direct modulation LD	Poor	Poor	Poor	Fair	Fine	Fair
High power CW LD + LN modulator	Fine	Fine	Fair	Poor	Poor	Fair
EML	Poor	Fine	Fair	Poor	Fine	Fair
Direct mod. + Booster Amp.	Fine	Fine	Fair	Bad	Poor	Fair

Power Budget Expansion (3/8)

- High sensitivity photo detector

	Receive Sensitivity	High speed responsibility	Dynamic range	Cost	Total
PIN-PD	Poor (-17dBm)	Fine	Fine	Fine	Fair
APD	Fine (-24dBm)	Fine	Fair	Poor	Fair
PIN-PD + PreAmp.	Fine	Fine	Fair	Poor or Bad	Fair



Power Budget Expansion (4/8)

- Optical amplifier

Direction	Type	Bandwidth	Gain	Noise Figure	Power Consumption	Burst amp.	Cost	Total
Down (Booster amp.)	EDFA	Fair	Fine	-	Fair	-	Fine	Fine
	SOA	Fair	Fine	-	Fair	-	Fair	Fine
	Raman	Excellent	Fair	-	Poor	-	Poor	Fair
Up (Preamp.)	PDFA	Fair	Fair	Fine	Fair	Possibly Fine	Possibly Fine	Fair
	SOA	Fair	Fair	Poor	Fair	Fine	Fair	Fair
	Raman	Excellent	Fair	Fine	Poor	Fine	Poor	Fine

Power Budget Expansion (5/8)

- Combination of optical source and receiver

	Optical budget	Cost (*note)
LN + PIN-PD	Fair (24dB)	Fine (300%)
Direct Mod. + APD	Fair (25dB)	Fair (500%)
EML + APD	Fair (25dB)	Poor (600%)
LN + APD	Excellent (31dB)	Bad (700%)
Direct mod. + Amp + PIN-PD	Excellent (> 35dB)	Bad (>1000%)

*note: 100% is EPON cost (only transceiver).

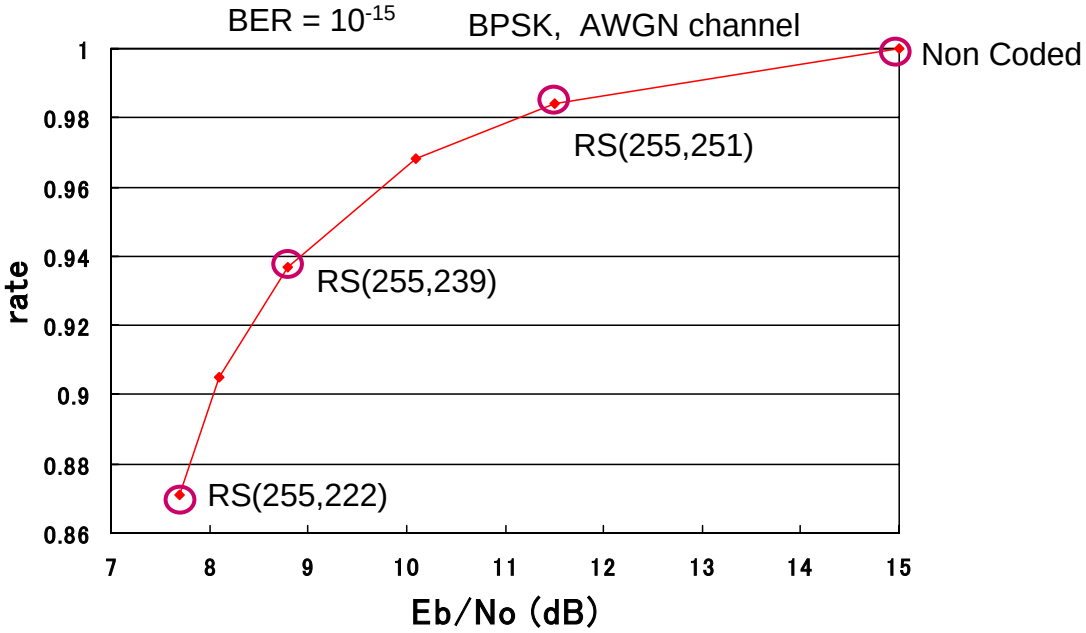
Power Budget Expansion (6/8)

- FEC
  - Expected performance is a key for a selection of FEC technology.

Method	Pros	Cons	Applying Standards	Cost
RS (255, 239)	Effective for burst error Low redundancy Smaller delay	Low gain	G.709 OTN: RS(255,239) 802.3ah EFM: RS(255,239)	Fine
BCH (4359,4320)	Very low redundancy	Very low gain Moderate Delay	G.707 SDH: BCH-3 (4359,4320)	Fine
LDPC (2048,1723)	High gain	High redundancy High complexity	802.3an 10GBASE-T	Fair(?)

Power Budget Expansion (7/8)

- FEC (Reed-Solomon)



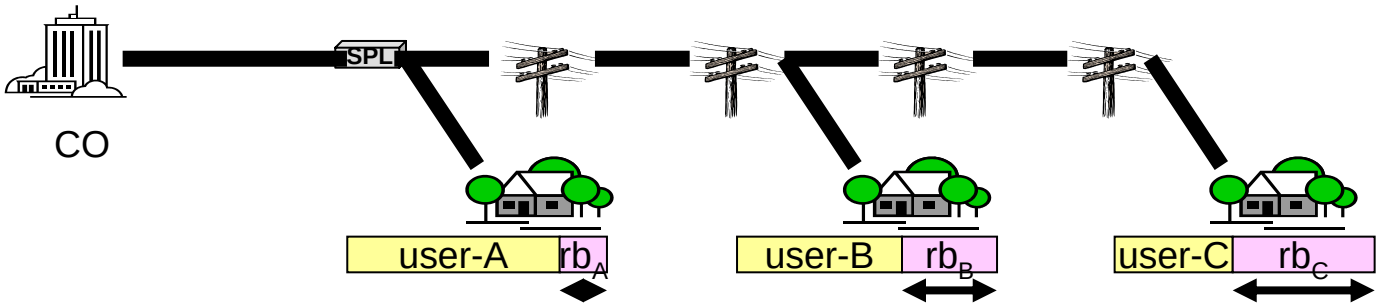
Greater redundancy increases gain at the expense of data rate.

Power Budget Expansion (8/8)

- Consider advanced FEC feature

  For example;

  - Automated code redundancy adjustment by ONU distance bias by DBA
  - Greater redundancy for long reach ONU, smaller redundancy for short reach ONU



Improvement on dispersion tolerance

	Power loss	Dispersion tolerance	Reach limit	Cost	Total
Direct Mod. + EDC	Fine	Fair	Fair	Fine	Fair
Direct Mod. + DCF	Poor	Fair	Poor (*note1)	Poor	Poor
External Mod.	Fine	Fine	Fine (*note2)	Fair	Fair

*note1: -Constant value of dispersion can be compensated by DCF.
Dynamic range is the same as limit for direct modulation.
*note2: -Direct modulation method
For example (1490nm);
Transmission distance limited 4～5km by maximum values of dispersion (80ps/nm).
-External modulation method is achievable at 10Gbps.
For example (1490nm);
Transmission distance limited 40km

Upstream burst multiple technology

- 1Gpbs upstream
  Existing (802ah)

- 10Gpbs upstream:
  We should consider the following items,
  - Acceptable optical power level difference under burst mode operation
  - Burst bit synchronization time
  - 8B/10B or 64B/66B for block synchronization

Conclusions

10G E-PON transceiver is technically feasible.
However, we have to carefully select the optimal combination of optical source and receiver from the view point of required performance and cost.
We should not discuss only the existing devices but also consider new technology which will appear in the near future.