Feasibility of high speed TDM in NG-EPON

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Outline

- *General Requirements*
- *Data Rate choices*
- *Link Budget*
- *Available Wavelength Resources*
- *Technology and Device Maturity*
- *Summary*

General Rrequirements

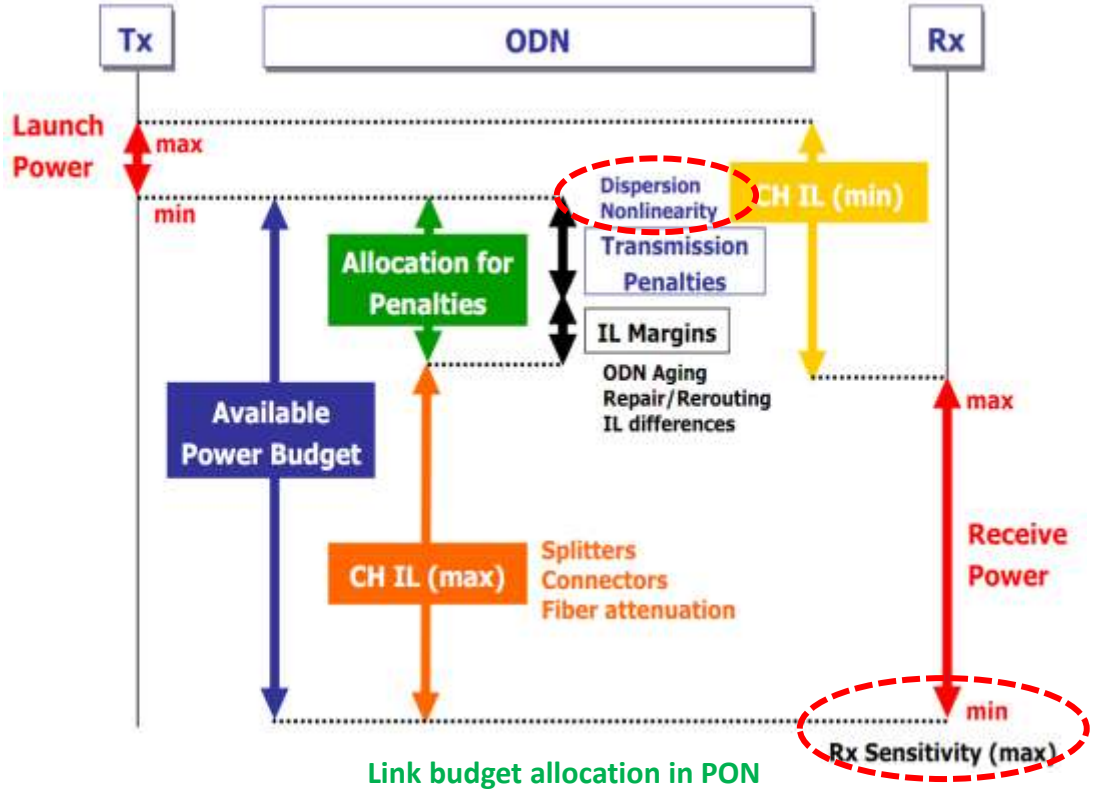
(Huawei view)

- Providing higher system capacities. (Shall)
  - *The data rate shall be higher than 10Gbps.*
  - *Link budget shall meet EPON requirement, this will be discussed in detail below.*
- Coexistence with 1G-EPON, 10G-EPON and RF overlay. (Shall)
  - *Wavelength plan is very important, needs detailed analysis.*
- Can be applicable to mobile backhaul. (Shall)
  - *An emerging requirement, mainly affecting the system capability.*
  - *Fronthaul is optional, depending on the performance.*
- Legacy ODN reuse. (Shall)
  - *This requirement has been agreed in previous discussion.*

Data Rate Choices

- **Data rate of 1G-EPON**
  - *Downstream: 1G(1.25Gbps)*
  - *Upstream: 1G(1.25Gbps)*
- **Data rate of 10G-EPON**
  - *Downstream: 10G(10.3125Gbps)*
  - *Upstream: 1G(1.25Gbps, Asymmetric) or 10G(10.3125Gbps, Symmetry)*
- **What will be the most feasible single wavelength speed in NG-EPON?**
  - *Downstream: 25G ? or 40G ?*
  - *Upstream: 10G ? or 25G ?*

Link Budget I



Link budget allocation in PON

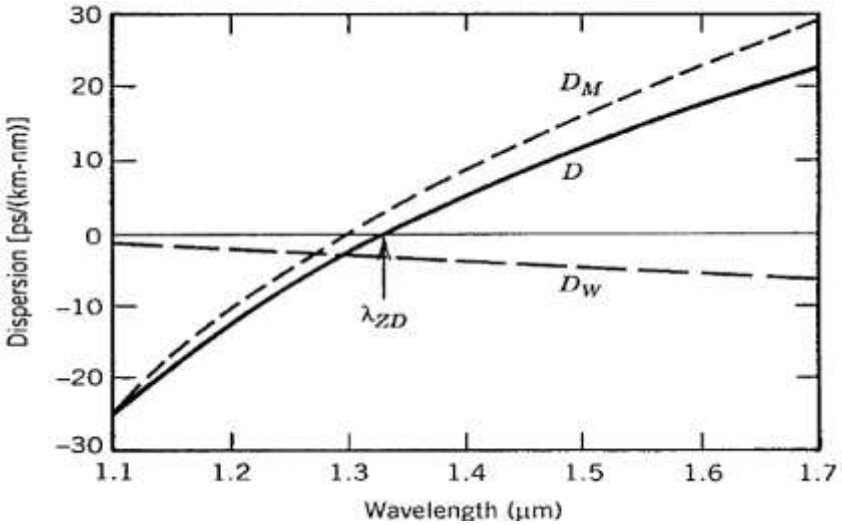
Rx Sensitivity:

- *The relationship between Rx Sensitivity (Si APD@BER 10^{-9}) and Baud rate is:*

$$P_{\min} \propto B^{7/6}$$

- *So the Rx Sensitivity of 25Gbps/40Gbps (Si APD@BER 10^{-9}) is about 4dB/7dB lower than that of 10G.*

Link Budget II



Dispersion coefficient of G.652 fiber

Dispersion Penalty:

- *Dispersion tolerance (1dB power penalty) in TDM PON described by :*

$$D_{[ps/km/nm]} * L_{[km]} \approx 10^5 / B^2_{[Gbit/s]}$$

Where, D , L and B are the dispersion coefficient , transmission distance and data rate respectively.

- *With the data rate upgrade from 10G to 25G(40G), the dispersion tolerance will be 6(16) times lower, and the dispersion penalty will be 3.3dB(9.3dB).*

Data rate (Gbps)	Dispersion Tolerance (ps/nm)	Max D (ps/km/nm) for penalty <1dB in 20km transmission	Dispersion penalty for 20km transfer of 1.55um(dB)
10	1000	50	0.124
25	160	8	3.2926
40	62.5	3.1	9.26

- *Multi-level modulation is a good way to reduce dispersion penalty. But...*
  - *It tends to reduce the receiver sensitivity (loss budget) as well.*
  - *Cost and complexity must be concerned.*

Link Budget III

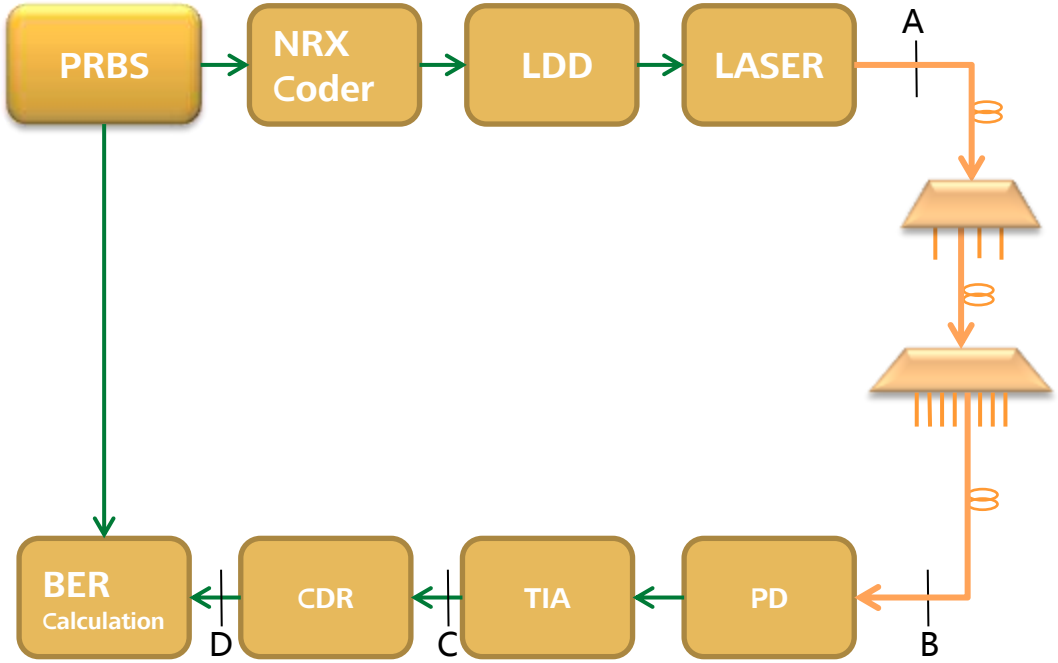
theoretical analysis

Data rate (Gbps)	Receiver Sensitivity(dBm)	Dispersion Penalty(dB)	Link Budget(dB)	
10	a	b	c	Existing
25	↓4	↑3.3	↑7.3	challenge
40	↓7	↑9.3	↑16.3	Huge challenge
Multi-level modulation	↓? (depends on the modulation type)	≈b	↑?	Cost? Complexity?

Link Budget IV

Simulation setup

- **Structure of simulation environment**



Data rate = 25Gbps

Laser: 25G EML (3dB bandwidth=19GHz)

Output power of laser: 3dBm

PD: 25G APD

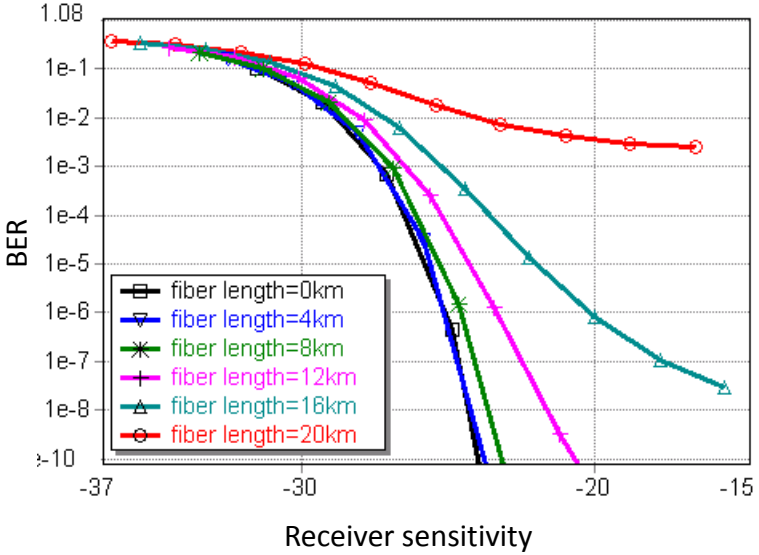
TIA: 3dB bandwidth=19GHz

Splitter ratio = 1:32

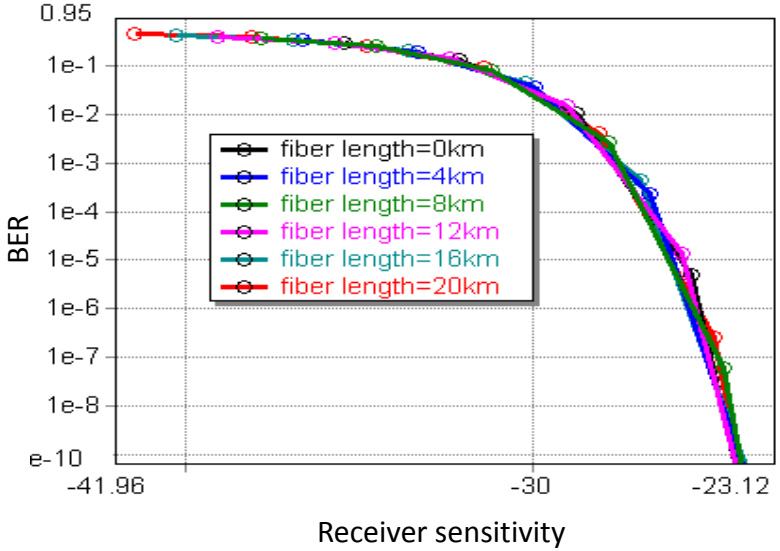
Link Budget V

Simulation results

25G EML in C band

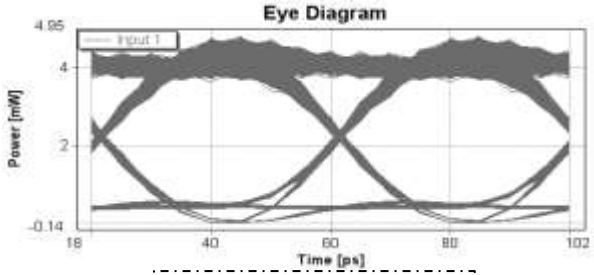


25G EML in O band

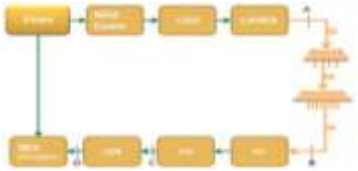


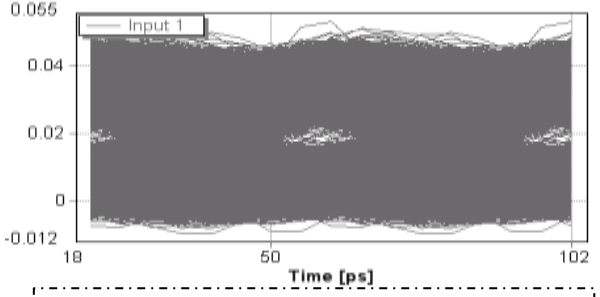
Link Budget VI

Simulation results

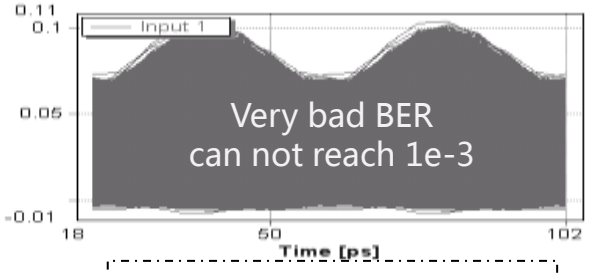


Eye Diagram at point A

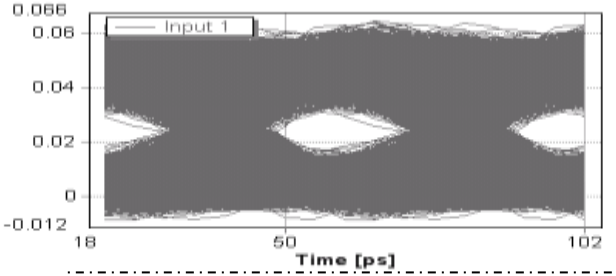




Eye Diagram at point D
Fiber length =10km,BER=1e-3,EML: C band



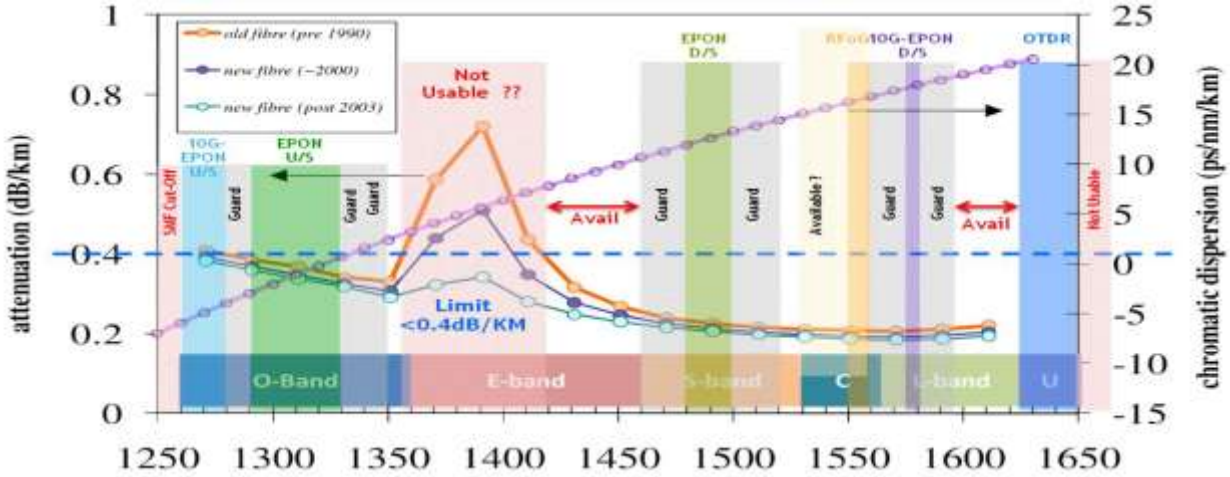
Eye Diagram at point D
Fiber length =20km , EML: C band



Eye Diagram at point D
Fiber length =20km,BER=1e-3,EML: O band

- *20km transmission length can not be supported when EML is C band and data rate is 25Gbps from the simulation results.*
- *O band is OK from the simulation, but there is another problem that the receiver sensitivity of 25G PIN/APD is about -17dbm/-23dbm@ 1e-3 in theory. So the power budget is still not enough.*

Available Wavelength Resources



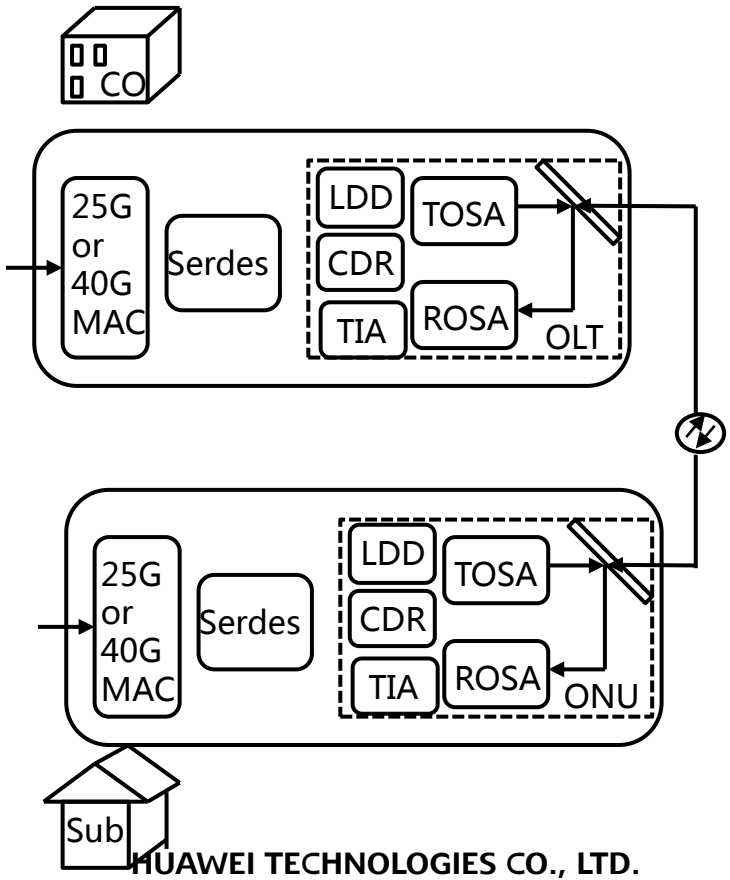
Attenuation and chromatic dispersion in different fiber types[1]

- Spectrum availability for high speed TDM PON in NGEPON is very limited if coexistence with 1G-EPON, 10G-EPON and RF overlay.

- New fiber attenuation in E band with water peak is less than 0.4dB/km, maybe E band can be considered in NG-EPON due to lower dispersion coefficient D.

Note[1]: hajduczenia_ngepon_01_0314.pdf Fig 5,page 7

Technology and Device Maturity



- The rate class of optoelectronic devices will be 25G or 40G in High Speed TDM PON applications.
  - *25G or 40G MAC*
  - *25G or 40G electrical devices (LDD, TIA , Serdes, etc)*
  - *25G or 40G optical devices (Laser, PD, etc)*

- 25G or 40G MAC
  - *Considering the success in long haul optical 100G/200G transport, 25G or 40G MAC is promising.*
- 25G or 40G electrical devices (LDD, TIA , Serdes, etc)
  - *This part is mature in practical applications.*
- **25G or 40G optical devices(Laser, PD, etc)**
  - *25G or 40G lasers in O band are available, but other bands have not seen large-scale use. Also relative cost is very high, industry chain is not mature.*
  - *25G or 40G PIN receivers are available, but its sensitivity is a concern, which will result in a lack of power budget in access network applications.*
  - *25G APD is a huge challenge, and still in the research process.*

Summary

- *High Speed TDM PON have some merits, such as*
  - *ODN reuse.*
  - *Simple structure.*
  - *Maybe can reduce energy consumption in the OLT because N customers share a single OLT transmission and reception?*
- *But also have many demerits, such as*
  - *Requires all ONUs to have transceivers operating at the overall PON data rate, but many customers only require very little data capacity.*
  - *Link budget (C band, 25Gbps NRZ) is not sufficient based on theoretical analysis and simulation results, and O band performance is also affected by receiver sensitivity of 25G PD. —— **A fatal problem.***
  - *25G/40G optical devices (C band EML, APD) are not technically mature, cost is very high. ——**Challenge.***
  - *Multi-level modulation tends to reduce the receiver sensitivity (loss budget) as well.*
- *From above all, it seems that 10Gbps per wavelength has many practical advantages in comparison to the higher rates.*

Thank you!