400GBASE-LR4
Link Budget Proposal

P802.3cu 100 Gb/s and 400 Gb/s over SMF at
100 Gb/s per Wavelength Task Force
9 September 2019

Chris Cole

IEEE

FINISAR

Introduction

- At the May Interim, there was discussion of alternatives to 400G LR4 spec based on worst case 10km SMF link
  - What's so special about 10km?
    http://www.ieee802.org/3/cu/public/May19/cole_3cu_02c_0519.pdf
  - Two SMF Spec Limit Types for 802.3 PMDs Proposal
    http://www.ieee802.org/3/cu/public/May19/cole_3cu_01a_0519.pdf
- At the July Plenary, one of the considered paths for moving forward was to reduce the 400G LR4 10km reach objective
- While 10km has some operating advantages, end users are not willing to pay a cost premium for this exact reach over a shorter reach with same link and loss budget
- Previous versions of this presentation were discussed on:
  http://www.ieee802.org/3/cu/public/cu_adhoc/cu_archive/cole_3cu_adhoc_082119.pdf
  http://www.ieee802.org/3/cu/public/cu_adhoc/cu_archive/cole_3cu_adhoc_090419.pdf

Network Operator Support

- Weiqiang Cheng, China Mobile
- Junjie Li, China Telecom
  Need similar link budget as LR8 and shorter reach is acceptable
- Glenn Wellbrock, Verizon
  We prefer a lower-cost, lower-reach version that leverages FR4 volumes. The loss budget is important but not the dispersion budget because we would rarely if ever use this optic for inter-office connections.
- Sam Sambasivan, ATT
  Need is for backwards compatibility between 400G LR4 and 400G FR4 to leverage investment in 400G FR4.
- Ralf-Peter Braun, Deutsche Telekom
  Reduced-reach high-volume cheaper device is better than more expensive 10 km device because in a Telco environment exact reach does not make a big difference

Cost is King

- CWDM grid has technical cost advantages:
  - No TEC, and associated simpler assembly techniques
  - Simpler WDM filters
- However, main cost drivers are:
  - Volume
  - Manufacturing margin
- 400G FR4 in 3+ years is expected to be a high volume interface in the cloud datacenter
- Using TF contributions, worst case 10km SMF link CWDM4 spec does not have good, if any, manufacturing margin
- Ideal spec leverages the FR4 volume and has good manufacturing margin (multiple yield sigmas)

400GBASE-LR4 Link Budget Proposal

Illustrative Link Power Budget		
Description	400GBASE-LR4	Unit
Power budget (for max TDECQ)	10.5	dB
Operating distance	6	km
Channel insertion Loss	5.0	dB
Allocation for penalties (for max TDECQ)	4.2	dB
Additional insertion loss allowed	1.3	dB

Leaves unaddressed the problem identified by Brian of how to prevent bad transmitters (excessive transmitter penalty) for middle wavelengths

L Suffix 802.3 Reach, Budget Comparisons

Code	Illustrative Power Budget dB	Total Channel Insertion Loss dB	Operating Distance km
1000 LX	8.0	4.7	5
1000 LX10	10.5	8.0	10
10G LR	9.4	6.2	10
40G LR4	9.3	6.7	10
100G LR4	8.5	6.3	10
200G LR4	10.2	6.3	10
400G LR8	10.1	6.3	10
Proposed 400G LR4	10.5	6.3	6

- Long Wavelength Serial, i.e. O-band Serial
- Serial no longer applies to WDM PMDs
- LR common misuse is Long Reach

S Suffix 802.3 Reach Comparisons

Code	Minimum modal bandwidth @ 850 nm (MHz•km)	Operating range max (meters)
1000BASE-SX	160, 200	220, 275
	400, 500	500, 550
10GBASE-SR	160 / 200	26 / 33
	400 / 500	66 / 82
	2000	300
40GBASE-SR4 100GBASE-SR10	2000	100
	4700	150
100GBASE-SR4 400GBASE-SR16	2000	70
50GBASE-SR 100GBASE-SR2 200GBASE-SR4	4700	100

- Short Wavelength Serial, originally 850nm Serial
- Serial no longer applies to WDM PMDs
- SR common misuse is Short Reach

E, C, R Suffix 802.3 Use

- E suffix
  - Extended Long Wavelength Serial, originally C-band Serial
  - Serial no longer applies to WDM PMDs
  - Used for 30km and 40km reach, in C-band and O-band
  - ER common misuse is Extended Reach
- C suffix
  - Short-haul Copper, i.e. copper cable
  - Used for 2m to 25m reach, function of rate, coding, cable construction, and other parameters
- K suffix
  - Backplane Copper, i.e. PCB copper traces
  - Up to 1m reach

L, S, VSR ITU-T USE

- G.959.1 application codes:
  - L indicates long haul (22dB span attenuation)
  - S indicates short haul (11dB span attenuation)
  - Reach is function of budget, fiber type and rate
- G.695 application codes:
  - L indicates long-haul span distance
  - S indicates short-haul span distance
  - Reach is function of budget, fiber type and rate
- G.693 application codes:
  - VSR600, VSR1000 and VSR2000 indicate target distances of 0.6 km, 1 km and 2 km, respectively
  - Attenuation categories are 4 dB, 6 dB, 12 dB, 16dB
  - Reach is function of budget, fiber type and rate

L Suffix Use Extension

- There will be 200 Gb/s and 400 Gb/s per wavelength specs. (hopefully we will write them when industry is ready)
- It is unreasonable to expect that regardless of technology break-points, the L Suffix is artificially tied to just 10km reach
- 802.3cu is a good place to extend the use of L Suffix to include reaches other than 10km, and stop the proliferation of arbitrary letters tied to specific reaches
- No other standard ties a Suffix to just one reach
- We don’t have to go back and fix other standard names
- This will additionally provide guidance to industry to replace the patch work of +, -, lite, and other modifiers to indicate different reaches

400GBASE-LR4 Link Budget Proposal

Thank You

Appendix

- Additional clarifying material in response to discussion and questions about the main presentation material
- Support on page 3 does not apply to this Appendix

Procedure Used for Defining Reach Objective

- Start with end user requirements
  - CWDM4 grid (to leverage FR4 volume)
  - 10.2 - 10.5dB Link Budget (10.5dB used in this example)
  - 6.3dB total Loss Budget (w/ unallocated insertion loss)
- Assume a range of reaches to estimate DGD and MPI
  - 5km to 7km
  - DGD + MPI penalty = ~0.6dB
    (final DGD + MPI penalty to be based on exact reach)
- Calculate resulting allocation for TDECQ penalty
  - 3.6dB (= 10.5 - 6.3 - 0.6)
- Calculate reach supported by this TDECQ penalty
  - 6km (based on reviewing 802.3cu contributions)
- Iterate reach, if necessary

Further Historical Perspective on Naming

- A letter suffix has never meant single reach in any standard, with one recent unfortunate exception
- ITU-T
  - VSR, S, L: three SMF reach ranges
- IEEE
  - S, C, K: wide reach ranges, over three different media
  - L, E: two reach ranges, over SMF
  - F introduced in 802.3bg, created third SMF reach, corresponding to ITU-T VSR2000
  - D introduced in 802.3bs, for 500m reach and PSM4: double mistake
    - F should cover datacenter reach range, just as in ITU-T VSR covers central office reach range (not just 2km)
    - PSM & WDM solved in 802.3: ex. SR4.2
- It would be bad precedent to start creating a new letter to designate every new reach between 2km and 10km

GigE is Excellent Precedent

- 802.3z defined 5km reach for 1000GBASE-LX, based on technology at the time
- 802.3av defined 10km reach for 1000GBASE-LX10 when the technology improved and enabled penalty decrease and link budget increase
- A similar approach in 802.3cu would define LR4 5km reach
- 400GBASE-LR4 would be the 5km PMD name
- Explicit 5km reach designation not needed since it's the first 400G LR4 PMD
- Future TF, when technology improvement enables penalty decrease, can define longer reach, for example 8km
- Reach is then introduced into the name, for example: 400GBASE-LR4-8 (or less desirable 400GBASE-LR1.4-8)

Appendix

Thank You