Baseline CD_Q Values for 800GBASE-FR4

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IEEE P802.3dj Task Force
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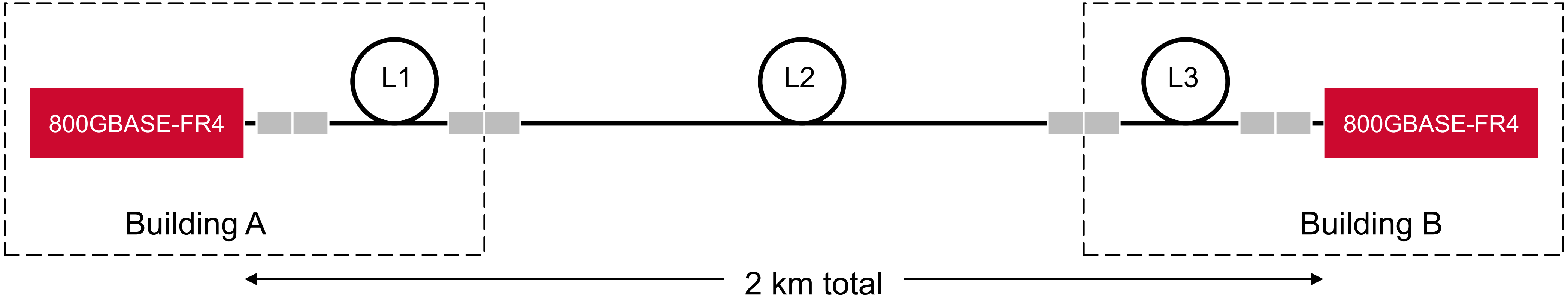
Motivation

- IEC 86A WG1 and ITU-T SG15 Q5 are leading efforts to gather data from fiber vendors in order to create a statistical model for chromatic dispersion (CD), which will be used to generate realistic CD_Q limits for 200G/L PMDs. (Ferretti_3dj_optx_01_230615)
  – The statistical methodology for CD_Q has been previously established in ITU-T G.652 for PMD_Q.
  – The fiber datasets will use correlated values of zero dispersion wavelength (ZDW) and dispersion slope (S_0) from manufacturing data that is not publicly available.
  – This process will produce the most accurate results possible, but the timeline may be long.
- The 802.3dj Task Force needs best-effort baseline CD_Q limits that can be used today to progress the new 200G/L optical specifications.
  – This can be achieved using statistical models based on reasonable assumptions for the distribution of fiber parameters, such as six-sigma manufacturing.
  – Reasonable assumptions about the number of cable segments in a link (M) and the confidence limit for economic feasibility (Q) should be made using input from operators and installers.
  – Liu_3dj_optx_01_230615 used a Monte Carlo model based on Cole_3dj_01_2305 for ZDW and a constant maximum value for dispersion slope to calculate CD_Q for 800GBASE-LR4 using Q = 1E-4.
- In this contribution, a Monte Carlo model with statistical distributions for both ZDW and S_0 is used to calculate CD_Q for use as the initial baseline for 800GBASE-FR4.

Statistical Fiber Models

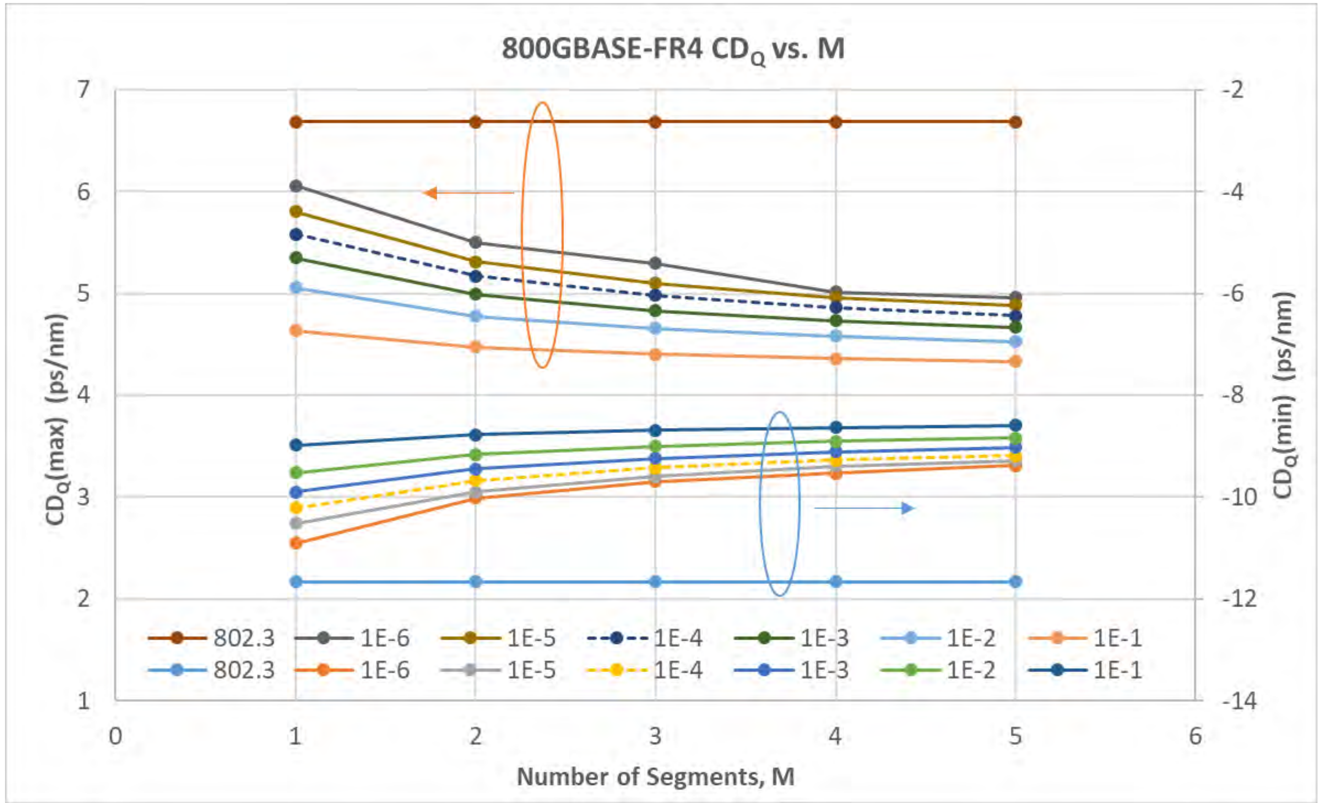
- In lieu of actual fiber vendor data for (ZDW, S_0) pairs, progress can be made using assumed uncorrelated distributions of ZDW and S_0. Statistical models based on six-sigma manufacturing are a reasonable starting point as discussed in Cole_3dj_01_2305.
- A distribution for ZDW based on six-sigma principles was proposed by Cole
  - Mean ZDW of each cable segment is Uniformly distributed on [1309, 1315] nm
  - ZDW of each cable segment is Normally distributed with a standard deviation of 2nm
  - If all M cable segments in a link are from a single supplier, a model with all segments having the same mean may be appropriate, as used in Liu_3dj_optx_01_230615 for 800GBASE-LR4
- G.652 limits for S_0 are 0.073 to 0.092 ps/nm^2/km, while 802.3 historically uses a single worst case value of 0.093 ps/nm^2/km (for example, Clause 121.11.1).
- A Normal distribution of S_0 with mean of 0.0825 and standard deviation of 0.002 truncated to [0.073, 0.092] (9.5σ range) is a conservative approximation based on six-sigma principles.
- Worst case 1264.5 and 1337.5 nm laser wavelengths are conservatively assumed for 800GBASE-FR4. As always, specific TX implementations may guarantee tighter wavelength ranges and can thus take advantage of lower CD limits.

Datacenter Cabling Assumptions



- Structured cabling solutions may be used with short indoor fiber cables connected to a longer outdoor fiber cable between buildings
  - L1 and L3 from the transceiver to the building edge could be up to ~500m, but may be shorter
  - L2 in an underground cable duct across a campus could be up to ~2km in the worst case
  - Since the indoor lengths may be relatively short, using a conservative assumption of a single 2km cable (M = 1) is appropriate to use for 800GBASE-FR4 CD_Q baseline
- The value of Q is still being discussed
  - Q should be viewed as a cost factor, since up to 2Q links may require replacing a transceiver with insufficient margin for $|CD| > |CD_Q|$ with another transceiver having more margin.
  - Q = 1E-4 (0.02% additional cost) is a reasonable choice for an initial baseline, consistent with the objectives of low-cost 200G/L Ethernet. This is the value used by Liu for LR4 CD_Q.

800GBASE-FR4 CD_Q Monte Carlo



- Dashed lines highlight Q = 1E-4
- The flat lines are the 802.3 worst case CD with ZDW = 1300 or 1324nm and S_0 = 0.093 ps/nm^2/km.
  - CD_{MIN} = -11.7 ps/nm
  - CD_{MAX} = 6.7 ps/nm

- Monte Carlo calculation of CD_Q:
  - ZDW = *N*(*U*(1309,1315), 2) nm for each segment
  - S_0 = *N*(0.0825, 0.002) ps/nm^2/km for each segment
  - N = 2E6 trials
  - Evaluate CD_Q at 1264.5 and 1337.5 nm
- At Q = 1E-4 and M = 1, CD_Q limits for 800GBASE-FR4 are:
  - CD_Q(min) = -10.2 ps/nm
  - CD_Q(max) = 5.6 ps/nm (Note this is higher than CD_Q for LR4!)
- Significantly more relaxation of CD_Q occurs for M > 1
- CD_Q increases only ~5% for each order of magnitude reduction in Q

Conclusions

- In order to progress the 800GBASE-FR4 baseline, the Task Force should adopt CD_Q estimates based on reasonable six-sigma manufacturing assumptions, pending availability of more accurate values to be provided by IEC 86A WG1 and ITU-T SG15 Q5.
- The CD_Q methodology is an important tool to achieve low-cost 200G/lane Ethernet by avoiding over-designing for statistically insignificant links
  - CD_Q provides cost savings by trading off the cost of designing and testing all optics for worst case CD vs. an initial failure rate of order Q for optics designed for CD_Q.
  - Even for single 2km segments, CD_Q provides a significant reduction (~15%) in the magnitude of CD that 800GBASE-FR4 transceivers must meet at a conservative Q = 1E-4.
- The following CD_Q limits based on conservative assumptions are proposed to be adopted as interim baseline values for 800GBASE-FR4:
  - CD_Q(min) = -10.2 ps/nm
  - CD_Q(max) = 5.6 ps/nm

Thank you!