The challenges for a 10km PMD @ 800G

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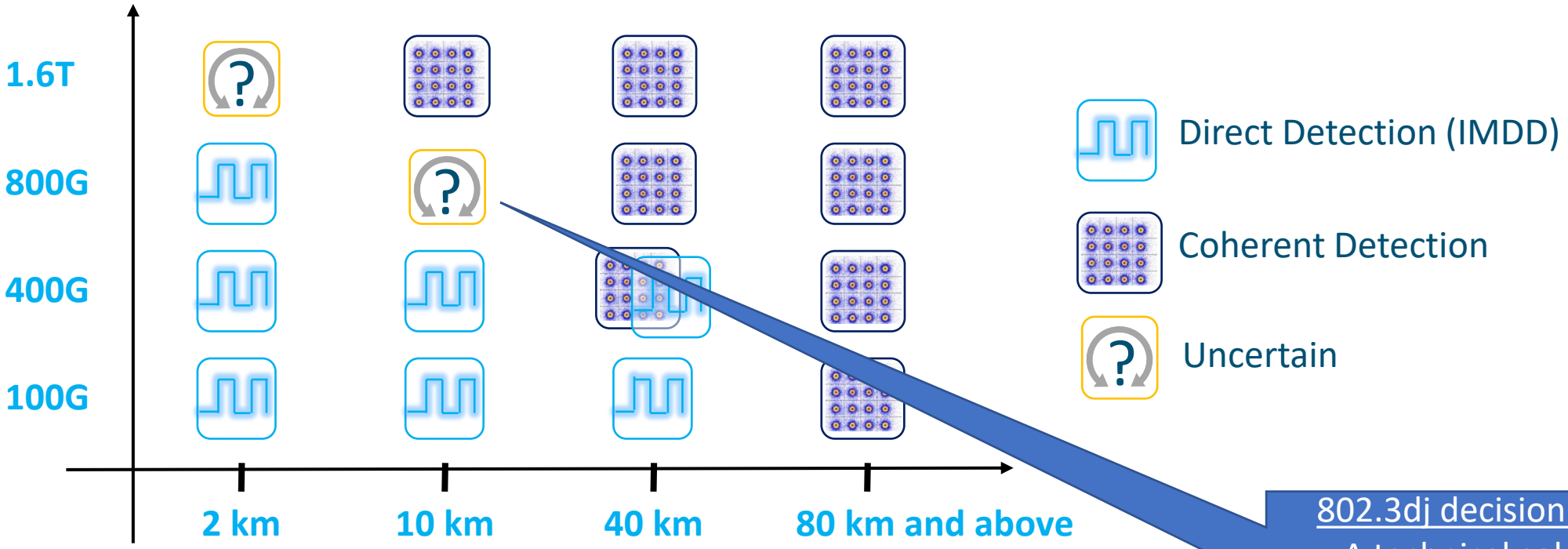
Overview

- Ethernet 10km SMF PMDs have been adopted across the industry for a broad set of applications:
  - Campus, Mobile, Access deployments.
  - Service Provider applications where 100G-LR4 was widely adopted as the initial 100G SMF (and needs an upgrade path). Inter-building applications, peering points etc.
  - Intra-DC or Intra-building environments when infrastructure requires.

Ethernet 10km PMDs

- From a product roadmap perspective, they are the:
  - Shortest of the longer reach products
  - Longest of the shorter reach products
- Development ROI of 10km modules benefits strongly from high leverage of one of these groups
- Alignment Option 1: 10km and high volume 2km solutions have 100% design consistency which can then use binning & tuning in a production environment to produce the necessary 10km units.
- Alignment Option 2: 10km and 40km solutions have common architecture and design that can yield the necessary 40km or 10km units.

The challenge with 10km @ 800G



802.3dj decision needed here.
A technical solution can be defined for both IMDD and Coherent. What will serve the needs of the user base better?

Duplex fiber solutions: As bit rate increases, longer reaches become more difficult. Creates a transition of technologies to keep up.

10km standards alignment

Observation on IEEE and industry history around 10 km reaches

		2km	10km	40km
25GbE	Single λ	-	Single λ	Single λ [1]
50 GbE	Single λ	Single λ	Single λ	Single λ
100GbE	Single λ	Single λ	Single λ	Single λ [2]
	4 λ	CWDM	LAN WDM CWDM	LAN WDM
200 GbE	4 λ	CWDM	LAN WDM	LAN WDM
400GbE	4 λ	CWDM	CWDM	~~LAN WDM~~ N/A
	8 λ	LAN WDM	LAN WDM	LAN WDM

Notes:
[1] tighter wavelength range
[2] tighter spectral width

Observations:
- IEEE 802.3 has history of grouping technical solutions between reaches for leverage and economy of scale
- Lowest cost solution always used for highest volume reach (2km)
  - That solution generally extended to max reach possible
- History of grouping 10km & 40km when 2km solution not practical for those reaches (100G and 200G)
- No history of separate solutions for each reach

800G Projections:

- 2 km based on CWDM IMDD
- 40km based on coherent
- 10 km is TBD

*Table replicated from [williams_3df_01_220222.pdf]

Ethernet PMD market success factors

Cost and interop are very important considerations

- Costs are strongly affected by volume
  - IMDD: Adjacency to high volume 2km helps if significant leverage
  - Coherent: Traditionally lower volume, IEEE adoption changes that, reduces costs (see: williams_3df_01a_220329.pdf)
- Costs are affected by margin/yield
  - Greater product design margin and yield drives cost efficiencies
- Costs are impacted by development costs
  - Greater leverage or minimized additional development lowers cost
- Interop → link budget margin is the #1 contributor to ensure interop

Achieving Technical feasibility

10km SMF impairments create new challenges for an 800G PMD than at lower data rates previously defined.

- Chromatic dispersion (CD) introduces ISI with penalty increasing by a factor of four with every doubling of baud rate
- Four-wave mixing (FWM) – interactions between closely spaced wavelengths – introduces a power penalty depending on fiber zero dispersion wavelength
- Polarization mode dispersion (PMD) – introduces ISI with penalty increasing with baud rate

These are all additional challenges for IMDD @ 10km on top of the challenges with achieving 200Gb/s per λ

Coherent detection can compensate for CD and PMD. As a single wavelength solution, coherent does not suffer any FWM penalty

Fiber Impairments

- Fiber impairments drive technology changes
  - Transition from IMDD to coherent occurs when fiber impairment penalties force increasingly complex implementations
- 802.3cu reduced reach from 10km to 6km for 400GBASE-LR4
- Jan 2020 Joint ITU/IEEE workshop discussed tightening fiber specifications (zero CD wavelength). See:
  - https://www.itu.int/en/ITU-T/Workshops-and-Seminars/202001/Documents/Pondillo.pdf
  - Data presented indicated the specs for existing classes of G.652 would not be changed.
  - Creating a new tighter specification is an option
- 800G specifications in 802.3dj will need to address existing fiber
  - Requiring characterization of existing fiber plant would bring additional cost

Addressing these 10km technical challenges

	IMDD	Coherent
Chromatic Dispersion	• CD impact on FWM and ISI not fully characterized. • Redefining fiber specs may be needed to limit penalties.	Built in compensation in DSP • Supports existing fiber specs up to 40km or more. • CD @ 10km is a relaxation of 40km requirement.
Four Wave Mixing	New polarization interleaving schemes and/or channel gapping are required to mitigate ISI. (untested in volume production)	No issue
Polarization Mode dispersion	Presentations to date suggest a modification of fiber specs is need to gain relief.	• PMD compensation is well known DSP function. DGD + SoPMD @ 10km is a relaxation of 40km requirement. • Tested in volume production.
MPI	Needs analysis – penalty needs to be considered in link budget	DSP compensation techniques well known.
Interop/link budget margin	Unknown at this time.	Significant link margin. Predictable performance lowers risk of interop issues.

Note: Analysis for PMD + CD for worst case ISI is needed to evaluate MLSE capability & complexity

IMDD Development Impact: FR4 vs LR4

- How does the LR4 design diverge from the FR4?
  - New wavelength grid requiring cooled lasers
  - Polarization interleaving (or unequal wavelength spacings)
  - Chirp management
  - MLSE – potentially increases complexity of FR4 DSP
- Even with these modifications, new fiber specs may still be required to mitigate impairments
- Proposed LR4 implementations require significant technical changes and will not interop with an FR4

Summary

4x200G IMDD for 10km 800GbE presents technical challenges that are not present for 2km

*The LR application needs to address **CD, PMD, and FWM** with a **high yielding** implementation*

→ *These are not aligned **with DR/FR** reaches*

→ *Addressing these will place a burden on IMDD DSP design*

Coherent implementations address these impairments with significant margin.

A 10km 800GbE coherent implementation can be designed to align with the 40km application