The case for a 4 Lane 400Gb/s SMF PMD

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IEEE P802.3bs 400 Gb/s Ethernet Task Force
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- Beck Mason - JDSU
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- Matt Brown - AppliedMicro
- Ed Ulrichs - Source Photonics
- Tom Issenhuth - Microsoft
- Brad Booth - Microsoft
- Thananya Baldwin - Ixia
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Introduction

- The goal of this presentation is to build consensus around a 4 Lane optical solution(s) to address the 400GbE SMF objectives:
- Why a 4 Lane optical solution ?
  - It is what the industry / market desires
  - Growing band of evidence demonstrating technical feasibility, with a path to additional link margin as component technology matures
  - It has some longevity associated with it, and will not be immediately obsoleted

Assumptions

- This presentation is addressing the optical interface only
- The optical and electrical lane rates do not need to be coupled (nicholl_3bs_01_0714.pdf)
  - MLD (Multi Lane Distribution) was introduced in 802.3ba with the recognition that the initial optical and electrical lane rates/widths were likely to be different, and evolve on different timelines
  - 400Gb/s Ethernet architecture is expected to be also based on MLD (gustlin_3bs_02_0714.pdf)
  - Historically for the introduction of a new higher data rate in the industry, the optical and electrical lane rates have always been different (with optical > electrical)

802.3bs 400GbE Objectives

Project Objectives

- Support a MAC data rate of 400 Gb/s
- Support a BER of better than or equal to 10^{-13} at the MAC/PLS service interface (or the frame loss ratio equivalent)
- Support full-duplex operation only
- Preserve the Ethernet frame format utilizing the Ethernet MAC
- Preserve minimum and maximum FrameSize of current Ethernet standard
- Provide appropriate support for OTN
- Specify optional Energy Efficient Ethernet (EEE) capability for 400 Gb/s PHYs
- Support optional 400 Gb/s Attachment Unit Interfaces for chip-to-chip and chip-to-module applications
- Provide physical layer specifications which support link distances of:
  - At least 100 m over MMF
  - At least 500 m over SMF
  - At least 2 km over SMF
  - At least 10 km over SMF

IEEE P802.3bs 400GbE Task Force * Approved by IEEE 802.3 WG, 20-Mar-2014

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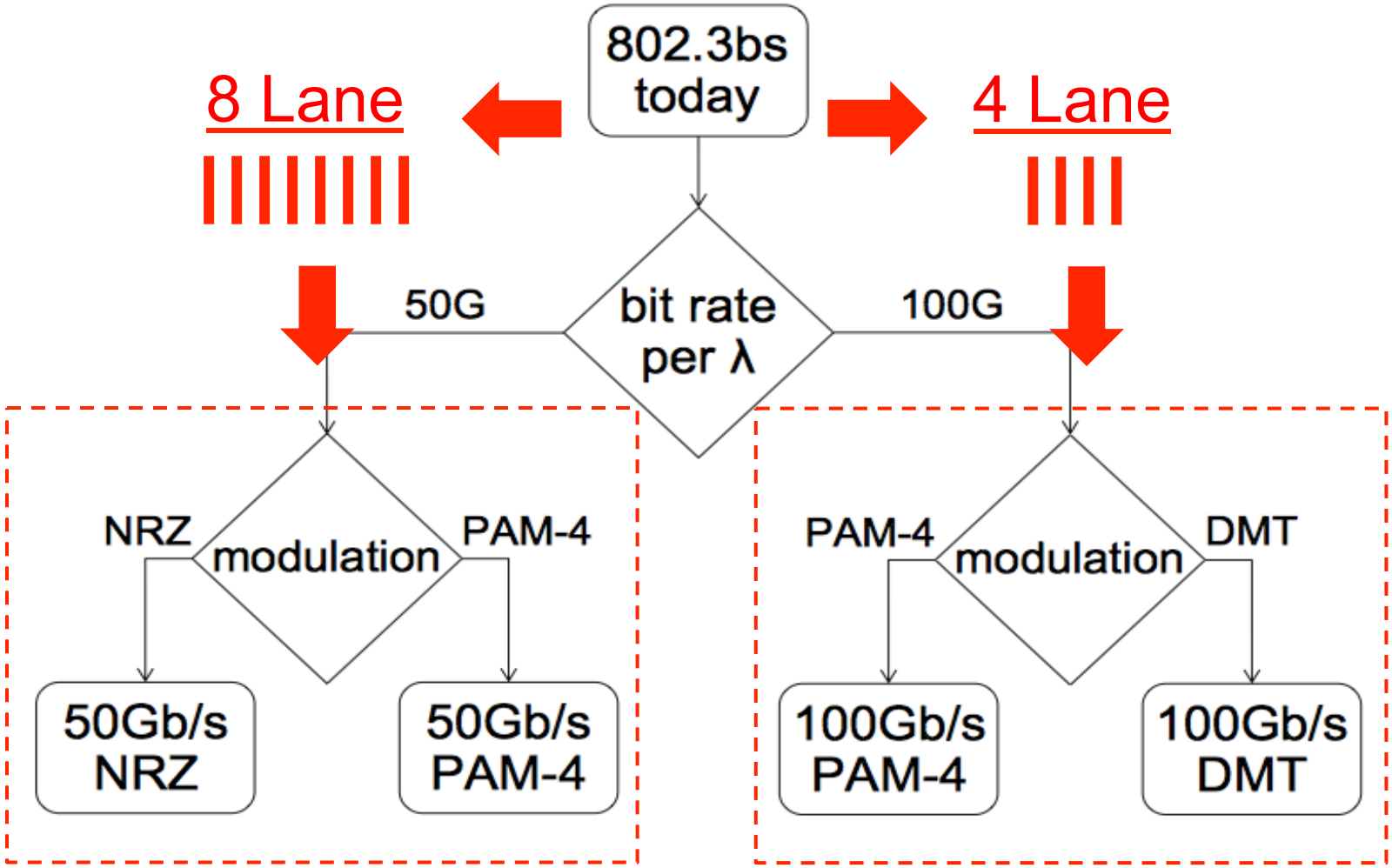
Source: Objectives_14_0320.pdf

This presentation focuses on the 400Gb/s SMF objectives only

802.3bs 400Gb/s SMF PMD Decision Tree

Source: cole_3bs_01a_0514



Lane Decision Concerns/Considerations

- If the TF chooses an 8 Lane 400GbE solution, the risk is that it may be immediately obsolete (or at least have a very limited lifespan)
- If the TF chooses a 4 Lane 400GbE solution, the risk is that it may miss the initial market need (i.e. if the schedule gets pushed out)
- It is clear that no matter what decision we make in the 802.3bs TF that 4 Lane 400GbE solutions will happen, so a vote for an 8 Lane 400GbE solution is a vote for a two phase (generation) approach:
  - what is the lifespan of the 8 lane 400GbE solution ?
  - there will be no optical interoperability between an 8 lane 400Gbe solution and a future 4 lane 400GbE solution (interface proliferation)

Optical Solutions – A Historical Perspective

Data Rate	16 Lane	10 Lane	8 Lane	4 Lane	2 Lane	1 Lane
1G						1GE-LR 1GE-SR
10G		OC192-VSR		10GE-LX4		OC192-SR 10GE-LR
40G				40GE-SR4 40GE-LR4 40GE-ER4	40GE-BiDi	OC-768 SR 40GE-FR *40GE-PAM4 ?*
100G		100GE-SR10 100GE-"LR 10"		100GE-SR4 100GE-LR4 100GE-ER4 100GE-CWDM4 100GE-CLR4	*100GE-nR2 ?*	*100GE-LR ?*
400G	?	?	?	?	?	?

Red: Short lifespan. *Italics : Trend for next gen interfaces.*

Limited eco-system support for solutions > 4 optical lanes

System benefits of a 4 Lane 400GbE solution

- Cost
  - historically fewer lanes has always led to lower cost
  - potential for CWDM (leveraging 100GE experience/trend)
- Forward compatibility and Interface longevity
  - minimizes interface churn (and associated eco-system cost)
  - up to 3x gens of electrical interface evolution before requiring inverse mux in module, and with full optical interop between generations (maki_3bs_01a_0514.pdf)
- Downward compatibility with lower rate four lane based solutions
  - e.g. could run in 4x25G mode to support 100GbE
- Breakout
  - enables high density 100GbE solutions in the future with 4x100G breakout

802.3bs TF Contributions on 4 Lane solutions

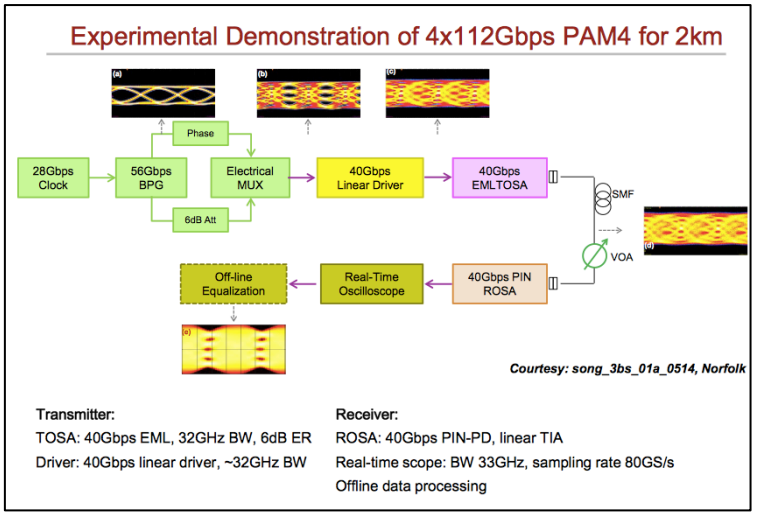
Meeting	Contributions related to 4 Lane optical solution
Norfolk, May 2014.	nicholl_3bs_01_0514.pdf, welch_3bs_01_0514.pdf, bhoja_3bs_01_0514.pdf, hirai_3bs_01_0514.pdf, lewis_3bs_01_0514.pdf, song_3bs_01a_0514.pdf, isono_3bs_01_0514.pdf, tanaka_3bs_01_0514.pdf, way_3bs_01a_0514.pdf,
San Diego, July 2014.	welch_3bs_01b_0714.pdf, stassar_3bs_01_0714.pdf, lewis_3bs_01_0714.pdf, dedic_3bs_01a_0714.pdf, zhu_3bs_01_0714.pdf, tanaka_3bs_01a_0714.pdf, bhatt_3bs_01a_0714.pdf, sone_3bs_01_0714.pdf, lecheminant_3bs_01_0714.pdf,

- Significant and broad industry activity around 4 Lane 400GbE optical solutions
- Multiple demonstrations showing technical feasibility and with multiple different technical approaches

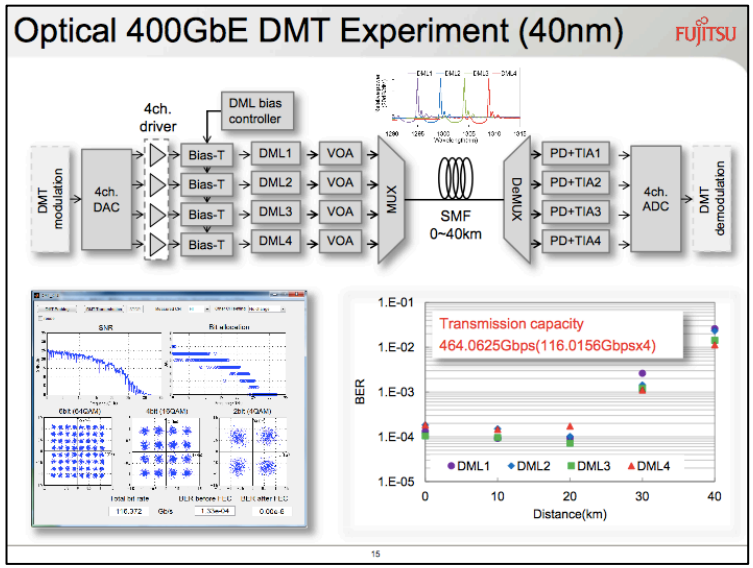
4 Lane 400GbE Technical Feasibility

- There is a growing band of evidence building in support of technical feasibility for a 4 Lane 400GbE SMF PMD(s):
  - Link budget analysis / simulation
  - Link budget experimental verification
  - Serdes technology from multiple chip suppliers
  - Low latency FEC options
  - Low power ADC/DACs becoming available

4 Lane 400GbE Technical Feasibility

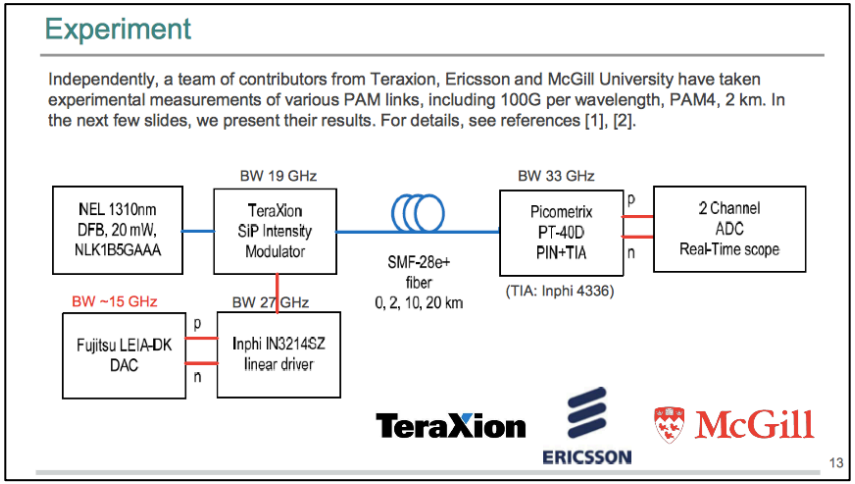


- stassar_3bs_01_0714.pdf
- experimental demo of 56Gbaud PAM4 for 2km
- Some open questions on manufacturing margins for some optical parameters

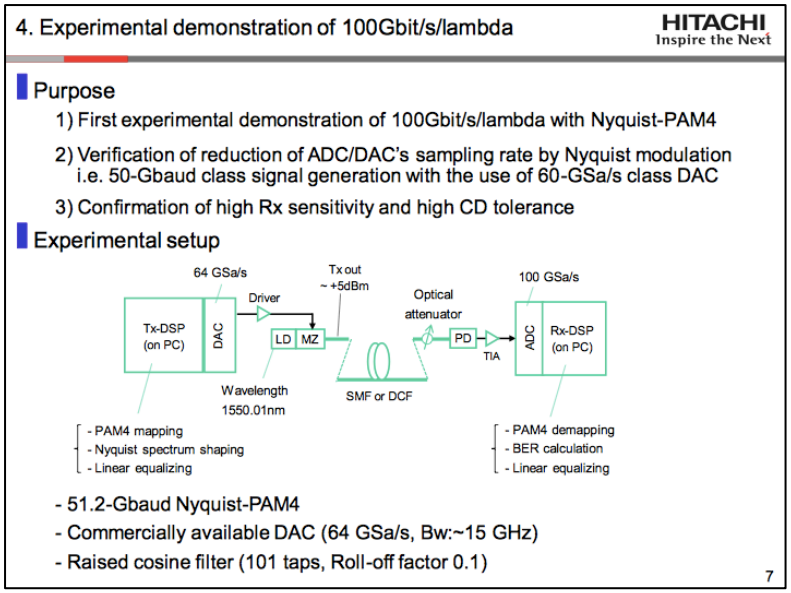


- dedic_3bs_01a_0714.pdf
- experimental demonstration of 4 Lambda 400Gb/s using DMT
- 0-40km.

4 Lane 400GbE Technical Feasibility

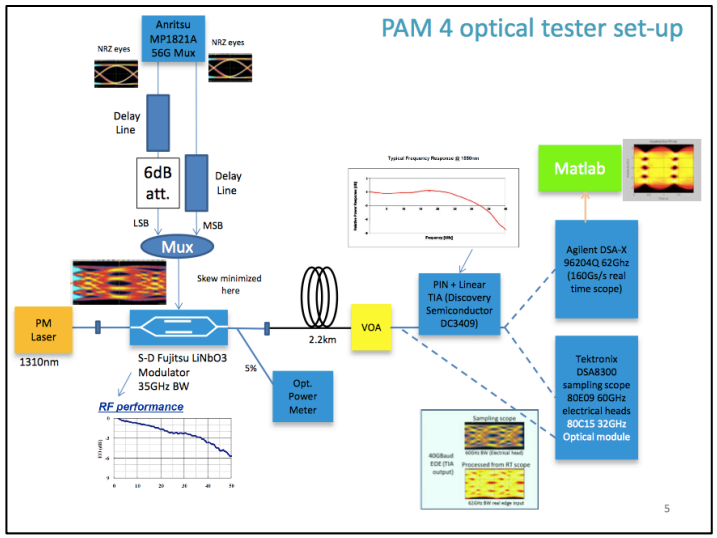


- bhatt_3bs_01a_0714.pdf
- experimental measurements on 56Gbaud PAM4 over 2km
- reconciled Inphi link model with experimental measurements

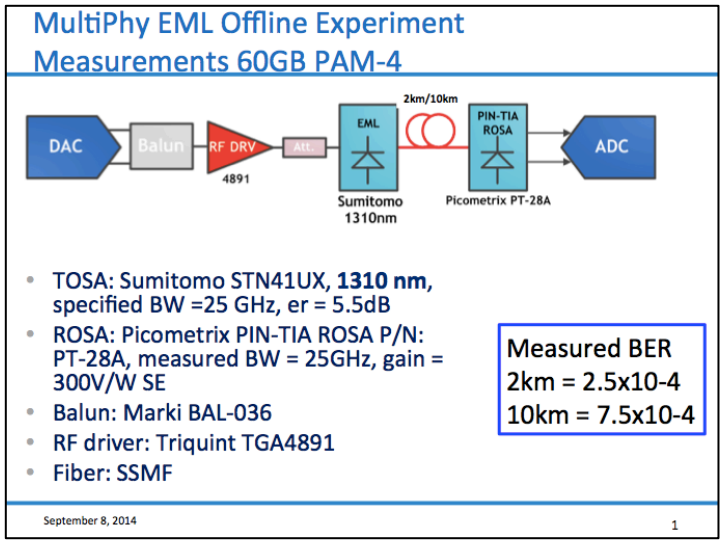


- hirai_3bs_01a_0714.pdf
- Experimentally verified 2-km SMF transmission using 56Gbaud Nyquist PAM-4

4 Lane 400GbE Technical Feasibility

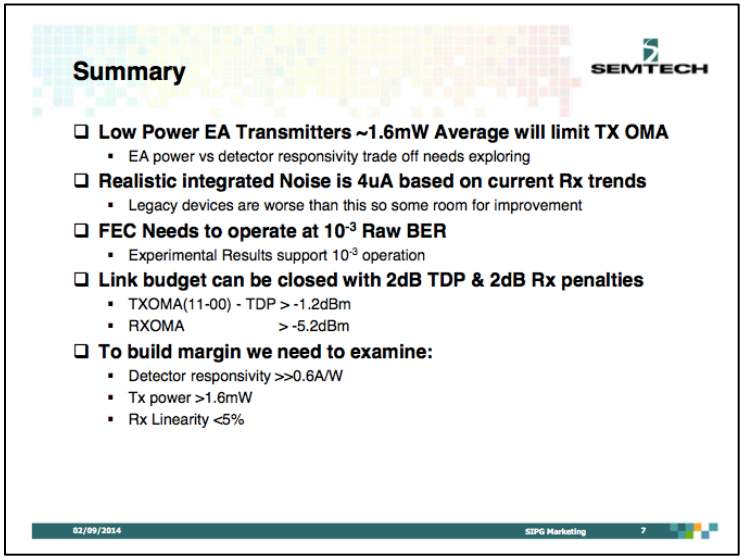


- mazzini_01a_0814_smf.pdf
- experimental verification of 56GBaud PAM4 over 2km of SMF
- non optimum lab setup
- measured Rx sensitivity in ball park of multiple link budget analysis



- conroy_3bs_01_0914
- experimental measurements of 60Gbaud PAM-4 over 2km and 10km of SMF, based on MLSE
- based on off-the-shelf components (non-optimum)
- results well within capabilities of low latency FEC solutions.

4 Lane 400GbE Technical Feasibility



Summary

SEMTECH

- **Low Power EA Transmitters ~1.6mW Average will limit TX OMA**
  - EA power vs detector responsivity trade off needs exploring
- **Realistic integrated Noise is 4uA based on current Rx trends**
  - Legacy devices are worse than this so some room for improvement
- **FEC Needs to operate at 10^{-3} Raw BER**
  - Experimental Results support 10^{-3} operation
- **Link budget can be closed with 2dB TDP & 2dB Rx penalties**
  - TXOMA(11-00) - TDP > -1.2dBm
  - RXOMA > -5.2dBm
- **To build margin we need to examine:**
  - Detector responsivity >>0.6A/W
  - Tx power >1.6mW
  - Rx Linearity <5%

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- tipper_3bs_0914.pdf
- component perspective on 56Gaud PAM-4
- Link budget can be closed with current technology
- additional margin possible as component technology matures

Summary

- Historical precedent in Ethernet for 4 lane solutions, with a tendency towards single lane as technology matures.
- Clear preference for a 4 Lane solution for a 400GbE SMF PMD(s).
- Growing evidence that such a 4 lane 400GbE solution is technically feasible with today's technology, and with a path to additional link margin as component technology matures
- A 4 Lane 400GbE SMF PMD solution will have some longevity, and will not be immediately obsoleted
- Next step – Build consensus towards a baseline presentation(s) for November.

Thank You