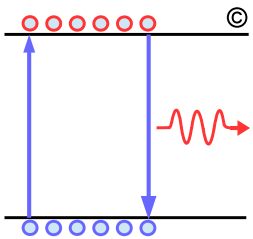

Path to Consensus on 400 GbE PMDs

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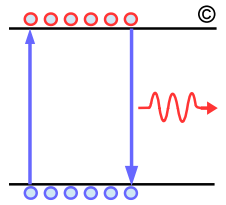
IEEE 802.3bs Task Force

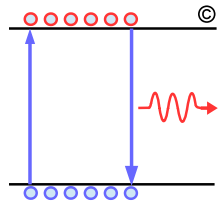
May 2014 Interim

Overview



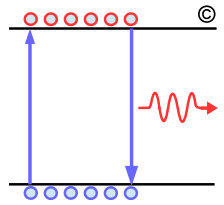
- **Current objective review**
- **Possible evolution of 400 GbE PMDs**
  - Don't develop any higher speed PMDs 16x25G
  - Develop 50 Gb/s/lane PMDs
  - Develop 100 Gb/s/lane PMDs
- **Developing consensus require focus and making some tough decision early on.**

Current HSSG Objective Per Dallas Meeting



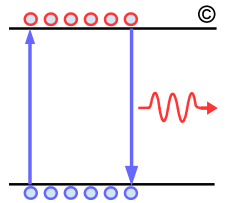
- **Provide physical layer specifications which support link distances of at least 100 m over MMF**
- **Provide physical layer specifications which support link distances of at least 500 m over SMF**
- **Provide physical layer specifications which support link distances of 2 km on SMF**
- **Provide physical layer specifications which support link distances of at least 10 km over SMF**
- **Key questions where consensus need to be developed are:**
  - Do we define in .bs more efficient PMDs?
  - Do we define higher bit rate narrower CDAUI in .bs?

PMD Evolution Options



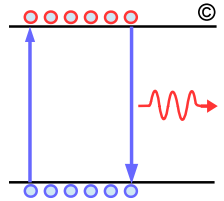
- **Current Gen 16x25G – Signaling NRZ**
  - Advantage: mature technology and reuse
  - Dis-advantages: SR16/PSM16 high cost associated with 32 fibers, LR16 is high cost effectively a Metro WDM
    - 16x25G will be a distraction and will push out more practical lower cost PMDs
- **1st Gen 8x50G – Signaling (NRZ, Duo-binary, PAM4, DMT, Multi-Cap)**
  - Advantage: Common 50 Gb/s signaling and host based moderate gain FEC ~ 6 dB is sufficient for SR8, PSM8, FR8, and LR8 increases supply base, and lowers the cost
  - Disadvantage: Narrower interface eventually would deliver lower cost
- **2nd Gen 4x100G – Signaling (PAM4, DMT, Multi-Cap)**
  - Advantage: With 4 lasers eventually lower cost could be achieved
  - Disadvantage: Project will take longer, high gain FEC >9 dB would required, higher BW component such as as MZM/EA needed, VCSEL/DFB-DML may not have sufficient power/BW, and/or more complex DSP required.

Toward Consensus



- **To reach consensus it may require making some tough decision early in the project**
  - Making some tough decision early on could bring focus to solve common technical solution
  - It will help project timeline Nov 2014 the proposed last technical solution
- **Trying to standardize 16x25G, 8x50G, and 4x100G all in one project is an enormous undertaking for the BS task force, for component/OEMs to develop the products, and for end user to manage all the deployment and interoperability issues**
- **Here is scenario how 400 GbE could turn into quagmire**
  - SR16 is based on 16x25 Gb/s with BJ FEC
  - PSM8 is based on 8x50 Gb/s with BJ or moderate gain FEC
  - FR4 based on 4x100 Gb/s with high gain FEC
  - LR4 based on 4x100 Gb/s with high gain FEC
- **It is an enormous undertaking to develop 3 different SerDes possibly based on 3 different signaling with 3 different FECs**
- **The industry and IEEE need to focus on the next generation PMDs based on 8x50G for economy of scale, lower cost and for more efficient 400 GbE Interface.**

Natural Evolution of 400 GbE PMDs Cont.

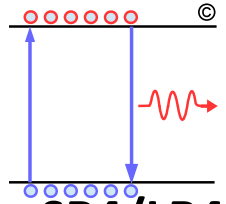


- **In 802.3bs we need to focus on common 50 Gb/s signaling and a common FEC for all optical PMDs**
  - Initial electrical interface based on CADUI-16
  - We should let OIF continue developing CADUI-8 signaling which will serve 400 GbE CFP2 MSA (1st Gen+) and will become the electrical interface on the 2nd Gen 400 GbE PMDs

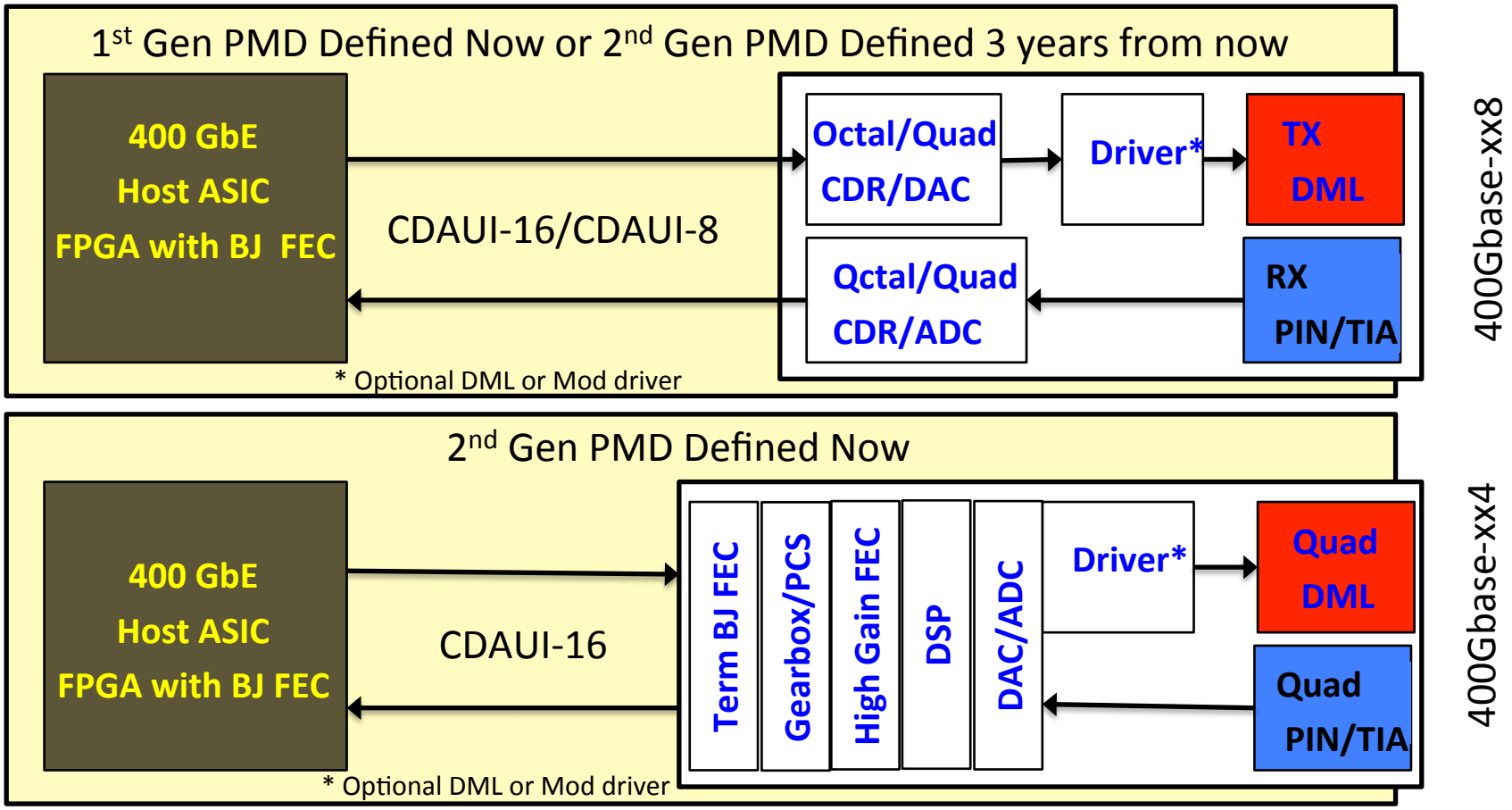
PMD	1st Gen (50 Gb/s/lane)	1st Gen+ (50 Gb/s/lane)#	2nd Gen (100 Gb/s/lane)#	2nd Gen+ (100 Gb/s/lane)#
CDAUI	CADUI-16	CADUI-8	CADUI-8	CADUI-4
100 m MMF	SR-8	SR-8	SR-8+WDM*	SR-8+WDM*
500 m SMF	PSM-8, WDM-8	PSM-8, WDM-8	PSM-4 or WDM-4	PSM-4 or WDM-4
2 km SMF	WDM-8	WDM-8	WDM-4	WDM-4
10 km SMF	WDM-8	WDM-8	WDM-4	WDM-4

 # Some form of HOM (Higher order modulation is an option)
*** WDM in case of MMF could mean 100+ nm spacing and in case of SMF could mean 100's GHz spacing**

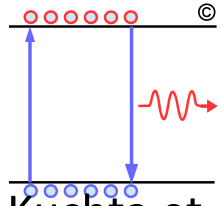
400 GbE PMD Architecture



- **8x50G could create ubiquitous interface similar to todays' 100Gbase-SR4/LR4**
  - Developing 2nd Gen PMD now require more complex DSP, higher gain FEC, high cost, and the solution likely will be sub-optimum than waiting ~ 3 years to develop 100 Gb/s/lane in the next project!

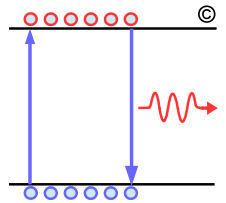


Notable Key Advancement to Enable Next Generation PMDs



- 56.1 Gb/s NRZ Modulated 850 nm VCSEL-Based Optical Link, D. M. Kuchta et al., OW1B.5, OFC 2013
  - With only transmit FFE
- Toward 400Gbase 4 lane Solution Direct Detection of MultiCap Signal in 14 GHz Bandwidth per Lane, Migue Iglesias Olmedo et al., Post Deadline, OFC 2013
  - A DML with only 14 GHz was able to operate at 100 Gbps
- Experimental Demonstration of 448-Gbps+ DMT Transmission over 30-km SMF, Toshiki Tanaka, et al. OFC 2014, M2I.5
  - DML had BW of ~28 GHz
- A Low-Cost 100GE Optical Transceiver Module for 2km SMF Interconnect with PAM4 Modulation, Jiangwei Man et al., OFC2014 M2.E7
- O-band 400 Gbit/s Client Side Optical Transmission Link, Tianjian Zuo et al., OFC 2014 M2E.4
  - 6 Band Multi-cap
- 64Gb/s Transmission over 57m MMF using an NRZ Modulated 850nm VCSEL, Daniel Kuchta et al., OFC 2014, Th3C.2
  - With only 2 tap transmit FFE, VCSEL had BW ~27 GHz,
- Serial 103.125-Gb/s Transmission over 1 km SSMF for Low-Cost, Short-Reach Optical Interconnects, Jeffery Lee et al., OFC 2014, post deadline Th5A.5
  - Duo-binary transmission, MZM had 30 GHz BW.

Summary



- **In 802.3bs need to focus on a set of PMDs meeting objective of the task force**
  - The goal should not be to back fill 100 GbE PMDs that .bm could not reach consensus
  - We should let OIF to continue development of CDAUI-8/OIF-56G-VSR and leverage CDAUI-16 for the .bs initial PMDs implementation
- **802.3bs objective for PMD reaches of 100 m, 500 m, 2 km, and 10 km can be address several ways**
  - Based on todays available technology such as SR16/PSM16/FR16/LR16
    - Cable cost and/or number of source makes the solution impractical
  - Based on 50 Gb/s/lane does require some level of development
    - But it could deliver a solution that can address all PMDs SR8/PSM8/FR8/LR8
  - Based on 100 Gb/s require significant amount of development
    - It will take longer to develop solution and may not address VCSELs/MMF
    - May end up with multiple HOM SerDes and FEC
- **The 400 GbE market likely will follow 100 GbE market which took some 5 years before reaching 100k see ghiasi_400_01a_0513.pdf**
  - Splitting the 400 GbE market beween 25 Gb/s/lane, 50 Gb/s/lane, and 100 Gb/s/lane PMDs will only fragment the market, reduce supply base, and drive up cost
  - Our mantra should be “Common Signaling – Common FEC”.