CFI - 100GbE Beyond 10km Optical PHYs

Consensus Presentation

Background (to be removed for actual CFI)

- It is expected that, if successful, this CFI will expand the scope of the current "Beyond 10k" Study Group
  - A straw poll or motion will be requested in the B10k study group in November to assess support from those participants to accept the increased scope if the CFI is successful.
  - Until then, we can only state we are requesting a new Study Group
- We anticipate that this would result in an expanded scope of: "Beyond 10km Optical PHYs for 50 Gb/s, 100 Gb/s, 200 Gb/s, and 400 Gb/s Ethernet"
- This CFI is focused only on the inclusion of the additional data rate into the B10k discussions
  - Therefore technology feasibility is discussed, but technology choices and trade-offs remain the domain of the Study Group, not the CFI

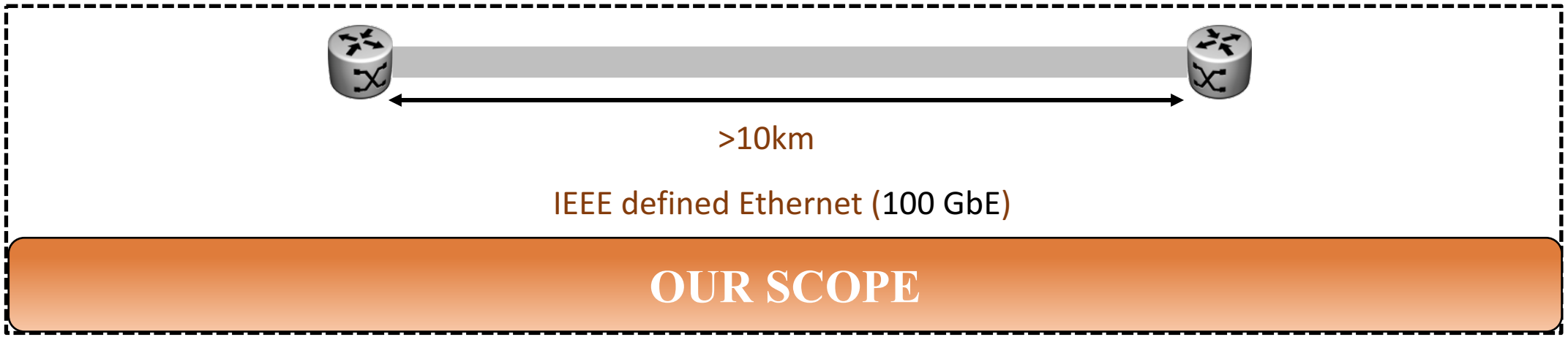
Supporters

Objective for this Meeting

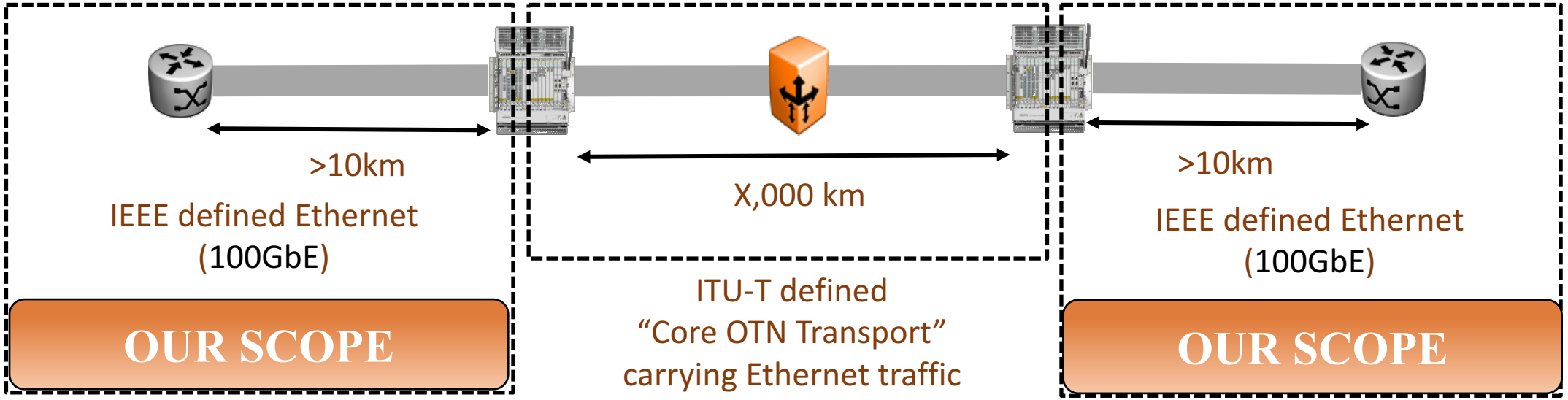
- To ***measure the interest*** in starting a study group to address:
  - Beyond 10 km Optical PHYs for 100GbE
- We don't need to
  - Fully explore the problem
  - Debate strengths and weaknesses of solutions
  - Choose any one solution
  - Create PAR or five criteria
  - Create a standard or specification
- Anyone in the room may speak / vote
- RESPECT… give it, get it

What Are We Talking About?

Scenario #1



Scenario #2

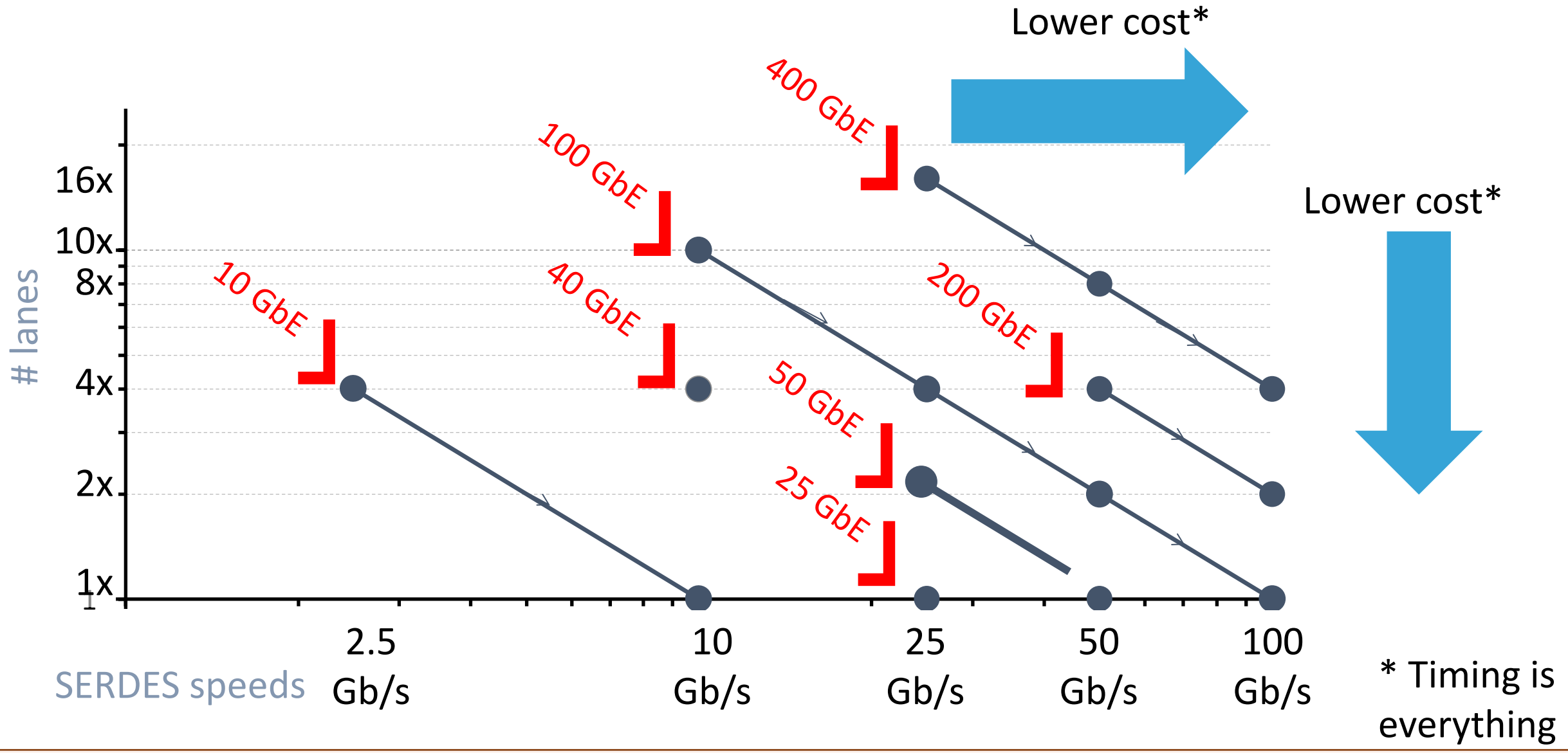


Agenda

- Market Drivers
  - tbd
- Technical Feasibility
  - tbd
- Why Now?
  - Mark Nowell
- Q&A Panel
- Straw Polls

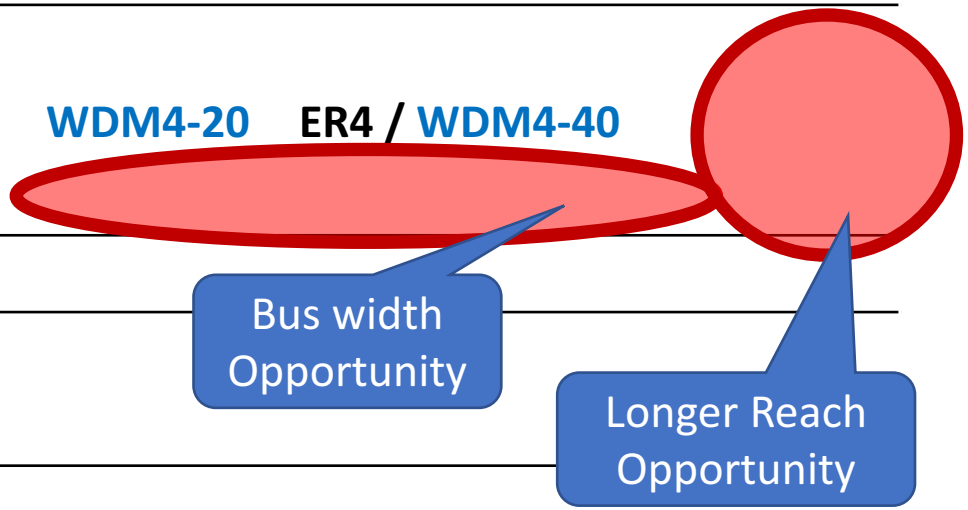
Market Drivers for 100GbE beyond 40km

Optics and SERDES – optimizing the solution



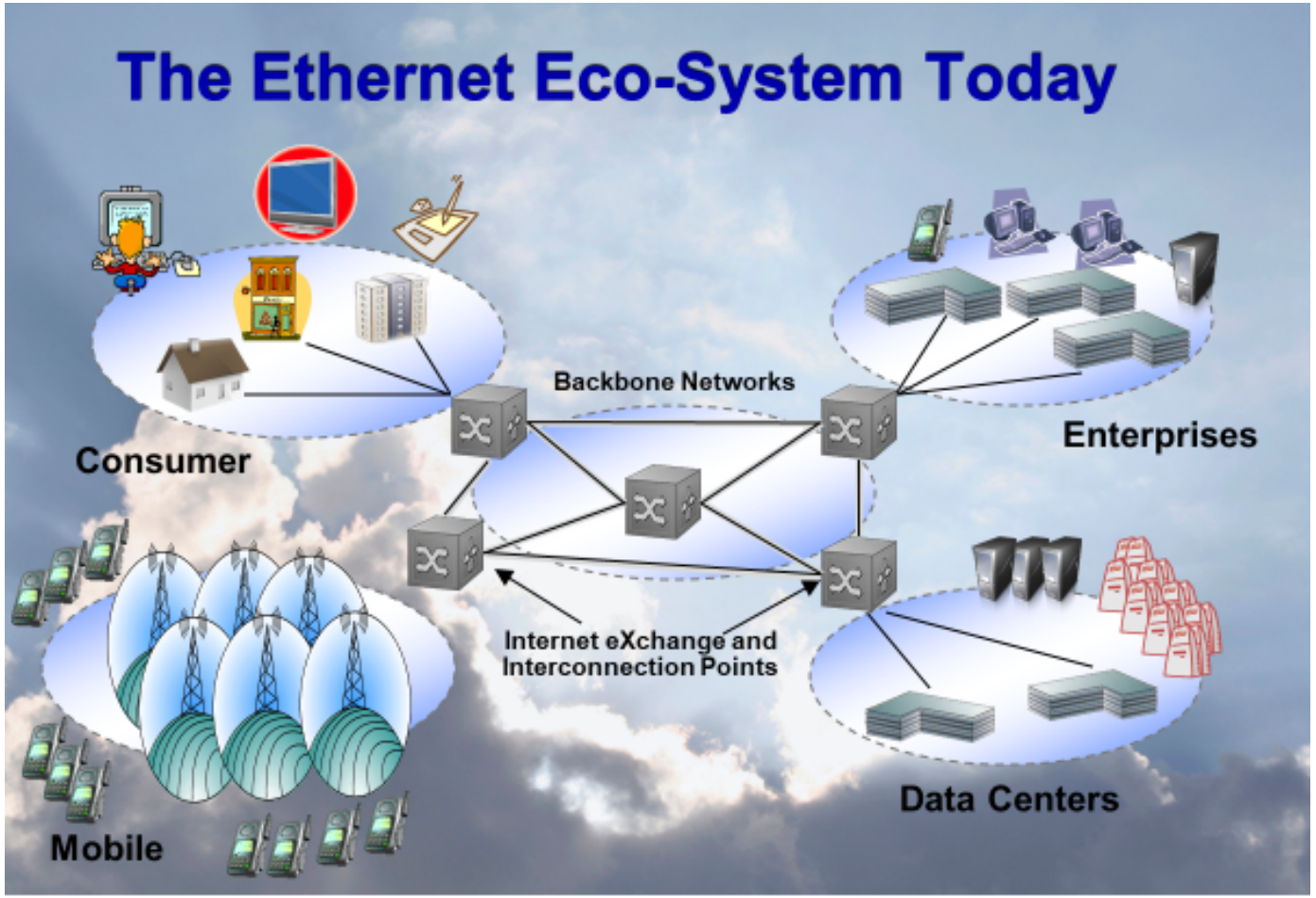
Today's Point-to-Point SMF Ethernet Family

	Lanes	500m	2km	10km	20km	40km	70 – 80km
1000BASE-	1		LX	LX10 / LH		EX	ZX
10GBASE-	1			LR		ER	ZR
25GBASE-	1			LR		ER	
40GBASE-	4	PSM4		LR4		ER4	
	1		FR				
50GBASE-	1		FR	LR			
100GBASE-	10		10X10				
	4	PSM4	CWDM4 / CLR4	LR4 / WDM4-10	WDM4-20	ER4 / WDM4-40	
	1	DR					
200GBASE-	4		FR4	LR4			
400GBASE-	8		FR8	LR8			
	4	DR4					



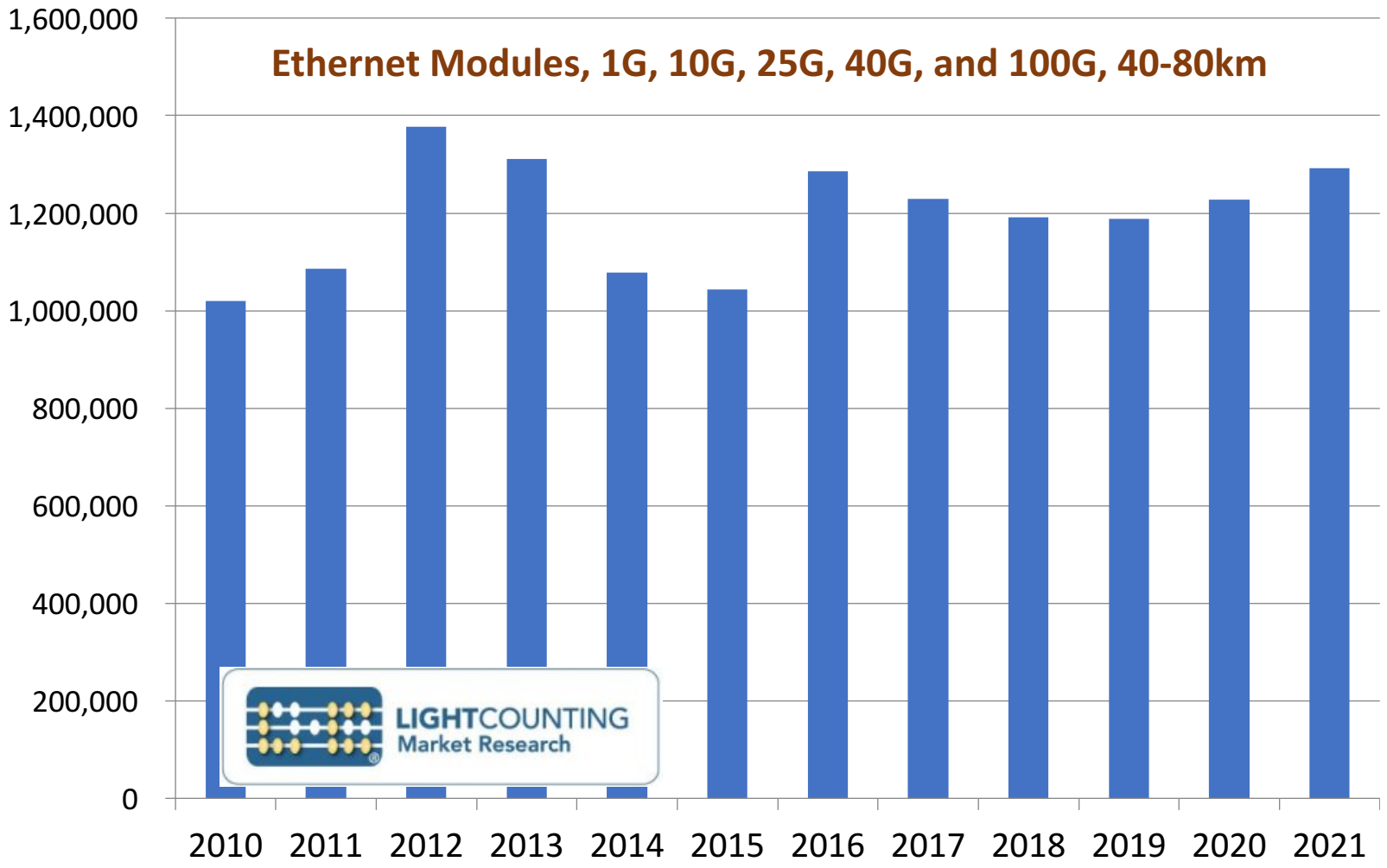
Black Text IEEE Standard
Red Text In Standardization
Blue Text Non-IEEE standard but complies to IEEE electrical interfaces

Beyond 10km Optics Throughout The Eco-System



- Not “Data Center”
- Exists throughout the Eco-System
- 3 Million units for 40km and beyond shipped annually (see next page)
- Continuing bandwidth growth factors resonate throughout the ecosystem
- Being addressed in B10K study group for 50GbE, 200GbE, and 400GbE

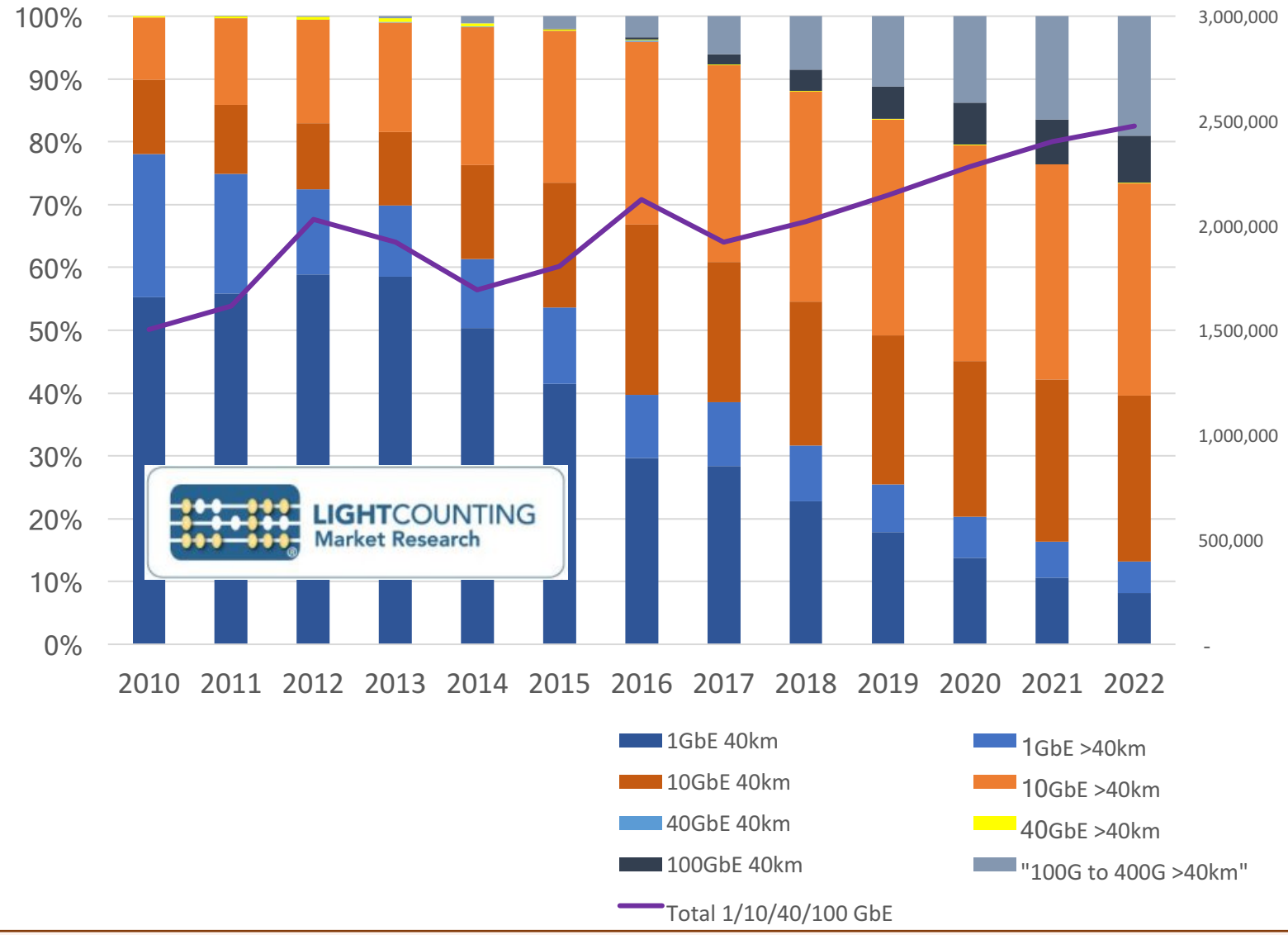
Annual Shipments for 40km+ Applications



- For 100GbE, 40km, LightCounting projects a market that will roughly triple in value from 2017 to 2021.
- SONET 40-80km shipments represent another half-million units in 2016. SONET is transitioning to Ethernet.
- 1 / 2.5 / 10 Gb/s DWDM / CWDM 40km & 80km optics will exceed 1M units this year and growing
- Totals are for merchant supplier shipments. Captive supply could add another half-million units.
- Data courtesy of LightCounting

Optical Module Volumes: 40km and Beyond 40km

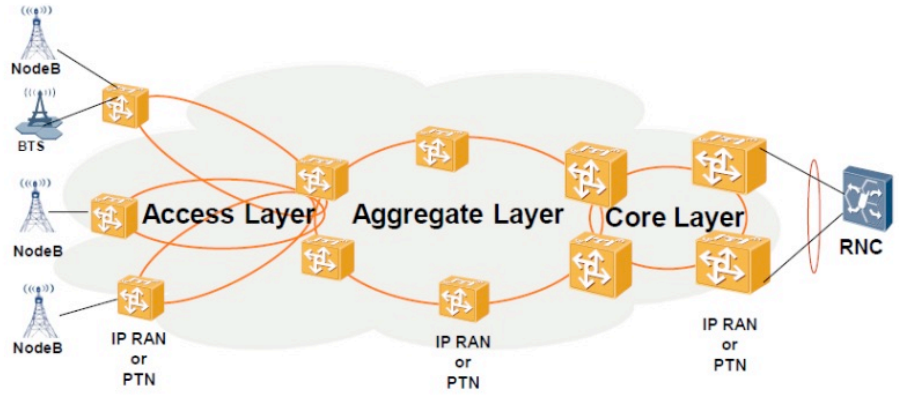
- LightCounting forecasts optical modules for Ethernet and non-Ethernet applications
  - Totals are for merchant supplier shipments
- The market for 40km and >40km optical modules continues to grow
- The >40km market space for both 10Gb and 100Gb is significant and growing faster than the 40km
- Data courtesy of LightCounting



Mobile Backhaul Demand for Beyond 10km

Copied from JohnD's CFI deck Permission pending

40km Reach in Mobile Backhaul Network



- In huang_ecdc_01_0716 and observation from shipment in Carrier network, 40km volume is increasing

Statistics for 10GE & 100GE Modules used in PTN, as of June, 2016				
Transmission Distance	<2km	10km	40km	80km
10GE distribution	0.28%	44.46%	44.05%	11.20%
100GE distribution (more than 15K modules)	0	56.43%	34.59%	8.97%

HUAWEI TECHNOLOGIES CO., LTD. Page 7 HUAWEI

Source: Xinyuan Wang Huawei,
http://www.ieee802.org/3/ad_hoc/ngrates/public/16_09/wang_ecdc_01_0916.pdf

Present status and forecast

- According to our survey, long distance module is a mandatory requirement for us

Statistics for 10GE & 100GE Modules used in PTN, as of June, 2016				
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10GE distribution	0.28%	44.46%	44.05%	11.20%
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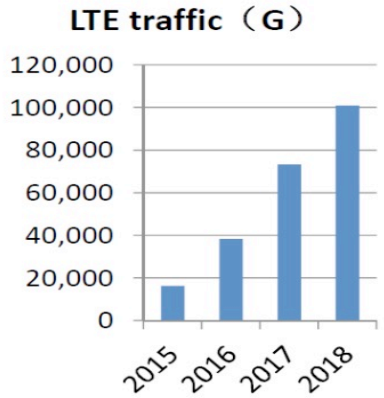
- According to the increase of LTE traffic, as LTE backhaul network, PTN will face 4~5 times traffic in 2017 or 2018.
- Then we will have to use 400GE interface in the same scenario and take the same percentage with 100GE and 10GE.
- In 2018~2019, we expected the requirement for 400GE ER modules will be more than 10K.

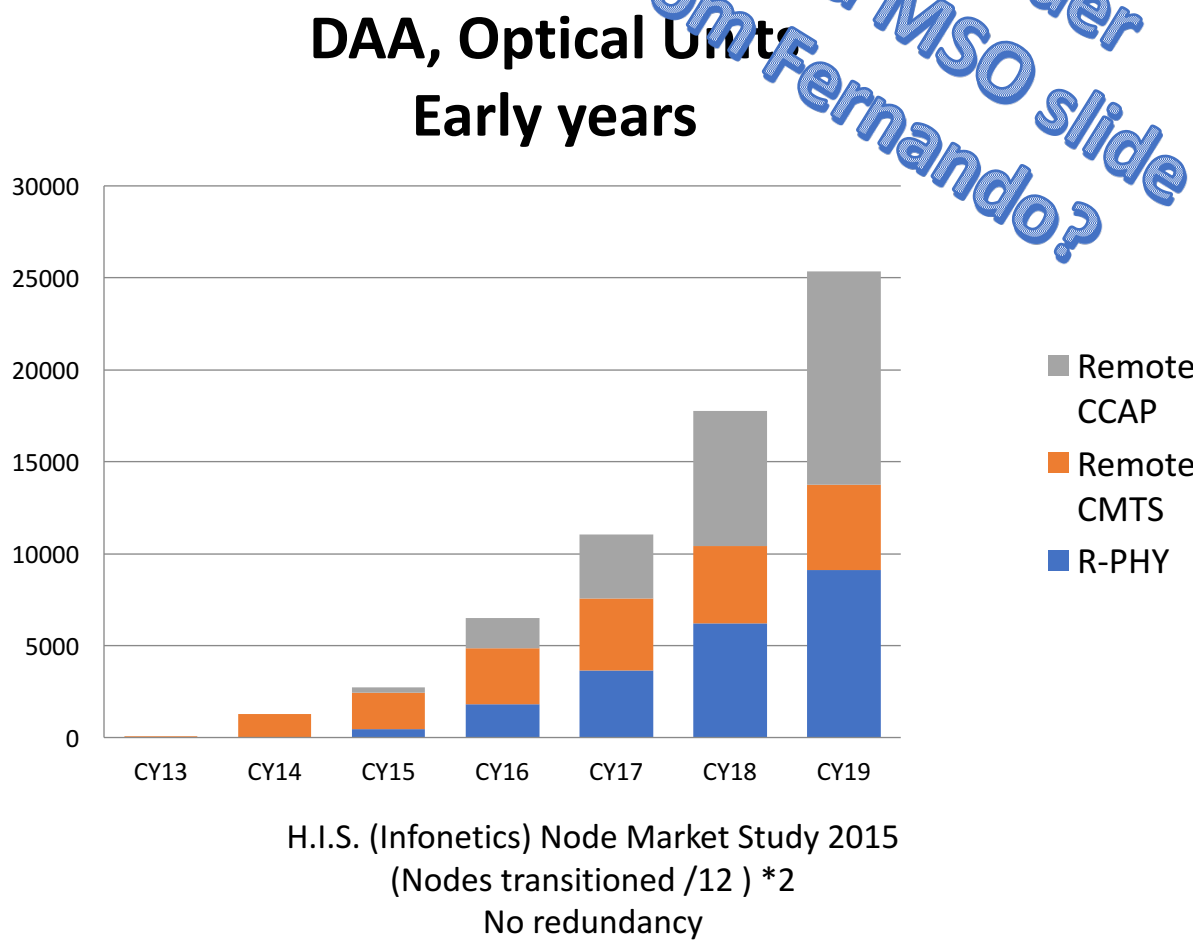


Source: Huang/ Cheng, China Mobile,
http://www.ieee802.org/3/ad_hoc/ngrates/public/16_07/huang_ecdc_01_0716.pdf

HFC Market Evolution: Estimate

Placeholder
Updated MSO slide
from Fernando?

- DAA Addressable Nodes: **1.2 M**
  - Not including China / India
  - Avg. homes passed / node: 500
- Current Nodes become aggregation points:
  - → **1.2 M** backhaul lines
  - 100G+ to distribution point
- Evolution timeframe
  - 10 yr +
- Further Growth Potential: Mobile, business services



H.I.S. (Infonetics) Node Market Study 2015
(Nodes transitioned /12) *2
No redundancy

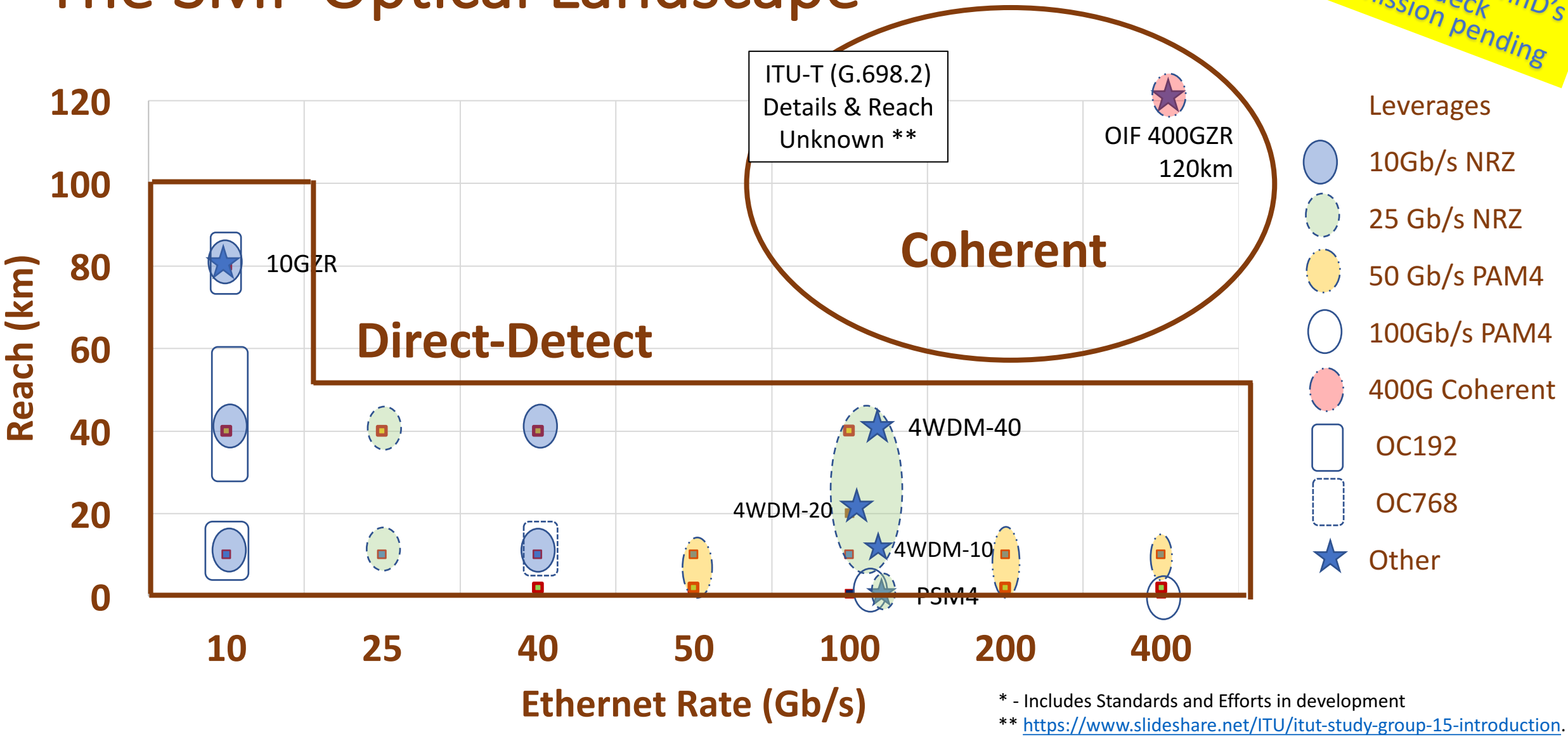
Summary

- **Established Ethernet market shows use case for >10KM**
  - **3 Million units (GbE to 100GbE) for 40km and beyond shipped annually**
  - **Bandwidth growth throughout EcoSystem**
  - **“Geographically challenged” applications exist throughout Ecosystem**
  - **Not a data center application!**
- **New markets coming to Ethernet where these are more important**
  - **Emerging applications to drive future traffic over mobile networks**
  - **Mobile Traffic in China alone exceeds other regions of the world**
  - **MSO bullet**
- **Technologies are evolving toward narrower bus widths – both electrically and optically**
- **Growing market for 100GE – meanwhile SerDes speeds narrowing to Nx 50G**

Technical Feasibility
100GbE Beyond 40km Optical PHY

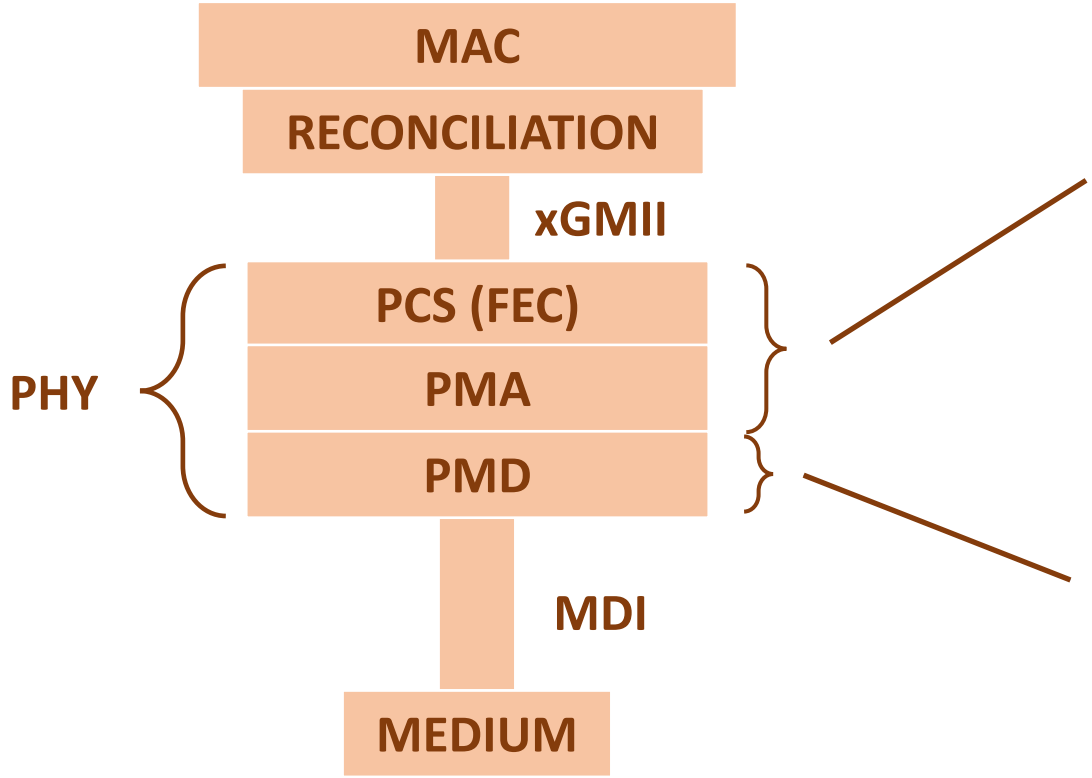
The SMF Optical Landscape *

Copied from JohnD's CFI deck
Permission pending



* - Includes Standards and Efforts in development
** https://www.slideshare.net/ITU/itut-study-group-15-introduction.

An Ethernet Overview of the Problem

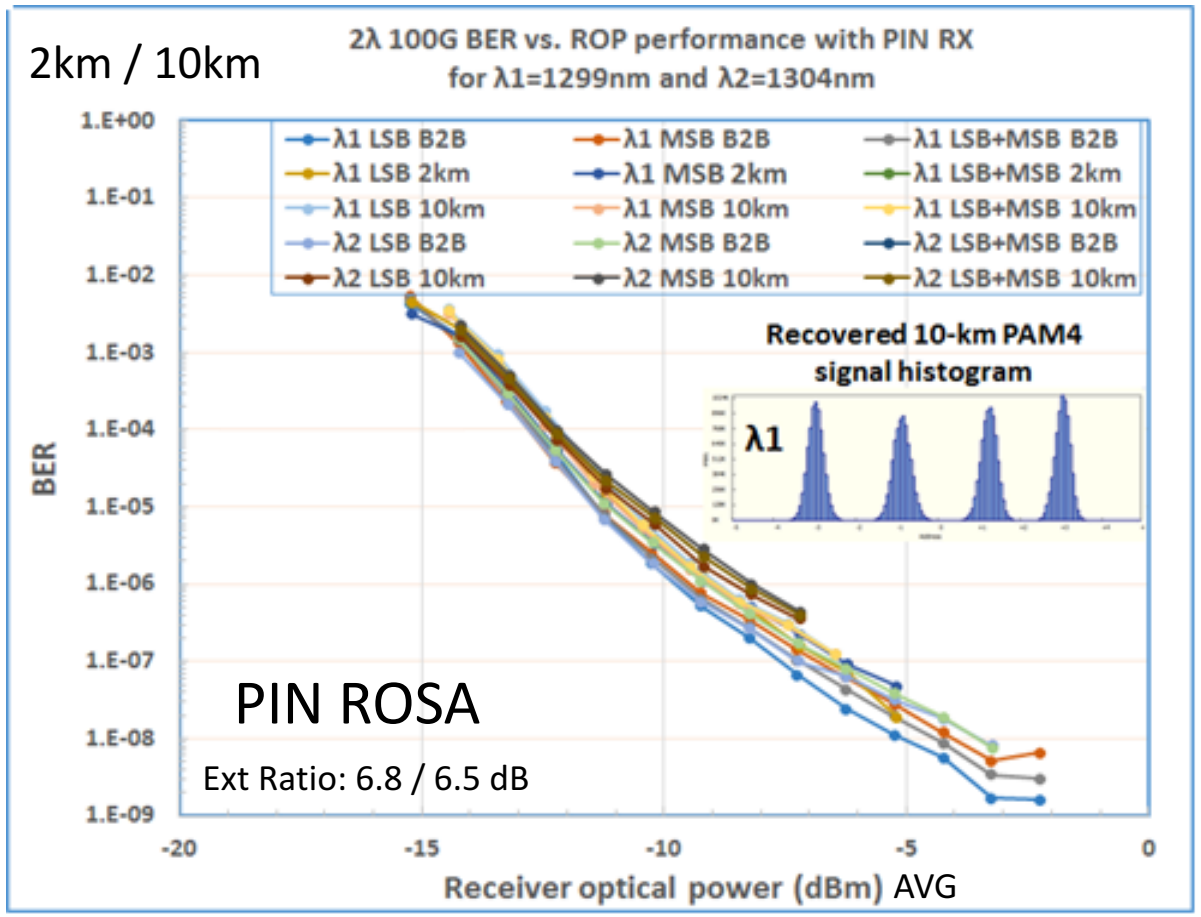


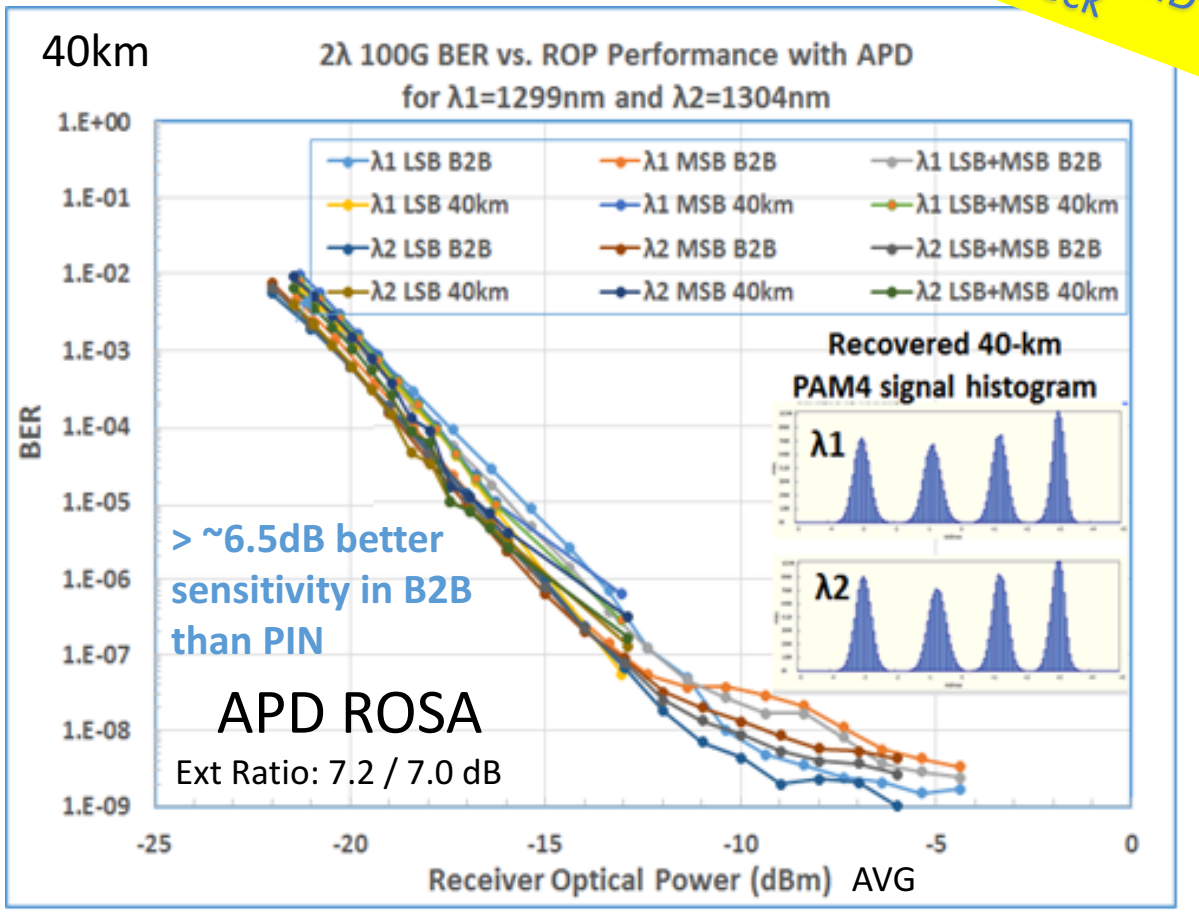
Approaches to Longer Reach

- Stronger FEC
- Improved Tx / Rx
- APD
- DSP
- Coherent
- Other (SOA, ….)

Impact of Use of APD (2λ @ 51.5625 Gb/s PAM4)

Copied from JohnD's CFI deck





Data: PRBS31
Used actual chip implementation with real-time Rx DSP **with 10+ taps FFE** embedded inside the silicon

Source: Frank Chang, Inphi, "OFC 2016: Link Performance Investigation of Industry First 100G PAM4 IC Chipset with Real-time DSP for Data Center Connectivity ", OFC'16 Th1G.2

Use of Stronger FEC

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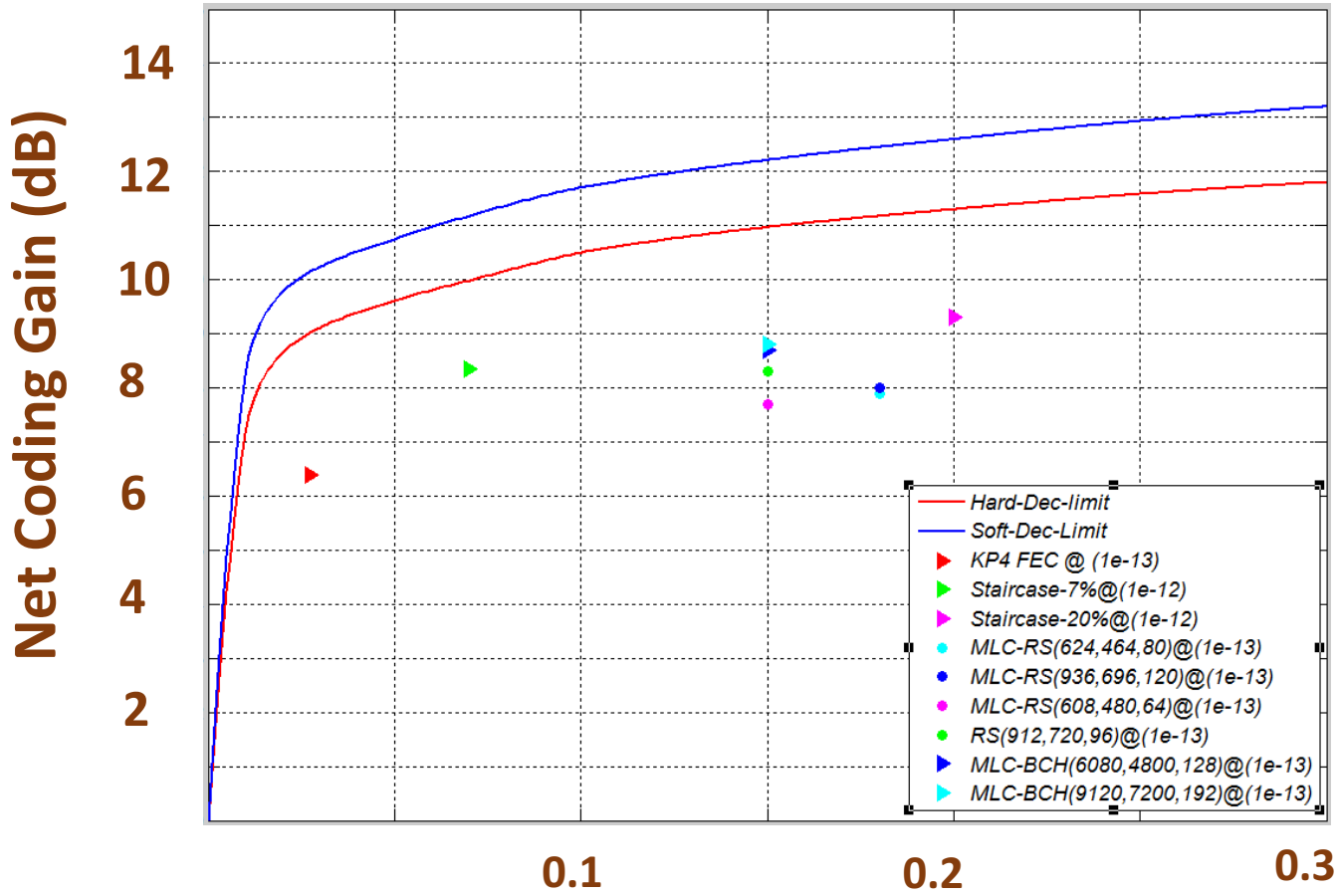
Several Potential HD-FECs can help to achieve beyond 10km 400GbE RS-FEC, BCH-FEC, MLC-FEC or Staircase FEC. (wang_ecdc_01_0316)



Overhead

Notes –

- **This is a theoretical analysis that assumes penalty for increased bit rate is just the noise bandwidth increase and does not include other penalties.**
- **Assumes post BER @ 1E-13 objective**

Targeting 40km with Coherent Technology

Modified from JohnD's CFI deck
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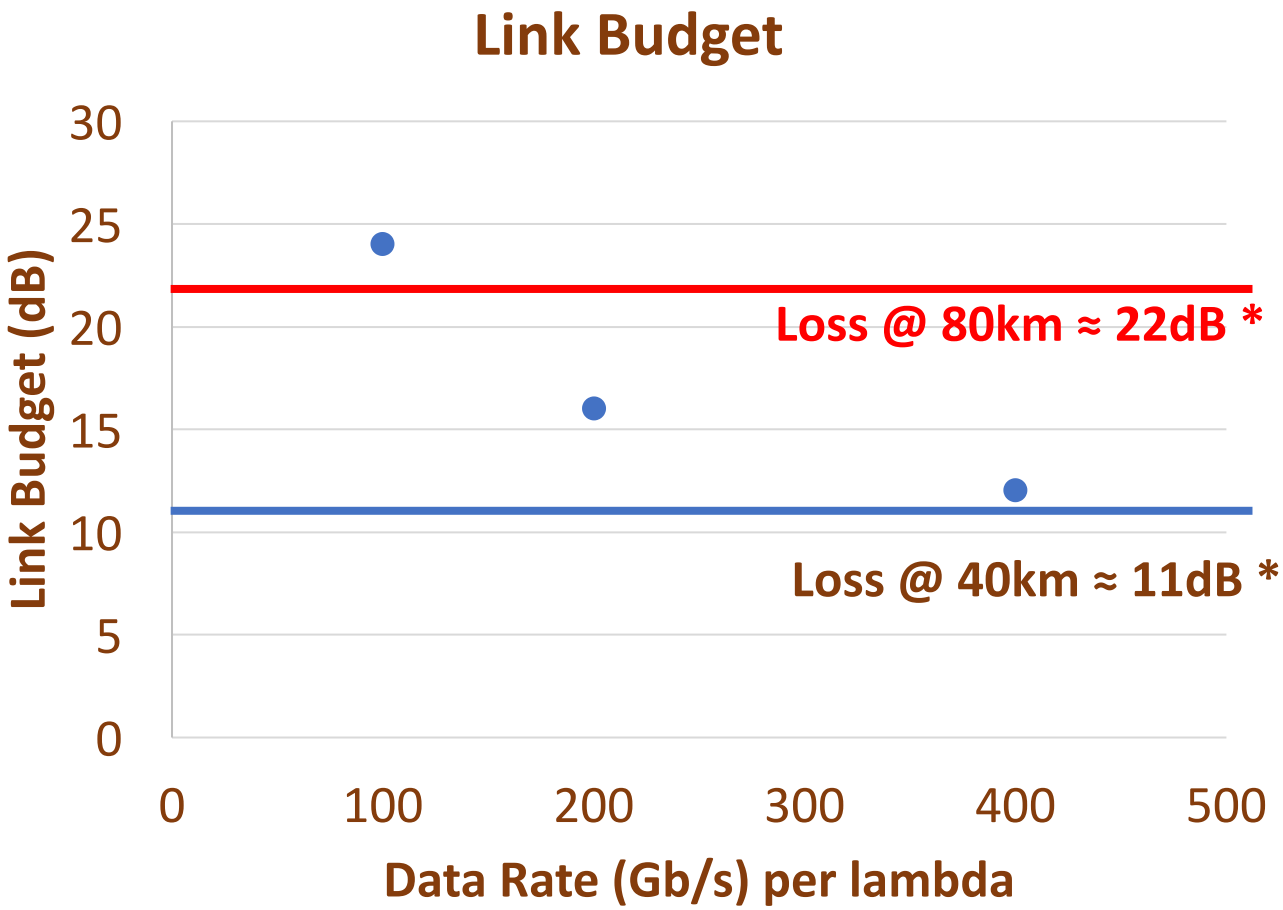

Assumptions

- Modulation Format
  - 100G – QPSK @ ~30Gbaud
  - 200G – 16QAM @ ~30Gbaud
  - 400G – 16QAM @ ~60Gbaud
- Tx and Rx power levels achievable with high yield and multiple optical technologies
- Note – Longer reach, ie. higher link budgets, can be supported by transmit SOA/EDFA or with additional amplification

* - http://www.ieee802.org/3/ba/public/tools/Fibre_characteristics_V_3_0.xls

Source: Tom Williams, Acacia

Implementation Cost Considerations

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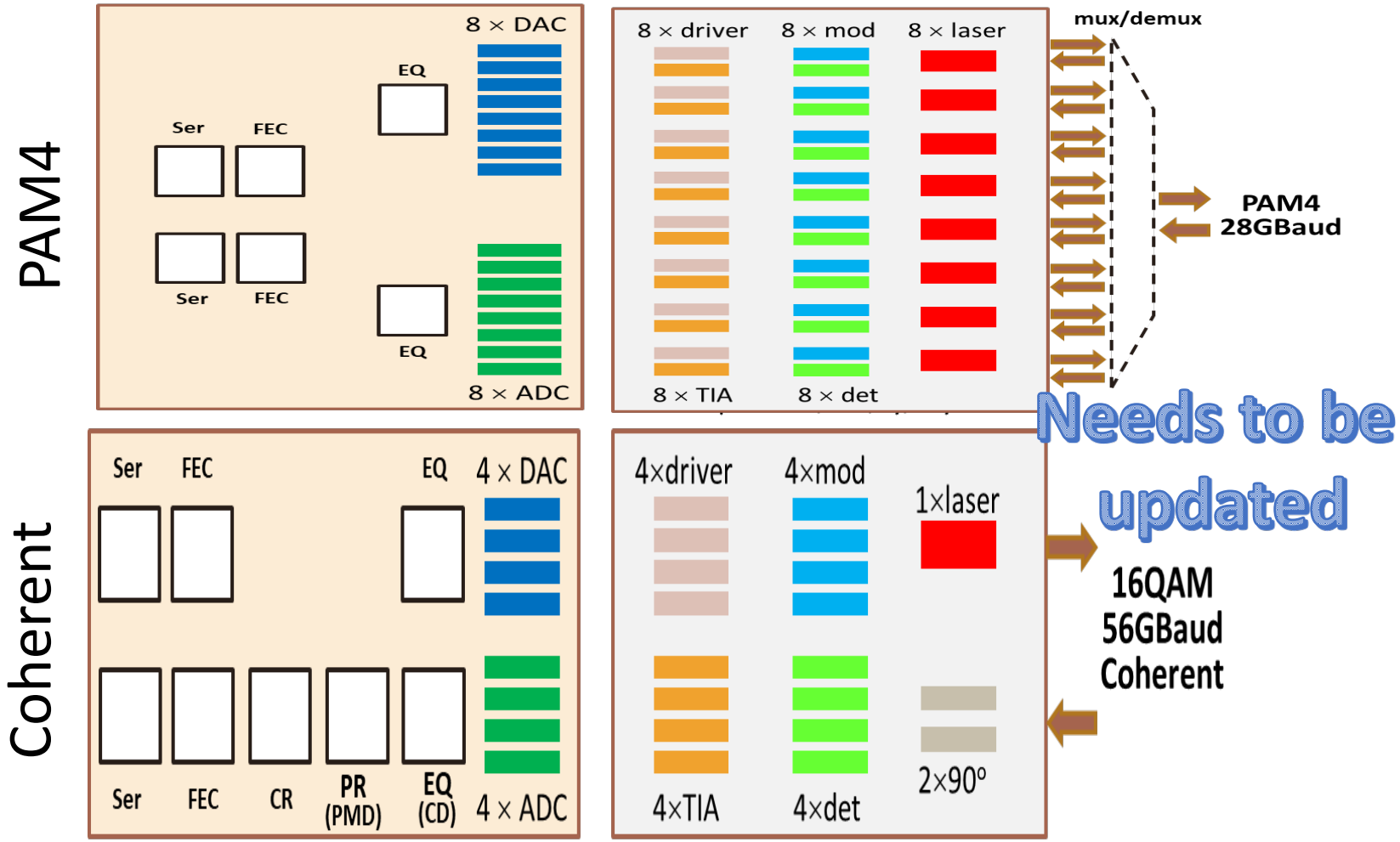

Implementation costs need to be studied –

- **Inclusion of components**
- **Number of components**
- **Operation rate of components**
- **Specifications of components**

Source: Tom Williams, Acacia

Technical Feasibility of Beyond 10km Optical PHYs

- **Growing evidence of different ways to support reaches beyond 10km for 50GbE, 200GbE, 400GbE**
  - **PAM4 (Direct Detect) test data for 40km provided**
    - **Higher Power EML Transmitters**
    - **APDs**
    - **Advanced DSP**
    - **FEC**
  - **Coherent Optics**
    - **Shipping today**
    - **Industry development efforts that may be leveraged.**
      - **ITU-T (ITU-T G.698.2)**
      - **OIF 400GZR (120km)**
- **Real challenge – determining the right solution for the right reach / rate!**

Why Now?

Why Now?

- Existing 100GbE solution for 40km (100GBASE-ER4) does not address narrower bus widths – optical and electrical
- Opportunity to align with the Beyond 10KM effort underway on 50GbE, 200GbE, and 400GbE
- New markets with 100G focus – example MSO

- Applications for Beyond 10km Optical PHYs
  - Everywhere - ≈3M units shipped annually addressing 40+km
  - Not same volumes as Data Center – but relevant to overall EcoSystem
- Traffic is growing everywhere
  - More users
  - More ways to access the internet faster
  - Higher bandwidth content
  - New applications enabled
  - And it goes on

Supporters

Straw Polls

Straw Poll 1: Call-For-Interest

- **Should a Study Group be formed to consider Beyond 10km Optical PHYs for 100GbE?**

Y: **N:** **A:**

Room Count:

Straw Poll 2: Scope

- **I would support expanding the scope of the existing Beyond 10KM Study Group to include 100GbE.**

Y: **N:** **A:**

Room Count:

Participation

- **I would participate in the “Beyond 10km Optical PHYs for 100GbE” Study Group in IEEE 802.3.**

Tally:

- **My company would support participation in the “Beyond 10km Optical PHYs for 100GbE” Study Group in IEEE 802.3.**

  Tally:

Future Work

- **Ask 802.3 on Thursday**
  - **Form Beyond 10km Optical PHYs Study Group**
- **If approved, on Friday**
  - **Request 802 EC form "Beyond 10km Optical PHYs for 100GbE" Study Group**