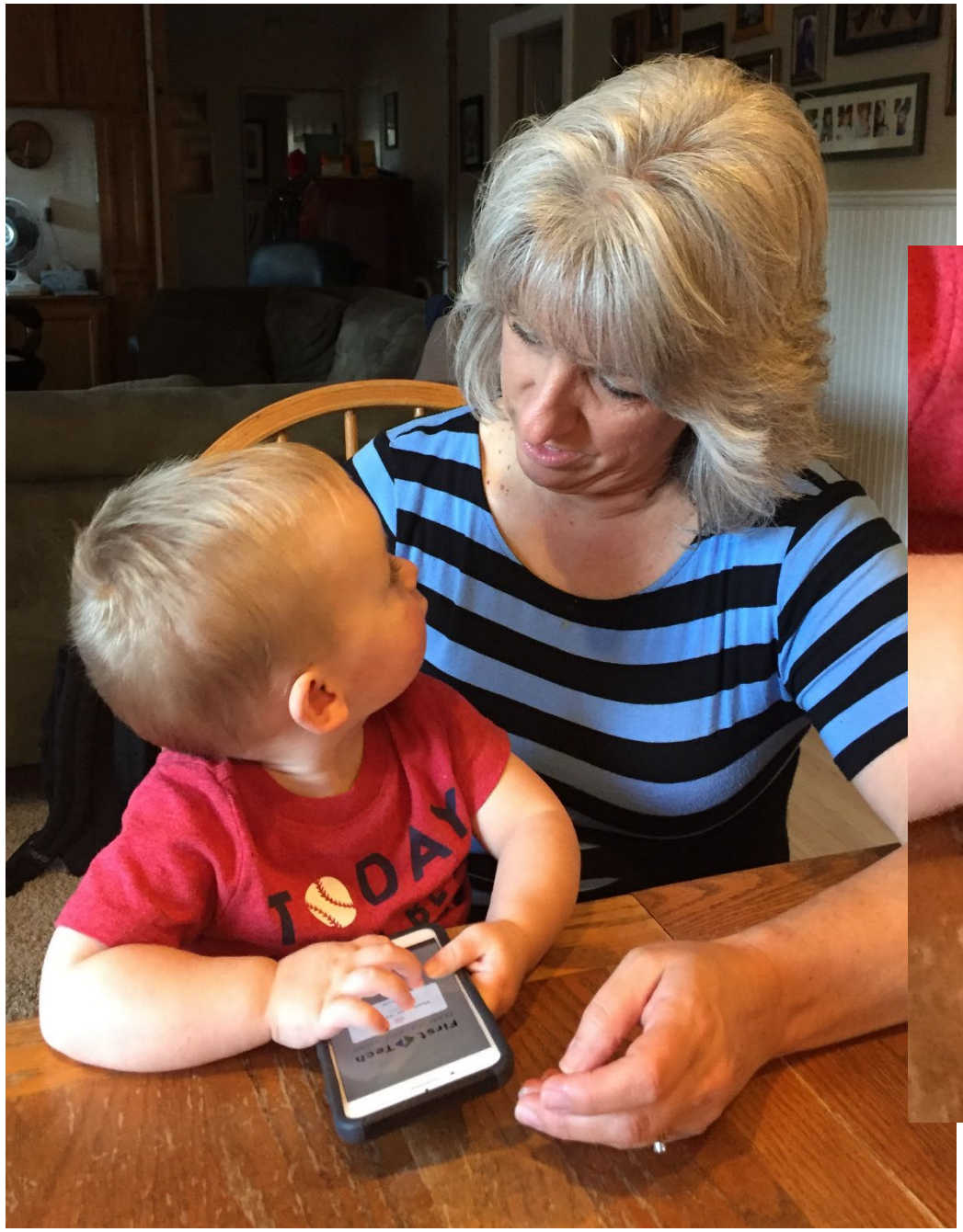
KEYSIGHT WORLD 2019

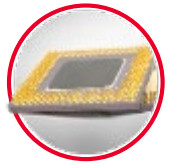
Data Center and Optical Network Innovation: Enabling the 5G Ecosystem

Internet Infrastructure, VP/GM / Keysight Technologies

Greg D. Le Cheminant for Joachim Peerlings



Enabling the 5G Communications Eco-System



Components & Chipsets

Devices

Base Stations

Transport and Data Centers

Server

Layers 2-7

Layer 1

Mobile Device Test

BTS Drive Test

Drive Test

Mobile Network Test

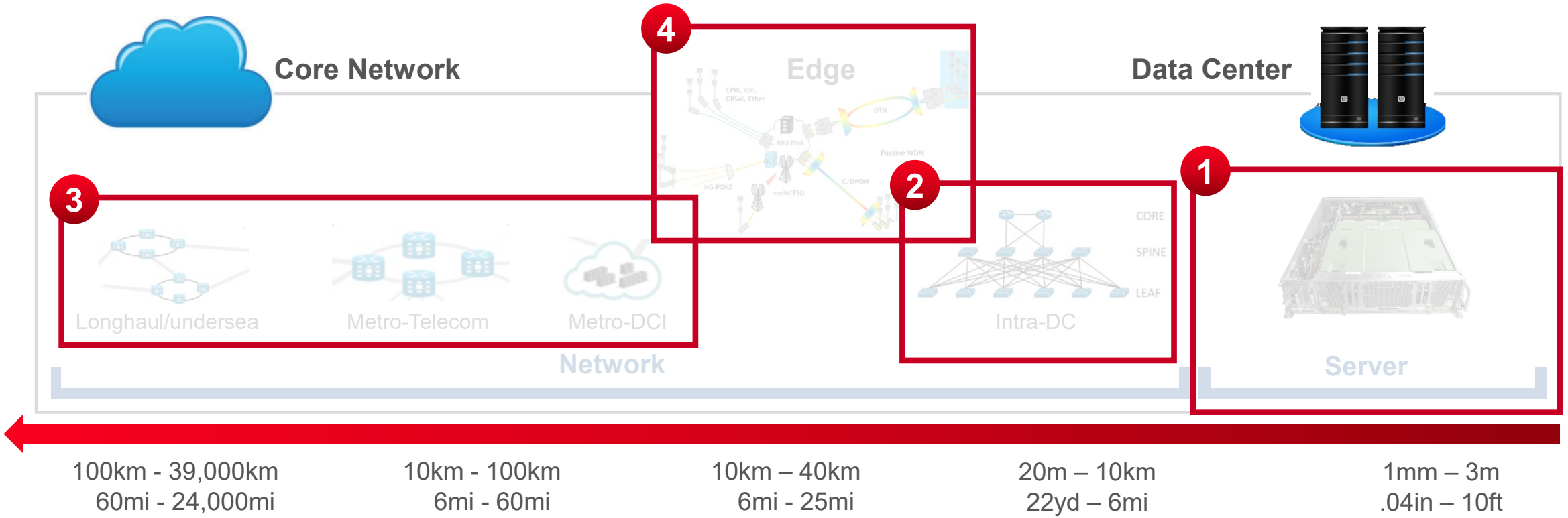
Customer Experience Management

Network Test, Visibility and Security

Electrical, Optical and Wireless Test

Channel Emulation

Wireline Internet Infrastructure



Trends and Challenges – Bandwidth, Power, Cost, Size

1

Spectral efficiency of copper not exhausted: Move to more complex modulation schemes.
Challenges: Signal integrity and latency.
Leverage from data center networking.

2

Intra-DC

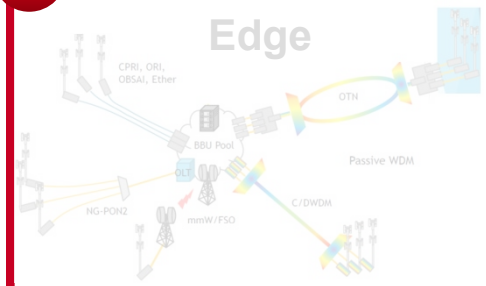
Spectral efficiency can be improved.
Challenges: Forward Error Correction. Direct detection limited by signal integrity.
Leverage from telecom long haul transport.

3

Telecom Transport/DCI

Spectral efficiency out-optimized.
Challenges: Further bandwidth increase w/o fiber deployments.

4



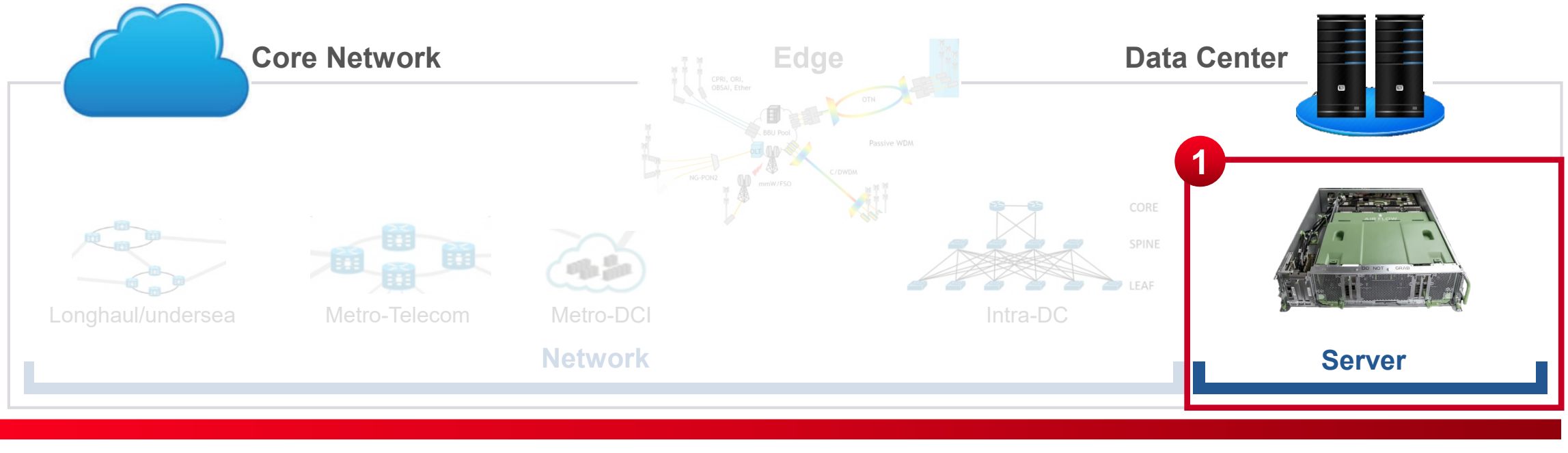
Network slicing demands multiple network architectures.
Challenges: High bandwidth at tough environmental conditions. Latency requirements.
Leverage from data center, telecom and wireless.

Conclusions

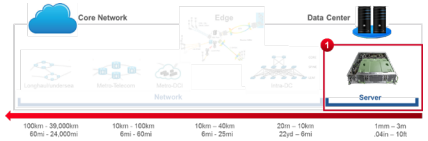
1. A pool of technology building blocks exist that can solve the challenges in all infrastructure segments.
Industry needs to leverage available technology. No fundamental roadblock exists.

2. Today's engineers need to be multi-discipline.
Need to understanding wireline & wireless, electrical & optical, Physical layer & protocol.

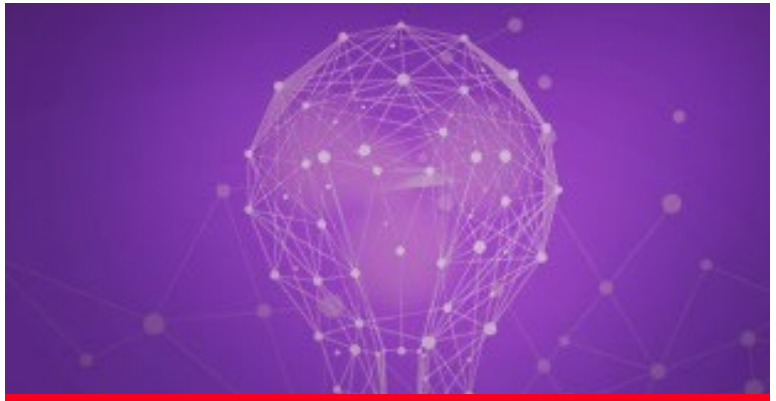
Wireline Internet Infrastructure



Requirements on Server Performance



Data Analytics



Artificial Intelligence

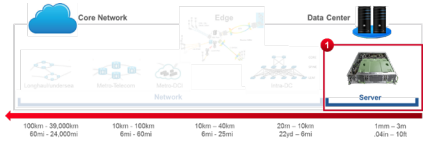
Video Transcoding

Cyber Security

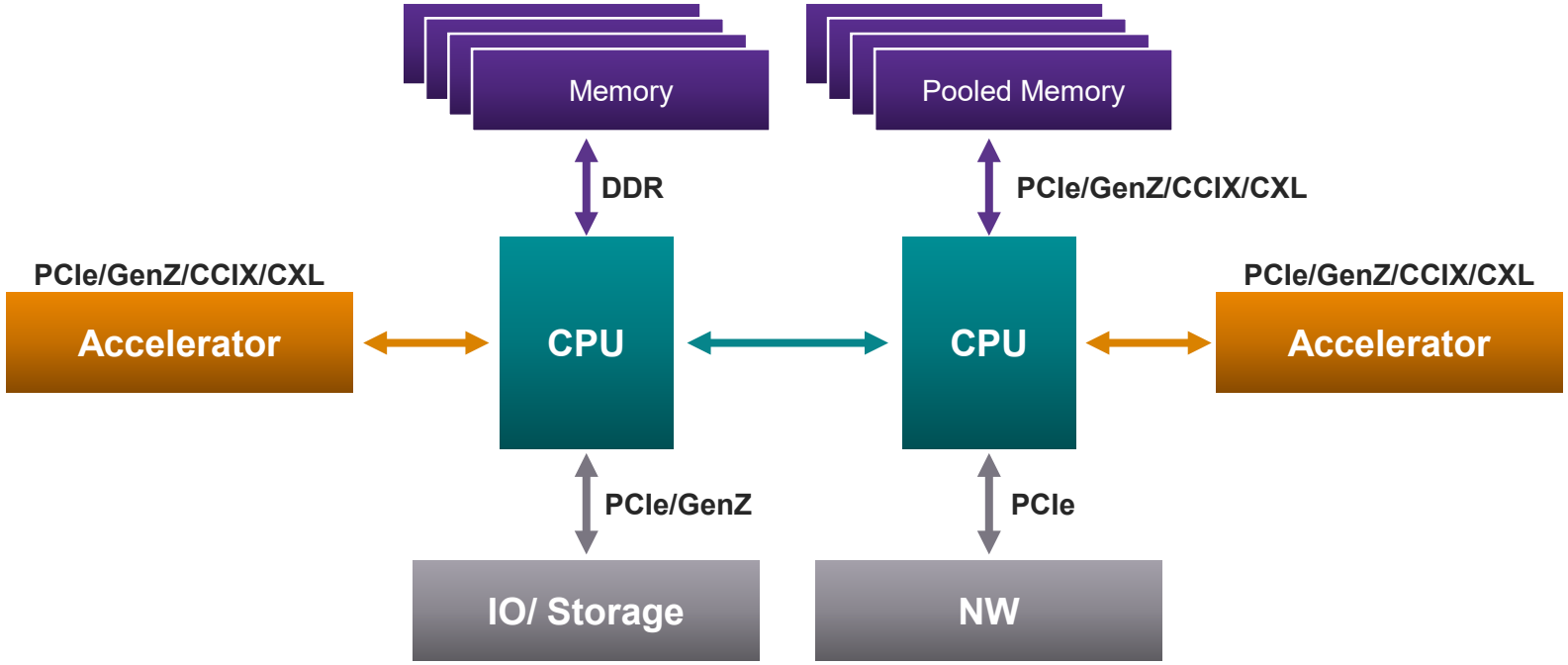
Financial Acceleration

Genomics

Server Architecture Evolution



DISAGGREGATION AND ACCELERATION

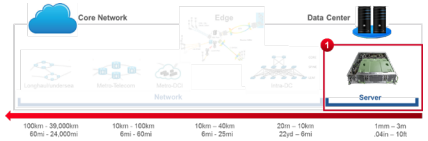


90%
of compute happens off CPU

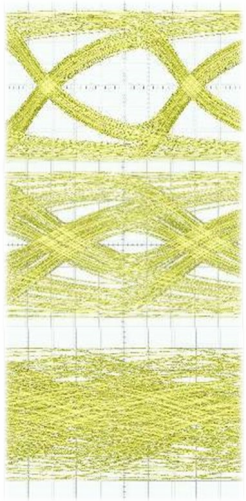
Improve memory utilization by
30%

https://www.microsoft.com/en-us/research/uploads/prod/2018/04/oi2018_final.pdf

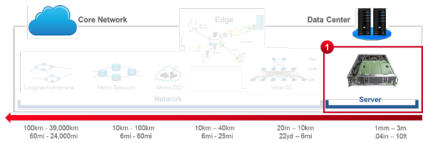
Dis-aggregation Drives BW



		Raw Baud Rate/Lane	Total x16 Bandwidth	Modulation
2003	PCIe 1.x	2.5GT/s	32Gb/s	NRZ
2006	PCIe 2.x	5.0GT/s	64Gb/s	NRZ
2010	PCIe 3.x	8.0GT/s	126Gb/s	NRZ
2017	PCIe 4.x	16.0GT/s	~252Gb/s	NRZ
2019	PCIe 5.x	32.0GT/s	~504Gb/s	NRZ
2022?	**PCIe 6.x**	**64.0GT/s?**	**~1000Gb/s?**	**PAM4?**



End-to-End Automated Test Solutions for High-Speed I/O



Physical Layer Interconnect Design

ADS Design Software

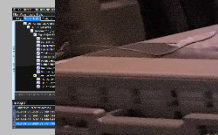
86100D DCA-X/TDR

N5227B PNA w/ PLTS

Verify PCIe 5.0 Compliant Channels; Verify Return Loss Compliance; Capture break-out channel S-Params

Physical Layer Transmitter Test

UXR-Seri
Time



D9050P
5.0
compl

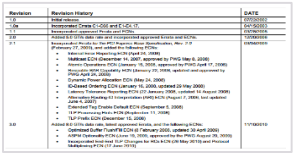
86100C
Jitte
Meas

DSA UXF
Real-Ti

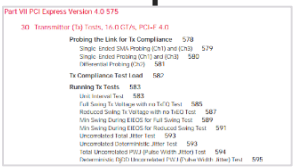
Physical Layer Receiver Test

PCI SIG KEYSIGHT TECHNOLOGIES

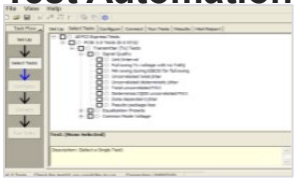
Standards document



Method Of Implementation

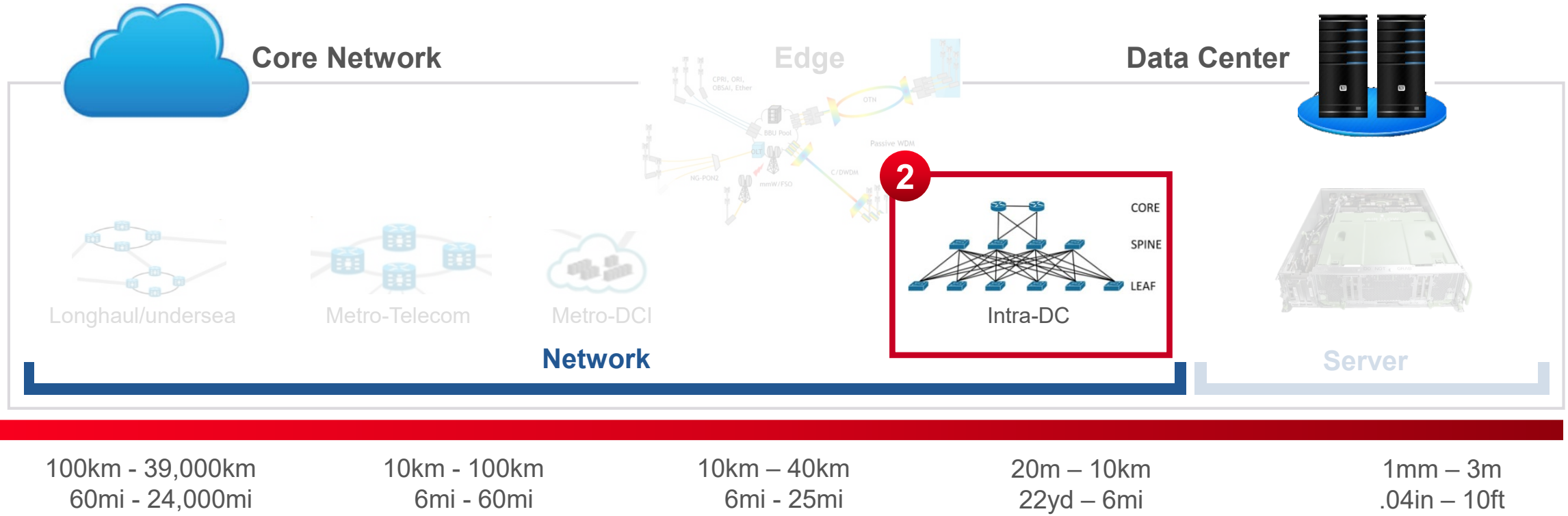


Test Automation

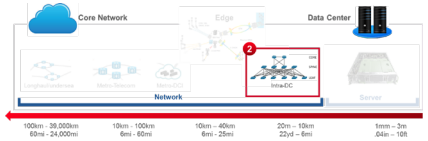


We enable next generations high-speed I/O by working with market makers, standard bodies, open communities

Wireline Internet Infrastructure



100G in the Cloud Network



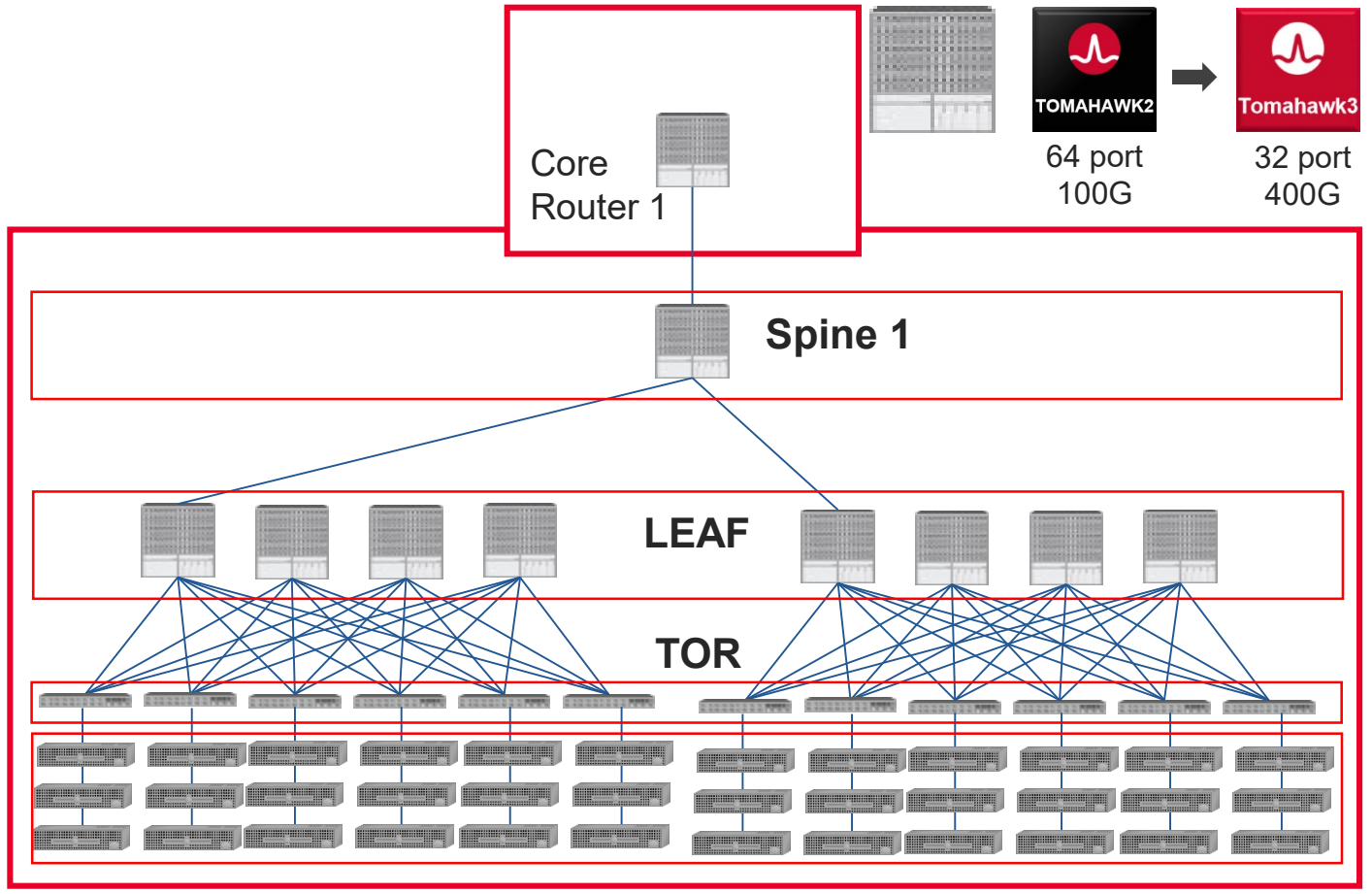
< 10-120km
100G-DCO
ColorZ

< 1000m (10km)
100G-LR4

< 500m (2km)
100G-CWDM4
100G-PSM4

< 20m
100G-AOC

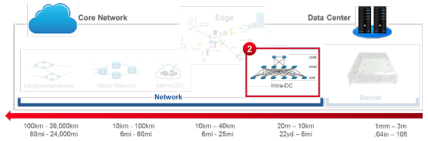
< 3m
100G-CR4
25G-CR1



PCIe4/DDR4

Source: Brad Booth, Tom Issenhuth, Microsoft, IEEE 802bs

400G in the Cloud Network



< 10-120km

400G-DCO

< 1000m (10km)

400G-LR4

< 500m (2km)

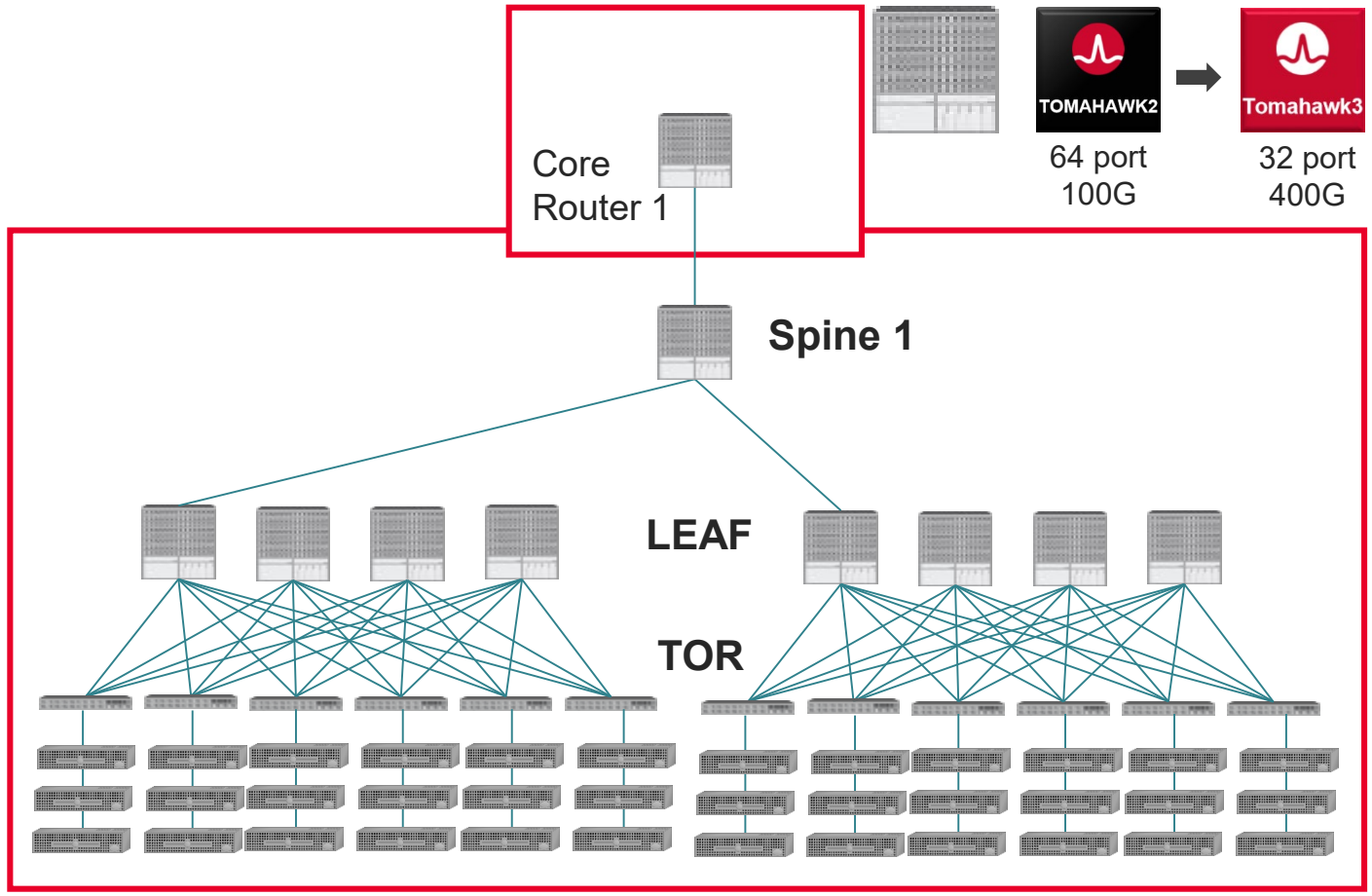
400G-FR4
400G-DR4

< 20m

400G-AOC
400G-SR8

< 3m

400G-CR8
50G-CR



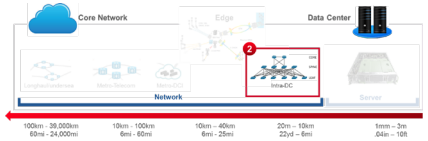
64 port
100G

32 port
400G

PCIe5/DDR5

Source: Brad Booth, Tom Issenhuth, Microsoft, IEEE 802bs

Silicon Switch Evolution

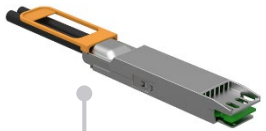


THE POWER BRICK-WALL FOR PLUGGABLES

100Gbps/port
QSFP28

400Gbps/port
QSFP56DD

800Gbps/port
OSFP



Optical engine

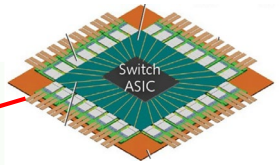


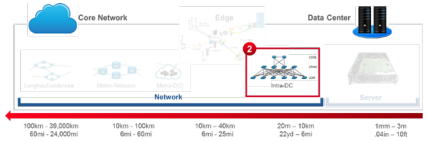
Image: Courtesy of Luxtera

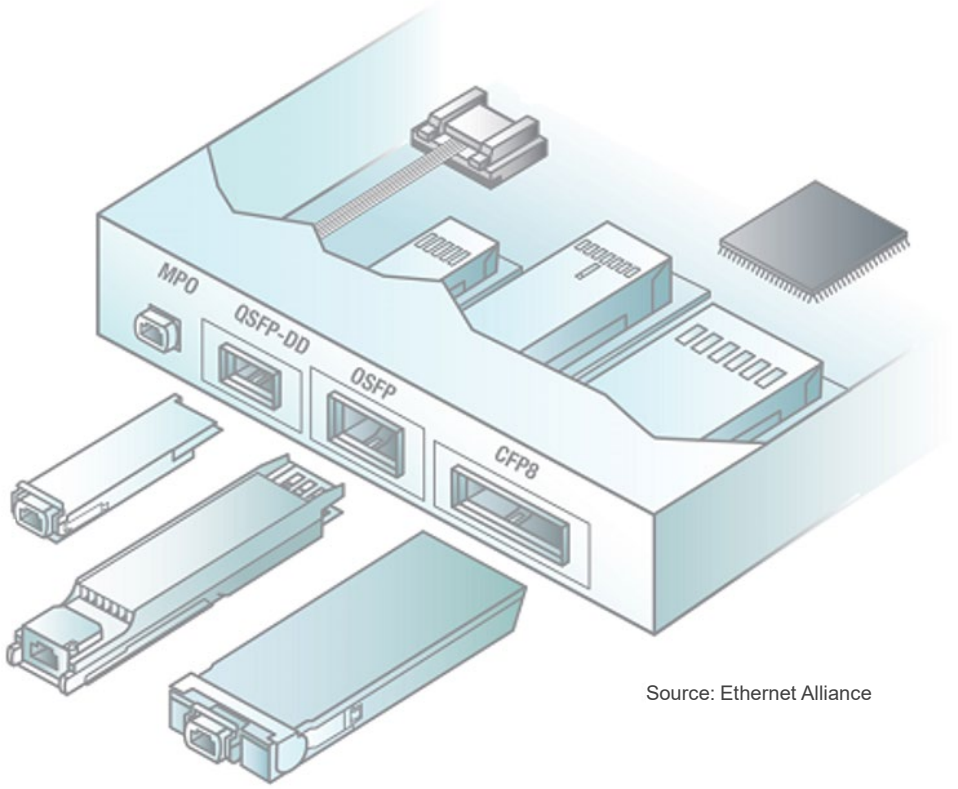
2014 | 3.2 Tbps | 2015 | 2016 | 6.4 Tbps | 2017 | 12.8 Tbps | 2018 | 12.8 Tbps | 2019 | 2020 | 25.6 Tbps | 2021 | 2022 | 51.2 Tbps | 2023 | 2024

- 3.2 Tbps: SERDES Speed 25Gb/s
- 6.4 Tbps: SERDES Speed 25Gb/s
- 12.8 Tbps: SERDES Speed 25Gb/s
- 12.8 Tbps: SERDES Speed 50Gb/s
- 25.6 Tbps: SERDES Speed 100Gb/s
- 51.2 Tbps: **Power consumption wall for pluggable optics**

https://www.laserfocusworld.com/articles/print/volume-54/issue-10/features/photonics-for-datacenters-integrated-optics-permeate-datacenter-networks.html

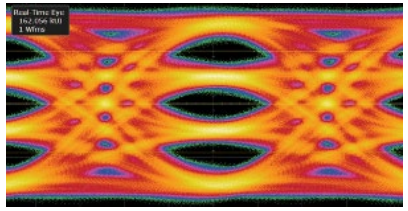
Data Center Networking Choices



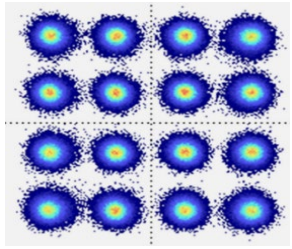


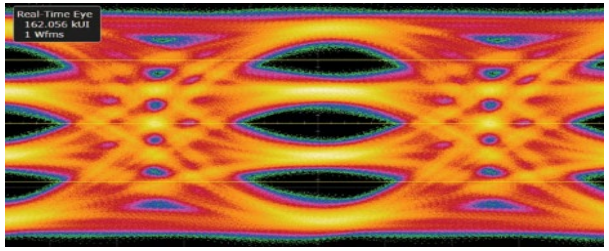
Source: Ethernet Alliance

100G or 400G

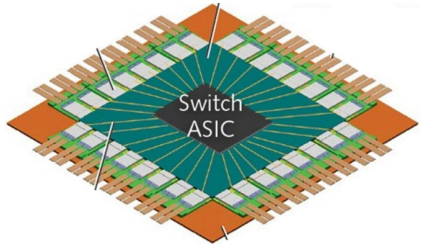


Coherent or Direct Detection



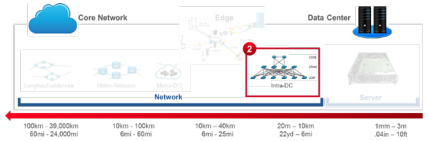


Pluggable or Co-package

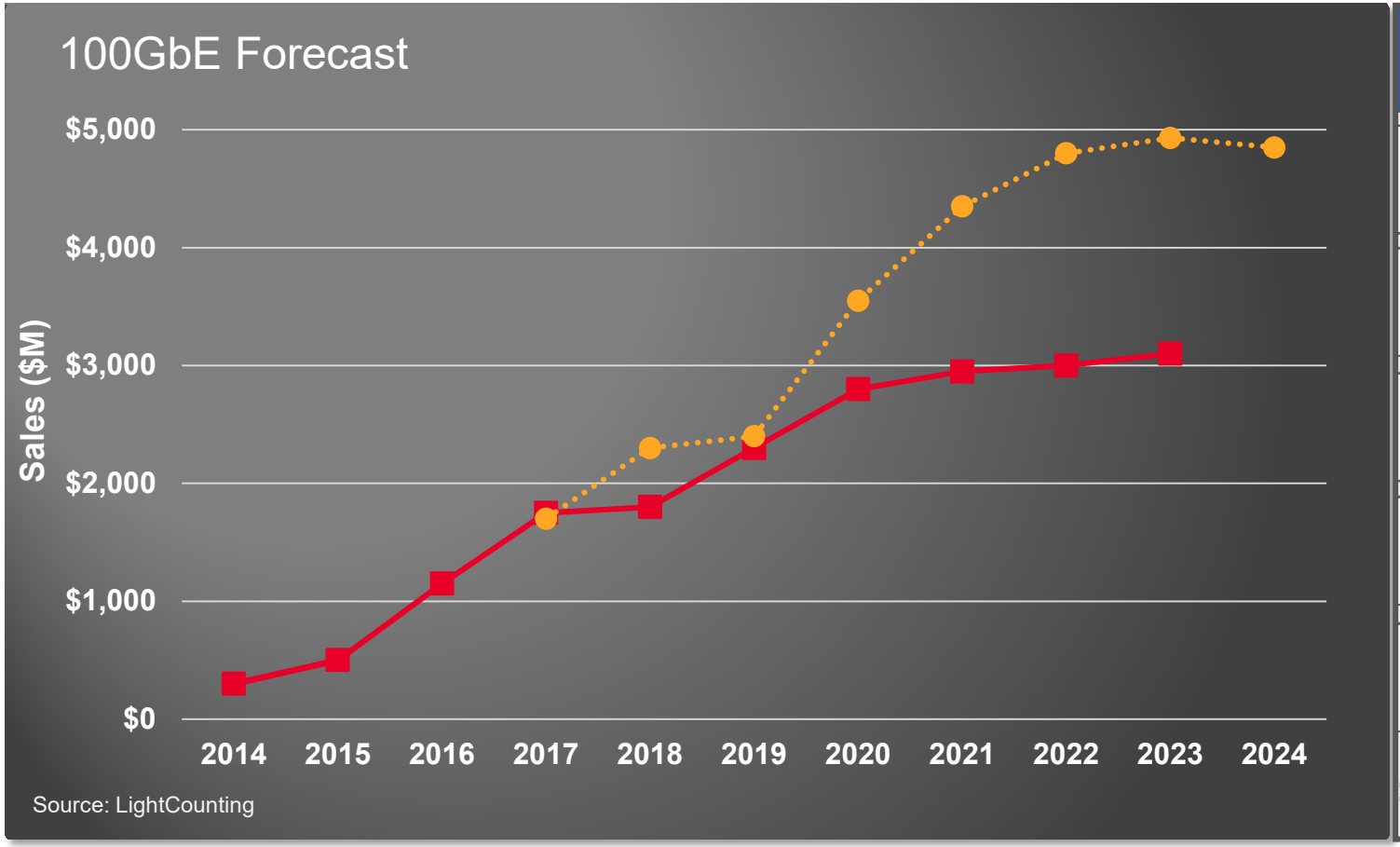


https://www.laserfocusworld.com/articles/print/volume-54/issue-10/features/photonics-for-datacenters-integrated-optics-permeate-datacenter-networks.html

100G vs. 200G/400G



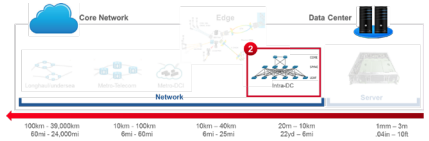
VOLUME AND TIMING



facebook	100G CWDM-4 demand increase in H2 2019
Google	2x200GbE deployments have started demand will peak in 2022 transition to 2x400GbE in 2022
amazon	4x100GbE DR4 (400G-DR4)
阿里巴巴 Alibaba.com	Deployment 100G in 2017; 400G planned for 2019
Tencent 腾讯	Deployment 100G started (2017-2021) 400G planned for end 2019
Baidu 百度	Deployment 100G in 2017 400G planned for 2021

> 13 companies showed 400G readiness at OFC 2019

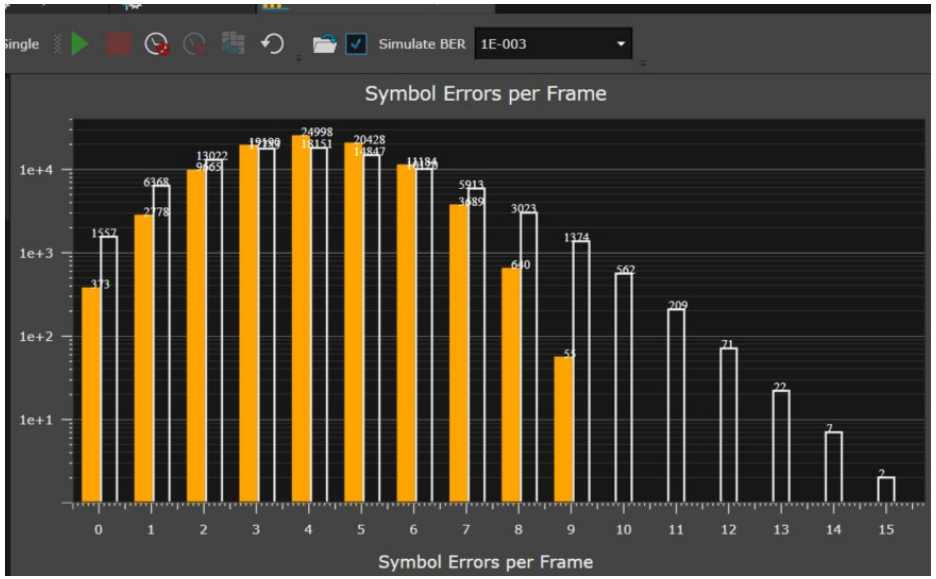
Characterizing Error Mechanisms

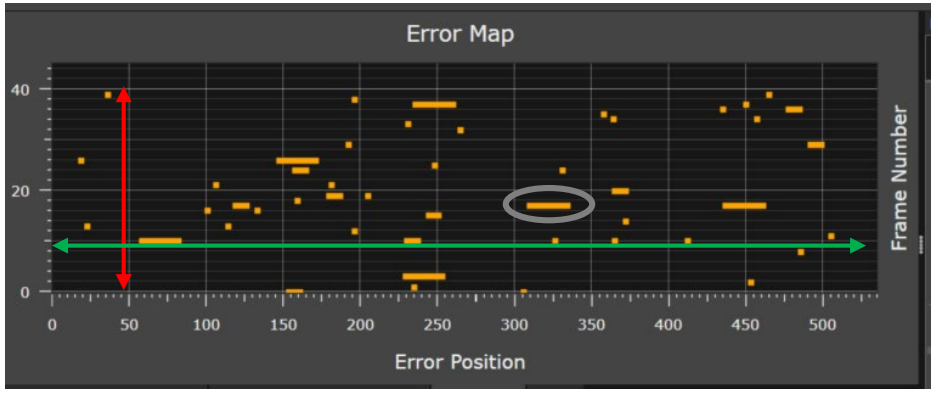


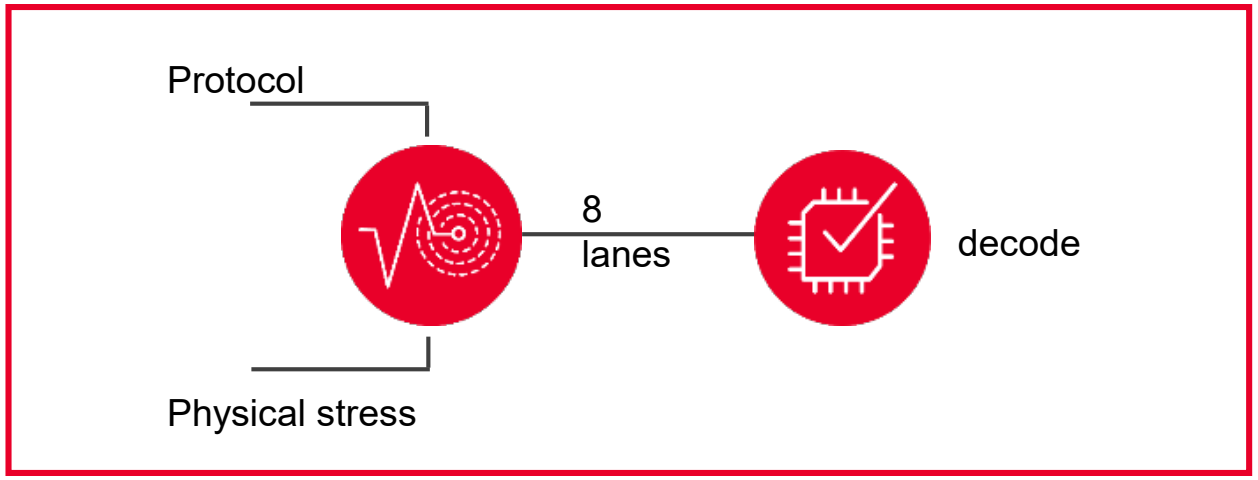
Layer 2, 64B – 14,000B frames

(FEC) Interoperability

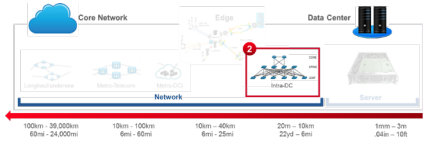
FEC symbol errors

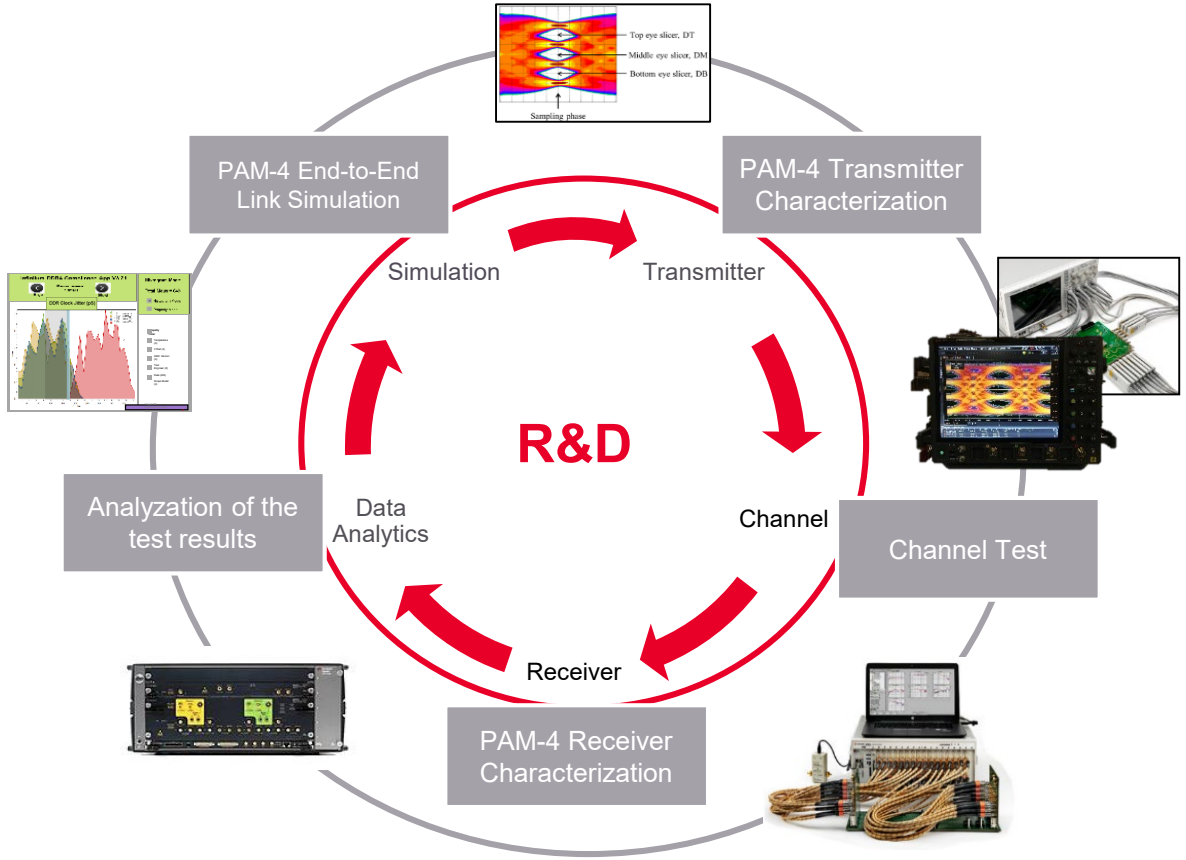


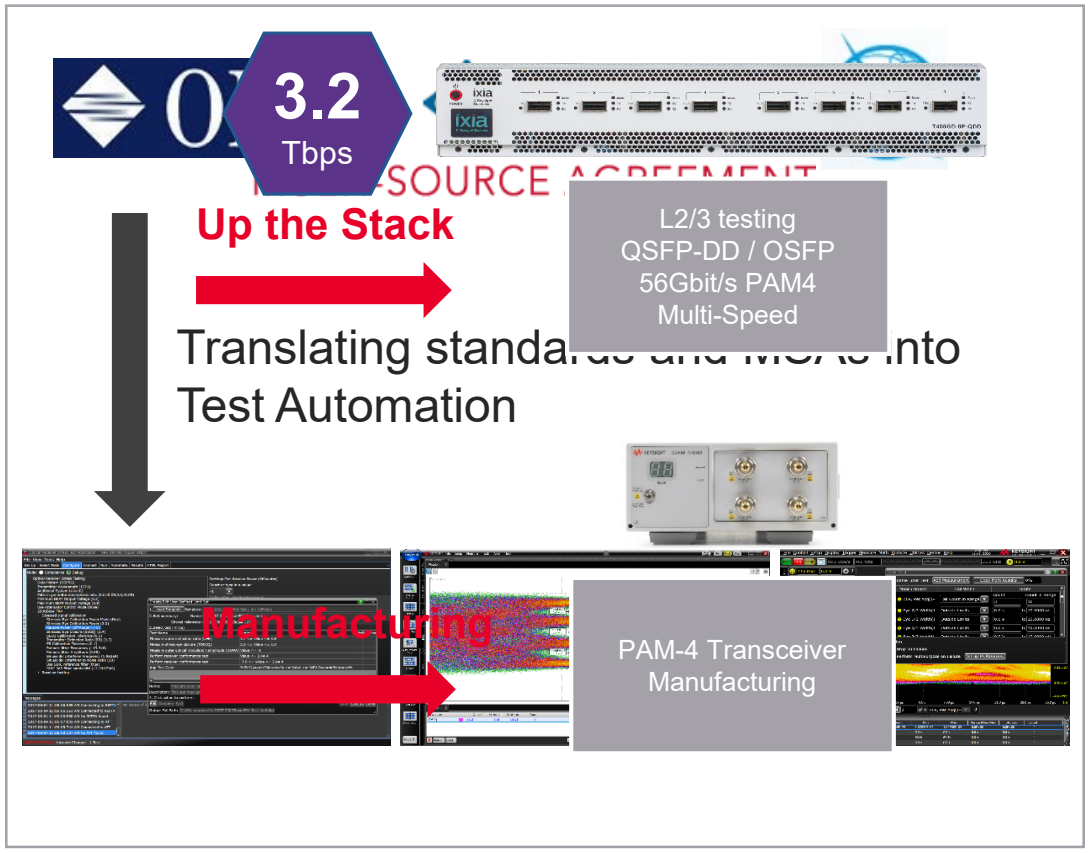




End-to-End Automated Test Solutions for Direct Detection

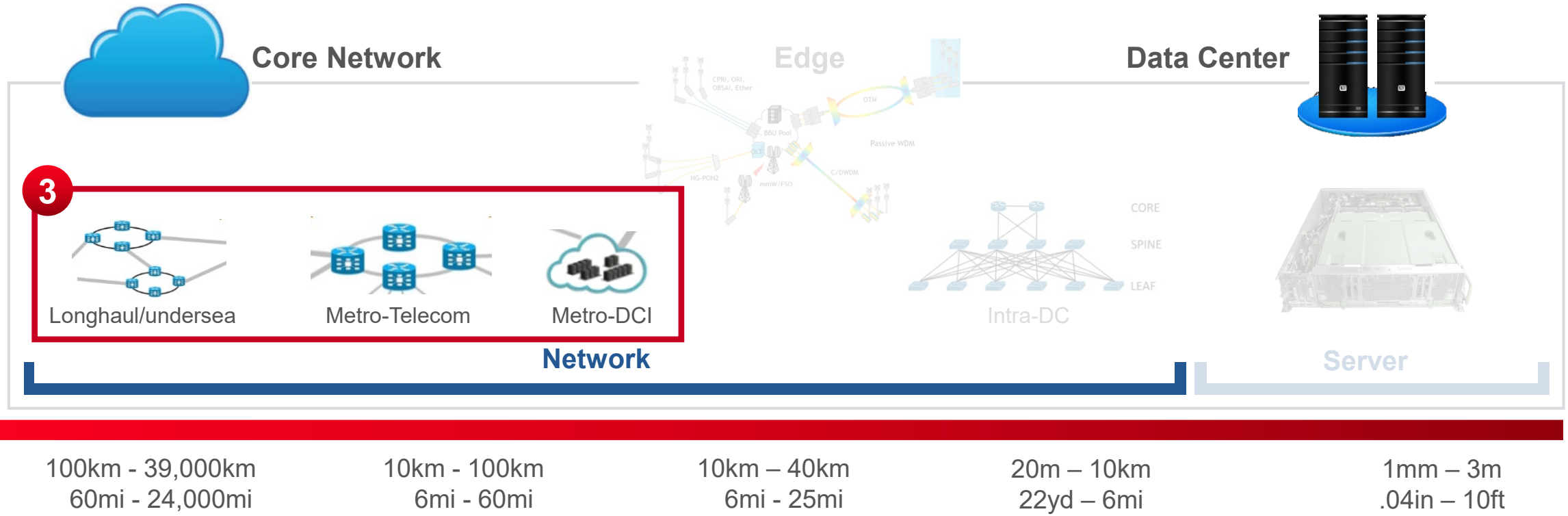




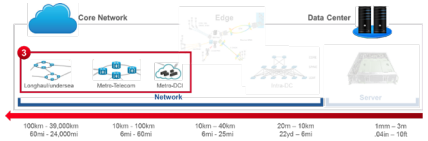


Keysight partners with key players in the optical component and transceiver industry and OIF, IEEE, OCP, ODCC

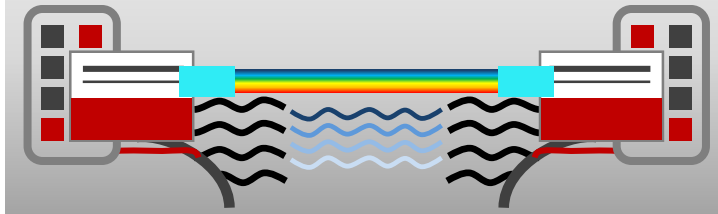
Wireline Internet Infrastructure



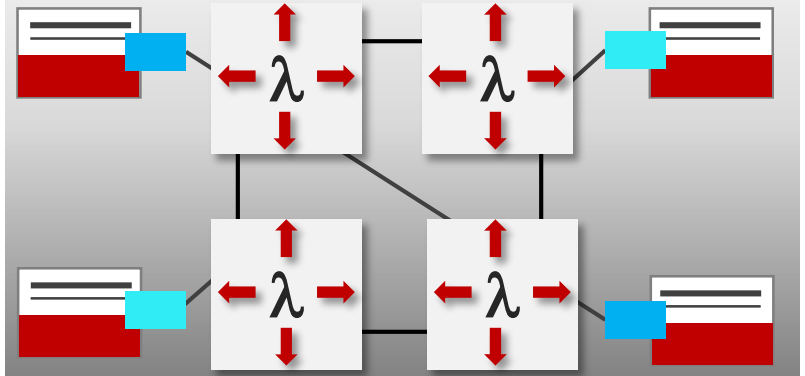
Different Challenges for Long-Haul and Metro/DCI



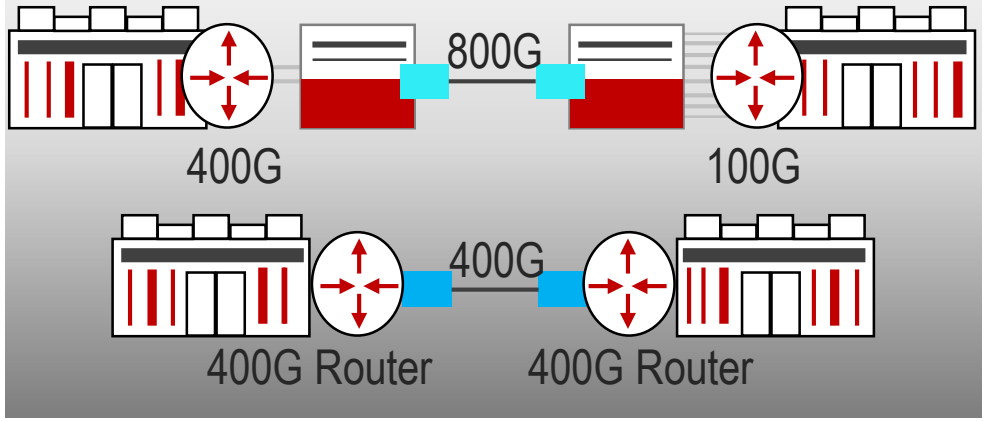
Sub-Sea



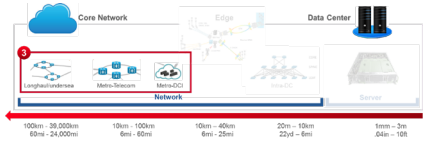
Terrestrial Long Distance



DCI



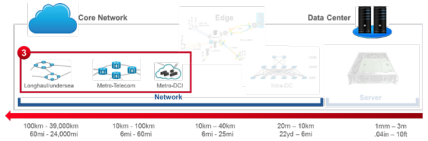
Coherent DSP Silicon for 400G, 600G and 800G



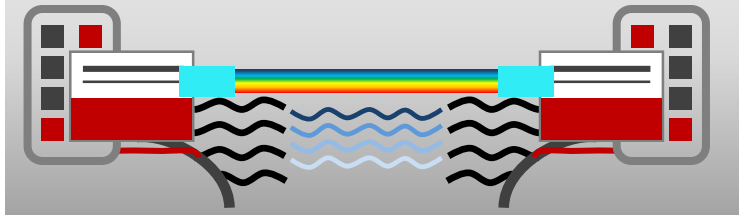
2018/2019 DSP INTRODUCTIONS

	Acacia Pico	NEL	Nokia PSE-3	Infinera ICE5 Stopped Coriant 600G offering	Infinera ICE6	Ciena Wavelogic Ai	Ciena Wavelogic 5	Inphi M200 LightSpeed-III
Speed-classes	100G-600G	100G-600G	100G-600G	100G-600G	800G	100G-400G	800G	100/200G
Availability	Second half 2018, commercial	Second half 2018, commercial	Second half 2018, internal	Second half 2018, internal	OFC announcement	2017, licensed to Lumentum, Oclaro, NeoPhotonics	OFC announcement	2018, commercial

Different Challenges for Long-Haul and Metro/DCI



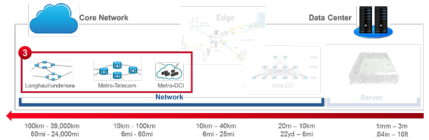
Sub-Sea

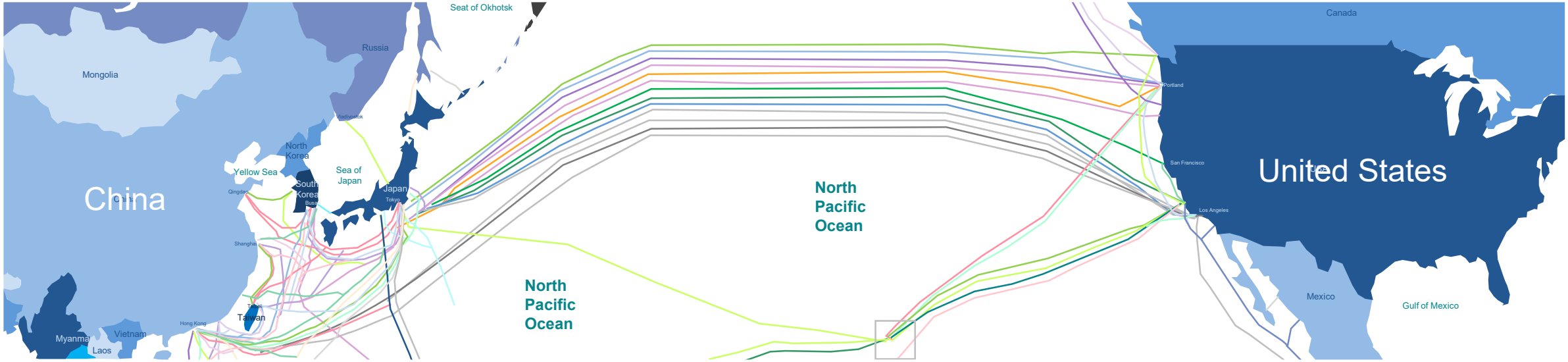


Terrestrial Long Distance

DCI

Subsea Cable Deployment





100
new cables between 2016 and 2020

Content providers used
54%
of subsea bandwidth in 2018

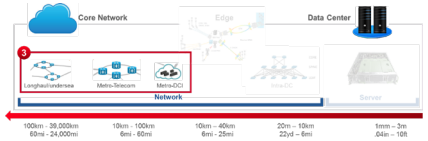
Content providers will used
80%
of subsea bandwidth by 2027

Content Provider Investments

Consortium Member | Major Capacity Customer | Sole Owner

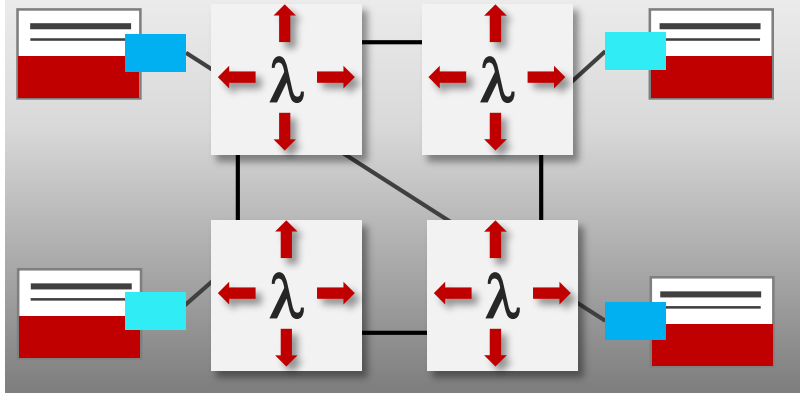
RFS 2010	2013	2015	2016	2017	2018	2019	2020
Unity Google	**SJC** Google	**GTT Express** Microsoft	**FASTER** Google	**Monet** Google	**Tannat** Google	**PLCN** Facebook Google	**SJC2** Facebook
			AEC-1 Facebook Microsoft		**Junior** Google	**KH-G** Google	**Dunant** Google
			APG Facebook		**Hawaiki** Amazon	**INDIGO-Central** Google	**HKA** Facebook
					MAREA Facebook Microsoft	**INDIGO-West** Google	**JUPITER** Amazon Facebook
					NDCP Microsoft	**JGA-S** Google	**Malbec** Facebook
						Curle Google	
						Havfrue Facebook Google	

Different Challenges for Long-Haul and Metro/DCI



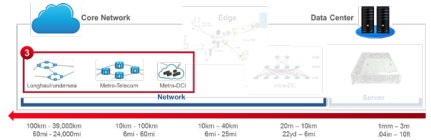
Sub-Sea

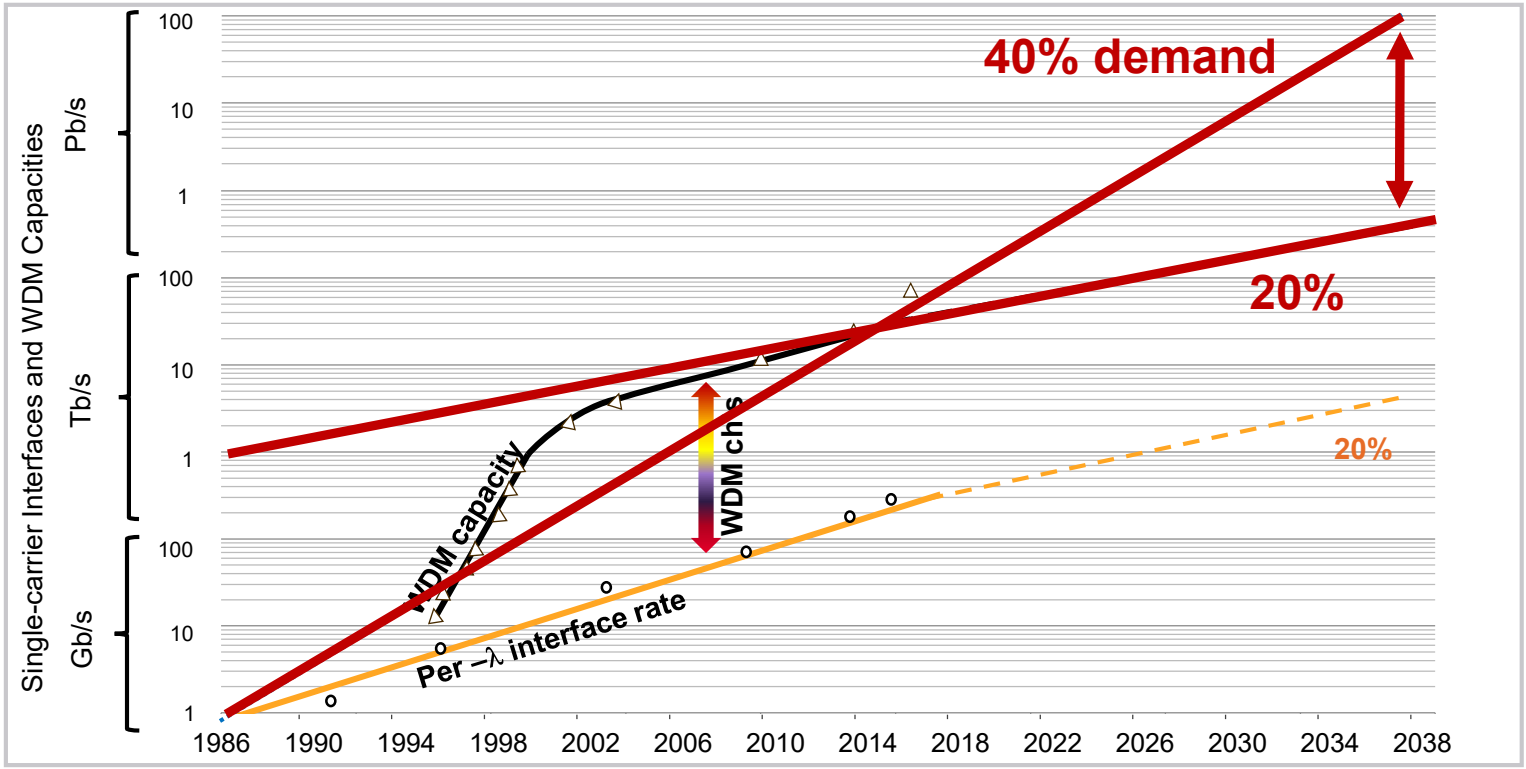
Terrestrial Long Distance



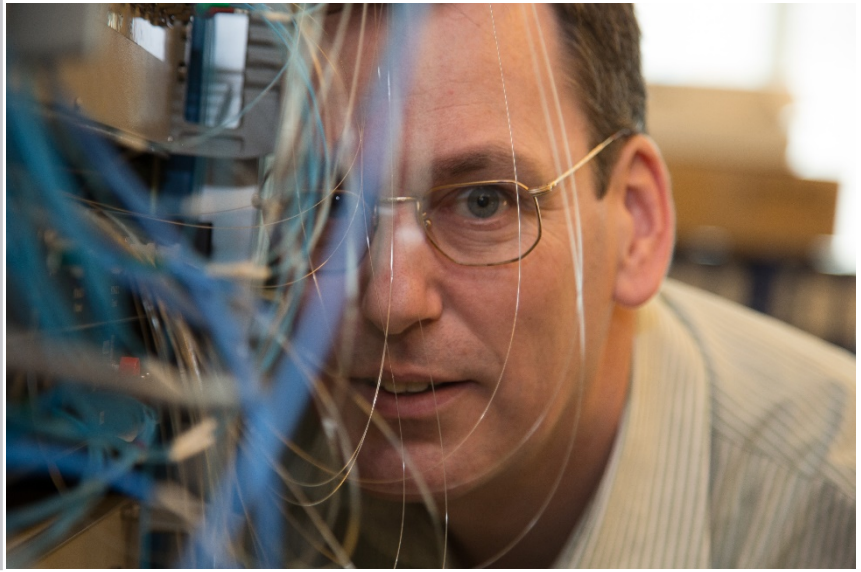
DCI

Capacity Crunch in Long-Distance/Metro

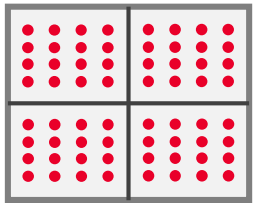




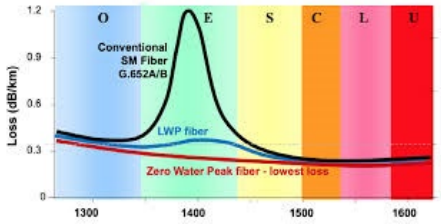
Source: Nokia



Improvement potential

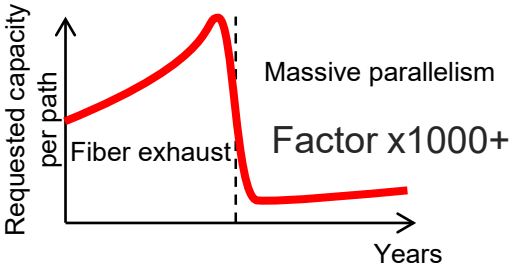


Factor x2

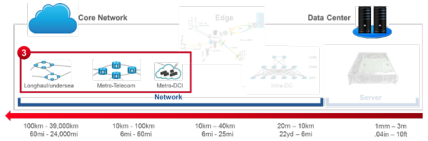


Factor x2 –x5

Factor x2



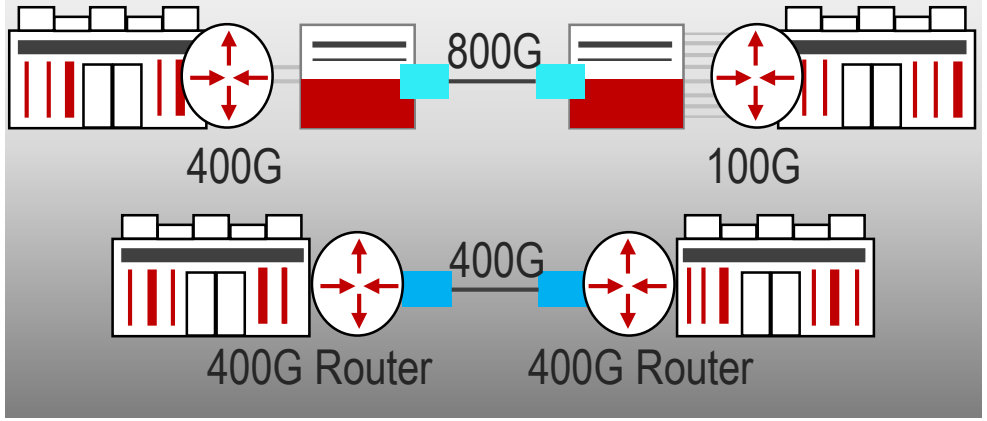
Different Challenges for Long-Haul and Metro/DCI



Sub-Sea

Terrestrial Long Distance

DCI



Coherent Optical Standards Activities

ITU

- 100G OTN over up to 450 km using DP-DQPSK

OIF

- Project **400ZR**
- 400G Ethernet over up to 80 km using DP-16QAM

IEEE

- Project 802.3ct
- 100G & 400G Ethernet over up to 80 km

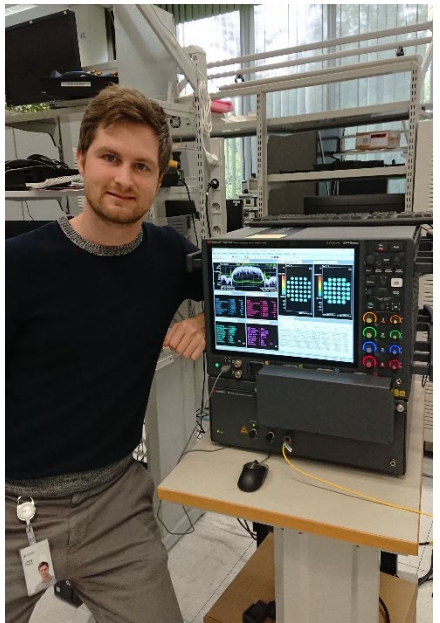
CableLabs

- 100G full duplex coherent for cable access networks

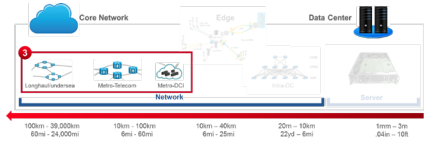
OpenROADM

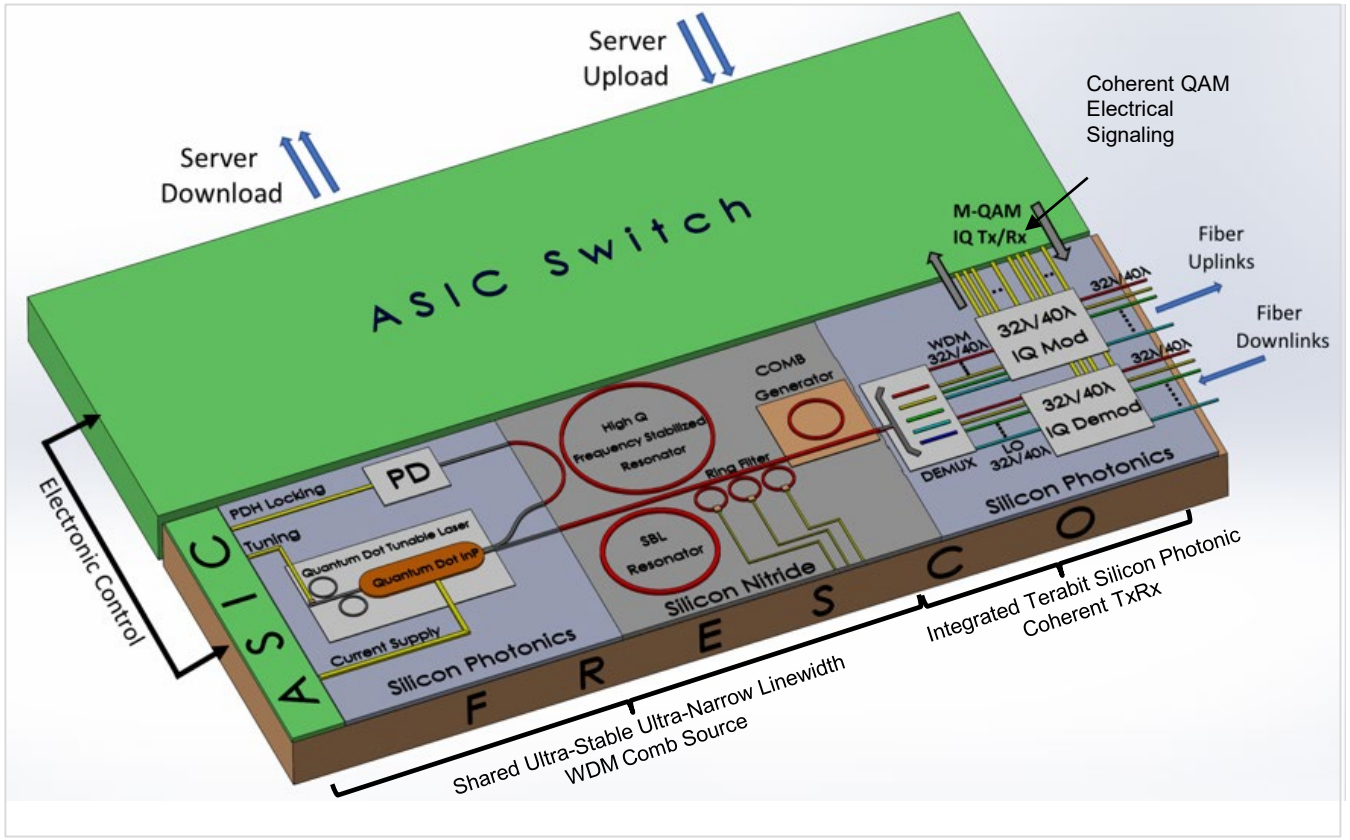
- 100G, 200G, 300G, 400G for metro applications

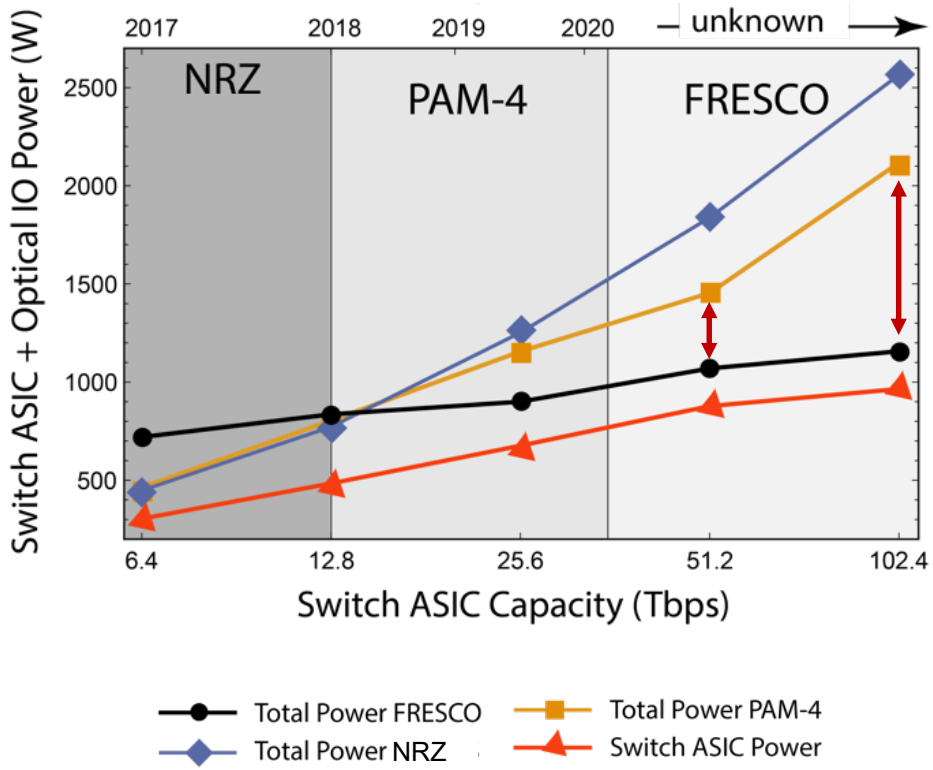
Speed-class	Coherent	Direct-detection
400G (2019+)	> 10 km	< 10 km
600G/800G (2023+)	> 2 km	< 2 km



Advance in Integrated Photonics - FRESCO

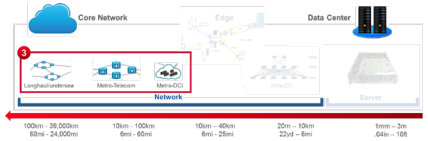






UCSB Yale Northern Arizona University Photonics NIST Microsoft Barefoot Networks Stanford University Keysight Technologies

Integrated Photonics Requires On-Wafer Test



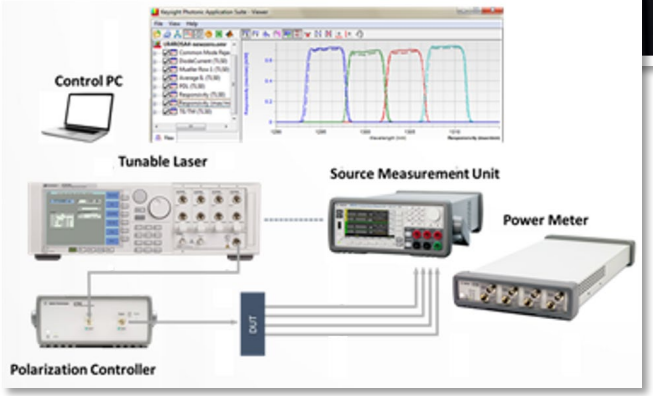
Electrical and Optical RF Measurement

Time-Domain Measurement

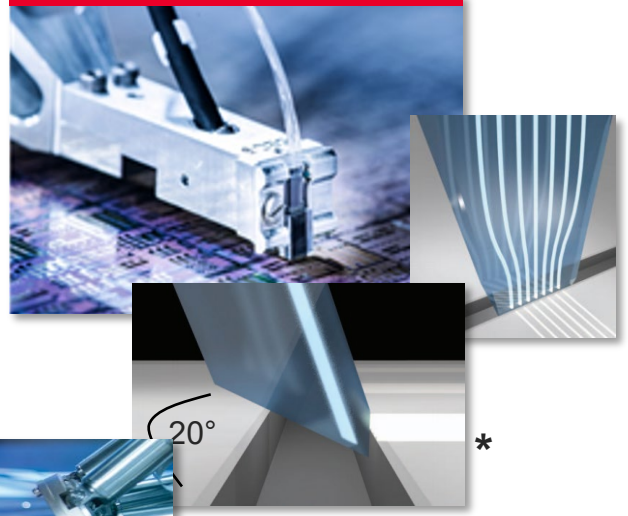
Wafer Probing and Alignment

Keysight partnering with FormFactor / Cascade Micro

Optical and DC Electro-Optical Measurement



Fiber Probing



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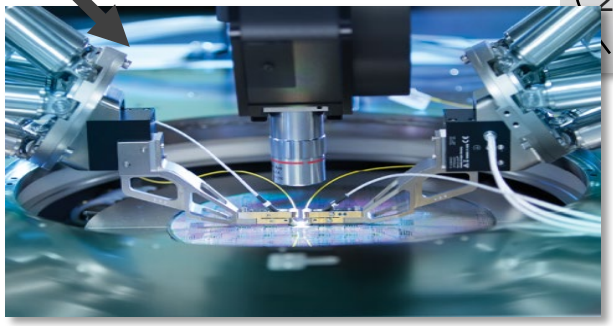
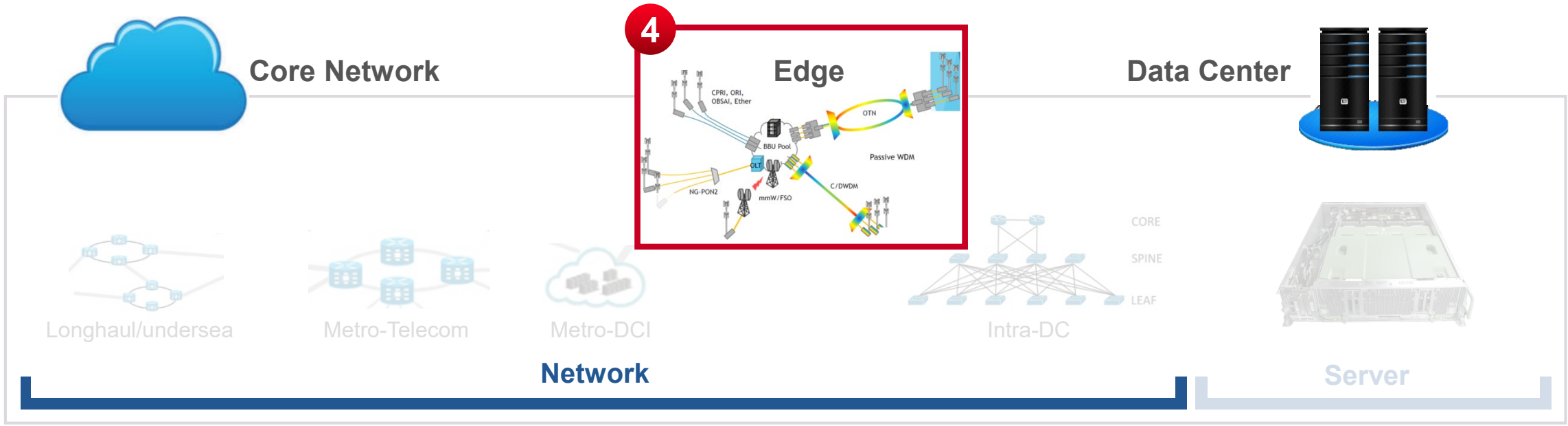


Optical
RF
DC Probing

* Columbia University: Wafer-scale high-density edge coupling for high throughput testing of silicon photonics

Wireline Internet Infrastructure

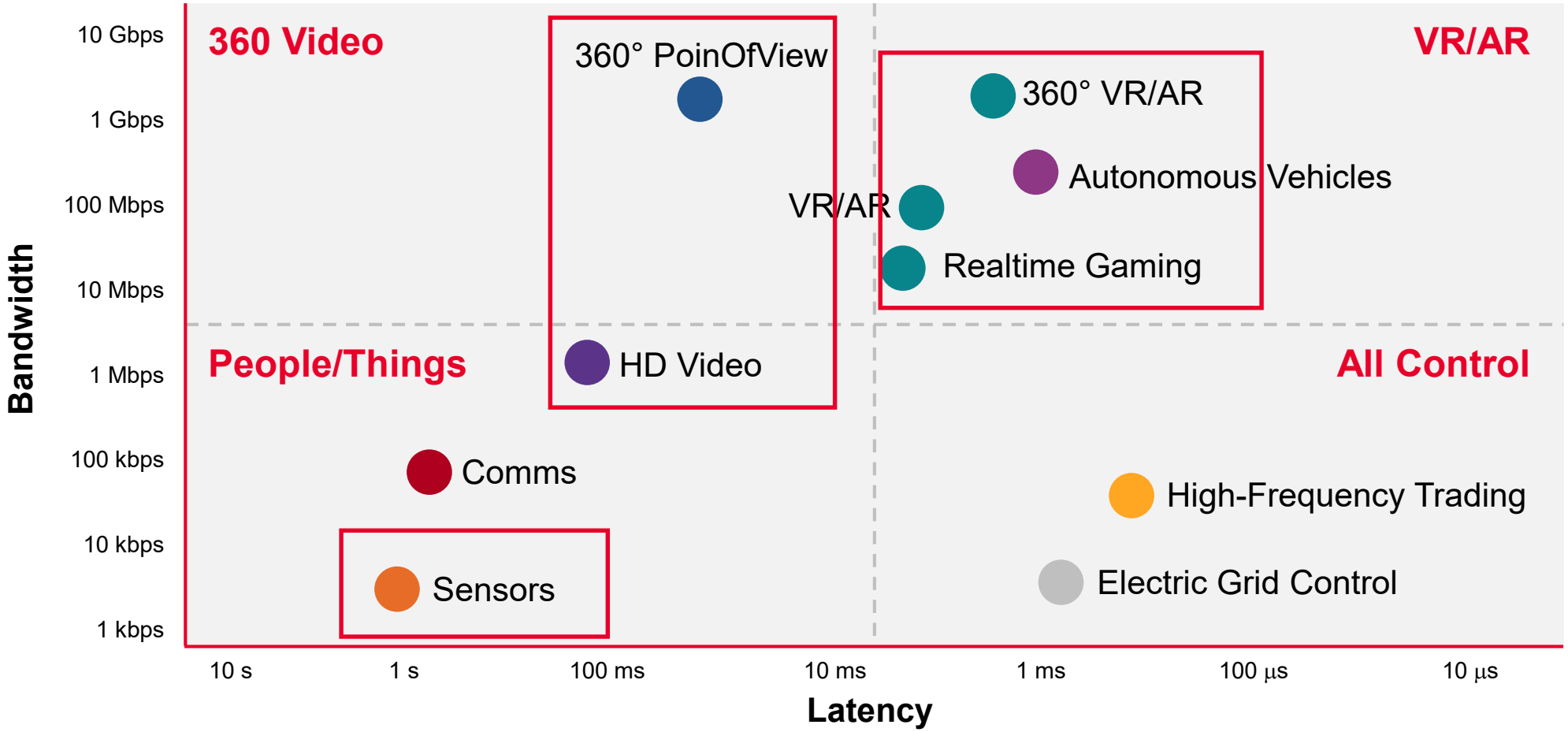


100km - 39,000km 60mi - 24,000mi	10km - 100km 6mi - 60mi	10km – 40km 6mi - 25mi	20m – 10km 22yd – 6mi	1mm – 3m .04in – 10ft

Fiberization of Planet Earth

Applications and Latency Requirements

HIGH-BANDWIDTH AND LOW LATENCY



Data Center and Optical Network Innovation

ENABLING THE 5G ECOSYSTEM

1. Test can be seen as a cost.

2. Test can be seen as competitive advantage.

3. Keysight can accelerate your innovation throughout the whole communication infrastructure.

Test enables and accelerates innovation. Keysight is here to make test your competitive advantage.


KEYSIGHT
WORLD 2019