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

加速5G實現之資料中心及光通訊網路創新

Joe Lin	11-Mar-2020
Sr. Project Manager / Keysight Technologies	

KEYSIGHT TECHNOLOGIES

Our communication expectations are growing

ACCESS ANYTIME, ANYWHERE

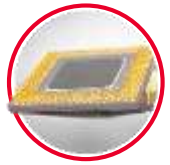
Today's 2G/3G/4G NW

- ✓ Mobile data is real
- ✓ Works most of the time
- x Works *well* some of the time
- x WiFi works but not integrated
- x Don't try this in a crowd!
- x Consumes 2% of WW power

Tomorrow's 5G Network

- ✓ **Great Service in a Crowd**
- ✓ Amazingly Fast, Reliable, Real-time
- ✓ All Things Communicating
- ✓ Centralized, Virtual, and Seamless Networks

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

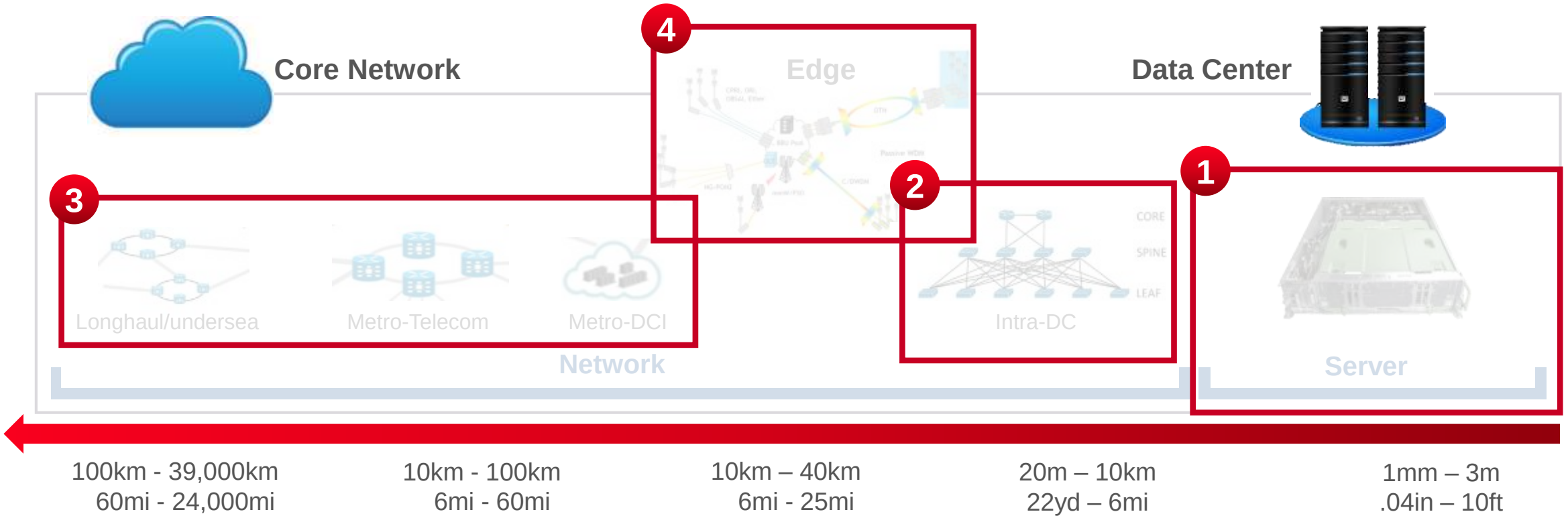
Customer Experience Management

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

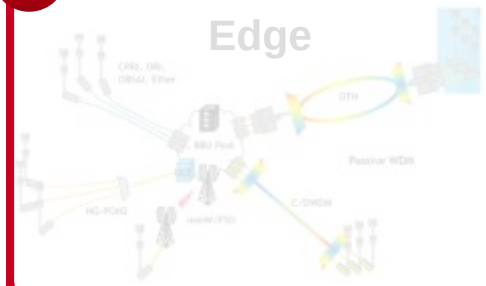
Spectral efficiency can be improved.
Challenges: Forward Error Correction. Direct detection limited by signal integrity.
Leverage from telecom long haul transport.

3

Telecom Transport/DCI

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

4



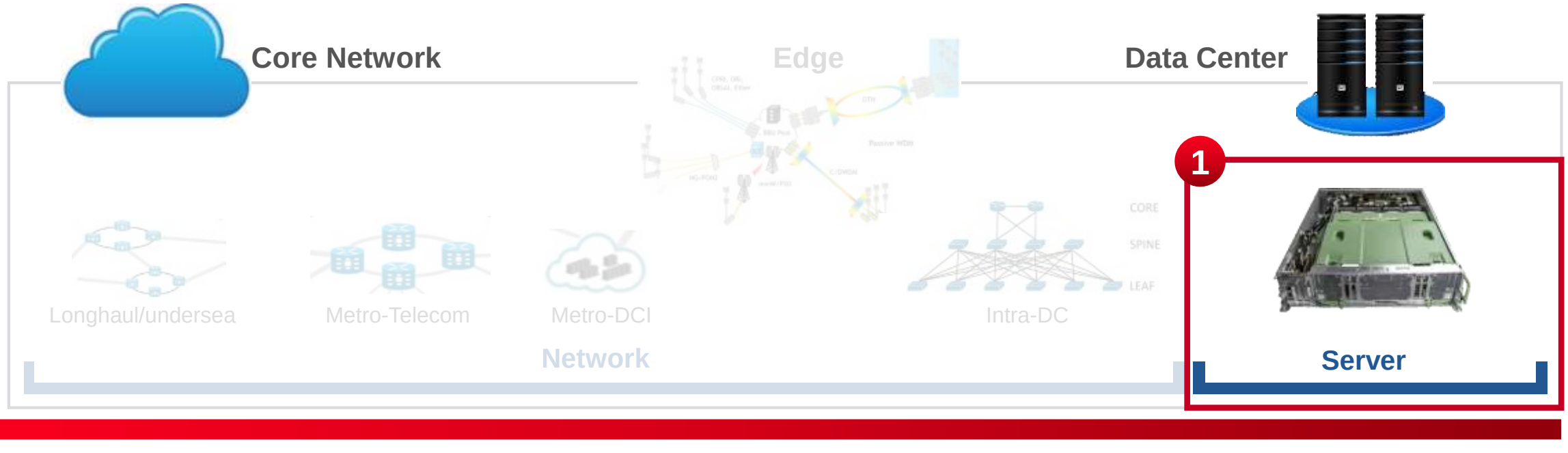
Network slicing demands multiple network architectures.
Challenges: High bandwidth at tough environmental conditions. Latency requirements.
Leverage from data center, telecom and wireless.

Conclusions

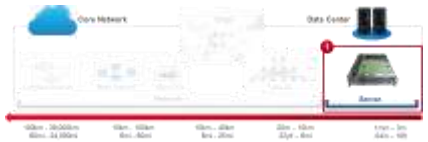
1. A pool of technology building blocks exist that can solve the challenges in all infrastructure segments.
Industry needs to leverage available technology. No fundamental roadblock exists.

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

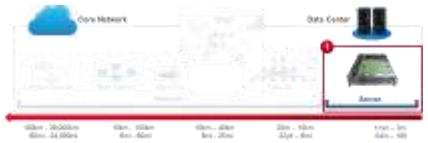
Video Transcoding

Cyber Security

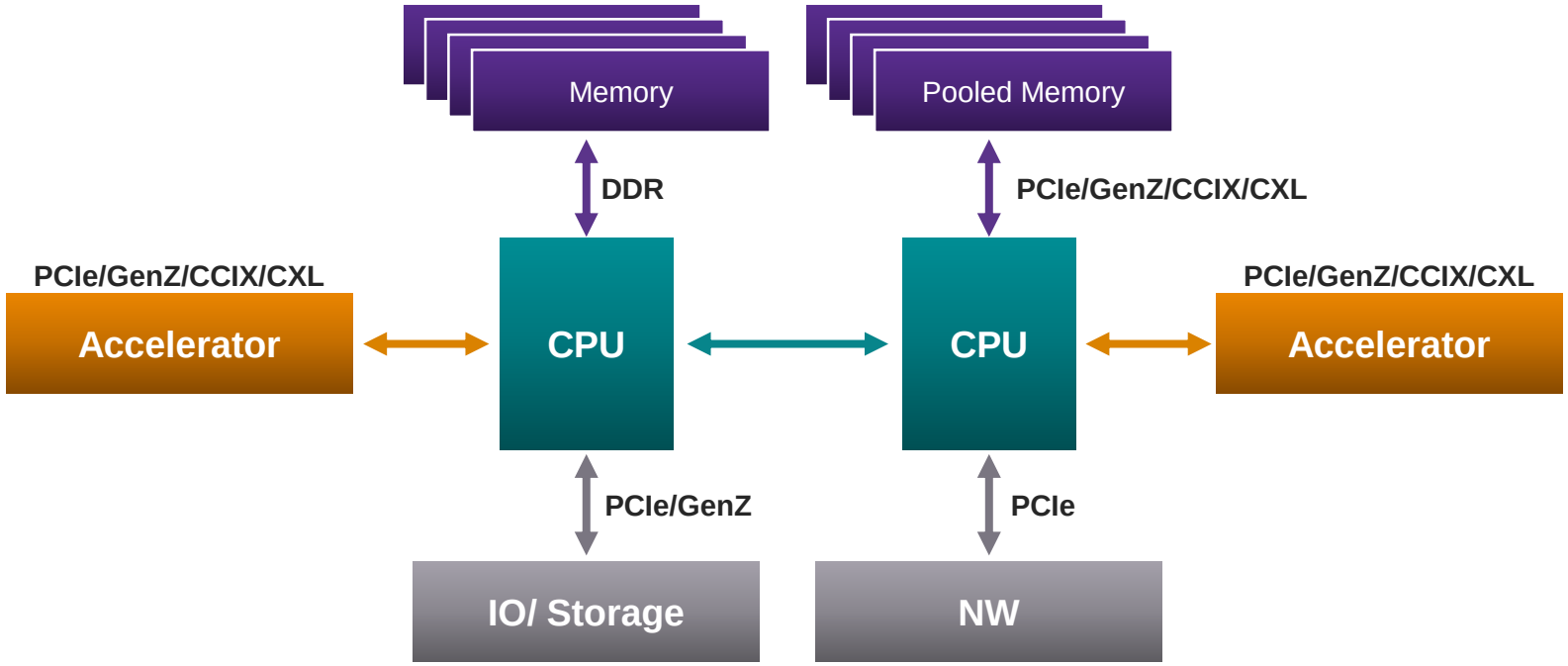
Financial Acceleration

Genomics

Server Architecture Evolution



DISAGGREGATION AND ACCELERATION



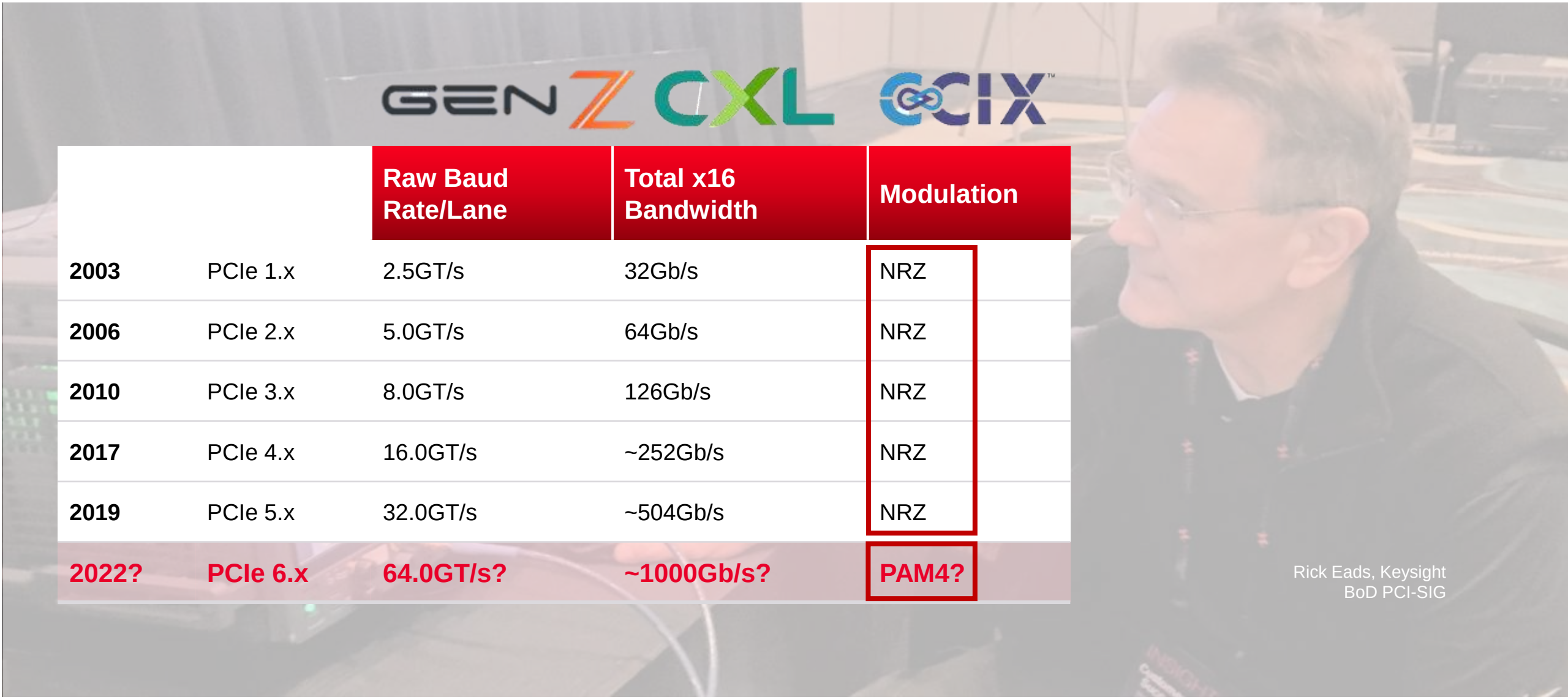
90%
of compute happens off CPU

Improve memory utilization by
30%

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

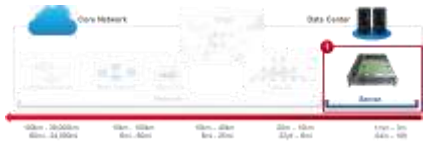
Dis-aggregation Drives BW

		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?**



Rick Eads, Keysight
BoD PCI-SIG

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-Series, Z-Series Real-Time Oscilloscopes

D9050PCIC PCI Express 5.0 TX Electrical compliance software

86100CU-400 PLL and Jitter Spectrum Measurement SW

DSA UXR-Series & Z-Series Real-Time Oscilloscopes

Physical Layer Receiver Test

M8046A J-BERT High Performance BERT w/ integrated CDR + M80454A Interference Source

M8049A-1 Substitute PCIe 5 BASE Channel board

N5991PB5A
PCIe 5.0 32GT/s RX Test Software

Automated RX Test software
- Accurate, Efficient
- Comprehensive RX Testing

PCI SIG KEYSIGHT TECHNOLOGIES

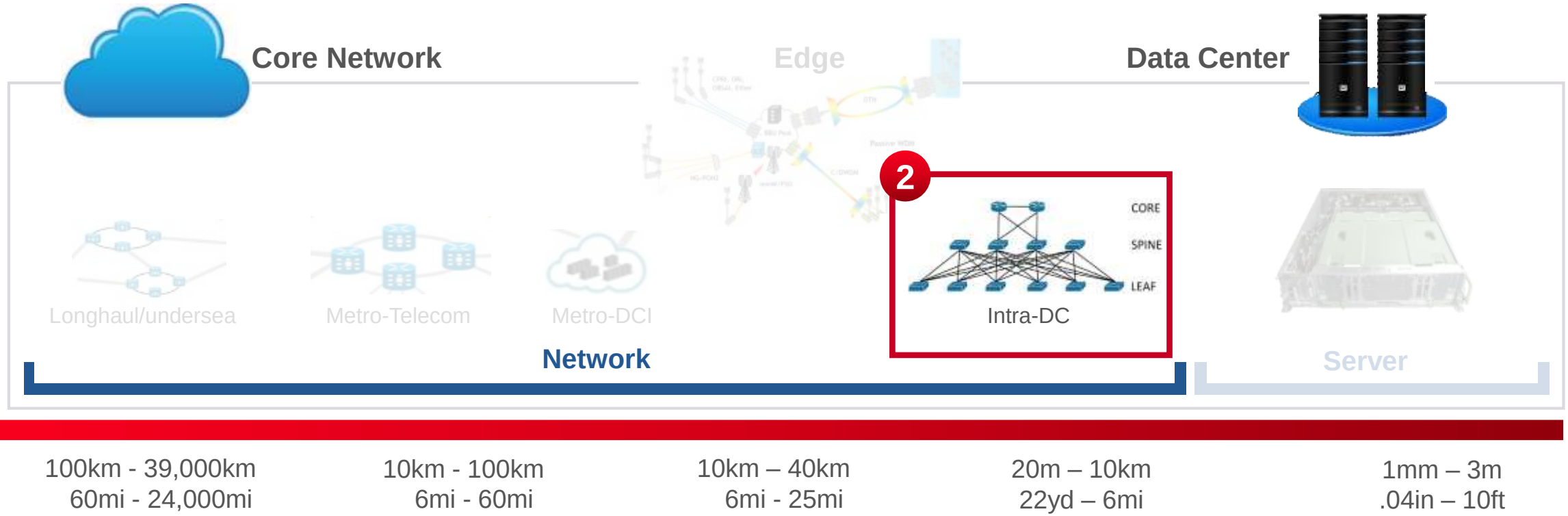
Standards document

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

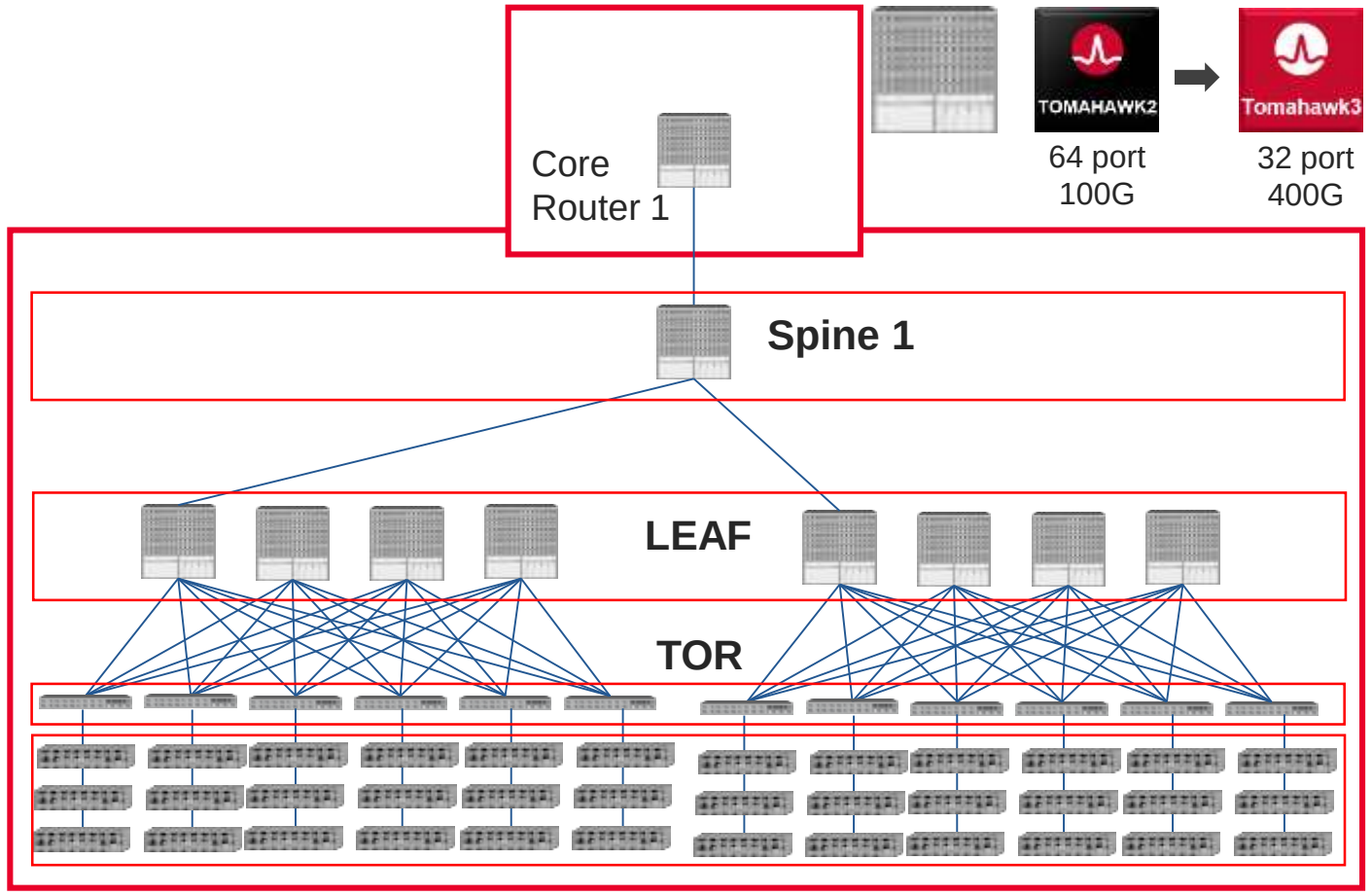
< 10-120km
100G-DCO
ColorZ

< 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)

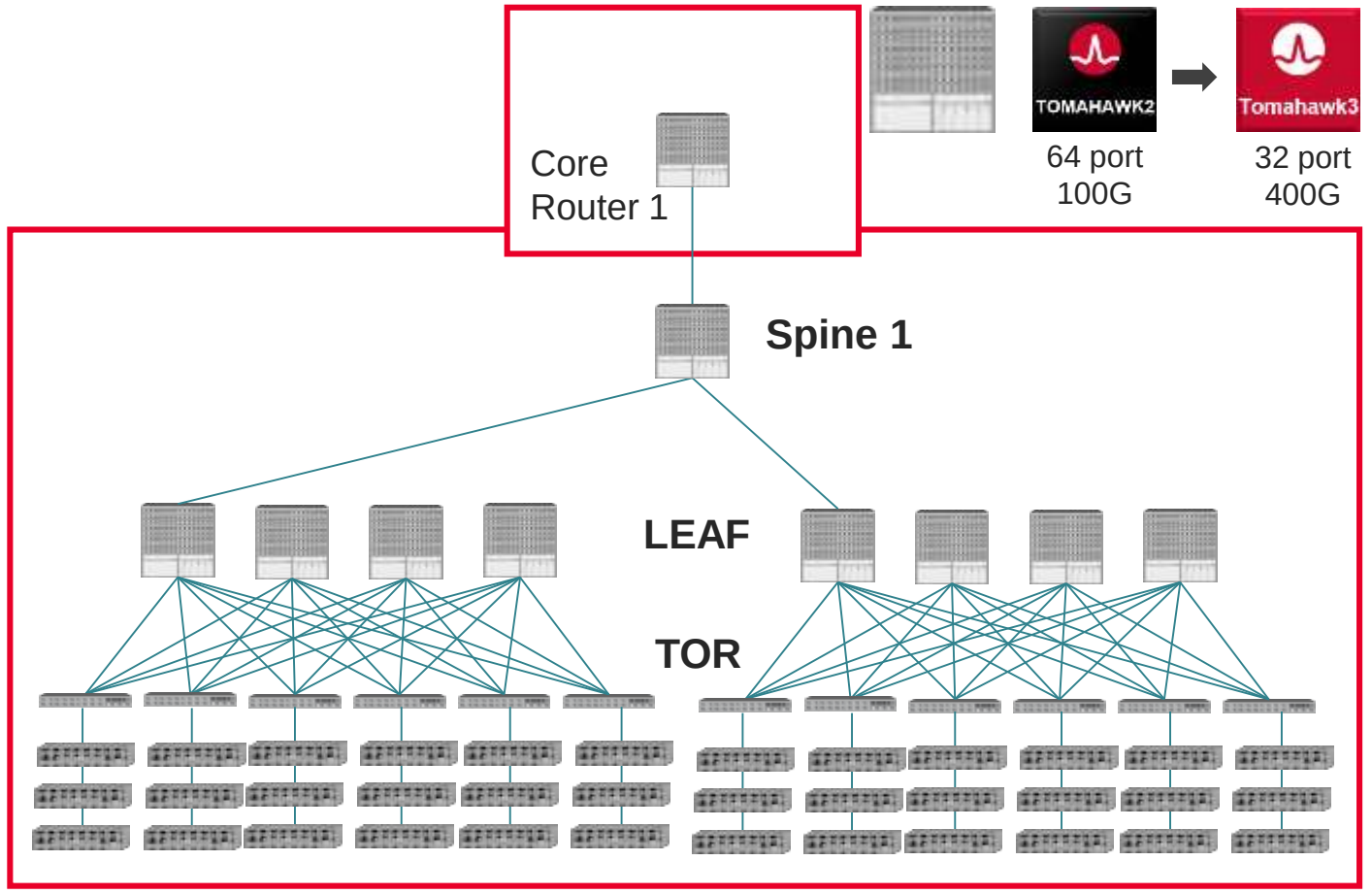
400G-FR4
400G-DR4

< 20m

400G-AOC
400G-SR8

< 3m

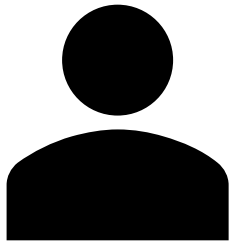
400G-CR8
50G-CR



PCIe5/DDR5

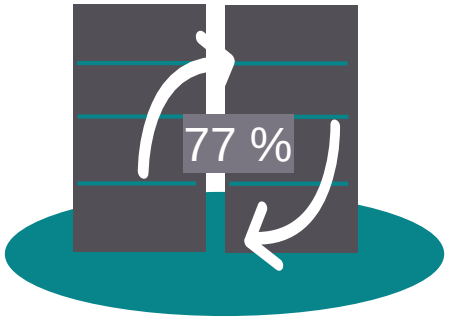
Source: Brad Booth, Tom Issenhuth, Microsoft, IEEE 802bs

Networks & Data Center Bandwidth Needs



14 % Data Center to User
e.g. Web,
email,
Webex,
Video

9 % Data center to Data Center
e.g. Replication,
CDN,
intercloud links



77 % Within Data Center
e.g. Storage,
production and development data,
authentication

Source: Cisco Global Cloud Index, 2015-2020

Silicon Switch Evolution

Jerry Pepper, Ixia
IEEE

100Gbps/port
QSFP28

400Gbps/port
QSFP56DD

800Gbps/port

Optical engine

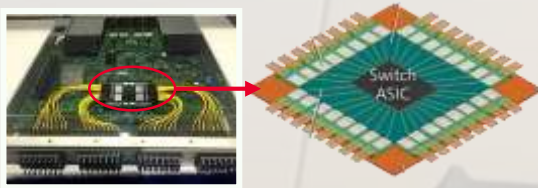


Image: Courtesy of Luxtera

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

SERDES Speed
25Gb/s

SERDES Speed
25Gb/s

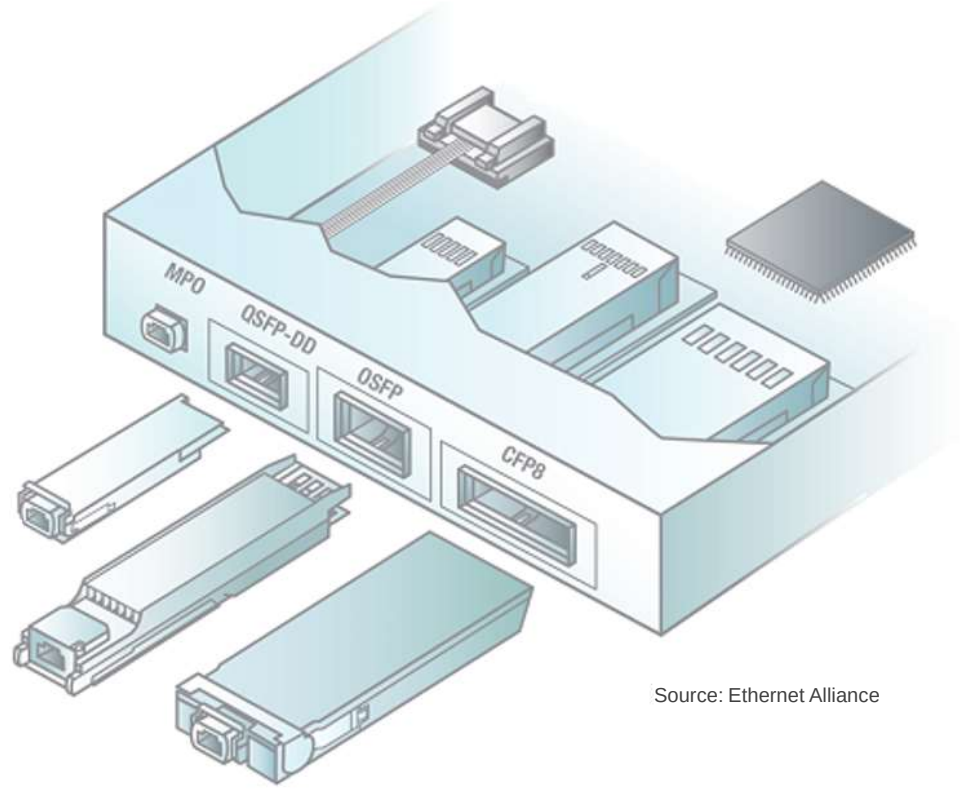
SERDES Speed
50Gb/s

SERDES Speed
100Gb/s

Power consumption wall for pluggable optics

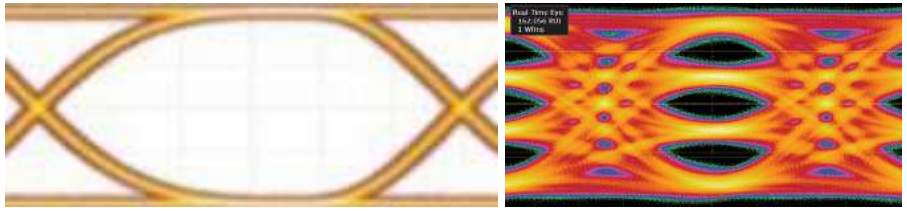
https://www.laserfocusworld.com/articles/print/volume-54/issue-10/features/photonics-for-datacenters-integrated-optics-permeate-datacenter-networks.html

Data Center Networking Choices

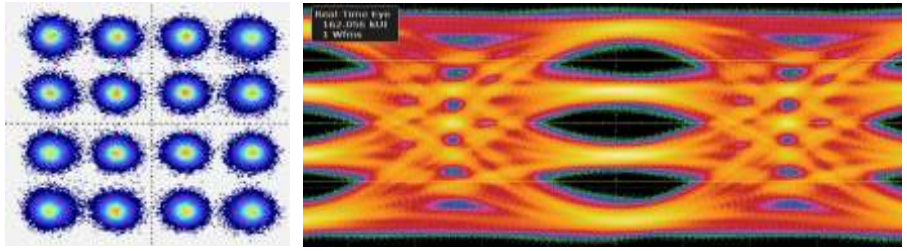


Source: Ethernet Alliance

100G or 400G



Coherent or Direct Detection

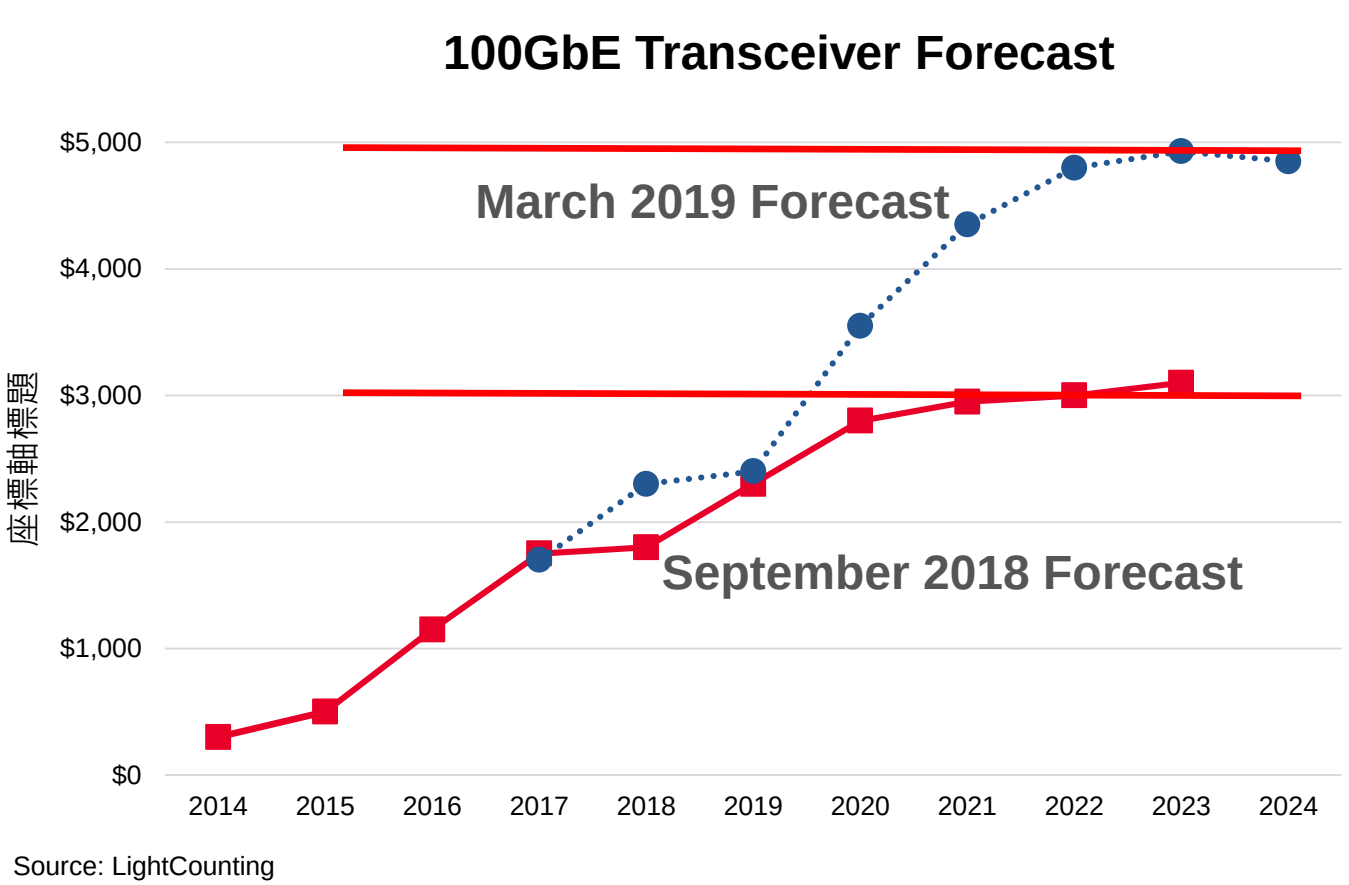


Pluggable or Co-package

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



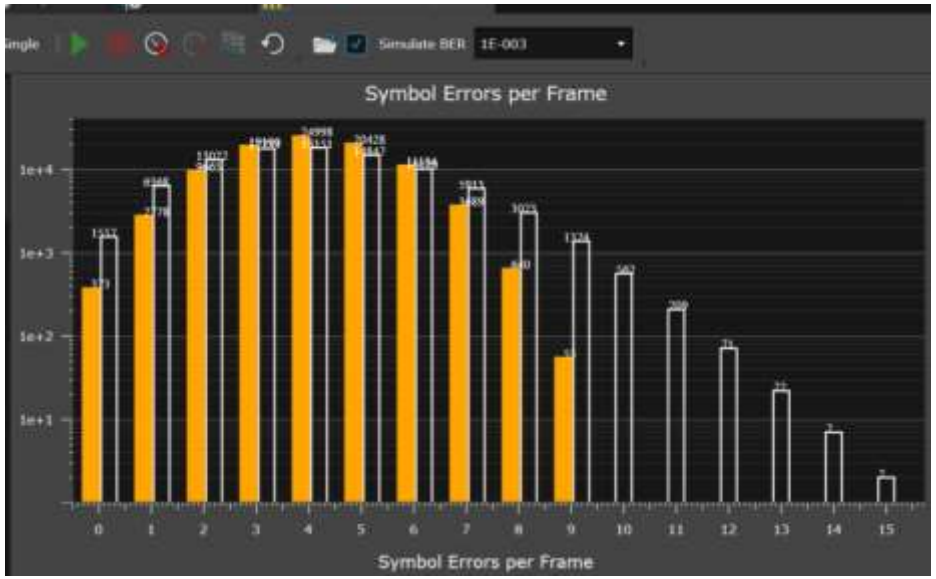
Source: LightCounting

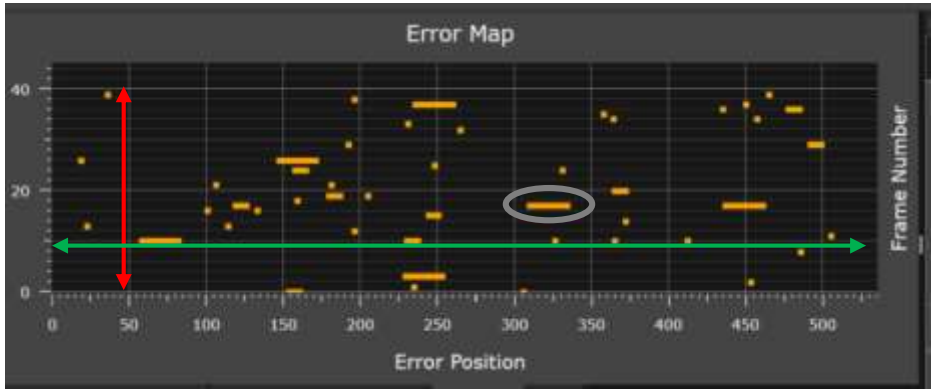
facebook	100G CWDM-4 demand increase in H2 2019
Google	2x200GbE now 2x400GbE in 2022
amazon	4x100GbE DR4 (400G-DR4)
阿里巴巴 Alibaba.com	100G since 2017 400G planned for 2019
Tencent 腾讯	100G started (2017-2021) 400G planned for end 2019
Baidu 百度	100G in 2017 400G planned for 2021

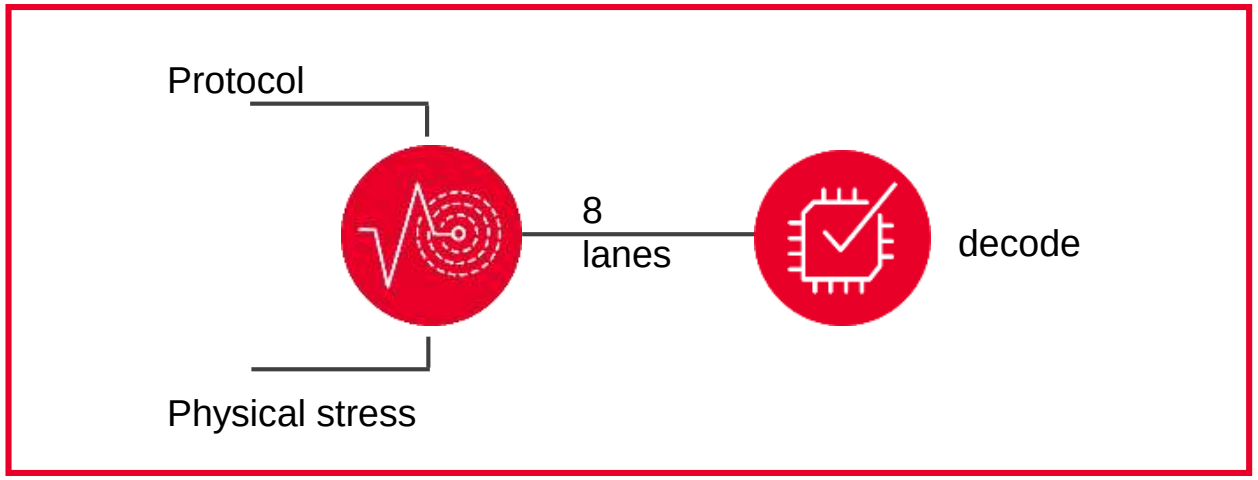
> 13 companies showed 400G readiness at OFC 2019

Characterizing Error Mechanisms

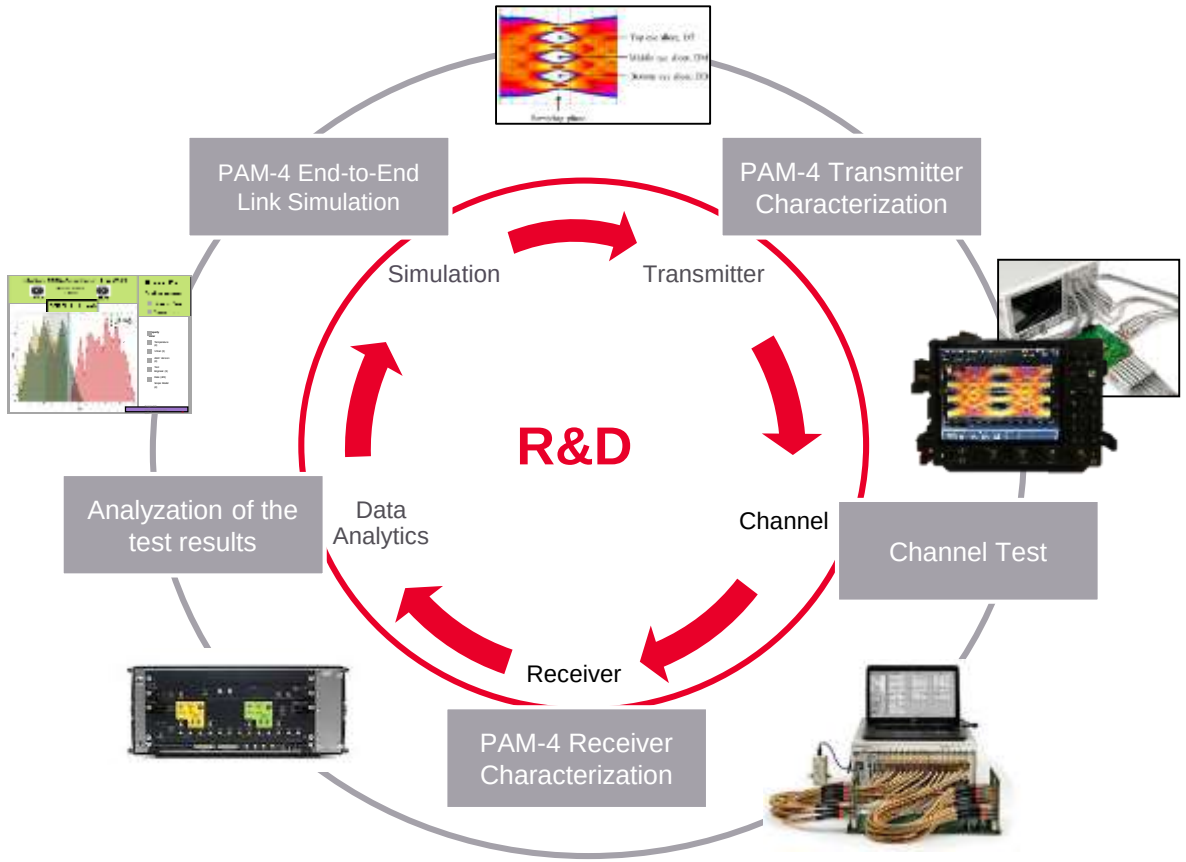
- Layer 2, 64B – 14,000B frames
- (FEC) Interoperability
- FEC symbol errors

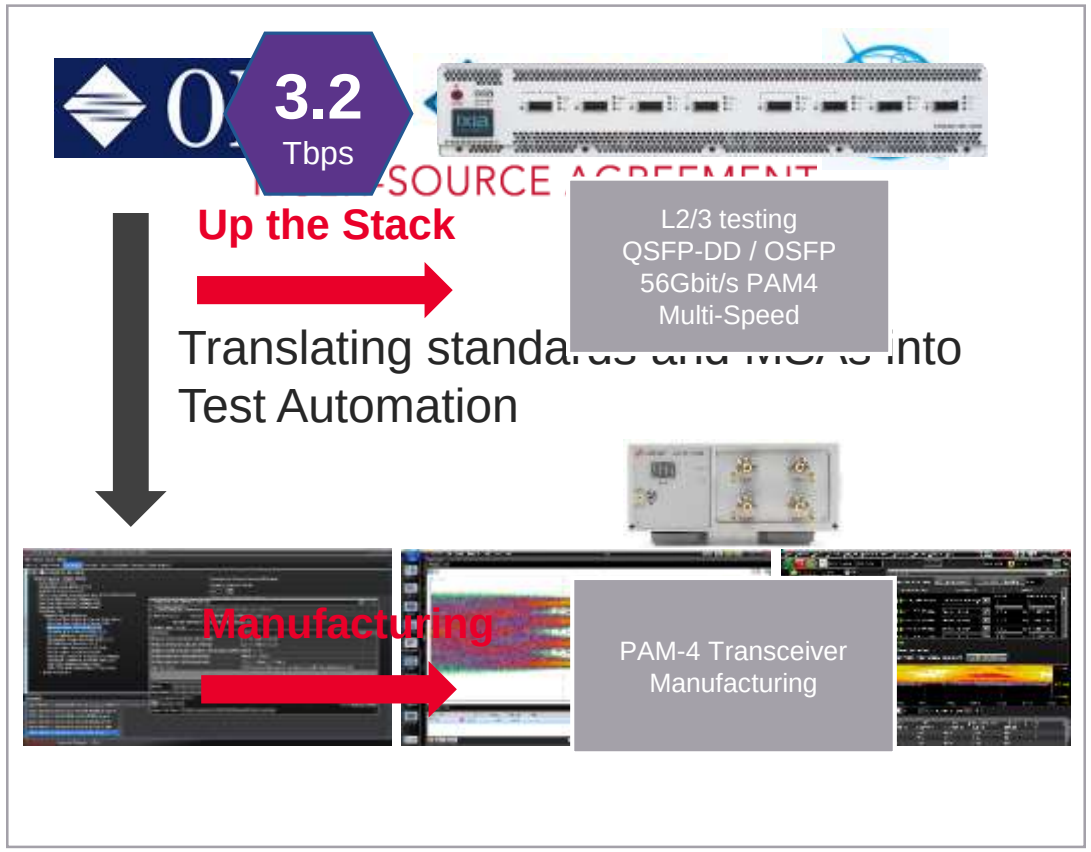






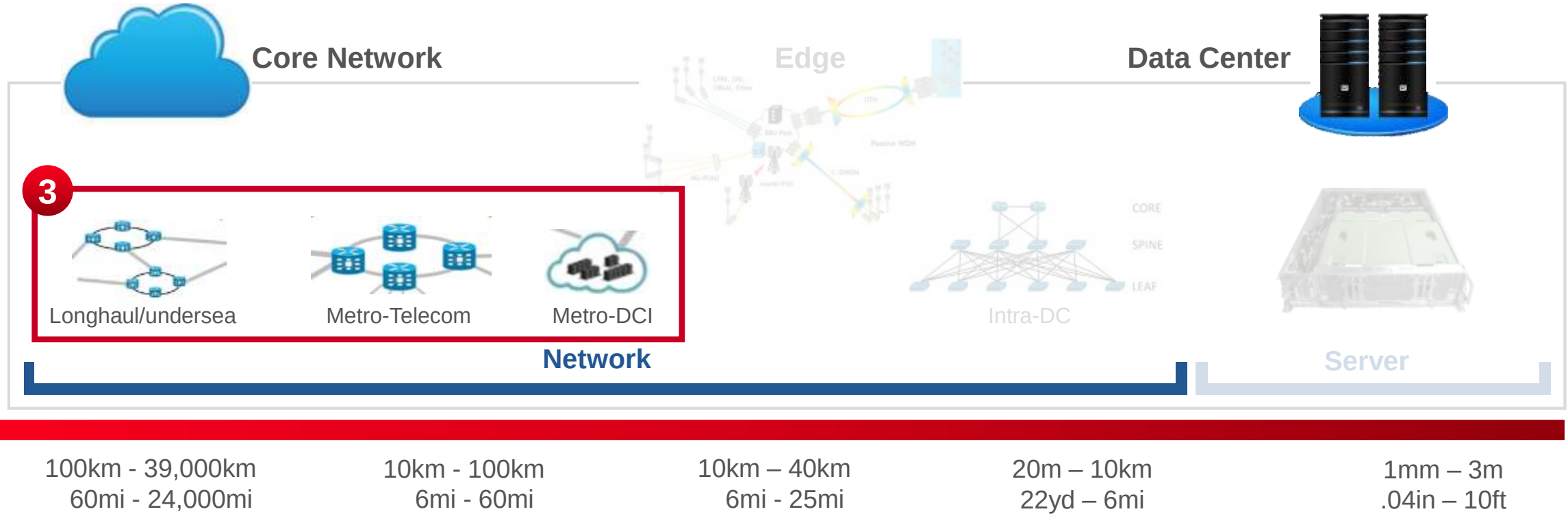
End-to-End Automated Test Solutions for Direct Detection



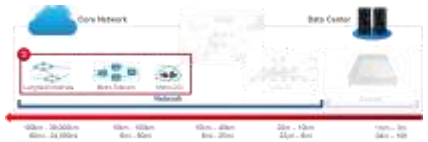


Keysight partners with key players in the optical component and transceiver industry and OIF, IEEE, OCP, ODCC

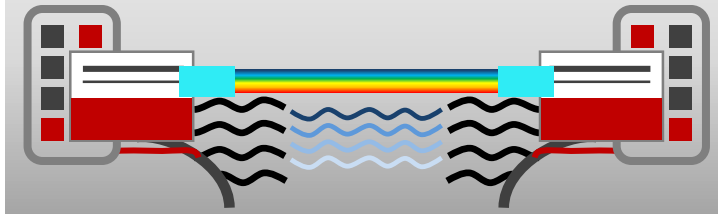
Wireline Internet Infrastructure



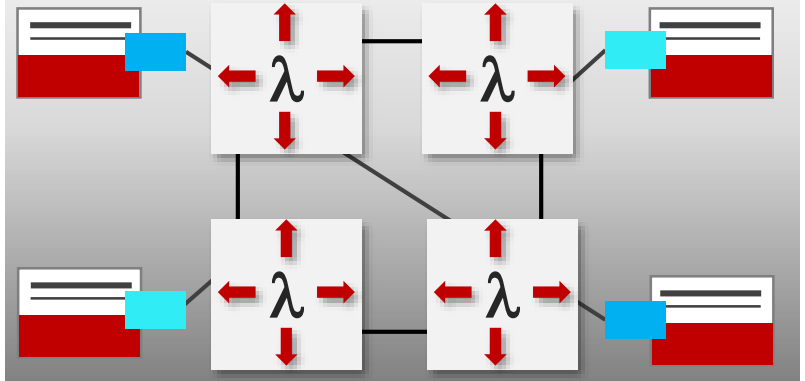
Different Challenges for Long-Haul and Metro/DCI



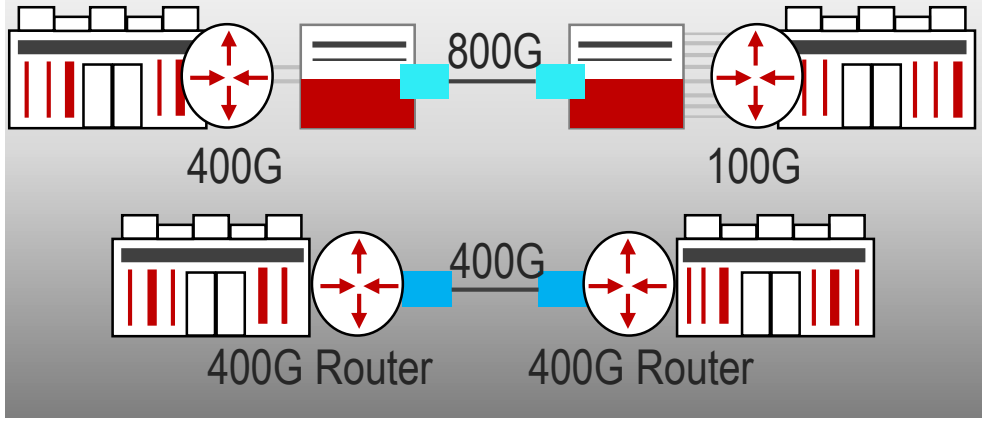
Sub-Sea



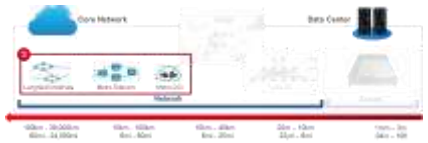
Terrestrial Long Distance



DCI



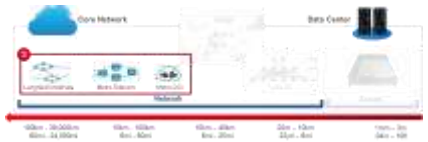
Coherent DSP Silicon for 400G, 600G and 800G



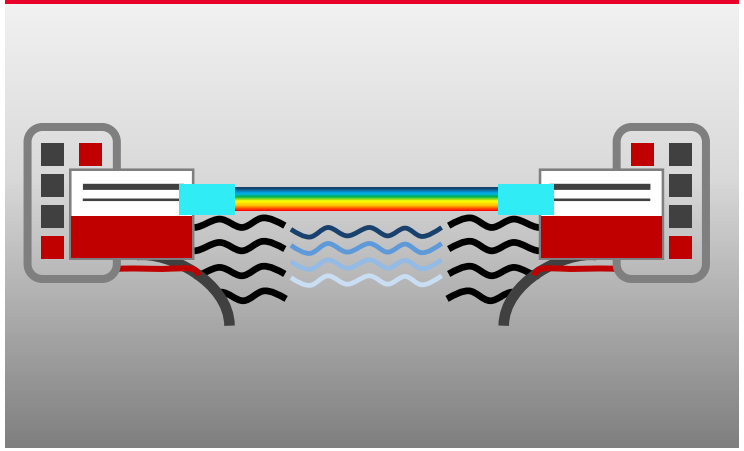
2018/2019 DSP INTRODUCTIONS

	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



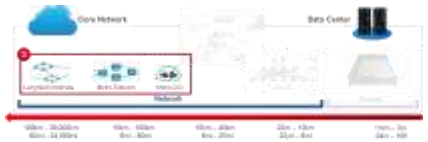
Sub-Sea

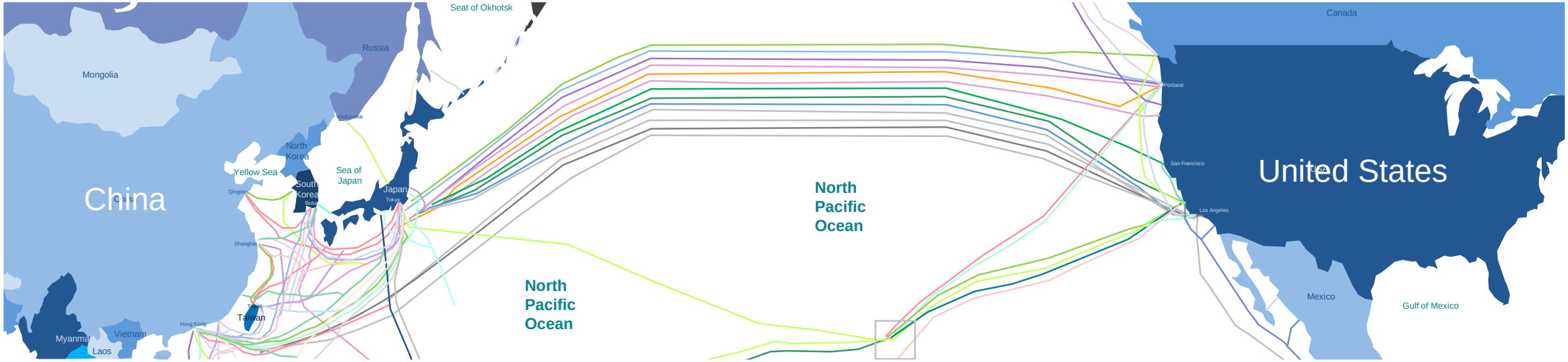


Terrestrial Long Distance

DCI

Subsea Cable Deployment





100
new cables between 2016 and 2020

Content providers used
54%
of subsea bandwidth in 2018

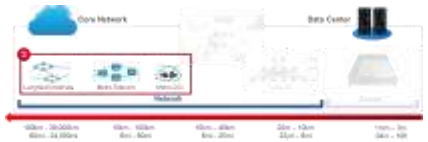
Content providers will used
80%
of subsea bandwidth by 2027

Content Provider Investments

Consortium Member | Major Capacity Customer | Sole Owner

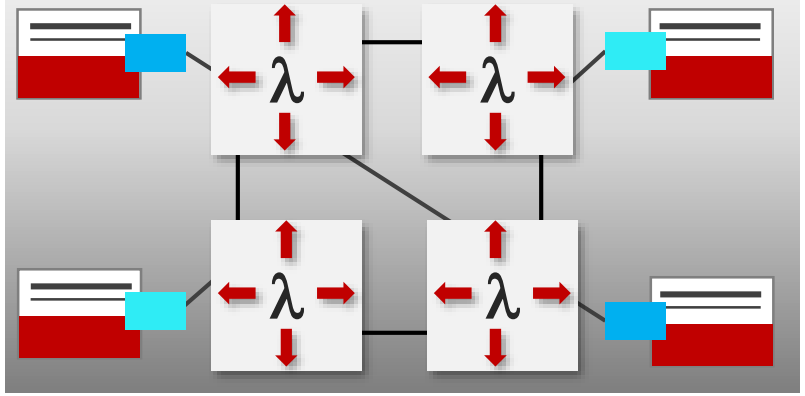
RFS 2010	2013	2015	2016	2017	2018	2019	2020
						Curle Google	
						Havfrue Facebook Google	
					Junior Google	KH-G Google	Dunant Google
					Hawaiki Amazon	INDIGO-Central Google	HKA Facebook
			AEC-1 Facebook Microsoft		MAREA Facebook Microsoft	INDIGO-West Google	JUPITER Amazon Facebook
			APG Facebook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

Different Challenges for Long-Haul and Metro/DCI



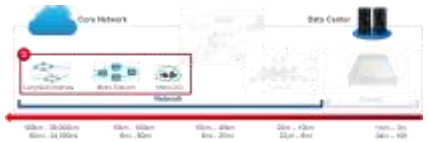
Sub-Sea

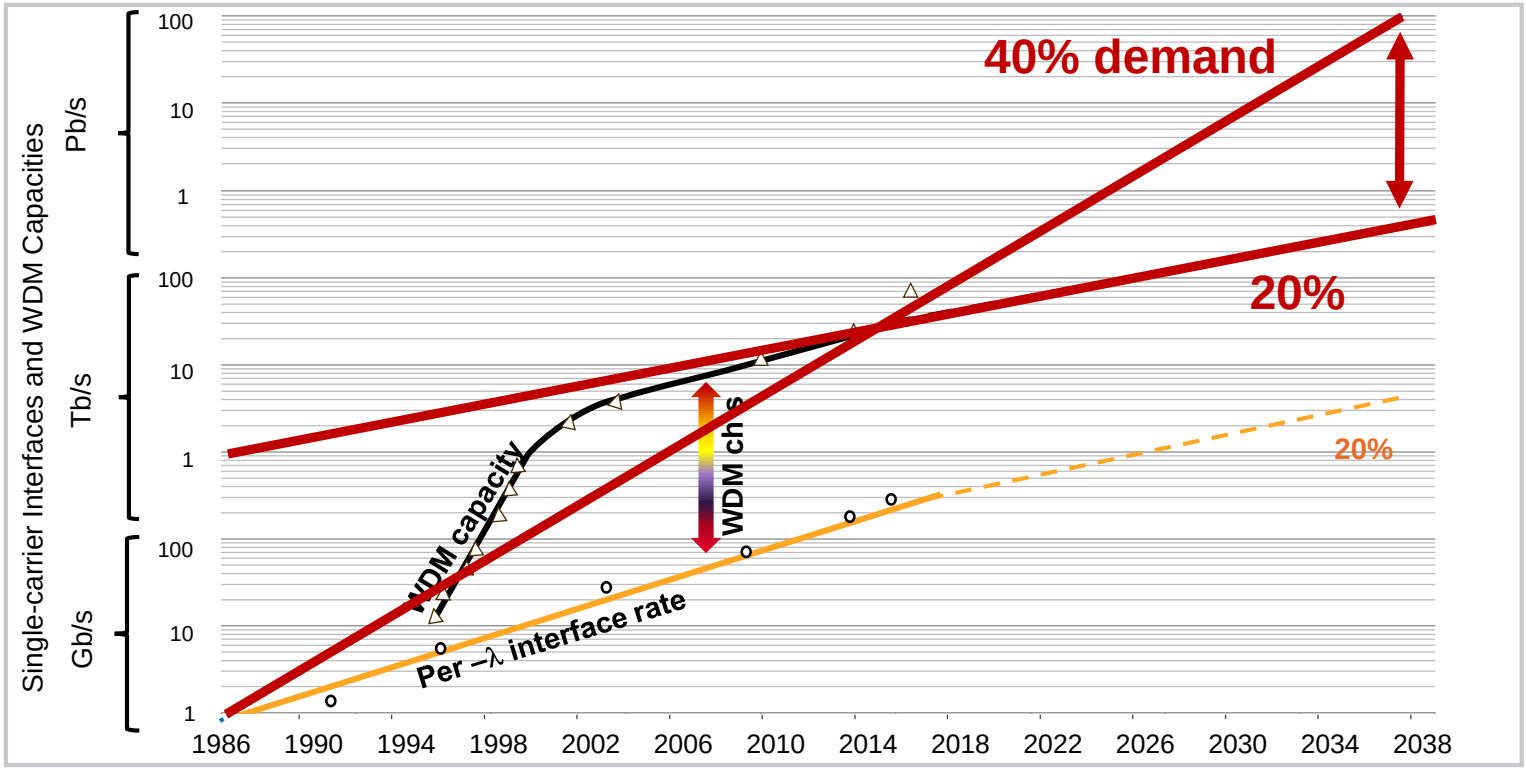
Terrestrial Long Distance



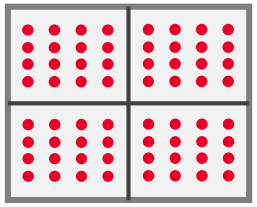
DCI

Capacity Crunch in Long-Distance/Metro

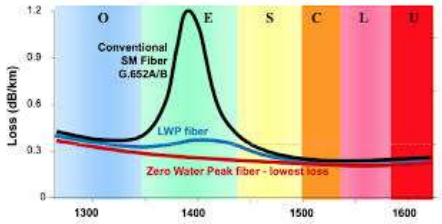




Improvement potential

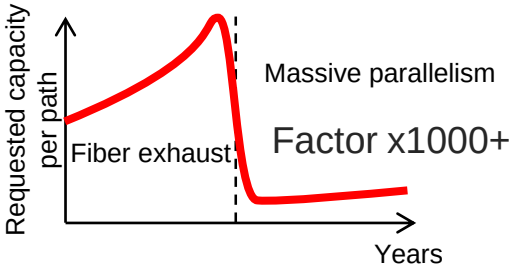


Factor x2



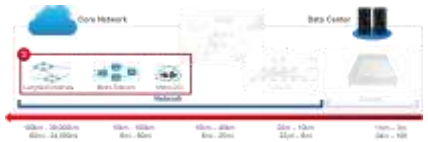
Factor x2 –x5

Factor x2



Source: Nokia

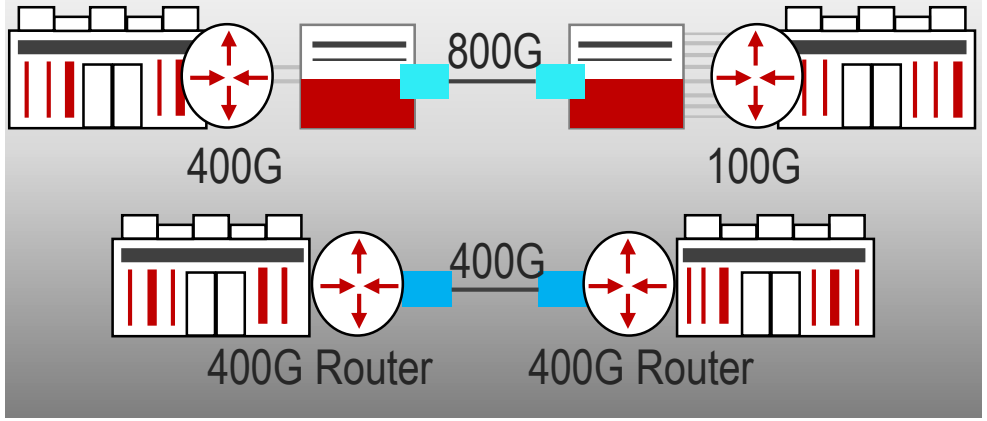
Different Challenges for Long-Haul and Metro/DCI



Sub-Sea

Terrestrial Long Distance

DCI



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

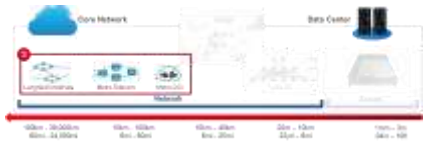
OpenROADM

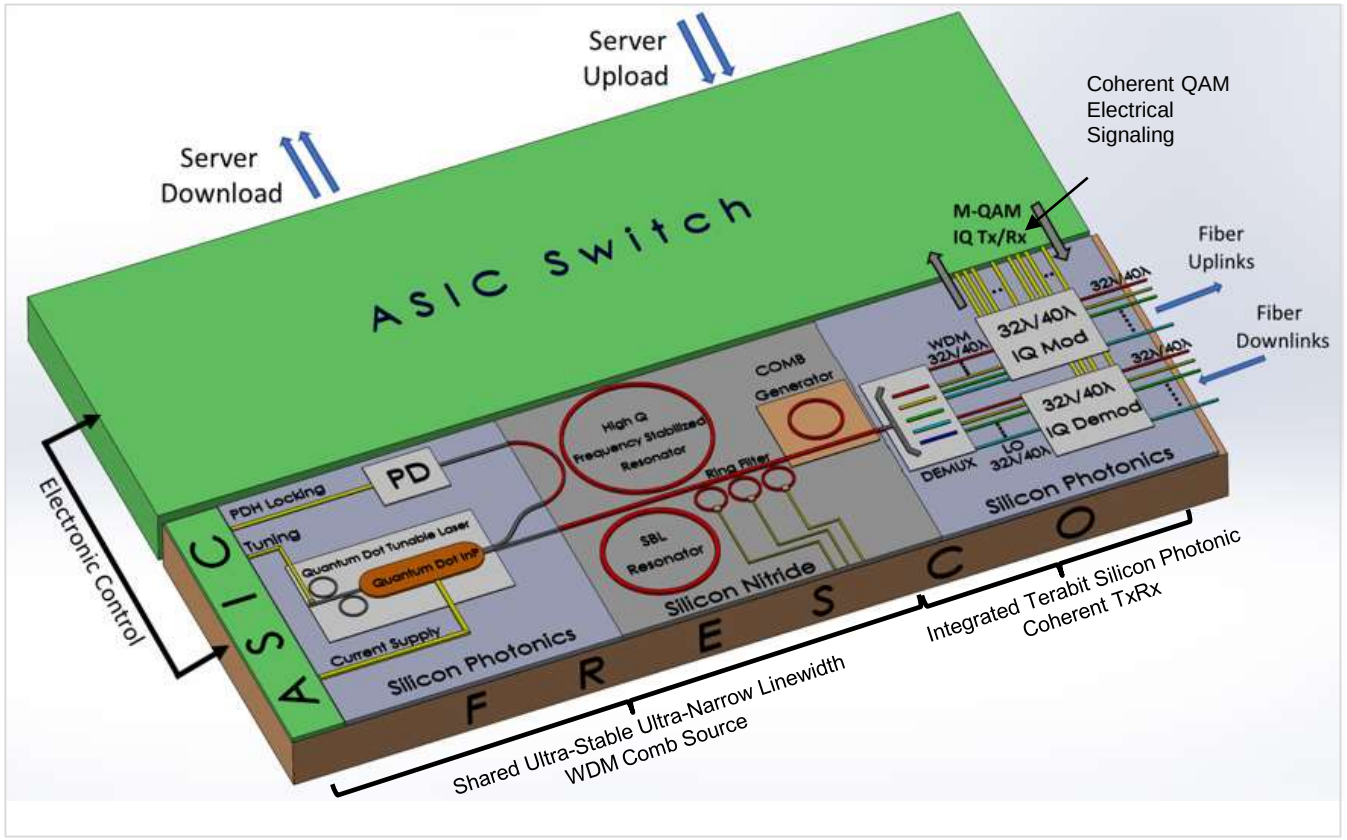
- 100G, 200G, 300G, 400G for metro applications

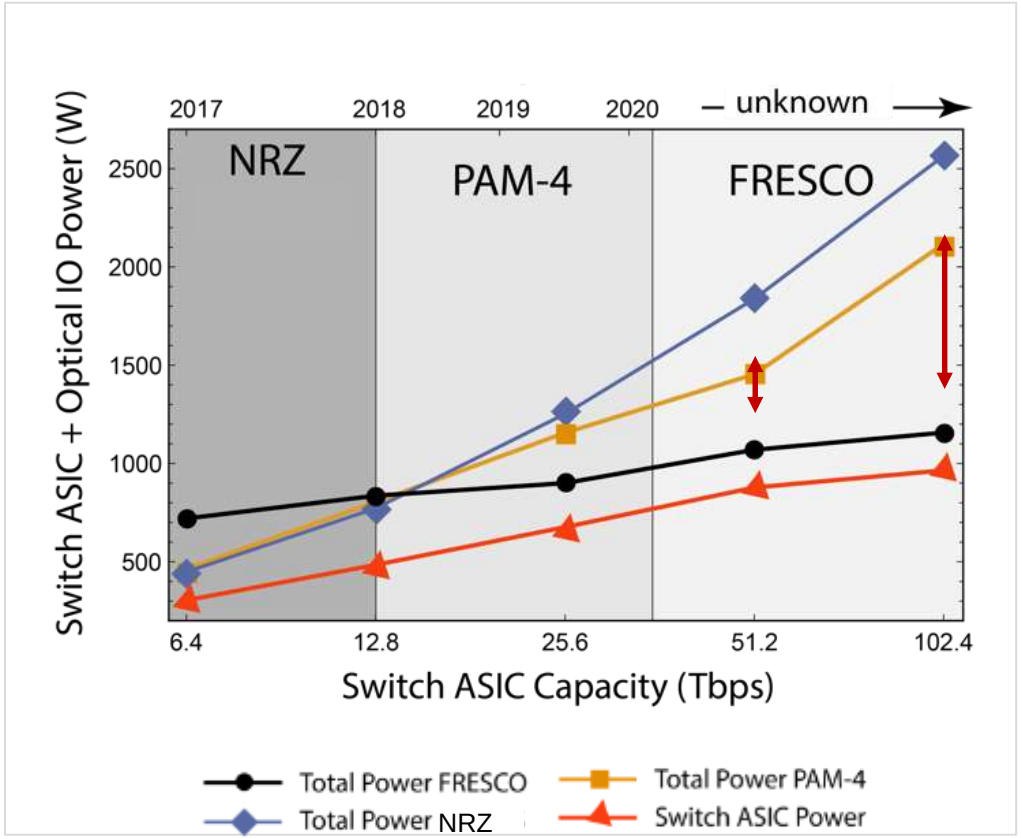
Speed-class	Coherent	Direct-detection
400G (2019+)	> 10 km	< 10 km
800G (2023+)	> 2 km	< 2 km

Joerg Pfeifle, Keysight
Coherent standards

Advance in Integrated Photonics - FRESCO

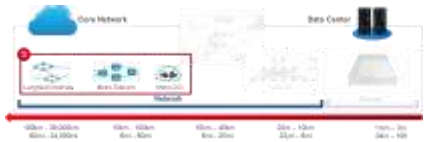






UCSB Yale Northern Arizona University Photonics NIST Microsoft Barefoot Networks Stanford University Keysight Technologies

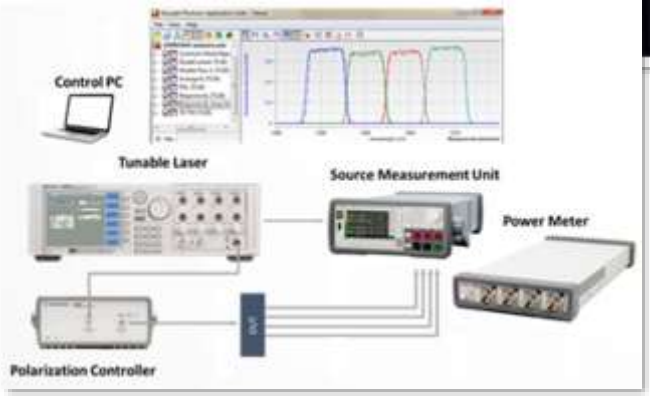
Integrated Photonics Requires On-Wafer Test



Electrical and Optical RF Measurement

Time-Domain Measurement

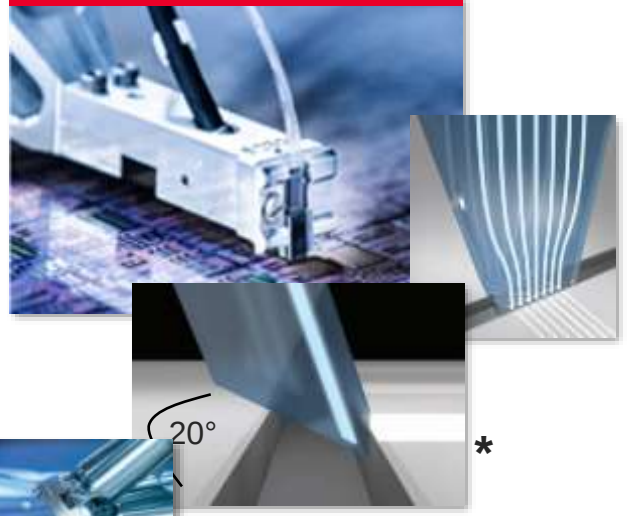
Optical and DC Electro-Optical Measurement



Wafer Probing and Alignment

Keysight partnering with FormFactor / Cascade Micro

Fiber Probing



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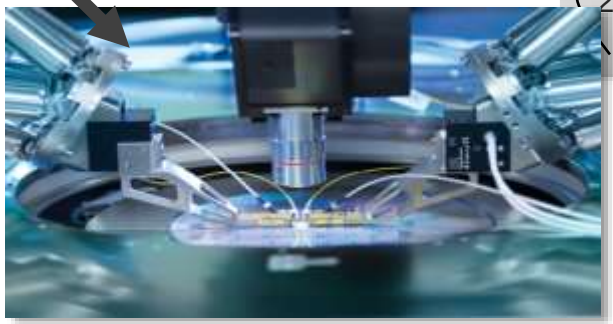


Optical RF DC Probing

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

Silicon Photonics Test Automation

SPEED UP AND SIMPLIFY YOUR TEST

Proprietary Application

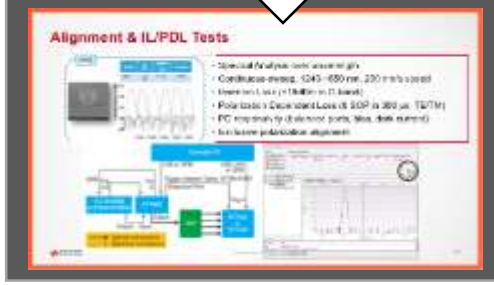
PATHWAVE

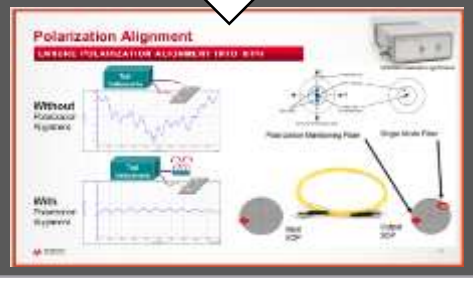
GUI

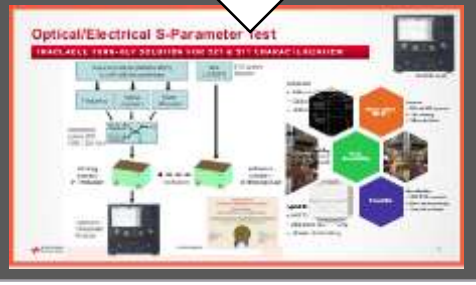
API & command line interface

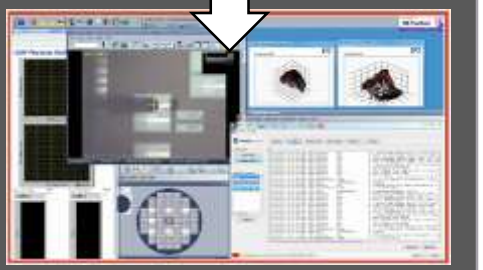
Fast execution and test flow analysis

Plug-Ins & Driver

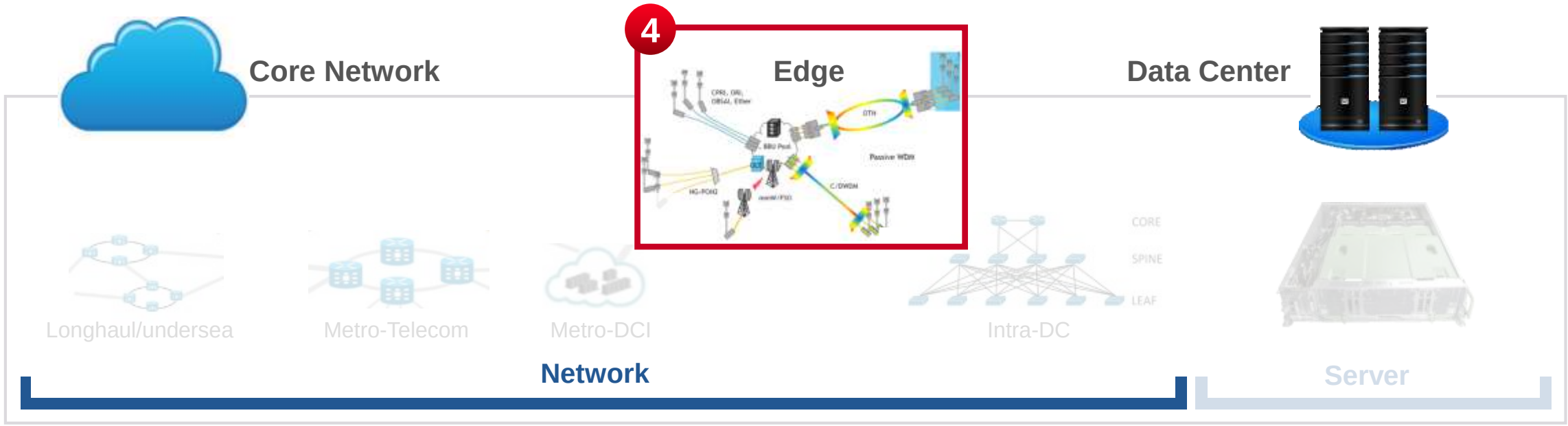




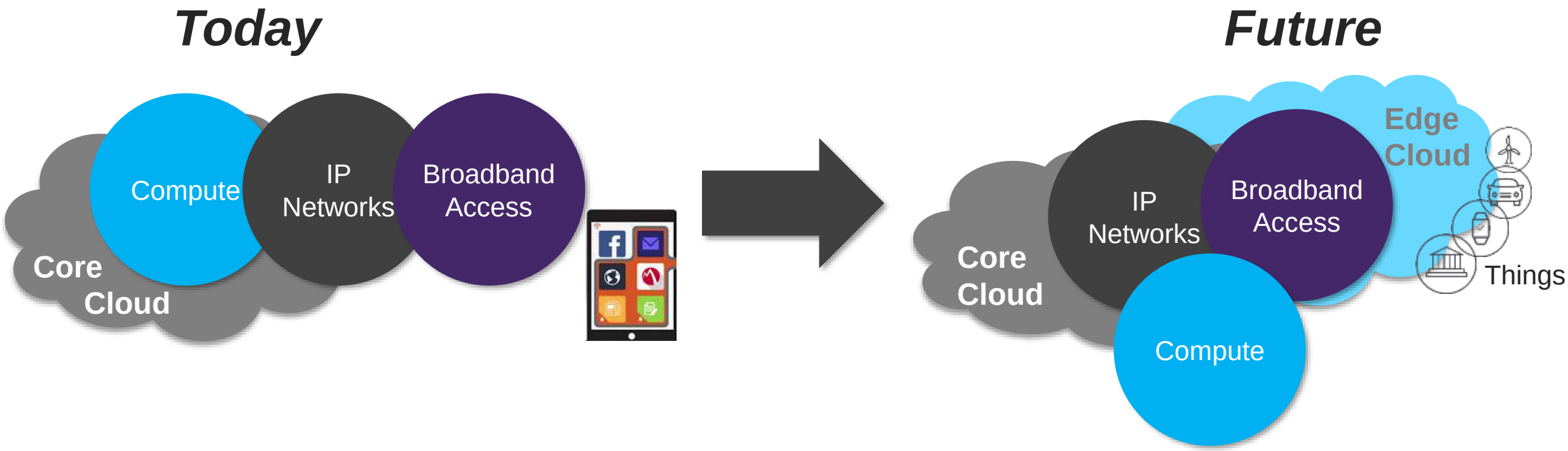




Wireline Internet Infrastructure

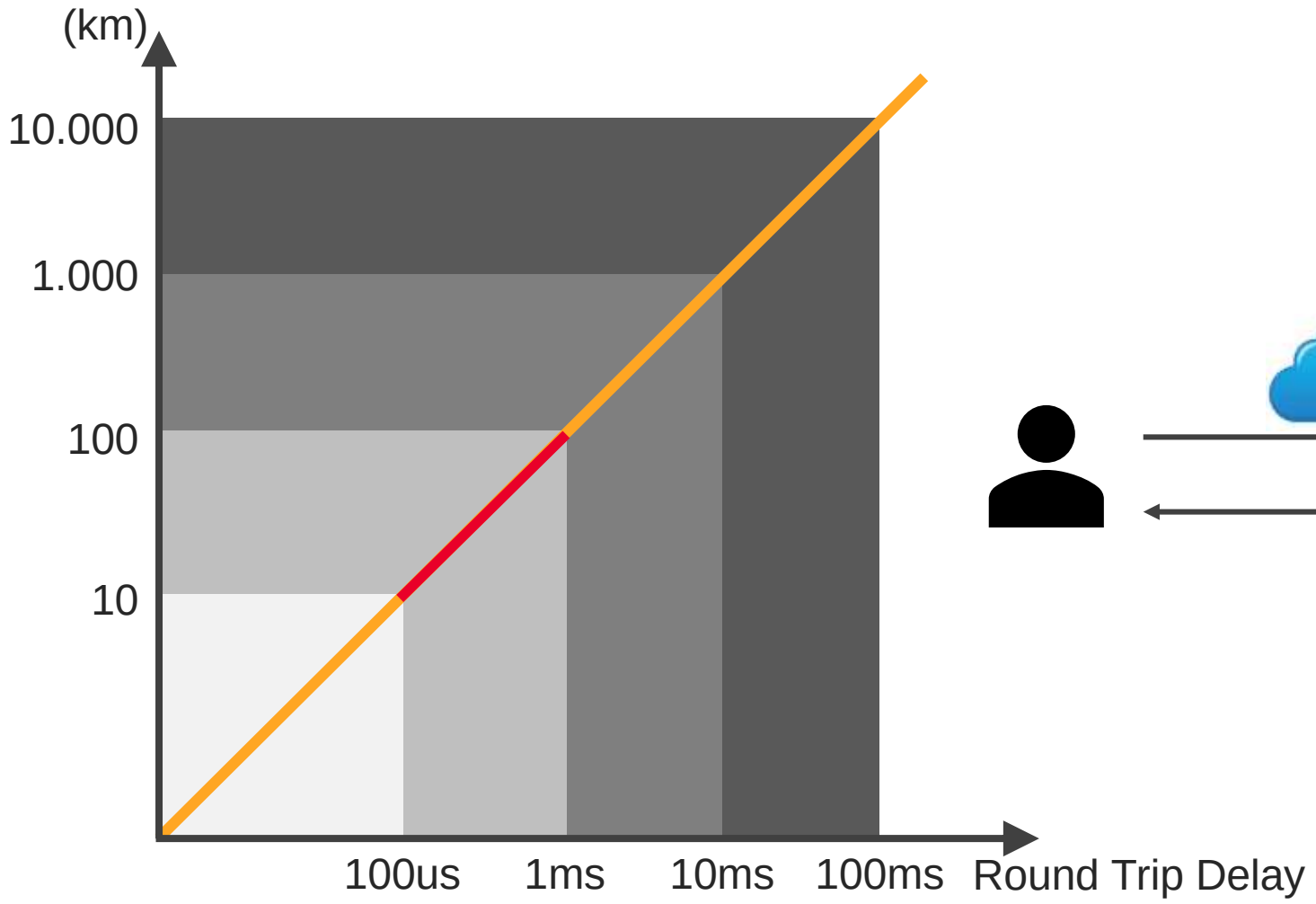


Edge Cloud to enable Low Latency

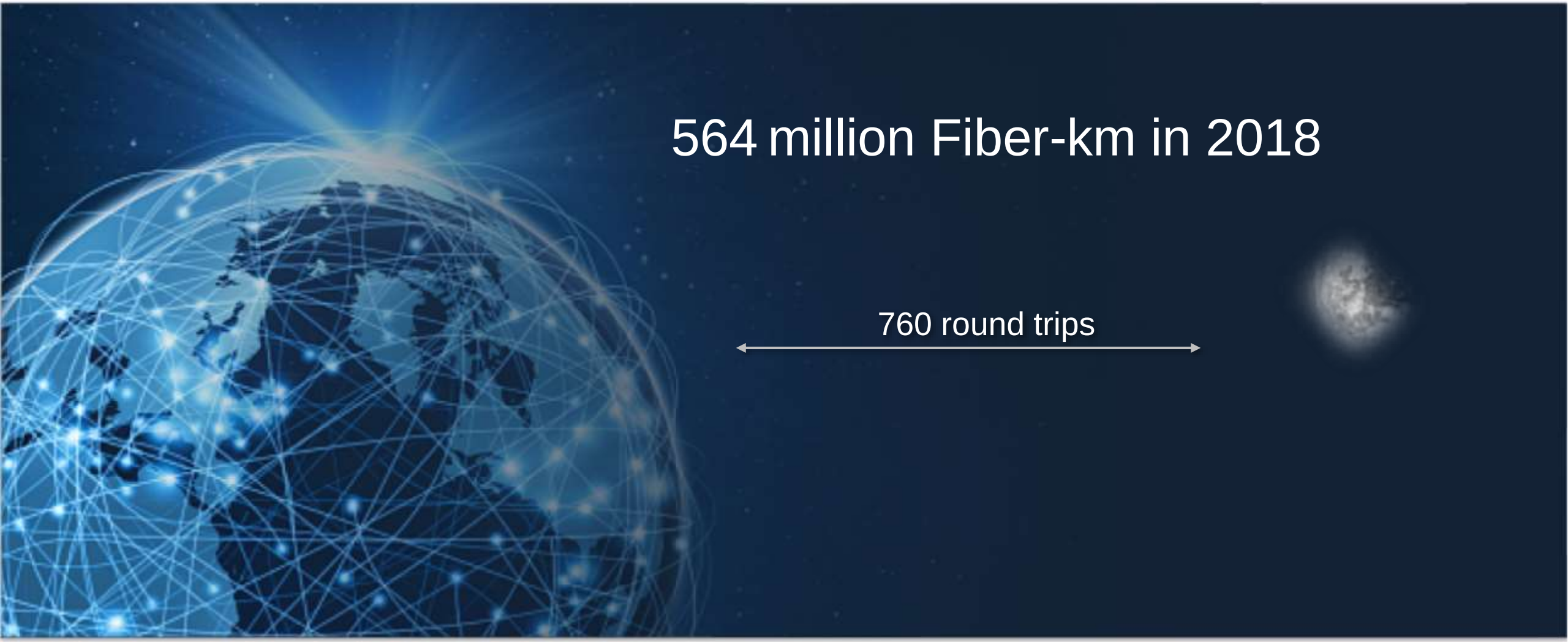


New Applications Demand Low Latency

1MS-THE NEW REQUIREMENT TO CAPITALIZE ON 5G

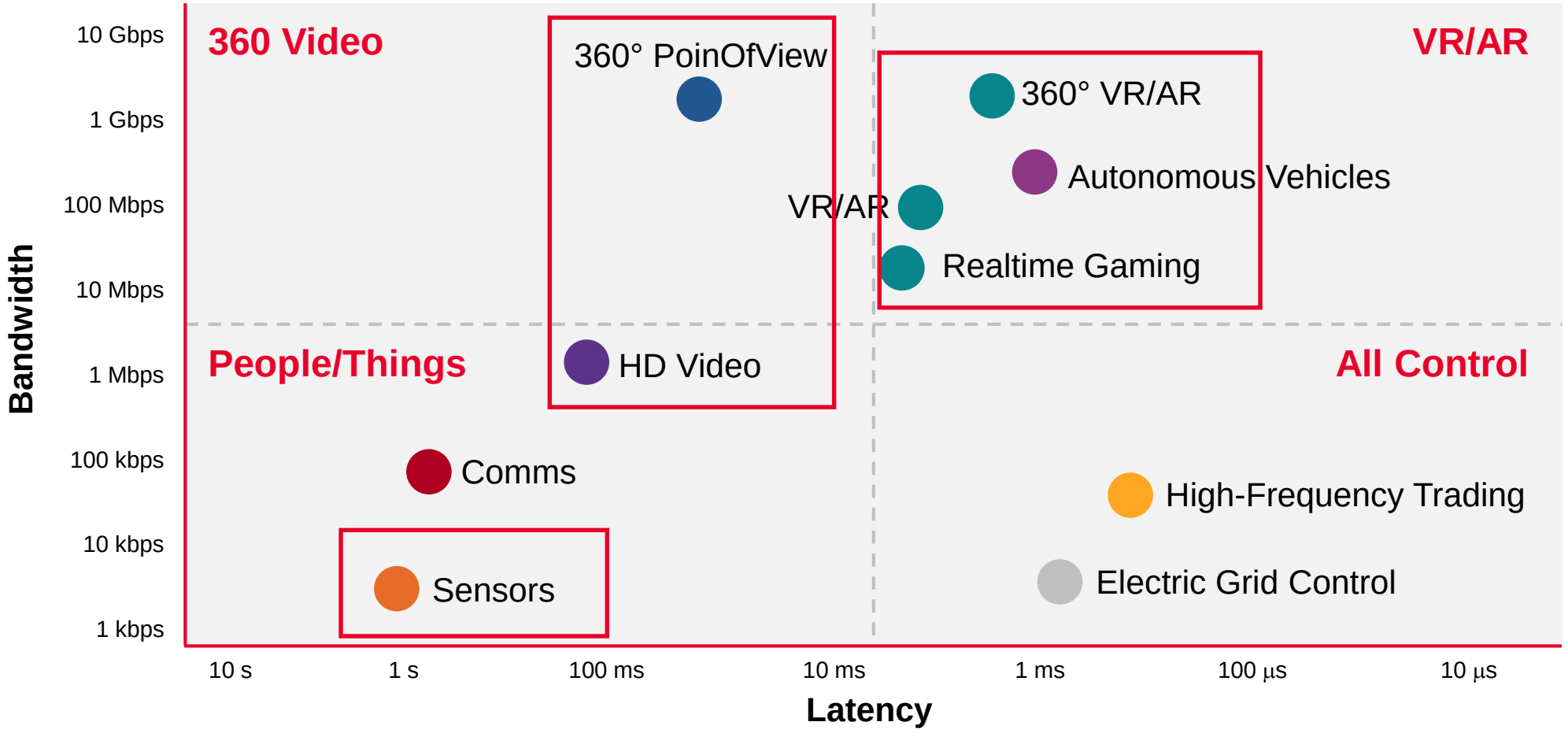


Fiberization of Planet Earth



Applications and Latency Requirements

HIGH-BANDWIDTH AND LOW LATENCY

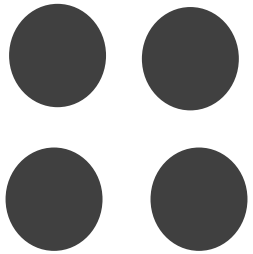


Different services have different requirements

SLICING: ALLOCATE RESOURCES WHEN NEEDED

M2M / IoT
Device Oriented
Ultra-low latency

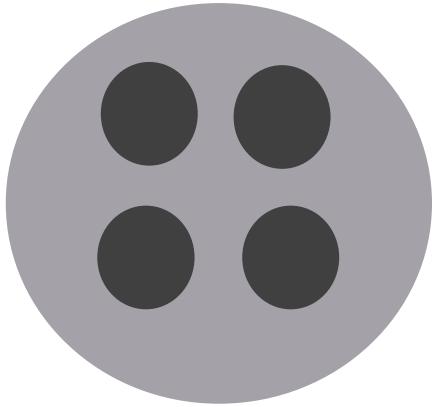
Hard Slicing



No shared resources

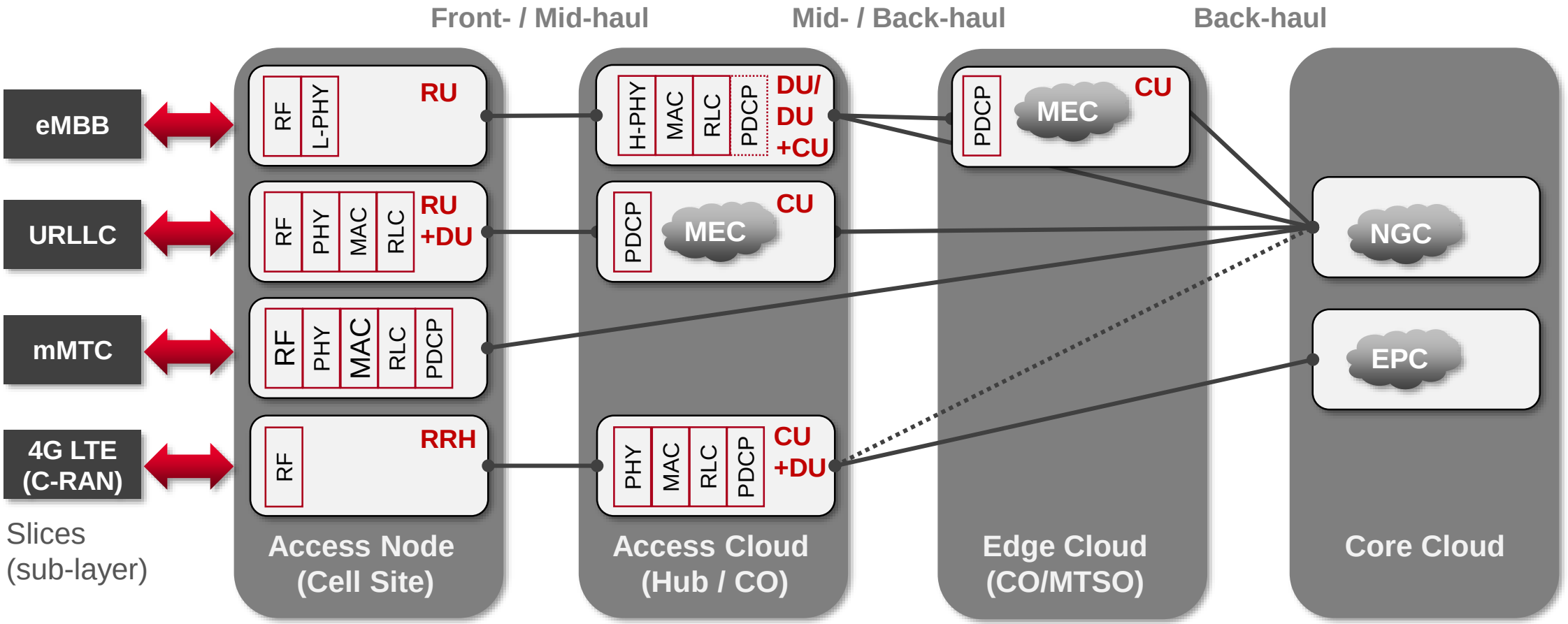
Mobile broadband service
Increasing bandwidth
Connection oriented

Soft Slicing



Packet based

NW Slicing, RAN Functional Split and Interfaces



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: Test enables and accelerates innovation.

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
TECHNOLOGIES