IEEE 802.3 NEA Ad hoc

IEEE 802.3 Call for Interest
Draft Development

“Beyond 400 GbE“
CFI Consensus Presentation

John D’Ambrosia
Futurewei Technologies
U.S. Subsidiary of Huawei

OBJECTIVE FOR THE MEETING

- To measure the interest in starting a study group to address "Beyond 400 Gb/s Ethernet and Breakout Ethernet Rates"
- 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

Contributors

- John D’Ambrosia, Futurewei, U.S. Subsidiary of Huawei
- Matt Brown, Huawei Canada
- Joel Goergen, Cisco
- Mark Gustlin, Cisco
- Xinyuan Wang, Huawei

Today's Panel

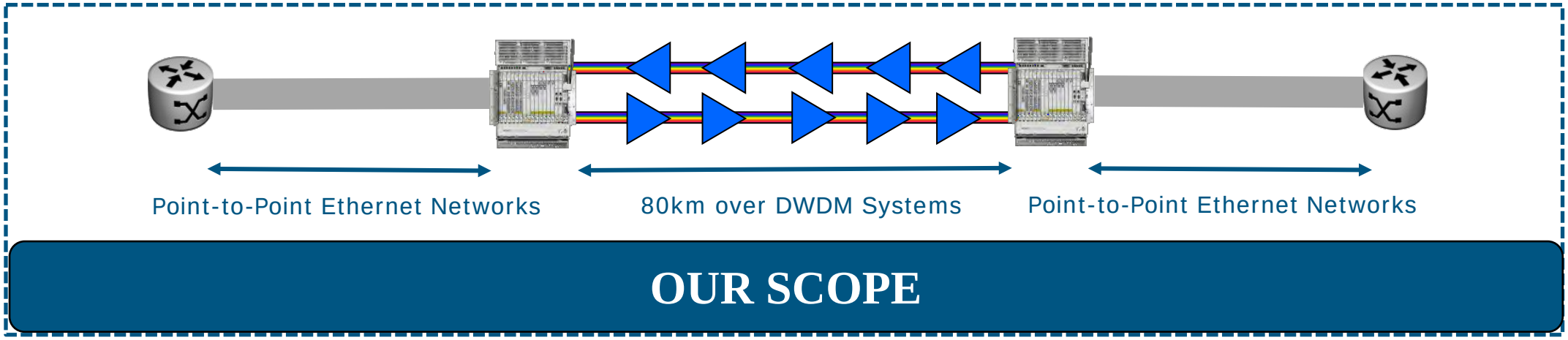
- To be identified

AGENDA

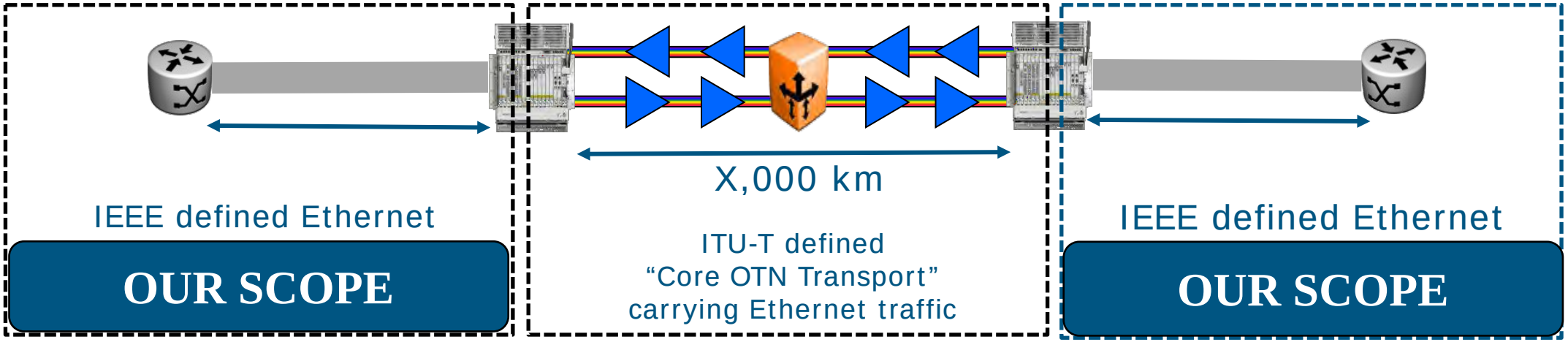
- Introduction
- Presentations
  - Market Pressures for Beyond 400 GbE
  - The Technical Roadmap to Beyond 400 GbE
  - Why Now?
- Straw Polls
- Future Work

THE SCOPE OF ETHERNET TODAY

Scenario #1



Scenario #2



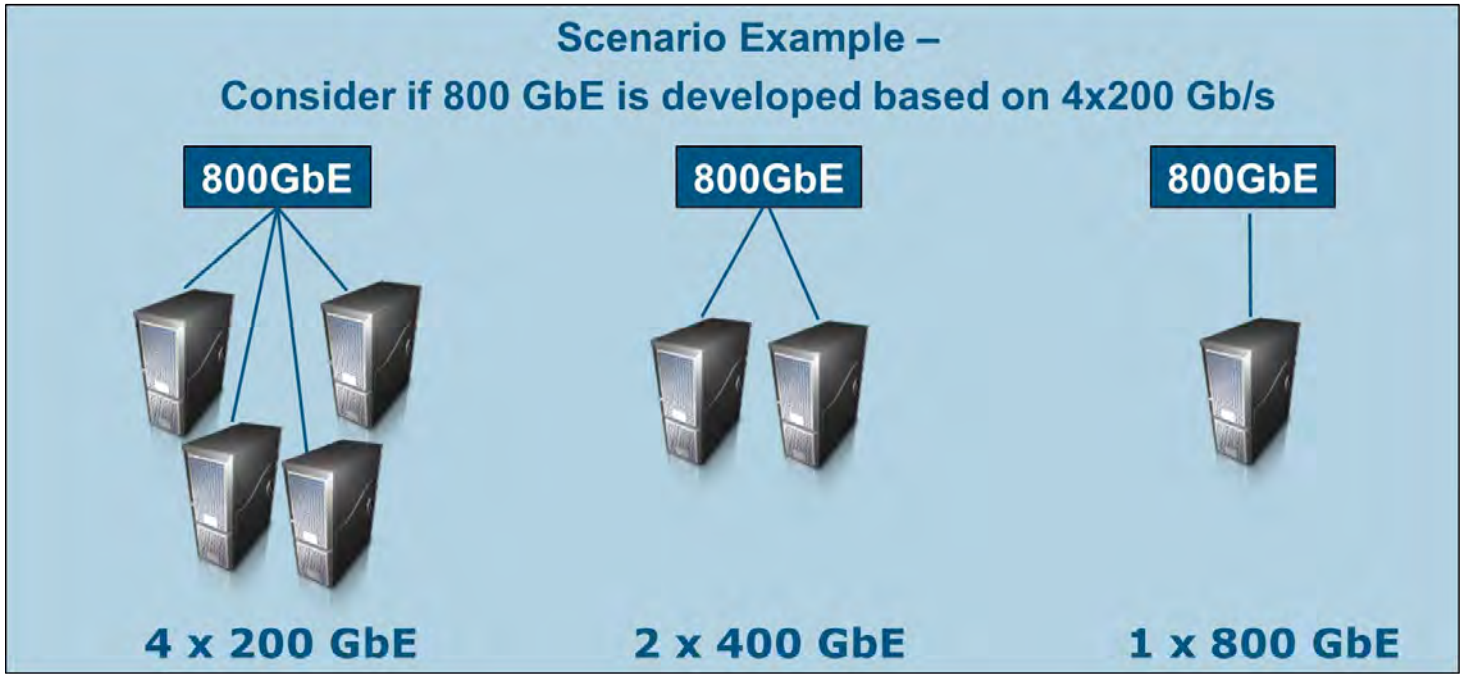
The Ethernet “Breakout Scenario” Ecosystem

TODAY

Image courtesy of David Piehler, Dell-EMC

32 400GbE ports break out into 128 100GbE ports

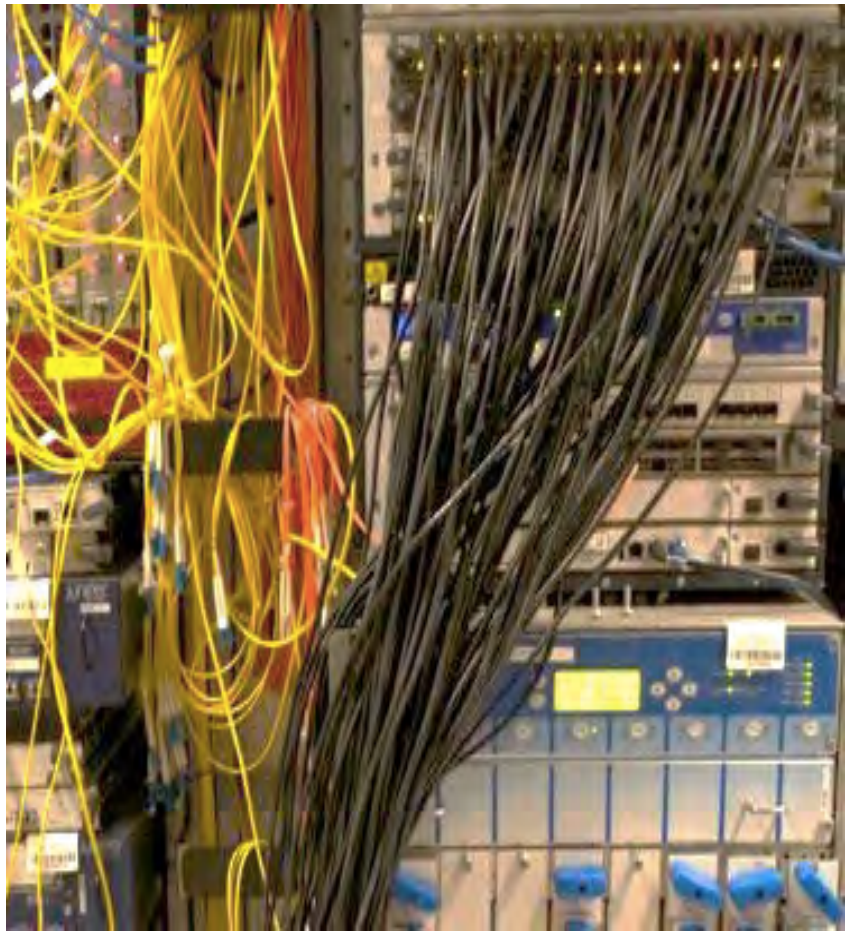
A POSSIBLE FUTURE



“It has been my experience at Google that we have used optical and cu modules to support breakout applications as well as applications requiring the maximum capacity as a single port.”

Cedric Lam, Google

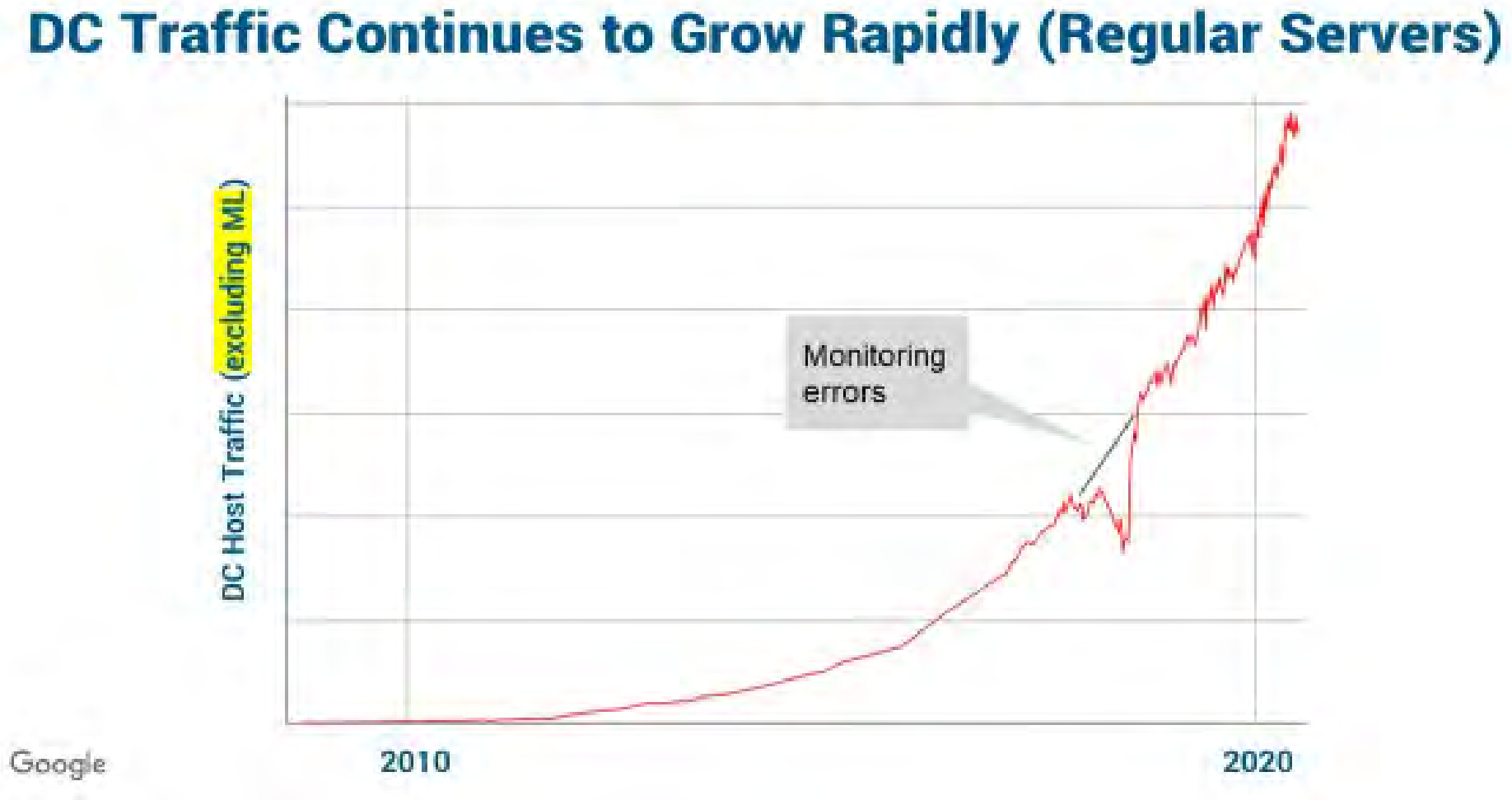
LINK AGGREGATION WILL NOT SUFFICE



Courtesy, David Ofelt, Juniper.

- Problem: Need to scale the Network (density & cost)
- Temporary Solution: Link Aggregation
- Pros:
  - Addresses bandwidth requirements between releases of faster links
- Cons:
  - Non-deterministic performance
  - Fastest flow limited to individual link speed
  - Exponential bandwidth growth implies:
    - Exponential growth in number of links
    - Growth in operational & management issues
  - Doesn't scale forever.
- Faster links address these issues ***and they will be LAGGed!***

DATA CENTERS CONTINUE AS A PRIMARY DRIVER



Courtesy - Cedric Lam, Google

COVID-19 TRENDS, APRIL 2020

CAGR data from various industry sources and Inphi estimates

Source - Inphi blog post 'Bandwidth in the Age of COVID-19' posted 22nd April 2020 by Ford Tamer, President and CEO, Inphi Corporation <https://www.inphi.com/blog/>

MARKET PRESSURES FOR BEYOND 400 GbE

THE SONG REMAINS THE SAME

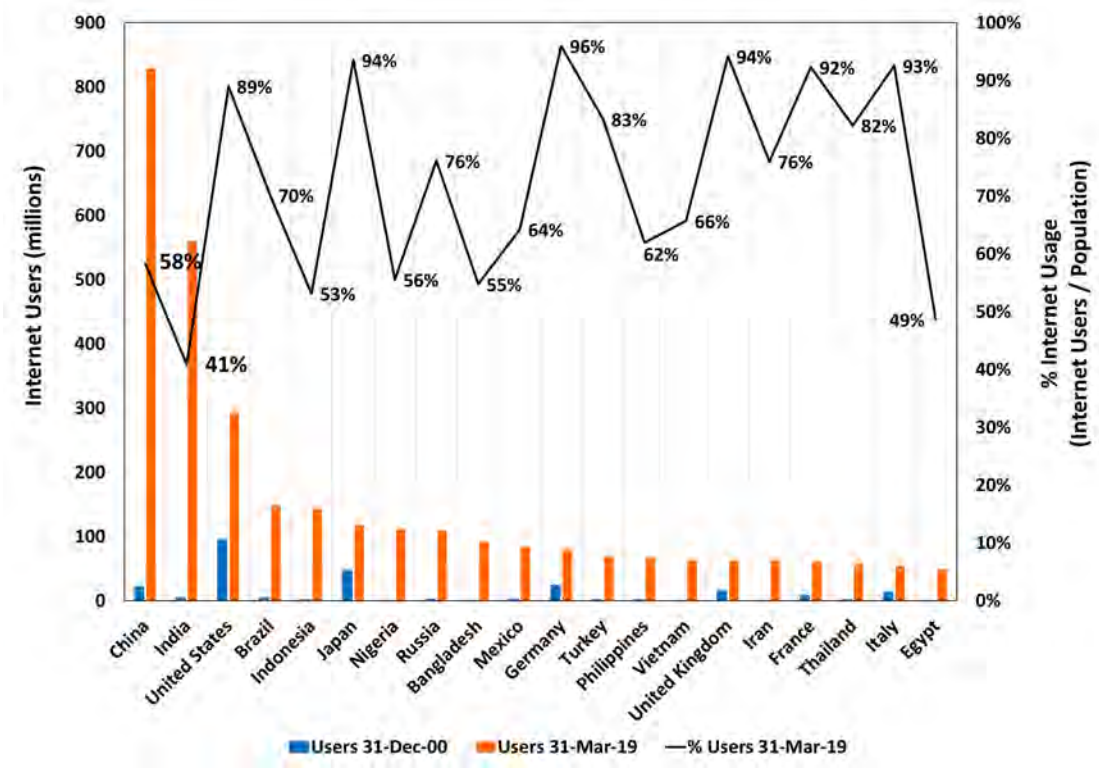
Increased # of users	x	Increased access methods and rates	x	Increased services	=	Bandwidth Explosion

WORLD INTERNET USAGE

Total World	As of 3/31/19 [1]	As of 12/31/19 [3]	Increase	As of 7/20/20 [2]	Increase
Population	7,716,223,209	7,796,615,710	80,392,501	7,796,949,710	80,726,501
Internet Users	4,383,810,342	4,574,150,134	190,339,792	4,833,521,806	449,711,464
Internet Penetration	57%	59%	2%	62%	5%

Top 20 Countries	As of 3/31/19 [1]	As of 12/31/19 [3]	Increase
Population	5,187,499,066	5,233,377,837	45,878,771
Internet Users	3,117,533,898	3,241,273,512	123,739,614
Internet Penetration	60%	62%	2%

Rest of World	As of 3/31/19 [1]	As of 12/31/19 [3]	Increase
Population	2,565,984,143	2,563,237,873	-2,746,270
Internet Users	1,229,027,955	1,332,876,622	103,848,667
Internet Penetration	48%	52%	4%



Observations

- **Only 8 countries had at least 80% connectivity**
- **≈ 450 million users increase**
- **5% increase in Total World Internet Penetration since Mar 31 2019**

1. IEEE 802.3 BWA, PART II
2. HTTPS://WWW.INTERNETWORLDSTATS.COM/STATS.HTM
3. HTTPS://WWW.INTERNETWORLDSTATS.COM/TOP20.HTM

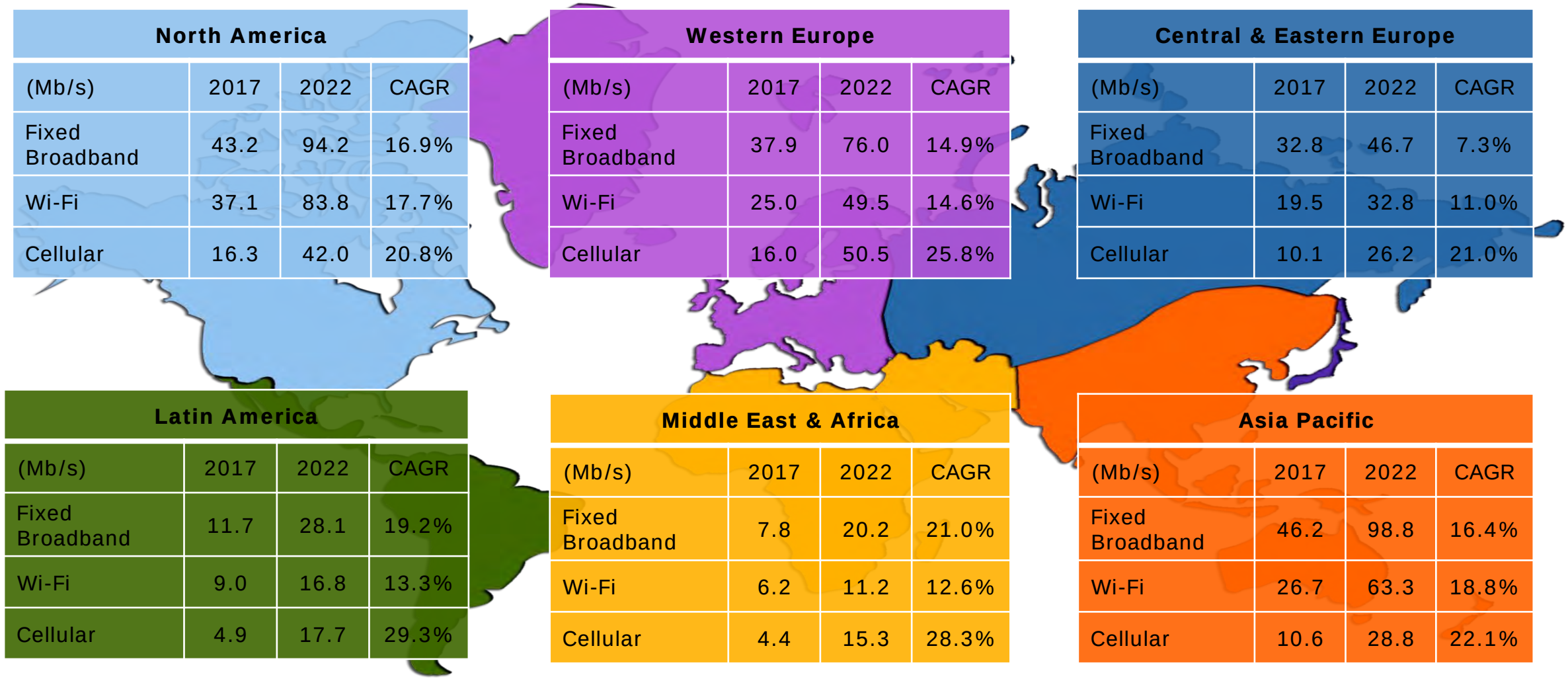
GLOBAL DEVICES / CONNECTIONS AVERAGE PER CAPITA

	2017	2022	Growth
Average Number of Devices and Connections per **Capita**	2.4	3.6	50%
Average Traffic per User per Month **GB**	29	85	193%

Number of connected devices per capita is growing
The average traffic per user is growing at a much faster rate

Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

GLOBAL DEVICE CONNECTION GROWTH (AVERAGE)



North America			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	43.2	94.2	16.9%
Wi-Fi	37.1	83.8	17.7%
Cellular	16.3	42.0	20.8%

Western Europe			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	37.9	76.0	14.9%
Wi-Fi	25.0	49.5	14.6%
Cellular	16.0	50.5	25.8%

Central & Eastern Europe			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	32.8	46.7	7.3%
Wi-Fi	19.5	32.8	11.0%
Cellular	10.1	26.2	21.0%

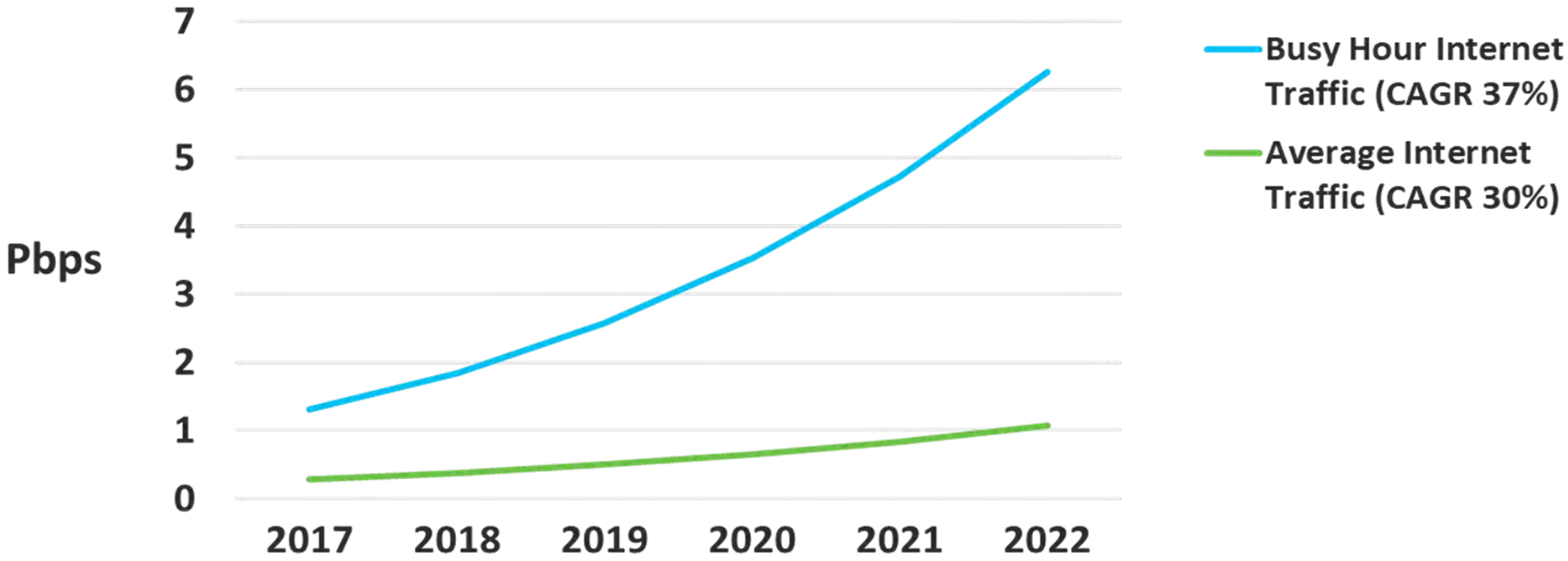
Latin America			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	11.7	28.1	19.2%
Wi-Fi	9.0	16.8	13.3%
Cellular	4.9	17.7	29.3%

Middle East & Africa			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	7.8	20.2	21.0%
Wi-Fi	6.2	11.2	12.6%
Cellular	4.4	15.3	28.3%

Asia Pacific			
(Mb/s)	2017	2022	CAGR
Fixed Broadband	46.2	98.8	16.4%
Wi-Fi	26.7	63.3	18.8%
Cellular	10.6	28.8	22.1%

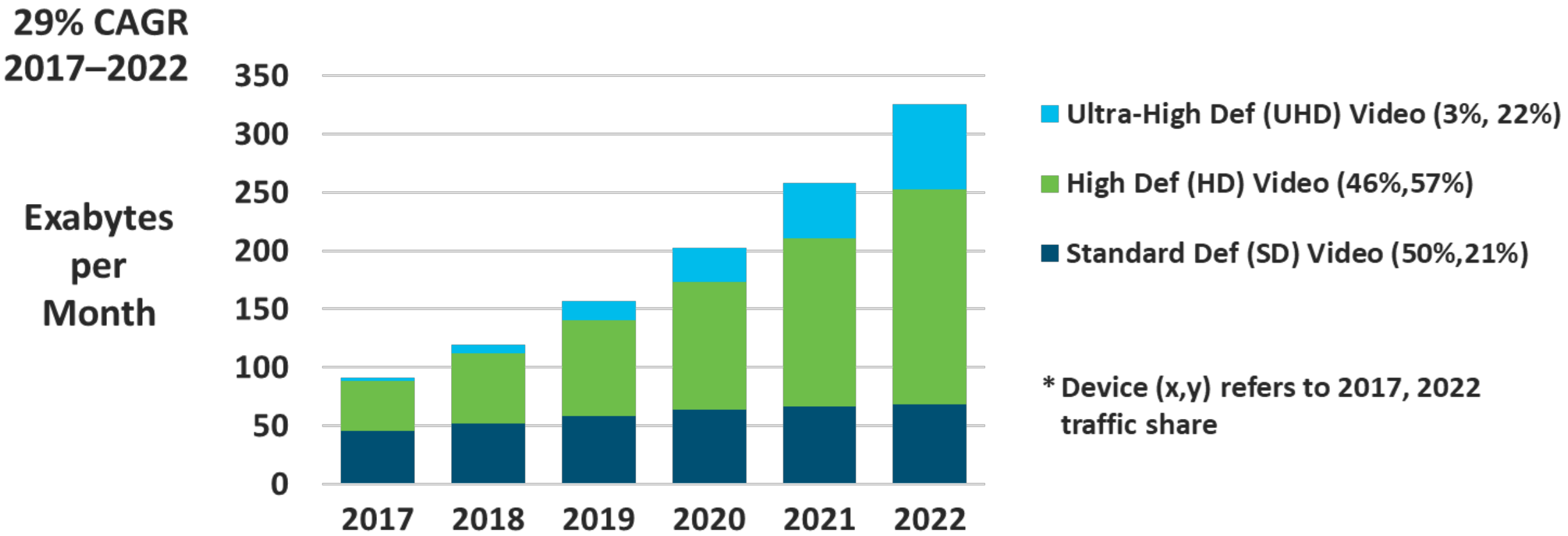
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

GLOBAL INTERNET TRAFFIC BUSY-HOUR VS AVERAGE HOUR



Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

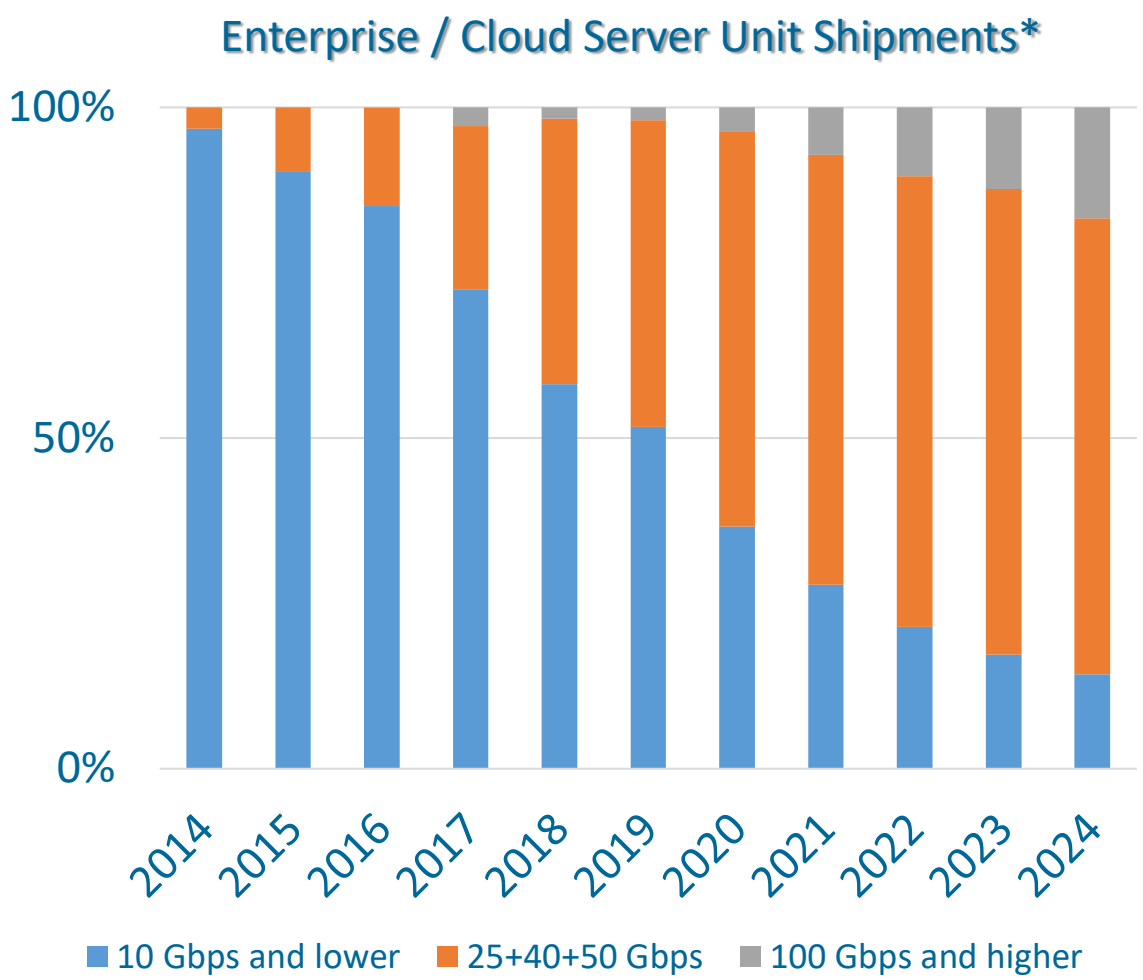
IMPACT OF "DEFINITION' ON IP VIDEO GROWTH

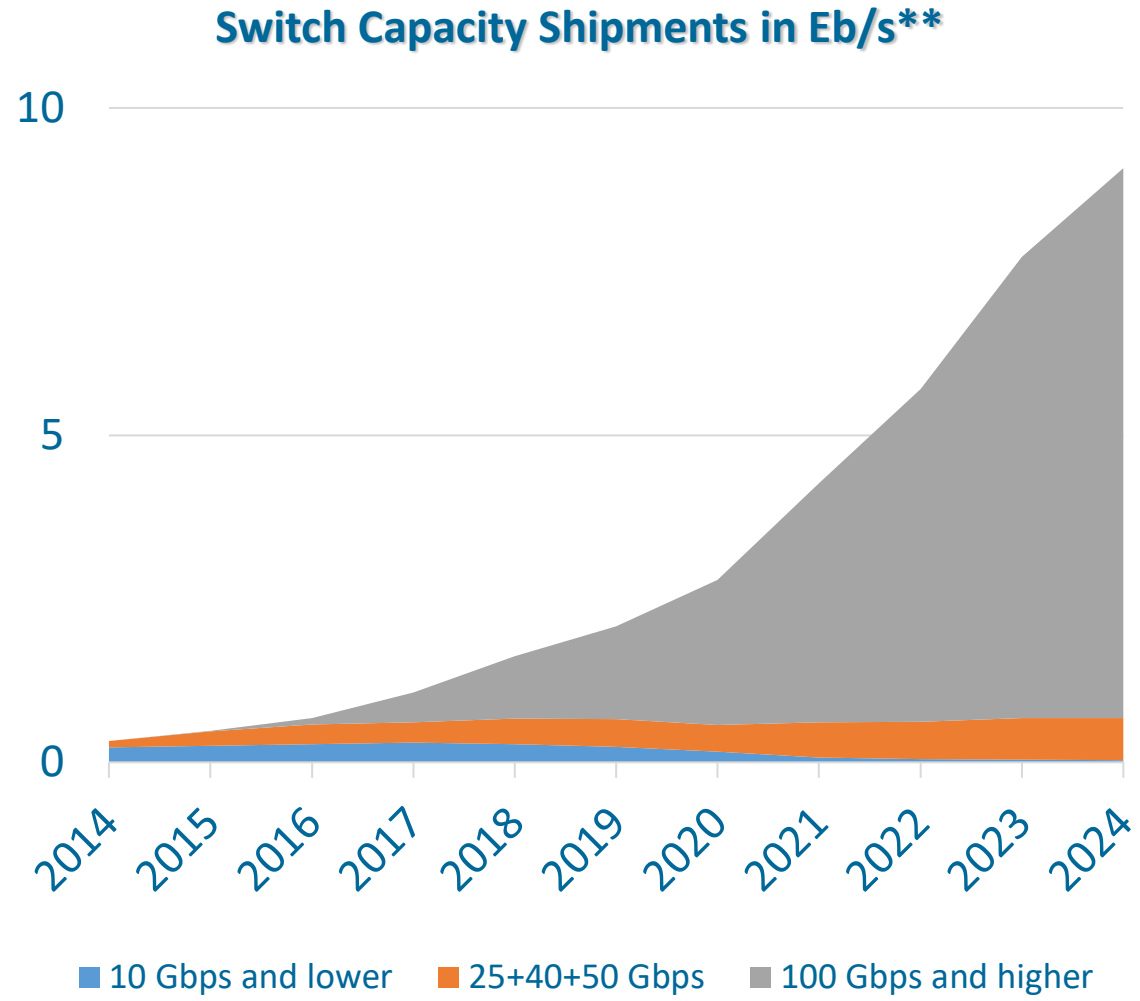


Growth in the adoption of HD and UHD dominate IP video traffic

Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

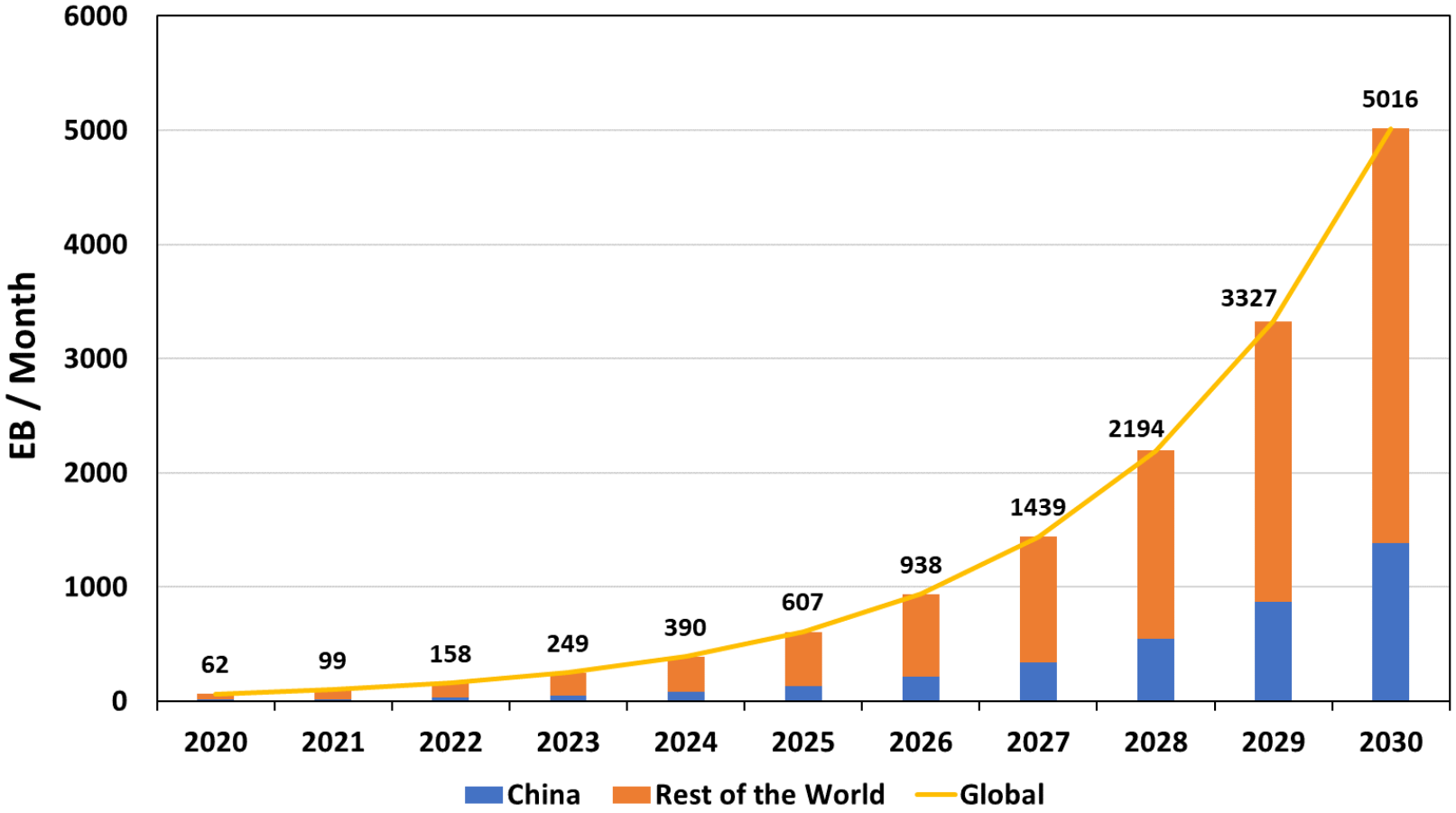
DATA CENTER CAPACITY CONTINUES TO GROW





* Percent of annual server shipments categorized by speed of the attached controllers and adapters
** Annual port capacity shipped on Data Center Ethernet Switches measured in exabits per second

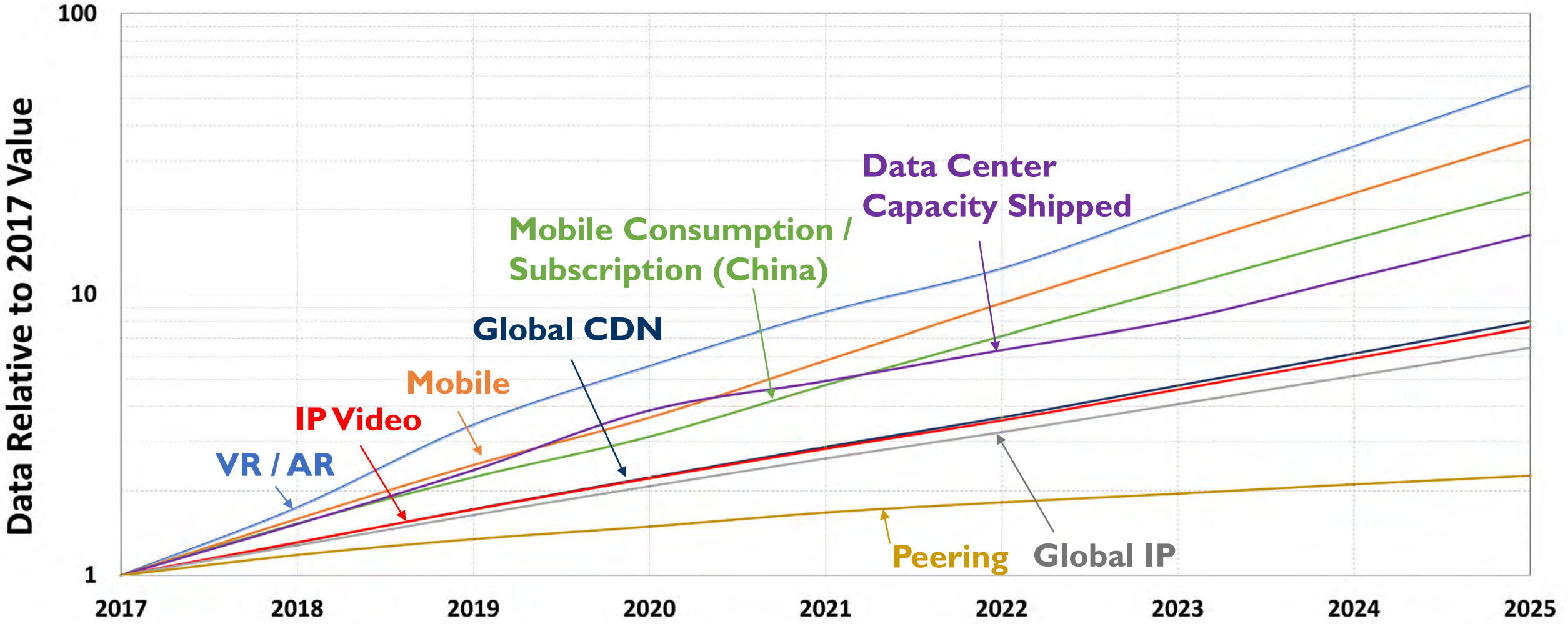
ESTIMATION OF MOBILE TRAFFIC



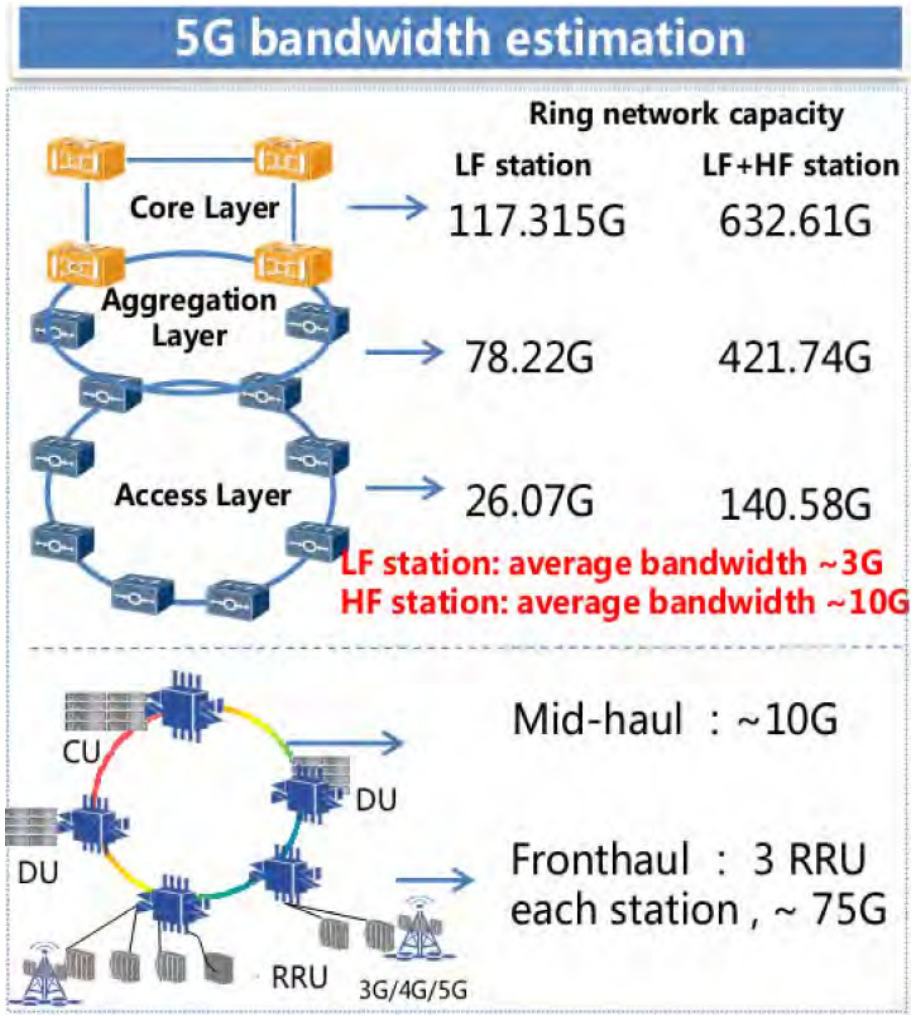
Global mobile traffic is expediential and may even be underestimated

Source: Report ITU-R M.2370-0: IMT traffic estimates for the years 2020 to 2030, https://www.itu.int/pub/R-REP-M.2370-2015

The 2020 Ethernet Bandwidth Assessment



EXAMPLE EMERGING APPLICATION – 5G BACKHAUL

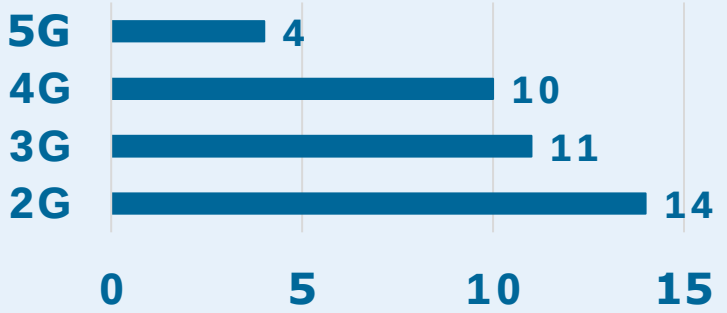


Source: http://www.ieee802.org/3/B10K/public/18_01/wang_b10k_01b_0118.pdf

	LTE	LTE Advanced	5G
Africa	145	42	4
Asia & Pacific	162	74	29
Eastern Europe	93	59	14
Latin America & Caribbean	127	50	8
Middle East	44	29	12
U S & Canada	20	11	7
Western Europe	88	70	31
Global Totals	683	335	105

Source: as of 8/14/2020, https://www.5gamericas.org/resources/deployments/

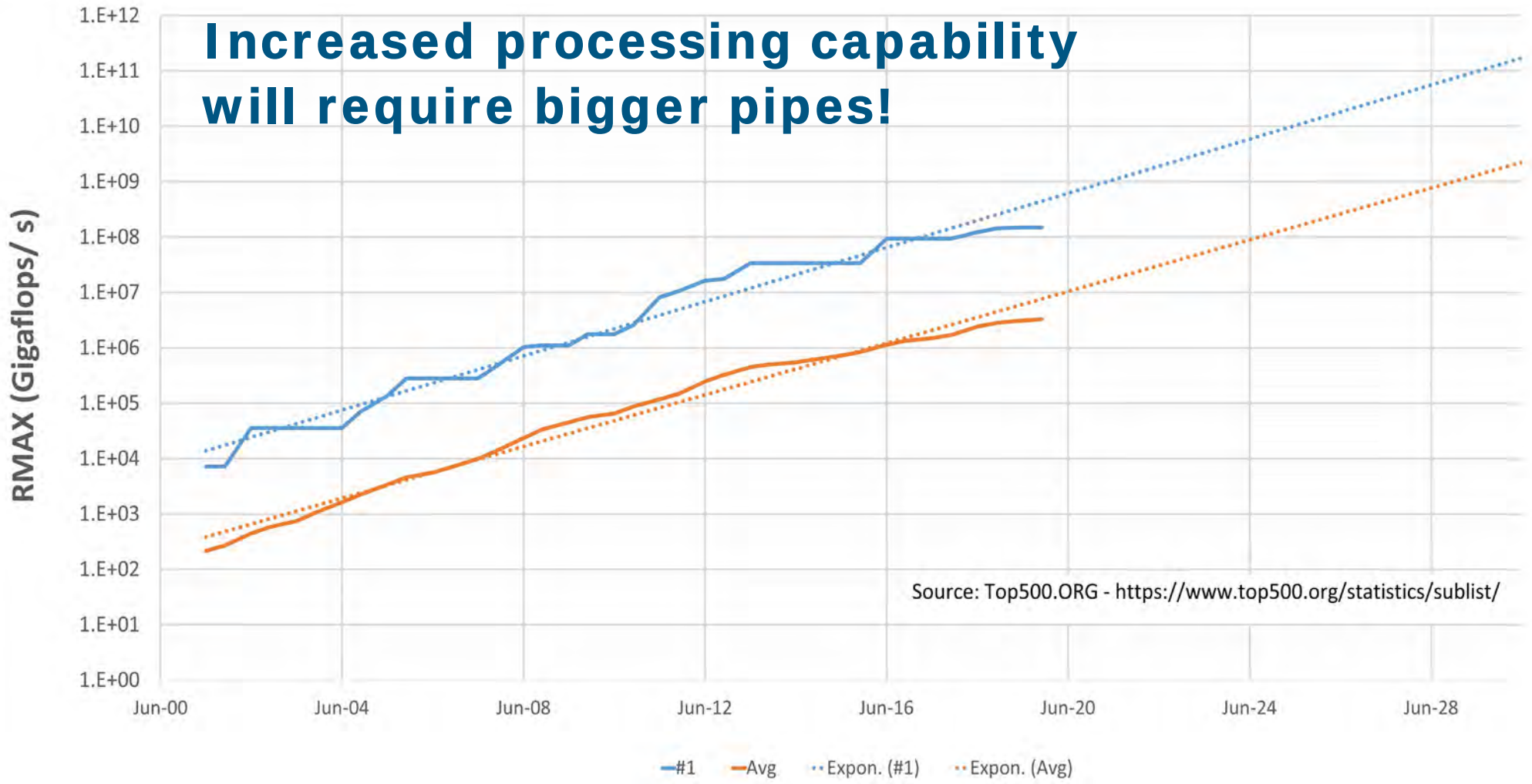
Omdia projects 91 million global 5G connections by end of 2020



# of Quarters to ≈17.8 million Connections

Source: https://www.5gamericas.org/5gs-year-one-fast-start-and-healthy-growth/

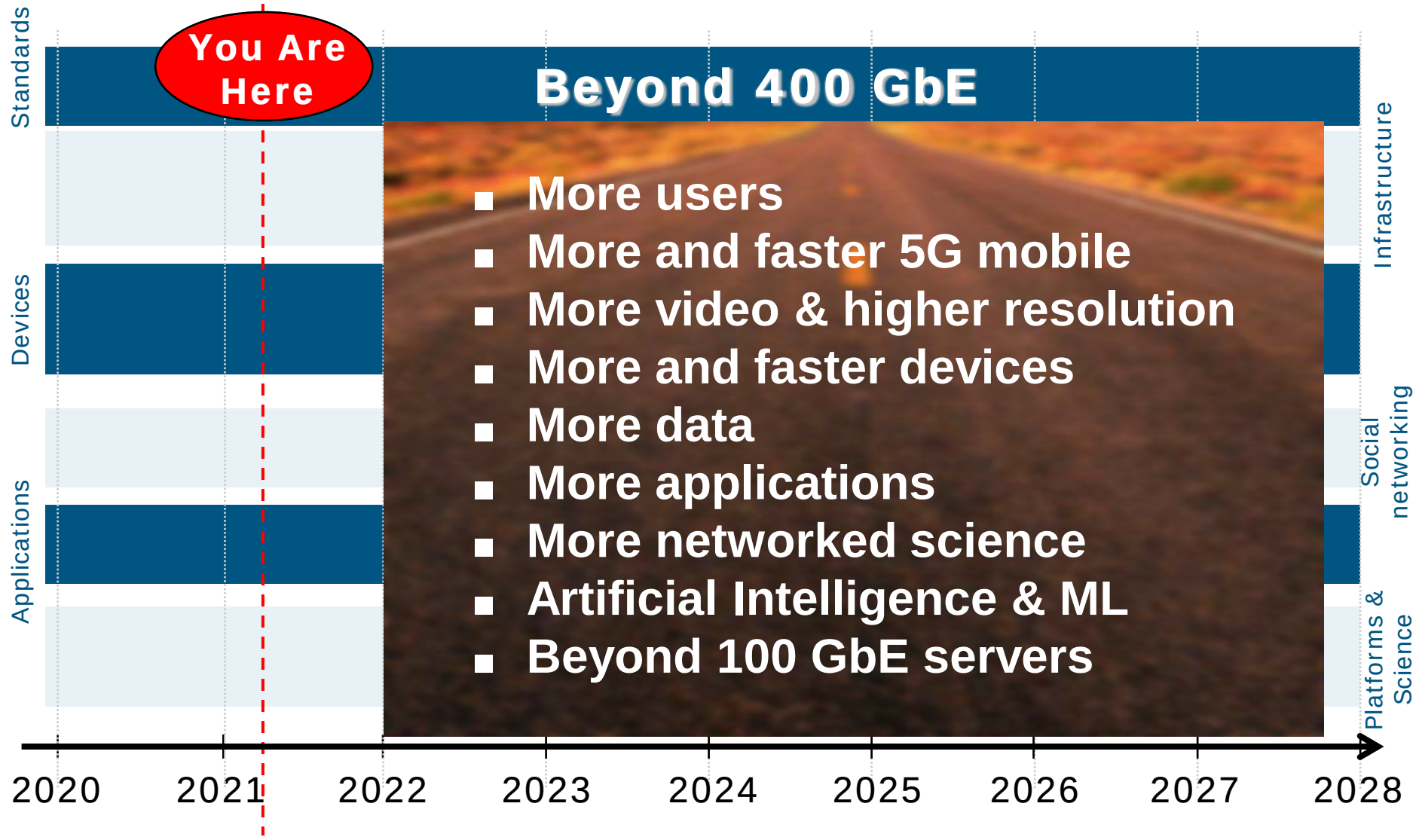
HIGH PERFORMANCE COMPUTING



ARTIFICAL INTELLIGENCE & COMPUTE

- **Two Distinct Eras**
  - **First Era (Before 2012)**
    - **Moore's Law – 2-year doubling for compute**
    - **Uncommon to use GPUs for machine learning**
  - **Modern Era (2012 and later)**
    - **2012 – 2014: most results used 1-8 GPUs rated at 1-2 TFLOPS**
    - **2014 – 2016: large-scale results used 10-100 GPUs rated at 5-10 TFLOPS**
    - **2016 – 2017: greater algorithmic parallism (huge batch sizes, architecture search, expert iteration), specialized hardware (TPUs), faster interconnects**
- **Source: https://openai.com/blog/ai-and-compute/**

MORE OF THE SAME.....

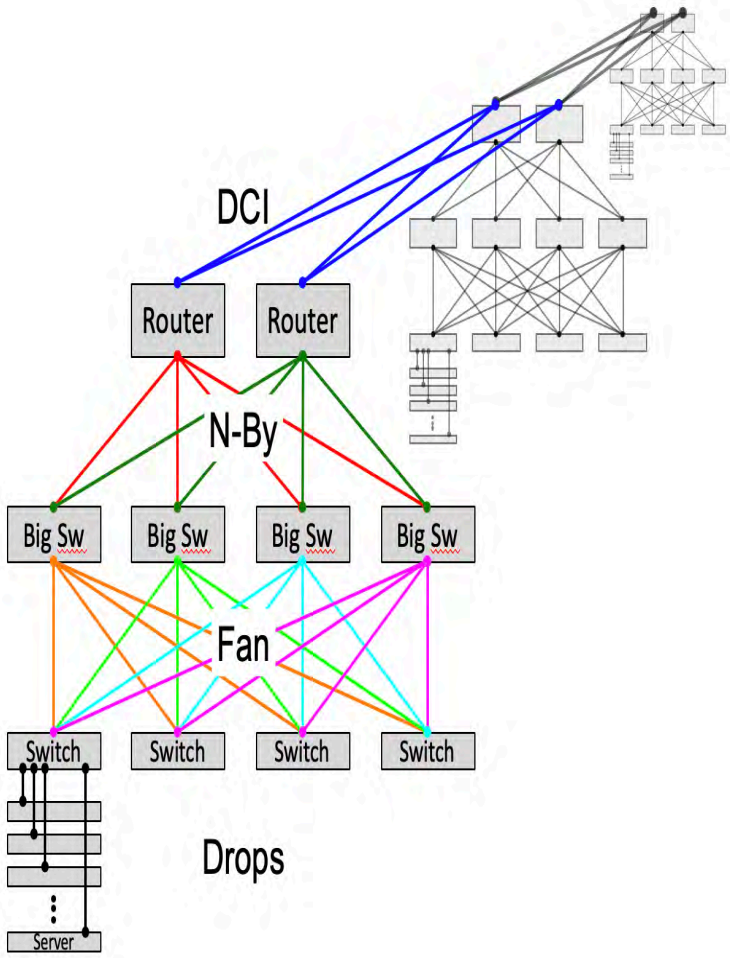


SUMMARY

- Bandwidth growth continues and underlying factors indicate further bandwidth growth
  - Video and mobile!
  - Increasing delta between “peak” and “average”
- New applications fueling bandwidth growth
- In today’s COVID world
  - Connectivity has been critical!
  - “Instantaneous” growth in multiple application spaces
- “Up and to the right” continues

THE TECHNICAL ROADMAP TO BEYOND 400 GbE

Understanding the Physical Challenges



Beyond 400GbE (Serial)	80km	SMF	DWDM
Beyond 400GbE (Parallel)	2km to 40 km	SMF	Duplex Fiber
	50m to 500m	SMF MMF	Parallel Cable (Breakout)
> 100 GbE	< 30m	MMF Twin Axial	

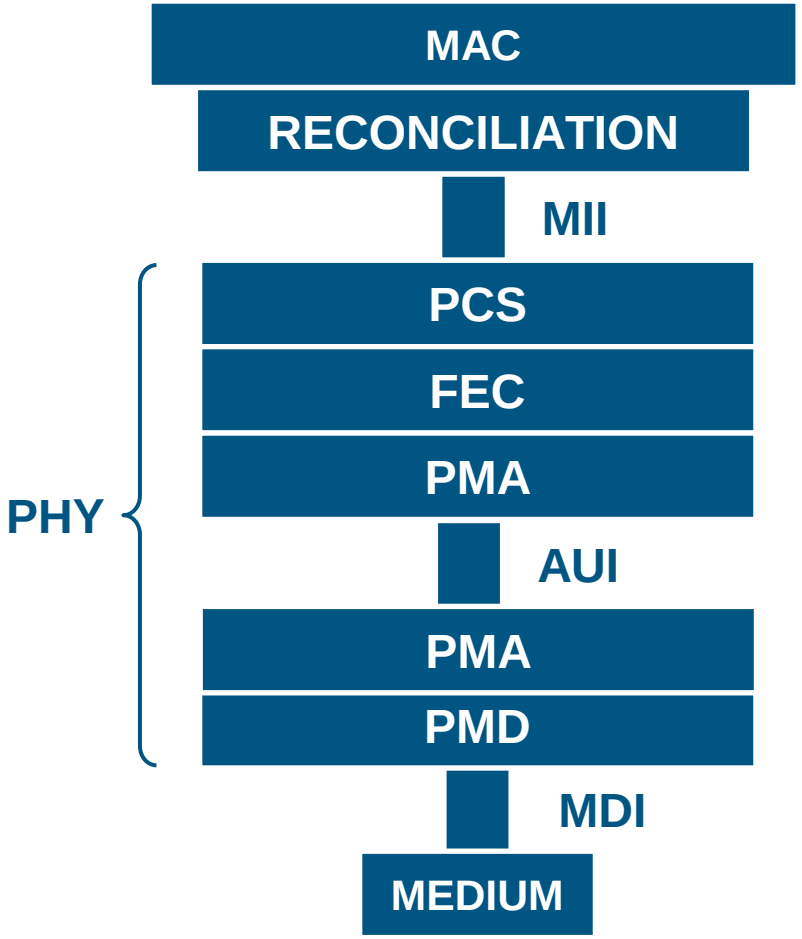
Coherent

Direct Detect

Beyond 400 GbE C2C / C2M AUI Development

Courtesy Jim Theodoras, HG Genuine

THE CHALLENGES TO BEYOND 400 GBE



Forward Error Correction

- AUI Specific?
- PHY Specific?
- Multiple variants? Architecture impact?

Electrical Functions

- Increase interface channel count?
- Increase interface rate?
- Increase interface modulation order?

Optical Functions

- Increase interface channel count?
- Increase interface rate?
- Increase interface modulation order?

Media

- Increase interface channel count?
- Increase fiber count?
- Increase lambda count?
- Breakout?

MAC/PCS Technical Feasibility

- **The options below are very feasible in near term technology (as an example, actual rate(s) are TBD)**

MAC Rate	Technology Node	Device Type	Bus Width	Clock Rate
800 Gb/s	5nm	ASIC	1024b	800 MHz
	5nm	ASIC	512b	1.6 GHz
	7nm	FPGA	1536b	533MHz
1.6 Tb/s	5nm	ASIC	2048b	800 MHz
	5nm	ASIC	1024b	1.6 GHz
	5nm (or equiv)	FPGA	3072b	533MHz

Source – Mark Gustlin, Cisco

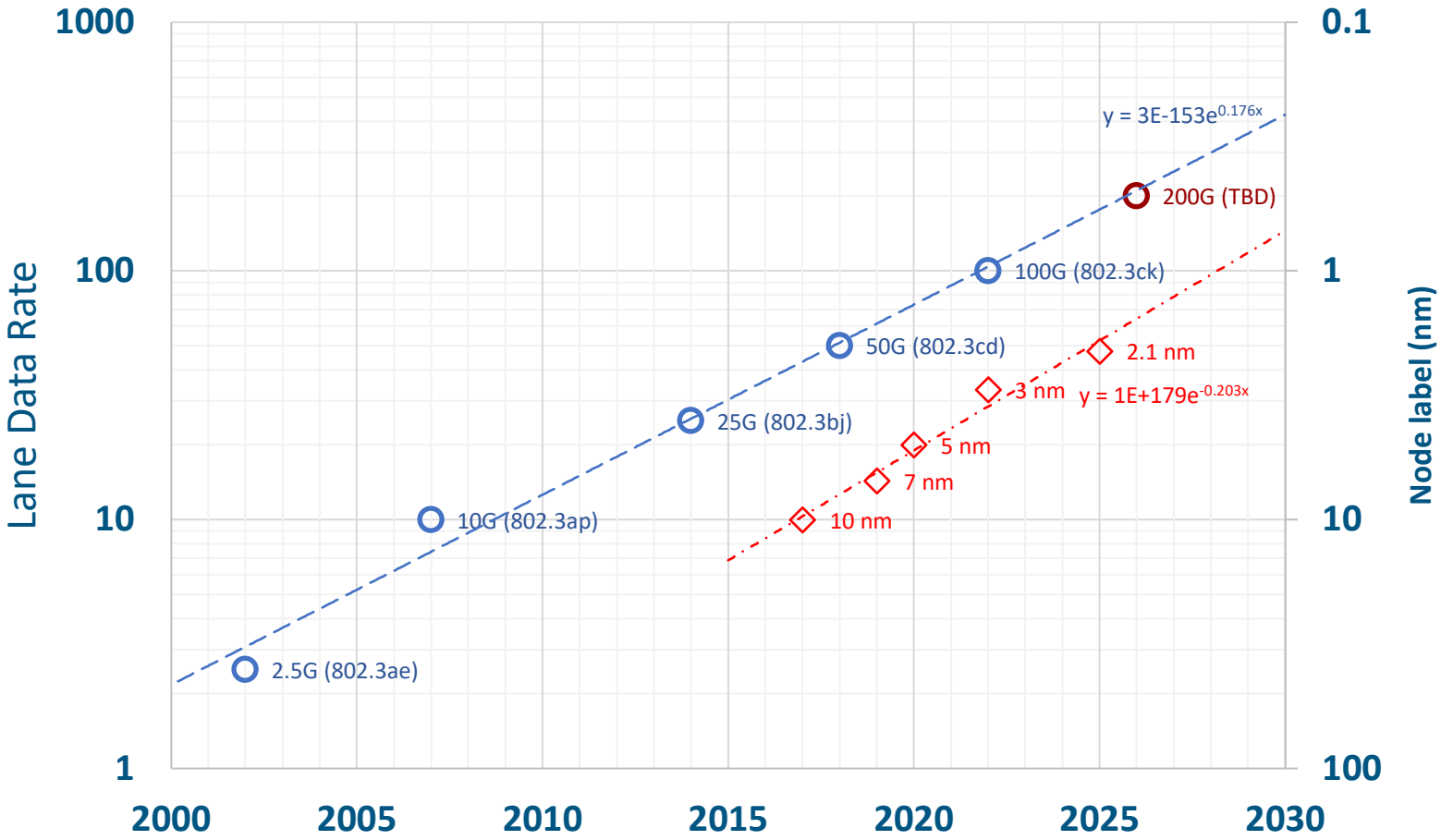
PCS / FEC

- Previous PCS concepts could be re-used
  - 64b/66b, transcoding, scrambling, AMs
- Will likely want a new stronger FEC for 200G lanes (if the project chooses to define 200G lanes)
  - Multiple FEC options for direct detect, coherent light and longer reach coherent?
  - Still support end to end FEC for some options?
  - Optimize gain, latency, power and implementation burden for chosen FECs
    - While minimizing the overall # of FEC options

Source – Mark Gustlin, Cisco

CMOS Roadmap

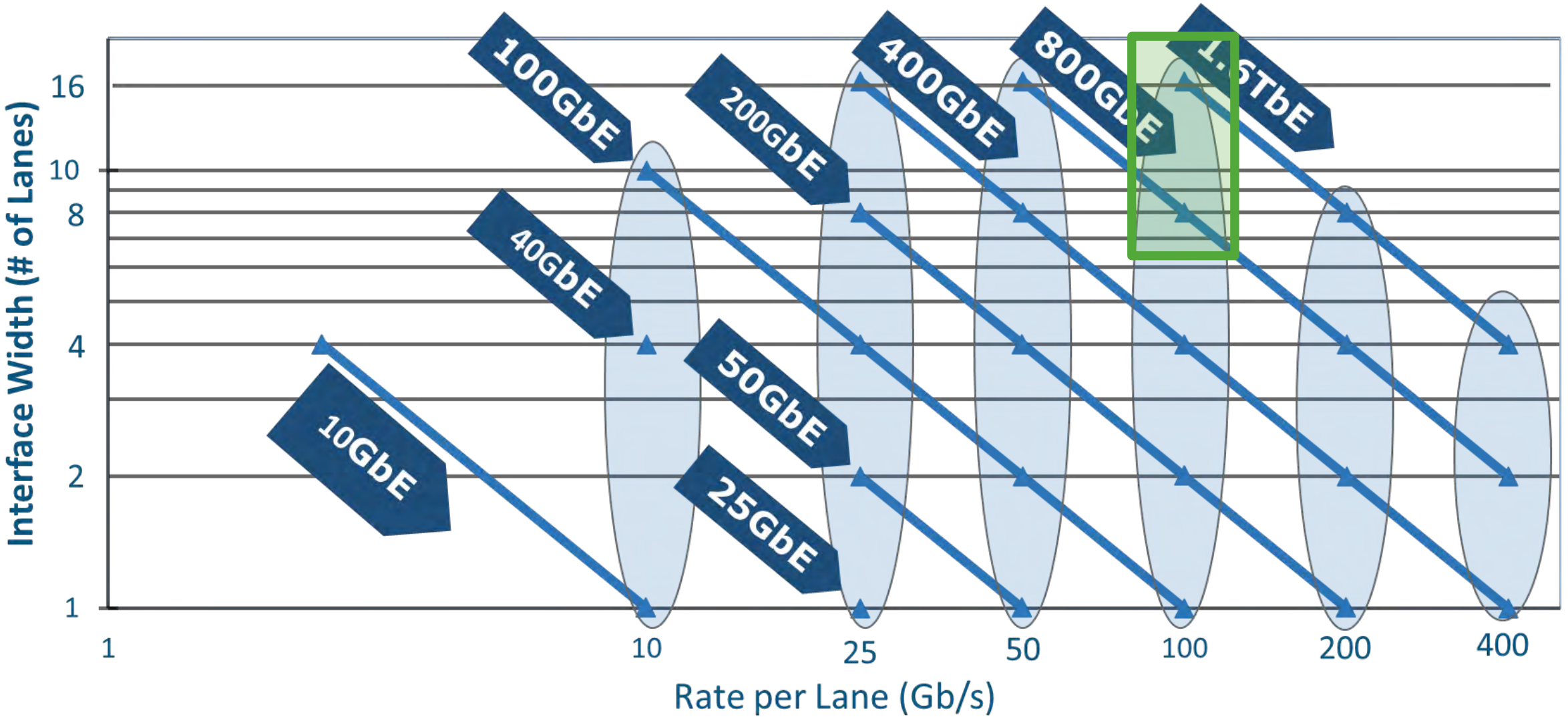
Comparison of Lane Data Rate and Node Label Timelines



- The upper data (blue) shows evolution of electrical lane data rate over time.
- The lower data (red) shows the evolution of node label over time.
- Current designs for 100 Gb/s per lane are in 7 nm and are moving to 5 nm.
- 3 nm and 2.1 nm will be available when 200 Gb/s per lane is standardized.
- The node label (halving every 3.4 years) is progressing faster than the electrical lane rate (doubling every 3.9 years).

Source – Matt Brown, Huawei Canada

Beyond 400 GbE - Leveraging 100 Gb/s

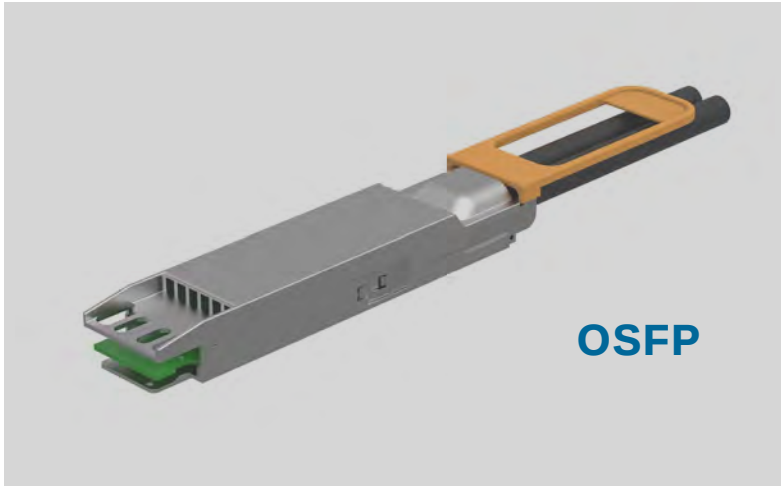


Industry Efforts - 100 Gb/s Signaling

- IEEE 802.3
  - Standard – IEEE P802.3bs – 400GBASE-DR4 (4x100G)
  - In Development
    - IEEE P802.3ck 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Force
    - IEEE P802.3cu 100 Gb/s and 400 Gb/s over SMF at 100 Gb/s per Wavelength Task Force
    - IEEE P802.3db 100 Gb/s, 200 Gb/s, and 400 Gb/s Short Reach Fiber Task Force
- Other Industry Efforts
  - OIF Common Electrical Interface 112G Efforts
  - 100G Lambda MSA (100Gb/s optical interfaces specifications)

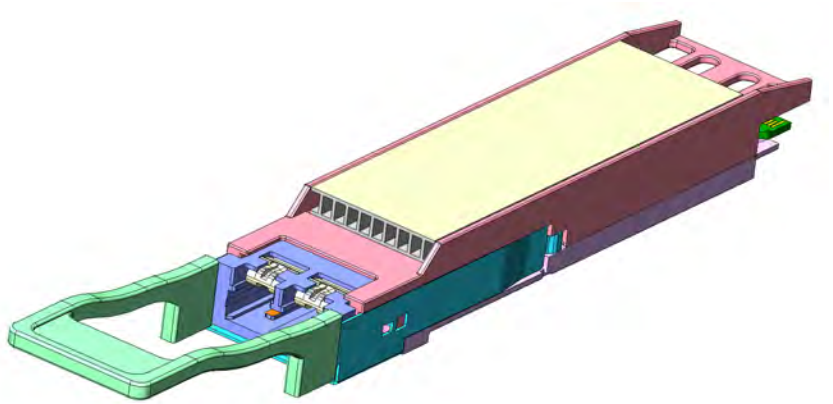
800 Gb/s Industry Activities

- **Ethernet Technology Consortium**
  - https://ethernettechnologyconsortium.org/
  - "The 800 GbE specification introduces a new media access control (MAC) and Physical Coding Sublayer (PCS)"
- **QSFP-DD800 MSA**
  - http://www.qsfp-dd800.net/
  - Rev 1.0 released Mar 6 2020
- **OSFP**

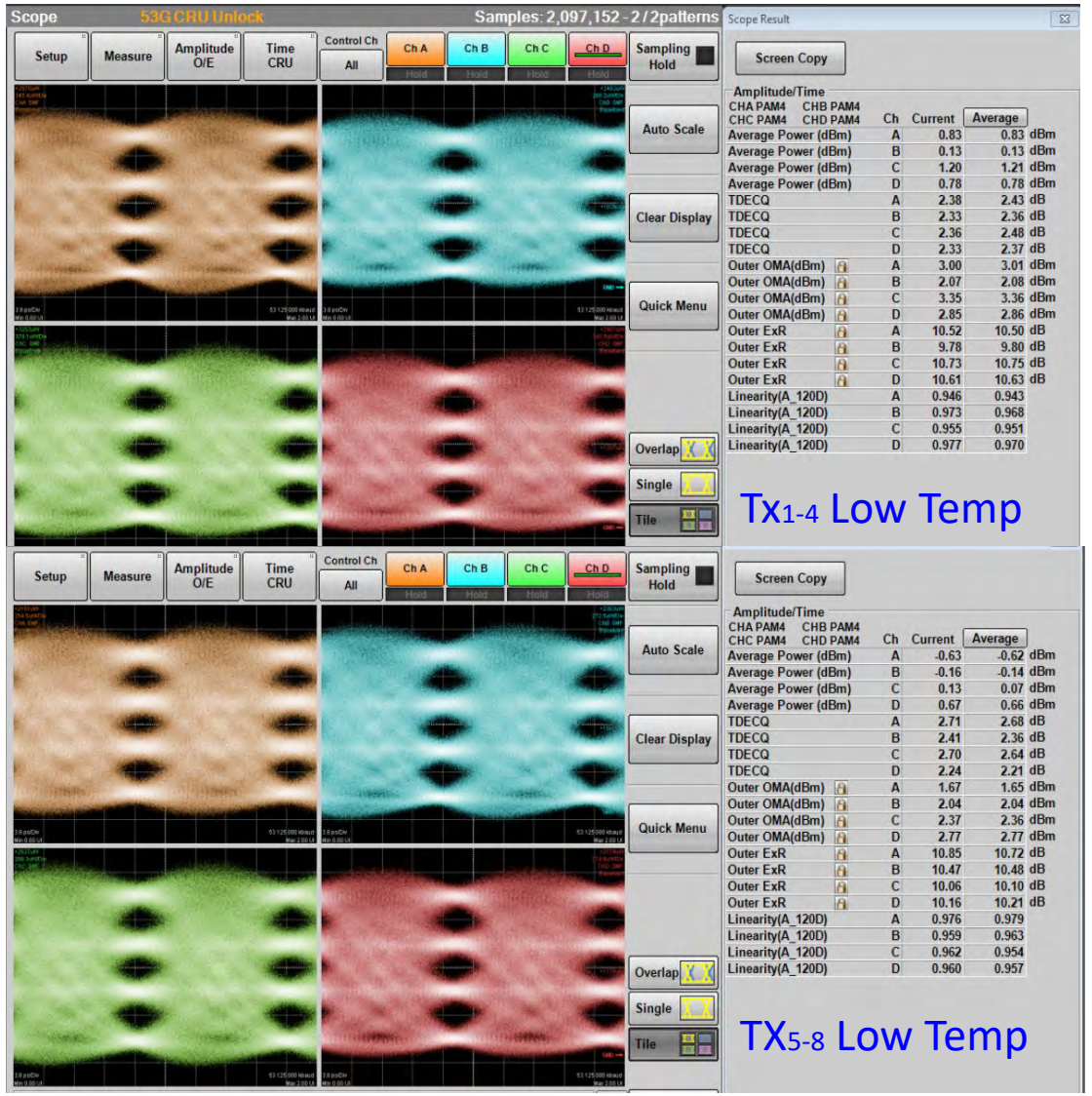


Source– Nathan Tracy, TE Connectivity

Example: 800 Gb/s OSFP Capacity Module

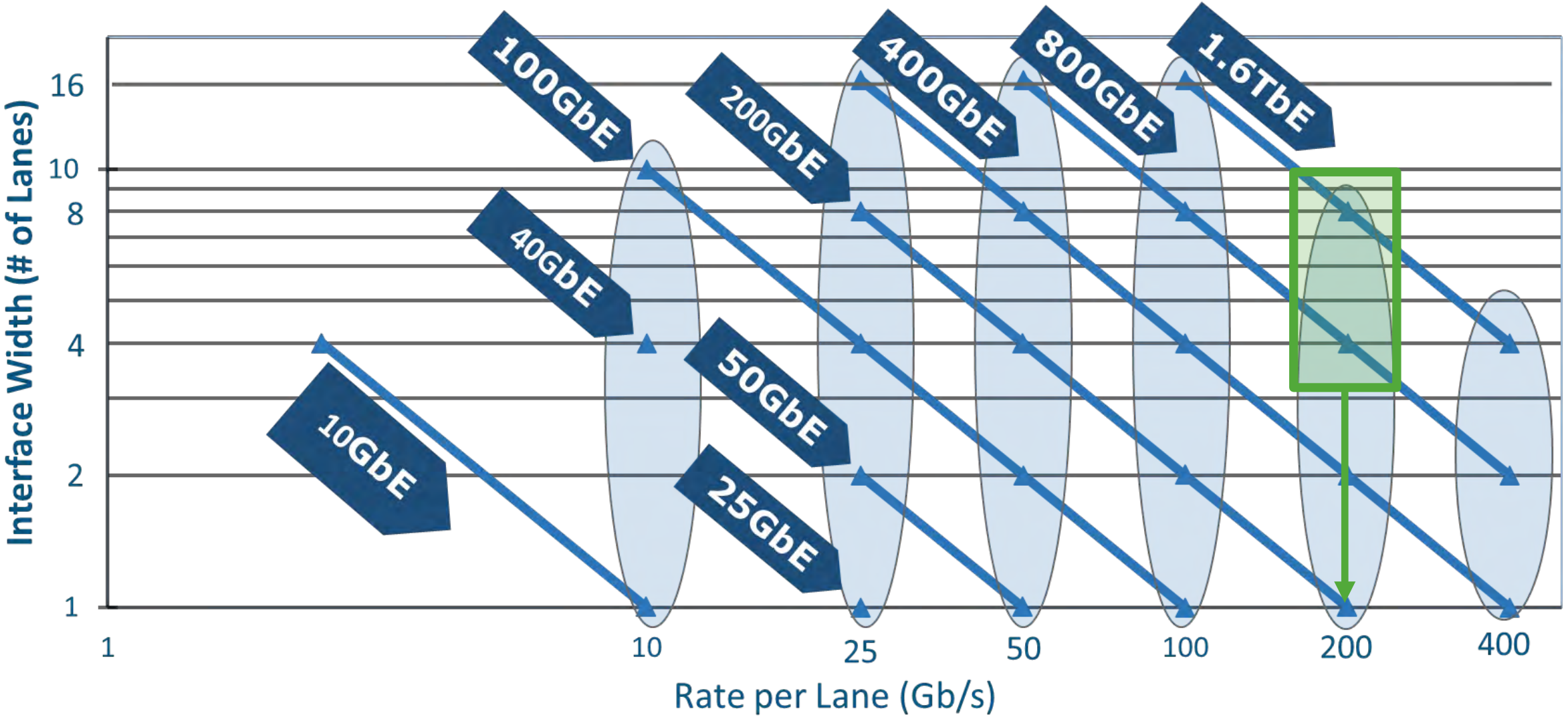


- OSFP Form Factor
- 8x100G DR8+ 2km with MPO-16 and 2x400G FR4 with CS connector
- OIF CEI-112G-VSR interface
- PMD spec follows 400G DR4+ and FR4. interoperable with 400G
- 0~70degC 18W, 10~60C 17W
- 7nm DSP inside



Source – Tedros Tsegaye, Innolight

Beyond 400 GbE - Leveraging 100 Gb/s



Examples of Beyond 100 Gb/s Research

- S. Yamaoka et al., “239.3-Gbit/s net rate PAM-4 transmission using directly modulated membrane lasers on high-thermal-conductivity SiC” in Proceedings of European Conference on Optical Communication (ECOC), 2019/9.
- X. Pang et al., 200 Gbps/lane IM/DD Technologies for Short Reach Optical Interconnects, https://core.ac.uk/download/pdf/289286726.pdf, 2019/04/24.
- W. Heni et al., Ultra-High-Speed 2:1 Digital Selector and Plasmonic Modulator IM/DD Transmitter Operating at 222 GBaud for Intra-Datacenter Applications, https://www.osapublishing.org/jlt/abstract.cfm?URI=jlt-38-9-2734, 2020/9.
- S Lange et al., 100 GBd Intensity Modulation and Direct Detection with an InP-based Monolithic DFB Laser Mach-Zehnder Modulator, Journal of Lightwave Technology, https://www.researchgate.net/publication/319259046_100_GBd_Intensity_Modulation_and_Direct_Detection_with_an_InP-based_Monolithic_DFB_Laser_Mach-Zehnder_Modulator, 2017/8.
- E. Sentieri et al., "12.2 A 4-Channel 200Gb/s PAM-4 BiCMOS Transceiver with Silicon Photonics Front-Ends for Gigabit Ethernet Applications," 2020 IEEE International Solid- State Circuits Conference - (ISSCC), San Francisco, CA, USA, 2020, pp. 210-212, doi: 10.1109/ISSCC19947.2020.9062992.
- T. Wettlin et al., "Beyond 200 Gb/s PAM4 transmission using Tomlinson-Harashima precoding," 45th European Conference on Optical Communication (ECOC 2019), Dublin, Ireland, 2019, pp. 1-4, doi: 10.1049/cp.2019.0834.

200 Gb/s Signaling – The Next Generation?

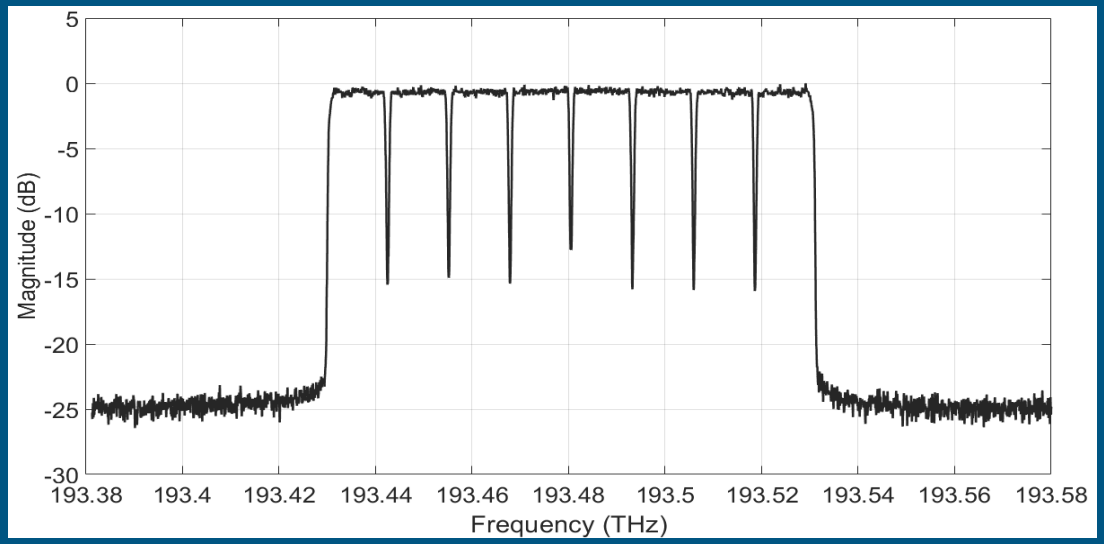
- **OIF CEI 224G**
  - **Use of 200 Gb/s enables a new generation of 200 GbE / 400 GbE solutions related to the breakout of the physical media for "Beyond 400 GbE" physical layer specifications**

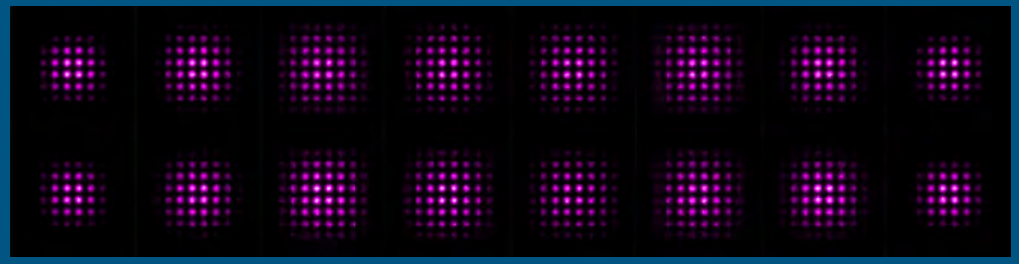
800 Gb/s Single Wavelength Transmission

The Future of Coherent is emerging ….

- **Successful trial of 800 Gb/s single-wave transmission over 950 km - *https://bit.ly/2Wdkh8e***
- **Platform supporting 200 Gb/s to 800 Gb/s single-carrier - *https://bit.ly/2KLpW05***
- **"Industry's first 800G tunable ultra-high-speed optical module" *https://bit.ly/2yTYNFK***
- **"Verizon says it has successfully transmitted an 800-Gb/s wavelength on its live network" - *https://bit.ly/3d2GX1M***

800 Gb/s single wavelength transmission over 730km in real world long-haul network





8 subcarrier constellation

https://www.lightreading.com/optical-ip/infinera-windstream-tout-optical-networking-milestone/d/d-id/761738

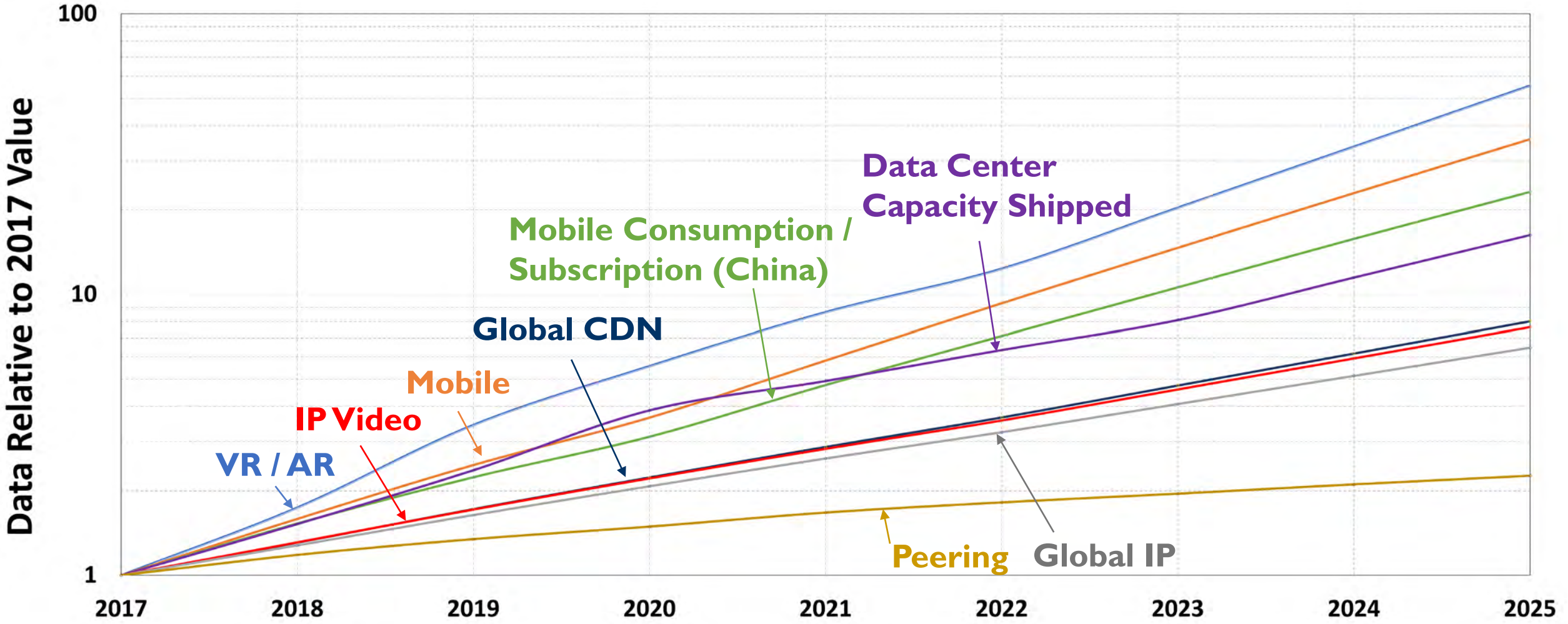
Source – Ted Sprague, Infinera

SUMMARY

- A path to Beyond 400 GbE exists
- Leverage 100 Gb/s building blocks
- 800 GbE building blocks and example available now
- Plausible implementations for today and next generation
- 800 Gb/s over a single wavelength for DWDM systems is emerging now

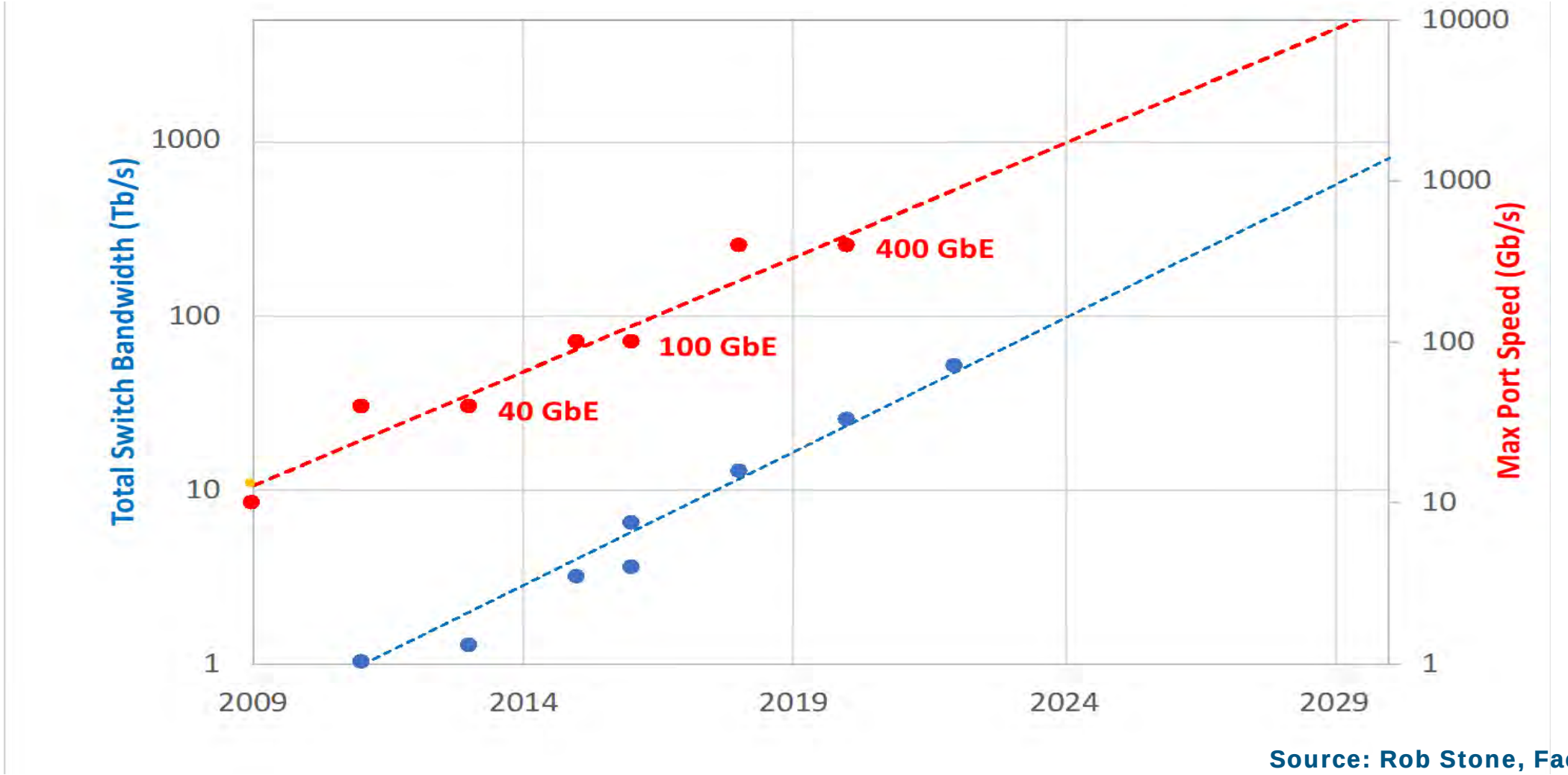
BEYOND 400 GbE
WHY NOW?

The 2020 Ethernet Bandwidth Assessment



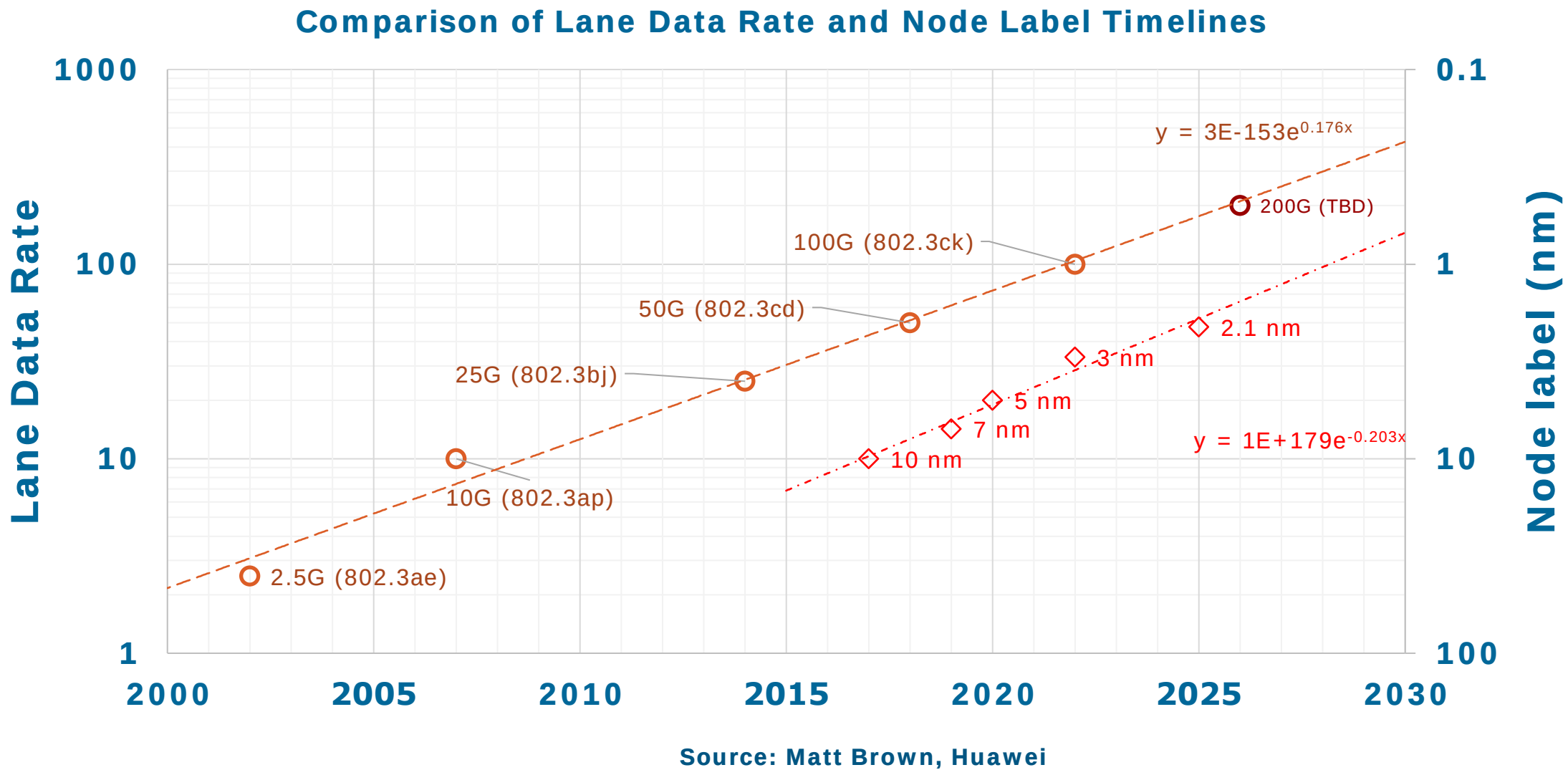
Source: https://bit.ly/802d3bwa2

TRENDLINE – SWITCH CAPACITY



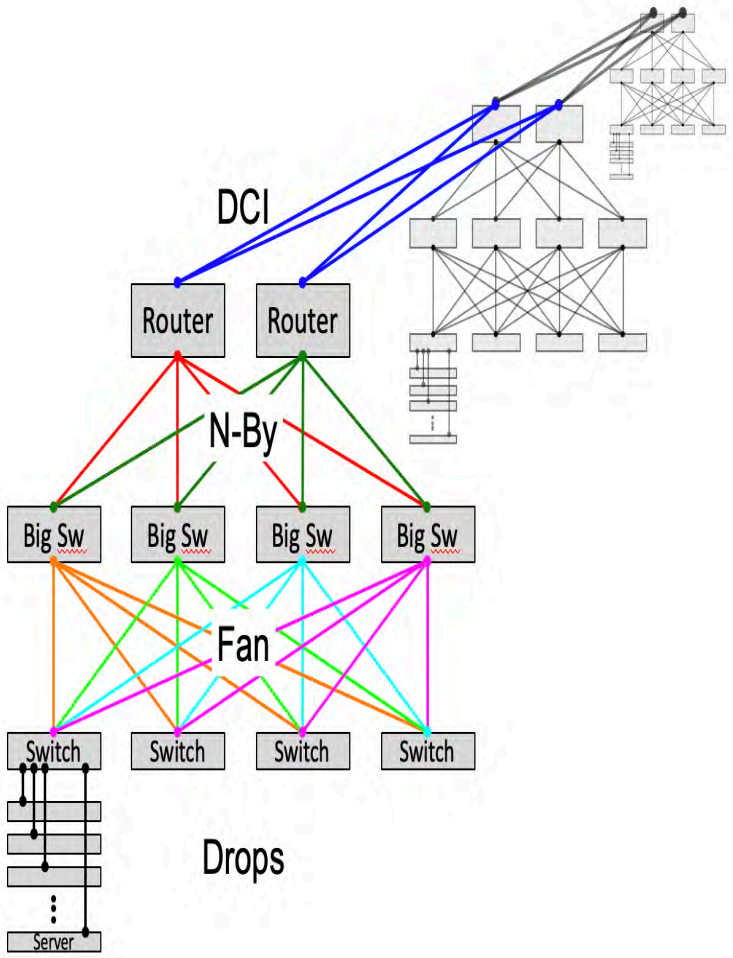
Source: Rob Stone, Facebook

TRENDLINE – SERDES DEVELOPMENT



Source: Matt Brown, Huawei

What is needed?



Beyond 400GbE (Serial)	80km	SMF	DWDM
Beyond 400GbE (Parallel)	2km to 40 km	SMF	Duplex Fiber
	50m to 500m	SMF MMF	Parallel Cable (Breakout)
> 100 GbE	< 30m	MMF Twin Axial	

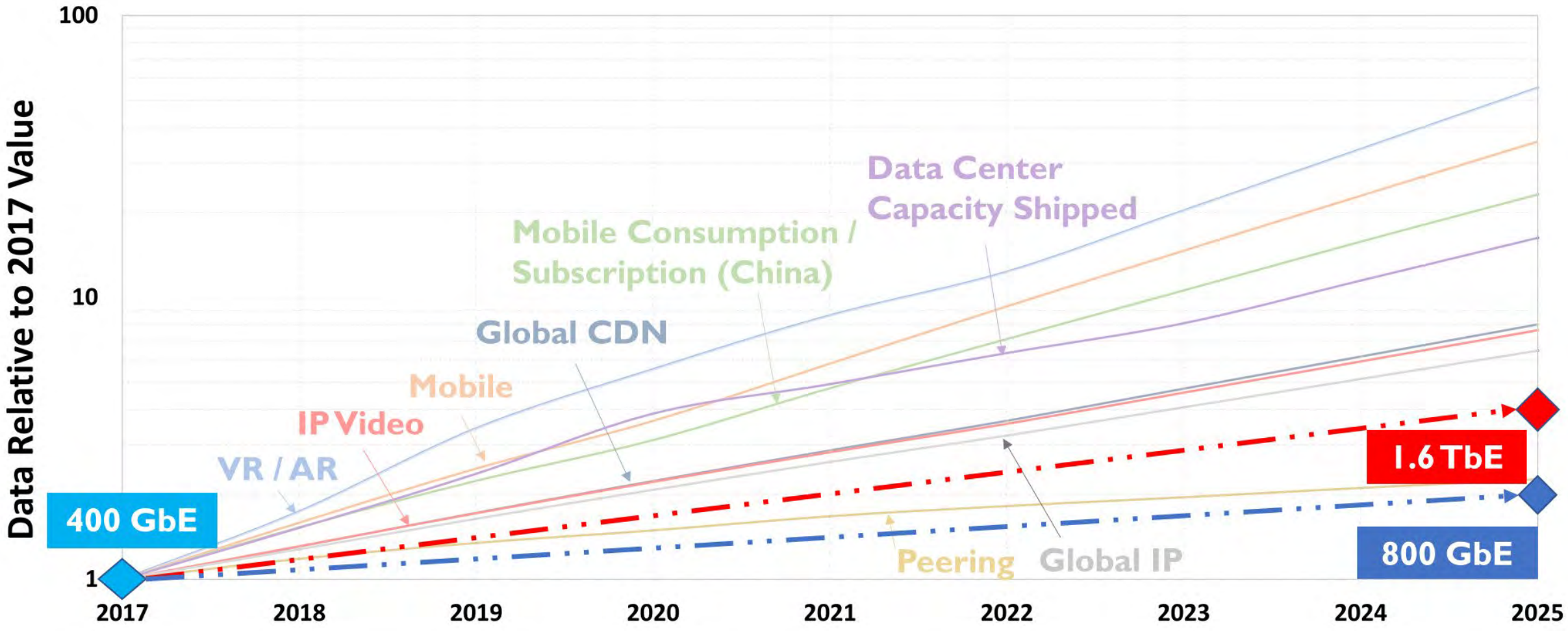
Coherent

Direct Detect

Beyond 400 GbE C2C / C2M AUI Development

Courtesy Jim Theodoras, HG Genuine

CONSIDERING THE NEXT ETHERNET RATE STANDARD



Source: https://bit.ly/802d3bwa2

SUMMARY

- Bandwidth –
  - Underlying factors all indicate continued growth
  - Exponential growth continues!
- New bandwidth generating applications constantly being introduced
  - Mobile (5G) / Video
  - Artificial Intelligence
  - Virtual / Augmented Reality
- Today's world stressing the need for connectivity and bandwidth
- Last two "Higher Speed" efforts (from CFI to standard ratification)
  - 40 / 100 GbE – 3 years, 11 months
  - 200 / 400 GbE – 4 years, 9 months
- There is some time between standard ratification and product introduction
  - The bandwidth problem will only continue to grow
- We need to begin the process to study the problem! Big questions to consider
  - Next speed or speeds?
  - What physical layer specifications?

Supporters (as of 8/24/20)

Vipul	Bhatt	II-VI Incorporated
Leon	Bruckman	Huawei
John	D'Ambrosia	Futurewei, U.S. Subsidiary of Huawei
Bob	Grow	RMG Consulting
Mark	Gustlin	Cisco
Cedric	Lam	Google
Earl	Parsons	CommScope
Rob	Stone	Facebook
Tomoo	Takahara	Fujitsu
Jim	Theodoras	HG Geuine USA
Yangling	Wen	Futurewei
Xiang	Zhou	Google

STRAW POLLS

Call-for-interest

- Should a Study Group be formed for ……
  - TBD (Study Group Scope in definition at this time)

- YES
- No
- Abstain

- Room Count

participation

- I would participate in the “TBD” Study Group in IEEE 802.3

  Tally:

- I believe my company would support participation in the “TBD” Study Group in IEEE 802.3

  Tally:

Future work

- Ask 802.3 WG for approval
- If approved, request formation of “TBD” Study Group by 802 EC
- If approved,
  - Creation of Study Group page
  - First “TBD” Study Group anticipated for Jan 21 Interim

THANK YOU!