THE FINDINGS OF THE IEEE 802.3 INDUSTRY CONNECTIONS NEW ETHERNET APPLICATIONS AD HOC:

ETHERNET BANDWIDTH ASSESSMENT, PART II

IEEE 802 MARCH 2020 PLENARY

ATLANTA, GA, USA

MARCH 16, 2020

DRAFT PRESENTATION

PRESENTERS

- John D'Ambrosia, Futurewei Technologies, U.S. Subsidiary of Huawei
- TBD

AGENDA

- Introduction
- Findings
  - Users
  - Access Rates & Methods
  - Services
  - Bandwidth Explosion
- Summary

DISCLAIMERS

- This presentation is a supplement to the IEEE Industry Connections Ethernet Bandwidth Assessment, Part 2, D1.2, which is pending final approval (this week) by the IEEE 802.3 Working Group
- All contributed information is solely the perspective of the respective contributors.
- The views expressed in the Assessment solely represent the views of the IEEE 802.3 Working Group, and do not necessarily represent a position of the IEEE, the IEEE Standards Association, or IEEE 802.

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INTRODUCTION

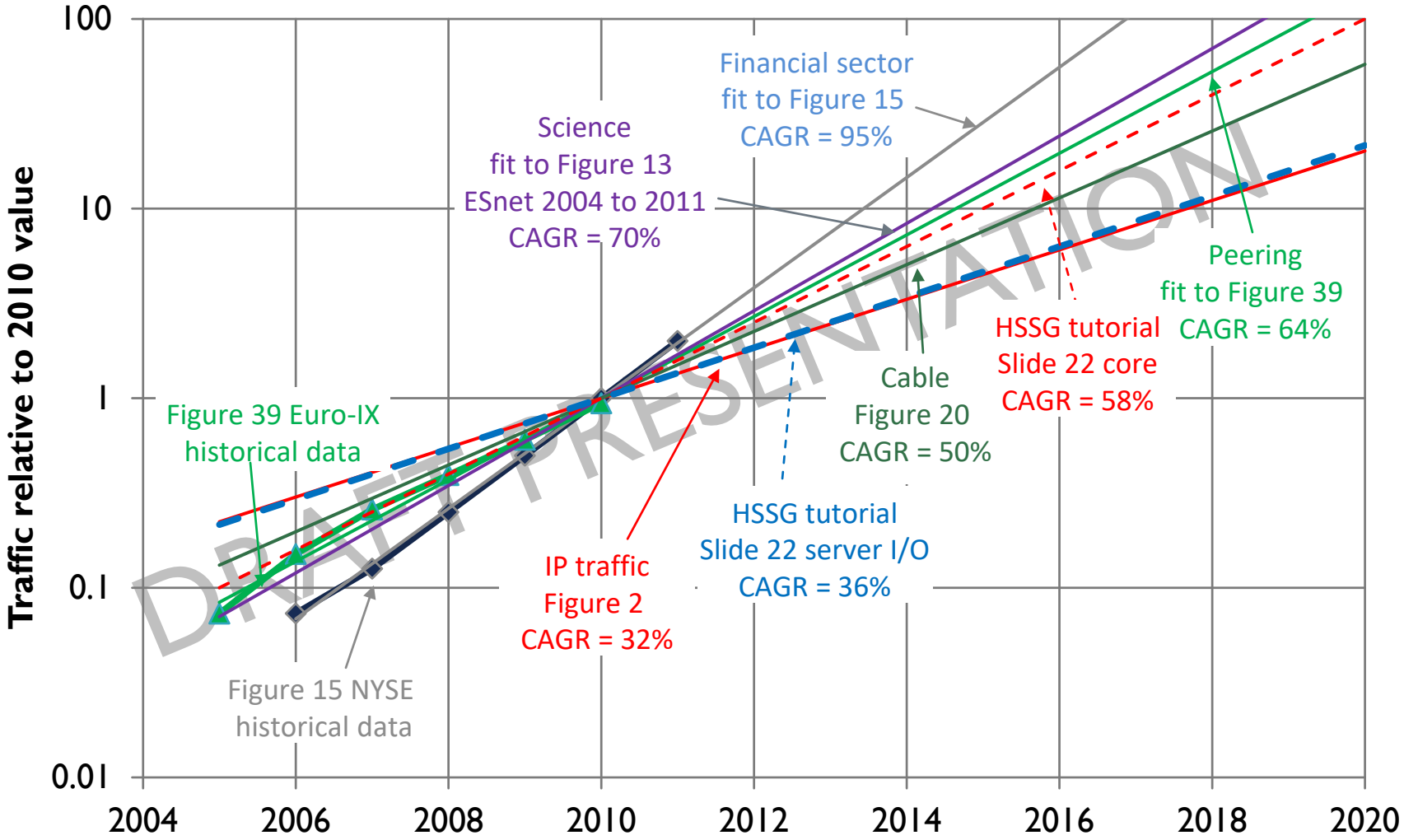
Why Higher Speed Ethernet?

Fundamental bottlenecks are happening everywhere

Increased # of users	+	Increased access rates and methods	+	Increased services	=	Bandwidth explosion everywhere
As demonstrated by the number of ISPs: Comcast, AOL, YahooBB, NTT, Cox, EasyNet, Rogers, BT, …		EFM, xDSL, WiMax, xPON, Cable, WiFi, 3G/4G…		YouTube, BitTorrent, VOD, Facebook, Kazaa, Netflix, iTunes, 2nd life, Gaming…		

The basic equation has remained the same

IEEE 802.3 ETHERNET BANDWIDTH ASSESSMENT (2012)



September 2018

What are the bandwidth trends now?

ETHERNET BANDWIDTH ASSESSMENT WEB & REFLECTOR INFORMATION

- **Charter and Scope**
  - **Evaluate Ethernet wireline bandwidth needs of the industry**
  - **Reference material for a future activity**
  - **The role of this ad hoc is to gather information, not make recommendations or create a CFI**

- **Webpage -** http://www.ieee802.org/3/ad_hoc/bwa/index.html
- **Reflector -** http://www.ieee802.org/3/ad_hoc/bwa/reflector.html
- **Public request for data -** http://www.ieee802.org/3/ad_hoc/bwa/public/anslow_01a_0411.pdf

ASSESSMENT LIMITATIONS

- Assessment Duration: 18 months maximum
  - One year for information gathering (Sept 2018 – Sept 2019)
  - All potential application spaces may not have been studied
  - Prevent data from becoming dated
  - Information provided snapshot at time of submission
- Past trends may not be an accurate predictor of the future
  - Emerging applications
  - Technology
  - Standardization Efforts
  - Will Ethernet cost per gigabit continue to decrease?
- Underlying assumptions
  - Market adoption
  - Continuation of applications that require increasing bandwidth

SUMMARY OF DATA SUBMISSIONS (1 OF 2)

1. John D'Ambrosia, Futurewei
   - "Introduction – Ethernet Bandwidth Assessment, Part II"
     - http://www.ieee802.org/3/ad_hoc/ngrates/public/18_09/dambrosia_bwa_01_0918.pdf
   - "Available Industry Data"
     - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0611/dambrosia_bwa_01a_190611.pdf
   - "Review of Networks in PeeringDB"
     - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0827/dambrosia_bwa_01a_190827.pdf
   - "Email Summary of Published Reports on Broadband Findings"
     - American Broadband Initiative, "Milestones Report, February 2019" https://broadbandusa.ntia.doc.gov/sites/default/files/resource-files/american_broadband_initiative_milestones_report_feb_2019_0.pdf
     - European Commission, "Connectivity- Broadband market developments in the EU" https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=60010
     - European Court of Auditors, "Broadband in the EU Member States" https://www.eca.europa.eu/Lists/ECADocuments/SR18_12/SR_BROADBAND_EN.pdf
   - Email - Inclusion of Mobile Network Data Submitted to the B10K Study Group
     - http://www.ieee802.org/3/ad_hoc/bwa2/email/msg00064.html
2. Wenyu Zhao, CAICT," Broadband Development Status and Trend in China"
   - http://www.ieee802.org/3/ad_hoc/ngrates/public/18_11/zhao_nea_01_1118.pdf

SUMMARY OF DATA SUBMISSIONS (2 OF 2)

3. Steve Carlson, High Speed Design, Inc, "Trends in Automotive Networks"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0402/carlson_bwa_01_190402.pdf
4. Mark Laubach, Broadcom, "Future EPON Bandwidth Needs"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0402/laubach_bwa_01_190402.pdf
5. Vladmir Kozlov, LightCounting, "Traffic Growth in Telecom Networks and Mega DataCenters"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0409/kozlov_bwa_01_190409.pdf
6. Mark Nowell, Cisco, "CISCO VNI Forecast Update"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf
7. Christoph Dietzel, "The European IXP Scene"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0709/dietzel_bwa_01b_190709.pdf
8. Guo, Liang, "Next Generation Data Center Connections in China"
   - http://www.ieee802.org/3/ad_hoc/ngrates/public/19_09/guo_bwa_01_0919.pdf
9. Baron Fung, Sameh Boujelbene, Shin Umeda, Dell'Oro, "Data Center Ethernet Switch and Server Bandwidth Assessment for IEEE"
   - http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0927/fung_bwa_01a_190927.pdf.

ACKNOWLEDGEMENTS

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- Cisco VNI Forecast reprinted with permission from Cisco, Cisco Visual Networking Index (VNI) Complete Forecast Update, 2017–2022, 2018 Global Presentation, ©2018.

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FINDINGS

INFORMATION GATHERING APPROACH

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

Information gathering focused on each aspect of this equation

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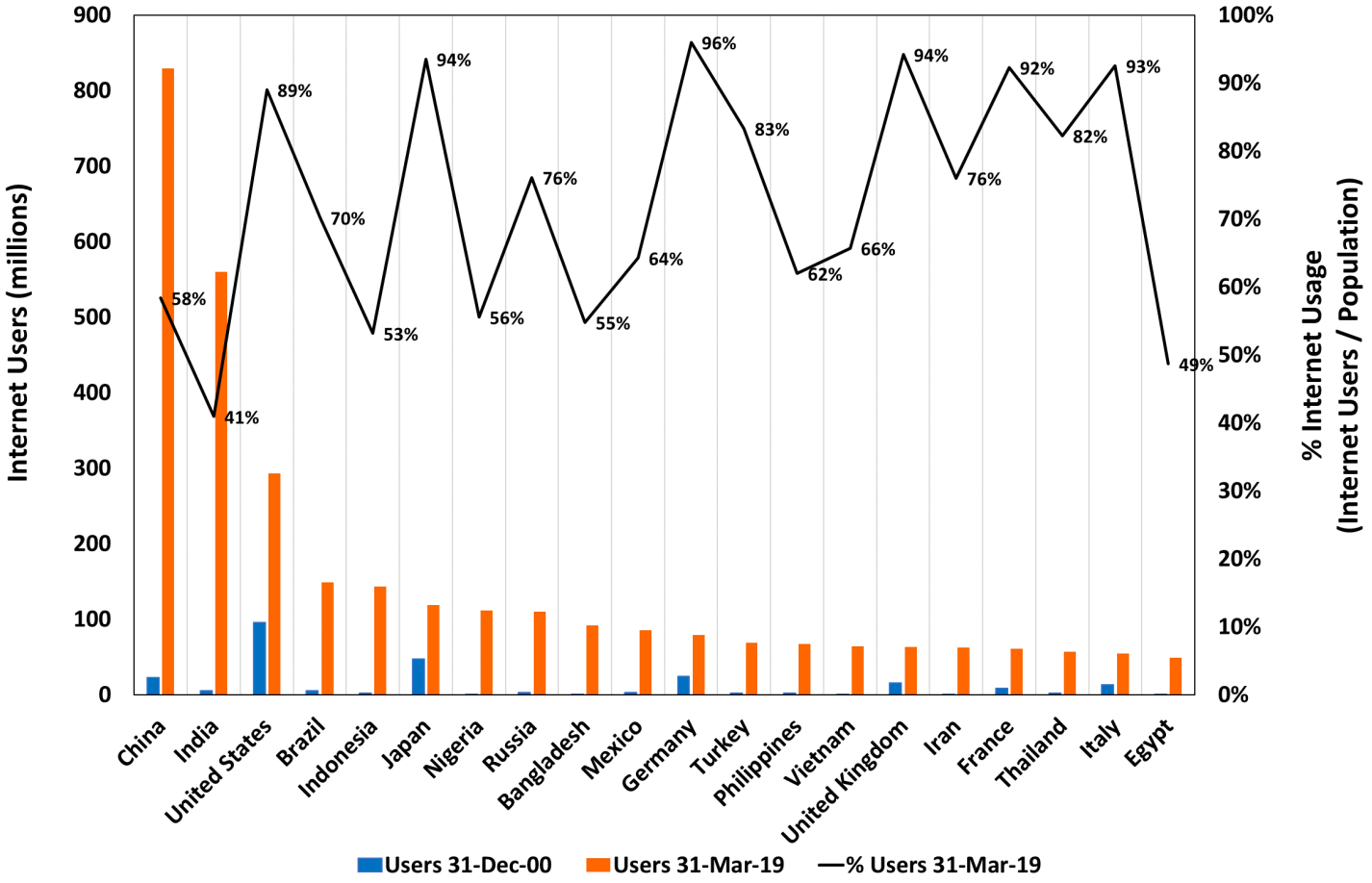
USERS

INTERNET WORLD STATISTICS

	Total World	Top 20 Countries	Rest of the World
Population	7,716,223,209	5,187,499,066	2,565,984,143
Internet Users	4,383,810,342	3,117,533,898	1,229,027,955
Internet Usage	57%	60%	48%

Source: Internet World Stats (as of 31 March 2019)
https://www.internetworldstats.com/stats.htm

INTERNET USAGE – TOP 20 COUNTRIES

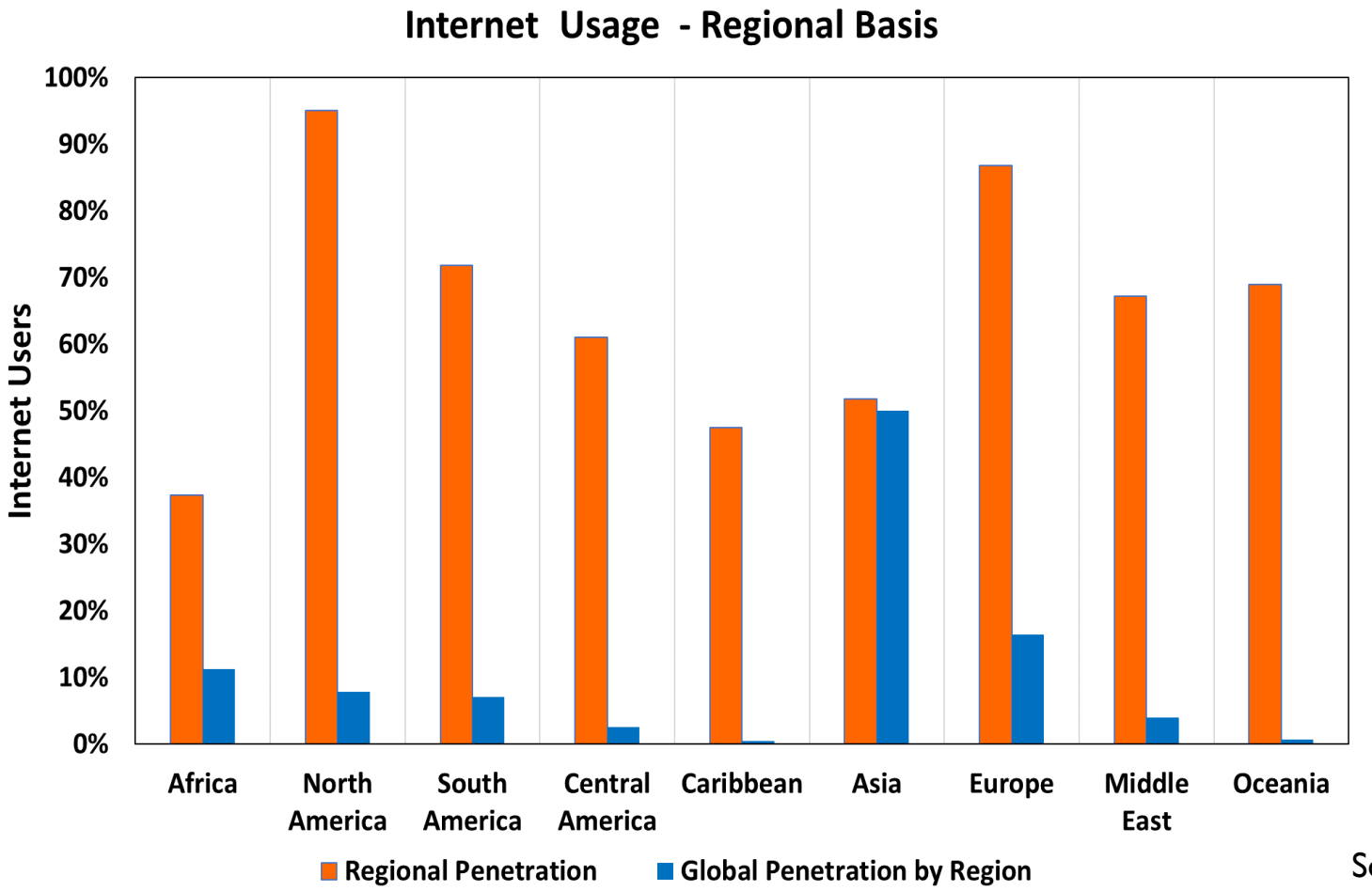


Observations

- Only 8 countries had at least 80% connectivity
- ≈2 billion people in Top 20 countries remain to be connected
- China had the largest number of internet users (829 million), but only 58% of the population was connected
- India has the second largest number of internet users (560 million), but only 41% of the population was connected

Source: Internet World Stats (as of 31 March 2019)
https://www.internetworldstats.com/stats.htm

INTERNET USAGE – REGIONAL BASIS

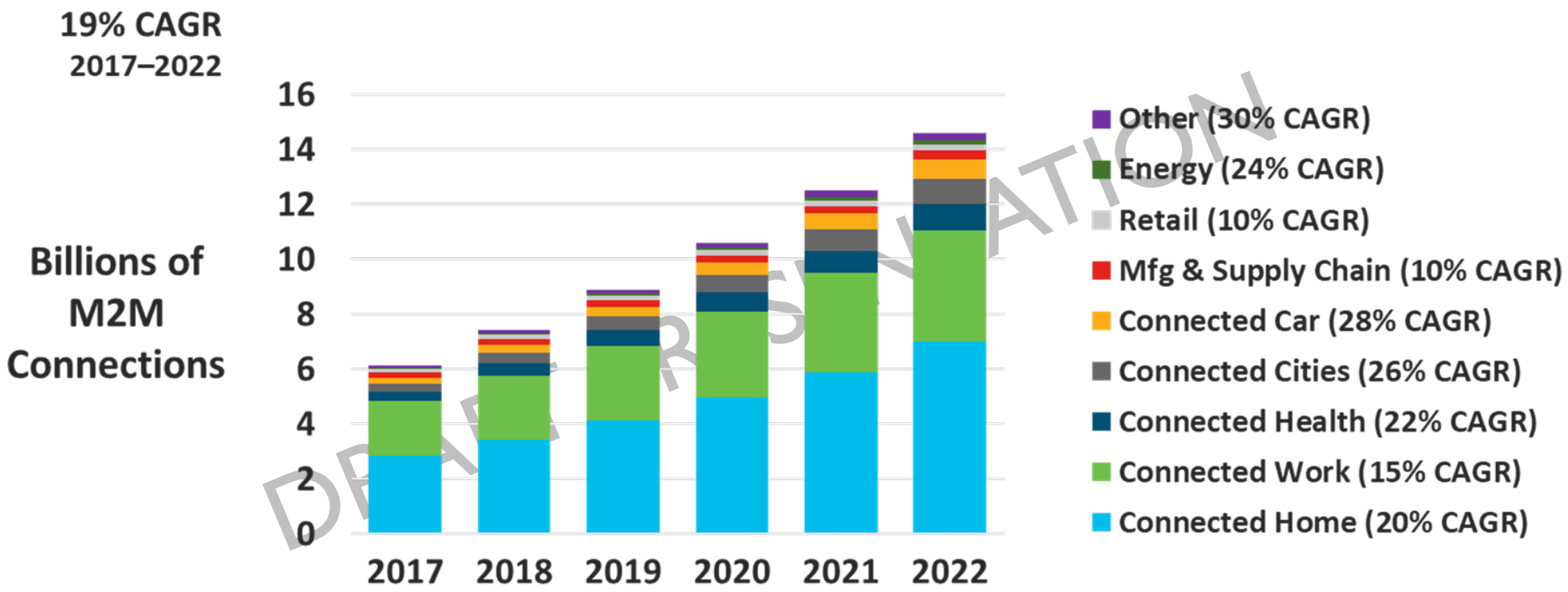


Observations

- Connectivity varies greatly on regional basis
- Asia accounts for 50% of the world's internet users, but only 52% of the region is connected.

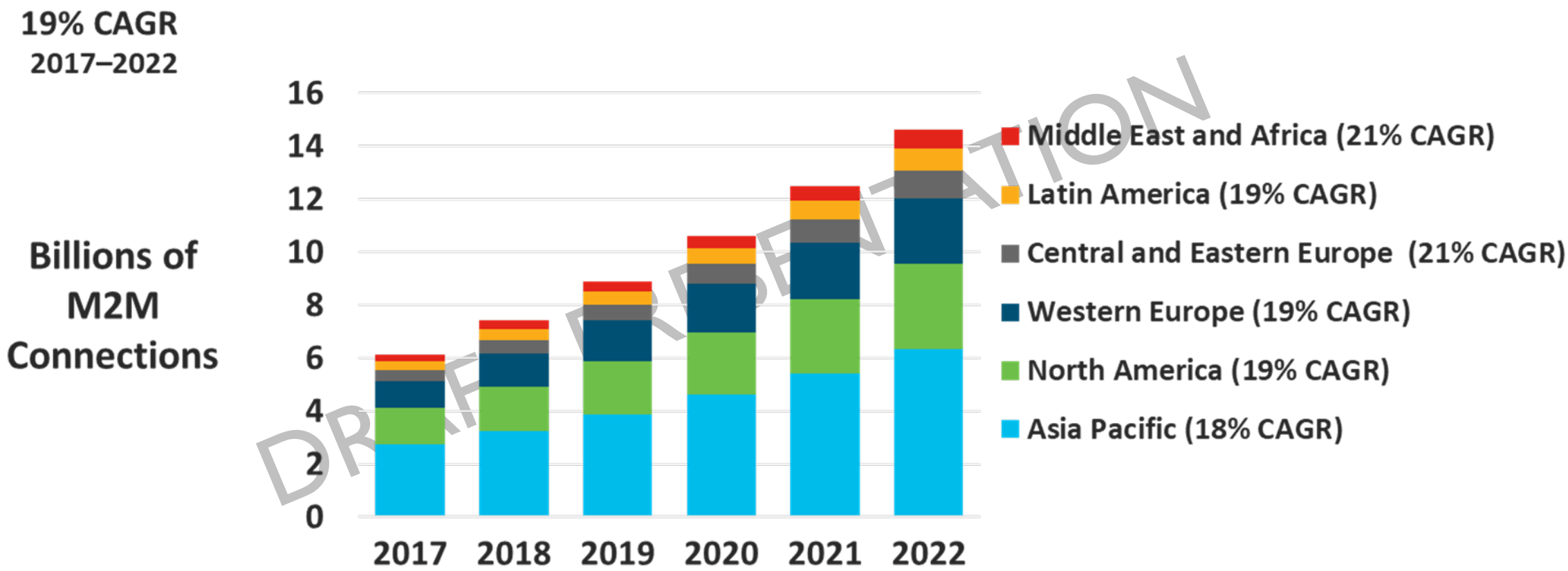
Source: Internet World Stats (as of 31 March 2019)
https://www.internetworldstats.com/stats.htm

GLOBAL M2M CONNECTIONS BY VERTICAL



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

GLOBAL M2M CONNECTIONS BY GLOBAL REGION

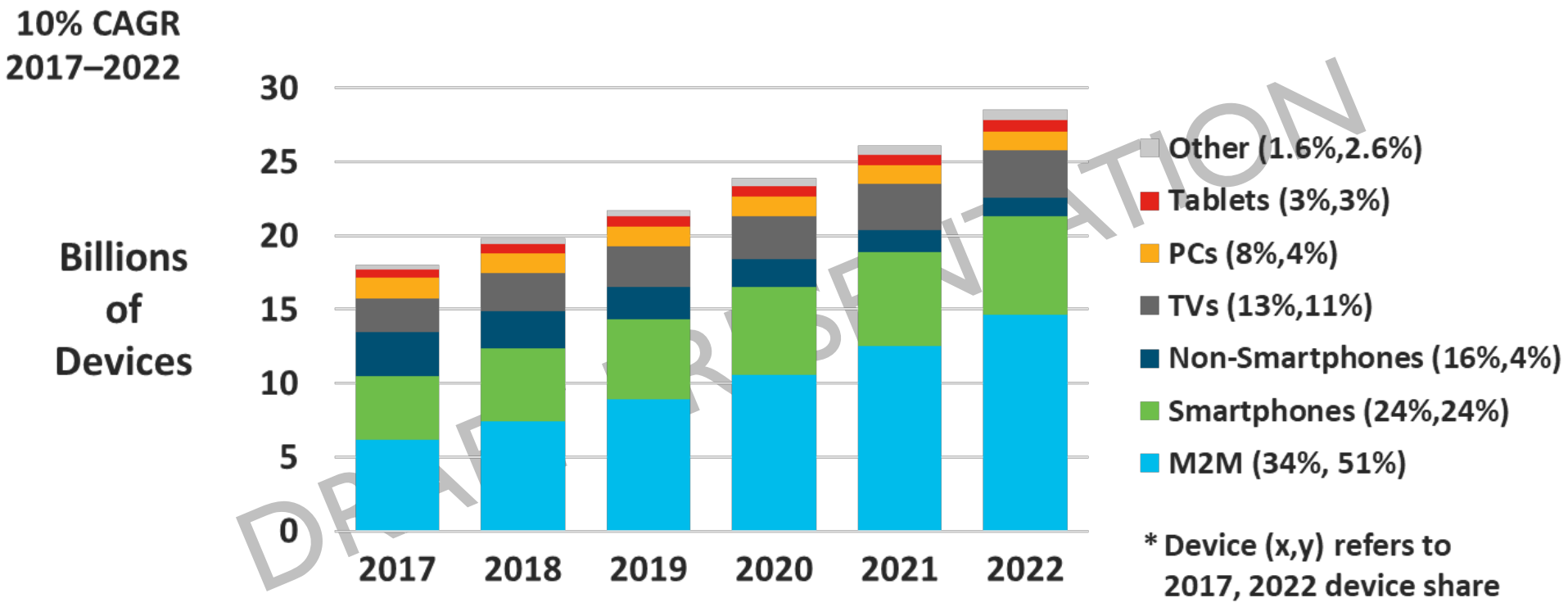


Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

SUMMARY - USERS

ACCESS RATES & METHODS

GLOBAL DEVICE / CONNECTION GROWTH



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

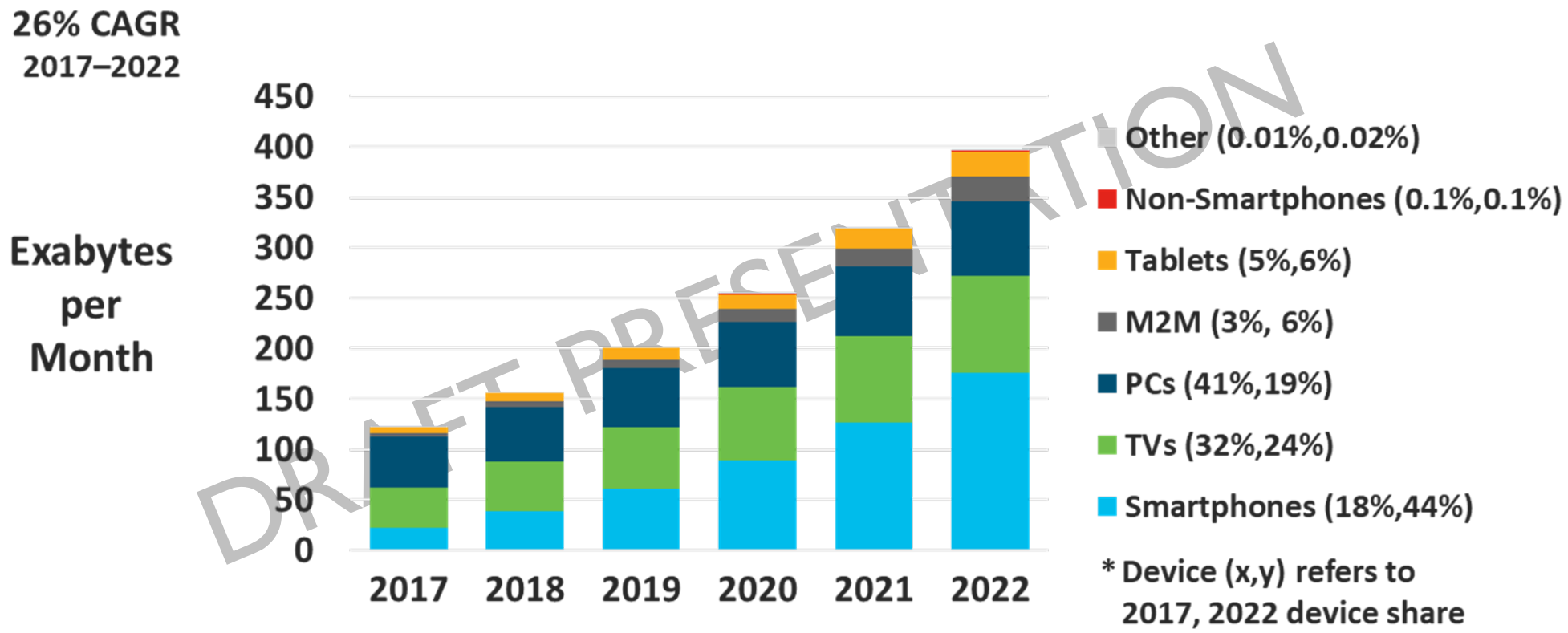
TRENDS

	2017	2022	Growth
Avg # of Devices / Connections per Capita	2.4	3.6	50%
Avg # of Devices / Connections per Household *	6.4	9	41%

* Note - only includes consumer devices and connections

	2017	2022	Growth
Average Traffic per User per Month	29 GB	85 GB	193%
Average Traffic per Household per Month	82 GB	240 GB	193%

GLOBAL IP TRAFFIC PER DEVICE TYPE



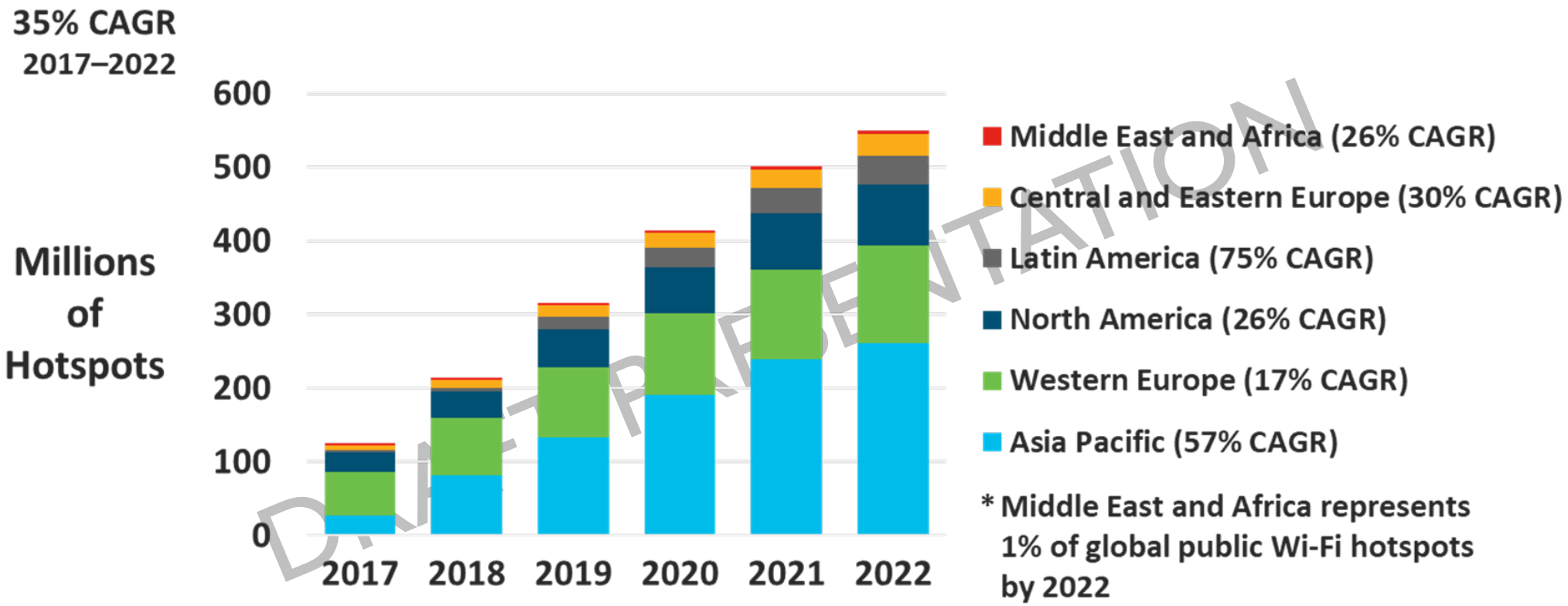
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

GLOBAL DEVICE / CONNECTION GROWTH

	Fixed Broadband				Wi-Fi (Avg)				Cellular (Avg)		
In Mb/s	2017	2022	CAGR		2017	2022	CAGR		2017	2022	CAGR
Global	39.0	75.4	14.1%		24.4	54.2	17.3%		8.7	28.5	26.8%
By Region											
Asia Pacific	46.2	98.8	16.4%		26.7	63.3	18.8%		10.6	28.8	22.1%
Latin America	11.7	28.1	19.2%		9	16.8	13.3%		4.9	17.7	29.3%
North America	43.2	94.2	16.9%		37.1	83.8	17.7%		16.3	42	20.8%
Western Europe	37.9	76.0	14.9%		25	49.5	14.6%		16	50.5	25.8%
Central and Eastern Europe	32.8	46.7	7.3%		19.5	32.8	11.0%		10.1	26.2	21.0%
Middle East & Africa	7.8	20.2	21.0%		6.2	11.2	12.6%		4.4	15.3	28.3%

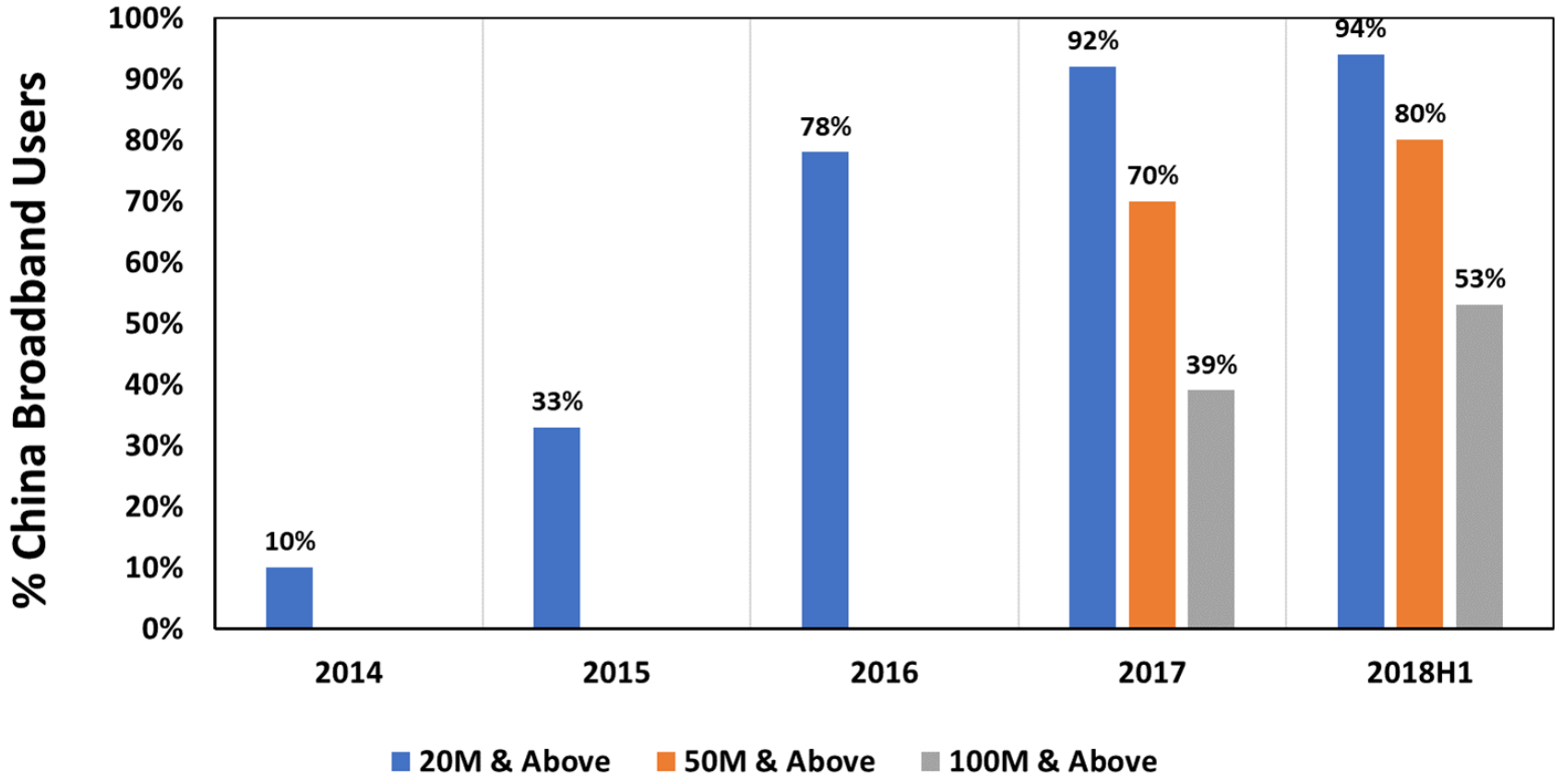
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

GLOBAL PUBLIC WI-FI HOTSPOTS



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

CHINA BROADBAND ACCESS RATES



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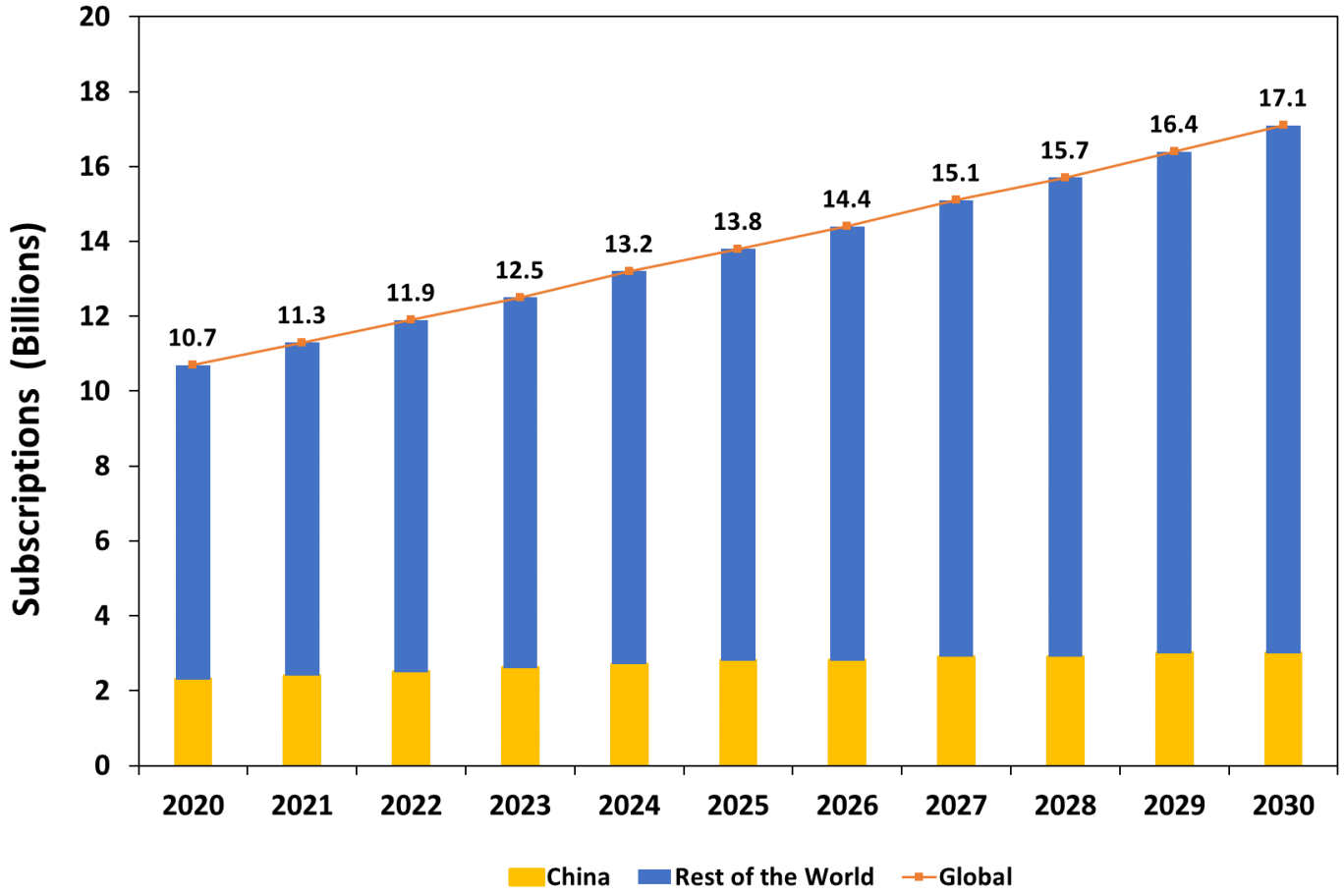
MOBILE SUBSCRIPTIONS



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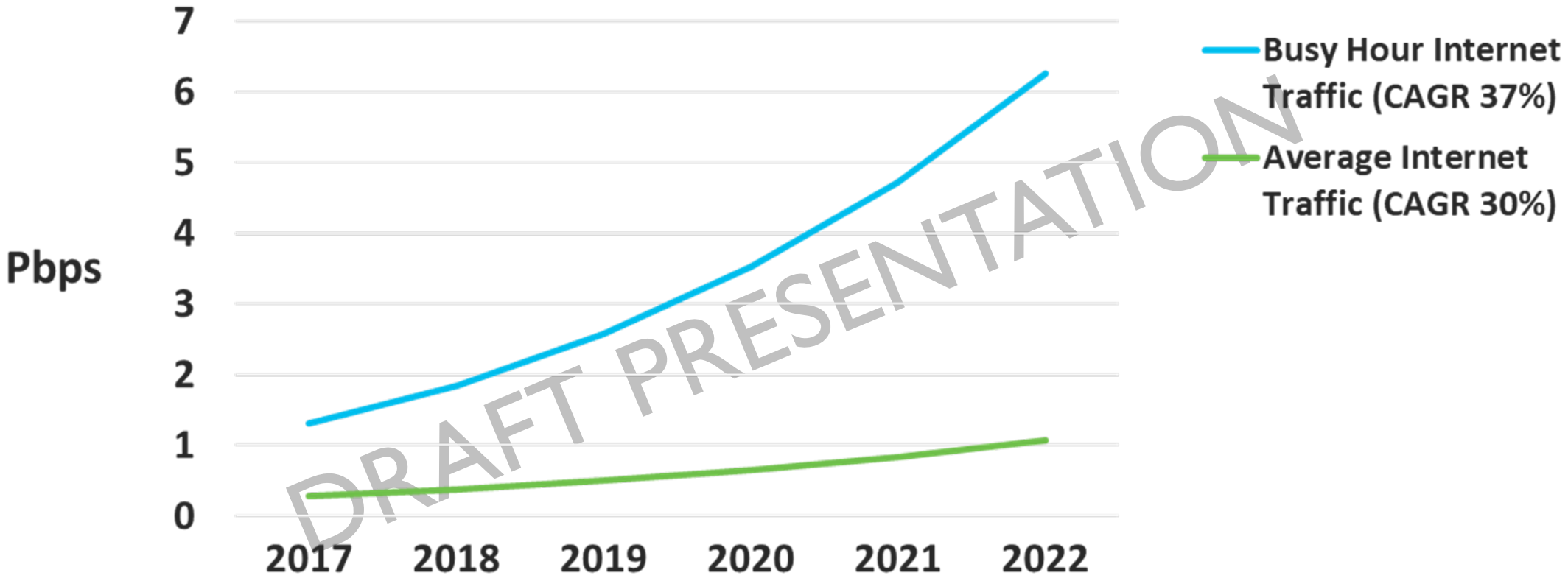
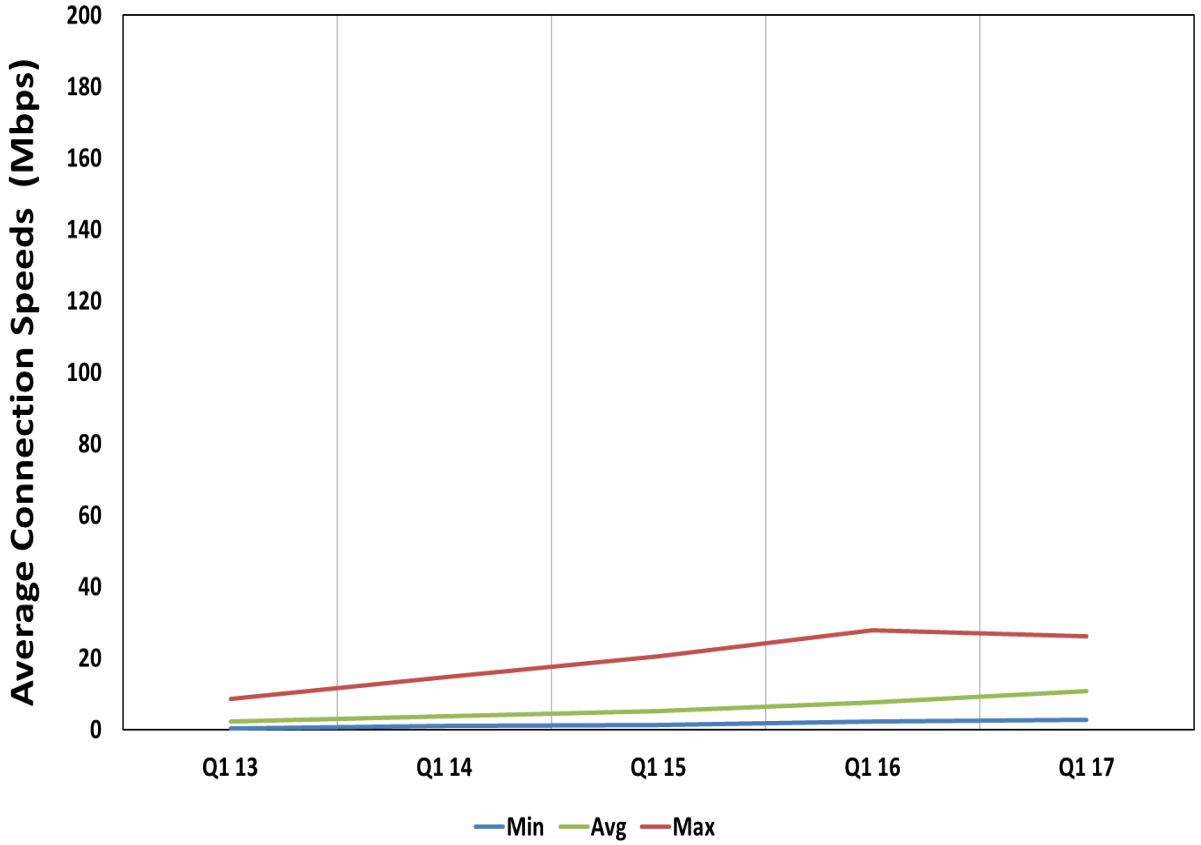
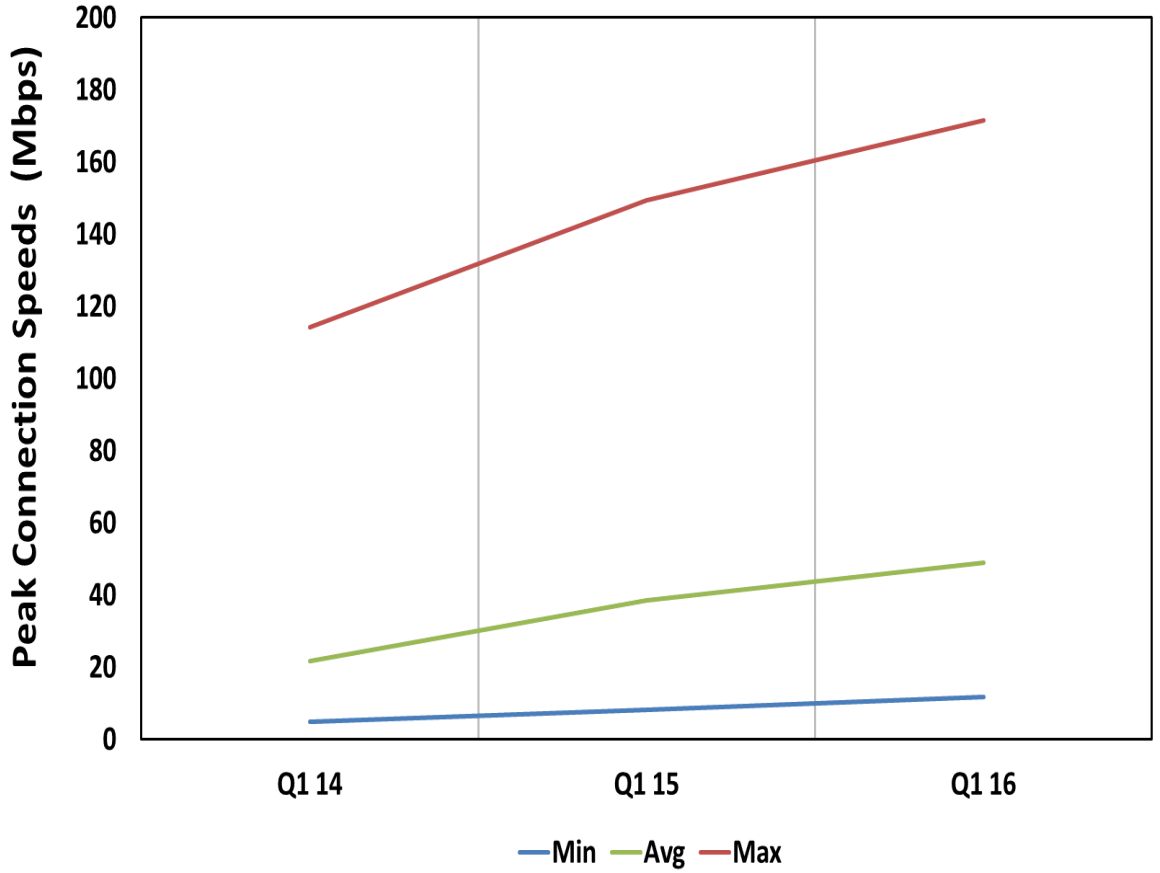
GLOBAL BUSY-HOUR VS AVERAGE HOUR INTERNET TRAFFIC



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

MOBILE NETWORK CONNECTION SPEEDS – ≈ 90 COUNTRIES





Source: Summary of data from Akamai from "Available Industry Data", http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0611/dambrosia_bwa_01a_190611.pdf

FINDINGS: ACCESS RATES AND METHODS

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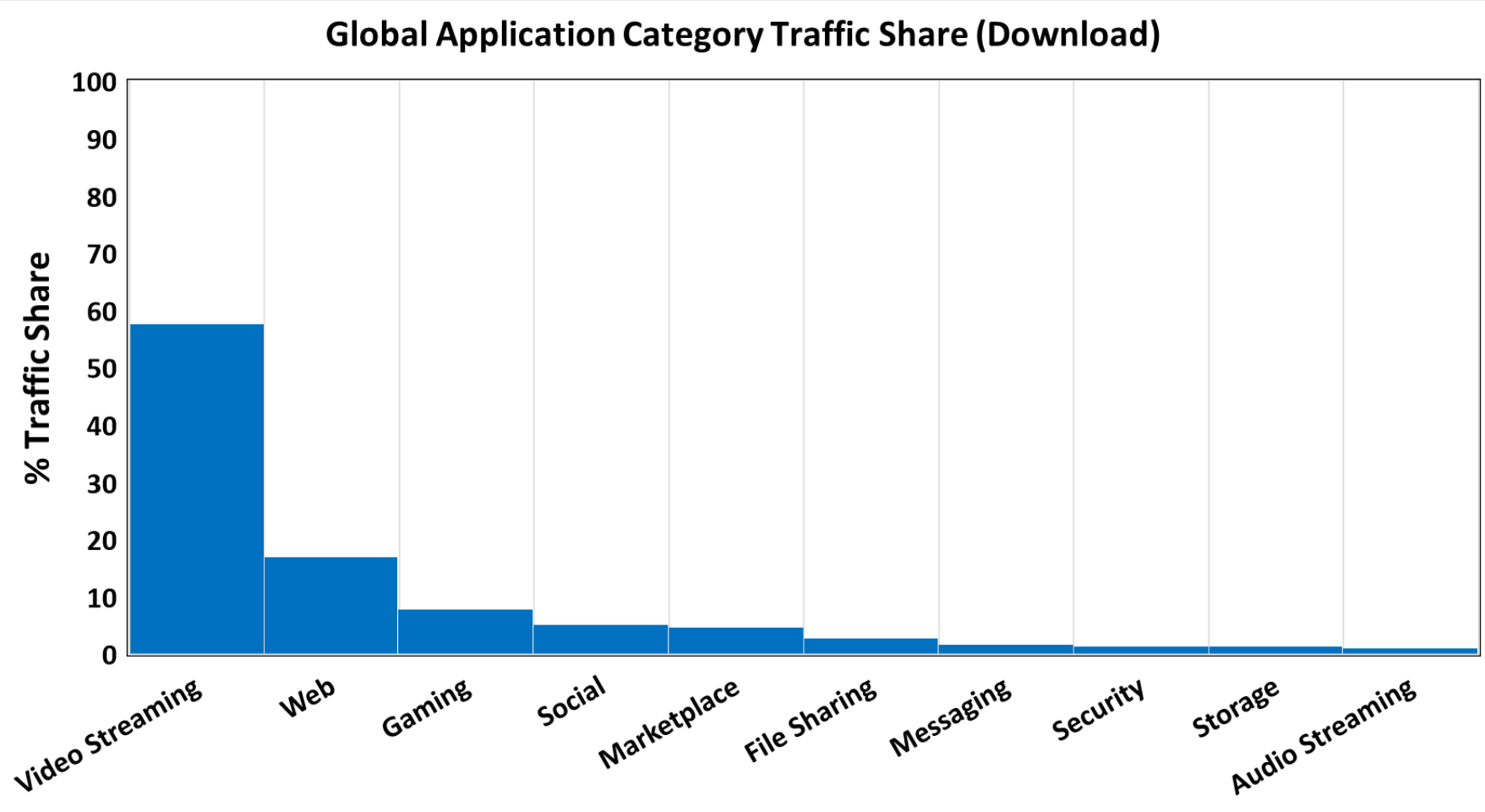
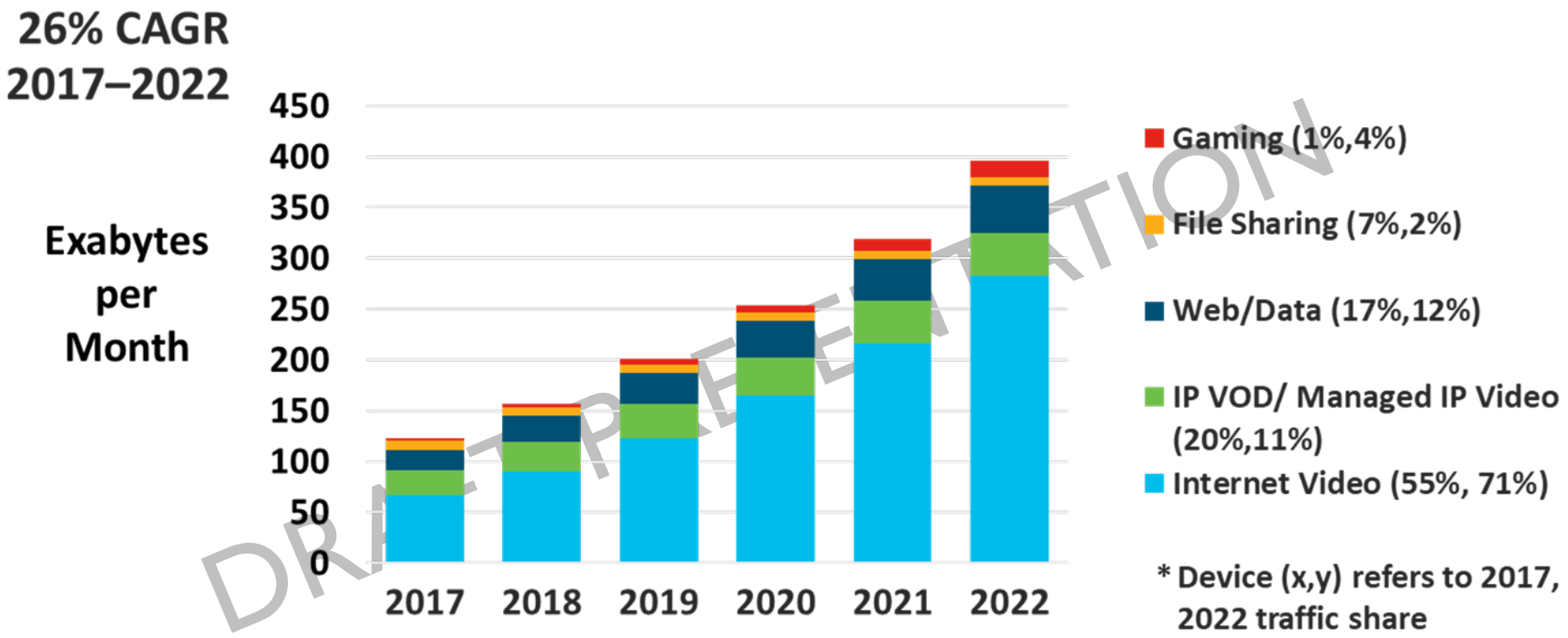
SERVICES

GLOBAL APPLICATION CATEGORY TRAFFIC (DOWNLOAD)



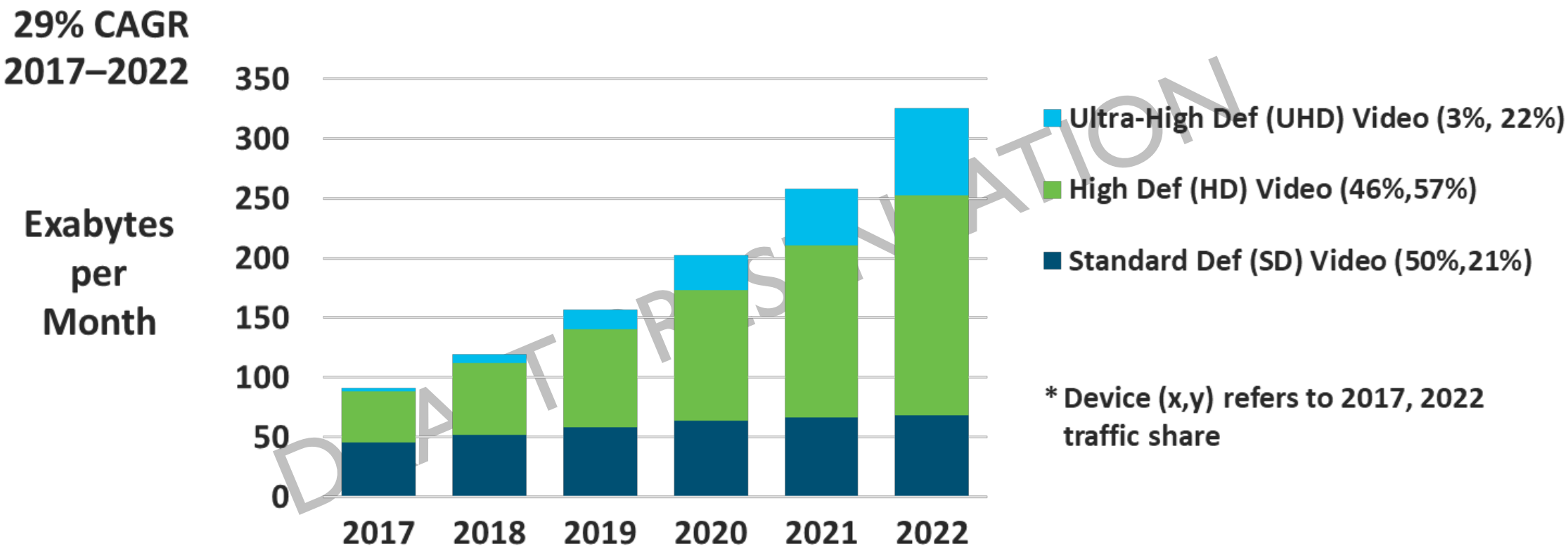
Source: Summary of data from Sandvine from "Available Industry Data", http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0611/dambrosia_bwa_01a_190611.pdf

GLOBAL IP TRAFFIC BY APPLICATION TYPE



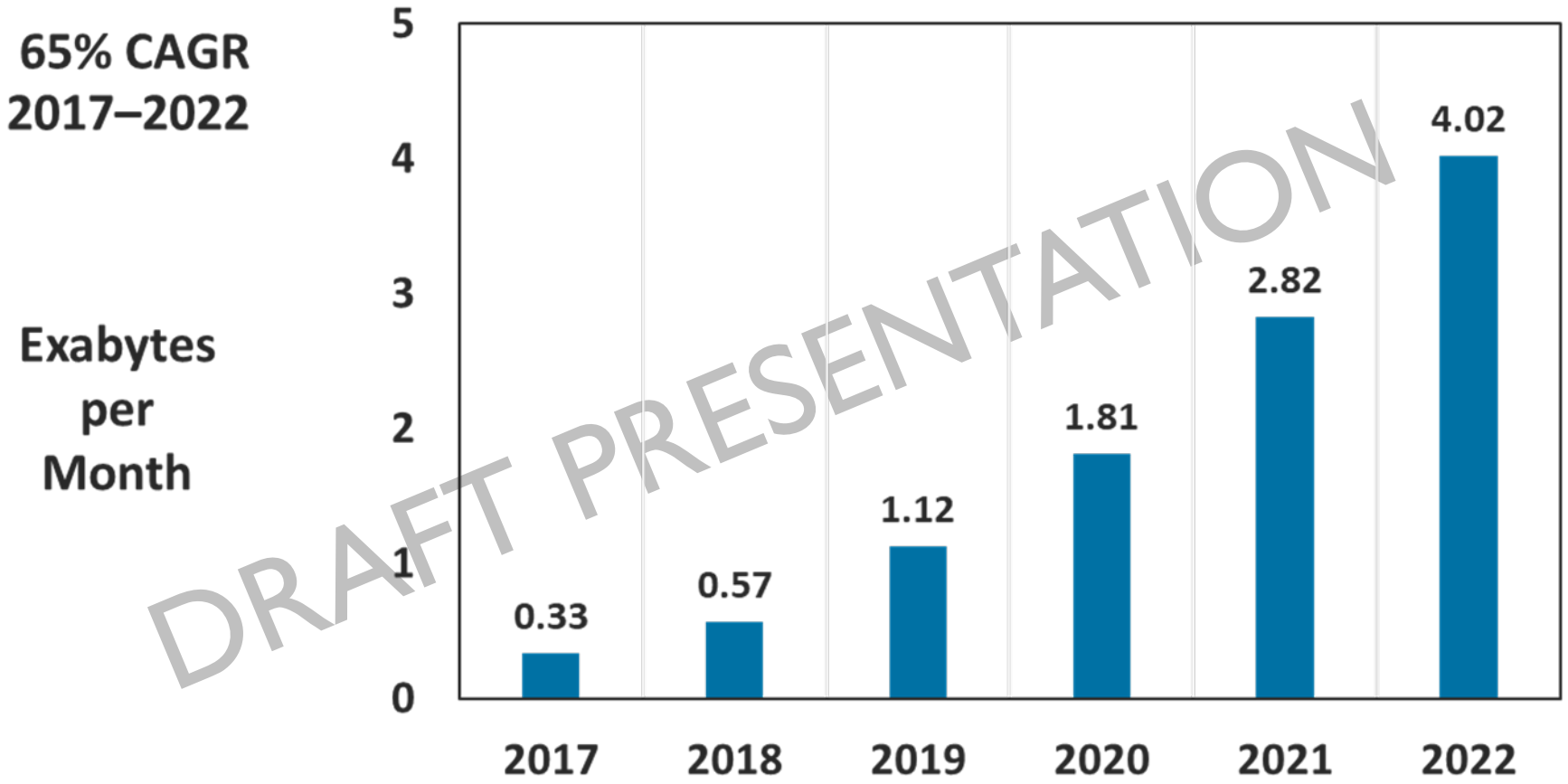
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

IMPACT OF "DEFINITION" ON IP VIDEO GROWTH



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

VIRTUAL AND AUGMENTED REALITY

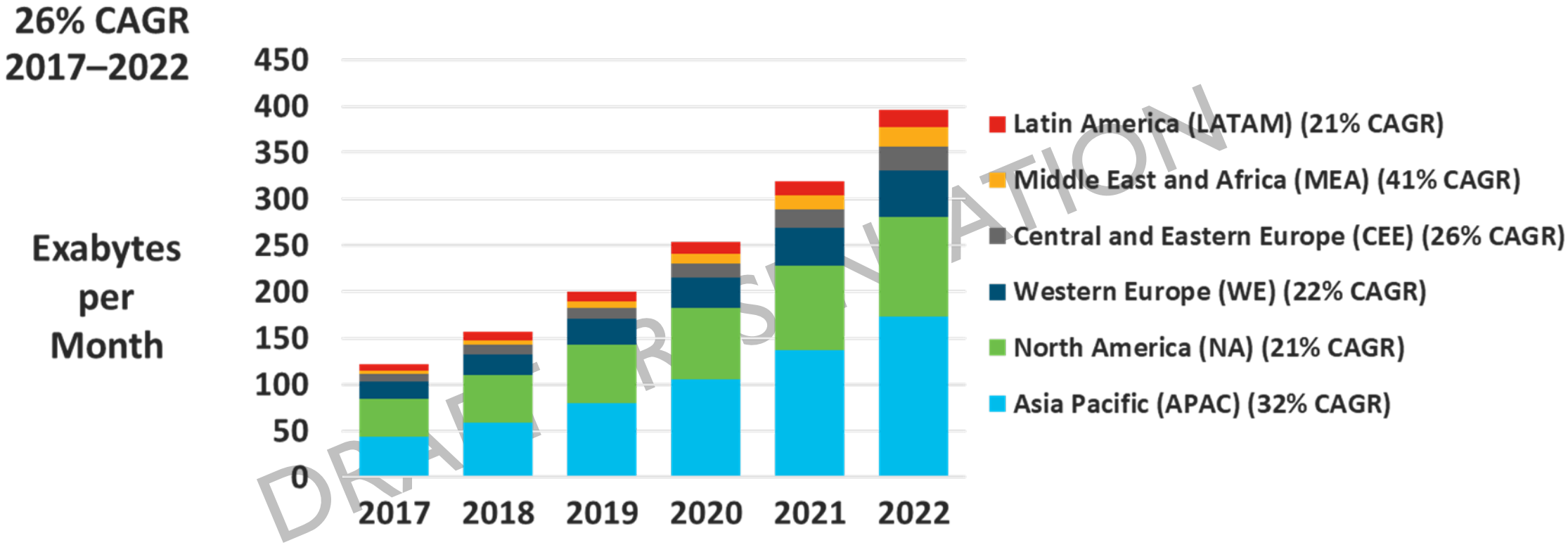


Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

FINDINGS: APPLICATIONS

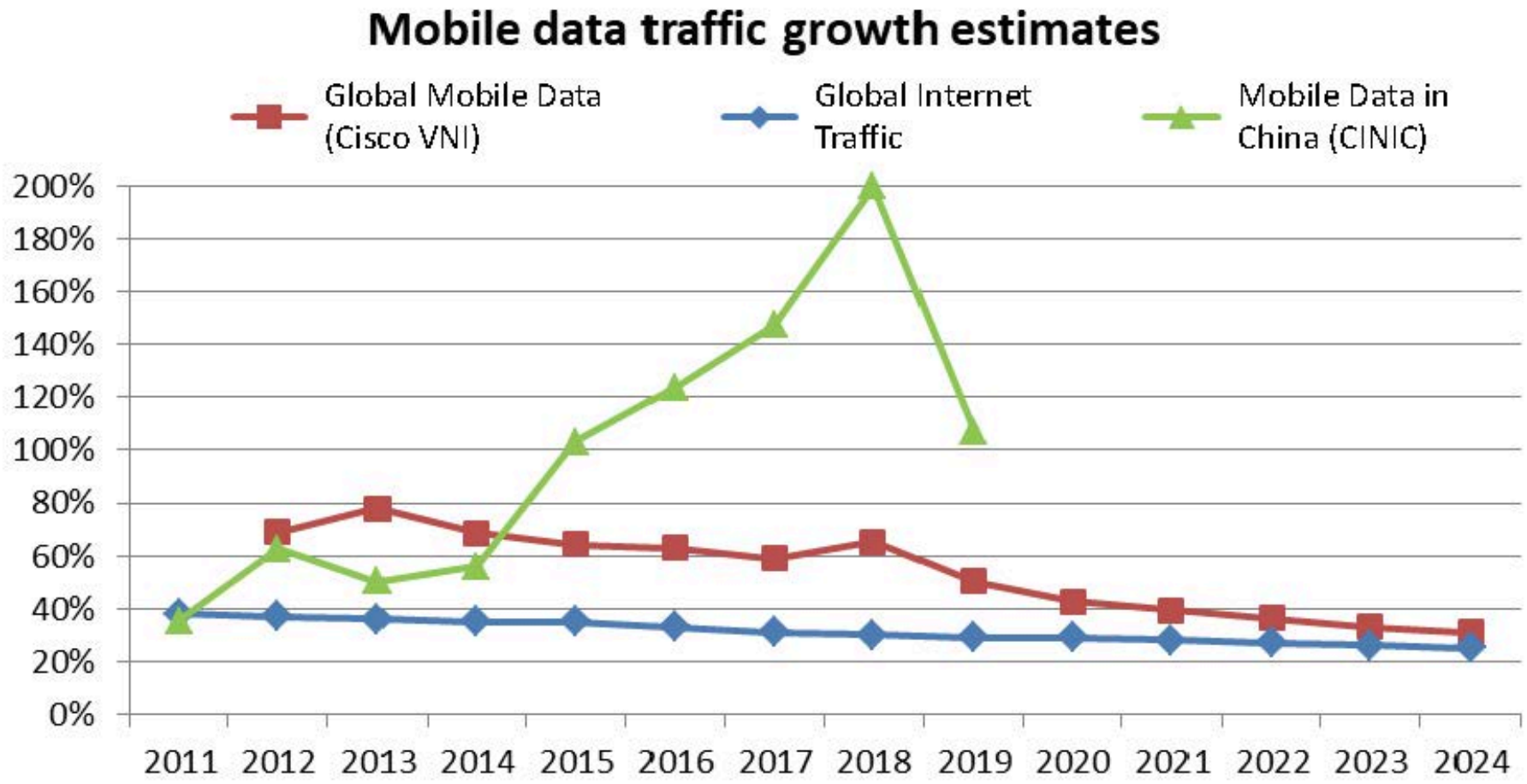
BANDWIDTH EXPLOSION

GLOBAL IP TRAFFIC GROWTH BY REGION



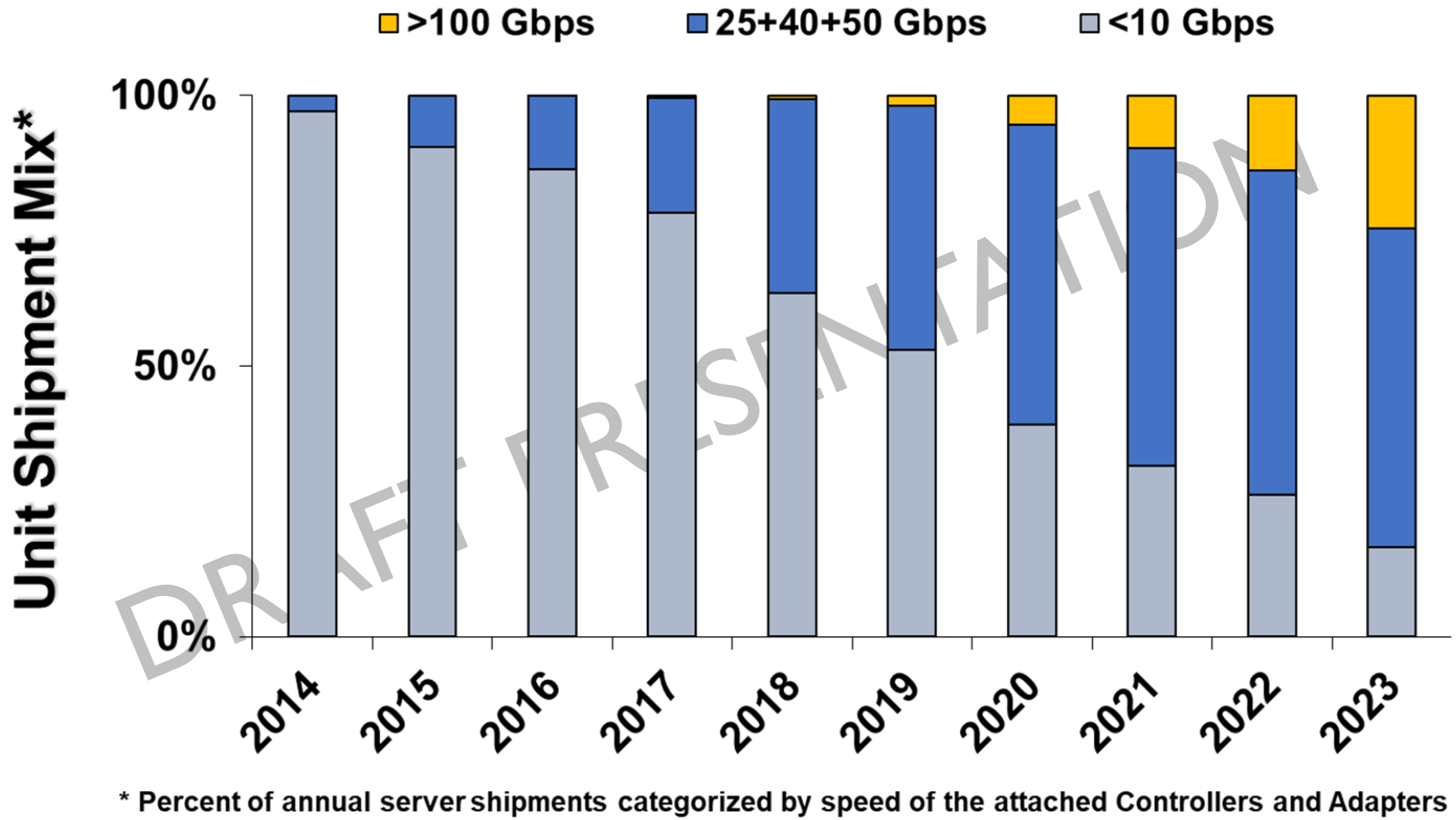
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

COMPARISON OF BANDWIDTH GROWTH RATES



Source: Vlad

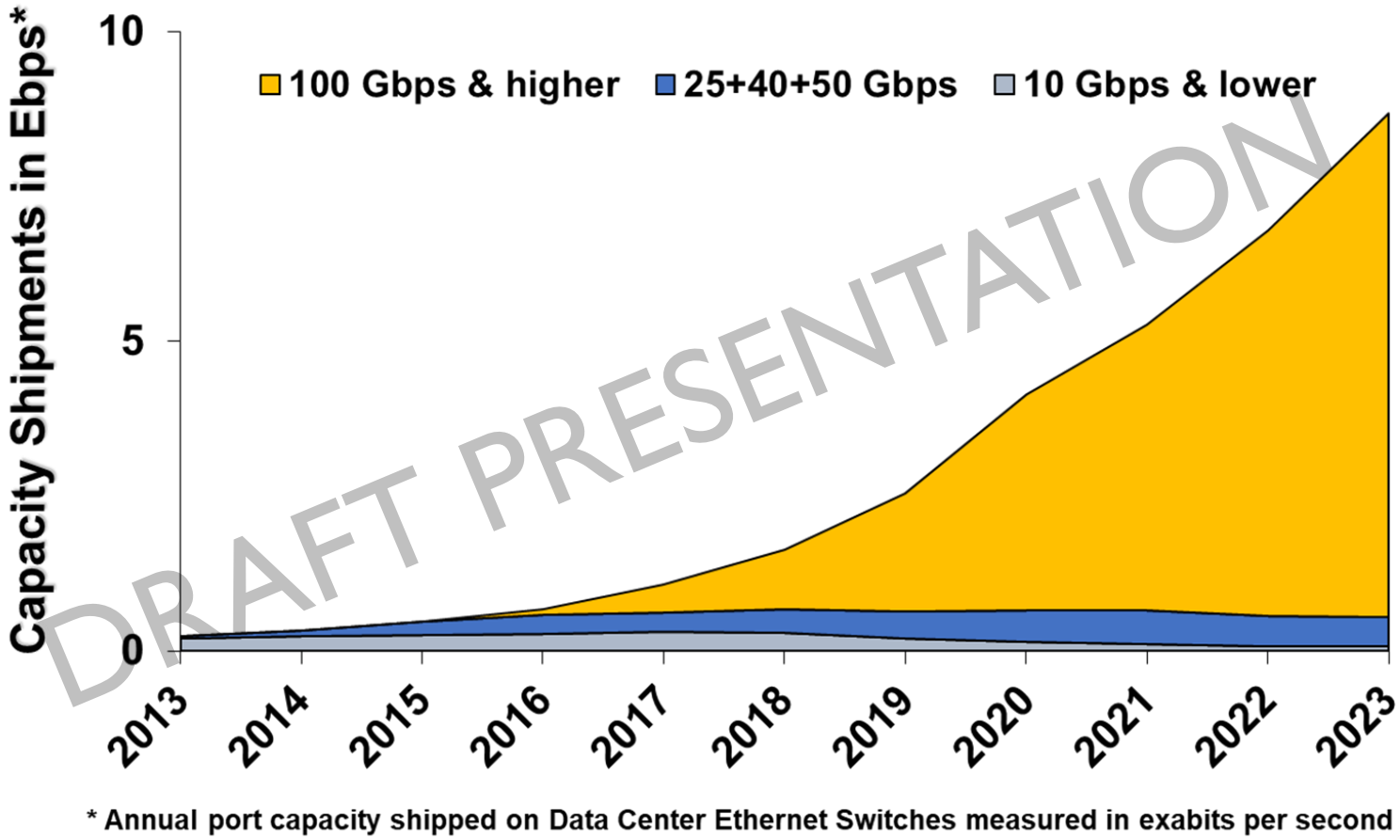
ENTERPRISE AND CLOUD SERVER UNIT SHIPMENTS



* Percent of annual server shipments categorized by speed of the attached Controllers and Adapters

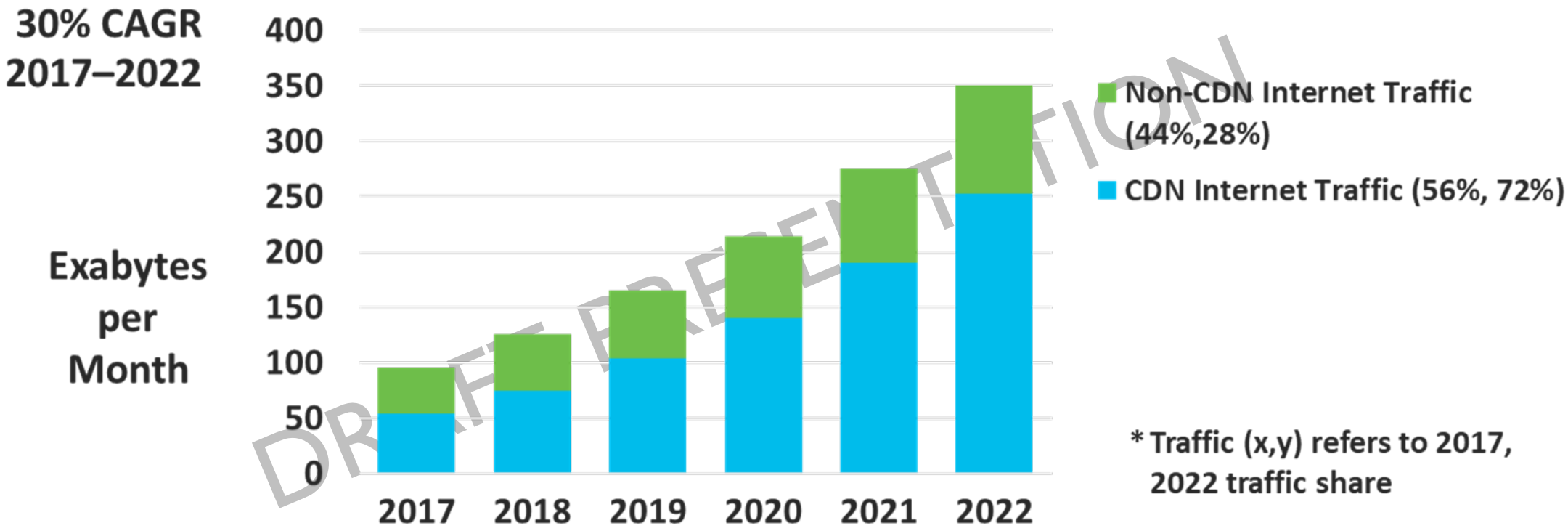
Source: Dell'Oro

DATA CENTER ENTHERNET SWITCH CAPACITY SHIPMENTS



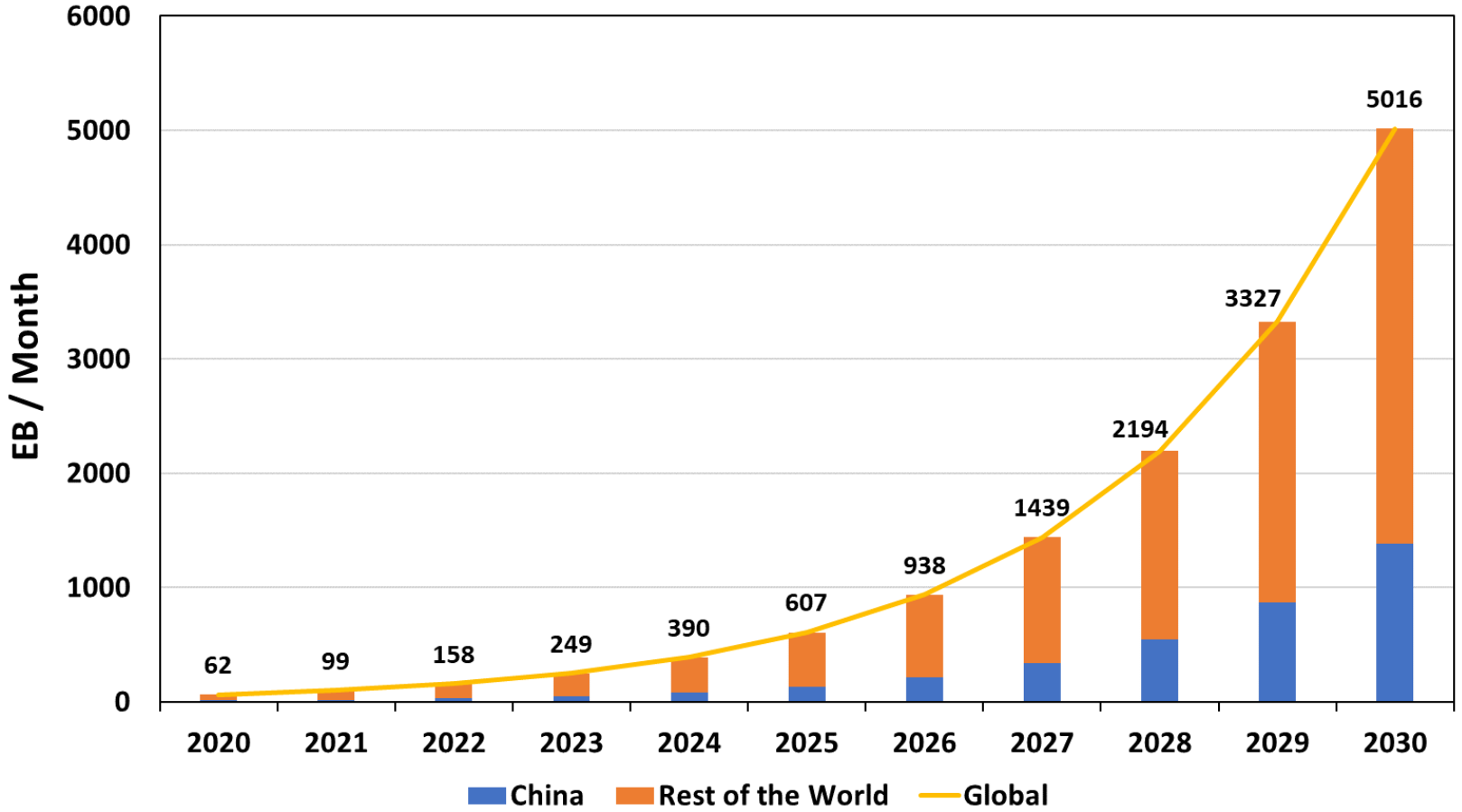
Source: Dell'Oro

GLOBAL CONTENT DELIVERY NETWORK (CDN) TRAFFIC



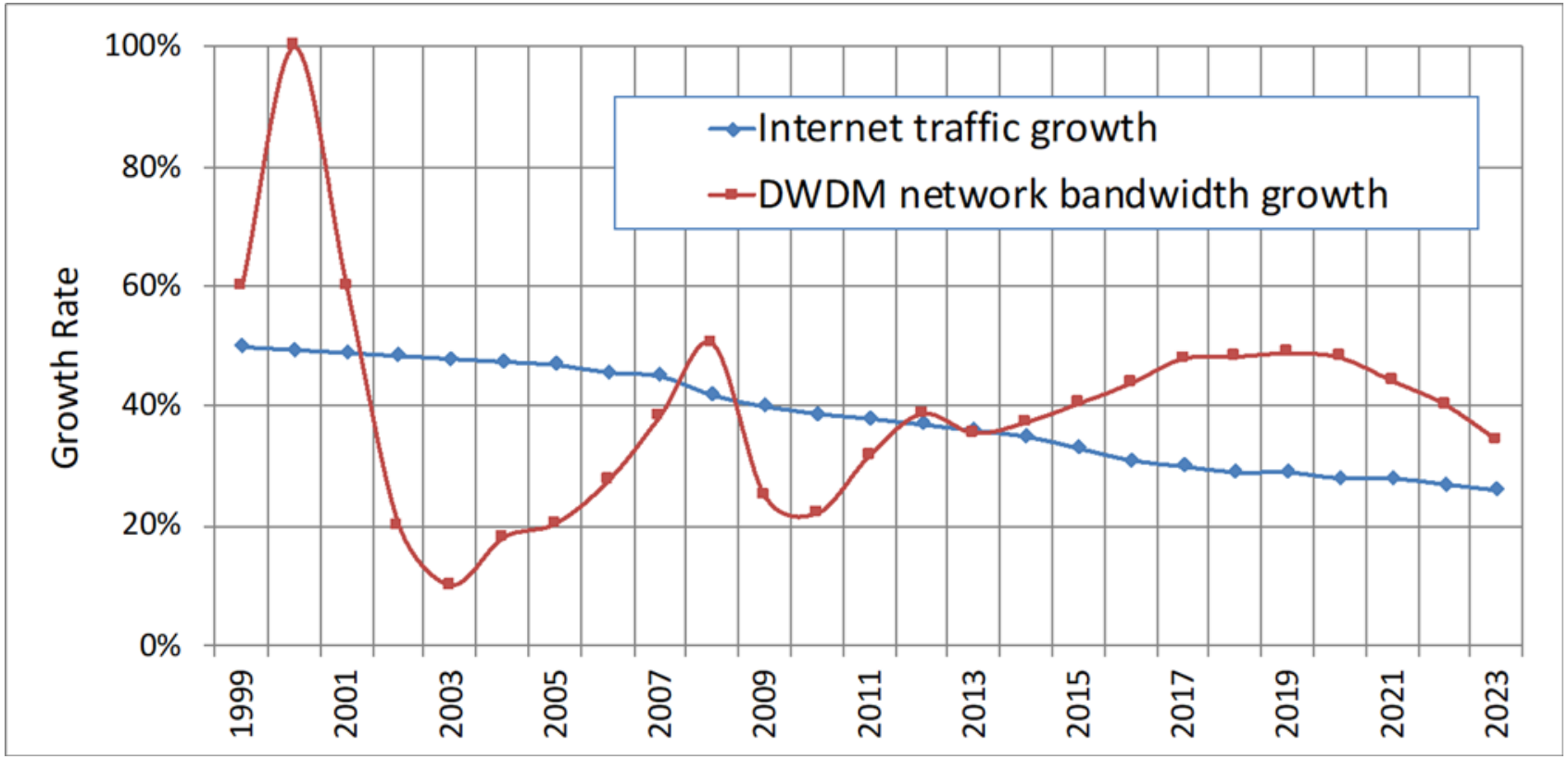
Source: Cisco VNI Forecast Update, http://www.ieee802.org/3/ad_hoc/bwa2/public/calls/19_0624/nowell_bwa_01_190624.pdf

ESTIMATION OF MOBILE TRAFFIC



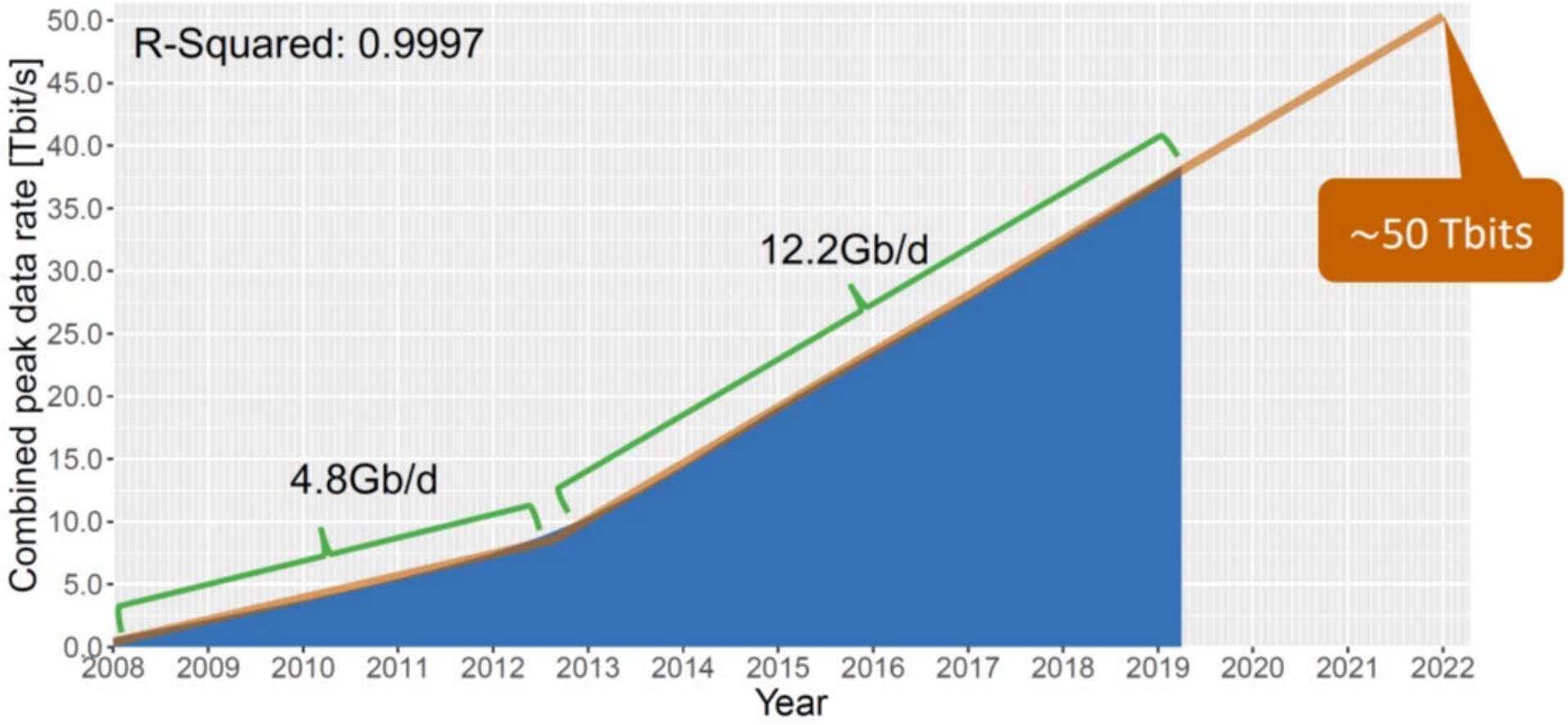
Source: Dell'Oro

INTERNET TRAFFIC VERSUS DWDM NETWORK TRAFFIC GROWTH



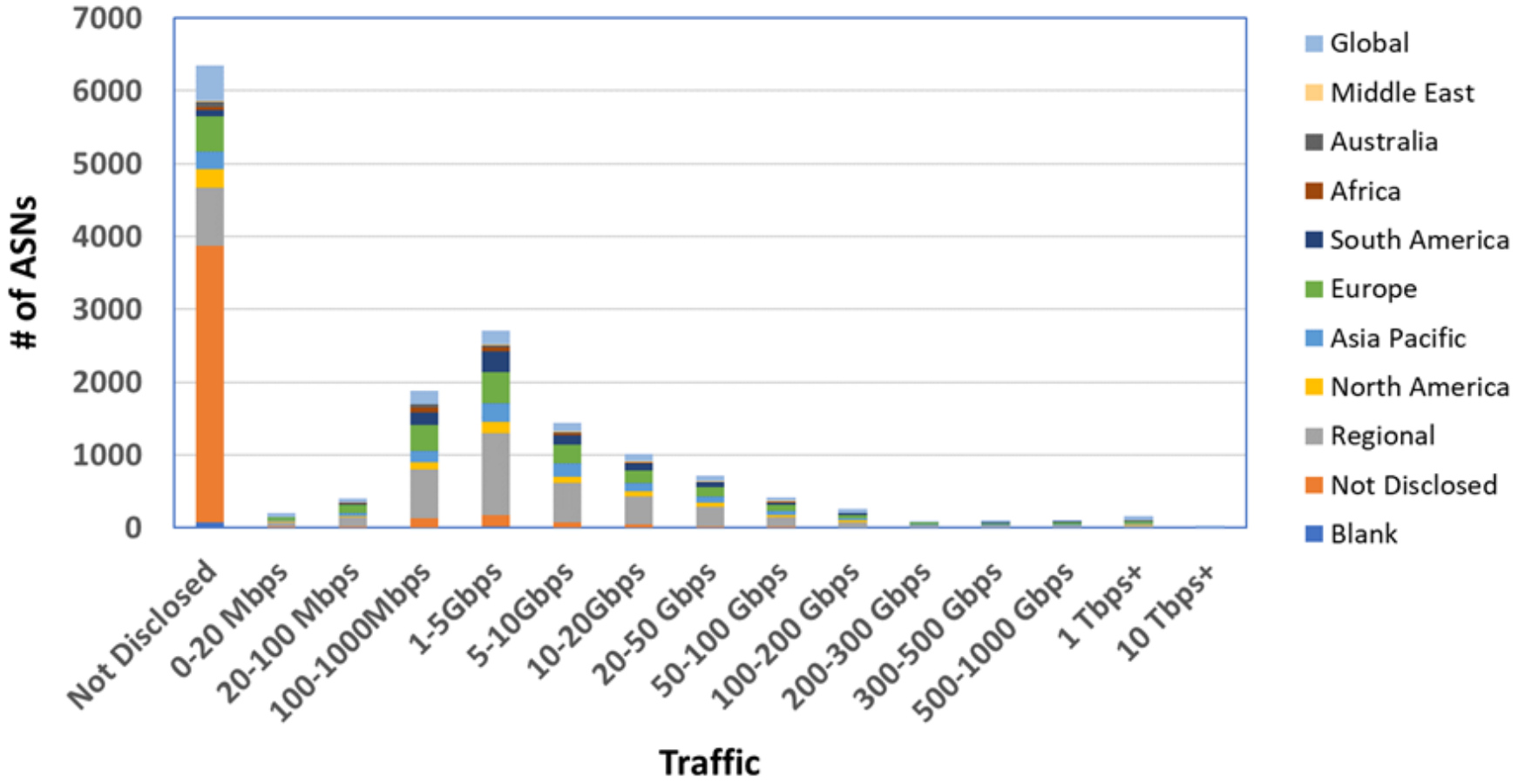
Source: Dell'Oro

EURO-IX IXP PEAK DATA RATE TREND



Source: Dell'Oro

PUBLIC PEERING: TRAFFIC PER NETWORK TYPE



Source: Dell'Oro

FINDINGS: BANDWIDTH

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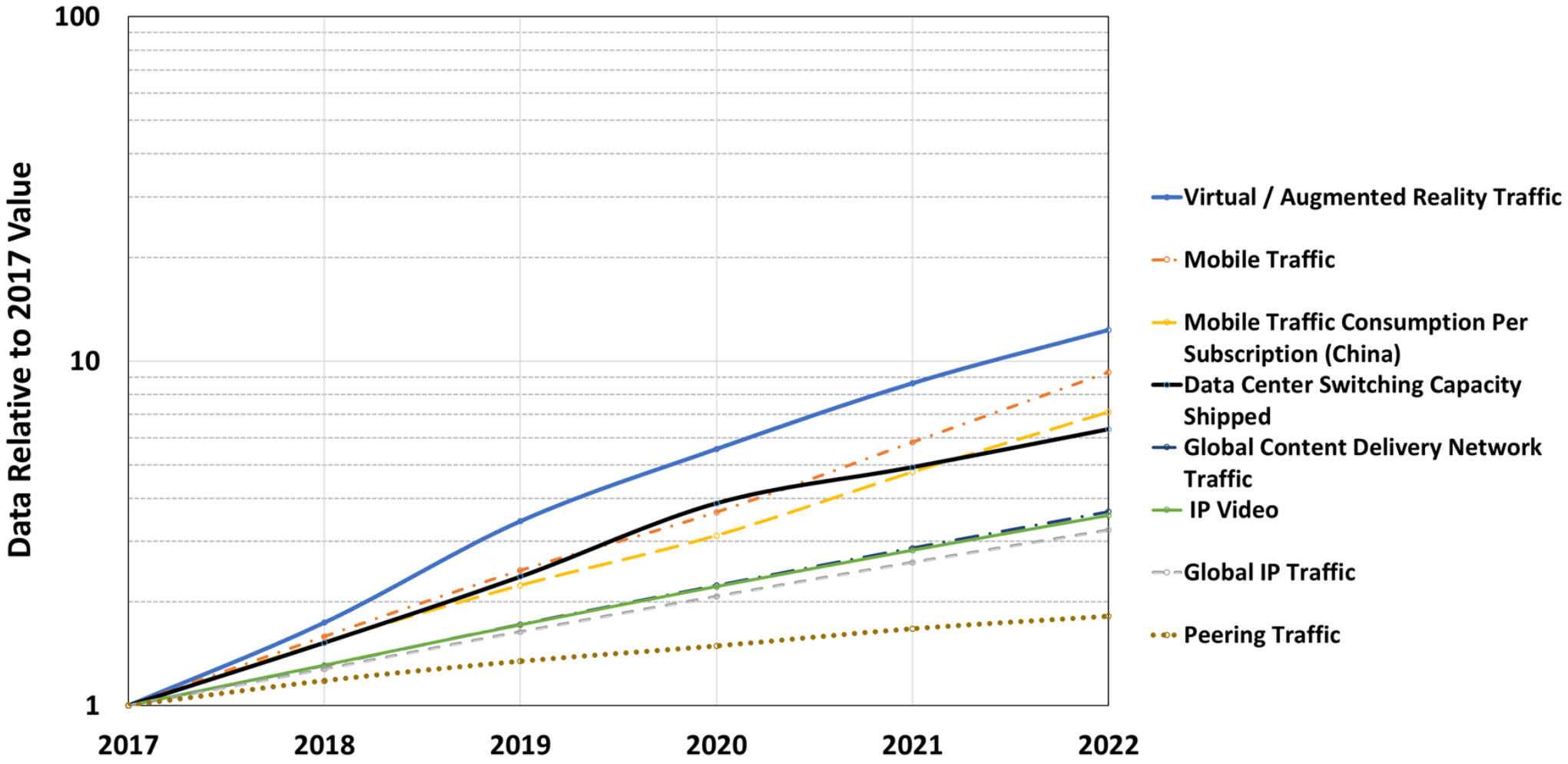
SUMMARY

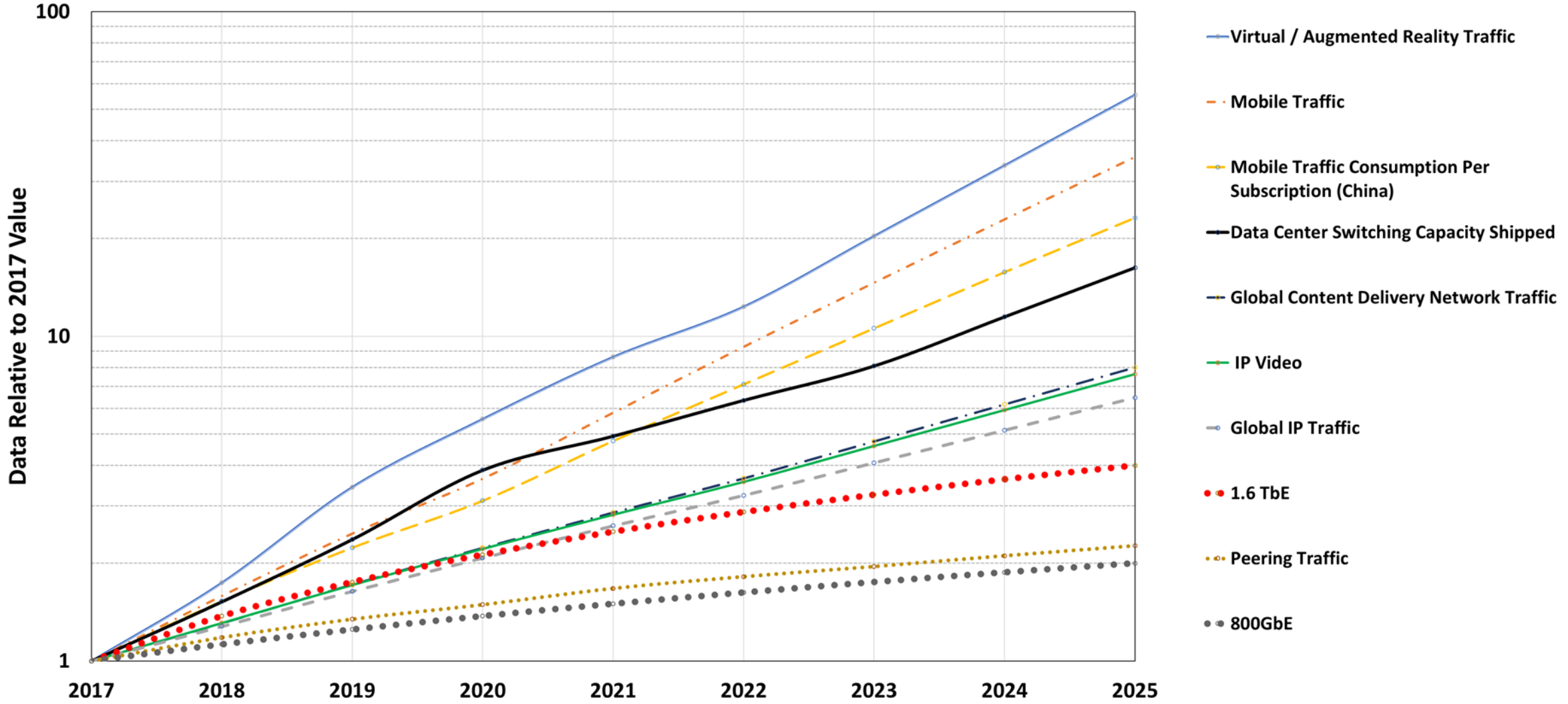
SUMMARY: ANALYSIS METHODOLOGY

- Step 1: Data Comparison for 2017 to 2022
  - Submitted bandwidth curves normalized to 2017 values
    - Data availability
    - Ratification of IEEE 802.3bs 200 GbE / 400 GbE Standard
- Step 2: Bandwidth curves extended to 2025
  - 5-year forecast
  - Estimated completion of a new higher speed Ethernet standard
  - Curves extended by either:
    - Curve fitting
    - Assume consistent CAGR for years 2022 to 2025

GROWTH RATE TRENDS (2017 – 2022)



GROWTH RATE TRENDS (2017 – 2025)



VARIATION TRENDS

PUBLICATION INFORMATION

- IEEE 802.3 Industry Connections
  Ethernet Bandwidth Assessment Ad Hoc Report is pending final approval this week.

- Upon approval final report to be published:
  - http://www.ieee802.org/3/ad_hoc/bwa/BWA_Report.pdf

ABBREVIATIONS

1GbE	1 Gb/s Ethernet
10GbE	10 Gb/s Ethernet
25GbE	25 Gb/s Ethernet
40GbE	40 Gb/s Ethernet
50GbE	50 Gb/s Ethernet
100GbE	100 Gb/s Ethernet
200GbE	200 Gb/s Ethernet
400GbE	400 Gb/S Ethernet
ASN	autonomous system networks
BW	bandwidth
CAGR	compound annual growth rate
CDN	content delivery network
EPON	Ethernet passive optical network
HD	high-definition
HSSG	Higher Speed Study Group
IoT	Internet of Things
IP	Internet Protocol
IXP	Internet exchange point
LAN	local area network
M2M	machine to machine
SD	standard definition
SP	service provider
UHD	ultra-high definition
VOD	video on demand