

Networking Trends



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Audio/Video recordings of this class lecture are available at:

<http://www.cse.wustl.edu/~jain/cse570-21/>

Student Questions

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- ❑ Sources of Trends
- ❑ Processor, Storage, Clouds and Mobile Apps
- ❑ Cisco Visual Networking Index
- ❑ Gartner Hype Cycle 2014*
- ❑ Google Trends

***Updated trends slides, including Gartner Hype Cycle 2021, are included at the end. These new slides are not in the video and will be discussed in the class during Q&A session.**

Student Questions

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Sources of Trends

- ❑ Activities in technical industry organizations: IEEE, IETF, ITU
- ❑ NSF funding areas
- ❑ Venture capital investments
- ❑ Industry analytics companies like Gartner
- ❑ Google searches by people all over the world



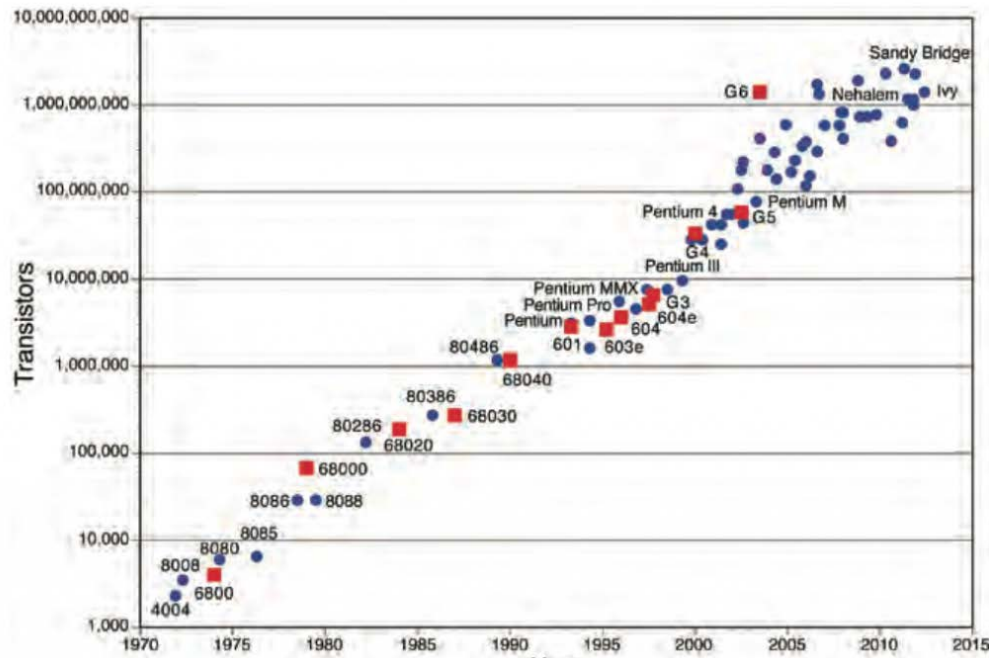
“VCs have a herd mentality.”

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 - ✓ Fifth Level

Processor Growth: Moore's Law

- Garden Moore, Director of R&D, Fairchild Semiconductor
1965: Transistor density doubling every two years



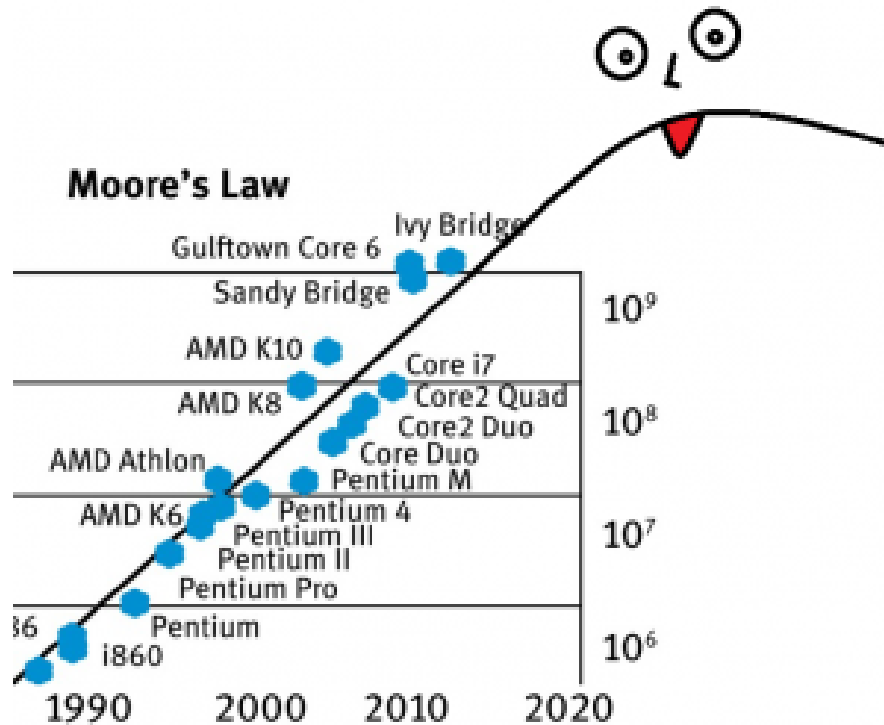
Student Questions

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 - ✓ Fifth Level

Ref: M. Czerniak, "What lies beneath? 50 years of enabling Moore's Law," Solid State Technology,
<http://electroiq.com/blog/2015/11/what-lies-beneath-50-years-of-enabling-moores-law/>

Will Moore's Law Continue?

□ A debate has begun...



Student Questions

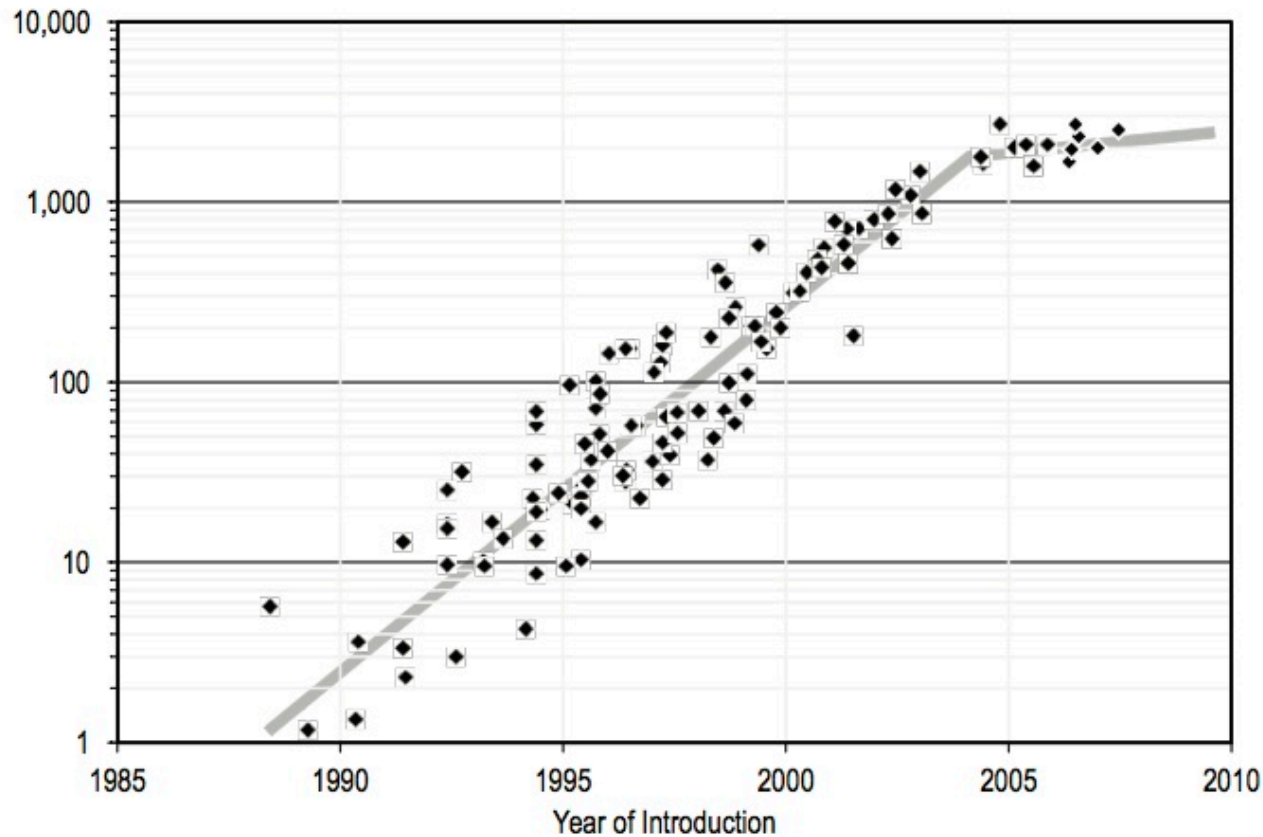
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 - ✓ Fifth Level

Ref: B. James, "Moore's Law sad that no one believes in it anymore," The Hard Time, October 23, 2017, <http://thehardtime.com/moores-law-sad-no-one-believes-anymore>
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Will Moore's Law Continue? (Cont)

- It may have broken down in 2004...

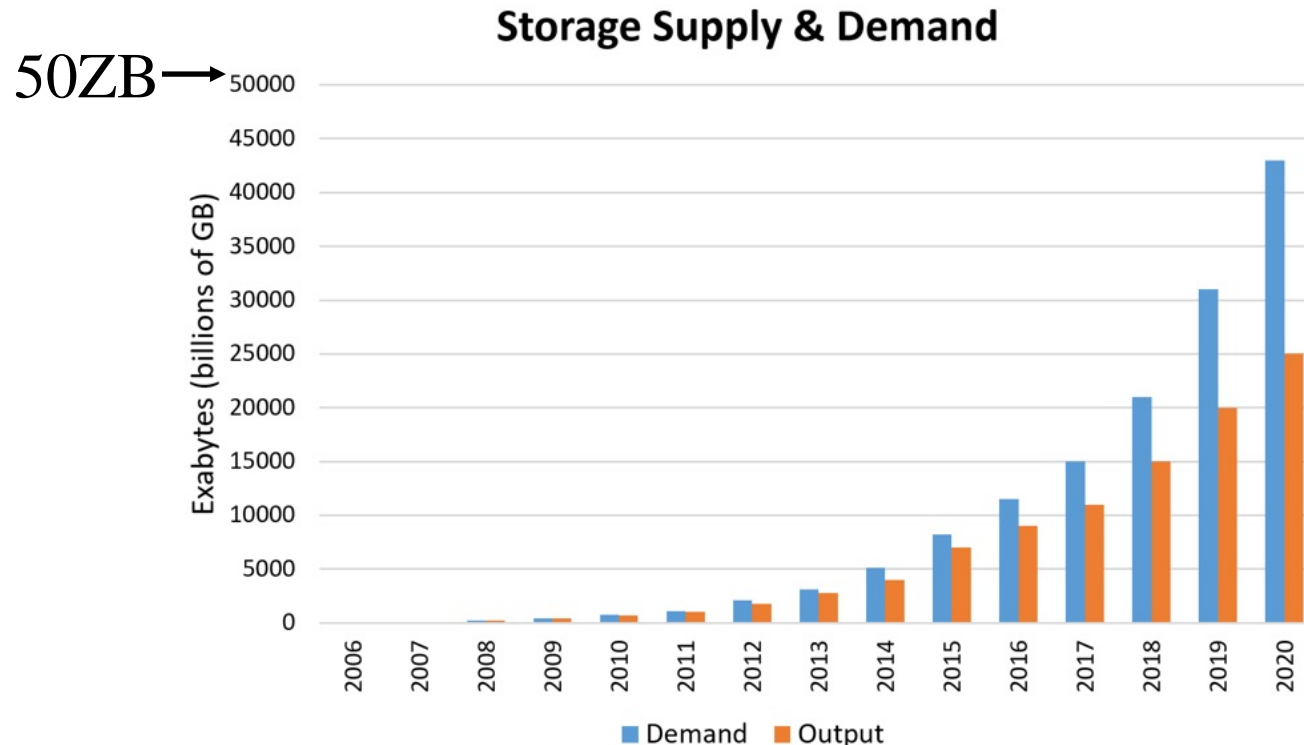


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Storage Capacity

- Exa=10¹⁸, Zetta=10²¹, Yotta=10²⁴. Scales extended from Giga to Yotta in 1991
42% compound annual growth rate (CAGR)



Ref: L. Rizzatti, "Digital Data Storage is Undergoing Mind-Boggling Growth," EE Times, September 14, 2016,
https://www.eetimes.com/author.asp?section_id=36&doc_id=1330462
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Clouds and Mobile Apps

- ❑ August 25, 2006: Amazon announced EC2
⇒ Birth of Cloud Computing in reality
(Prior theoretical concepts of computing as a utility)



- ❑ June 29, 2007: Apple announced iPhone
⇒ Birth of Mobile Internet, Mobile Apps
 - Almost all services are now mobile apps: Google, Facebook, Bank of America, ...
 - Almost all services need to be global (World is flat)
 - Almost all services use cloud computing



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Networks need to support efficient service setup and delivery

Cloud Computing Statistics

By 2020:

- ❑ 11/12th of workload in **clouds**, 1/12th in traditional data center
- ❑ 92% Data center IP traffic in clouds, 8% in traditional data center
- ❑ 3X growth in cloud workload in 5 years
3X growth in IP traffic in 5 years
- ❑ 5X growth in data center **storage**
7/8th in cloud, 1/8th in traditional data centers
2/3rd in public clouds, 1/3rd in private clouds
- ❑ 59% of consumers will use cloud storage (Under estimate)
- ❑ **SDN/NFV** transporting 22% of datacenter traffic to 44% by 2020

Ref: Cisco, "Cisco Global Cloud Index: Forecast and Methodology, 2015-2020," 2016,

<https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf>

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Cisco Visual Networking Index

Between 2016-2021 (5 Years):

- ❑ 3× growth in IP traffic \Rightarrow 3 ZB/year
127× growth in 16 years (2005-2021)
- ❑ 5× growth in **busy hour** traffic
- ❑ PC traffic will be only 1/4th compared to 1/2 in 2016
Smart phone traffic will be 1/3rd compared to 1/8th in 2016
- ❑ 10% CAGR PC
21% CAGR for TV
29% CAGR for Tablets
49% CAGR for Smart phones
49% CAGR for Machine-to-Machine
- ❑ **3 device per capita** worldwide
7 devices per user (North America) \Rightarrow 14 by 2020

Ref: Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2016-2021," June 6, 2017,

<https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf>

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Video and Mobile Traffic

Between 2016-2021 (5 Years):

- ❑ 4/5th of IP traffic will be **video**
4x growth in 5 years
- ❑ 1/8th of Internet video traffic will be **live video**
15x growth in 5 years
- ❑ 3.4% of Internet video traffic will be **surveillance video**
7x growth
- ❑ Million minutes of video crossing the network per second
⇒ 60 Ms = 5 M years to watch video created in 1 second
- ❑ 20x growth in **virtual reality** (VR) and **augmented reality** (AR) traffic
- ❑ **Mobile traffic** will grow twice as fast as fixed IP traffic

Ref: Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2016-2021," June 6, 2017,

<https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf>

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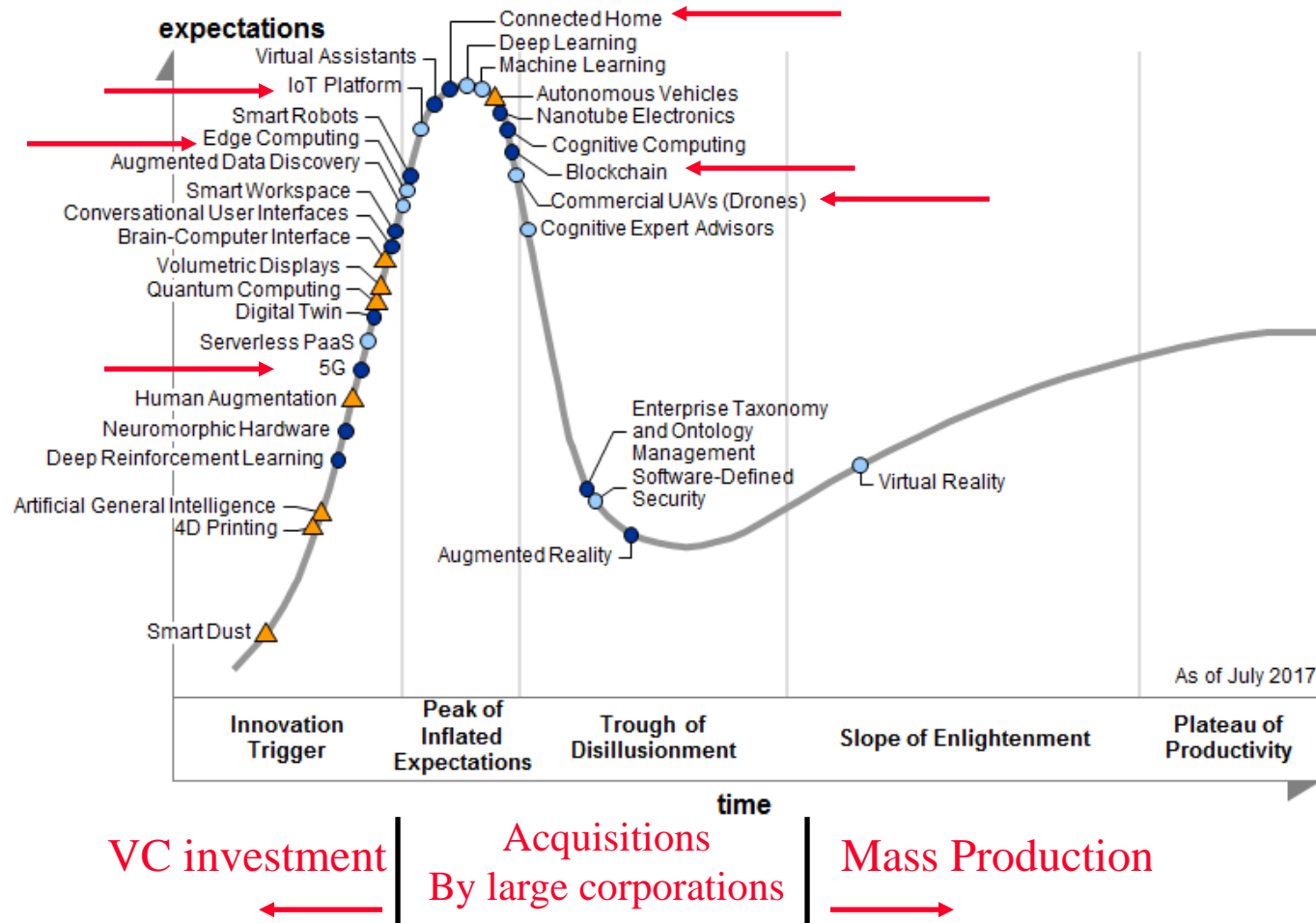
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Gartner Hype Cycle 2017



Student Questions

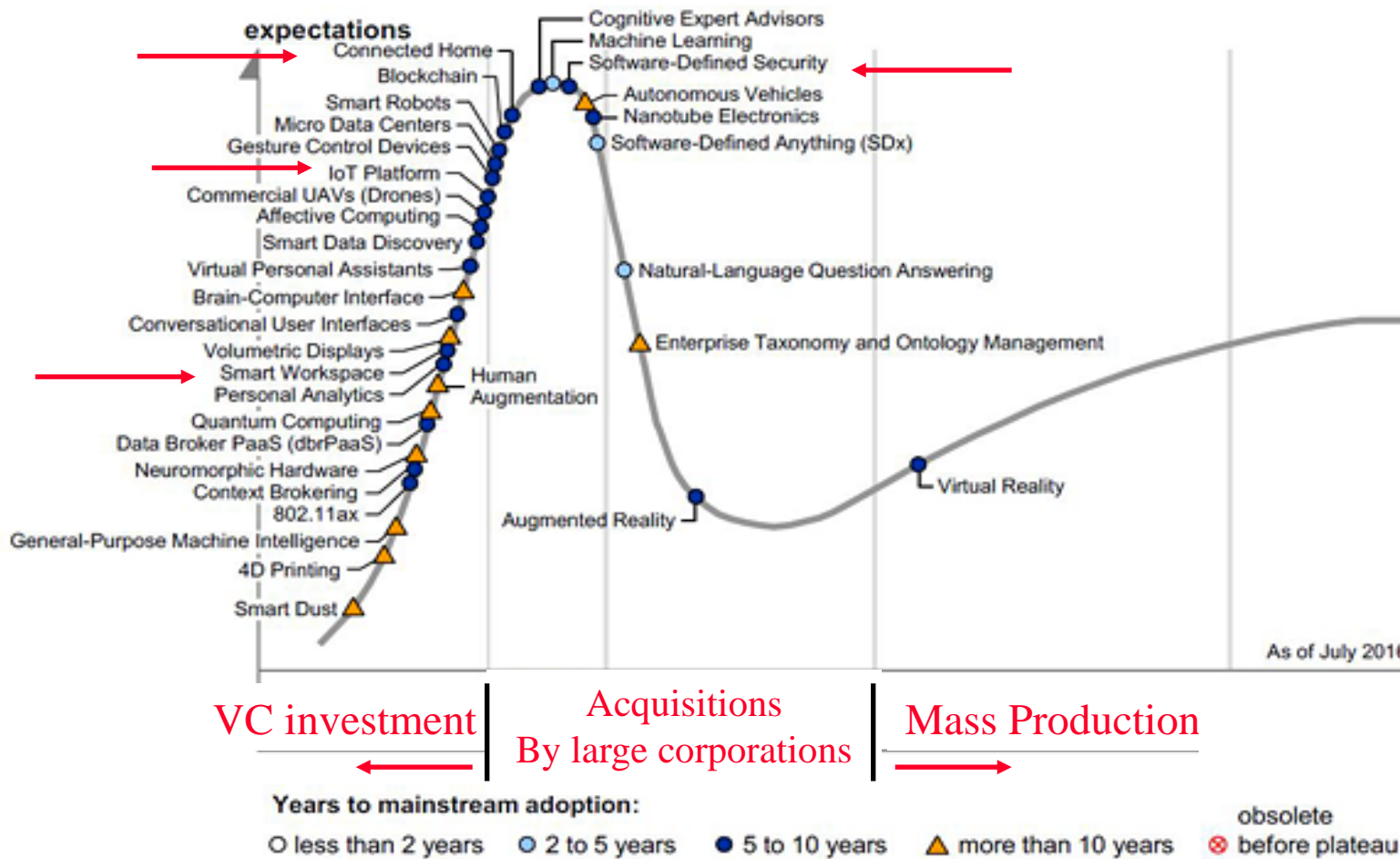
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Ref: Gartner, "Hype Cycle for Emerging Technologies, 2017," July 2017, [subscribers only]
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<http://www.cse.wustl.edu/~jam/cse570-21/>

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Gartner Hype Cycle 2016



Source: Gartner (July 2016)

Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], gartner.com/document/3383817

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<http://www.cse.wustl.edu/~jain/cse570-21/>

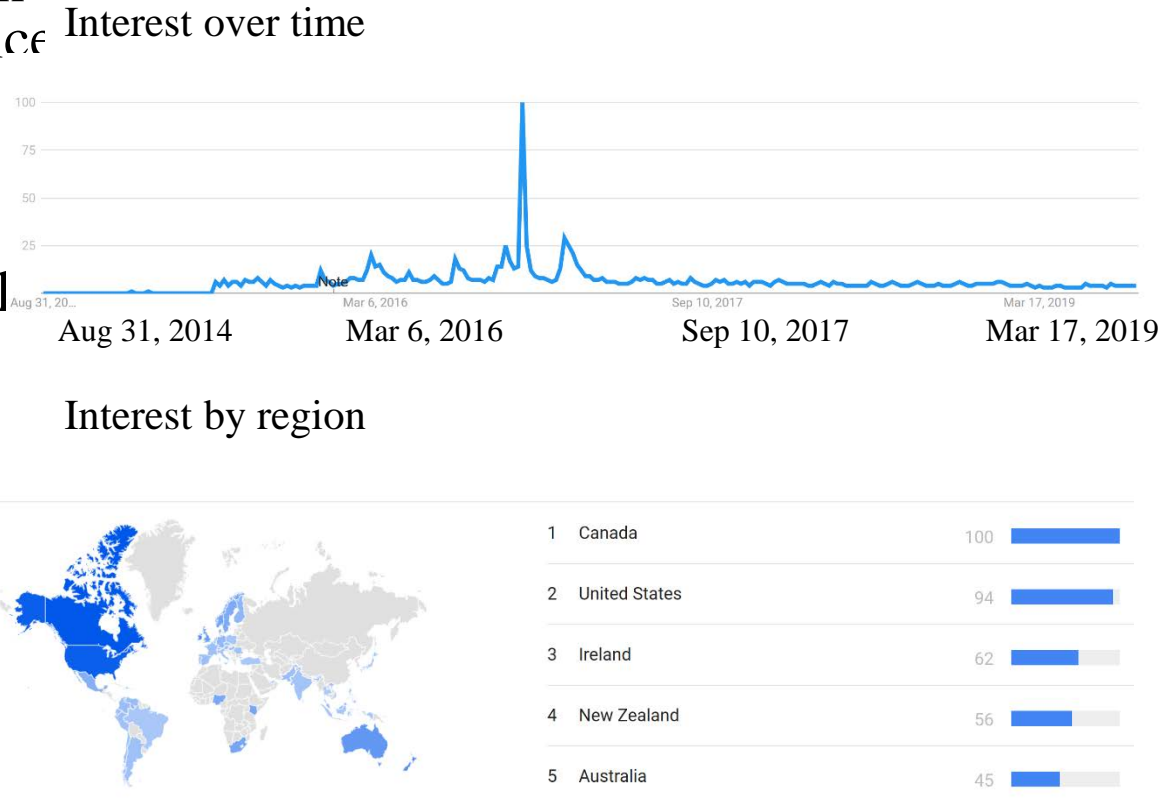
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What is Google Trends?

- ❑ A time series graph of number of searches on any term of your choice
- ❑ Scaled to 100%. 100=Maximum over time
- ❑ Includes geographical distribution of those searches
- ❑ Includes major news items
- ❑ Example: “Donald Trump” Popular in Canada



Snapshot: Aug 27, 2019

Ref: <https://trends.google.com/trends/explore?date=today%205-y&q=donald%20trump>

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Google Trends and GDP

- ❑ Internet users from countries with higher GDP are more likely to search for future topics than about the past.
- ❑ Economic indicators are correlated to on-line behavior.

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Ref: C. Johnston, "Google Trends reveals clues about the mentality of richer nations,"

<http://arstechnica.com/gadgets/2012/04/google-trends-reveals-clues-about-the-mentality-of-richer-nations/>

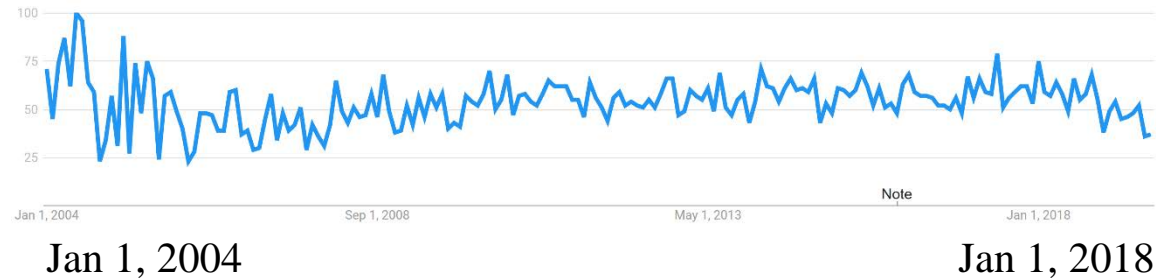
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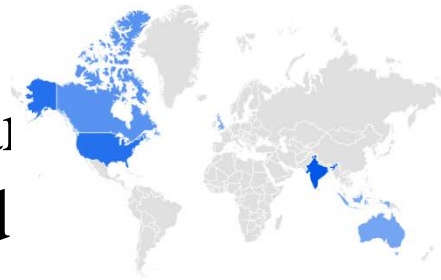
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Data Center Network: Google Trends

❑ Stable, Neither declining nor increasing



❑ Mostly in USA and India



❑ USA and India are highly correlated probably because Indian IT industry services US companies

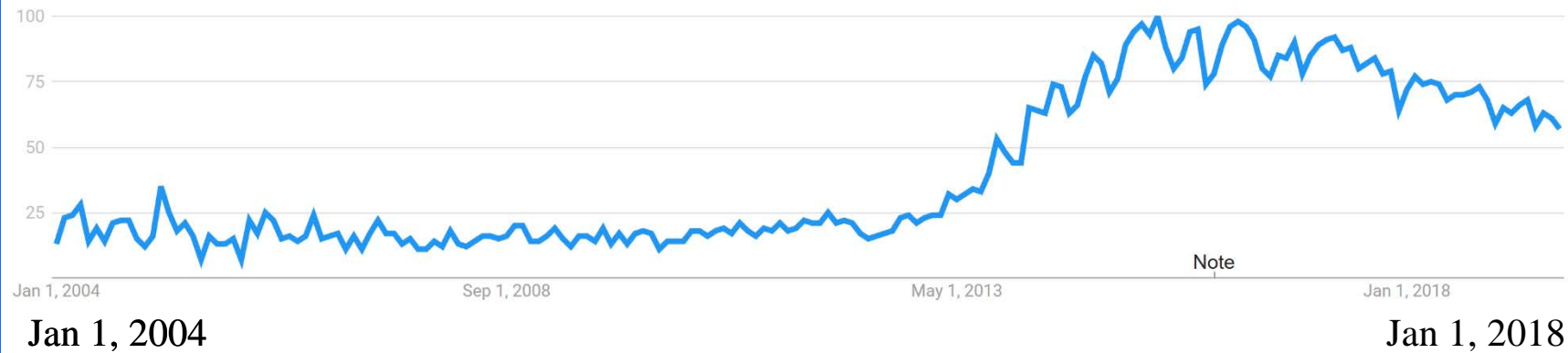


Snapshot: August 27, 2019

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Network Virtualization: Google Trends



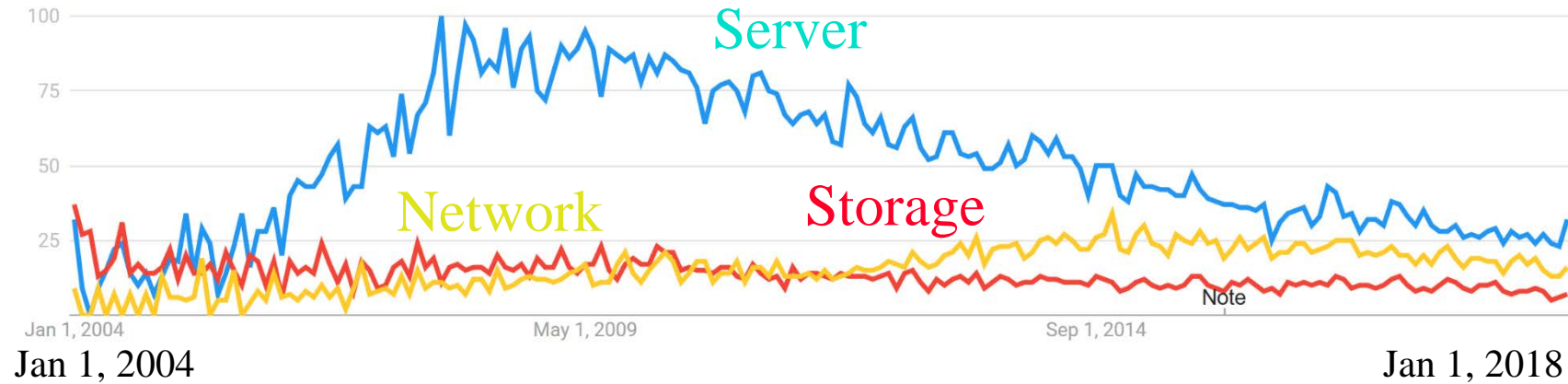
Interest is decreasing slowly

Snapshot: August 27, 2019

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Virtualization: Google Trends



Virtualization

- Server
- Storage
- Network

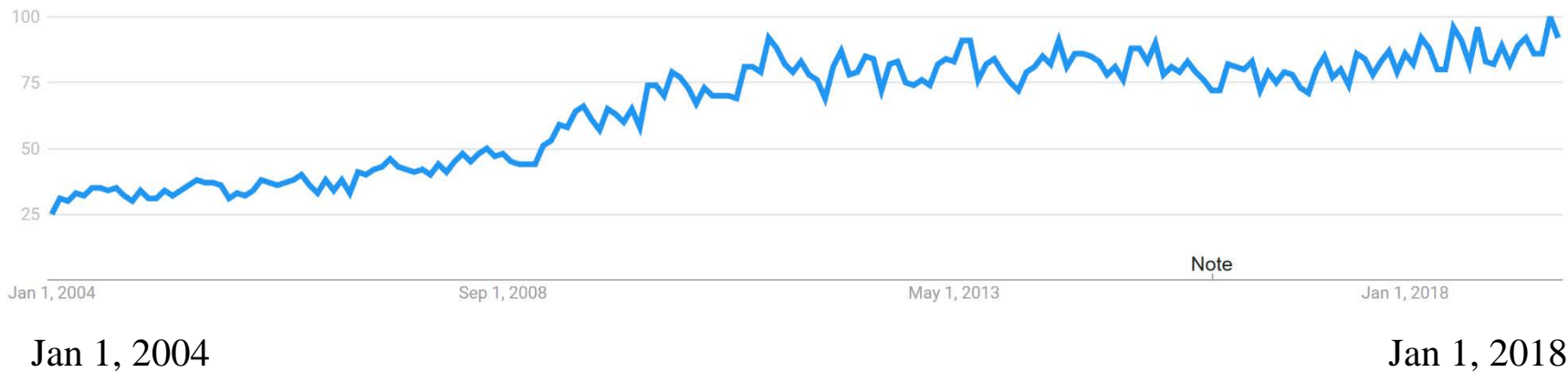
Increasing curiosity about network virtualization

Snapshot: August 27, 2019

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SDN: Google Trends



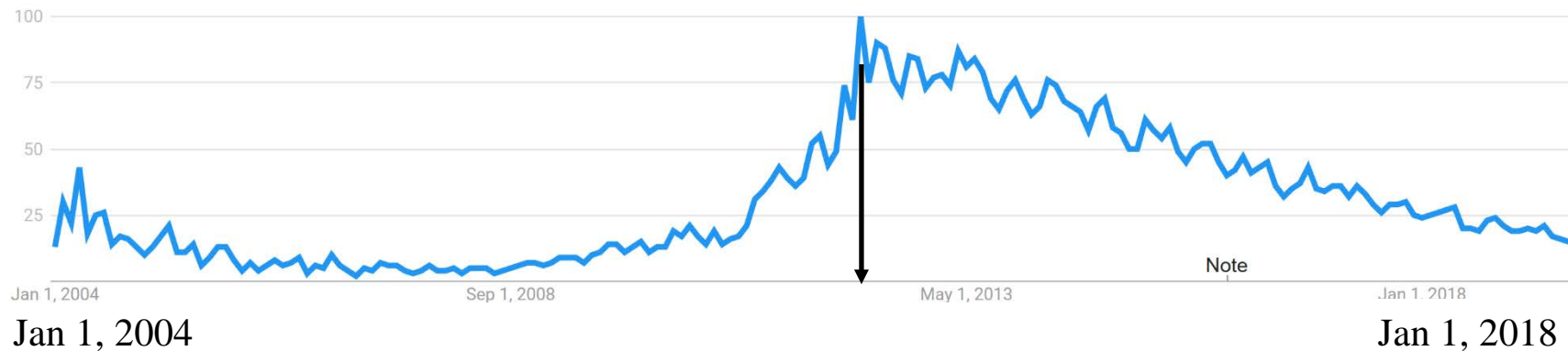
- ❑ Started May 21, 2011: Open Networking Foundation formed
- ❑ Software defined networking, Software defined network have slightly different trends

Snapshot: August 27, 2019

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OpenFlow: Google Trends

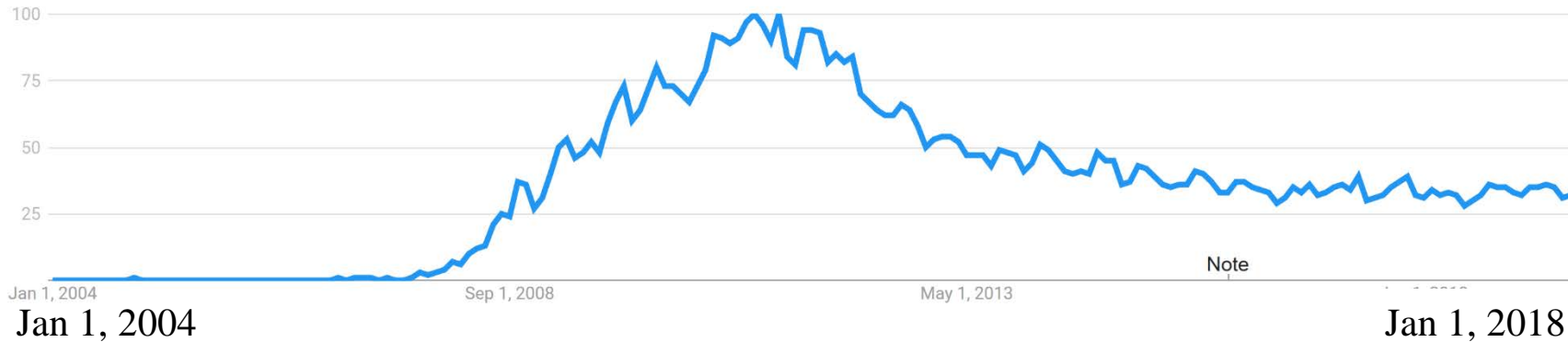


- ❑ Started April 2004
- ❑ Past the peak
(Everyone who needs to know knows)
- ❑ Peak at Open Networking Summit (April/May 2012)
- ❑ High interest in Korea, Taiwan, Japan, China Snapshot: August 27, 2019

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Cloud Computing: Google Trends



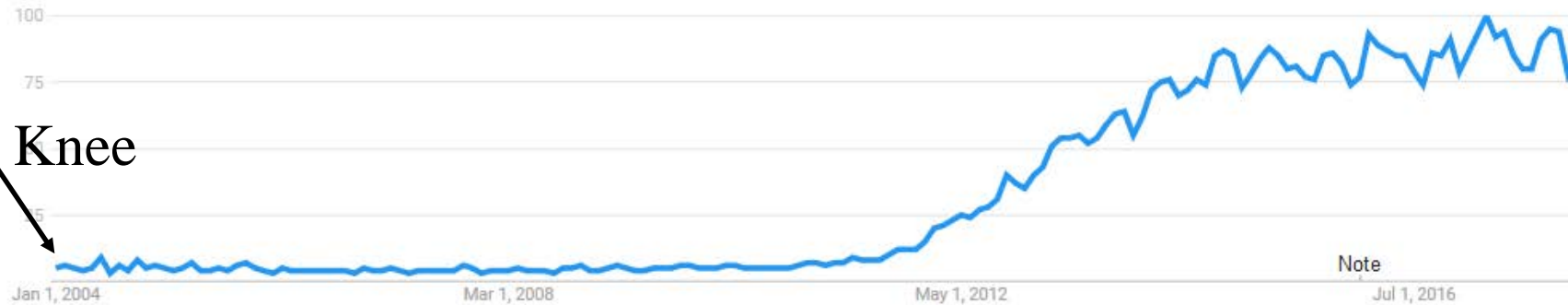
- ❑ Past-Hype phase.
As in Gartner graphs

Snapshot: August 27, 2019

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 - ✓ Fifth Level

Big Data: Google Trends

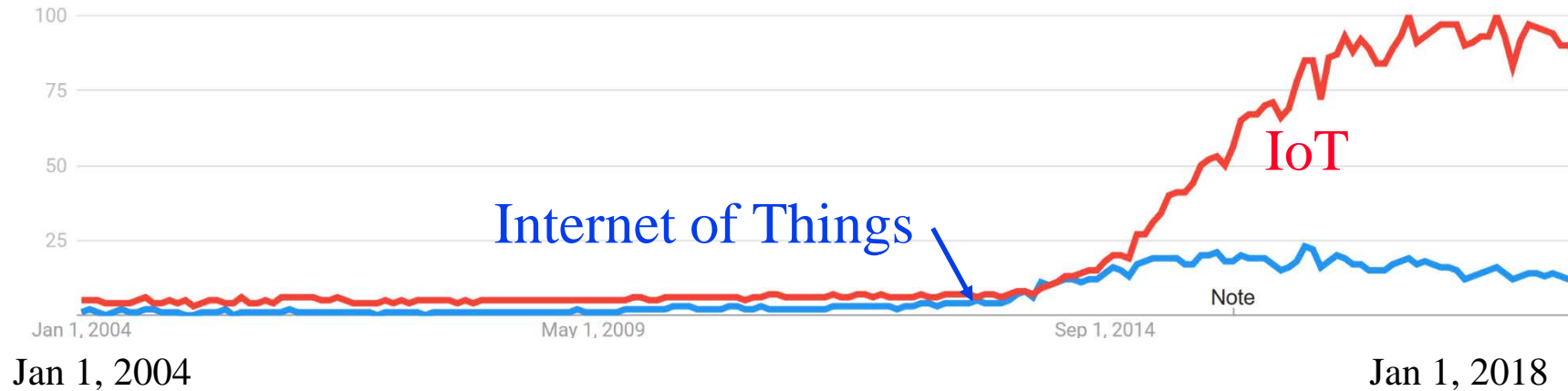


- ❑ Near the peak
- ❑ Knee on March 27, 2012 (Point G): Obama goes big on big data. Federal agencies host a webcast outlining their plan for big data.

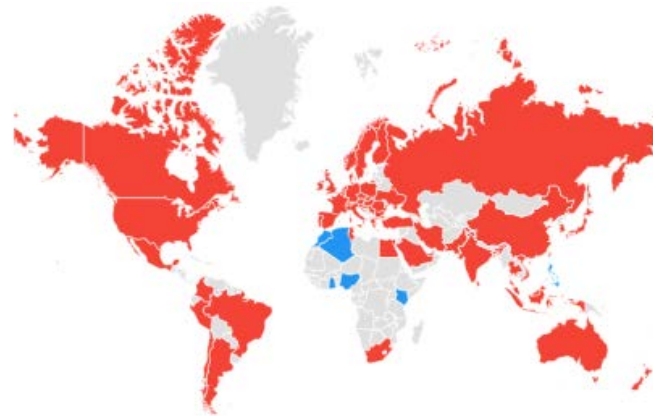
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IoT: Google Trends



- ❑ Still growing
- ❑ High interest all around the world



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Other Trends

- ❑ IT/Network Automation
- ❑ Open Networking
- ❑ Mobility
- ❑ Security
- ❑ Analytics
- ❑ Containers – Docker
- ❑ DevOps: Developers and Operational personnel cooperation

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Research Funding

- ❑ Networking and Information Technology Research and Development (NITRD)
 - Group of 15 Federal agencies: NSF, NIH, NASA, DOE, DARPA, ONR, ...
 - Recommends supplement to the president's annual budget
- ❑ Computing-Enabled Human Interaction
- ❑ Computing-Enabled Network Physical Systems
- ❑ Cyber Security and Privacy
- ❑ Enabling R&D for high-Capability Computing Systems
- ❑ Large Scale Networking
- ❑ Health Information Technology R&D
- ❑ Video and Image Analytics

Ref: NITRD, "NITRD Program Supplement to the President's Budget – FY 2019," August 2018, 46 pp.,
<https://www.nitrd.gov/pubs/FY2019-NITRD-Supplement.pdf>

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Internet Engineering Task Force (IETF)

- ❑ Internet of Things
- ❑ Autonomic networking to enable self-managing, self-healing, self-configuring, self-optimizing networks
- ❑ Intent based networking
- ❑ Computing in Networks
- ❑ Decentralized Internet
- ❑ Information Centric Networking
- ❑ Quantum Communications
- ❑ Time Sensitive Networking
- ❑ Routing inside Data Centers
- ❑ Security

Ref: <http://ietf.org/>
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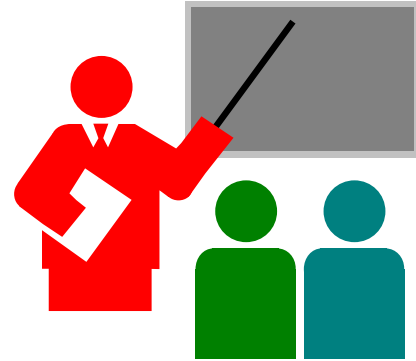
IEEE 802 LAN/MAN Standards

- ❑ Security
- ❑ Automotive Ethernet
- ❑ Time Sensitive Networking
- ❑ 200 Gbps Ethernet, 400 Gbps PHY
- ❑ Backplane Ethernet

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Summary



1. Google trends is an interesting easy way to find world interest on a topic of your research interest
2. Gartner hype cycle, Google trends, and Standards activities seem highly correlated
(Does Gartner look at Google trends before publishing their graphs? It would be unwise not to.)
3. IoT is at the peak. Cloud is main stream.
Network virtualization, SDN are done.
4. All forecasting is based on the past \Rightarrow Continuous.
Real future is invented \Rightarrow Discontinuous

Student Questions

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Reading List

Required Reading:

1. Cisco, “Cisco Annual Internet Report (2018–2023),” March 2020, <https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html>

Not Required:

1. Cisco, “Cisco Visual Networking Index: Forecast and Methodology, 2017-2022,” Feb 27, 2019, <https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html>
2. Cisco, “Cisco Global Cloud Index: Forecast and Methodology, 2016-2021,” Nov 19, 2018, <https://www.cisco.com/c/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.html>

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Acronyms

- ❑ CAGR Cumulative Annual Growth Rate
- ❑ DARPA Defense Advanced Research Project Agency
- ❑ DOE Department of Energy
- ❑ EC European Continent
- ❑ GDP Gross Domestic Product
- ❑ IEEE Institution of Electrical and Electronics Engineers
- ❑ IETF Internet Engineering Task Force
- ❑ IoT Internet of Things
- ❑ IT Information Technology
- ❑ ITU International Telecommunications Union
- ❑ NASA National Aeronautics and Space Administration
- ❑ NIH National Institute of Health
- ❑ NITRD Networking and Information Technology Research and Development
- ❑ NSF National Science Foundation
- ❑ PB Peta Byte

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Acronyms (Cont)

- ❑ PC Personal Computer
- ❑ SDN Software Defined Networking
- ❑ SDI Software Defined Infrastructure
- ❑ SDX Software Defined Exchanges
- ❑ SWaP Size Weight and Power
- ❑ VCs Venture Capitalists
- ❑ WiFi Wireless Fidelity

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Updates

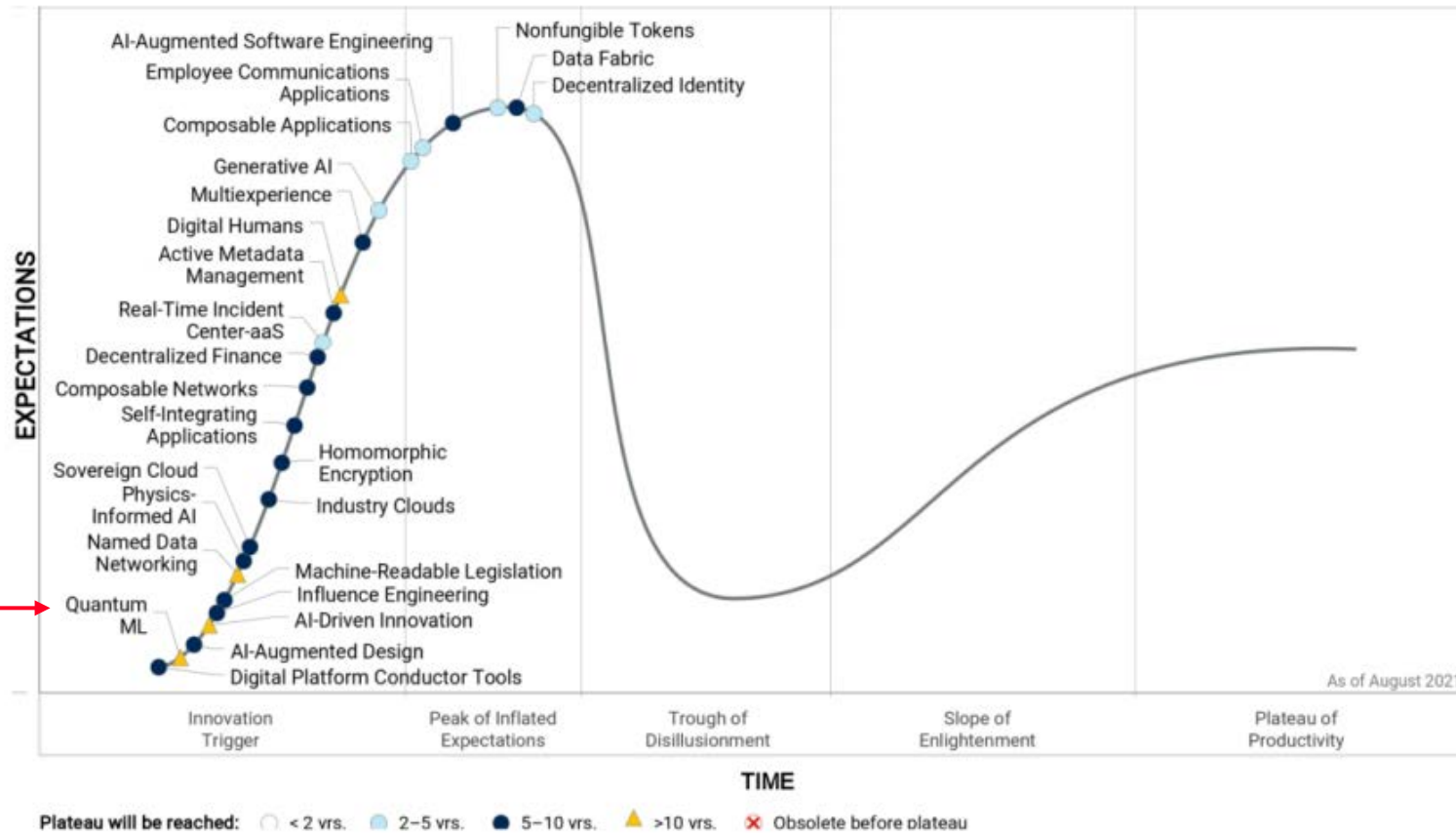


Note: The updates presented next will be discussed in the class, and the video recording of the discussion will be posted. Please check the course website.

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Gartner's Emerging Technology Hype Cycle 2021

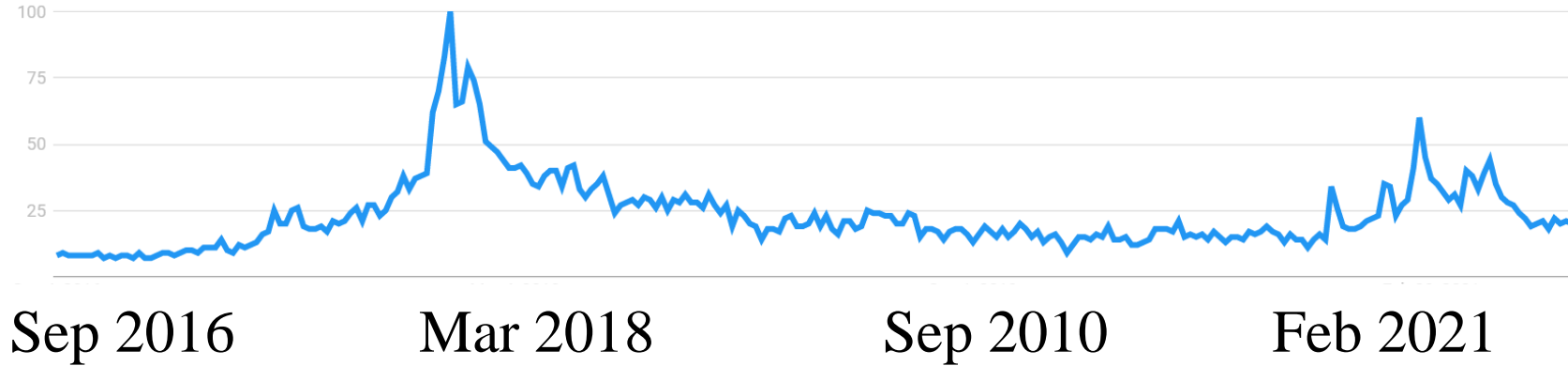


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Ref: B. Burke, M. Davis, P. Dawson, "Hype Cycle for Emerging Technologies, 2021," Gartner ID G00747576, 11 August 2021 (Available by subscription).

Blockchain



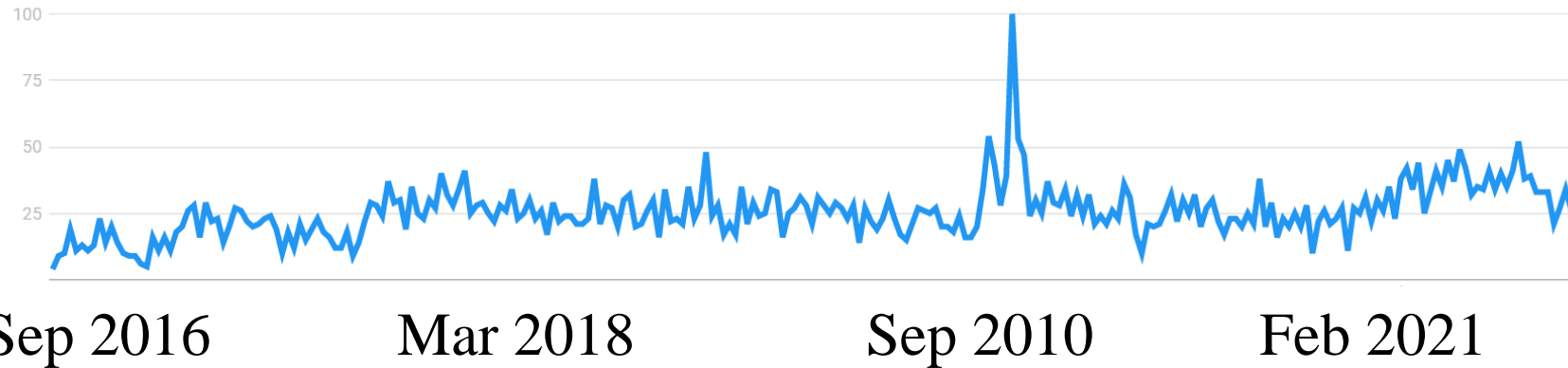
Snapshot 8/29/21

- ❑ Peaked in 2018.
- ❑ Increasing again with interest in Cryptocurrencies

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Quantum Computing



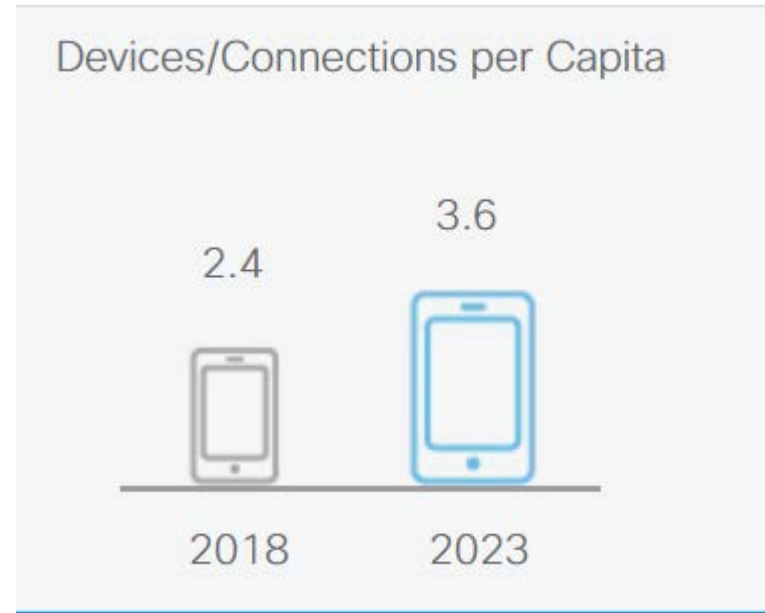
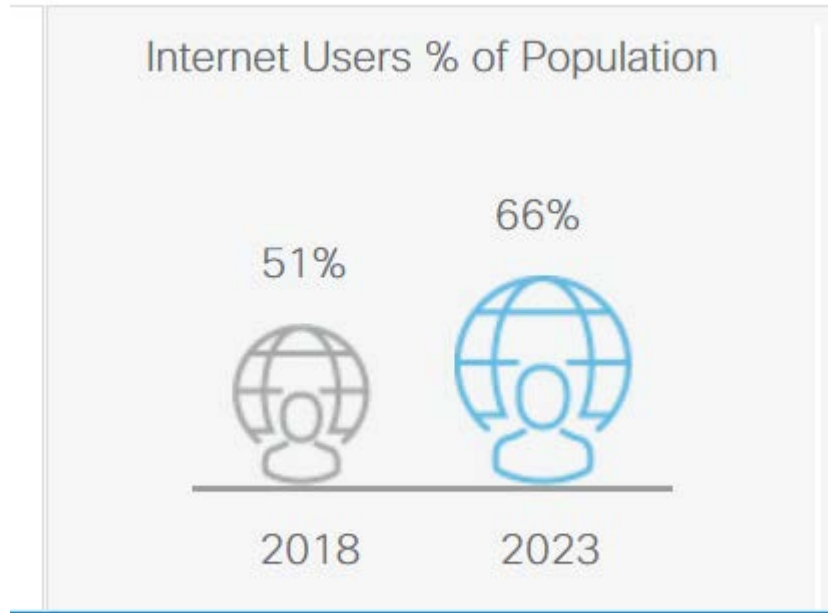
Snapshot 8/29/21

- ❑ Has been around for quite some time
- ❑ Public interest is up and down
- ❑ Expected to go up with US research funding

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Cisco Annual Report 2020 Highlights



□ There are more devices than people.

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Ref: Cisco, “Cisco Annual Internet Report (2018–2023),” March 2020,

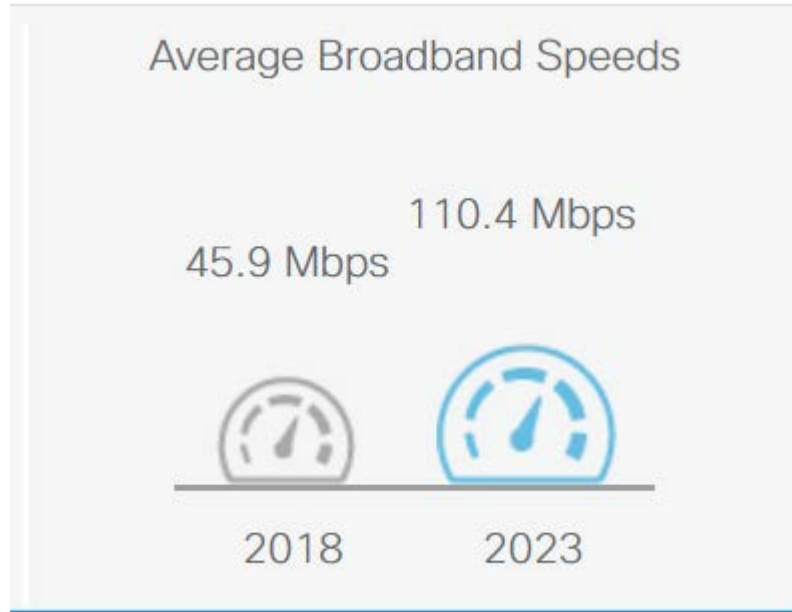
<https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html>

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Cisco Annual Report 2020 Highlights (Cont)



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<http://rajjain.com>

http://www.cse.wustl.edu/~jain/cse570-21/m_02trn.htm

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Related Modules



CSE 567: The Art of Computer Systems Performance Analysis

https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e_10TiDw



CSE 570: Recent Advances in Networking (Spring 2013)

<https://www.youtube.com/playlist?list=PLjGG94etKypLHyBN8mOgwJLHD2FFIMGq5>

CSE571S: Network Security (Spring 2011),

<https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u>



Video Podcasts of Prof. Raj Jain's Lectures,

<https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw>

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