Networking Trends

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

http://www.cse.wustl.edu/~jain/cse570-23/

Student Questions

Overview

❑ 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 2023, are included at the end. These new slides are outside the video and will be discussed in the class during the Q&A session.

Student Questions

Sources of Trends

❏ Activities in technical industry organizations: IEEE, IETF, ITU

❏ NSF funding areas

❏ Venture capital investments

❏ Industry analytics companies like Gartner

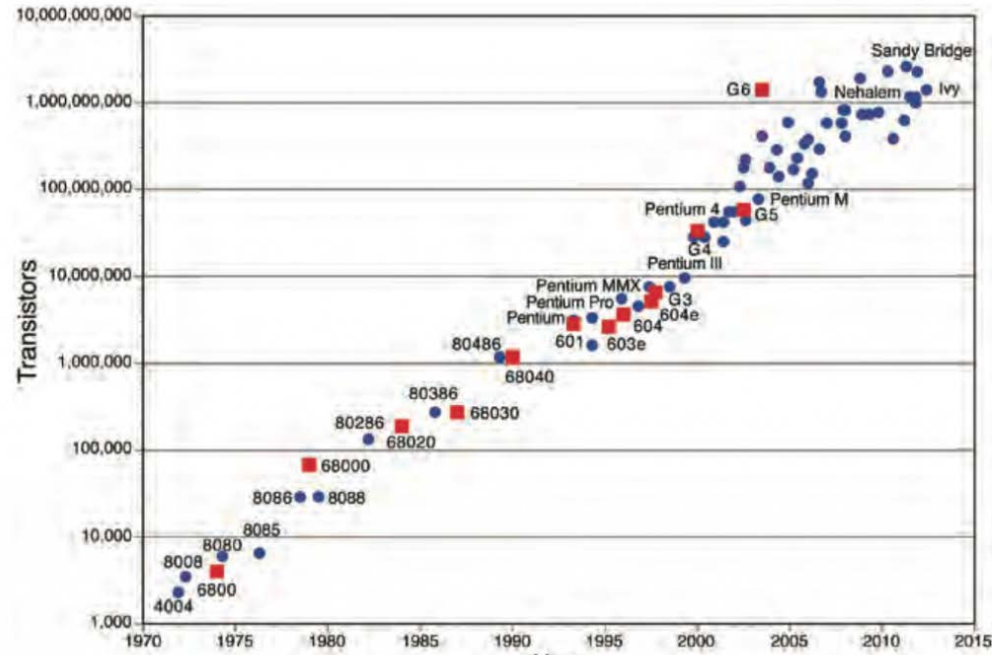❏ Google searches by people all over the world

"VCs have a herd mentality."

Student Questions

Processor Growth: Moore's Law

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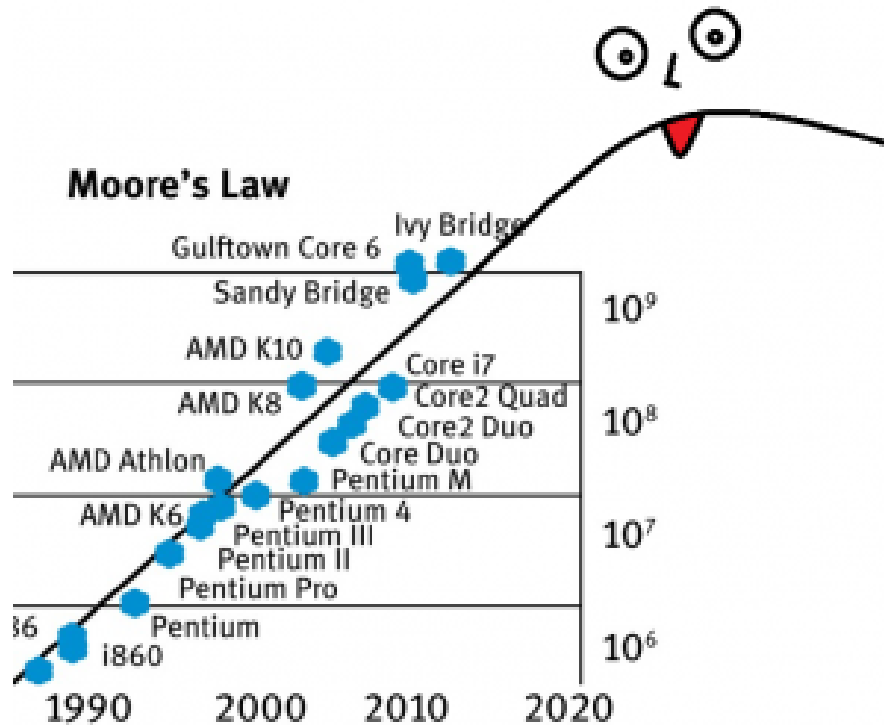

Student Questions

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?
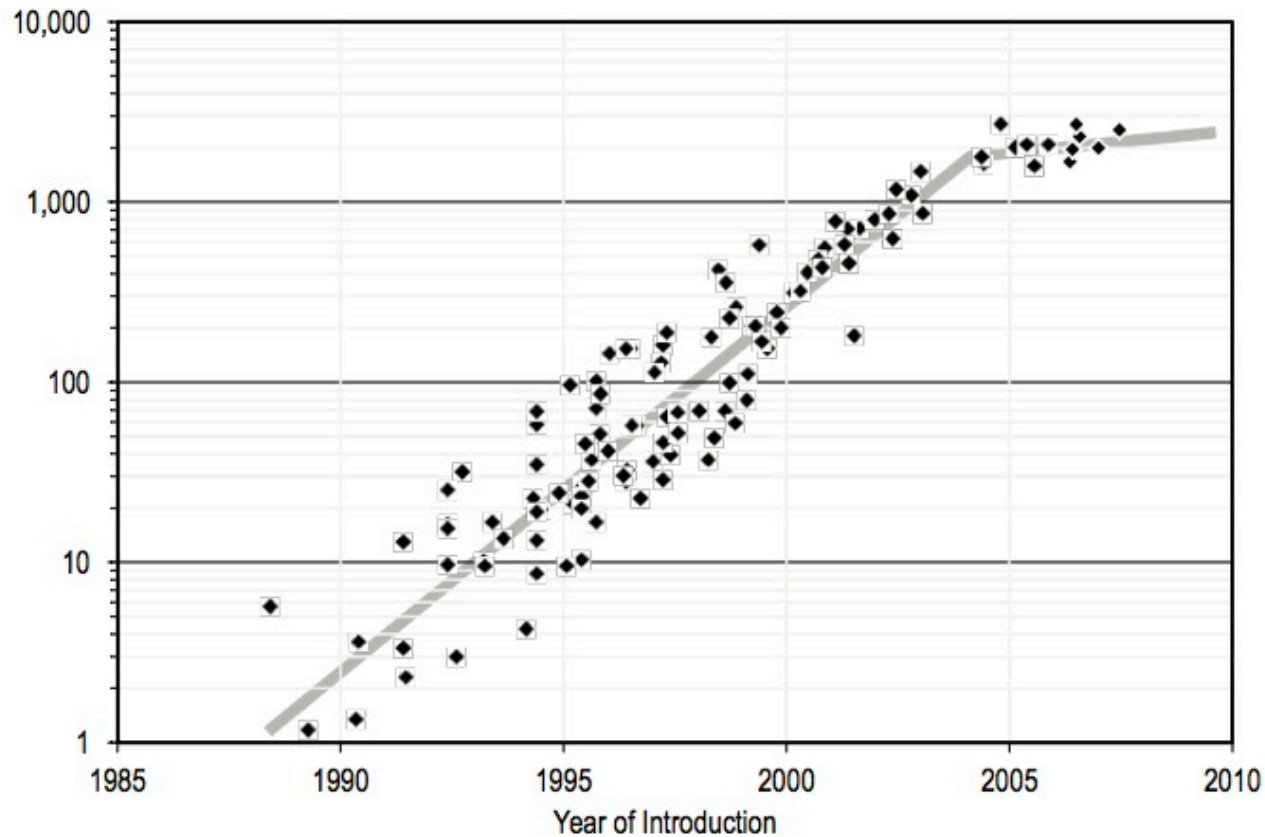
❑A debate has begun…

Student Questions

❑ Do you think Moore Laws is still relevant to us? Since there is good consensus now that it is not holding at least in semiconductors as we reach higher and higher transistors per chip.

Yes, it is no longer relevant.

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

Will Moore's Law Continue? (Cont)

❑ It may have broken down in 2004…

Ref: R. Jones, "Economics after Moore's Law," Soft Machines, July 21, 2107, http://www.softmachines.org/wordpress/'?p=2097
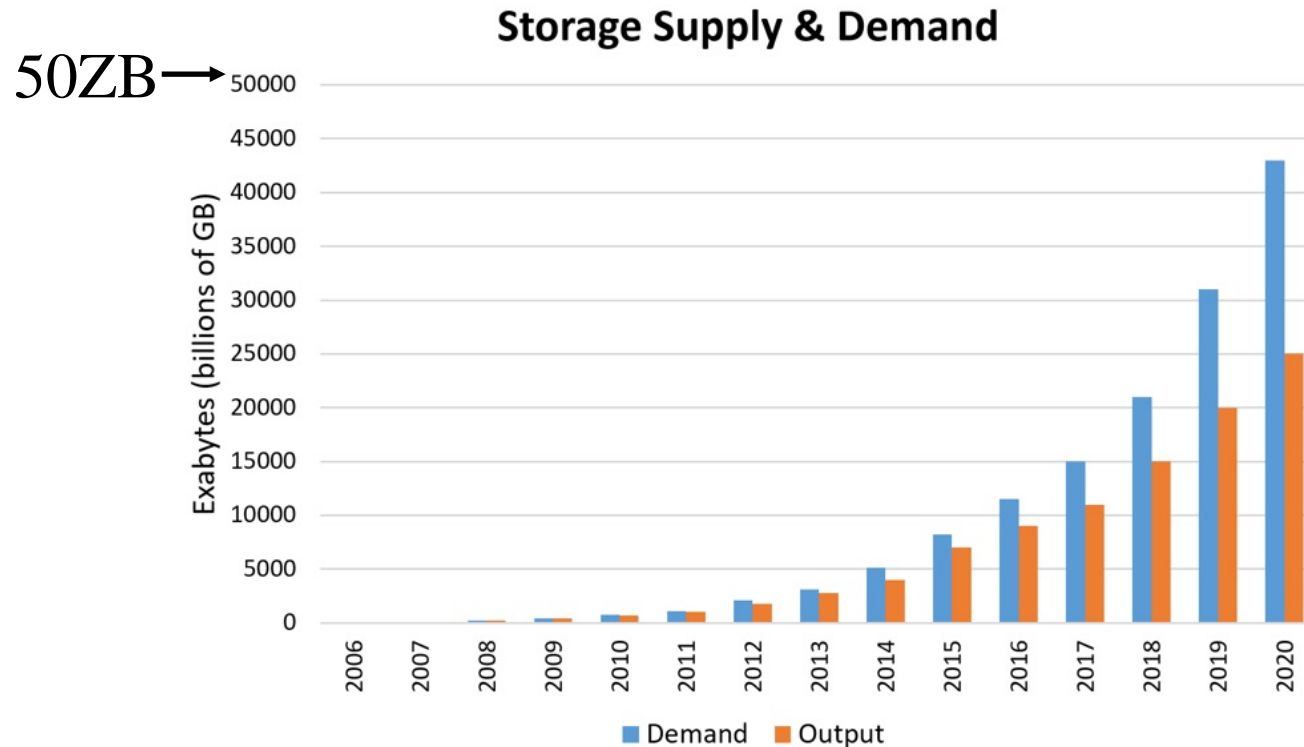
Student Questions

Storage Capacity

❑ Exa=10^{18}, Zetta=10^{21}, Yotta=10^{24}. Scales extended from Giga to Yotta in 1991
42% compound annual growth rate (CAGR)

Storage Supply & Demand

50ZB ➔

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

Student Questions

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, Face
Bank of America, …

➢ Almost all services need to be global (World is flat)

➢ Almost all services use cloud computing

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 the 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/m/en_us/service-provider/ciscoknowledgenetwork/files/622_11_15-16-Cisco_GCI_CKN_2015-2020_AMER_EMEAR_NOV2016.pdf


Student Questions

- How is a Cloud Datacenter different than a traditional one? Since both are hosted physically and provide services via some form of online link.
- The traditional data center and cloud just differs in how user are using them(physical / virtual machines)? Are their hardware still the same?

Data center = Owner occupied

Cloud = Rented
⇒ More security between VMs.
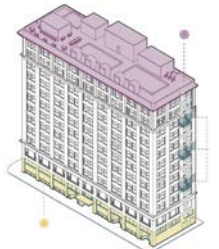
Cisco Visual Networking Index

Between 2016-2021 (5 Years):

- ❑ 3× growth in IP traffic ⇒ 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 ½ in 2016
  Smartphone 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 Smartphones
  49% CAGR for Machine-to-Machine

- ❑ **3 devices per capita** worldwide
  7 devices per user (North America) ⇒ 14 by 2020

Ref: Cisco, "Cisco Global Cloud Index: Forecast and Methodology, 2015-2020," 2016,
https://www.cisco.com/c/dam/m/en_us/service-provider/ciscoknowledgenetwork/files/622_11_15-16-Cisco_GCI_CKN_2015-2020_AMER_EMEAR_NOV2016.pdf

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Student Questions

- ❑ Does traffic between machine-to-machine also represent traffic between PCs, Tablets, Smartphones, etc., in a non-server/client environment (e.g. does it account for P2P traffic)?

Machine=A computer without a user sitting there, e.g., IoT

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
  $\Rightarrow$ 60 Ms = 5 M years to watch videos 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 Global Cloud Index: Forecast and Methodology, 2015-2020," 2016,
https://www.cisco.com/c/dam/m/en_us/service-provider/ciscoknowledgenetwork/files/622_11_15-16-Cisco_GCI_CKN_2015-2020_AMER_EMEAR_NOV2016.pdf
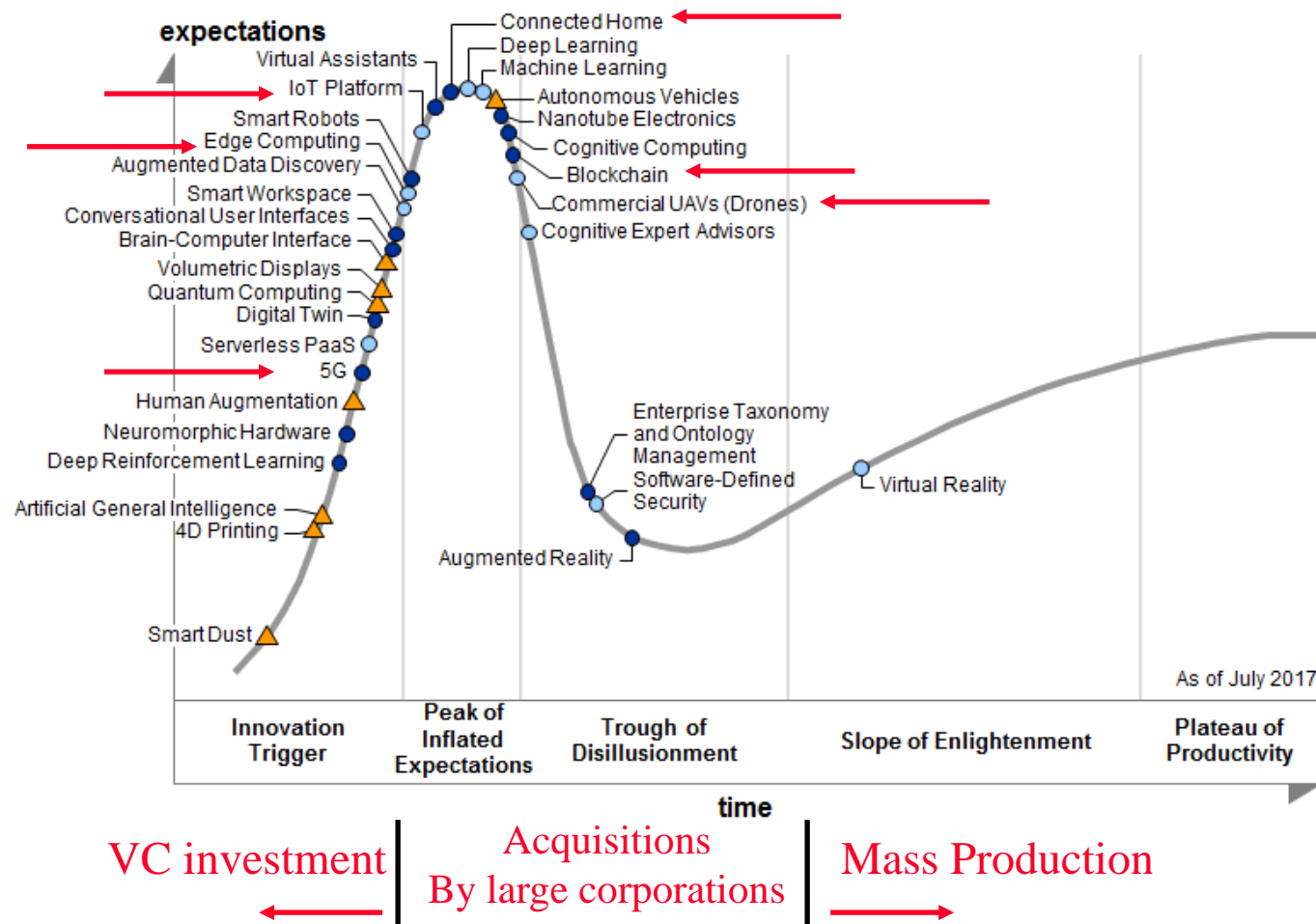
Student Questions

- According to Cisco's expectation on VR and AR, they were likely to grow a lot. But it's hard to find them in real life. Has it increased by 20 times? The Cisco was wrong about that or don't I know?

20 times zero is still zero

- What kind of new obstacles do you believe AR/VR traffic poses for networks?

Real-Time constraints

Gartner Hype Cycle 2017

Ref: Gartner, "Hype Cycle for Emerging Technologies, 2017," July 2017, [subscribers only]

Student Questions

- How exactly is "hype" measured by the Gartner Hype Cycle?

Hype is not measured it is believed.

- Can you demonstrate how to view the Gartner Hype Cycle in 2023 via WUSTL?

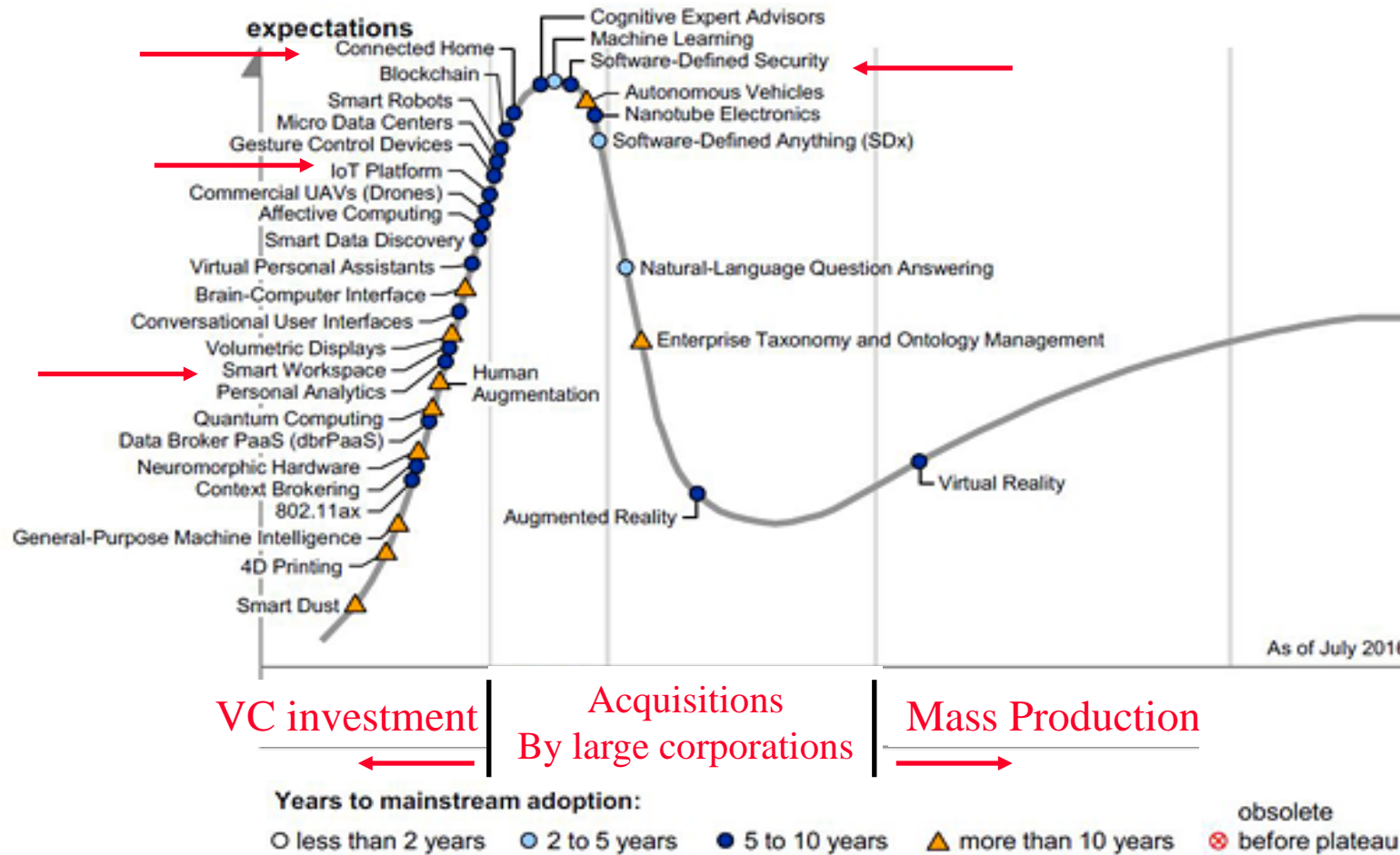*https://it.wustl.edu/2021/07/gartner-campus-access/*

Gartner Hype Cycle 2016

Student Questions

VC investment

Acquisitions
By large corporations

Mass Production

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

What is Google Trends?
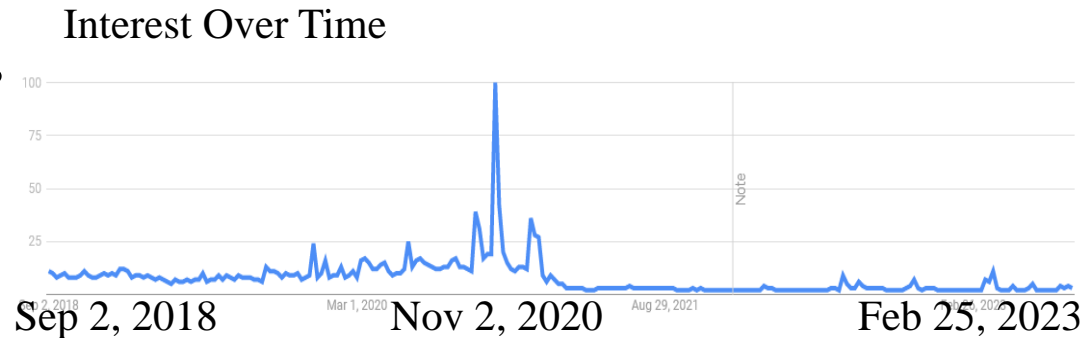
- A time series graph of the number of searches on any term of your choice
- Scaled to 100%. 100=Maximum over time
- Includes geographical distribution of those searches
- Includes major news items
- Example: "Donald Trump" Popular in Canada

Interest Over Time

Sep 2, 2018   Nov 2, 2020   Feb 25, 2023

Interest By Region

1	Canada	100
2	United States	97
3	Ireland	60
4	New Zealand	52
5	Australia	46

Student Questions

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

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.

Ref: C. Johnston, "Google Trends reveals clues about the mentality of richer nations,"
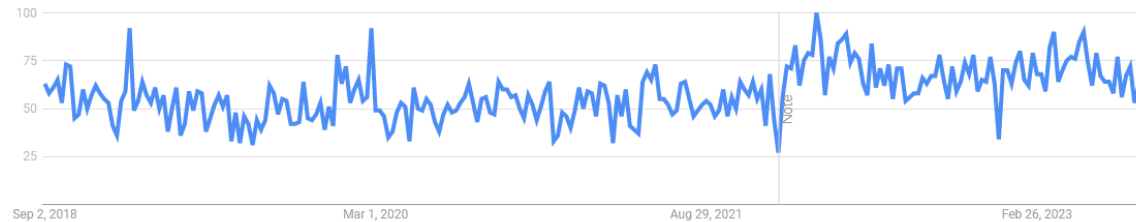http://arstechnica.com/gadgets/2012/04/google-trends-reveals-clues-about-the-mentality-of-richer-nations/
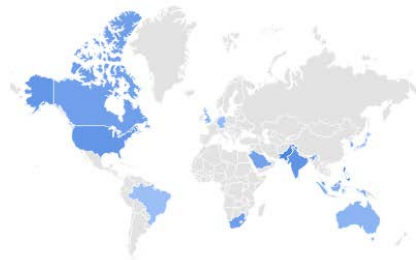
Data Center Network: Google Trends

□ Stable, Neither declining nor increasing

□ Mostly in USA and Singapore

□ Highly correlated probably because of IT industry services for US companies
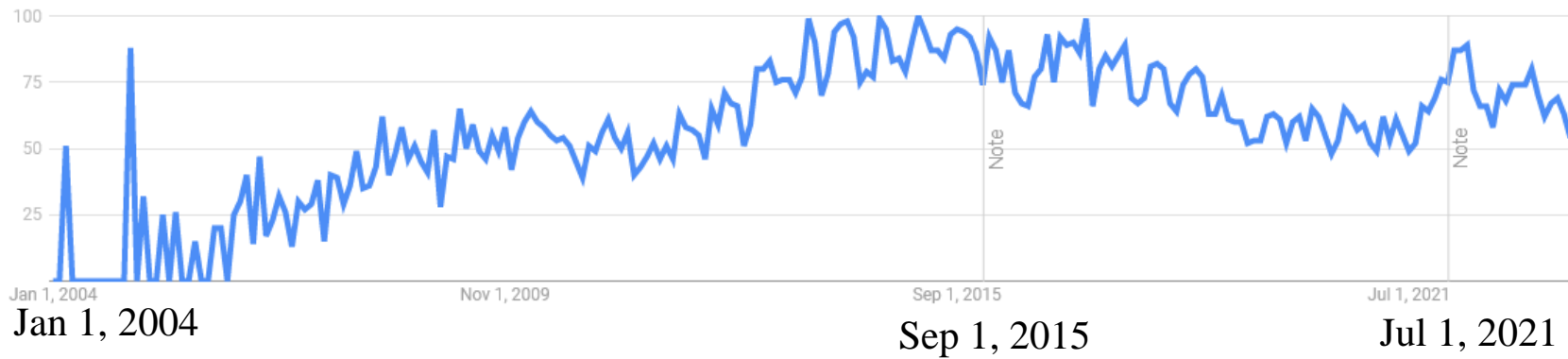

Sep 2, 2018   Nov 2, 2020   Feb 25, 2023

1 Singapore	100	
2 Philippines	75	
3 Pakistan	58	
4 India	45	
5 United States	43	

Student Questions

Network Virtualization: Google Trends

Jan 1, 2004   Sep 1, 2015   Jul 1, 2021

❑ Interest is
decreasing slowly

Student Questions

Virtualization: Google Trends

Jan 1, 2004   Jul 1, 2021
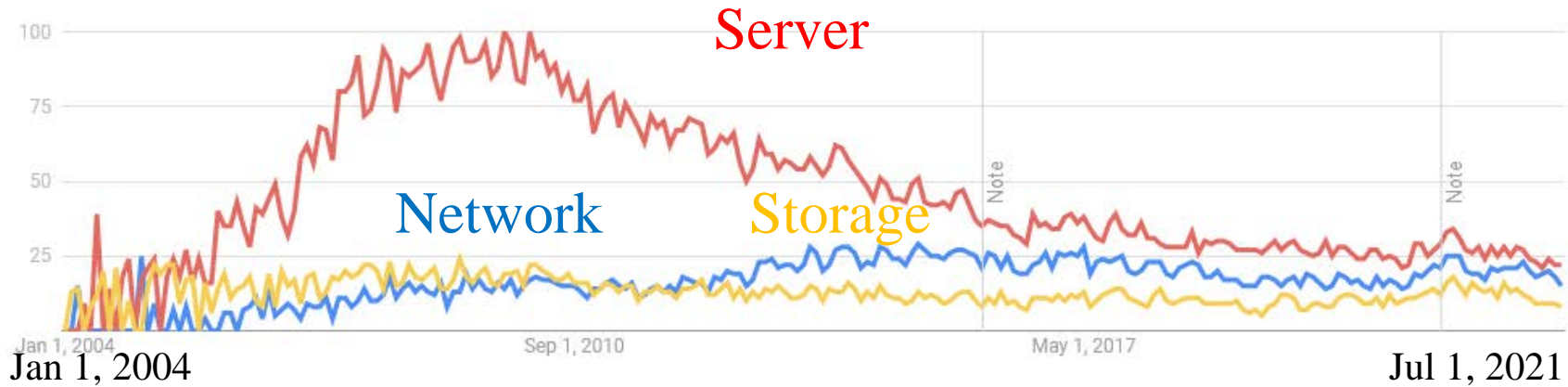
Student Questions

❑ Virtualization
- ➢ Server
- ➢ Network
- ➢ Storage

❑ Increasing curiosity about network virtualization

SDN: Google Trends

Jan 1, 2004

Jul 1, 2021
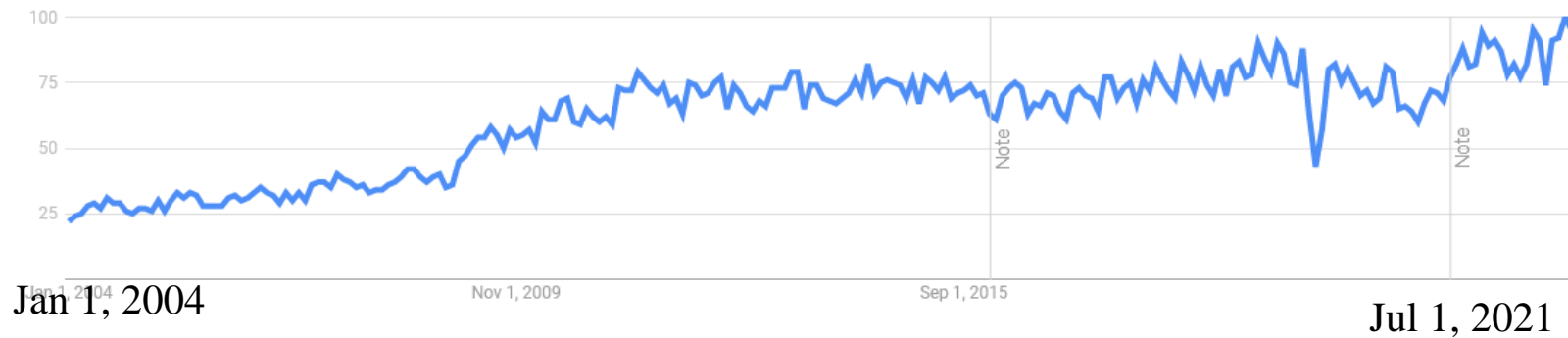
Student Questions
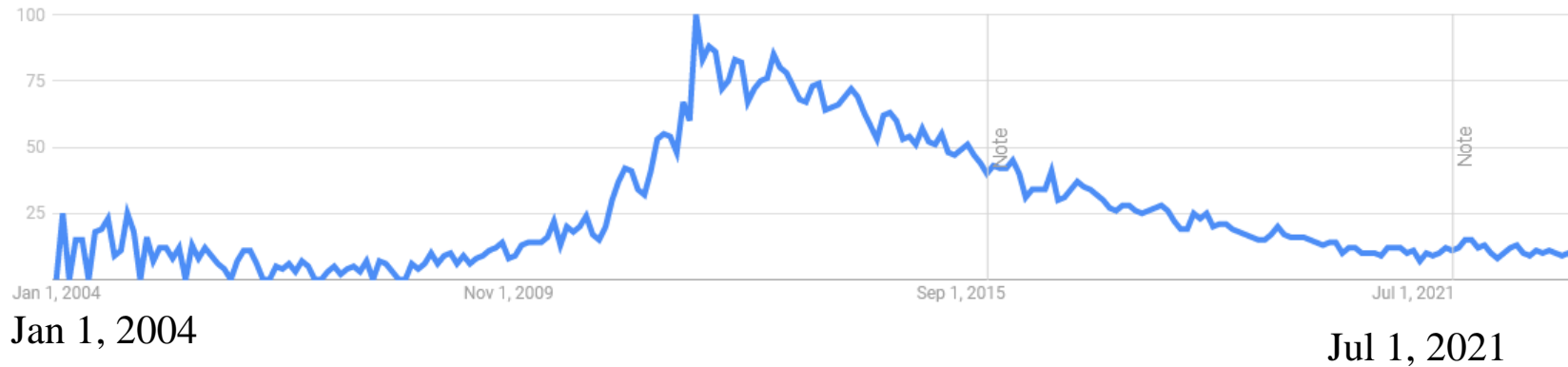
❑ Started May 21, 2011: Open Networking Foundation formed

❑ Software-defined networking, Software-defined network have slightly different trends

OpenFlow: Google Trends

Jan 1, 2004

Jul 1, 2021

❑Started April 2004

❑Past the peak
  (Everyone who needs to know knows)

❑Peak at Open Networking Summit (April/May 2012)

❑High interest in China, Taiwan, South Korea, Japan

Student Questions

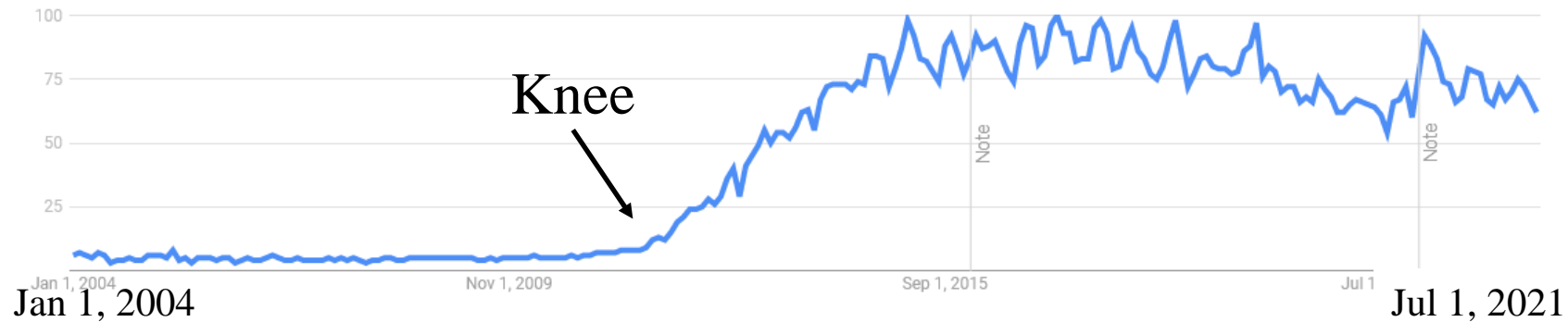# Cloud Computing: Google Trends

Jan 1, 2004   Jul 1, 2021

❑Past-Hype phase.
  As in Gartner's graphs

Snapshot: August 27, 2019

Student Questions

Big Data: Google Trends

Jan 1, 2004   Jul 1, 2021
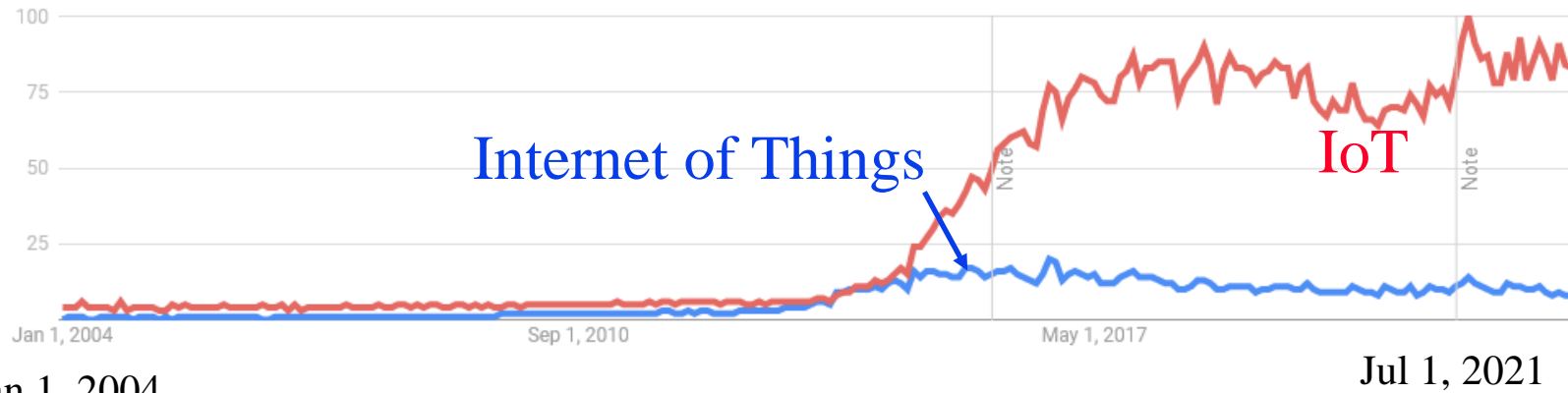
❑ Near the peak

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

Student Questions

IoT: Google Trends

Jan 1, 2004

Jul 1, 2021

❑ Still growing

❑ High interest all around the world

Student Questions

Other Trends

❑ IT/Network Automation

❑ Open Networking

❑ Mobility

❑ Security

❑ Analytics

❑ Containers – Docker

❑ DevOps: Developers and Operational personnel cooperation

Student Questions

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 Data Management and Analysis

❑ Software Productivity, Sustainability, and Quality

Ref: NITRD, "Networking & Information Technology R&D Program and the National Artificial Intelligence Initiative Office: Supplement to the President's FY 2023 Budget," Nov 2022, 103 pp.,

Student Questions

Internet Engineering Task Force (IETF)

❑ Internet of Things

❑ Autonomic networking to enable self-managing, self-healing, self-configuring, and self-optimizing networks

❑ Intent-based networking

❑ Computing in Networks

❑ Decentralized Internet

❑ Information Centric Networking

❑ Quantum Communications

❑ Time Sensitive Networking

❑ Routing inside Data Centers

❑ Security

Student Questions

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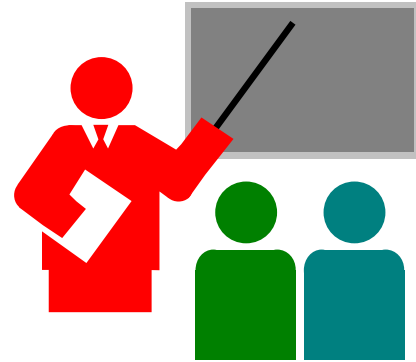
IEEE 802 LAN/MAN Standards

❑Security

❑Automotive Ethernet

❑Time Sensitive Networking

❑200 Gbps Ethernet, 400 Gbps PHY

❑Backplane Ethernet

Student Questions

Washington University in St. Louis   http://www.cse.wustl.edu/~jain/cse570-23/   ©2023 Raj Jain

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 mainstream.
Network virtualization and SDN are done.

4. All forecasting is based on the past ⇒ Continuous.
Real future is invented ⇒ Discontinuous

Student Questions

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

Student Questions

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

Student Questions

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
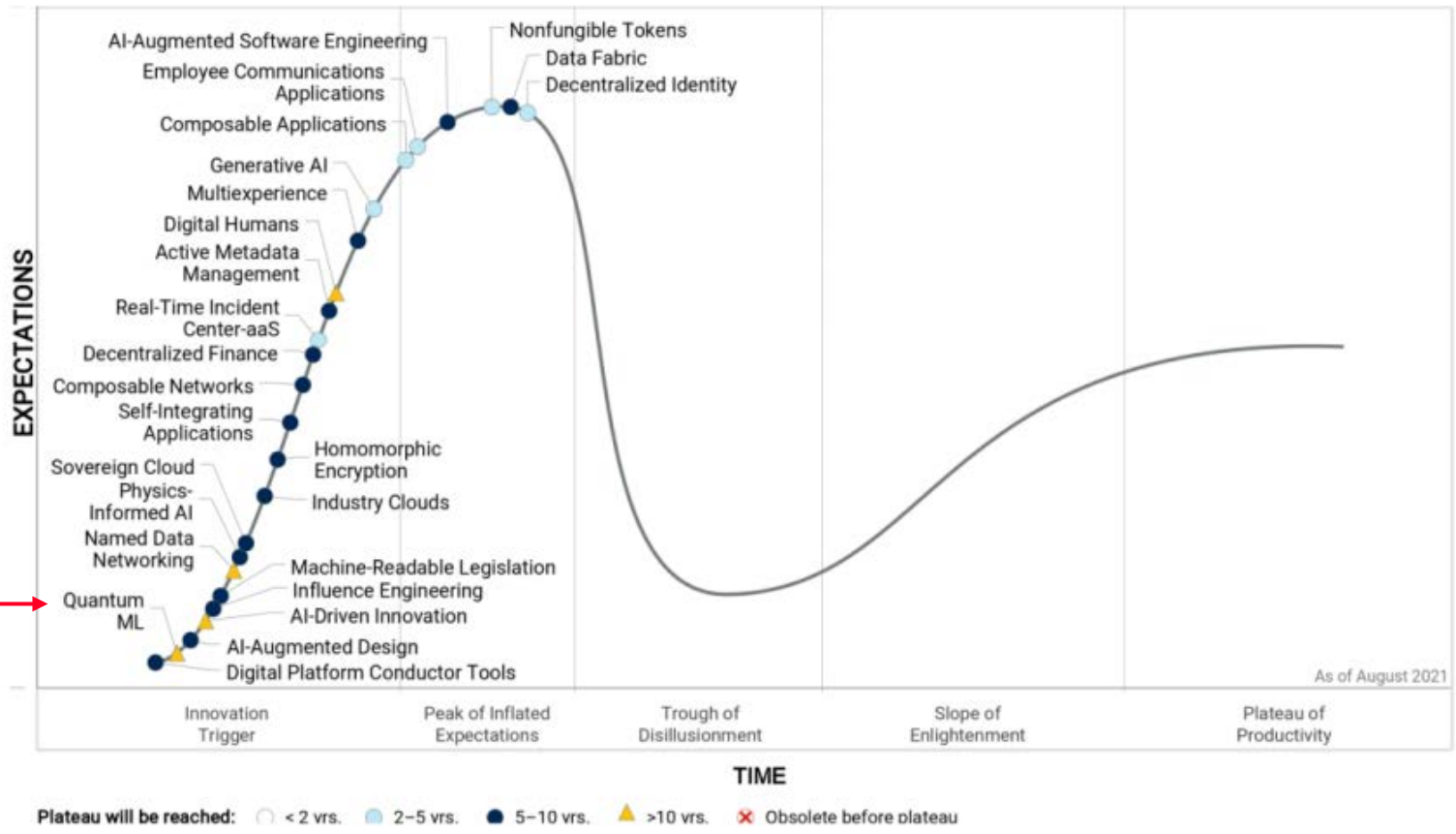- WiFi   Wireless Fidelity

Student Questions

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.
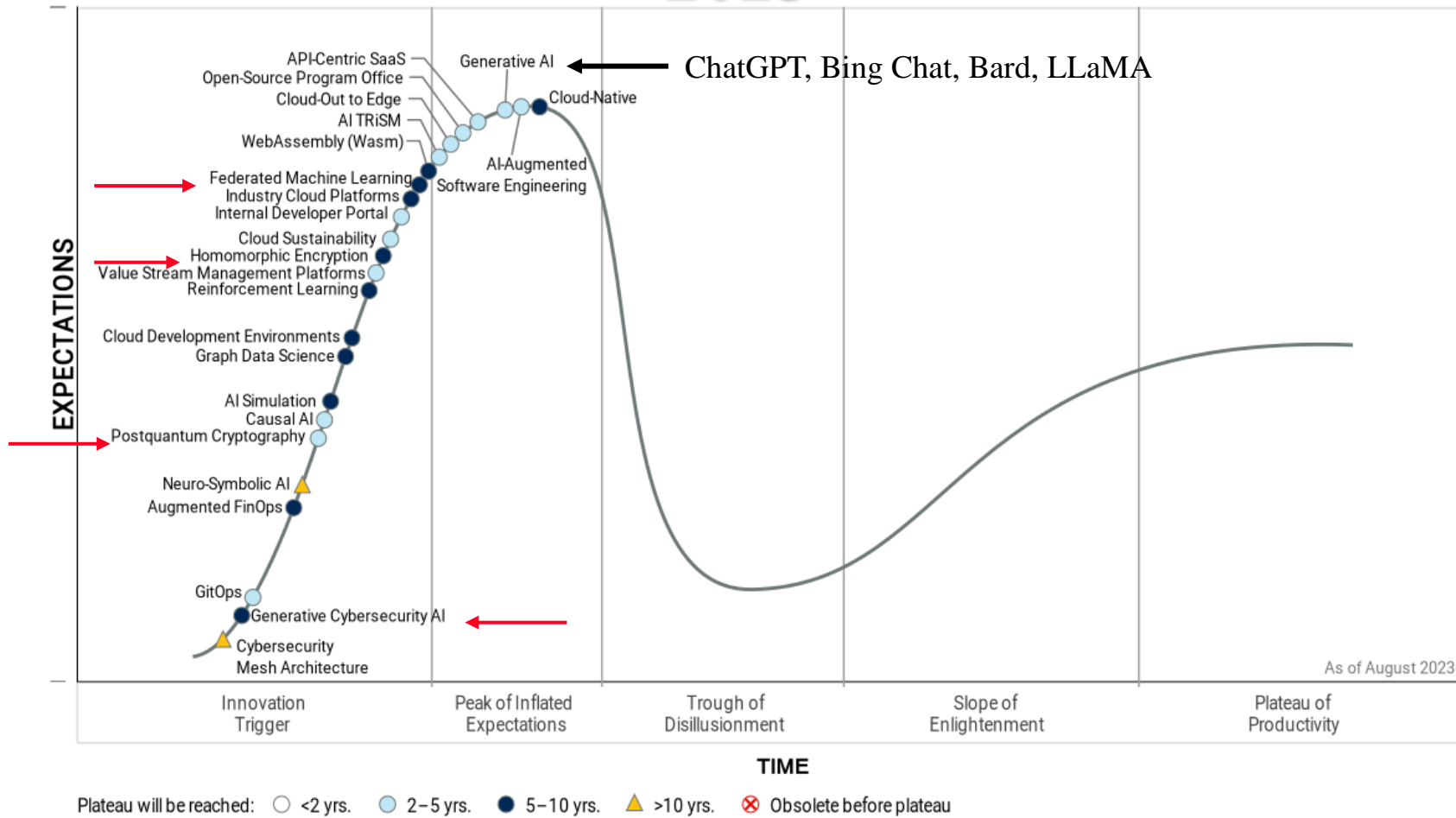
Student Questions

Gartner's Emerging Technology Hype Cycle 2021

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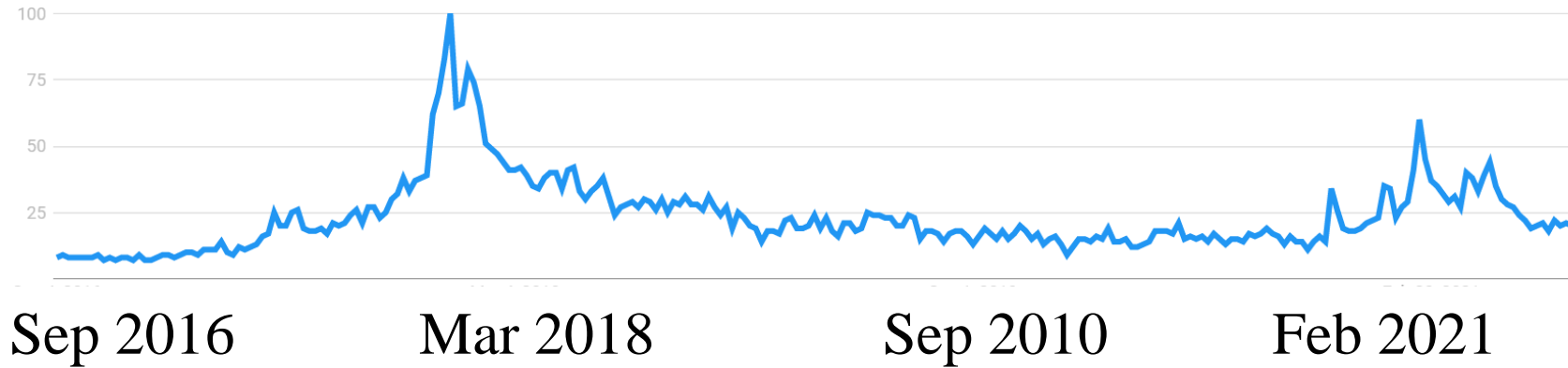
Student Questions

Gartner's Emerging Technology Hype Cycle 2023

ChatGPT, Bing Chat, Bard, LLaMA

Student Questions

Ref: A. Chandrasekaran, M. Davis, "Hype Cycle for Emerging Technologies, 2023," Gartner ID G00793566, 2 August 2023 (Available by subscription).
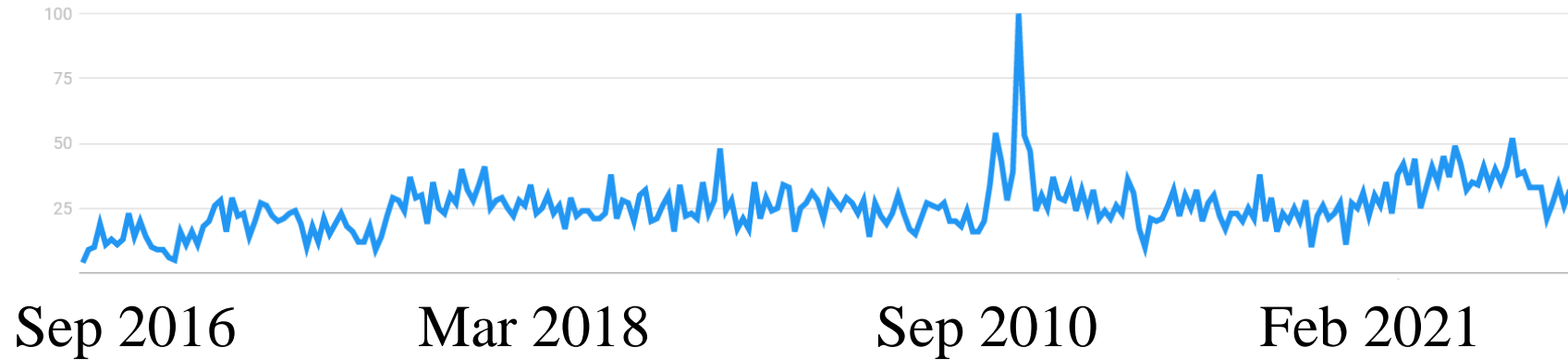
Blockchain

Sep 2016   Mar 2018   Sep 2010   Feb 2021

Snapshot 8/29/21

❑ Peaked in 2018.

❑ Increasing again with interest in Cryptocurrencies

Student Questions

Quantum Computing

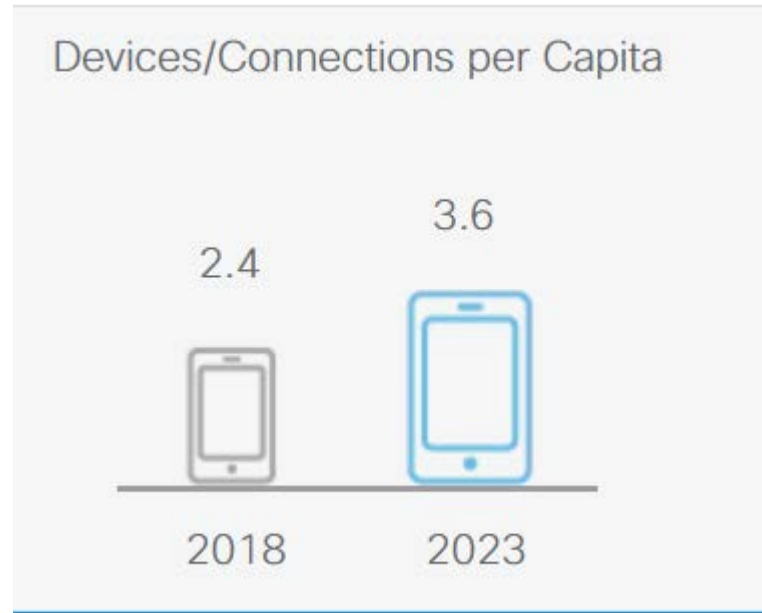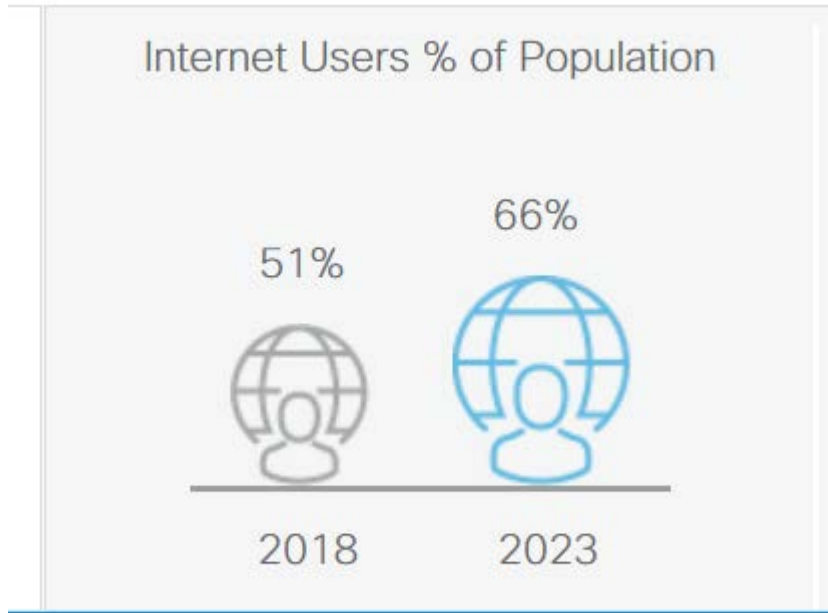Sep 2016   Mar 2018   Sep 2010   Feb 2021

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

Student Questions

http://www.cse.wustl.edu/~jain/cse570-23/

Cisco Annual Report 2020 Highlights

Internet Users % of Population

51% — 2018
66% — 2023

Devices/Connections per Capita

2.4 — 2018
3.6 — 2023

❑ There are more devices than people.

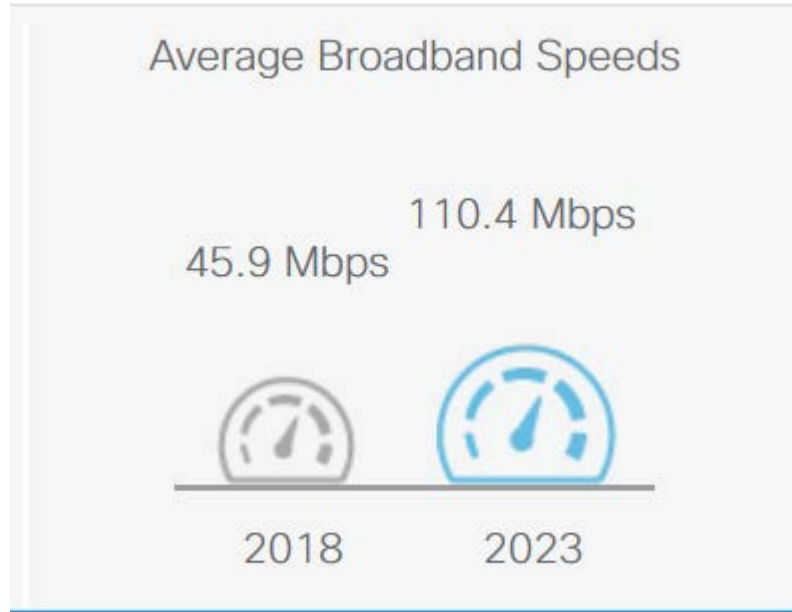Ref: Cisco, "Cisco Annual Internet Report (2018–2023)," March 2020,
https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Student Questions

Cisco Annual Report 2020 Highlights (Cont)

Average Broadband Speeds

45.9 Mbps

110.4 Mbps

2018   2023

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Raj Jain

http://rajjain.com

Student Questions

Grading: Both video on canvas and google form are required for video review assignments. Missing either one will result in a zero score. Only six have filled out the Google form. Ten have viewed the video. Seven are not participating in either.

http://www.cse.wustl.edu/~jain/cse570-23/m_02trn.htm

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=PLjGG94etKypJWOSPMh8Azcgy5e_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

Student Questions