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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      - ❖ Fourth Level
        - ✓ Fifth Level

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 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
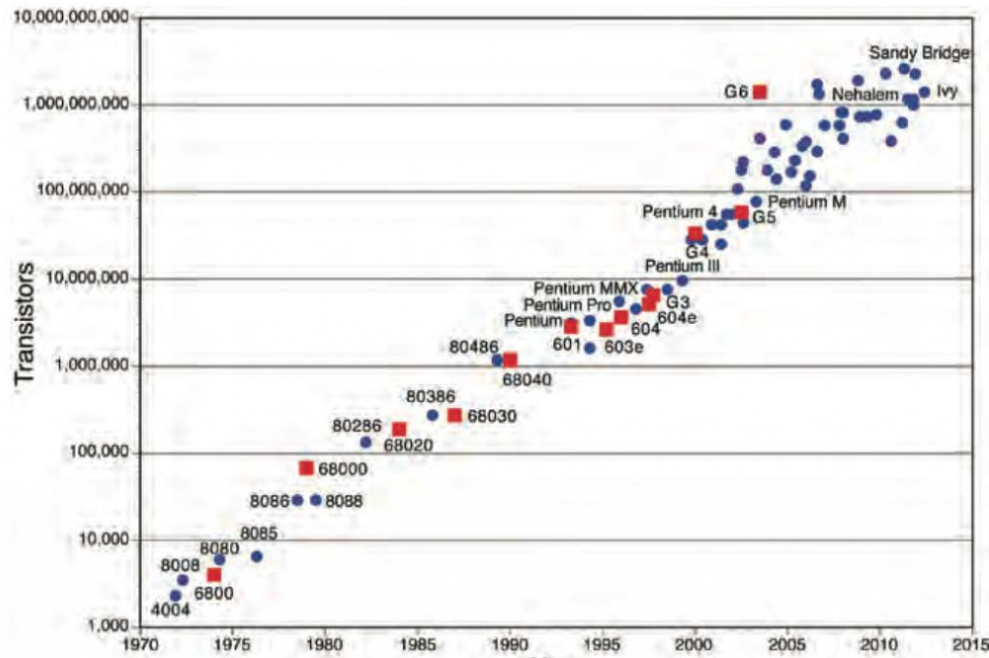
❑ Google searches by people all over the world

"VCs have a herd mentality."

Student Questions

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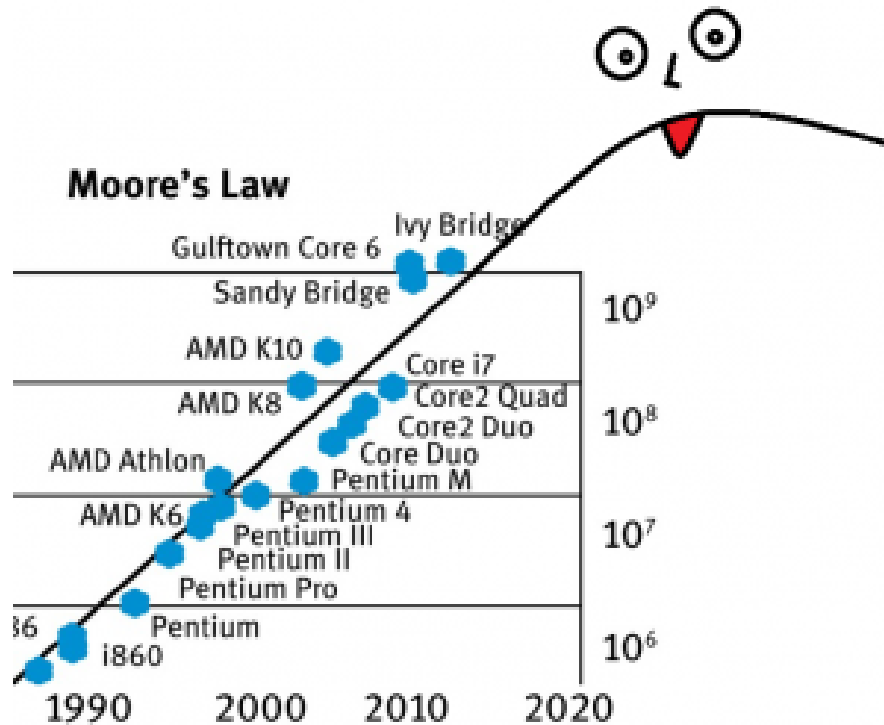
Ref: B. James, "Moore's Law sad that no one believes in it anymore," The Hard Time, October 23, 2017,
http://thehardtime.com/moores-law-sad-no-one-believes-anymore

Will Moore's Law Continue? (Cont)

❑ It may have broken down in 2004…
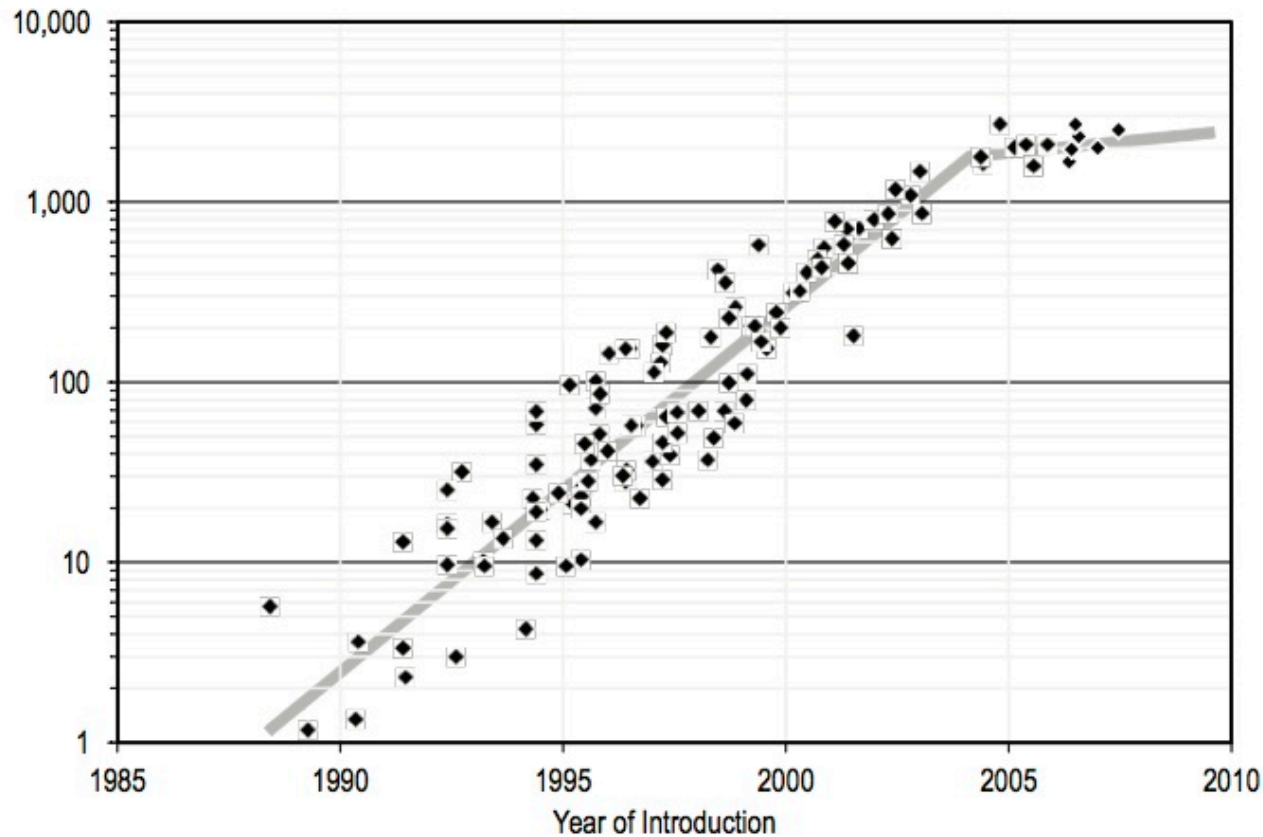
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Ref: R. Jones, "Economics after Moore's Law," Soft Machines, July 21, 2107, http://www.softmachines.org/wordpress/?p=2097

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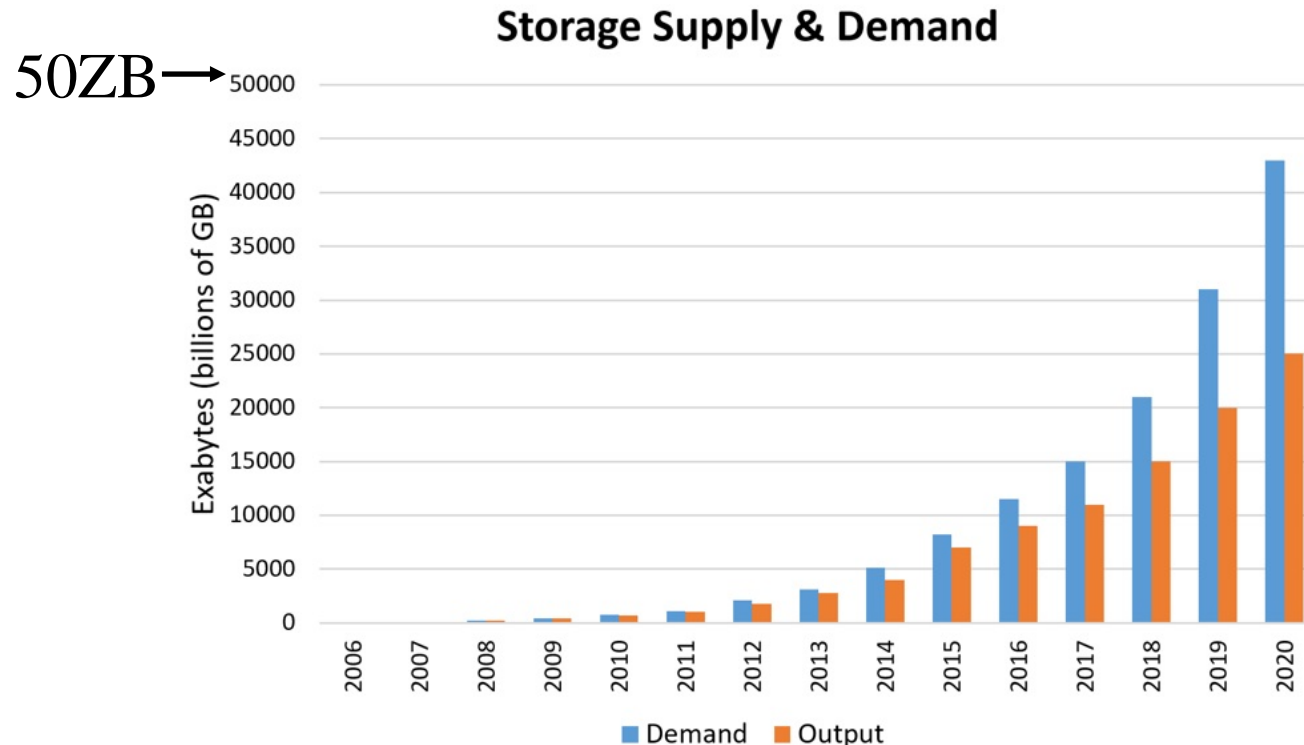
Ref: L. Rizzatti, "Digital Data Storage is Undergoing Mind-Boggling Growth," EE Times, September 14, 2016,
https://www.eetimes.com/author.asp?section_id=36&doc_id=1330462

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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, 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

Student Questions

• You said that developing mobile apps is not a scalable solution because their number, somehow, grows at a rate similar to the growth rate of the new websites and services. what is the definition of scalability? Is it just linear or a fixed growth rate?

Only one client – Firefox or Chrome is required for a million businesses. I don't need to store each website in my computer. With Apps, you need a million apps and you need to store them. Only Apple wins. Customer resources are not bounded. Scalability can be defined as linear, exponential, etc. Web solution is constant.

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

Student Questions

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
  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) ⟹ 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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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 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 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

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Gartner Hype Cycle 2017

expectations

- Connected Home ←
- Deep Learning
- Machine Learning
- Virtual Assistants
- IoT Platform ←
- Autonomous Vehicles
- Nanotube Electronics
- Smart Robots
- Edge Computing ←
- Augmented Data Discovery
- Cognitive Computing
- Smart Workspace
- Blockchain ←
- Conversational User Interfaces
- Commercial UAVs (Drones) ←
- Brain-Computer Interface
- Cognitive Expert Advisors
- Volumetric Displays
- Quantum Computing
- Digital Twin
- Serverless PaaS
- 5G ←
- Human Augmentation
- Neuromorphic Hardware
- Deep Reinforcement Learning
- Artificial General Intelligence
- 4D Printing
- Smart Dust

Enterprise Taxonomy and Ontology Management

Software-Defined Security

Virtual Reality

Augmented Reality

As of July 2017

| Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity |

time

VC investment ←

Acquisitions By large corporations

Mass Production →

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

Student Questions

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Gartner Hype Cycle 2016

expectations

Connected Home
Blockchain
Smart Robots
Micro Data Centers
Gesture Control Devices
IoT Platform
Commercial UAVs (Drones)
Affective Computing
Smart Data Discovery
Virtual Personal Assistants
Brain-Computer Interface
Conversational User Interfaces
Volumetric Displays
Smart Workspace
Personal Analytics
Quantum Computing
Data Broker PaaS (dbrPaaS)
Neuromorphic Hardware
Context Brokering
802.11ax
General-Purpose Machine Intelligence
4D Printing
Smart Dust

Cognitive Expert Advisors
Machine Learning
Software-Defined Security
Autonomous Vehicles
Nanotube Electronics
Software-Defined Anything (SDx)

Natural-Language Question Answering

Enterprise Taxonomy and Ontology Management

Human Augmentation

Virtual Reality

Augmented Reality

As of July 2016

VC investment

Acquisitions By large corporations

Mass Production

Years to mainstream adoption:
○ less than 2 years ◔ 2 to 5 years ● 5 to 10 years ▲ more than 10 years ⊗ obsolete before plateau

Source: Gartner (July 2016)

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

Student Questions

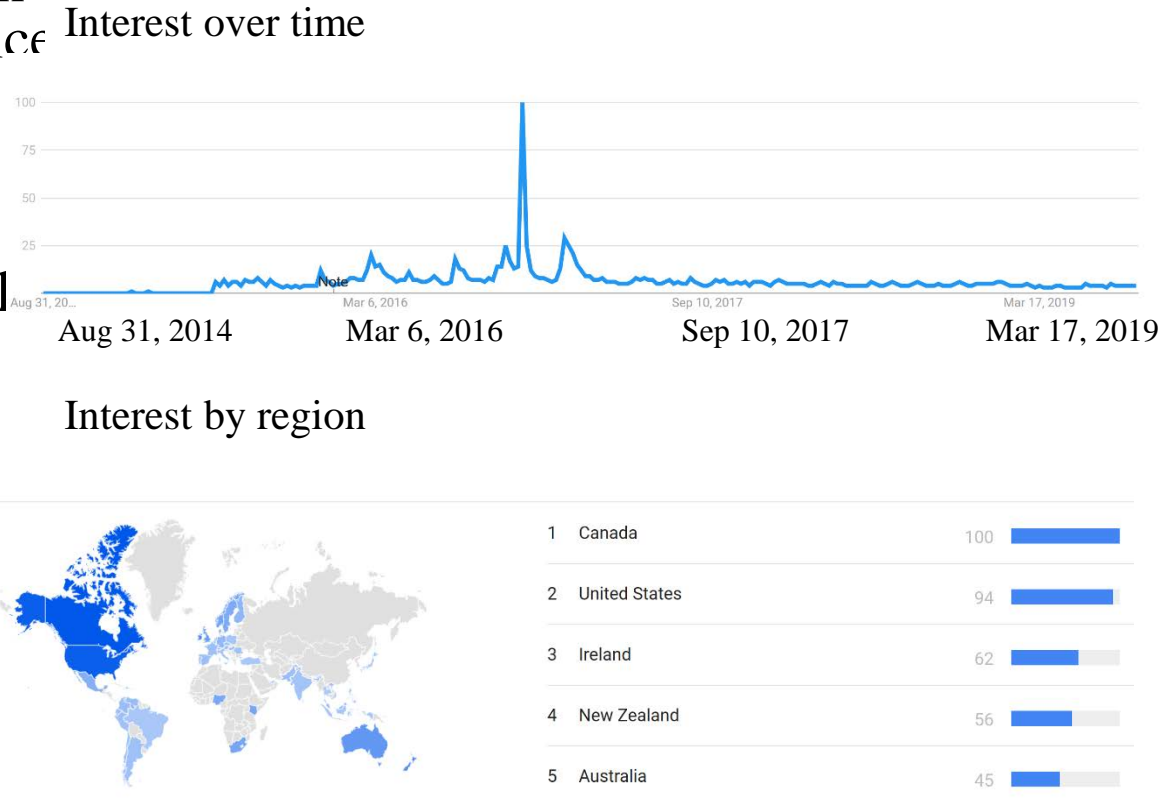- Click to edit Master text styles
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What is Google Trends?

- 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

Interest over time

Interest by region

Snapshot: Aug 27, 2019

1	Canada	100
2	United States	94
3	Ireland	62
4	New Zealand	56
5	Australia	45

Aug 31, 2014   Mar 6, 2016   Sep 10, 2017   Mar 17, 2019

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

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2-14

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.

Student Questions
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        ✓ Fifth Level

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
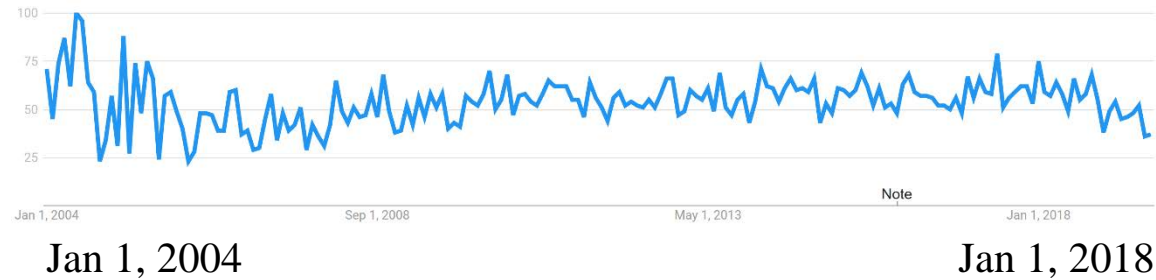
❑ Mostly in USA and India

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

Jan 1, 2004   Jan 1, 2018

1	India	100
2	United States	79
3	Canada	50
4	Australia	35
5	Indonesia	31

Snapshot: August 27, 2019

Student Questions

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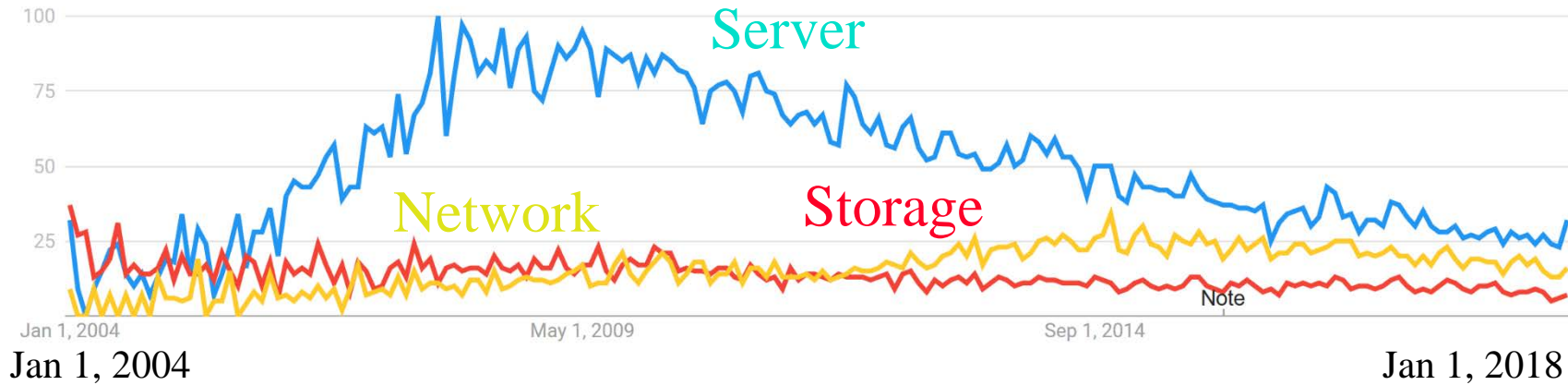   ✓ Fifth Level

Network Virtualization: Google Trends

Jan 1, 2004   Jan 1, 2018
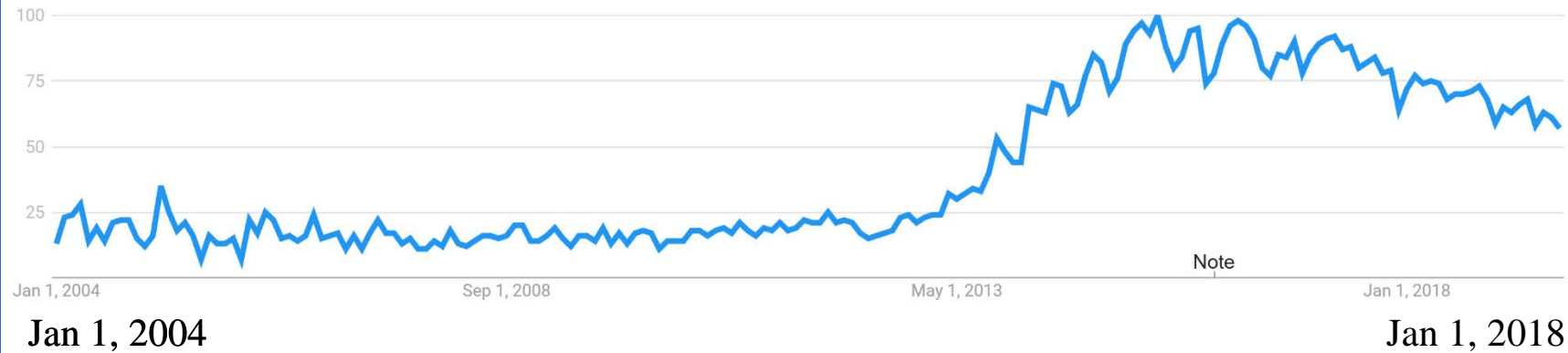
❑Interest is
decreasing slowly

Snapshot: August 27, 2019

Student Questions

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    ❑ Third Level
      ❖ Fourth Level
        ✓ Fifth Level

Virtualization: Google Trends

Server
Network
Storage

Jan 1, 2004   Jan 1, 2018

Snapshot: August 27, 2019

❑ Virtualization
  ➢ Server
  ➢ Storage
  ➢ Network
❑ Increasing curiosity about network virtualization

Student Questions
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        ✓ Fifth Level

SDN: Google Trends

Jan 1, 2004   Jan 1, 2018
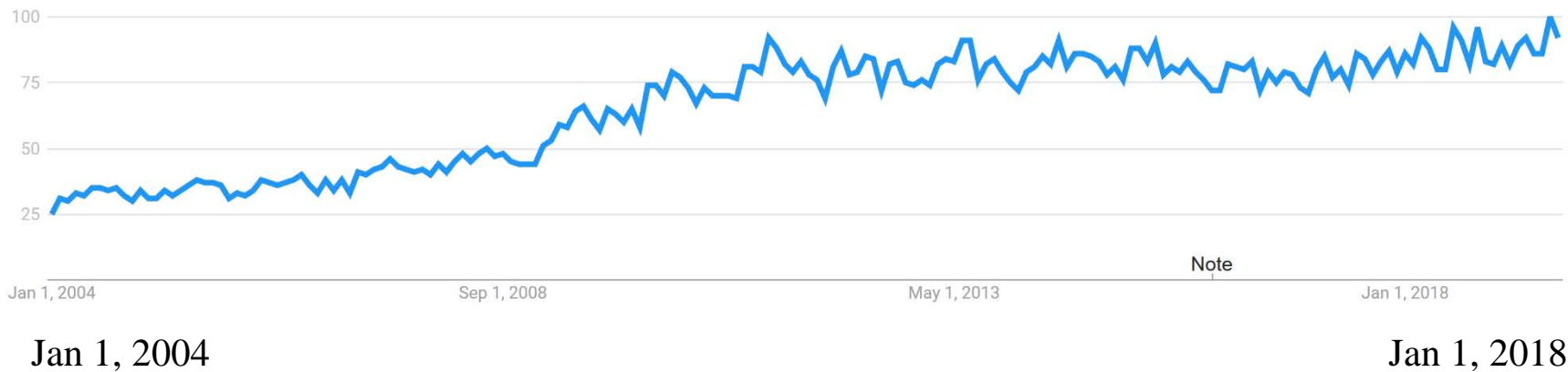
❑ Started May 21, 2011: Open Networking Foundation formed

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

Snapshot: August 27, 2019

Student Questions
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OpenFlow: Google Trends

Jan 1, 2004   Jan 1, 2018
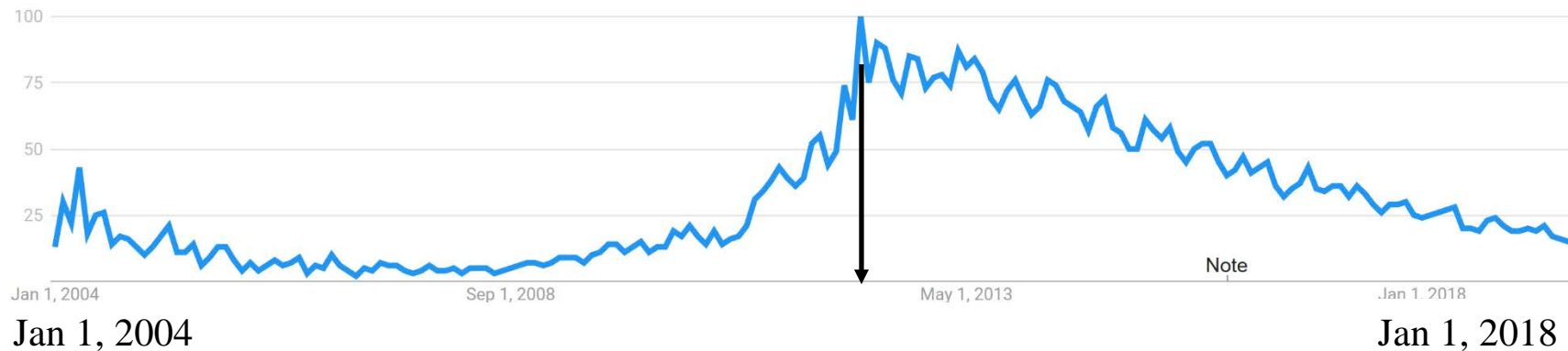
❑ Started April 2004
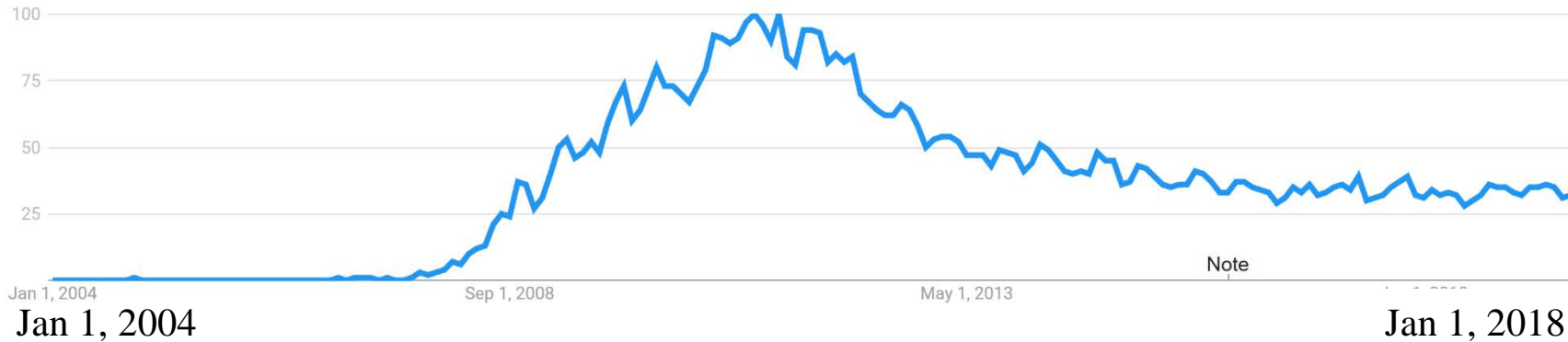
❑ Past the peak
(Everyone who needs to know knows)

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

❑ High interest in Korea, Taiwan, Japan, China Snapshot: August 27, 2019

Student Questions

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Cloud Computing: Google Trends
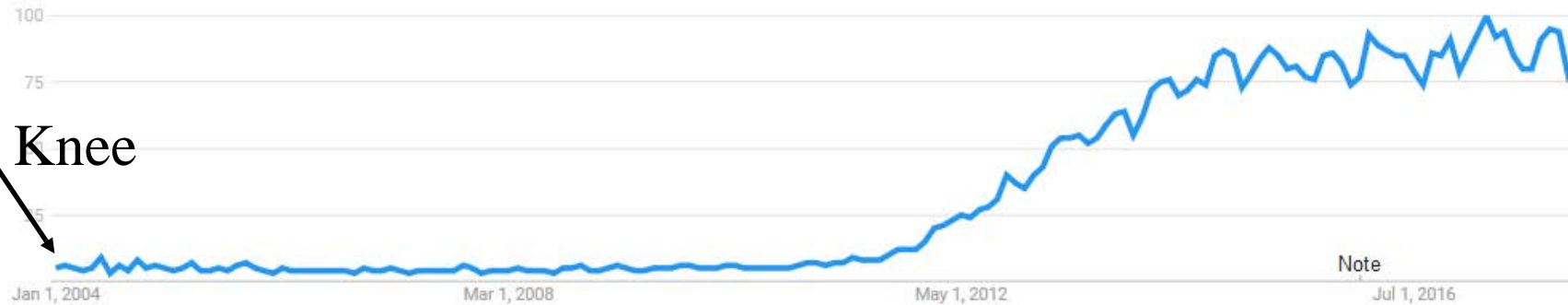

Jan 1, 2004   Jan 1, 2018

❑ Past-Hype phase.
As in Gartner graphs

Snapshot: August 27, 2019

Student Questions
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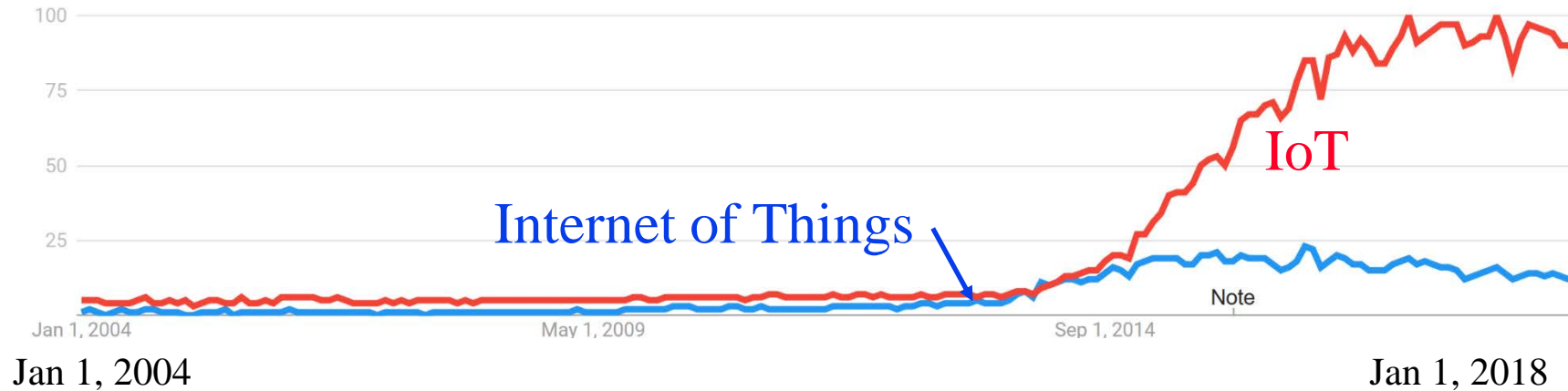   - ✓ Fifth Level

Big Data: Google Trends

Knee

Snapshot: January 21, 2018

❑ 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.
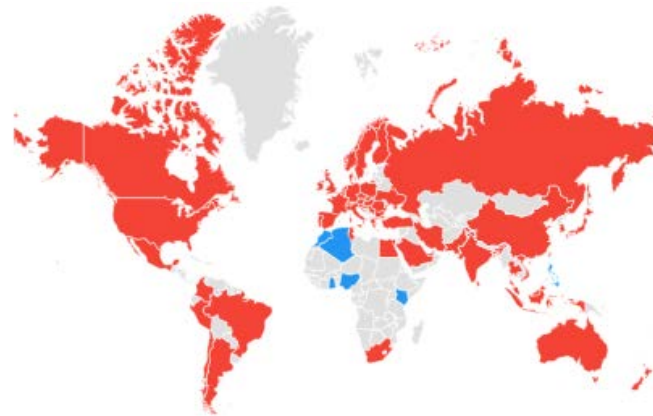
Student Questions
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         ❖ Fourth Level
            ✓ Fifth Level

IoT: Google Trends

Jan 1, 2004

Jan 1, 2018

❑ Still growing

❑ High interest all around the wo

Snapshot: August 27, 2019

Student Questions

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      ❖ Fourth Level
        ✓ Fifth Level

Other Trends

❑ IT/Network Automation

❑ Open Networking

❑ Mobility

❑ Security

❑ Analytics

❑ Containers – Docker

❑ DevOps: Developers and Operational personnel cooperation

Student Questions

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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

Student Questions

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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

Student Questions

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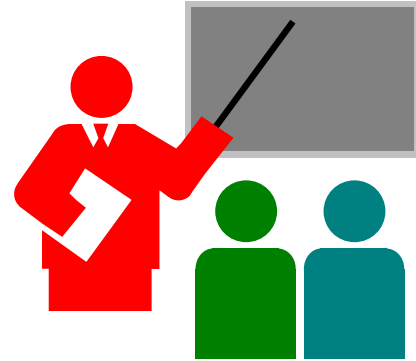   ❖ Fourth Level
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Ref: http://ietf.org/

IEEE 802 LAN/MAN Standards

❑ Security

❑ Automotive Ethernet

❑ Time Sensitive Networking

❑ 200 Gbps Ethernet, 400 Gbps PHY

❑ Backplane Ethernet

Student Questions
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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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      ❖ Fourth Level
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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

Student Questions
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      - Fourth Level
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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

Student Questions

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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

Student Questions

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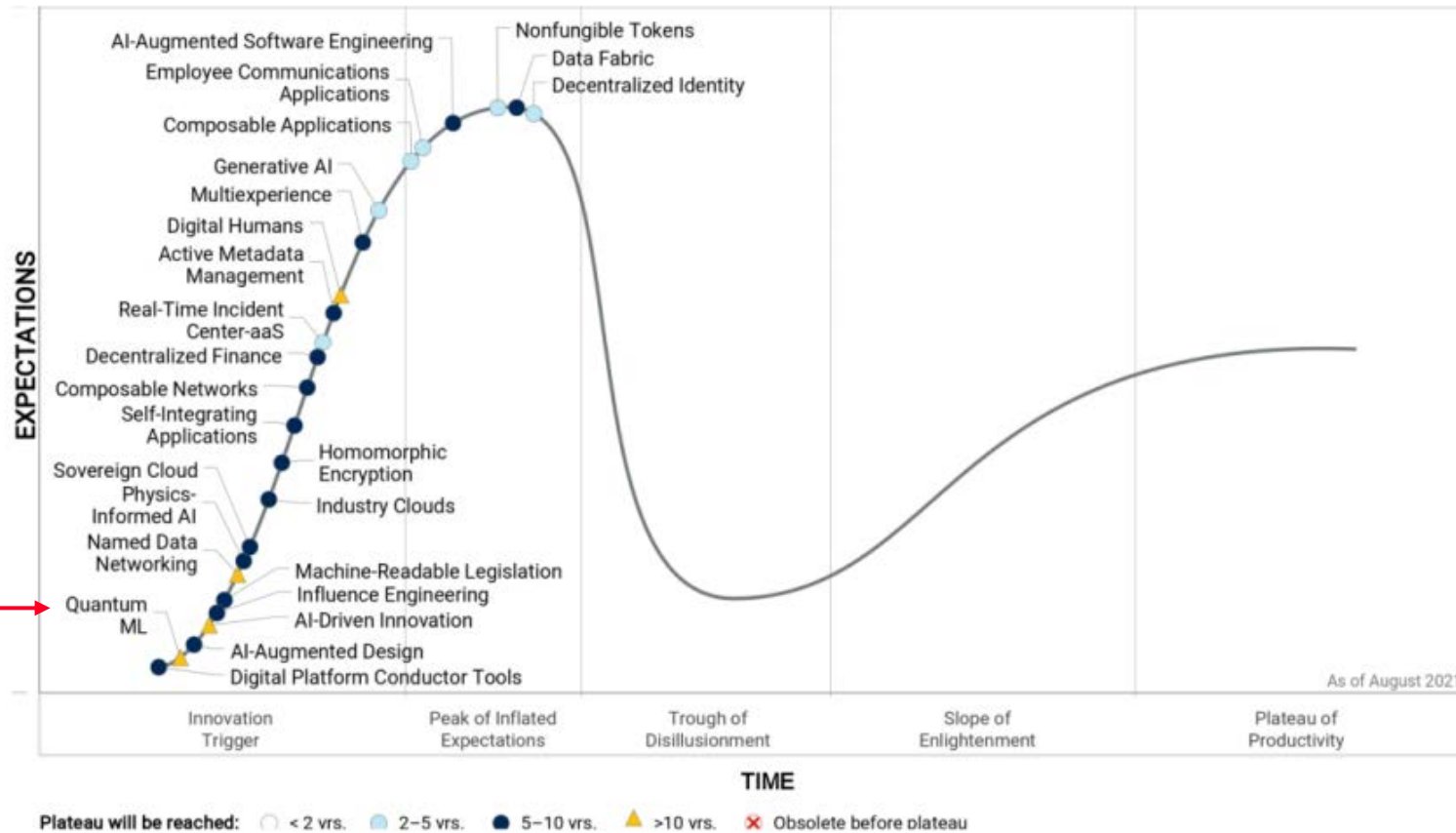   ❖ Fourth Level
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Updates

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

EXPECTATIONS vs **TIME**

AI-Augmented Software Engineering
Employee Communications Applications
Composable Applications
Nonfungible Tokens
Data Fabric
Decentralized Identity
Generative AI
Multiexperience
Digital Humans
Active Metadata Management
Real-Time Incident Center-aaS
Decentralized Finance
Composable Networks
Self-Integrating Applications
Sovereign Cloud
Physics-Informed AI
Named Data Networking
Quantum ML
Homomorphic Encryption
Industry Clouds
Machine-Readable Legislation
Influence Engineering
AI-Driven Innovation
AI-Augmented Design
Digital Platform Conductor Tools

Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity

As of August 2021

Plateau will be reached: ○ < 2 yrs. ○ 2–5 yrs. ● 5–10 yrs. ▲ >10 yrs. ✕ Obsolete before plateau

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

Student Questions

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Blockchain

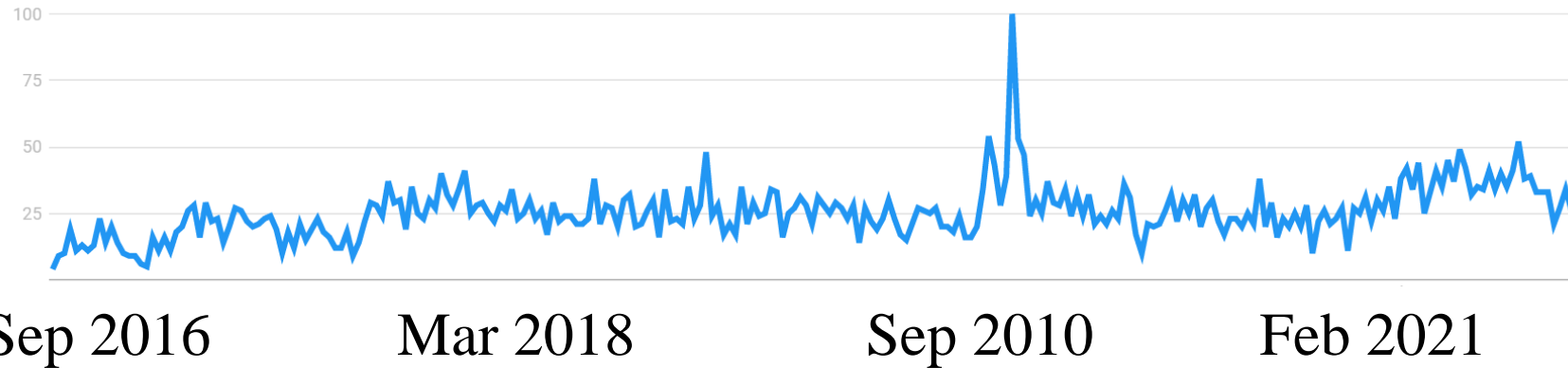Sep 2016   Mar 2018   Sep 2010   Feb 2021
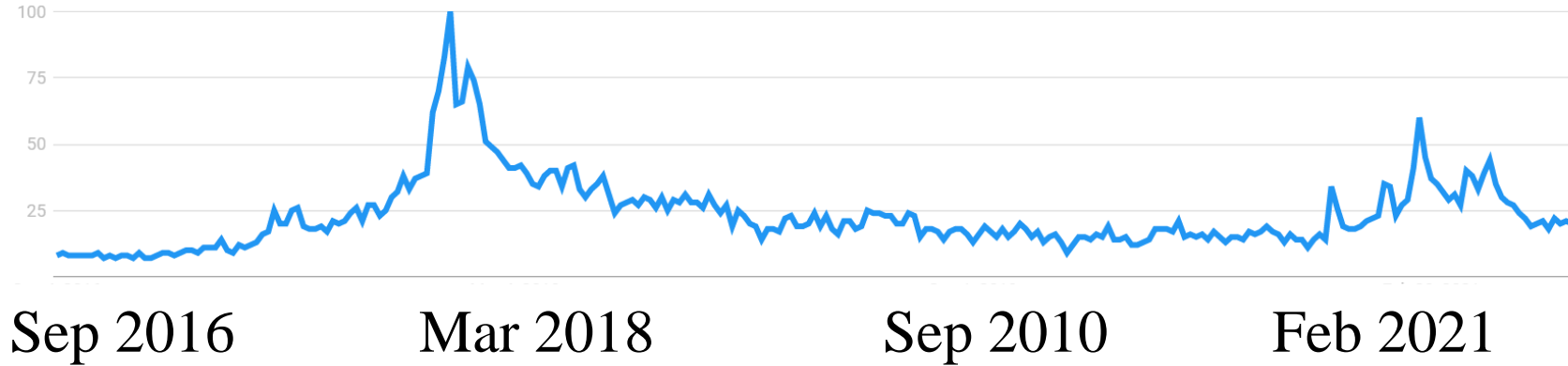
Snapshot 8/29/21

❑ Peaked in 2018.

❑ Increasing again with interest in Cryptocurrencies

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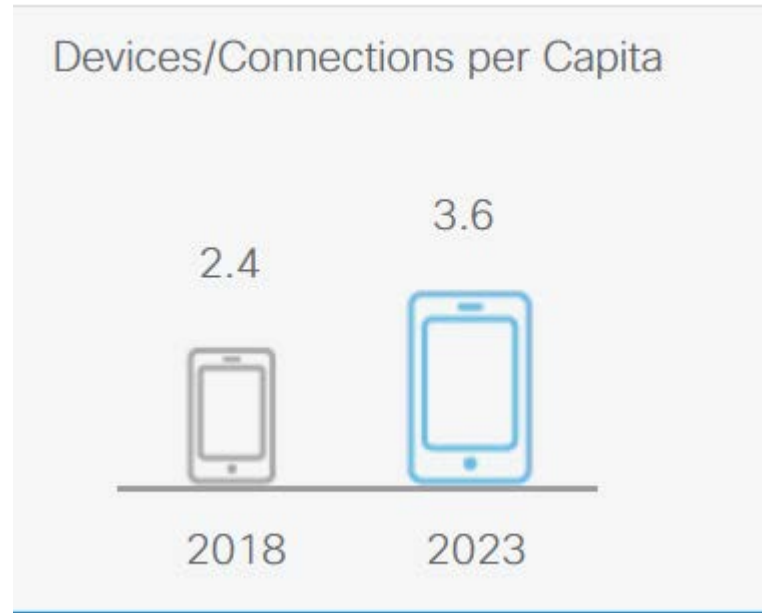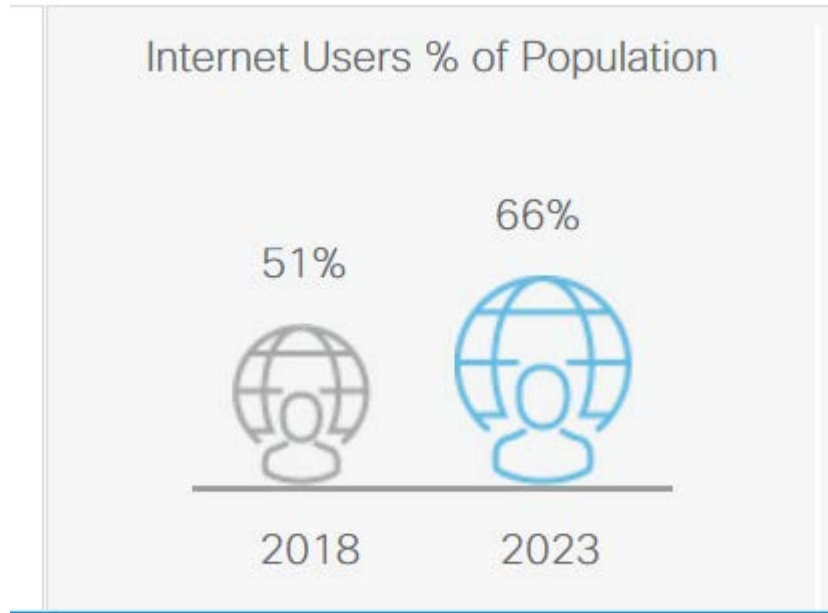# Quantum Computing

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

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      ❖ Fourth Level
        ✓ Fifth Level

Cisco Annual Report 2020 Highlights

Internet Users % of Population

66%

51%

2018   2023

Devices/Connections per Capita

3.6

2.4

2018   2023

❑ There are more devices than people.

Student Questions
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      ❖ Fourth Level
        ✓ Fifth Level

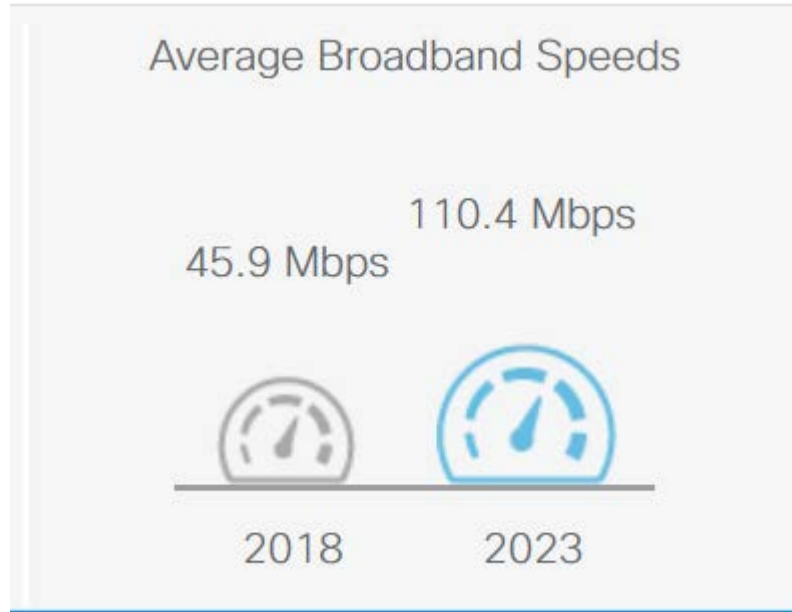Ref: Cisco, "Cisco Annual Internet Report (2018–2023)," March 2020,
https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Washington University in St. Louis   http://www.cse.wustl.edu/~jain/cse570-21/   ©2021 Raj Jain

Cisco Annual Report 2020 Highlights (Cont)

Average Broadband Speeds
45.9 Mbps
110.4 Mbps
2018   2023

Student Questions

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      ❖ Fourth Level
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      - ❖ Fourth Level
        - ✓ Fifth Level

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

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      - ❖ Fourth Level
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