

# 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**



- ❑ 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

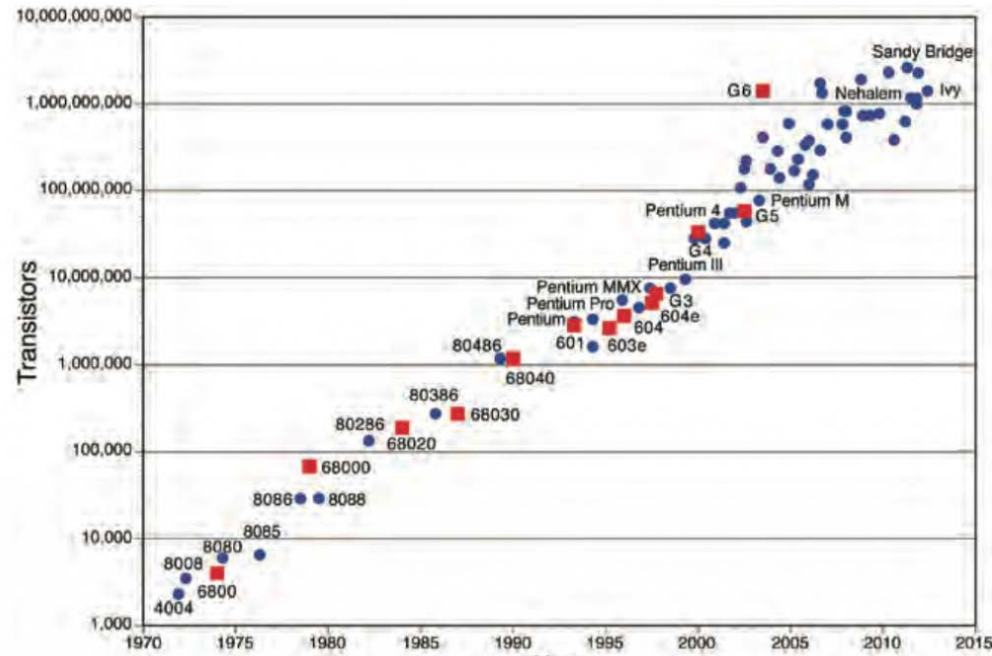


“VCs have a herd mentality.”

## Student Questions

# Processor Growth: Moore's Law

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

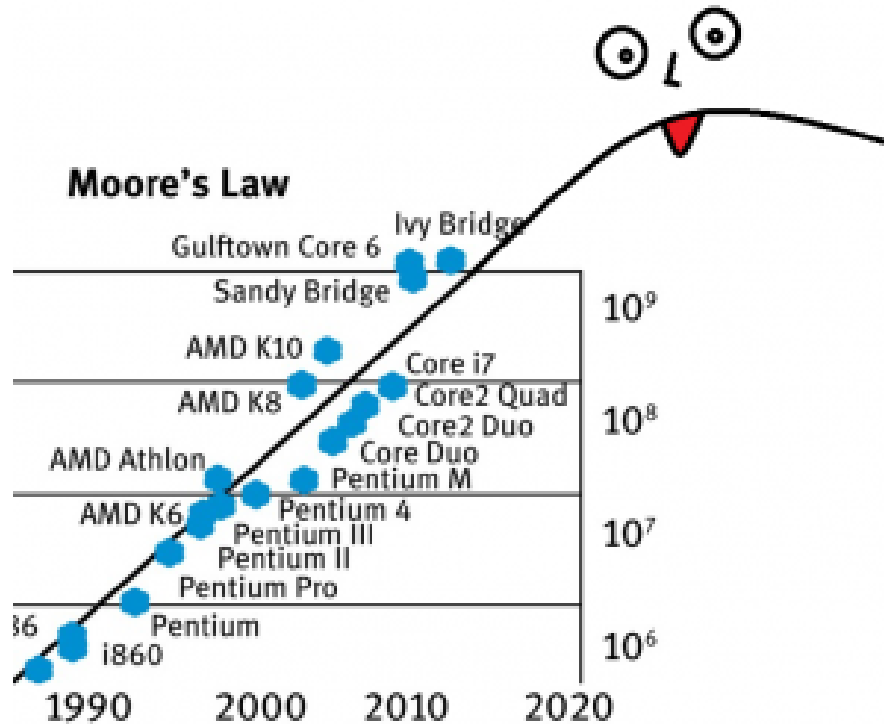


## Student Questions

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...



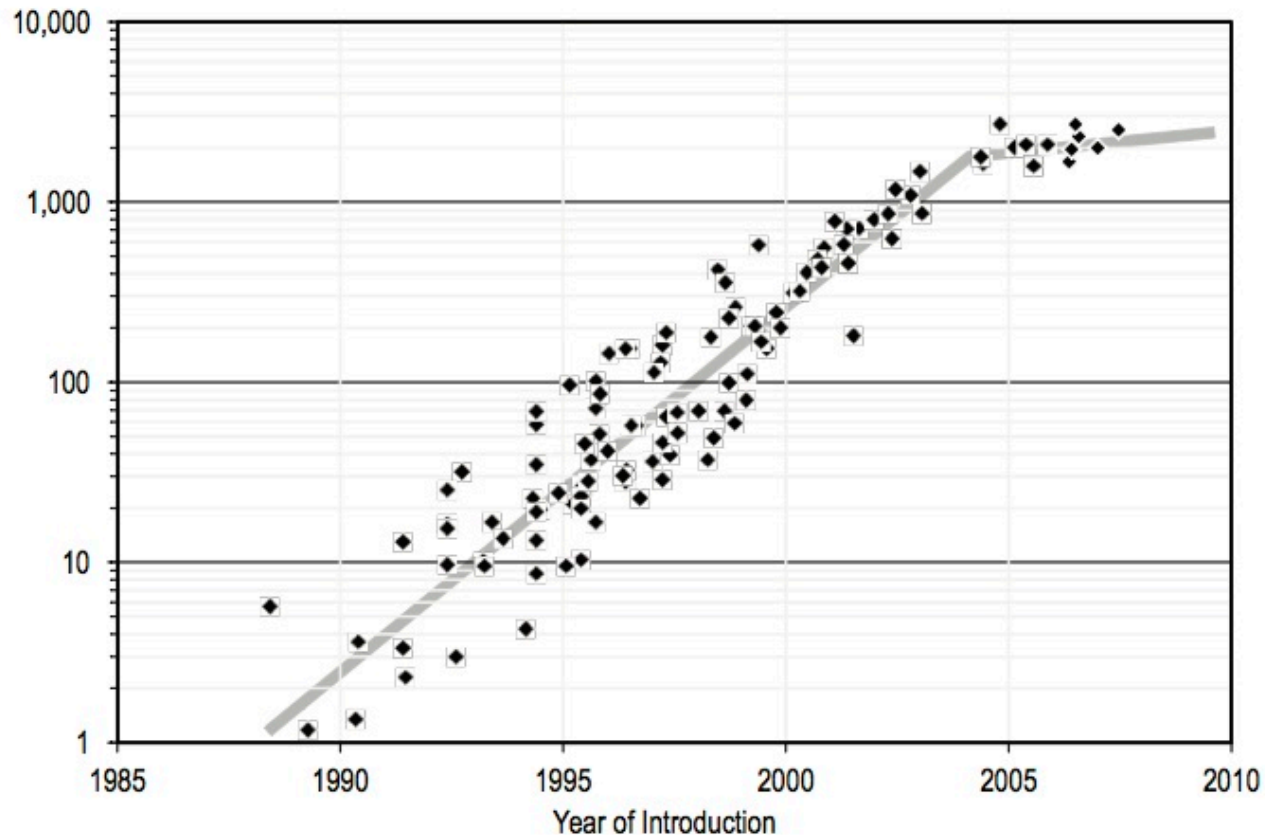
## Student Questions

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>  
Washington University in St. Louis <http://www.cse.wustl.edu/~jain/cse570-23/>

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# Will Moore's Law Continue? (Cont)

- It may have broken down in 2004...



## Student Questions

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

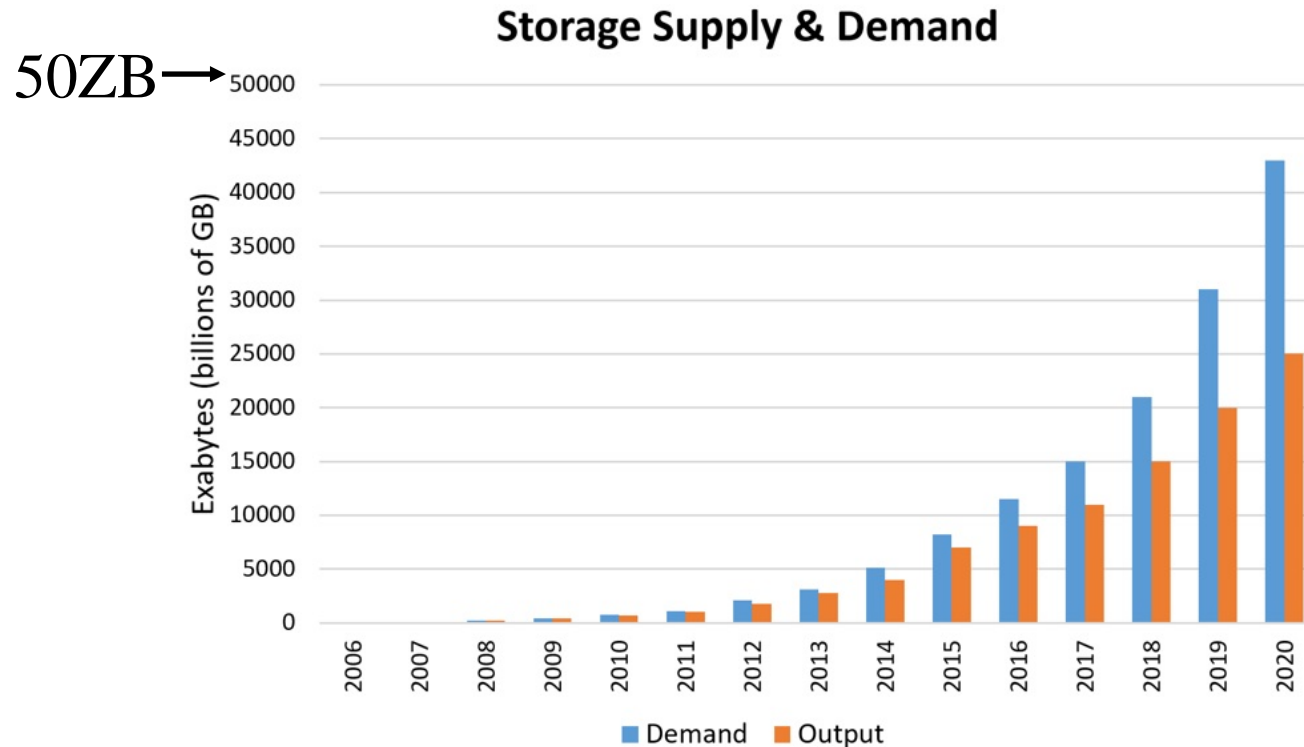
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# Storage Capacity

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



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](https://www.eetimes.com/author.asp?section_id=36&doc_id=1330462)

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## 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, Facebook, 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:

- ❑ 11/12<sup>th</sup> of workload in **clouds**, 1/12<sup>th</sup> 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**  
7/8<sup>th</sup> in cloud, 1/8<sup>th</sup> in traditional data centers  
2/3<sup>rd</sup> in public clouds, 1/3<sup>rd</sup> 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](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  $\Rightarrow$  3 ZB/year  
127× growth in 16 years (2005-2021)
- ❑ 5× growth in **busy hour** traffic
- ❑ PC traffic will be only 1/4<sup>th</sup> compared to 1/2 in 2016  
**Smartphone** traffic will be 1/3<sup>rd</sup> compared to 1/8<sup>th</sup> 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)  $\Rightarrow$  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](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

# Video and Mobile Traffic

## Between 2016-2021 (5 Years):

- ❑ 4/5<sup>th</sup> of IP traffic will be **video**  
4x growth in 5 years
- ❑ 1/8<sup>th</sup> 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 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](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)

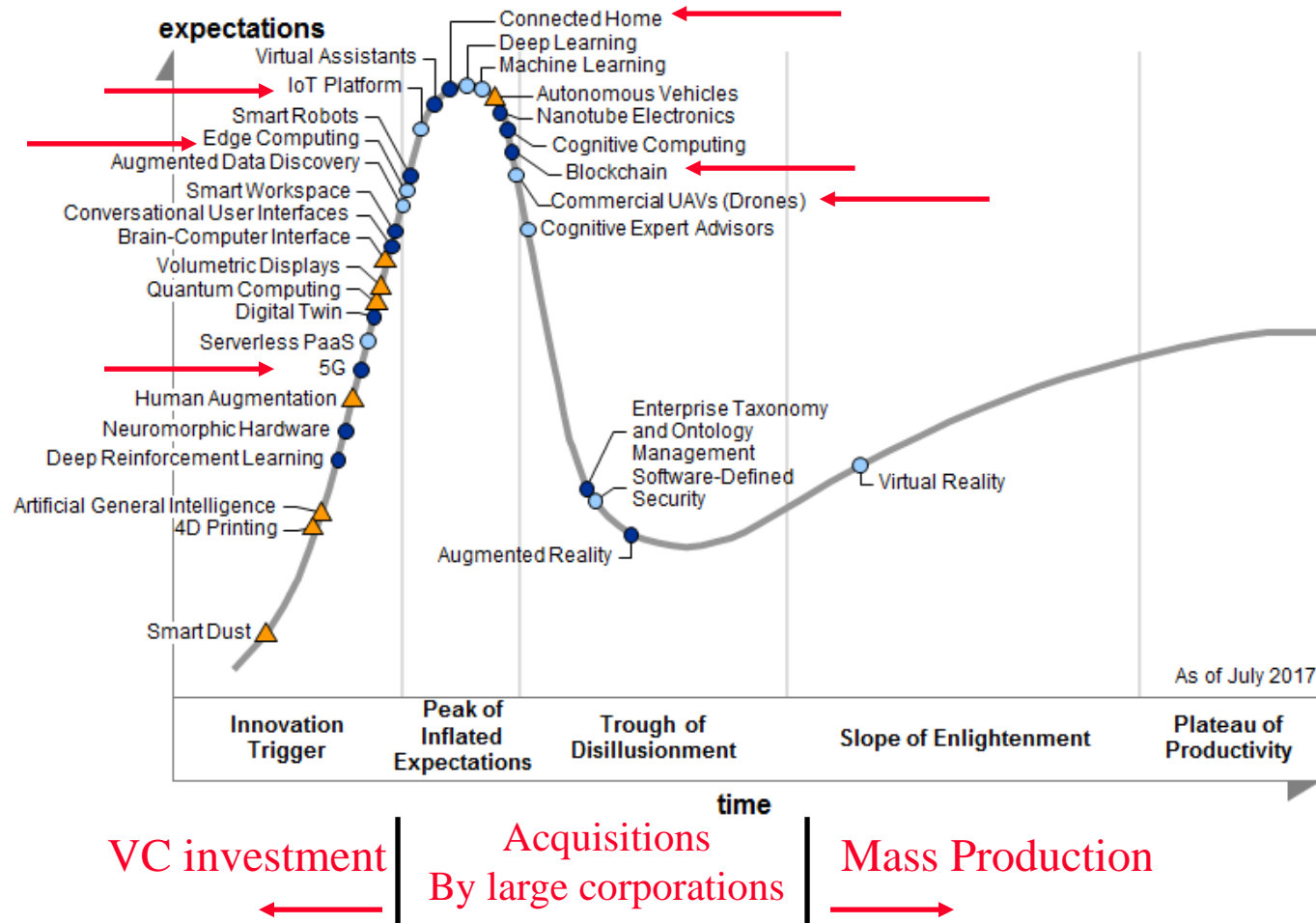
## Student Questions

- ❑ 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



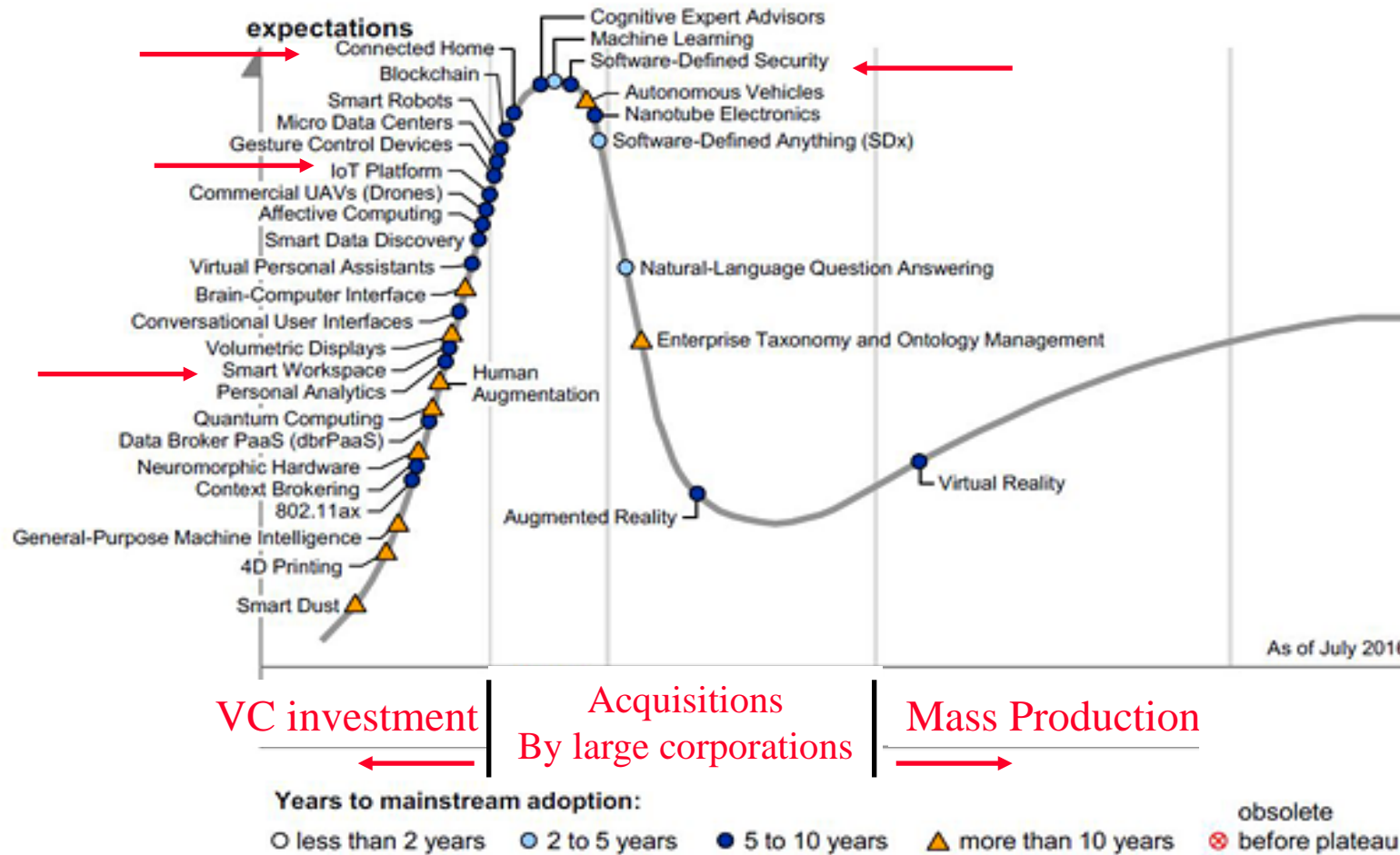
## Student Questions

Ref: Gartner, "Hype Cycle for Emerging Technologies, 2017," July 2017, [subscribers only]  
 washington University in St. Louis

<http://www.cse.wustl.edu/~jam/cse570-25/>

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# Gartner Hype Cycle 2016



**Student Questions**

Source: Gartner (July 2016)

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

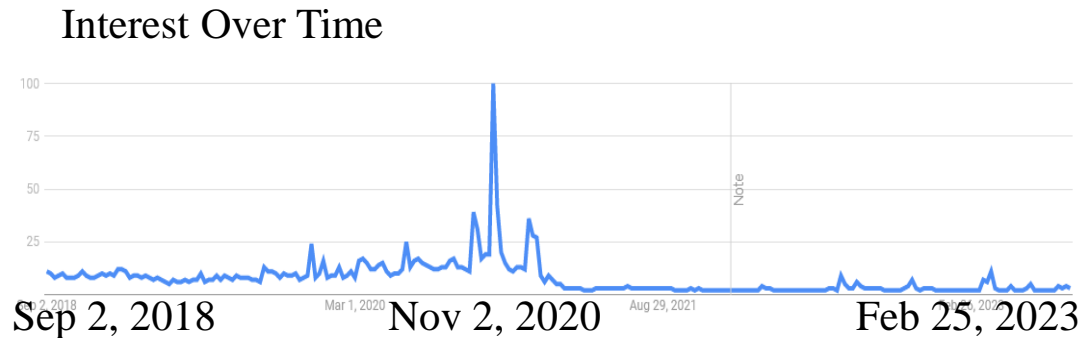
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# What is Google Trends?

- ❑ 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



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

## Student Questions

# 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

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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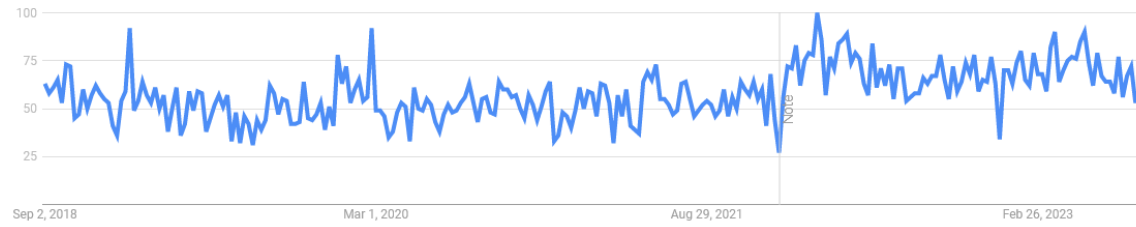
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# Data Center Network: Google Trends

❑ Stable, Neither declining nor increasing

❑ Mostly in USA and Singapore

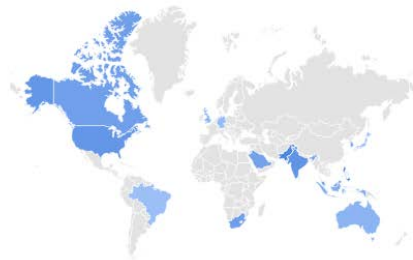
❑ Highly correlated probably because of IT industry services for US companies



Sep 2, 2018

Nov 2, 2020

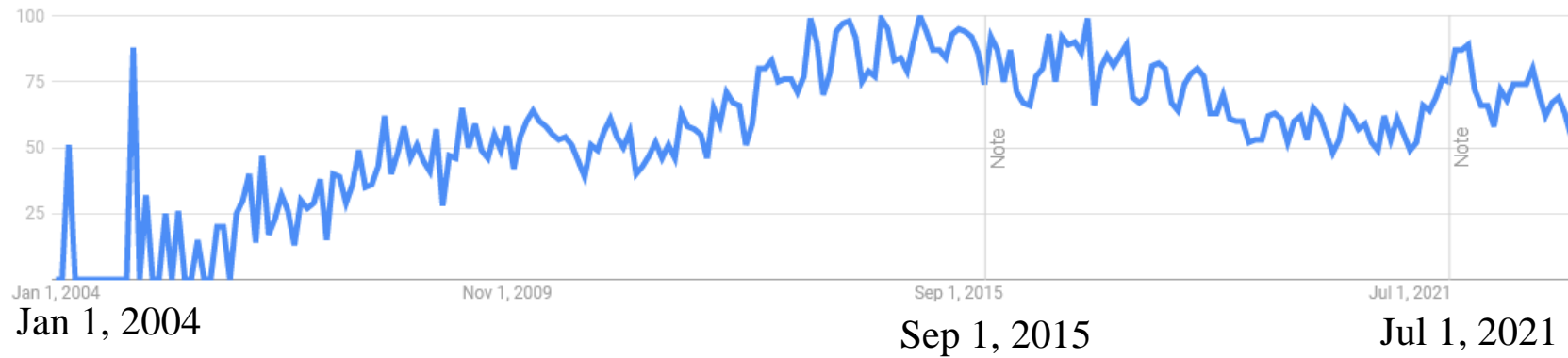
Feb 25, 2023



## Student Questions



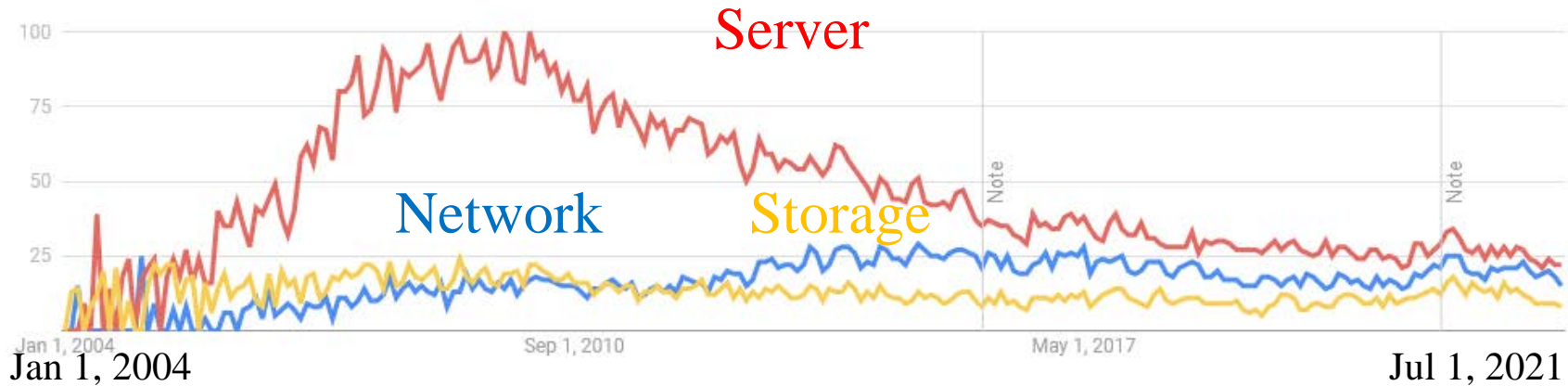
# Network Virtualization: Google Trends



- ❑ Interest is decreasing slowly

## Student Questions

# Virtualization: Google Trends



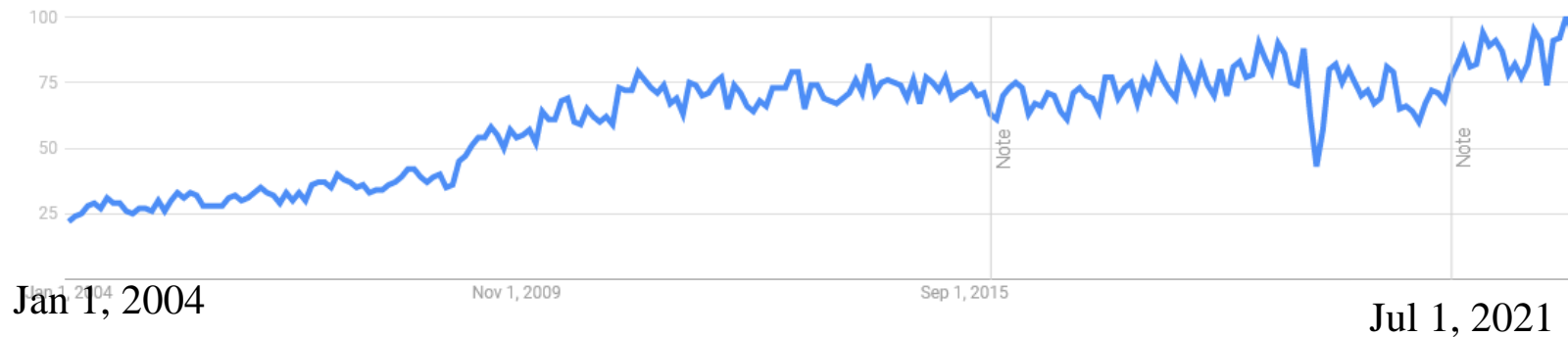
## Student Questions

### Virtualization

- Server
- Network
- Storage

### Increasing curiosity about network virtualization

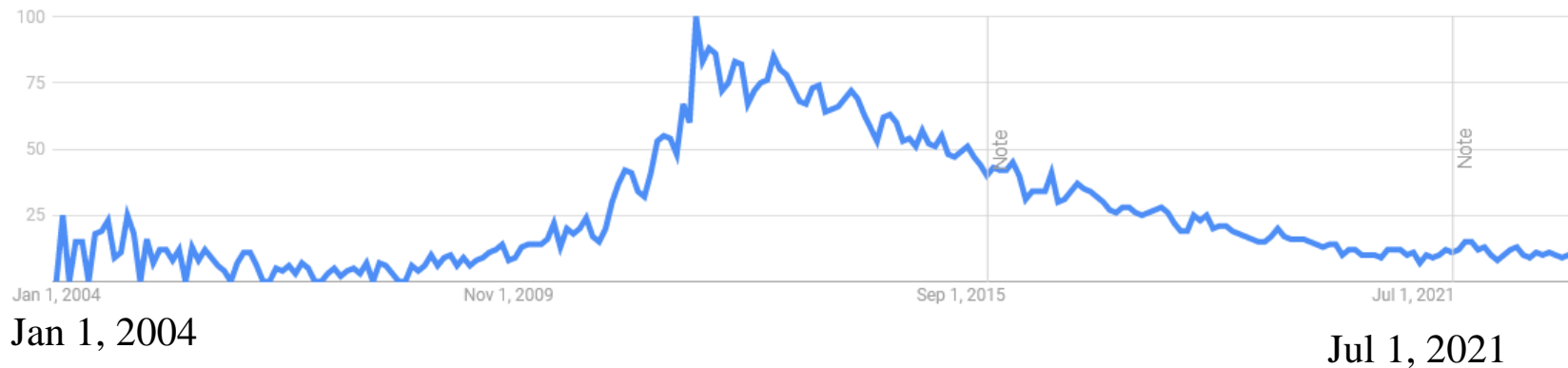
# SDN: Google Trends



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

## Student Questions

# 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 China, Taiwan, South Korea, Japan

## Student Questions

# Cloud Computing: Google Trends



Jan 1, 2004

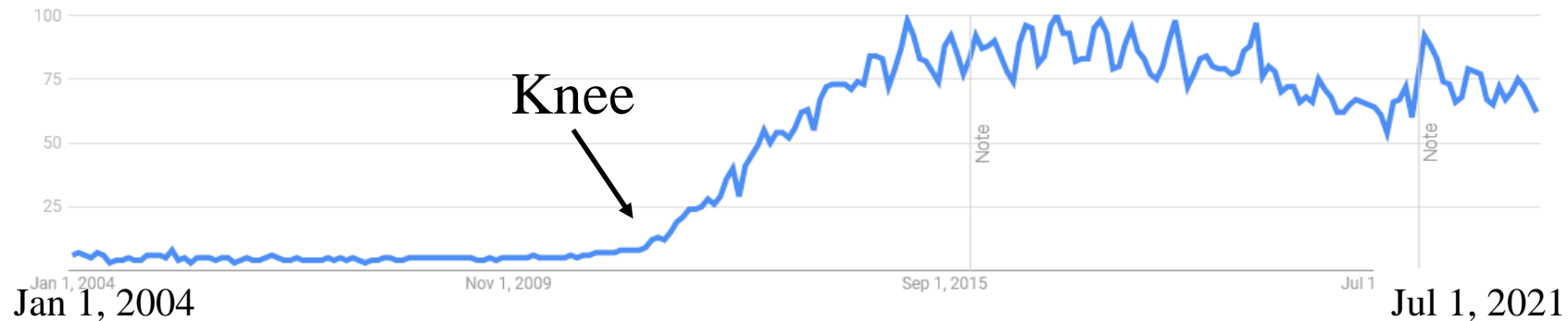
Jul 1, 2021

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

Snapshot: August 27, 2019

## Student Questions

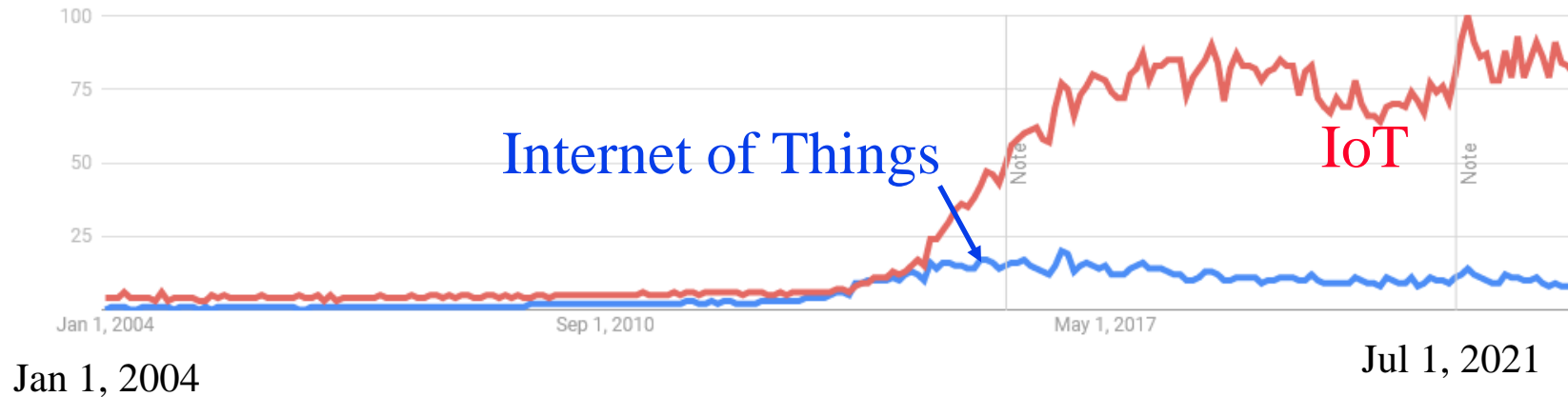
# Big Data: Google Trends



- ❑ 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

Ref: <http://ietf.org/>  
Washington University in St. Louis

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

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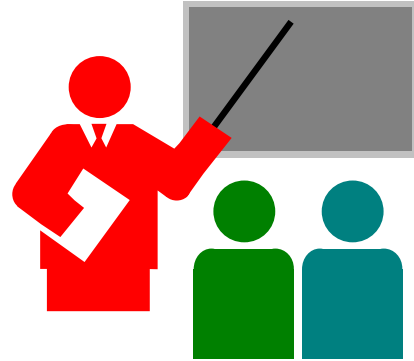
## Student Questions

# IEEE 802 LAN/MAN Standards

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

## Student Questions

# 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  $\Rightarrow$  Continuous.  
Real future is invented  $\Rightarrow$  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

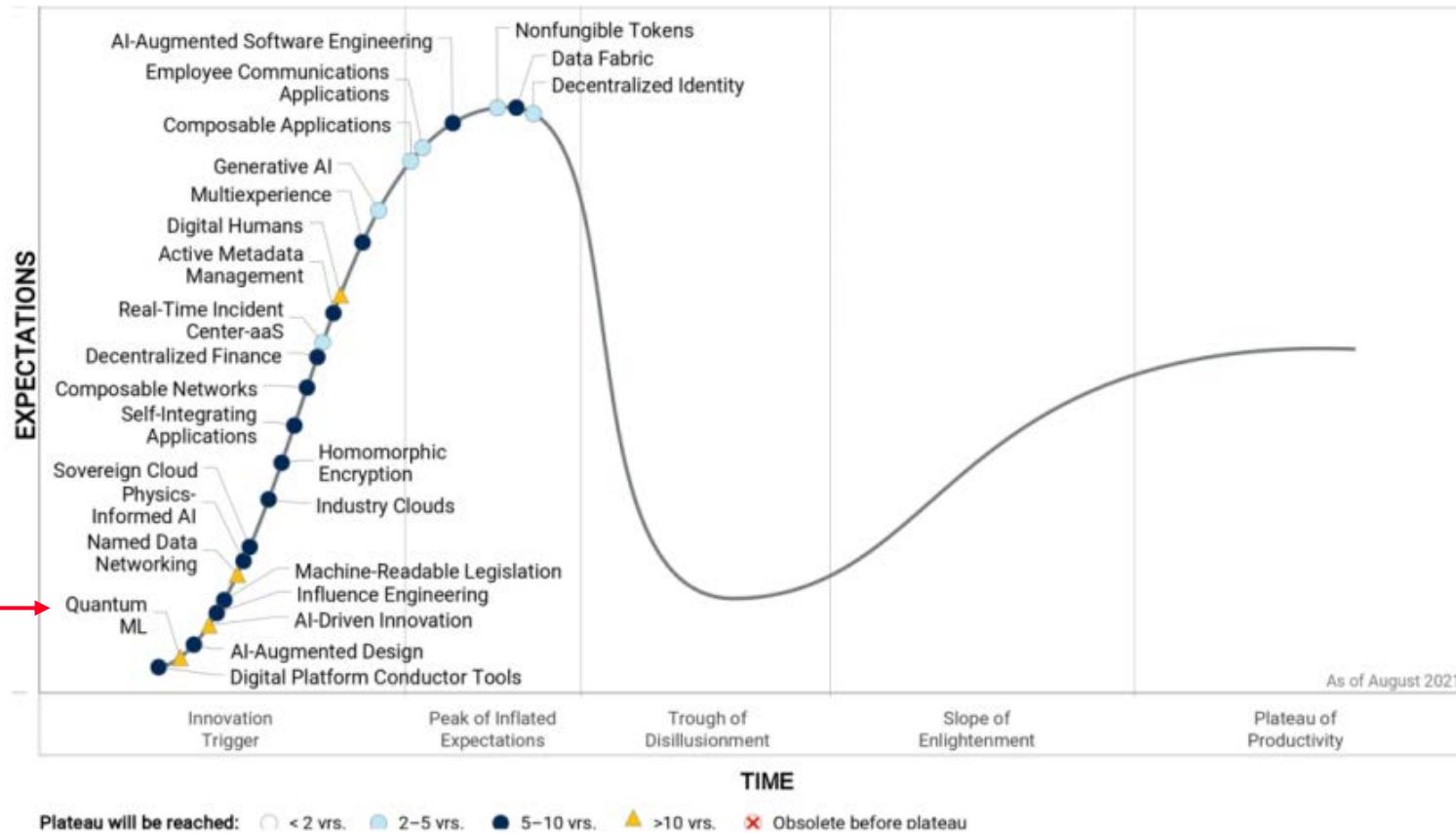


**Note:** The updates presented next will be discussed in the class, and the video recording of the discussion will be posted. Please check the course website.

## Student Questions



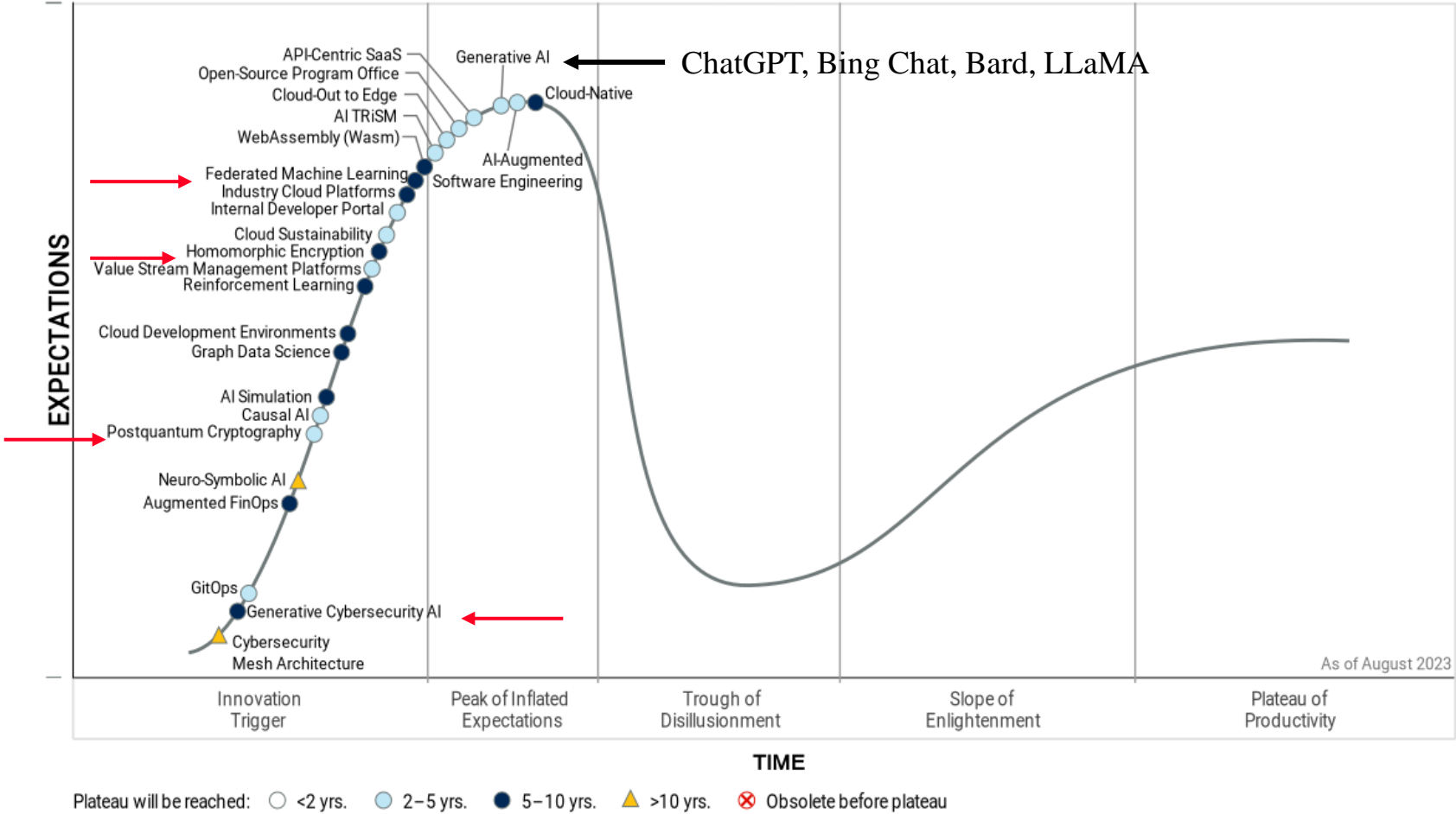
# Gartner's Emerging Technology Hype Cycle 2021



## Student Questions

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

# Gartner's Emerging Technology Hype Cycle 2023



## Student Questions

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

# Blockchain

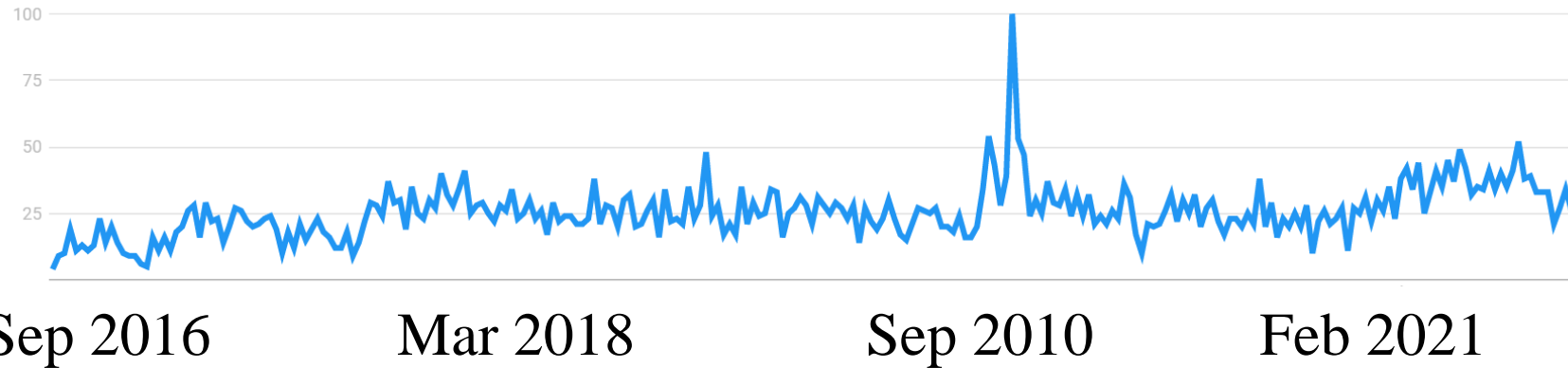


Snapshot 8/29/21

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

## Student Questions

# Quantum Computing

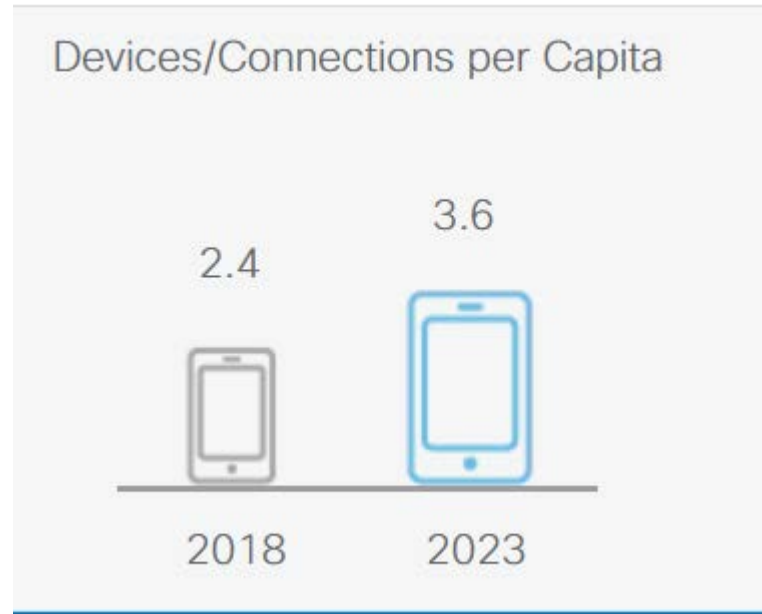
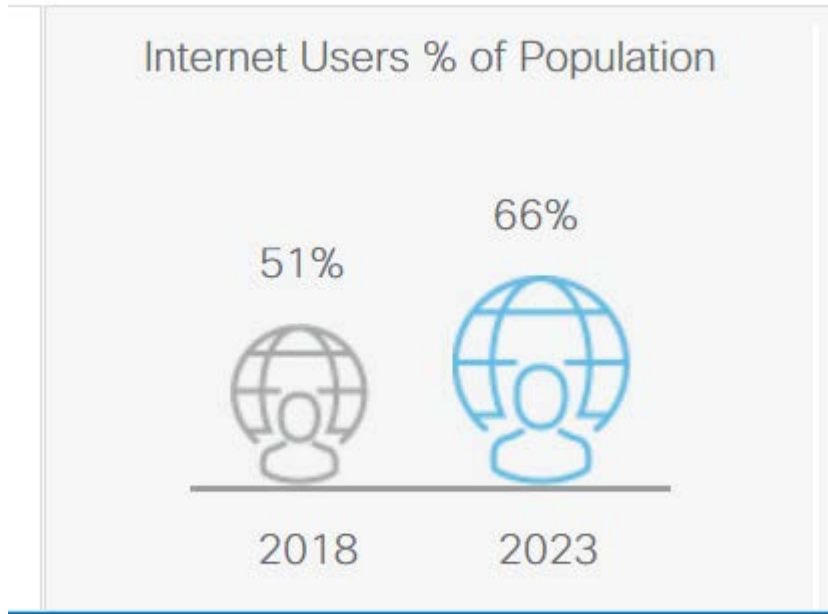


Snapshot 8/29/21

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

## Student Questions

# Cisco Annual Report 2020 Highlights



## Student Questions

□ There are more devices than people.

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

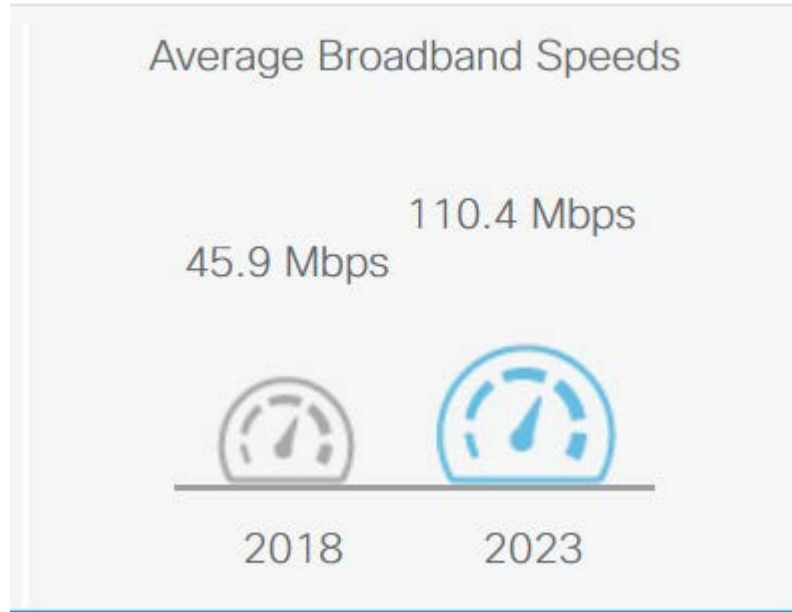
<https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html>

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# Cisco Annual Report 2020 Highlights (Cont)



## Student Questions

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[http://www.cse.wustl.edu/~jain/cse570-23/m\\_02trn.htm](http://www.cse.wustl.edu/~jain/cse570-23/m_02trn.htm)

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**Student Questions**

# Related Modules



CSE 567: The Art of Computer Systems Performance Analysis

[https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n\\_1X0bWWNyZcof](https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof)

CSE473S: Introduction to Computer Networks (Fall 2011),

[https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e\\_10TiDw](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>

## Student Questions