Networking Trends

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

http://www.cse.wustl.edu/~jain/cse570-18/

Overview

❑ Sources of Trends

❑ Processor, Storage, Clouds and Mobile Apps

❑ Cisco Visual Networking Index

❑ Gartner Hype Cycle 2014

❑ Google Trends

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."

Processor Growth: Moore's Law

❑ Garden Moore, Director of R&D, Fairchild Semiconductor 1965: Transistor density doubling every two years
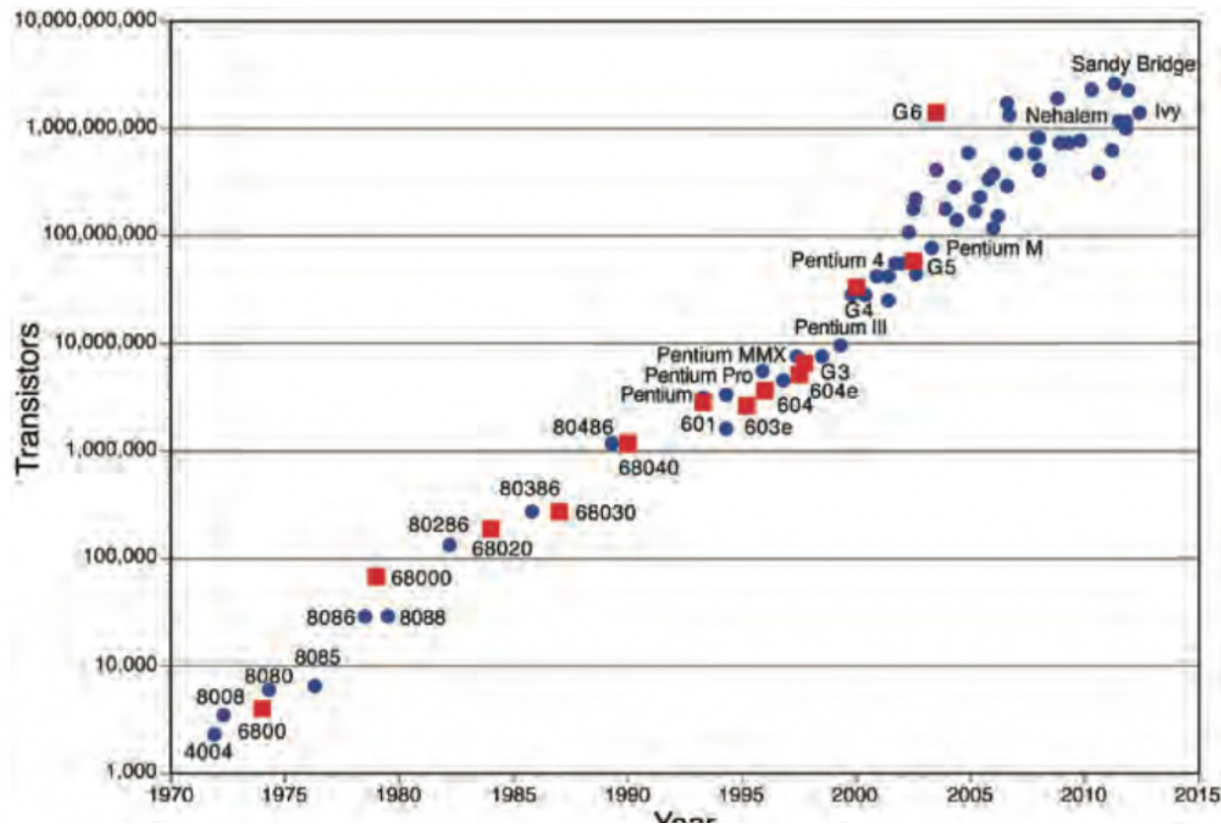
Ref: M. Czerniak, "What lies beneath? 50 years of enabling Moore's Law," Solid State Technology, http://electroiq.com/blog/2015/11/what-lies-beneath-50-years-of-enabling-moores-law/

Will Moore's Law Continue?

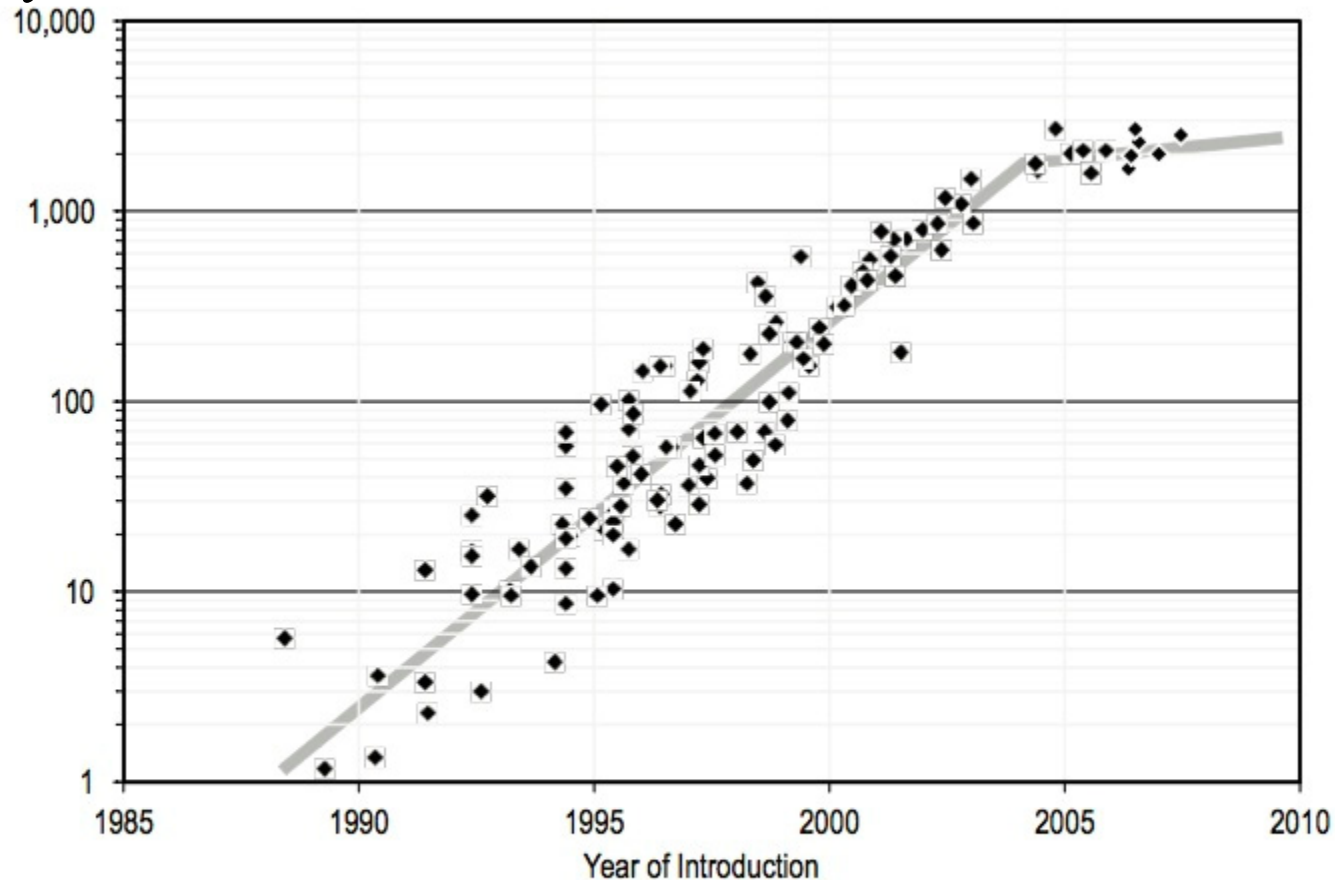❏ A debate has begun…
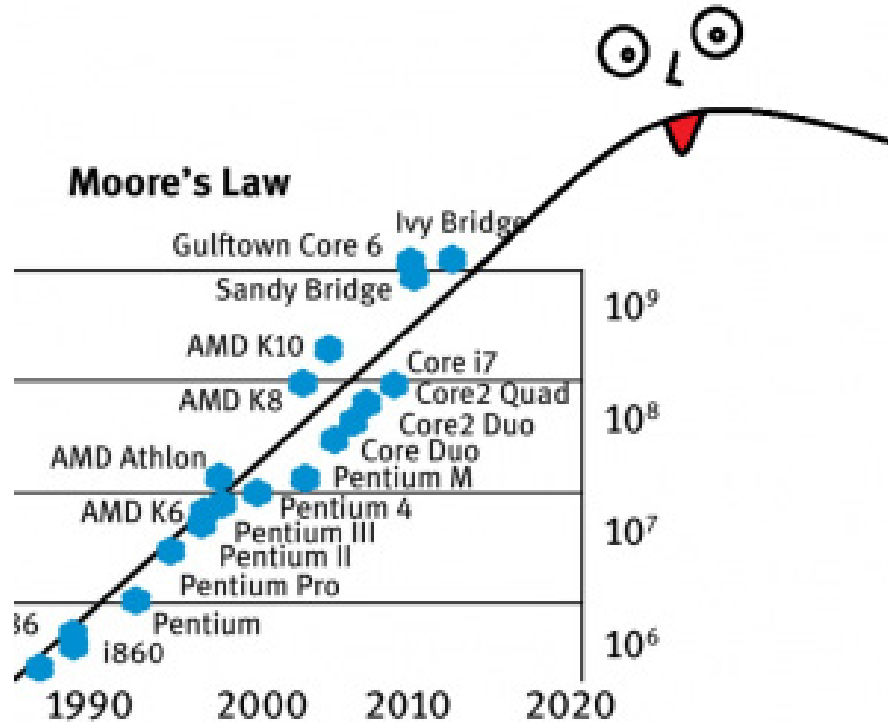
Ref: B. James, "Moore's Law sad that no one believes in it anymore," The Hard Time, October 23, 2017,
http://thehardtime.com/moores-law-sad-no-one-believes-anymore

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2-5

Will Moore's Law Continue? (Cont)

❑ It may have broken down in 2004…

Year of Introduction

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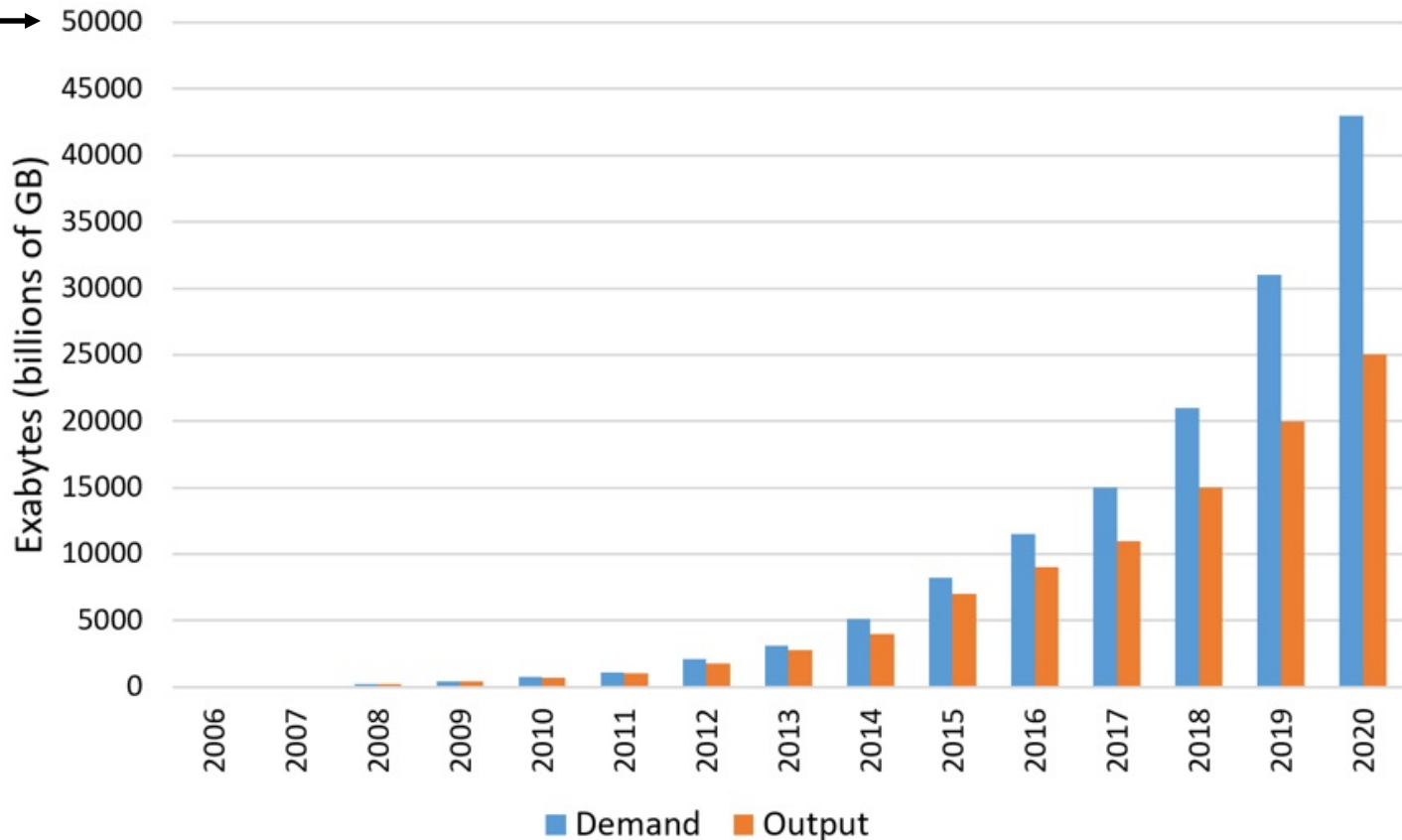
Storage Capacity

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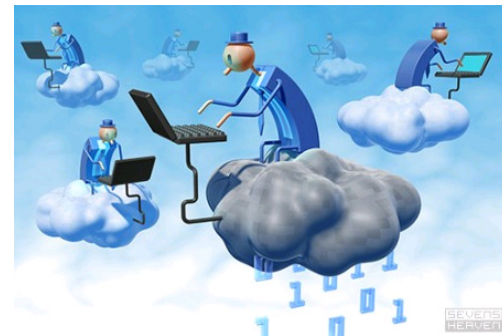 42% compound annual growth rate (CAGR)

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

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

Cloud Computing Statistics

By 2020:

❑ $11/12^{th}$ of workload in **clouds**, $1/12^{th}$ 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**
$7/8^{th}$ in cloud, $1/8^{th}$ in traditional data centers
$2/3^{rd}$ in public clouds, $1/3^{rd}$ 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

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 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) $\Rightarrow$ 14 by 2020

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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 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
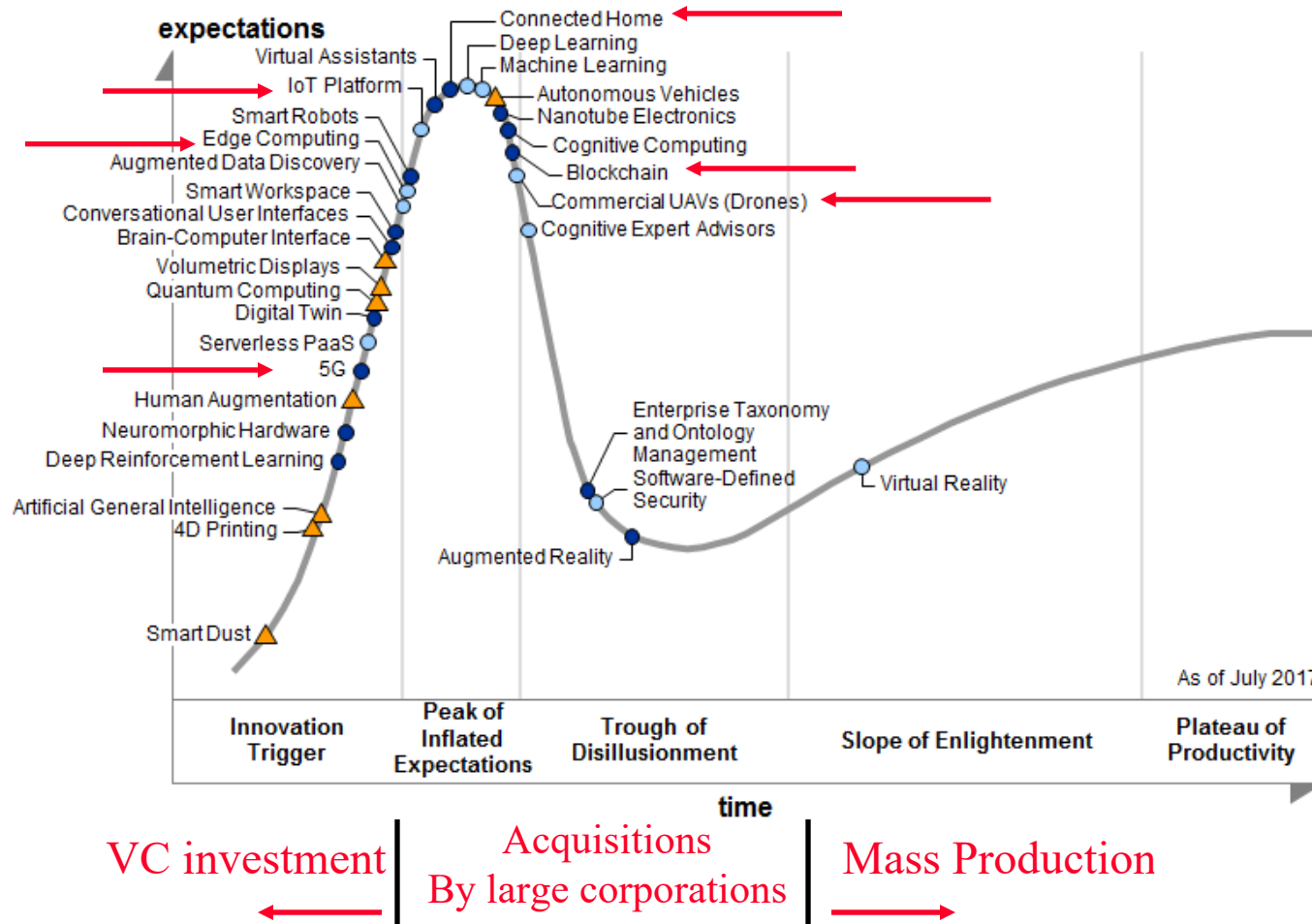
Gartner Hype Cycle 2017

expectations

Virtual Assistants
IoT Platform
Smart Robots
Edge Computing
Augmented Data Discovery
Smart Workspace
Conversational User Interfaces
Brain-Computer Interface
Volumetric Displays
Quantum Computing
Digital Twin
Serverless PaaS
5G
Human Augmentation
Neuromorphic Hardware
Deep Reinforcement Learning
Artificial General Intelligence
4D Printing
Smart Dust

Connected Home
Deep Learning
Machine Learning
Autonomous Vehicles
Nanotube Electronics
Cognitive Computing
Blockchain
Commercial UAVs (Drones)
Cognitive Expert Advisors

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]

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)

Human Augmentation

- Natural-Language Question Answering
- Enterprise Taxonomy and Ontology Management
- 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

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 over time

75
50
25

Jan 22, 2017   May 14, 2017   Sep 3, 2017   Dec 24, 2017

Jan 22, 2017   May 14, 2017   Sep 3, 2017   Dec 24, 2017

Interest by region ⓘ   Region ▾

Interest by region

1	Canada	100	
2	United States	75	
3	Ireland	70	
4	New Zealand	54	
5	United Kingdom	44	

Snapshot: January 21, 2018

https://trends.google.com/trends/explore?q=Donald%20Trump
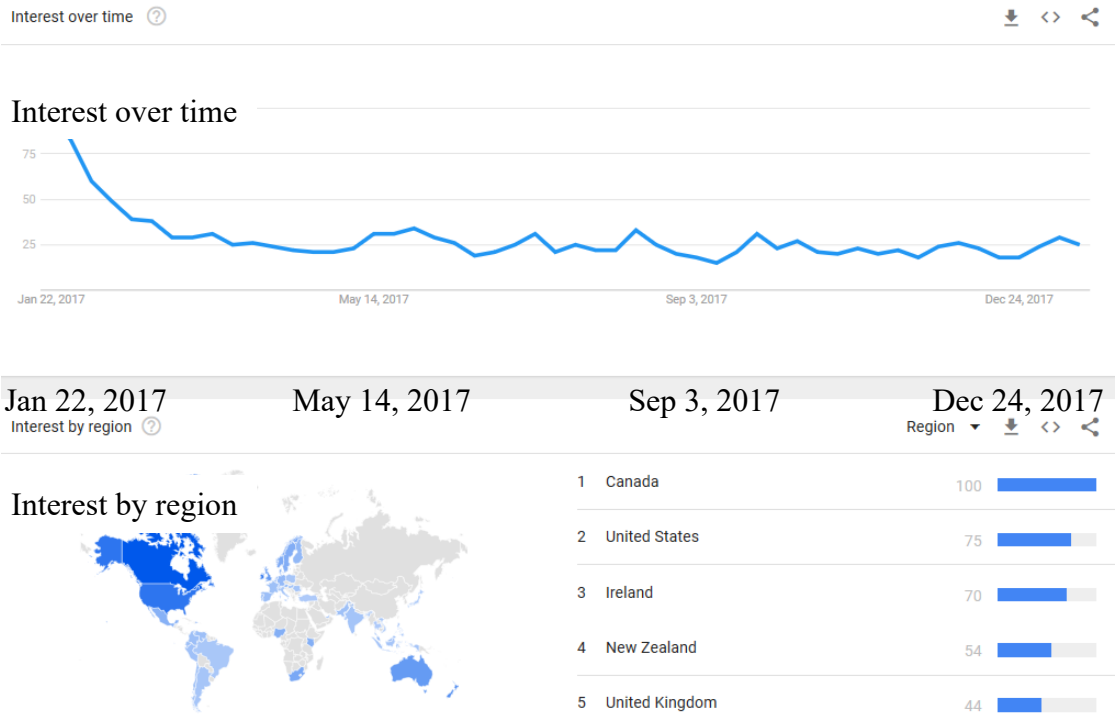
Google Trends and GDP

❑ 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 India

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

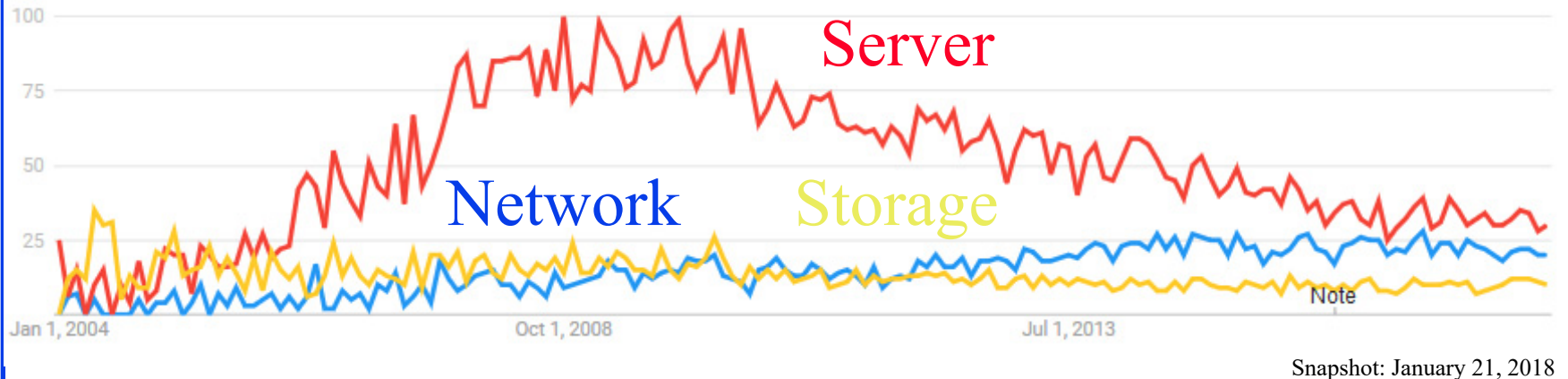Jan 2013   Jul 2017

1 India	100	
2 United States	74	
3 United Kingdom	30	

Snapshot: January 21, 2018
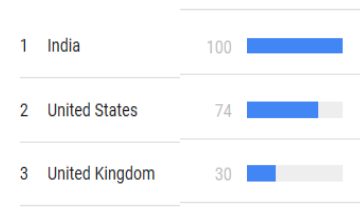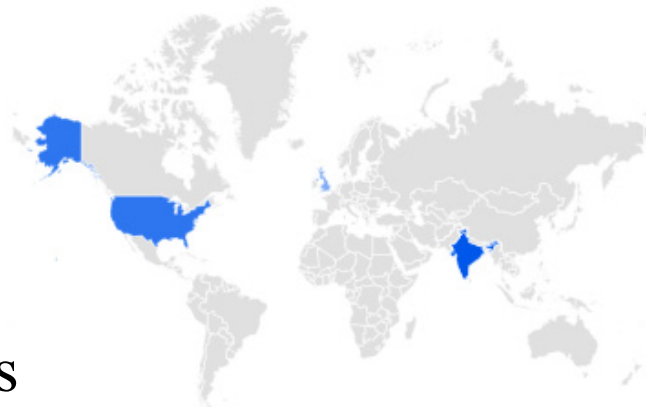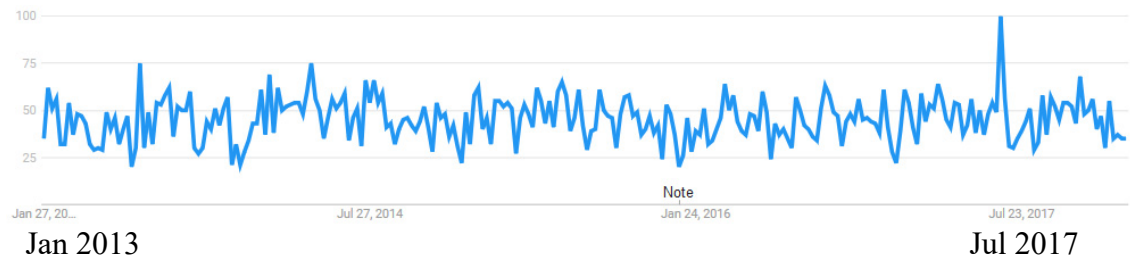
http://www.cse.wustl.edu/~jain/cse570-18/

Network Virtualization: Google Trends

Snapshot: January 21, 2018

❑ Still before the knee

http://www.cse.wustl.edu/~jain/cse570-18/

Virtualization: Google Trends

Snapshot: January 21, 2018

❑ Virtualization
  ➢ Server
  ➢ Storage
  ➢ Network

❑ Increasing curiosity about network virtualization

SDN: Google Trends

Snapshot: January 21, 2018

❑ Started May 21, 2011: Open Networking Foundation formed
  ⇒ Announced standardizing OpenFlow

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

OpenFlow: Google Trends

Snapshot: January 21, 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

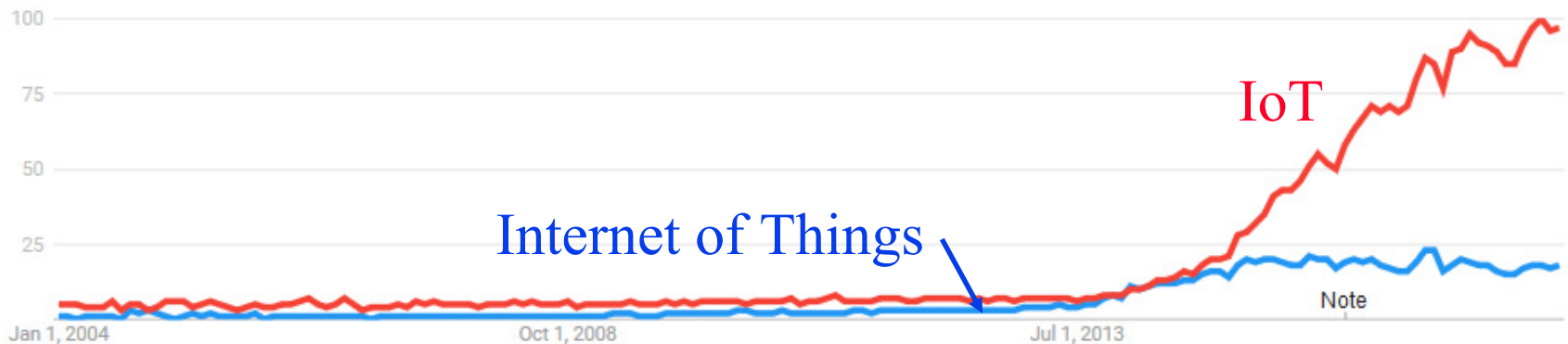# Cloud Computing: Google Trends

Snapshot: January 21, 2018

❑ Past-Hype phase.
  As in Gartner graphs
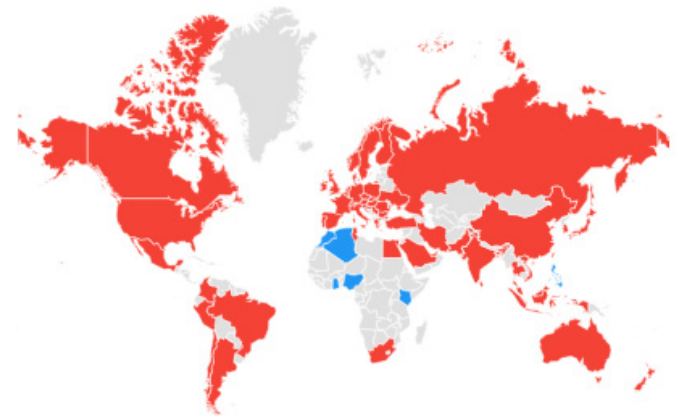
Big Data: Google Trends

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.

IoT: Google Trends

100
75
50
25

IoT

Internet of Things

Note

Jan 1, 2004   Oct 1, 2008   Jul 1, 2013

❑ Still growing

❑ High interest all around the world

Snapshot: January 21, 2018

Other Trends

❑ IT/Network Automation

❑ Open Networking

❑ Mobility

❑ Security

❑ Analytics

❑ Containers – Docker

❑ DevOps: Developers and Operational personnel cooperation

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

❑ Software Defined Networking (SDN)

❑ Software Defined Infrastructure (SDI)

❑ SDN Exchanges (SDXs)

❑ Efficient Size, Weight, and Power (SWaP) networking

❑ Identity management

❑ Network Security

Ref: NITRD, "NITRD Program Supplement to the President's Budget – FY 2018," October 2017, 98 pp.,
https://www.nitrd.gov/pubs/2018supplement/FY2018NITRDSupplement.pdf

Internet Engineering Task Force (IETF)

❑ Automated Network Management
  ➢ YANG modeling language to describe data sources
  ➢ NETCONF network configuration protocol
  ➢ Autonomic networking to enable self-managing, self-healing, self-configuring, self-optimizing networks
❑ Internet of Things
❑ New Transport Technologies
  ➢ TCPINC: TCP increased security – unauthenticated encryption and integrity protection
  ➢ QUIC: UDP-Based stream-multiplexing encrypted transport

IEEE 802 LAN/MAN Standards

❑ Security

❑ Time Sensitive Networking

❑ Addressing and Data Center Bridging

❑ Open Mobile Networking Interface Region Area Network (OmniRAN) – Unifying many access networks such as WiFi, 5G, Ethernet, …

❑ 200 Gbps Ethernet, 400 Gbps PHY

❑ Automotive Ethernet

❑ Backplane Ethernet

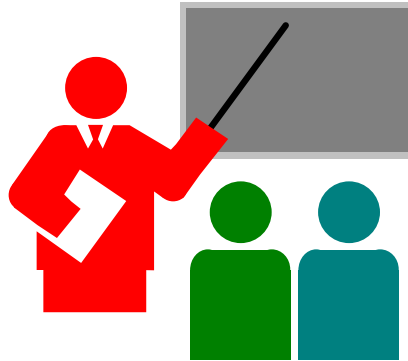# Summary

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 ⇒ Continuous.
   Real future is invented ⇒ Discontinuous

Reading List

1. 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

2. 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

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

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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Related Modules

CSE567M: Computer Systems Analysis (Spring 2013),

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

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcgy5e_10TiDw

Wireless and Mobile Networking (Spring 2016),

https://www.youtube.com/playlist?list=PLjGG94etKypKeb0nzyN9tSs_HCd5c4wXF

CSE571S: Network Security (Fall 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