

Networking Trends



Raj Jain

Washington University in Saint Louis

Saint Louis, MO 63130

Jain@cse.wustl.edu

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

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



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

Sources of Trends

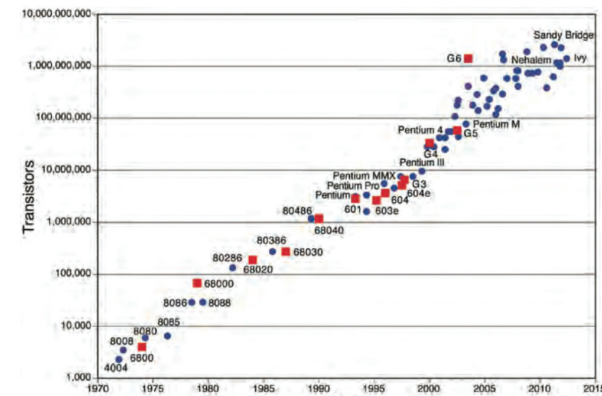
- Activities in technical industry organizations: IEEE, IETF, ITU
- NSF funding areas
- Venture capital investments
- Industry analytics companies like Gartner
- Google searches by people all over the world



“VCs have a herd mentality.”

Processor Growth: Moore's Law

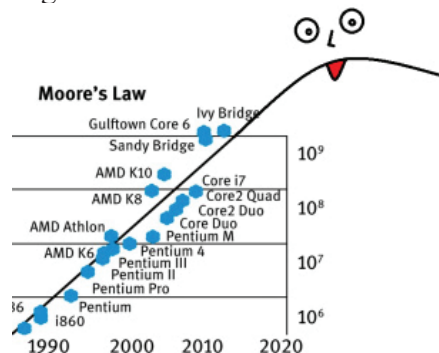
- Garden Moore, Director of R&D, Fairchild Semiconductor
1965: Transistor density doubling every two years



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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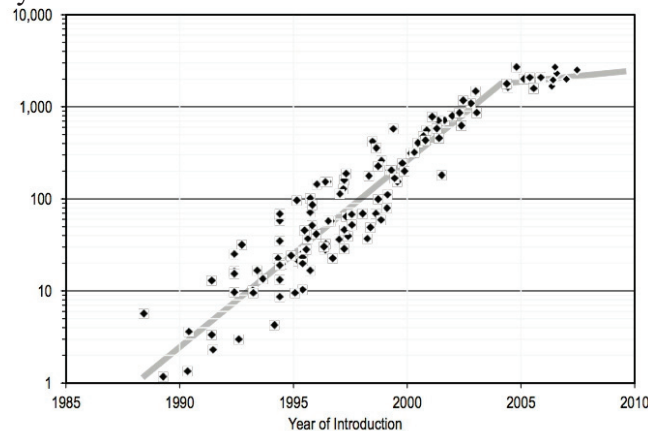
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Will Moore's Law Continue? (Cont)

- It may have broken down in 2004...



Ref: R. Jones, "Economics after Moore's Law," Soft Machines, July 21, 2017, <http://www.softmachines.org/wordpress/?p=2097>

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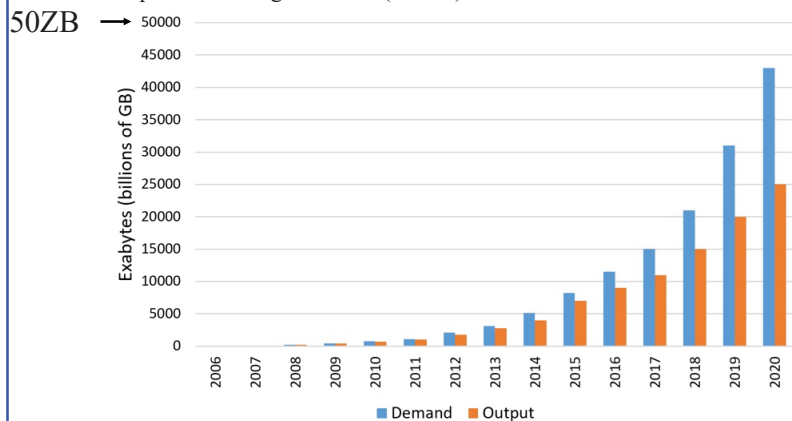
<http://www.cse.wustl.edu/~jain/cse2/0-16/>

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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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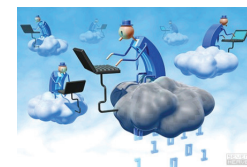
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Clouds and Mobile Apps

- 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



Networks need to support efficient service setup and delivery

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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 ⇒ 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) ⇒ 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

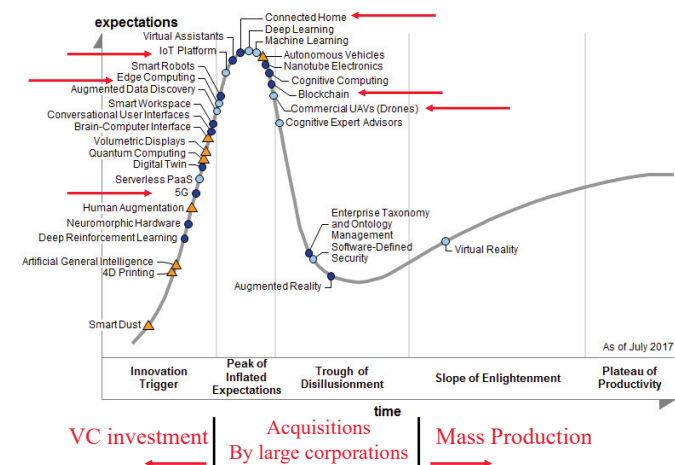
Between 2016-2021 (5 Years):

- 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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Gartner Hype Cycle 2017



Ref: Gartner, "Hype Cycle for Emerging Technologies, 2017," July 2017, [subscribers only]
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Gartner Hype Cycle 2016

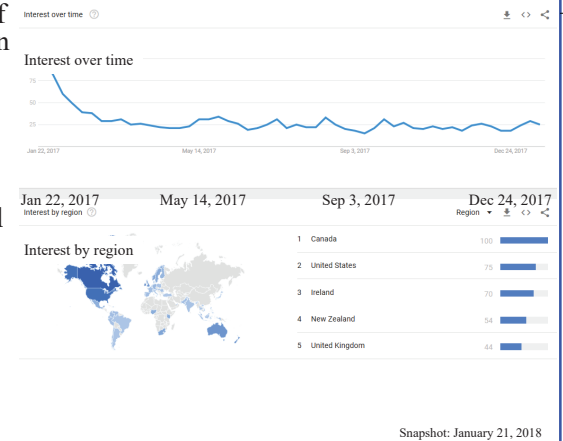


Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], gartner.com/document/3383817
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What is Google Trends?

- 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



<https://trends.google.com/trends/explore?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.

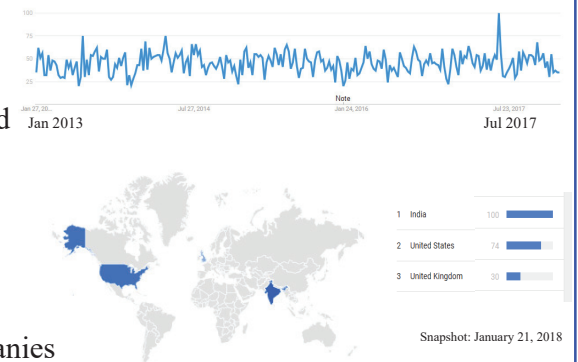
Ref: C. Johnston, "Google Trends reveals clues about the mentality of richer nations," <http://arstechnica.com/gadgets/2012/04/google-trends-reveals-clues-about-the-mentality-of-richer-nations/>
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Data Center Network: Google Trends

- Stable, Neither declining nor increasing
- Mostly in USA and India
- USA and India are highly correlated probably because Indian IT industry services US companies



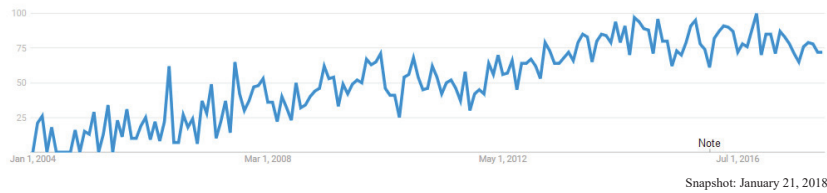
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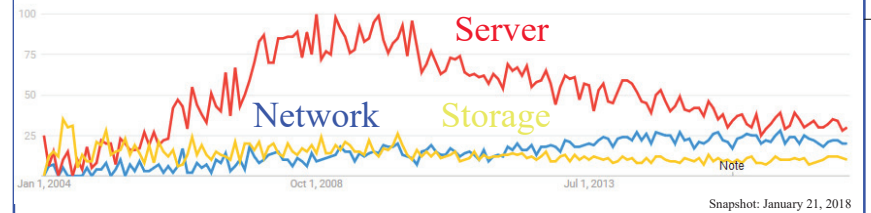
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Network Virtualization: Google Trends



- ❑ Still before the knee

Virtualization: Google Trends



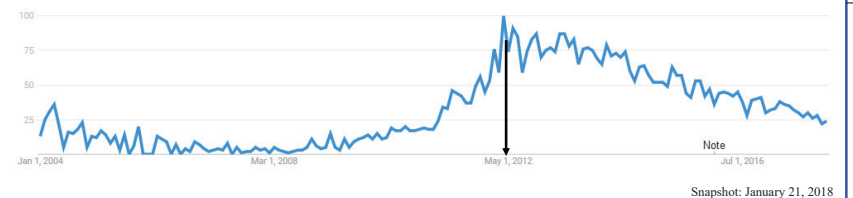
- ❑ Virtualization
 - Server
 - Storage
 - Network
- ❑ Increasing curiosity about network virtualization

SDN: Google Trends



- ❑ 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



- ❑ 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



- ❑ Past-Hype phase.
As in Gartner graphs

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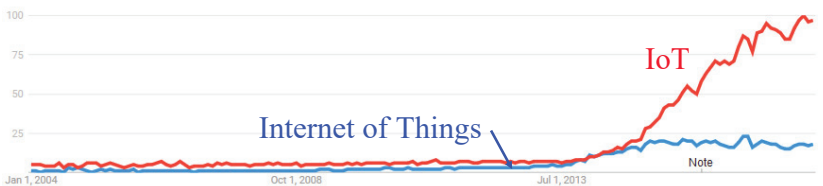
Big Data: Google Trends



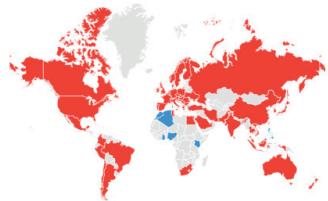
- ❑ Near the peak
- ❑ Knee on March 27, 2012 (Point G): Obama goes big on big data. Federal agencies host a webcast outlining their plan for big data.

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IoT: Google Trends



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



Snapshot: January 21, 2018

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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
- ❑ 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>

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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

Ref: <http://ietf.org/>

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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

Ref: <http://ieee802.org/>

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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 ⇒ Continuous. Real future is invented ⇒ Discontinuous

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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=PLjGG94etKypJWOSPMh8Azcg5e_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>

