

Networking Trends



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

<http://www.cse.wustl.edu/~jain/cse570-19/>



- ❑ Sources of Trends
- ❑ Processor, Storage, Clouds and Mobile Apps
- ❑ Cisco Visual Networking Index
- ❑ Gartner Hype Cycle 2019
- ❑ Google Trends

Sources of Trends

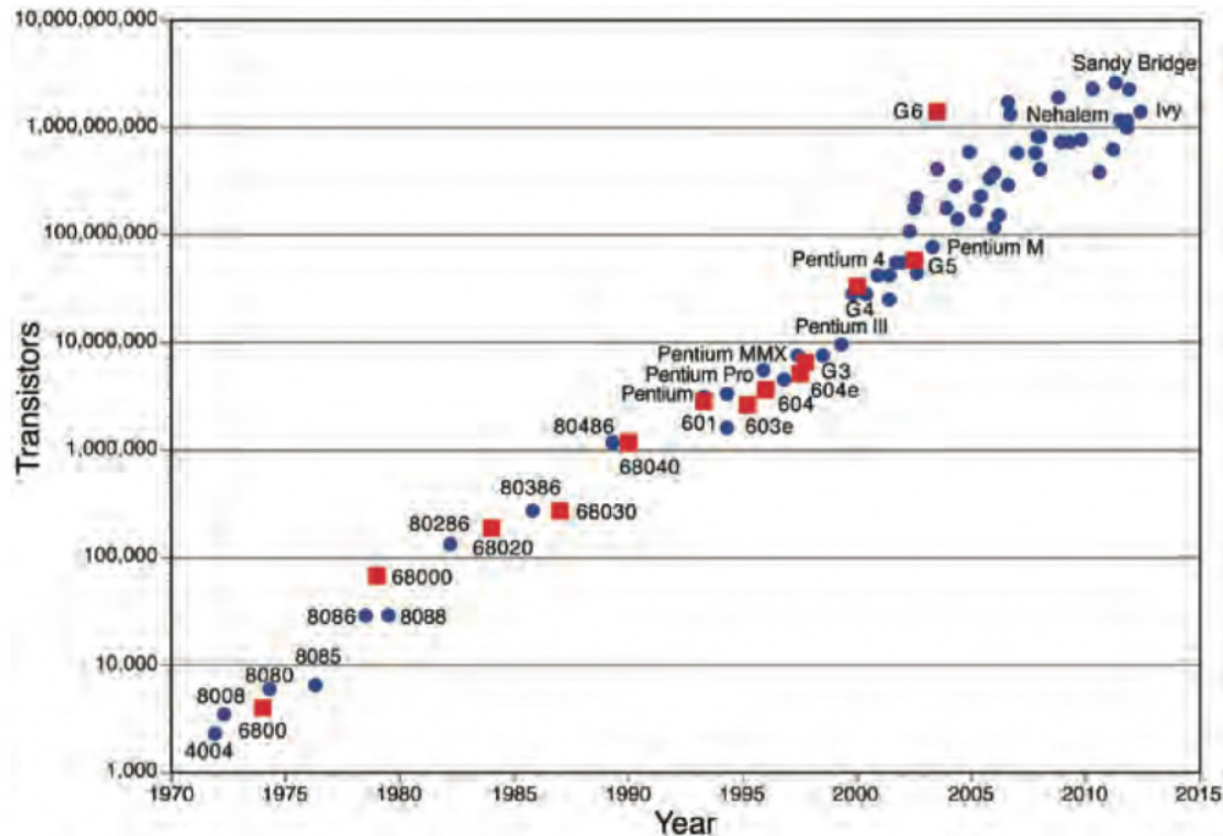
- ❑ Activities in technical industry organizations: IEEE, IETF, ITU
- ❑ NSF funding areas
- ❑ Venture capital investments
- ❑ Industry analytics companies like Gartner
- ❑ Google searches by people all over the world



“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

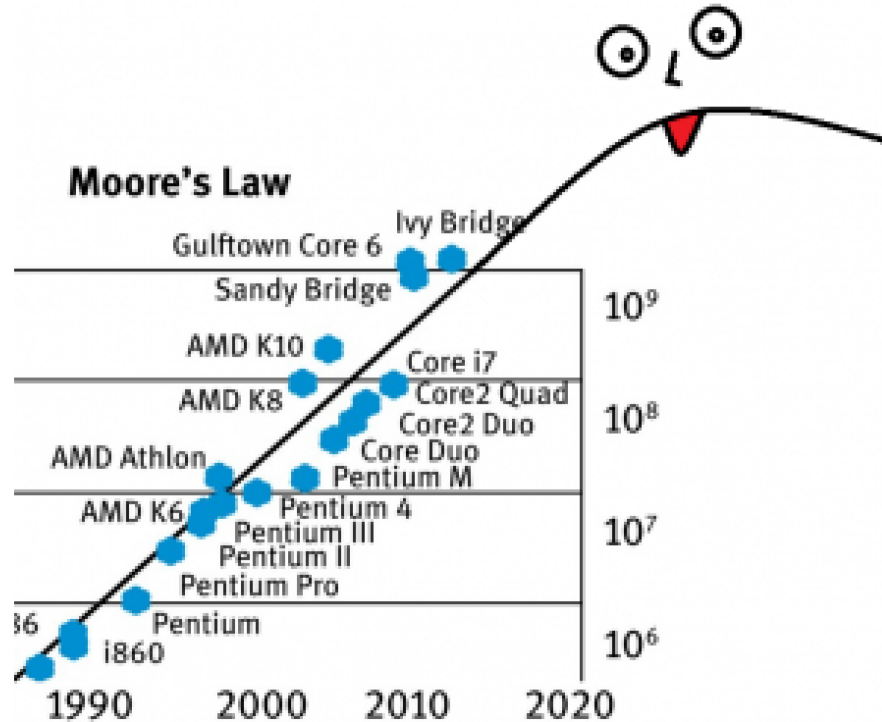


Ref: M. Czerniak, "What lies beneath? 50 years of enabling Moore's Law," Solid State Technology, 58, 25-28,

http://de.edwardsvacuum.com/uploadedFiles/Content/Articles/2015_October_Solid_State_Technology_50_Years_Moores_Law.pdf

Will Moore's Law Continue?

- A debate has begun...

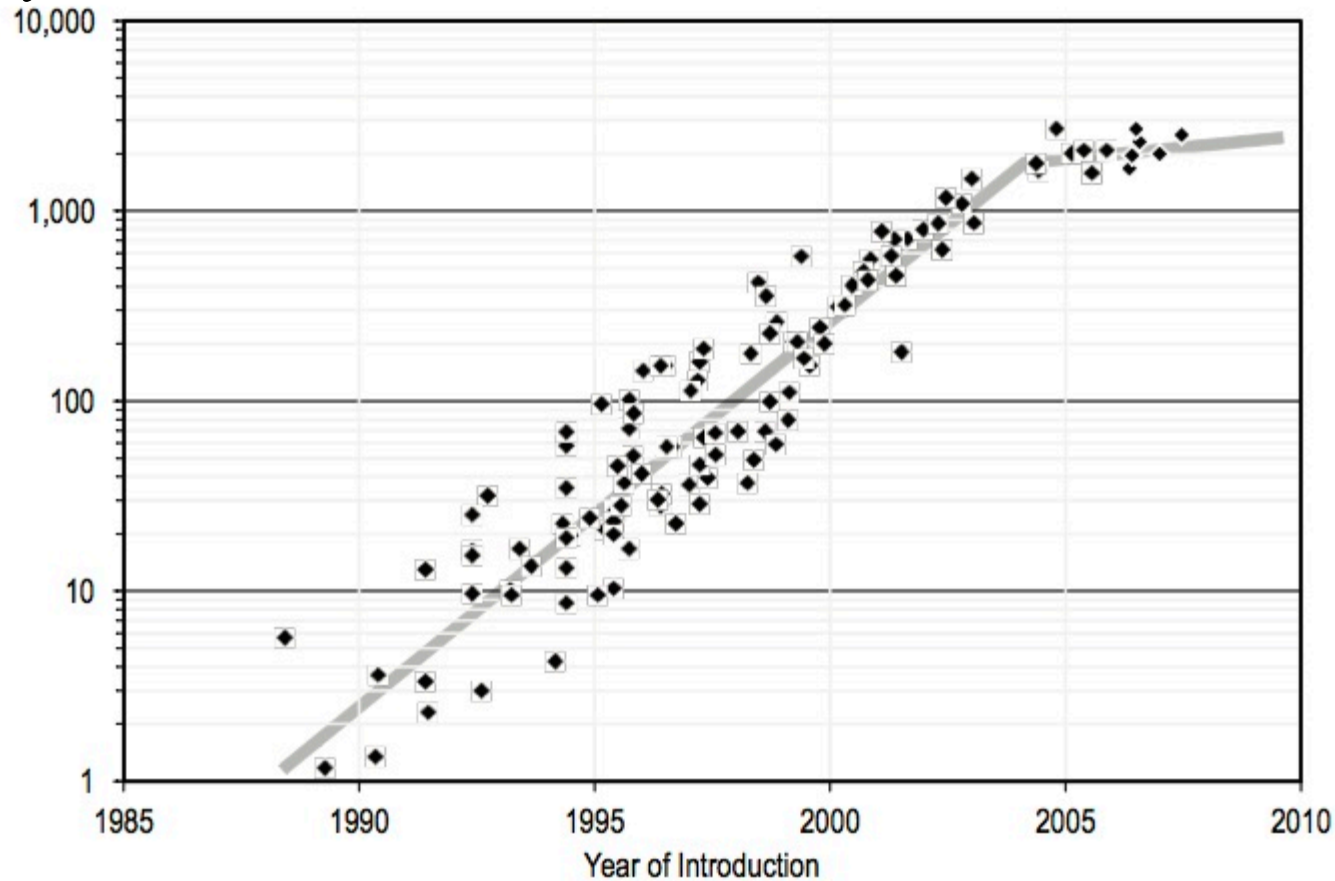


Ref: S. Crawford, "Moore's Law Is Ending... So, What's Next?" Feb 25, 2019, <http://redhat-linux.com.my/2033-2/>
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Will Moore's Law Continue? (Cont)

- 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>

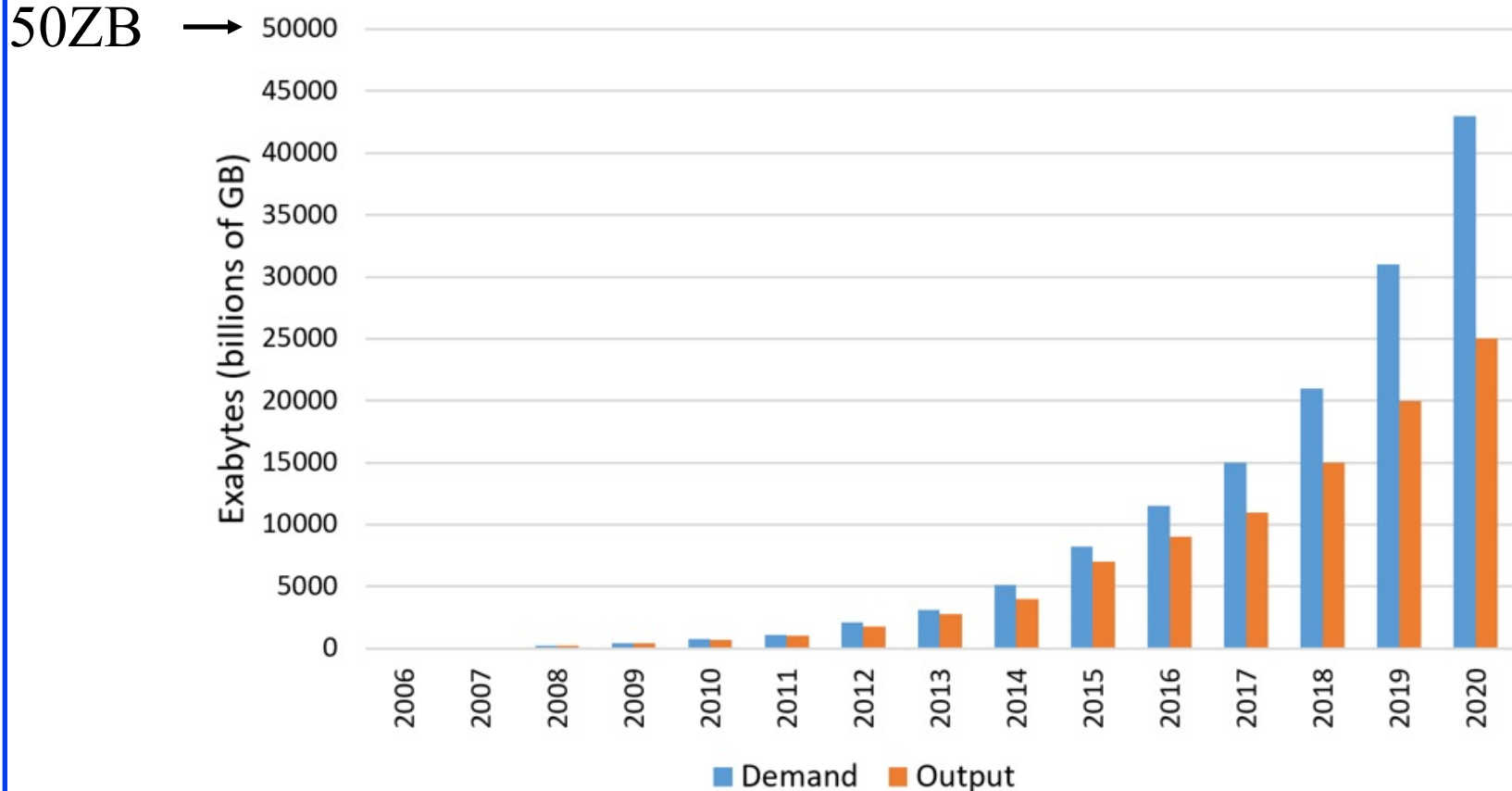
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Storage Capacity

- 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

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 Trends

❑ Trend 1: Bigger Data centers

- Hyperscale operators: Multi-billion dollars in cloud revenue
- Hyperscale Data Centers: # will double in 5 years (2016-2021)
 - ❑ Compound Annual Growth Rate (CAGR) of 15%
- 55% of traffic inside all data centers will be in these hyperscale data centers

❑ Trend 2: More data center traffic

- Global data center traffic (to/from data centers) will triple in 5 years (2016-2021) to 20.6 ZB/year \Rightarrow 25% CAGR
 - ❑ 95% of this traffic will be IP

❑ Trend 3: More computation in clouds

- 94% of compute workloads will be processed by clouds. Only 6% by traditional data centers.
- 13.2 compute instances per physical server (up from 8 in 2016)

Ref: 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>

Cloud Computing Trends (Cont)

❑ Trend 4: More public clouds

- 73% of compute in Public clouds, 27% in private clouds

❑ Trend 5: Mostly SaaS

- 75% Software-as-a-service
- 9% Platform-as-a-service
- 16% Infrastructure-as-a-service

Application	SaaS
Operating System	PaaS
Virtual Machine	IaaS

❑ Trend 6: Mostly Analytics, IoT, Streaming, and Social Networking

- Fastest Growing Applications:
 - ❑ Database/analytics and IoT for enterprise (21% CAGR)
 - ❑ Video streaming and social networking for consumers (24% CAGR)

Cloud Computing Trends (Cont)

❑ Trend 7: Data explosion

- Storage capacity in data centers: 2.6 ZB
 - ❑ Stored data 1.3ZB CAGR of 36%
- Data stored in devices = $4.5 \times$ data stored in data centers
- Data created 847 ZB/year
 - ❑ 100 times more than that stored

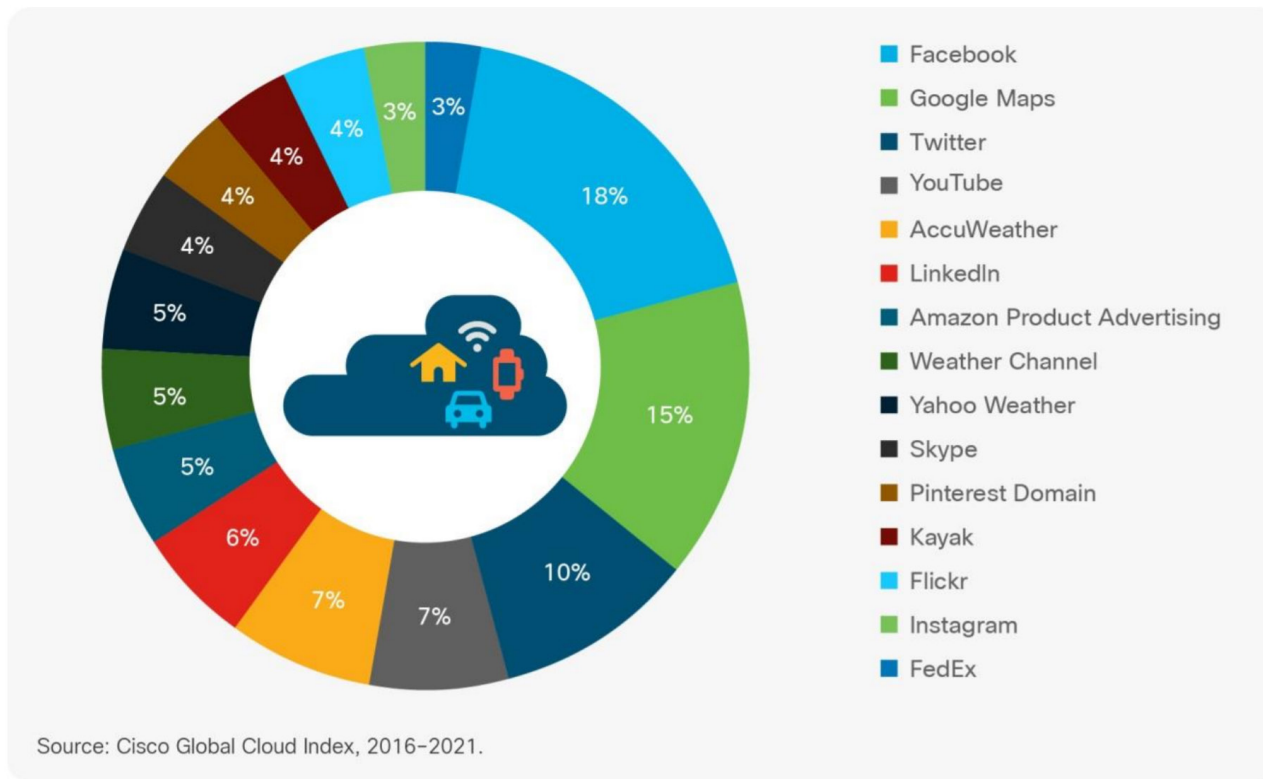
❑ Trend 8: Asia Pacific faster than North America

- Regional network speeds:
 - ❑ Asia Pacific: 46.2 Mbps download
 - ❑ North America: 43.2 Mbps download



Cloud Computing Trends

Trend 9: Most popular web APIs are all cloud based



Networking Trends

Between 2017-2022 (5 Years):

❑ **Trend 1: Global IP Traffic will grow 3X**

- 3X growth over 5 years = 26% CAGR
- Busy hour traffic is growing more rapidly: 3.7X

❑ **Trend 2: IP Devices will be more than the world population**

- **3.6 device per capita** worldwide
- M2M connections will more than half of these

❑ **Trend 3: Smart phone traffic will exceed the PC traffic**

- Only 19% of traffic due to PC, 44% due to smart phones

❑ **Trend 4: Traffic from Wireless devices will exceed that due to wired devices**

- 29% wired, 71% wireless

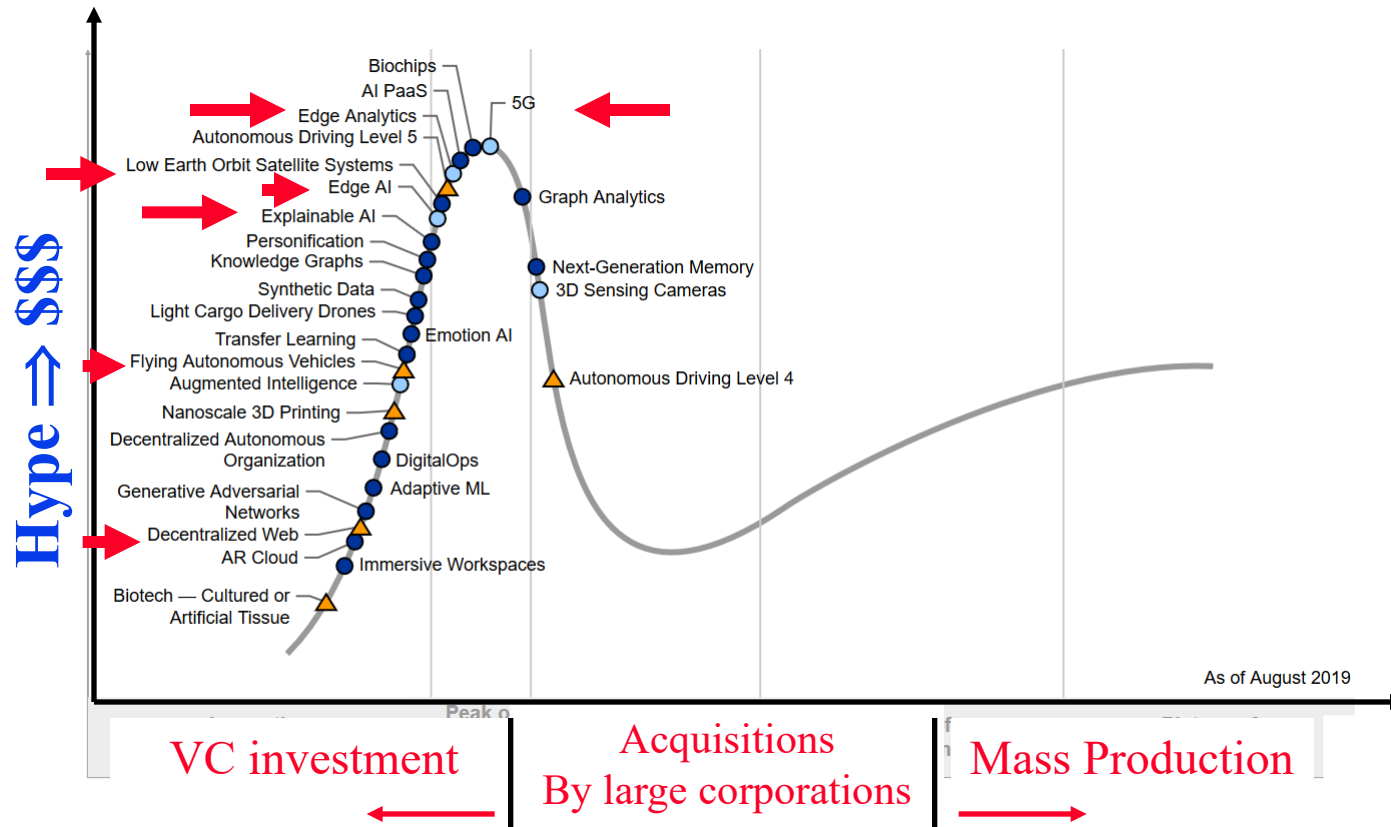
Ref: Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2017-2022," Feb 27, 2019,

<https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html>

Networking Trends (Cont)

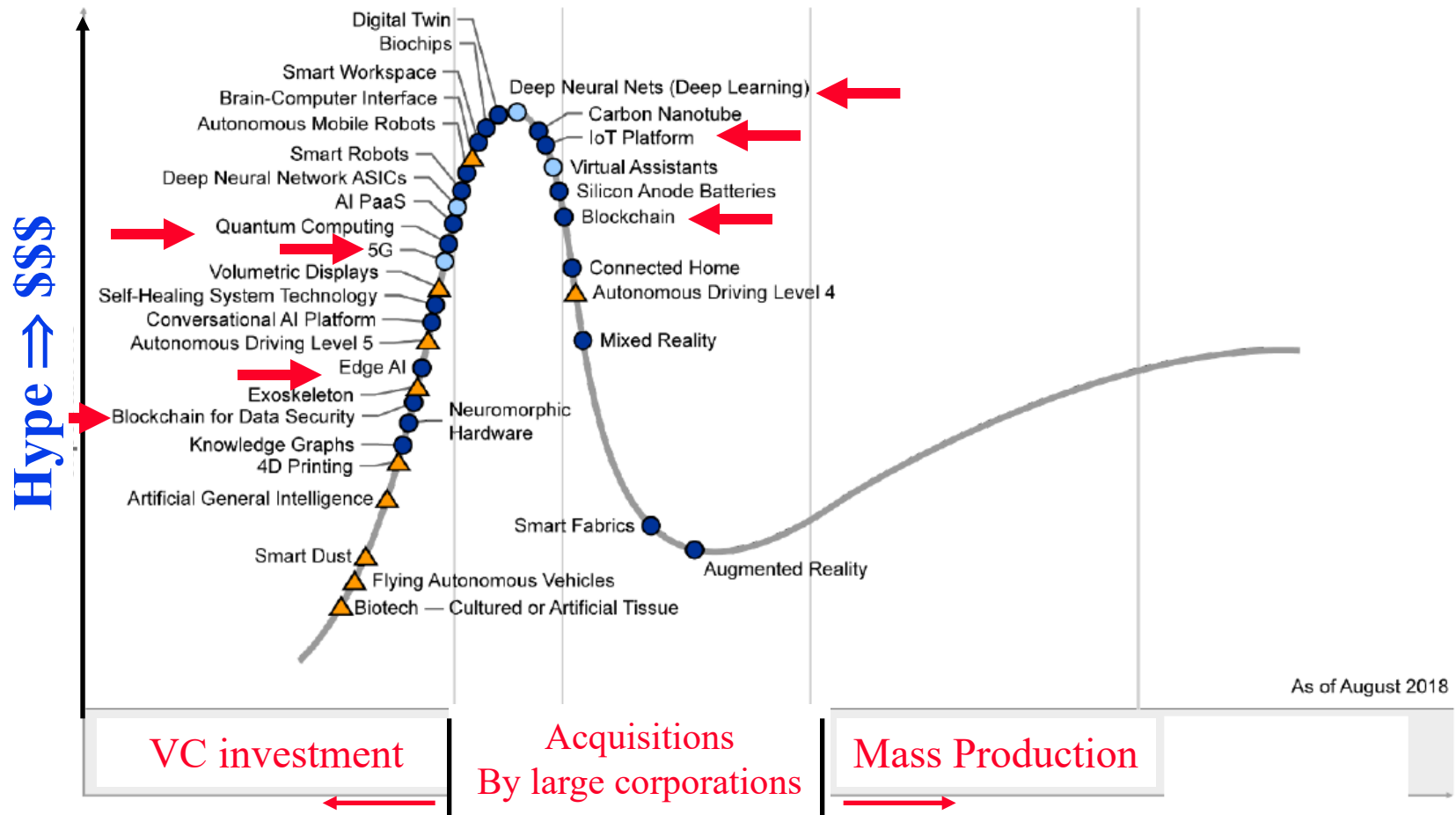
- ❑ **Trend 5: Mobile data traffic will grow twice as fast as fixed IP traffic**
 - 24% CAGR for fixed, 46% CAGR for Mobile
 - 12% of mobile traffic due to 5G
- ❑ **Trend 6: Mostly video traffic**
 - 82% Video 4X
 - Live video will be 17% of all video but will grow 15X
 - Internet Video surveillance traffic will increase 7X
- ❑ **Trend 7: Broadband speeds will double to 75 Mbps**
- ❑ **Trend 8: Traffic growing fastest in Middle East, Africa**

Gartner Hype Cycle of Emerging Tech 2019



Ref: B. Burke, D. Smith, "Hype Cycle for Emerging Technologies, 2018," Gartner Report G00370466, 6 Aug. 2019, 68 pp.

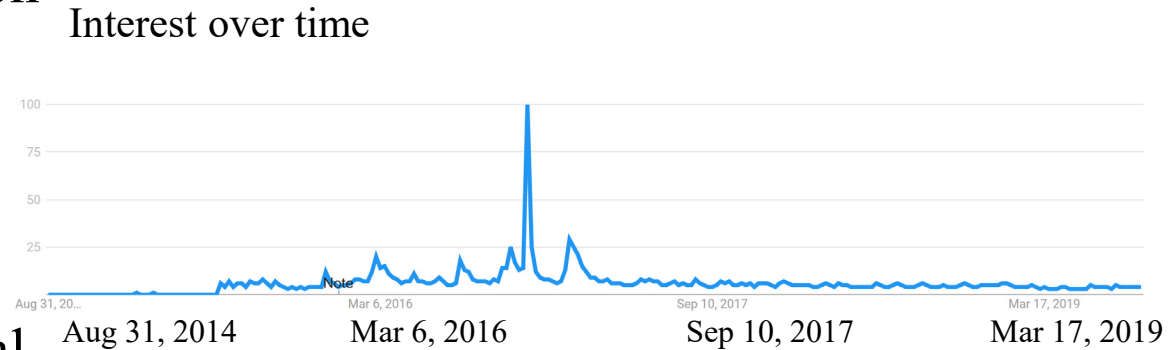
Gartner Hype Cycle of Emerging Tech 2018



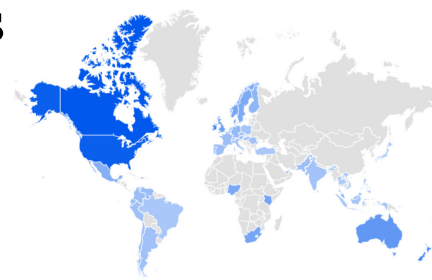
Ref: M. Walker, "Hype Cycle for Emerging Technologies, 2018," Gartner Report G00340159, 6 Aug. 2018, 73 pp.

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 by region



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

Snapshot: Aug 27, 2019

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

Google Trends and GDP

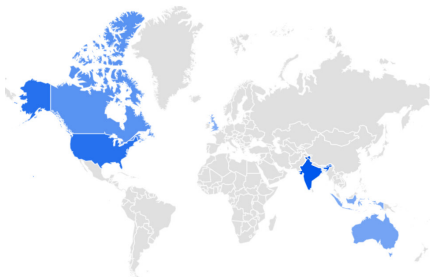
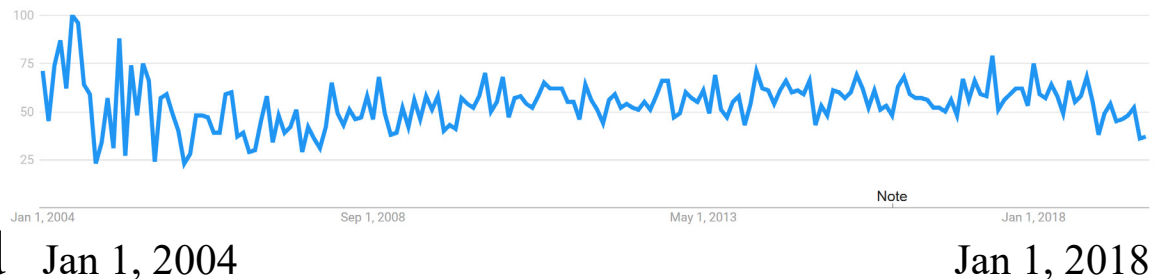
- ❑ Internet users from countries with higher GDP are more likely to search for future topics than about the past.
- ❑ Economic indicators are correlated to on-line behavior.

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



1	India	100	<div style="width: 100%;"></div>
2	United States	79	<div style="width: 79%;"></div>
3	Canada	50	<div style="width: 50%;"></div>
4	Australia	35	<div style="width: 35%;"></div>
5	Indonesia	31	<div style="width: 31%;"></div>

Snapshot: August 27, 2019

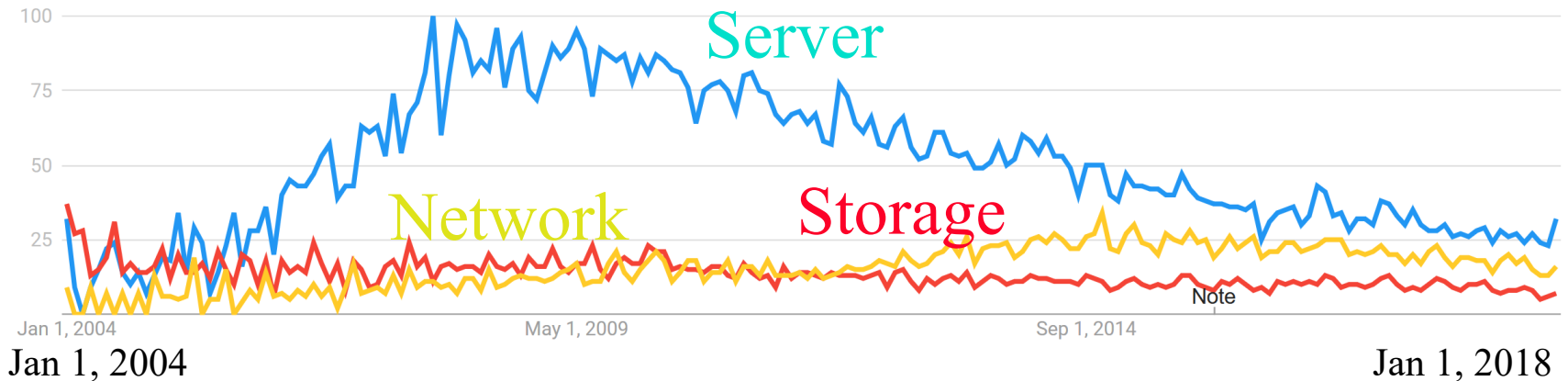
Network Virtualization: Google Trends



- ❑ Interest is decreasing slowly

Snapshot: August 27, 2019

Virtualization: Google Trends



Virtualization

- Server
- Storage
- Network

Increasing curiosity about network virtualization

Snapshot: August 27, 2019

SDN: Google Trends



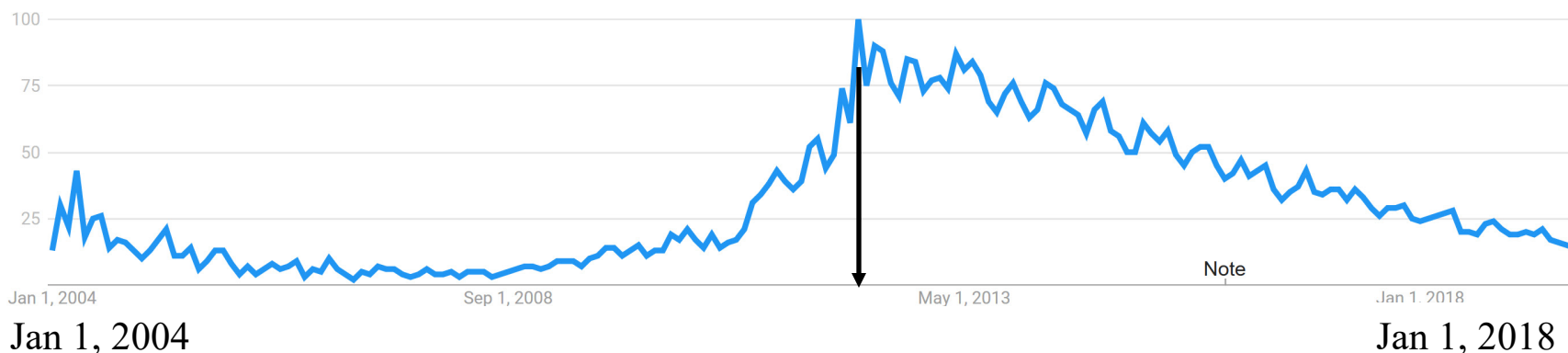
Jan 1, 2004

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

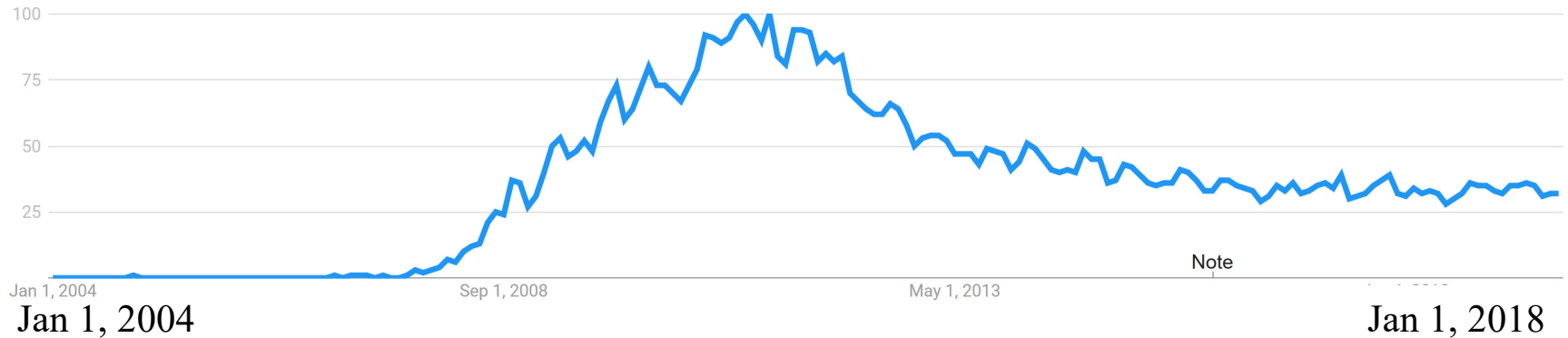
OpenFlow: Google Trends



- ❑ 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

Snapshot: August 27, 2019

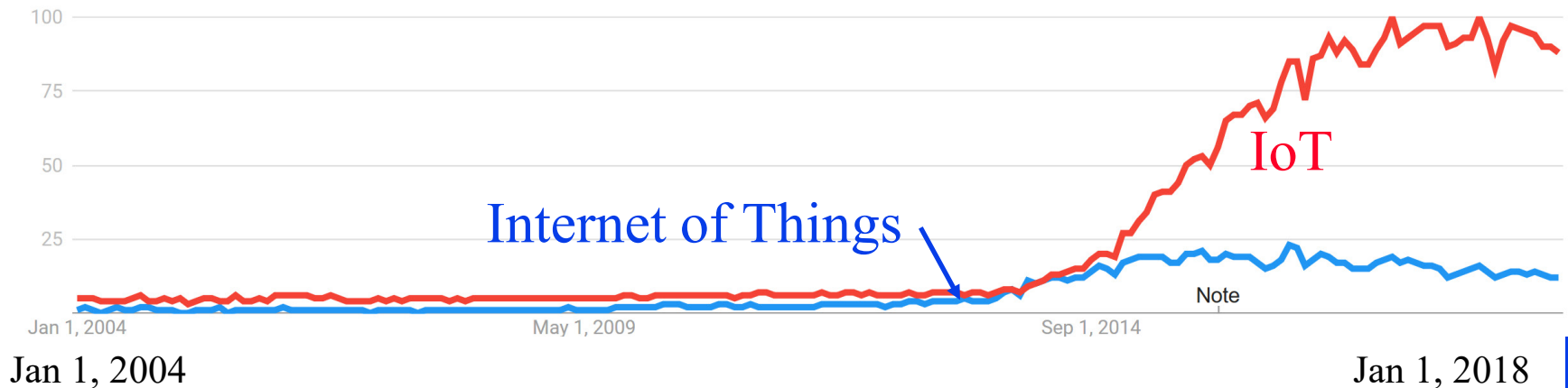
Cloud Computing: Google Trends



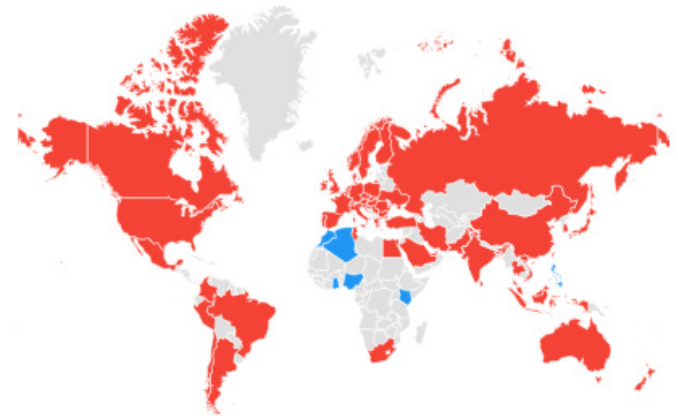
- ❑ Past-Hype phase.
As in Gartner graphs

Snapshot: August 27, 2019

IoT: Google Trends

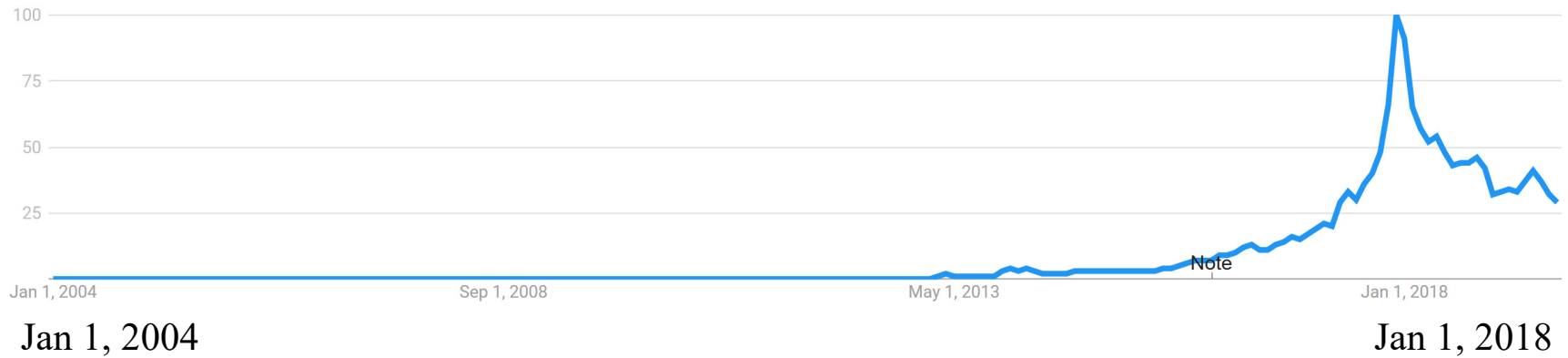


- ❑ Still growing
- ❑ High interest all around the world



Snapshot: August 27, 2019

Blockchain



❑ Peaked last year

Quantum Computing



- ❑ Has been around for quite some time
- ❑ Interest is up again

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
- ❑ 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>

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

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

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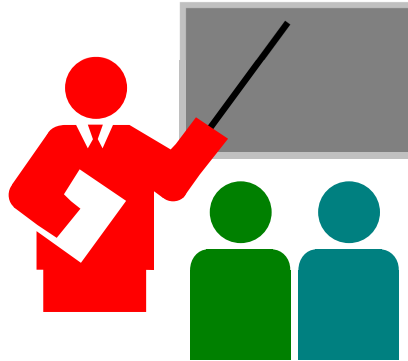
<http://www.cse.wustl.edu/~jain/cse570-19/>

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IEEE 802 LAN/MAN Standards

- ❑ Security
- ❑ Automotive Ethernet
- ❑ Time Sensitive Networking
- ❑ 200 Gbps Ethernet, 400 Gbps PHY
- ❑ 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 \Rightarrow Continuous.
Real future is invented \Rightarrow Discontinuous

Reading List

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>

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>