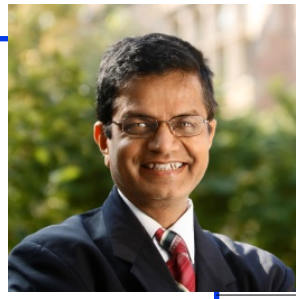
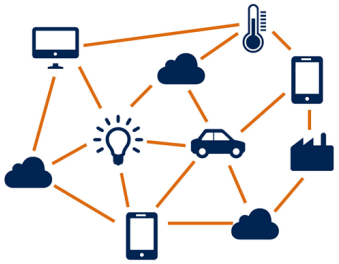
Our Research on Networking, Security, Internet of Things, Blockchains, and Drones





Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@wustl.edu

A talk in "CSE 591: Introduction to Graduate Studies in CSE"
September 20, 2019

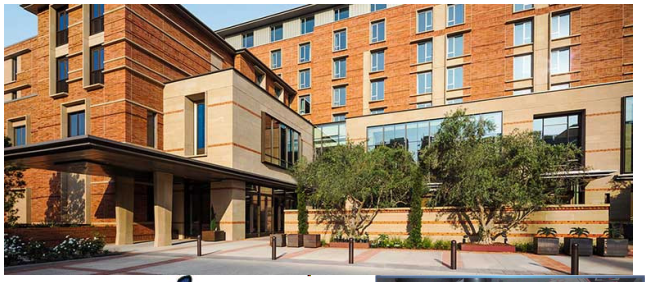
These slides and a video recording of this talk are at:
http://www.cse.wustl.edu/~jain/talks/cs59119.htm

Overview

1. Why networking is important
2. Recent trends and issues in networking
3. Our Research and its Distinctions
4. Required qualifications

Networking = "Plumbing"

- Networking is the "plumbing" of computing
- Almost all areas of computing are network-based.
  - Distributed computing
  - Big Data
  - Cloud Computing
  - Internet of Things
  - Smart Cities



- Networking is the backbone of computing.

Networking is already great!

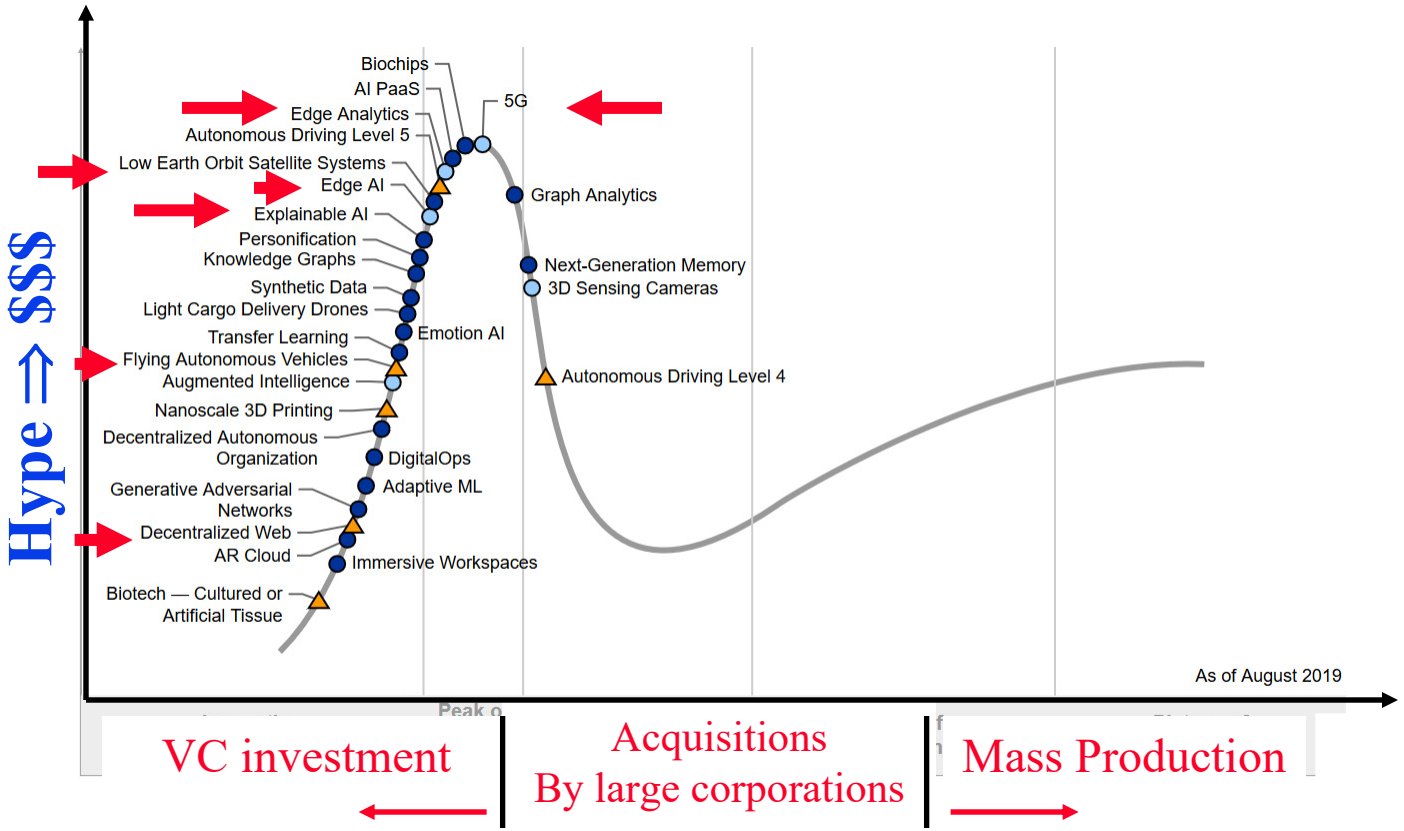
Networking is Fueling All Sectors of Economy

- Networking companies are among the most valued companies: Apple, AT&T, Samsung, Verizon, Microsoft, China Mobile, Alphabet, Comcast, NTT, IBM, Intel, Cisco, Amazon, Facebook, …

  ⇒ All tech companies that are hiring currently are networking companies
- Note: Apple became highly valued only after it switched from computing to communications (iPhone)

Networking = Economic Indicator

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.

Current Hot Topics in Networking

1. Internet of Things (IoT)
2. Security
3. Edge Computing and Multi-Cloud
4. Blockchains
5. Drones

Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

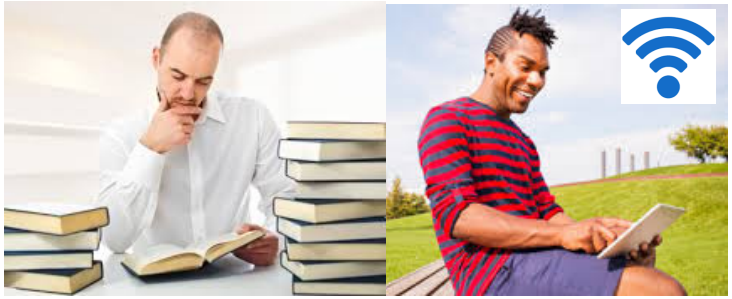
Smart Space

Smart Industries

Smart Cities

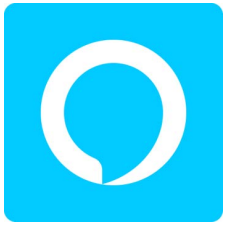
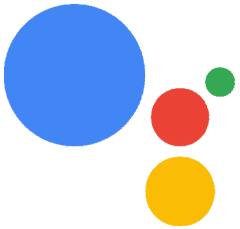
What's Smart?

- Old: Smart = Can think ⇒ Computation
  = Can Recall ⇒ Storage
- Now: Smart = Can find quickly, Can Delegate
  ⇒ Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …



Not-Smart Smart

Trend: Smart to Intelligent

 Intelligent Clock	 Intelligent TV	 Intelligent Car
 Intelligent Health	 Intelligent Home Security	 Intelligent Microwave
 Intelligent Light	 Amazon Alexa	 Google Assistant

Trend: AI to Explainable AI

- Data Imbalance (1 in a Billion packet is an attack packet).
  In most papers, 10-15% of the packets are attack packets
- Explainability issue
  ⇒ No idea of why the results are what they are
  Can't discover bugs in ML model implementations

Machine Learning is what only machines can do, but human cannot do and cannot explain

Ref: M. Zolanvari, M. A. Teixeira, R. Jain, "**Effect of Imbalanced Datasets on Security of Industrial IoT Using Machine Learning**," 2018 IEEE International Conference on Intelligence and Security Informatics (ISI), Miami FL, Nov. 9 - 11, 2018, 6 pp., http://www.cse.wustl.edu/~jain/papers/imb_isi.htm

M. Zolanvari, M. A. Teixeira, R. Jain, "**An Explainable Machine Learning Based Security Framework: A Special Case on Industrial IoT," Submitted February 2019.**

Trend: Managed to Self-Driven Networks

- **Self-Discover**: Find its components
- **Self-configure**: Trending. Predict.
- **Auto-Manage** = Auto-BSS (bill)/Auto-OSS (provision)
- **Self-Monitor**: Counters and Probes. Telemetry
- **Self-Diagnose and Self-Heal**: Self-Report to human operator
- **Self-Organizing Network (SON)** capabilities since 3GPP R8

Network Manager

Ref: Kireerti Kompella, https://datatracker.ietf.org/meeting/98/materials/slides-98-nmrg-self-driving-networks

Trend: Security & Cyber Warfare

- Security of computers, companies, smart grid, and nations
- Nation States are penetrating other nations computers
  5th domain of warfare (after land, sea, air, space)
- In 2010, US set up US Cyber Command
- UK, China, Russia, Israel, North Korea have similar centers
- Many cyber wars: North Korea vs. USA, Israel vs. Syria, South Korea vs. North Korea, India vs. Pakistan, …

Old

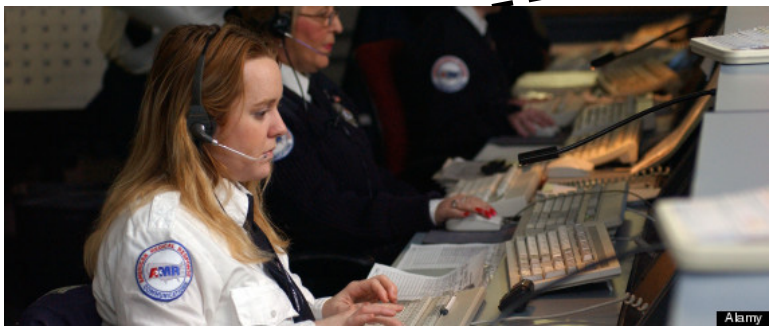
New

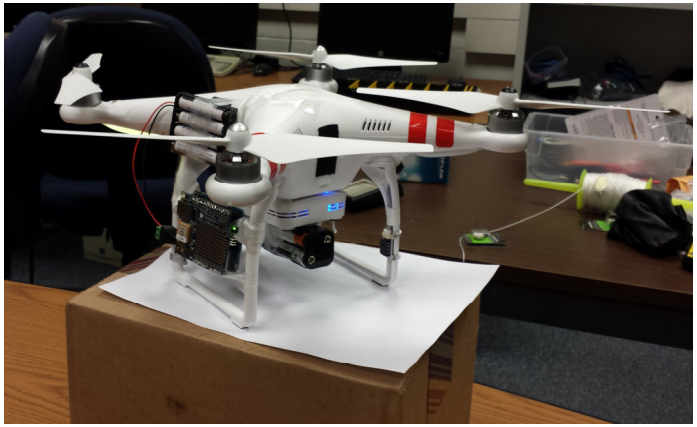
Ref: https://en.wikipedia.org/wiki/Cyberwarfare

Trend: Blockchains

- Blockchain is the technology that made Bitcoin secure
- Blockchain was invented by the inventor of Bitcoin
- After Bitcoin became successful, people started looking into the technology behind Bitcoin and found:
  - Blockchain is the key for its success
  - Blockchains can be leveraged for other applications

Trend: Drones





Our Research Projects

1. Multi-Cloud Management: Machine learning for Fault and performance management
2. Multi-Cloud for 5G: Network Function Virtualization Micro-edge computing, micro-service placement
3. IoT Security 1: Industrial Control Systems Security
4. IoT Security 2: Healthcare Security
5. Multi-Cloud Security: Scientific Collaboration Security

} **5 Funded Research Projects**

6. Blockchains for Security } **Approved**
7. Communication using UAVs } **Pending**

Techniques:

1. Machine learning and Deep Learning
2. Blockchains

Key Distinction of Our Research

- Goal: Impact to the real-world
  DECbit congestion indication in almost all networking architectures since its invention
- Funded by industry partners:
  Intel, Cisco, Broadcom, Boeing, …
- Impact real-world by participating in standards organizations and industry forums:
  ATM Forum, IEEE Standards, American National Standards Institute (ANSI), Internet Engineering Task Force (IETF), WiMAX Forum
- Work on long term as well as short term research

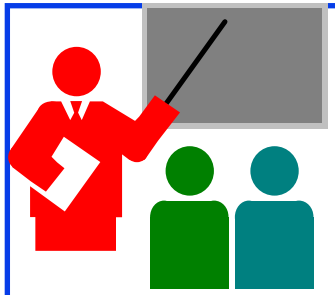
Networking Courses at WUSTL

- CSE 521S: Wireless Sensor Networks
- CSE 537S: Mobile Computing
- **CSE 570: Advanced Networking**
- CSE 571: Network Security
- **CSE 574S: Wireless and Mobile Networking**
- CSE 7700: Res Seminar On Networking

CSE 473S: Introduction to Networking

Requirements

- Have 3 students working on 5 projects + 1 approved
- Need 2 to 3 new Ph.D. students
- Requirements:
  - Background and interest in networking: CSE 473
  - Flexible – ability to work on the latest issues
  - Good communication skills
  - Machine learning (optional)
  - Preferably with a masters degree



Summary

1. Computer networking is the backbone of all computing
   ⇒ Cyber age. Networking companies are the leading edge.
2. Smart ≠ High-Speed Computation,
   Smart ≠ Big Data Storage,
   Smart = Networked
3. We are applying latest technologies to network security issues
4. Research for Impact

References: Class Recordings

- Recordings of all of my classes and talks are available on YouTube and on my website:
  1. CSE 473: Introduction to Computer Networks, http://www.cse.wustl.edu/~jain/cse473-19/index.html
  2. CSE 571S: Network Security, http://www.cse.wustl.edu/~jain/cse571-17/index.html
  3. CSE 574S: Wireless Networks, http://www.cse.wustl.edu/~jain/cse574-18/index.html
  4. CSE 567: Computer Systems Analysis http://www.cse.wustl.edu/~jain/cse567-17/index.html
  5. CSE 570: Recent Advances in Networking http://www.cse.wustl.edu/~jain/cse570-19/index.html

Recent Papers

- Maede Zolanvari, Marcio A. Teixeira, Lav Gupta, Raj Jain, "**Machine Learning Based Network Vulnerability Analysis of Industrial Internet of Things**," IEEE Internet of Things Journal, Vol. 6, Issue 4, Aug 2019, http://www.cse.wustl.edu/~jain/papers/vulnerab.htm
- L. Gupta, M. Samaka, R. Jain, A. Erbad, D. Bhamare, H. A. Chan, "**Fault and Performance Management in Multi-Cloud Based NFV using Shallow and Deep Predictive Structures**," Journal of Reliable Intelligent Environments, Vol. 3, No. 4, Dec. 2017, pp. 221-231, http://www.cse.wustl.edu/~jain/papers/jrie17.htm
- Tara Salman, Raj Jain, Lav Gupta, "**A Reputation Management Framework for Knowledge-Based and Probabilistic Blockchains**," IEEE 1st International Workshop on Advances in Artificial Intelligence for Blockchain (AIChain 2019), held in conjunction with the 2019 IEEE International Conference on Blockchain, Atlanta, July 14, 2019, http://www.cse.wustl.edu/~jain/papers/rpmcewa.htm
- Denise S. Ponchak, Fred L. Templin, Greg Sheffield, Pedro Taboso, Raj Jain, "**Advancing the Standards for Unmanned Air System Communications, Navigation, and Surveillance**," IEEE Aerospace Conference, Big Sky, Montana, Mar 2-9, 2019, http://www.cse.wustl.edu/~jain/papers/aerosp19.htm

Recent Talks

- Raj Jain, "**Recent Advances in Networking and their Impact on Smart Cities**," 2019 IEEE Industry Summit on future technology for Smart Cities, San Francisco, CA, April 6, 2019, http://www.cse.wustl.edu/~jain/talks/smart_cities.htm
- Raj Jain, "**Trends and Issues in Softwarization of Networks: What's In, What's Out**," Invited talk at IEEE Workshop on Network Automation, Piscata Way, NJ, Feb 25, 2018, http://www.cse.wustl.edu/~jain/talks/inetauto.htm
- Raj Jain, "**12 Trends in Networking: What's In, What's Out**," Keynote at International Conference on Computing, Networking and Communications (ICNC) 2019 Honolulu, Hawaii, February 20, 2019, http://www.cse.wustl.edu/~jain/talks/icnc19.htm
- Raj Jain, "**Extending Blockchains Beyond Smart Contracts**," Keynote at Blockchain Connect Conference, San Francisco, January 11, 2019, http://www.cse.wustl.edu/~jain/talks/pbc_svi.htm

Acronyms

- 3GPP Third Generation Partnership Project
- AI Artificial Intelligence
- ANSI American National Standards Institute
- AT&T American Telephone and Telegraph
- BSS Business Support Services
- CA California
- CGNAT Carrier Grade Network Address Translator
- CSE Computer Science and Engineering
- DECbit Digital Equipment Corporation Bit
- IEEE Institution of Electrical and Electronic Engineering
- IoT Internet of Things
- ML Machine Learning
- MO Missouri
- MS Master of Science
- NFV Network Function Virtualization
- NTT Nippon Telephone and Telegraph

Acronyms (Cont)

- OpenADN Open Application Delivery Networking
- OSS Operations Support Services
- SON Self-Organizing Networks
- TV Television
- UK United Kingdom
- US United States
- VC Venture Capital
- WAN Wide Area Network
- WiMAX Worldwide Interoperability for Microwave Access
- WUSTL Washington University in St. Louis

Scan This to Download These Slides

Raj Jain
Rajjain.com