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

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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.
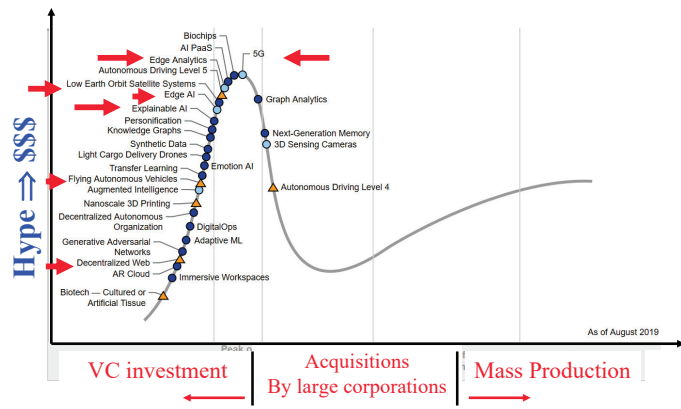
> Networking is already great!

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

Hype ⇒ $$$

Biochips
AI PaaS
5G
Edge Analytics
Autonomous Driving Level 5
Low Earth Orbit Satellite Systems
Edge AI
Explainable AI
Personification
Knowledge Graphs
Synthetic Data
Light Cargo Delivery Drones
Transfer Learning
Emotion AI
Flying Autonomous Vehicles
Augmented Intelligence
Nanoscale 3D Printing
Decentralized Autonomous Organization
Generative Adversarial Networks
Decentralized Web
AR Cloud
Biotech — Cultured or Artificial Tissue

Graph Analytics
Next-Generation Memory
3D Sensing Cameras
Autonomous Driving Level 4
DigitalOps
Adaptive ML
Immersive Workspaces

As of August 2019

Peak o

VC investment | Acquisitions By large corporations | Mass Production

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, …
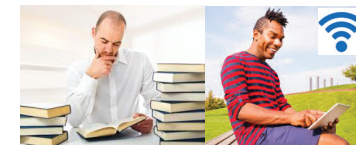
Not-Smart   Smart

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
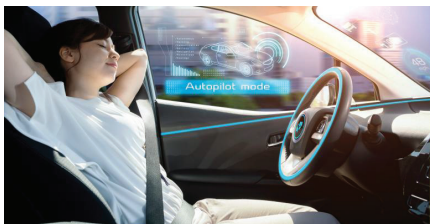Can't discover bugs in ML model implementations

> *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

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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 5375S: 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
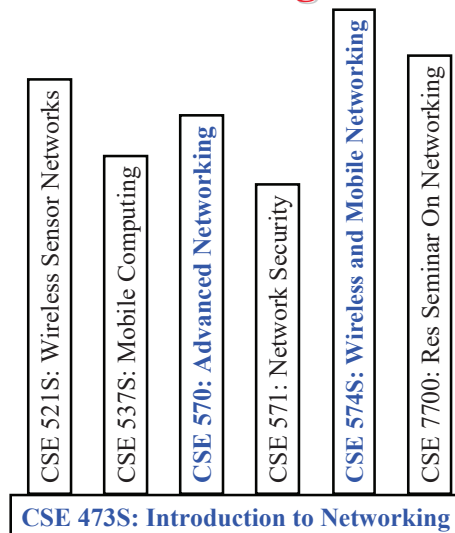
Requirements

❑ 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
   $\Rightarrow$ Cyber age. Networking companies are the leading edge.

2. Smart $\neq$ High-Speed Computation,
   Smart $\neq$ 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