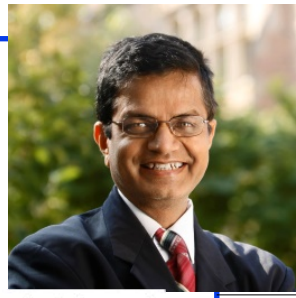
Our Research on New AI and Blockchain Techniques for Network Security



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A talk in "CSE 591: Introduction to Graduate Studies in CSE"
October 2, 2020

These slides and a video recording of this talk are at:
http://www.cse.wustl.edu/~jain/talks/cs59120.htm

Overview

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

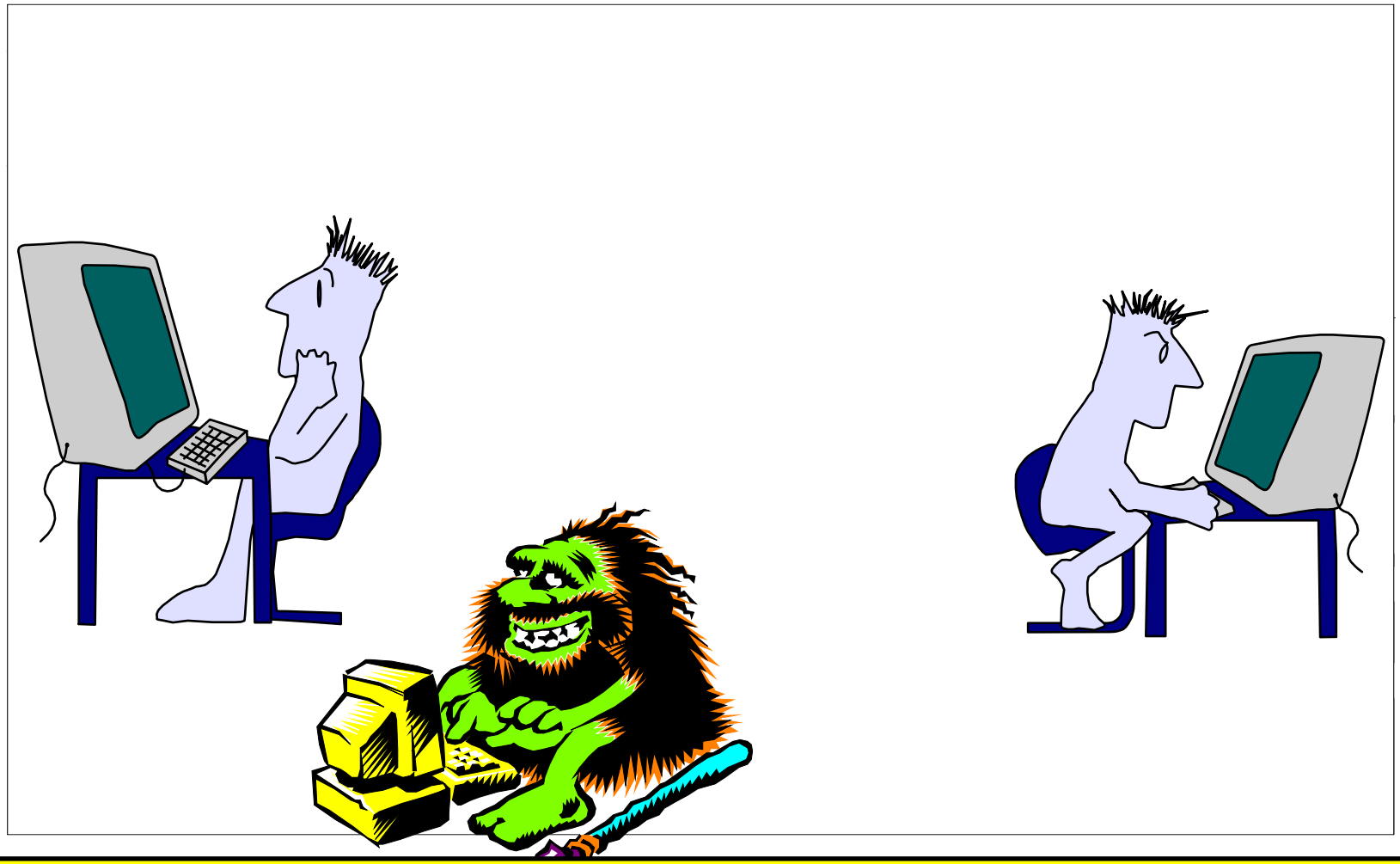
Networking is Fueling All Sectors of Economy

- 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)

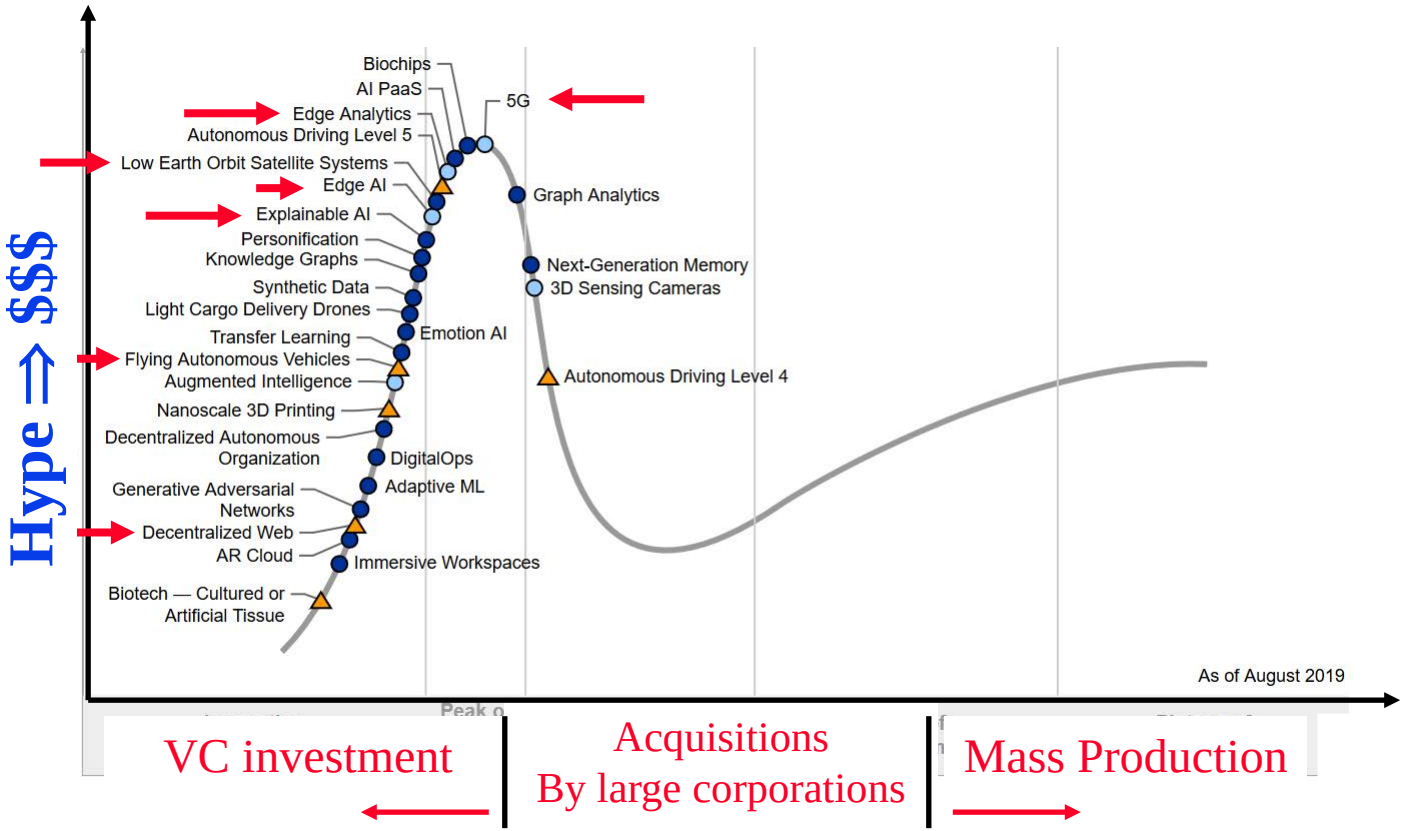
Networking = Economic Indicator

Cave Persons of 2020



Networking ⇒ Any where, Any time, Any place, Any dress, Any task

Gartner Hype Cycle of Emerging Tech 2019



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

Current Hot Topics in Networking

1. Internet of Things (IoT)
2. IoT Security
3. Artificial Intelligence
4. Blockchains
5. Drones

Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

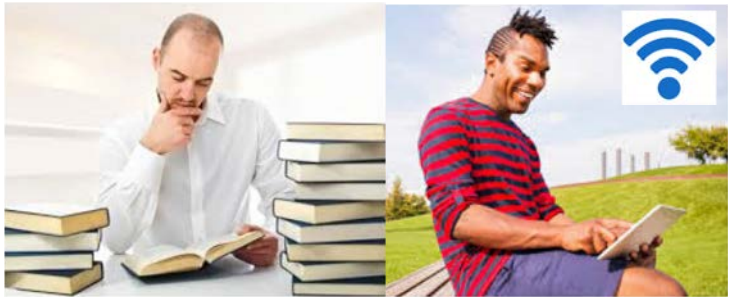
Smart Space

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

- Smart = Apply the latest **technology** to solve problems

Trend: Smart to Intelligent

Intelligent Clock

Intelligent TV

Intelligent Car

Intelligent Health

Intelligent Home Security

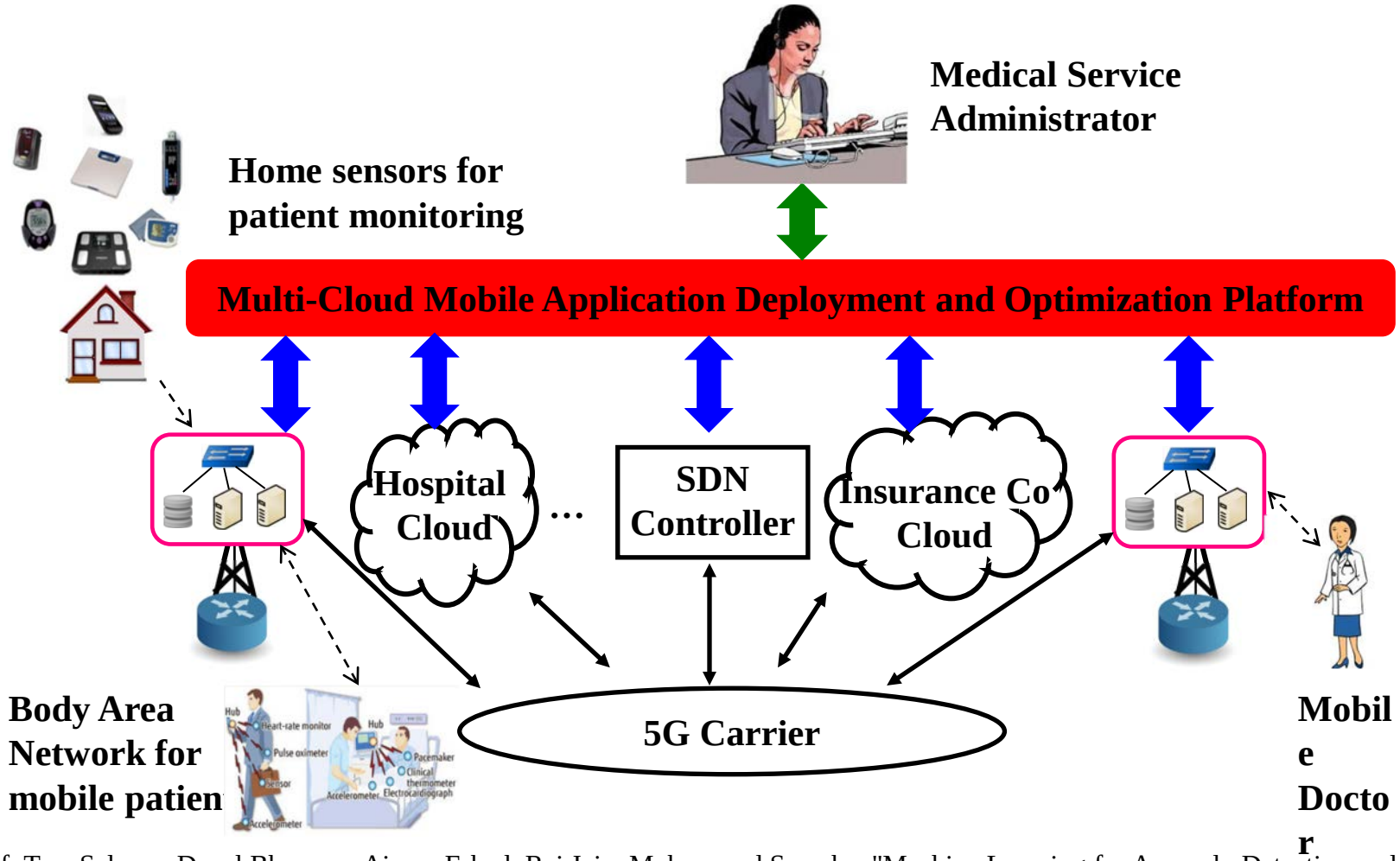
Intelligent Microwave

Intelligent Light

Amazon Alexa

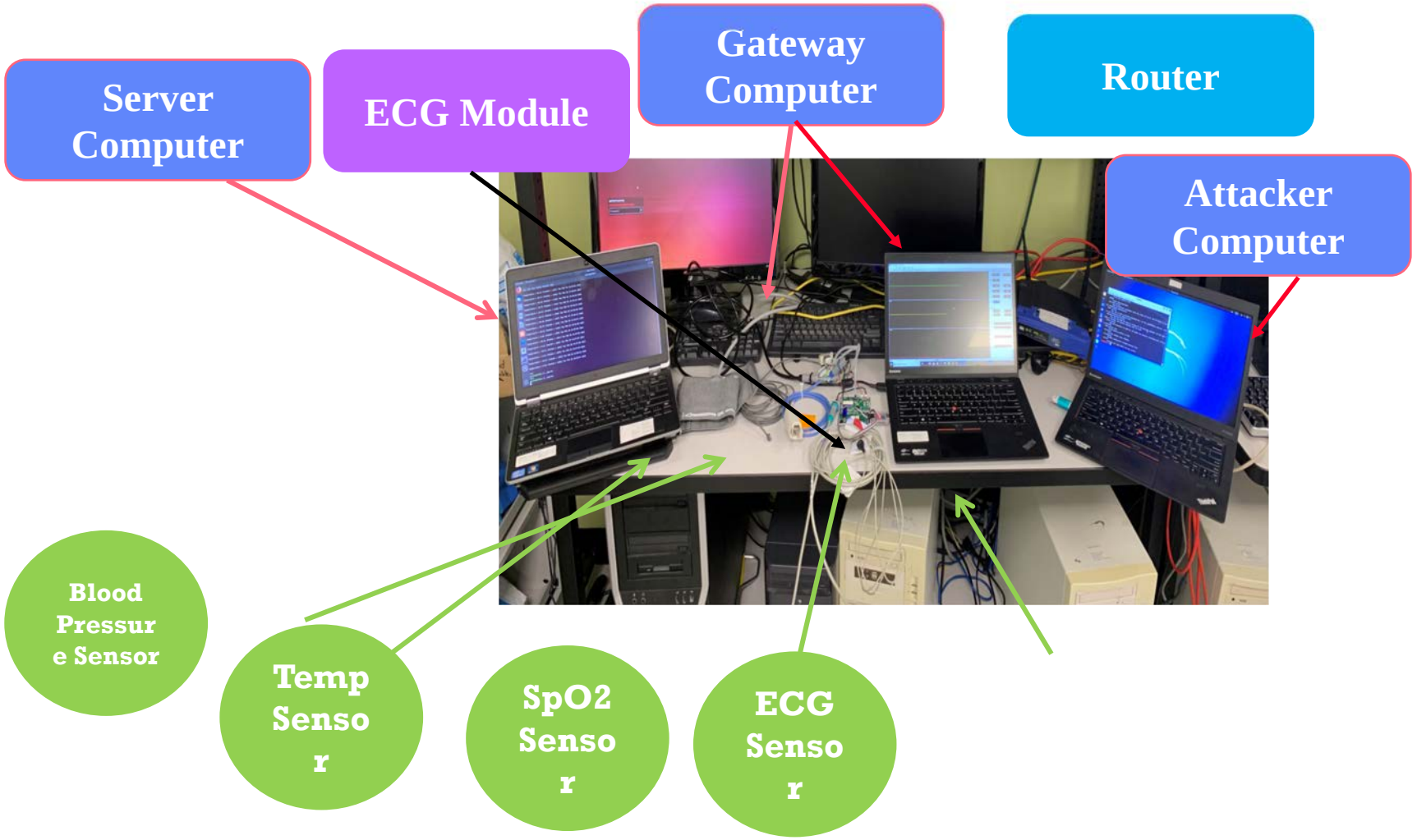
Google Assistant

Mobile Healthcare Use Case



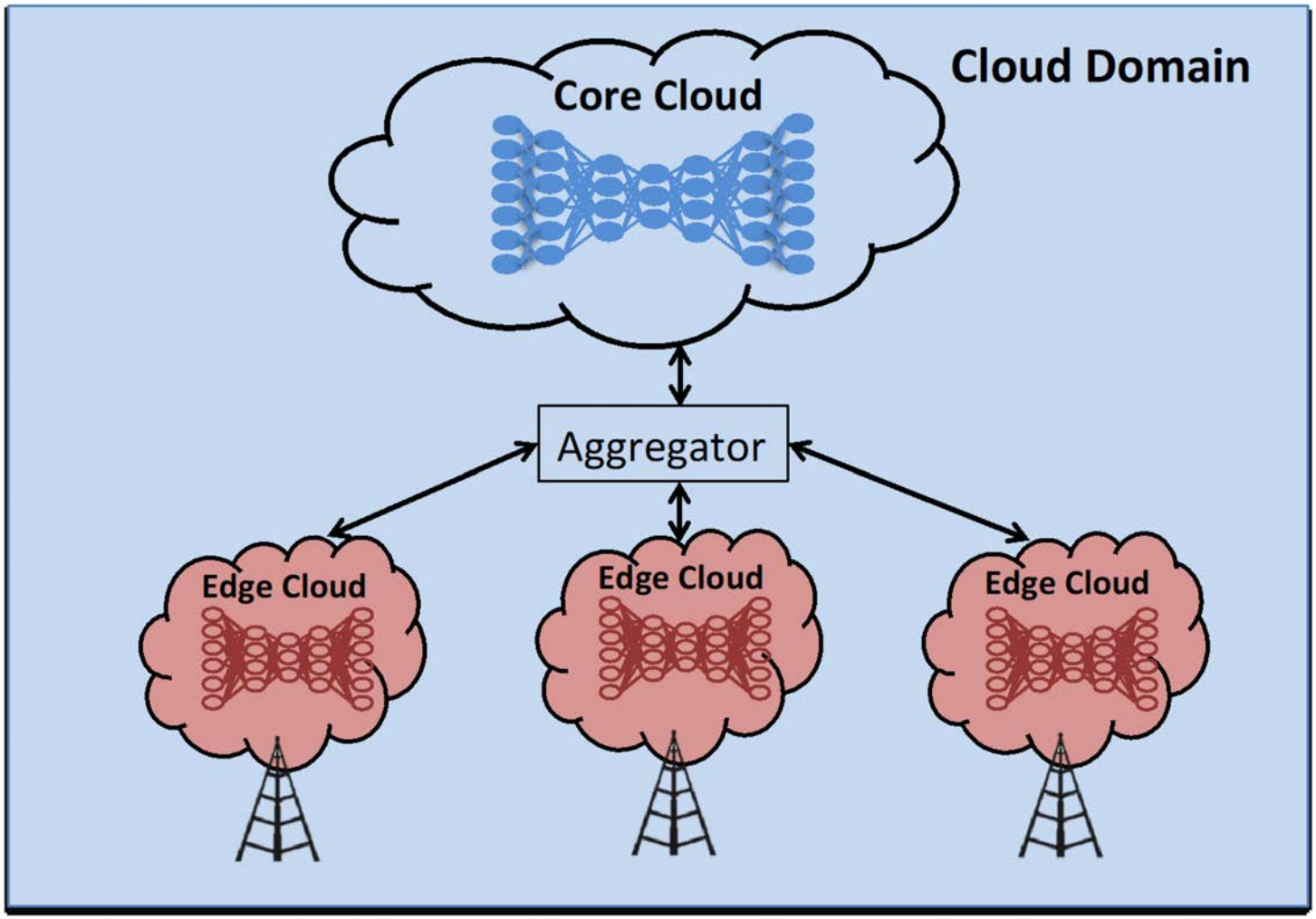
Ref: Tara Salman, Deval Bhamare, Aiman Erbad, Raj Jain, Mohammed Samaka, "Machine Learning for Anomaly Detection and Categorization in Multi-cloud Environments," The 4th IEEE International Conference on Cyber Security and Cloud Computing, June 26-28, 2017, http://www.cse.wustl.edu/~jain/papers/cscloud.htm

Hospital on Hospital on a Desk Testbed



Ref: Anar A. Hady, Ali H. Ghubaish, Tara Salman, Devrim Unal, Raj Jain, "Secure Healthcare Monitoring System using Machine Learning," Submitted.

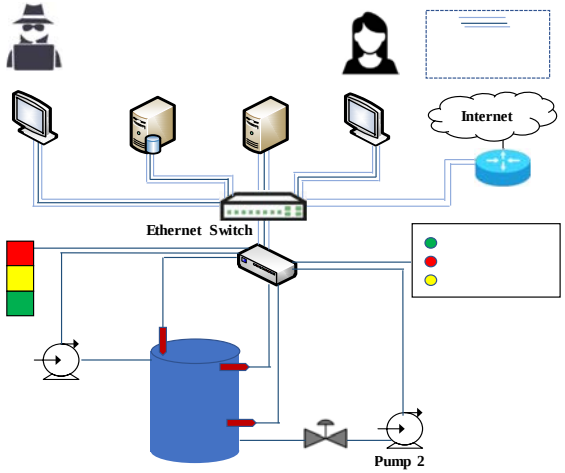
Innovations in Multi-Cloud
Hierarchical AI Model with Layer Reuse

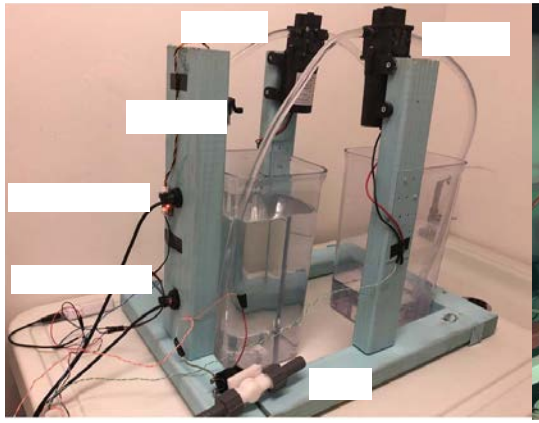


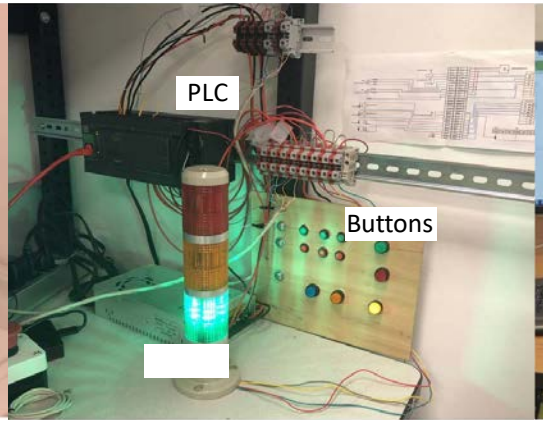
Industrial Control Systems Security

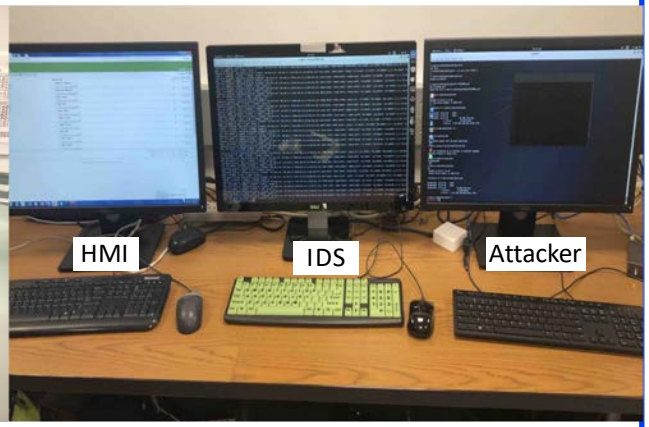
- Pre-Ethernet era networks and protocols: Modbus
- Extremely critical infrastructure
- Nation state level attacks
- Any weakness in the lifetime management, installation, or upgrades, may lead to attacks

ICS Testbed









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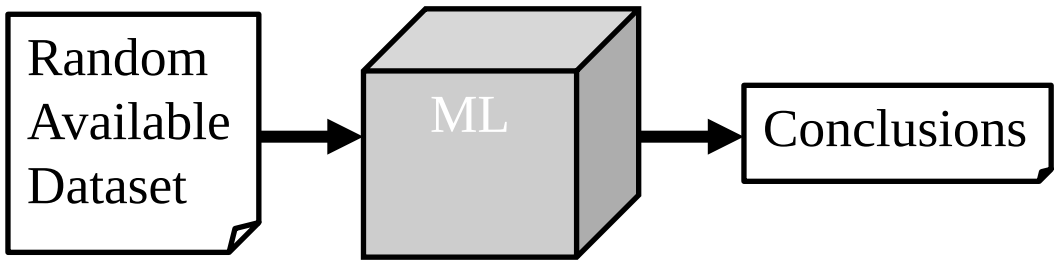
http://www.cse.wustl.edu/~jain/papers/ics_ml.htm

Machine Learning Challenges

- Machine learning is currently a black box
- ML algorithms are developed/used without domain expertise
- Data cleanliness, labeling, feature extractions, all require domain knowledge, e.g.,
  What is the distance between Port 80, Port 81, and Port 8080?
- Synthetic data is used ⇒ Garbage-In, Garbage-Out
- Results are stated without model validation.



AI for Security

- AI started with image analysis but needs to be extended for security
- Security data is very different from image data
  - Most security datasets are not representative of real world.
  - In most papers, 10-15% of the packets are attack packets
- In real-world, 1 in a billion packets is an attack packet
  - Mis-classify the attack packet ⇒ 99.9999% accuracy
  - Current metrics and methods not suitable for highly imbalanced data
- **Data imbalance** is a key issue in AI for security

1% attack =

http://www.cse.wustl.edu/~jain/talks/cs59120.htm

Trend: AI to Explainable AI

- 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.**

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
  - Two complete strangers can complete a transaction/contract without a third party

Innovations in Blockchain

1. Probabilistic Blockchains (Patent Pending)

- Allows probabilistic statements:
  - I am 50% sure that this is a spam
- Uses statistics/AI to create a knowledge summary
- Good for decisions based on large number of opinions

2. Reputation Management System

Ref: Tara Salman, Raj Jain, and Lav Gupta, "Probabilistic Blockchains: A Blockchain Paradigm for Collaborative Decision-Making," 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON 2018), New York, NY, November 8-10, 2018, 9 pp., http://www.cse.wustl.edu/~jain/papers/pbc_uem.htm

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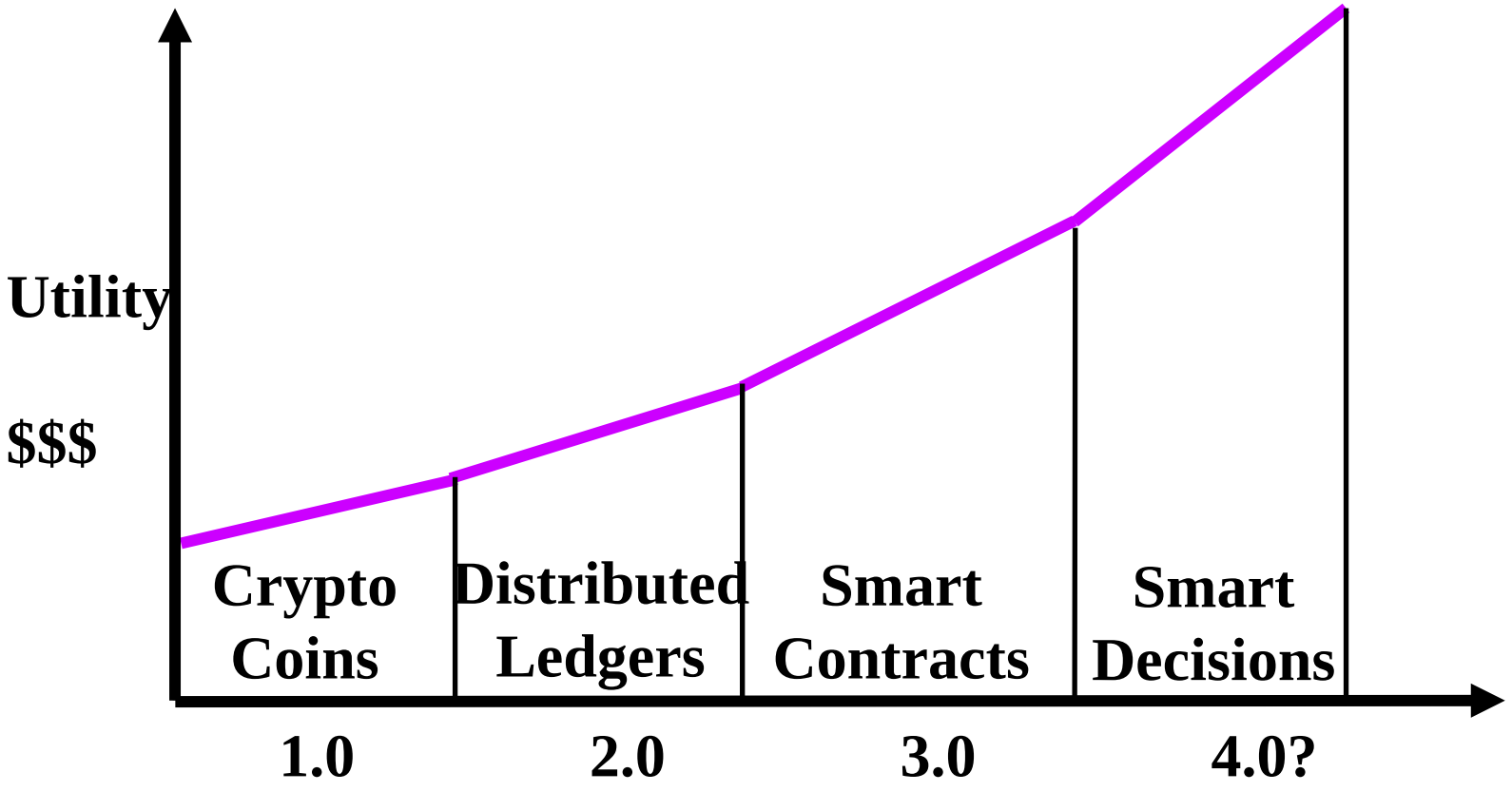
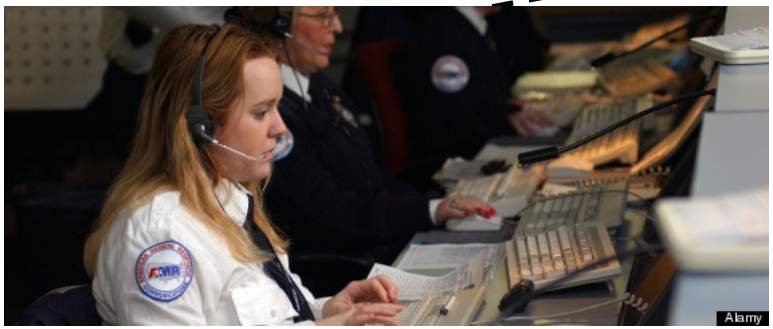
Blockchain Generations



Trend: Drones



Our Research Projects

1. IIoT Security: Industrial Control Systems Security
2. IoTM Security: Healthcare Security
3. Fault and Security of Datacenters using Deep Learning
4. Blockchains for Security
5. Communication using UAVs

3 Funded Research Projects

} Approved

} Pending

Techniques:

1. Machine learning and Deep Learning
2. Blockchains
3. Security
4. Networking

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

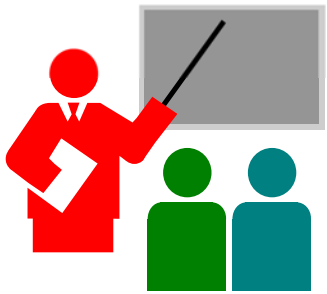
- CSE 521S: Wireless Sensor Networks
- CSE 537S: Mobile Computing
- **CSE 570: Advanced Networking**
- CSE 571: Network Security
- **CSE 574S: Wireless and Mobile Networking**
- CSE 7700: Res Seminar On Networking

CSE 473S: Introduction to Networking

Requirements

- Have 4 students working on 3 funded projects + 1 approved
- Need 1 more new Ph.D. student
- Requirements:
  - Background and interest in networking: CSE 473
  - Flexibility to work on the latest issues
  - Good communication skills
  - Machine learning (optional)
  - Preferably with a masters degree

Summary



1. Networking is the backbone of all computing
   $\Rightarrow$ Cyber age. Networking companies are leading
2. Smart $\neq$ High-Speed Computation,
   Smart $\neq$ Big Data Storage,
   Smart = Networked and Intelligent
3. We are developing new AI and Blockchain techniques for 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:

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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

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Our Publications on UAVs

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Our Publications on UAVs (cont)

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Our Publications on UAVs (Cont)

9. Ali Ghubaish, "Locating Unmanned Aerial Vehicles (UAVs)," MS Thesis, Department of Computer Science and Engineering, Washington University in Saint Louis, December 2017, 59 pp., http://www.cse.wustl.edu/~jain/theses/agms.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

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http://www.cse.wustl.edu/~jain/talks/cs59120.htm

Our Courses on YouTube

CSE567M: Computer Systems Analysis (Spring 2013),
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