Next Generation Internet, Wireless, and Network Security Research at Washington University in St. Louis

RAJ JAIN

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

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Overview

1. Why study networking?
2. Current Issues in Networking
3. Our research projects
4. Related networking research and courses

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Why Study Computer Networking?

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

- Fast growing field
- All top companies are networking companies: Apple, Google, Microsoft, Amazon, Facebook, Cisco, HP, Intel, IBM, …

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Current Hot Topics in Networking

1. Internet of Things
2. Security: Cyber Warfare
3. Datacenter Networking and Clouds
4. Mobile/Wireless Networking

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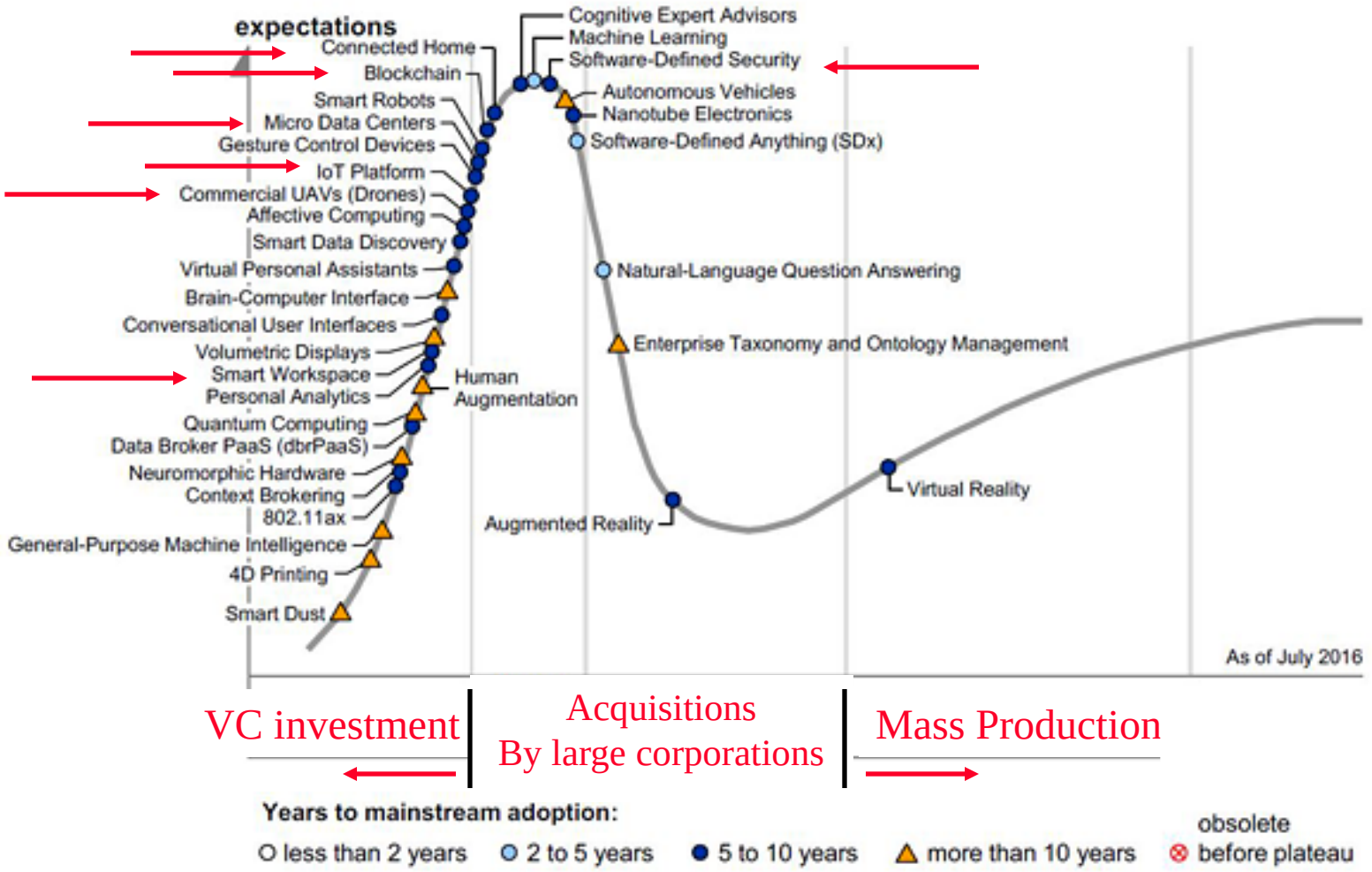
Gartner Hype Cycle 2016



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

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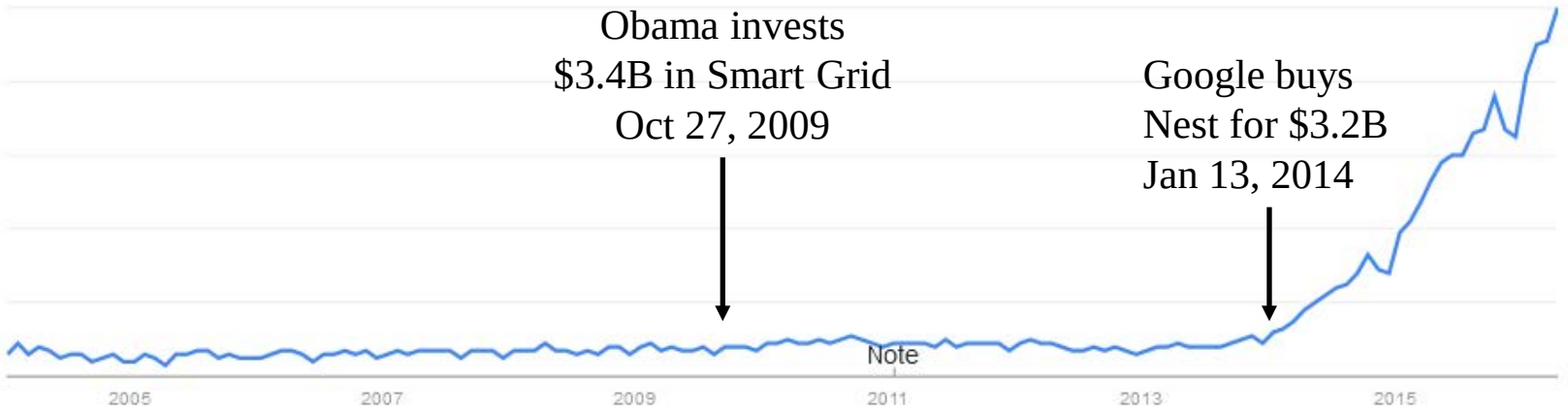
Google Trends



- Around for 10 years
- IERC-European Research Cluster on the Internet of Things funded under 7th Framework in 2009
  ⇒ "Internet of European Things"
- US interest started in 2009 w $3.4B funding for **smart grid** in American Recovery and Reinvestment Act of 2009

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1. Internet of Things

 Smart Watch	 Smart TV	 Smart Car
 Smart Health	 Smart Home	 Smart Kegs
 Smart Space	 Smart Industries	 Smart Cities

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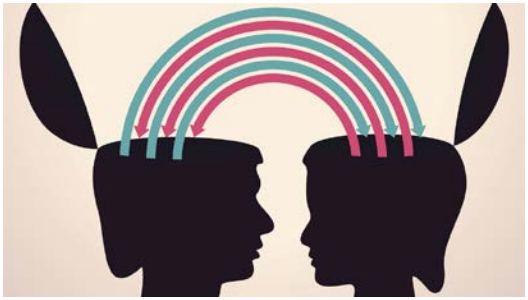
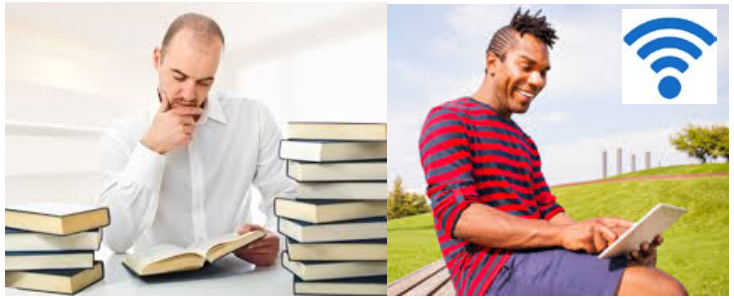
What's Smart?

- 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, …





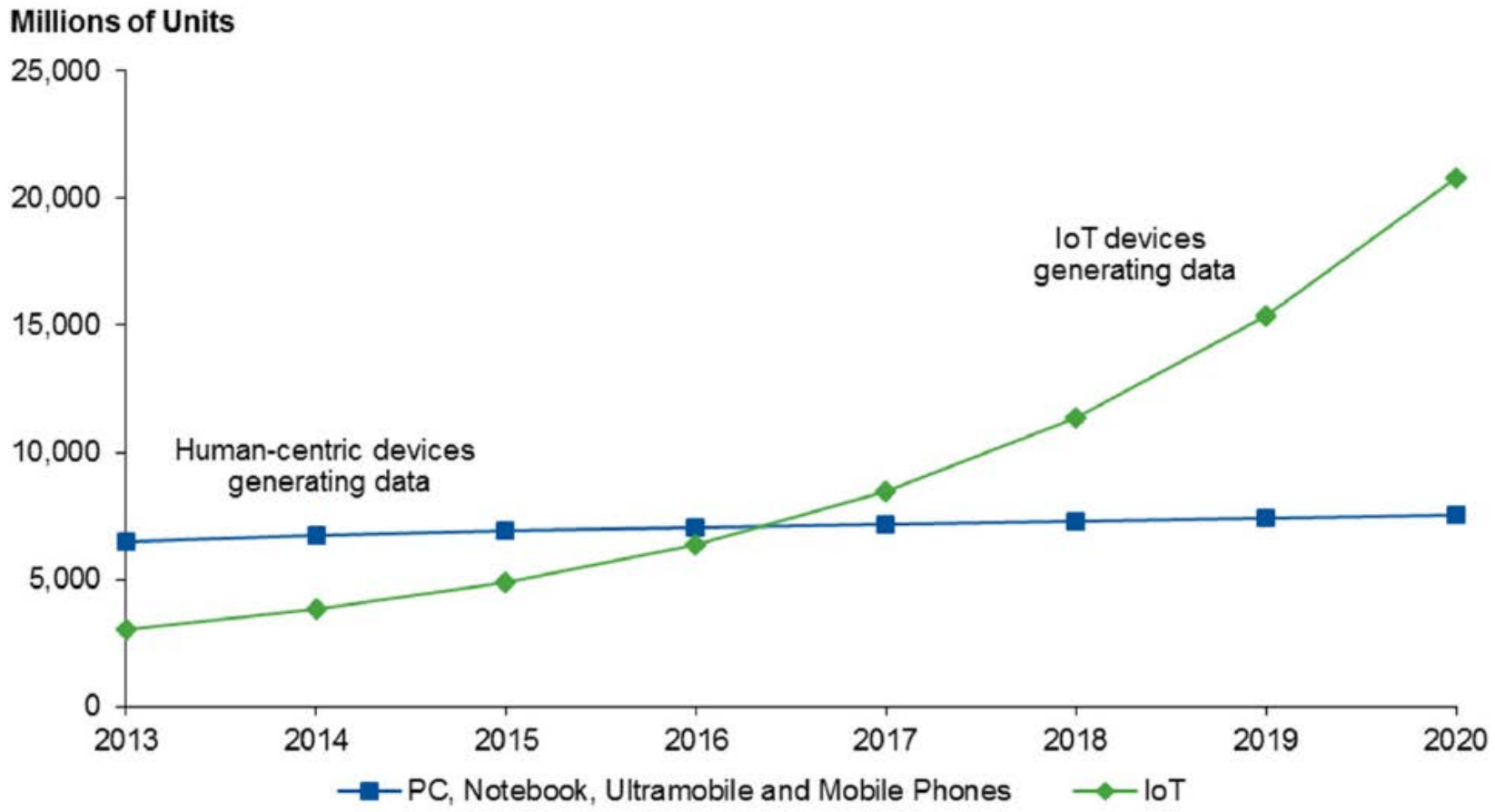
Not-Smart Smart

Cavemen of 2050

IoT is a Data ($) Mine

Ref: https://www.pinterest.com/iofficecorp/humor/

Computing vs. IoT



- 21 Billion devices by 2020

Ref: M. Moran, "Why the Internet of Things Will Dwarf Social (Big Data)," Gartner Report #G00289622, February 2016

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IoT Security: Popular Approach

Ref: http://cloudtweaks.com/2011/08/the-lighter-side-of-the-cloud-the-migration-strategy/

Internet of Harmful Things

Imagine, as researchers did recently at Black Hat, someone hacking your connected toilet, making it flush incessantly and closing the lid repeatedly and unexpectedly.

Ref: http://www.computerworld.com/article/2486502/security0/worm-may-create-an-internet-of-harmful-things--says-symantec--take-note--amazon-.html

DEFCON 2015

DEFCON 2015 (Cont)

- Hacking a Linux rifle
- Hacking smart safes
- Wirelessly steal cars
- Hack a Tesla
- Hack ZigBee
- Hacking IoT baby monitors
- Hacking FitBit Aria
- Cracking crypto currency
- Hack out of home detention
- Insteon's false security
- Hacking RFID, NFC
- DARPA Cyber Grand Challenge **$2M**

Ref: https://www.ethicalhacker.net/features/opinions/first-timers-experience-black-hat-defcon

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Attack Surface

1. **IoT Devices**
2. **IoT wireless access technology**: DECT, WiFi, Z-wave, …
3. **IoT Gateway**: Smart Phone
4. **Home LAN**: WiFi, Ethernet, Powerline, …
5. **IP Network**: DNS, Routers, …
6. **Higher-layer Protocols**
7. **Cloud**
8. **Management Platform**: Web interface
9. **Life Cycle Management**: Booting, Pairing, Updating, …

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2. 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: http://en.wikipedia.org/wiki/Cyber_war

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3. Cloud Computing

- August 25, 2006: Amazon announced EC2
  ⇒ Birth of Cloud Computing in reality
  (Prior theoretical concepts of computing as a utility)
  $10 B in 2016, a growth rate of 49% with 17% margins, much higher than the overall Amazon business

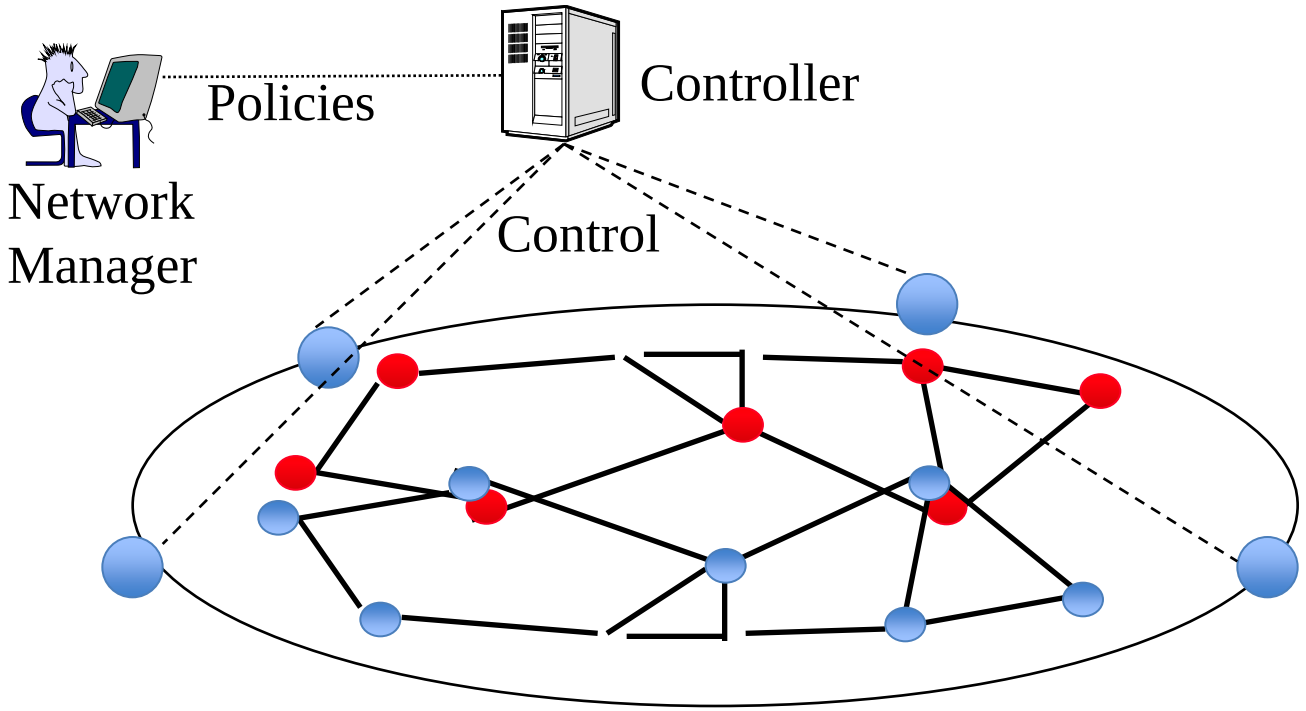
- Cloud Computing:
  - Applications through Internet (Google Docs)
  - Computing through Internet (Amazon EC3)
  - Storage and backup through Internet (iCloud, Google Drive)

4. Mobile/Wireless

- June 29, 2007: Apple announced iPhone
  ⇒ Birth of Mobile Internet, Mobile Apps
  - Almost all services are now mobile apps: Google, Facebook, Bank of America, …

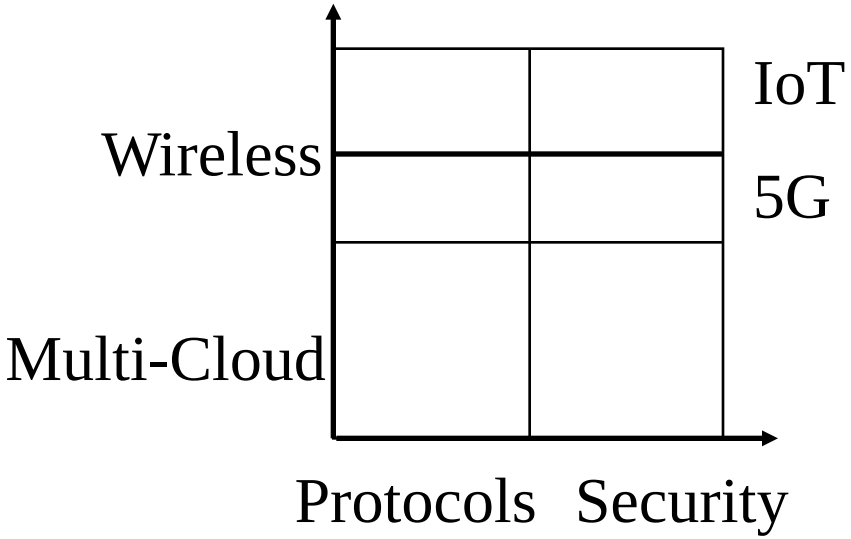
- Wireless (WiFi) is ubiquitous (Intel Centrino)
- New Developments:
  - 5G: 1Gbps
  - Vehicular Networking

5. Software Defined Networking



- Centralized controller for route computation
- Controller can be programmed ⇒Software Defined
- Policies can be changed on the fly.
- Easy orchestration of thousands of switches and routers

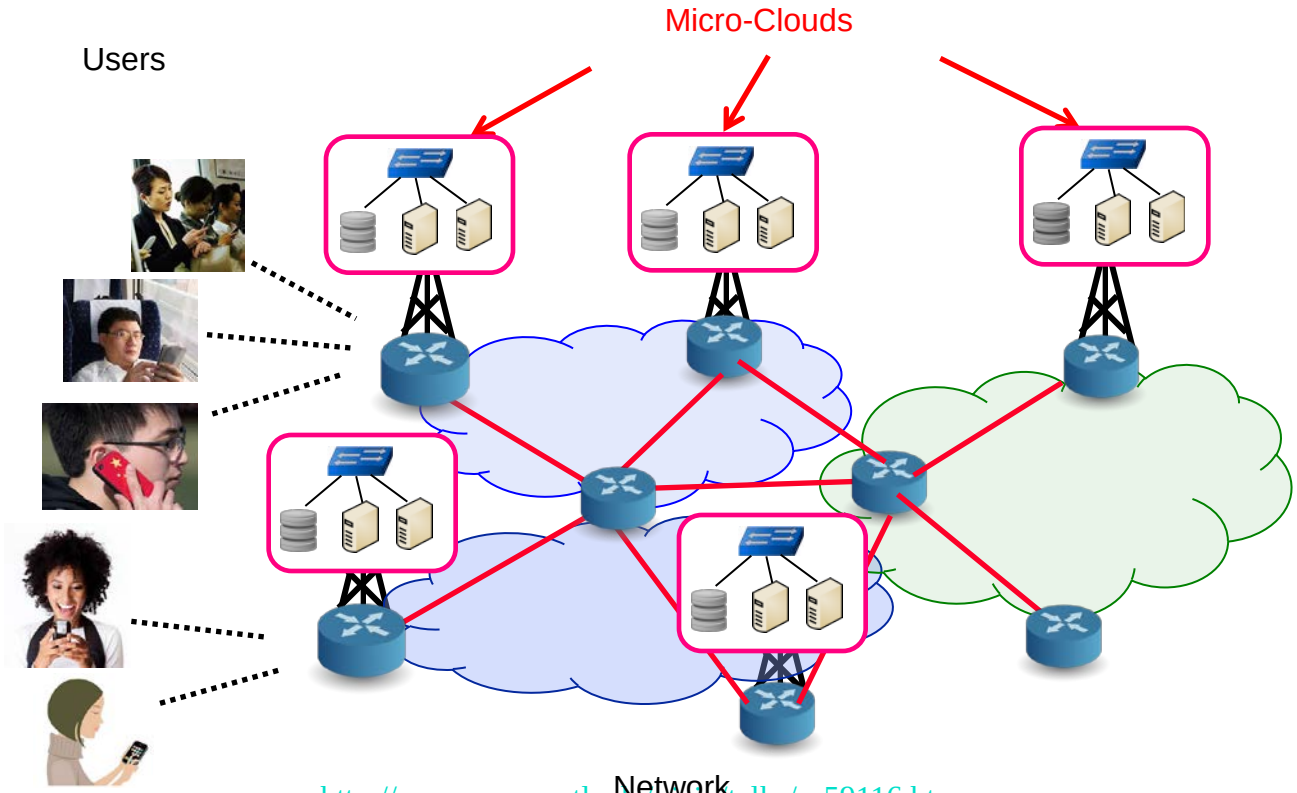
Our Research Areas



1. Multi-Cloud Management
2. Multi-Cloud for 5G: NFV
3. Protocols for IoT
4. IoT Security
5. Multi-Cloud Security
6. Communication using UAVs

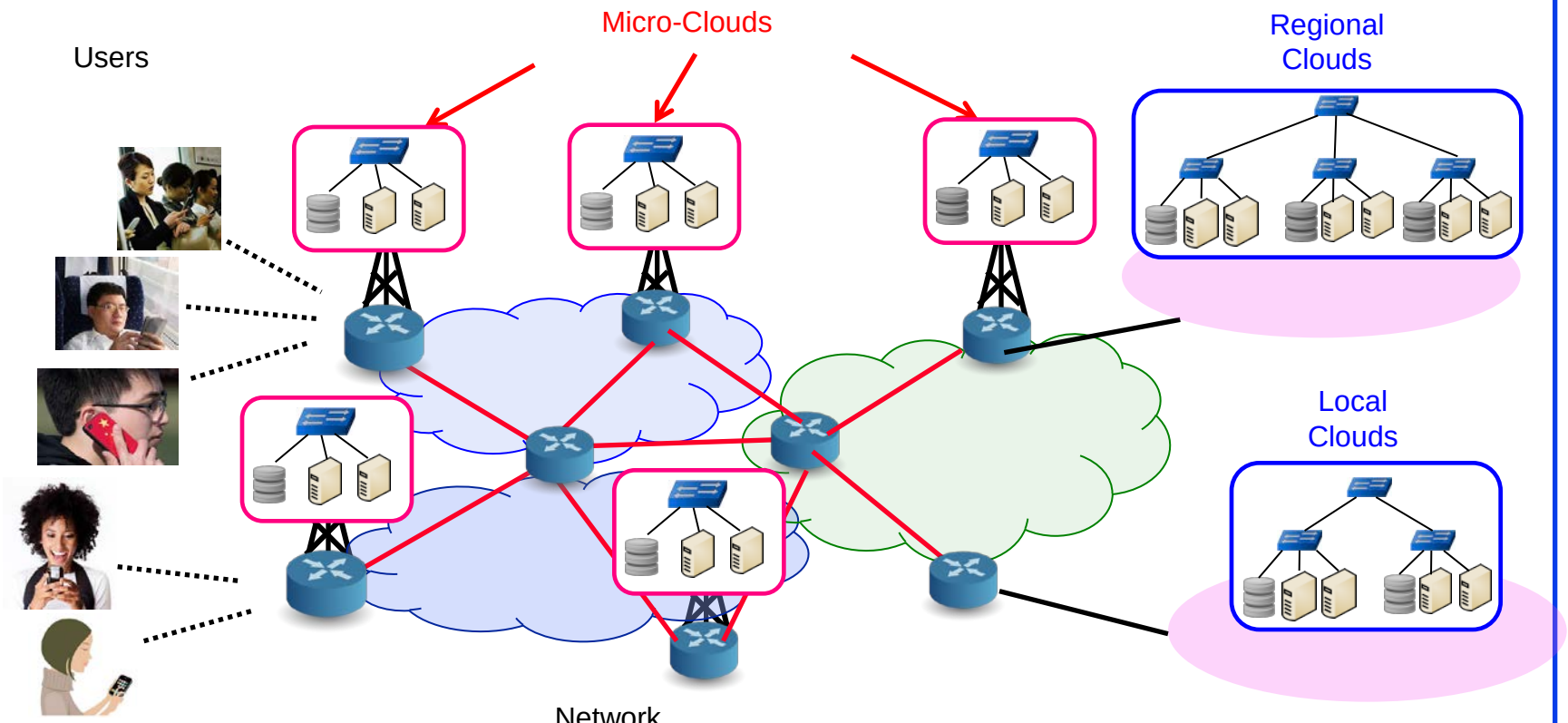
Trend: Computation in the Edge

- To service mobile users/IoT, the computation needs to come to edge ⇒ Micro-cloud on the tower
  ⇒ Mobile-Edge Computing

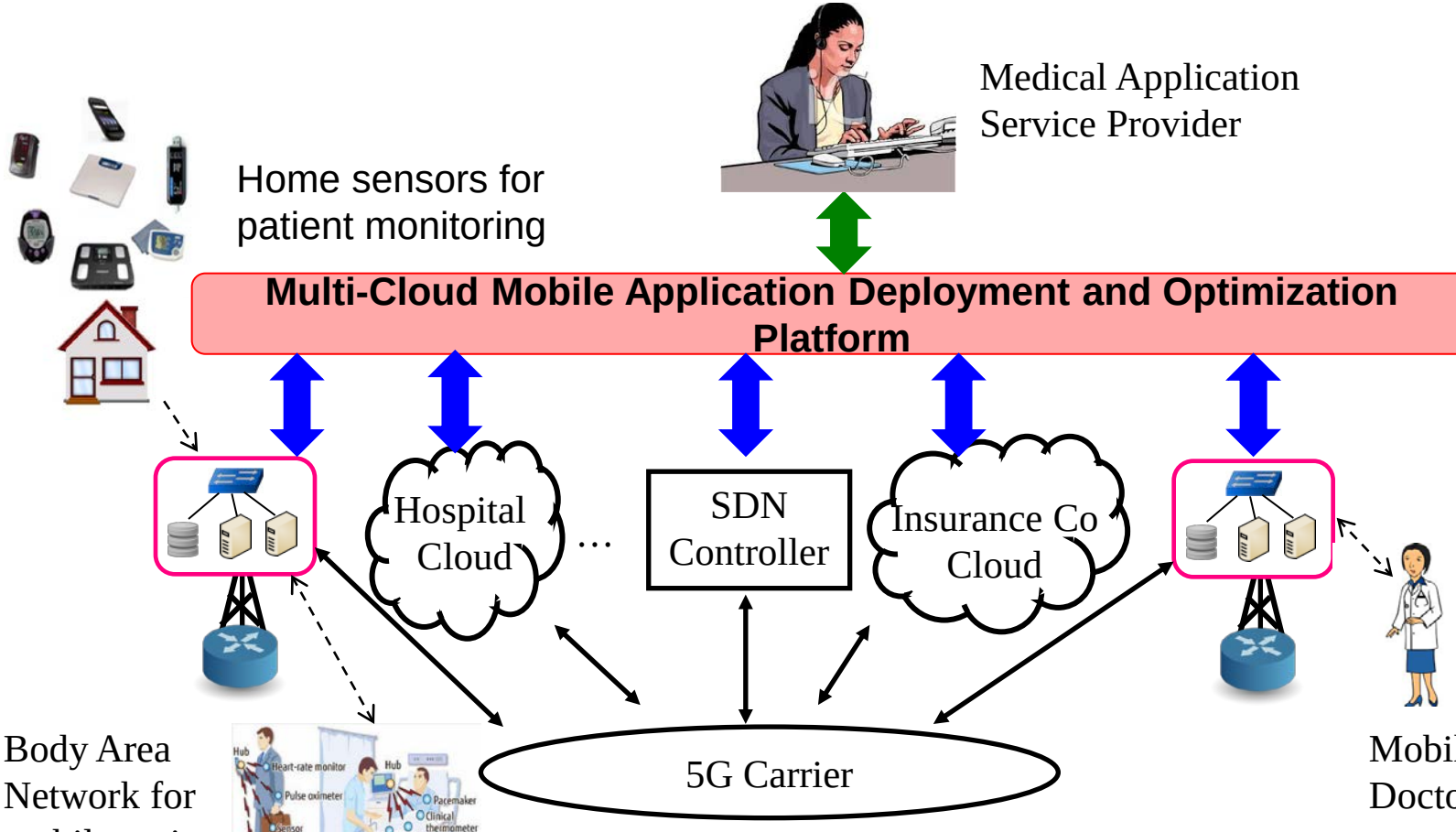


Trend: Multi-Cloud

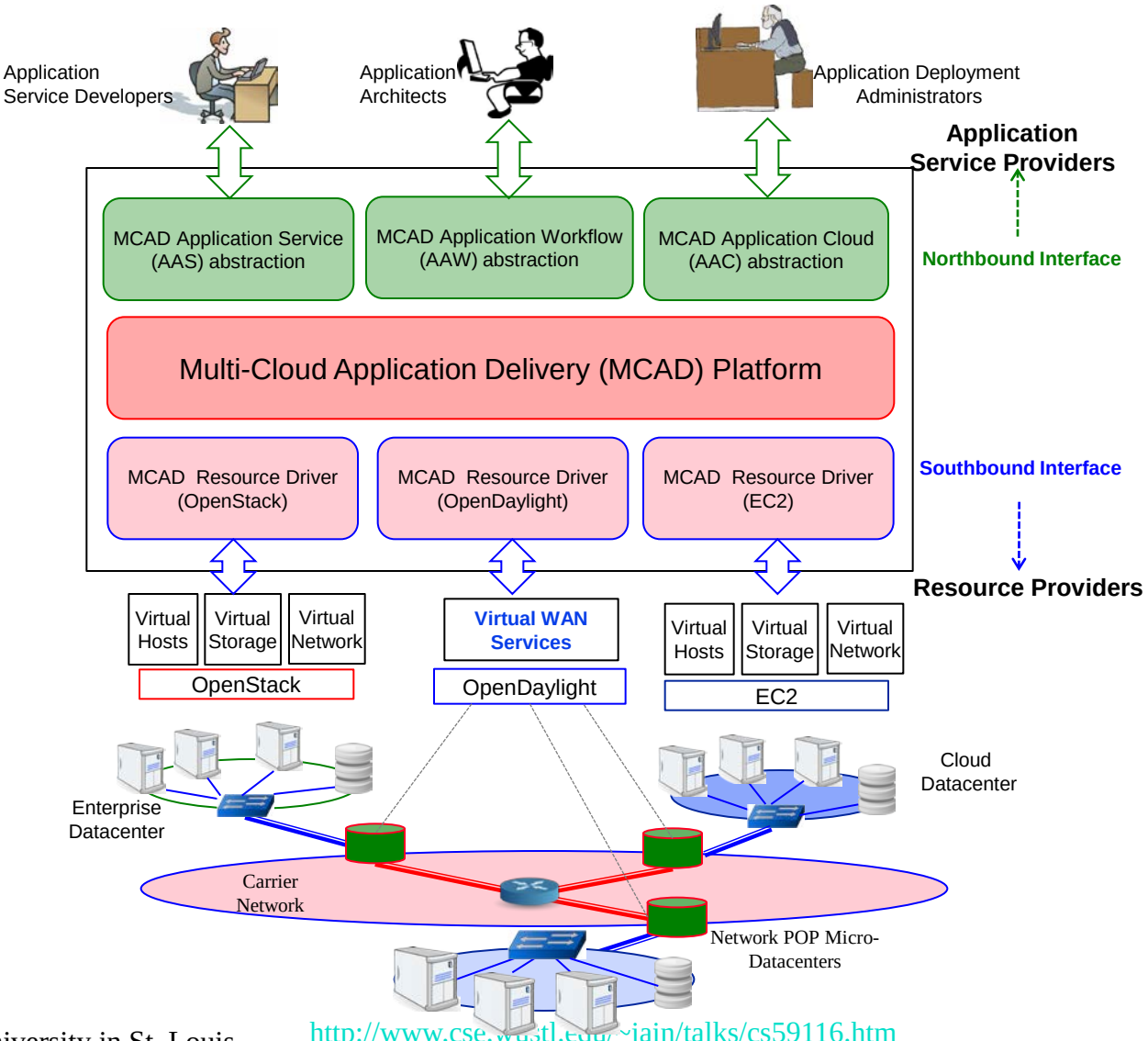
- Larger and infrequent jobs serviced by local and regional clouds ⇒ Fog Computing



Mobile Healthcare Use Case

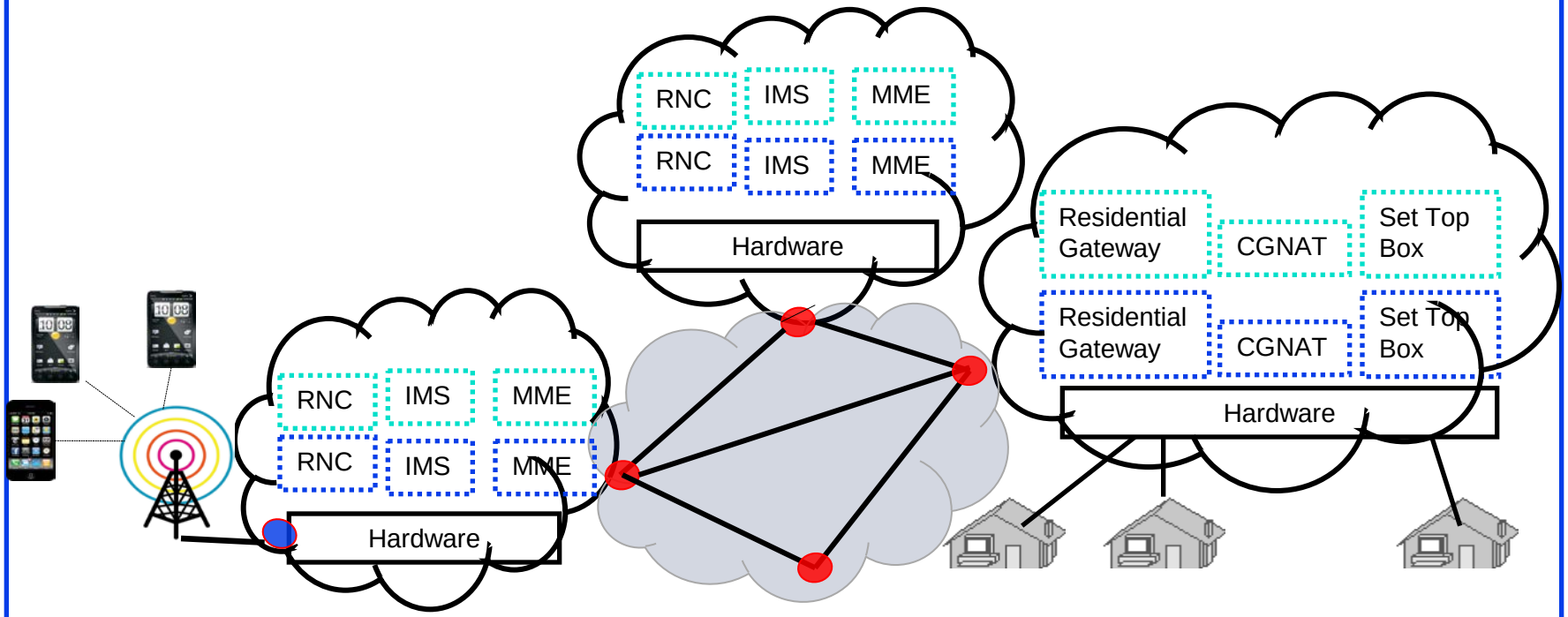


Multi-Cloud Management

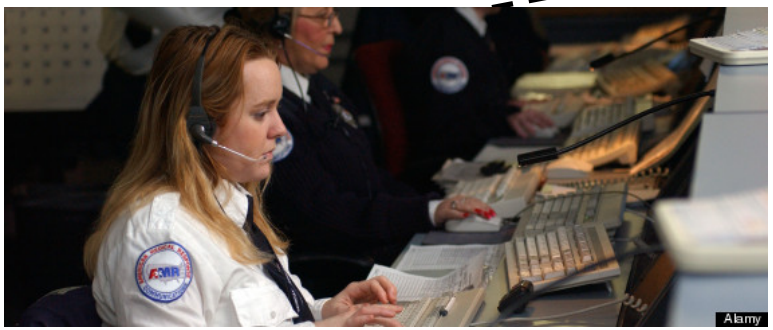


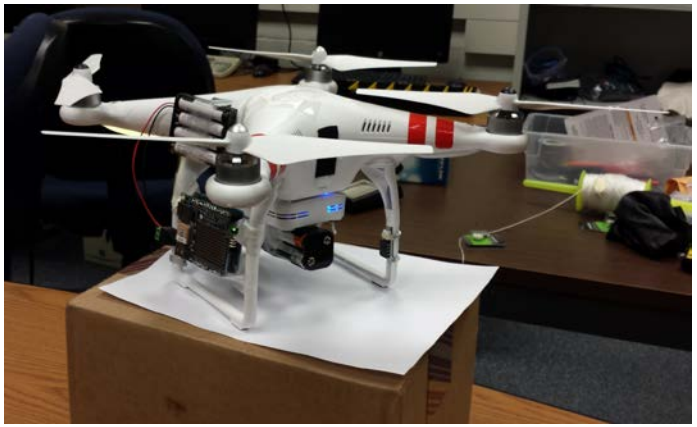
Multi-Cloud for 5G: NFV

- NFV = Network Function Virtualization
  Use of clouds by telecom carriers
- Problem: Where to place which function and move as the traffic pattern changes ⇒ Service Function Chaining



Communication using UAVs





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

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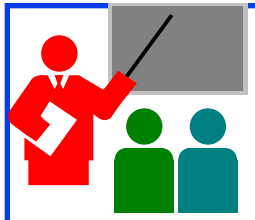

Summary

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. Computation is moving to the Edge
   ⇒ Fog Computing
   ⇒ Multi-Cloud/Inter-Cloud
4. Our MCAD abstracts/virtualizes the cloud interfaces and allows automated management of security and other policies of multi-cloud applications
5. We are working on:
   1. Multi-Cloud Management
   2. Multi-Cloud + IoT Security
   3. IoT + UAV Protocols

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References: Class Recordings

- Recordings of all of my classes and talks are available on YouTube and on my website:
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- Raj Jain, "**Internet of Things and Smart Cities Security: Challenges and Issues**," Keynote at 1st Annual Research Workshop on Advances & Innovations in Cyber Security, Memphis, TN, June 10, 2016, http://www.cse.wustl.edu/~jain/talks/iots_tns.htm
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Acronyms

- AAC Application Cloud Abstraction
- AAS Application Service Abstraction
- AAW Application Workflow Abstraction
- ABR Available Bit Rate
- ANSI American National Standards Institute
- API application programming interface,
- ATM Asynchronous Transfer Mode
- CGNAT Carrier Grade Network Address Translation
- CSE Computer Science and Engineering
- DARPA Defense Advanced Research Project Agency
- DECbit Digital Equipment Corporation Bit
- DEFCON D-E-F conference
- DNS Domain Name System
- EC2 Elastic Compute 2
- ECN Explicit congestion notification
- EFCI Explicit Forward Congestion Indication

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Acronyms (Cont)

- ESE Electrical Systems Engineering
- FECN Forward Explicit Congestion Notification
- GB Gigabyte
- IEEE Institution of Electrical and Electronic Engineering
- IERC European Research Cluster on the Internet of Things
- IETF Internet Engineering Task Force
- IMS Internet Multimedia System
- IoT Internet of Things
- IP Internet Protocol
- IRTF Internet Research Task Force
- ITU International Telecommunications Union
- LAN Local Area Network
- LTE Long Term Evolution
- MCAD Multi-Cloud Application Delivery
- MHz Mega Hertz
- MME Mobility Management Entity

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Acronyms (Cont)

- NFC Near Field Communication
- NFV Network Function Virtualization
- OpenADN Open Application Delivery Networking
- POP Point of Presence
- RFID Radio Frequency Identifier
- RNC Radio Network Controller
- SDN Software Defined Networking
- TCP Transmission Control Protocol
- TV Television
- UAV Unmanned Aerial Vehicle
- VC Venture Capitalist
- VM Virtual Machine
- WAN Wide Area Network
- WiFi Wireless Fidelity
- WiMAX Worldwide Interoperability for Microwave
- XML Extended Markup Language

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