

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



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Class, September 28, 2016

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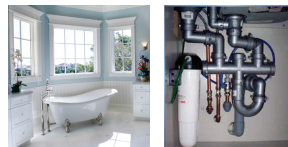
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1. Why study networking?
2. Current Issues in Networking
3. Our research projects
4. Related networking research and courses

## 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, ...

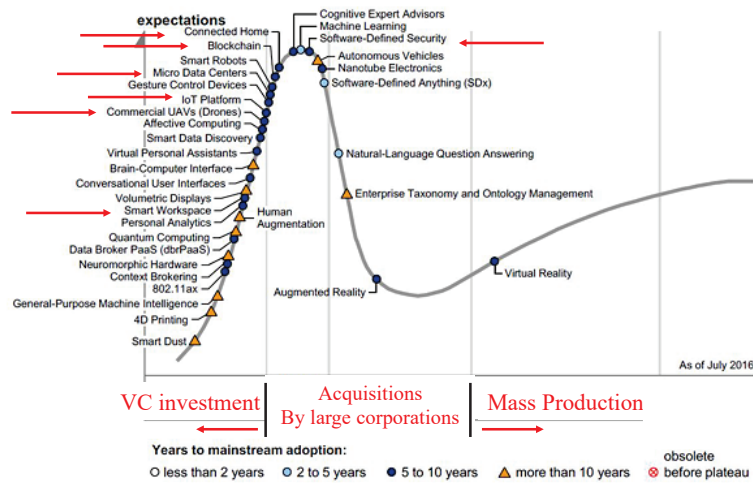


## Current Hot Topics in Networking



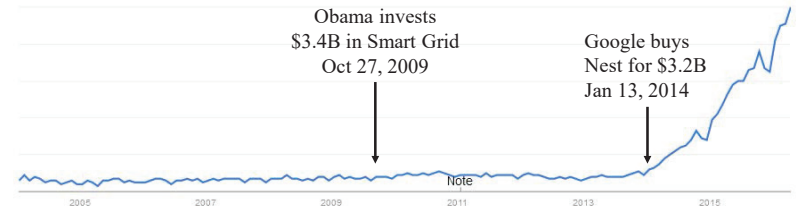
1. Internet of Things
2. Security: Cyber Warfare
3. Datacenter Networking and Clouds
4. Mobile/Wireless Networking

# Gartner Hype Cycle 2016



Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], [gartner.com/document/3383817](http://www.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 7<sup>th</sup> 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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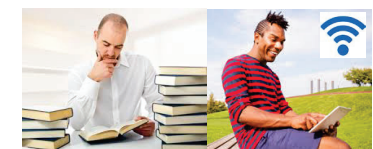
# 1. Internet of Things

 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

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## Cavemen of 2050



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## IoT is a Data (\$) Mine



Ref: <https://www.pinterest.com/officecorp/humor/>

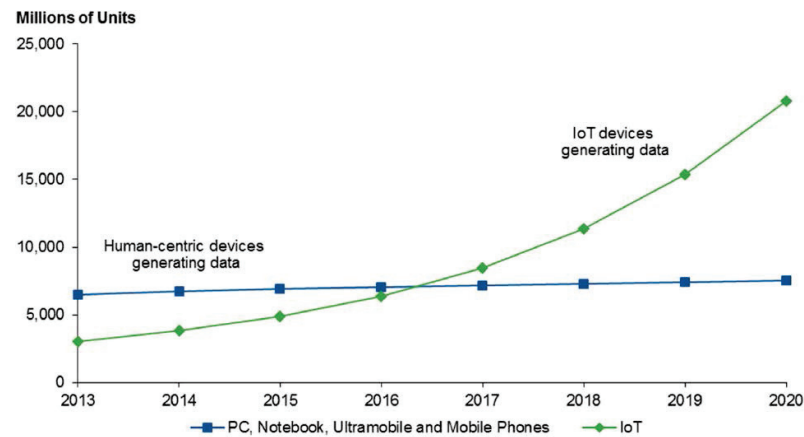
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## Computing vs. IoT



□ 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/>

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## 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/security/0/worm-may-create-an-internet-of-harmful-things--says-symantec--take-note--amazon-.html>  
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## DEFCON 2015



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## 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  
5<sup>th</sup> 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](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)

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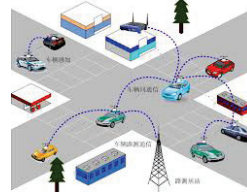
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## 4. Mobile/Wireless

- ❑ 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



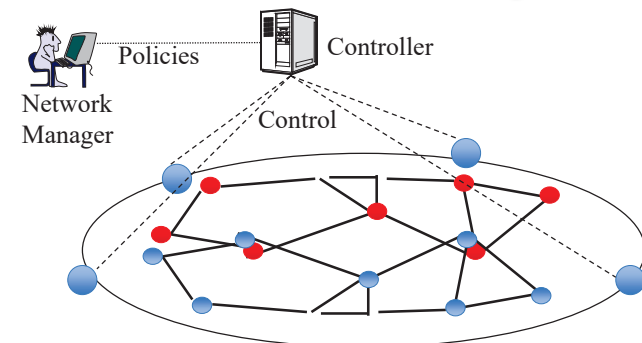
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## 5. Software Defined Networking



- ❑ 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

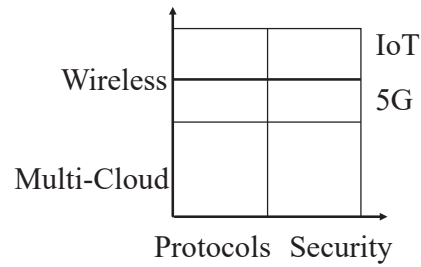
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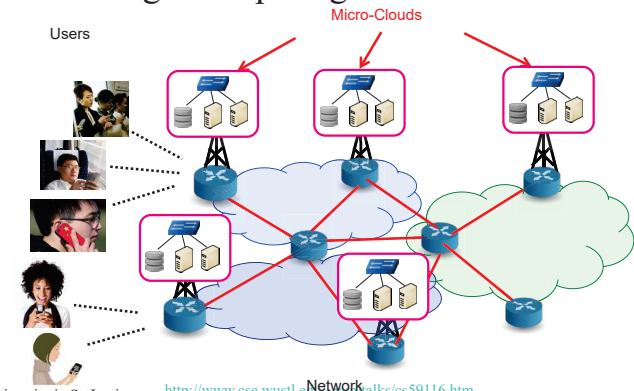
## Our Research Areas



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

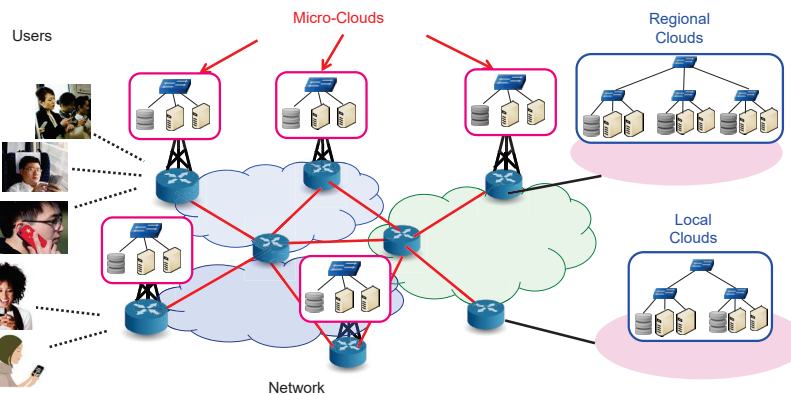
## Trend: Computation in the Edge

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

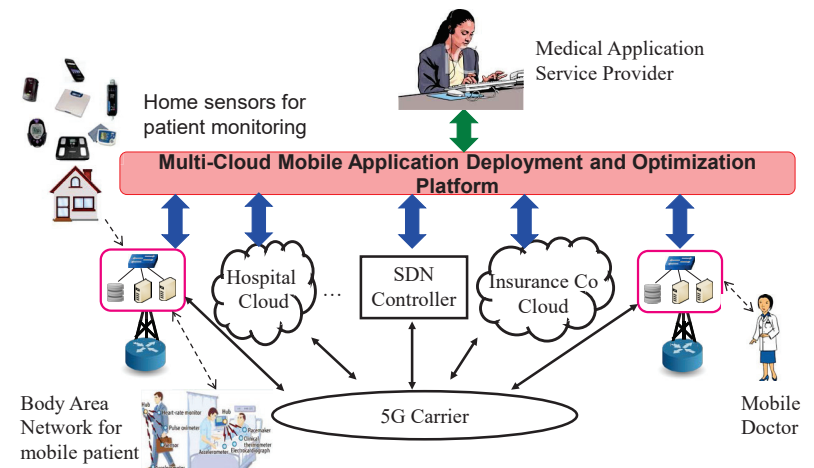


## Trend: Multi-Cloud

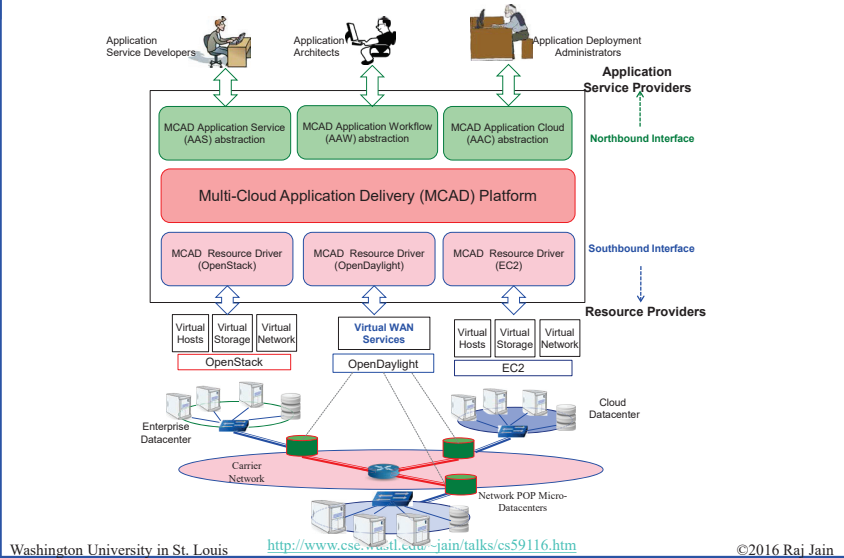
- Larger and infrequent jobs serviced by local and regional clouds  $\Rightarrow$  Fog Computing



## Mobile Healthcare Use Case



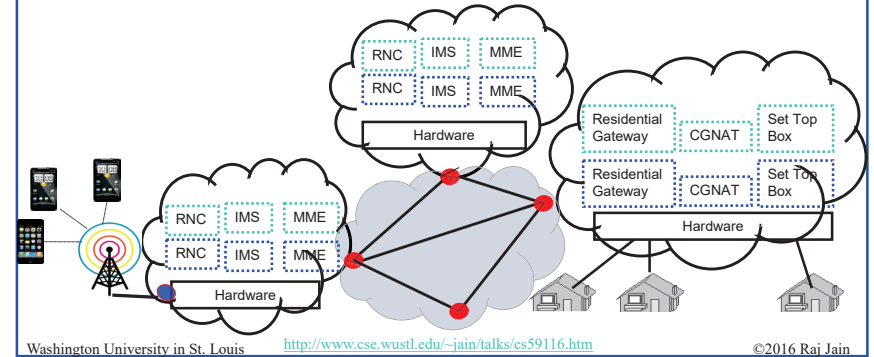
## Multi-Cloud Management



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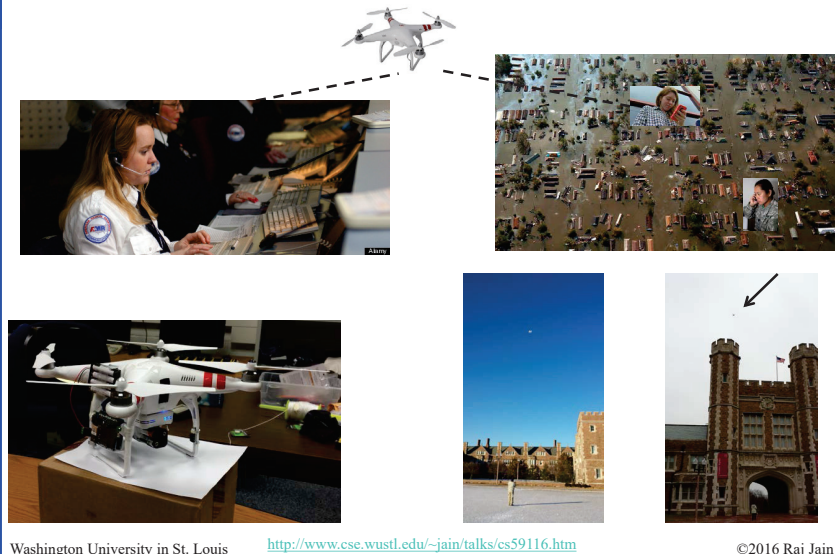
## Multi-Cloud for 5G: NFV

- 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



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## Communication using UAVs



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## 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

## References: Class Recordings

- Recordings of all of my classes and talks are available on YouTube and on my website:
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## Recent Talks

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- Raj Jain, "**Software Defined Networking at the Tactical Edge**," Talk at Bharat Electronics Limited, Bangalore, India, September 10, 2016, [http://www.cse.wustl.edu/~jain/talks/sdn\\_bel.htm](http://www.cse.wustl.edu/~jain/talks/sdn_bel.htm)
- 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](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

## 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

## 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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