Internet of Things Security: Challenges and Issues

RAJ JAIN

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

Keynote at 9th Central Area Networking and Security Workshop (CANSec), University of Central Missouri, Warrensburg, MO, April 16, 2016

These slides are available on-line at:
http://www.cse.wustl.edu/~jain/talks/iots_ucm.htm

Overview

1. IoT Hype
2. A Layered Model of IoT and Smart Cities
3. Areas of Research for IoT
4. IoT Security
5. Software Defined Secure Multi-Cloud Application Management for IoT

Trend 1: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

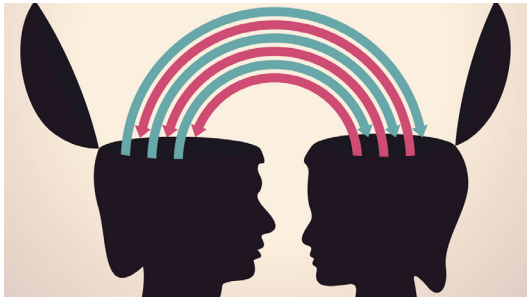
Smart Space

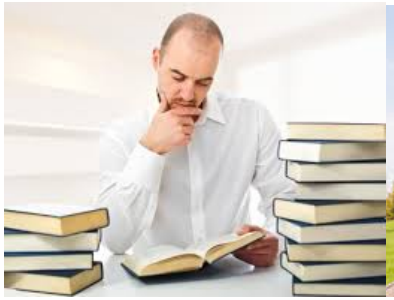
Smart Industries

Smart Cities

What's Smart?

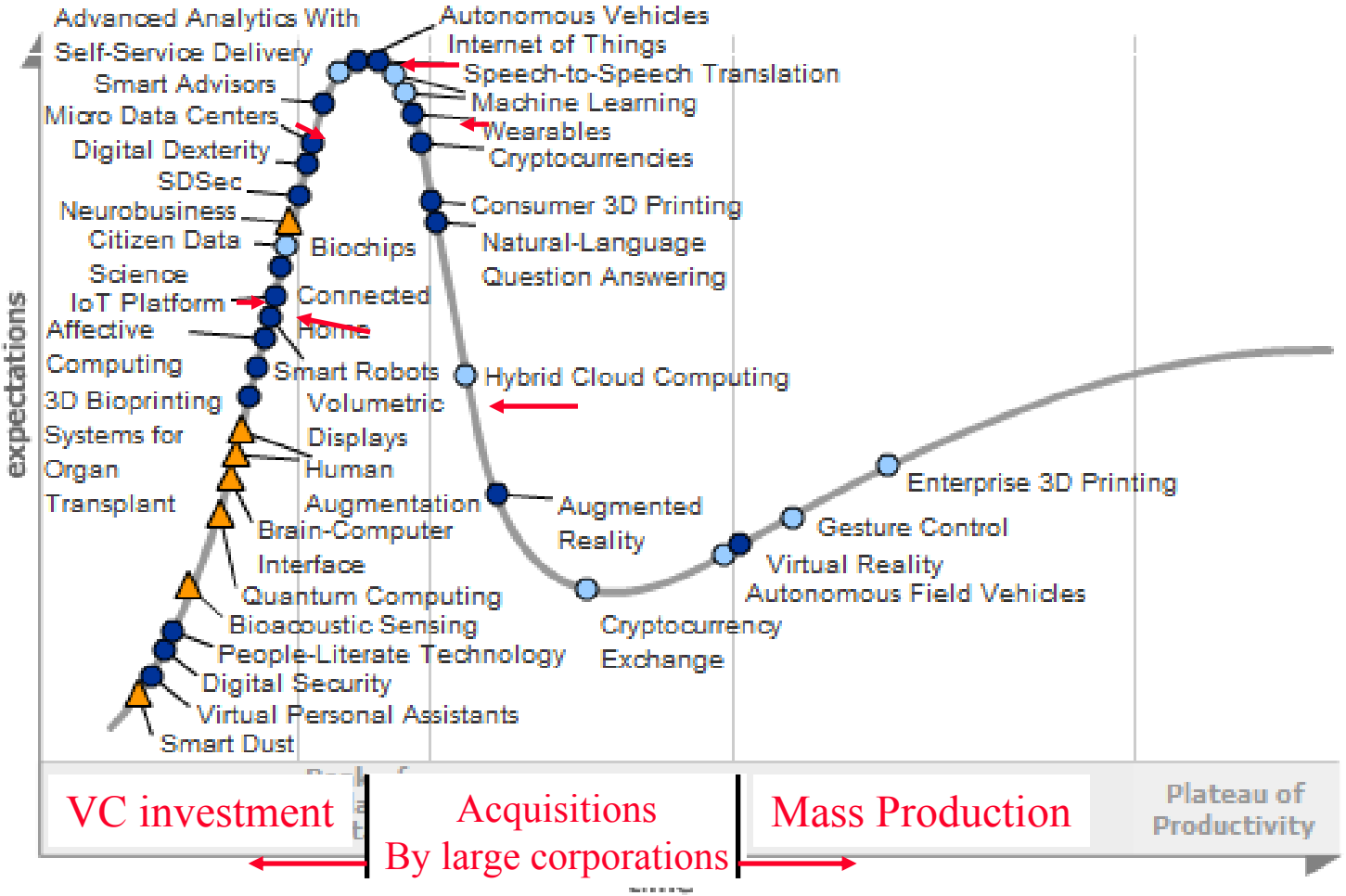
- Old: Smart = Can think ⇒ Computation
  = Can Recall ⇒ Storage
- Now: Smart = Can find quickly, Can Delegate
  ⇒ Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …





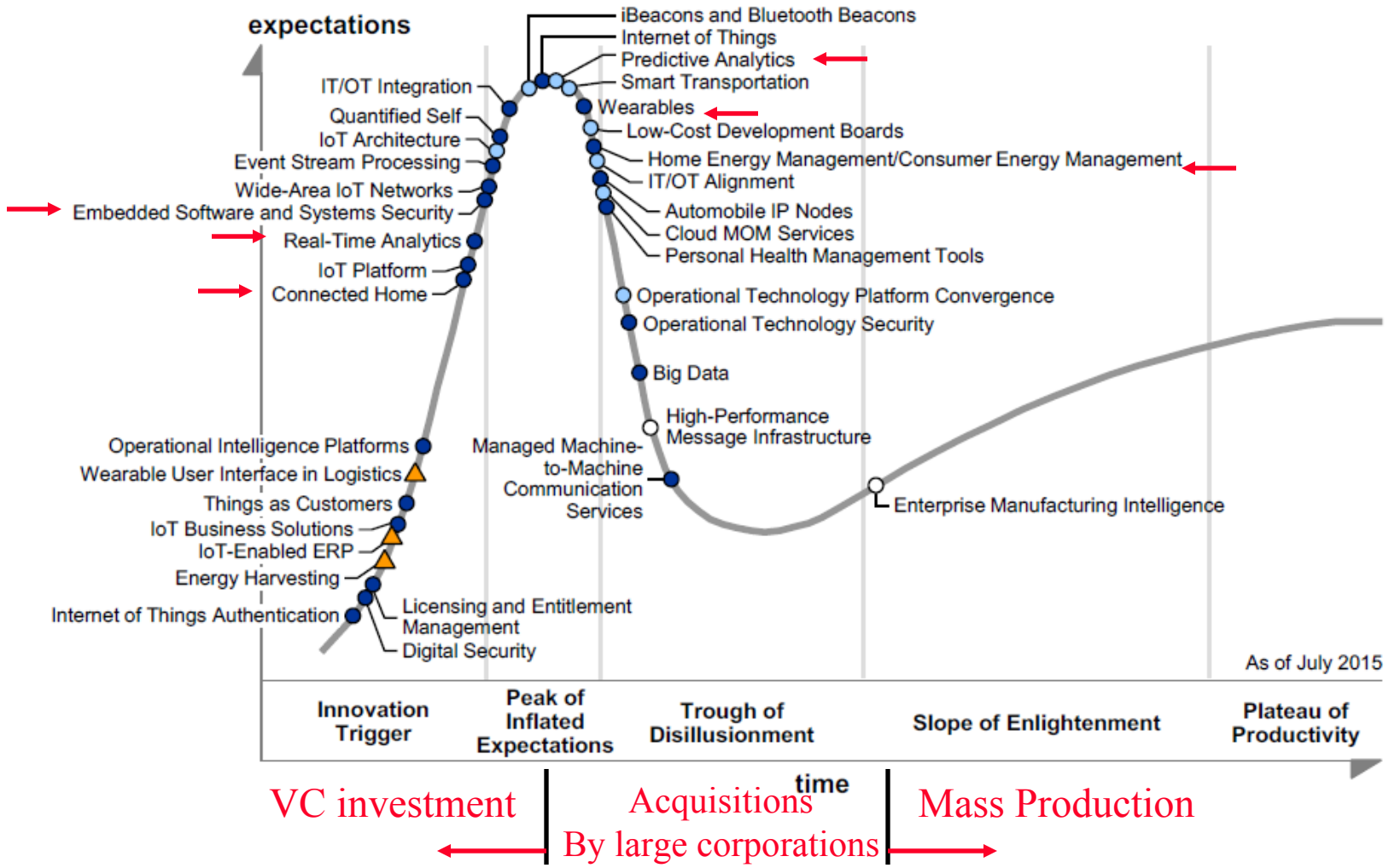
Not-Smart Smart

Gartner Hype Cycle 2015



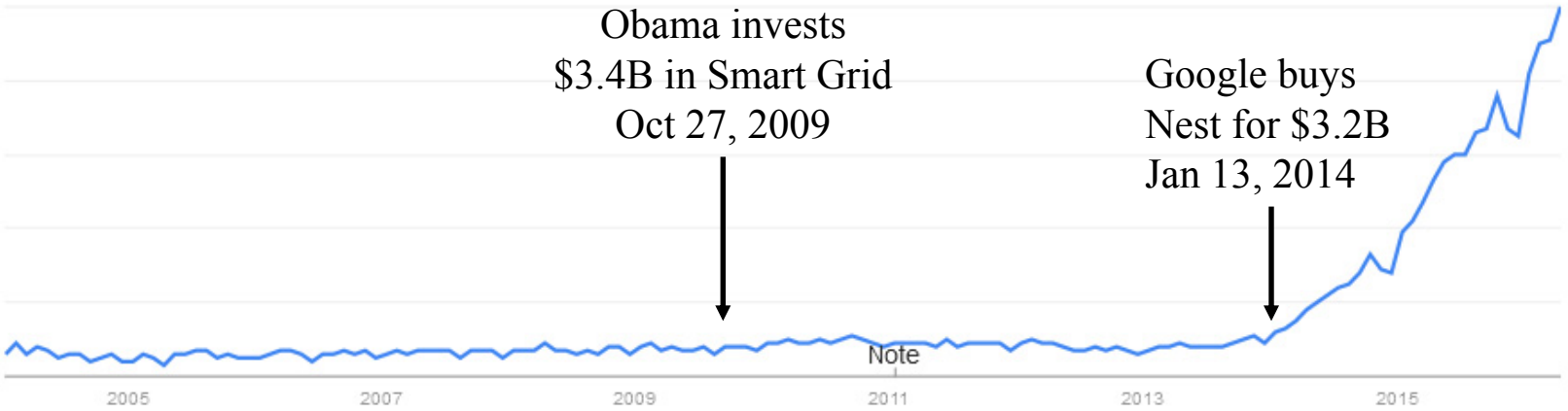
Ref: Gartner, "Hype Cycle for Emerging Technologies, 2015," July 2015, [Available to subscribers only], http://www.gartner.com/document/3100227?ref=QuickSearch&sthkw=hype%20cycle%202015&refval=156919648&qid=fe61993355944ace1c8c01ec2df676d9

Gartner's Hype Cycle For IoT 2015



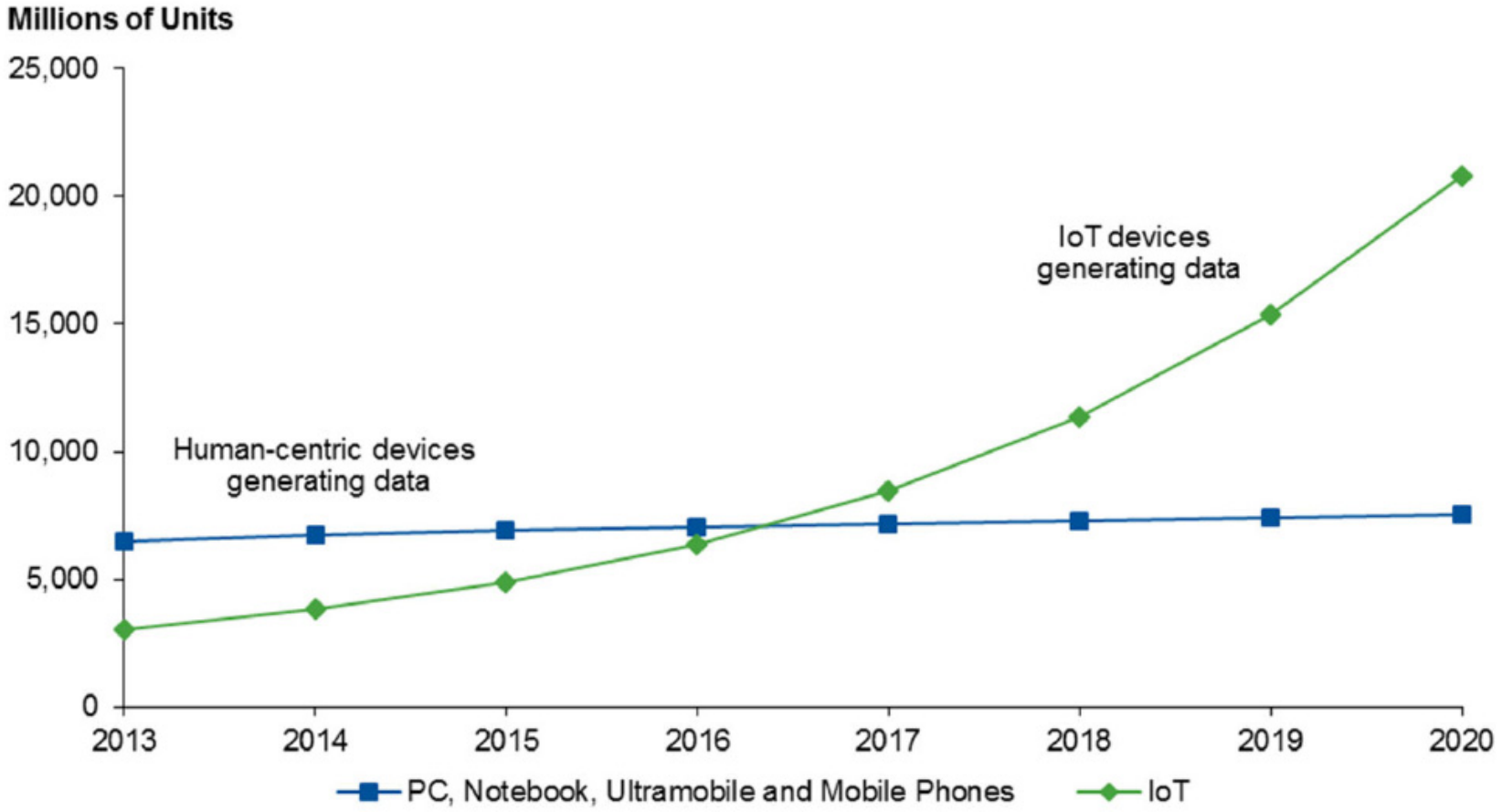
Ref: A Velosa, et al, "Hype Cycle for the Internet of Things, 2015" Gartner Report, G00272399, July 2015, 69 pp.

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

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

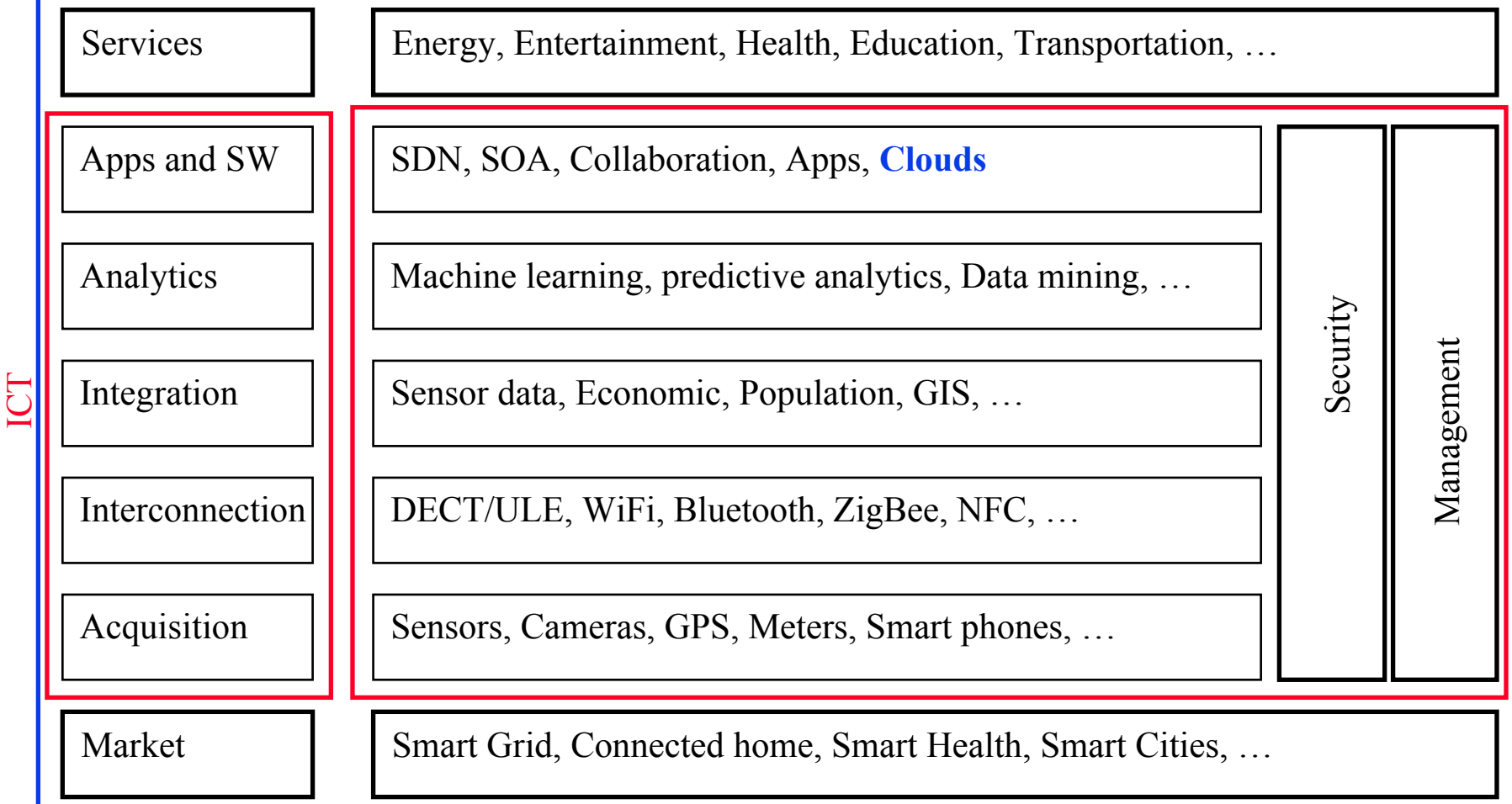
IoT Business Opportunity

- $1.7 Trillion by 2020 - IDC
- $7.1 Trillion - Gartner
- $10-15 Trillion just for Industrial Internet – GE
- $19 Trillion – Internet of Everything - Cisco

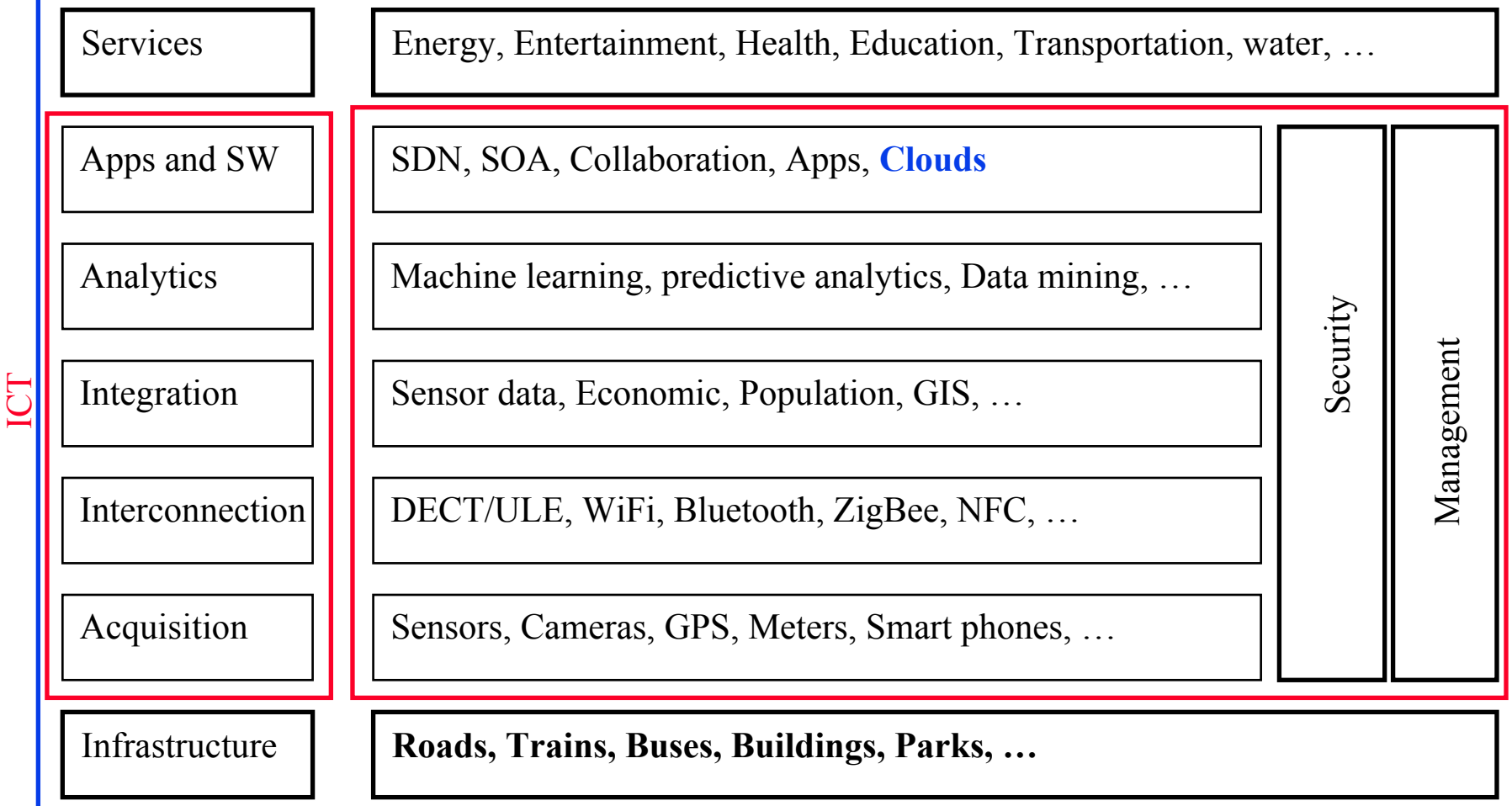
Ref: http://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/

http://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/

A 7-Layer Model of IoT



A 7-Layer Model of Smart Cities



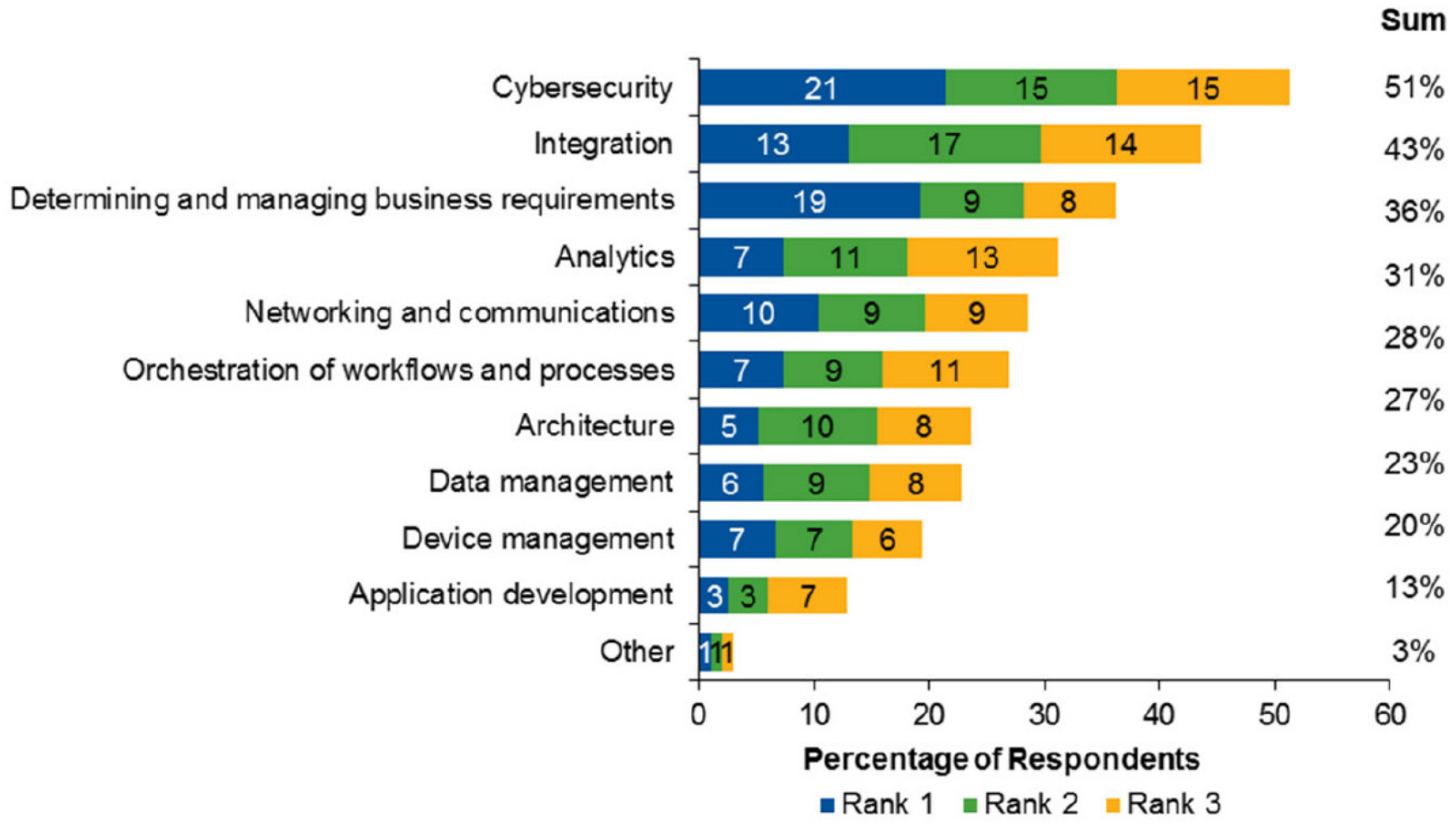
IoT is a Data ($) Mine

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

Areas of Research for IoT

1. **PHY**: Smart devices, sensors giving real-time information, *Energy Harvesting*
2. **Datalink**: WiFi, Bluetooth, ZigBee, 802.11ah, … Broadband: DSL, FTTH, Wi-Fi, 5G, …
3. **Routing**: *Multiple interfaces,* Mesh networking, …
4. **Analytics**: Big-data, data mining, Machine learning, Predictive analytics, …
5. **Apps & SW**: SDN, SOA, Cloud computing, Web-based collaboration, Social networking, HCI, Event stream processing, …
6. **Applications**: Remote health, On-line education, on-line laboratories, …
7. **Security:** Privacy, Trust, Identity, Anonymity, …

Top Inhibitors to the Adoption of the IoT



Ref: B. Lheurex, et al, "Survey Analysis: Users Cite Ambitious Growth and formidable Technical Challenges in IoT Adoption," Gartner Report #G00300127, March 2016,

Washington University in St. Louis http://www.cse.wustl.edu/~jain/talks/iots_ucm.htm

IoT Security: Popular Approach

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

Current IoT Security

- HP Study
  - 80% had privacy concerns
  - 70% lacked encryption
  - 60% had insecure updates
- Symantec Study:
  - 1/5th of Apps did not use SSL (Secure transfers)
  - None of the devices provided mutual (gateway) authentication
  - No lock-out/delaying measures against repeated attacks
  - Common web application vulnerabilities
  - Firmware upgrades were not encrypted

Ref: http://fortifyprotect.com/HP_IoT_Research_Study.pdf

Ref: M. Barcena and C. Wueest, "Insecurity in the Internet of Things," Symantec, March 2015,

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

Security ≠ AES-128

- CIA = Confidentiality, Integrity, Availability
  = Encryption + Message Authentication Code + Denial of Service Prevention
- Use of AES-128 does not guarantee security.
- Insecurity:
  - How strong is the key?
  - Where the key is stored?
  - Bugs in system code
  - Backdoors

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

Door Locks Insecurity

- **Onity Door Locks**:
  - Used on hotel doors with magnetic strips
  - Information is encrypted using a hotel-specific secret key
  - **Programming port** on the bottom
  - Security Key can be read through programming port
  - Firmware update not possible ⇒ Replace hardware
- **Sigma Design's Z-Wave Door Locks**:
  - Z-Force tool can monitor traffic and have the lock accept a an arbitrary encryption key
- **Kwikset Kevo Door Locks**:
  - **Password** can be reset by email
  - Hijacked email addresses and phishing attack

Ref: N. Dhanjani, "Abusing the Internet of Things: Blackouts, Freakouts, and Stakeouts," O'Reilly, 2015, ISBN: 978-1-491-90233-2

Attack Surface

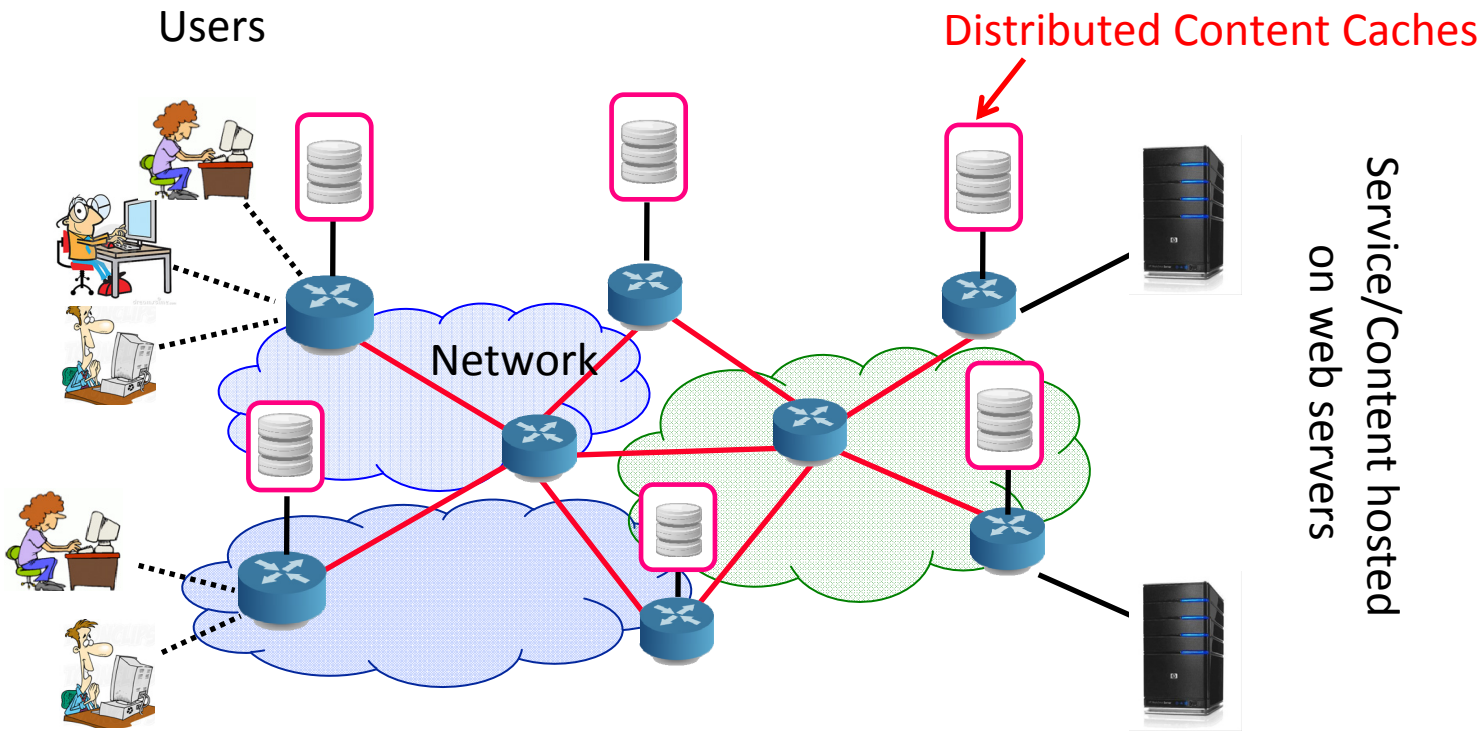
1. **IoT Devices**
2. **IoT wireless access technology**: DECT, WiFi, Z-wave, …
3. **IoT Gateway**: Smart Phone
4. **Home LAN**: WiFi, Ethernet, Powerline, …
5. **IP Network**: DNS, Routers, …
6. **Higher-layer Protocols**
7. **Cloud**
8. **Management Platform**: Web interface
9. **Life Cycle Management**: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

Recent Protocols for IoT

Session	MQTT, SMQTT, CoRE, DDS, AMQP , XMPP, CoAP, IEC,…	**Security**	**Management**
Network	Encapsulation 6LowPAN, 6TiSCH, 6Lo, Thread… Routing RPL, CORPL, CARP	IEEE 1888.3, TCG, Oath 2.0, SMACK, SASL, EDSA, ace, DTLS, Dice, …	IEEE 1905, IEEE 1451, IEEE 1377, IEEE P1828, IEEE P1856
Datalink	WiFi, 802.11ah, Bluetooth Low Energy, Z-Wave, ZigBee Smart, DECT/ULE, 3G/LTE, NFC, Weightless, HomePlug GP, 802.15.4e, G.9959, WirelessHART, DASH7, ANT+, LTE-A, LoRaWAN, ISA100.11a, DigiMesh, WiMAX, …		

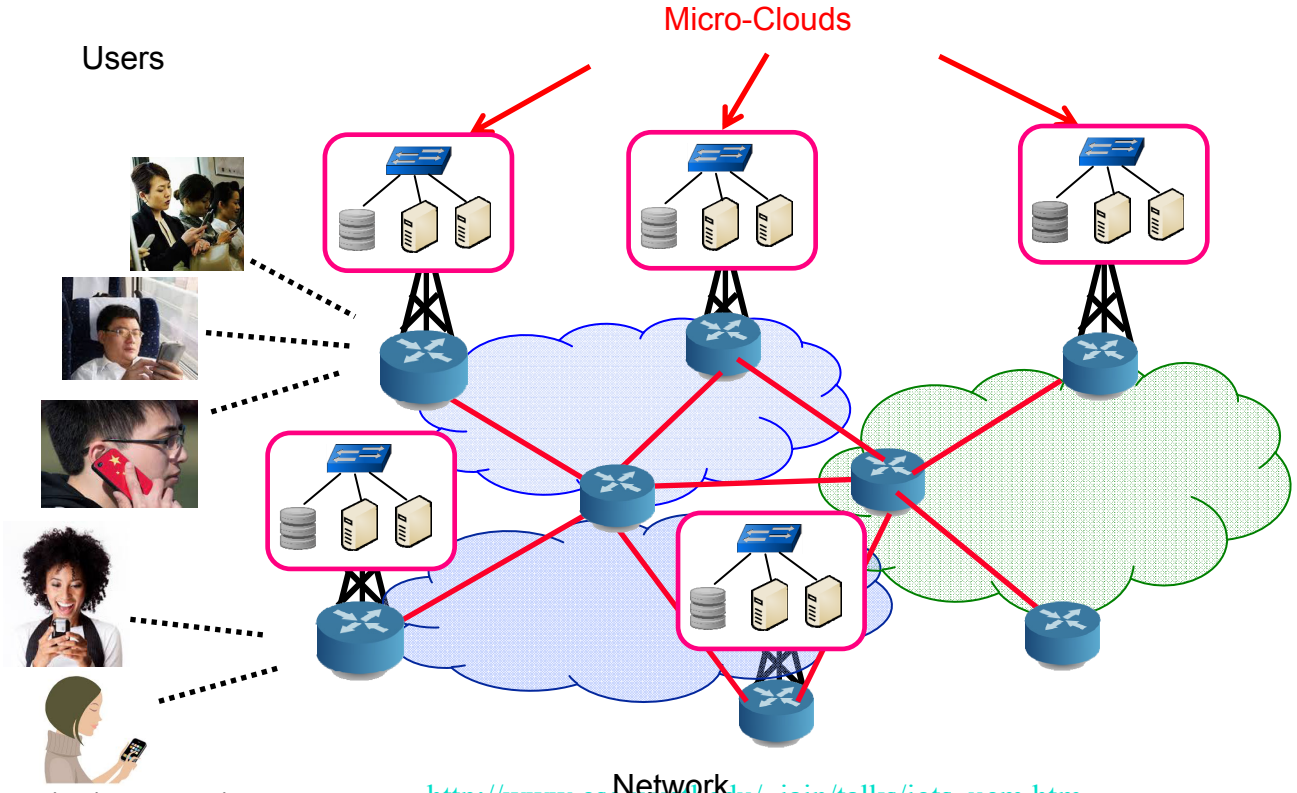
Past: Data in the Edge

- To serve world-wide users, latency was critical and so the data was replicated and brought to edge



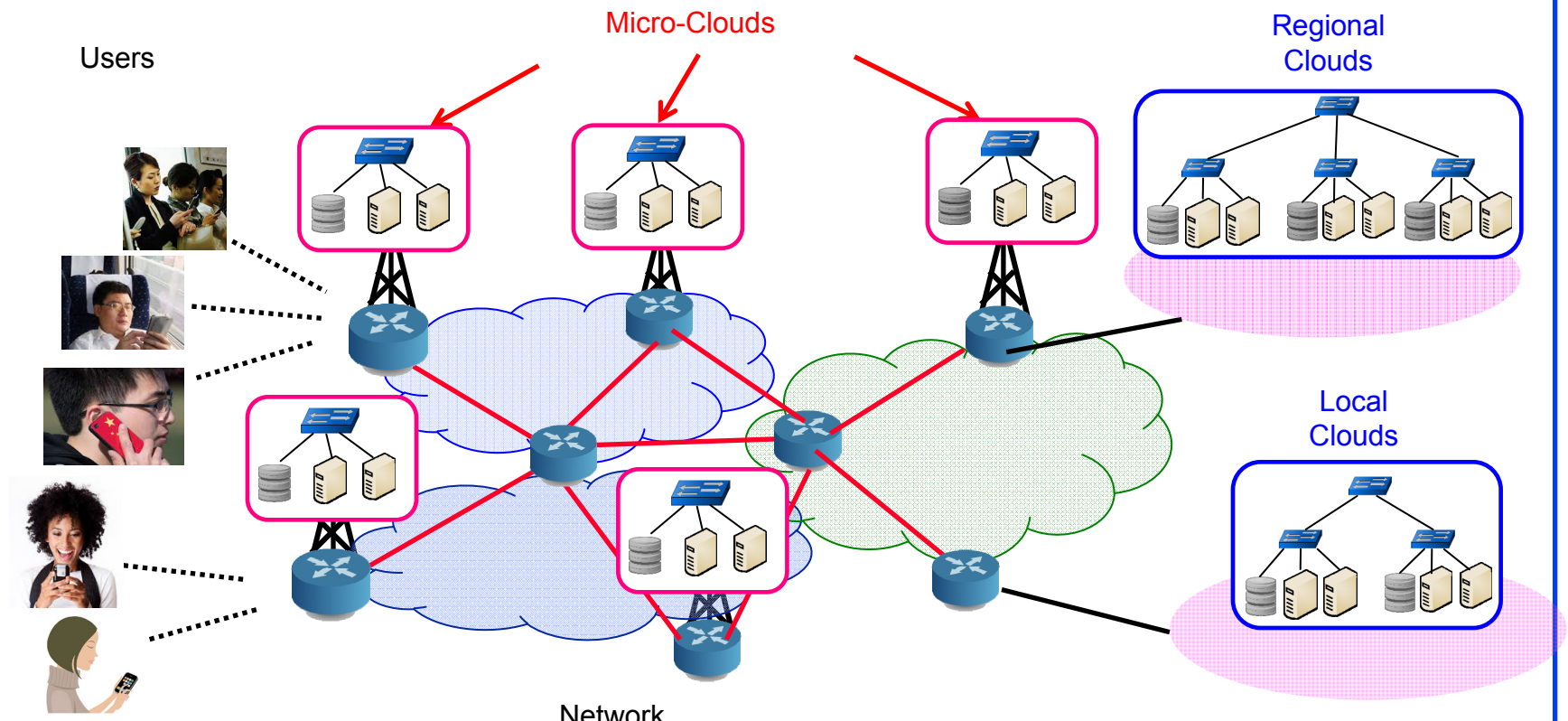
Trend: Computation in the Edge

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



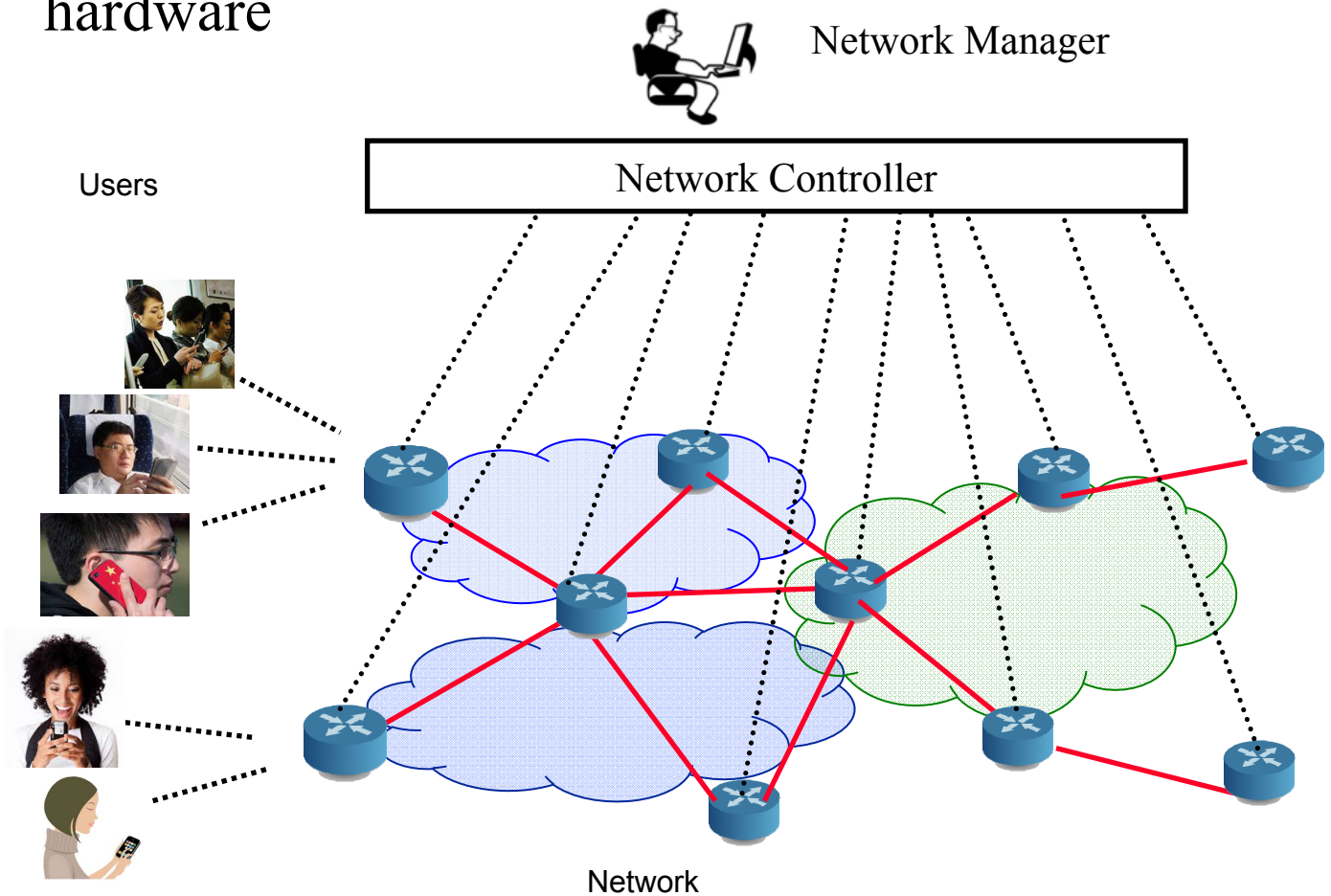
Trend: Multi-Cloud

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



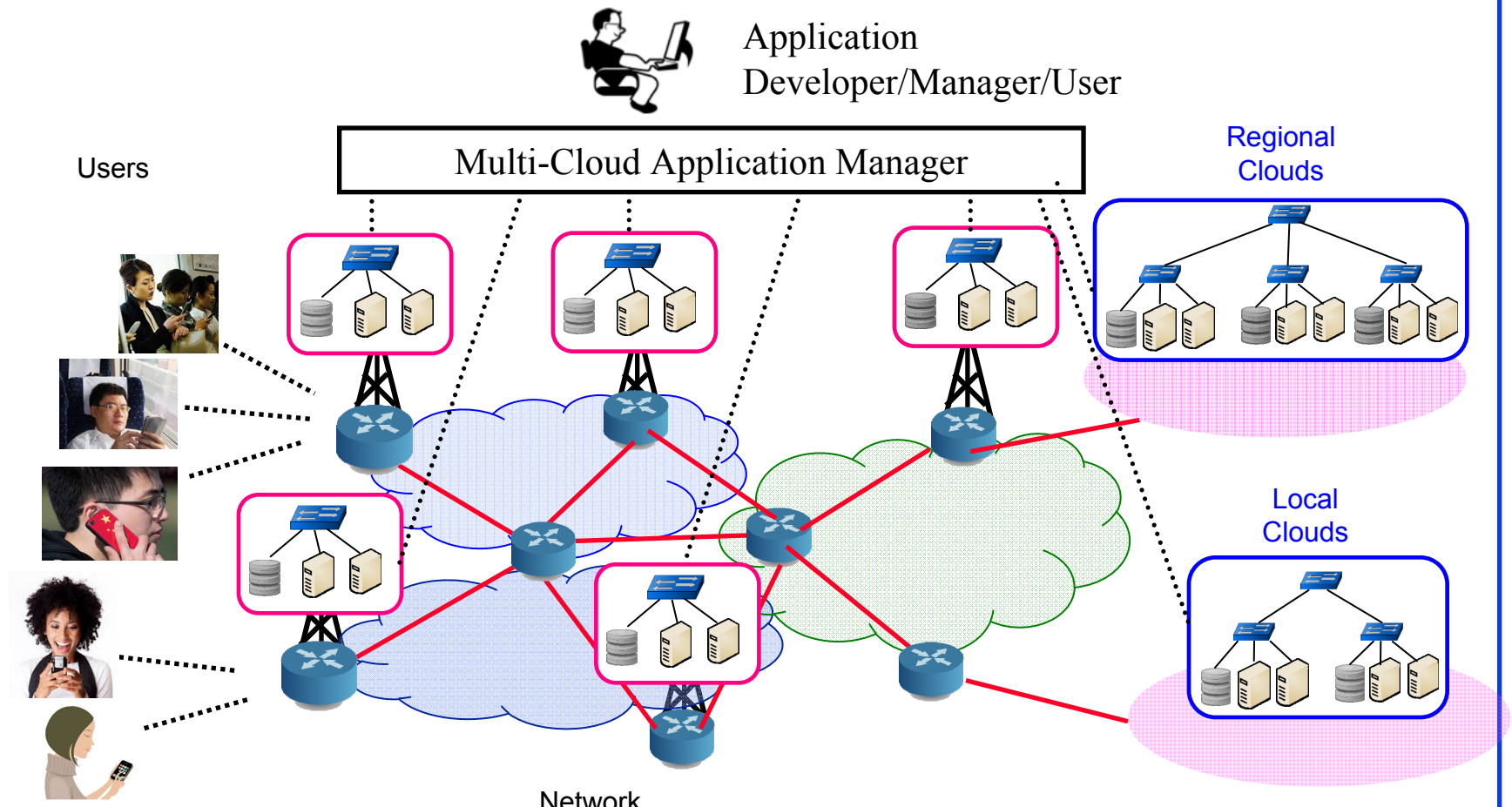
Past: Software Defined Networking

- Network can be managed w/o worrying about individual device hardware

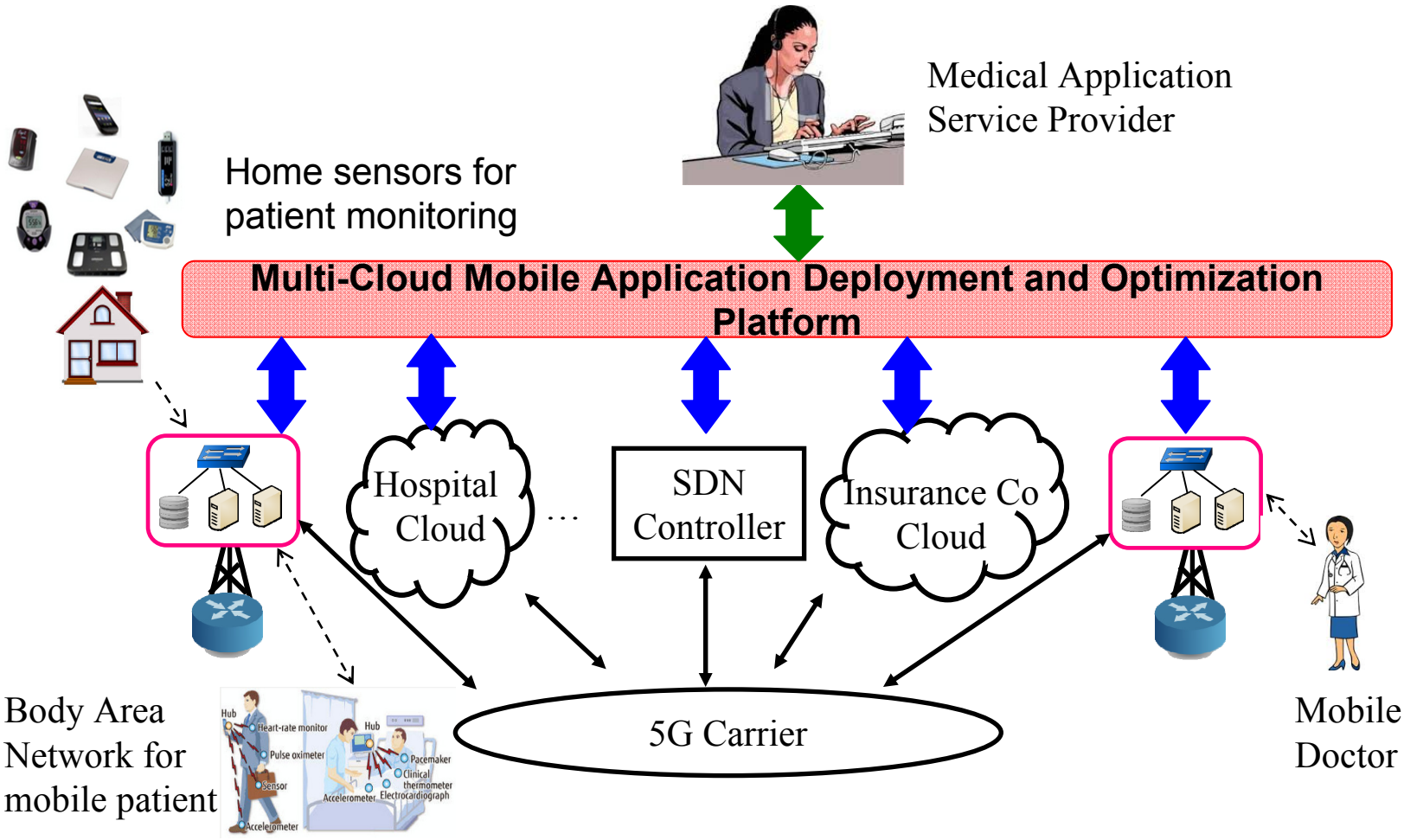


Trend: Software Defined Multi-Cloud Application Delivery

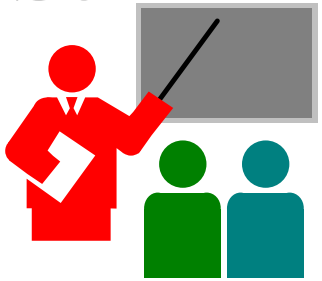
- Cloud MOM (message oriented middleware)



Mobile Healthcare Use Case



Summary



1. IoT research areas are easy via the 7-layer model
2. IoT has brought in research issues in every layer: Sensors, datalink, routing, applications, analytics.
3. Security and privacy are most important issues
4. Computation is moving to the Edge ⇒ Fog Computing ⇒ Multi-Cloud/Inter-Cloud
5. Our MCAD abstracts/virtualizes the cloud interfaces and allows automated management of security and other policies of multi-cloud applications

Recent Talks on IoT

- Raj Jain, "**Internet of Things: Research Issues**," NSF Applications and Services Workshop, January 27, 2016, http://www.cse.wustl.edu/~jain/talks/iot_nsf.htm
- Raj Jain, "**Internet of Things: Research Challenges and Issues**," Keynote at the Internet of Things World Forum, Research and Innovation Symposium, Dubai, December 5-6, 2015, http://www.cse.wustl.edu/~jain/talks/iotwrld.htm
- Raj Jain, "**Internet of Things Security**," Keynote at STLCybercon 2015, University of Missouri, St. Louis, November 20, 2015, http://www.cse.wustl.edu/~jain/talks/iots_um.htm
- Raj Jain, "**Smart Cities: Technological Challenges and Issues**," IEEE CS Keynote at 21st Annual International Conference on Advanced Computing and Communications (ADCOM) 2015, Chennai, India, September 19, 2015, Chennai, India, September 18, 2015, http://www.cse.wustl.edu/~jain/talks/smrtcit.htm
- Raj Jain, "**Internet of Things: Challenges and Issues**," **IEEE CS Keynote** at 20th Annual Conference on Advanced Computing and Communications (ADCOM 2014), Bangaluru, India, September 19, 2014, http://www.cse.wustl.edu/~jain/talks/iot_ad14.htm

Recent Papers on Multi-Cloud

- Subharthi Paul, Raj Jain, Mohammed Samaka, Jianli Pan, "Application Delivery in Multi-Cloud Environments using Software Defined Networking," Computer Networks Special Issue on cloud networking and communications, Available online 22 Feb 2014, http://www.cse.wustl.edu/~jain/papers/comnet14.htm
- Raj Jain and Subharthi Paul, "Network Virtualization and Software Defined Networking for Cloud Computing - A Survey," IEEE Communications Magazine, Nov 2013, pp. 24-31, http://www.cse.wustl.edu/~jain/papers/net_virt.htm
- Subharthi Paul, Raj Jain, Mohammed Samaka, Aiman Erbaud, "Service Chaining for NFV and Delivery of other Applications in a Global Multi-Cloud Environment," ADCOM 2015, Chennai, India, September 19, 2015, http://www.cse.wustl.edu/~jain/papers/adn_in15.htm
- Deval Bhamare, Raj Jain, Mohammed Samaka, Gabor Vaszkun, Aiman Erbad, "Multi-Cloud Distribution of Virtual Functions and Dynamic Service Deployment: OpenADN Perspective," Proceedings of 2nd IEEE International Workshop on Software Defined Systems (SDS 2015), Tempe, AZ, March 9-13, 2015, 6 pp. http://www.cse.wustl.edu/~jain/papers/vm_dist.htm

Acronyms

- 6TiSCH IPv6 over Time Slotted Channel Hopping Mode of IEEE 802.15.4e
- ADCOM Advanced Computing and Communications
- AES-128 Advanced Encryption Standard
- AMQP Advanced Message Queuing Protocol
- ANT A proprietary open access multicast wireless sensor network
- ANT+ Interoperability Function added to ANT
- CANSec Central Area Networking and Security
- CARP Channel-Aware Routing Protocol
- CIA Confidentiality, Integrity, Availability
- CoAP Constrained Application Protocol
- CoRE Constrained RESTful Environment
- CORPL Cognitive RPL
- CS Computer Society
- DARPA Defense Advance Research Project Agency
- DASH-7 Named after last two characters in ISO 18000-7
- DDS Data Distribution Service

Acronyms (Cont)

- DECT Digital Enhanced Cordless Telephone
- DECT/ULE Digital Enhanced Cordless Telephone with Ultra Low Energy
- DEFCON d-e-f conference (named after alphabets d, e, f)
- DNS Domain Name System
- DSL Digital Subscriber Line
- DTLS Datagram Transport Layer Security
- ECC Error Correcting Code
- EDSA Embedded Device Security Assurance
- FTTH Fiber to the home
- GB Gigabyte
- GE General Electric
- GIS Geographical Information Systems
- GP Green PHY
- GPS Global Positioning System
- HCI Human Computer Interface
- HMAC Keyed-Hash Message Authentication Code

Acronyms (Cont)

- HP Hewlett Packard
- HTTP Hyper Text Transfer Protocol
- ICS Industrial Control Systems
- ICT Information and Communications Technology
- IDC International Data Corporation
- IDs Identifiers
- IEC International Engineering Council
- IEEE Institution of Electrical and Electronic Engineers
- IETF Internet Engineering Task Force
- IoT Internet of Things
- IP Internet Protocol
- IRTF Internet Research Task Force
- ISA International Society of Automation
- ITU International Telecommunications Union
- LAN Local Area Network
- LoRaWAN Long Range Wide Area Network

Acronyms (Cont)

- LowPAN — Low Power Personal Area Network
- LTE — Long-Term Evolution
- MCAD — Multi-Cloud Application Delivery
- MHz — Mega Hertz
- MOM — Message Oriented Middleware
- MQTT — Message Queue Telemetry Transport
- NFC — Near Field Communication
- NSF — National Science Foundation
- OAuth — Open Protocol of Secure Authorization
- OpenADN — Open Application Delivery Networking
- PHY — Physical Layer
- PKI — Public Key Infrastructure
- RFC — Request for Comment
- RFID — Radio Frequency Identifier
- RPL — Routing Protocol for Low Power and Lossy Networks
- RSA — Rivest, Shamir, and Adleman

Acronyms (Cont)

- SASL Simple Authentication and Security Layer
- SDLA Requirements for Security Development Lifecycle Assurance
- SDN Software Defined Networking
- SDS Software Defined Systems
- SMACK Simple Mandatory Access Control Kernel for Linux
- SOA Service Oriented Architecture
- SSA Software Security Assurance
- SSL Secure Session Layer
- SW Software
- TCG Trusted Computing Group
- TCP Transmission Control Protocol
- TLS Transport Level Security
- TNC Trusted Network Connect
- TPM Trusted Platform Module
- TV Television
- UDP User Datagram Protocol

Acronyms (Cont)

- ULE Ultra Low Energy
- US United States
- VC Virtual Circuit
- VM Virtual Machine
- WAN Wide Area Network
- WiFi Wireless Fidelity
- WiMAX Worldwide Interoperability of Microwave Access
- WirelessHART Wireless Highway Addressable Remote Transducer Protocol

Scan This to Download These Slides

Raj Jain
http://www.rajjain.com