Internet of Things and Smart Cities: Challenges and Issues

RAJ JAIN

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

Keynote at 2nd IEEE International Workshop on Sensors and Smart Cities

(SSC2016), St. Louis, MO, May 18, 2016

These slides are available on-line at:

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

Overview

1. A Layered Model of IoT and Smart Cities

2. City IQ: How to measure smartness of a city

3. Challenges: Non-Technical and Technical

4. IoT/Smart City Security

5. Software Defined Secure Multi-Cloud Application Management for IoT

Trend: Smart Everything

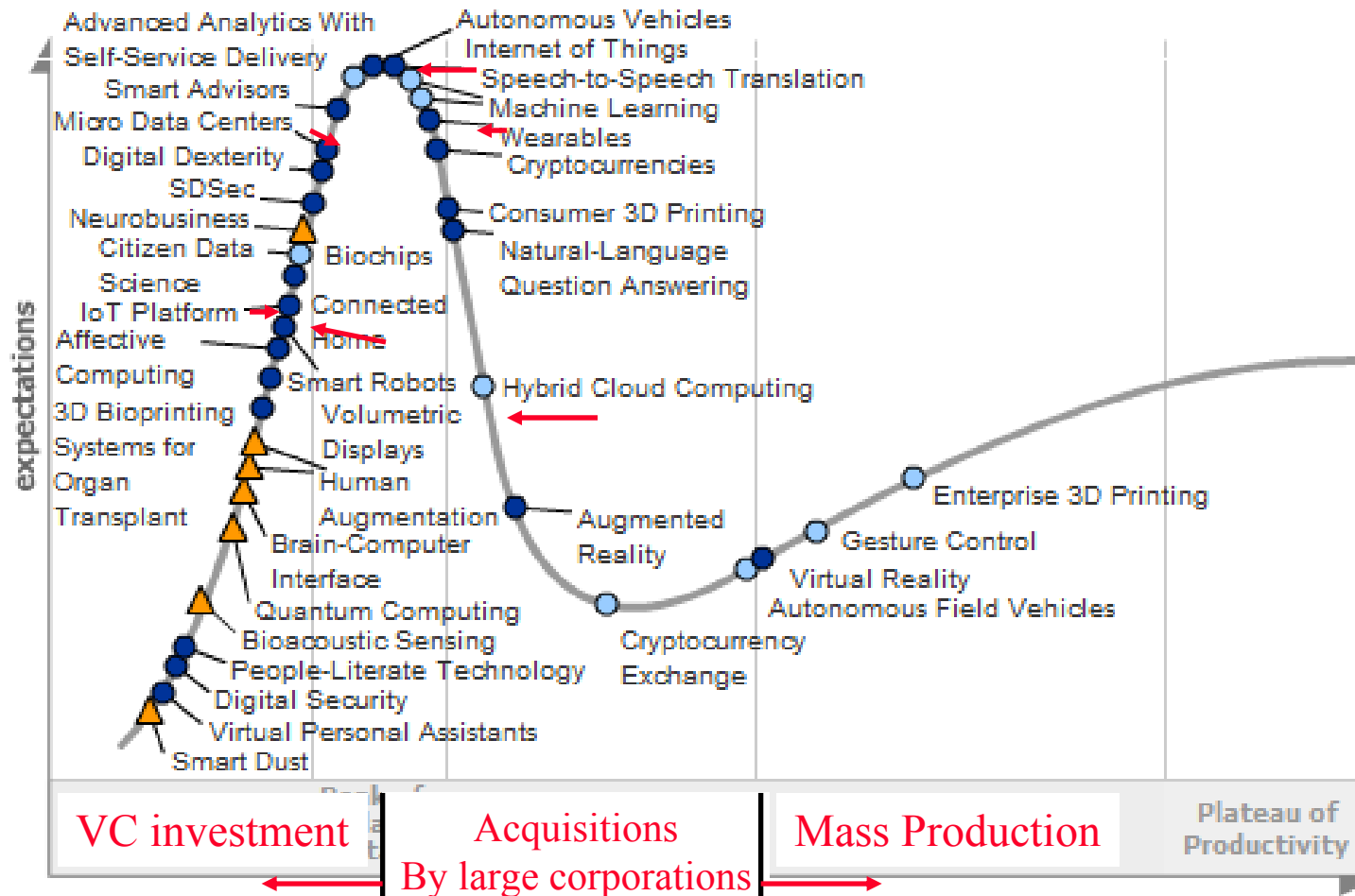|		
Smart Watch	Smart TV	Smart Car
Smart Health	Smart Home	Smart Kegs
Smart Space	Smart Industries	Smart Cities

What's Smart?

❑ Old: Smart = Can think $\Rightarrow$ Computation

   = Can Recall $\Rightarrow$ Storage

❑ Now: Smart = Can find quickly, Can Delegate
   $\Rightarrow$ Communicate = Networking

❑ Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …
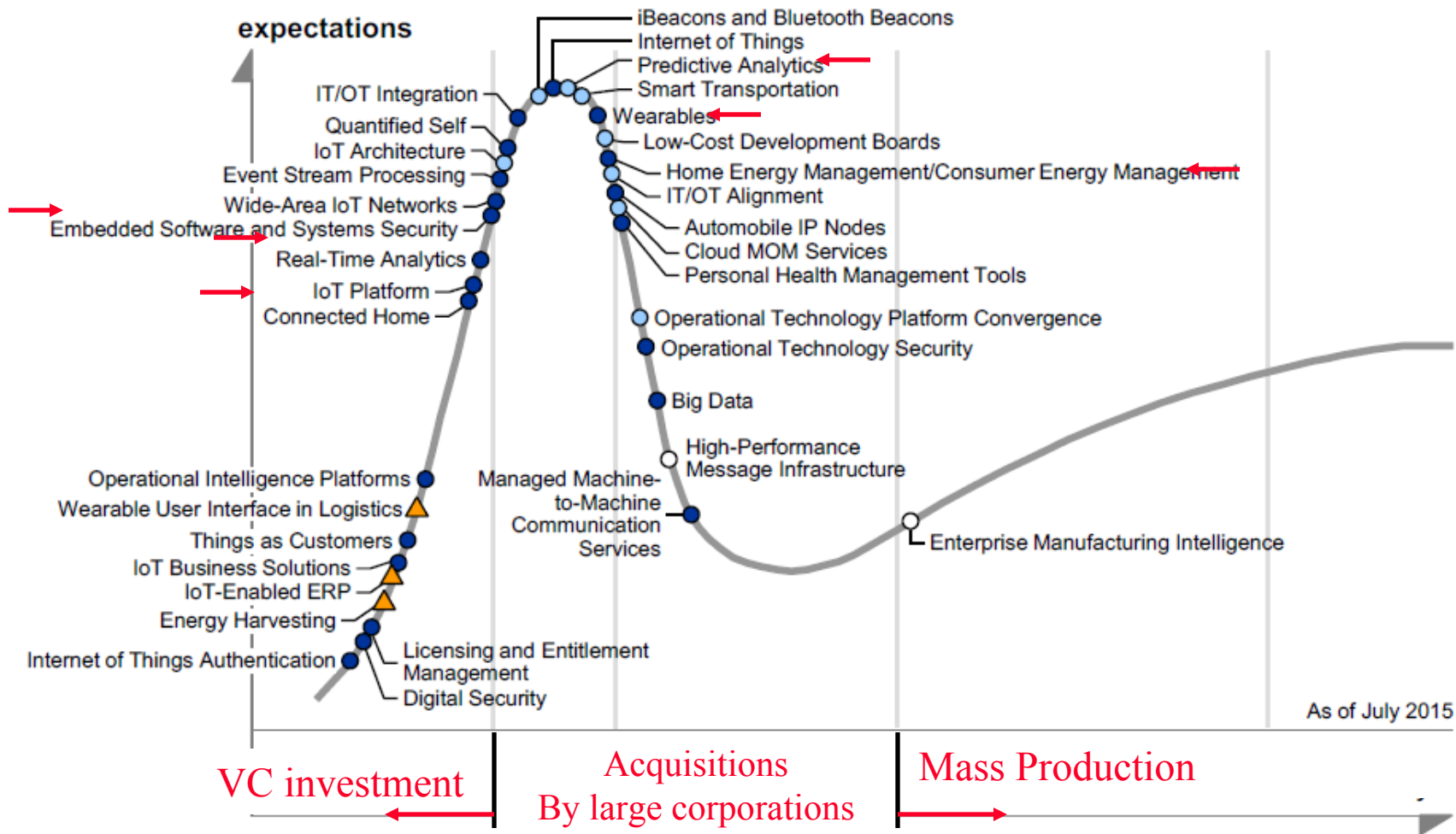
Not-Smart   Smart

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

Gartner Hype Cycle 2015

Advanced Analytics With Self-Service Delivery
Smart Advisors
Micro Data Centers
Digital Dexterity
SDSec
Neurobusiness
Citizen Data Science
IoT Platform
Affective Computing
3D Bioprinting Systems for Organ Transplant

Autonomous Vehicles
Internet of Things
Speech-to-Speech Translation
Machine Learning
Wearables
Cryptocurrencies
Consumer 3D Printing
Natural-Language Question Answering

Biochips
Connected Home
Smart Robots
Volumetric Displays
Human Augmentation
Brain-Computer Interface
Quantum Computing
Bioacoustic Sensing
People-Literate Technology
Digital Security
Virtual Personal Assistants
Smart Dust

Hybrid Cloud Computing
Augmented Reality
Cryptocurrency Exchange

Enterprise 3D Printing
Gesture Control
Virtual Reality
Autonomous Field Vehicles

expectations

VC investment

Acquisitions
By large corporations

Mass Production

Plateau of Productivity

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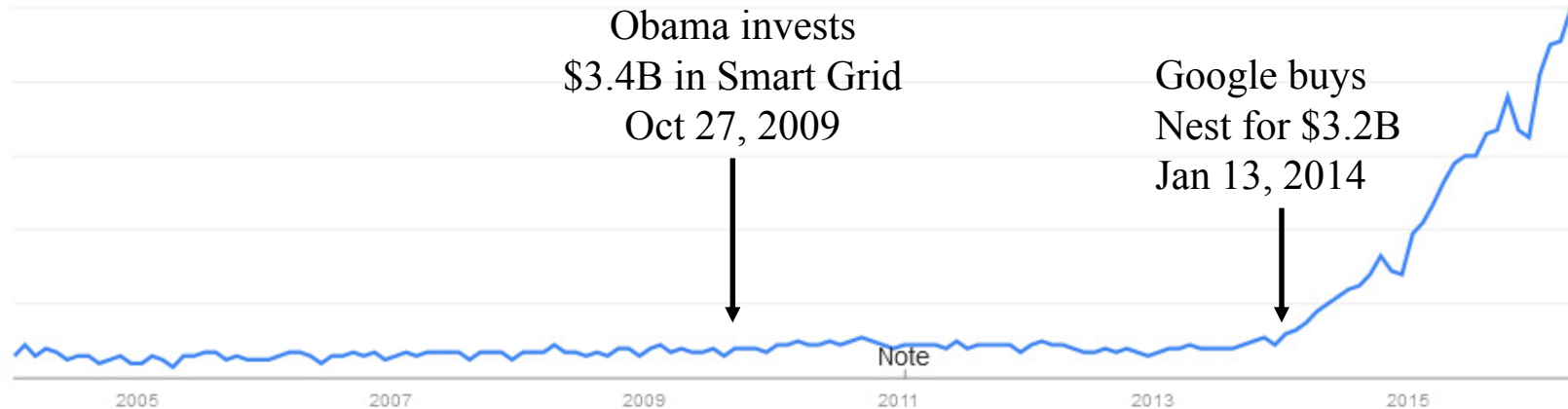
http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm

Gartner's Hype Cycle For IoT 2015

expectations

- iBeacons and Bluetooth Beacons
- Internet of Things
- Predictive Analytics ←
- Smart Transportation

- IT/OT Integration
- Quantified Self
- IoT Architecture
- Event Stream Processing
- Wide-Area IoT Networks
- Embedded Software and Systems Security →
- Real-Time Analytics
- IoT Platform →
- Connected Home

- Wearables ←
- Low-Cost Development Boards
- Home Energy Management/Consumer Energy Management ←
- IT/OT Alignment
- Automobile IP Nodes
- Cloud MOM Services
- Personal Health Management Tools

- Operational Technology Platform Convergence
- Operational Technology Security

- Big Data

- High-Performance Message Infrastructure

- Operational Intelligence Platforms
- Wearable User Interface in Logistics
- Things as Customers
- IoT Business Solutions
- IoT-Enabled ERP
- Energy Harvesting
- Internet of Things Authentication

- Managed Machine-to-Machine Communication Services

- Enterprise Manufacturing Intelligence

- Licensing and Entitlement Management
- Digital Security

As of July 2015

VC investment ←   **Acquisitions By large corporations**   **Mass Production** →

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

Washington University in St. Louis   http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm   ©2016 Raj Jain

6

Google Trends

Obama invests
$3.4B in Smart Grid
Oct 27, 2009

Google buys
Nest for $3.2B
Jan 13, 2014

Note

2005   2007   2009   2011   2013   2015

❑ Around for 10 years

❑ IERC-European Research Cluster on the Internet of Things funded under 7th Framework in 2009
$\Rightarrow$ "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

Millions of Units
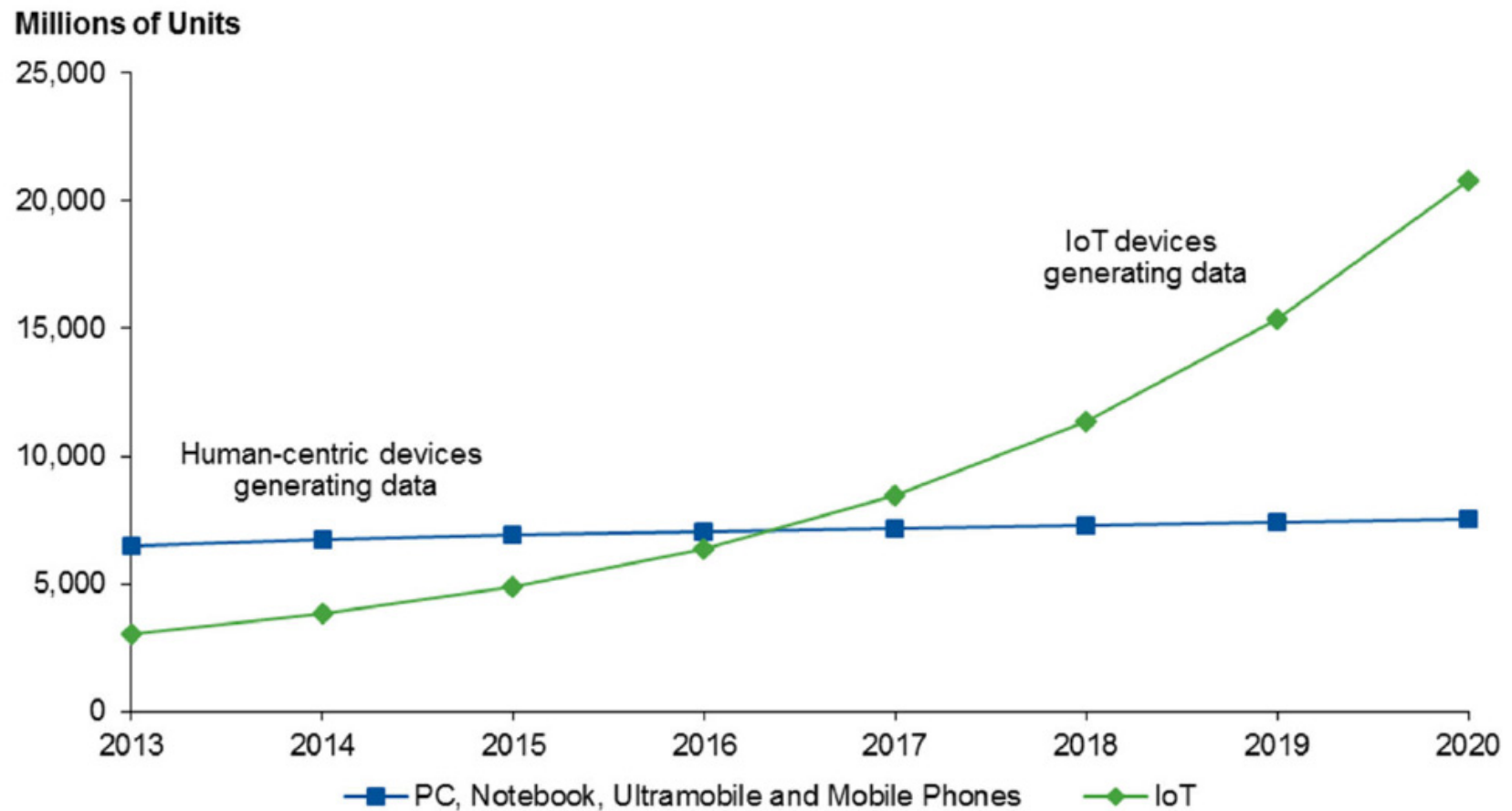
- ❑ 21 Billion devices by 2020

Washington University in St. Louis   http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm   ©2016 Raj Jain

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

Services	Energy, Entertainment, Health, Education, Transportation, …
Apps and SW	SDN, SOA, Collaboration, Apps, **Clouds**
Analytics	Machine learning, predictive analytics, Data mining, …
Integration	Sensor data, Economic, Population, GIS, …
Interconnection	DECT/ULE, WiFi, Bluetooth, ZigBee, NFC, …
Acquisition	Sensors, Cameras, GPS, Meters, Smart phones, …
Market	Smart Grid, Connected home, Smart Health, Smart Cities, …

ICT

Security

Management

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

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, …

IoT is a Data ($) Mine

12

A 7-Layer Model of Smart Cities

Services	Energy, Entertainment, Health, Education, Transportation, water, …
Apps and SW	SDN, SOA, Collaboration, Apps, **Clouds**
Analytics	Machine learning, predictive analytics, Data mining, …
Integration	Sensor data, Economic, Population, GIS, …
Interconnection	DECT/ULE, WiFi, Bluetooth, ZigBee, NFC, …
Acquisition	Sensors, Cameras, GPS, Meters, Smart phones, …
Infrastructure	**Roads, Trains, Buses, Buildings, Parks, …**

ICT

Security

Management

What's the Problem?

- ❑ City = 100,000+ population

- ❑ Over 50% of world population lives in cities and growing.
  By 2050, 75% will live in urban areas

- ❑ Mega city = 10+ million population

  - ➢ 11 in Asia, 4 in Latin America, 2 in Africa, 2 in Europe, 2 in North America = 21 Total in 2010

  - ➢ 29-37 in 2025 with 14-22 in Asia

- ❑ City population is growing much faster than resources
  ⇒ Need **sustainable** ways to **manage** resources for city living:
  Water, Electricity, Housing,…⇒ Quality of life ⇒ Smart City

Ref: V. Aillaud, "Digital economy and smart métropolies : a joint future? ," http://www.europmetrocci.eu/l/Portals/0/EuropmetrocciDocuments/london%2030-31%20october%202013/PARIS%20Smart-cities%20Valerie%20AILLAUD.ppt
J. Bélissent, "Getting Clever About Smart Cities: New Opportunities Require New Business Models," Forester, Nov 2010, 33 pp., http://193.40.244.77/iot/wp-content/uploads/2014/02/getting_clever_about_smart_cities_new_opportunities.pdf

Old vs. New

❑ Governments: Last to adopt new technologies

❑ Amazon, Face book, Google: Use the latest technologies
Internet, smart phones, tablets, RFID, sensors, social media

❑ Smart ⇒ Run a city like Amazon.com
User driven, Dynamic, Real-time, Technology-oriented

Numerous offices

Single interface for all services

Is This a New Problem?

❑ Google Trends:

A

B

G

E

DC

E

F

G

B

2005   2007   2009   2011   2013   2015

</>
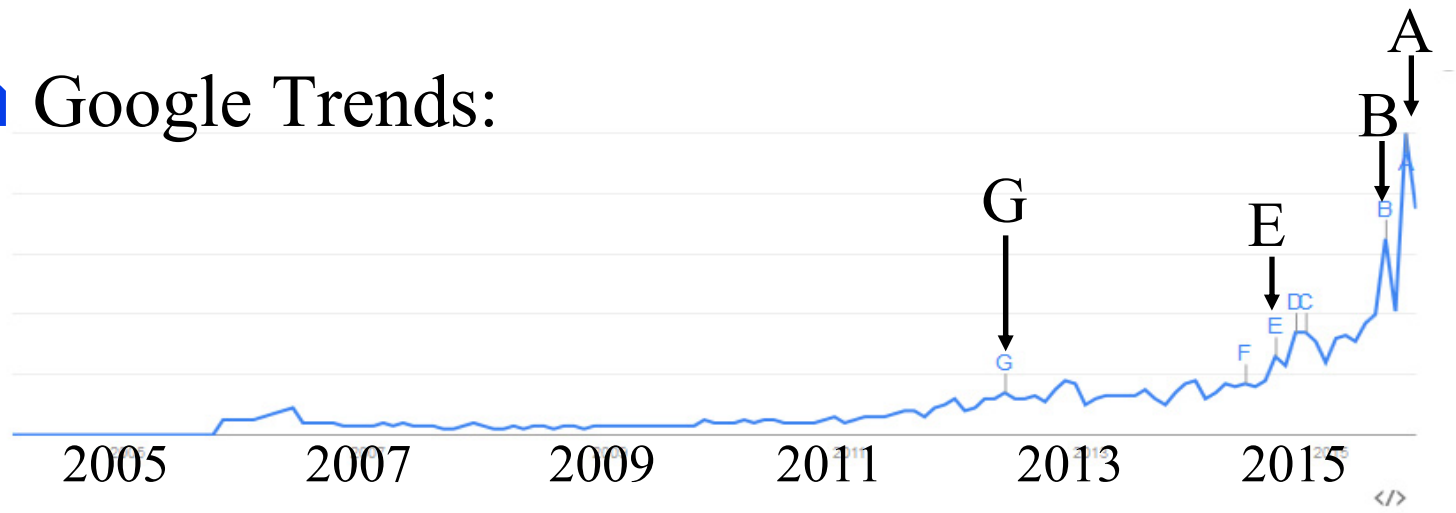
❑ G (April 5, 2012): Italian national observatory launches "Smart Cities" program

❑ E (July 11, 2014): Rs. 7,060 crore for 100 smart cities (BJP Election Manifesto)

❑ B (June 30, 2015): Cisco launches IoT systems to make smart cities smarter

❑ A (August 27, 2015): List of 98 smart cities announced in India

❑ 1992: World Foundation for Smart Communities –
Smart City = Technology, Innovation, Globalization ⇒ 33 yr old problem

Ref: Gibson, D.V., Kozmetsky, G., Smilor, R.W. (eds.), "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks," Rowman & Littlefield, New York (1992)

Why Are We Solving the Problem Now?

- ❏ $27.5 billion annual revenue in smart city technology by 2023
  $174 billion investment by 2023

- ❏ Cisco, Intel, Huawei, IBM, Fujitsu, SIEMENS are all selling ICT for smart cities

- ❏ India government will spend ~$7 billion for smart cities in the next five years

Ref: Navigant Research, "Smart Cities," https://www.navigantresearch.com/research/smart-cities

http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm   ©2016 Raj Jain

17

Smart Cities Research in US

❑ White House "Smart Cities Week" (Sep 15-18, 2015, Next: Sep 27-29, 2016)

❑ $40 M Research funding from NSF

➢ Gigabit applications healthcare, energy, transportation, manufacturing, education and learning, and public safety.

➢ Cyber physical systems

❑ Make Broadband construction faster:

➢ Websites to list all federal assets available for broadband

➢ Broadband installation during new road construction

❑ US Ignite Program: Multi-gigabit Applications ⇒ Uncompressed video

Ref: NSF, "Cultivating Smart and Connected Communities," http://nsf.gov/news/news_summ.jsp?cntn_id=136253
Smart City Week, http://www.smartcitiesweek.com/

Hype Cycle for Smart Cities

Ref: N. Nakano, A. Kim, B. Tratz-Ryan, "Hype Cycle for Smart City Technologies and Solutions, 2015," Gartner Report G00277202, 27 July 2015

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

Smart Services: Examples

❑ London's Datastore: Jobs, Waste, Crime, Visitors, … All open to public, http://data.london.gov.uk/

❑ New Songdo City, Incheon, South Korea: All city services available via Internet, video conferencing, http://www.songdo.com/

❑ Delhi police app to report crime 55,000 reports in 6 months

❑ In Melbourne, All trees have been assigned ID numbers so that public can report tree problems, overgrown branches, fallen trees, etc.
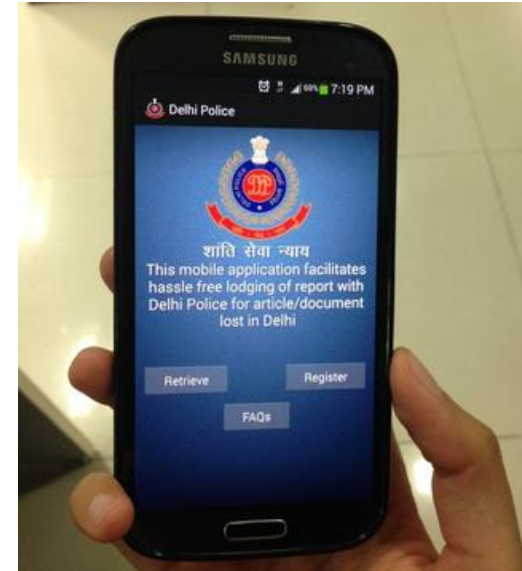
City IQ: Benchmark for Smartness
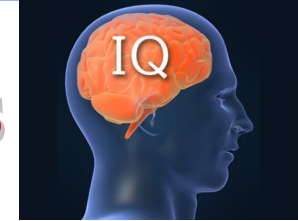
❑ ISO 37120:2014 Sustainable Development of Communities: Indicators for City Services and Quality of Life

❑ Using 17 themes and 100 indicators for city services and quality of life, World Council of City Data (WCCD) give a city one of five levels.

ISO 37120	ISO 37120	ISO 37120	ISO 37120	ISO 37120
30-45 Aspirational	46-59 Bronze	60-75 Silver	76-90 Gold	91-100 Platinum

Ref: WCCD, "WCCD ISO 37120 Certification," http://www.dataforcities.org/iso

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

Washington University in St. Louis

©2016 Raj Jain

List of Smart Cities

❑ World Council on City Data (WCCD): Partial List

City	Country	Year	Level
Amsterdam	Netherlands	2014	Aspirational
Helsinki	Finland	2014	Aspirational
Johannesburg	South Africa	2014	Aspirational
Shanghai	China	2014	Aspirational
Buenos Aires	Argentina	2014	Gold
Makkah	Saudi Arabia	2014	Gold
Melbourne	Australia	2014	Gold
Barcelona	Spain	2014	Platinum
Boston	United States of America	2014	Platinum
Dubai	United Arab Emirates	2014	Platinum
London	United Kingdom	2014	Platinum
Rotterdam	Netherlands	2014	Platinum
Toronto	Canada	2014	Platinum
Los Angeles	United States of America	2015	Platinum

Ref: http://www.dataforcities.org/registry

Areas Measured by ISO 37120:2014

1. Economy
2. Education
3. Energy
4. Environment
5. Finance
6. Fire and emergency response
7. Governance
8. Health
9. Recreation
10. Safety
11. Shelter
12. Solid waste
13. Telecommunications and innovation
14. Transportation
15. Urban planning
16. Wastewater
17. Water and sanitation

Indicators

- ❑ **Indicators**: Quantitative, qualitative, or descriptive measures
  47 of 100 are core.
- ❑ Core (Required), Supporting (Recommended), Profile (Informative) indicators
- ❑ Example: Education
  1. % of female school aged population enrolled in schools (core)
  2. % of students completing primary education: survival rate (core)
  3. % of students completing secondary education: survival rate (core)
  4. Primary education student/teacher ratio (core)
  5. % of male school-aged population enrolled in schools (supporting)
  6. % of school-aged population enrolled in schools (supporting)
  7. # of higher education degrees per 100,000 population (supporting)

Ref: ANSI, "ISO 37120-2014 Preview Final V2, http://publicaa.ansi.org/sites/apdl/ANSI%20Network%20on%20Smart%20and%20 Sustainable%20Cities/ISO+37120-2014_preview_final_v2.pdf

Challenges

1. **Financing**: Self-sustaining $\Rightarrow$ Revenue generating.
    Federal or state financing is just "seed" funding
    Private Partnerships $\Rightarrow$ Revenue sharing or bartering

2. Ensuring **fairness** to all localities of a city
    $\Rightarrow$ Private companies want the best revenue generating areas

3. **Public Trust**: in government, the data, and expect actions
    Lack of transparency $\Rightarrow$ Waste of money on technologies

4. **Customization**: Every city is different.
    Private companies want to reuse their "one solution for all"

5. **Turnover**: Technology gets outdated every year or two

6. Digital **Disruption**

7. **Security and Privacy**

J. Bélissent, "Getting Clever About Smart Cities: New Opportunities Require New Business Models," Forester, Nov 2010, 33 pp.,
http://193.40.244.77/iot/wp-content/uploads/2014/02/getting_clever_about_smart_cities_new_opportunities.pdf

Washington University in St. Louis http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm ©2016 Raj Jain

Public Trust

Washington University in St. Louis

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

©2016 Raj Jain

Digital Disruptions

❑ New methods ⇒ Improvements ⇒ Disruption to old methods

❑ Automation ⇒ Better efficiency ⇒ What to do with those replaced

❑ Privatization, Automation, Change ⇒ Strikes

No Privatization
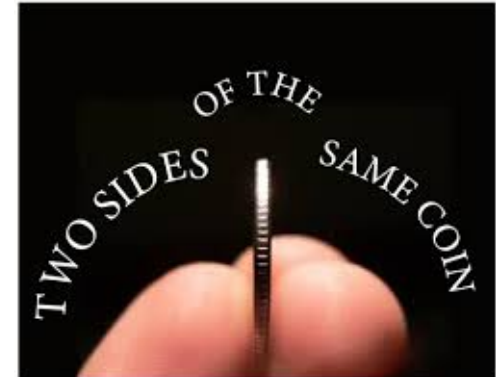
Top Inhibitors to the Adoption of the IoT

	Rank 1	Rank 2	Rank 3	Sum
Cybersecurity	21	15	15	51%
Integration	13	17	14	43%
Determining and managing business requirements	19	9	8	36%
Analytics	7	11	13	31%
Networking and communications	10	9	9	28%
Orchestration of workflows and processes	7	9	11	27%
Architecture	5	10	8	23%
Data management	6	9	8	20%
Device management	7	7	6	20%
Application development	3	3	7	13%
Other	1	1	1	3%

Percentage of Respondents

■ Rank 1   ■ Rank 2   ■ Rank 3

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_ssc.htm

28

IoT Security: Popular Approach

Washington University in St. Louis

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

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,

Washington University in St. Louis

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

©2016 Raj Jain

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.

Bluetooth
My SATIS

Ref: http://www.computerworld.com/article/2486502/
security0/worm-may-create-an-internet-of-harmful-things--says-symantec--take-note--amazon-.html
Washington University in St. Louis
http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm

31

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

Washington University in St. Louis   http://www.cse.wustl.edu/~jain/talks/iots_ssc.htm   ©2016 Raj Jain

NEST Insecurity

❑ Log files with usage statistics are stored locally and uploaded to cloud when connected to Internet

❑ User network credentials are stored in the device in plain text

❑ Can be booted from its USB port, if boot configuration pin on the board sys_boot[5] is high

❑ Your heating personnel have full control over the house

  ➢ Away detection

  ➢ Remote control

  ➢ Network credentials => Control other NEST devices

❑ Attack: Press the reset button for 10 seconds causing sys_boot[5] to high, inject code through USB

❑ This must have changed since August 2014

Ref: G. Hernandez, et al, "Smart Nest Thermostat A Smart Spy in Your Home," Black hat USA 2014, 43 slides,
https://www.blackhat.com/docs/us-14/materials/us-14-Jin-Smart-Nest-Thermostat-A-Smart-Spy-In-Your-Home.pdf

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, …

| Things | Access | Gateway | WAN | Cloud | Users |

Smart City Insecurity

❑ **Smart Court House**: Placer county courthouse accidently summoned 1200 people to jury duty on a morning in May 2012 causing traffic jams

❑ **Smart Metro**: Bay Area Rapid Transit (BART) was shut down by a technical problem affecting 500 to 1000 passengers on 19 trains (November 2013)

❑ **Smart Electricity**: 55 Million people in Northeast USA lost electric power due to a software bug

❑ Not marking a pipeline on the map lead to a gas pipe line explosion and fire in Johnson County, Texas by workers installing electrical lines

❑ Nation states and cyber terrorists know how to make use of public data ⇒ **Smart Wars**

Ref: C. Cerrudo, "Hacking smart cities," RSA Conference 2015,
http://www.rsaconference.com/writable/presentations/file_upload/hta-t10-hacking-smart-cities_final.pdf

Past: Data in the Edge

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

Users

Distributed Content Caches

Network

Service/Content hosted on web servers
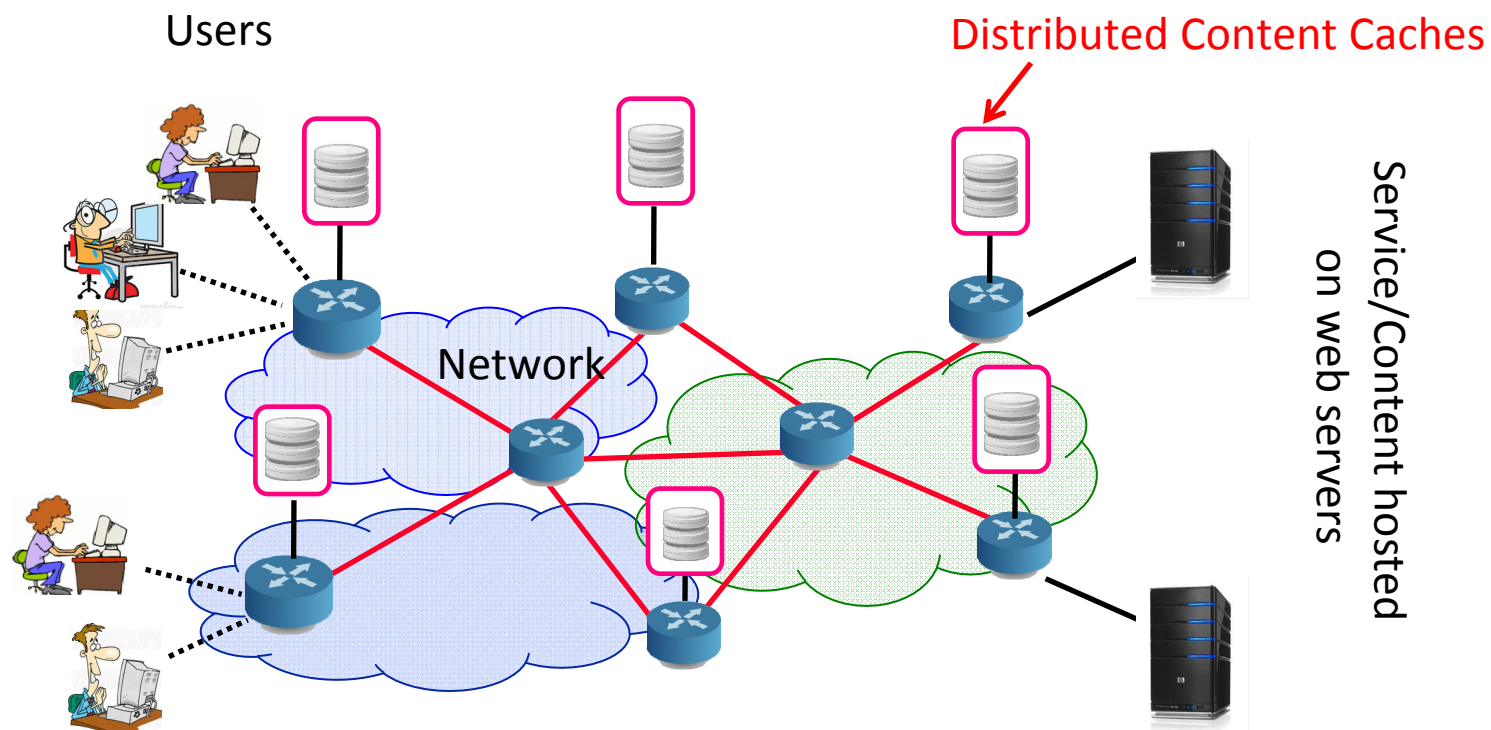
Trend: Computation in the Edge
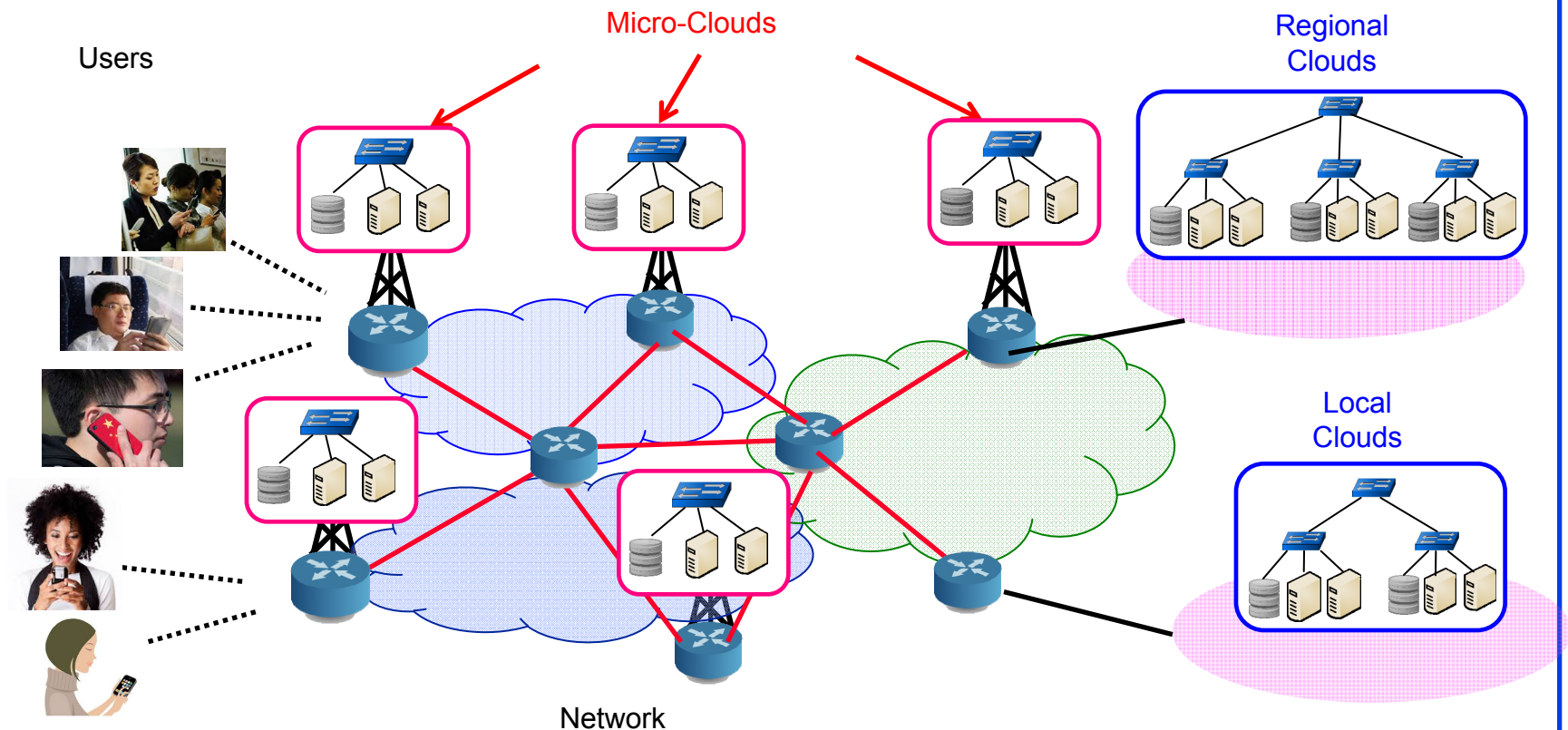
❑ To service mobile users/IoT, the computation needs to come to edge ⇒ Micro-cloud on the tower
⇒ Mobile-Edge Computing
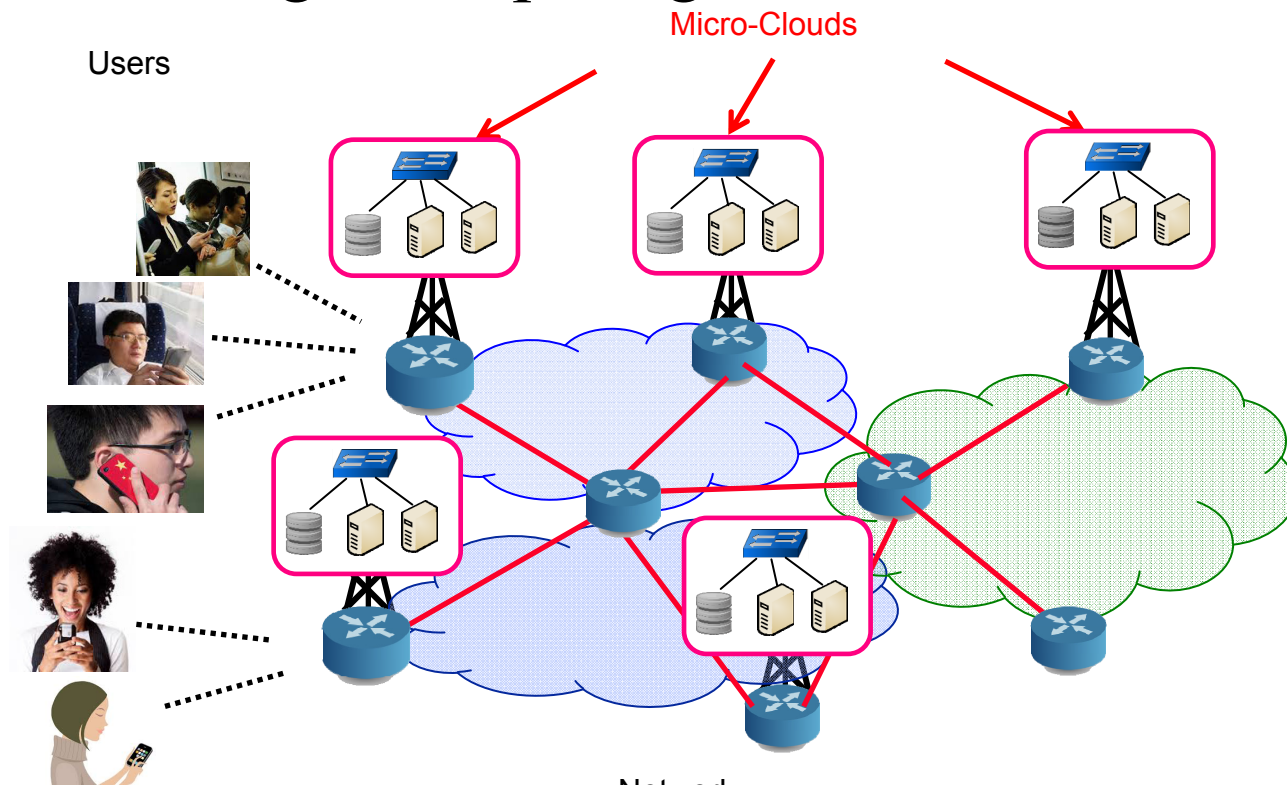
Trend: Multi-Cloud

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

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

Past: Software Defined Networking

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

Network Manager

Network Controller

Users
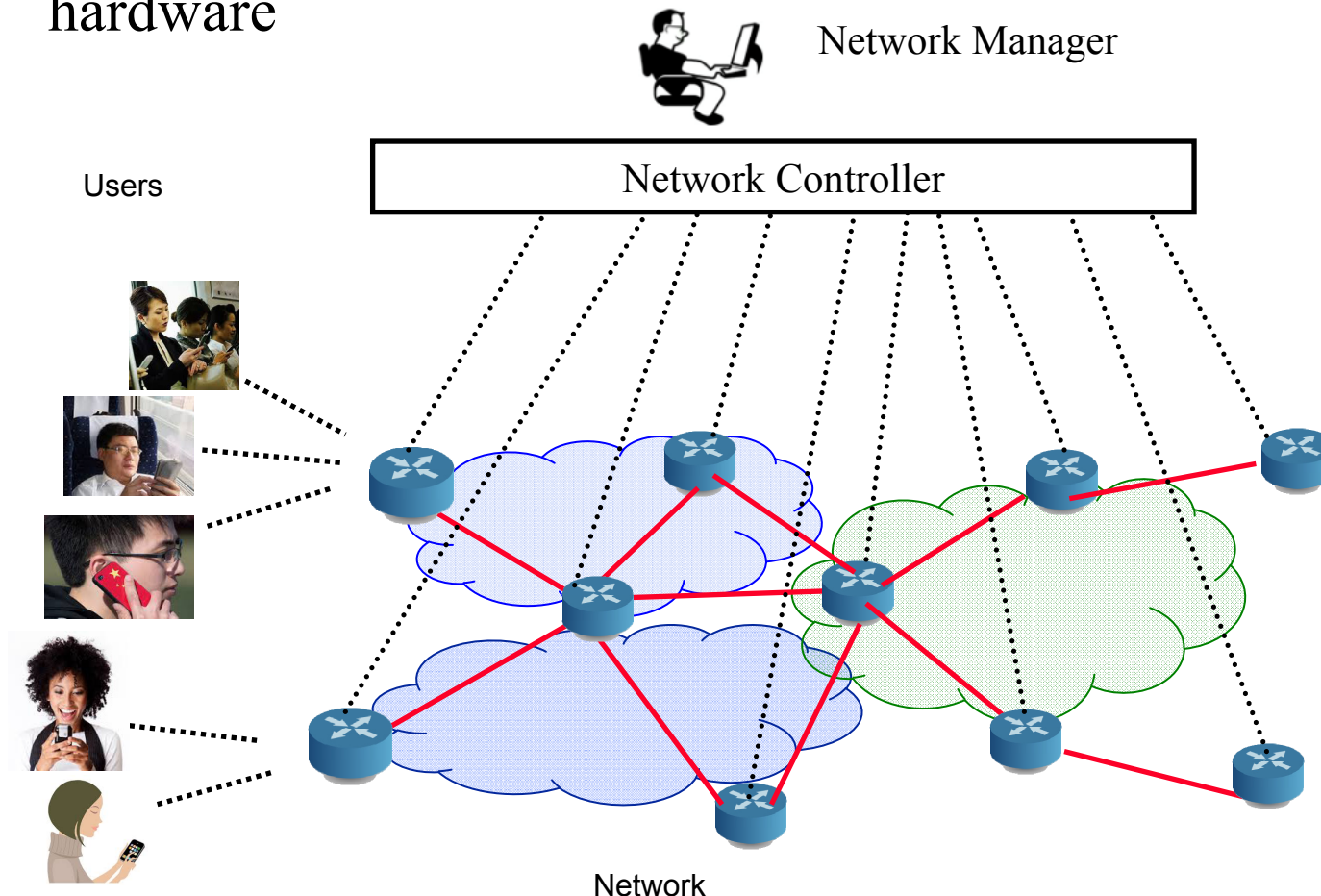
Network

Trend: Software Defined Multi-Cloud Application Delivery

❑ Cloud MOM (message oriented middleware)

Application Developer/Manager/User

Multi-Cloud Application Manager

Users

Regional Clouds

Local Clouds

Network

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

©2016 Raj Jain
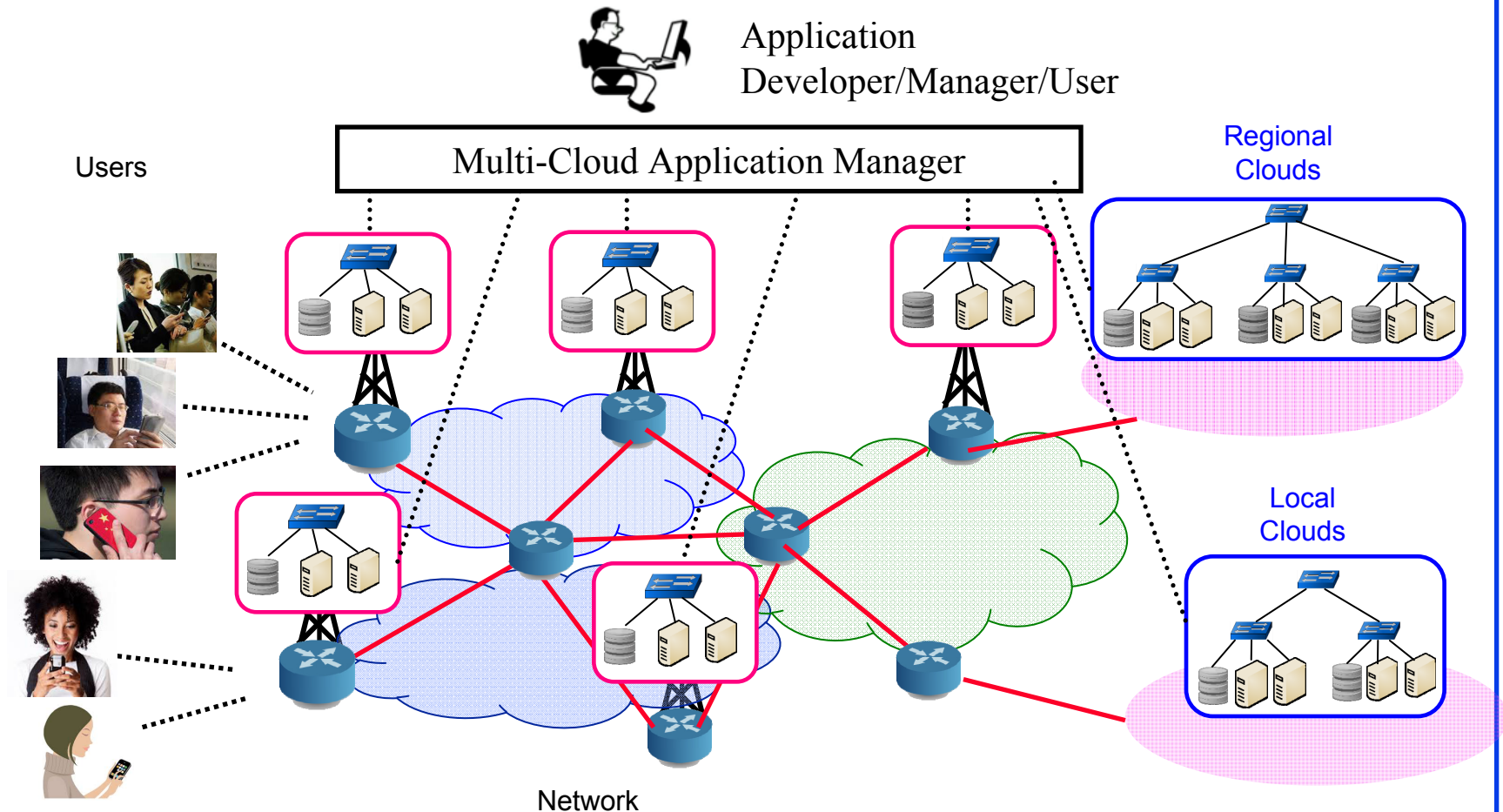
Mobile Healthcare Use Case

Medical Application Service Provider

Home sensors for patient monitoring

Multi-Cloud Mobile Application Deployment and Optimization Platform

Hospital Cloud … SDN Controller Insurance Co Cloud

Body Area Network for mobile patient

5G Carrier

Mobile Doctor

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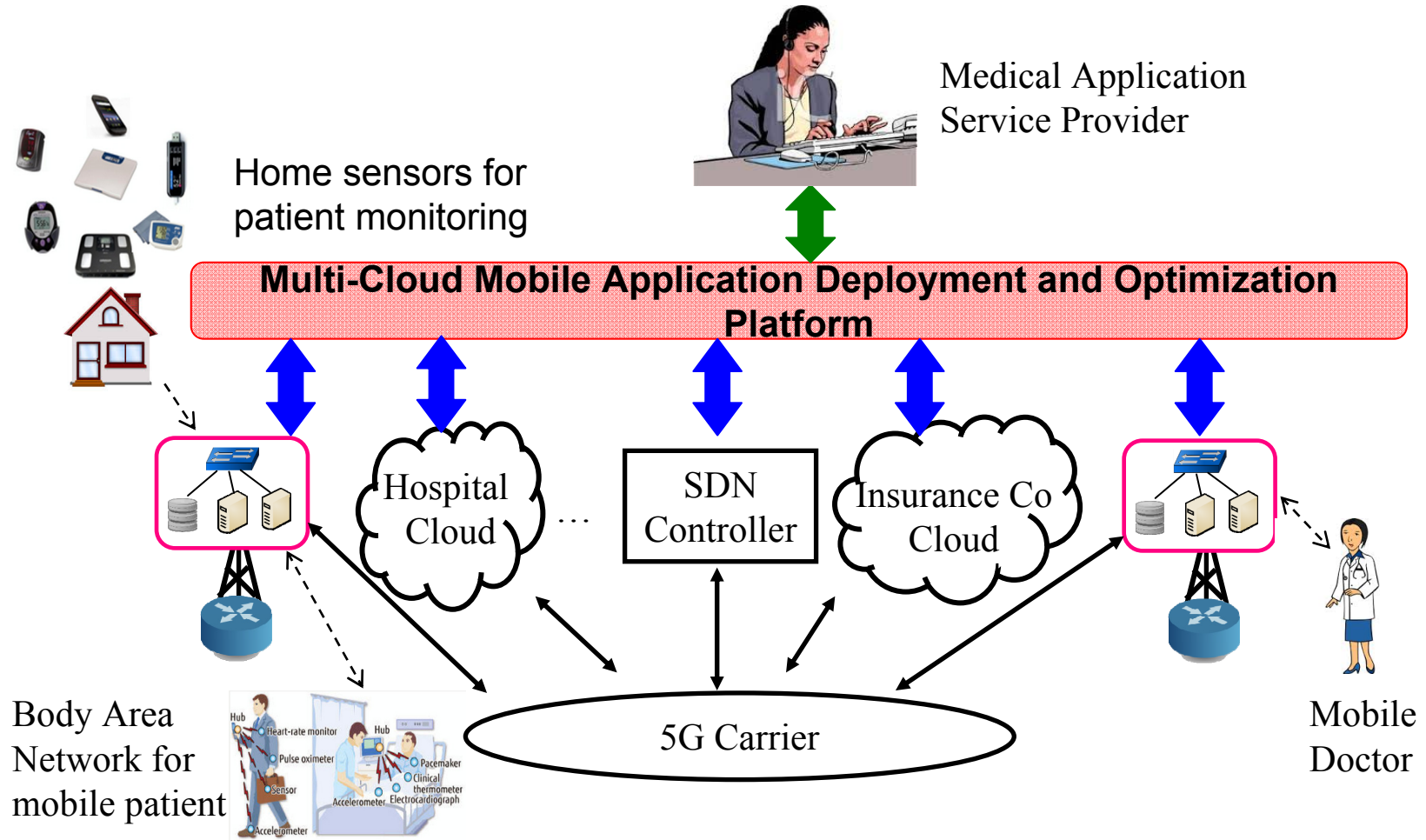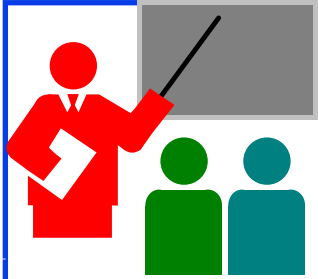
Summary

1. Smart $\neq$ High-Speed Computation, Smart $\neq$ Big Data Storage, Smart = Networked

2. IoT/Smart Cities research areas are easy via the 7-layer model They have brought in research issues in every layer: Sensors, datalink, routing, applications, analytics.

3. Numerous challenges: Sustainable partnerships, Digital disruption, fast technology turnover, trust. Security and privacy are most important issues

4. Computation is moving to the Edge $\Rightarrow$ Fog Computing $\Rightarrow$ 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/Smart Cities

❑ 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

- 4G   Fourth Generation
- 5G   Fift Generation
- 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
- ANSI   American National Standards Institute
- ANT   A proprietary open access multicast wireless sensor network
- ANT+   Interoperability Function added to ANT
- BS   British Standard
- BSI   British Standards Institute
- CARP   Channel-Aware Routing Protocol
- CD   Committee Draft
- CEN   European Committee for Standardization
- CENELEC   European Committee for Electro technical Standardization
- CG   Coordination Group

Acronyms (Cont)

- CIA   Confidentiality, Integrity, Availability
- CoAP   Constrained Application Protocol
- CoRE   Constrained RESTful Environment
- CORPL   Cognitive RPL
- CS   Computer Society (IEEE)
- DARPA   Defense Advance Research Project Agency
- DASH-7   Named after last two characters in ISO 18000-7
- DDS   Data Distribution Service
- 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)
- DIN   Deutsches Institut für Normung (German Institute for Standardization)
- DIS   Draft International Standard
- DNS   Domain Name System
- DSL   Digital Subscriber Line

Acronyms (Cont)

- DTLS   Datagram Transport Layer Security
- DTS   Draft Technical Specification
- ECC   Error Correcting Code
- EDSA   Embedded Device Security Assurance
- ETSI   European Telecommunications Union
- FG-SSC   Focus group on smart sustainable cities
- FTTH   Fiber to the home
- FTTx   Fiber to the X
- GB   Gigabyte
- GDP   Gross Domestic Production
- 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
- ID   Identification
- IDC   International Data Corporation
- IDs   Identifiers
- IEC   International Engineering Council
- IEC/SEG   IEC Systems Evaluation Group
- IEEE   Institution of Electrical and Electronic Engineers
- IETF   Internet Engineering Task Force
- IFC   Industry Foundation Classes
- IMS   IP Multimedia System
- IoT   Internet of Things
- IP   Internet Protocols
- IQ   Intelegence Quotient

Acronyms (Cont)

- IRTF   Internet Research Task Force
- ISA   International Society of Automation
- ISBN   International Standard Book Number
- ISO   International Standards Organization
- IT   Information Technology
- ITU-T   International Telecommunications Union - Telecommunication Standardization Sector
- JTC   Joint Technical Committee
- KPI   Key Performance Indicator
- LAN   Local Area Network
- LoRaWAN   Long Range Wide Area Network
- LowPAN   Low Power Personal Area Network
- LTE   Long-Term Evolution
- MCAD   Multi-Cloud Application Delivery
- MHz   Mega Hertz
- MO   Missouri
- MOM   Message Oriented Middleware

Acronyms (Cont)

- MQTT   Message Queue Telemetry Transport
- NFC   Near Field Communication
- NIST   National Institute of Technology
- NSF   National Science Foundation
- OAuth   Open Protocol of Secure Authorization
- OpenADN   Open Application Delivery Networking
- OS   Operating System
- PAS   Publicly Available Specification
- PD   Published Document
- PHY   Physical Layer
- PKI   Public Key Infrastructure
- RFC   Request for Comment
- RFID   Radio Frequency Identifier
- RoW   Rest of the World
- RPL   Routing Protocol for Low Power and Lossy Networks
- RSA   Rivest, Shamir, and Adleman

Acronyms (Cont)

- RTS   Road traffic safety
- SASL   Simple Authentication and Security Layer
- SC   Smart community
- SDLA   Requirements for Security Development Lifecycle Assurance
- SDN   Software Defined Networking
- SDS   Software Defined Systems
- SEG   System Evaluation Group
- SG5   Study Group 5
- SMACK   Simple Mandatory Access Control Kernel for Linux
- SOA   Service oriented Architecture
- SSA   Software Security Assurance
- SSC   Smart and Sustainable Cities and
- SSCC-CG   Smart and Sustainable Cities and Communities Coordination Group
- SSL   Secure Session Layer
- SW   Software
- TC   Technical Committee

Acronyms (Cont)

- TCG   Trusted Computing Group
- TCP   Transmission Control Protocol
- TLS   Transport Level Security
- TMB   Technical Management Board
- TNC   Trusted Network Connect
- TPM   Trusted Platform Module
- TR   Technical Report
- TS   Technical Specification
- TV   Television
- UDP   User Datagram Protocol
- ULE   Ultra Low Energy
- US   United States
- USA   United States of America
- VC   Virtual Circuit
- VDE   Association for Electrical, Electronic & Information Technologies
- VM   Virtual Machine

Acronyms (Cont)

- WAN   Wide Area Network
- WCCD   World Council on City Data
- WG   Working Group
- 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