

Internet of Things and Smart Cities Security: Challenges and Issues



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These slides are available on-line at:

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



1. A Layered Model of IoT and Smart Cities
2. Challenges: Non-Technical and Technical
3. IoT/Smart City Security
4. 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



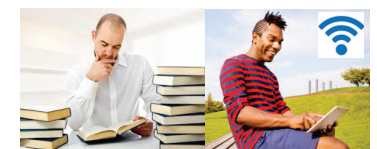
Smart Industries



Smart Cities

What's Smart?

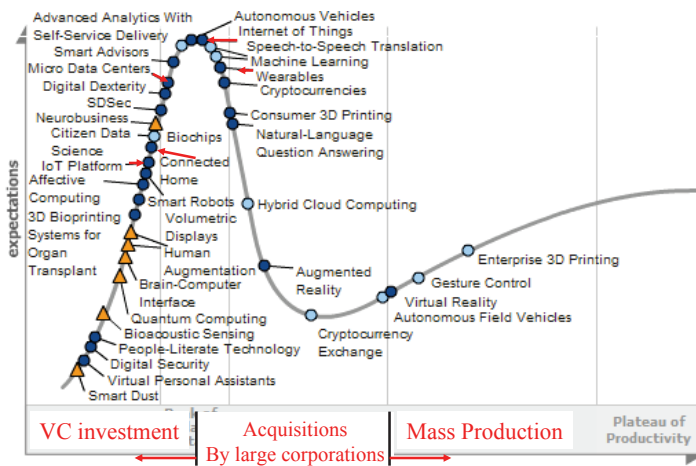
- ❑ Old: Smart = Can think \Rightarrow Computation
 = Can Recall \Rightarrow Storage
- ❑ Now: Smart = Can find quickly, Can Delegate
 \Rightarrow Communicate = Networking
- ❑ Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, ...



Not-Smart

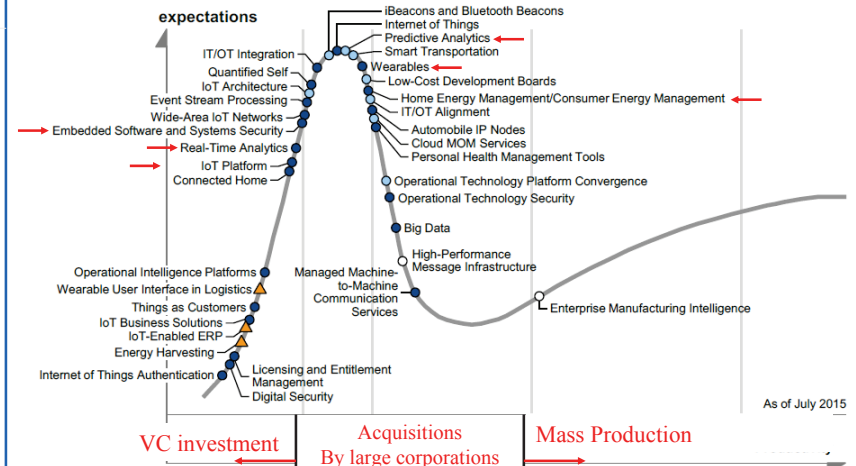
Smart

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&stkw=hype%20cycle%202015&refval=156919648&qid=f661993355944ace1c8c01ec2df676d9>
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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.
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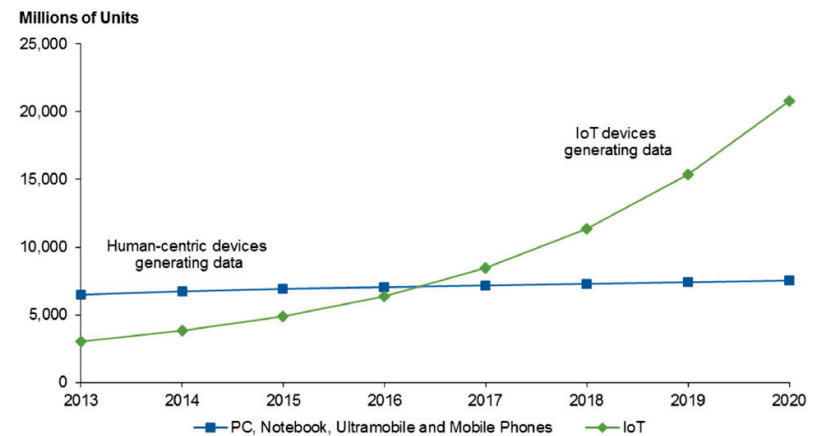
Google Trends



- 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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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 Business Opportunity

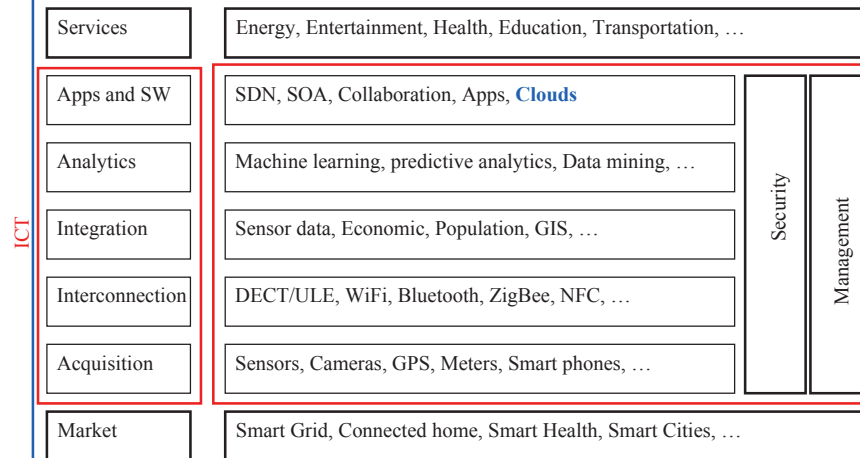


- ❑ \$1.7 Trillion by 2020 - IDC
- ❑ \$7.1 Trillion - Gartner
- ❑ \$10-15 Trillion just for Industrial Internet – GE
- ❑ \$19 Trillion – Internet of Everything - Cisco

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/>

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A 7-Layer Model of IoT



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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, ...

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IoT is a Data (\$) Mine

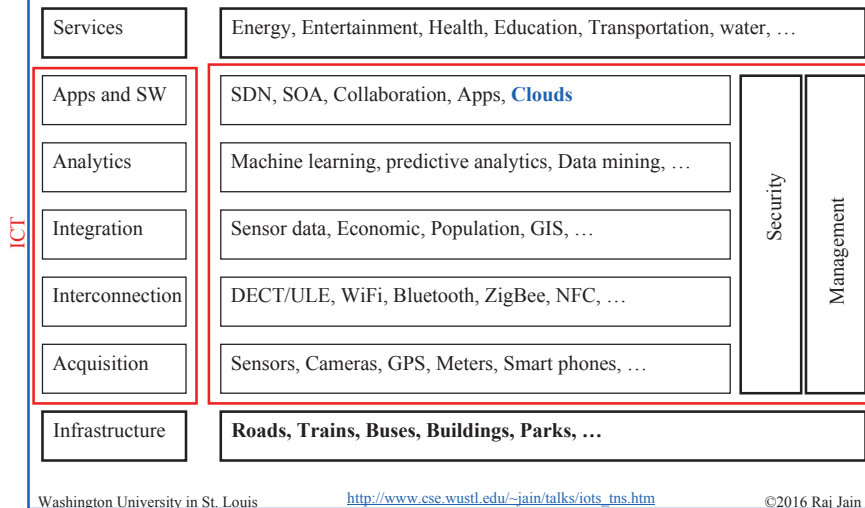


Ref: <https://www.pinterest.com/iofficecorp/humor/>
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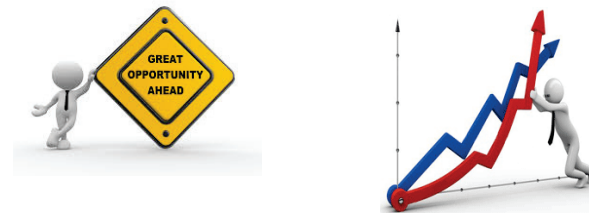
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A 7-Layer Model of Smart Cities



13

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>
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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/>

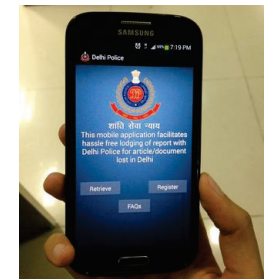
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Smart Services: Examples

- 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.



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Challenges

- Financing:** Self-sustaining \Rightarrow Revenue generating.
Federal or state financing is just “seed” funding
Private Partnerships \Rightarrow Revenue sharing or bartering
- Ensuring **fairness** to all localities of a city
 \Rightarrow Private companies want the best revenue generating areas
- Public Trust:** in government, the data, and expect actions
Lack of transparency \Rightarrow Waste of money on technologies
- Customization:** Every city is different.
Private companies want to reuse their “one solution for all”
- Turnover:** Technology gets outdated every year or two
- Digital **Disruption**
- 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
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Public Trust

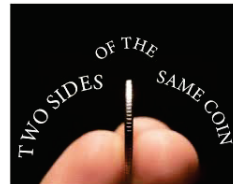


Ref: http://macleodcartoons.blogspot.in/2011/11/01_archive.html
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Digital Disruptions

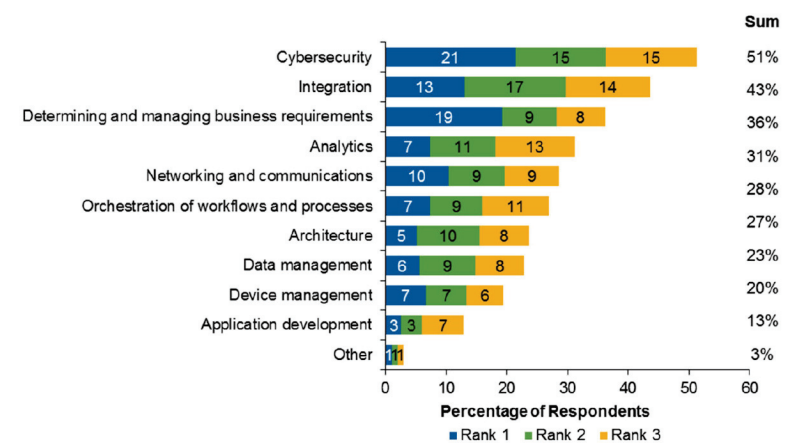
- New methods \Rightarrow Improvements
 \Rightarrow Disruption to old methods
- Automation \Rightarrow Better efficiency
 \Rightarrow What to do with those replaced
- Privatization, Automation, Change \Rightarrow Strikes



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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,
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20

IoT Security: Popular Approach

I have finished studying other companies' IoT Security strategies. "Close your eyes and hope for the best!" seems to be the most popular.



Ref: <http://cloudtweaks.com/2011/08/the-lighter-side-of-the-cloud-the-migration-strategy/>
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21

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,
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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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23

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



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

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27

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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Smart City Insecurity

- ❑ **Smart Court House:** Placer county courthouse accidentally 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

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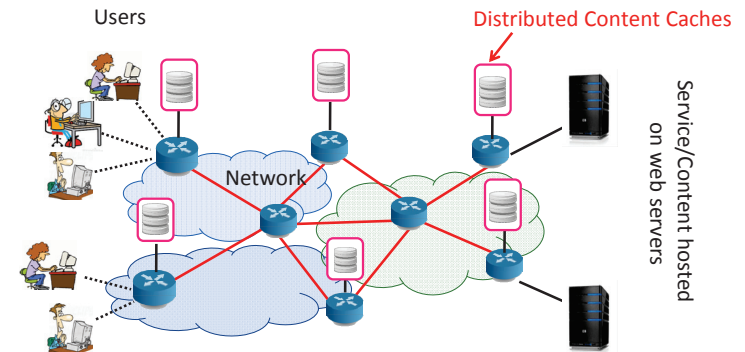
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Past: Data in the Edge

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



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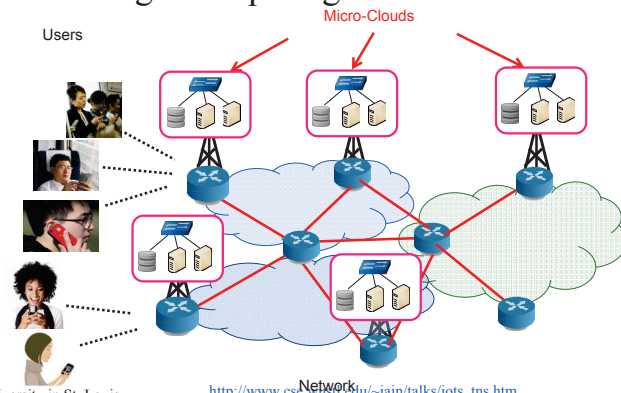
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Trend: Computation in the Edge

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



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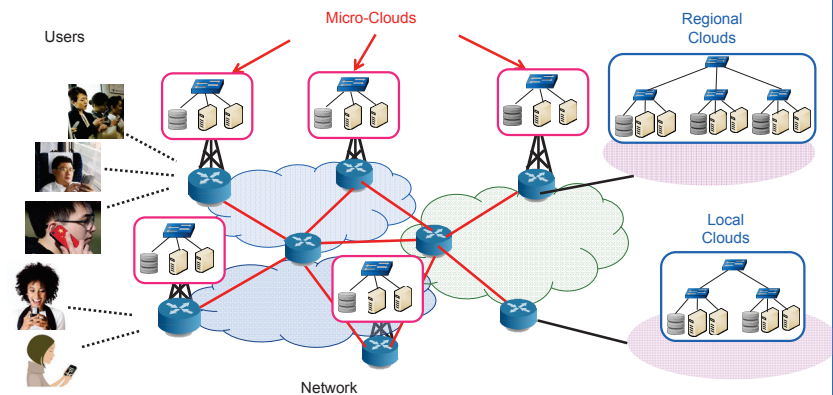
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Trend: Multi-Cloud

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



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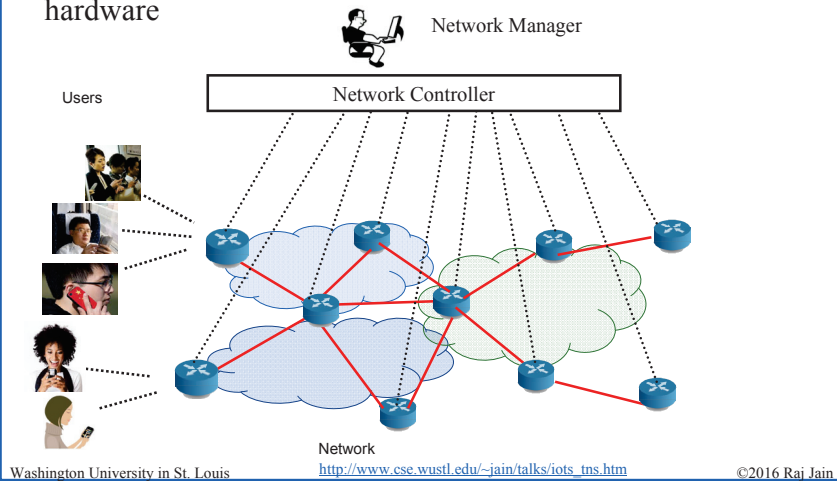
http://www.cse.wustl.edu/~jain/talks/iots_tns.htm

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Past: Software Defined Networking

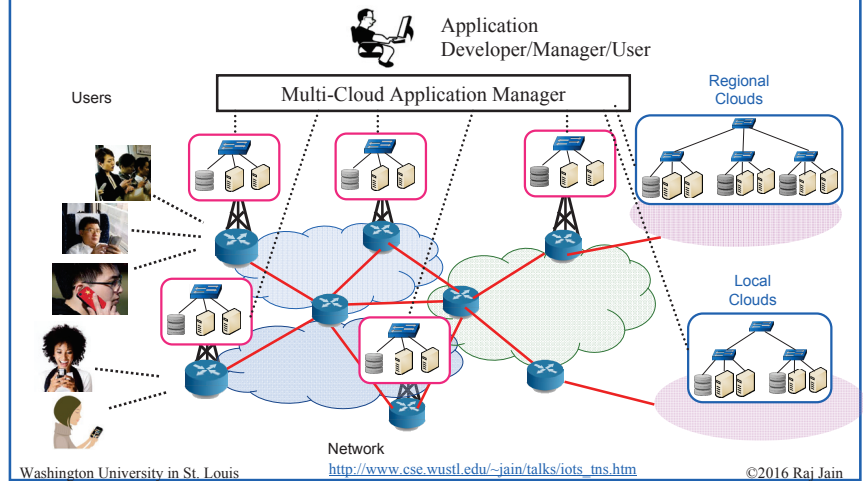
- Network can be managed w/o worrying about individual device hardware



33

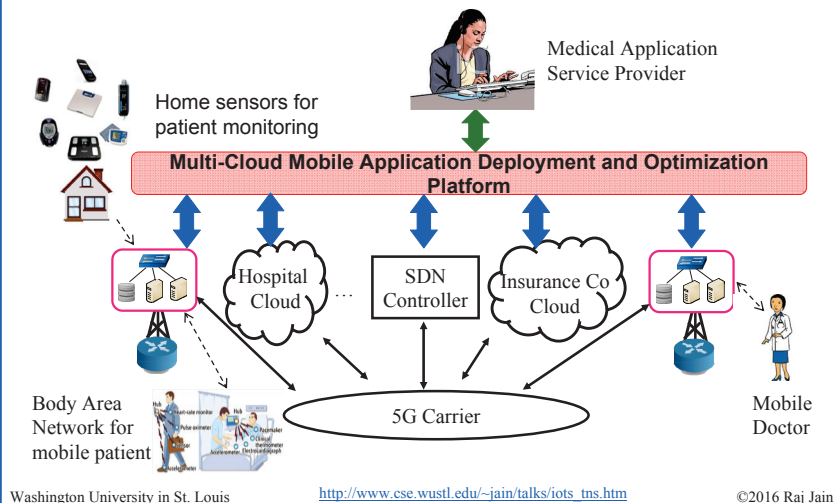
Trend: Software Defined Multi-Cloud Application Delivery

- Cloud MOM (message oriented middleware)



34

Mobile Healthcare Use Case



35



Summary

- Smart \neq High-Speed Computation, Smart \neq Big Data Storage, Smart = Networked
- 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.
- Numerous challenges: Sustainable partnerships, Digital disruption, fast technology turnover, trust. Security and privacy are most important issues
- Computation is moving to the Edge \Rightarrow Fog Computing \Rightarrow Multi-Cloud/Inter-Cloud
- Our MCAD abstracts/virtualizes the cloud interfaces and allows automated management of security and other policies of multi-cloud applications

36

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/iotworld.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 Erbad, "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 Intelligence 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)

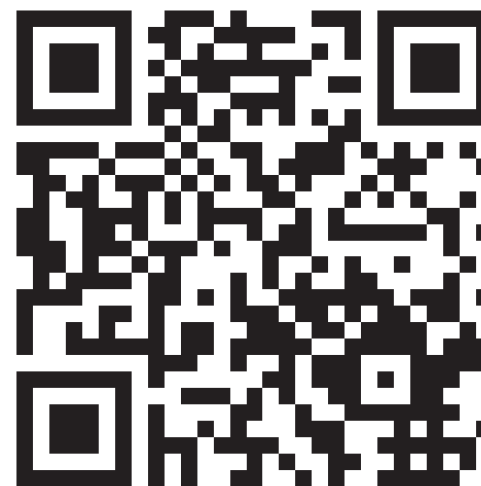
- ❑ TCG Trusted Computing Group
- ❑ TCP Transmission Control Protocol
- ❑ TLS Transport Level Security
- ❑ TMB Technical Management Board
- ❑ TNC Trusted Network Connect
- ❑ TPM Trusted Platform Module
- ❑ TR Technical Report
- ❑ TS Technical Specification
- ❑ TV Television
- ❑ UDP User Datagram Protocol
- ❑ 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

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