Recent Advances in Networking and their Impact on Smart Cities

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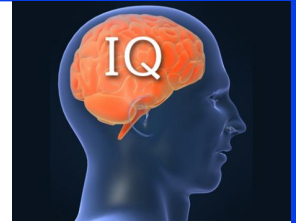Keynote at 4th IEEE International Smart Cities Conference (ISC2), Kansas City, MO, September 16-19, 2018

These slides and a video of this talk are at:
http://www.cse.wustl.edu/~jain/talks/smrtciti.htm

Overview

1. Areas of Research for Smart Cities
2. Security
3. Blockchains
4. AI and Machine Learning
5. Micro-Clouds, Edge Computing

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	46-59	60-75	76-90	91-100
Aspirational	Bronze	Silver	Gold	Platinum

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

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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)

List of Smart Cities

❑ World Council on City Data (WCCD): Worldwide 90 cities are on the list. Only five from US:

Year	City	Level
2014	Boston	Platinum
2015	Los Angeles	Platinum
2016	San Diego	Platinum
2016	Doral	Platinum
2017	Portland	Platinum

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

Trend: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

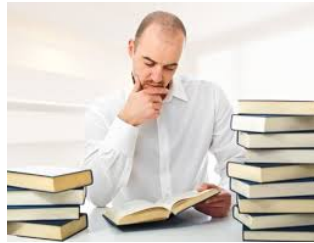Smart Space

Smart Industries

Smart Cities

What's Smart?

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

❑ Later: Smart = Can recall $\Rightarrow$ Storage

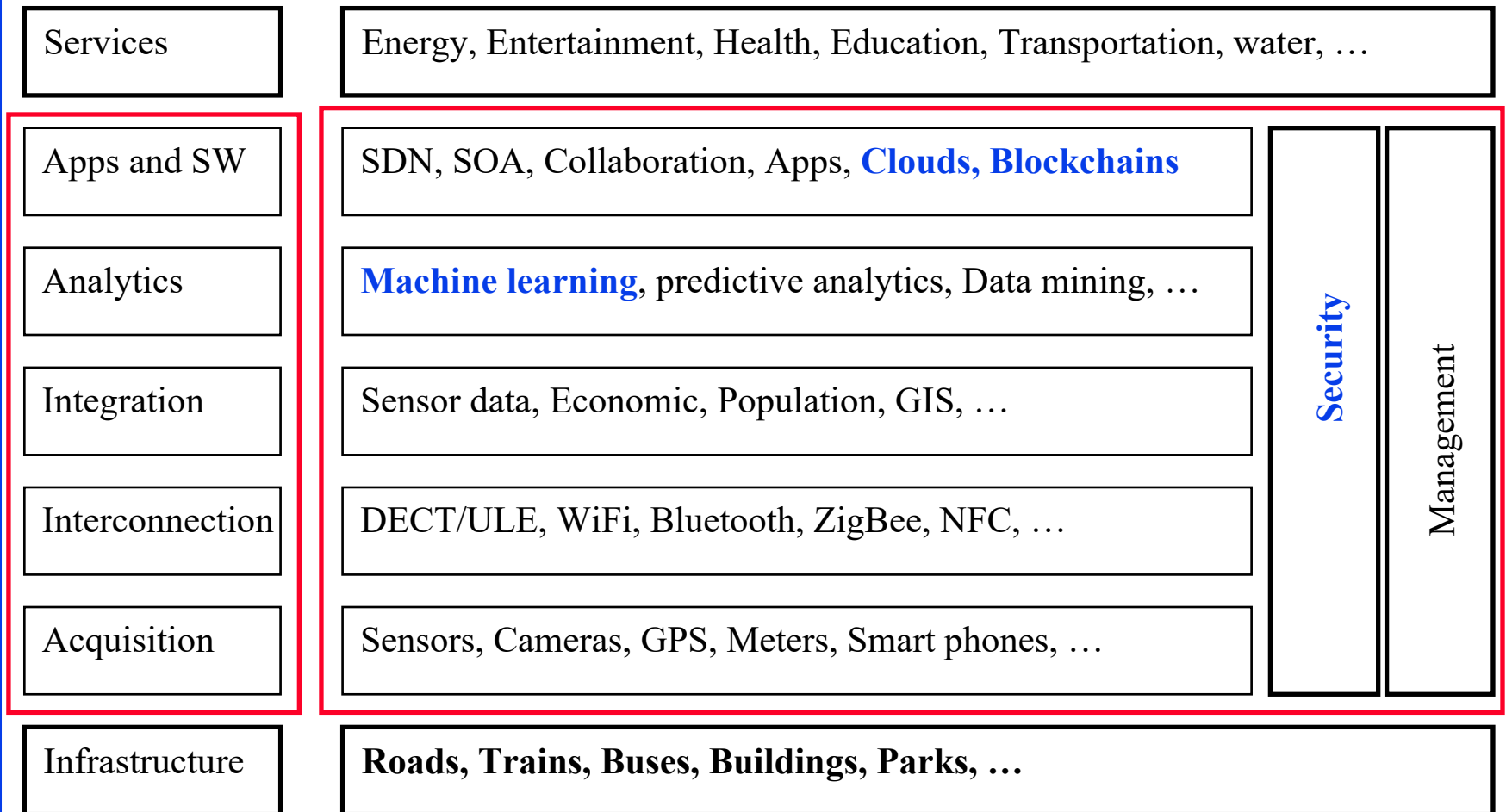❑ Now: Smart = Can communicate $\Rightarrow$ Connected

Not-Smart Smart

❑ Smart City predates all other smart things:
1992: World Foundation for Smart Communities –
Smart City = Technology, Innovation, Globalization
$\Rightarrow$ 36 years old problem

❑ Smart = Apply the latest **technology** to solve problems

Ref: Gibson, D.V., Kozmetsky, G., Smilor, R.W. (eds.), "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks," Rowman & Littlefield, New York (1992), 224 pp., ISBN:0847677583

A 7-Layer Model of Smart Cities

Services	Energy, Entertainment, Health, Education, Transportation, water, …
Apps and SW	SDN, SOA, Collaboration, Apps, **Clouds, Blockchains**
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

Ref: ISO/IEC JTC 1, "Smart Cities," 2014, http://www.iso.org/iso/smart_cities_report-jtc1.pdf

Areas of Research for Smart Cities

1. PHY: Smart devices, cameras, sensors giving real-time information

2. Datalink: WiFi, Bluetooth, ZigBee, IEEE 802.15.4, … Broadband: DSL, FTTH, Wi-Fi, 5G, …

3. Routing: Mesh networking, …

4. Data Analytics: Big-data, data mining, **Machine learning**, Predictive analytics, …

5. Apps & Software: SDN, SOA, **Cloud computing**, Web-based collaboration, Social networking, **Blockchains**, …

6. **Security**: Privacy, Trust, Identity, Anonymity, …

Internet of Harmful Things

Researchers at DEFCON 3, hacked a smart toilet, making it flush incessantly and closing the lid repeatedly and unexpectedly. Causing a **Denial of Service (DoS)** Attack.

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

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DEFCON

- ❑ Hacker's conference
- ❑ Held in Las Vegas every July
- ❑ 25,000+ attendees
- ❑ All anonymous

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

Recent DEFCON Topics

- Hacking voting machines
- Outsmarting the smart city (2018)
- Abusing smart cities (2016)
- How to track government spy planes
- Hack connected vehicles
- Hacking the cloud
- Hacking travel routers
- Clone RFID in real time
- Breaking the Uber badge ciphers
- Counterfeit hardware security devices, RSA tokens
- Fool antivirus software using AI
- Break bitcoin hardware wallets
- DARPA Cyber Grand Challenge (2015, 2016)
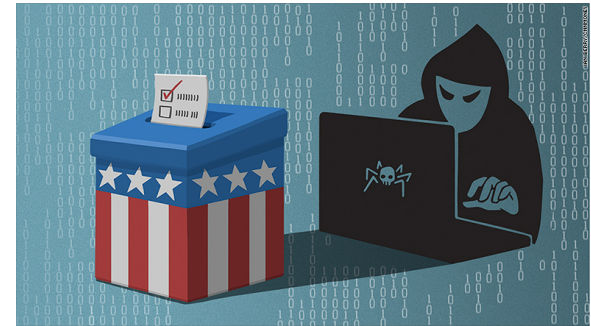
Smart City Cyber Insecurity

❑ **Default passwords**: Admin

❑ Shell injection attacks on **web interface**

❑ **Faulty interface**: Shows device location w/o password

❑ Authentication bypass by tweaking a URL

❑ Traffic control sensors use communication in **clear**

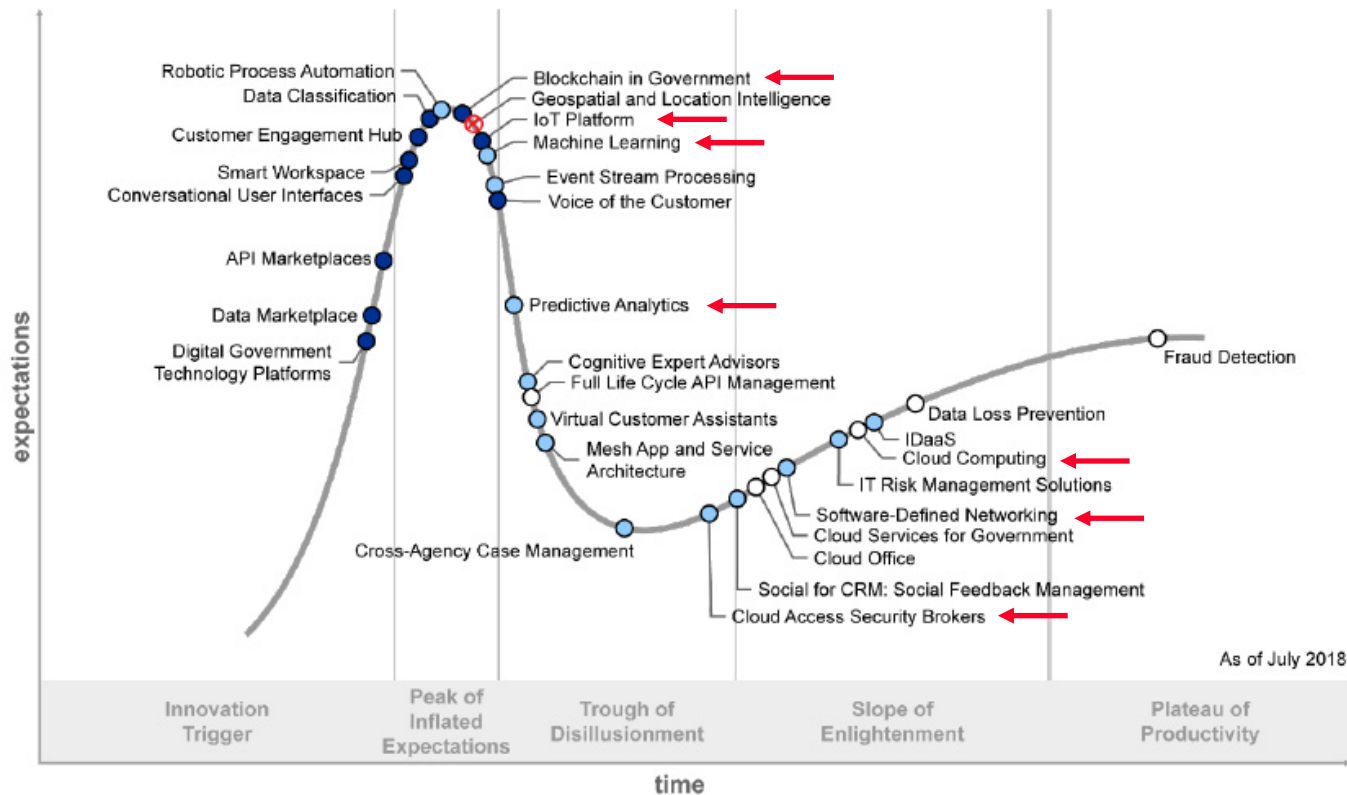❑ **Nation state actors**: Russia vs. USA, North Korea vs. South Korea, India vs. Pakistan

Ref: B. Freed, "It's pretty easy to hack a smart city, cybersecurity researchers find," Statescoop, Aug 9, 2018, https://statescoop.com/its-pretty-easy-to-hack-a-smart-city-cybersecurity-researchers-find

Hype Cycle for Digital Government Technology 2018

Ref: R. Holgate, "Hype Cycle for Digital Government Technology, 2018," Garner Report ID G00340212, 27 July 2018, 68 pp.

Trend: Blockchains

❑ Blockchain is the technology that made Bitcoin secure

❑ Blockchain was invented by the inventor of Bitcoin in October 2008 with source code on 9 January 2009.

❑ After Bitcoin became successful, people started looking into the technology behind Bitcoin and found:

➢ Blockchain is the key for its success

➢ Two complete strangers can complete a transaction/contract without a third party

Example of a Contract: Wedding

Wedding (Cont)

Centralized Trust

Distributed Trust

- Centralized registry

- Single point of failure

- Easier to hacked

- Decentralized

- No single point of failure

- Very difficult to hack

Trend: Centralized to Distributed

❑ **Trend**: Make everything decentralized with no central point of trust

❑ Two perfect strangers can exchange money, make a contract without a trusted third party

❑ Decentralized systems are

1. More secure: Attack tolerant

2. No single bottleneck

3. More reliable: Fault tolerant

4. No single point of control $\Rightarrow$ No monopoly

❑ Blockchain is one way to do this among **untrusted multi-domain** systems.

Time is a cycle: Distributed vs. Centralized debate

Examples of Centralized Systems

❑ **Banks**: Allow money transfer between two accounts

❑ **City Records**

❑ **Voting Authorities**

❑ **Networks:** Certificate Authorities, DNS

❑ In all cases:

1. There is a central third party to be trusted

2. Central party maintains a large database of information
   $\Rightarrow$ Attracts Hackers

3. Central party may be hacked $\Rightarrow$ affects millions

4. Central party is a single point of failure.
   Can malfunction or be bribed.

Ref: Tara Salman, Maede Zolanvari, Aiman Erbad, Raj Jain, and Mohammed Samaka, **"Security Services Using Blockchains:A State of the Art Survey"** IEEE Communications Surveys and Tutorials, Accepted September 2018, 28 pp., http://www.cse.wustl.edu/~jain/papers/bcs.htm

Blockchain Applications for Smart Cities

❑ **Taxes**: Arizona considering accepting Bitcoin for tax payment, [The Motely Fool, Feb 18, 2018]

❑ **Elections**: "Brazilian Electoral System to Use Ethereum Blockchain Network." [NewsBTC, 8 January 2018].

❑ **Social/Disability Assistance**: New York uses Blockchain to give Homeless a Digital Identity. [Fast Company, 6 December 2017].

❑ **Identity**: e-Residency in Estonia, Wired, 27 March 2017 ⇒ 33000 e-residents, 5000 companies

❑ **Entire City Government:** Dubai Sets Its Sights on Becoming the World's First Blockchain-Powered Government. [Forbes, 28 December 2017].

❑ …

Ref: M. Jun, "Blockchain Government," 2018
Ref: R. Holgate, D. Furlonger, R. Howard, "Promising, Practical Blockchain Use Cases for Governments,"
Gartner Report ID G00350893, 12 March 2018, 11 pp.

Blockchain Challenges

❑ High computational cost $\Rightarrow$ 7 bitcoin transactions per second vs. 1,700 visa credit card transactions

❑ Software bugs $\Rightarrow$ Stolen money $\Rightarrow$ Forking in Ethereum

❑ All data is public in public blockchains

Trend: Managed to Self-Driven Networks

❑ **Self-Discover**: Find its components

❑ **Self-Organize and Self-configure**: Trending. Predict.

❑ **Auto-Manage** = Auto-BSS (bill)/Auto-OSS (provision)

❑ **Self-Monitor**: Counters and Probes. Telemetry

❑ **Self-Diagnose and Self-Heal**: Self-Report to human operator

Network Manager

Intent-Based Policy Management

❑ **Intent**: Tell what you want. Not how you want it done. E.g., Tell Google maps where you want to go. Not how to.

❑ **Invariance**: Intent doesn't change if the network changes, devices fail, …

❑ **Portability**: Independent of infrastructure, equipment vendors, service providers, protocols used, media used, …

❑ **Compose-ability**: Can use any infrastructure, …

❑ **Scalable**: From one to billions. Single controllers not scalable.

❑ Action requires context: Actions need to adopt to changes in infrastructure

❑ OpenDaylight has a new project on Network Intent Composition (NIC)

Ref: https://www.sdxcentral.com/articles/contributed/network-intent-summit-perspective-david-lenrow/2015/02/
https://wiki.opendaylight.org/view/Project_Proposals:Network_Intent_Composition

Trend: Smart Cities to Intelligent Cities

❑ **Pollution Control**: Beijing predicts air-pollution based on weather, traffic, and industrial activity

❑ **Real-Time Traffic Prediction**: Hangzhou uses video to monitor accidents, predict congestion and recommend routes

❑ **Disability Assistance**: Barcelona is testing camera glasses for people with visual disabilities. Sound guidance for safe navigation and crossing roads

❑ **Speech API**: for all city applications

Ref: M. Xiang, "Three Rules When Using AI to Add Value to Your IoT Smart Cities," Gartner Report ID G00348452, 29 March 2018, 14 pp.

Machine Learning Challenges

❑ Machine learning is currently a blackbox

❑ ML algorithms are developed/used without domain expertise

❑ Data cleanliness, labeling, feature extractions, all require domain knowledge, e.g.,
What is the distance between Port 80, Port 81, and Port 8080?

❑ Data Imbalance (1 in a million packet is an attack packet).

❑ Use Synthetic data is used $\Rightarrow$ Garbage-In, Garbage-Out

❑ Results are stated without model validation.

❑ Explainability issue $\Rightarrow$ No idea of why the results are what they are

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Random Available Dataset  →  ML  →  Conclusions
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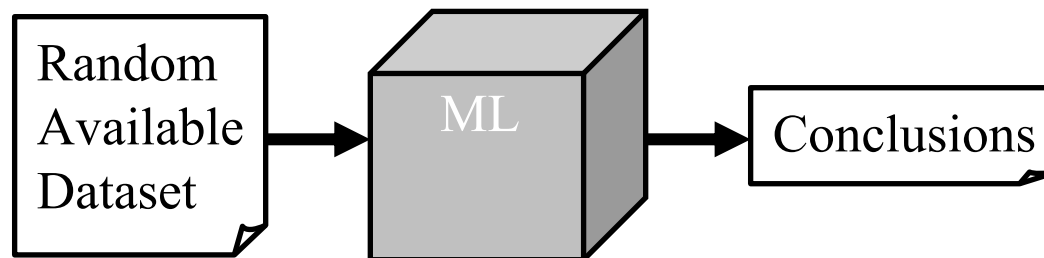
Trend: Clouds to Micro-Clouds

❑ Cloud computing was invented in 2006

❑ Then: Cloud = Large Data Center
Multiple VMs managed by a cloud
management system (OpenStack)

❑ Today: Cloud = Computing using virtual
resources

> μCloud = Cloud in a server with
multiple VMs.

> VMs managed via cloud management
SW, e.g., OpenStack
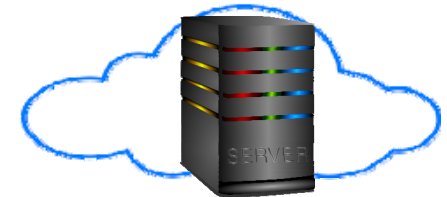
Trend: Core to Edge Computing

❑ To service mobile users/IoT, the computation needs to come to edge ⇒ Mobile Edge Computing
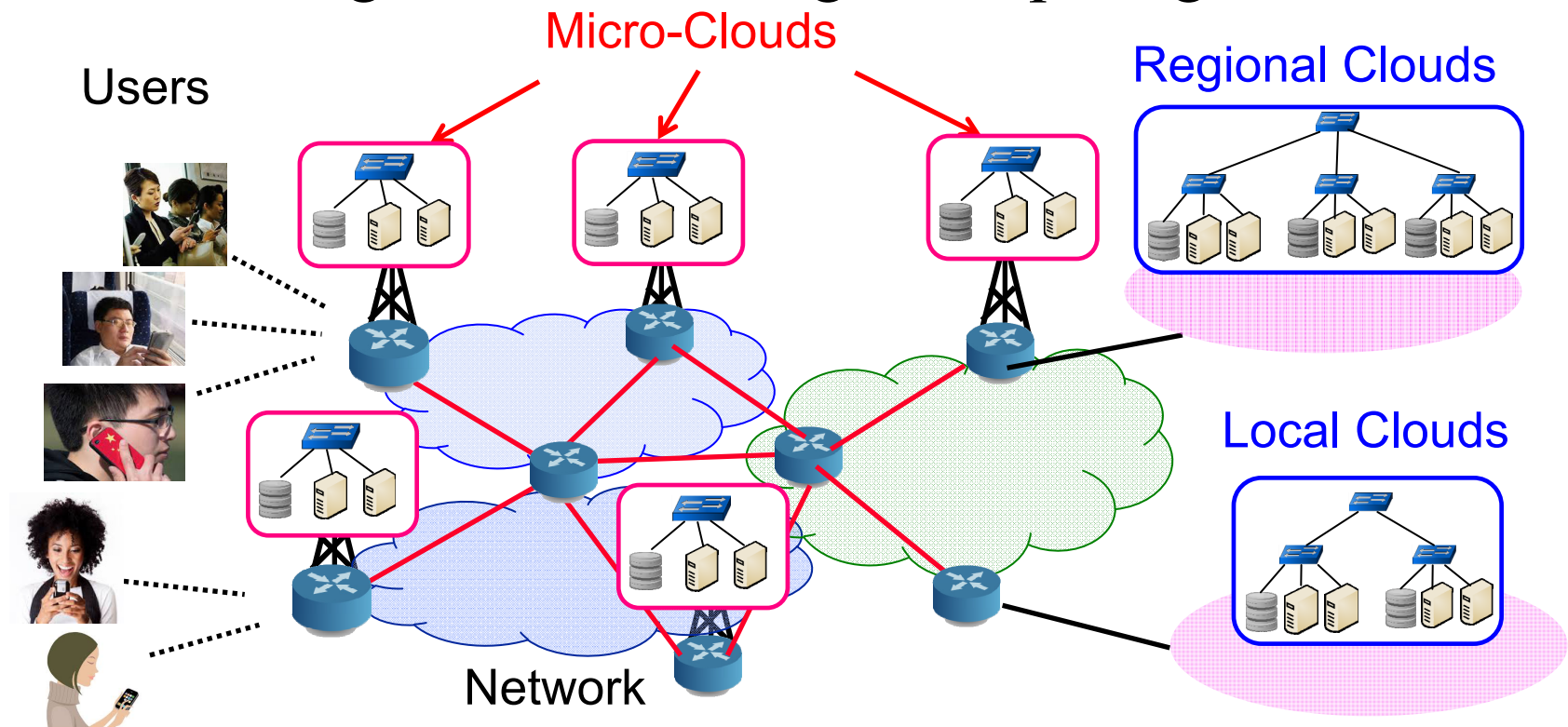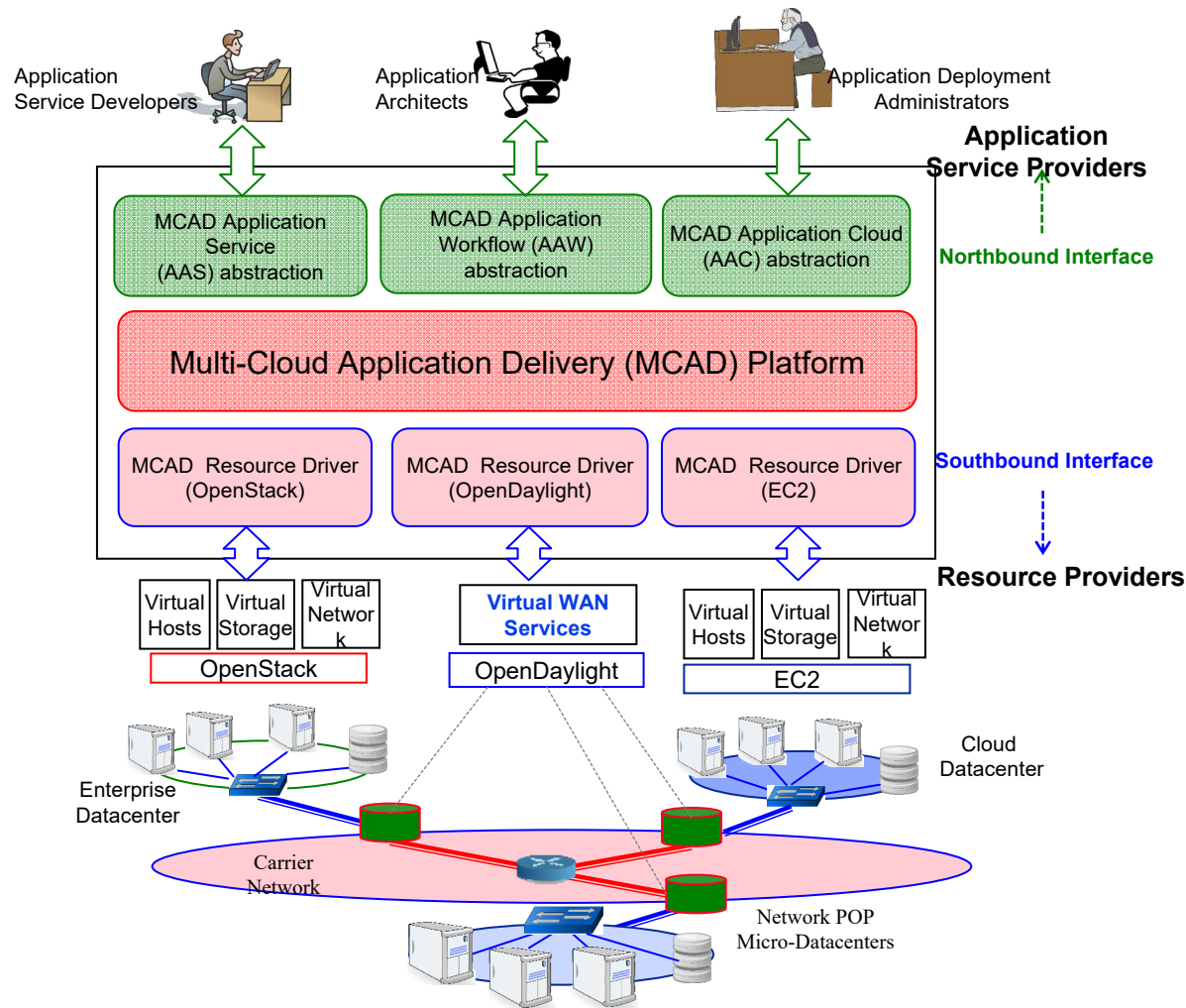

Ref: Lav Gupta, Raj Jain, H. Anthony Chan, "Mobile Edge Computing - an important ingredient of 5G Networks," IEEE Softwarization Newsletter, March 2016, http://www.cse.wustl.edu/~jain/papers/mec16.htm

OpenADN Multi-Cloud Management

Application Service Developers

Application Architects

Application Deployment Administrators

Application Service Providers

MCAD Application Service (AAS) abstraction

MCAD Application Workflow (AAW) abstraction

MCAD Application Cloud (AAC) abstraction

Northbound Interface

Multi-Cloud Application Delivery (MCAD) Platform

MCAD Resource Driver (OpenStack)

MCAD Resource Driver (OpenDaylight)

MCAD Resource Driver (EC2)

Southbound Interface

Resource Providers

Virtual Hosts | Virtual Storage | Virtual Network

OpenStack

Virtual WAN Services

OpenDaylight

Virtual Hosts | Virtual Storage | Virtual Network
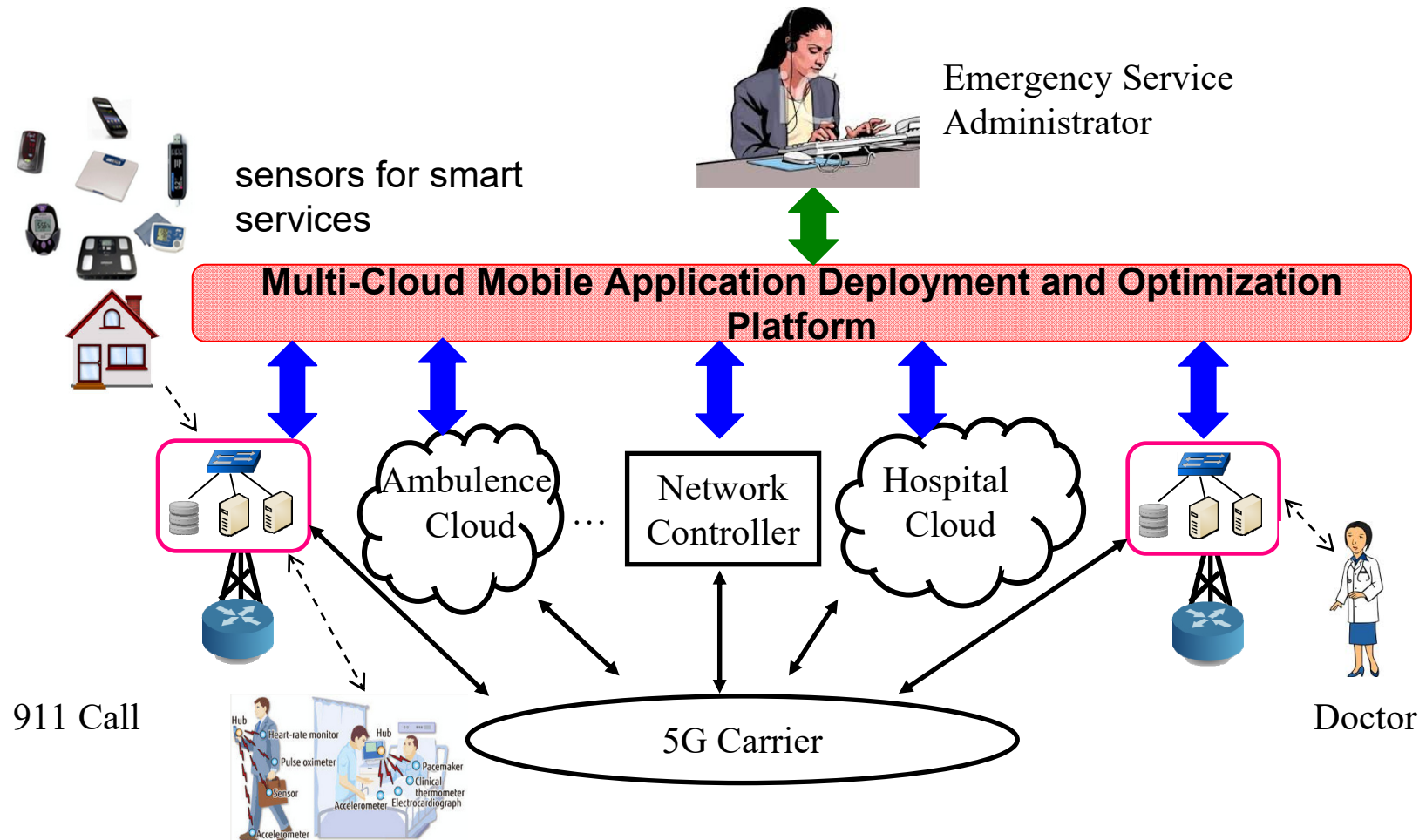
EC2

Enterprise Datacenter

Cloud Datacenter

Carrier Network

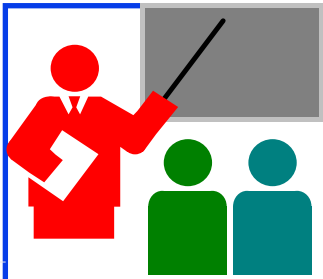Network POP Micro-Datacenters

Ref: Lav Gupta, Raj Jain, Mohammed Samaka, "Analysis of Application Delivery Platform for Software Defined Infrastructures," International Journal of Communication Networks and Distributed Systems, 2016, Vol. 5, http://www.cse.wustl.edu/~jain/papers/ijcnds16.htm

Smart City Use Case for Multi-Clouds

Emergency Service Administrator

sensors for smart services

Multi-Cloud Mobile Application Deployment and Optimization Platform

Ambulence Cloud

...

Network Controller

Hospital Cloud

911 Call

Doctor

5G Carrier

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

Summary

1. Smart ≠ High-Speed Computation, Smart ≠ Big Data Storage, Smart = Networked, Smart = Latest Technology

2. Smart Cities research areas are easy via the 7-layer model Research issues in every layer: Sensors, data link, routing, applications, analytics.

3. Security is the biggest issue with no simple solutions but need to avoid common simple mistakes

4. Blockchains offer a distributed alternative to centralized solutions for cities

5. AI, Machine Learning, Deep Learning is here.
   Need to move from smart cities to intelligent cities

6. Clouds are getting smaller $\Rightarrow$ Micro-Cloud, Edge Computing $\Rightarrow$ Multi-Cloud

Related Papers

Multi-Cloud:

❑ Deval Bhamare, Mohammed Samaka, Aiman Erbad, Raj Jain, Lav Gupta, H. Anthony Chan, **"Optimal Virtual Network Function Placement and Resource Allocation in Multi-Cloud Service Function Chaining Architecture**," Computer Communications, Vol. 102, April 2017, pp. 1-16, http://www.cse.wustl.edu/~jain/papers/comcom17.htm

❑ Deval Bhamare, Raj Jain, Mohammed Samaka, Aiman Erbad, "**A Survey on Service Function Chaining**," Journal of Network and Computer Applications, Vol. 75, Nov 2016, pp. 138-155, http://www.cse.wustl.edu/~jain/papers/jnca16.htm

❑ Lav Gupta, Prof Raj Jain, Prof Mohammed Samaka, Prof Aiman Erbad, and Dr. Deval Bhamare, **"Performance Evaluation of Multi-Cloud Management and Control Systems**," Recent Advances in Communications and Network Technology, 2016, Vol. 5, Issue 1, pp. 9-18, http://www.cse.wustl.edu/~jain/papers/racnt.htm

❑ Subharthi Paul, Raj Jain, Mohammed Samaka, Aiman Erbaud, **"Service Chaining for NFV and Delivery of other Applications in a Global Multi-Cloud Environment**," 21st Annual International Conference on Advanced Computing and Communications (ADCOM) 2015, Chennai, India, September 18-20, 2015, http://www.cse.wustl.edu/~jain/papers/adn_in15.htm

Related Papers (Cont)

Edge Computing:

❑ Lav Gupta, Raj Jain, H. Anthony Chan, "**Mobile Edge Computing - an important ingredient of 5G Networks**," IEEE Softwarization Newsletter, March 2016, http://sdn.ieee.org/newsletter/march-2016/mobile-edge-computing-an-important-ingredient-of-5g-networks

❑ Deval Bhamare, Aiman Erbad, Raj Jain, Mohammed Samaka, "**Automated Service Delivery Platform for C-RANs**," The IEEE Third International Workshop on Mobile Cloud Computing systems, Management, and Security (MCSMS) 2017, Valencia Spain, May 8-11, 2017, http://www.cse.wustl.edu/~jain/papers/mcsms17.htm,

Related Papers (Cont)

AI for Networking:

- Lav Gupta, M. Samaka, Raj Jain, Aiman Erbad, Deval Bhamare, H. Anthony Chan, **"Fault and Performance Management in Multi-Cloud Based NFV using Shallow and Deep Predictive Structures**," 26th International Conference on Computer Communications and Networks (ICCCN 2017), Vancouver, Canada, July 31-Aug 3, 2017, http://www.cse.wustl.edu/~jain/papers/icccn17.htm

- Tara Salman, Deval Bhamare, Aiman Erbad, Raj Jain, Mohammed Samaka, **"Machine Learning for Anomaly Detection and Categorization in Multi-cloud Environments**," The 4th IEEE International Conference on Cyber Security and Cloud Computing (IEEE CSCloud 2017), New York, June 26-28, 2017, http://www.cse.wustl.edu/~jain/papers/cscloud.htm

- Lav Gupta, Mohammed Samaka, Raj Jain, Aiman Erbad, Deval Bhamare, Chris Metz, **"COLAP: A Predictive Framework for Service Function Chain Placement in a Multi-cloud Environment**," The 7th IEEE Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, Jan 9-11, 2017, http://www.cse.wustl.edu/~jain/papers/clp_ccwc.htm

- Deval Bhamare, Tara Salman, Mohammed Samaka, Aiman Erbad, Raj Jain, **"Feasibility of Supervised Machine Learning for Cloud Security**," 3rd International Conference on Information Science and Security (ICISS2016), December 19th - 22nd, 2016, Pattaya, Thailand,, http://www.cse.wustl.edu/~jain/papers/iciss16.htm

Related Talks/Class Lectures

❑ Raj Jain, "**CSE 570: Recent Advances in Networking**," Spring 2018, http://www.cse.wustl.edu/~jain/cse570-18/index.html

❑ Raj Jain, "**Blockchains: Networking Applications**," An invited talk at the 38th IEEE Sarnoff Symposium, Newark, NJ, Sep 19, 2017, http://www.cse.wustl.edu/~jain/talks/blc_srnf.htm

❑ Raj Jain, "**The Catch-up Game: Quest for the Impact**," Keynote at ACM SIGCOMM 2017, Los Angeles, CA, August 22, 2017, http://www.cse.wustl.edu/~jain/talks/sigcomm.htm

❑ Raj Jain, "**Multi-Cloud Global Application Delivery for Smart Cities**," International Summit on Smart World and Smart Cities, Fremont, CA, USA, Aug 5, 2017, http://www.cse.wustl.edu/~jain/talks/smrtwrld.htm

Related Papers (Cont)

IoT:

❑ Tara Salman, Raj Jain, **"A Survey of Protocols and Standards for Internet of Things**," Advanced Computing and Communications, Vol. 1, No. 1, March 2017, http://www.cse.wustl.edu/~jain/papers/iot_accs.htm

Blockchains:

❑ Tara Salman, Maede Zolanvari, Aiman Erbad, Raj Jain, and Mohammed Samaka, **"Security Services Using Blockchains:A State of the Art Survey"** IEEE Communications Surveys and Tutorials, Accepted September 2018, 28 pp., http://www.cse.wustl.edu/~jain/papers/bcs.htm

List of Acronyms

- AAS   Application Service Abstraction
- AAW   Application Workload Abstraction
- AI   Artificial Intelligence
- API   Application Programming Interface
- BGP   Border Gateway Protocol
- CapEx   Capital Expenditure
- CCWC   Computing and Communication Workshop and Conference
- DARPA   Defense Advanced Research Project Agency
- DECT   Digital Enchanced Cordless Communication
- DEFCON   D-E-F Conference
- DNS   Domain Name Service
- DSL   Digital Subscriber Line
- EC2   Elastic Compute 2
- FTTH   Fiber to the home
- GIS   Geographic Information System

Acronyms (Cont)

- GPS   Global Positioning System
- HP   Hewlett Packard
- ICISS   International Conference on Information Science and Security
- ICT   Information and Communications Technologies
- ID   Identifier
- IoT   Internet of Things
- IP   Internet Protocol
- MCAD   Multi-Cloud Application Delivery
- MCSMS   Mobile Cloud Computing systems, Management, and Security
- MIT   Massachusetts Institute of Technology
- ML   Machine Learning
- NFC   Near-Field Communication
- OpenADN   Open Application Delivery Network
- SDN   Software Defined Networking
- SW   Software
- TCP   Transmission Control Protocol

Acronyms (Cont)

- ❏ TV   Television
- ❏ ULE   Ultra-Low Energy
- ❏ URL   Uniform Resource Locator
- ❏ VC   Venture Capitalist
- ❏ Wi-Fi   Wireless Fidelity
- ❏ XML   eXtended Markup Language

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