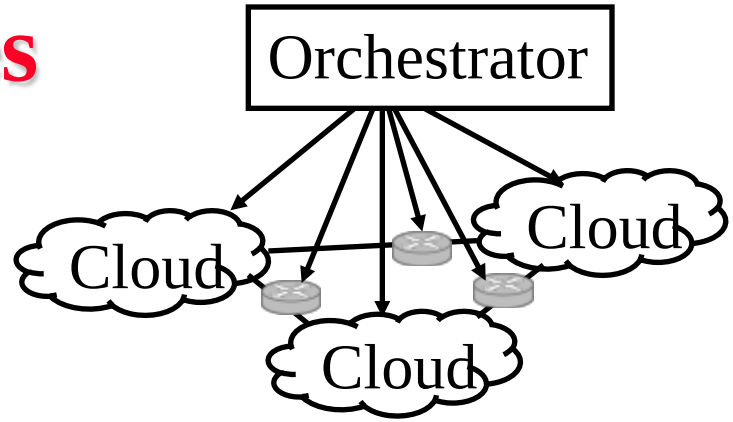
Current Trends in Networking With Applications to Internet of Things and Smart Cities



Raj Jain
Washington University in Saint Louis
Jain@wustl.edu

Keynote at 2017 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT), Amman, Jordan, October 12, 2017

These slides and recording of this talk are available on-line at:
http://www.cse.wustl.edu/~jain/talks/aeect17.htm

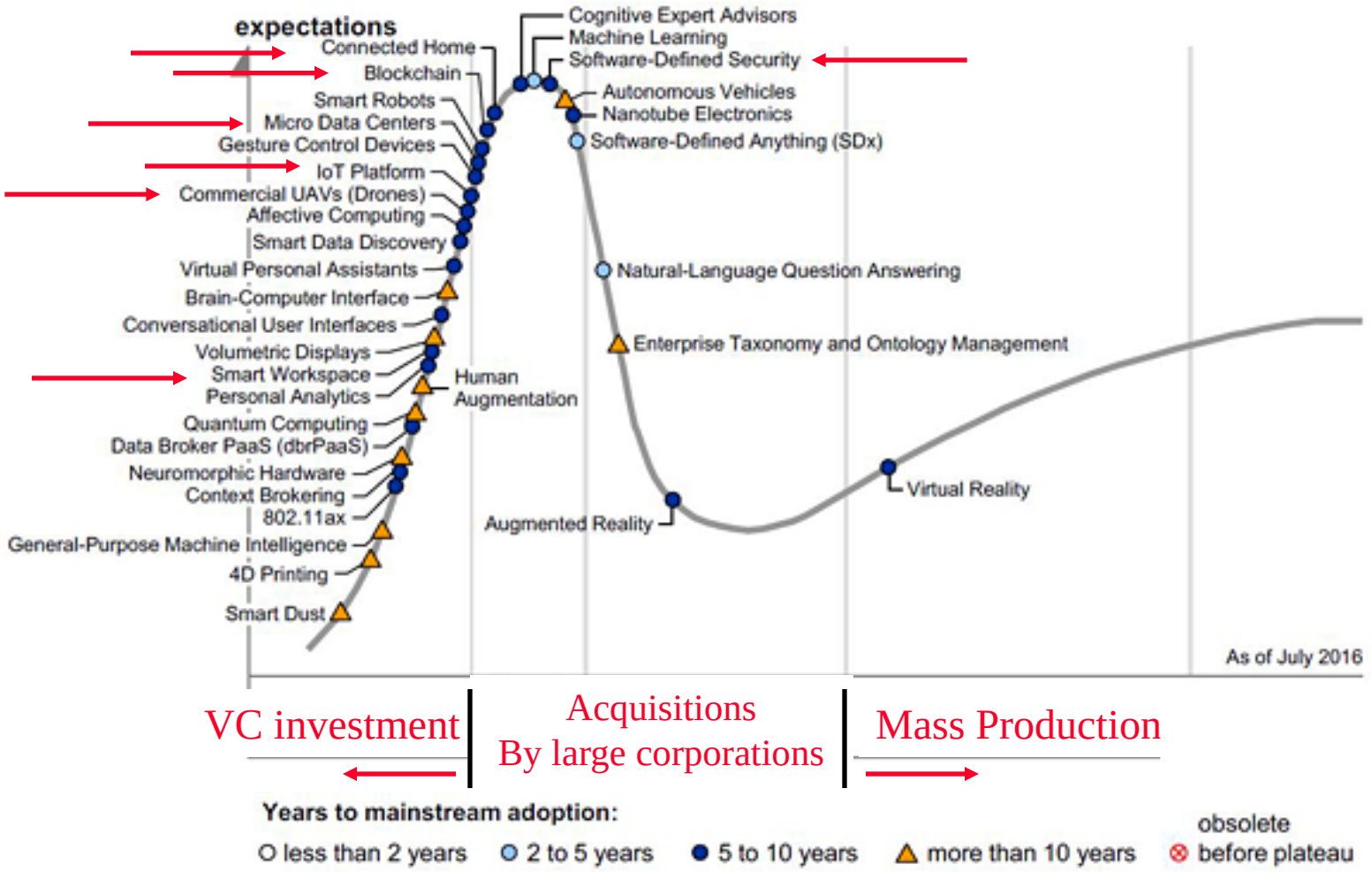
Overview

1. Hot topics for research impact
2. Current Trends/hot topics in Networking
3. Areas for Research for Smart Cities
4. Blockchains for Smart Cities and Cyber Security

Selecting the Right Problems

- Important question for **students**, academics, entrepreneurs, and companies
- Goal: To impact
- Follow the **paradigm shifts**:
  - 1980: Ethernet
  - 1990: ATM Networks
  - 2000: Optical Networks
  - 2005: Wireless Networks
  - 2010: Next Generation Internet/SDN
  - 2013: Multi-Cloud Computing
  - 2017: Whatever is being **hyped** this year?

Gartner Hype Cycle 2016



Ref: Gartner, "Hype Cycle for Emerging Technologies, 2016," July 2016, [subscribers only], gartner.com/document/3383817

Trend 1: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

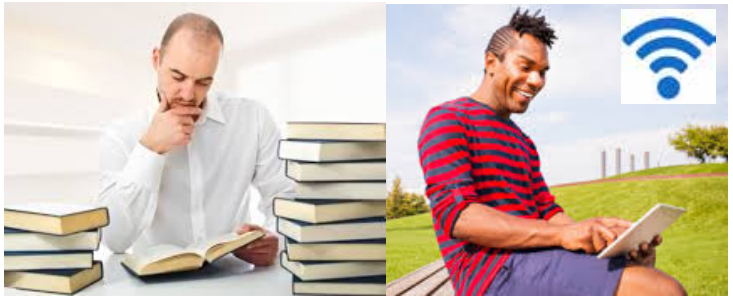
Smart Space

Smart Industries

Smart Cities

What's Smart?

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



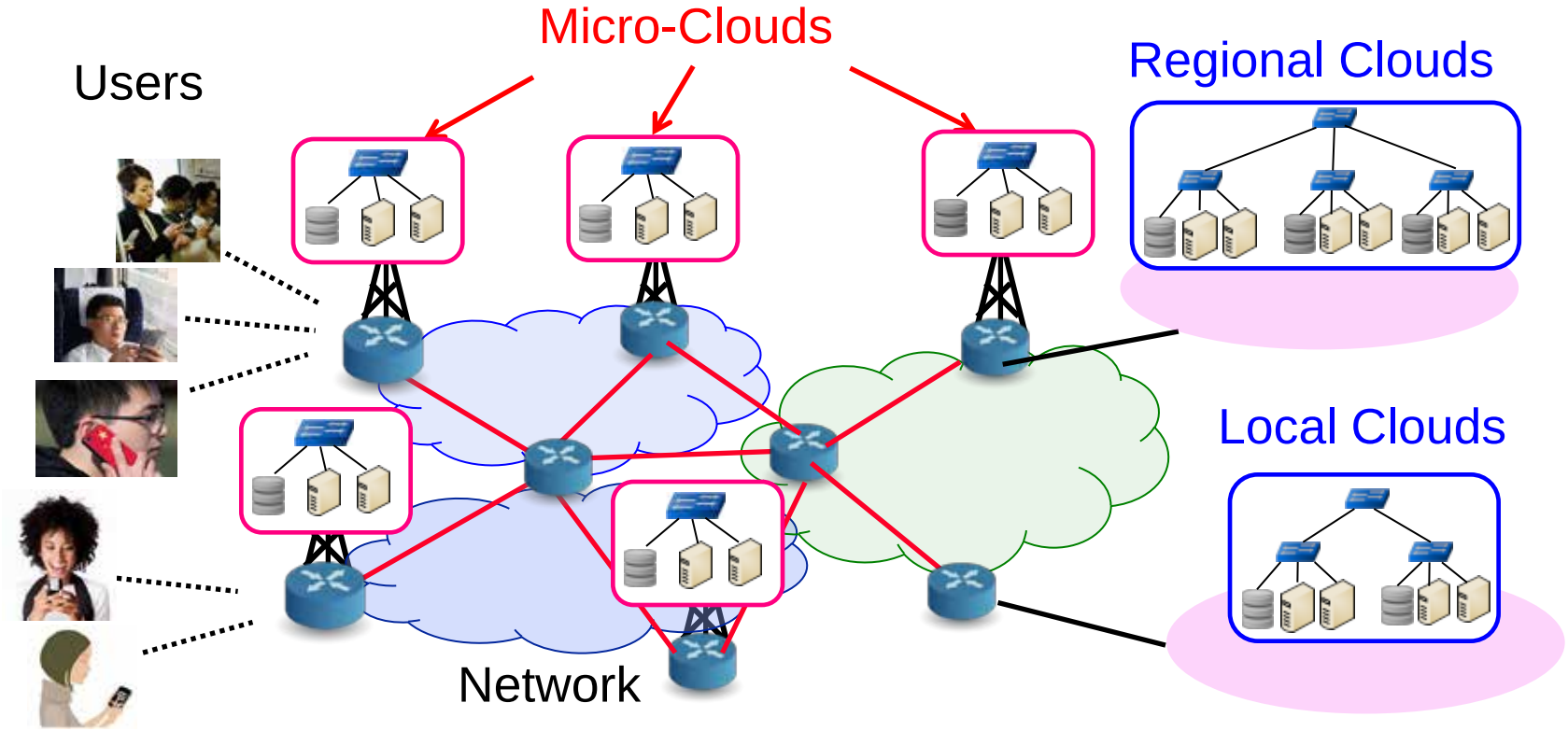
Not-Smart Smart

Trend 2: Micro-Cloud Computing

- 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
  - mCloud = Cloud in a server with multiple VMs.
  - Each VM with Multiple Containers Þ Multiple Services

Trend 3: Mobile Edge Computing

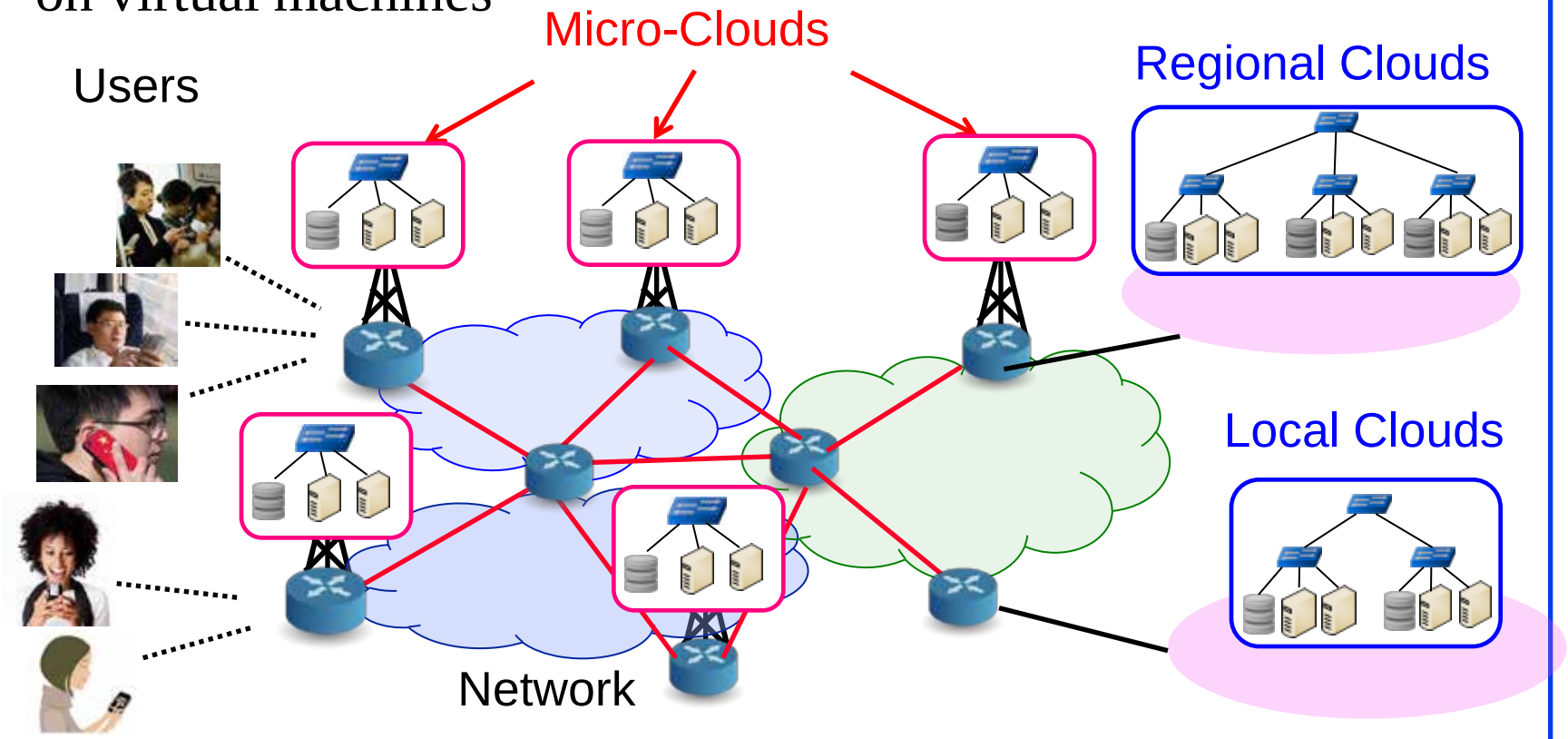
- To service mobile users/IoT, the computation needs to come to edge Þ Mobile Edge Computing



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

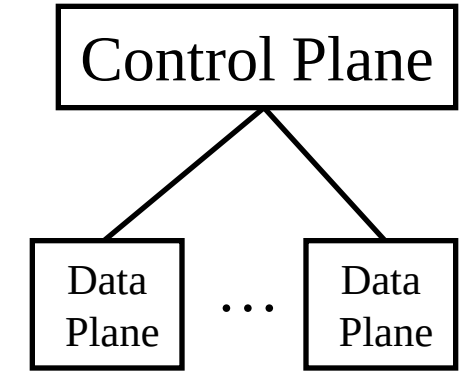
Trend 4: Micro-Services

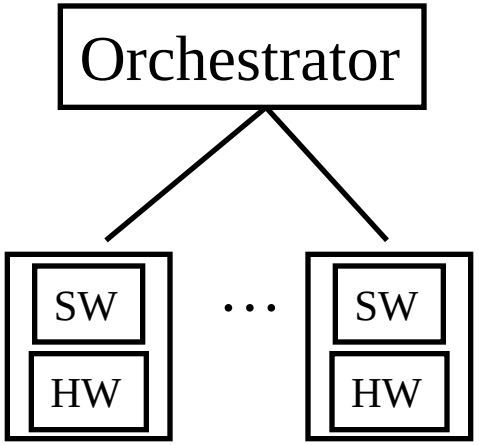
- All major applications, such as, Facebook, Netflix, etc. consist of a number of micro-services that are instantiated on demand on virtual machines



Trend 5: Software Defined Everything

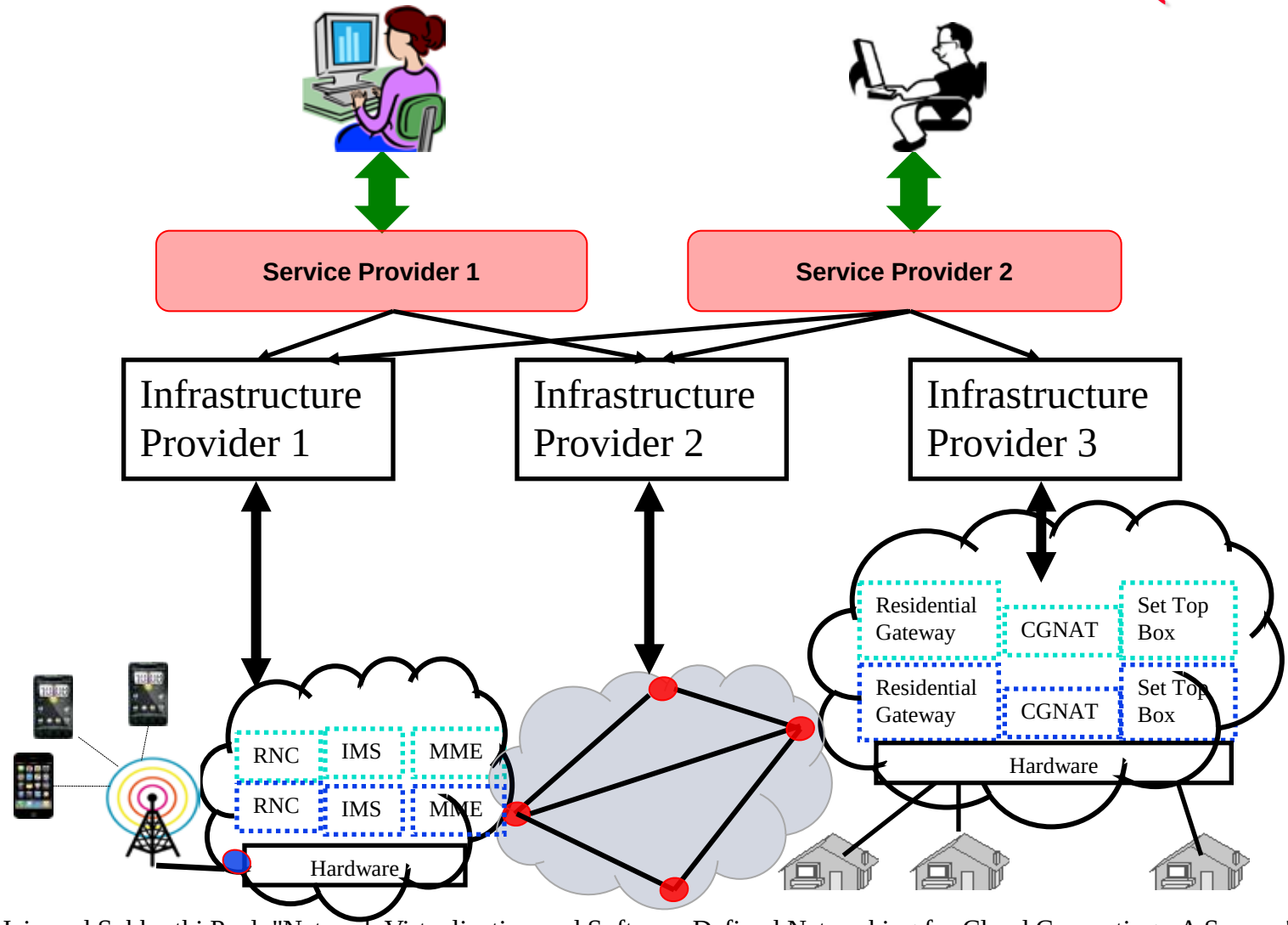
- SDN was invented in 2009
- Then: SDN:
  - Separation of control and data planes
  - Centralization of Control
  - Standard Protocol between the planes
- Now: Software Defined Everything (SDE) = **Disaggregation** of hw/sw
  - Commodity hardware
  - Software that runs on commodity hw
  - Open Source Software
    - Service industry
  - Controller replaced by Orchestrator
  - Centralization of policies





Ref: D. M Batista, G. Blair, F. Kon, R. Boutaba, D. Hutchison, R. Jain, R. Ramjee, C. Rothenberg, "Perspectives on software-defined networks: interviews with five leading scientists from the networking community" Journal of Internet Services and Applications 2015, 6:22, http://www.cse.wustl.edu/~jain/papers/jisa15.htm

Trend 6: Network Function Virtualization (NFV)

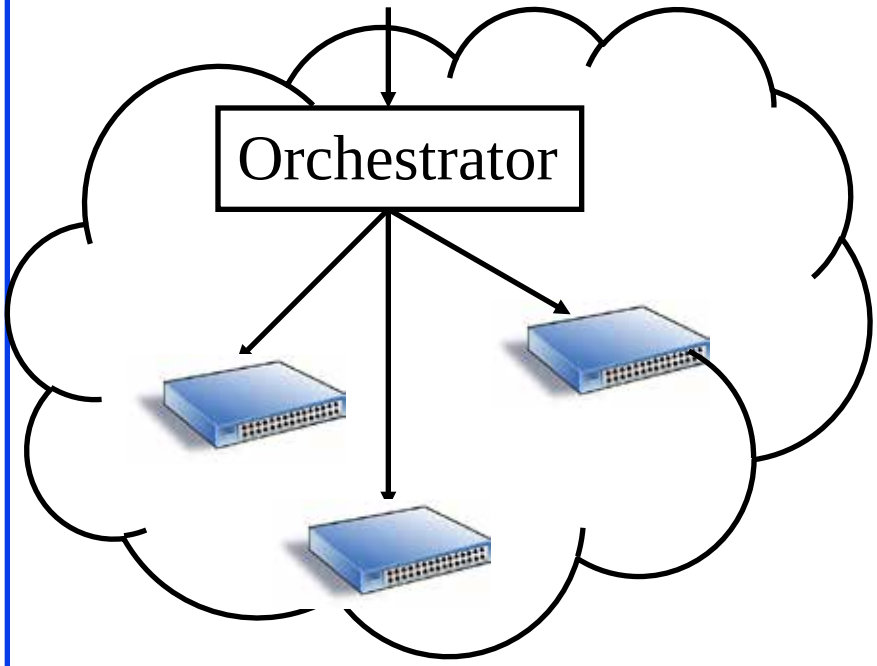


Ref: Raj Jain and Subharthi Paul, "Network Virtualization and Software Defined Networking for Cloud Computing - A Survey," IEEE Communications Magazine, Nov 2013, pp. 24-31, http://www.cse.wustl.edu/~jain/papers/net_virt.htm

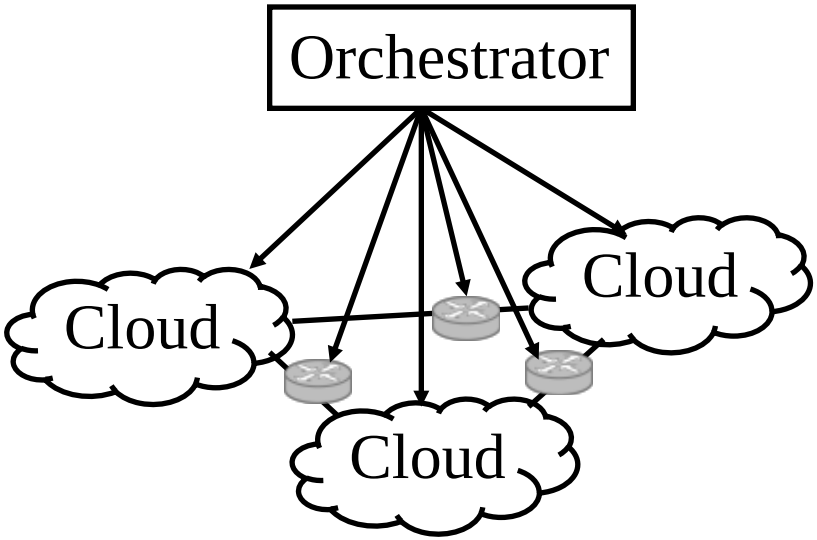
Trend 7: Software Defined Multi-Cloud

- Orchestrating devices to Orchestrating Clouds

Datacenter Applications

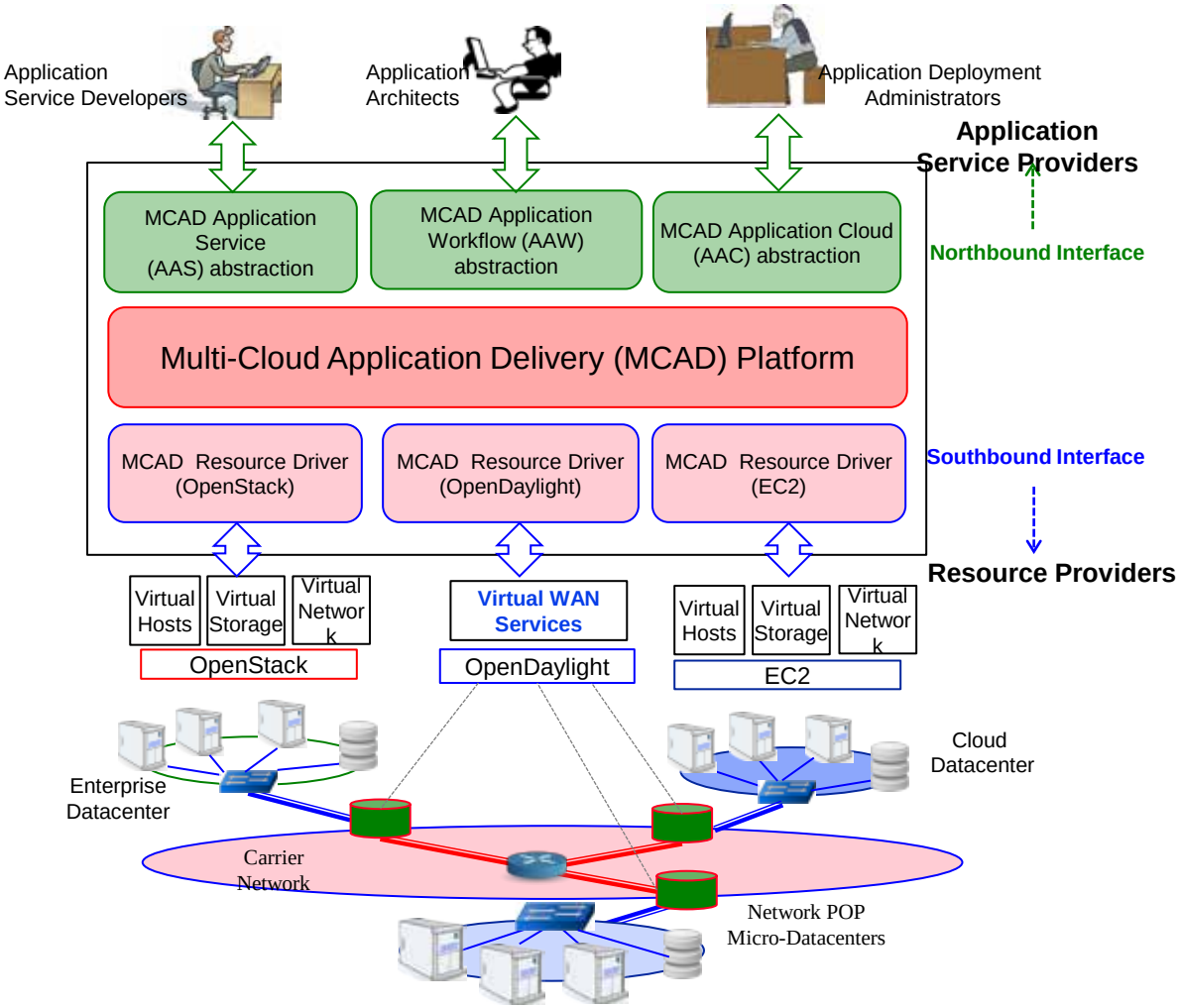


Global Applications



Ref: 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, December 2013, http://www.cse.wustl.edu/~jain/papers/comnet14.htm

OpenADN Multi-Cloud Management



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

Mobile Healthcare Use Case

Medical Service Administrator

Home sensors for patient monitoring

Multi-Cloud Mobile Application Deployment and Optimization Platform

Hospital Cloud

…

SDN Controller

Insurance Co Cloud

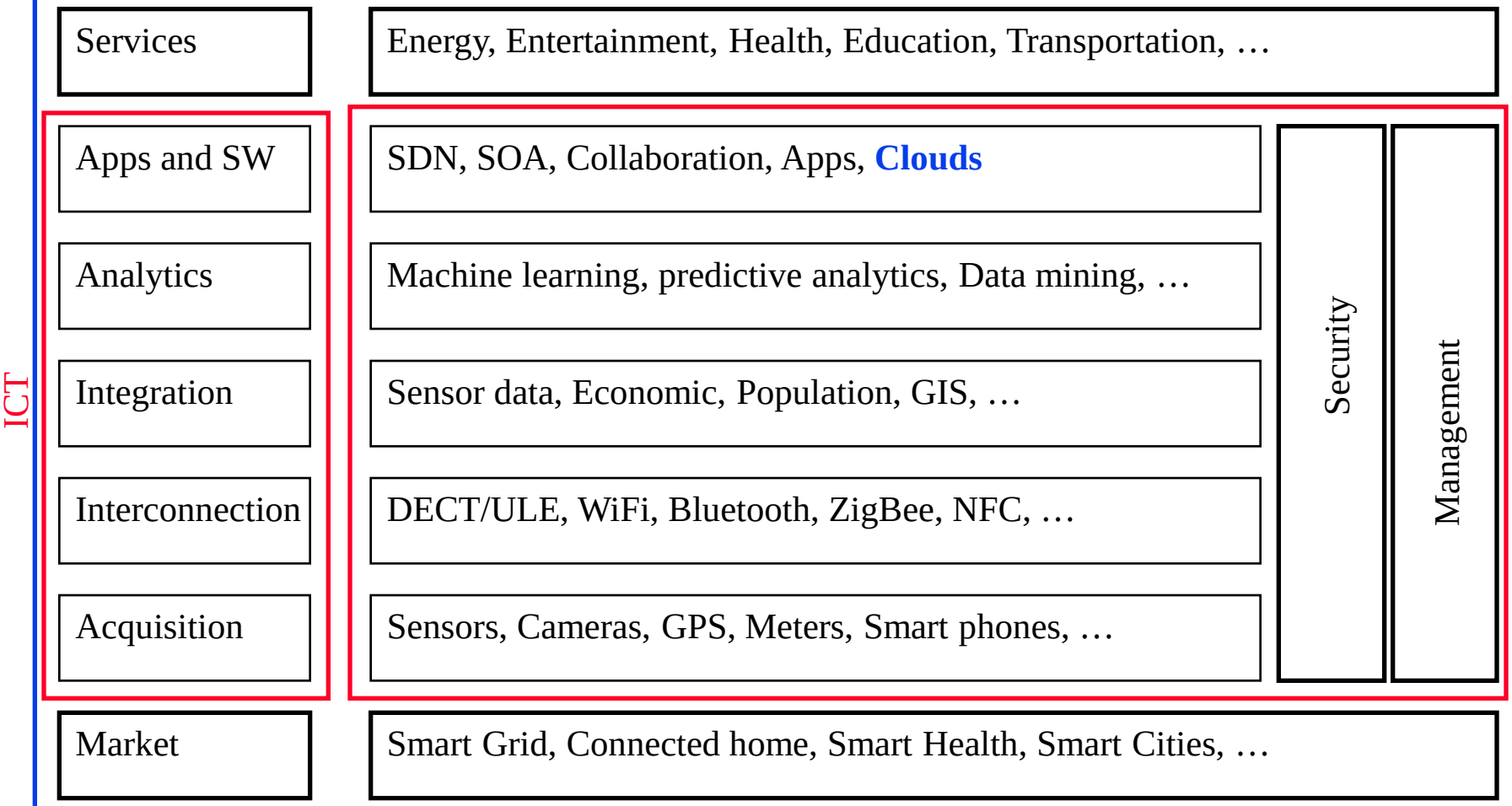
Body Area Network for mobile patient

5G Carrier

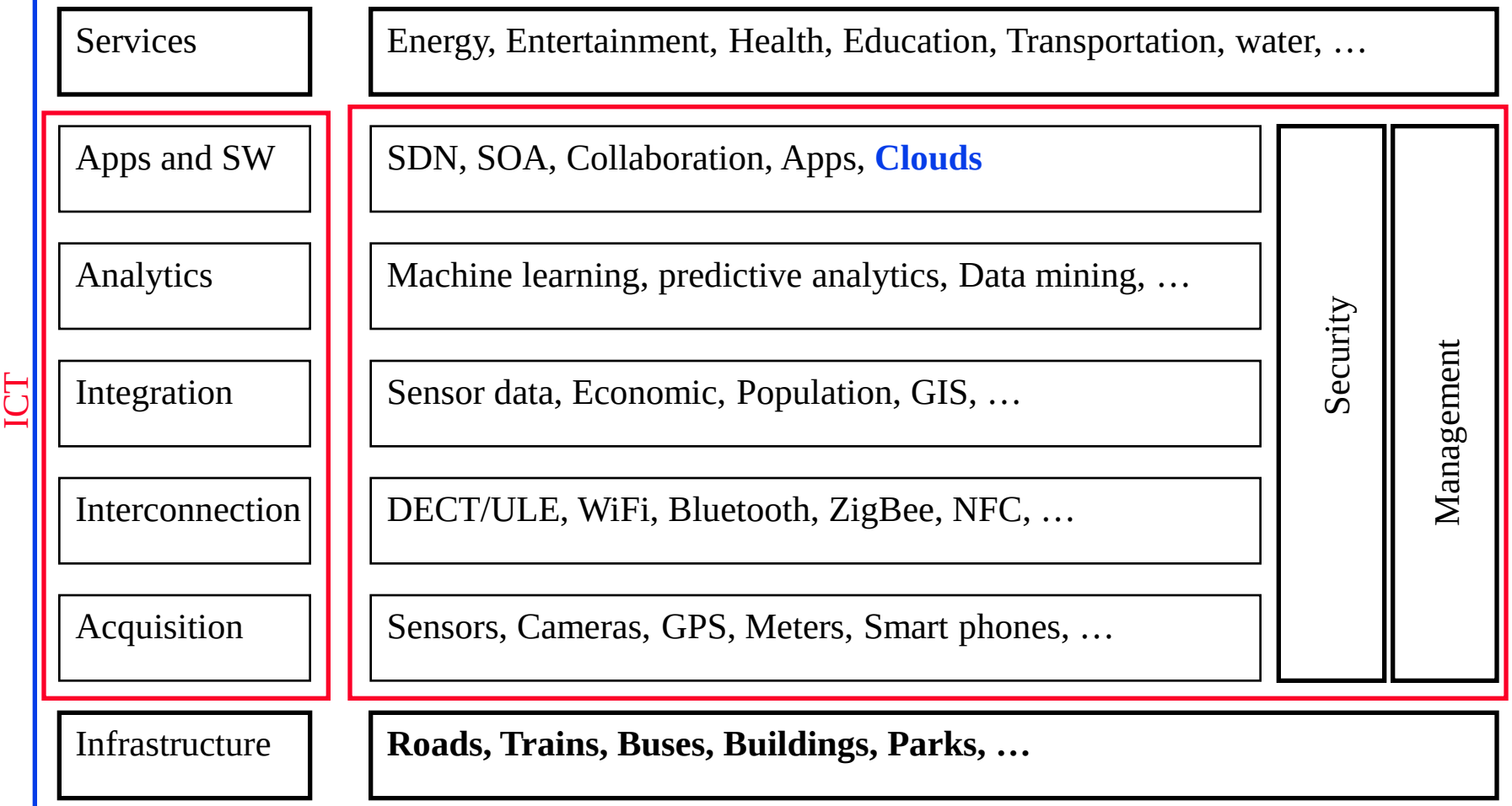
Mobile Doctor

What are the Research Problems for IoT and Smart Cities?

A 7-Layer Model of IoT



A 7-Layer Model of Smart Cities



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

Areas of Research for IoT/Smart Cities

1. PHY: Smart devices, 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. Analytics: Big-data, data mining, Machine learning, Predictive analytics, …
5. Apps & SW: SDN, SOA, Cloud computing, Web-based collaboration, Social networking, …
6. Applications: Remote health, On-line education, on-line laboratories, …
7. **Security: Privacy, Trust, Identity, Anonymity, …**

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, …

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** Attack.

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

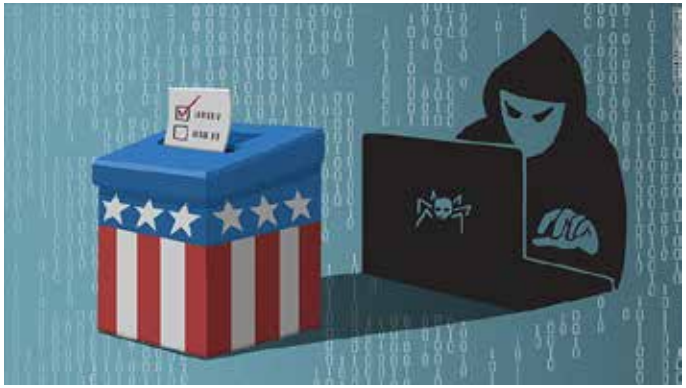
DEFCON

- Hacker's conference
- Held in Las Vegas every July
- 20,000+ attendees
- All anonymous

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

DEFCON 2017

- Hacking voting machines
- 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
- How to track government spy planes
- Break bitcoin hardware wallets
- DARPA Cyber Grand Challenge (2015, 2016)



Confidentiality
Integrity
Authentication

Teaching CIA methods w/o hacking is not sufficient

Trend 8: Blockchains

- Blockchain is the technology that made Bitcoin secure
- Blockchain was invented by the inventor of Bitcoin
- 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 without a third party

Example of a Contract: Wedding

Wedding (Cont)

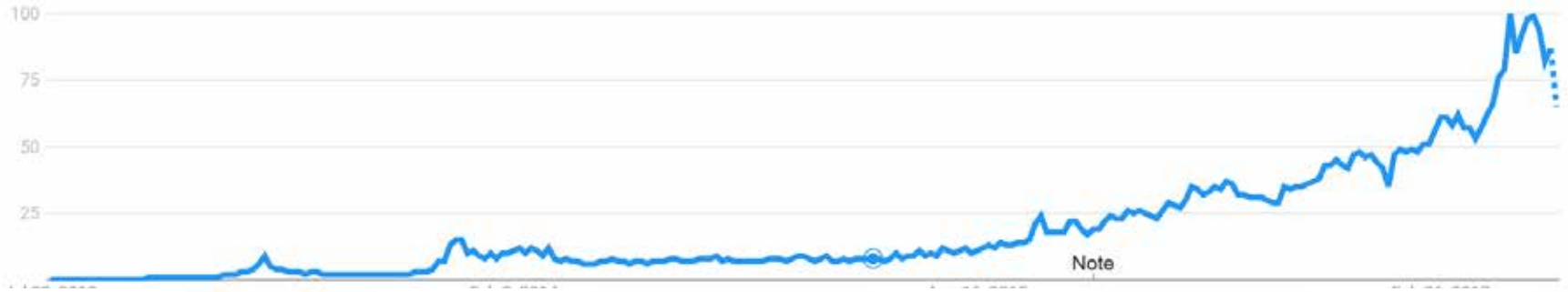
- **Centralized**

- Centralized registry
- Single point of failure
- Easier to hacked

- **Decentralized**

- Decentralized
- No single point of failure
- Very difficult to hack

Google Trend: Blockchains



Jul 2012 Feb 2014 Aug 2015 Mar 2017

- Countries with most interest in Blockchains:

1	Ghana	100
2	Nigeria	68
3	Singapore	25
4	Hong Kong	22
5	South Africa	20

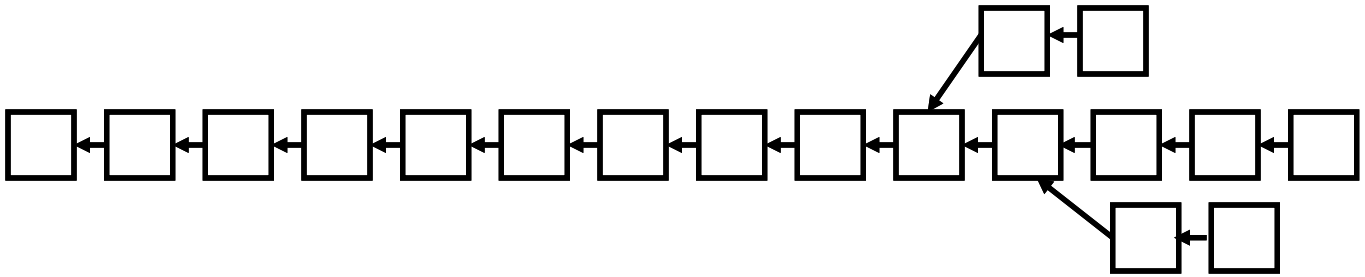
Trend: Centralized to Decentralized

- **Trend**: Make everything decentralized with no central point of control
- Two perfect strangers can exchange money, make a contract without a trusted third party
- Decentralized systems are
  1. More reliable: Fault tolerant
  2. More secure: Attack tolerant
  3. No single bottleneck Þ Fast
  4. No single point of control Þ No monopoly
- Blockchain is one way to do this among **untrusted multi-domain** systems.

Time is a cycle: Distributed vs. Centralized debate

Blockchains

- **How** is it done?
  - A singly linked chain of blocks of verified signed transactions is replicated globally on millions of nodes
  - You will have to change millions of nodes to attack/change



- **Who** is interested: Banks, Hospitals, Venture Capitalists, …
  - Researchers, students, …

Examples of Centralized Systems

- **Banks**: Allow money transfer between two accounts
- **Currency**: Printed and controlled by the government
- **Stock Exchanges**: Needed to buy and sell stocks
- **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 Þ Attracts Hackers
  3. Central party may be hacked Þ affects millions
  4. Central party is a single point of failure. Can malfunction or be bribed.

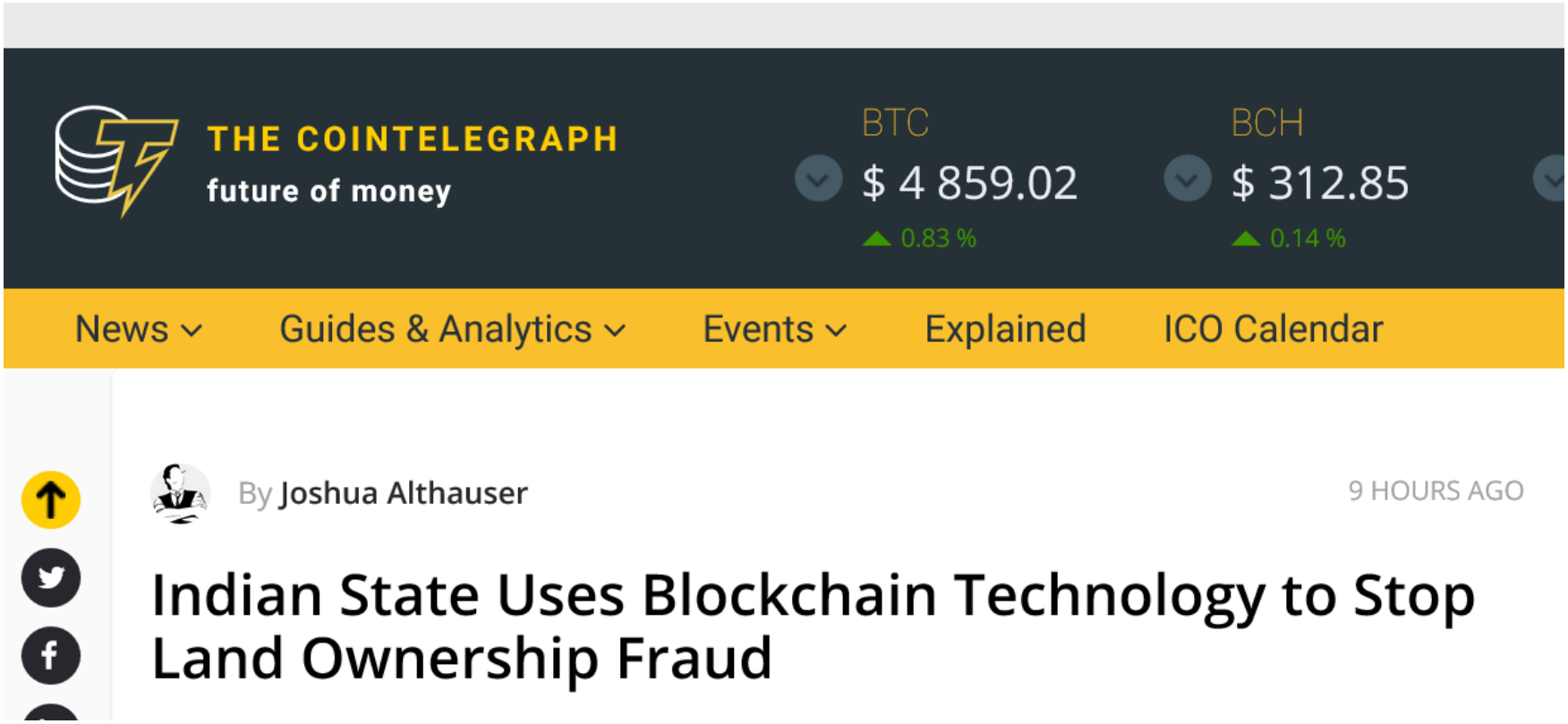
Ref: A. Narayanan, et al, "Bitcoin and Cryptocurrency Technologies," Princeton University Press, 2016, 304 pp.

Blockchains For Cities

- Land titles
- Vehicle registries
- Business license
- Criminal records
- Passports
- Birth certificates
- Death certificates
- Building permits
- Gun permits

Ref: http://ledracapital.com/blog/2014/3/11/Bitcoin-series-24-the-mega-master-blockchain-list

Blockchains for Cities (Cont)



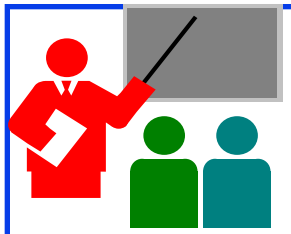
Networking Applications of Blockchains

- Multi-Domain Systems:
  - Multiple Cloud Service Providers
  - Multiple cellular providers
  - Multi-Interface devices: WiFi, Cell, Bluetooth, …
  - BGP: BGP Authentication
- Globally Centralized Systems:
  - DNS
  - Certificate Authorities

Explore blockchains for multi-domain/centralized systems

City-University Partnership

- Presence of universities is a weak predictor of new educational startups Þ Universities need to connect
- Universities can help local government with the technology development, adoption, training, and analytics
- What Can we (Researchers) Do?
  - Extend our research in to applications that are large scale
  - Develop collaborations for integration of fields
  - Provide proof-of-concepts
  - Provide Open-Source development environment



Summary

1. Smart ≠ High-Speed Computation, Smart ≠ Big Data Storage, Smart = Networked
2. Smart Cities research areas are easy via the 7-layer model
   Research issues in every layer: Sensors, data link, routing, applications, analytics.
3. Clouds are getting smaller, Carriers and enterprises moving to clouds, leading to clouds everywhere Þ multi-cloud
4. Our MCAD abstracts/virtualizes the cloud interfaces and allows automated management of security and other policies of multi-cloud applications
5. Cyber security is important for smart cities and blockchains may offer a potential solution to some problems.

Related Papers

- 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
- 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
- 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
- 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

Related Papers (Cont)

- 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.17, No.3, pp.296 - 314, http://www.cse.wustl.edu/~jain/papers/ijcnds16.htm
- 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
- Deval Bhamare, Mohammed Samaka, Aiman Erbad, Raj Jain, Lav Gupta, H. Anthony Chan, "**Multi-Objective Scheduling of Micro-Services for Optimal Service Function Chains**," International Conference on Communications (ICC 2017), May 21-25, 2017, http://www.cse.wustl.edu/~jain/papers/icc17.htm

Related Papers (Cont)

- 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,
- 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
- 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)

- Deval Bhamare, Raj Jain, Mohammed Samaka, Gabor Vaszkun, Aiman Erbad, "**Multi-Cloud Distribution of Virtual Functions and Dynamic Service Deployment: OpenADN Perspective**," 2015 IEEE International Conference on Cloud Engineering (IC2E), Tempe, AZ, March 9-13, 2015, pp. 299-304, http://www.cse.wustl.edu/~jain/papers/vm_dist.htm
- Lav Gupta, Raj Jain, Mohammed Samaka, "**Dynamic Analysis of Application Delivery Network for Leveraging Software Defined Infrastructures**," 2015 IEEE International Conference on Cloud Engineering (IC2E), Tempe, AZ, March 9-13, 2015, pp. 305-310, http://www.cse.wustl.edu/~jain/papers/profile.htm

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Raj Jain
Jain@wustl.edu
www.rajjain.com