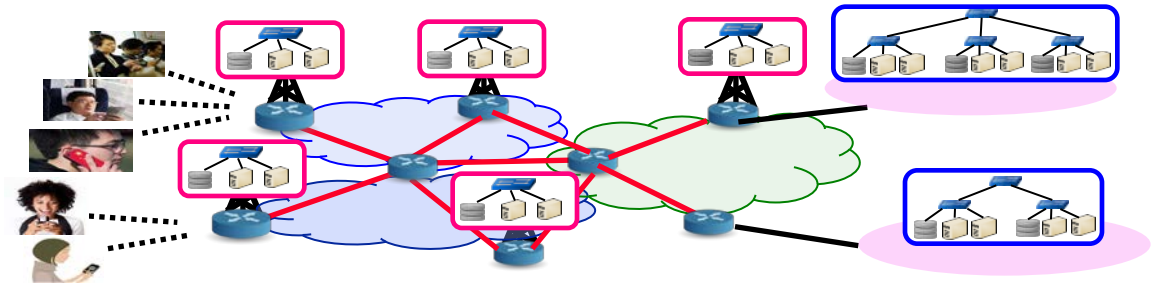
Multi-Cloud Global Application Delivery for Internet of Things and Smart Cities



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Keynote at the 7th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), Vancouver, Canada, October 14, 2016

These slides and recording of this talk are available on-line at:

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

or http://bit.ly/jain_iemcon

Overview

- Why Multi-Cloud?
  - 1. Internet of Things and Smart Cities
  - 2. Mobile Traffic Explosion: NFV
  - 3. Any Function Virtualization
  - 4. Mobile Edge Computing
- OpenADN Multi-Cloud Management
- Service Function Placement Problem

Trend: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

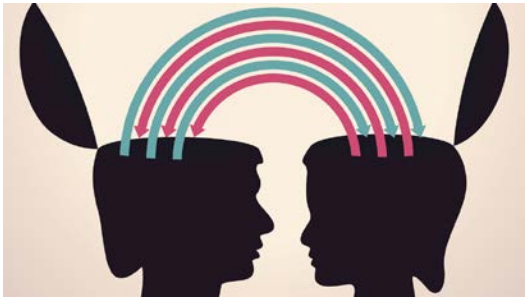
Smart Space

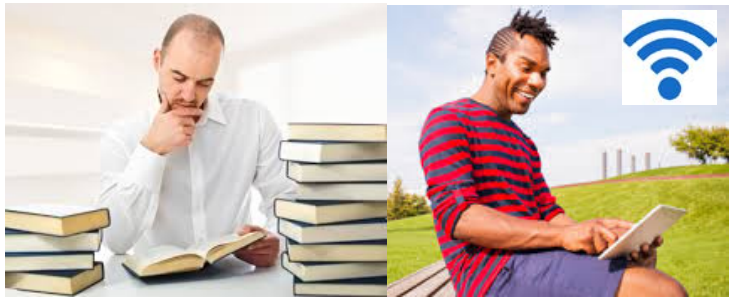
Smart Industries

Smart Cities

What's Smart?

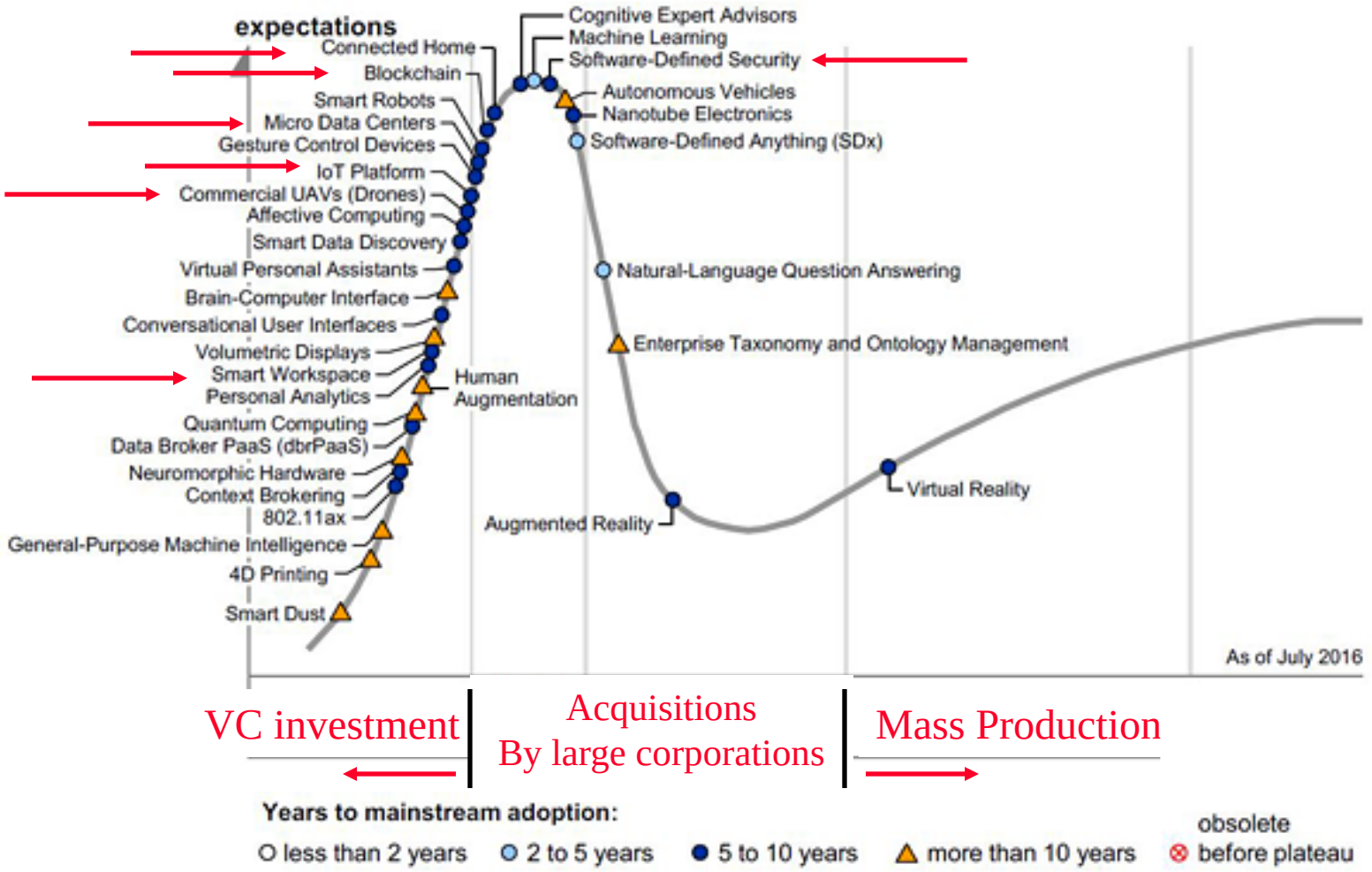
- Old: Smart = Can think ⇒ Computation
  = Can Recall ⇒ Storage
- Now: Smart = Can find quickly, Can Delegate
  ⇒ Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …





Not-Smart Smart

Gartner Hype Cycle 2016



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

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/
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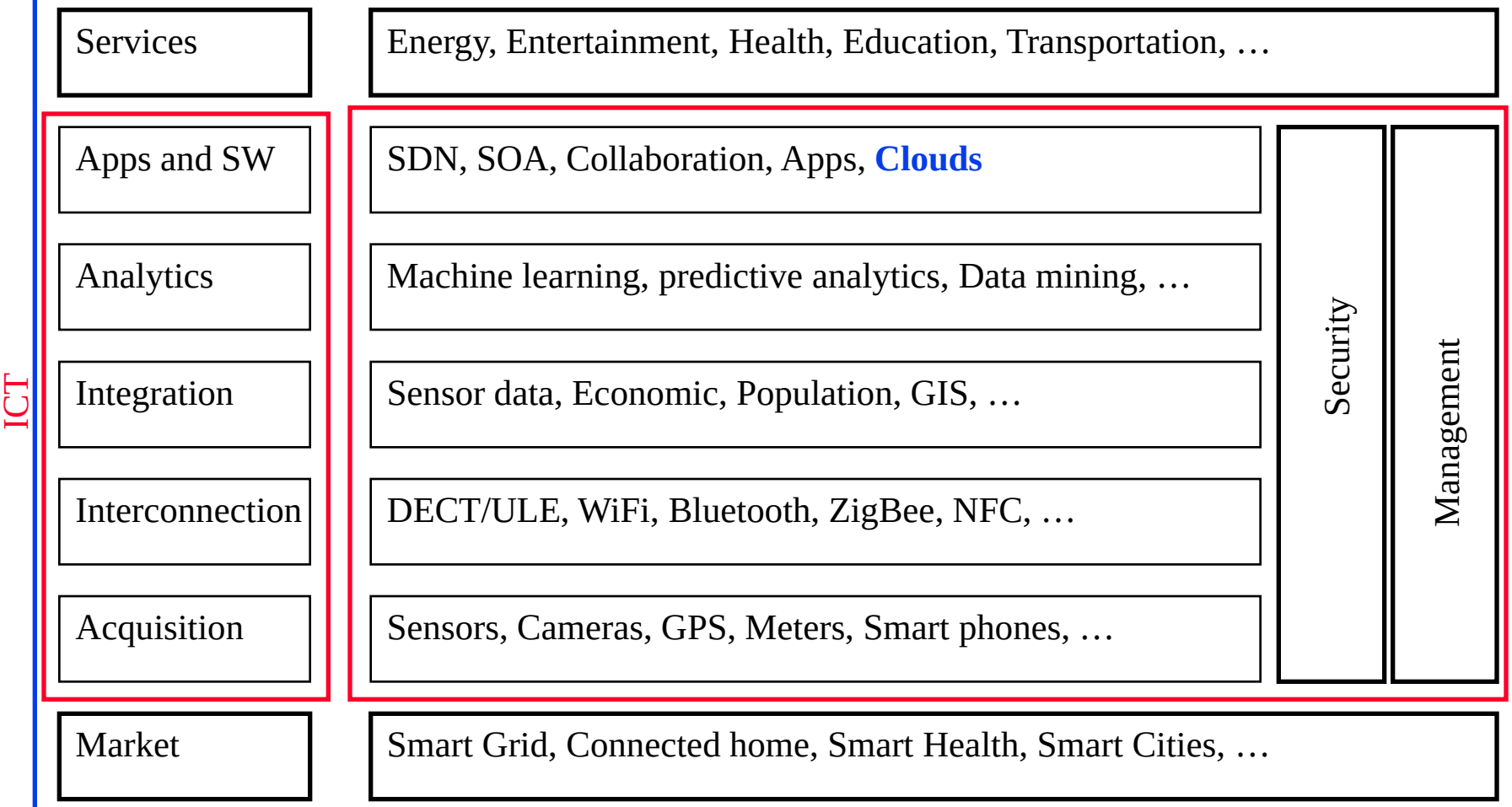
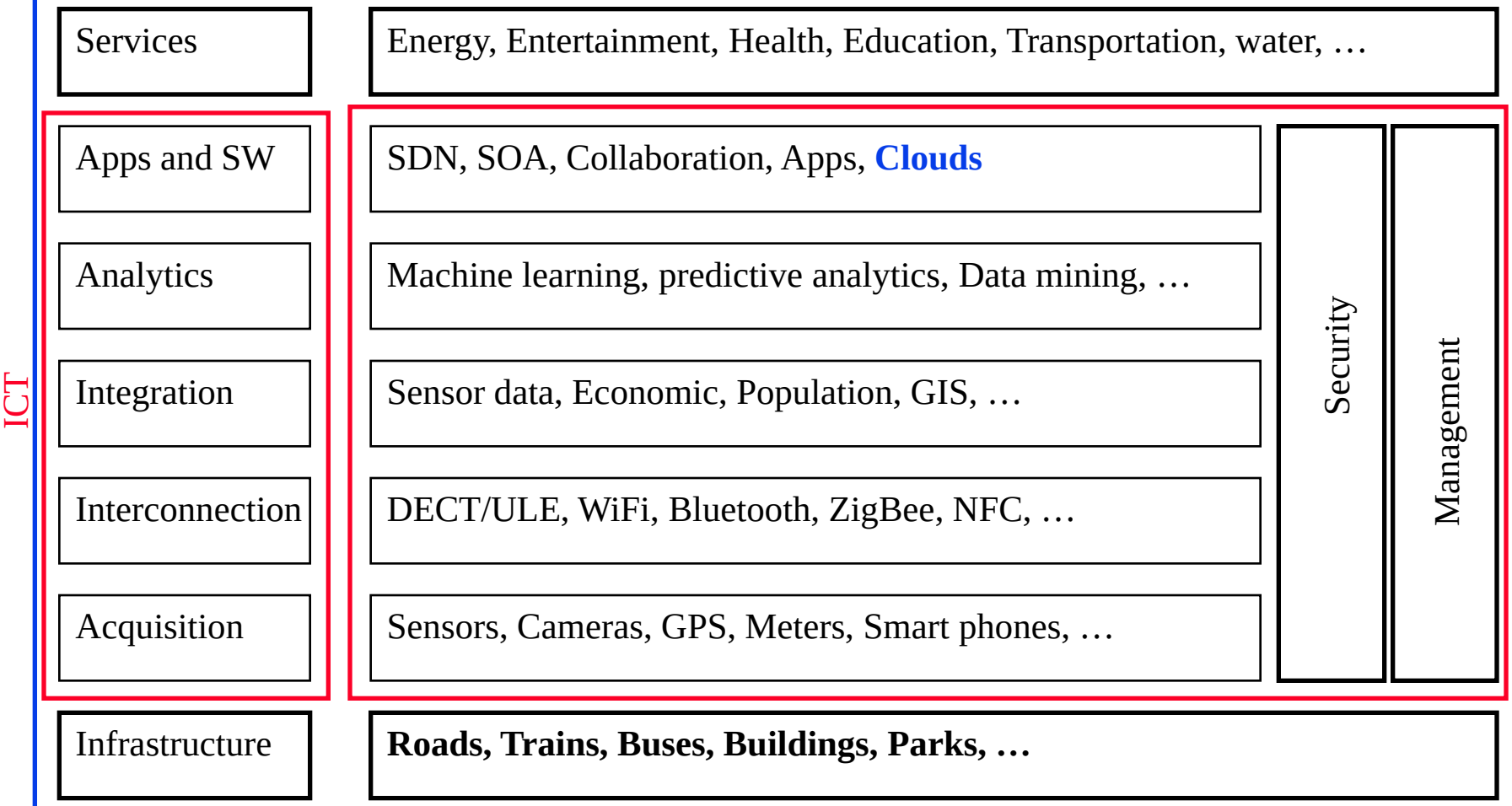
A 7-Layer Model of IoT



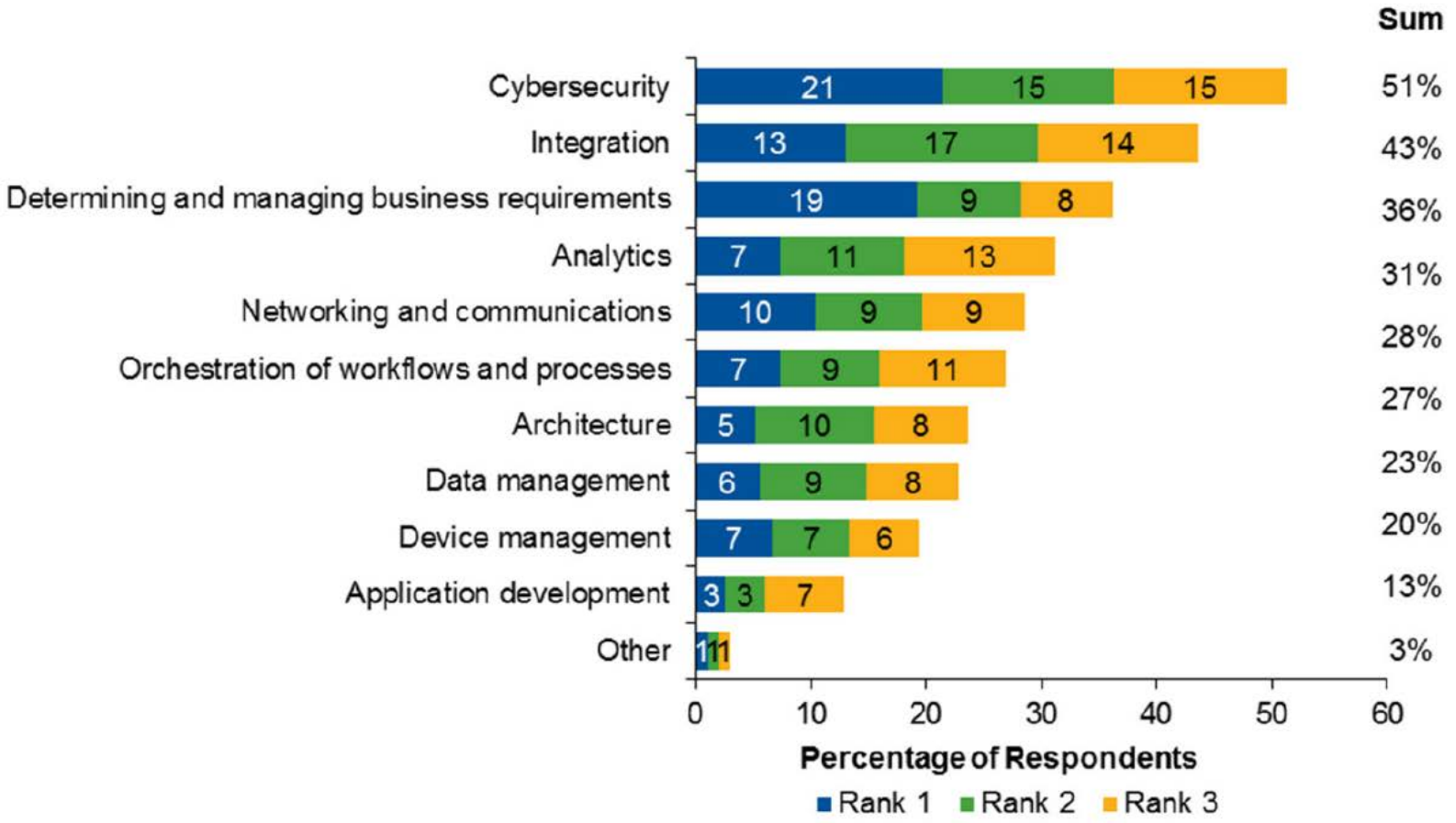
A 7-Layer Model of Smart Cities



IoT is a Data ($) Mine

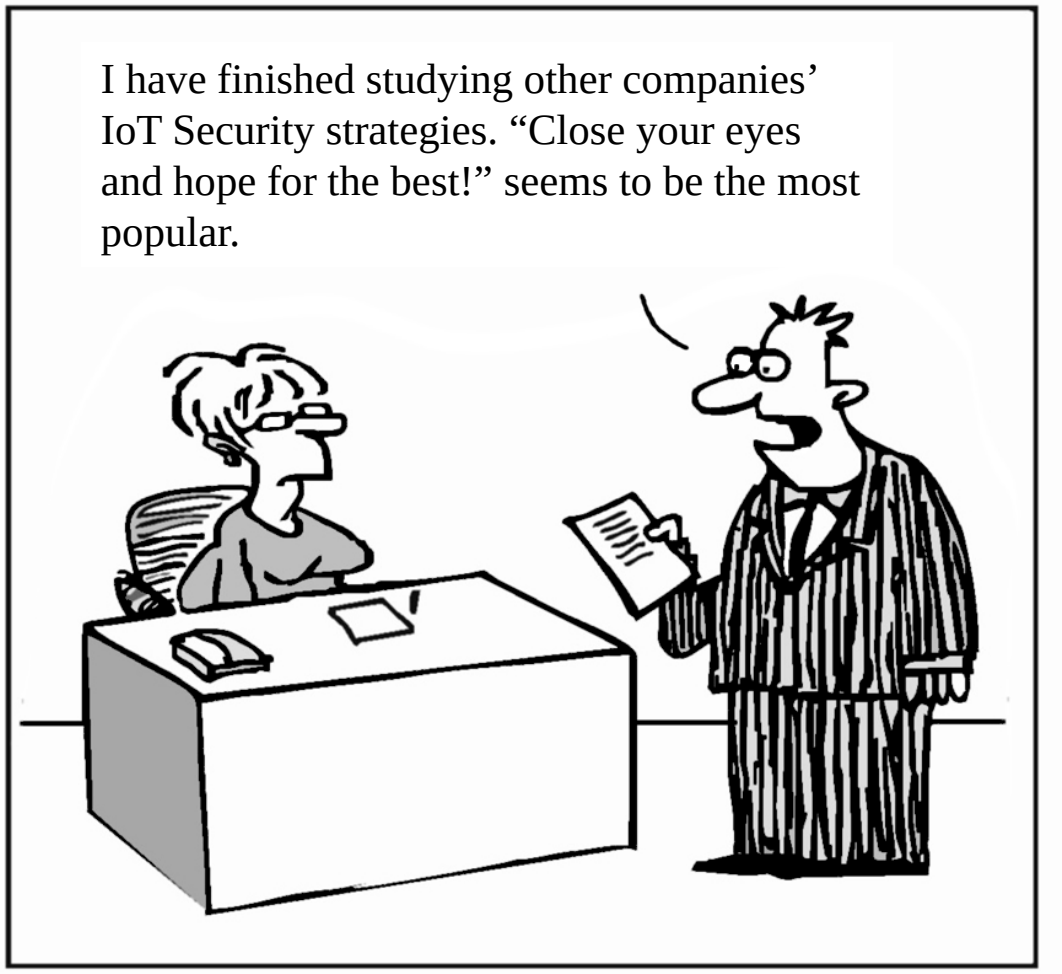
Ref: https://www.pinterest.com/iofficecorp/humor/

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,

IoT Security: Popular Approach



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

Current IoT Security

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

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

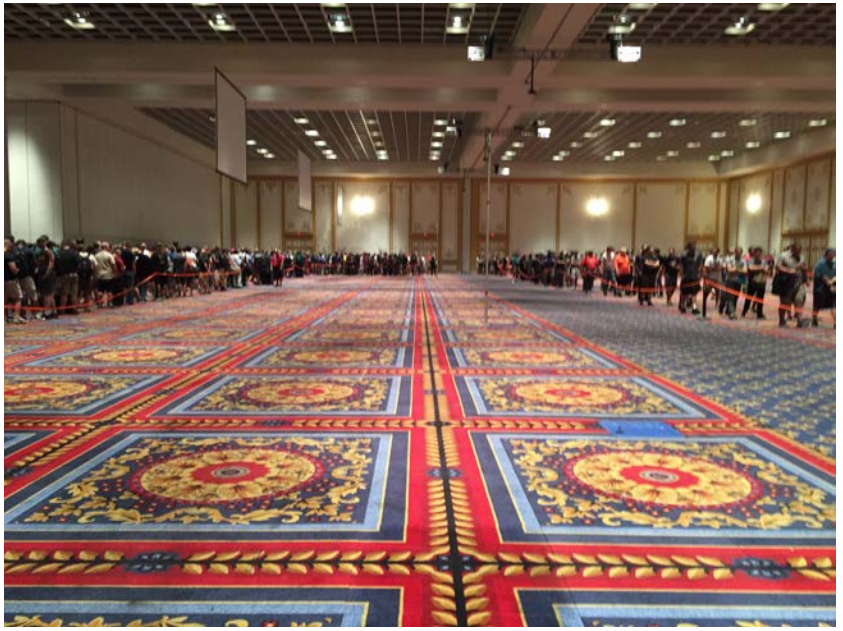
Ref: M. Barcena and C. Wueest, "Insecurity in the Internet of Things," Symantec, March 2015,

Internet of Harmful Things

Imagine, as researchers did recently at Black Hat, someone hacking your connected toilet, making it flush incessantly and closing the lid repeatedly and unexpectedly.

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

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

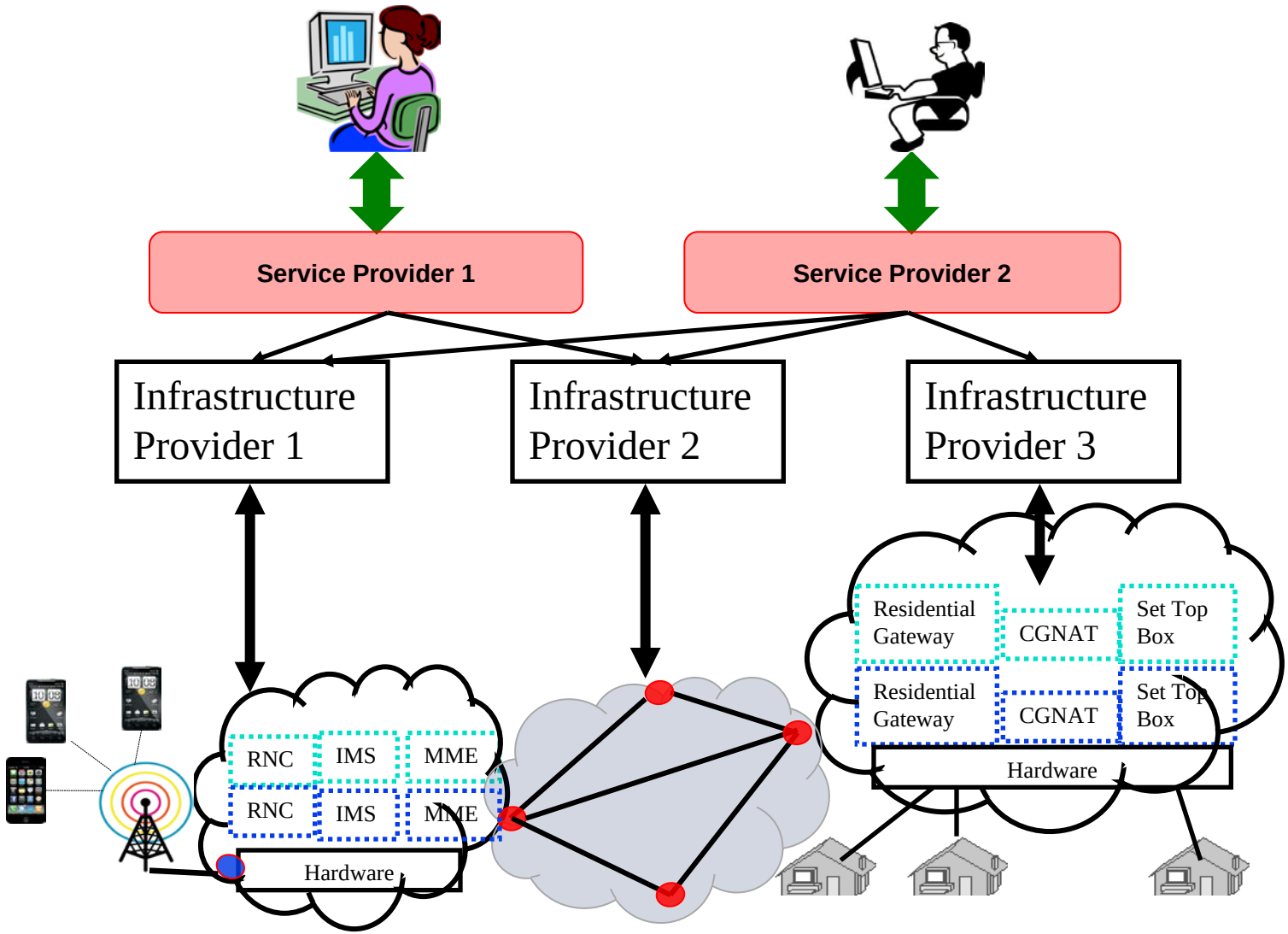
Attack Surface

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

Trend: 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
  - µCloud = Cloud in a server with multiple VMs.
  - Each VM with Multiple Containers ⇒ Multiple Services

Network Function Virtualization (NFV)



Any Function Virtualization (FV)

- "Network" function virtualization of interest to Network service providers
- But the same concept can be used by any other industry, e.g., financial industry, banks, stock brokers, retailers, mobile games, …
- Everyone can benefit from:
  - Functional decomposition of there industry
  - Virtualization of those functions
  - Service chaining those virtual functions (VFs) or **Apps**

Networking App Market: Lower CapEx

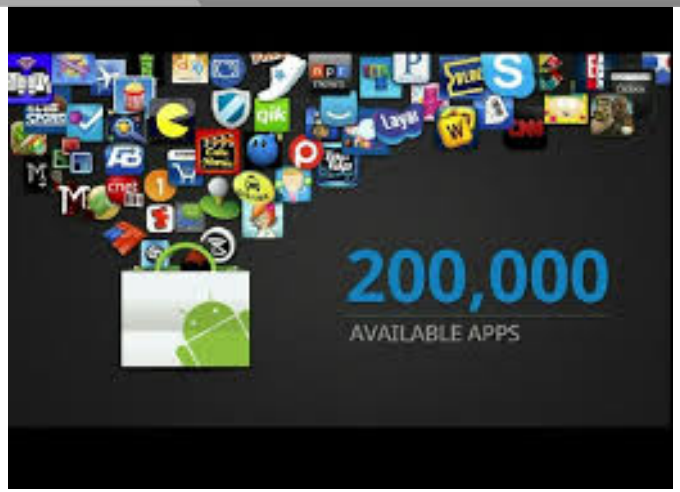
Virtual IP Multimedia System

Available on the App Store

CISCO

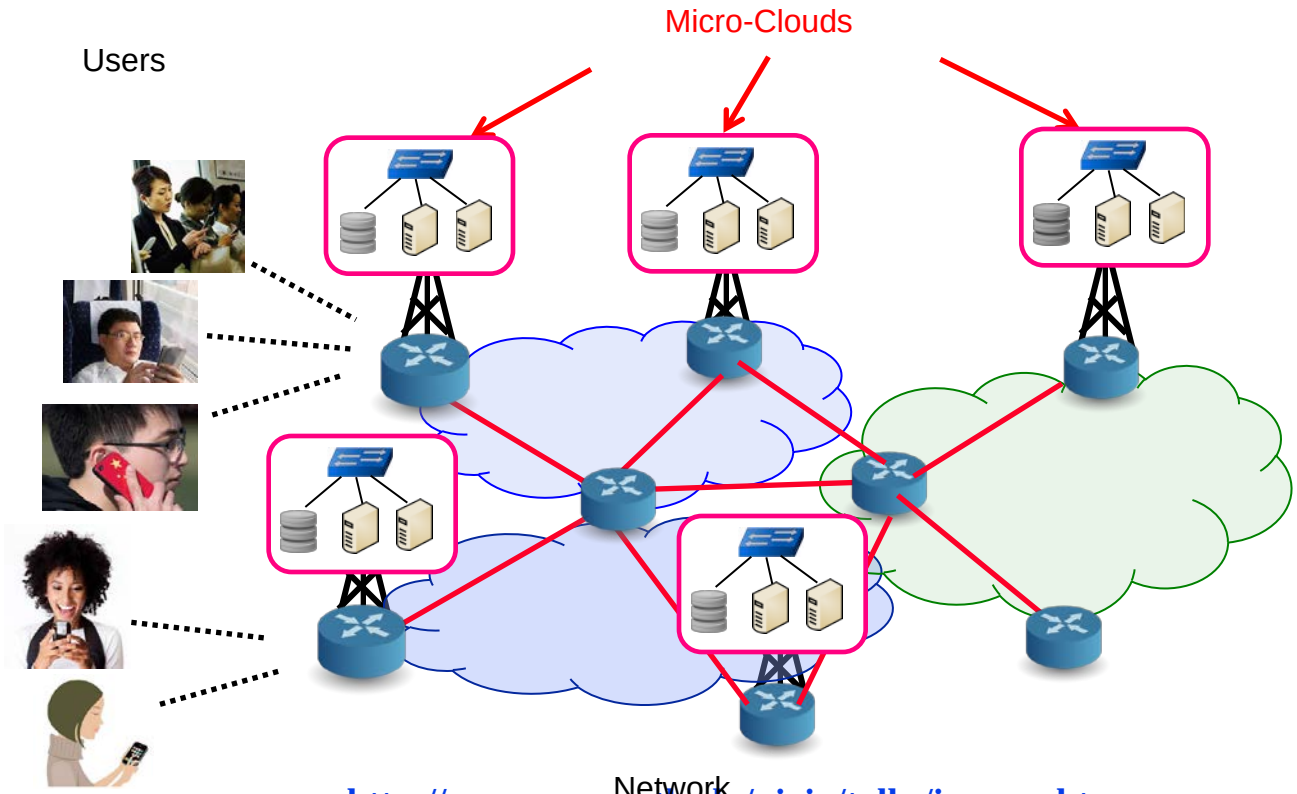
App Store

vRouter vRADIUS vVRN



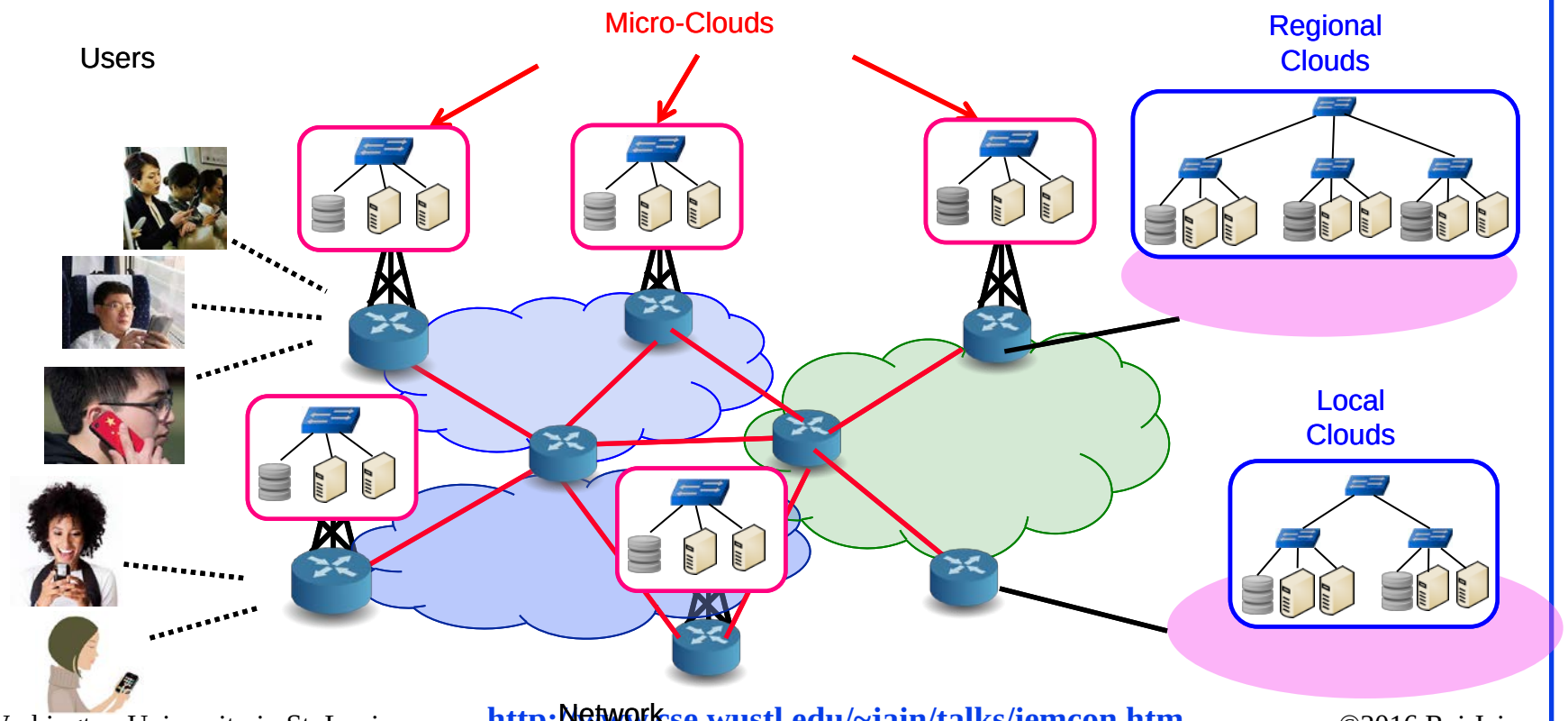
Trend: Mobile Edge Computing

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

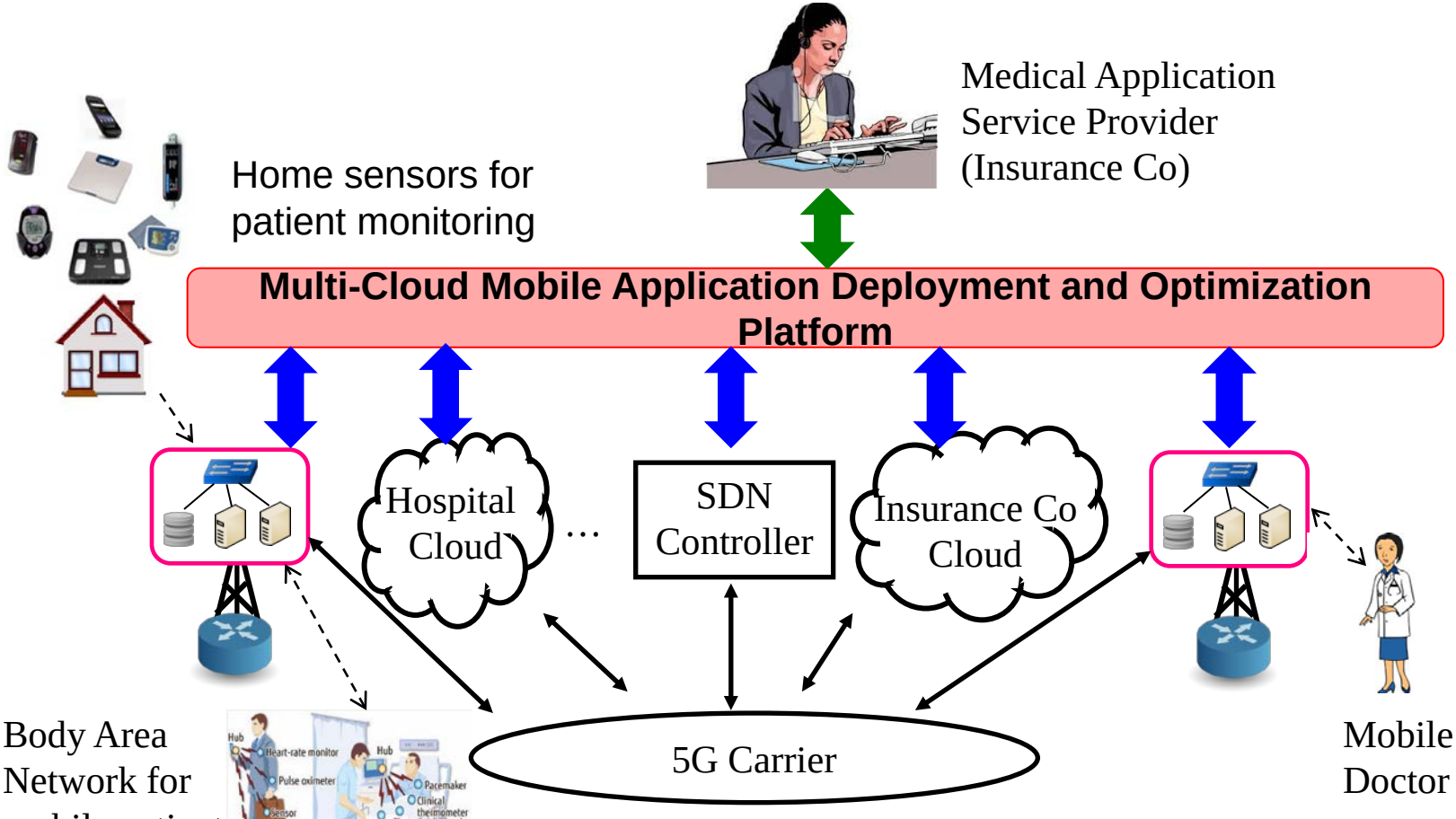


Trend: Micro-Services

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

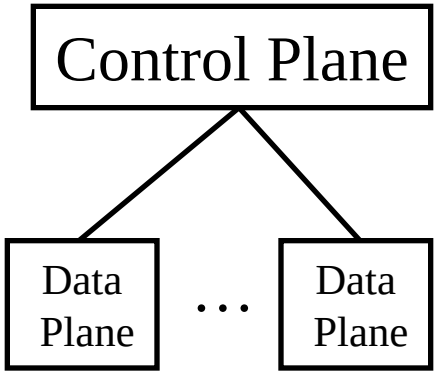


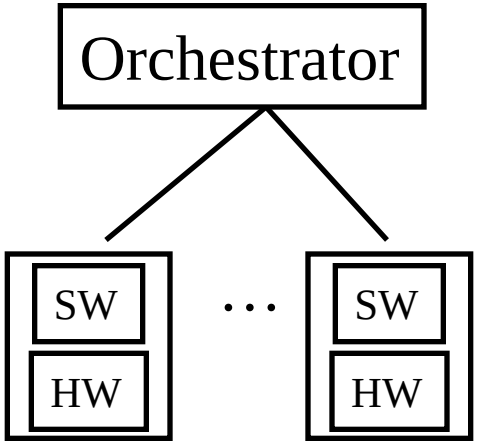
Mobile Healthcare Use Case



Software Defined Networking (SDN)

- 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

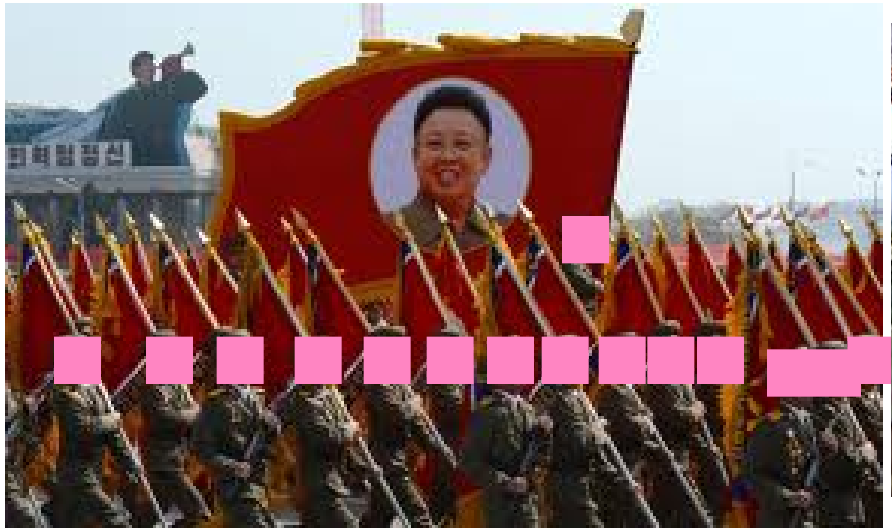




Separation vs. Centralization

Separation of Control Plane

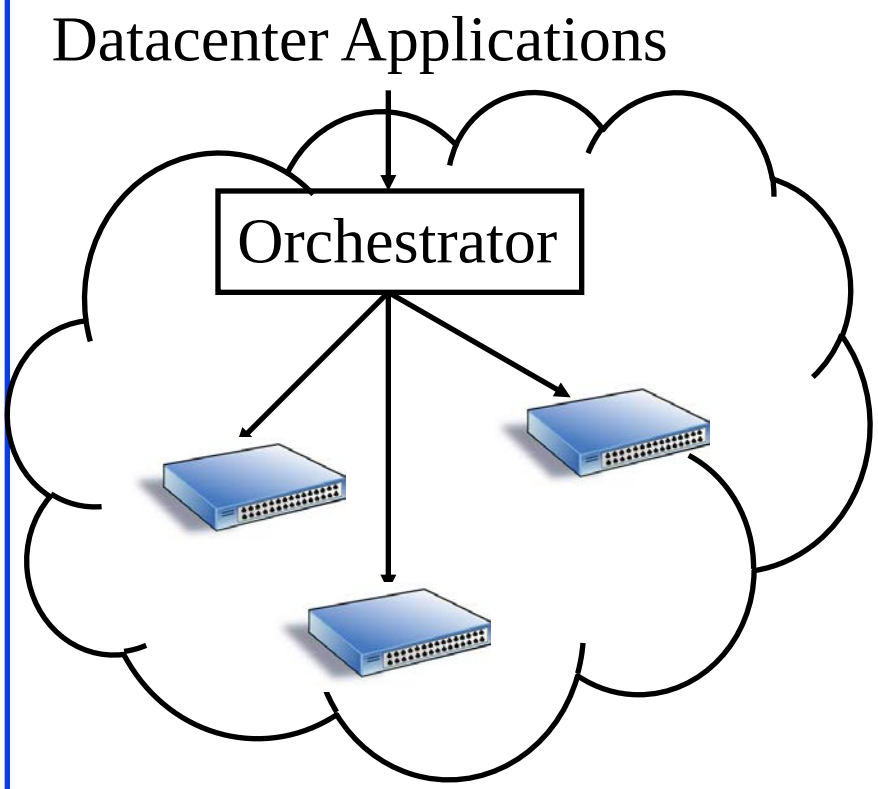
Centralization of Policies

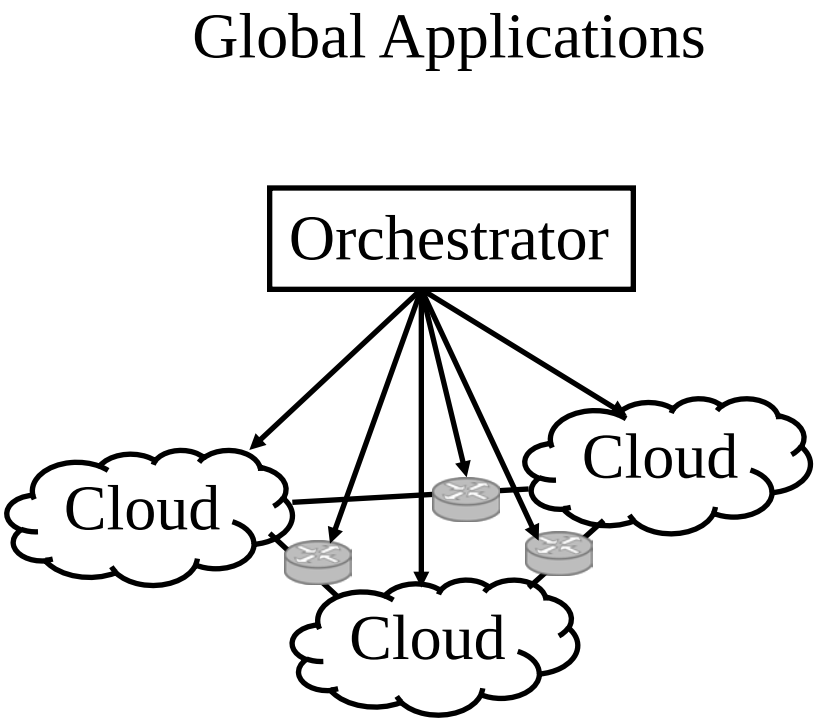


Micromanagement is not scalable

Software Defined Multi-Cloud

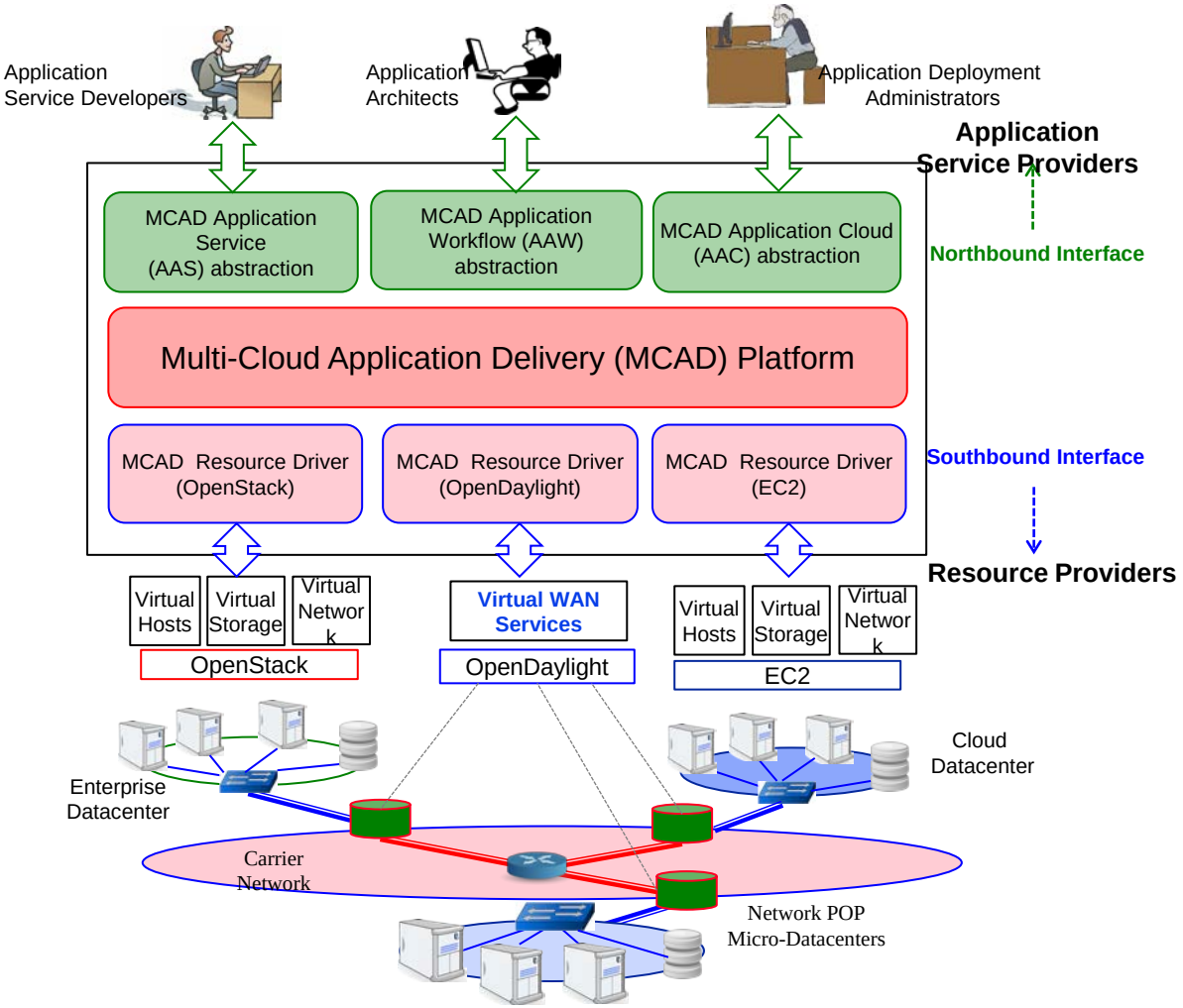
- Orchestrating devices to Orchestrating Clouds



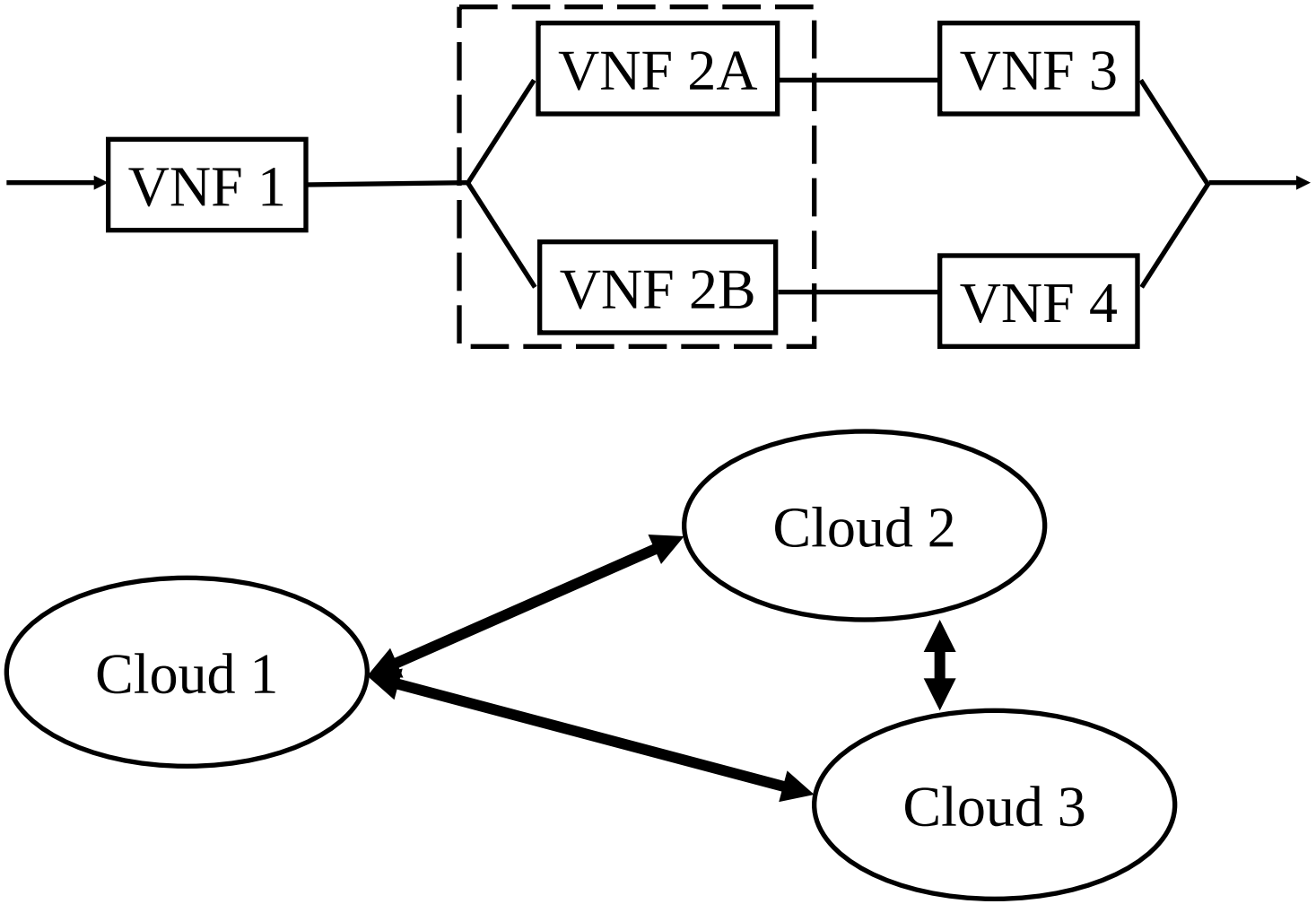


Ref: AT&T, "Domain 2.0 White paper,"
https://www.att.com/Common/about_us/pdf/AT&T%20Domain%202.0%20Vision%20White%20Paper.pdf

OpenADN Multi-Cloud Management

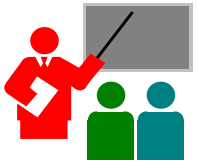


Service Function Placement Problem



Challenges in Service Placement

- **Delay constraints**
- **WAN links bottleneck:** Need to model link queues
- **Complexity**: NP-complete ⇒ Need efficient heuristics
- **Affinity:** VNF1 and VNF2 should be co-located
  - Significant communication exchanges
  - Duplicate memory pages in VMs (same OS and Libraries)
- **Anti-Affinity**: VNF1 and VNF2 should not be placed on the same physical server.
  - CPU-intensive applications
  - VMs belonging to different users in a cloud may cause security risk such as cross-VM attacks
  - Duplicate VMs used to improve fault tolerance and availability



Summary

1. Value of IoT is in the data it produces. Privacy and Security are the key issues.
2. Clouds are getting smaller, Carriers and enterprises moving to clouds, Internet of things are leading to clouds everywhere $\Rightarrow$ multi-cloud applications.
3. SDN is about orchestration and centralization of policy. Not about separation of control and data planes.
4. Software Defined Multi-Cloud Orchestration: Our Multi-cloud application management system (MCAD) allows policy-based deployment and management of multi-cloud applications.
5. Service function placement problem is NP complete. Challenges included delay constraints, WAN Link bottlenecks, and affinity

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Acronyms

- ATM Asynchronous Transfer Mode
- ECN Explicit congestion notification
- EFCI Explicit Forward Congestion Indication
- FECN Forward Explicit Congestion Notification
- GB Gigabyte
- IEEE Institution of Electrical and Electronic Engineering
- IETF Internet Engineering Task Force
- IoT Internet of Things
- IP Internet Protocol
- IRTF Internet Research Task Force
- ITU International Telecommunications Union
- LAN Local Area Network
- LTE Long Term Evolution
- MHz Mega Hertz
- OpenADN Open Application Delivery Networking
- SDN Software Defined Networking

Acronyms (Cont)

- TCP Transmission Control Protocol
- TV Television
- VM Virtual Machine
- WAN Wide Area Network
- WiFi Wireless Fidelity
- WiMAX Worldwide Interoperability for Microwave Access

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