

Internet of Things Security



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These slides are available on-line at:

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



1. A Layered Model of IoT and Smart Cities
2. Areas of Research for IoT
3. IoT Security
4. Trend: Computation in the Edge, Multi-Cloud
5. Software Defined Multi-Cloud Application Management

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 \Rightarrow Can compute
- ❑ 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, ...



Think



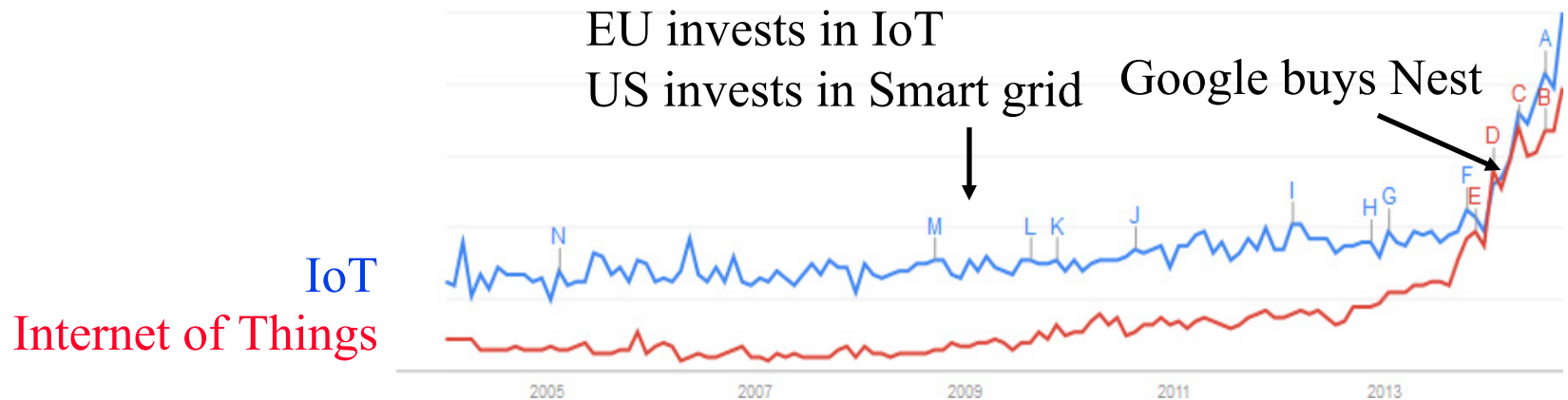
Communicate



Not-Smart

Smart

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 \$4B funding for **smart grid** in American Recovery and Reinvestment Act of

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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IoT is a Data (\$) Mine



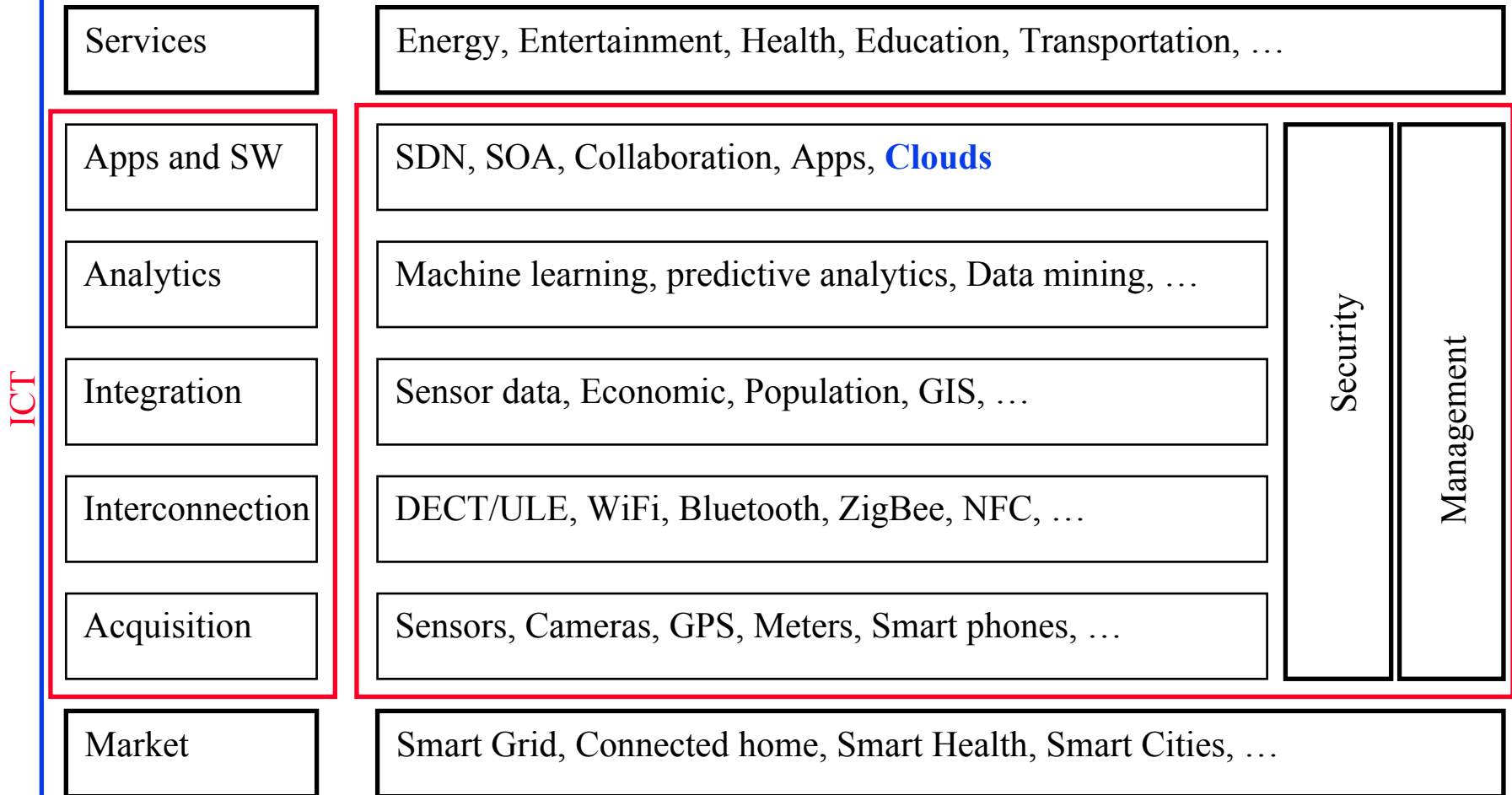
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Ref: <https://www.pinterest.com/iofficecorp/humor/>

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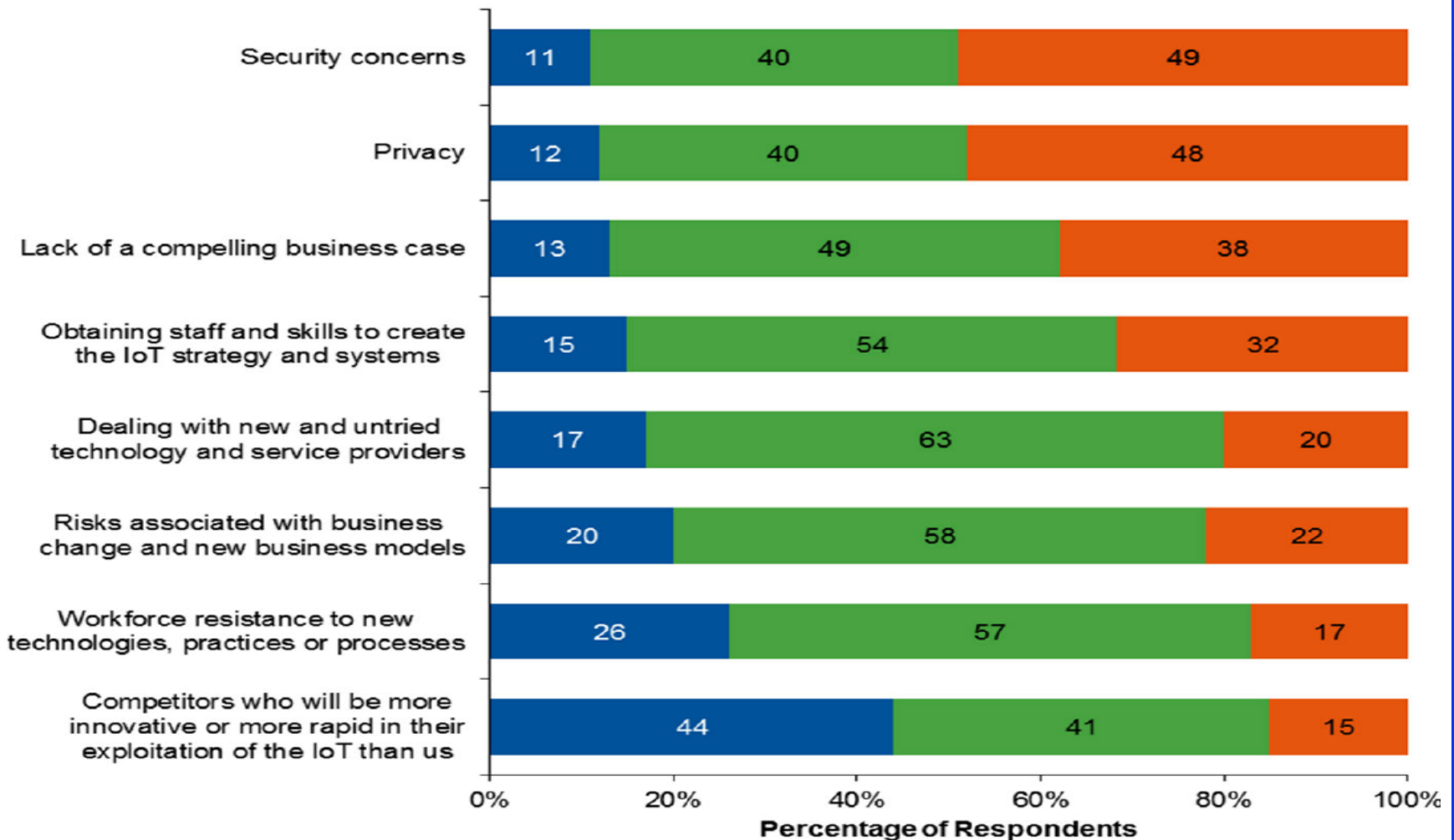
A 7-Layer Model of IoT



Areas of Research for IoT

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, ...

Top Inhibitors to the Adoption of the IoT



Ref: D. Mishra and E. Perkins, "Address Cybersecurity Challenges Proactively to Ensure Success With Outsourced IoT Initiatives," May 2015, 10 pp.

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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.

News

Worm may create an Internet of Harmful Things, says Symantec (Take note, Amazon)

Security firm Symantec says it has found a Linux worm aimed at Internet of Things devices

By Patrick Thibodeau

December 3, 2013 01:22 PM ET [Add a comment](#)



Computerworld - Security researchers are gradually raising warnings that the Internet of Things will increase, by multitudes, the number of things that can be hacked and attacked.

The Hitchcockian plotlines are endless. Replace [The Birds](#) with flying [Amazon delivery drones](#). Or 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>

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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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What is Security?

- ❑ 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



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

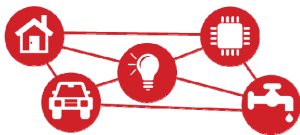
❑ Kwikset Kevo Door Locks:

- **Password** can be reset by email
- Hijacked email addresses and phishing attack



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

IoT Ecosystem

Applications	Smart Health, Smart Home, Smart Grid Smart Transport, Smart Workspaces, ...	Security TCG, Oath 2.0, SMACK, SASL, ISASecure, ace, CoAP, DTLS, Dice	Management IEEE 1905, IEEE 1451, ...
Session	MQTT, CoRE, DDS, AMQP , ...		
Routing	6LowPAN, RPL, 6Lo, 6tsch, Thread, 6-to-nonIP , ...		
Datalink	WiFi, Bluetooth Smart, ZigBee Smart, Z-Wave, DECT/ULE, 3G/LTE, NFC, Weightless, HomePlug GP, 802.11ah, 802.15.4, G.9959, WirelessHART, DASH7, ANT+ , LoRaWAN, ...		
Software	Mbed, Homekit, AllSeen, IoTvity, ThingWorks, EVERYTHING , ...		
Operating Systems	Linux, Android, Contiki-OS, TinyOS, ...		
Hardware	ARM, Arduino, Raspberry Pi, ARC-EM4, Mote, Smart Dust, Tmote Sky, ...		

Different Password for Everything

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**“I memorized all of my e-mail addresses, passwords,
and PIN numbers...but now I don’t remember my name!”**

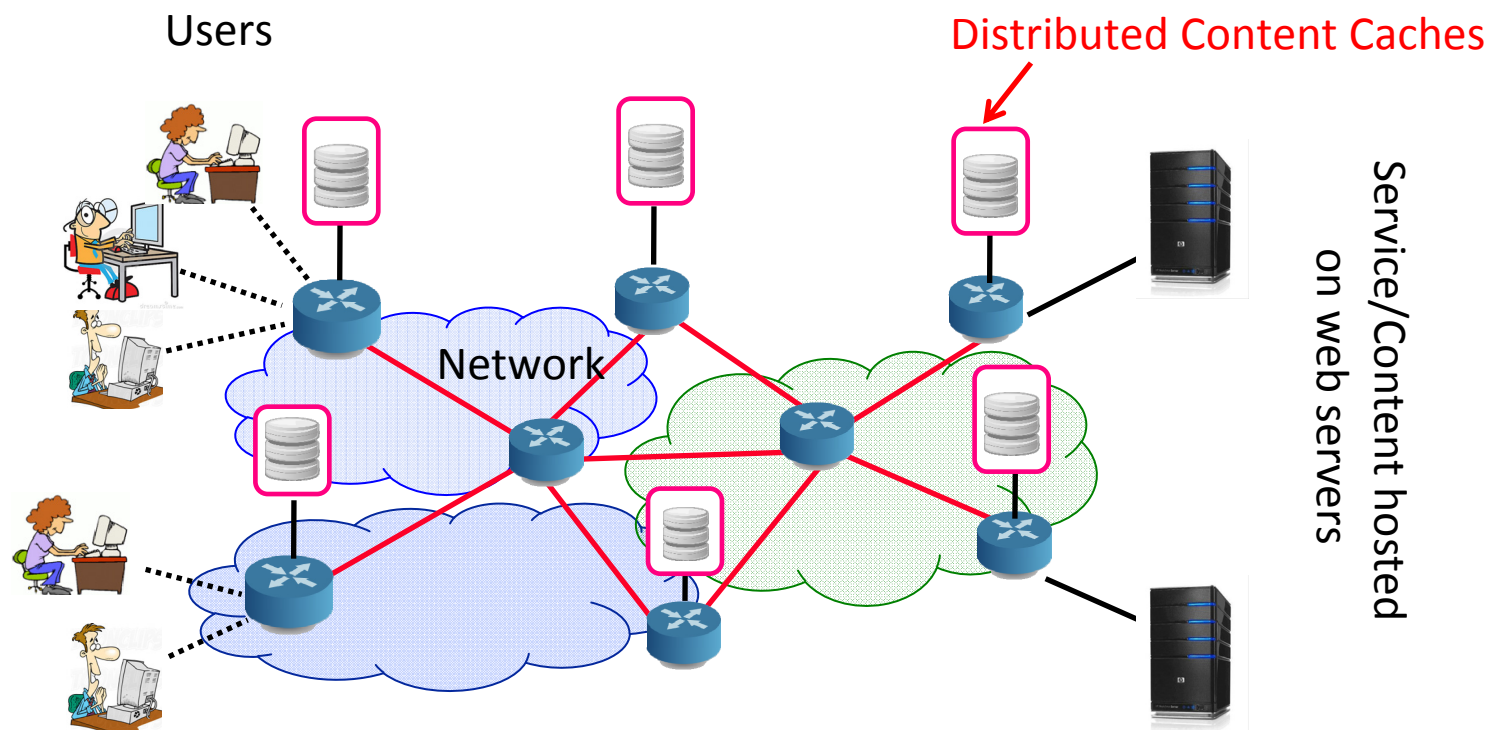
Ref: <https://www.pinterest.com/pin/496733033878121293/>

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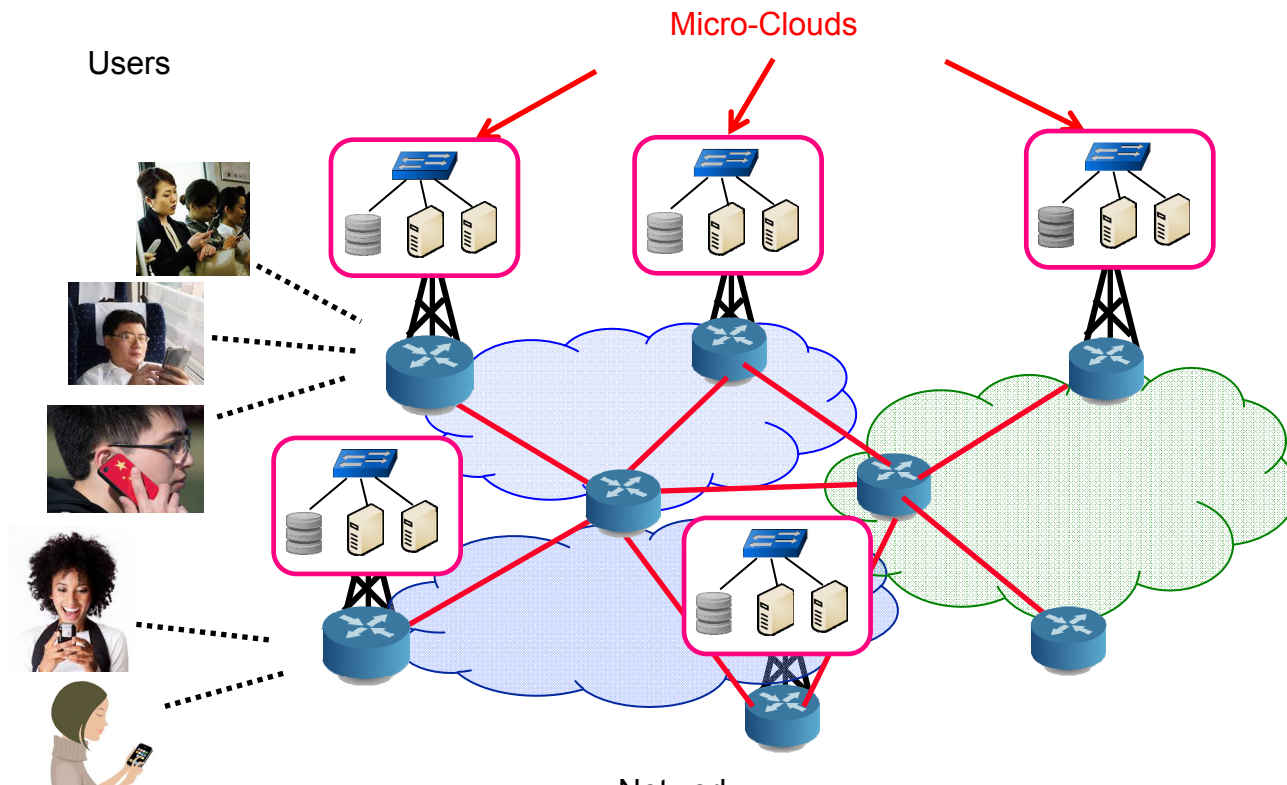
Past: Data in the Edge

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



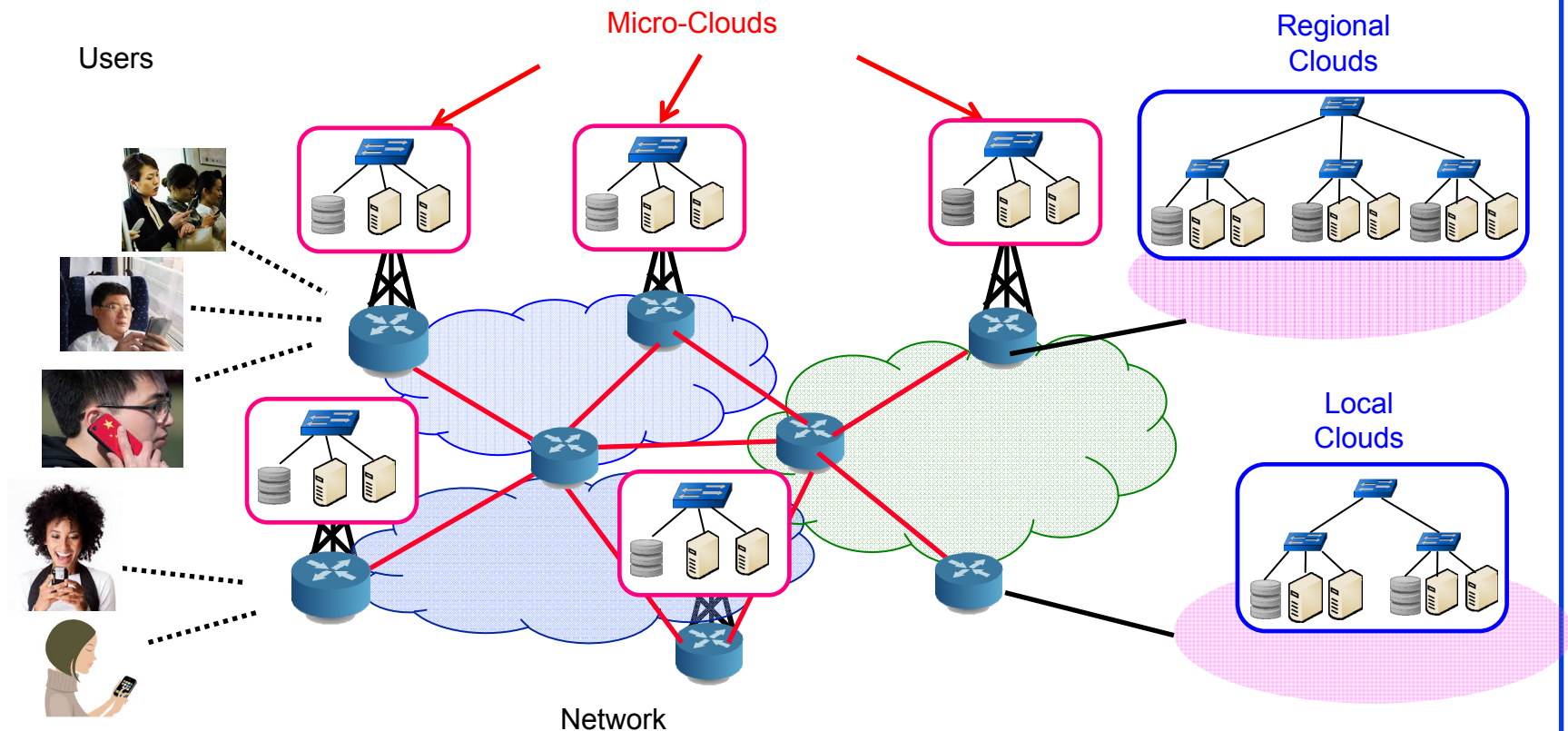
Trend 2: Computation in the Edge

- To service mobile users/IoT, the computation needs to come to edge \Rightarrow Micro-cloud on the tower

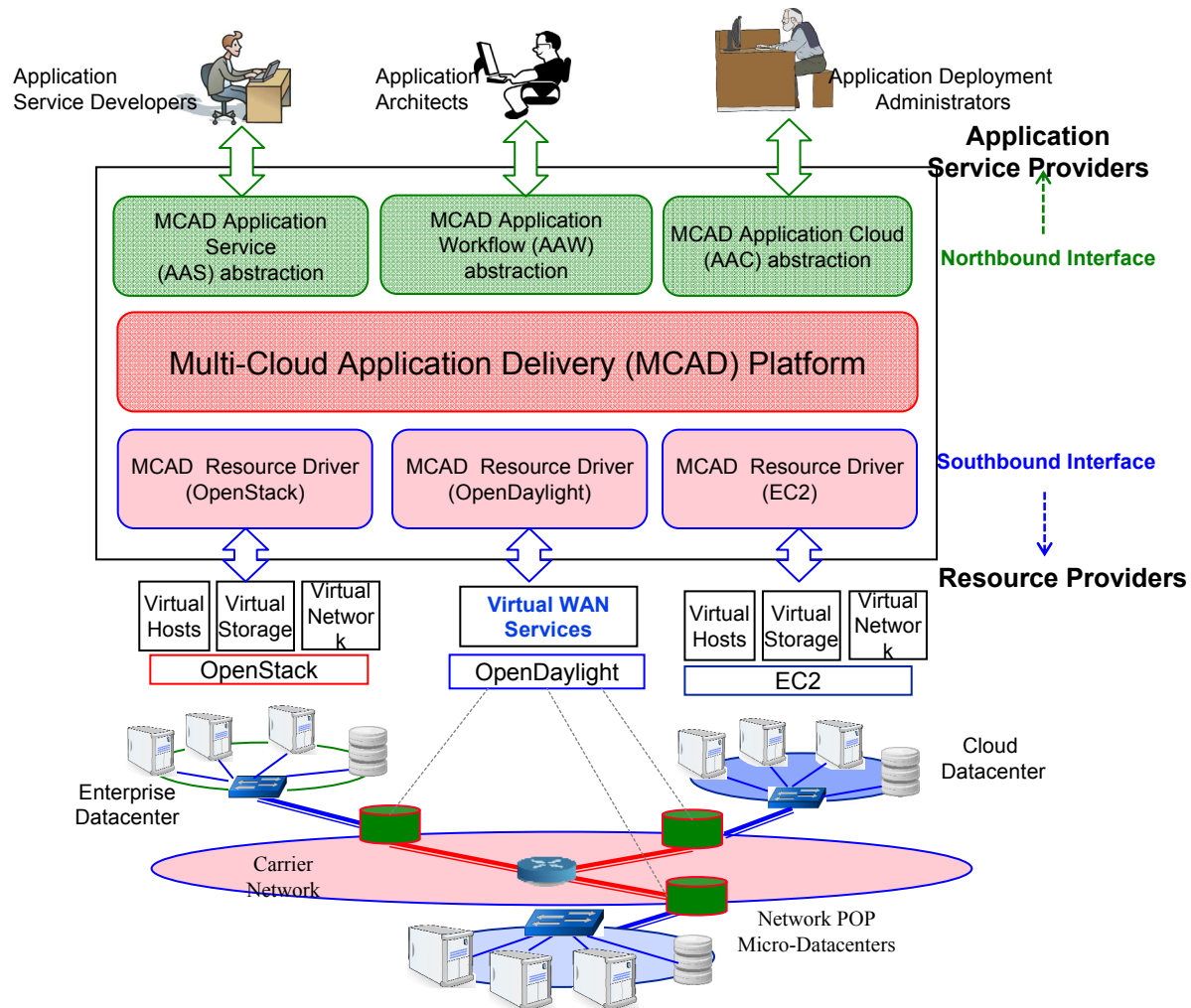


Trend 3: Multi-Cloud

- Larger and infrequent jobs serviced by local and regional clouds \Rightarrow Fog Computing



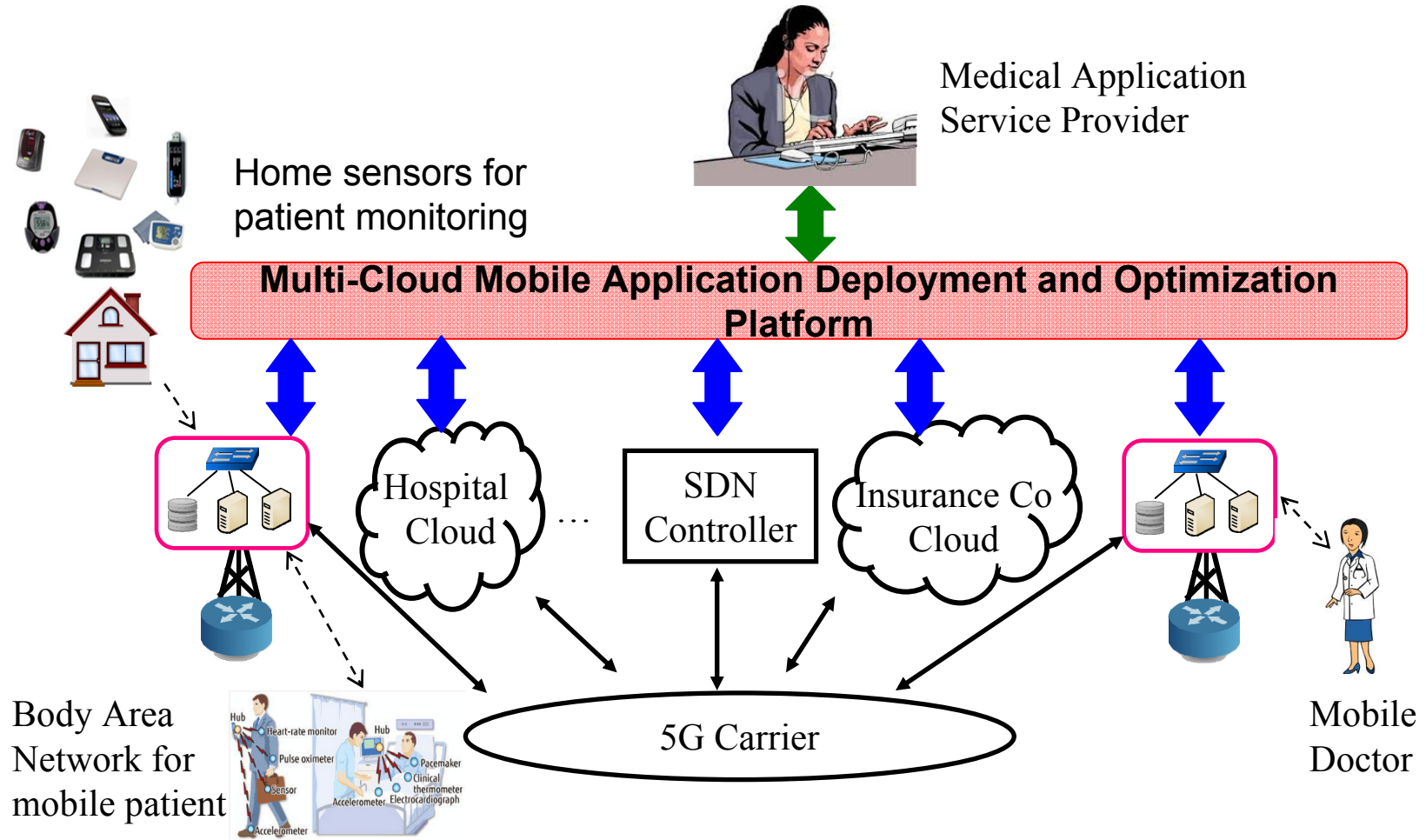
Software Defined Multi-Cloud Application Management



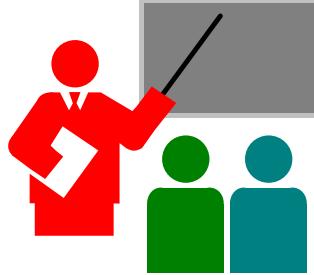
MCAD Features

- ❑ **Automate** the entire process of creating new workflows and installing them, managing them during runtime, uninstalling them as necessary
 - Allow **Deployment Administrators** specify policies for quantity and location of resources inside various clouds.
- ❑ Workflow creation includes virtual networks, computers, storage inside the clouds as well as the network between the clouds
- ❑ **WAN bandwidth** and latency is the key to placement. Allows manual approval and override.
- ❑ Physical infrastructure owners keep complete control over their resources while the tenant service providers can deploy their applications according to their desired policies
- ❑ All communication is via APIs. All interfaces initially XML based. GUI based in future.

Mobile Healthcare Use Case



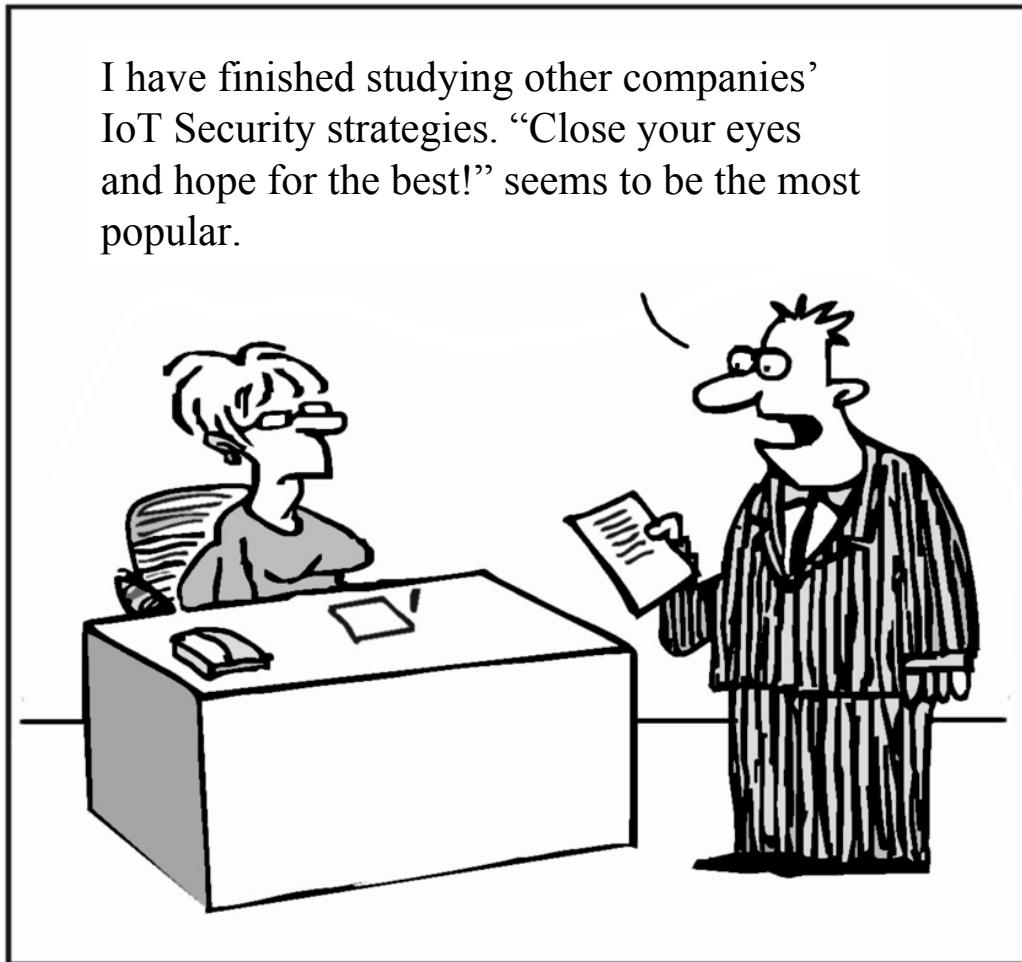
Summary



1. IoT research areas are easy via the 7-layer model
2. IoT has brought in research issues in every layer: Sensors, datalink, routing, applications, analytics.
3. Security and privacy are most important
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 multi-cloud applications

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

Recent Papers

- ❑ 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
- ❑ Raj Jain, Mohammed Samaka, "Application Deployment in Future Global Multi-Cloud Environment," The 16th Annual Global Information Technology Management Association (GITMA) World Conference, Saint Louis, MO, June 23, 2015, http://www.cse.wustl.edu/~jain/papers/apf_gitp.htm

Recent Papers (Cont)

- 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

Recent Talks

- ❑ 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/smrctcit.htm>
- ❑ Raj Jain, "**Five Trends in Computing Leading to Multi-Cloud Applications and Their Management**," 2015 CMG Performance and Capacity Conference, San Antonio, TX, November 5, 2015, http://www.cse.wustl.edu/~jain/talks/apf_cmg.htm
- ❑ Raj Jain "**Application Deployment in Future Global Multi-Cloud Environment**," OIN Workshop, Saint Louis, MO, October 20, 2015, http://www.cse.wustl.edu/~jain/talks/apf_oin.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

Acronyms

- ❑ 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
- ❑ TCP Transmission Control Protocol
- ❑ TV Television
- ❑ VM Virtual Machine
- ❑ WAN Wide Area Network
- ❑ WiFi Wireless Fidelity