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

Orchestrator

Cloud

Cloud

Cloud

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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
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### Trend 1: Smart Everything

<table>
<thead>
<tr>
<th>Smart Watch</th>
<th>Smart TV</th>
<th>Smart Car</th>
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<td>Smart Health</td>
<td>Smart Home</td>
<td>Smart Kegs</td>
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<td>Smart Space</td>
<td>Smart Industries</td>
<td>Smart Cities</td>
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What’s Smart?

Old: Smart = Can think \implies \text{Computation}
             = Can Recall \implies \text{Storage}

Now: Smart = Can find quickly, Can Delegate
       \implies \text{Communicate} = \text{Networking}

Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …
Trend 2: Micro-Cloud Computing

q Cloud computing was invented in 2006

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

q Today: Cloud = Computing using virtual resources

  ŷ µCloud = Cloud in a server with multiple VMs.

  ŷ Each VM with Multiple Containers ⇒ Multiple Services
Trend 3: Mobile Edge Computing

To service mobile users/IoT, the computation needs to come to edge \( \Rightarrow \) Mobile Edge Computing

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

Trend 6: Network Function Virtualization (NFV)


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Trend 7: Software Defined Multi-Cloud

Orchestrating devices to Orchestrating Clouds

Datacenter Applications

Global Applications

Orchestrator

Cloud

Cloud

Orchestrator


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OpenADN Multi-Cloud Management


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Mobile Healthcare Use Case

Home sensors for patient monitoring

Multi-Cloud Mobile Application Deployment and Optimization Platform

- Hospital Cloud
- Insurance Co Cloud
- 5G Carrier

Medical Service Administrator

SDN Controller

Body Area Network for mobile patient

Mobile Doctor

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What are the Research Problems for IoT and Smart Cities?
A 7-Layer Model of IoT

- **Services**: Energy, Entertainment, Health, Education, Transportation, …
- **Apps and SW**: SDN, SOA, Collaboration, Apps, Clouds
- **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, …
- **Market**: Smart Grid, Connected home, Smart Health, Smart Cities, …

ICT

Security

Management
## A 7-Layer Model of Smart Cities

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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.


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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)

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

Countries with most interest in Blockchains:

1. Ghana
2. Nigeria
3. Singapore
4. Hong Kong
5. South Africa
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 $\Rightarrow$ Fast
  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
Blockchains

q **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

q **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 ⇒ Attracts Hackers
3. Central party may be hacked ⇒ affects millions
4. Central party is a single point of failure. Can malfunction or be bribed.

Blockchains For Cities

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

Blockchains for Cities (Cont)

Indian State Uses Blockchain Technology to Stop Land Ownership Fraud
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 ⇒ 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 ⇒ 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

Related Papers (Cont)


Related Papers (Cont)


Related Papers (Cont)

