Internet of Things: Research Issues

Washington University in St. Louis
Saint Louis, MO ns
NSF Applications and Services Workshop, Washington DC,
January 27, 2016

These slides are available on-line at:
http://www.cse.wustl.edu/~jain/talks/iot_nsf.htm
Overview

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

<table>
<thead>
<tr>
<th>Smart Watch</th>
<th>Smart TV</th>
<th>Smart Car</th>
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<tr>
<td><img src="image1" alt="Smart Watch" /></td>
<td><img src="image2" alt="Smart TV" /></td>
<td><img src="image3" alt="Smart Car" /></td>
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<tr>
<th>Smart Health</th>
<th>Smart Home</th>
<th>Smart Kegs</th>
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<td><img src="image4" alt="Smart Health" /></td>
<td><img src="image5" alt="Smart Home" /></td>
<td><img src="image6" alt="Smart Kegs" /></td>
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<th>Smart Space</th>
<th>Smart Industries</th>
<th>Smart Cities</th>
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<td><img src="image7" alt="Smart Space" /></td>
<td><img src="image8" alt="Smart Industries" /></td>
<td><img src="image9" alt="Smart Cities" /></td>
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</tbody>
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What’s Smart?

- Old: Smart = Can think \implies Can compute
- Now: Smart = Can Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …
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, …
A 7-Layer Model of Smart Cities

- **Infrastructure**
  - Roads, Trains, Buses, Buildings, Parks, …

- **Acquisition**
  - Sensors, Cameras, GPS, Meters, Smart phones, …

- **Interconnection**
  - DECT/ULE, WiFi, Bluetooth, ZigBee, NFC, …

- **Integration**
  - Sensor data, Economic, Population, GIS, …

- **Analytics**
  - Machine learning, predictive analytics, Data mining, …

- **Apps and SW**
  - SDN, SOA, Collaboration, Apps, Clouds

- **Services**
  - Energy, Entertainment, Health, Education, Transportation, water, …

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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, …
IoT is a Data ($) Mine

Ref: https://www.pinterest.com/iofficecorp/humor/
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Top Inhibitors to the Adoption of the IoT

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


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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](http://fortifyprotect.com/HP_IoT_Research_Study.pdf)
Ref: M. Barcena and C. Wueest, “Insecurity in the Internet of Things,” Symantec, March 2015,
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.

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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, …
Past: Data in the Edge

- To serve world-wide users, latency was critical and so the data was replicated and brought to edge
Trend: Computation in the Edge

- To service mobile users/IoT, the computation needs to come to edge ⇒ Micro-cloud on the tower ⇒ Mobile-Edge Computing
Trend: Multi-Cloud

- Larger and infrequent jobs serviced by local and regional clouds ⇒ Fog Computing
Past: Software Defined Networking

- Network can be managed w/o worrying about individual device hardware

![Diagram of network management](network_diagram.png)
Trend: Software Defined Multi-Cloud Application Delivery

Multi-Cloud Application Manager

Application Developer/Manager/User

Users

Network

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Trend: Adaptive Everything

- Smart = Connected
- Adaptive = Machine Learning
  Aka “Intelligent”
  Aka “Autonomous”
- Adaptive Security
- Proactive fault diagnosis
Trend: Personal Clouds

- **Digital Mesh**: All “Things” belonging to a person
  - Computing and communication, Wearables, transportation
  - Social interactions, Communities, Business, …
- Analytics of information, machine learning
- **Personal Clouds** ⇒ “Smart” personal environments
- Autonomous Personal Assistants ⇒ Predicts personal needs
- Same applies to families, communities, and cities
Hype Cycle of Emerging Technologies 2015


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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 ⇒ Fog Computing ⇒ Mobile-Edge Computing
5. SDN concepts need to move up a layer – from Virtualizing routers to Virtualizing clouds
Recent Papers


Recent Papers (Cont)

  http://www.cse.wustl.edu/~jain/papers/vm_dist.htm
Recent Talks


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

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