Recent Advances in Networking and their Impact on Smart Cities

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These slides and a video of this talk are at:
http://www.cse.wustl.edu/~jain/talks/smrtciti.htm
Overview

1. Areas of Research for Smart Cities
2. Security
3. Blockchains
4. AI and Machine Learning
5. Micro-Clouds, Edge Computing
City IQ: Benchmark for Smartness

- ISO 37120:2014 Sustainable Development of Communities: Indicators for City Services and Quality of Life
- Using 17 themes and 100 indicators for city services and quality of life, World Council of City Data (WCCD) give a city one of five levels.

- **Aspirational**: 30-45
- **Bronze**: 46-59
- **Silver**: 60-75
- **Gold**: 76-90
- **Platinum**: 91-100

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Areas Measured by ISO 37120:2014

1. Economy
2. Education
3. Energy
4. Environment
5. Finance
6. Fire and emergency response
7. Governance
8. Health
9. Recreation
10. Safety
11. Shelter
12. Solid waste
13. Telecommunications and innovation
14. Transportation
15. Urban planning
16. Wastewater
17. Water and sanitation
Indicators

- Indicators: Quantitative, qualitative, or descriptive measures. 47 of 100 are core.
- Core (Required), Supporting (Recommended), Profile (Informative) indicators
- Example: Education
  1. % of female school-aged population enrolled in schools (core)
  2. % of students completing primary education: survival rate (core)
  3. % of students completing secondary education: survival rate (core)
  4. Primary education student/teacher ratio (core)
  5. % of male school-aged population enrolled in schools (supporting)
  6. % of school-aged population enrolled in schools (supporting)
  7. # of higher education degrees per 100,000 population (supporting)

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List of Smart Cities

- World Council on City Data (WCCD): Worldwide 90 cities are on the list. Only five from US:

<table>
<thead>
<tr>
<th>Year</th>
<th>City</th>
<th>Level</th>
</tr>
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<tbody>
<tr>
<td>2014</td>
<td>Boston</td>
<td>Platinum</td>
</tr>
<tr>
<td>2015</td>
<td>Los Angeles</td>
<td>Platinum</td>
</tr>
<tr>
<td>2016</td>
<td>San Diego</td>
<td>Platinum</td>
</tr>
<tr>
<td>2016</td>
<td>Doral</td>
<td>Platinum</td>
</tr>
<tr>
<td>2017</td>
<td>Portland</td>
<td>Platinum</td>
</tr>
</tbody>
</table>

Ref: [http://www.dataforcities.org/registry](http://www.dataforcities.org/registry)

<table>
<thead>
<tr>
<th>Trend: Smart Everything</th>
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<tbody>
<tr>
<td><strong>Smart Watch</strong></td>
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<tr>
<td><strong>Smart TV</strong></td>
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<td><strong>Smart Car</strong></td>
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<td><strong>Smart Health</strong></td>
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<td><strong>Smart Kegs</strong></td>
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<td><strong>Smart Space</strong></td>
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<td><strong>Smart Industries</strong></td>
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<td><strong>Smart Cities</strong></td>
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What’s Smart?

- Old: Smart = Can think ⇒ Computation
- Later: Smart = Can recall ⇒ Storage
- Now: Smart = Can communicate ⇒ Connected

Not-Smart  Smart

- Smart City predates all other smart things:
  - 1992: World Foundation for Smart Communities –
    - Smart City = Technology, Innovation, Globalization
    ⇒ 36 years old problem
- Smart = Apply the latest **technology** to solve problems

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, Blockchains
- Services: Energy, Entertainment, Health, Education, Transportation, water, …

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Areas of Research for Smart Cities

1. **PHY**: Smart devices, cameras, 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. **Data Analytics**: Big-data, data mining, **Machine learning**, Predictive analytics, …
5. **Apps & Software**: SDN, SOA, **Cloud computing**, Web-based collaboration, Social networking, **Blockchains**, …
6. **Security**: Privacy, Trust, Identity, Anonymity, …
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 (DoS) Attack.


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DEFCON

- Hacker’s conference
- Held in Las Vegas every July
- 25,000+ attendees
- All anonymous

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

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Recent DEFCON Topics

- Hacking voting machines
- Outsmarting the smart city (2018)
- Abusing smart cities (2016)
- How to track government spy planes
- 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
- Break bitcoin hardware wallets
- DARPA Cyber Grand Challenge (2015, 2016)
Smart City Cyber Insecurity

- **Default passwords**: Admin
- Shell injection attacks on **web interface**
- **Faulty interface**: Shows device location w/o password
- Authentication bypass by tweaking a URL
- Traffic control sensors use communication in **clear**
- **Nation state actors**: Russia vs. USA, North Korea vs. South Korea, India vs. Pakistan


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Hype Cycle for Digital Government Technology 2018

Trend: Blockchains

- Blockchain is the technology that made Bitcoin secure.
- Blockchain was invented by the inventor of Bitcoin in October 2008 with source code on 9 January 2009.
- 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/contract without a third party.
Example of a Contract: Wedding
Wedding (Cont)

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

- Distributed Trust
  - Decentralized
  - No single point of failure
  - Very difficult to hack
Trend: Centralized to Distributed

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

**Time is a cycle: Distributed vs. Centralized debate**
Examples of Centralized Systems

- **Banks**: Allow money transfer between two accounts
- **City Records**
- **Voting Authorities**
- **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.

Blockchain Applications for Smart Cities

- **Taxes**: Arizona considering accepting Bitcoin for tax payment, [The Motely Fool, Feb 18, 2018]
- **Elections**: "Brazilian Electoral System to Use Ethereum Blockchain Network." [NewsBTC, 8 January 2018].
- **Social/Disability Assistance**: New York uses Blockchain to give Homeless a Digital Identity. [Fast Company, 6 December 2017].
- **Identity**: e-Residency in Estonia, Wired, 27 March 2017
  \[33000\text{ e-residents, 5000 companies}\]
- **Entire City Government**: Dubai Sets Its Sights on Becoming the World's First Blockchain-Powered Government. [Forbes, 28 December 2017].

...
Blockchain Challenges

- High computational cost ⇒ 7 bitcoin transactions per second vs. 1,700 visa credit card transactions
- Software bugs ⇒ Stolen money ⇒ Forking in Ethereum
- All data is public in public blockchains
Trend: Managed to Self-Driven Networks

- **Self-Discover**: Find its components
- **Self-Organize and Self-configure**: Trending. Predict.
- **Auto-Manage** = Auto-BSS (bill)/Auto-OSS (provision)
- **Self-Monitor**: Counters and Probes. Telemetry
- **Self-Diagnose and Self-Heal**: Self-Report to human operator


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Network Manager

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Intent-Based Policy Management

- **Intent**: Tell what you want. Not how you want it done. E.g., Tell Google maps where you want to go. Not how to.

- **Invariance**: Intent doesn’t change if the network changes, devices fail, …

- **Portability**: Independent of infrastructure, equipment vendors, service providers, protocols used, media used, …

- **Compose-ability**: Can use any infrastructure, …

- **Scalable**: From one to billions. Single controllers not scalable.

- **Action requires context**: Actions need to adopt to changes in infrastructure

- **OpenDaylight has a new project on Network Intent Composition (NIC)**

[https://wiki.opendaylight.org/view/Project_Proposals:Network(Intent_Composition](https://wiki.opendaylight.org/view/Project_Proposals:Network(Intent_Composition)
Trend: Smart Cities to Intelligent Cities

- **Pollution Control**: Beijing predicts air-pollution based on weather, traffic, and industrial activity.

- **Real-Time Traffic Prediction**: Hangzhou uses video to monitor accidents, predict congestion and recommend routes.

- **Disability Assistance**: Barcelona is testing camera glasses for people with visual disabilities. Sound guidance for safe navigation and crossing roads.

- **Speech API**: for all city applications.

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Machine Learning Challenges

- Machine learning is currently a blackbox
- ML algorithms are developed/used without domain expertise
- Data cleanliness, labeling, feature extractions, all require domain knowledge, e.g., What is the distance between Port 80, Port 81, and Port 8080?
- Data Imbalance (1 in a million packet is an attack packet).
- Use Synthetic data is used ⇒ Garbage-In, Garbage-Out
- Results are stated without model validation.
- Explainability issue ⇒ No idea of why the results are what they are
Trend: Clouds to Micro-Clouds

- 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.
  - VMs managed via cloud management SW, e.g., OpenStack
Trend: Core to Edge Computing

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

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OpenADN Multi-Cloud Management

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Smart City Use Case for Multi-Clouds

Multi-Cloud Mobile Application Deployment and Optimization Platform

911 Call

Ambulance Cloud

Network Controller

Hospital Cloud

5G Carrier

Doctor

sensors for smart services

Emergency Service Administrator

911 Call Doctor Hospital Cloud

5G Carrier
Summary

1. Smart ≠ High-Speed Computation, Smart ≠ Big Data Storage, Smart = Networked, Smart = Latest Technology

2. Smart Cities research areas are easy via the 7-layer model
   Research issues in every layer: Sensors, data link, routing, applications, analytics.

3. Security is the biggest issue with no simple solutions but need to avoid common simple mistakes

4. Blockchains offer a distributed alternative to centralized solutions for cities

5. AI, Machine Learning, Deep Learning is here. Need to move from smart cities to intelligent cities

6. Clouds are getting smaller ⇒ Micro-Cloud, Edge Computing ⇒ Multi-Cloud
Related Papers

**Multi-Cloud:**


Related Papers (Cont)

Edge Computing:


Related Papers (Cont)

AI for Networking:


Related Talks/Class Lectures


Related Papers (Cont)

**IoT:**

**Blockchains:**
List of Acronyms

- AAS: Application Service Abstraction
- AAW: Application Workload Abstraction
- AI: Artificial Intelligence
- API: Application Programming Interface
- BGP: Border Gateway Protocol
- CapEx: Capital Expenditure
- CCWC: Computing and Communication Workshop and Conference
- DARPA: Defense Advanced Research Project Agency
- DECT: Digital Enhanced Cordless Communication
- DEFCON: D-E-F Conference
- DNS: Domain Name Service
- DSL: Digital Subscriber Line
- EC2: Elastic Compute 2
- FTTH: Fiber to the home
- GIS: Geographic Information System
Acronyms (Cont)

- GPS  Global Positioning System
- HP   Hewlett Packard
- ICISS International Conference on Information Science and Security
- ICT  Information and Communications Technologies
- ID   Identifier
- IoT  Internet of Things
- IP   Internet Protocol
- MCAD Multi-Cloud Application Delivery
- MCSMS Mobile Cloud Computing systems, Management, and Security
- MIT  Massachusetts Institute of Technology
- ML   Machine Learning
- NFC  Near-Field Communication
- OpenADN Open Application Delivery Network
- SDN  Software Defined Networking
- SW   Software
- TCP  Transmission Control Protocol
Acronyms (Cont)

- TV  Television
- ULE  Ultra-Low Energy
- URL  Uniform Resource Locator
- VC  Venture Capitalist
- Wi-Fi  Wireless Fidelity
- XML  eXtended Markup Language