Recent Advances in Networking and their Impact on Smart Cities

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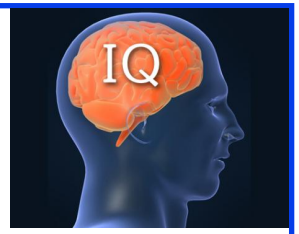
These slides and a video of this talk are at:
http://www.cse.wustl.edu/~jain/talks/smart_cities.htm

Overview

1. IQ of Cities
2. AI and Machine Learning
3. Blockchains

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.

ISO 37120 Aspirational	ISO 37120 Bronze Certified	ISO 37120 Silver Certified	ISO 37120 Gold Certified	ISO 37120 Platinum Certified
30-45	46-59	60-75	76-90	91-100

Ref: WCCD, "WCCD ISO 37120 Certification," http://www.dataforcities.org/iso

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)

Ref: ANSI, "ISO 37120-2014 Preview Final V2, http://publicaa.ansi.org/sites/apdl/ANSI%20Network%20on%20Smart%20and%20Sustainable%20Cities/ISO+37120-2014_preview_final_v2.pdf

List of Smart Cities

- World Council on City Data (WCCD): Worldwide 101 cities are on the list.
- Only **five** from US:

City	Years	Level
Boston	2014-2017	Platinum
Doral	2016-2017	Platinum
Los Angeles	2017, 2015	Platinum
Portland	2017	Platinum
San Diego	2016	Platinum

Ref: https://www.dataforcities.org/global-cities-registry

Past: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

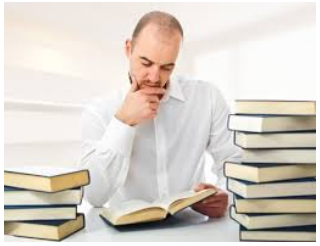
Smart Space

Smart Industries

What's Smart?

- Old: Smart = Can think ⇒ Computation
- Later: Smart = Can recall ⇒ Storage
- 2 yrs ago: Smart = Can communicate ⇒ Connected
- Smart watch, smart home, smart TV are smart simply because they are connected

Not-Smart



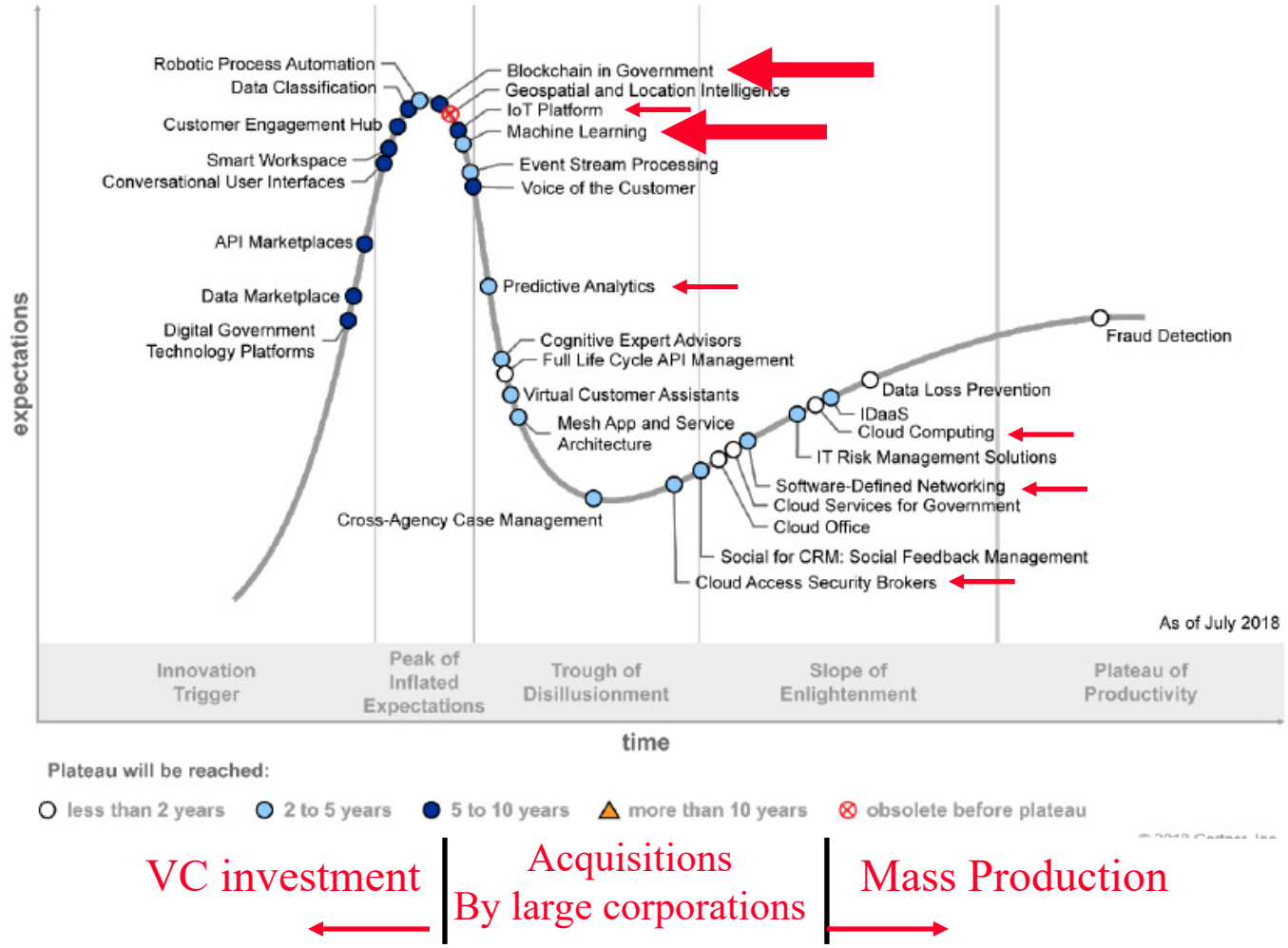
Smart

Smart City

- Smart City predates all other smart things:
  1992: World Foundation for **Smart Communities** –
  Smart City = Technology, Innovation, Globalization
  $\Rightarrow$ 37 years old problem
- Smart = Apply the **latest technology** to solve problems

Ref: Gibson, D.V., Kozmetsky, G., Smilor, R.W. (eds.), "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks," Rowman & Littlefield, New York (1992), 224 pp., ISBN:0847677583

Hype Cycle for Digital Government Technology 2018



VC investment ← | Acquisitions By large corporations | → Mass Production

Ref: R. Holgate, "Hype Cycle for Digital Government Technology, 2018," Garner Report ID G00340212, 27 July 2018, 68 pp.

Trend: Smart to Intelligent

Intelligent Clock

Intelligent TV

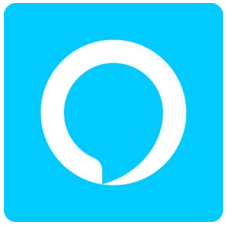
Intelligent Car

Intelligent Health

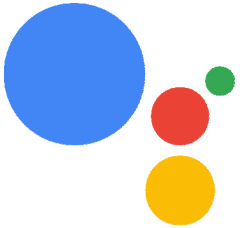
Intelligent Home Security

Intelligent Microwave

Intelligent Light



Amazon Alexa

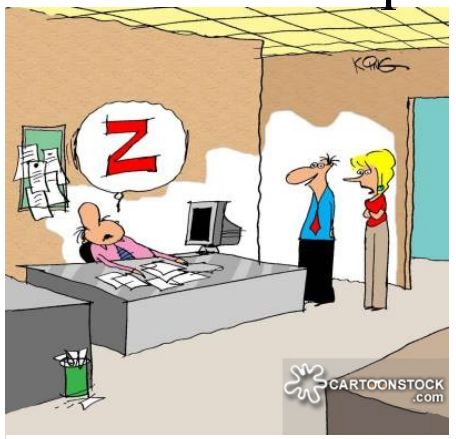


Google Assistant

Trend: Self-Driving City Systems

Water supply, Drainage, Traffic lights, Transportation, ….

- **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



City Manager

Ref: Kireerti Kompella, https://datatracker.ietf.org/meeting/98/materials/slides-98-nmrg-self-driving-networks

Intent-Based Network 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)

Ref: https://www.sdxcentral.com/articles/contributed/network-intent-summit-perspective-david-lenrow/2015/02/
https://wiki.opendaylight.org/view/Project_Proposals:Network_Intent_Composition

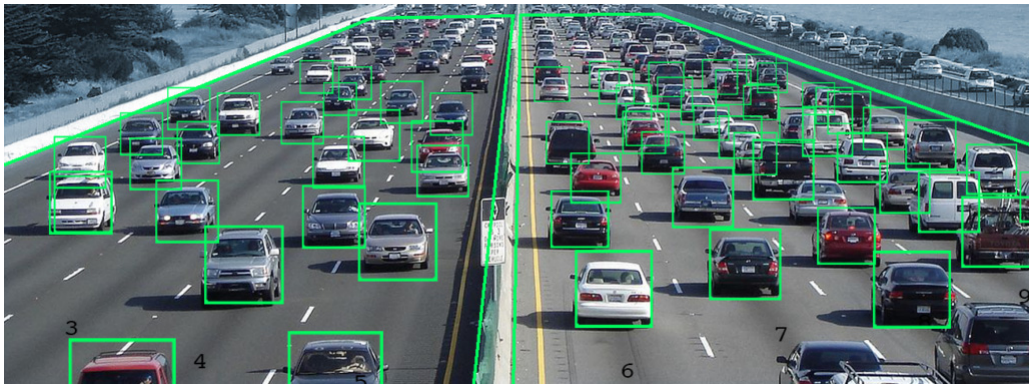
Trend: Smart Cities to Intelligent Cities

- **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

Ref: M. Xiang, "Three Rules When Using AI to Add Value to Your IoT Smart Cities," Gartner Report ID G00348452, 29 March 2018, 14 pp.

Edge AI

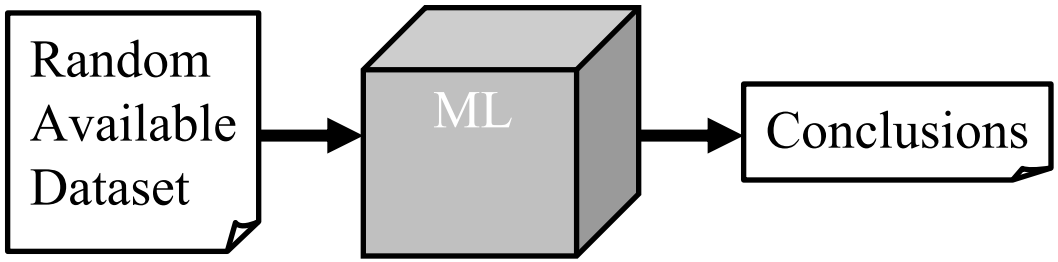
- Edge Computing + AI ⇒ AI in things
- Amazon's DeepLens camera has built-in AI
  Google Clips camera knows what to photograph
- Moving AI to the Edge ⇒ Anomaly Detection
- Deep Neural Network ASICs
  ⇒ GPUs replaced by Tensor Processing Units (TPUs)



Ref: A. Teng, G. Brocklehurst, "Hype Cycle for Semiconductors and Electronics Technologies, 2018," Gartner ID G00340360, 30 July 2018, 61 pp.

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?
- Synthetic data is used ⇒ Garbage-In, Garbage-Out
- Results are stated without model validation.



Trend: AI to Explainable AI

- Data Imbalance (1 in a Billion packet is an attack packet).
  In most papers, 10-15% of the packets are attack packets
- Explainability issue
  ⇒ No idea of why the results are what they are
  Can't discover bugs in ML model implementations

Machine Learning is what only machines can do, but human cannot do and cannot explain

Ref: M. Zolanvari, M. A. Teixeira, R. Jain, "**Effect of Imbalanced Datasets on Security of Industrial IoT Using Machine Learning**," 2018 IEEE International Conference on Intelligence and Security Informatics (ISI), Miami FL, Nov. 9 - 11, 2018, 6 pp., http://www.cse.wustl.edu/~jain/papers/imb_isi.htm

M. Zolanvari, M. A. Teixeira, R. Jain, "**An Explainable Machine Learning Based Security Framework: A Special Case on Industrial IoT," Submitted February 2019.**

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
- Distributed Trust

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

- 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.

Ref: Tara Salman, Maede Zolanvari, Aiman Erbad, Raj Jain, and Mohammed Samaka, "**Security Services Using Blockchains:A State of the Art Survey**" IEEE Communications Surveys and Tutorials, Accepted September 2018, 28 pp., http://www.cse.wustl.edu/~jain/papers/bcs.htm

Blockchains For Cities

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

Ref: http://ledracapital.com/blog/2014/3/11/Bitcoin-series-24-the-mega-master-blockchain-list

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
  $\Rightarrow$ 33000 e-residents, 5000 companies
- **Entire City Government:** Dubai Sets Its Sights on Becoming the World's First Blockchain-Powered Government. [Forbes, 28 December 2017].
- …

Ref: M. Jun, "Blockchain Government," 2018
Ref: R. Holgate, D. Furlonger, R. Howard, "Promising, Practical Blockchain Use Cases for Governments," Gartner Report ID G00350893, 12 March 2018, 11 pp.

Can the Blockchains be Enhanced?

Limitation 1: Only facts are recorded

- Alice is married to Bob
- Alice gave 20 coins to Bob
- Alice signed a contract with Bob to pay 10 coins for 1 kg of xx.

Limitation 2: Binary Validity

- All transactions recorded on the blocks that are committed are valid
- Those not on the committed blocks and old are invalid
- So the recording is binary: only 0 or 1.

Limitation 3: Deterministic Events only

- Can not record that I am only 90% sure that Alice gave 20 coins to Bob.

Ideas to Enhance Blockchains

- Blockchain is just a distributed **data storage** of valid transactions
- All transactions are ***deterministic***
- What's Wrong?
  - Need to convert data to knowledge
  - We are in big data and machine learning age
  - Real life is probabilistic
  - Most to the decisions we make are probabilistic
    ⇒ All decisions have some risk

Ref: T. Salman, R. Jain, and L. Gupta, "**Probabilistic Blockchains: A Blockchain Paradigm for Collaborative Decision-Making**," 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON 2018), New York, NY, Nov. 8-10, 2018, 9 pp., http://www.cse.wustl.edu/~jain/papers/pbc_uem.htm

Risk Propels Progress

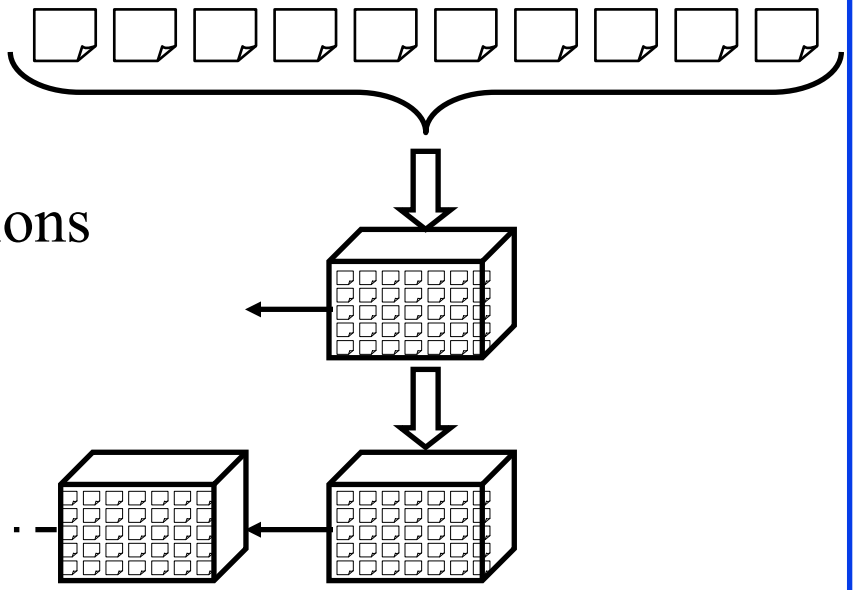
- Banks take money from risk-averse savers and give them interest
- Banks invest the money in corporations ⇒ Takes the country forward
- Venture capitalists take risk by investing in half-cooked ideas
- Startups take risk by working in unchartered territories

Our Goal

- Moving the chain from deterministic to **probabilistic**
- Moving the chain from storage to **computation**
- Moving the chain from data to **knowledge**
- Moving the chain from information to **decision making**
- A blockchain that provides knowledge
  – A **knowledge chain** would be more useful

Blockchain Process

1. **Users** broadcast signed transactions or smart contracts

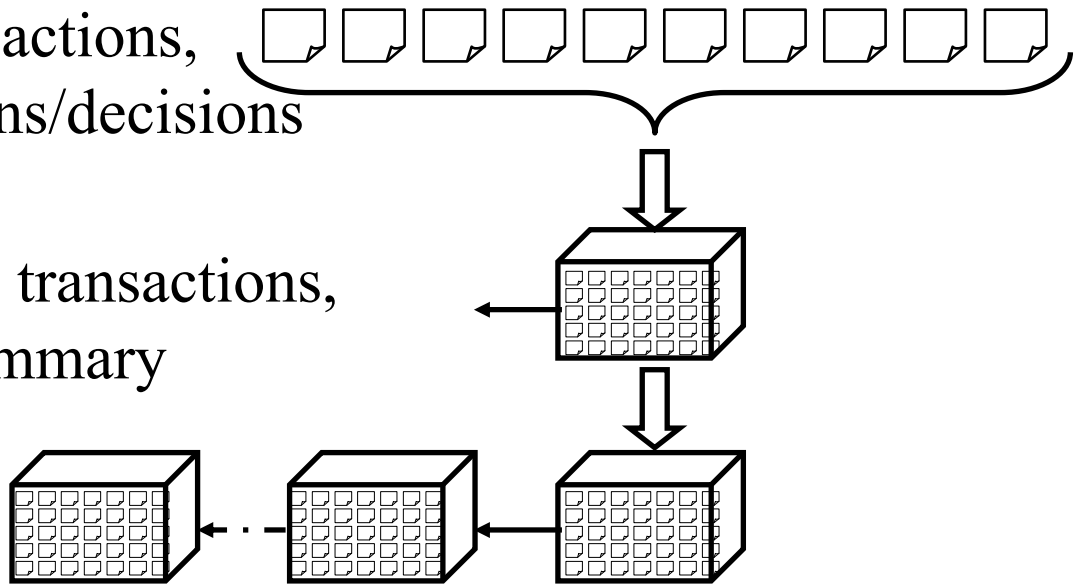


2. **Mining nodes** validate transactions and create blocks.
   Point to previous block.
3. **Blockchain nodes** validate blocks and construct a chain

- There are many users, many mining nodes, and many blockchain nodes.
  More nodes ⇒ Better. Less ⇒ Blockchain not required/useful.

Probabilistic Blockchain Process

1. **Agents** broadcast transactions,
   Transactions = Opinions/decisions



2. **Mining nodes** validate transactions,
   create a knowledge summary
   and create blocks
3. **Blockchain nodes**
   validate blocks
   and construct a chain

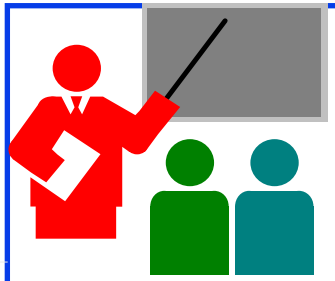
- Two types of users:
  - **Agent nodes** provide their probabilistic opinions/decisions
  - **Management nodes** that inquire the blockchain and use it for group decisions

Blockchain 4.0: Database to Knowledge Base

- Blockchain = Distributed database of smart contracts
- Probabilistic blockchain = Knowledge + database
- **Database**: Who bought, who sold, what quantity, what price, what time
- **Knowledge**:
  - Where the market is going?
  - Whether we should buy, sell, or hold?

Application Examples

1. Spam from Email/IP Addresses/Cloud providers/source/public IP
2. Intrusions/attacks from IP Addresses. Anonymously share attack information.
3. Error/reliability statistics of network/IoT devices
4. Virus in software
5. Insurability assessment
6. Crowd-sourced knowledge, crowd source decisions
7. Air-quality assessment



Summary

1. Smart ≠ High-Speed Computation, Smart ≠ Big Data Storage, Smart = Networked, **Smart = Latest Technology**
2. AI, Machine Learning, Deep Learning is here.
   Need to move from smart cities to **intelligent cities**
3. Blockchains offer a **decentralized** alternative to centralized solutions for cities
4. We have extended blockchains to **probabilistic blockchains** which allow risk assessment and distibuted decision making

Related Papers

AI for Networking:

- Lav Gupta, M. Samaka, Raj Jain, Aiman Erbad, Deval Bhamare, H. Anthony Chan, "**Fault and Performance Management in Multi-Cloud Based NFV using Shallow and Deep Predictive Structures**," 26th International Conference on Computer Communications and Networks (ICCCN 2017), Vancouver, Canada, July 31-Aug 3, 2017, http://www.cse.wustl.edu/~jain/papers/icccn17.htm
- Tara Salman, Deval Bhamare, Aiman Erbad, Raj Jain, Mohammed Samaka, "**Machine Learning for Anomaly Detection and Categorization in Multi-cloud Environments**," The 4th IEEE International Conference on Cyber Security and Cloud Computing (IEEE CSCloud 2017), New York, June 26-28, 2017, http://www.cse.wustl.edu/~jain/papers/cscloud.htm
- Lav Gupta, Mohammed Samaka, Raj Jain, Aiman Erbad, Deval Bhamare, Chris Metz, "**COLAP: A Predictive Framework for Service Function Chain Placement in a Multi-cloud Environment**," The 7th IEEE Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, Jan 9-11, 2017, http://www.cse.wustl.edu/~jain/papers/clp_ccwc.htm

Related Papers (Cont)

- Deval Bhamare, Tara Salman, Mohammed Samaka, Aiman Erbad, Raj Jain, "**Feasibility of Supervised Machine Learning for Cloud Security**," 3rd International Conference on Information Science and Security (ICISS2016), December 19th - 22nd, 2016, Pattaya, Thailand,, http://www.cse.wustl.edu/~jain/papers/iciss16.htm

Blockchains:

- Tara Salman, Maede Zolanvari, Aiman Erbad, Raj Jain, and Mohammed Samaka, "**Security Services Using Blockchains:A State of the Art Survey**" IEEE Communications Surveys and Tutorials, Accepted September 2018, 28 pp., http://www.cse.wustl.edu/~jain/papers/bcs.htm

Related Talks/Class Lectures

- Raj Jain, "**CSE 570: Recent Advances in Networking**," Spring 2018, http://www.cse.wustl.edu/~jain/cse570-18/index.html
- Raj Jain, "**Blockchains: Networking Applications**," An invited talk at the 38th IEEE Sarnoff Symposium, Newark, NJ, Sep 19, 2017, http://www.cse.wustl.edu/~jain/talks/blc_srnf.htm
- Raj Jain, "**The Catch-up Game: Quest for the Impact**," Keynote at ACM SIGCOMM 2017, Los Angeles, CA, August 22, 2017, http://www.cse.wustl.edu/~jain/talks/sigcomm.htm
- Raj Jain, "**Multi-Cloud Global Application Delivery for Smart Cities**," International Summit on Smart World and Smart Cities, Fremont, CA, USA, Aug 5, 2017, http://www.cse.wustl.edu/~jain/talks/smrtwrld.htm

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 Enchanced 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

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

