Recent Networking Developments for IoT: What's In What's Out

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

Overview

1. Current Trends in IoT ⇒ Research topics
2. Micro-Clouds, Edge Computing
3. Security
4. AI and Machine Learning
5. Blockchains

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Past: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

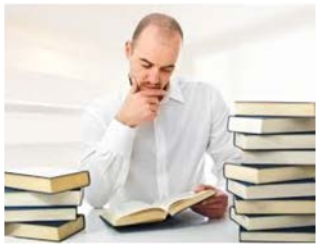
Smart Space

Smart Industries

What's Smart?

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

Not-Smart



Smart

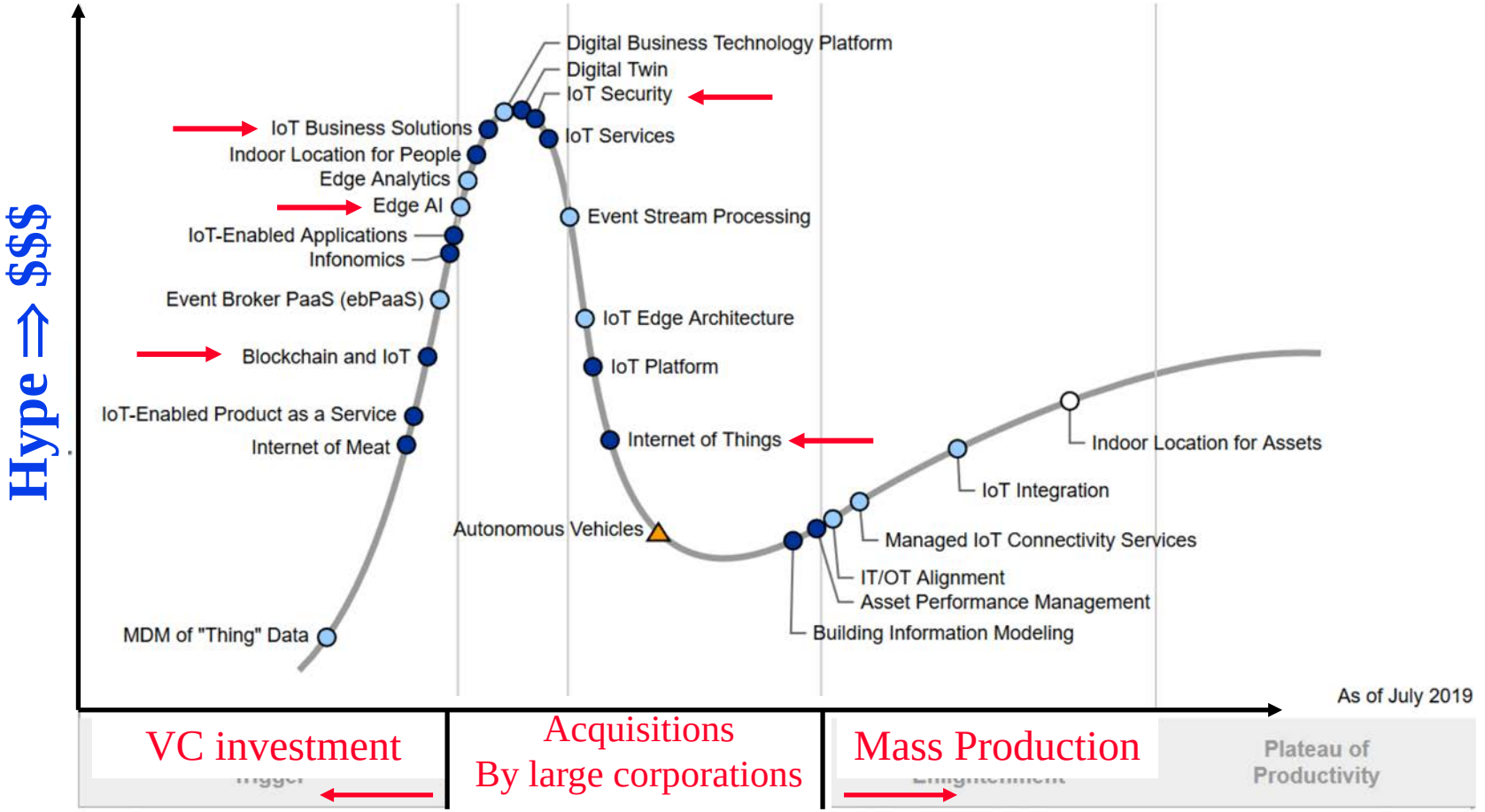
Ref: Gibson, D.V., Kozmetsky, G., Smilor, R.W. (eds.), "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks," Rowman & Littlefield, New York (1992), 224 pp., ISBN:0847677583

History of IoT

- Sensor based IoT around for 14 years (Since 2006)
  RFID was there before but not real networking.
- iPhone: January 9, 2007
- 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 $3.4B funding for **smart grid** in American Recovery and Reinvestment Act of 2009

Ref: Subharthi Paul, Jianli Pan, Raj Jain, "Architectures for the Future Networks and the Next Generation Internet: A Survey," Computer Communications, UK, Volume 34, Issue 1, 15 January 2011, pp. 2-42, http://www.cse.wustl.edu/~jain/papers/i3survey.htm

Gartner's Hype Cycle For IoT 2019



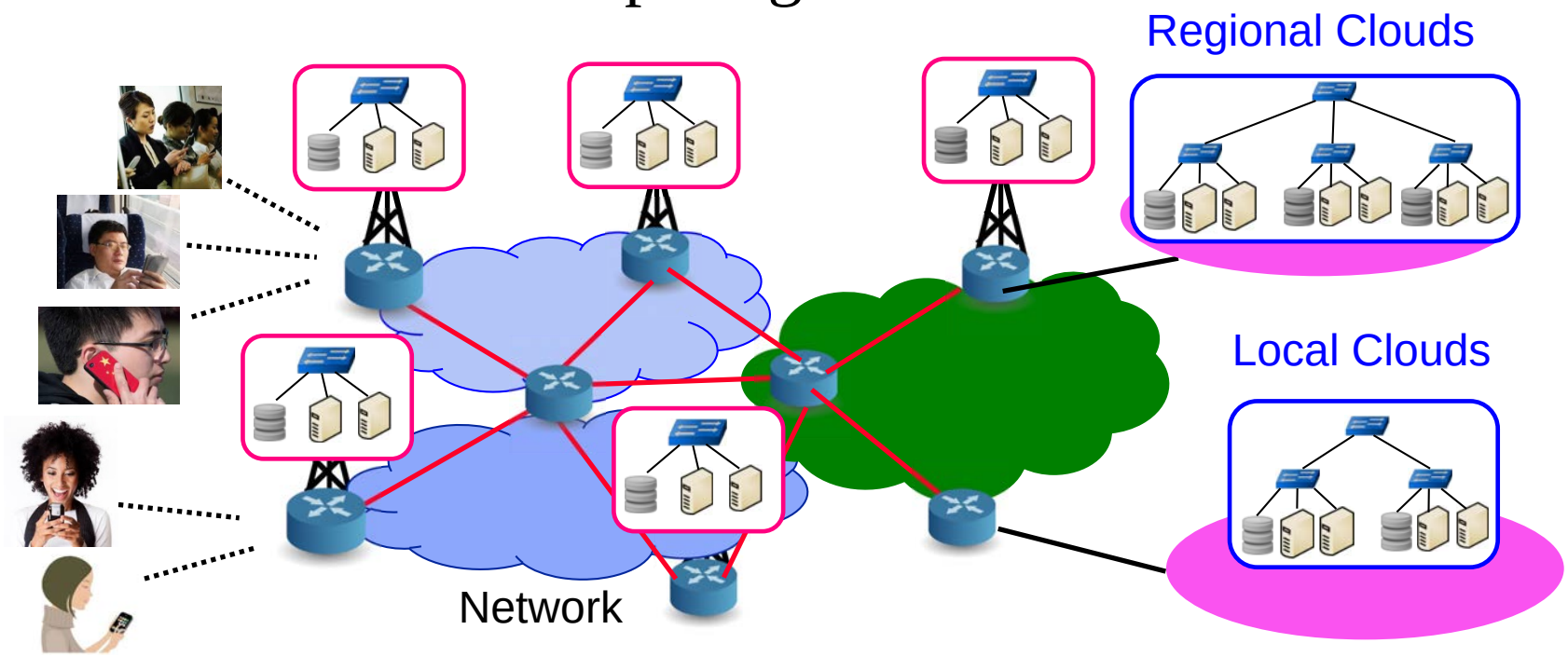
Ref: A. Velosa, W. R. Schulte, B. Lheureux,"Hype Cycle for the Internet of Things, 2019," Gartner ID: G00369467, 16 July 2019, 59 pp.

Trend 1: 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 2: Core to Edge Computing

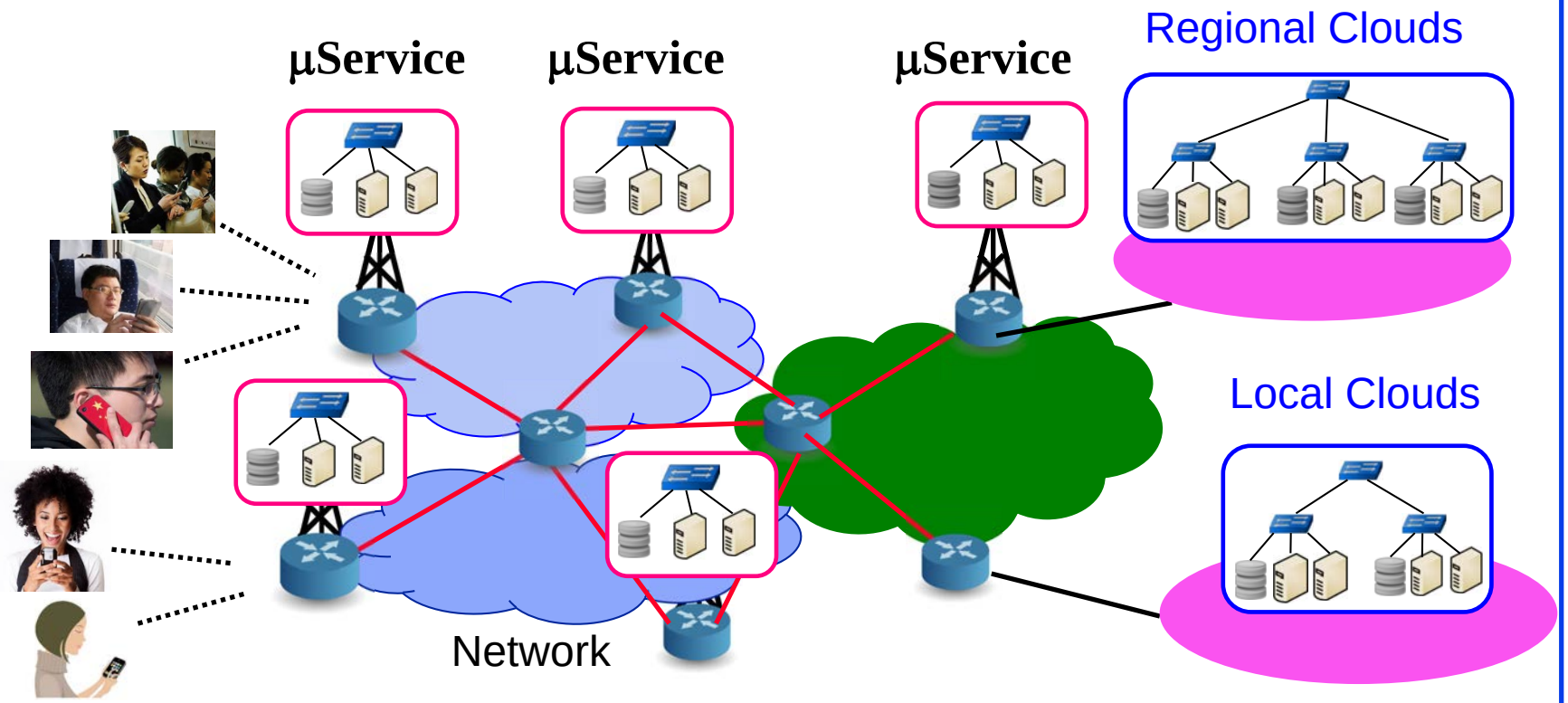
- To service mobile users/IoT, Computation needs to come to edge ⇒ Mobile Edge Computing
  ⇒ Multi-Cloud Computing



Ref: Lav Gupta, Raj Jain, H. Anthony Chan, "Mobile Edge Computing - an important ingredient of 5G Networks," IEEE Softwarization Newsletter, March 2016, http://www.cse.wustl.edu/~jain/papers/mec16.htm

Trend 3: Services to Micro-Services

- **Decomposition**: Applications are broken in to smaller pieces that run in isolation on multi-clouds

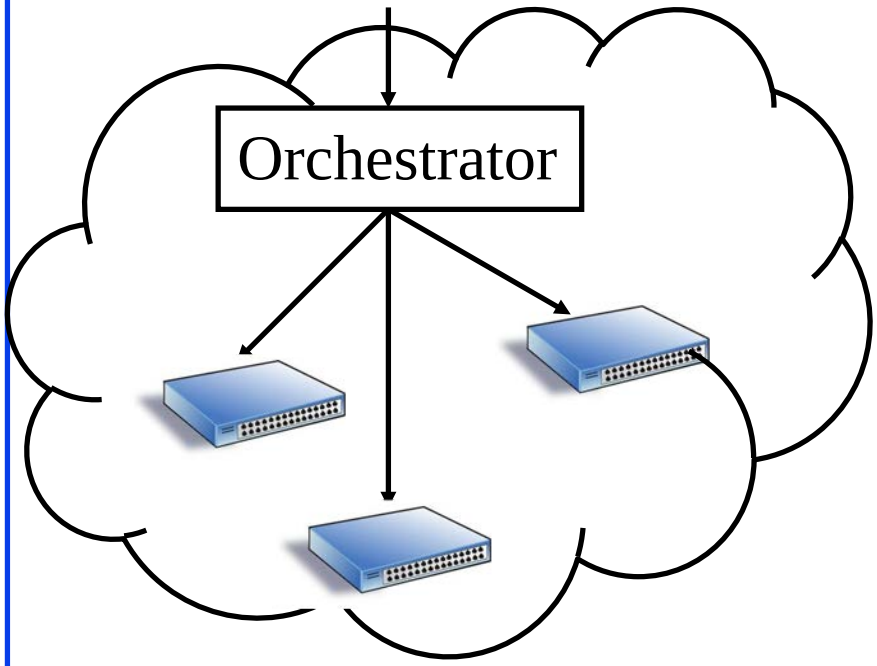


Ref: D. Bhamare, M. Samaka, A. Erbad, R. Jain, L. Gupta, H. A. Chan, "**Multi-Objective Scheduling of Micro-Services for Optimal Service Function Chains**," ICC 2017, May 21-25, 2017, http://www.cse.wustl.edu/~jain/papers/icc17.htm

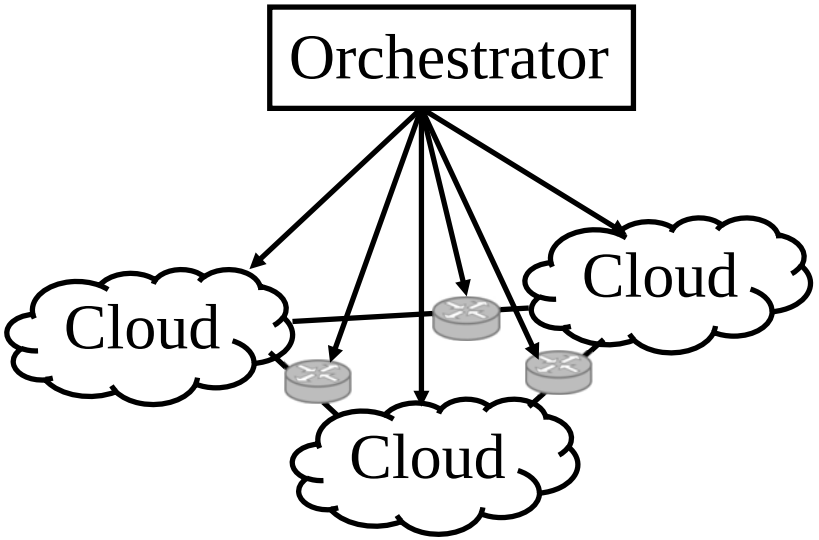
Trend 4: Orchestration of Switches to Orchestration of Multi-Cloud

- Orchestrating devices to Orchestrating Clouds
- Micro-Service placement and optimization in multi-clouds

Datacenter Applications

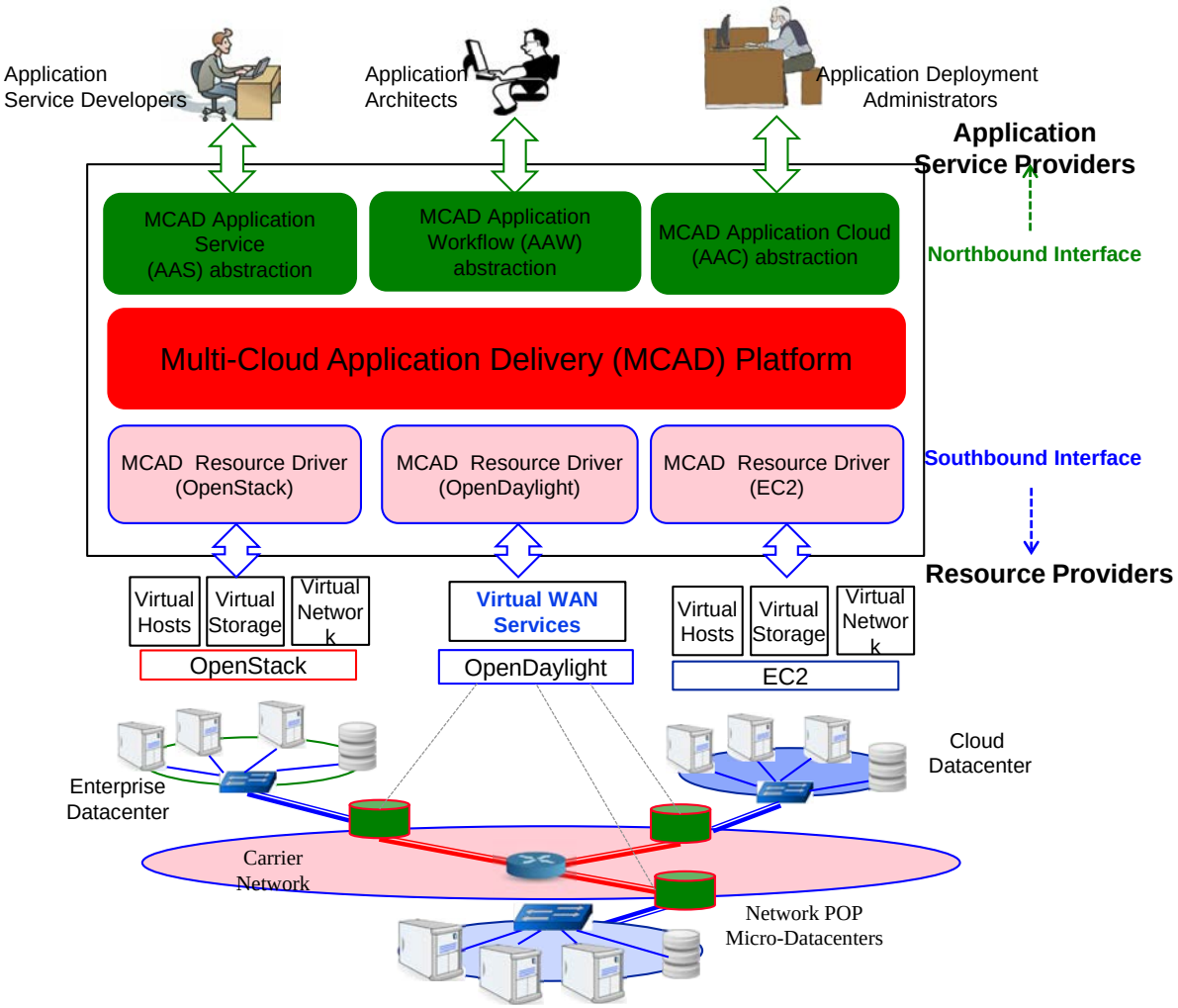


Global Applications



Ref: 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, December 2013, http://www.cse.wustl.edu/~jain/papers/comnet14.htm

OpenADN Multi-Cloud Management



Ref: Lav Gupta, Raj Jain, Mohammed Samaka, "Analysis of Application Delivery Platform for Software Defined Infrastructures," International Journal of Communication Networks and Distributed Systems, 2016, Vol. 5, http://www.cse.wustl.edu/~jain/papers/ijcnds16.htm

IoT Use Case for Multi-Clouds

Emergency Service Administrator

sensors for smart services

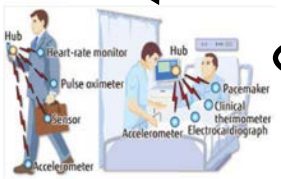
Multi-Cloud Mobile Application Deployment and Optimization Platform

Ambulance Cloud

Network Controller

Hospital Cloud

911 Call



5G Carrier

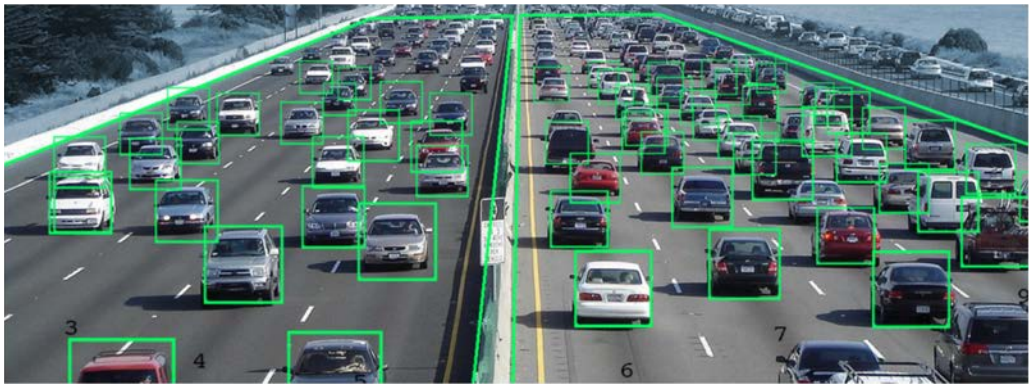
Doctor

Trend 6: Smart to Intelligent

 Intelligent Clock	 Intelligent TV	 Intelligent Car
 Intelligent Health	 Intelligent Home Security	 Intelligent Microwave
 Intelligent Light	 Amazon Alexa	 Google Assistant

Trend 7: Edge AI

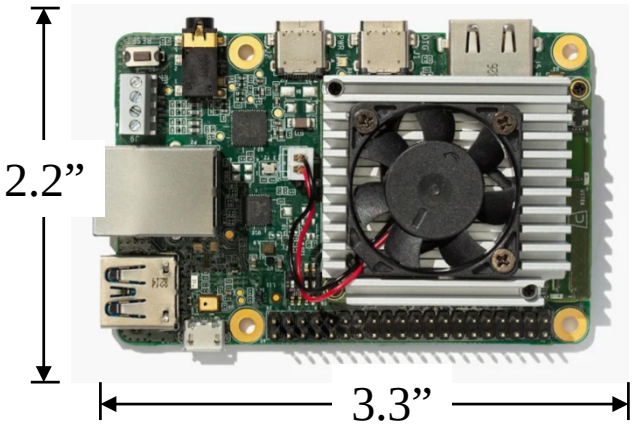
- Edge Computing + AI ⇒ AI in things
- Amazon's DeepLens camera has built-in AI
  Google Clips camera knows what to photograph
- Moving AI to the Edge ⇒ Anomaly Detection
- Deep Neural Network ASICs
  ⇒ GPUs replaced by Tensor Processing Units (TPUs)



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

Tensor Processing Units

- Moving AI to the Edge
  ⇒ Data Compression and Anomaly Detection
- **Google Coral Development Board**
  - Edge Tensor Processing Unit (TPU)
  - Machine learning accelerator
  - Low cost: Below $150
- Similar offerings from Nvidia (Jetson nano) and others



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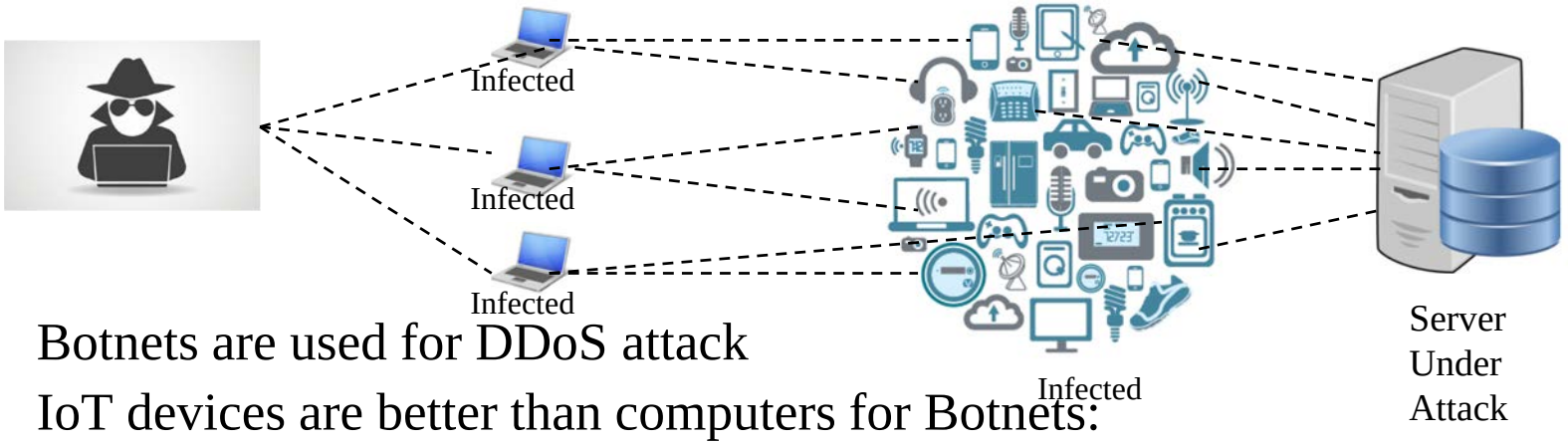
IoT as an Attack Weapon



- Botnets are used for DDoS attack
- IoT devices are better than computers for Botnets:
  - Very high population compared to computers
  - Mostly unprotected with default passwords, open ports
  - Cameras, Routers, …
- Oct 21, 2016: Mirai bot used 62 default usernames and passwords to infect 380,000 IoT devices and then caused a DDoS attack on a popular DNS service dyn.com
  ⇒ Disabled many other sites for hours
- Mirai bot has made its source code public ⇒ Any kid can use it.
  ⇒ Xiangmai has recalled 10,000 webcams.

Ref: T. Green, "The secret behind the success of Mirai IoT botnets," Network World, Oct 27, 2016, http://www.networkworld.com/article/3136314

Attack Surface

1. **IoT Devices**
2. **IoT wireless access technology**: DECT, Wi-Fi, Z-wave, …
3. **IoT Gateway**: Smart Phone
4. **Home LAN**: Wi-Fi, 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, …

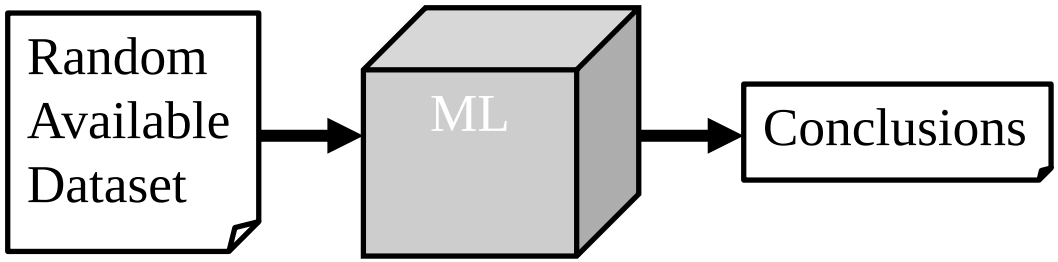
Things | Access | Gateway | WAN | Cloud | Users

Trend 8: AI Everywhere

- Intelligent security
- Intelligent human interface
- Intelligent data compression and analytics
  - Intelligent Things
  - Intelligent Gateways/Servers
  - Intelligent Edge/Core Clouds
  - Intelligent LAN/WAN Networks

Machine Learning Challenges

- Machine learning is currently a black box
- 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.



AI for Security

- AI started with image analysis but needs to be extended for security
- Security data is very different from image data
  - Most security datasets are not representative of real world.
  - In most papers, 10-15% of the packets are attack packets
- In real-world, 1 in a billion packets is an attack packet
  - Mis-classify the attack packet ⇒ 99.9999% accuracy
  - Current metrics and methods not suitable for highly imbalanced data
- **Data imbalance** is a key issue in AI for security

1% attack = 

Trend 9: AI to Explainable AI

- 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.**

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/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 10: Centralized to Decentralized

- **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: Decentralized vs. Centralized debate

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?

Probabilistic Blockchains

- Current blockchains allow **only valid** transactions
- Our Probabilistic Blockchains allow **probabilistic statements**:
  I think the attack is from Russia with 90% probability
  I am 80% confident that IBM stock will go up tomorrow 5%
- Allows risk assessment using a large number of opinions
  ⇒ **Crowd sourcing** of risk assessment
  ⇒ Particularly applicable to security risks
- Decisions are weighted by the reputation of the opinion makers
  Some people are experts on the topic ⇒ High Reputation
  Others are just bluffing ⇒ Low reputation after a few bluffs

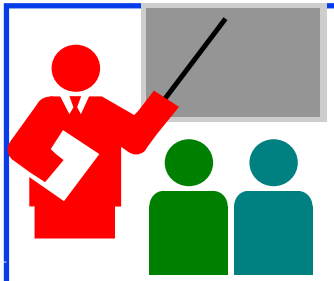
Ref: T. Salman, M. Zolanvari, A. Erbad, R. Jain, and M, Samaka, "**Security Services Using Blockchains: A State of the Art Survey**" IEEE Communications Surveys and Tutorials, 2019, Volume 21, Issue 1, 858-880 pp., http://www.cse.wustl.edu/~jain/papers/bcs.htm

T. Salman, R. Jain, and L. Gupta, "**Probabilistic Blockchains: A Blockchain Paradigm for Collaborative Decision-Making**," 9th IEEE UEMCON 2018, http://www.cse.wustl.edu/~jain/papers/pbc_uem.htm

T. Salman, R. Jain, L. Gupta, "**A Reputation Management Framework for Knowledge-Based and Probabilistic Blockchains**," 2019 IEEE International Conference on Blockchain, July 14, 2019, http://www.cse.wustl.edu/~jain/papers/rpmcewa.htm

Blockchain Applications for IoT

- Error/reliability statistics of network/IoT devices
- Crowd-sourced knowledge, crowd source decisions
- **Sensor Reputation => faulty sensors**



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 things to **intelligent things**
3. AI was originally designed for image and language processing. Needs significant innovations for security applications. **Imbalance** and **Explainability**.
4. Blockchains offer a **decentralized** alternative to centralized solutions for IoT
5. We have extended blockchains to **probabilistic blockchains** which allow risk assessment and distributed decision making

Related Papers: IoT

- Maede Zolanvari, Marcio A. Teixeira, Lav Gupta, Khaled Khan, Raj Jain, "**Machine Learning Based Network Vulnerability Analysis of Industrial Internet of Things**," IEEE Internet of Things Journal, Vol. 6, Issue 4, Aug 2019, http://www.cse.wustl.edu/~jain/papers/vulnerab.htm
- Tara Salman, Raj Jain, "**A Survey of Protocols and Standards for Internet of Things**," Advanced Computing and Communications, Vol. 1, No. 1, March 2017, http://www.cse.wustl.edu/~jain/papers/iot_accs.htm

Related Papers: Blockchains

- Tara Salman, Raj Jain, Lav Gupta, "**A Reputation Management Framework for Knowledge-Based and Probabilistic Blockchains**," IEEE 1st International Workshop on Advances in Artificial Intelligence for Blockchain (AIChain 2019), held in conjunction with the 2019 IEEE International Conference on Blockchain, Atlanta, July 14, 2019, http://www.cse.wustl.edu/~jain/papers/rpmcewa.htm
- Tara Salman, Raj Jain, and Lav Gupta, "**Probabilistic Blockchains: A Blockchain Paradigm for Collaborative Decision-Making**," 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON 2018), New York, NY, November 8-10, 2018, 9 pp., http://www.cse.wustl.edu/~jain/papers/pbc_uem.htm
- 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 Papers: AI

- Maede Zolanvari, Marcio A. Teixeira, Raj 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
- Lav Gupta, Tara Salman, Ria Das, Aiman Erbad, Raj Jain, Mohammed Samaka, "**HYPER-VINES: A HYbrid Learning Fault and Performance Issues ERadicator for VIrtual NEtwork Services over Multi-cloud**," International Workshop on Computing, Networking and Communications (CNC19) at the International Conference on Computing, Networking and Communications (ICNC 2019), Honolulu, Hawaii, Feb. 18-21, 2019, 7 pp., http://www.cse.wustl.edu/~jain/papers/hypervin.htm
- Lav Gupta, Tara Salman, Maede Zolanvari, Aiman Erbad, Raj Jain, "**Fault And Performance Management In Multi-Cloud Virtual Network Services Using AI: A Tutorial And A Case Study**," Computer Networks, Pre-Proof published on 14 Oct 2019, http://www.cse.wustl.edu/~jain/papers/fp_comst.htm

Related Papers: AI (Cont)

- Marcio Andrey Teixeira, Tara Salman, Maede Zolanvari, Raj Jain, Nader Meskin, and Mohammed Samaka, "**SCADA System Testbed for Cybersecurity Research Using Machine Learning Approach**," Future Internet 2018, 10(8), 76, http://www.cse.wustl.edu/~jain/papers/ics_ml.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, 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
- 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

Related Papers: Multi-Cloud

- Lav Gupta, Raj Jain, Aiman Erbadb, Deval Bhamare, "**The P-ART framework for placement of virtual network services in a multi-cloud environment**," Computer Communications, Volume 139, 1 May 2019, Pages 103-122, http://www.cse.wustl.edu/~jain/papers/p_art.htm
- Deval Bhamare, Aiman Erbad, Raj Jain, Maede Zolanvari, Mohammed Samaka, "**Efficient Virtual Network Function Placement Strategies for Cloud Radio Access Networks**," Computer Communications, Volume 127, May 2018, pp. 50-60, http://www.cse.wustl.edu/~jain/papers/cranp.htm
- 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**," Journal of Reliable Intelligent Environments, Vol. 3, No. 4, Dec. 2017, pp. 221-231, http://www.cse.wustl.edu/~jain/papers/jrie17.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

Recent Papers: Multi-Cloud (Cont)

- Deval Bhamare, Mohammed Samaka, Aiman Erbad, Raj Jain, Lav Gupta, H. Anthony Chan, "**Optimal Virtual Network Function Placement and Resource Allocation in Multi-Cloud Service Function Chaining Architecture**," Computer Communications, Vol. 102, April 2017, pp. 1-16, http://www.cse.wustl.edu/~jain/papers/comcom17.htm
- Deval Bhamare, Raj Jain, Mohammed Samaka, Aiman Erbad, "**A Survey on Service Function Chaining**," Journal of Network and Computer Applications, Vol. 75, Nov 2016, pp. 138-155, http://www.cse.wustl.edu/~jain/papers/jnca16.htm
- Lav Gupta, Prof Raj Jain, Prof Mohammed Samaka, Prof Aiman Erbad, and Dr. Deval Bhamare, "**Performance Evaluation of Multi-Cloud Management and Control Systems**," Recent Advances in Communications and Network Technology, 2016, Vol. 5, Issue 1, pp. 9-18, http://www.cse.wustl.edu/~jain/papers/racnt.htm
- Subharthi Paul, Raj Jain, Mohammed Samaka, Aiman Erbad, "**Service Chaining for NFV and Delivery of other Applications in a Global Multi-Cloud Environment**," 21st Annual International Conference on Advanced Computing and Communications (ADCOM) 2015, Chennai, India, September 18-20, 2015, http://www.cse.wustl.edu/~jain/papers/adn_in15.htm

Recent Papers: Multi-Cloud (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
- 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

Related Papers: Edge Computing/5G

- Xin Li, Chengcheng Guo, Lav Gupta, and Raj Jain, "**Efficient and Secure 5G Core Network Slice Provisioning Based on VIKOR Approach**," IEEE Access, 15 October 2019, http://www.cse.wustl.edu/~jain/papers/vikor.htm
- Xin Li, Chengcheng Guo, Jun Xu, Lav Gupta and Raj Jain, "**Towards Efficiently Provisioning 5G Core Network Slice Based on Resource and Topology Attributes**," Applied Sciences, September 2019, http://www.cse.wustl.edu/~jain/papers/5g_slice.htm
- Xin Li, Mohammed Samaka, H. Anthony Chan, Deval Bhamare, Lav Gupta, Chengcheng Guo, and Raj Jain, "**Network Slicing for 5G: Challenges and Opportunities**," IEEE Internet Computing, Vol. 21, Issue 5, September 18, 2017, pp. 20-27, http://www.cse.wustl.edu/~jain/papers/slic_ic.htm
- Lav Gupta, Raj Jain, H. Anthony Chan, "**Mobile Edge Computing - an important ingredient of 5G Networks**," IEEE Softwarization Newsletter, March 2016, http://sdn.ieee.org/newsletter/march-2016/mobile-edge-computing-an-important-ingredient-of-5g-networks

Related Papers: Edge Computing (Cont)

- Deval Bhamare, Aiman Erbad, Raj Jain, Mohammed Samaka, "**Automated Service Delivery Platform for C-RANs**," The IEEE Third International Workshop on Mobile Cloud Computing systems, Management, and Security (MCSMS) 2017, Valencia Spain, May 8-11, 2017, http://www.cse.wustl.edu/~jain/papers/mcsms17.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

Acronyms

- 5G Fifth Generation
- AAC Abstraction for Application Cloud
- AAS Application Service Abstraction
- AAS Application Service Abstraction
- AAW Abstraction for Application Workload
- ACM Automatic Computing Machinery
- ADCOM Advanced Computing and Communications
- AI Artificial Intelligence
- AI Artificial Intelligence
- ASIC Application Specific Integrated Circuits
- CCWC Computing and Communication Workshop and Conference
- COLAP Cost optimized latency aware placement
- COLAP Cost optimized latency aware placement
- CSCloud Computer Science Cloud
- CSE Computer Science and Engineering
- DARPA Defense Advanced Research Project Agency

Acronyms (Cont)

- DDoS Distributed Denial of Service
- DDoS Distributed Denial of Service
- DECT Digital Enhanced Cordless Communication
- DNS Domain Name System
- DNS Domain Name Service
- GPU Graphics Processing Units
- HP Hewlett Packard
- HYPER-VINES HYbrid Learning Fault and Performance Issues ERadicator for VIrtual NEtwork Services over a Multi-cloud
- IEEE Institution of Electrical and Electronic Engineers
- IERC European Research
- IERC IOT European Research Cluster
- IoT Internet of Things
- IoT Internet of Things
- IP Internet Protocol
- LAN Local Area Network

Acronyms (Cont)

- LPWAN Low-Power Wide Area Network
- MCAD Multi-Cloud Application Delivery
- ML Machine Learning
- ML Machine Learning
- NFV Network Function Virtualization
- NFV Network Function Virtualization
- OpenADN Open Application Delivery Network
- OpenADN Open Application Delivery Networking
- RAN Radio Access Networks
- RAN Radio Access Networks
- RFID Radio Frequence Identification
- RFID Radio Frequency Identifier
- SCADA Supervisory Control and Data Acquision
- SDS Software Defined Systems
- SIGCOMM Special Interest Group on Communications
- SW Software

Acronyms (Cont)

- SW Software
- TV Television
- TV Television
- VC Venture Capitalist
- VM Virtual Machine
- VM Virtual Machines
- WAN Wide Area Network
- Wi-Fi Wireless Fidelity
- XML eXtended Markup Language

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