Multi-Cloud Global Application Delivery for Internet of Things and Smart Cities

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These slides and recording of this talk are available on-line at:
http://www.cse.wustl.edu/~jain/talks/iemcon.htm
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Overview

- Why Multi-Cloud?
  - 1. Internet of Things and Smart Cities
  - 2. Mobile Traffic Explosion: NFV
  - 3. Any Function Virtualization
  - 4. Mobile Edge Computing
- OpenADN Multi-Cloud Management
- Service Function Placement Problem
## Trend: Smart Everything

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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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<td>Smart Watch</td>
<td>Smart TV</td>
<td>Smart Car</td>
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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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<td><img src="image8" alt="Smart Industries" /></td>
<td><img src="image9" alt="Smart Cities" /></td>
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<td>Smart Cities</td>
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What’s Smart?

- Old: Smart = Can think ⇒ Computation
  = Can Recall ⇒ Storage
- Now: Smart = Can find quickly, Can Delegate
  ⇒ Communicate = Networking
- Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …
Gartner Hype Cycle 2016

Ref: Gartner, “Hype Cycle for Emerging Technologies, 2016,” July 2016, [subscribers only], gartner.com/document/3383817
IoT Business Opportunity

- $1.7 Trillion by 2020 - IDC
- $7.1 Trillion - Gartner
- $10-15 Trillion just for Industrial Internet – GE
- $19 Trillion – Internet of Everything - Cisco

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

<table>
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<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Roads, Trains, Buses, Buildings, Parks, …</td>
</tr>
<tr>
<td>Acquisition</td>
<td>Sensors, Cameras, GPS, Meters, Smart phones, …</td>
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</tbody>
</table>

**ICT Security Management**
IoT is a Data ($) Mine

I THINK MY NEST SMOKE ALARM IS GOING OFF. GOOGLE ADWORDS JUST PITCHED ME A FIRE EXTINGUISHER AND AN OFFER FOR TEMPORARY HOUSING.

Ref: https://www.pinterest.com/iofficecorp/humor/
http://www.cse.wustl.edu/~jain/talks/iemcon.htm
Top Inhibitors to the Adoption of the IoT

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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.

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

DEFCON 2015 (Cont)

- Hacking a Linux rifle
- Hacking smart safes
- Wirelessly steal cars
- Hack a Tesla
- Hack ZigBee
- Hacking IoT baby monitors
- Hacking FitBit Aria
- Cracking crypto currency
- Hack out of home detention
- Insteon’s false security
- Hacking RFID, NFC
- DARPA Cyber Grand Challenge $2M

Ref: https://www.ethicalhacker.net/features/opinions/first-timers-experience-black-hat-defcon
http://www.cse.wustl.edu/~jain/talks/iemcon.htm

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Attack Surface

1. Users
2. IoT Devices
3. IoT wireless access technology: DECT, WiFi, Z-wave, …
4. IoT Gateway: Smart Phone
5. Home LAN: WiFi, Ethernet, Powerline, …
6. IP and higher layer protocols: DNS, Routers, …
7. Cloud
9. Life Cycle Management: Booting, Pairing, Updating, …
Trend: Micro-Cloud Computing

- 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.
  - Each VM with Multiple Containers ⇒ Multiple Services
Network Function Virtualization (NFV)

Service Provider 1

Infrastructure Provider 1

Service Provider 2

Infrastructure Provider 2

Infrastructure Provider 3

Residential Gateway

CGNAT

Set Top Box

Hardware

RNC
IMS
MME

RNC
IMS
MME

RNC
IMS
MME

Residential Gateway

Hardware

CGNAT

Set Top Box

Service Provider 1

Service Provider 2

Service Provider 3

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Any Function Virtualization (FV)

- “Network” function virtualization of interest to Network service providers
- But the same concept can be used by any other industry, e.g., financial industry, banks, stock brokers, retailers, mobile games, …
- Everyone can benefit from:
  - Functional decomposition of there industry
  - Virtualization of those functions
  - Service chaining those virtual functions (VFs) or Apps
Networking App Market: Lower CapEx

Available on the App Store

Virtual IP
Multimedia System

CISCO App Store

vRouter vRADIUS vVPN
Trend: Mobile Edge Computing

To service mobile users/IoT, the computation needs to come to edge ⇒ Mobile Edge Computing
Trend: 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.
Mobile Healthcare Use Case

Home sensors for patient monitoring

Medical Application Service Provider (Insurance Co)

Multi-Cloud Mobile Application Deployment and Optimization Platform

Hospital Cloud

Insurance Cloud

SDN Controller

5G Carrier

Mobile Doctor

Body Area Network for mobile patient

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Software Defined Networking (SDN)

- 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
Separation vs. Centralization

Separation of Control Plane

Centralization of Policies

Micromanagement is not scalable
Software Defined Multi-Cloud

- Orchestrating devices to Orchestrating Clouds

OpenADN Multi-Cloud Management

Multi-Cloud Application Delivery (MCAD) Platform

MCAD Application Service (AAS) abstraction
MCAD Application Workflow (AAW) abstraction
MCAD Application Cloud (AAC) abstraction

Application Service Providers

Application Architects

Application Deployment Administrators

Resource Providers

Northbound Interface

Southbound Interface

MCAD Resource Driver (OpenStack)
MCAD Resource Driver (OpenDaylight)
MCAD Resource Driver (EC2)

Virtual Hosts
Virtual Storage
Virtual Network

OpenStack
OpenDaylight
EC2

Cloud Datacenter
Network POP
Micro-Datacenters

Enterprise Datacenter

Carrier Network

Application Service Developers

Application Architects

Application Deployment Administrators

OpenADN Multi-Cloud Management

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Service Function Placement Problem

Cloud 1

VNF 1

VNF 2A

VNF 2B

VNF 3

VNF 4

Cloud 2

Cloud 3
Challenges in Service Placement

- Delay constraints
- **WAN links bottleneck:** Need to model link queues
- **Complexity:** NP-complete $\Rightarrow$ Need efficient heuristics
- **Affinity:** VNF1 and VNF2 should be co-located
  - Significant communication exchanges
  - Duplicate memory pages in VMs (same OS and Libraries)
- **Anti-Affinity:** VNF1 and VNF2 should not be placed on the same physical server.
  - CPU-intensive applications
  - VMs belonging to different users in a cloud may cause security risk such as cross-VM attacks
  - Duplicate VMs used to improve fault tolerance and availability
Summary

1. Value of IoT is in the data it produces. Privacy and Security are the key issues.

2. Clouds are getting smaller, Carriers and enterprises moving to clouds, Internet of things are leading to clouds everywhere ⇒ multi-cloud applications.

3. SDN is about orchestration and centralization of policy. Not about separation of control and data planes.

4. Software Defined Multi-Cloud Orchestration: Our Multi-cloud application management system (MCAD) allows policy-based deployment and management of multi-cloud applications.

5. Service function placement problem is NP complete. Challenges included delay constraints, WAN Link bottlenecks, and affinity.
References

References (Cont)


Acronyms

- ATM: Asynchronous Transfer Mode
- ECN: Explicit congestion notification
- EFCI: Explicit Forward Congestion Indication
- FECN: Forward Explicit Congestion Notification
- 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
Acronyms (Cont)

- TCP  Transmission Control Protocol
- TV   Television
- VM   Virtual Machine
- WAN  Wide Area Network
- WiFi Wireless Fidelity
- WiMAX Worldwide Interoperability for Microwave Access
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