Five Trends in Computing Leading to Multi-Cloud Applications and Their Management

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Seminar at Kindi Lab, Qatar University, Doha, Qatar
December 28, 2015

These slides are available on-line at:

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

Team Members

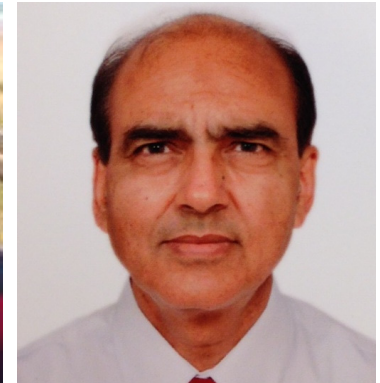Mohammed Samaka

Raj Jain

Aiman Erbad

Subharthi Paul
+ Many more …

Gabor Vaszkun

Deval Bhamare

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Overview

1. Recent Trends in Networking:
   1. Software Defined Networking (SDN)
   2. Network Function Virtualization (NFV)
   3. Internet of Things (IoT)
   4. Computing in the Edge (Fog Computing)
   5. Inter-Cloud/Multi-Cloud Applications
2. Management of Generalized Multi-Cloud Applications

Clouds and Mobile Apps

❑ August 25, 2006: Amazon announced EC2
⇒ Birth of Cloud Computing in reality
(Prior theoretical concepts of computing as a utility)
$4.6 B in 2014, $6.2 B in 2015, a growth rate of 49% with 17% margins, much higher than the overall Amazon business

❑ June 29, 2007: Apple announced iPhone
⇒ Birth of Mobile Internet, Mobile Apps

➤ App Market ⇒ $1.99 Programs

➤ Almost all services are now mobile apps: Google, Facebook, Bank of America, …

Trend 1: Software Defined Networking (SDN)

1. **Abstract the Hardware**: No dependence on physical infrastructure. Software API.

2. **Programmable**: Shift away from static manual operation to fully configurable and dynamic

3. **Centralized Control of Policies**: Policy delegation and management
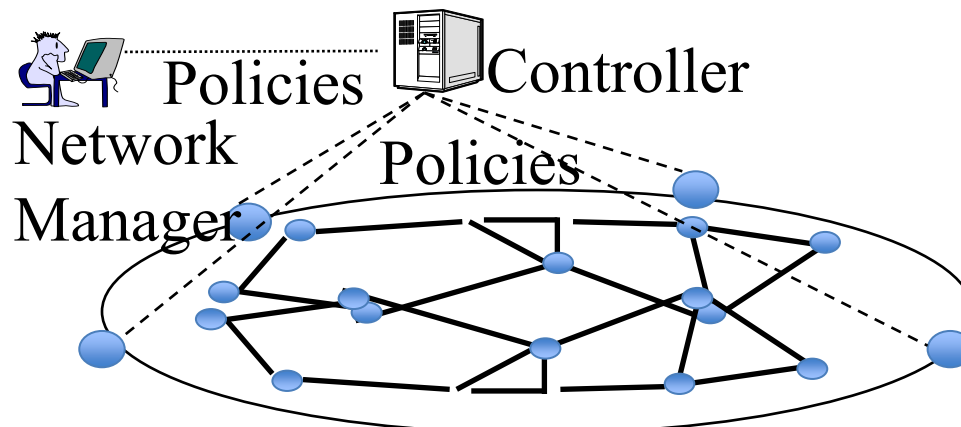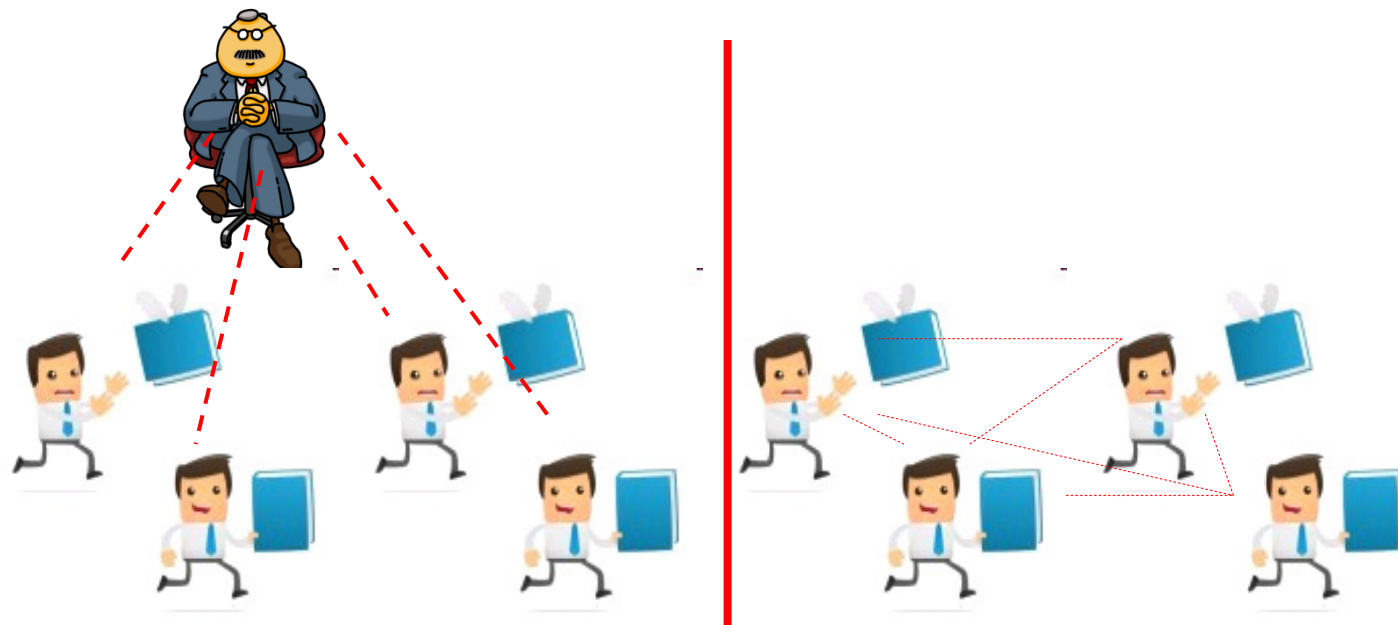
Ten Benefits of SDN

1.   **Programmability**: Can change behavior on the fly.
2.   **Automation**
3.   **Orchestration**: Manage thousands of devices
4.   **Visibility**: Centralized monitoring of state
5.   **Performance**: Optimize network device utilization
     FCAPS = Fault, Configuration, Accounting, Performance, Security
6.   **Virtualization**: Use resources without worrying about location, size, etc.
7.   **Dynamic Scaling**: Can change size, quantity
8.   **Multi-tenancy**
9.   **Service Integration**
10. **Openness**: <u>Full choice</u> of Modular plug-ins

Software Defined Anything (SDx)

❑ Tsunami of software defined everything:
  ➢ Software Defined Networking (SDN)
  ➢ Software Defined Datacenter (SDDC)
  ➢ Software Defined Storage (SDS)
  ➢ Software Defined Compute (SDC)
  ➢ Software Defined Infrastructure (SDI)

It seems like everything BUT the kitchen sink is software defined these days.

You were saying?

SOFTWARE DEFINED
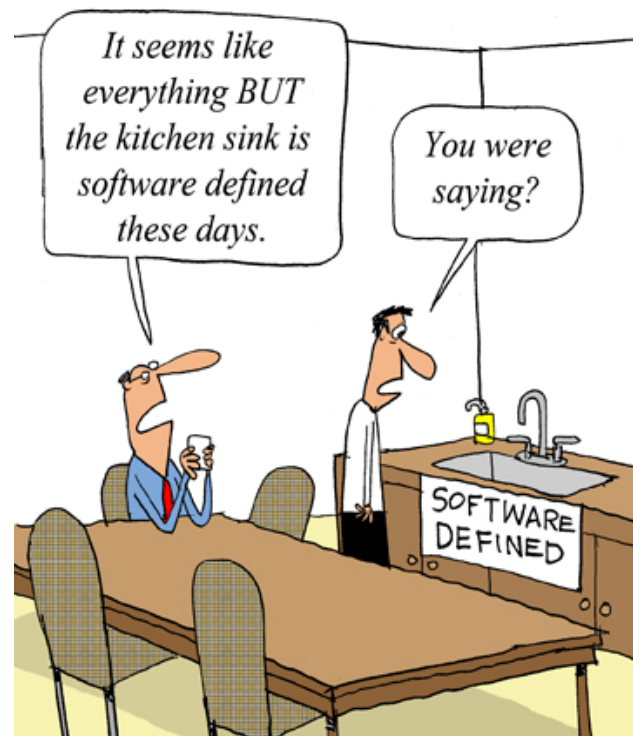
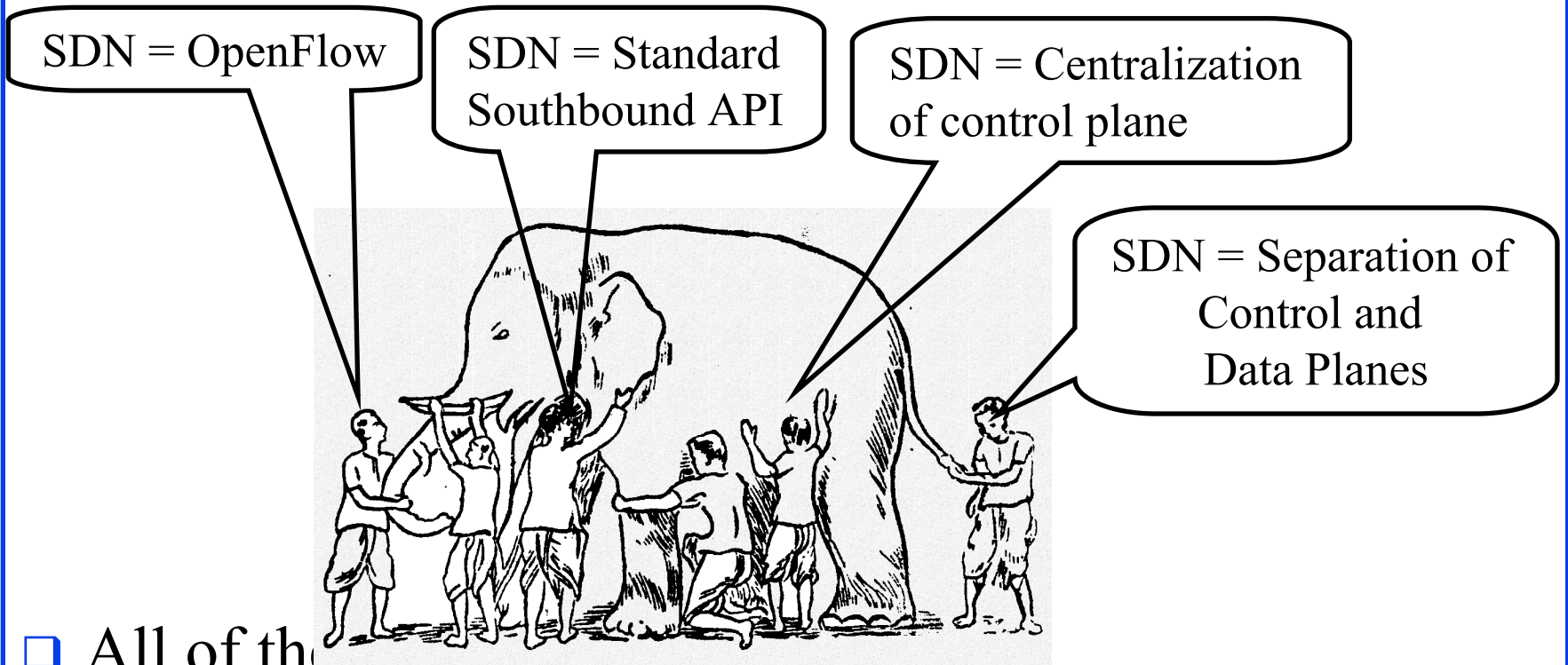# Centralized vs. Distributed

□ Fast Response to changes
□ Fast Consistency
□ Less overhead $\Rightarrow$ Scalable
□ Single Point of Failure

□ Time to converge
□ Slow consistency
□ Not scalable
□ Fault Tolerant

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What SDN is Not?

SDN = OpenFlow

SDN = Standard Southbound API

SDN = Centralization of control plane

SDN = Separation of Control and Data Planes

❑ All of these are mechanisms.

❑ SDN is *not* about a mechanism.

❑ It is a framework ⇒ Many solutions

Four Confusions About SDN

1. **Policies vs. Control**:
   Control = All bits and messages not sent by user
   In IP, control includes all headers and all routing messages.

2. **Separation of Control Plane**:
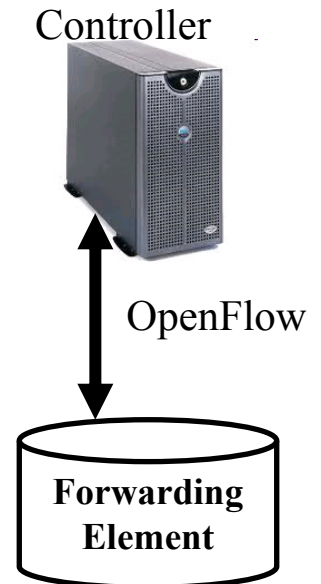   Elements have only data plane and have no brains

3. **SDN vs. OpenFlow**:
   OpenFlow is the father of SDN but not SDN.

4. **Need OpenFlow**: OpenFlow is micro-management.
   It is not scalable.
   For large infrastructure, need scalable solutions.

Controller

OpenFlow

Forwarding Element

Separation vs. Centralization
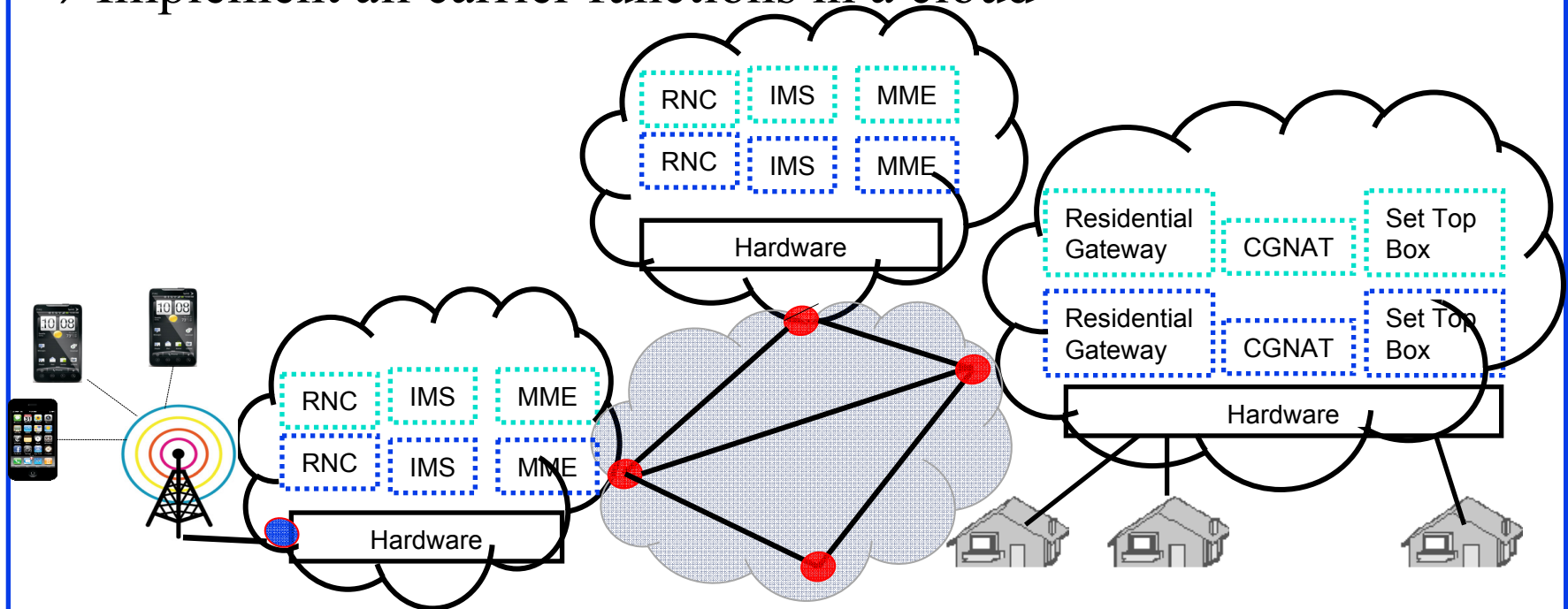
Separation of
Control Plane

Centralization of
Policies

Micromanagement is not scalable

Trend 2: Network Function Virtualization

❑ Standard hardware is fast and cheap
   ⇒ No need for specialized hardware

❑ Implement all functions in software

❑ Virtualize all functions ⇒ Create capacity on demand

⇒ Implement all carrier functions in a cloud

Service-Infrastructure Separation

❑ With cloud computing, anyone can super-compute on demand.

  ➢ Physical infrastructure is owned by Cloud Service Provider (CSP). Tenants get virtual infrastructure

  ➢ **Win-Win** combination

❑ With virtualization, an ISP can set up all virtual resources on demand

  ➢ Physical Infrastructure owned by NFV infrastructure service provider (NSP) and tenant ISPs get virtual NFVI services

  ➢ **Win-Win** combination

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)
⇒ A service provided by the next gen ISPs

Carrier App Market: Lower CapEx

Virtual IP Multimedia System

Available on the App Store

amazon.com
and you're done.™
App Store
ANDROID

200,000
AVAILABLE APPS

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

Trend 3: Smart Everything

Smart Watch

Smart TV

Smart Car

Smart Health

Smart Home

Smart Kegs

Smart Space

Smart Industries

Smart Cities

What's Smart?

❑ Old: Smart = Can think ⇒ Can compute

❑ Now: Smart = Can find quickly, Can Delegate
⇒ Communicate = Networking

❑ Smart Grid, Smart Meters, Smart Cars, Smart homes, Smart Cities, Smart Factories, Smart Smoke Detectors, …
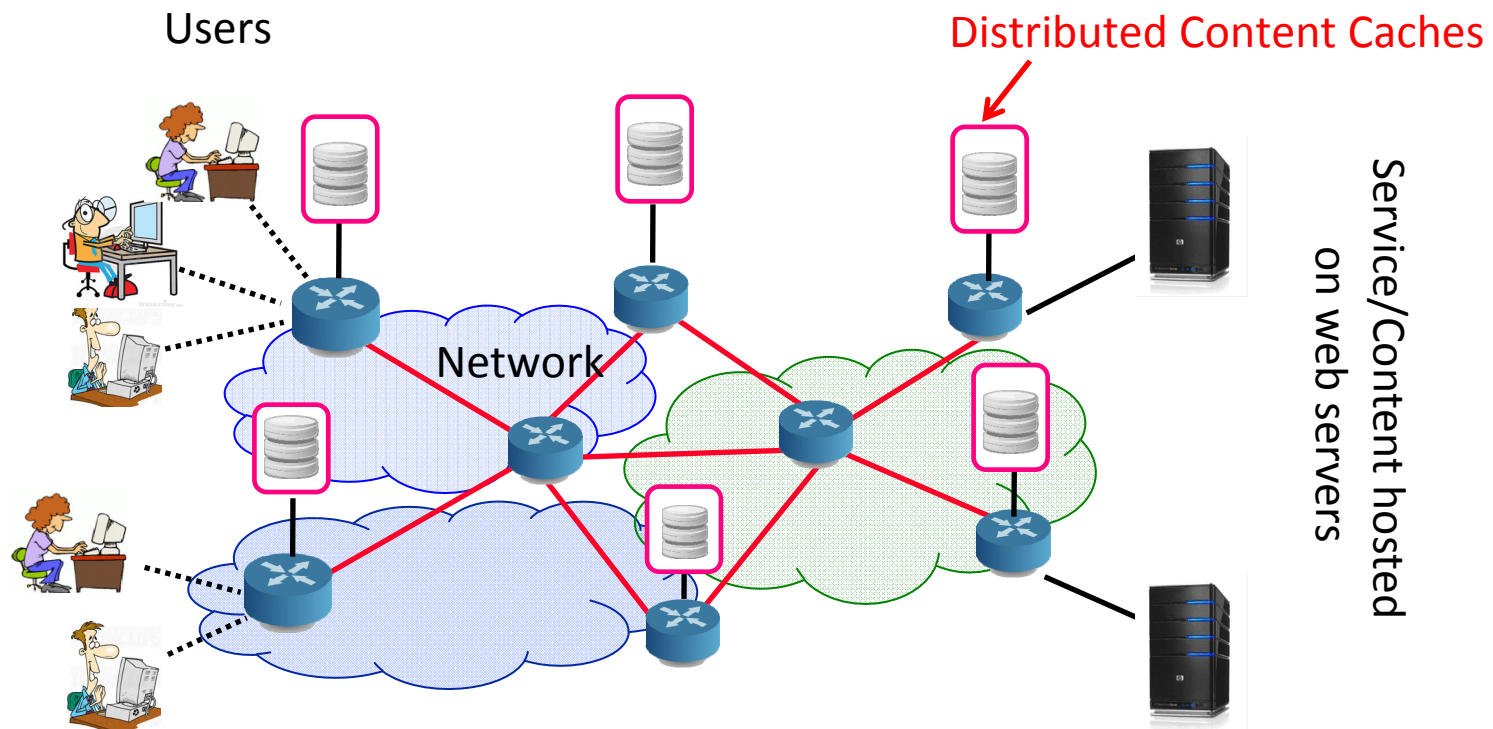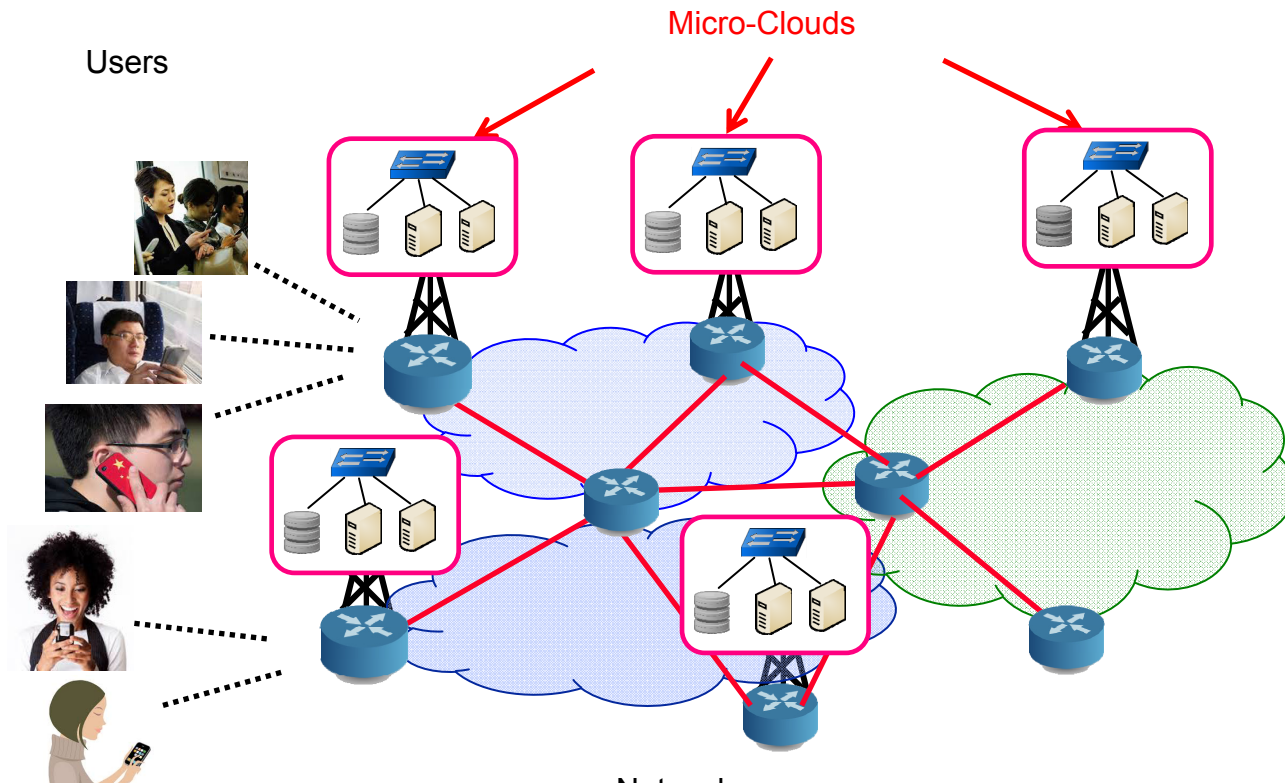

Think   Communicate   Not-Smart   Smart

Past: Data in the Edge

❑ To serve world-wide users, latency was critical and so the data was replicated and brought to edge

http://www.cse.wustl.edu/~jain/talks/apf_knd.htm
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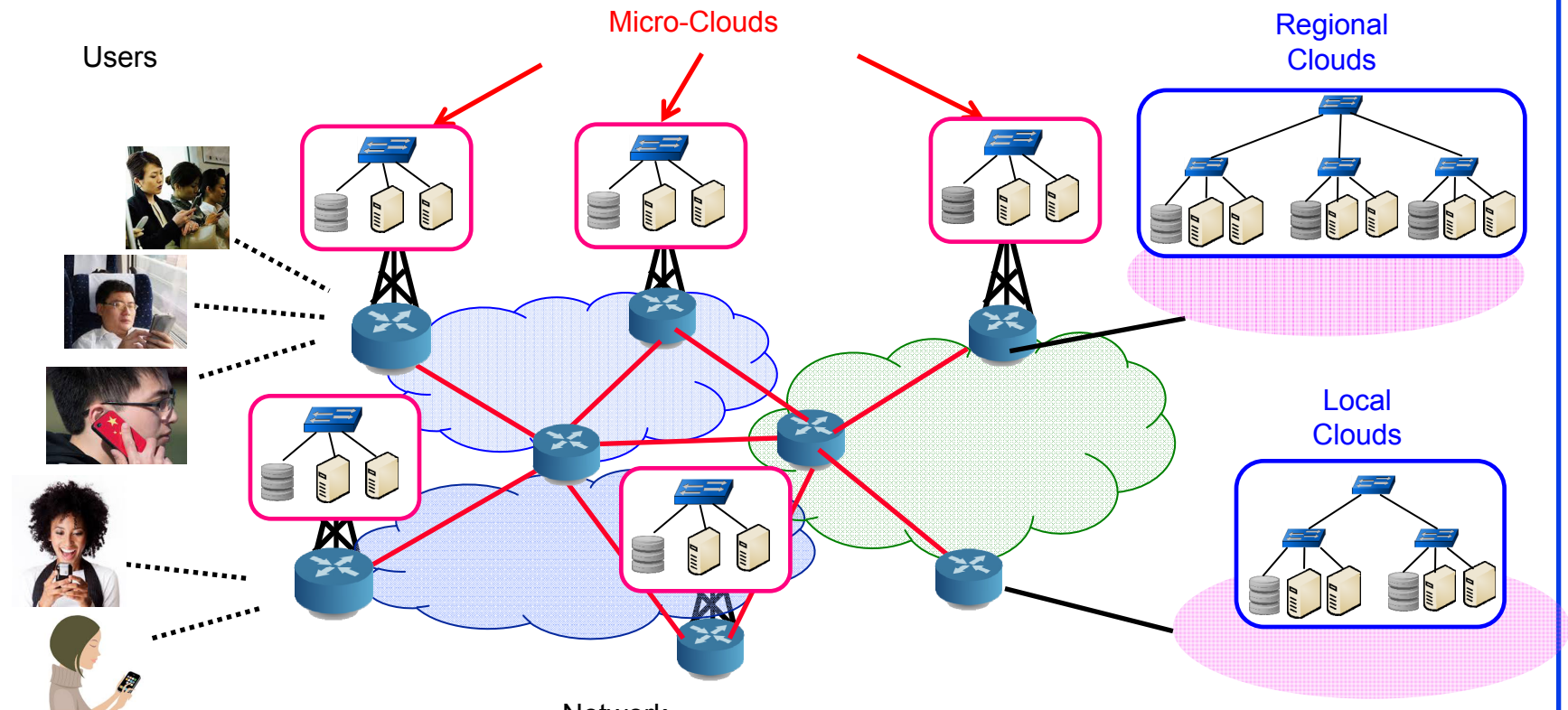# Trend 4: Computation in the Edge

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

Micro-Clouds

Users

Network

Trend 5: Multi-Cloud

❑ Larger and infrequent jobs serviced by local and regional clouds ⇒ Fog Computing

Micro-Clouds

Regional Clouds

Users

Local Clouds

Network

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

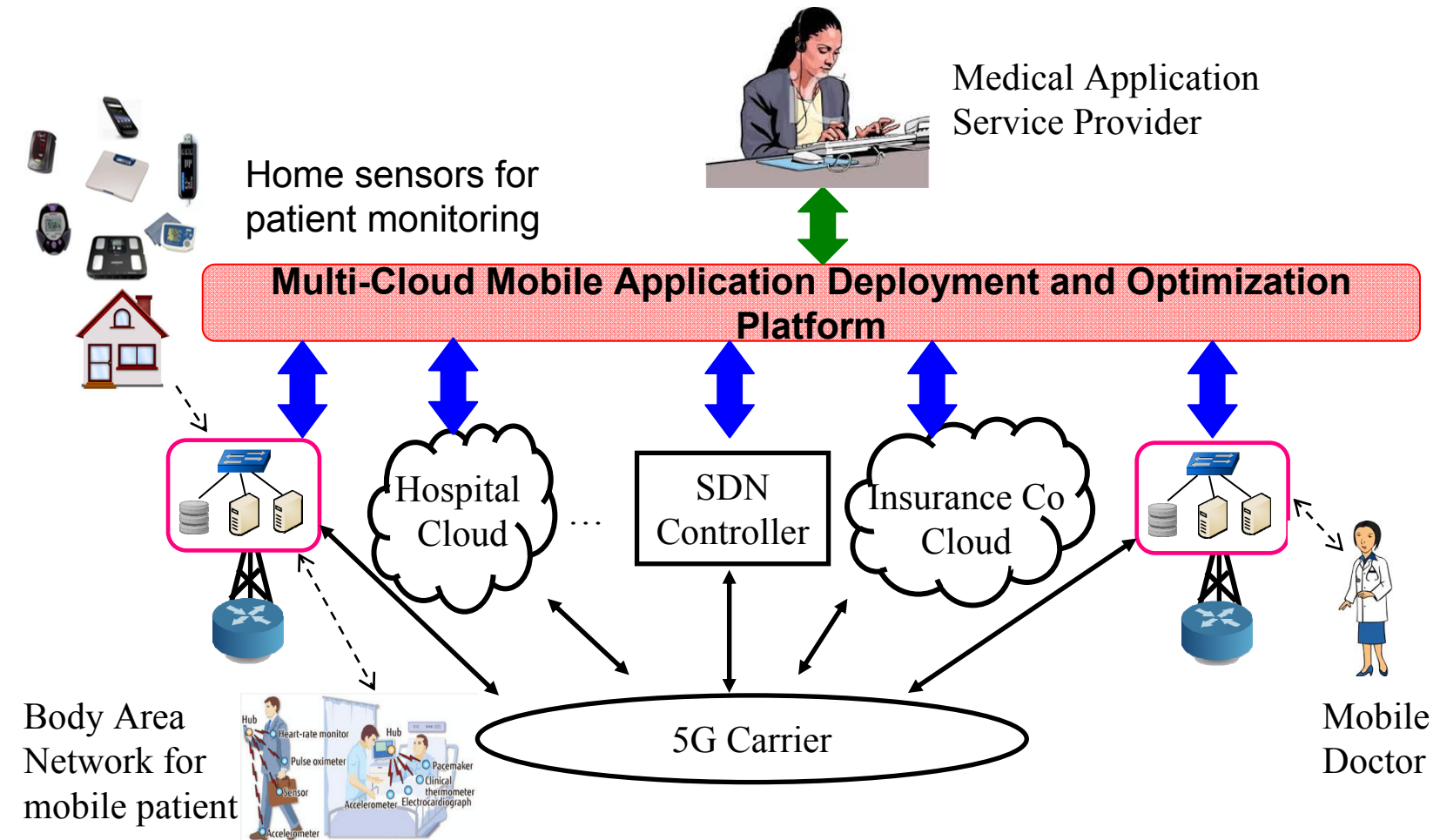# Software Defined Multi-Cloud Management
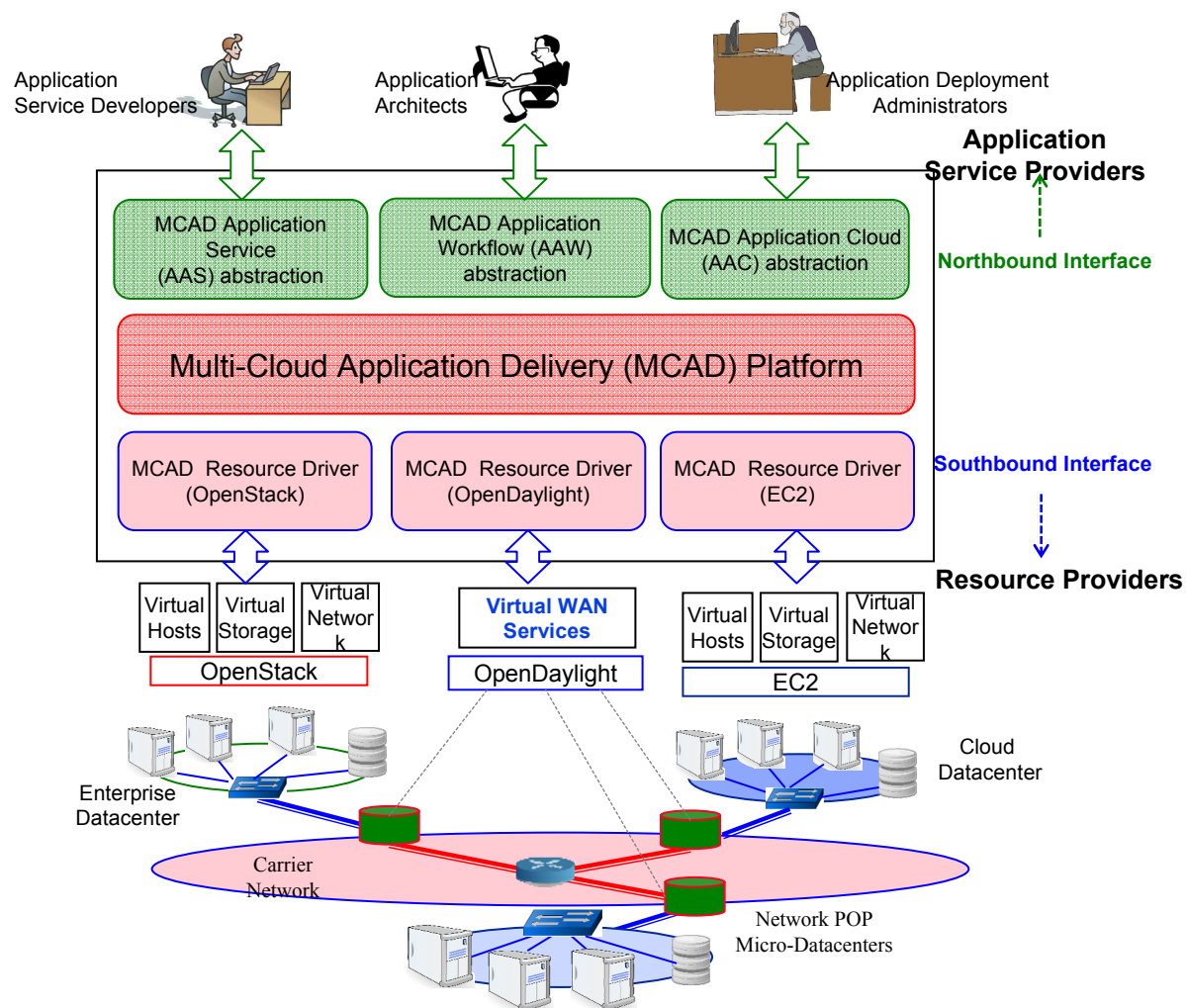
MCAD Features

❑ **Automate** the entire process of creating new workflows and installing them, managing them during runtime, uninstalling them as necessary

  ➢ Allow **Deployment Administrators** specify policies for quantity and location of resources inside various clouds.

❑ Workflow creation includes virtual networks, computers, storage inside the clouds as well as the network between the clouds

❑ **WAN bandwidth** and latency is the key to placement. Allows manual approval and override.

❑ Physical infrastructure owners keep complete control over their resources while the tenant service providers can deploy their applications according to their desired policies

❑ All communication is via APIs. All interfaces initially XML based. GUI based in future.

Key aspects of OpenADN Architecture
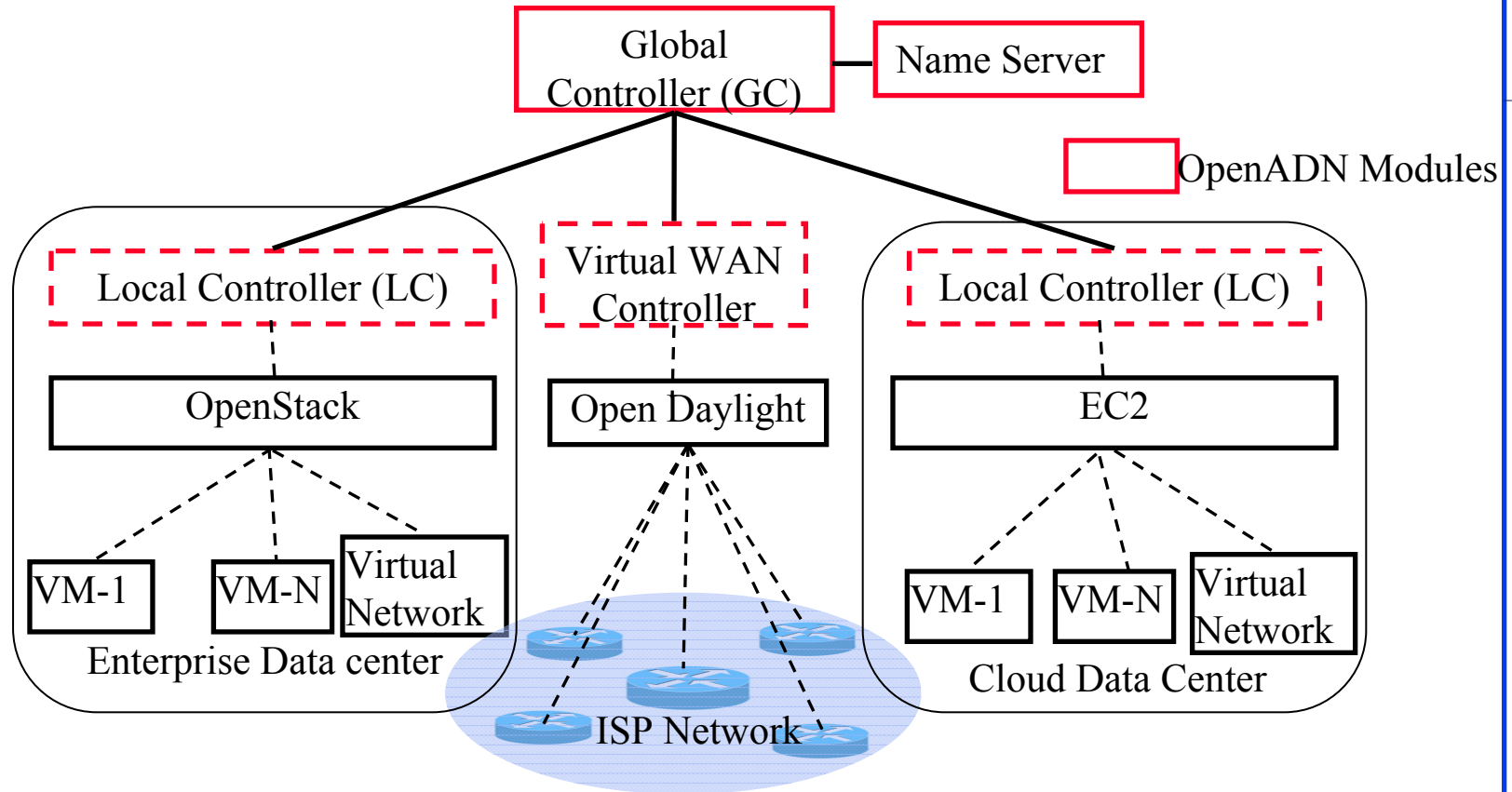
- ❑ Hybrid control – global and local controllers
- ❑ Centralized management, distributed data plane
- ❑ All services, servers, instances accessed by name

Mobile Healthcare Use Case

Medical Application
Service Provider

Home sensors for
patient monitoring

Multi-Cloud Mobile Application Deployment and Optimization Platform

Hospital
Cloud   …   SDN
Controller   Insurance Co
Cloud

Body Area
Network for
mobile patient

Hub — Heart-rate monitor   Hub — Pacemaker
Pulse oximeter   Clinical thermometer
Sensor   Electrocardiograph
Accelerometer
Accelerometer

5G Carrier

Mobile
Doctor

Gartner Hype Cycle for Emerging Technologies, 2015
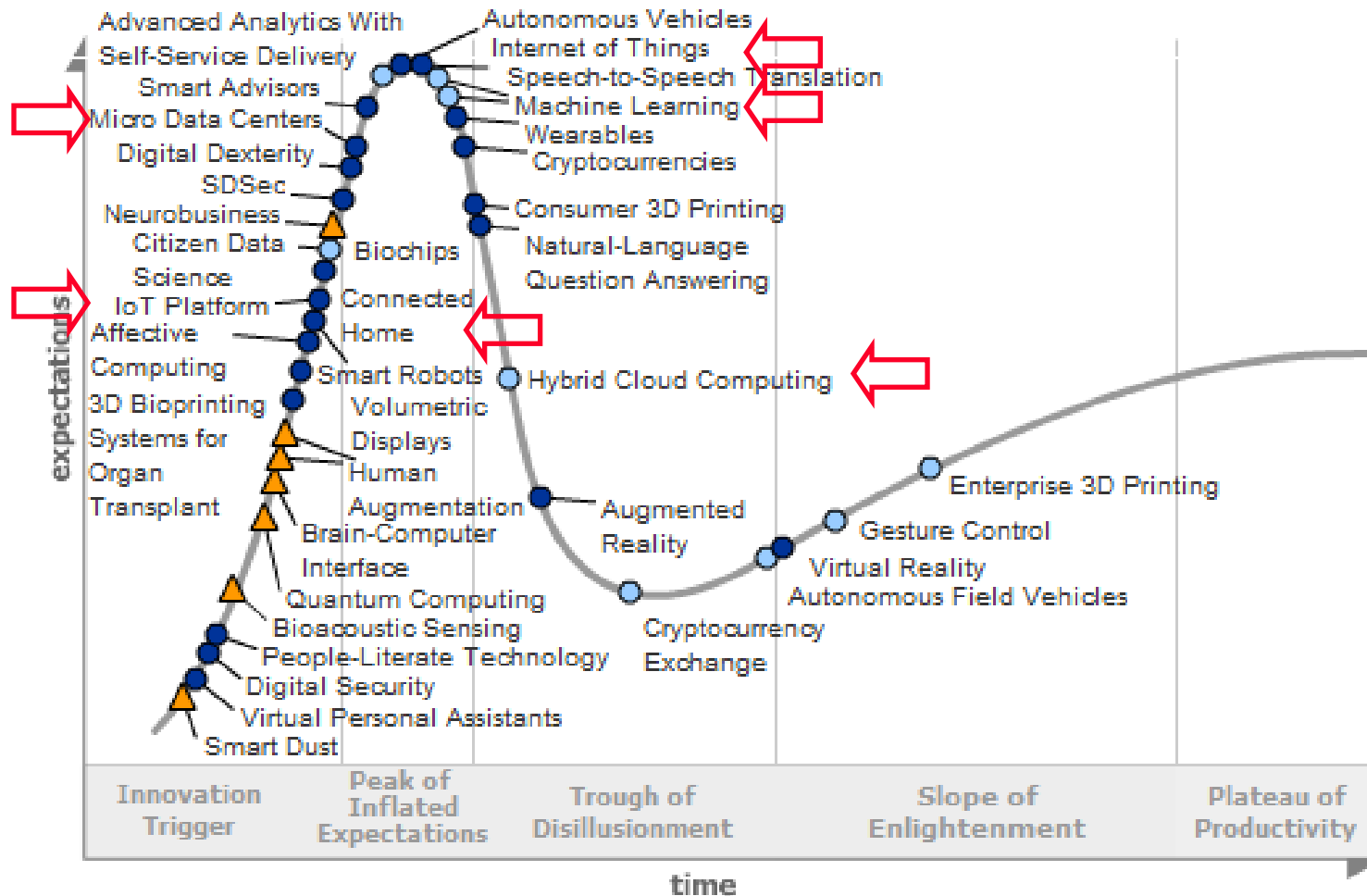
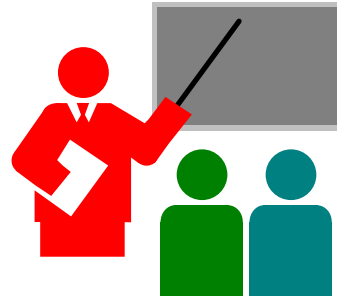Ref: Gartner, "Hype Cycle for Emerging Technologies, 2015," July 2015, [Available to subscribers only], http://www.gartner.com/document/3100227?ref=QuickSearch&sthkw=hype%20cycle%202015&refval=156919648&qid=fe61993355944ace1c8c01ec2df676d9

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

Summary

1. SDN is about abstracting the hardware, providing programmability, and centralizing policy control

2. Carriers are moving towards "Network Function Virtualization" $\Rightarrow$ Opportunity for key "Function virtualization" in other industry

3. IoT will impact CIO's $\Rightarrow$ FCAPS

4. Computation is moving to the Edge $\Rightarrow$ Fog Computing $\Rightarrow$ Multi-Cloud/Inter-Cloud

5. Our MCAD abstracts the cloud interfaces and allows automated management of multi-cloud applications

http://www.cse.wustl.edu/~jain/talks/apf_knd.htm
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Recent Papers

❑ 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

❑ Subharthi Paul, Raj Jain, Mohammed Samaka, Aiman Erbaud, "Service Chaining for NFV and Delivery of other Applications in a Global Multi-Cloud Environment," ADCOM 2015, Chennai, India, September 19, 2015, http://www.cse.wustl.edu/~jain/papers/adn_in15.htm

❑ Raj Jain, Mohammed Samaka, "Application Deployment in Future Global Multi-Cloud Environment," The 16th Annual Global Information Technology Management Association (GITMA) World Conference, Saint Louis, MO, June 23, 2015, http://www.cse.wustl.edu/~jain/papers/apf_gitp.htm

Recent Papers (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

Recent Talks

❑ Raj Jain "Application Deployment in Future Global Multi-Cloud Environment," OIN Workshop, Saint Louis, MO, October 20, 2015, http://www.cse.wustl.edu/~jain/talks/apf_oin.htm

❑ Raj Jain, "Virtualization and Software Defined Networking (SDN) for Multi-Cloud Computing," Invited talk at Indian Institute of Science, Bangaluru, September 18, 2014, http://www.cse.wustl.edu/~jain/talks/apf_iis.htm

❑ Raj Jain, "AppFabric: Application Deployment and Service Chaining in Future NFV Cloud WAN Environments," Cisco Research Seminar, San Jose, CA, May 15, 2014, http://www.cse.wustl.edu/~jain/talks/apf_csc.htm

❑ Raj Jain, "SDN and NFV: Facts, Extensions, and Carrier Opportunities," AT&T Labs SDN Forum Seminar, April 10, 2014, http://www.cse.wustl.edu/~jain/papers/adn_att.htm

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