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

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These slides are available on-line at:

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

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
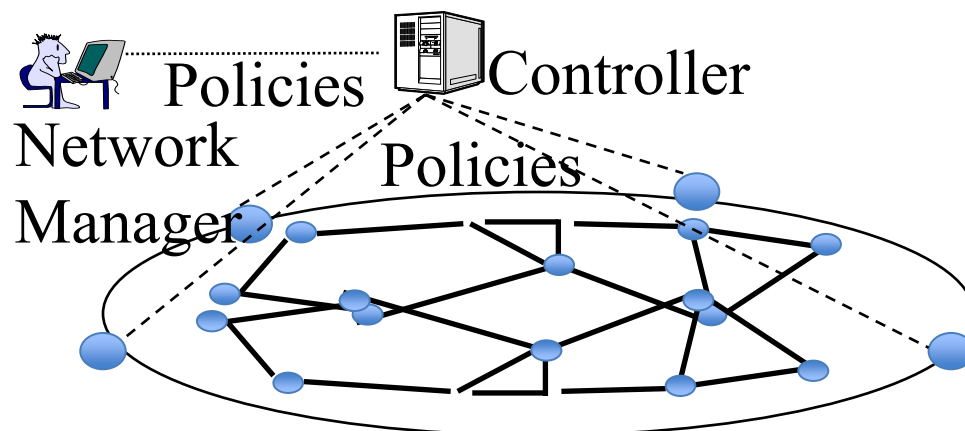
Software Defined Anything (SDx)

❑ Tsunami of software defined things

➢ Software Defined Networking (SDN)

➢ Software Defined Datacenter (SDDC)

➢ Software Defined Storage (SDS)

➢ Software Defined Compute (SDC)

➢ Software Defined Infrastructure (SDI)

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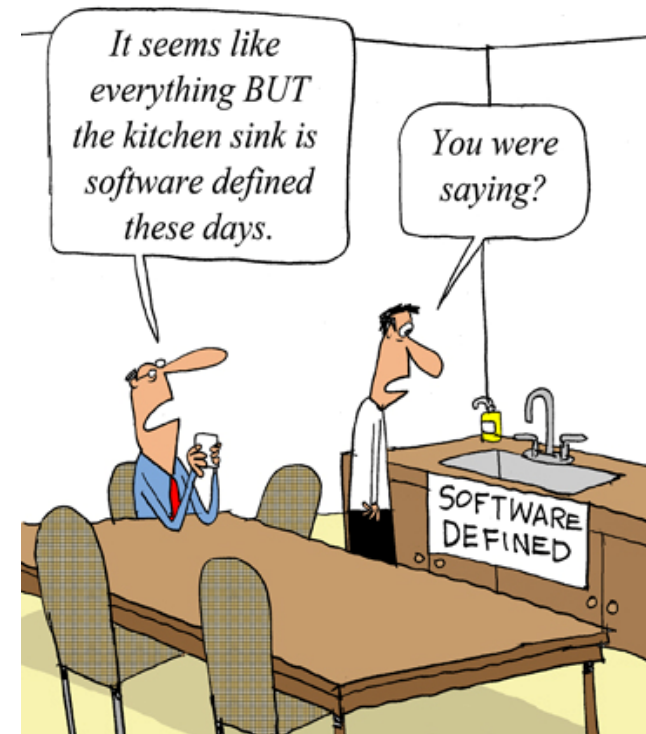
Ten Benefits of SDN

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

Centralized vs. Distributed
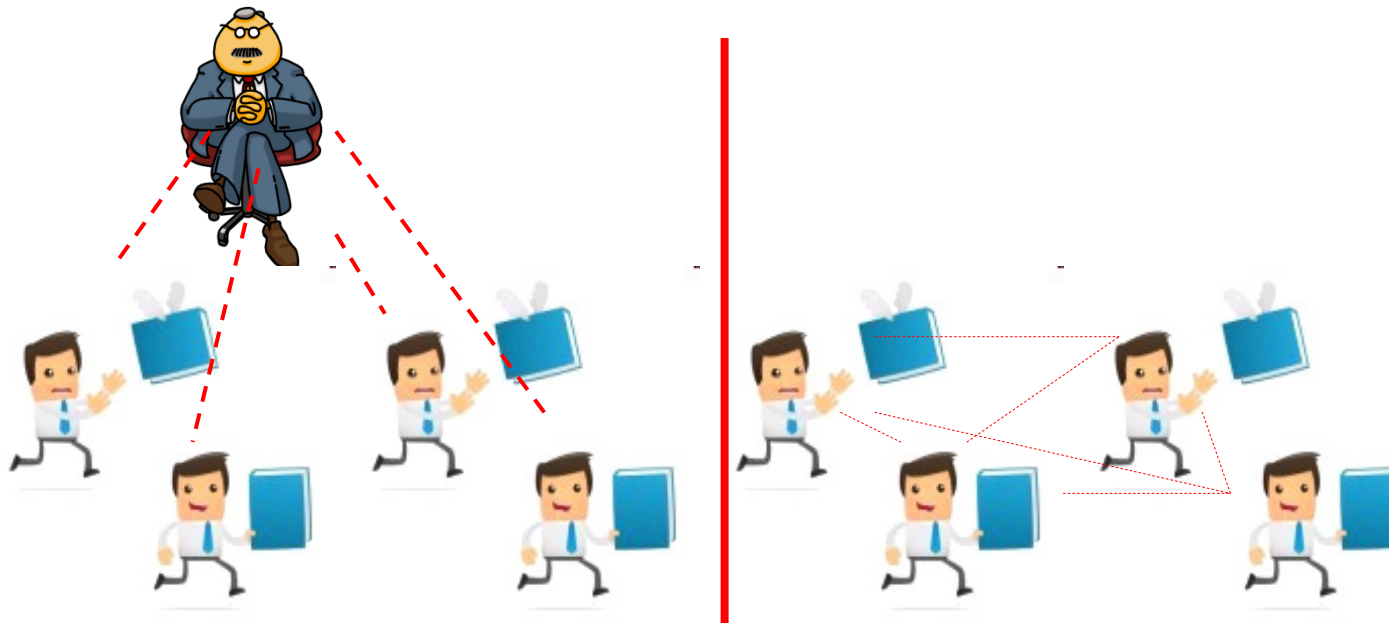
- ❑ Fast Response to changes
- ❑ Fast Consistency
- ❑ Less overhead $\Rightarrow$ Scalable
- ❑ Single Point of Failure

- ❑ Time to converge
- ❑ Slow consistency
- ❑ Not scalable
- ❑ Fault Tolerant

What SDN is Not?

SDN = OpenFlow

SDN = Standard Southbound API

SDN = Centralization of control plane

SDN = Separation of Control and Data Planes
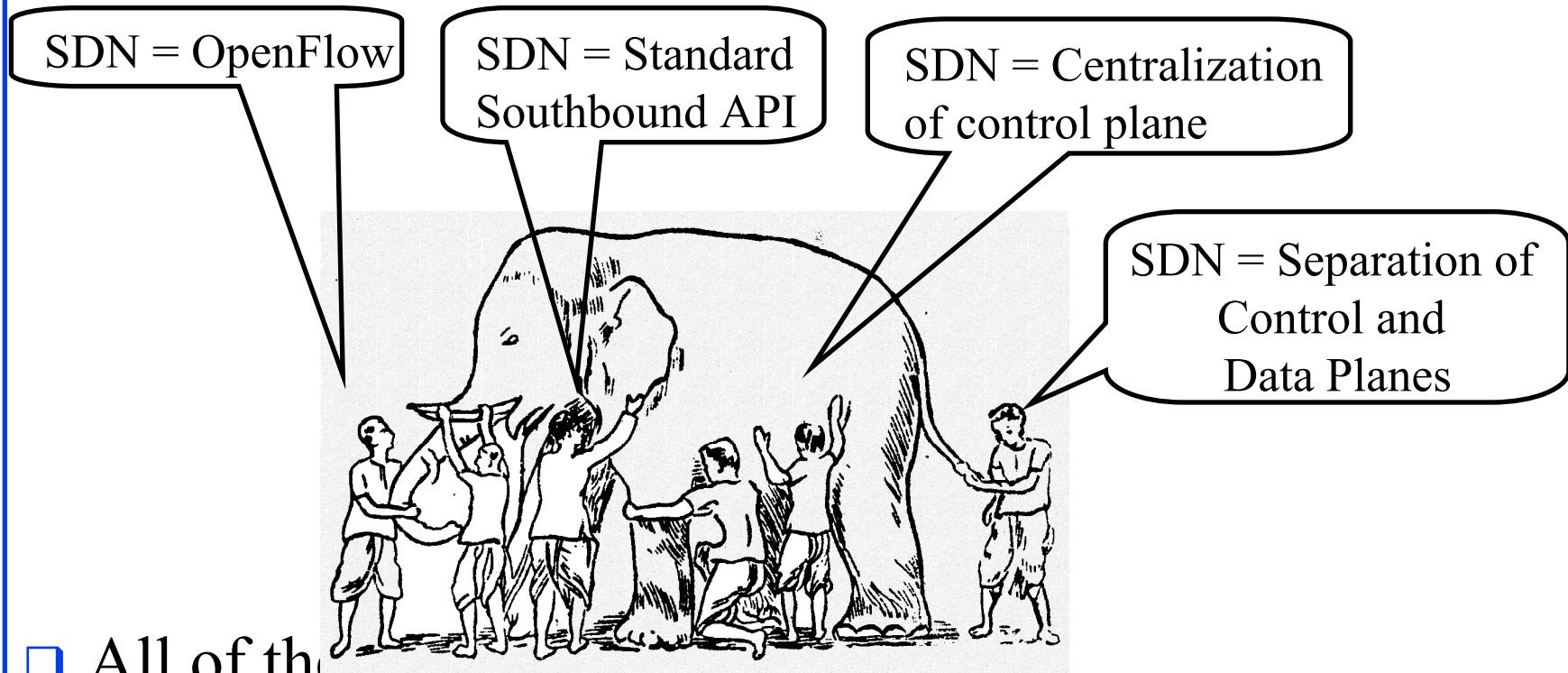
- ❑ All of these are mechanisms.
- ❑ SDN is *not* about a mechanism.
- ❑ It is a framework ⇒ Many solutions

Four Confusions About SDN

1. **Policies vs. Control**:
   Control = All bits and messages not sent by the 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.

Separation vs. Centralization

Separation of
Control Plane
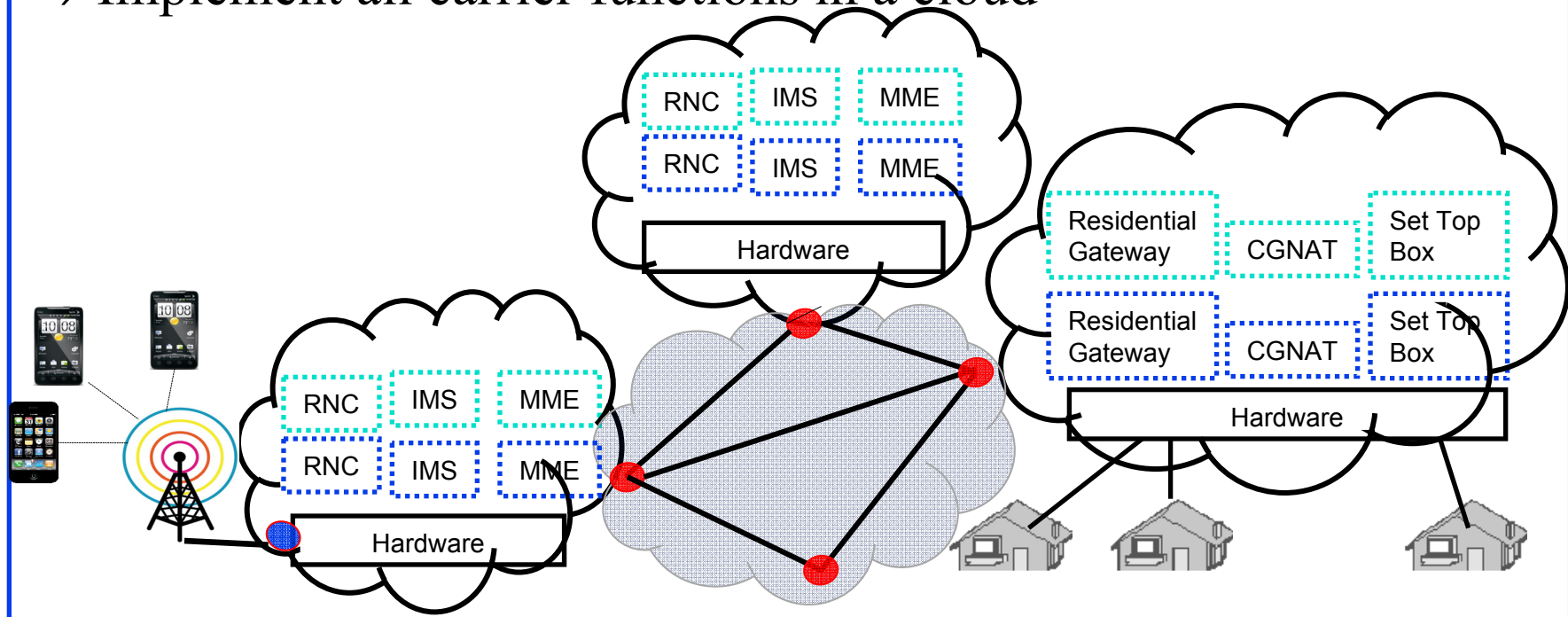
Centralization of
Policies

Micromanagement is not scalable

Trend 2: Network Function Virtualization

❑ Standard hardware is fast and cheap
   $\Rightarrow$ No need for specialized hardware

❑ Implement all functions in software

❑ Virtualize all functions $\Rightarrow$ Create capacity on demand

$\Rightarrow$ 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)
$\Rightarrow$ 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

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, …
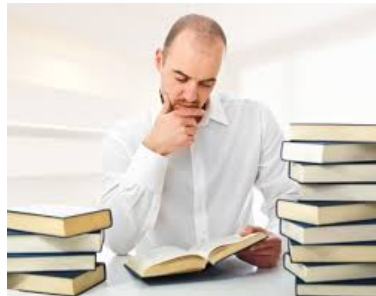
| Think | Communicate | Not-Smart | Smart |

Past: Data in the Edge

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

Users

Distributed Content Caches

Network

Service/Content hosted on web servers
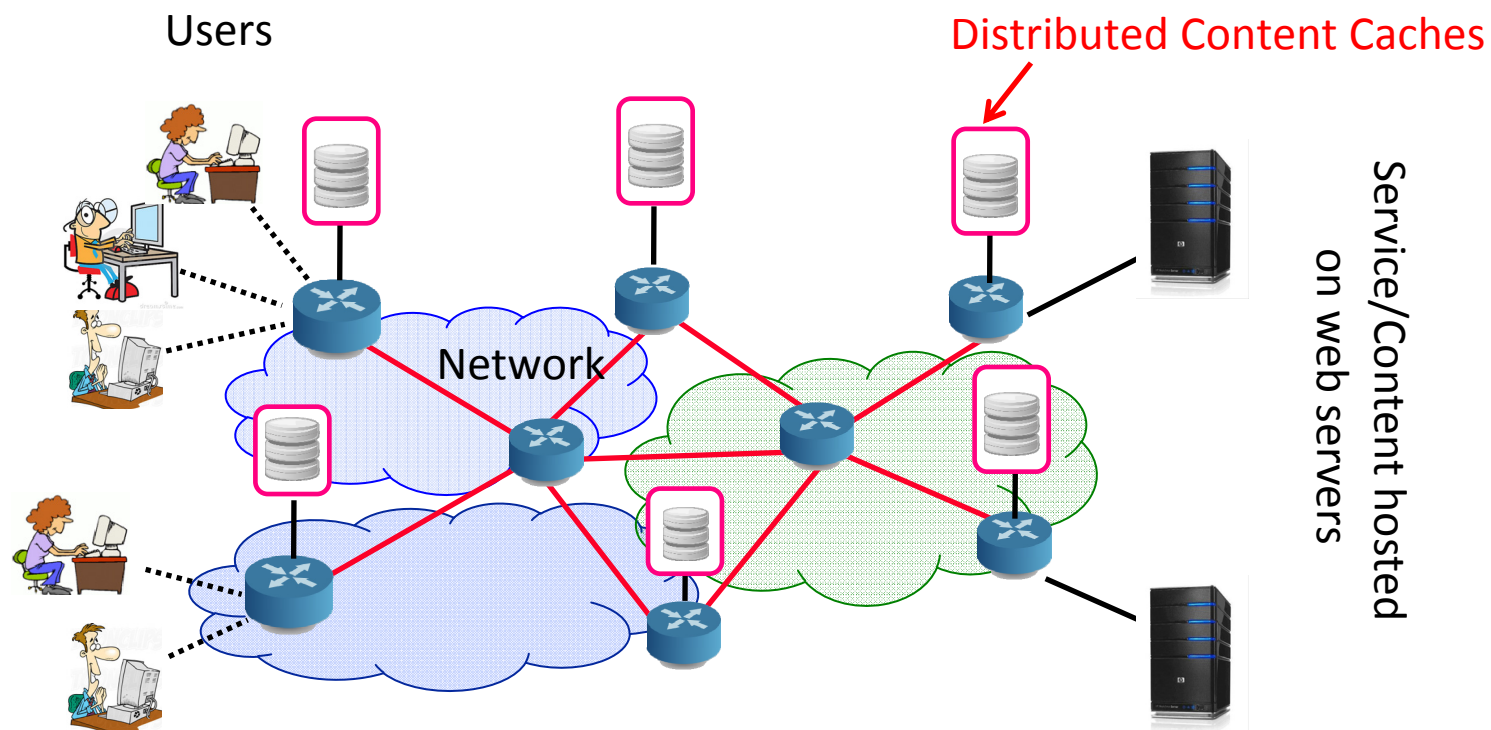
Trend 4: Computation in the Edge

❑ To service mobile users/IoT, the computation needs to come to edge ⇒ Micro-cloud on the tower
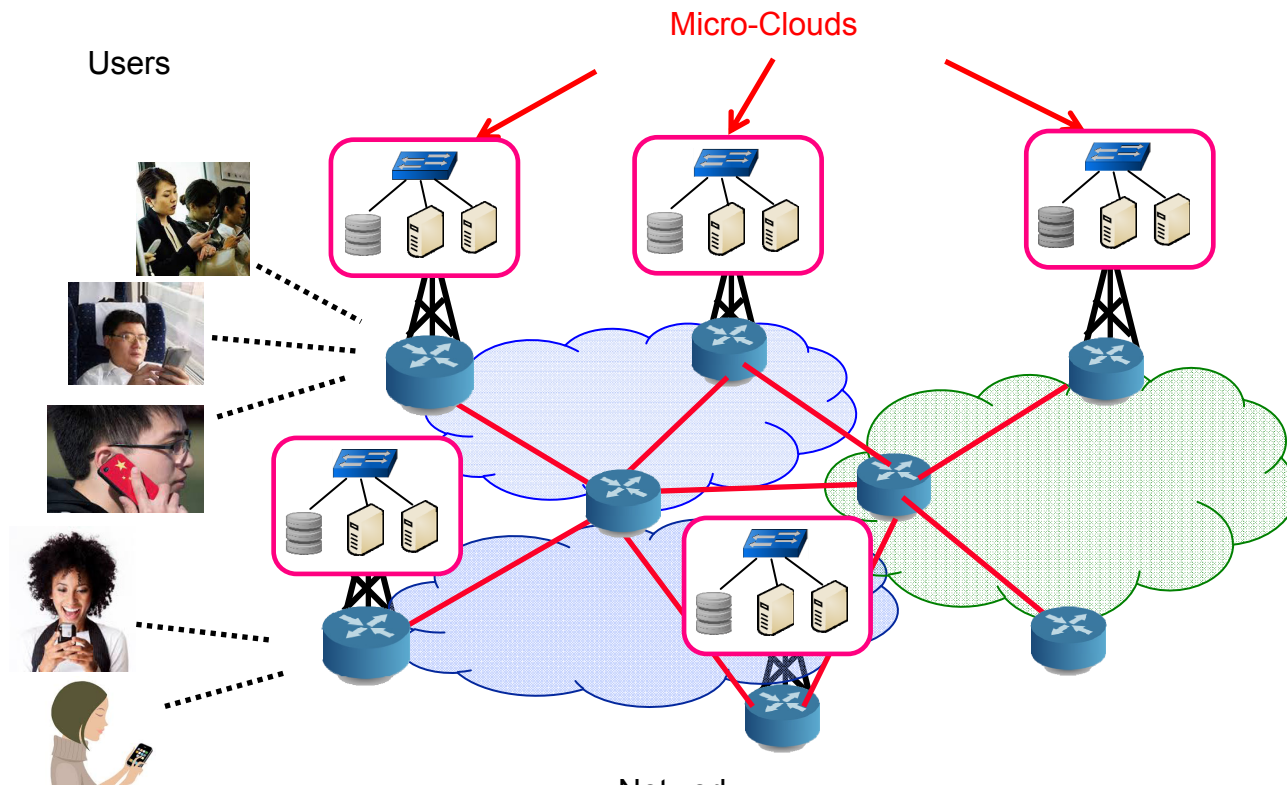
Trend 5: Multi-Cloud

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

Users

Micro-Clouds

Regional Clouds

Local Clouds

Network
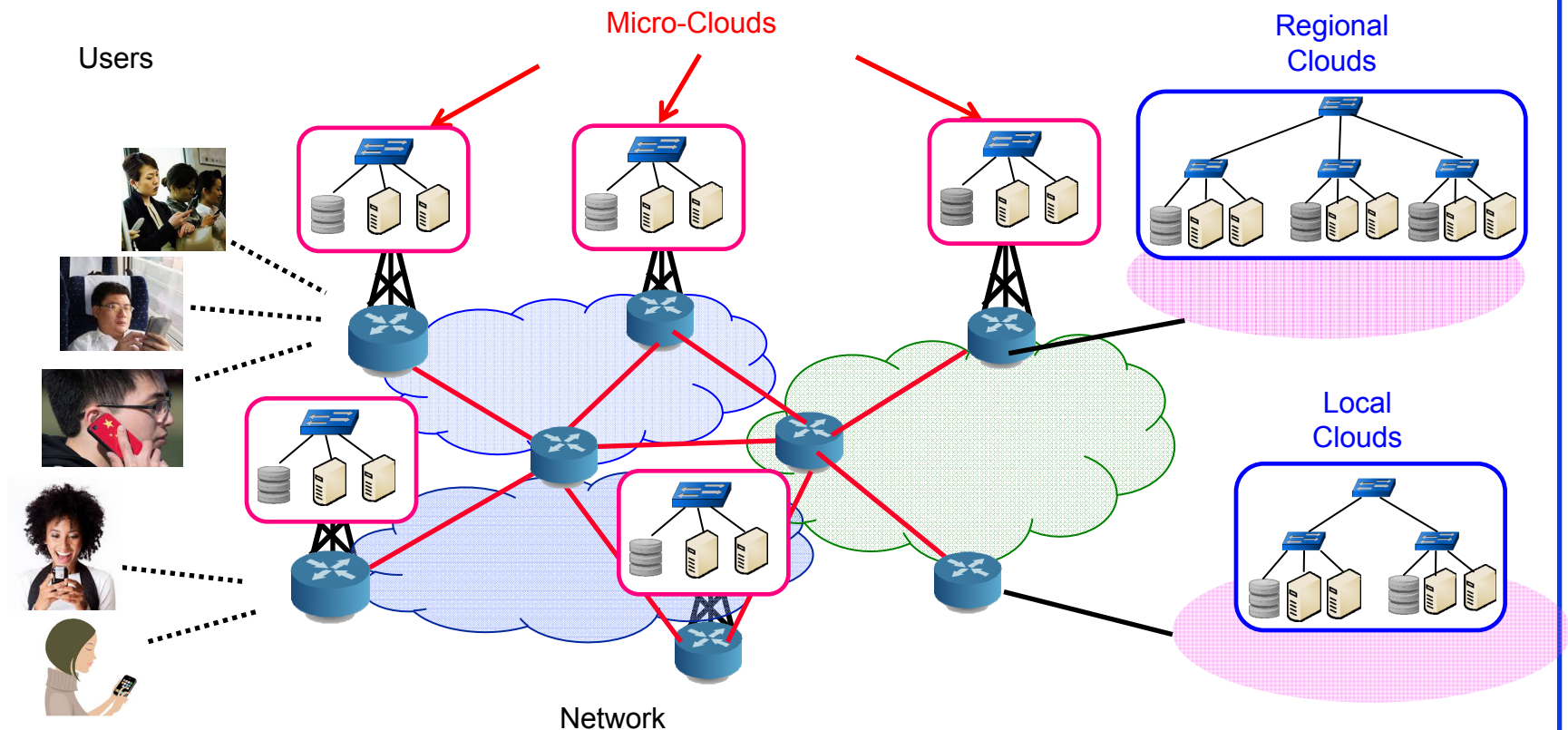
Trend: Multi-Clouds

Enterprise Cloud Strategy
1000+ employees

No plans
4%

Single public
13%

Single private
9%

Multi-Cloud
74%

Multiple private
11%

Multiple public
15%

Hybrid cloud
48%
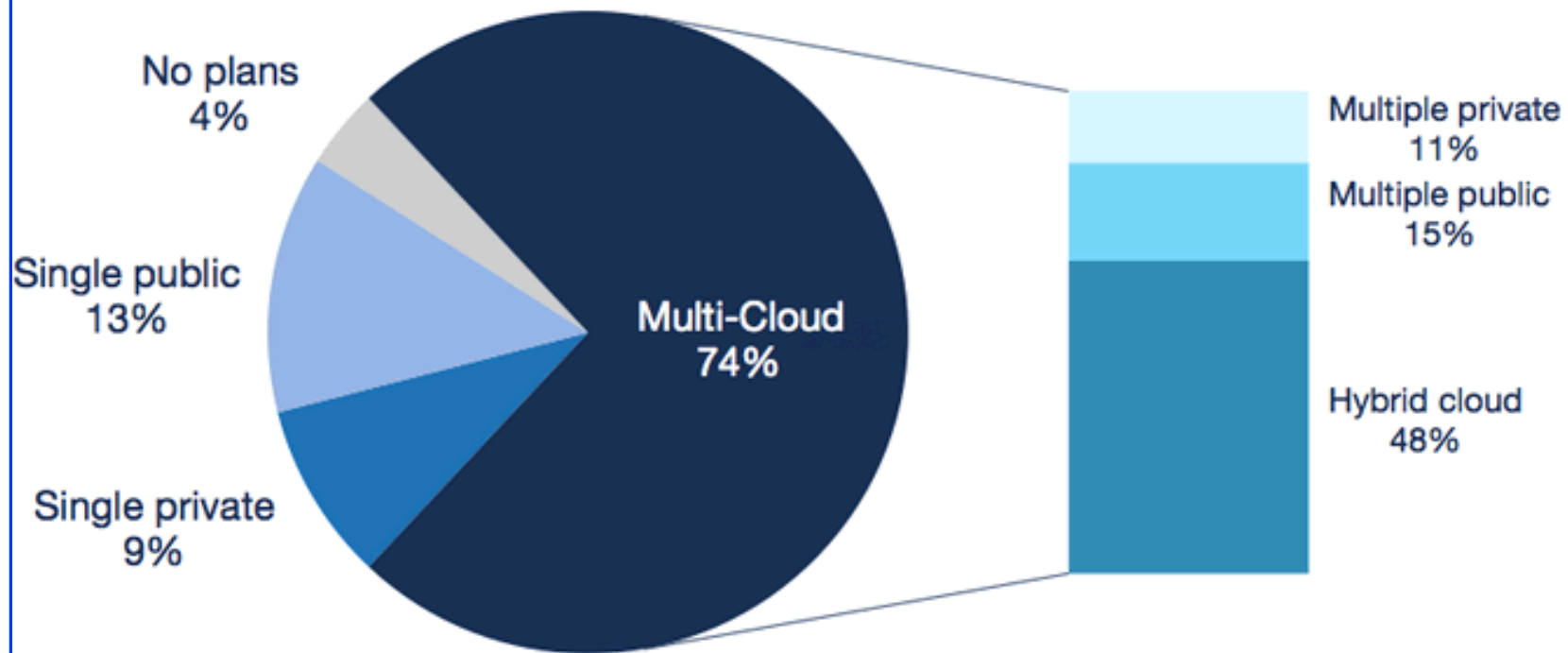
Source: RightScale 2014 State of the Cloud Report

❑ Most companies use more than one cloud.

Ref: http://www.rightscale.com/blog/cloud-industry-insights/cloud-computing-trends-2014-state-cloud-survey

Software Defined Multi-Cloud FCAPS Management

Application Service Developers

Application Architects

Application Deployment Administrators

Application Service Providers

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

Northbound Interface

Multi-Cloud Application Delivery (MCAD) Platform

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

Southbound Interface

Resource Providers

Virtual Hosts	Virtual Storage	Virtual Network

OpenStack

Virtual WAN Services

OpenDaylight

Virtual Hosts	Virtual Storage	Virtual Network

EC2

Enterprise Datacenter

Cloud Datacenter

Carrier Network

Network POP Micro-Datacenters

MCAD Features

❑ **Automate** the entire process of creating new workflows and installing them, managing them during runtime, uninstalling them as necessary
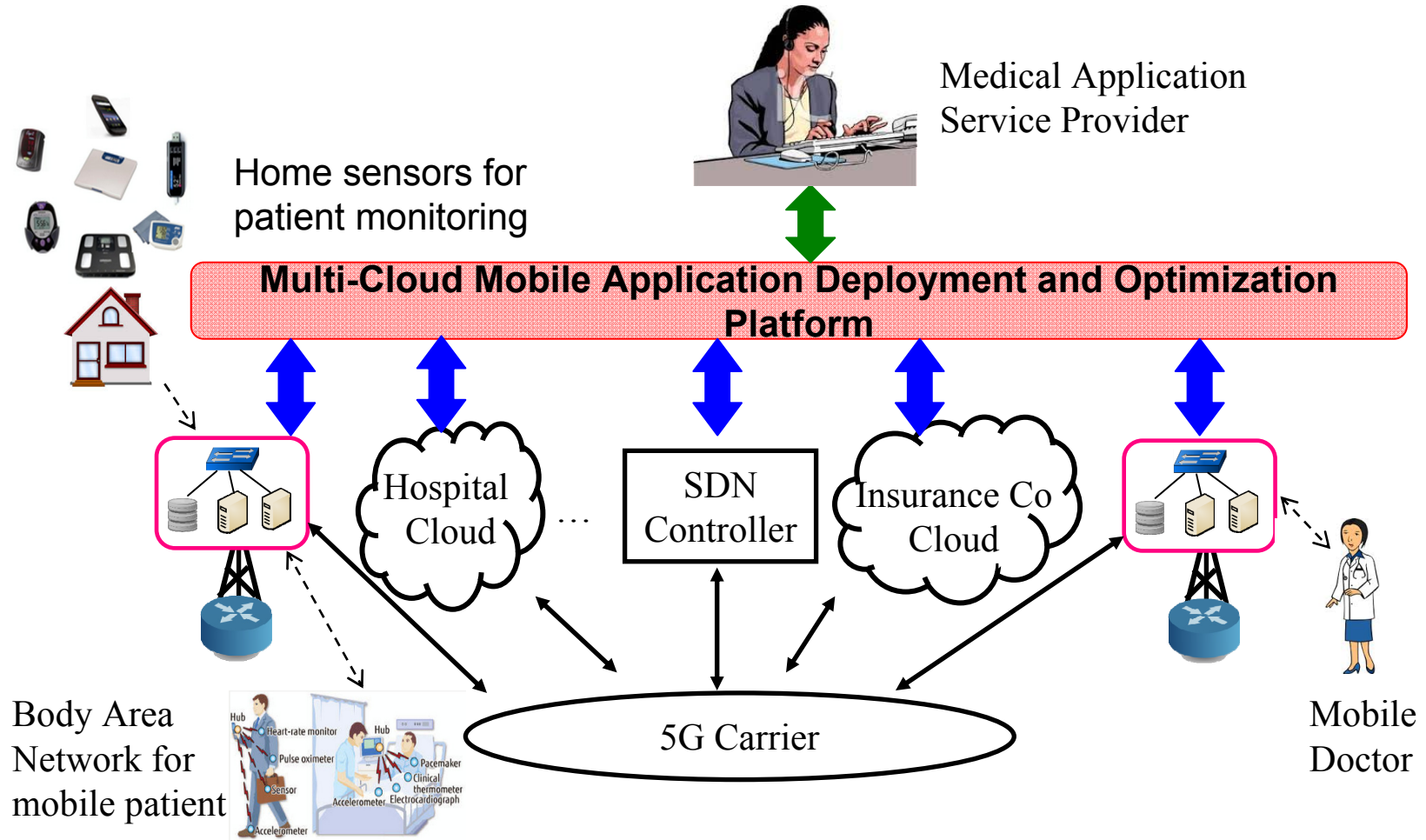 ➢ Allow **Deployment Administrators** specify policies for quantity and location of resources inside various clouds.
❑ Workflow creation includes virtual networks, computers, storage inside the clouds as well as the network between the clouds
❑ **WAN bandwidth** and latency is the key to placement. Allows 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.

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

Mobile Doctor

Body Area Network for mobile patient

5G Carrier

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23

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_cmg.htm

24

Gartner's Hype Cycle for Performance Management 2015

DevOps

Unified Communications Monitoring
Capacity-Planning and Management Tools
Cloud Management Platforms
Hosted Virtual Desktop Monitoring

IT Operations Analytics

Network Performance Monitoring and Diagnostics Tools

Network Fault Management

Web-Scale Operations

Application Performance Monitoring

IT Infrastructure Monitoring

IT Event Correlation and Analysis Tools

expectations

Technology Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity

time

Ref: Gartner, "Hype Cycle for IT Infrastructure Availability and Performance Management, 2015"

Summary
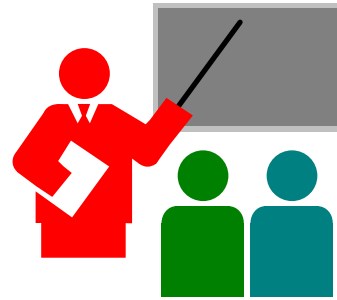
1. SDN is about abstracting the hardware, providing programmability, and centralizing policy control
2. Carriers are moving towards "Network Function Virtualization" $\Rightarrow$ Opportunity for key "Function virtualization" in other industry
3. IoT will impact CIO's $\Rightarrow$ FCAPS
4. Computation 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

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