MILCOM 2015
LEVERAGING TECHNOLOGY—THE JOINT IMPERATIVE
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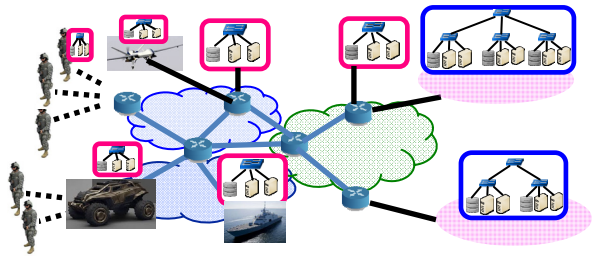
Software Defined Networking at the Tactical Edge



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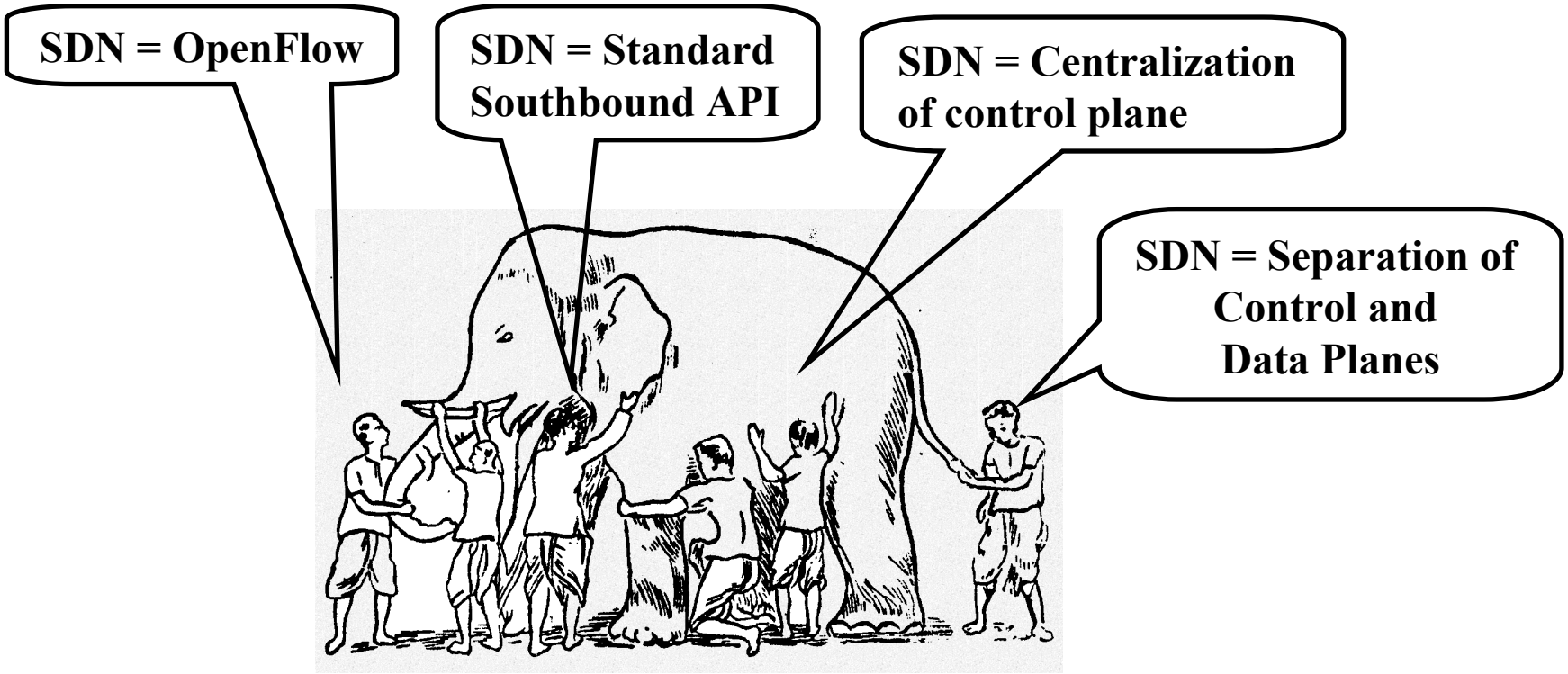
These slides are available on-line at:

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

1. What is SDN and What it is not?
2. Recent Trends in Networking
3. Software Defined Inter-Cloud
4. Inter-Cloud Use Cases

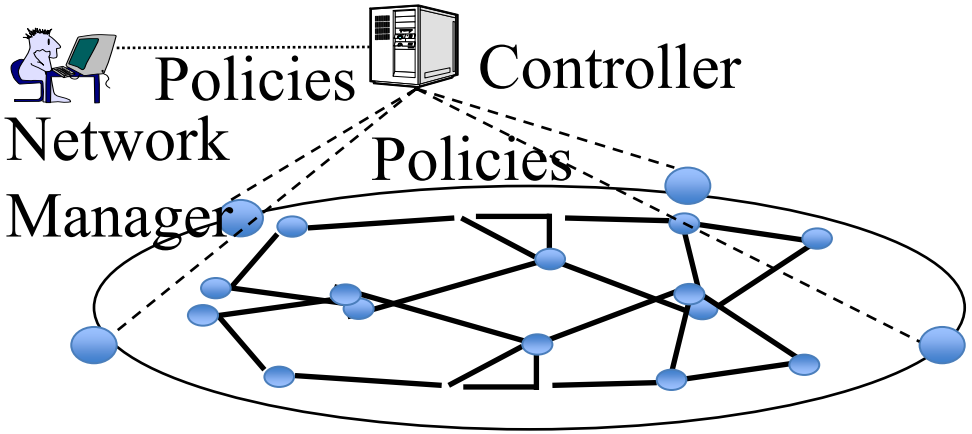
What SDN is Not?



- All of these are mechanisms.
- SDN is *not* about a mechanism.
- It is a framework ⇒ Many solutions

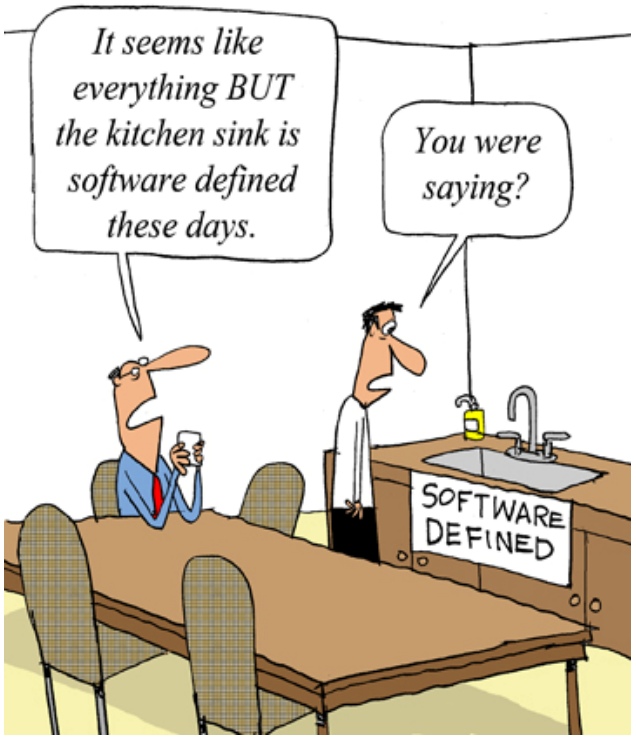
Three Features that Define SDN

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)

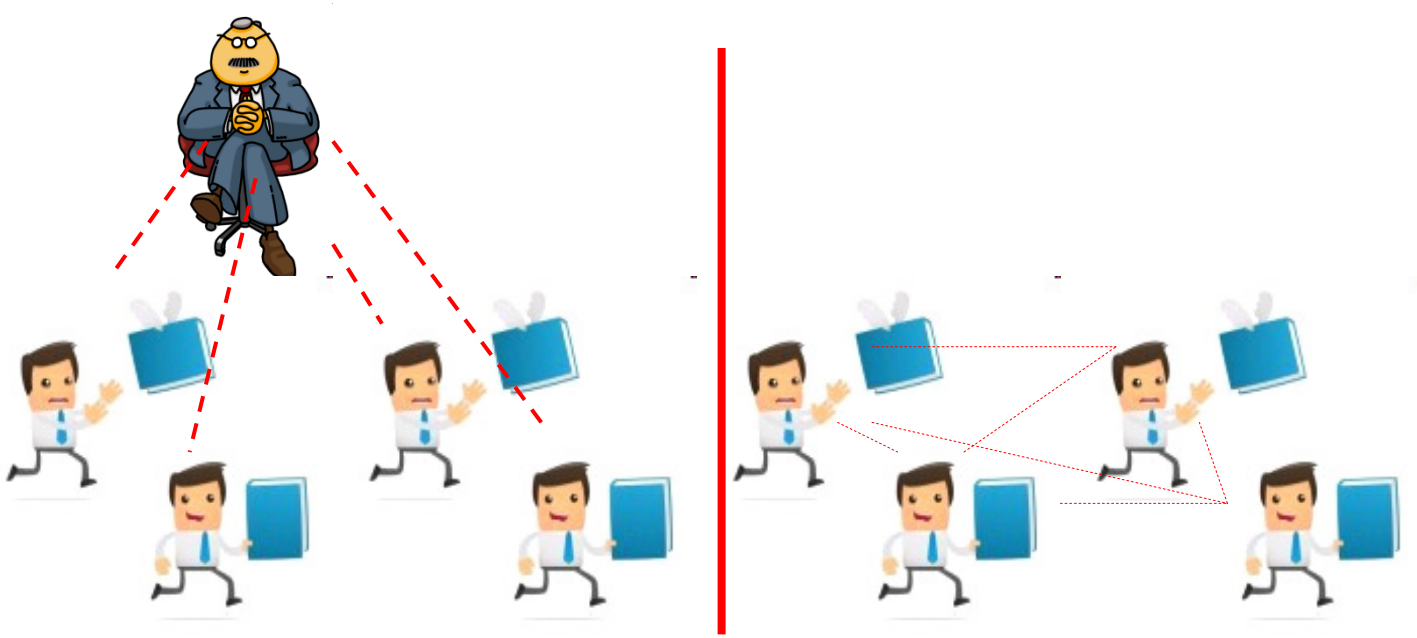
- **Tsunami of software defined things**
  - Software Defined Networking (SDN)
  - Software Defined Datacenter (SDDC)
  - Software Defined Storage (SDS)
  - Software Defined Compute (SDC)
  - Software Defined Infrastructure (SDI)



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**
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: Full choice of Modular plug-ins**

Centralized vs. Distributed



- Fast Response to changes
- Fast Consistency
- Less overhead ⇒ Scalable
- Single Point of Failure

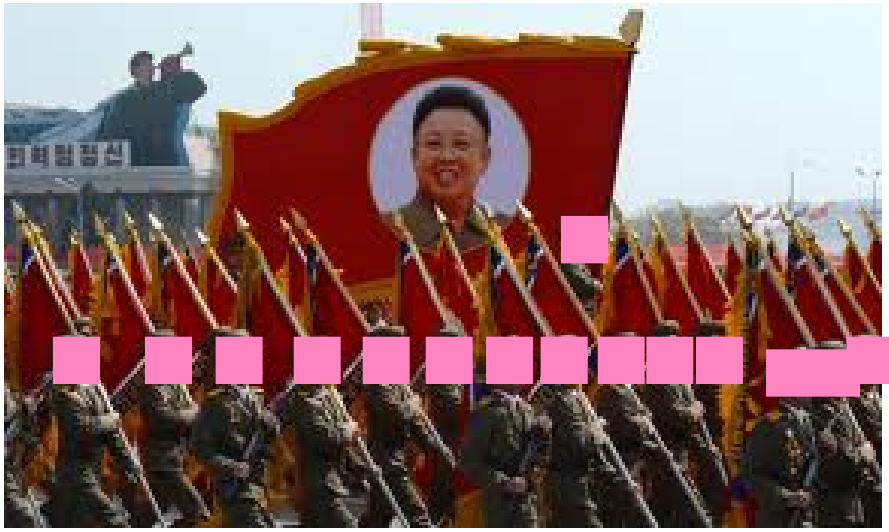
- Time to converge
- Slow consistency
- Not scalable
- Fault Tolerant

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

How to SDN?

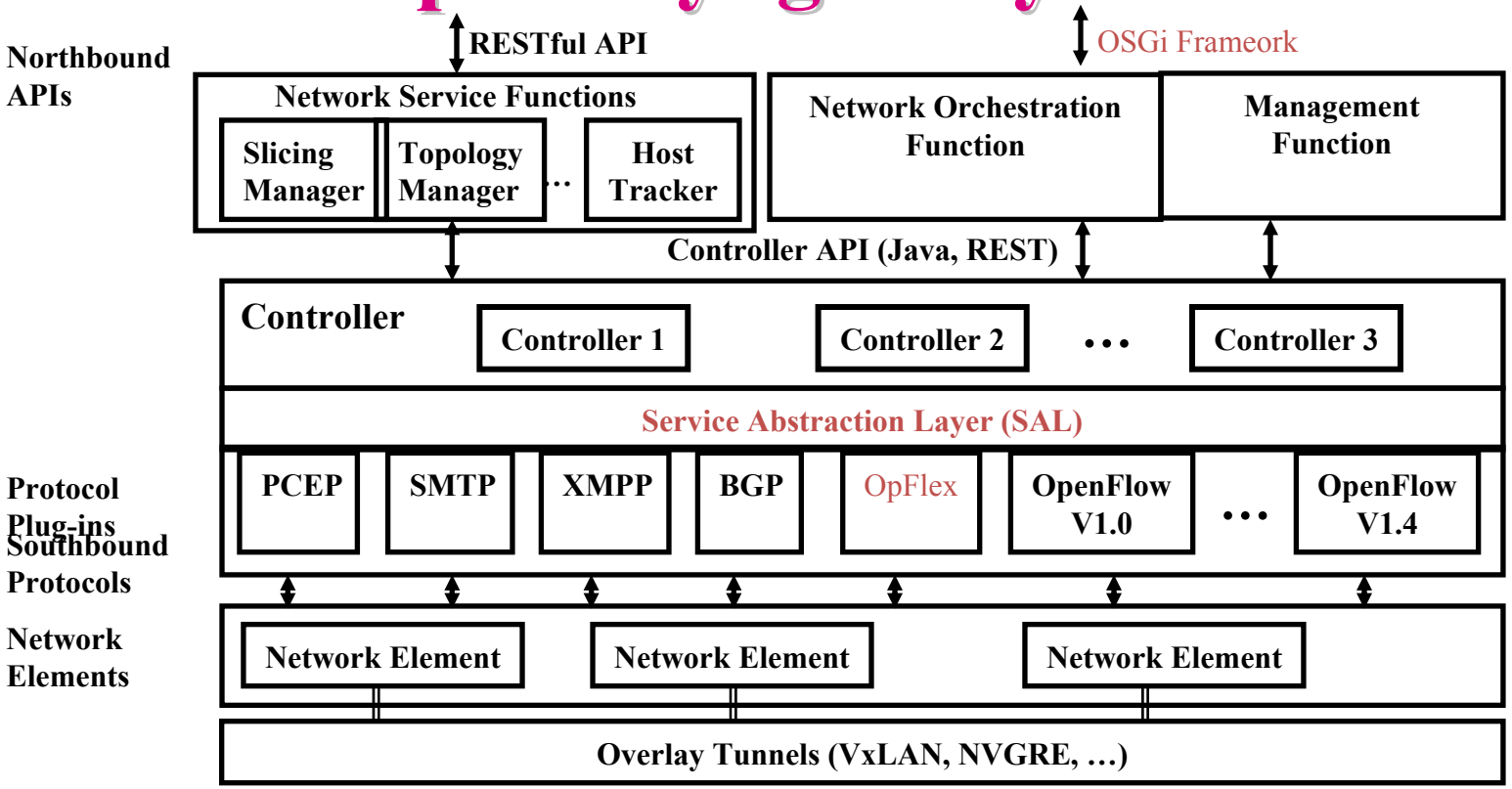
Current SDN Debate: What vs. How?

1. **SDN is easy if control is centralized but not necessary. Distributed/hierarchical solutions may be required for fail-safe operation.**
2. **Complete removal of control plane may be harmful. Exact division of control plane between centralized controller and distributed forwarders is yet to be worked out**

Current SDN Debate: What vs. How? (Cont)

3. **SDN is easy with a standard southbound protocol like OpenFlow but one protocol may not work/scale in all cases**
   1. Diversity of protocols is a fact of life.
   2. There are no standard operating systems, processors, routers, or Ethernet switches.
4. **If industry finds an easier way to solve the same problems by another method, that method may win. E.g., ATM vs. MPLS.**

SDN 2.0: OpenDaylight Style SDN



- NO-OpenFlow (Not Only **OpenFlow) Multi-Protocol**
- **New work in** IETF **XMPP, ALTO, I2RS, PCEP, ….**
- **Linux Foundation**

Flavors of SDN

1. **OpenDaylight:** Multi-Protocol Southbound
2. **Bare Metal Switches + Network Operating System**
   a. Switches from Dell, Edgecore, HP, Penguin, QCT, Agema, Supermicro
   b. Open Network Install Environment (ONIE)
   c. Network operating system: Alcatel-Lucent, Arista, Big Switch, Broadcom, Brocade, Cisco, Cumulus, Dell, Ericsson, Extreme, HP, Juniper, OCP, Pica8, Pluribus
3. **Network Virtualization/Overlay:** VMWare's NSX
4. **ONF SDN:** OpenFlow southbound

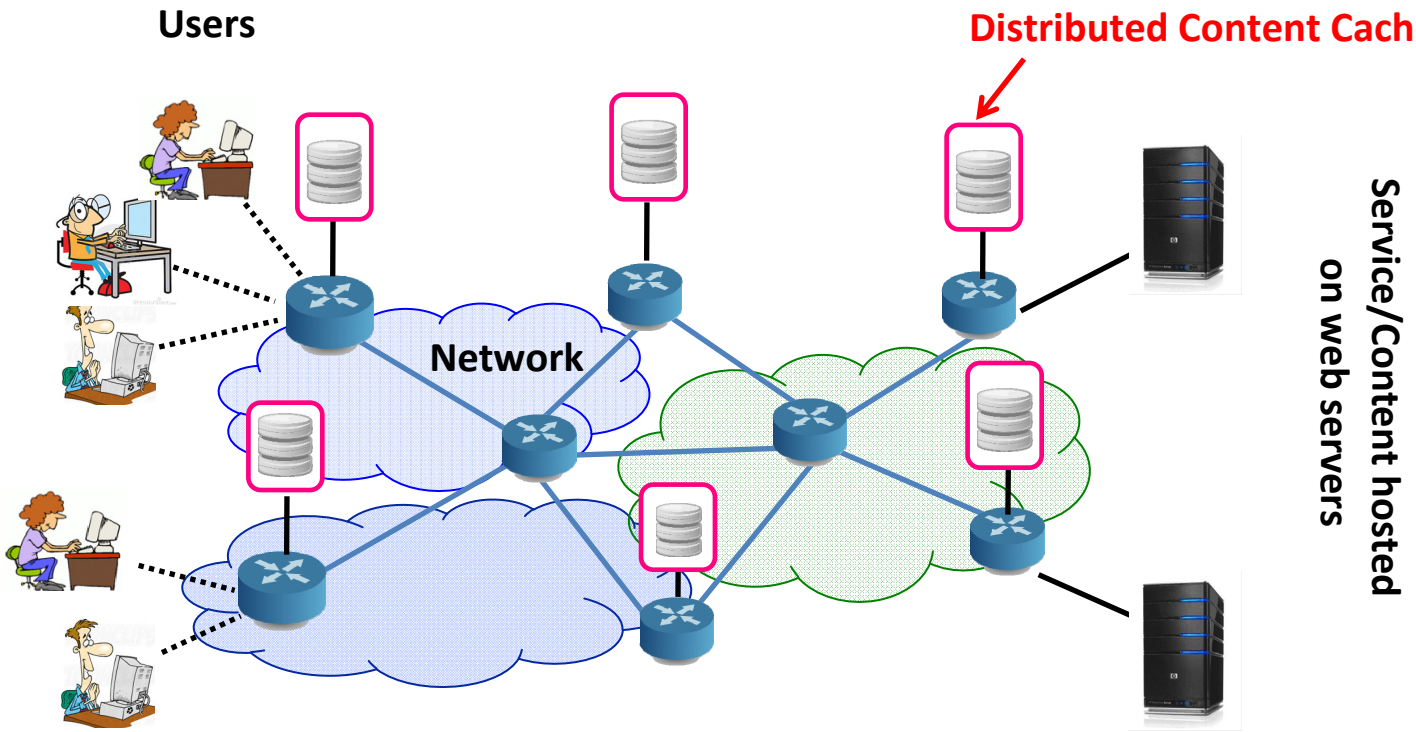
All provide: Abstraction, Programmability, and Centralization

Ref: http://cumulusnetworks.com/support/linux-hardware-compatibility-list/ , http://onie.org/

Source: Alan J Weissberger

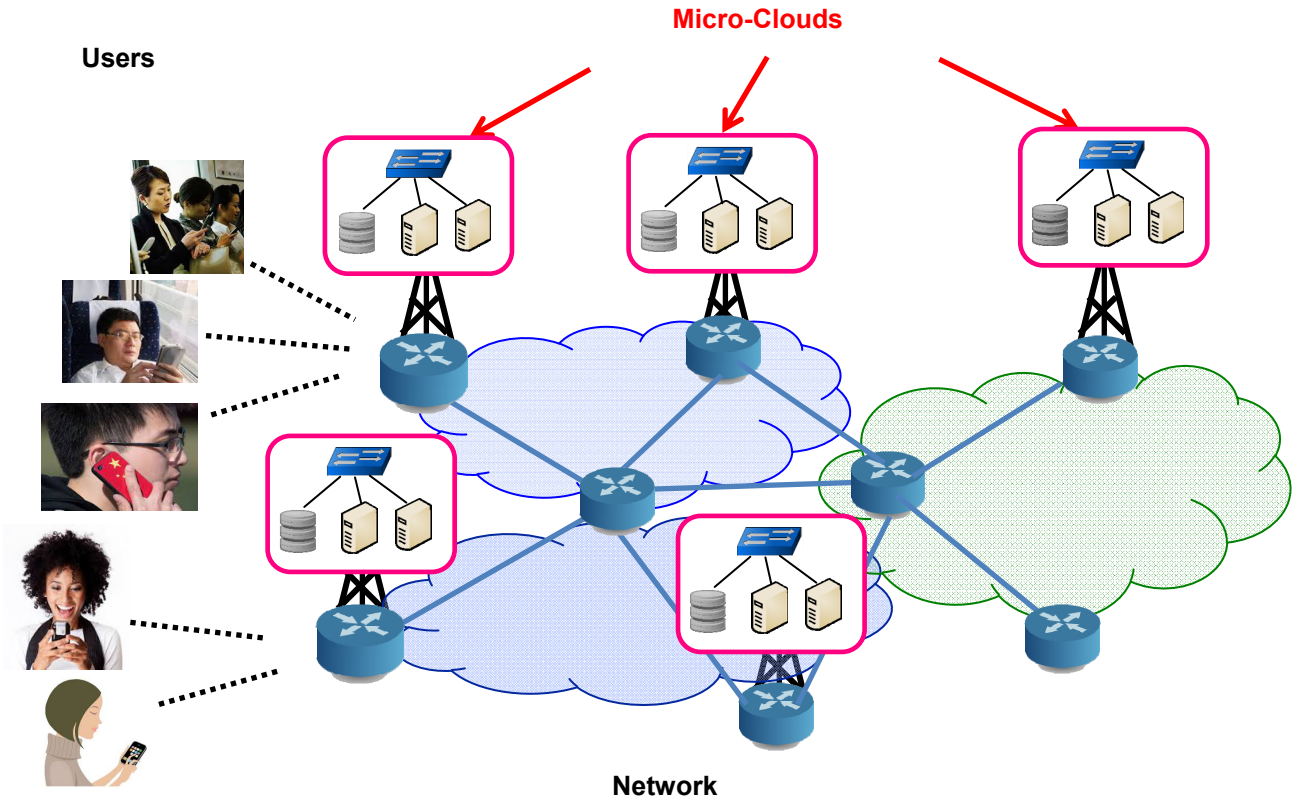
Past: Data in the Edge (CDN)

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



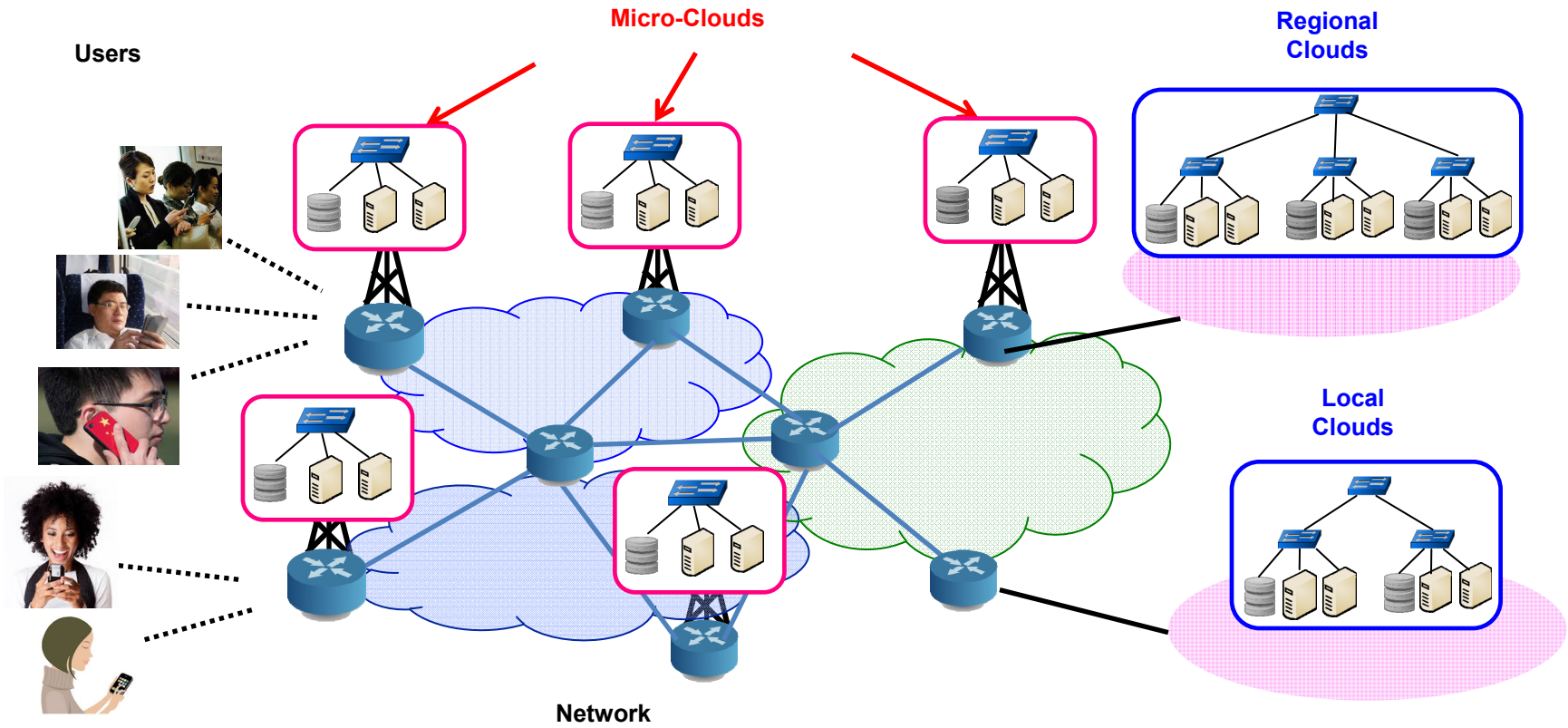
Trend 1: Computation in the Edge

- To service mobile users, the computation needs to come to edge ⇒ Micro-cloud on the tower

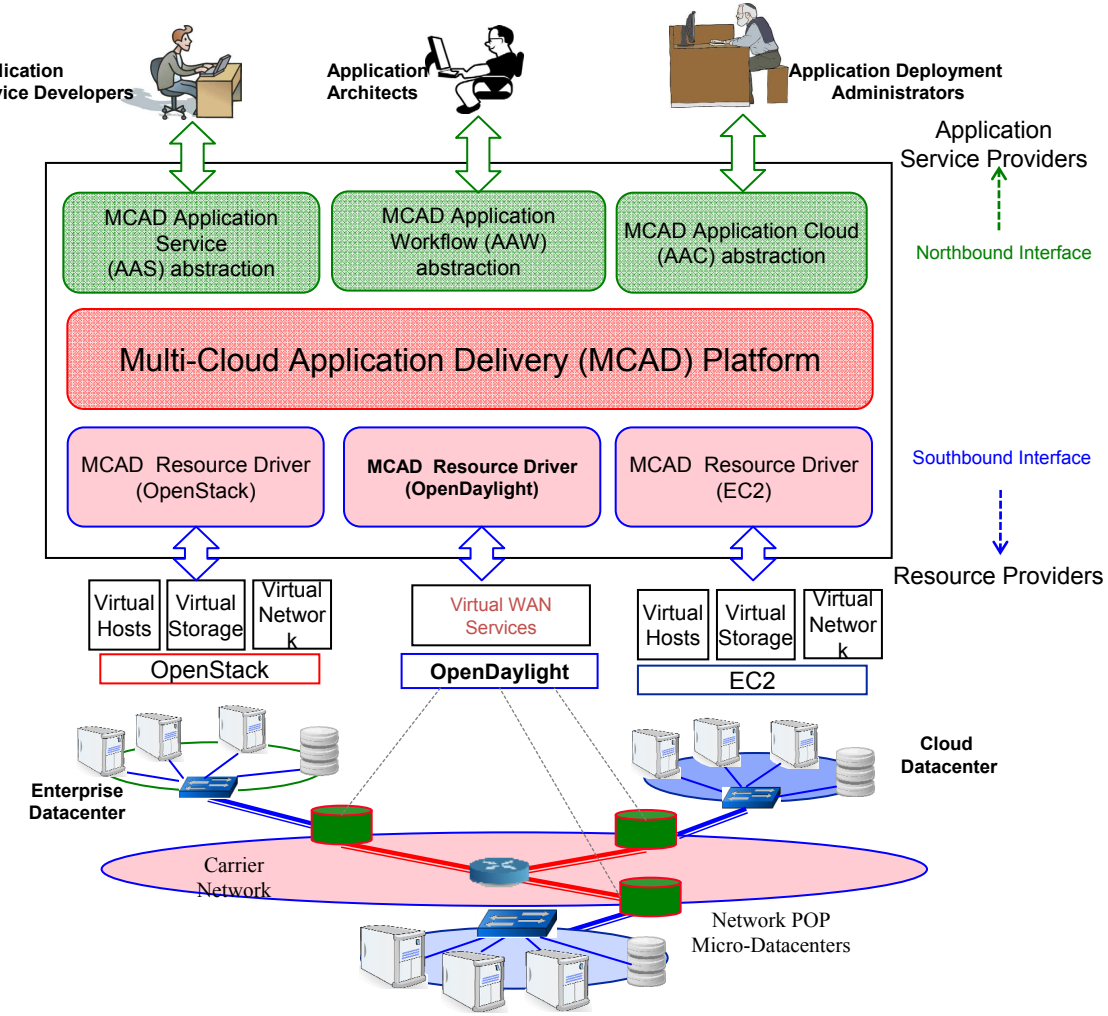


Trend 2: Hierarchical Computation

- **Larger and infrequent jobs serviced by local and regional clouds**



Software Defined Multi-Cloud Management



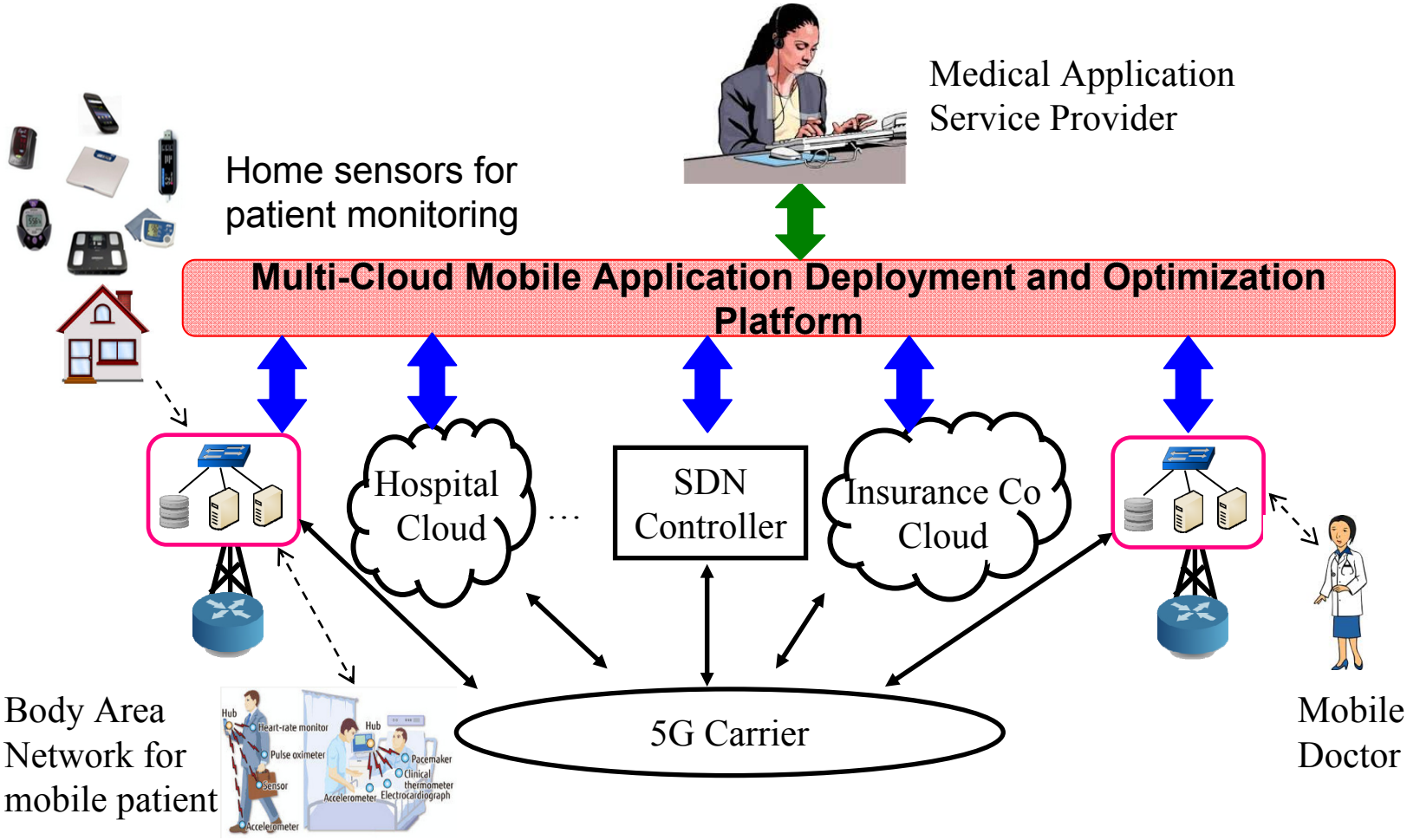
AppFabric Features

1. Allows application architects to specify guidelines for new workflows including middleboxes
2. Allows application developers to specify their resource requirements and design their application without worrying about physical infrastructure
3. Allows Deployment Administrators to specify policies for location of resources in clouds.
4. Automates the entire process of creating new workflows and installing them, managing them during runtime, uninstalling them as necessary
5. Cloud API's are virtualized. Policies are defined at deployment time. Gives all the benefits of SDN.
6. WAN bandwidth and latency is the key to placement.

Resource Control

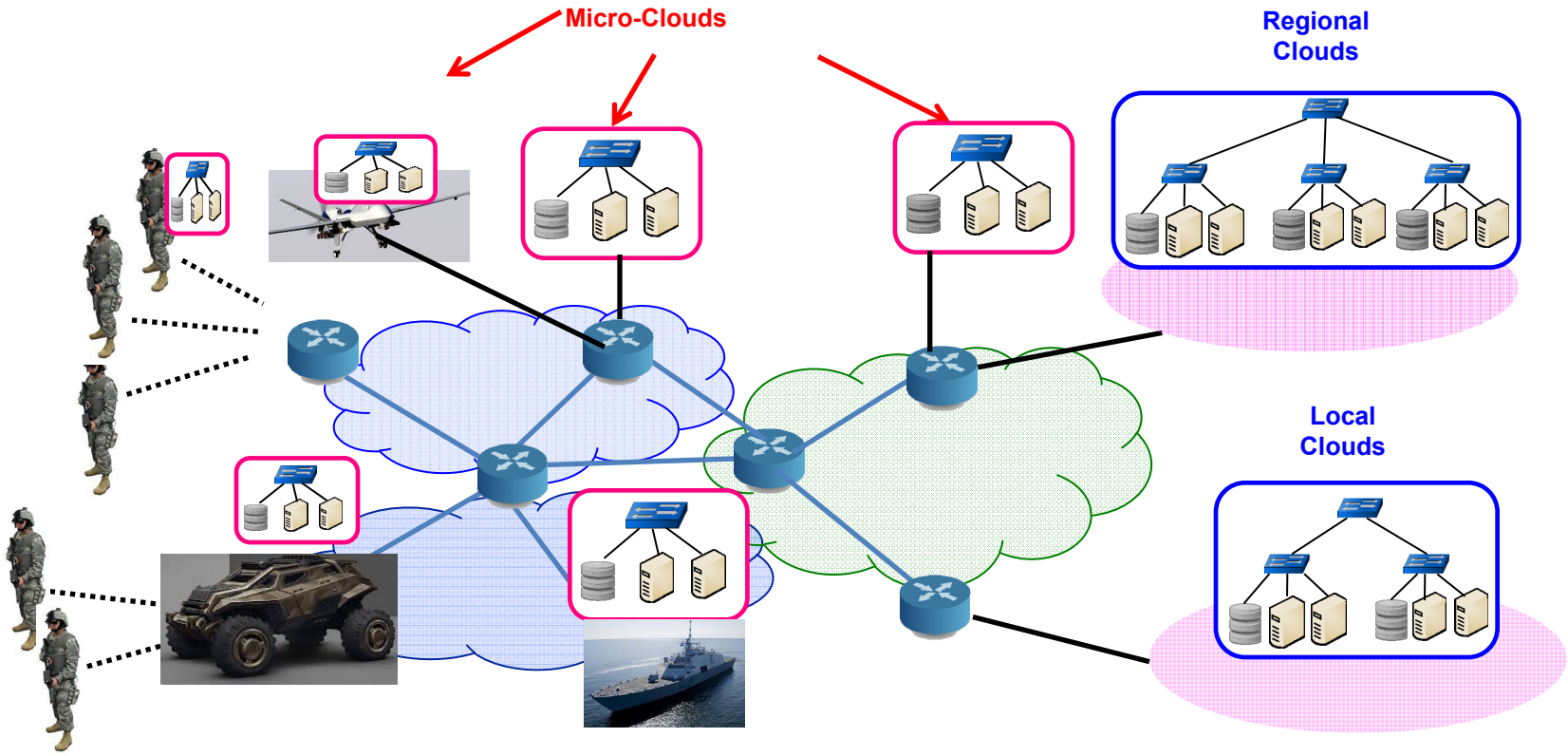
- Tenants keep complete control of their data.
  NSP does not have to look at the application data to enforce application level policies
- NSPs keep complete control of their equipment.
  tenants communicate their policies to NSP's control plane
- VFs and Middle boxes can be located anywhere on the global Internet (Of course, performance is best when they are close by)
- Tenants or NSPs can own OpenADN modules.
  NSPs can offer "Service Chaining" service

Mobile Healthcare Use Case



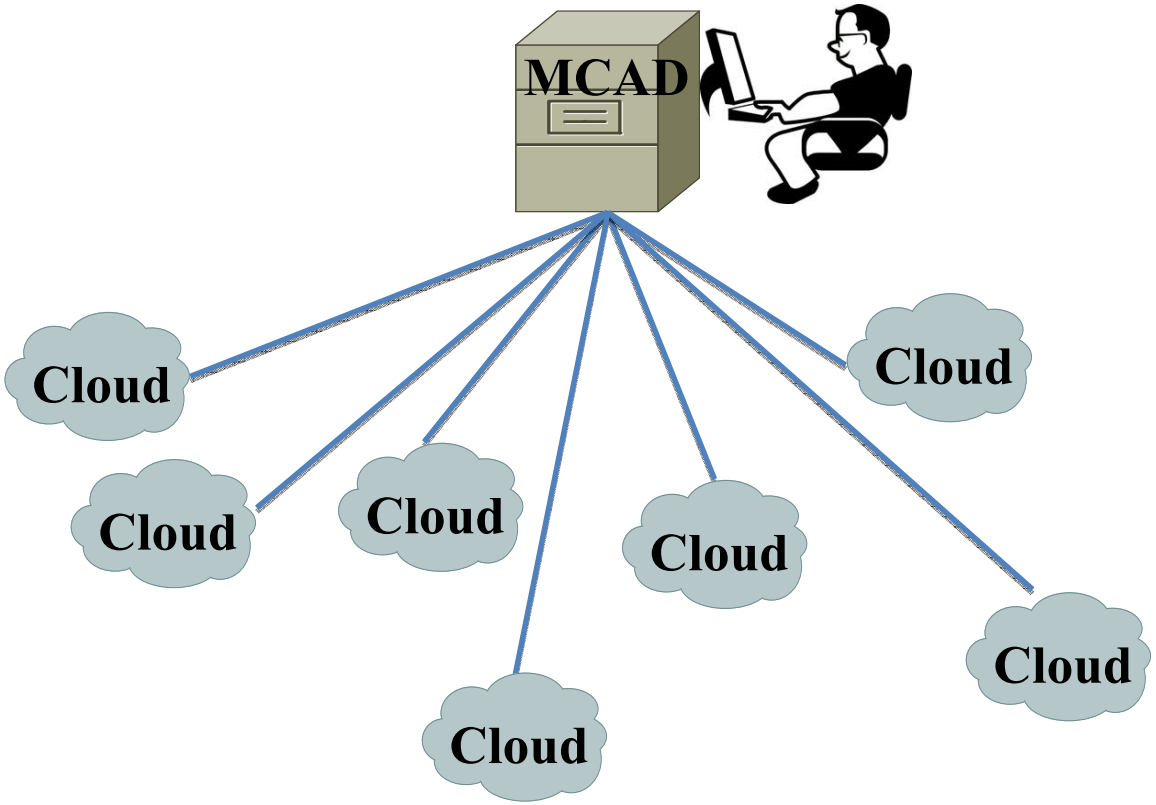
Tactical Application

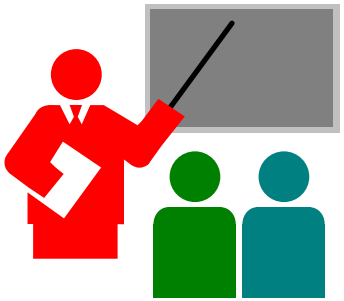
- **Computation in the edge**



Multi-Cloud Security

- Can one cloud provider be trusted by another?
  Would Google trust Microsoft, Amazon, or Apple?





Summary

1. SDN is about abstracting the hardware, providing programmability, and centralizing policy control
2. OpenFlow is micro-management. It is not scalable.
3. SDN in Data Centers is a solved problem.
   Need SDN for Multi-Cloud (or Inter-Cloud)
4. Our MCAD abstracts the cloud interfaces and allows automated management of multi-cloud applications
5. Multi-Cloud has important tactical 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 Managzine, 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**