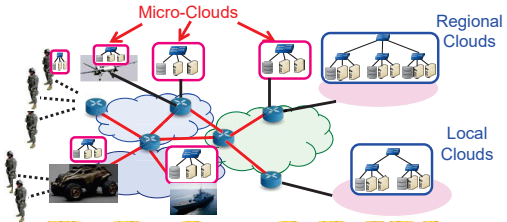
Software Defined Networking at the Tactical Edge



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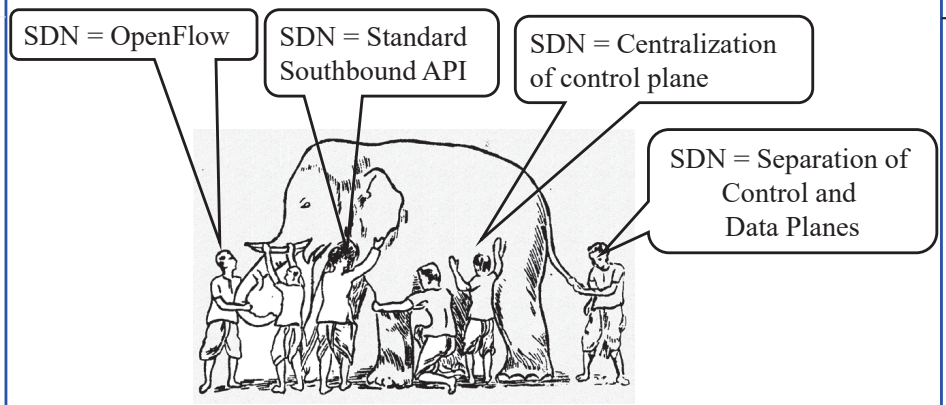
Talk at Bharat Electronics Limited, Bangaluru, Sept 10, 2016

These slides are available on-line at:

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

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

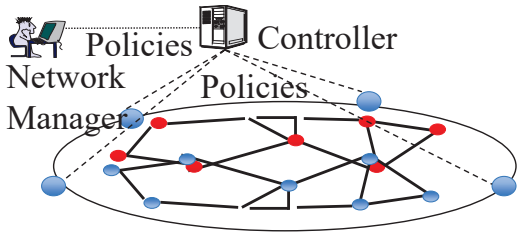
What SDN is Not?



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

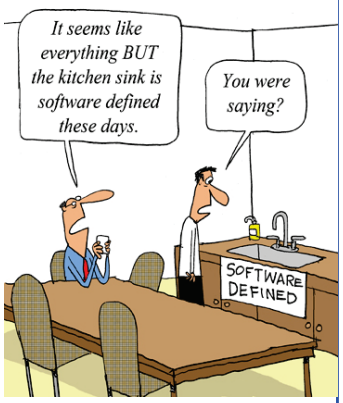
Three Features that Define SDN

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)

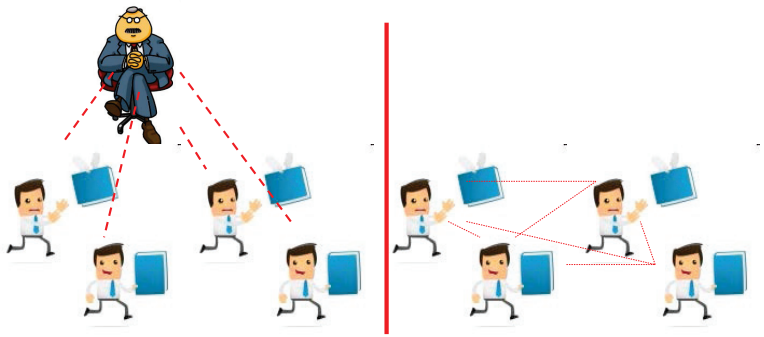
- Tsunami of software defined things
  - Software Defined Networking (SDN)
  - Software Defined Datacenter (SDDC)
  - Software Defined Storage (SDS)
  - Software Defined Compute (SDC)
  - Software Defined Infrastructure (SDI)



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

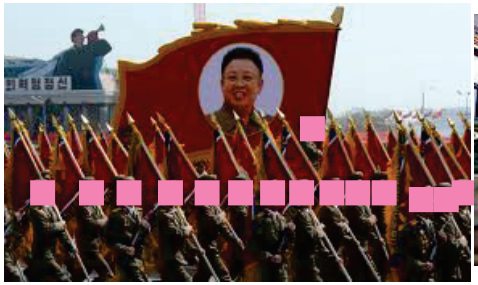
Four Confusions About SDN

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

Current SDN Debate: What vs. How?

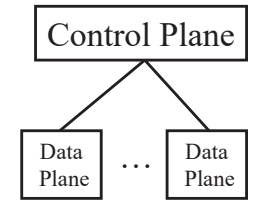
1. SDN is easy if control is centralized but not necessary.
   Distributed/hierarchical solutions may be required for fail-safe operation.
2. Complete removal of control plane may be harmful.
   Exact division of control plane between centralized controller and distributed forwarders is yet to be worked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

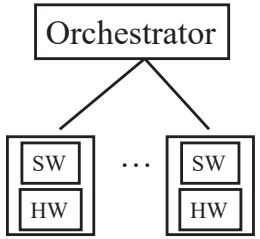
Current SDN Debate (Cont)

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 Evolution

- 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





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/

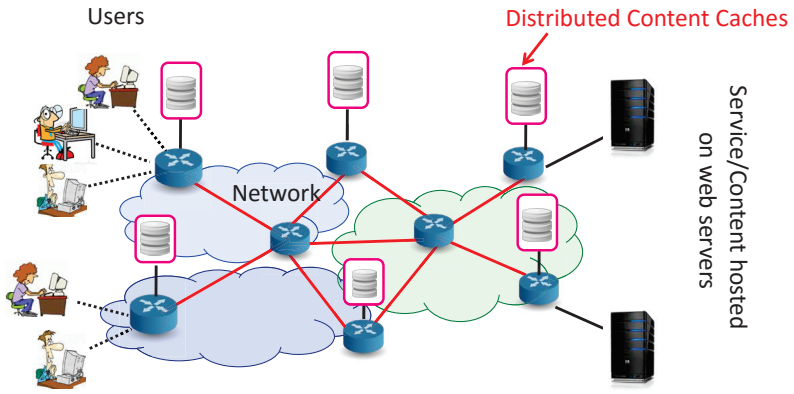
Source: Alan J Weissberger

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

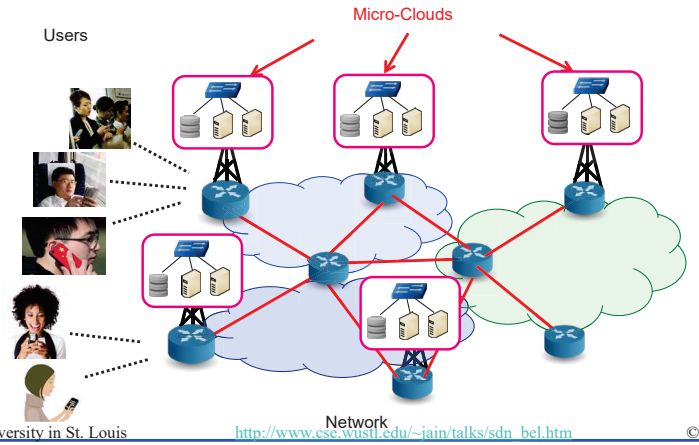
Past: Data in the Edge (CDN)

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



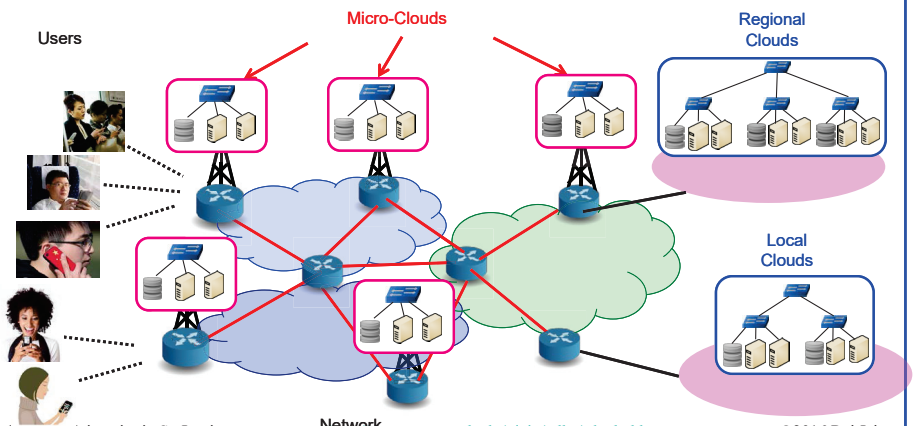
Trend: Computation in the Edge

- To service mobile users, the computation needs to come to edge ⇒ Mobile Edge Computing (MEC)



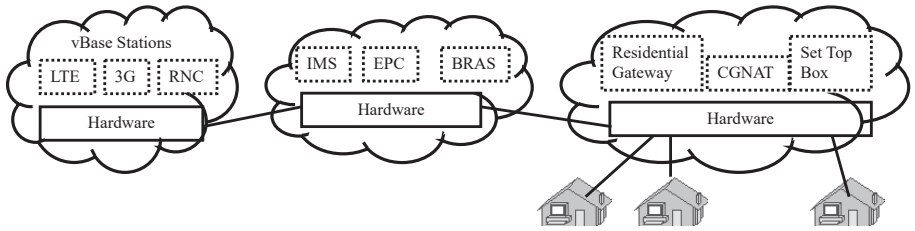
Trend: Multi-Cloud Hierarchy

- Wide area clouds, local area clouds (home routers with cloud features), Personal area clouds (cars), body area clouds (smart phone) ⇒ Fog Computing



NFV Multi-Cloud Use Case

- Virtual Machine/Cloud implementation of carrier functions
  ⇒ Virtual appliances
  ⇒ All advantages of virtualization (quick provisioning, scalability, mobility, Reduced CapEx, Reduced OpEx, …)
- Service Chaining: Where to place the virtual functions?



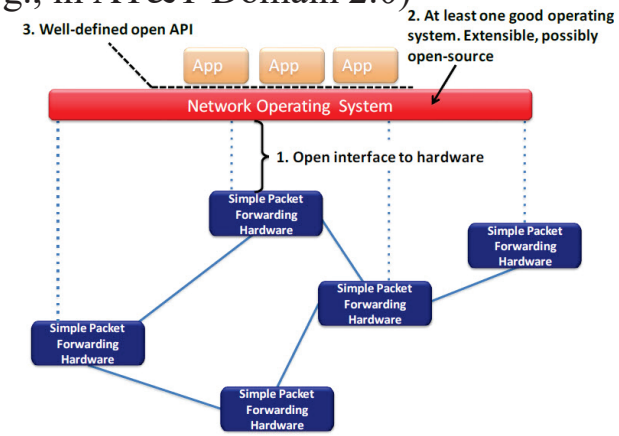
Any Function Virtualization (FV)

- "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

SDN Past

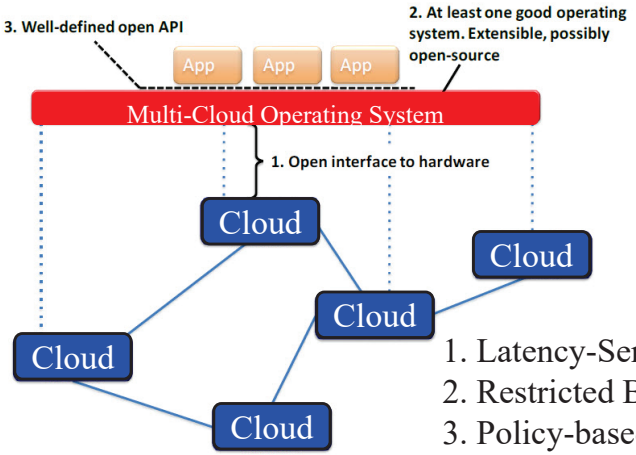
- Past: Virtualization of switches (e.g., in AT&T Domain 2.0)



Ref: AT&T, "Domain 2.0 White paper,"
https://www.att.com/Common/about_us/pdf/AT&T%20Domain%202.0%20Vision%20White%20Paper.pdf

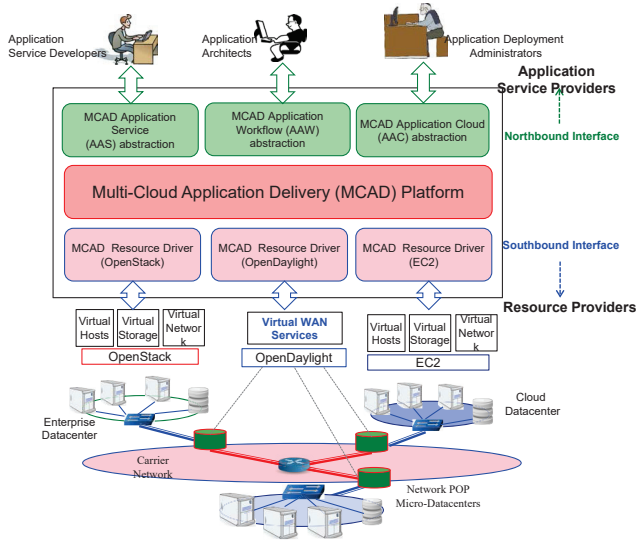
SDN Future

- Tomorrow: Virtualization of Clouds

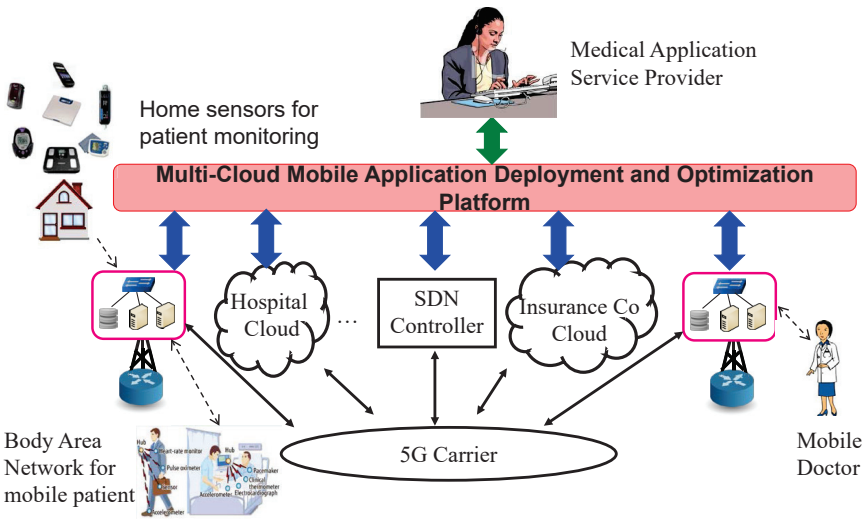


1. Latency-Sensitive
2. Restricted Bandwidth
3. Policy-based automation

OpenADN Multi-Cloud Management

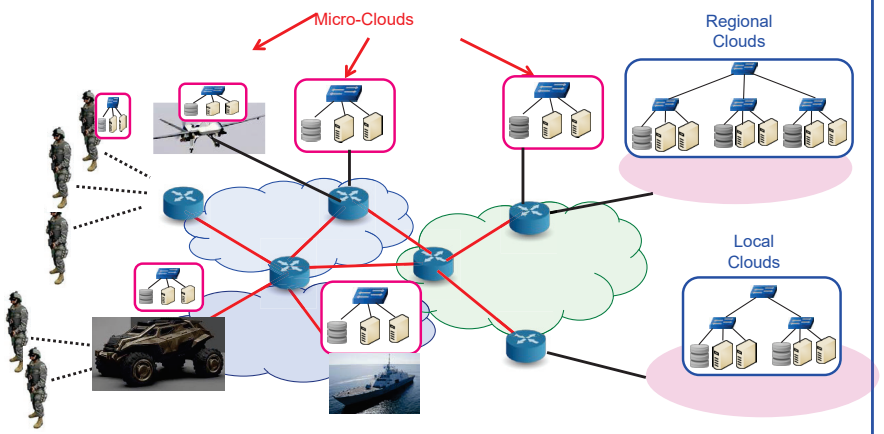


Mobile Healthcare Use Case



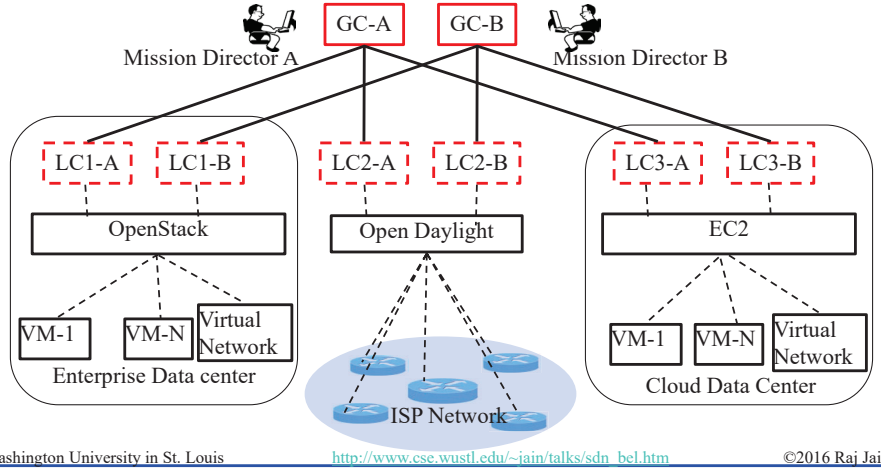
Tactical Application

- Computation in the edge



Multiple Applications and Providers

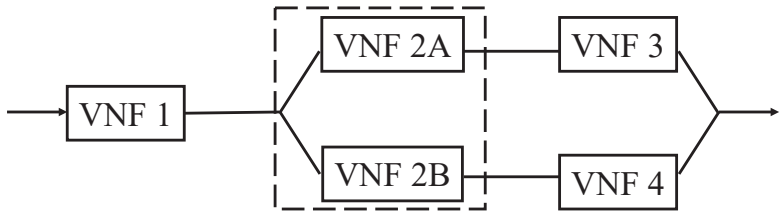
- Each mission has its own Global controller (GC) and local controllers (LC)
- Every one has its own policies and set of providers

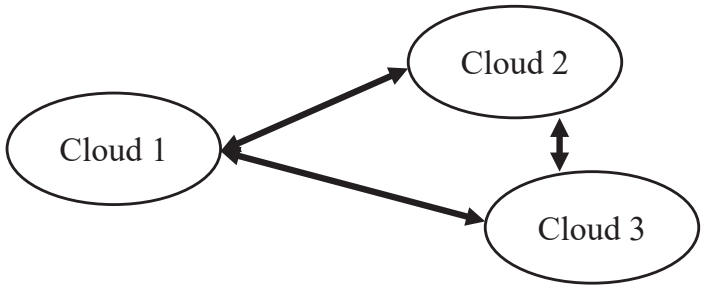


Challenges in Multi-Cloud Deployment

- **Dynamic**: Forwarding changes with state of the servers, links
- **Heterogeneous**: Different cloud providers, different services, different policies
- **Distributed Control**:
  - Equipment belongs to infrastructure provider
  - Data belongs to Tenants
- **Massive Scale**: Millions of enterprise applications sharing networks provided by many ISPs using cloud services from many CSPs

Service Function Placement Problem



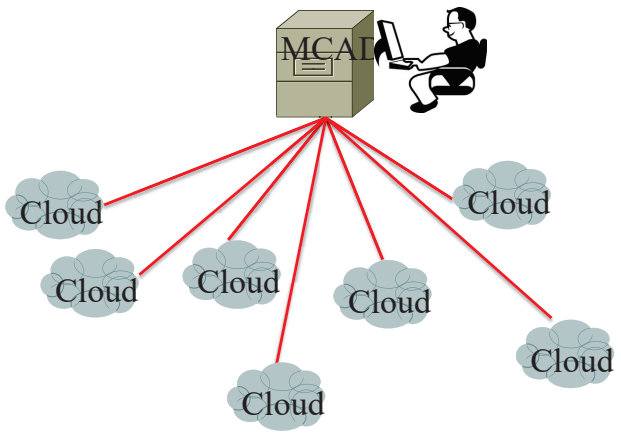


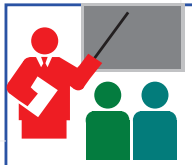
Challenges in Service Placement

- **Delay constraints**
- **WAN links bottleneck:** Need to model link queues
- **Complexity**: NP-complete ⇒ 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

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. Clouds getting smaller, Carriers and enterprises moving to clouds, Internet of things are leading to clouds everywhere ⇒ multi-cloud applications.
3. Our multi-cloud application management system (MCAD) allows policy-based deployment and management of multi-cloud application. Handles heterogeneous clouds and respects resource ownerships
4. Multi-Cloud has important tactical applications
5. Service function placement problem is NP complete. Challenges included delay constraints, WAN Link bottlenecks, and affinity

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 Managing, Nov 2013, pp. 24-31, http://www.cse.wustl.edu/~jain/papers/net_virt.htm
- Subharthi Paul, Raj Jain, Mohammed Samaka, Aiman Erbad, "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

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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