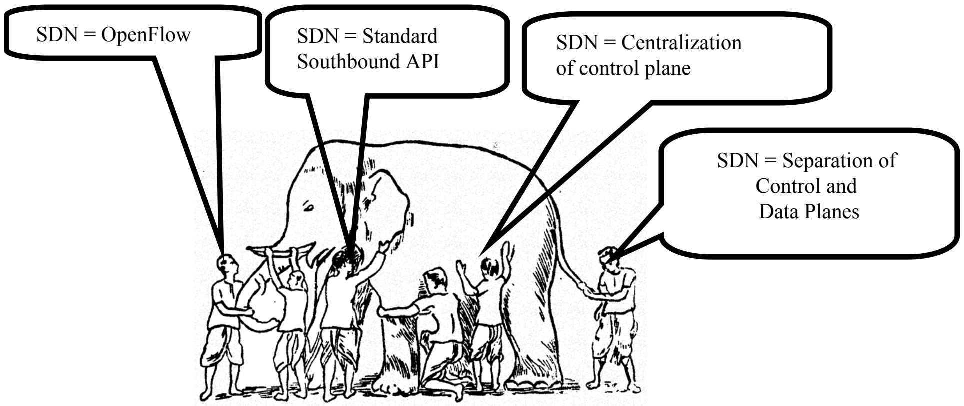
Virtualization and Software Defined Networking (SDN) for *Mobile* Carriers



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Keynote at WoWMoM 2014, Sydney, Australia, June 18, 2014

These slides and video recording of this presentation are at:

http://www.cse.wustl.edu/~jain/talks/wowmom14.htm

Overview

1. Five concepts/events that have changed the networking world: Virtualization, Cloud, Smart Phones, SDN, NFV
2. What really is SDN?: SDN 1.0 vs. SDN 2.0
3. Network Function Virtualization: Service Chaining
4. Mobile Apps ⇒ Global Cloud of Clouds

1. Virtualization

- Internet ⇒ Virtualization

- No need to get out for
  - Office
  - Shopping
  - Education
  - Entertainment

- Virtual Workplace
- Virtual Shopping
- Virtual Education
- Virtual Sex

Virtualization

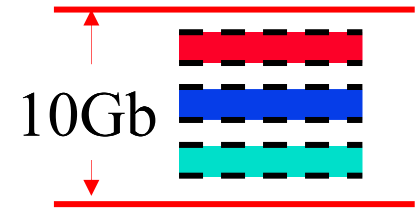
"*Virtualization means that Applications can use a resource without any concern for where it resides, what the technical interface is, how it has been implemented, which platform it uses, and how much of it is available.*"

-Rick F. Van der Lans

in Data Virtualization for Business Intelligence Systems

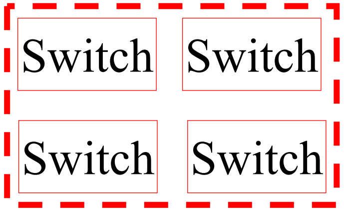
5 Reasons to Virtualize

1. Sharing: Break up a large resource
   Large Capacity or high-speed
   ⇒ Multi-Tenant



2. Isolation: Protection from other tenants

3. Aggregating: Combine many resources in to one



4. Dynamics: Fast allocation, Change/Mobility, Follow the sun (active users) or follow the moon (cheap power)

5. Ease of Management
   ⇒ Cost Savings. fault tolerance

Virtual Machines

"I ordered a computer from this company and this is all they sent me."

2. Cloud Computing

- August 25, 2006: Amazon announced EC2 ⇒ Birth of Cloud Computing in reality (Prior theoretical concepts of computing as a utility)
- *Web Services To Drive Future Growth For Amazon* ($2B in 2012, $7B in 2019) - Forbes, Aug 12, 2012
- Cloud computing was made possible by computing virtualization
- **Networking**: Plumbing of computing
  - IEEE: Virtual Bridging, …
  - IETF: Virtual Routers, …
  - ITU: Mobile Virtual Operators, …

3. Smart Phones and Mobile Apps

- June 29, 2007: Apple announced iPhone
  ⇒ Birth of Mobile Internet, Mobile Apps
- Almost all services are now mobile apps: Google, Facebook, Bank of America, …
- Almost all services need to be global (World is flat)
- Almost all services use cloud computing (Easy management)

Ref: Top 500 sites on the web, http://www.alexa.com/topsites

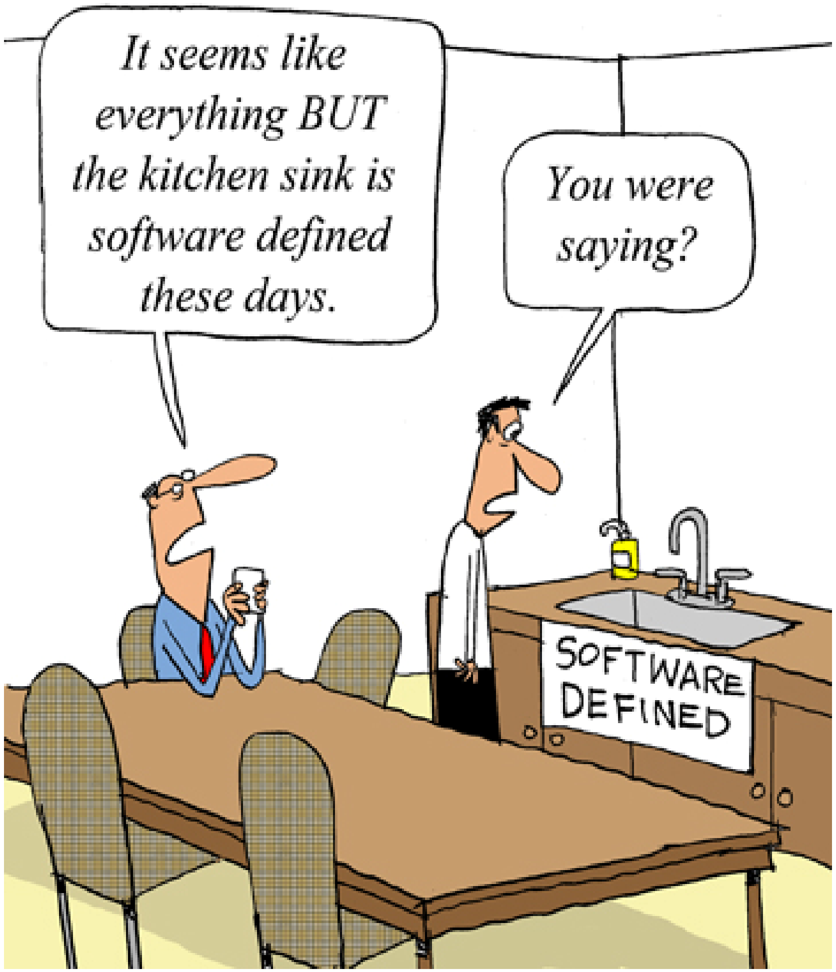
4. Software Defined Networking

- 2006: Martin Casado, a PhD student at Stanford and team propose a clean-slate security architecture (SANE) which defines a centralized control of security (in stead of at the edge as normally done). Ethane generalizes it to all access policies.
- April 2008: OpenFlow paper in ACM SIGCOMM CCR
- 2009: Stanford publishes OpenFlow V1.0.0 specs
- **March 2011**: Open Networking Foundation is formed
- **Oct 2011**: First Open Networking Summit
  ⇒ Software Defined Networking (**SDN 1.0**) = OpenFlow

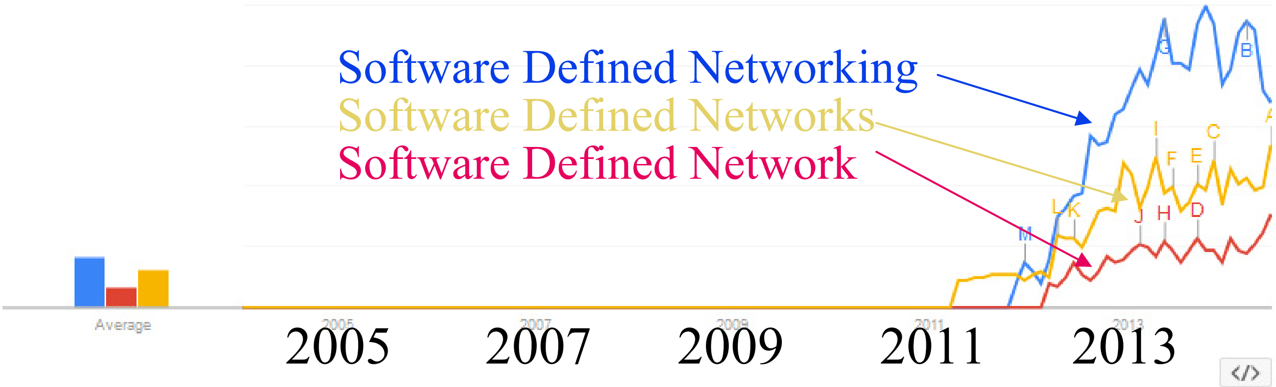
Ref: ONF, "The OpenFlow Timeline," http://openflownetworks.com/of_timeline.php

SDN Everywhere

- Software Defined Switches
- Software Defined Routers
- Software Defined Data Center
- Software Defined Storage
- Software Defined Base Stations
- Software Defined GPS
- Software Defined Radio
- Software Defined Infrastructure
- Software Defined Optical Switches



Google Trends: SDN



Regional interest

software define... software defined ... software defined ...

Region | Town/City

India	100
United States	51

Planes of Networking

- **Data Plane**: All activities involving as well as resulting from data packets sent by the end user, e.g.,
  - Forwarding
  - Fragmentation and reassembly
  - Replication for multicasting
- **Control Plane**: All activities that are necessary to perform data plane activities but do not involve end-user data packets
  - Making routing tables
  - Setting packet handling policies (e.g., security)

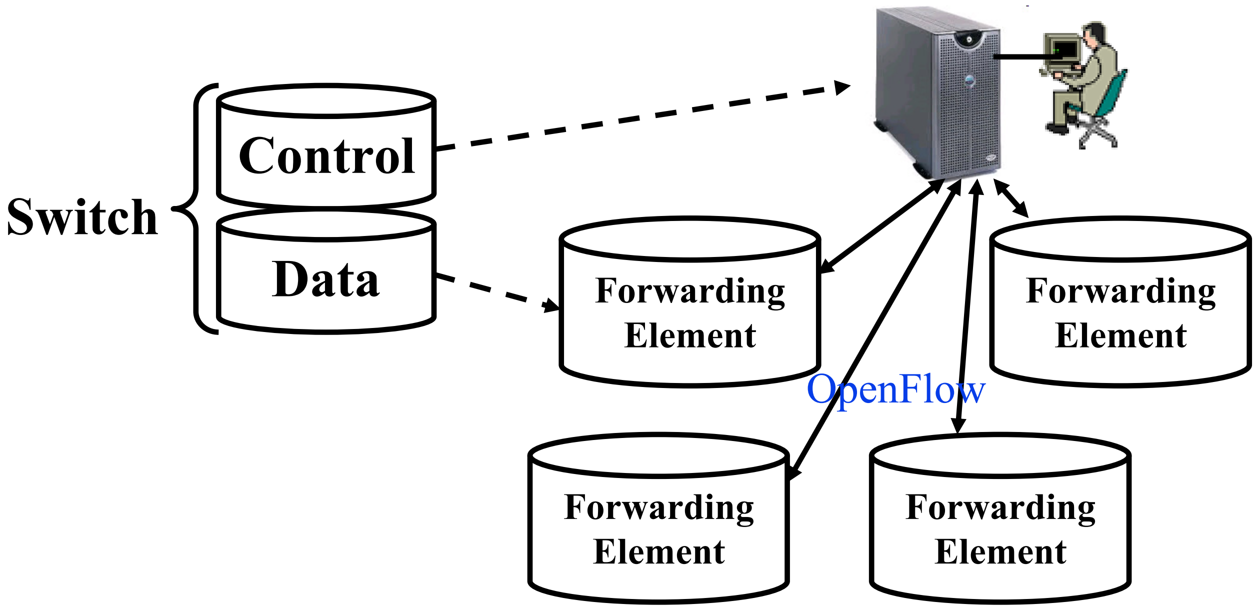
Dest.	Output Port	Next Hop

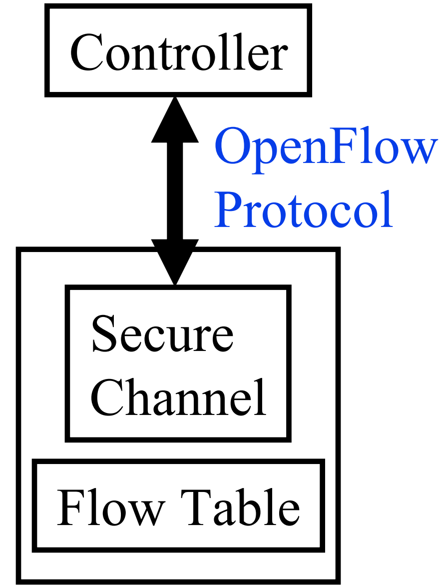
Ref: Open Data Center Alliance Usage Model: Software Defined Networking Rev 1.0,"
http://www.opendatacenteralliance.org/docs/Software_Defined_Networking_Master_Usage_Model_Rev1.0.pdf

Planes of Networking (Cont)

- **Management Plane**: All activities related to provisioning and monitoring of the networks
  - Fault, Configuration, Accounting, Performance and Security (**FCAPS**).
  - Instantiate new devices and protocols (Turn devices on/off)
  - Optional ⇒ May be handled manually for small networks.
- **Services Plane**: Middlebox services to improve performance or security, e.g.,
  - Load Balancers, Proxy Service, Intrusion Detection, Firewalls, SSL Off-loaders
  - Optional ⇒ Not required for small networks

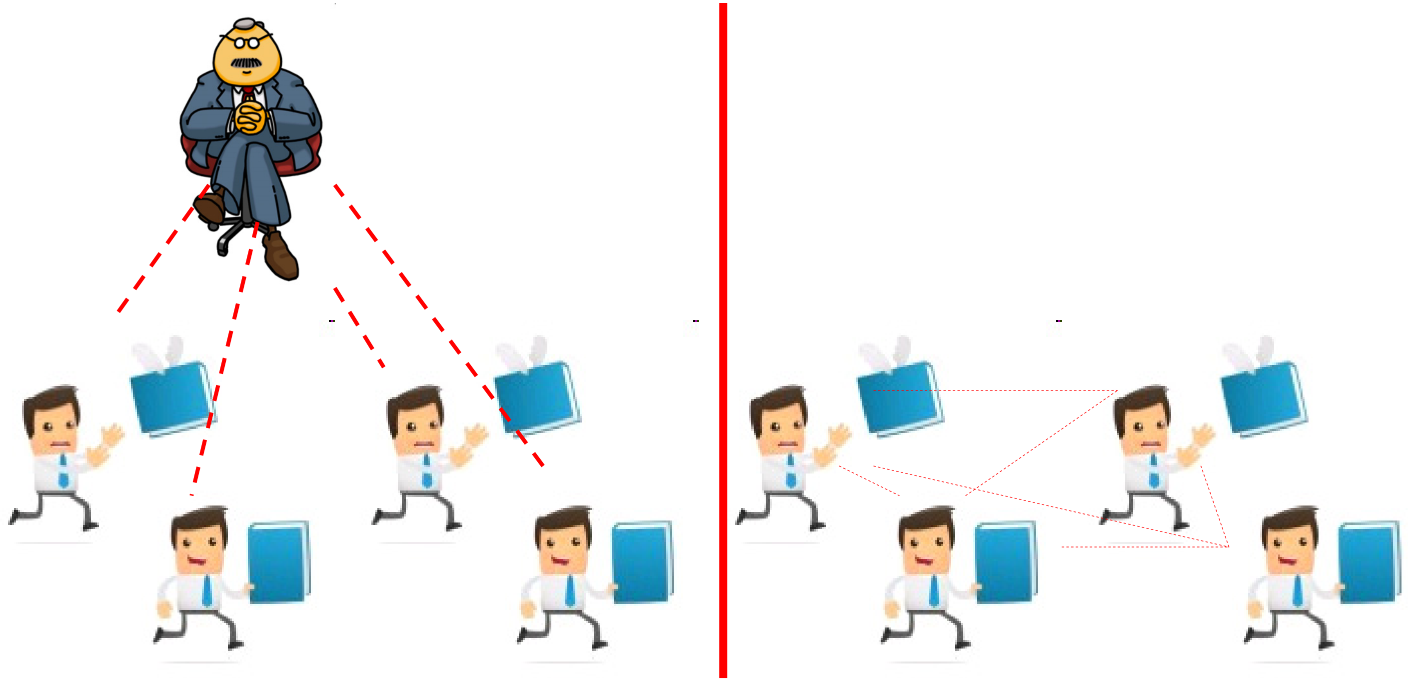
Separation of Control and Data Plane





- Control logic is moved to a central controller
- Switches only have forwarding elements
- One expensive controller with a lot of cheap switches
- OpenFlow is the protocol to send/receive forwarding rules from controller to switches

Centralization of Control Plane

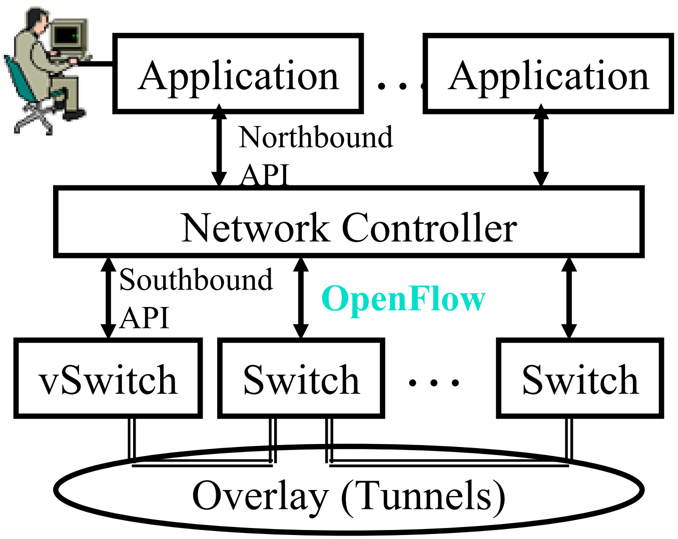


Centralized vs. **Distributed**

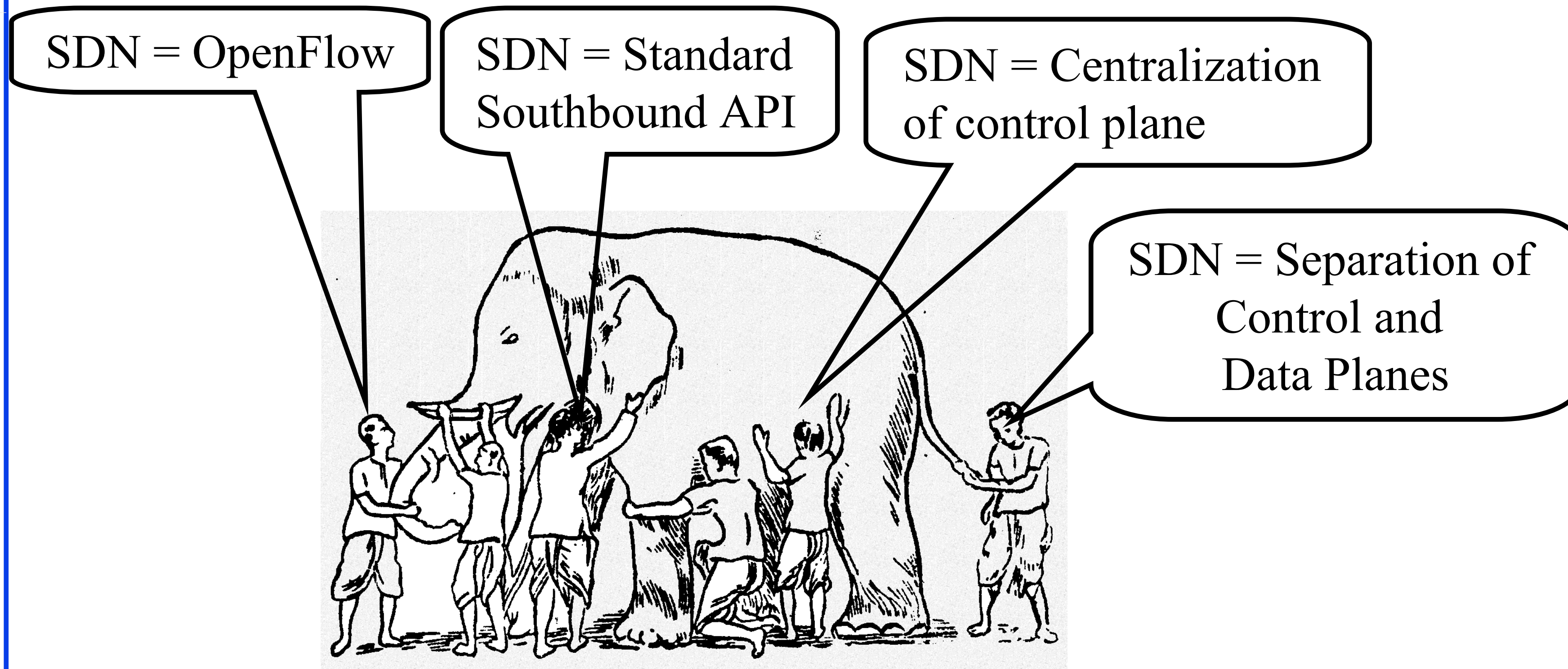
- Consistency
- Fast Response to changes
- Easy management of lots of devices

SDN 1.0: SDN Based on OpenFlow

- SDN originated from OpenFlow
- Centralized Controller
  ⇒ Easy to program
  ⇒ Change routing policies on the fly
  ⇒ Software Defined Network (SDN)
- Initially, SDN = OpenFlow



What is SDN?



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

ONF Definition of SDN

“***What is SDN?***

The physical separation of the network control plane from the forwarding plane, and where a control plane controls several devices.”

1. Directly programmable
2. Agile: *Abstracting control from forwarding*
3. Centrally managed
4. Programmatically configured
5. Open standards-based vendor neutral

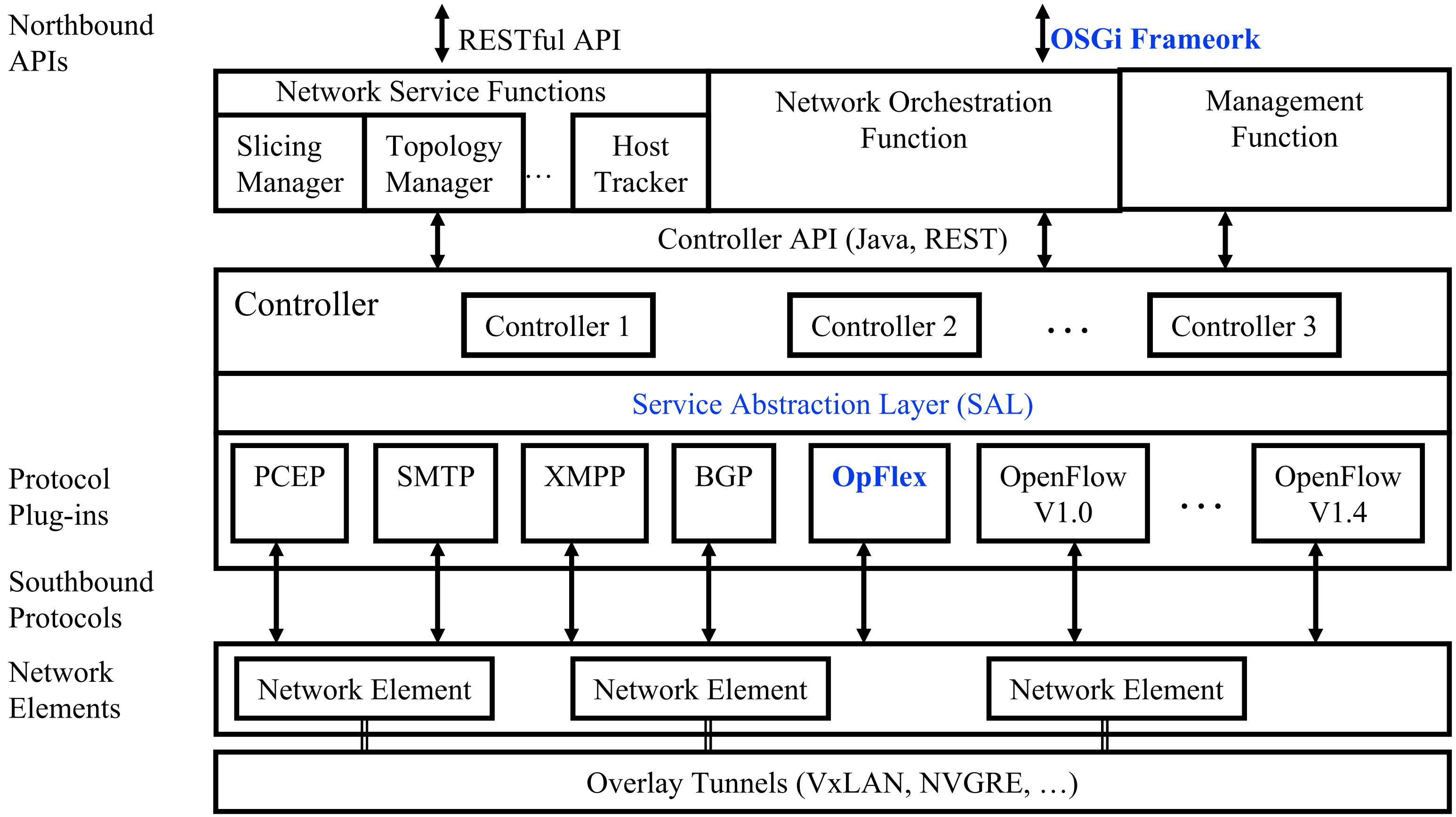
The above definition includes *How*.
Now many different opinions about ***How***.
⇒SDN has become more general.
Need to define by ***What***?

Ref: https://www.opennetworking.org/index.php?option=com_content&view=article&id=686&Itemid=272&lang=en

What do We need SDN for?

1. **Virtualization**: Use network resource without worrying about where it is physically located, how much it is, how it is organized, etc.
2. **Orchestration**: Manage thousands of devices
3. **Programmable**: Should be able to change behavior on the fly.
4. **Dynamic Scaling**: Should be able to change size, quantity
5. **Automation**: Lower OpEx
6. **Visibility**: Monitor resources, connectivity
7. **Performance**: Optimize network device utilization
8. **Multi-tenancy**: Sharing expensive infrastructure
9. **Service Integration**
10. **Openness**: Full choice of Modular plug-ins
11. **Unified management** of computing, networking, and storage

SDN 2.0: OpenDaylight Style SDN



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

Open Everything

- Open Networking Foundation
- OpenFlow
- OpenStack
- OpenDaylight
- Open Access
- Open Source

Current SDN Debate: What vs. How?

- SDN is easy if control plane is centralized but not necessary. Distributed solutions may be required for legacy equipment and for fail-safe operation.
- 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
- SDN is easy with a standard southbound protocol like OpenFlow but one protocol may not work/scale in all cases
  - Diversity of protocols is a fact of life.
  - There are no standard operating systems, processors, routers, or Ethernet switches.
- If industry finds an easier way to solve the same problems by another method, that method may win. E.g., ATM vs. MPLS.

Separation vs. Centralization

Separation of Control Plane

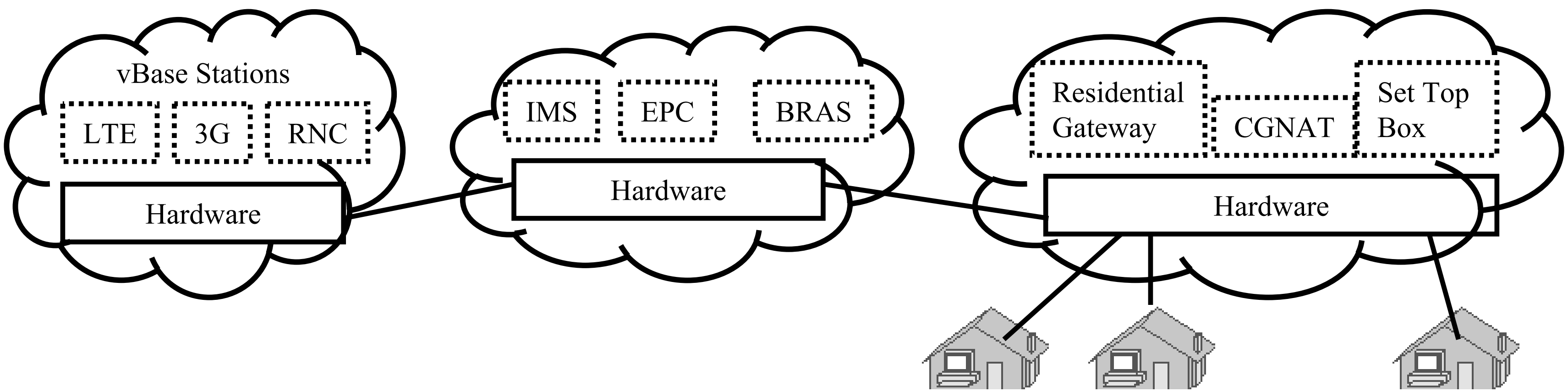
Centralization of Control ~~Plane~~

Micromanagement is not scalable

5. Network Function Virtualization (NFV)

1. Fast standard hardware ⇒ **Software based Devices**
   Routers, Firewalls, Broadband Remote Access Server (BRAS) ⇒ A.k.a. *white box* implementation

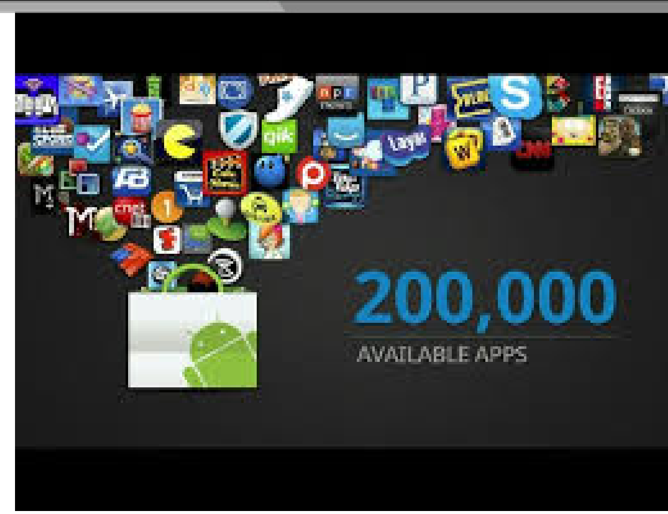
2. **Virtual Machine implementation**
   ⇒ Virtual appliances
   ⇒ All advantages of virtualization (quick provisioning, scalability, mobility, Reduced CapEx, Reduced OpEx, …)



Ref: ETSI, "NFV – Update White Paper," Oct 2013, http://www.tid.es/es/Documents/NFV_White_PaperV2.pdf (Must read)

Carrier App Market: Lower CapEx

Virtual IP Multimedia System



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

What can NFV do?

1. **Virtualization**: Use network resource without worrying about where it is physically located, how much it is, how it is organized, etc.
2. **Orchestration**: Manage thousands of devices
3. **Programmable**: Should be able to change behavior on the fly.
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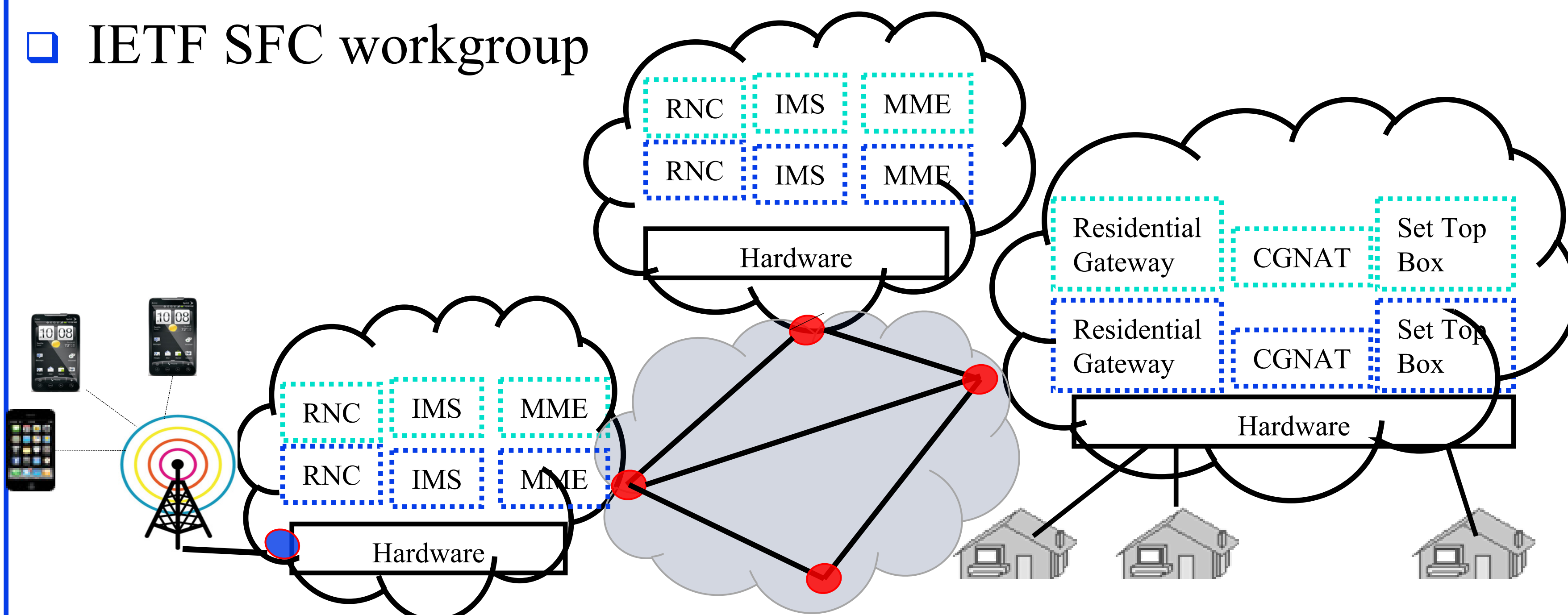
9. **Service Integration**
10. **Openness**: Full choice of Modular plug-ins

Note: These are almost the **same** reasons why we need SDN.

Service Chaining in a Multi-Cloud Multi-Tenant Environment

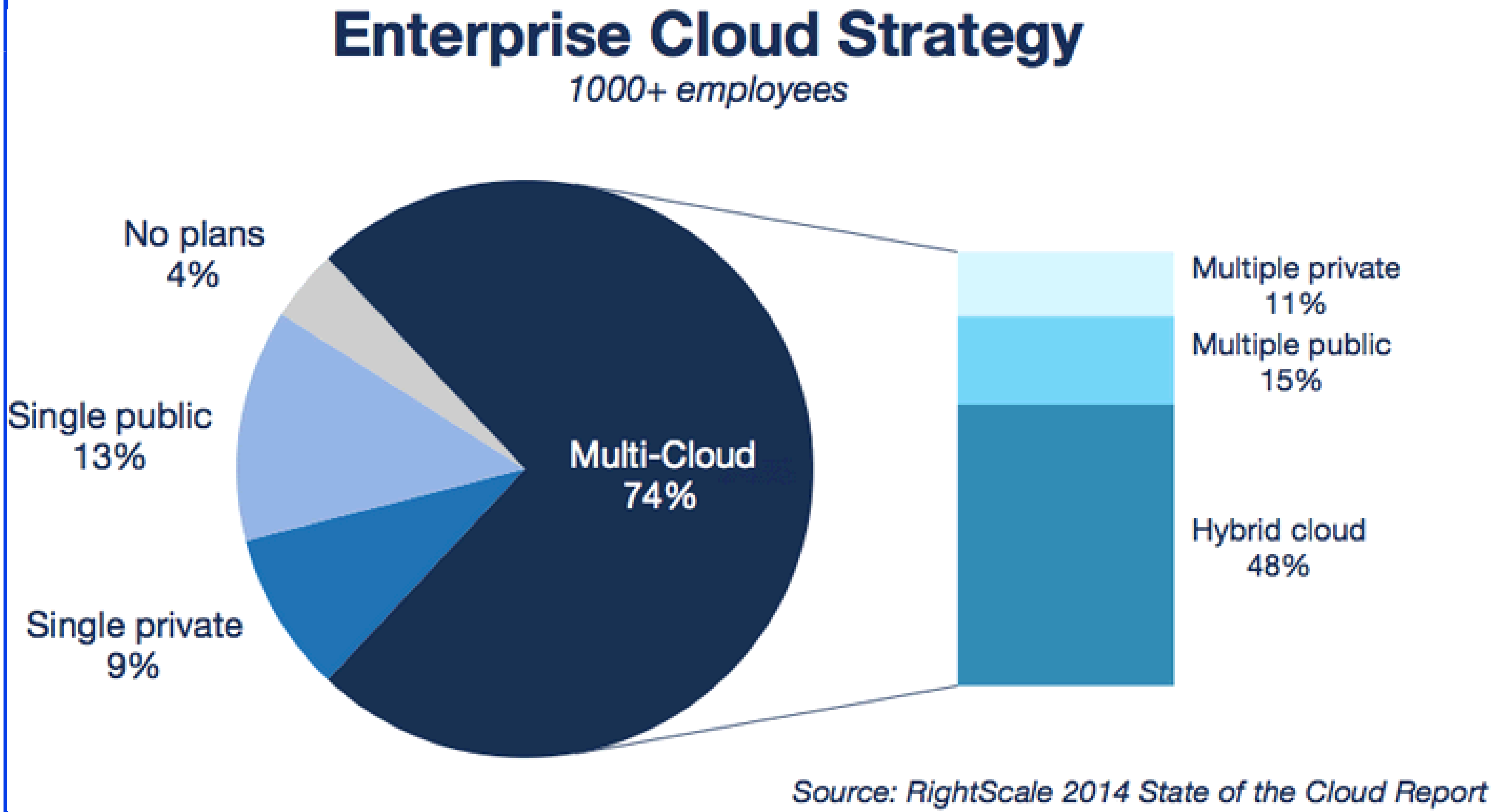
- VNFs (Virtual network fns) belong to tenants. Multiple tenants.
- Each Cloud belongs to a different Cloud Service Provider (CSP)
- Internet infrastructure belongs to an NFVI service provider (NSP)
- Service chain = Workflow
- IETF SFC workgroup



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

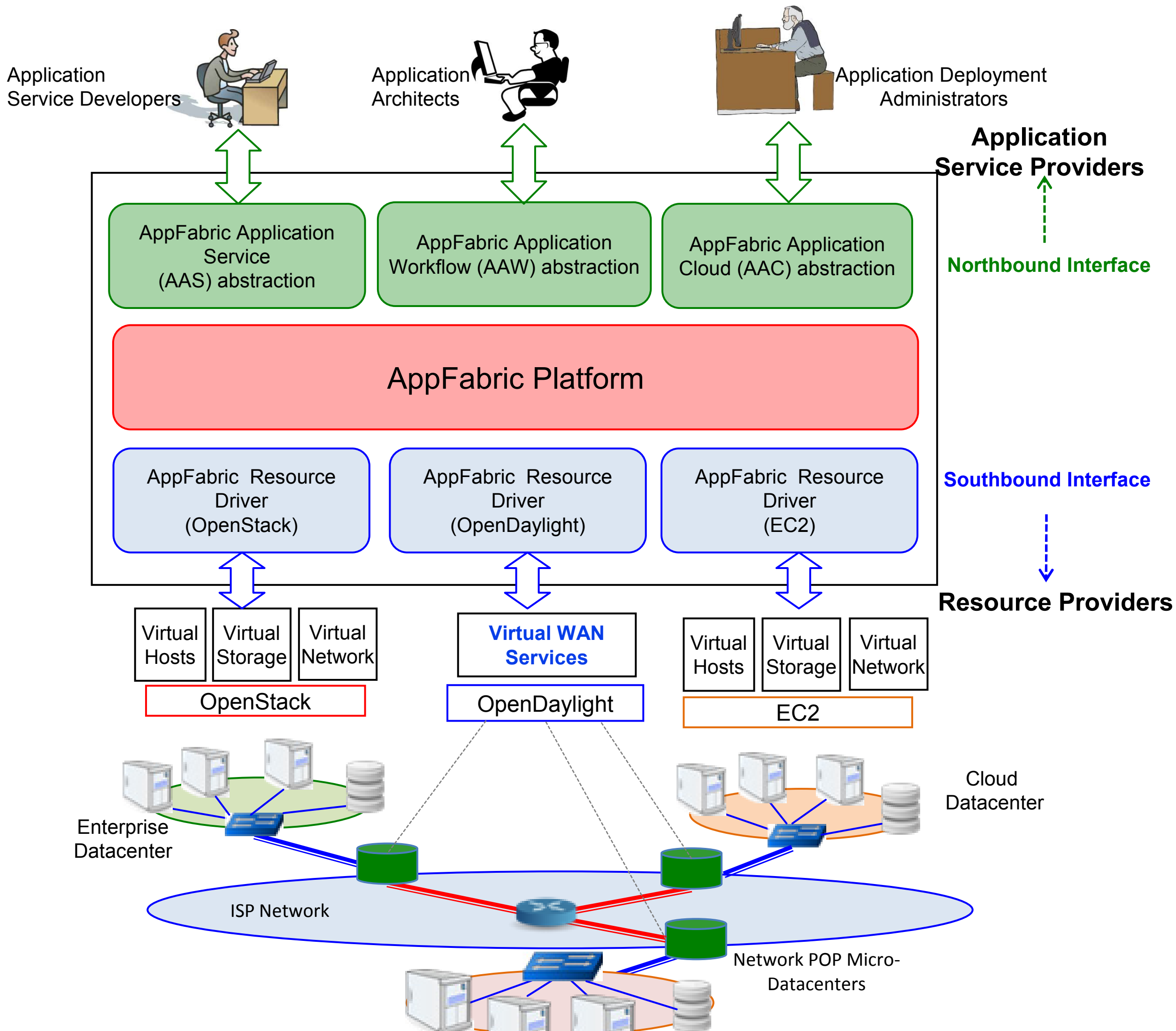
Trend: Multi-Clouds



- Most companies use more than one cloud.

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

Services in a Cloud of Clouds

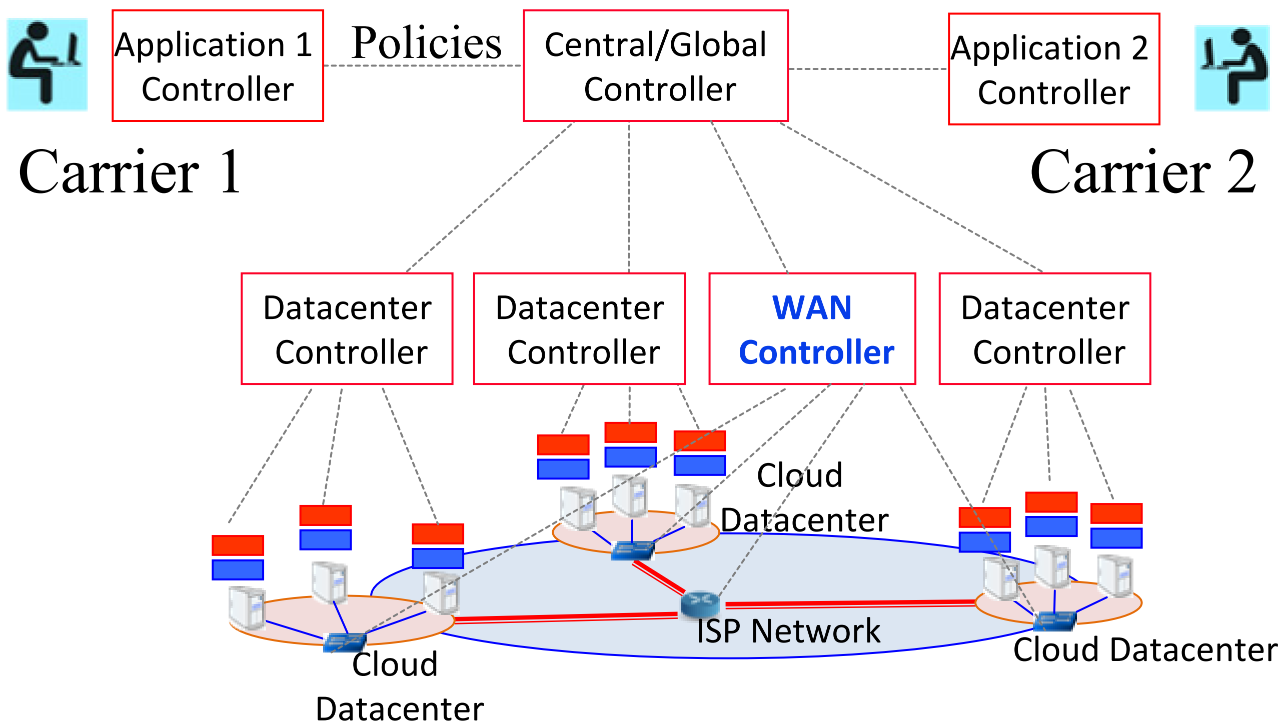


AppFabric Features

- Allows **application architects** to specify guidelines for creation of new workflows including middleboxes
- Allows **application developers** to specify their resource requirements and design their application without worrying about physical infrastructure
- Allows **Deployment Administrators** specify policies for quantity and location of resources inside various clouds.
- **Automates** the entire process of creating new workflows and installing them, managing them during runtime, uninstalling them as necessary
- 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.
- All interfaces initially XML based. GUI based in future.

Hierarchy of Controllers

- Controllers exchange and implement policies

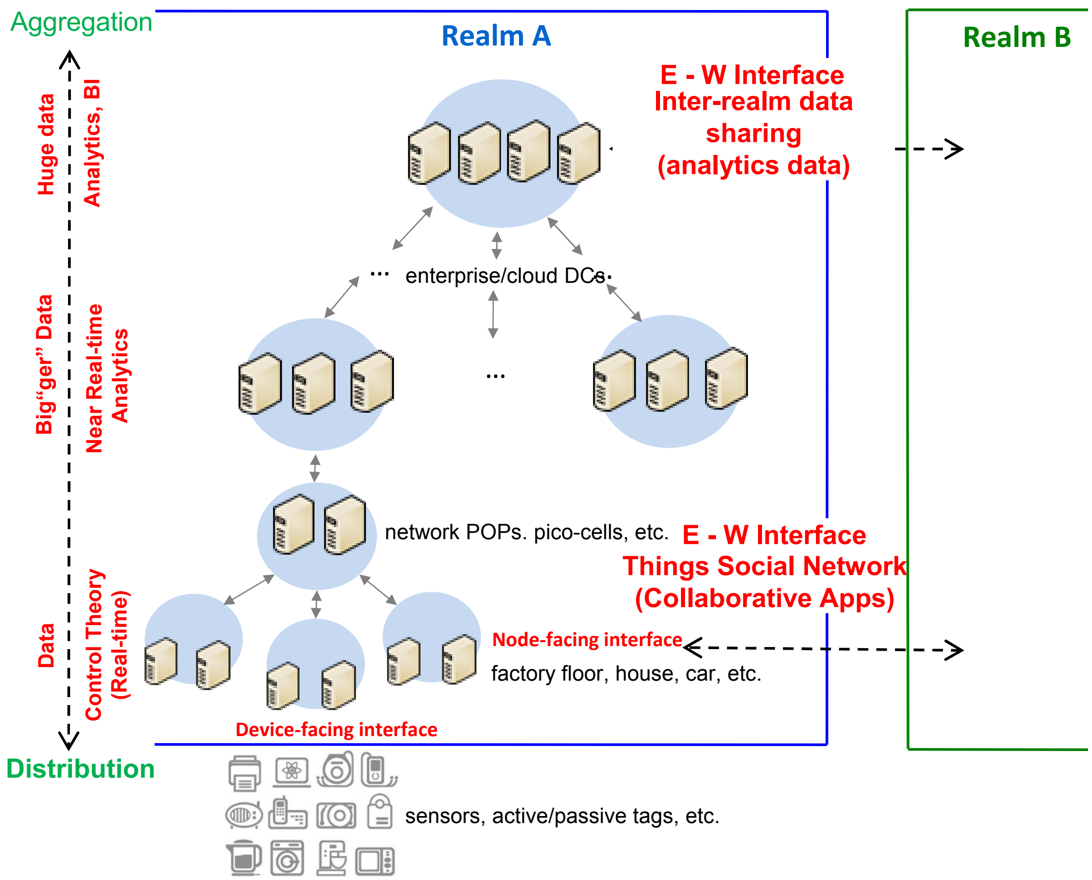


Challenges in Service Chaining

- **Dynamic**:
  - Forwarding changes with state of the servers, links, …
  - Cloud operators may want to move VMs themselves for security, reliability, performance, or in anticipation of load changes.
- **QoS vs. Cost**: Latency determined by link utilization. WAN links expensive. Need to keep the utilization high.
- **Content sensitive**:
  - Different for different types of videos, read-writes, …
- **Distributed Control**:
  - Equipment belongs to infrastructure provider
  - Data belongs to Tenants
- **Massive Scale**:
  - Billions of Users with different user context
- **Stateful Services**:
  - All packets of a flow should be sent to the same replica
    - Message level services (firewalls),
    - Packet level services (intrusion detection)

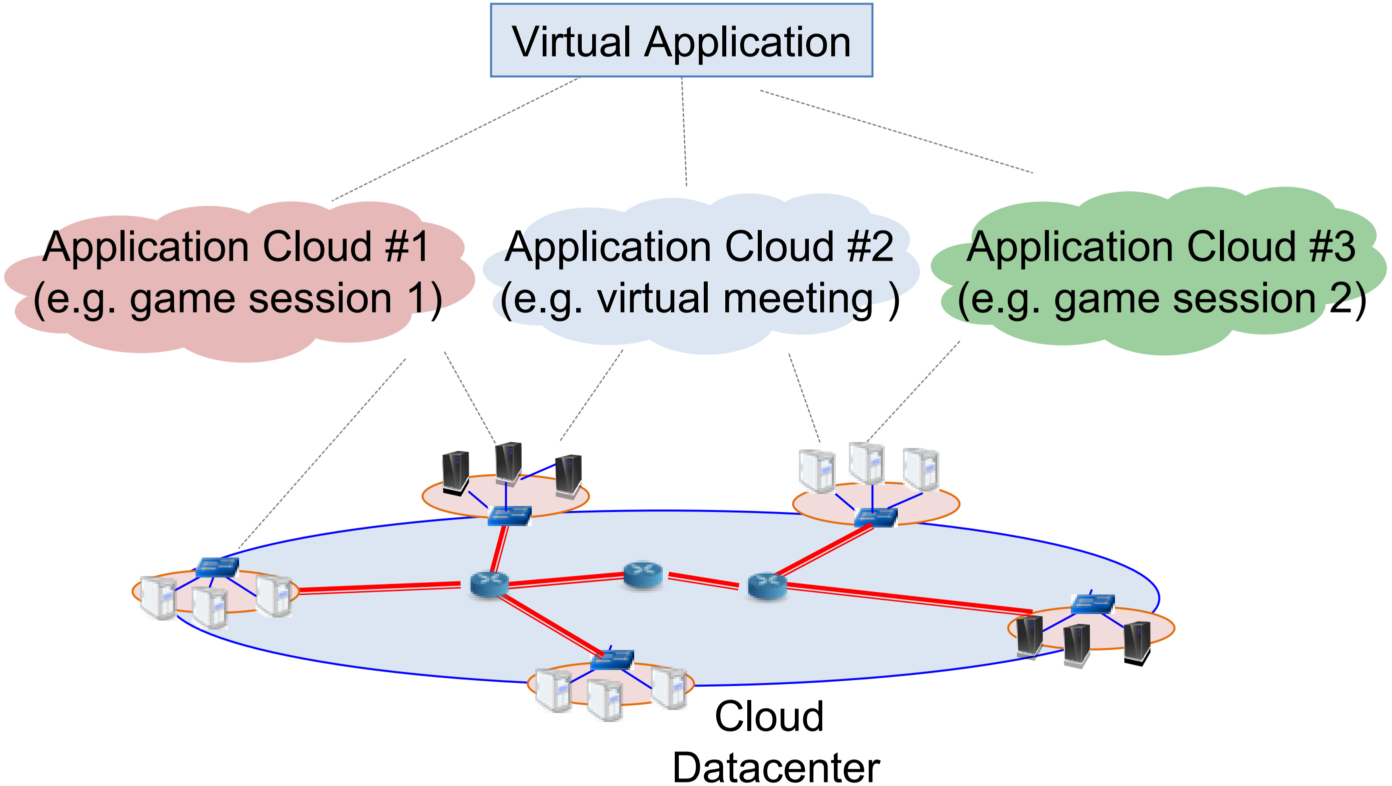
Use Case 1: Internet of Things

- Computing everywhere or Fog computing.
- Data aggregation and analytics at various levels



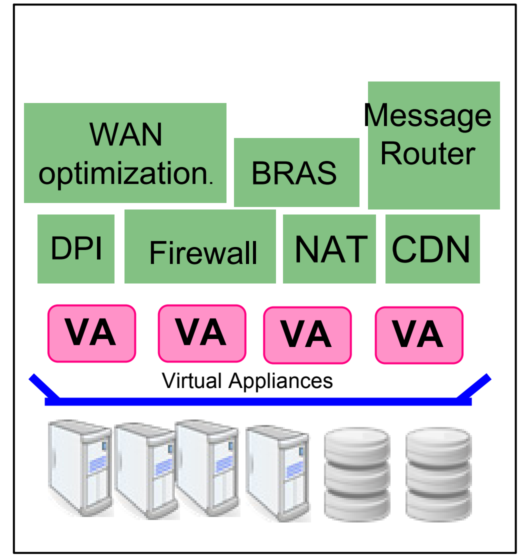
Use Case 2: Massively Distributed Apps

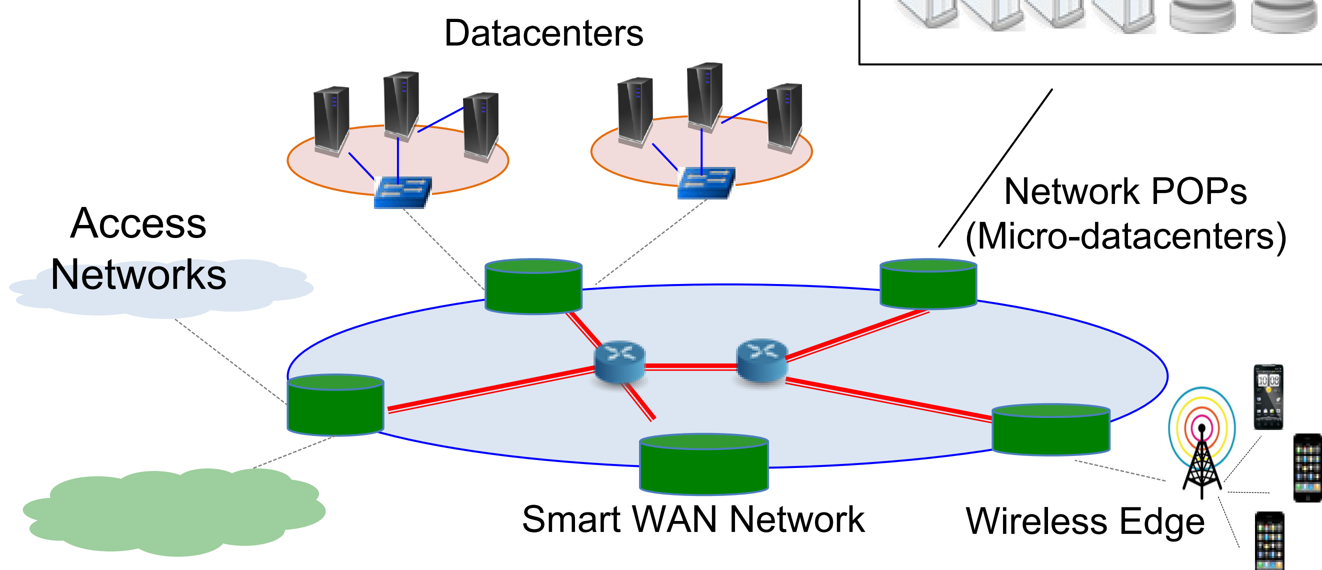
- Online games



Use Case 3: Smart WANs

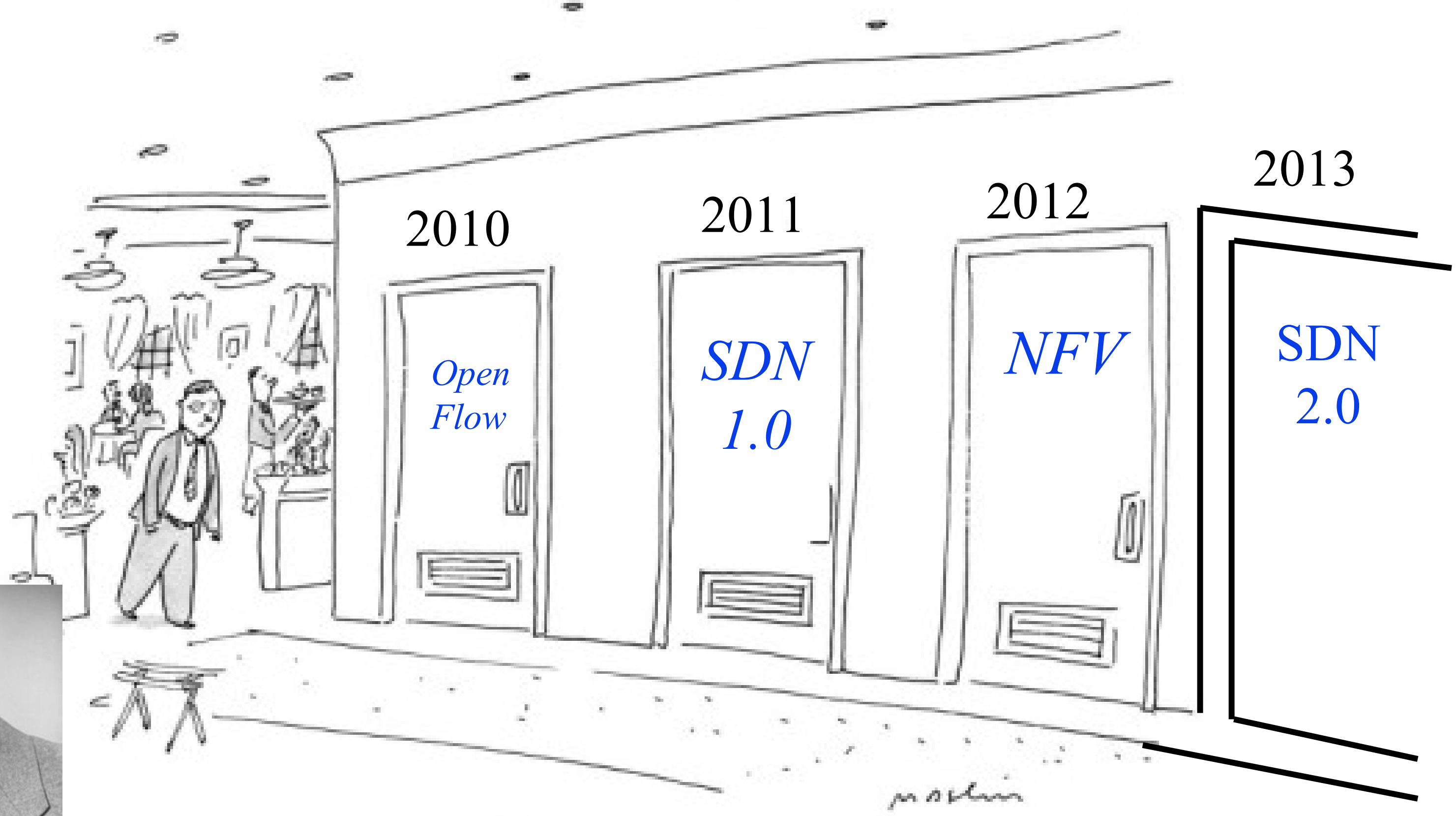
- Service Chaining
- Message-level Middleboxes
- Packet-level Middleboxes
- Dynamically place services at POPs based on application topology
- Provide differentiated transport
- Contextual mapping of messages to transport QoS





Technology is Changing Too Fast

- A new future every year…



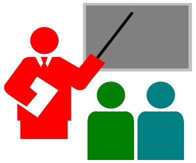
Telco = LARGE Infrastructure

- Telco's need a lot of infrastructure: Hardware, cable, spectrum, operators
- It used to take 10 years to change: 1G (1980), 2G (1990), 3G (2000), 3.9G (2010)
- WiMAX started in 2001. Became LTE in 2005. Deployed in 2010

10 SDN Research Issues

1. Centralization $\Rightarrow$ Reliability $\Rightarrow$ Distributed Controllers, Controller Synchronization
2. Performance of Controllers: Scalability, Caching
3. Multi-controller Load balancing, Latency Minimization
4. Security in the Control Plane: Confidentiality, Integrity, Authentication, Monitoring, Detection, Recovery, Trust
5. SDN in a Multi-Domain Environment: Hierarchical Organization of Policy Control
6. SDN in Specific Applications: High-Performance Computing, Network Virtualization, Big Data, IoT
7. Live traffic monitoring and fault detection in the Data Plane
8. Rules consistency checking
9. Live network reconfiguration and optimization
10. Security in data plane

Note: This is not a complete list.



Summary

1. Virtualization is revolutionizing networking. NFV allows virtual mobile services using virtual modules in a shared cloud environment ⇒ Key to CapEx OpEx reduction.
2. SDN is about centralized policy control. Separation of control plane is not necessary.
3. Virtual functions useful not only for networking but also for **all other global enterprises** and games
   ⇒ New business opportunity for FV Infrastructure service
4. **AppFabric** allows customers to select **multiple clouds** from different providers and **share wide area network** infrastructure and specify their policies

References

- 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