Network Virtualization and Application Delivery Using Software Defined Networking



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These slides and audio/video recordings are available at:
http://www.cse.wustl.edu/~jain/talks/adn_cwr.htm

Overview

1. Five reasons to virtualize
2. Five Innovations of SDN
3. Five Innovations of NFV
4. Our Research: Open Application Delivery

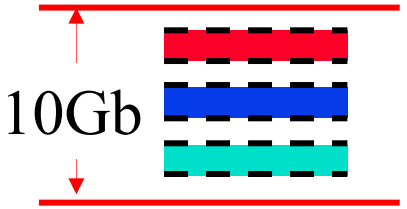
Virtualization of Life

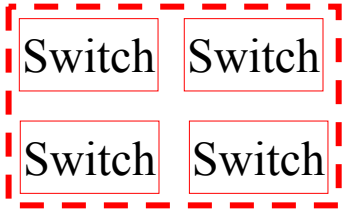
- Internet ⇒ Virtualization

- No need to get out for
  - Office
  - Shopping
  - Entertainment
  - Education
- Virtual Workplace
- Virtual Shopping
- Virtual Education
- Virtual Sex
- Virtual Computing

5 Reasons to Virtualize

1. Sharing: Break up a large resource
   Large Capacity or high-speed
2. Isolation: Protection from other tenants
3. Aggregating: Combine many resources in to one
4. Dynamics: Fast allocation, Change/Mobility, load balancing
5. Ease of Management
   ⇒ Cost Savings. fault tolerance

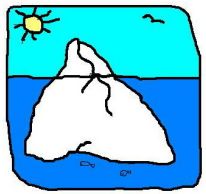




Virtualization in Computing

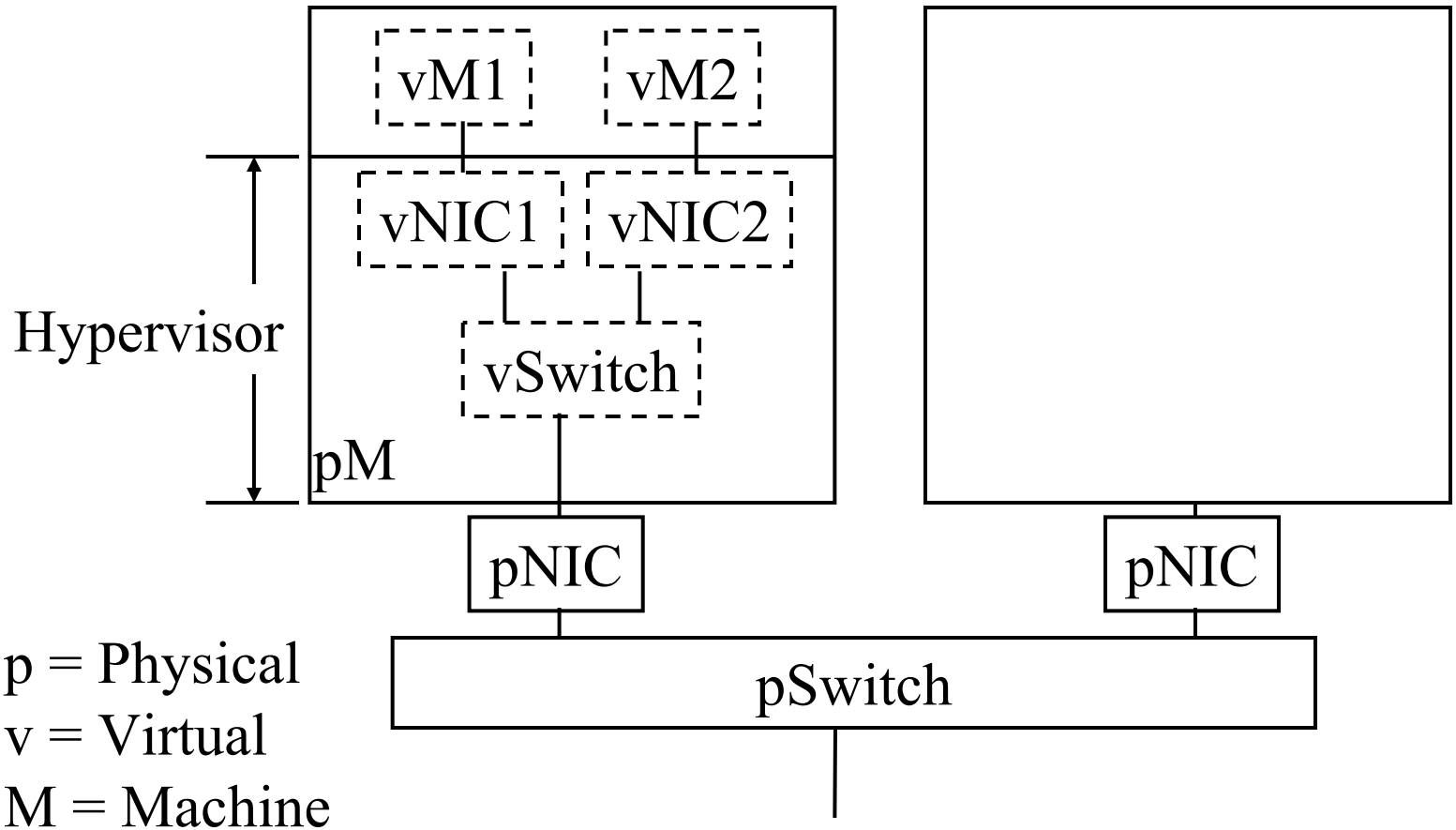
- **Storage**:
  - Virtual Memory ⇒ L1, L2, L3, ... ⇒ Recursive
  - Virtual CDs, Virtual Disks (RAID), Cloud storage
- **Computing**:
  - Virtual Desktop ⇒ Virtual Server ⇒ Virtual Datacenter

    Thin Client ⇒ VMs ⇒ Cloud
- **Networking**: Plumbing of computing
  - Virtual Channels, Virtual LANs, Virtual Private Networks
  - Quick review of recent technologies for network virtualization

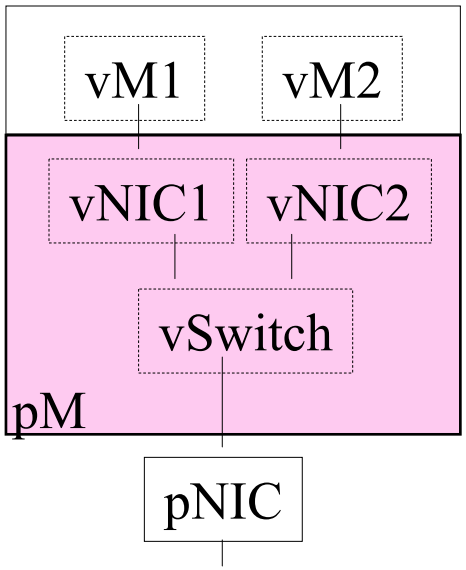


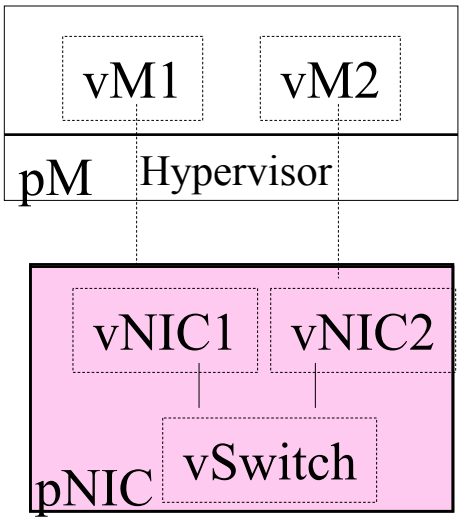
1. vNICs

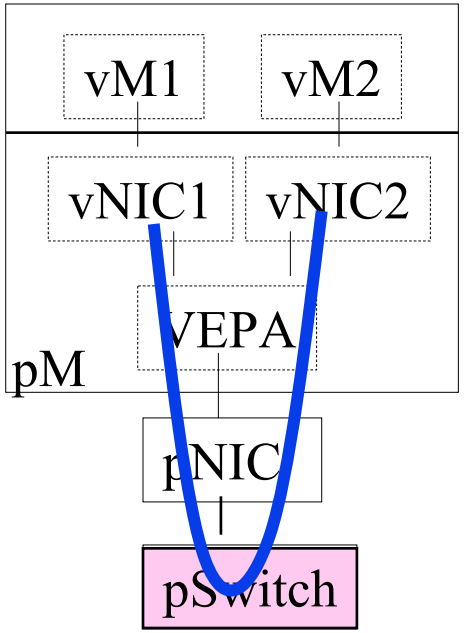
- Each VM needs its own network interface card (NIC)



vNICs (Cont)



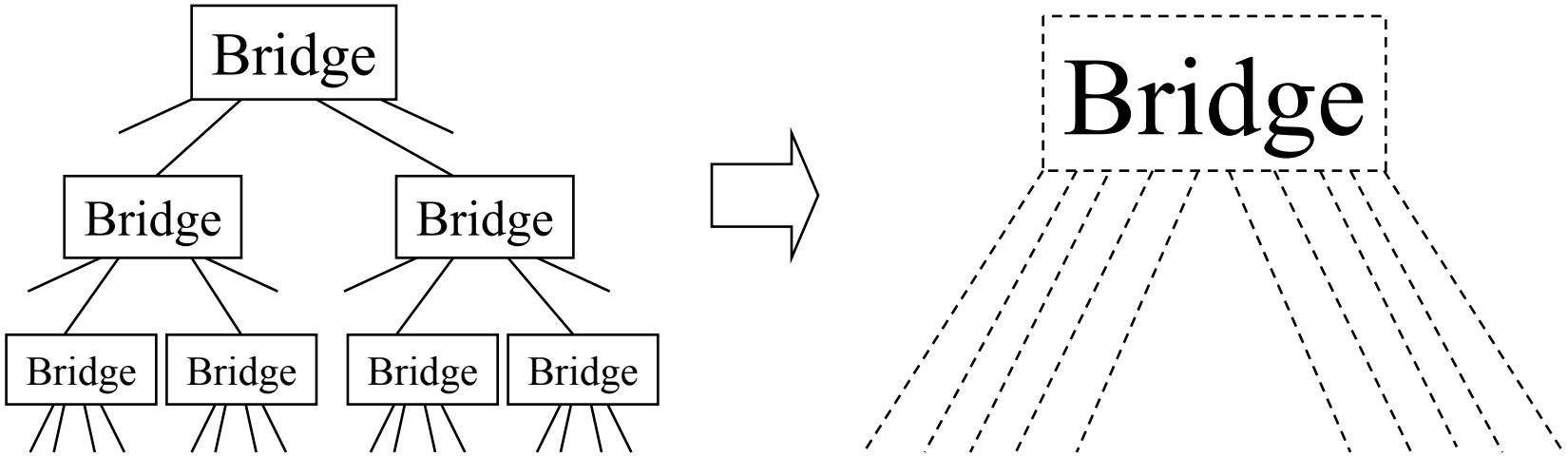




1. VM vendors: S/W NICs in Hypervisor w Virtual Ethernet Bridge (**VEB**)(overhead, not ext manageable, not all features)
2. NIC Vendors: NIC provides virtual ports using Single-Route I/O virtualization (**SR-IOV**) on PCI bus
3. Switch Vendors: Switch provides virtual channels for inter-VM Communications using virtual Ethernet port aggregator (**VEPA**): **802.1Qbg** (s/w upgrade), **802.1Qbh** (new switches)

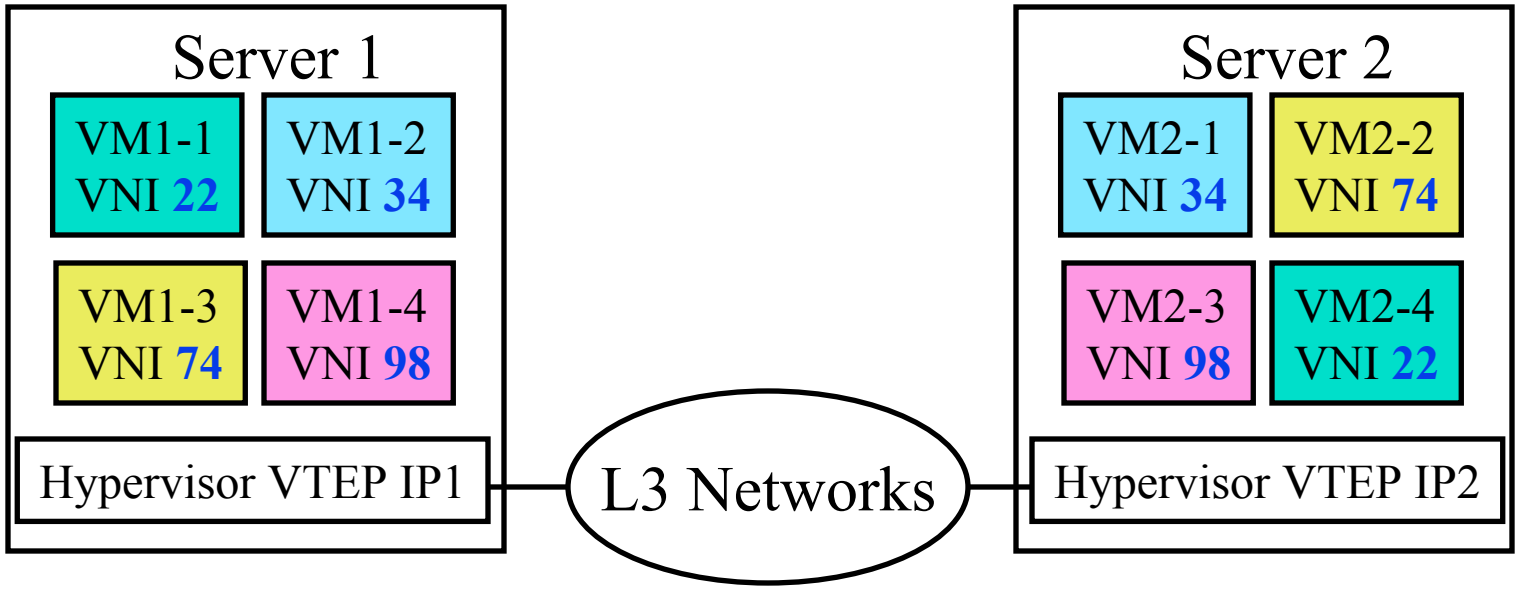
2. Bridge Port Extension

- Multiple physical bridges to make a single virtual bridge with a large number of ports
  ⇒ Easy to manage and configure
- **IEEE 802.1BR**



3. Multi-Tenants

- Each tenant needs its own networking domain with its VLAN IDs

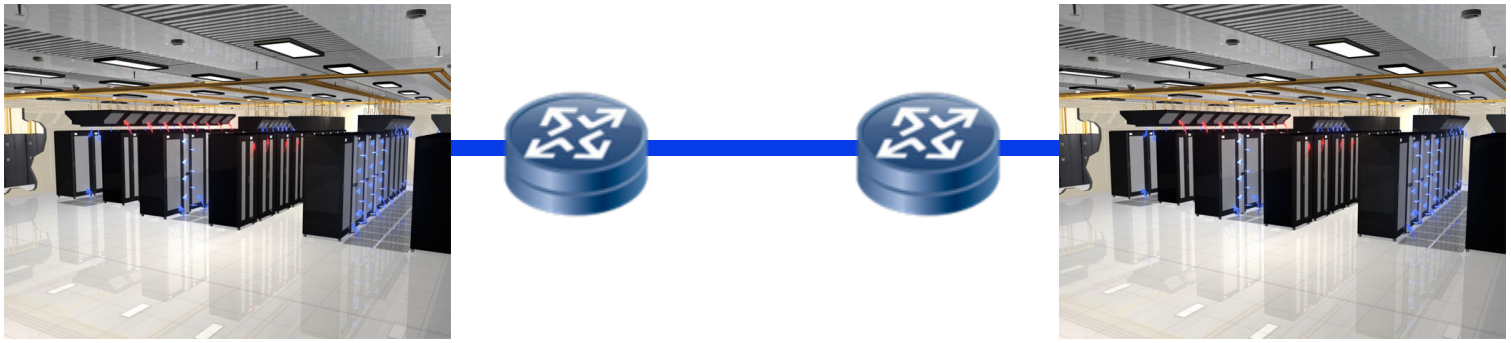


1. Virtual Extensible Local Area Networks (**VXLAN**)
2. Network Virtualization using Generic Routing Encapsulation (**NVGRE**)
3. Stateless Transport Tunneling Protocol (**STT**)

⇒ Network Virtualization over L3 (**NVO3**) group in IETF

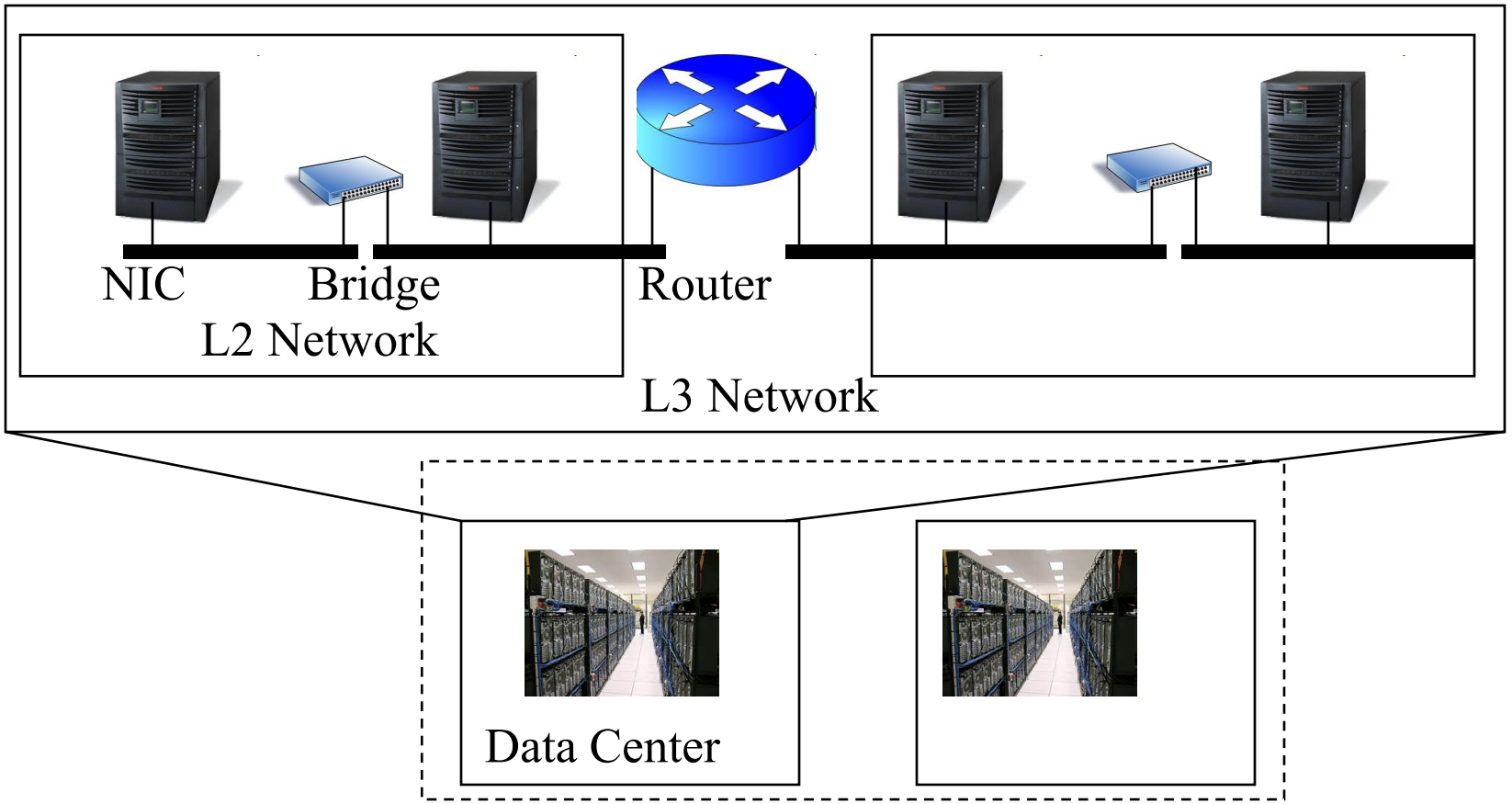
4. Multi-Site

- Better to keep VM mobility in a LAN (IP address changes if subnet changes)



- Solution: IP encapsulation
- Transparent Interconnection of Lots of Links (**TRILL**)

Levels of Network Virtualization



- Networks consist of: **Host Interface** - L2 Links - **L2 Bridges** - **L2 Networks** - L3 Links - L3 Routers - L3 Networks – **Data Centers** – **Global Internet**
- Each of these needs to be virtualized

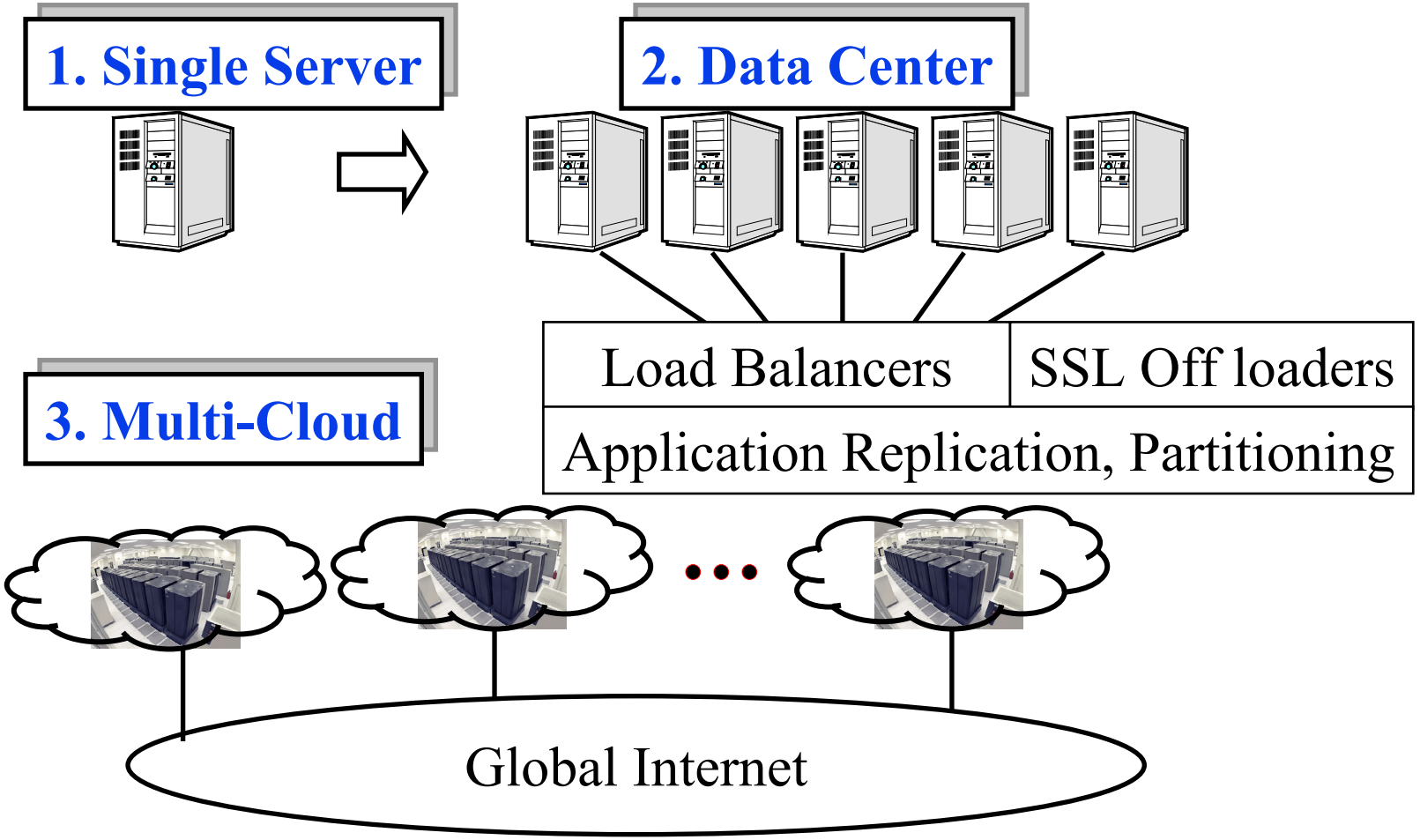
Clouds and Mobile Apps

- 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

- 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

Networks need to support efficient service setup and delivery

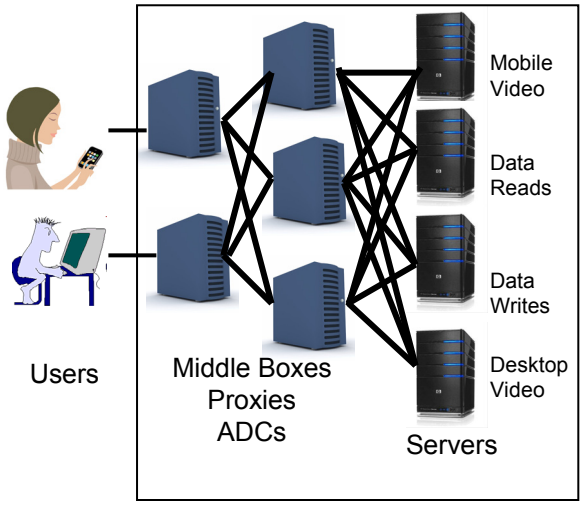
Service Center Evolution



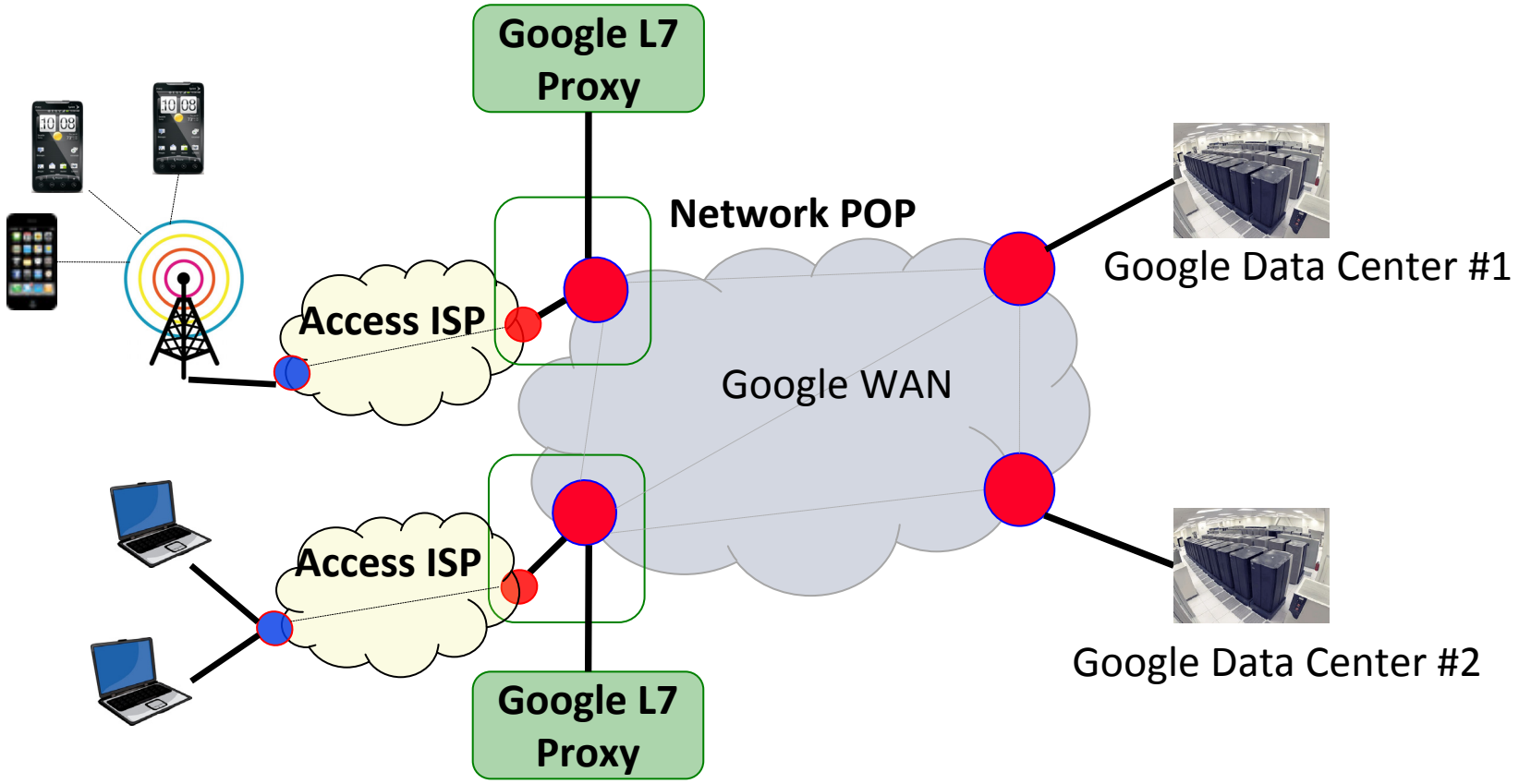
Need to make the global Internet look like a data center

Application Delivery in a Data Center

- **Replication**: Performance and Fault Tolerance
  - ✓ If Load on S1 >0.5, send to S2
  - ✓ If link to US broken, send to UK
- **Content-Based Partitioning**:
  - ➢ Video messages to Server S1
  - ➢ Accounting to Server S2
- **Context Based Partitioning**:
  - ➢ Application Context: Different API calls
    - ✓ Reads to S1, Writes to S2
  - ➢ User Context:
    - ✓ If Windows Phone user, send to S1
    - ✓ If laptop user, send to HD, send to S2
- **Multi-Segment**: User-ISP Proxy-Load Balancer-Firewall-Server



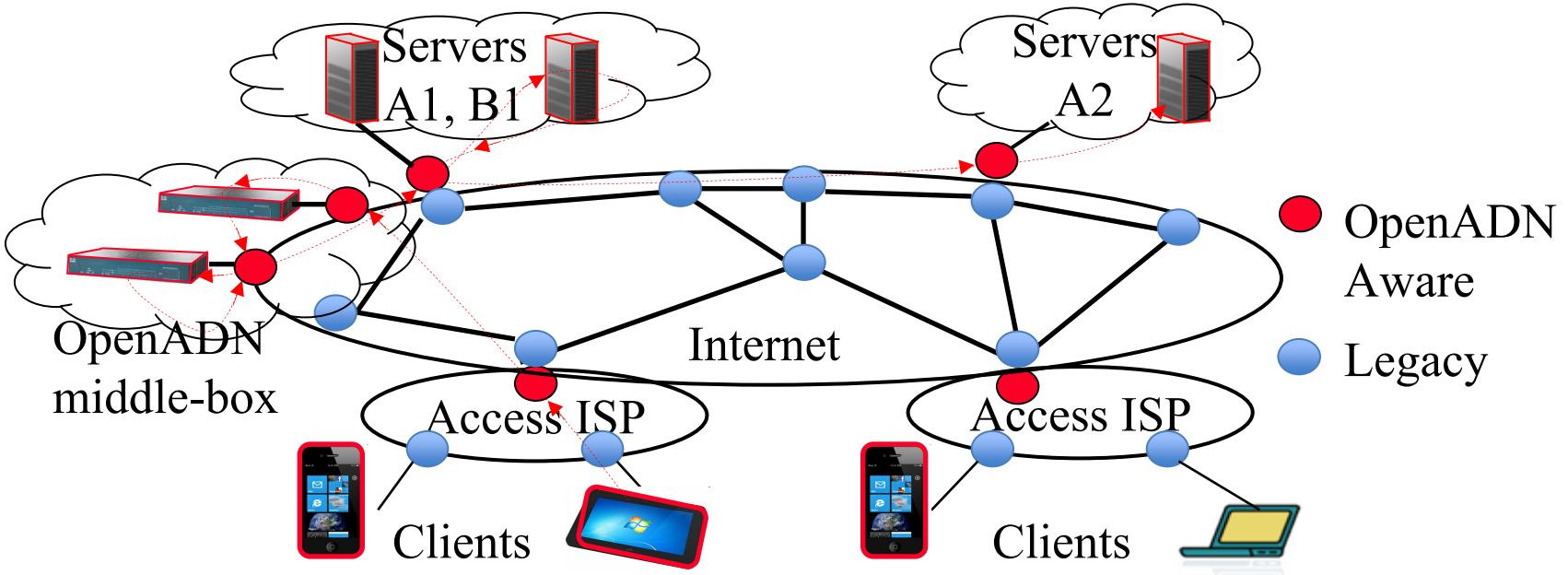
Google WAN



- Google appliances in Tier 3 ISPs
- Details of Google WAN are not public
- ISPs can not use it: L7 proxies require data visibility

Our Solution: OpenADN

- Open Application Delivery Networking Platform
  Platform = OpenADN aware clients, servers, switches, and middle-boxes
- Allows Application Service Providers (ASPs) to quickly setup services on Internet using cloud computing⇒ Global datacenter

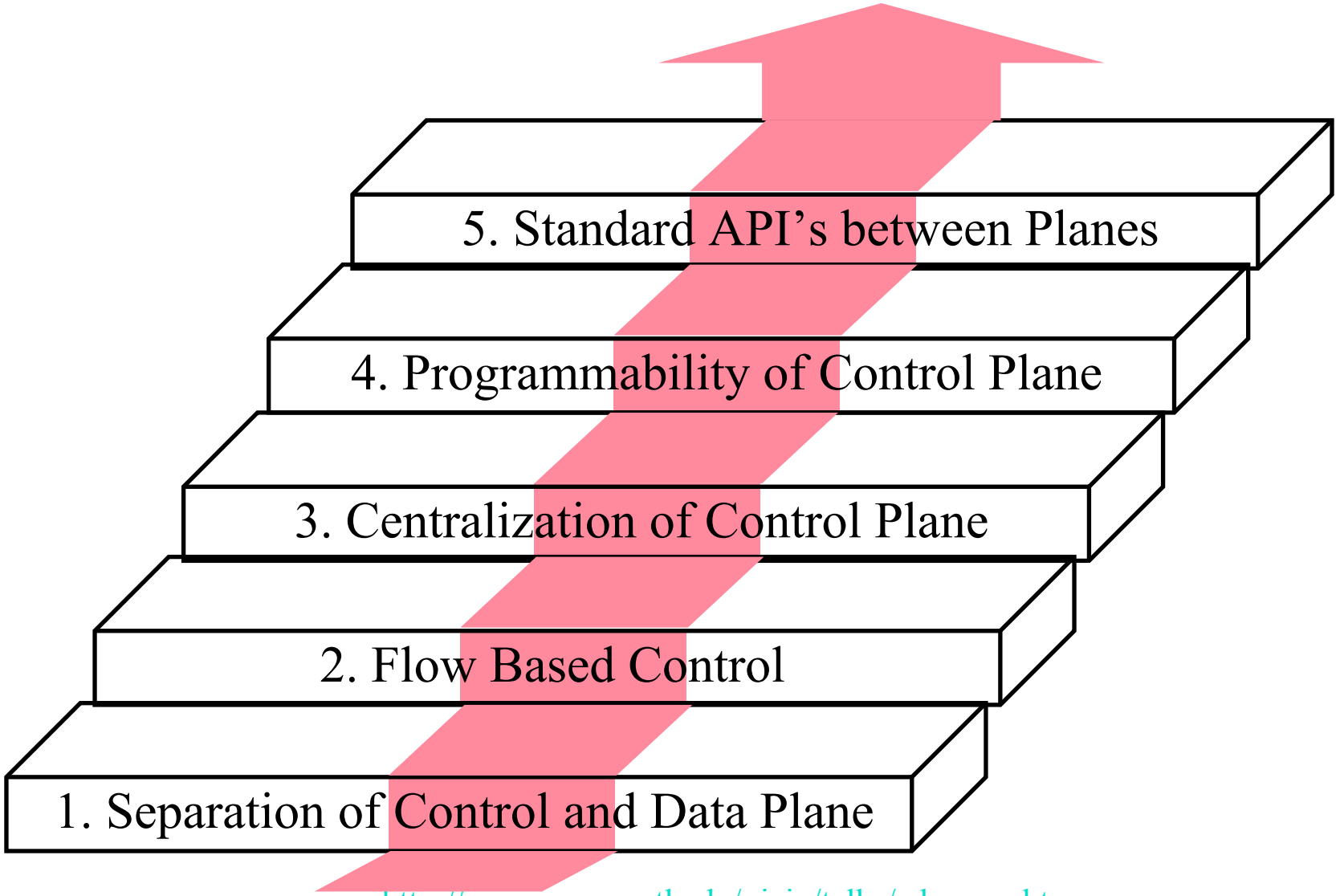


OpenADN: 5 Innovations

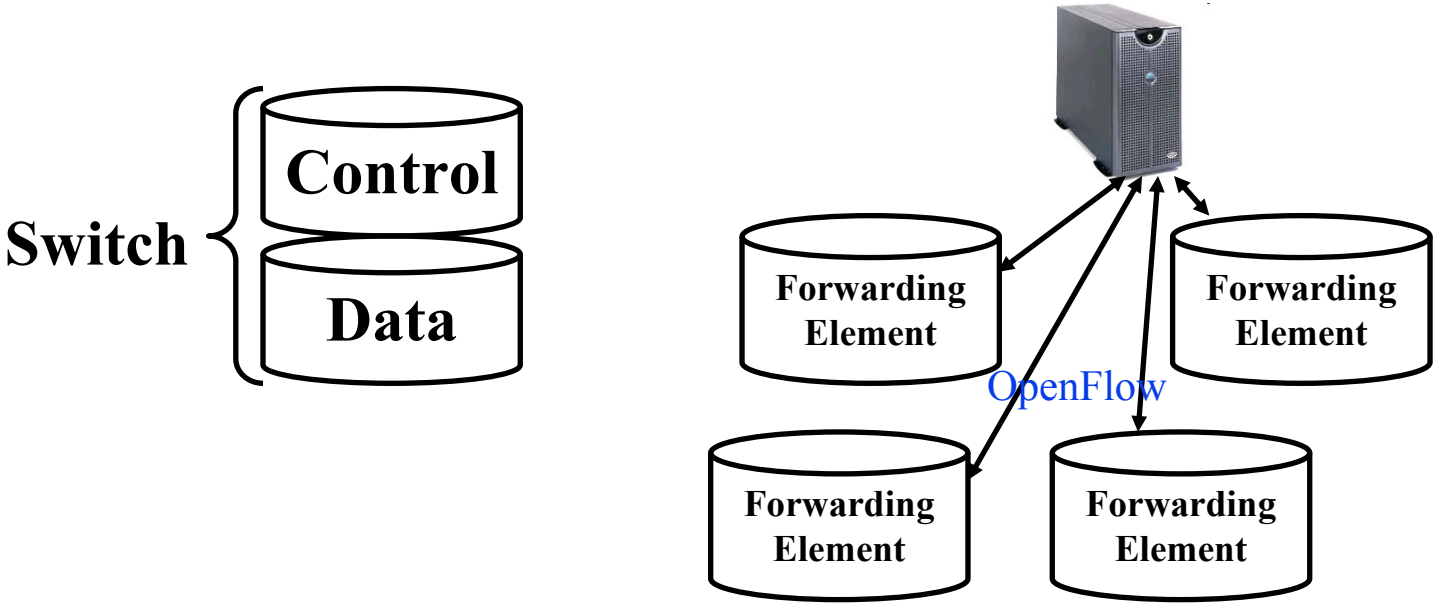
1. Uses the latest in networking:
    1. Software defined networking
    2. OpenFlow
2. Cross-Layer Communication
   OpenADN tags: Layer 7 Proxies without layer 7 visibility (MPLS like Labels => APLS)
3. ID/Locator Split
4. Late Multi-stage binding
5. Rule-Based Delegation

Ref: S. Paul, Raj Jain, "OpenADN: Mobile Apps on Global Clouds Using OpenFlow and Software Defined Networking," First Int. workshop on Management and Security technologies for Cloud Computing (ManSec-CC) 2012, Decenber 7, 2012, IEEE Globecom 2012, http://www.cse.wustl.edu/~jain/papers/adn_gc12.htm

SDN Definition: 5 Innovations



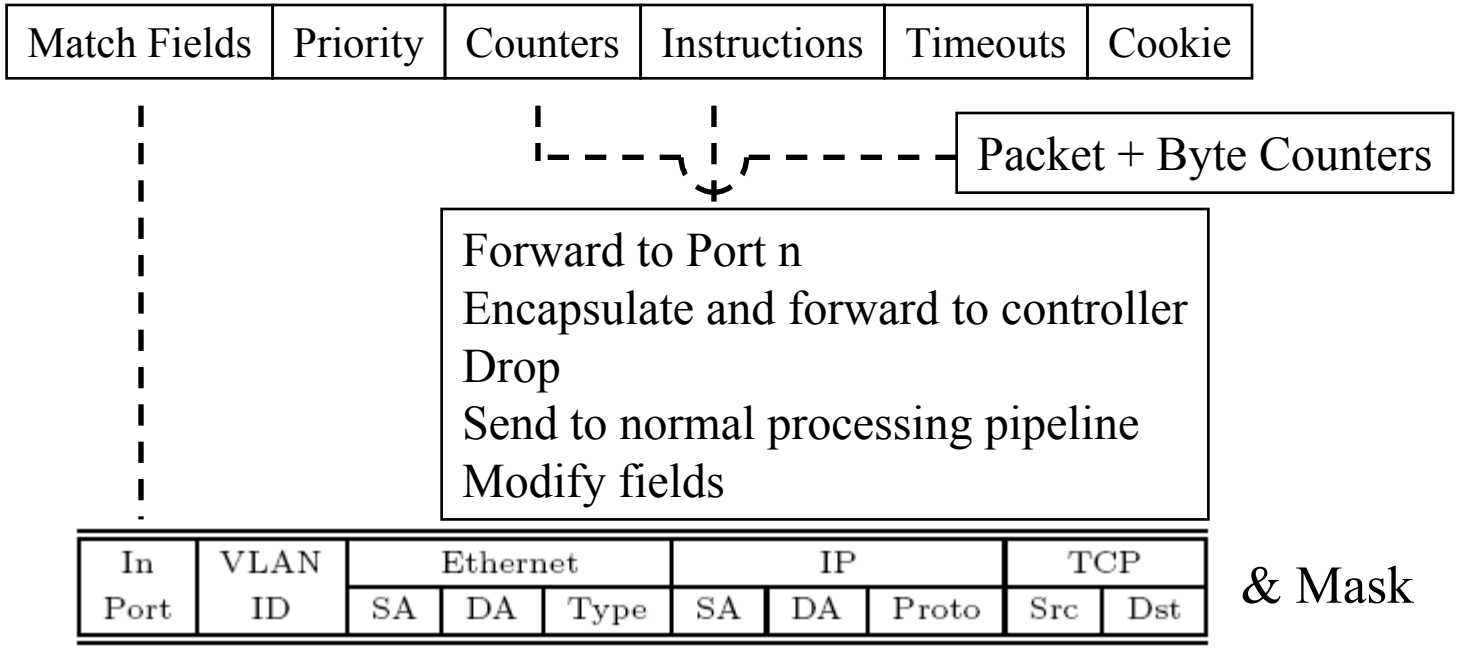
1. Separation of Control and Data Plane



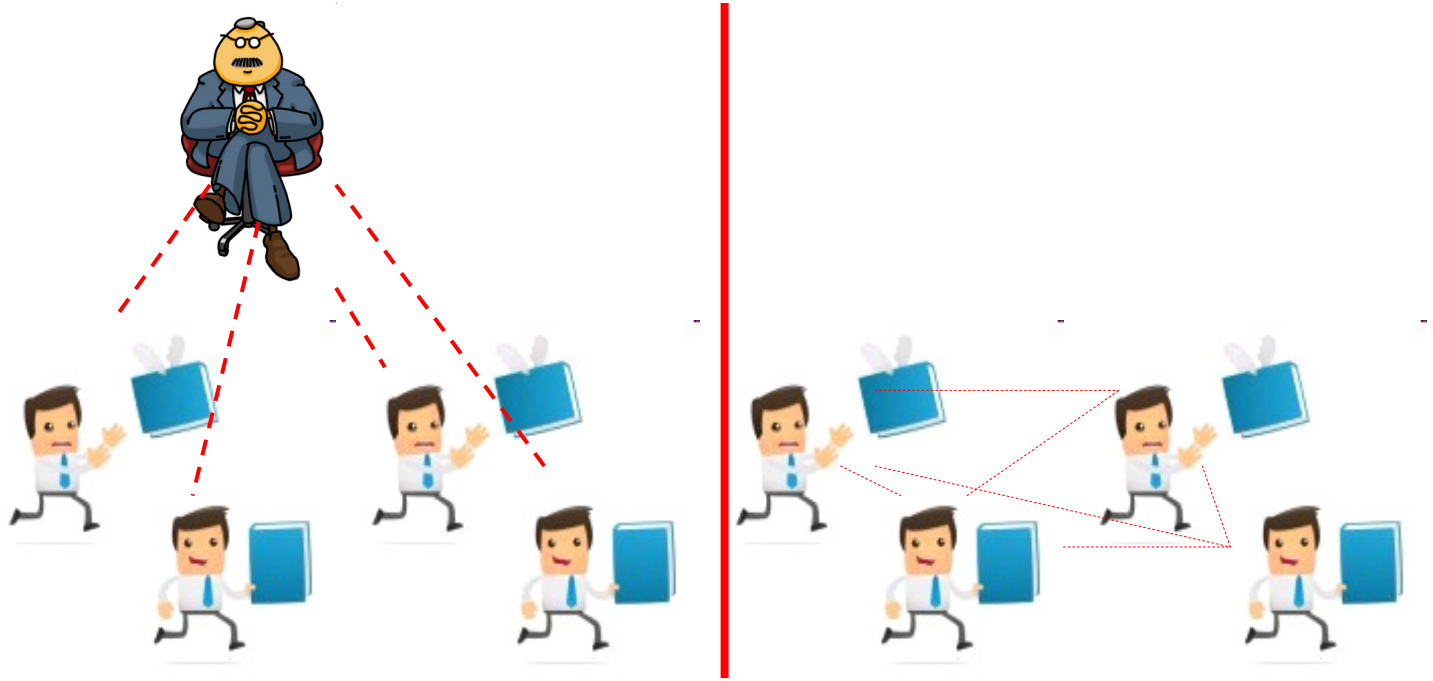
- Control Plane = Making forwarding tables
- Data Plane = Using forwarding tables
- Once vs. Billion times per second, Complex vs. fast
- One expensive controller with lots of cheap switches

2. Flow-based control

- Data/disk/Memory sizes are going up by Moore's Law
- Packet size has remained 1518 bytes since 1980
- Multimedia, big data ⇒ Packet Trains 
- Flow is defined by L2-L4 headers
- Decide once, use many times ⇒ Execution performance



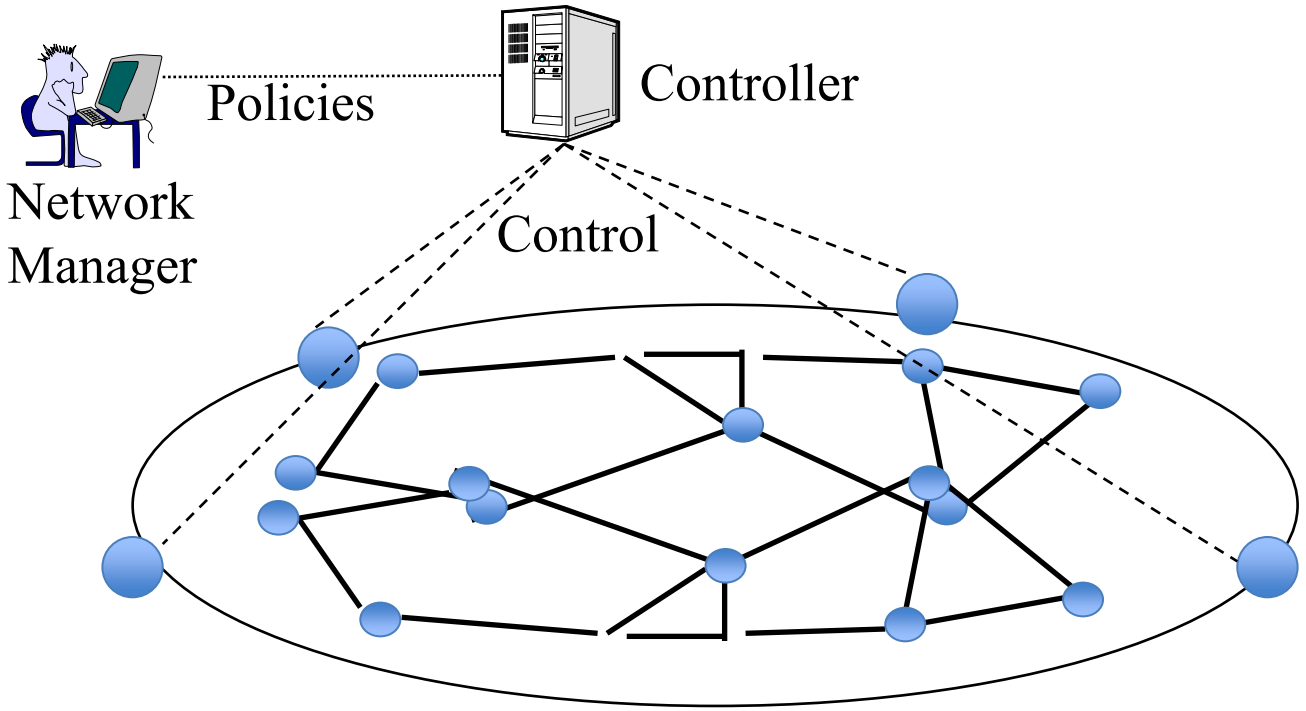
3. Centralization of Control Plane



Centralized vs. **Distributed**

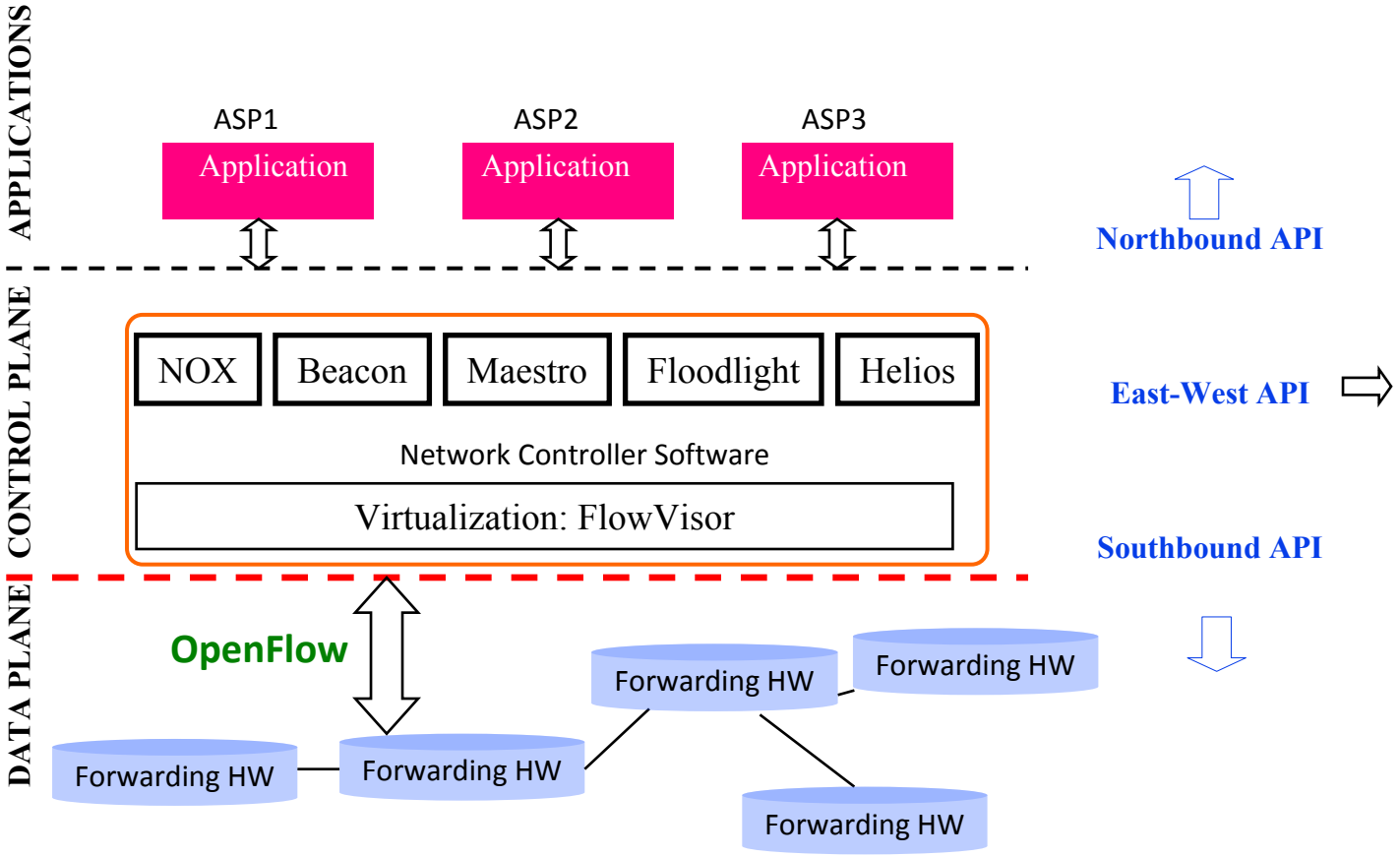
- Consistency
- Fast Response to changes
- Easy management of lots of devices

4. Programmable Control Plane



- Policies can be changed on the fly
  ⇒Software Defined

5. Standardized API between planes

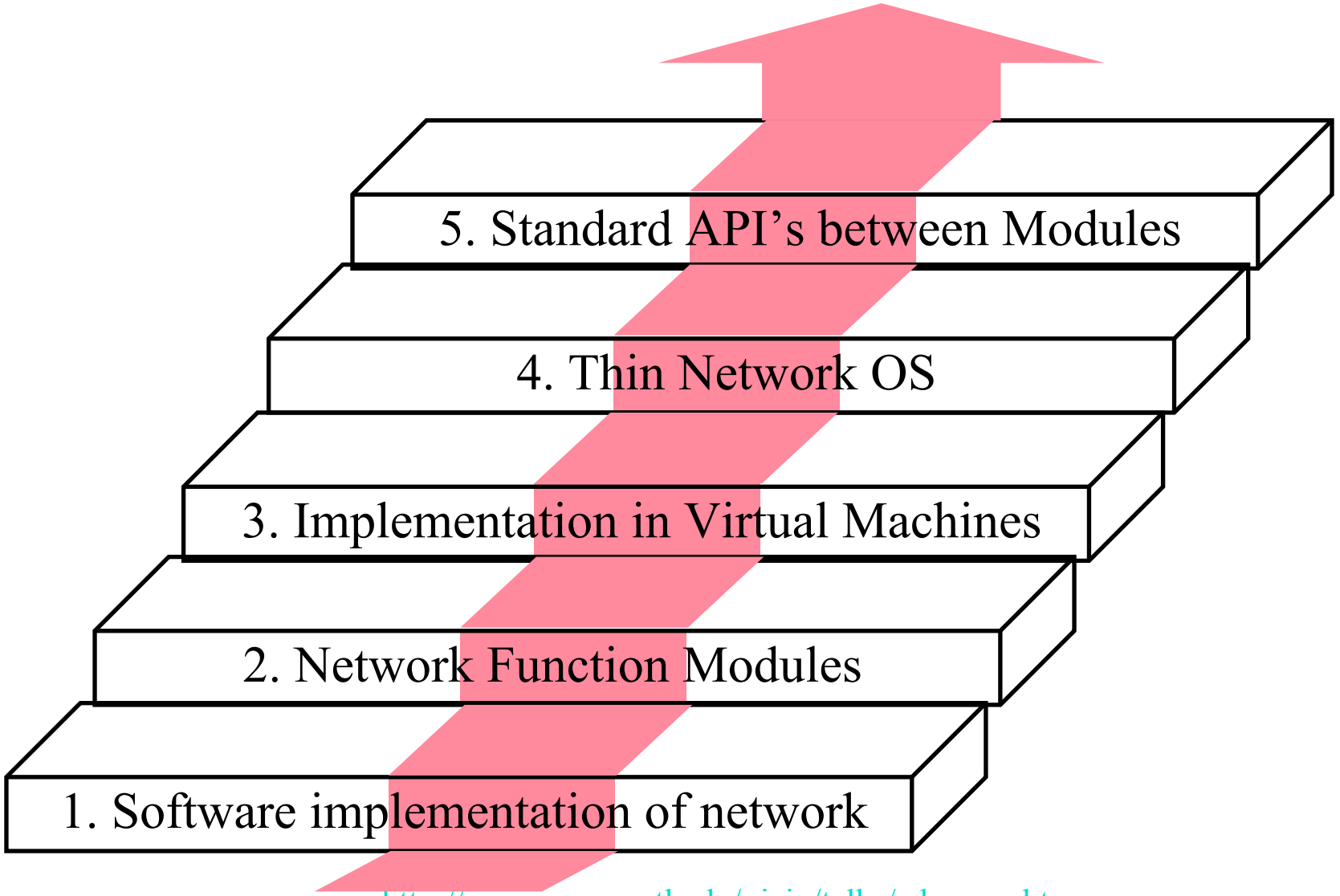


- Independent development of hw/control/applications
- Commoditization of HW/Control/Application
- South-Bound API: OpenFlow

SDN Impact

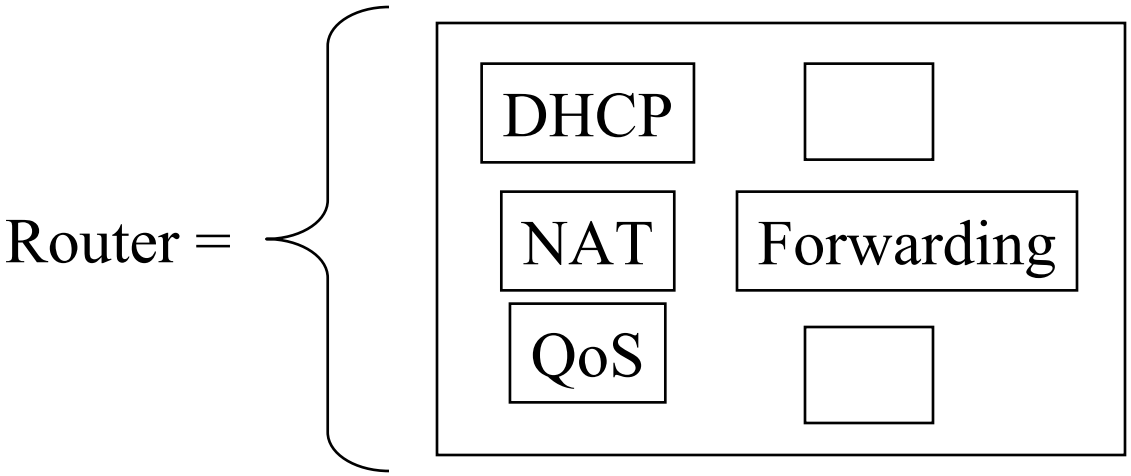
- Why so much industry interest?
  - Commodity hardware
    $\Rightarrow$ Lots of cheap forwarding engines $\Rightarrow$ Low cost
  - Programmability $\Rightarrow$ Customization
  - Those who buy routers, e.g., Google, Amazon, Docomo, DT will benefit significantly
- Tsunami of software defined devices:
  - Software defined wireless base stations
  - Software defined optical switches Programmable photonic layer
  - Software defined routers

NFV: 5 Innovations



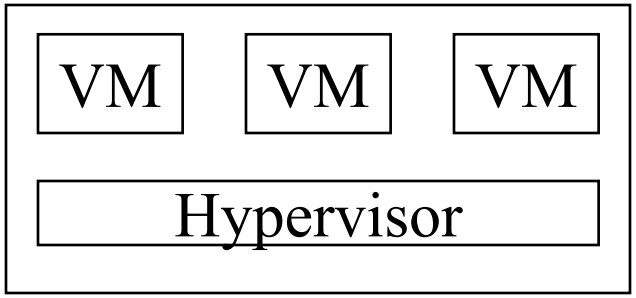
Network Function Virtualization (NFV)

1. Fast standard hardware ⇒ Software based Devices
   Routers, Firewalls, BRAS (Broadband Remote Access Server)
2. Function Modules (Both data plane and control plane)
   ⇒ DHCP (Dynamic Host control Protocol), NAT (Network Address Translation), Rate Limiting, HLR (Home Location Register), …

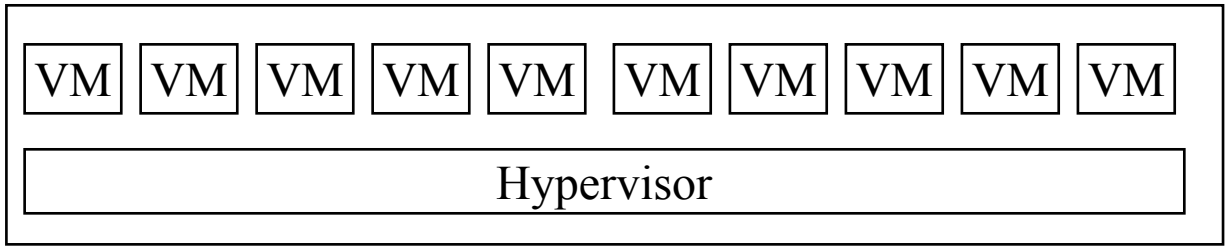


NFV (Cont)

3. Virtual Machine implementation ⇒ All advantages of virtualization (quick provisioning, scalability, mobility,…)



4. Thin Real-time OS
   ⇒ Minimize latency, max performance, Large scale sharing

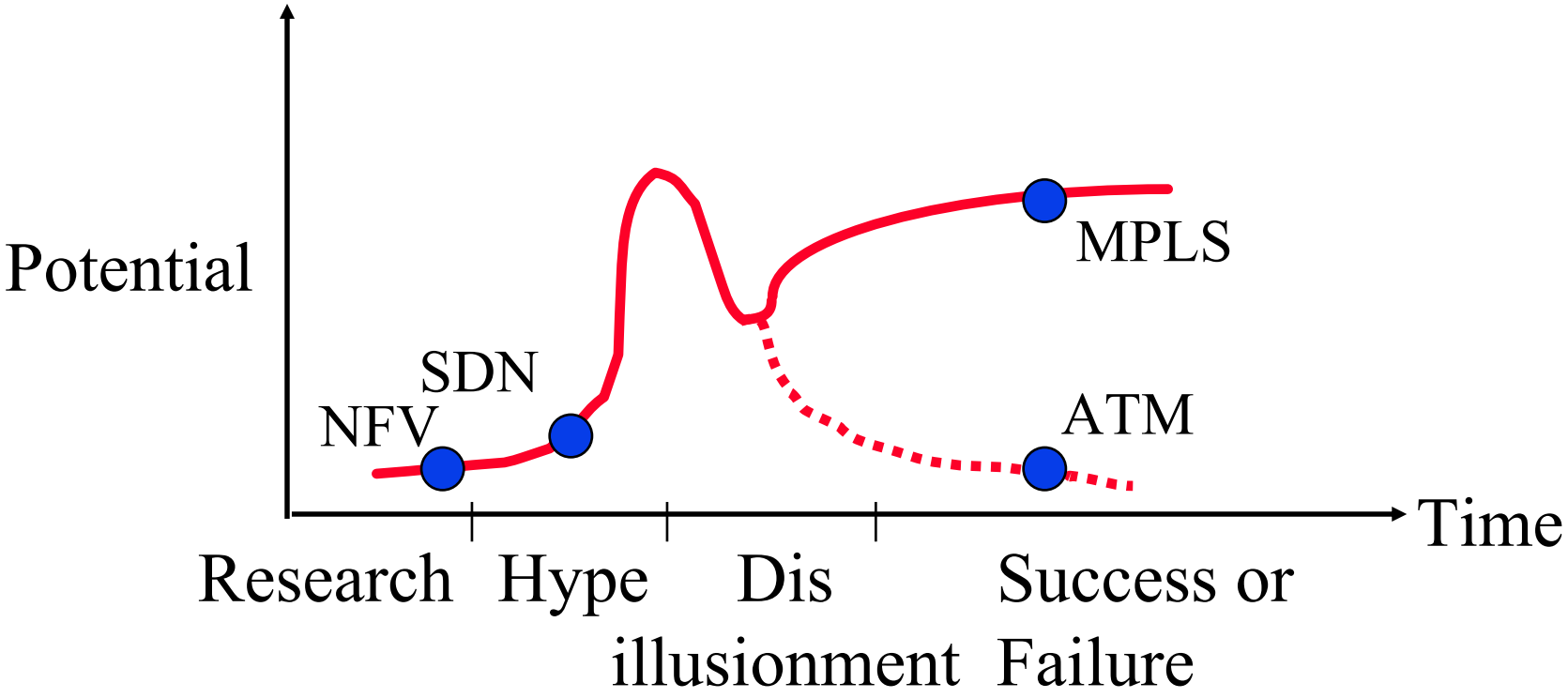


NFV (Cont)

5. Standard APIs: New ISG (Industry Specification Group) in ETSI (European Telecom Standards Institute) set up in November 2012

- Complementary to SDN. One does not depend upon the other. You can do SDN only, NFV only, or SDN and NFV.

Life Cycles of Technologies



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Industry Growth: Formula for Success

Innovators
⇒ Startups
⇒ Technology Differentiation

Big Companies
Manufacturing
⇒ Price differentiation

Number of Companies

New Entrants

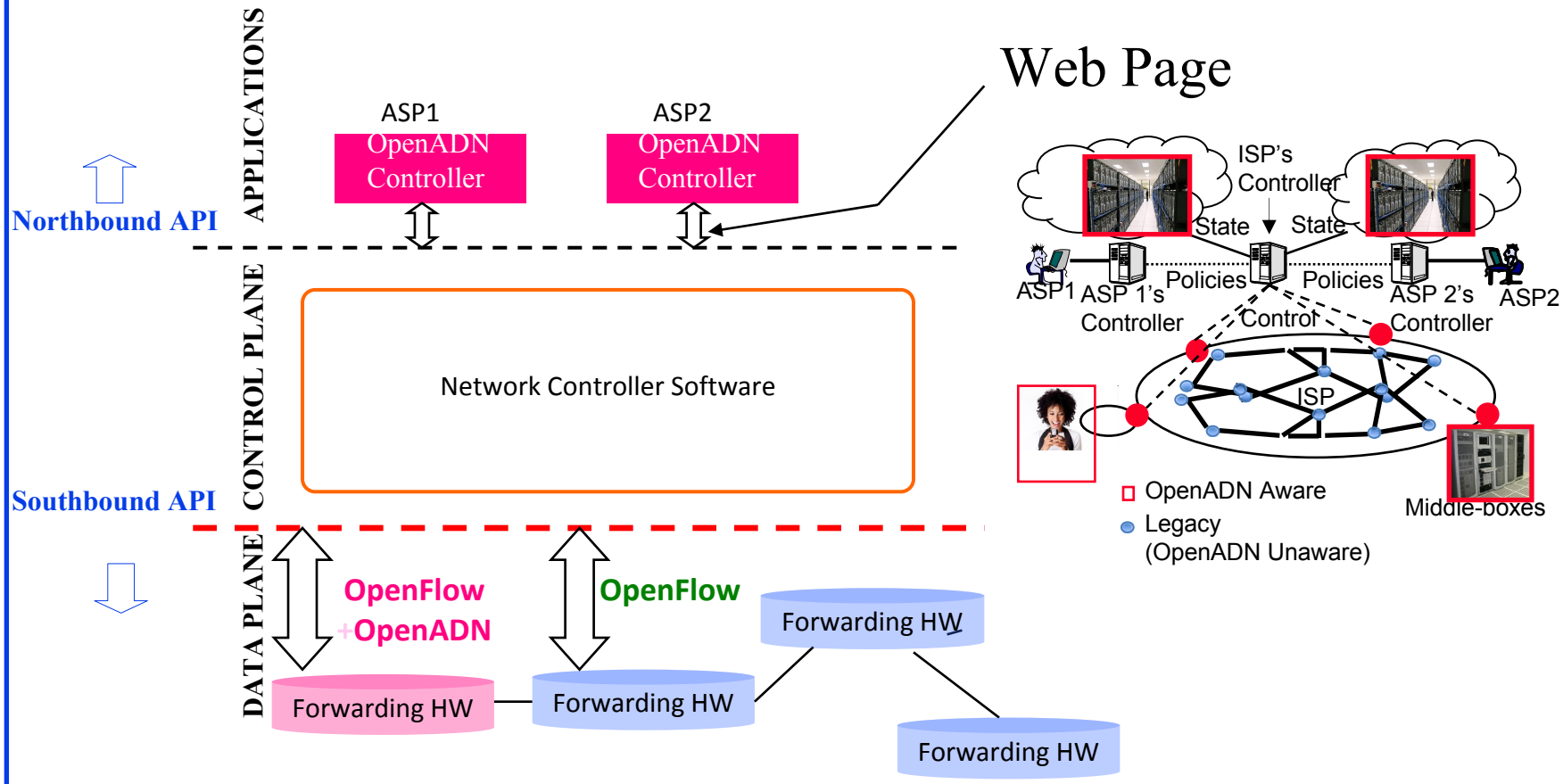
Consoli-dation

Stable Growth

Time

- Paradigm Shifts ⇒ Leadership Shift
- Old market leaders stick to old paradigm and loose
- Mini Computers→PC, Phone→Smart Phone, PC→Smart Phone

OpenADN in SDN's Layered Abstractions

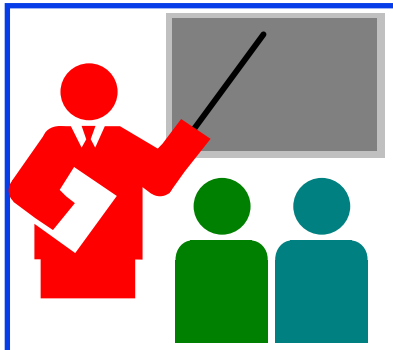


- SDN provides standardized mechanisms for distribution of control information
- OpenADN aware devices use enhanced OpenFlow

Key Features of OpenADN

1. Edge devices only.
   Core network can be current TCP/IP based, OpenFlow or future SDN based
2. Coexistence (Backward compatibility):
   Old on New. New on Old
3. Incremental Deployment
4. Economic Incentive for first adopters
5. Resource owners (ISPs) keep complete control over their resources

Most versions of Ethernet followed these principles.
Many versions of IP did not.



Summary

1. Cloud computing
   ⇒ Virtualization of computing, storage, and networking
   ⇒ Numerous recent standards related to networking virtualization both in IEEE and IETF
2. Centralization of Control plane
   ⇒ Hiearchy of controllers. Not just one controller.
3. Standardization of Southbound, Northbound, and East-west APIs ⇒ Software Defined Networking (SDN)
4. NFV will allow large scale deployment of networking devices using standard hardware.
5. OpenADN enables delivery of applications using Northbound SDN API