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_hwc.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

Cloud Computing

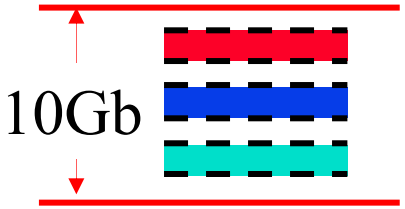
- August 25, 2006: Amazon announced EC2 ⇒ Birth of Cloud Computing in reality (Prior theoretical concepts of computing as a utility)
- *Web Services To Drive Future Growth For Amazon* ($2B in 2012, $7B in 2019) - Forbes, Aug 12, 2012

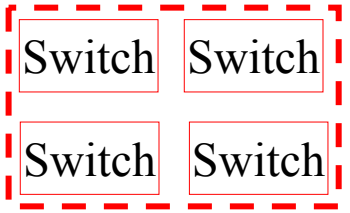
- Cloud computing was made possible by computing virtualization
- **Networking**: Plumbing of computing
  - Need to virtualize networks also

Networks need to support efficient service setup and delivery

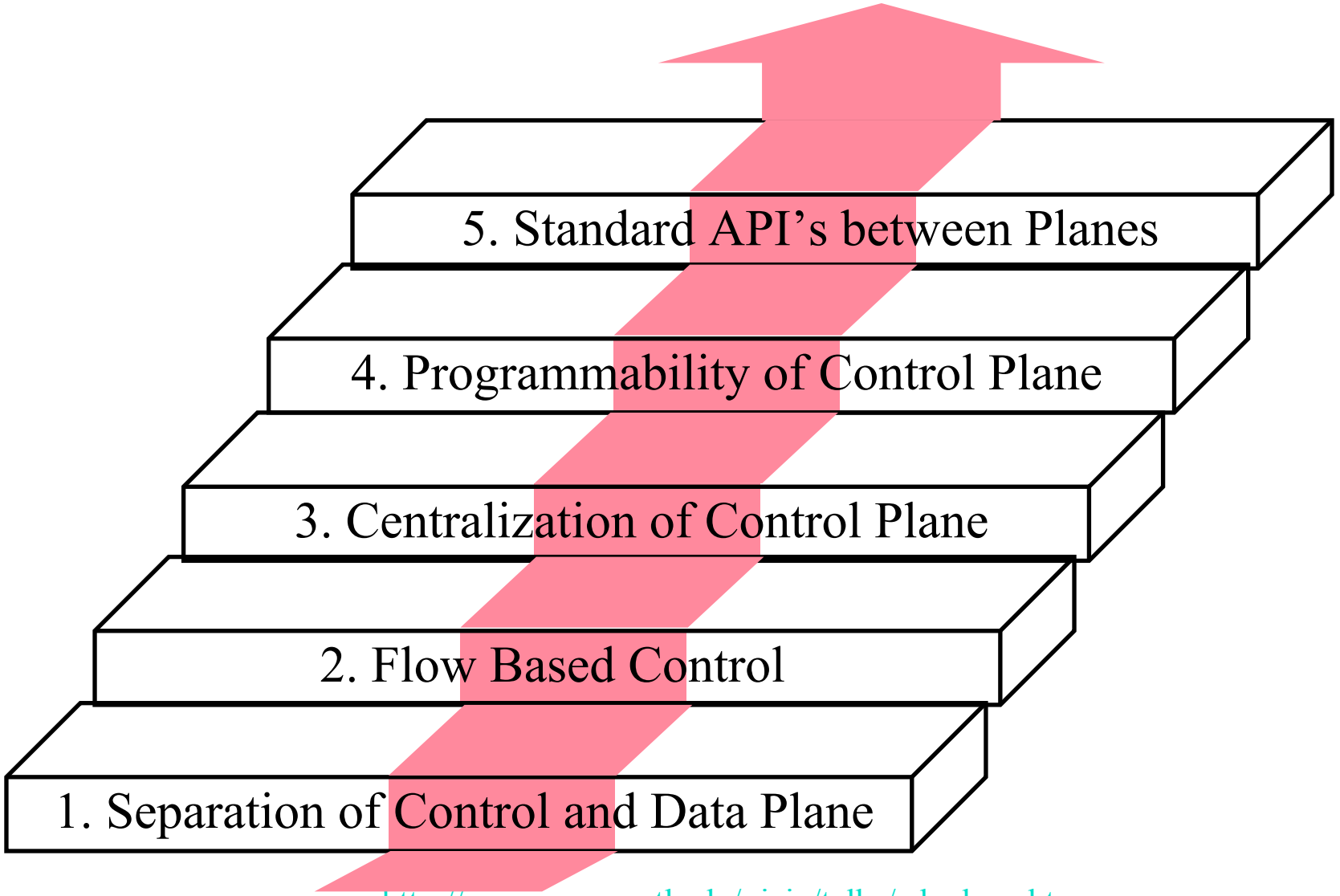
5 Reasons to Virtualize

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

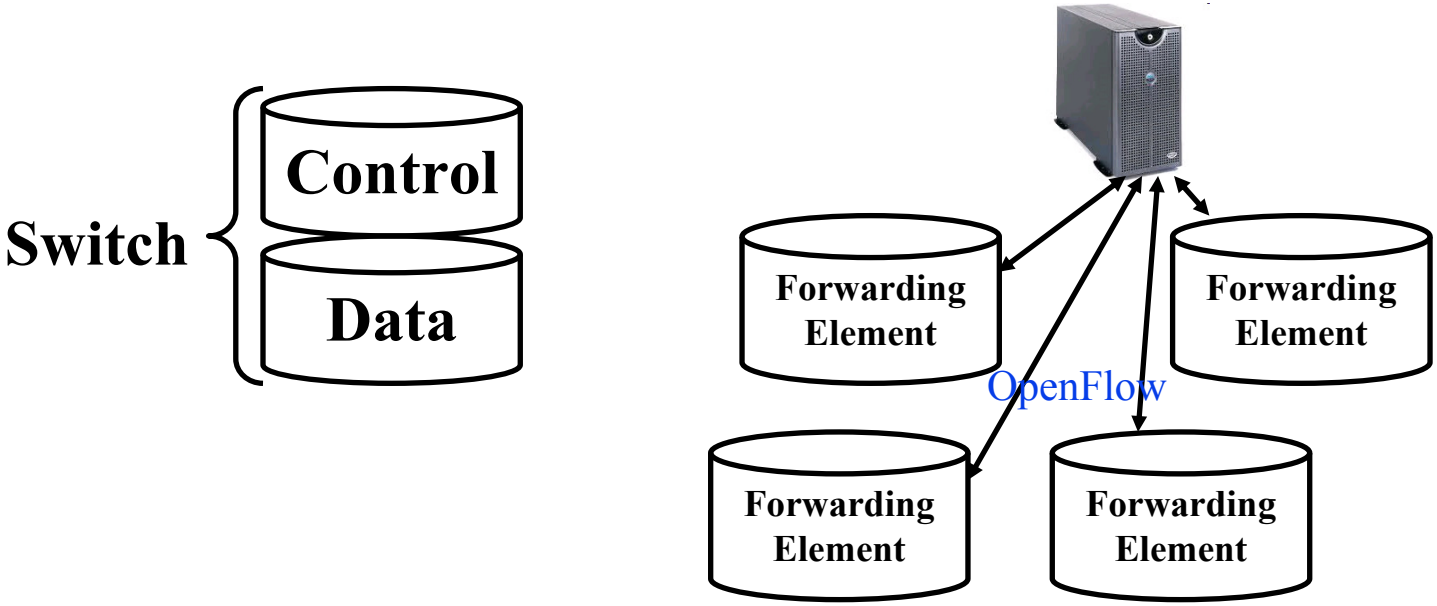




SDN Definition: 5 Innovations



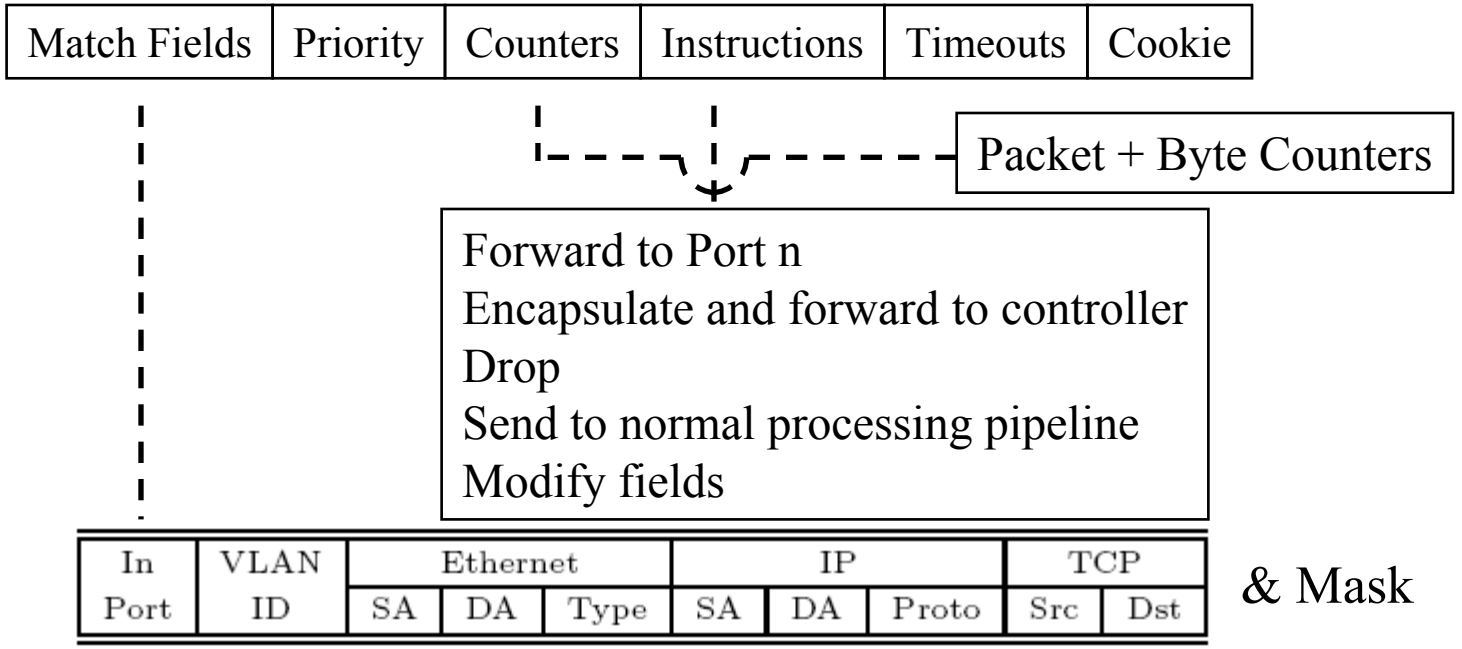
1. Separation of Control and Data Plane



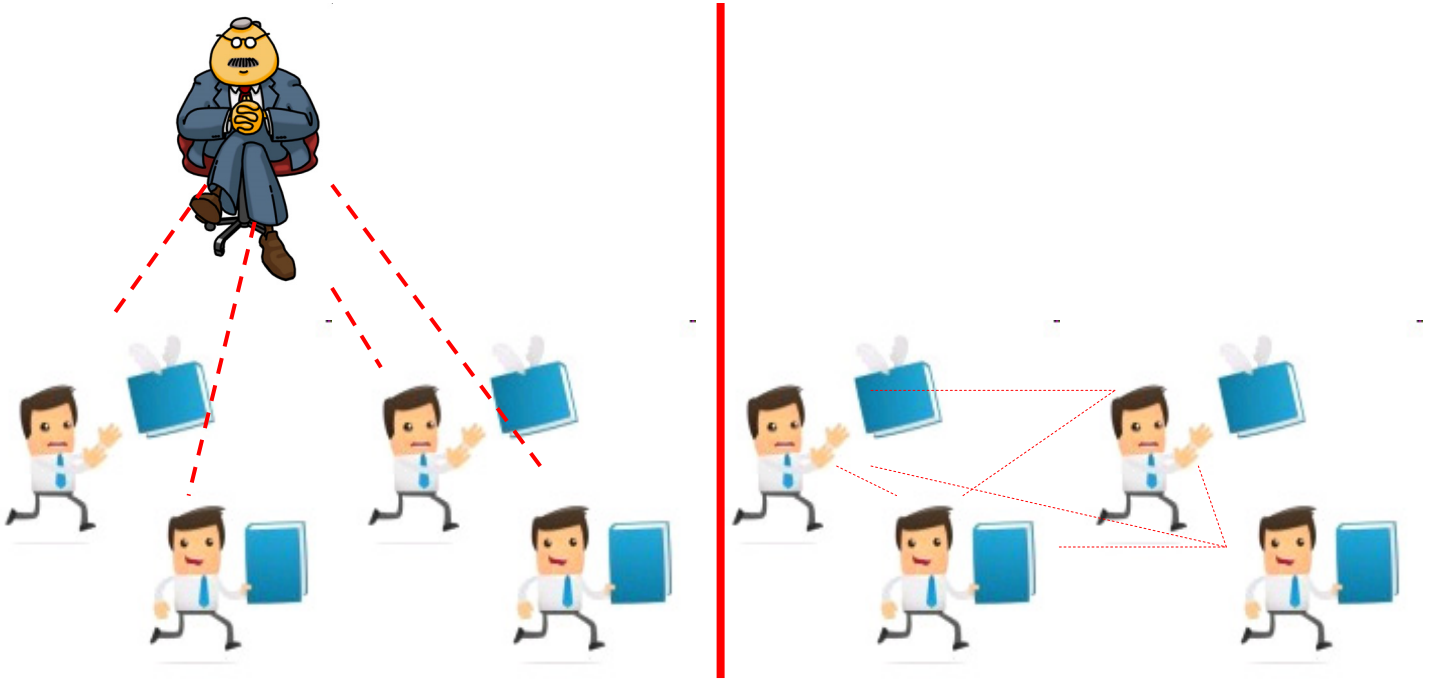
- Control Plane = Making forwarding tables
- Data Plane = Using forwarding tables
- Once vs. Billion times per second, Complex vs. fast
- One expensive controller with lots of cheap switches

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



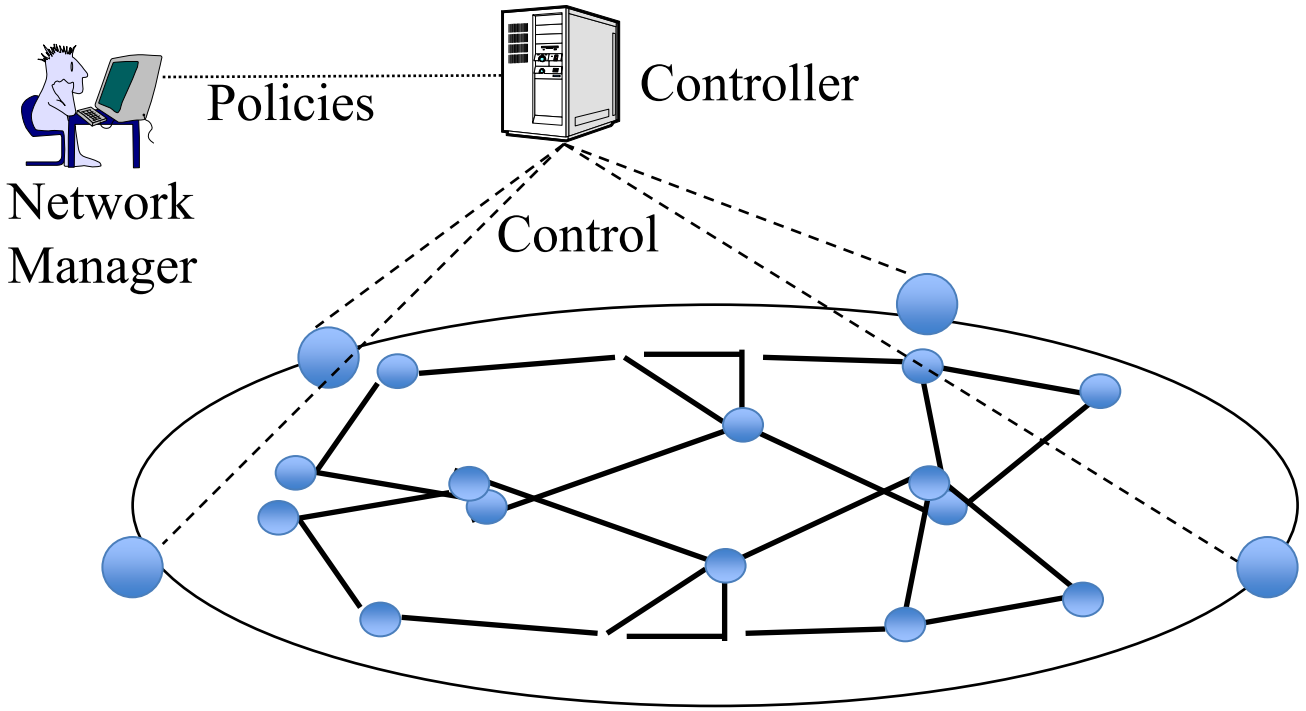
3. Centralization of Control Plane



Centralized vs. **Distributed**

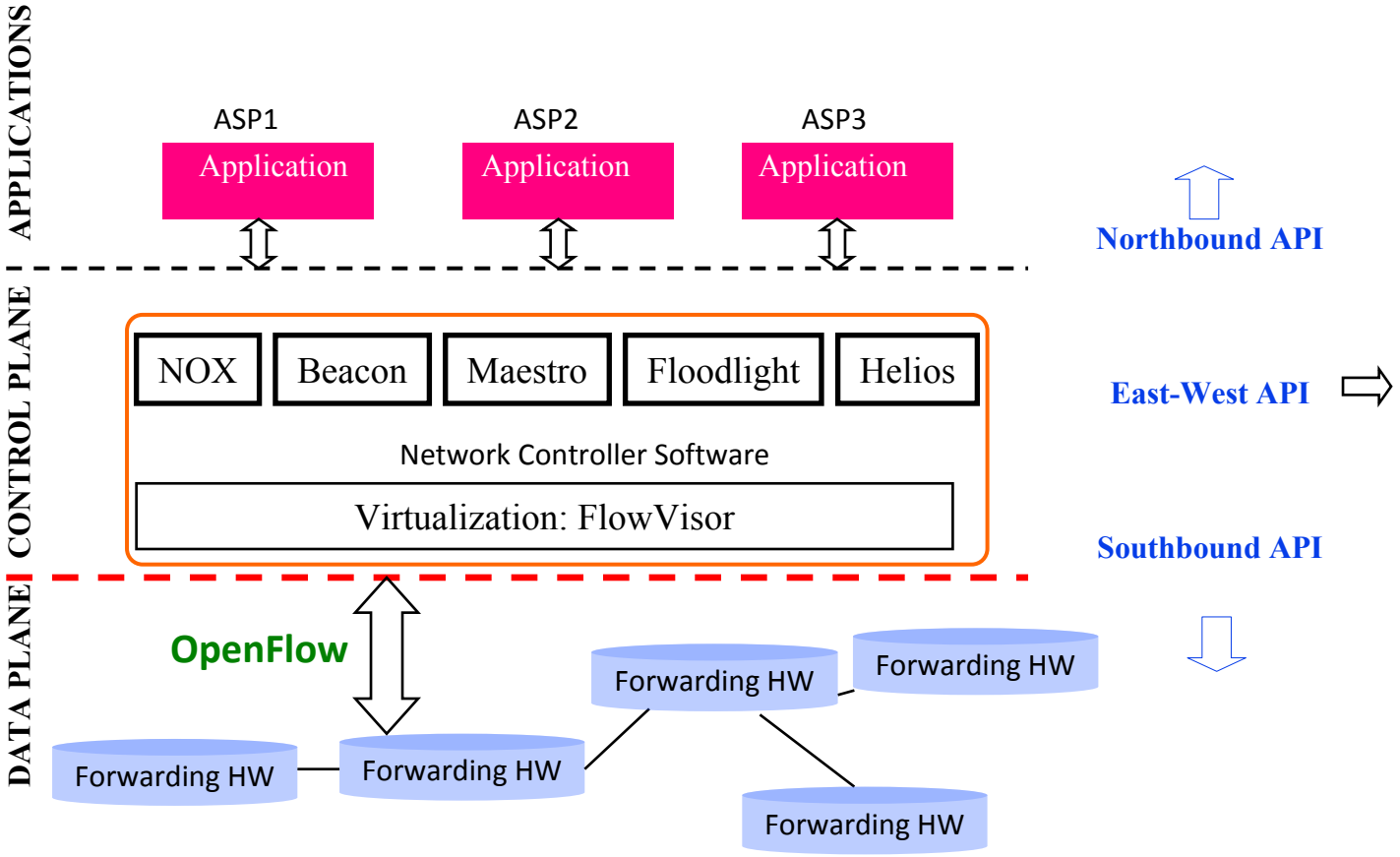
- Consistency
- Fast Response to changes
- Easy management of lots of devices

4. Programmable Control Plane



- Policies can be changed on the fly
  ⇒Software Defined

5. Standardized API between planes

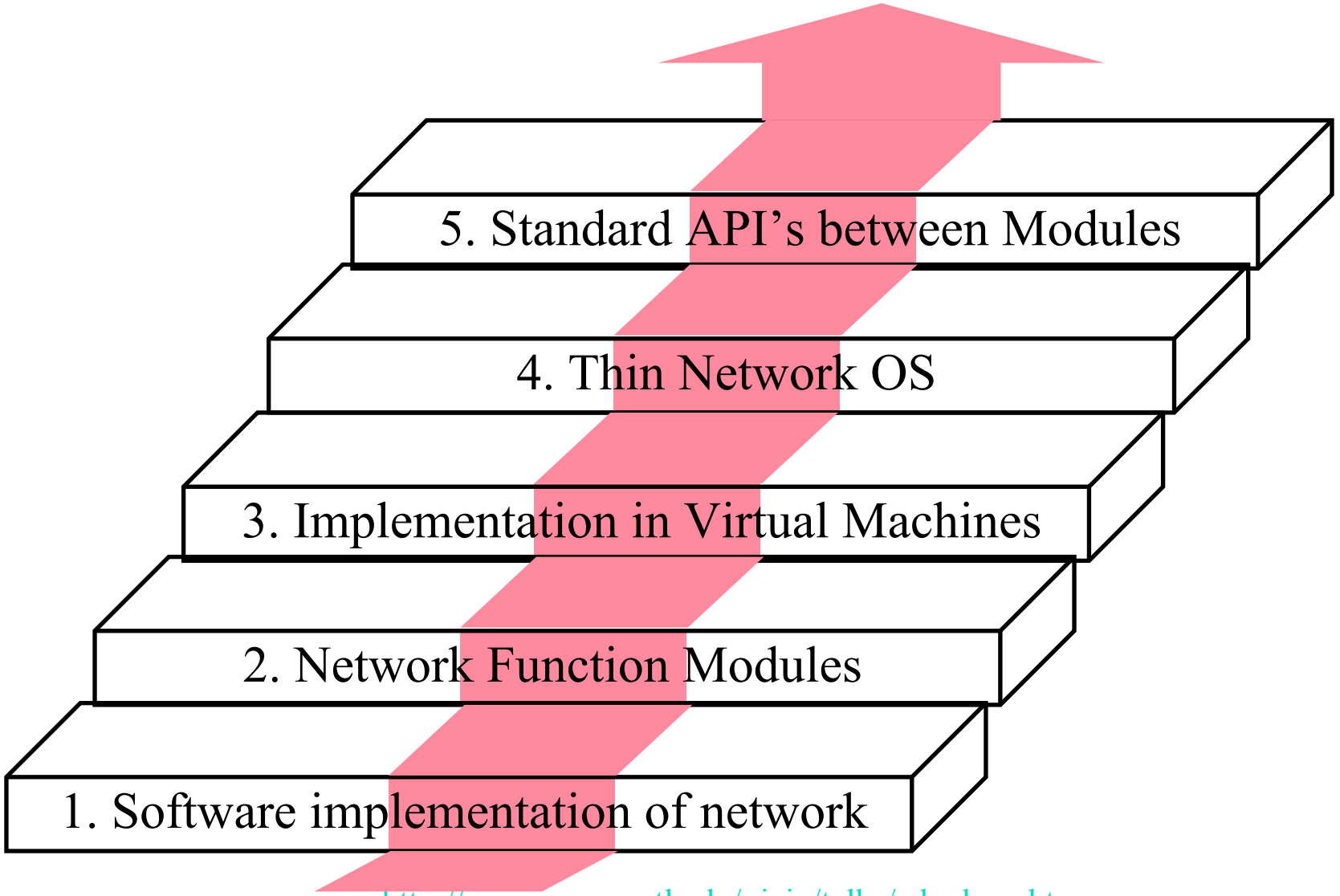


- Independent development of hw/control/applications
- Commoditization of HW/Control/Application
- South-Bound API: OpenFlow

SDN Impact

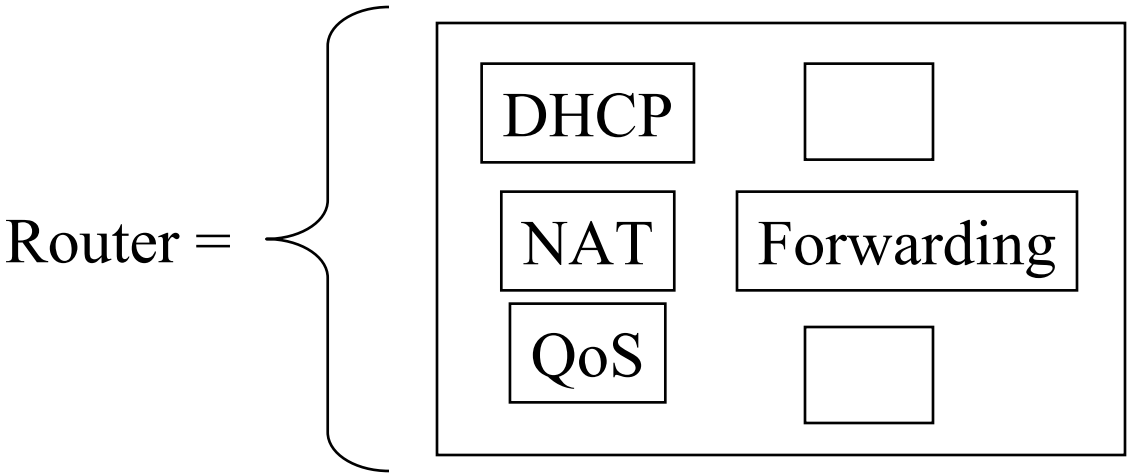
- Why so much industry interest?
  - Commodity hardware
    $\Rightarrow$ Lots of cheap forwarding engines $\Rightarrow$ Low cost
  - Programmability $\Rightarrow$ Customization
  - Those who buy routers, e.g., Google, Amazon, Docomo, DT will benefit significantly
- Tsunami of software defined devices: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

NFV: 5 Innovations



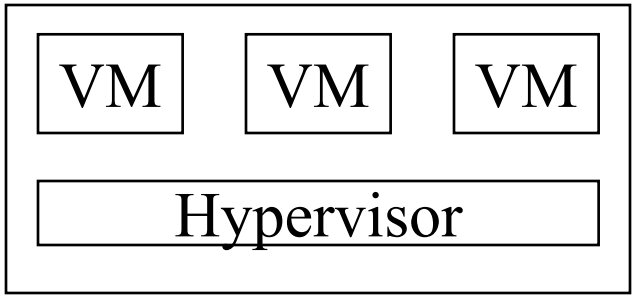
Network Function Virtualization (NFV)

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), …

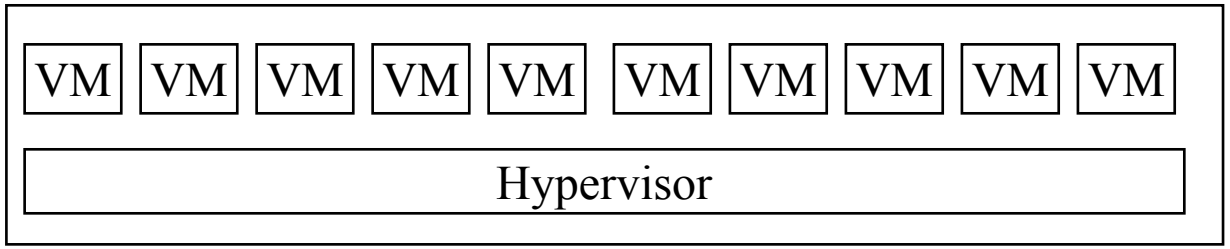


NFV (Cont)

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



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

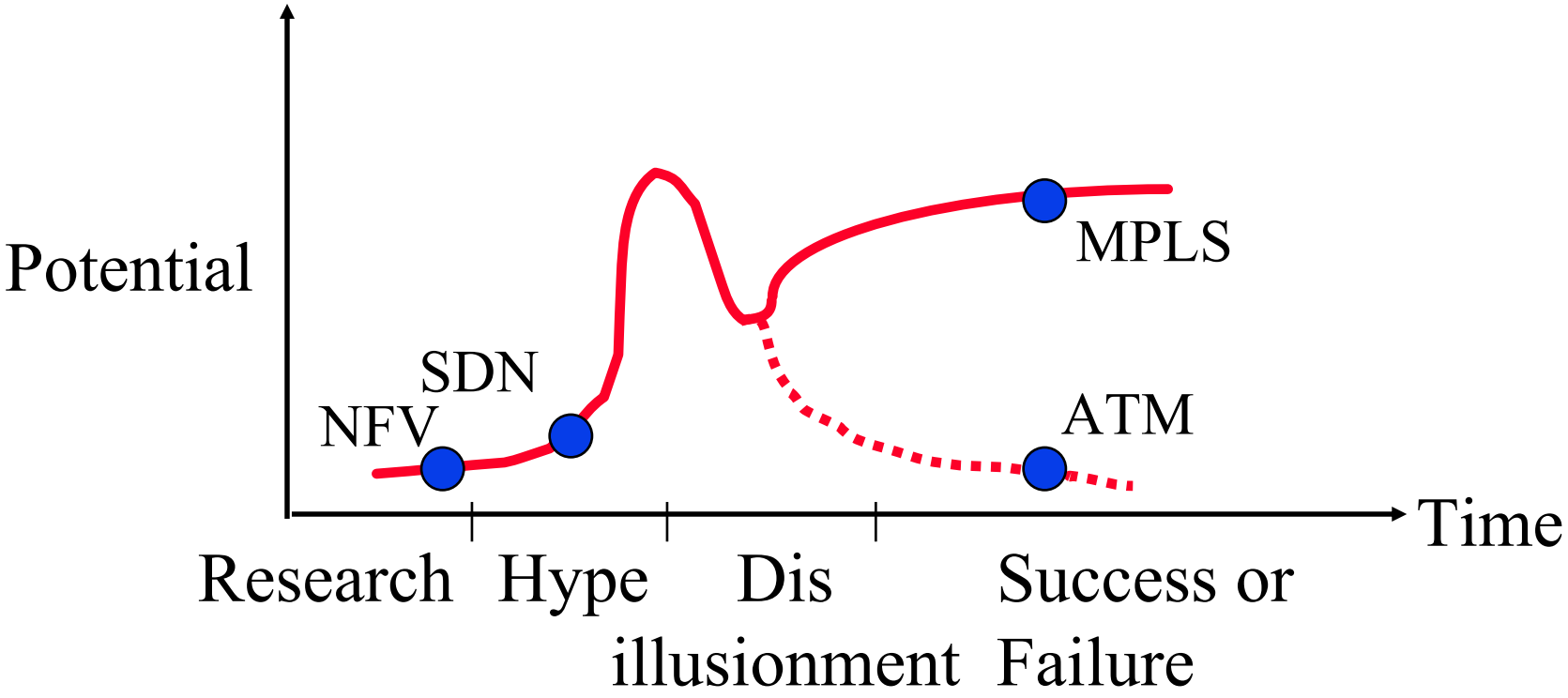


NFV (Cont)

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



Industry Growth: Formula for Success

Innovators
⇒ Startups
⇒ Technology Differentiation

Big Companies
Manufacturing
⇒ Price differentiation

Number of Companies

New Entrants

Consoli-dation

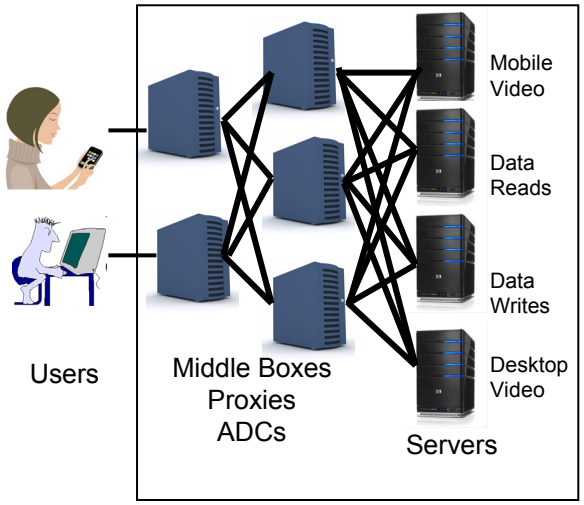
Stable Growth

Time

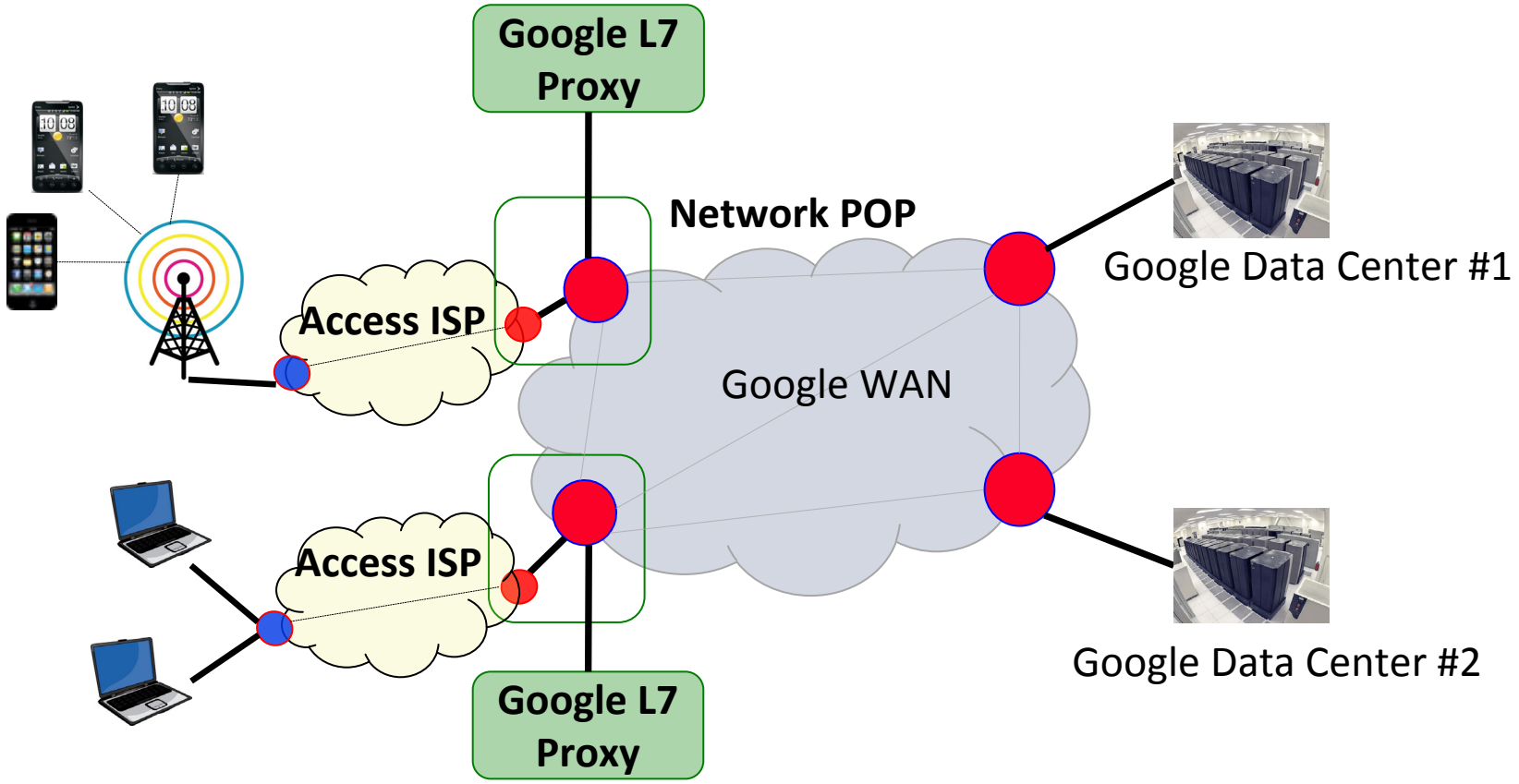
- Paradigm Shifts ⇒ Leadership Shift
- Old market leaders stick to old paradigm and loose
- Mini Computers→PC, Phone→Smart Phone, PC→Smart Phone

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



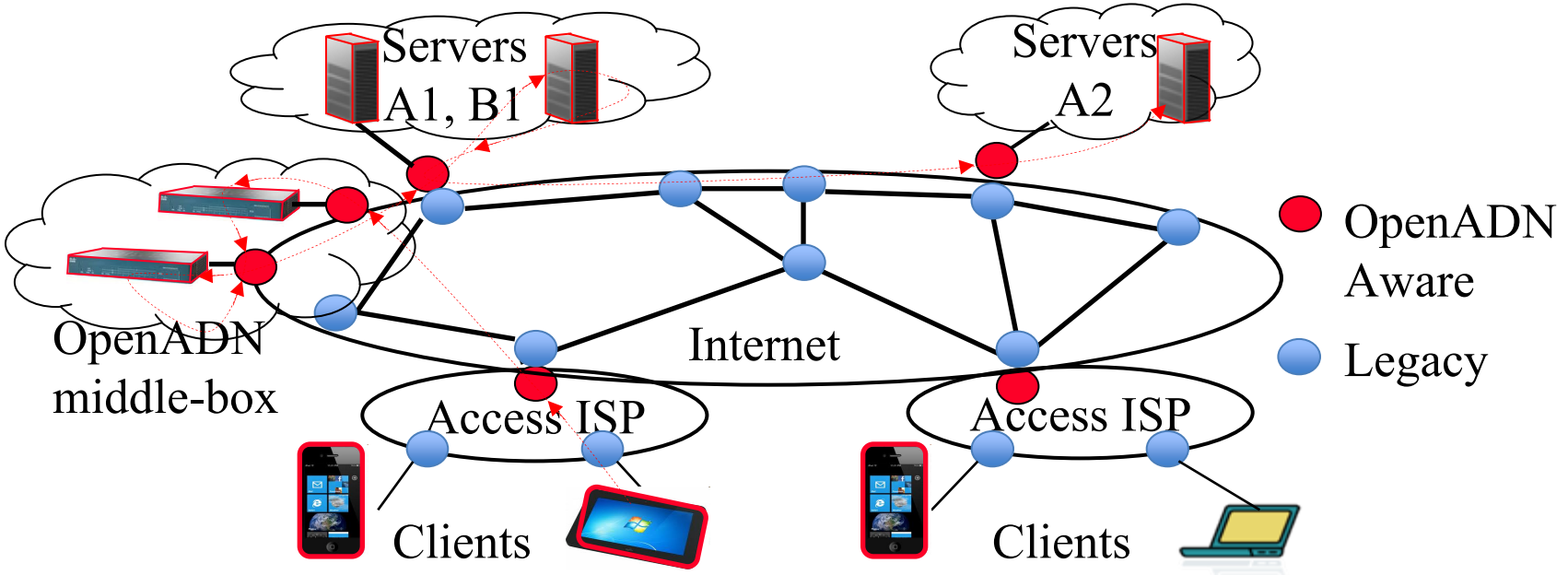
Google WAN



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

Our NaaS 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



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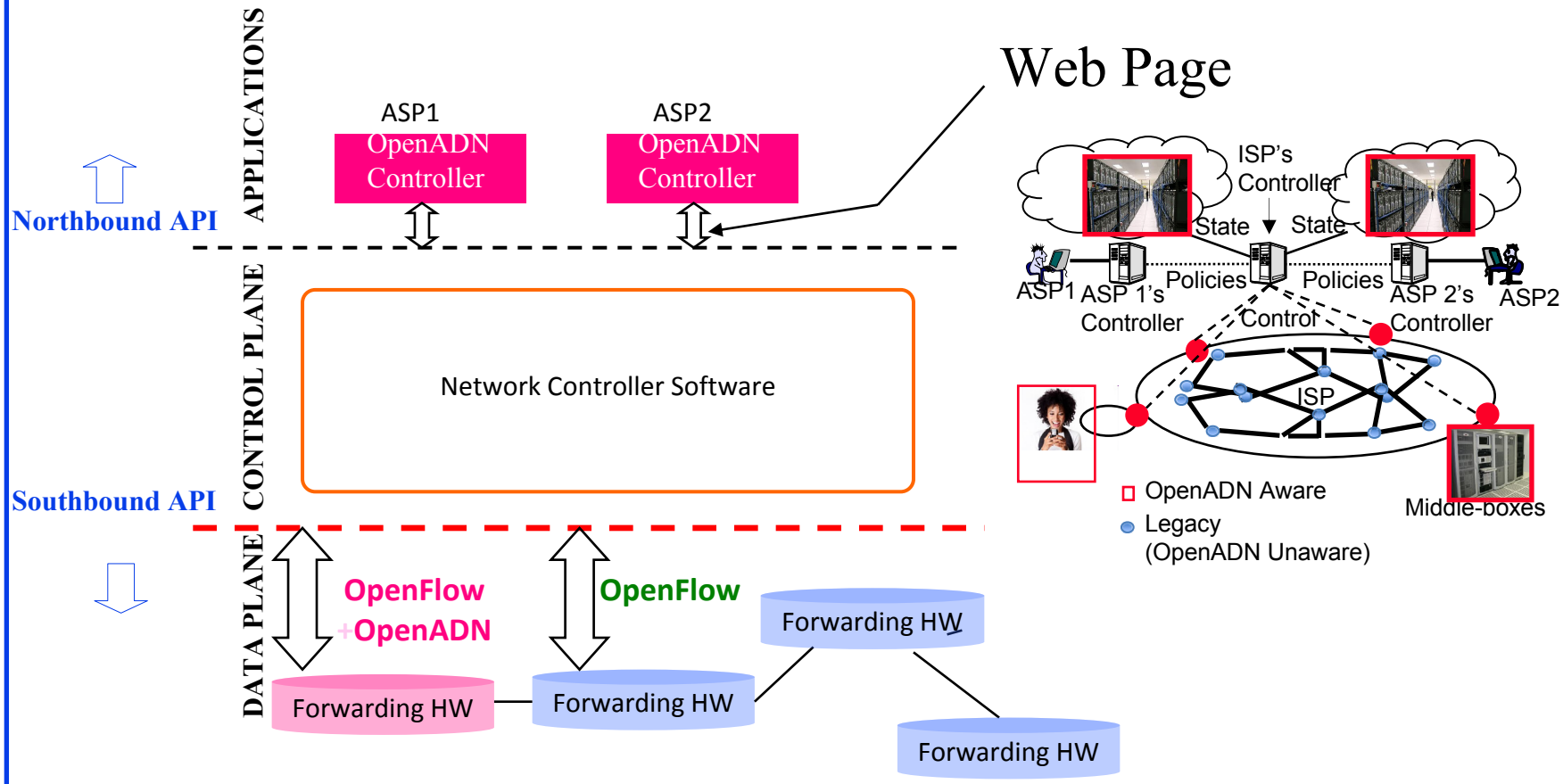
OpenADN in SDN's Layered Abstractions

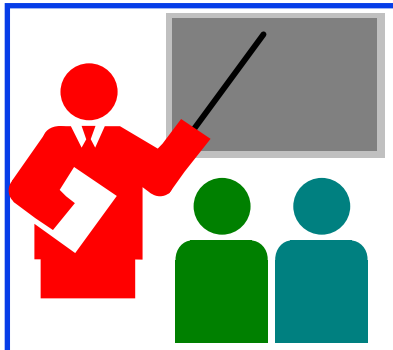


- SDN provides standardized mechanisms for distribution of control information
- OpenADN aware devices use enhanced OpenFlow

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

Summary (Cont)

- Network OS: Always proprietary + Open Source
  - PC Revolutions: Windows+Linux, Intel PC + …
  - Smart Phone Revolution: iOS + Android, iPhone+Nexus+
  - SDN+NFV Revolution: ??+Open Daylight
    Need a "Microsoft" for network operating system
- NFV modules will be Apps (Opportunity to develop the App store)
- In networking, legacy is important. How to make current equipment programmable ⇒ Evolution not just greenfield.
- Networking business segments: hardware, controllers, and apps
  ⇒ Three kinds of networking companies.
- Standard hardware, virtualizable controllers and apps
  ⇒ Networking in cloud