Next Gen Networking using Software Defined Networking (SDN) and Network Function Virtualization (NFV)

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

Overview

1. Trend: Centralization of Network Control
   Software Defined Networking (SDN)

2. Trend: High-Speed multi-core processors
   Network Function Virtualization (NFV)

3. Our Research: Open Application Delivery using SDN

4. Latest in Rural Access

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)

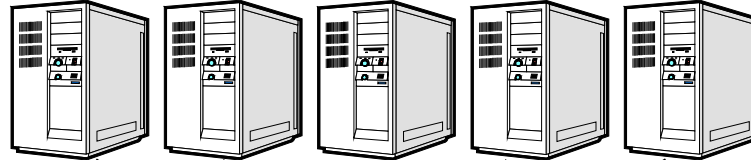 ➢ Almost all services use cloud computing

Networks need to support efficient service setup and delivery

Service Center Evolution

1. Single Server
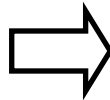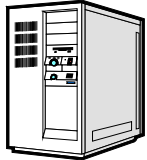
2. Data Center

Load Balancers	SSL Off loaders
Application Replication, Partitioning	

3. Multi-Cloud

Global Internet

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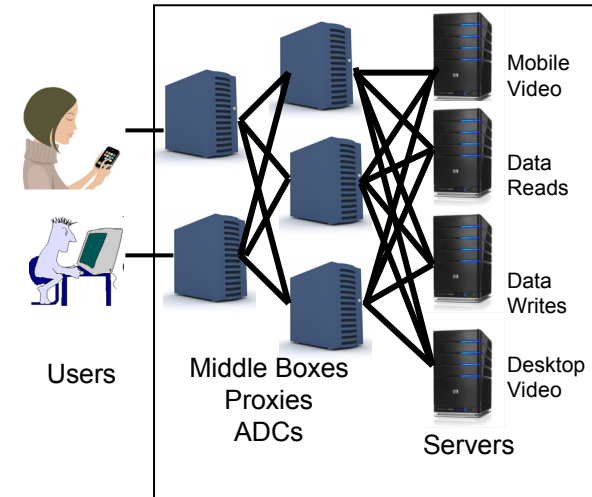   - ✓ If link to US broken, send to UK
- **Content-Based Partitioning**:
    - ➢ Video messages to Server S1
    - ➢ Accounting to Server S2
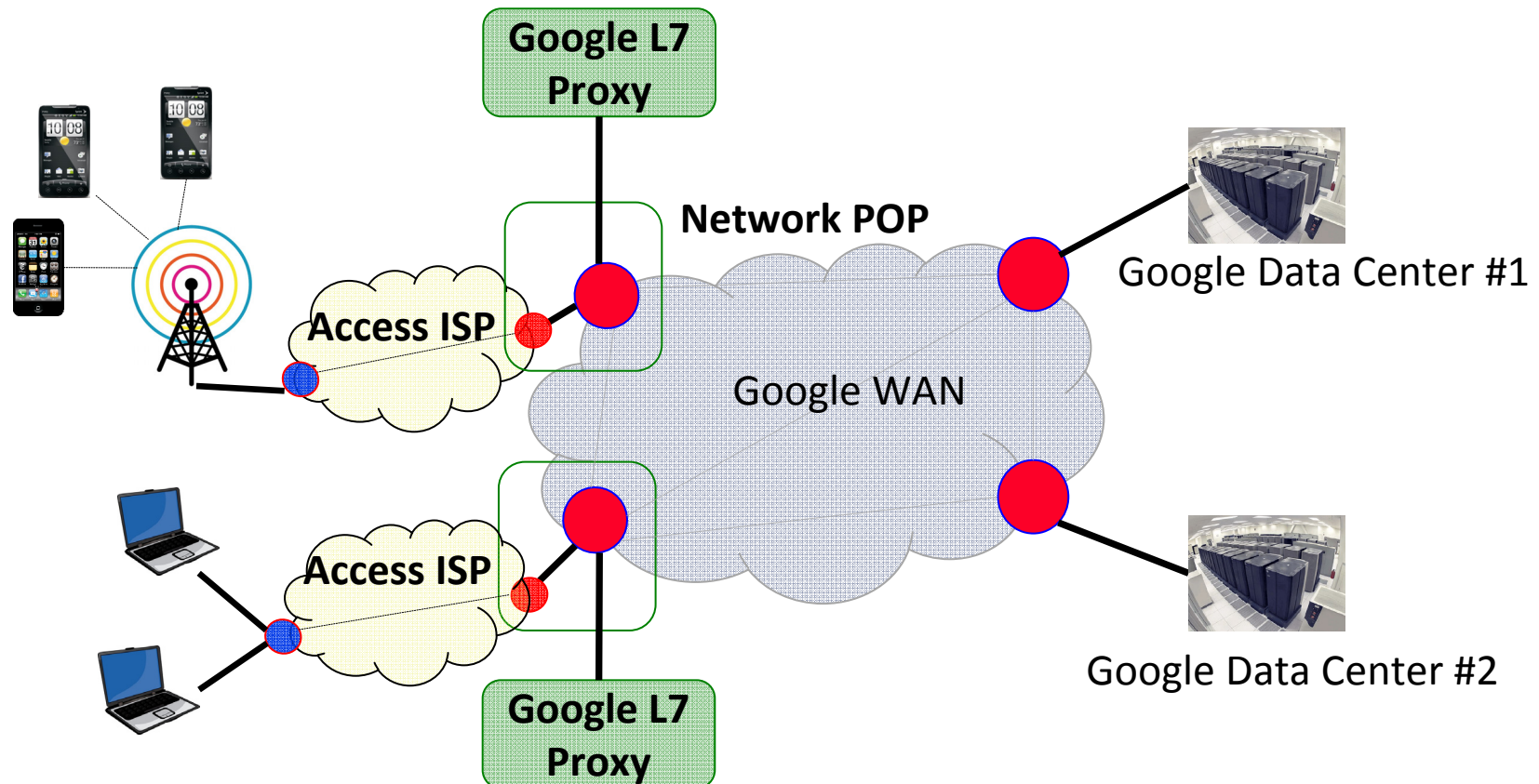- **Context Based Partitioning**:
    - ➢ Application Context: Different API calls
        - ✓ Reads to S1, Writes to S2
    - ➢ User Context:
        - ✓ If Windows Phone user, send to S1
        - ✓ If laptop user, send to HD, send to S2
- **Multi-Segment**: User-ISP Proxy-Load Balancer-Firewall-Server

Mobile
Video

Data
Reads

Data
Writes

Desktop
Video

Users

Middle Boxes
Proxies
ADCs

Servers

Google WAN

Google L7 Proxy

Network POP

Access ISP

Google WAN

Google Data Center #1

Access ISP

Google L7 Proxy

Google Data Center #2

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

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

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

http://www.cse.wustl.edu/~jain/talks/adn_iis.htm
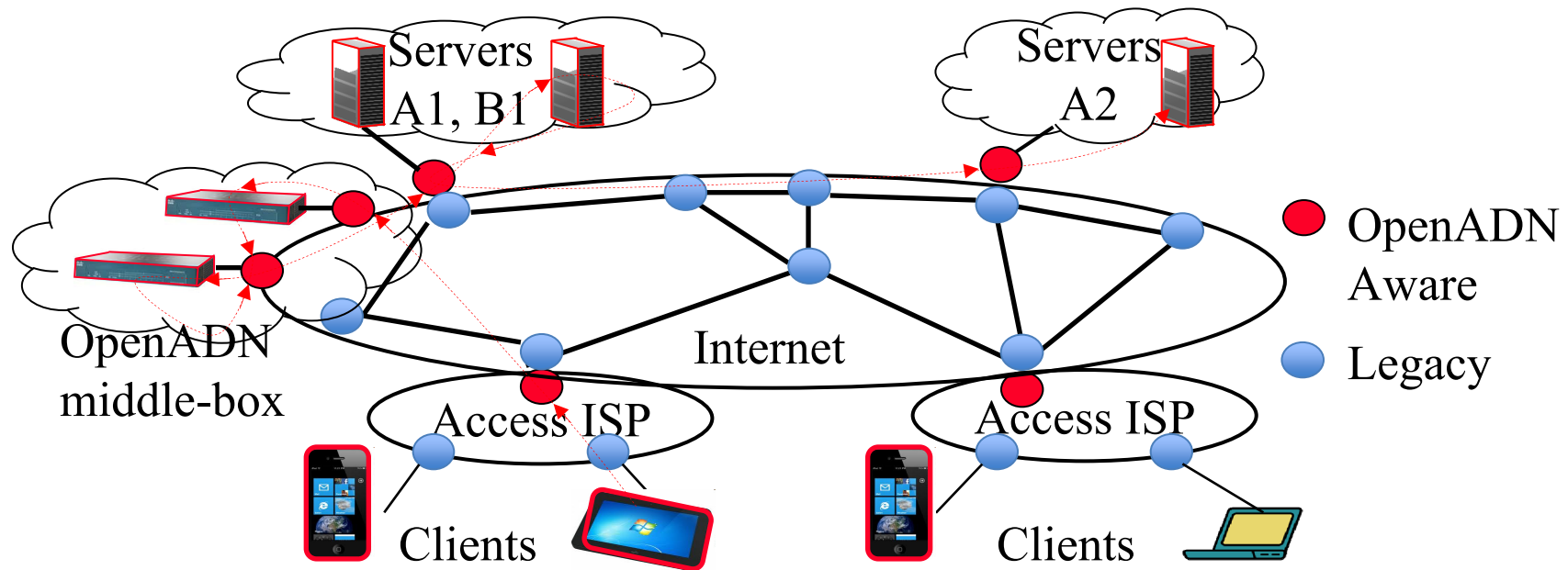
OpenADN: 5 Innovations

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
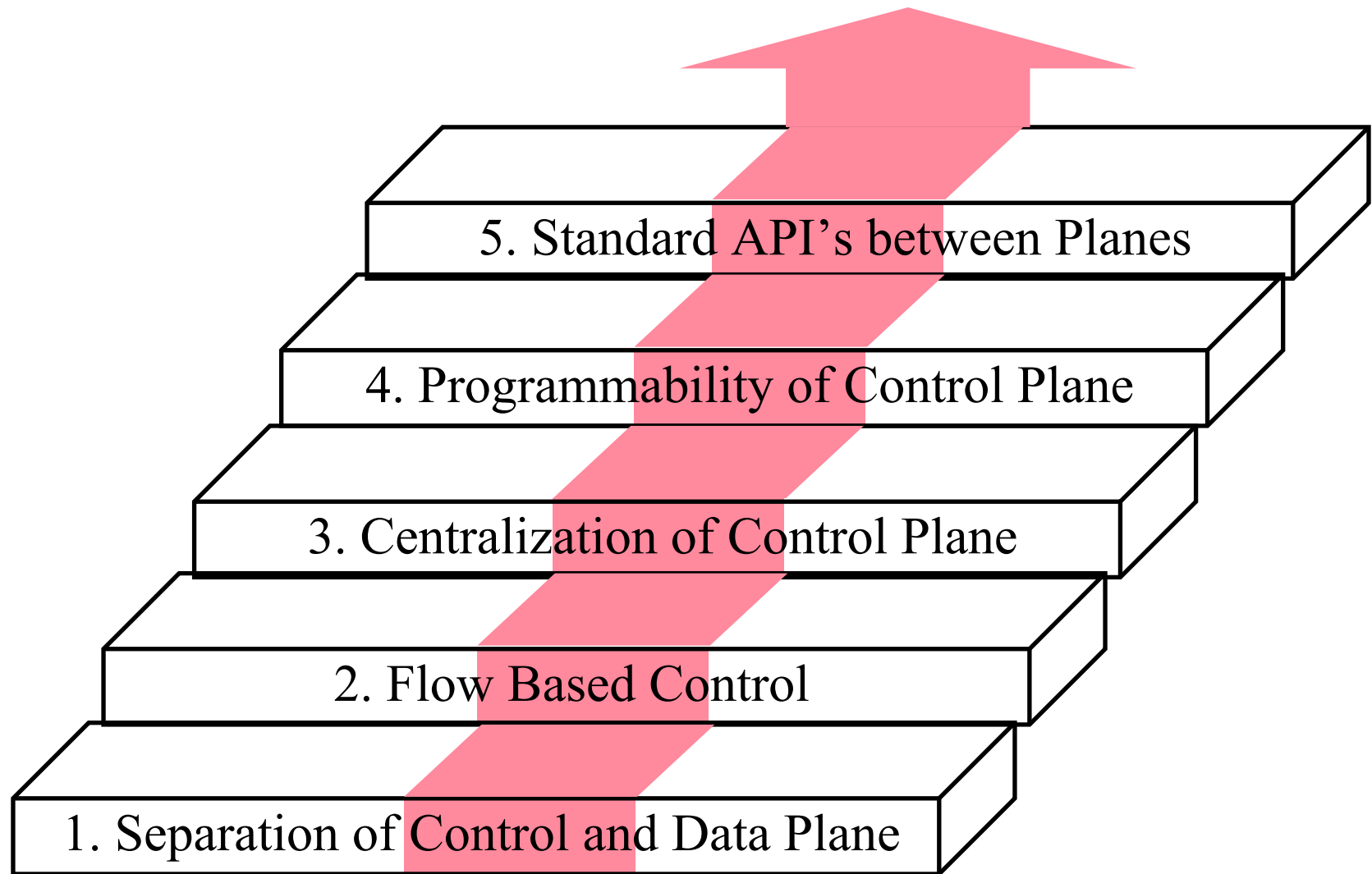
5. Rule-Based Delegation

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

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

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SDN Definition: 5 Innovations

5. Standard API's between Planes

4. Programmability of Control Plane

3. Centralization of Control Plane

2. Flow Based Control

1. Separation of Control and Data Plane

1. Separation of Control and Data Plane

Switch { Control / Data

Forwarding Element

Forwarding Element

Forwarding Element

Forwarding Element

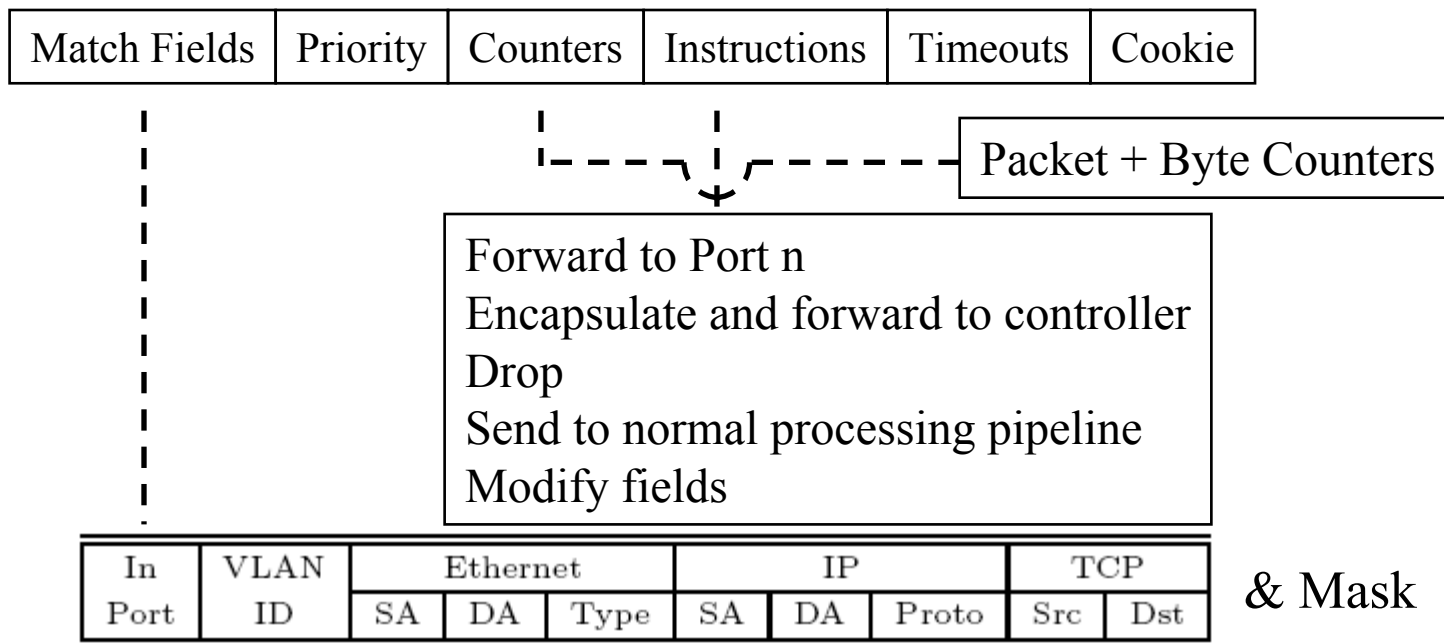OpenFlow
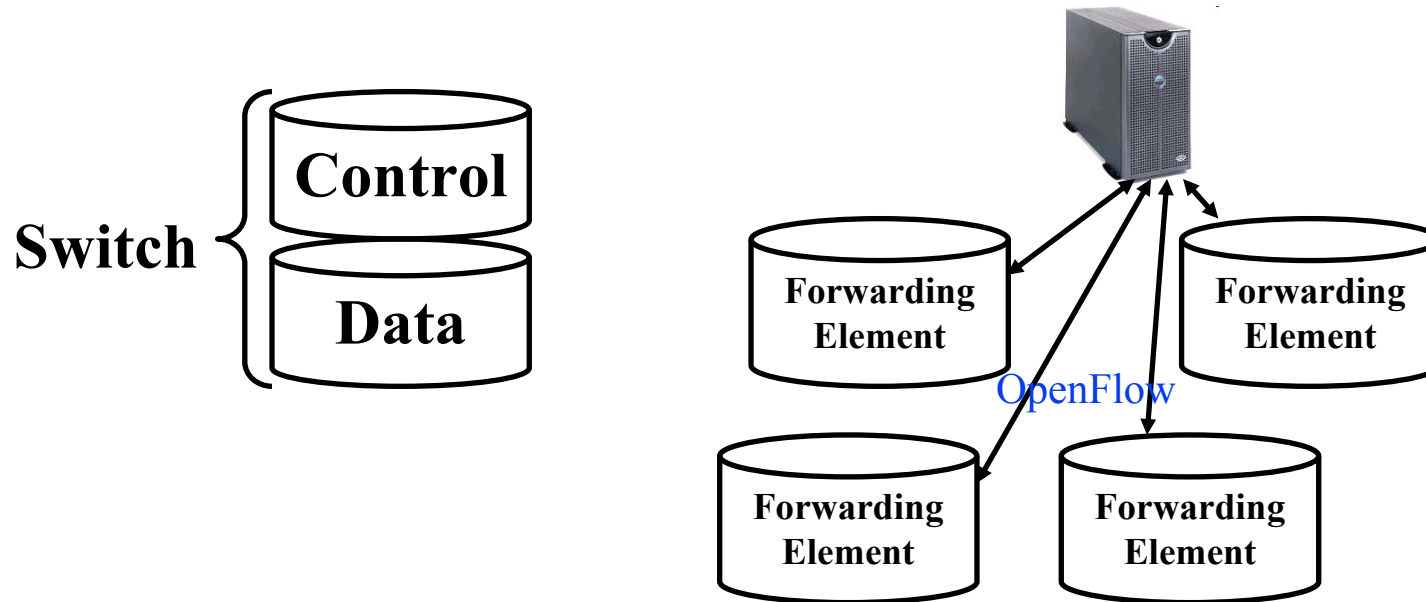
- ❑ Control Plane = Making forwarding tables
- ❑ Data Plane = Using forwarding tables
- ❑ Once vs. Billion times per second, Complex vs. fast
- ❑ One expensive controller with lots of cheap switches

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 $\Rightarrow$ Packet Trains
- Flow is defined by L2-L4 headers
- Decide once, use many times $\Rightarrow$ Execution performance

Match Fields	Priority	Counters	Instructions	Timeouts	Cookie

Packet + Byte Counters

Forward to Port n
Encapsulate and forward to controller
Drop
Send to normal processing pipeline
Modify fields

In Port	VLAN ID	Ethernet			IP			TCP	
		SA	DA	Type	SA	DA	Proto	Src	Dst

& Mask

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

3. Centralization of Control Plane
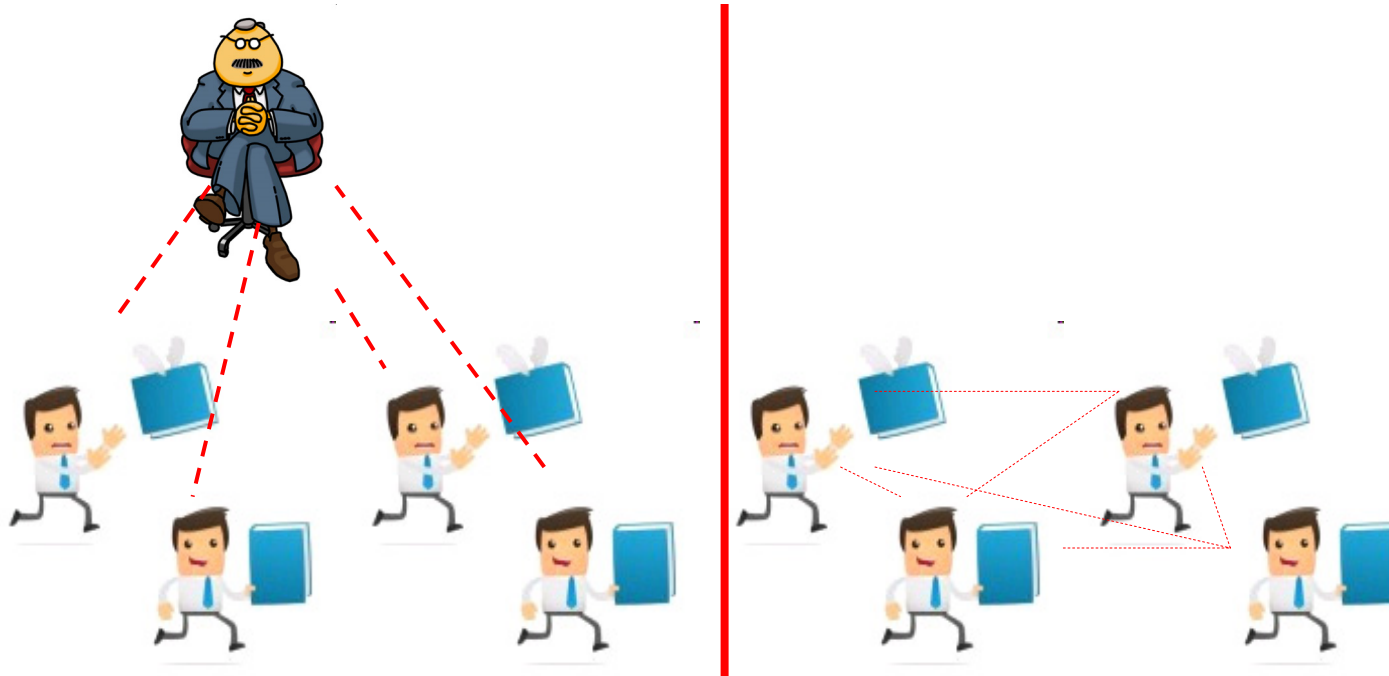
Centralized vs. **Distributed**

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

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Centralized vs. Distributed

❑ Networks are moving from distributed to centralized
❑ Storage is moving from centralized to distributed

Past   Present: Hadoop   Switch

Processor
Cluster   ⟷   Storage
                                Area
                                Network

Task Tracker Data Node	Job Tracker
Task Tracker Data Node	Name Node
Task Tracker Data Node	Task Tracker Data Node
Task Tracker Data Node	Task Tracker Data Node
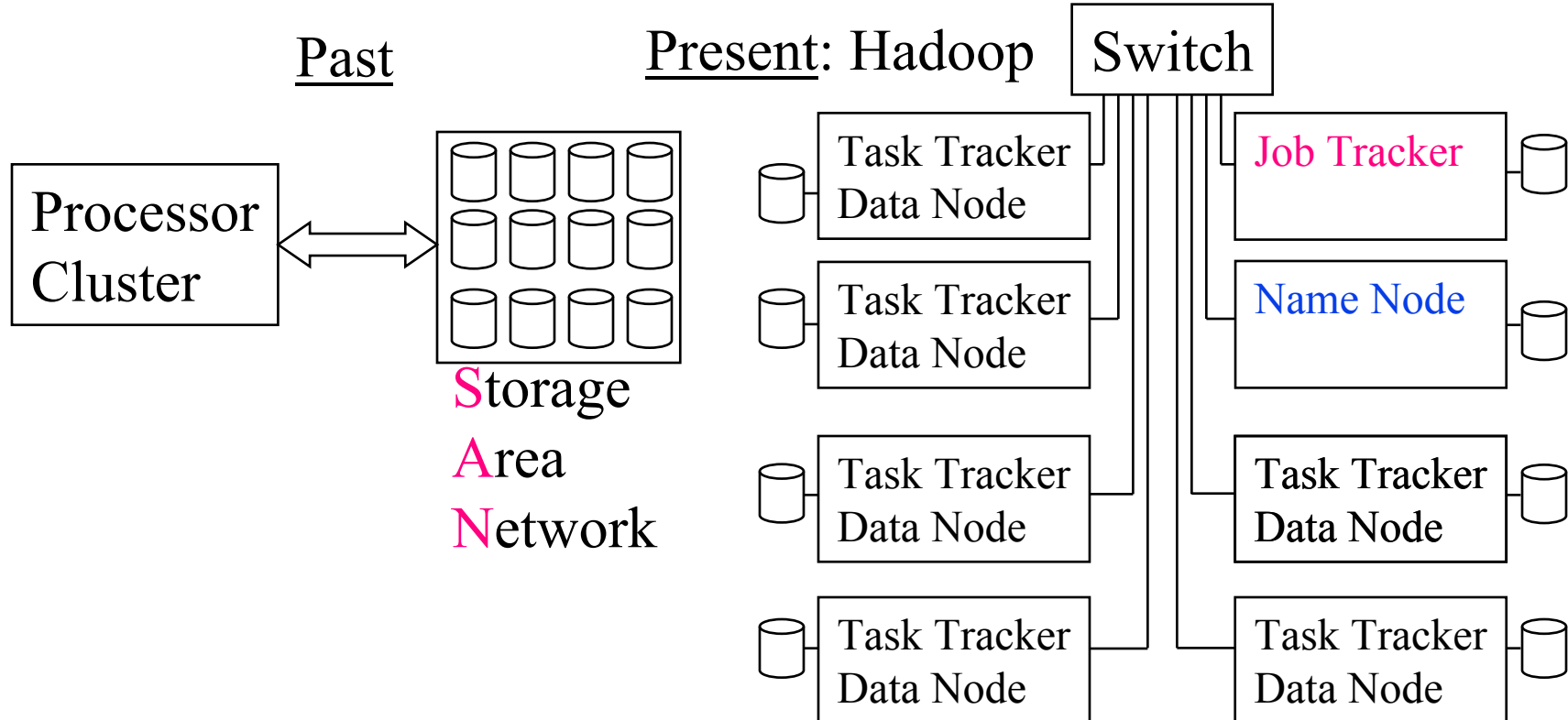
4. Programmable Control Plane

Policies

Controller

Network Manager
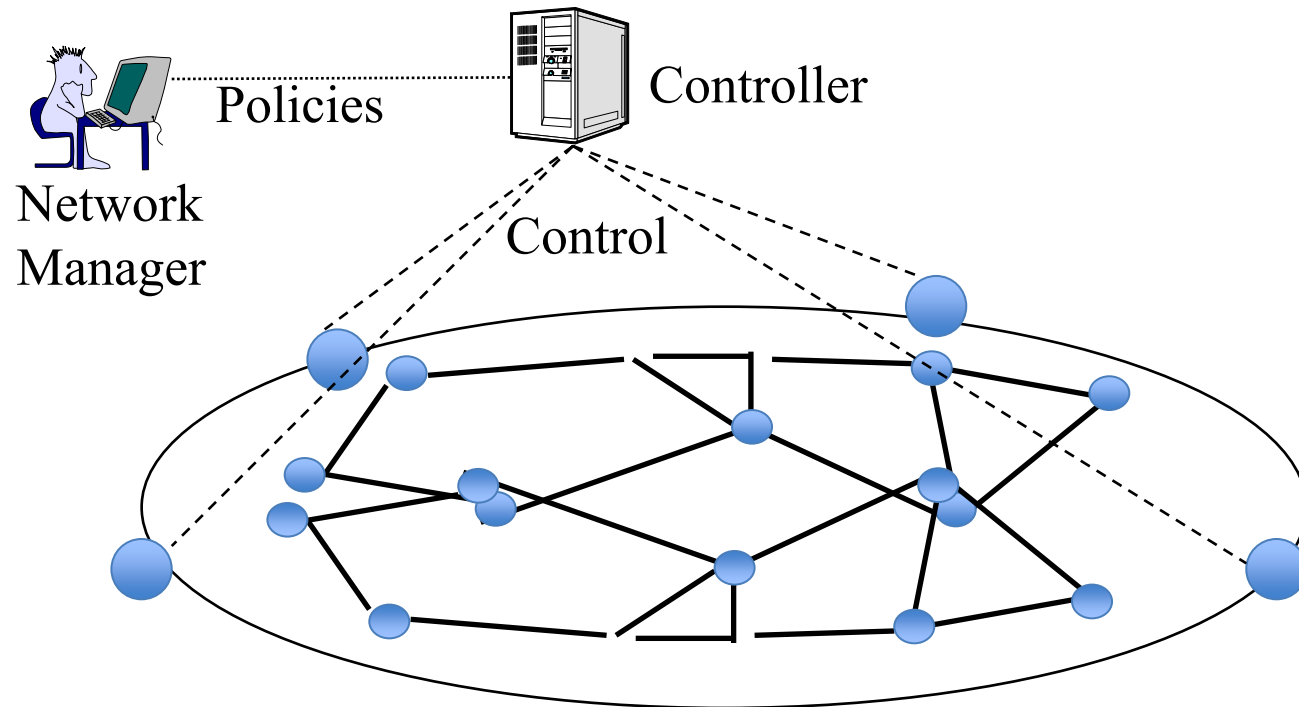
Control

❑ Policies can be changed on the fly
⇒Software Defined

5. Standardized API between planes

APPLICATIONS | CONTROL PLANE | DATA PLANE

ASP1
ASP2
ASP3

Application | Application | Application

Northbound API

| NOX | Beacon | Maestro | Floodlight | Helios |

Network Controller Software

Virtualization: FlowVisor

East-West API

Southbound API

OpenFlow

Forwarding HW

Forwarding HW

Forwarding HW

Forwarding HW

Forwarding HW
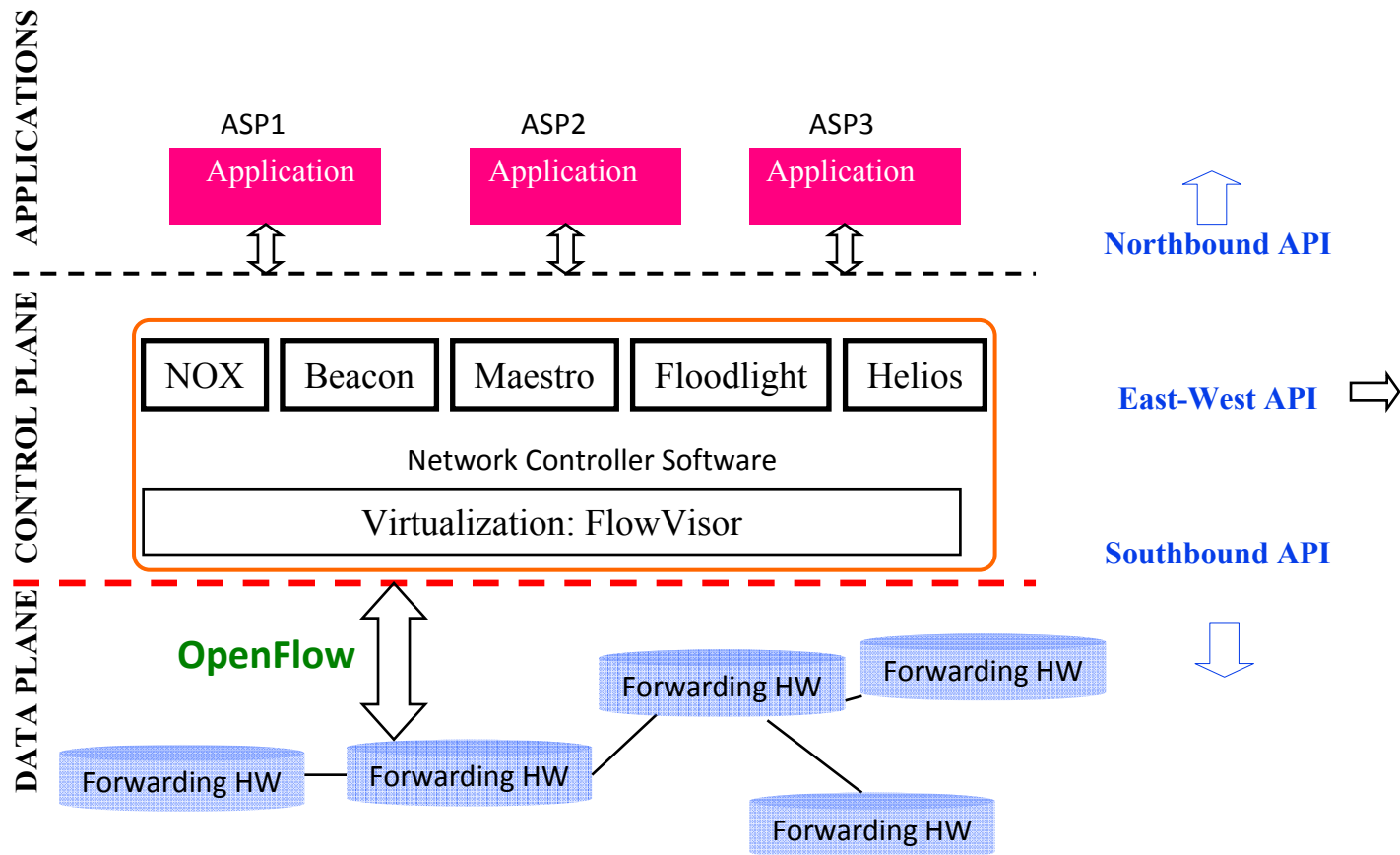
Forwarding HW

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

SDN Impact

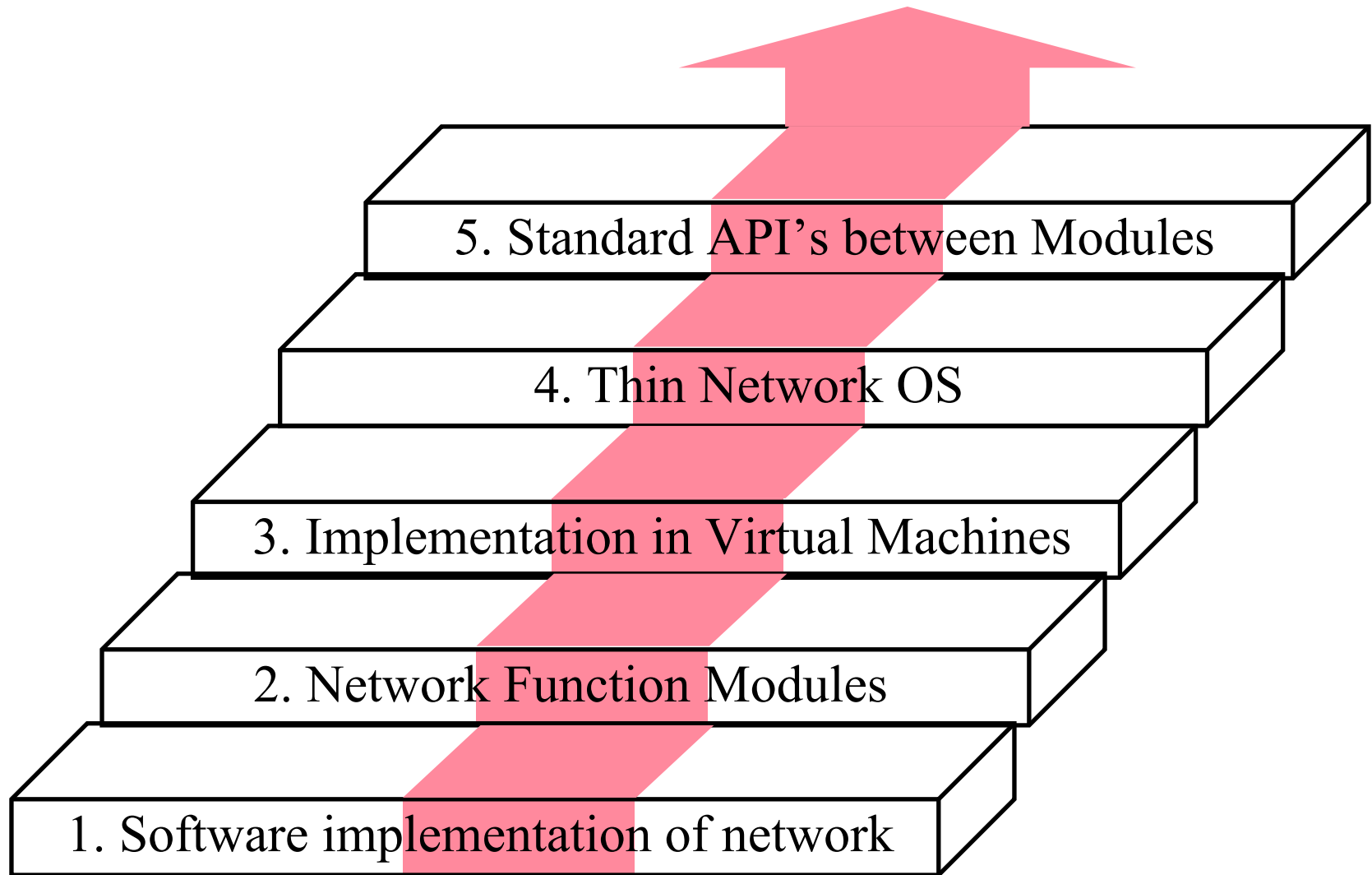❑ Why so much industry interest?

  ➢ 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

5. Standard API's between Modules

4. Thin Network OS

3. Implementation in Virtual Machines

2. Network Function Modules

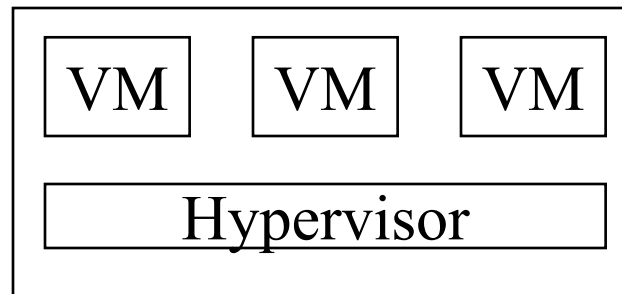1. Software implementation of network

Network Function Virtualization (NFV)

1. Fast standard hardware $\Rightarrow$ Software based Devices
   Routers, Firewalls, BRAS (Broadband Remote Access Server)

2. Function Modules (Both data plane and control plane)
   $\Rightarrow$ DHCP (Dynamic Host control Protocol), NAT (Network Address Translation), Rate Limiting, HLR (Home Location Register), …
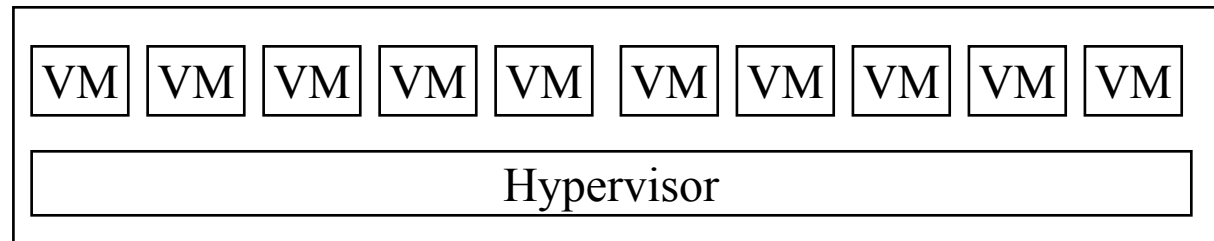
Router =

DHCP	
NAT	Forwarding
QoS	
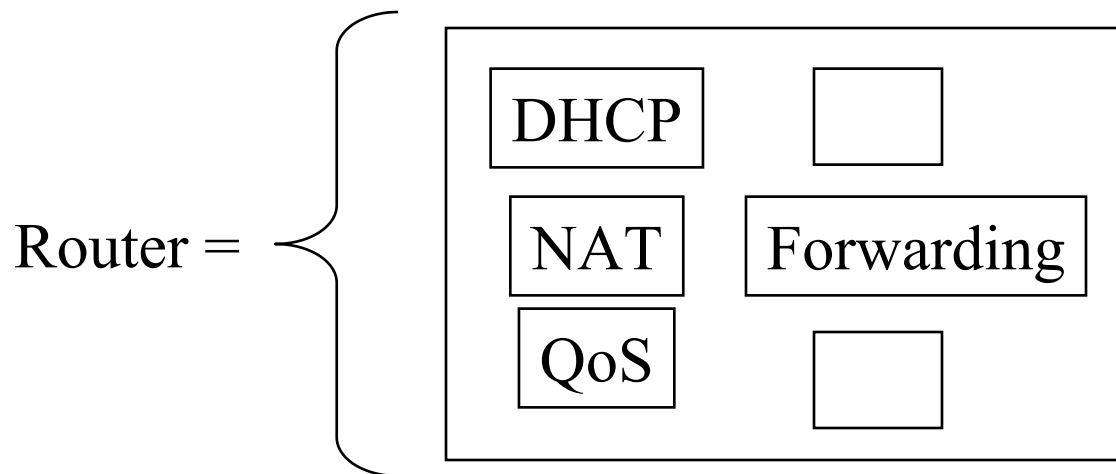
NFV (Cont)

3. Virtual Machine implementation $\Rightarrow$ All advantages of virtualization (quick provisioning, scalability, mobility,…)
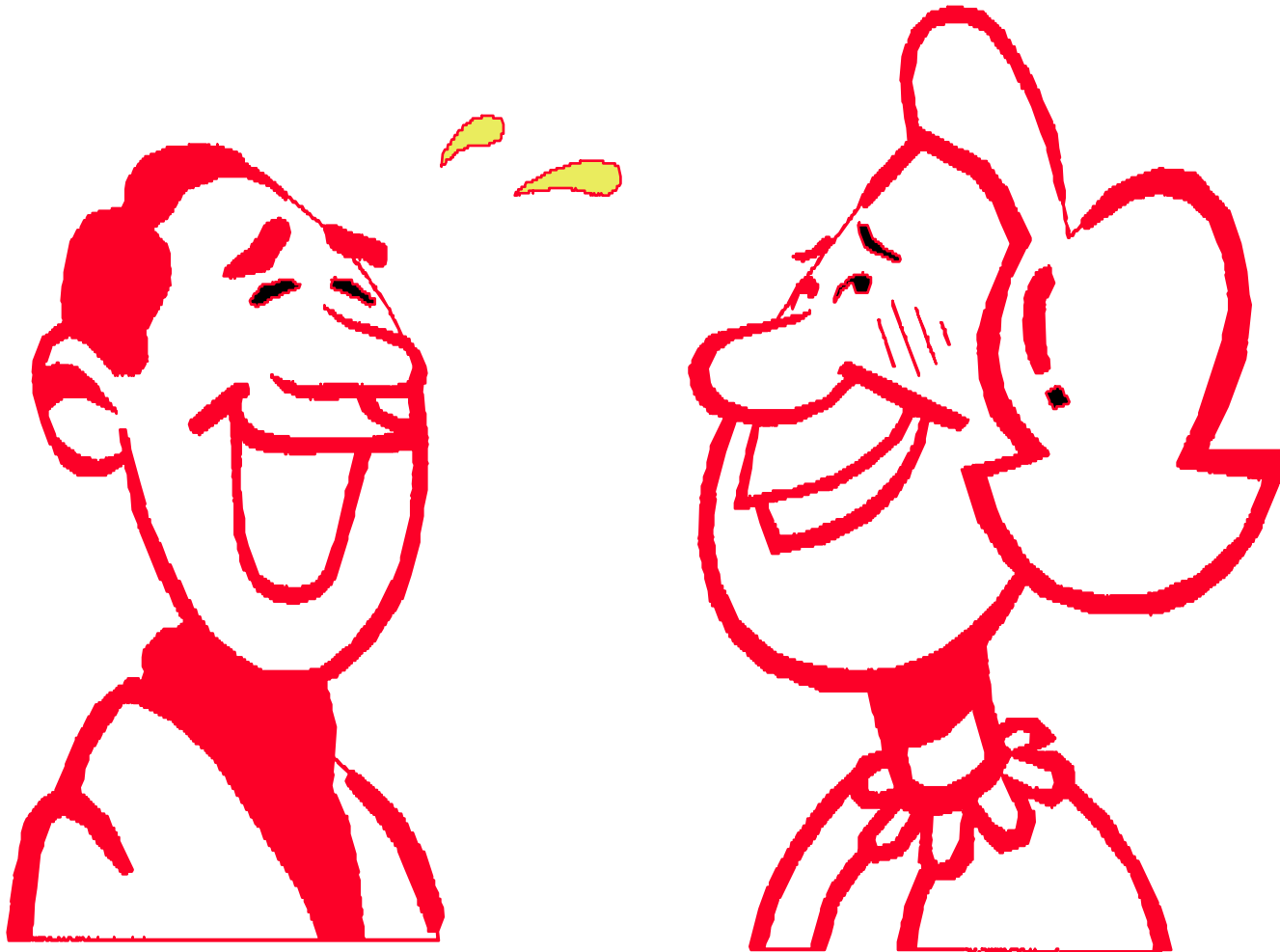
```
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│  ┌──────┐  ┌──────┐  ┌──────┐   │
│  │  VM  │  │  VM  │  │  VM  │   │
│  └──────┘  └──────┘  └──────┘   │
│  ┌───────────────────────────┐  │
│  │       Hypervisor          │  │
│  └───────────────────────────┘  │
└─────────────────────────────────┘
```

4. Thin Real-time OS
   $\Rightarrow$ Minimize latency, max performance, Large scale sharing

```
┌────────────────────────────────────────────────────────────────────┐
│ ┌──┐┌──┐┌──┐┌──┐┌──┐┌──┐┌──┐┌──┐┌──┐┌──┐                            │
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│ ┌────────────────────────────────────────────────────────────────┐ │
│ │                        Hypervisor                              │ │
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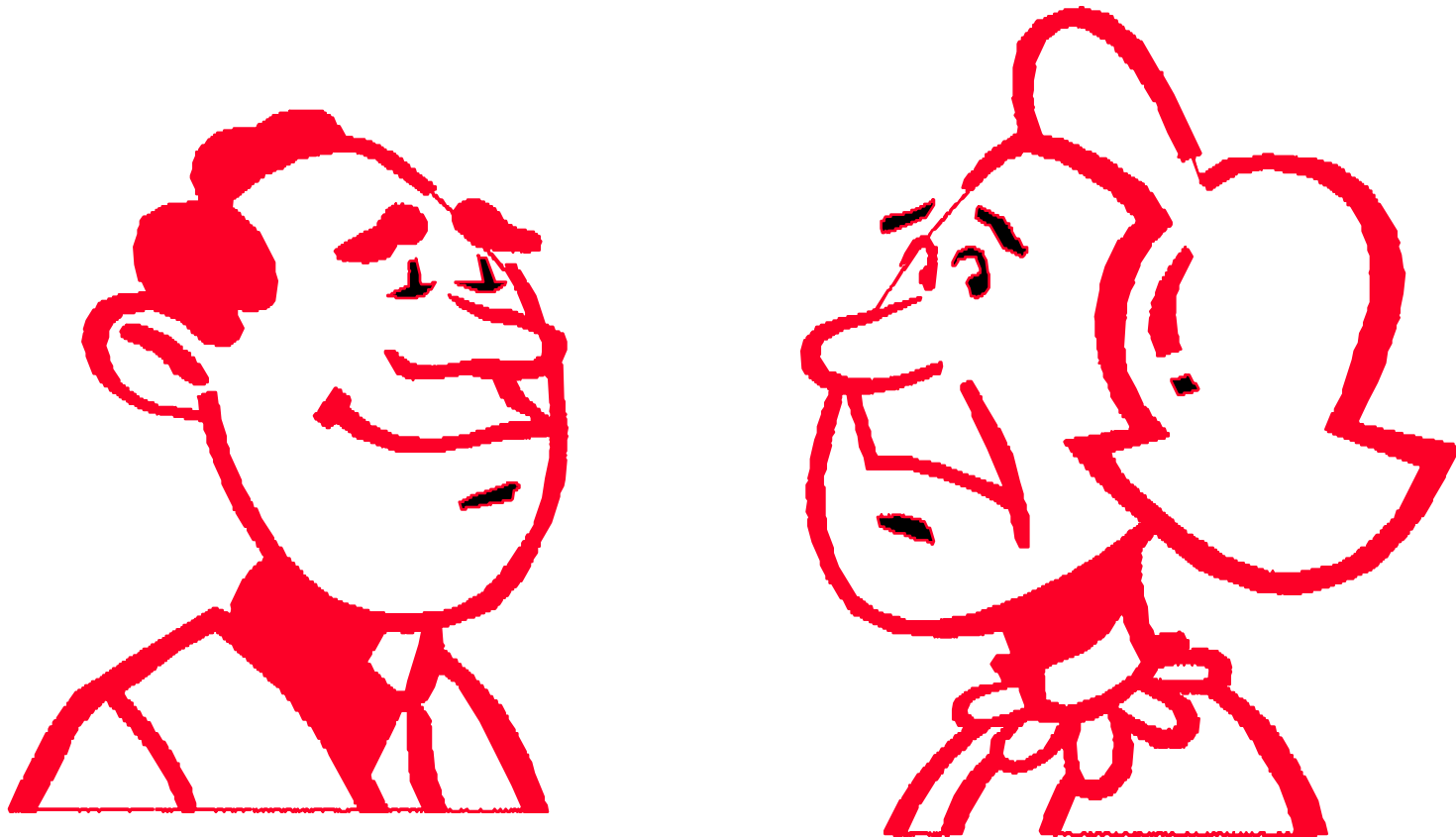
NFV (Cont)

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.
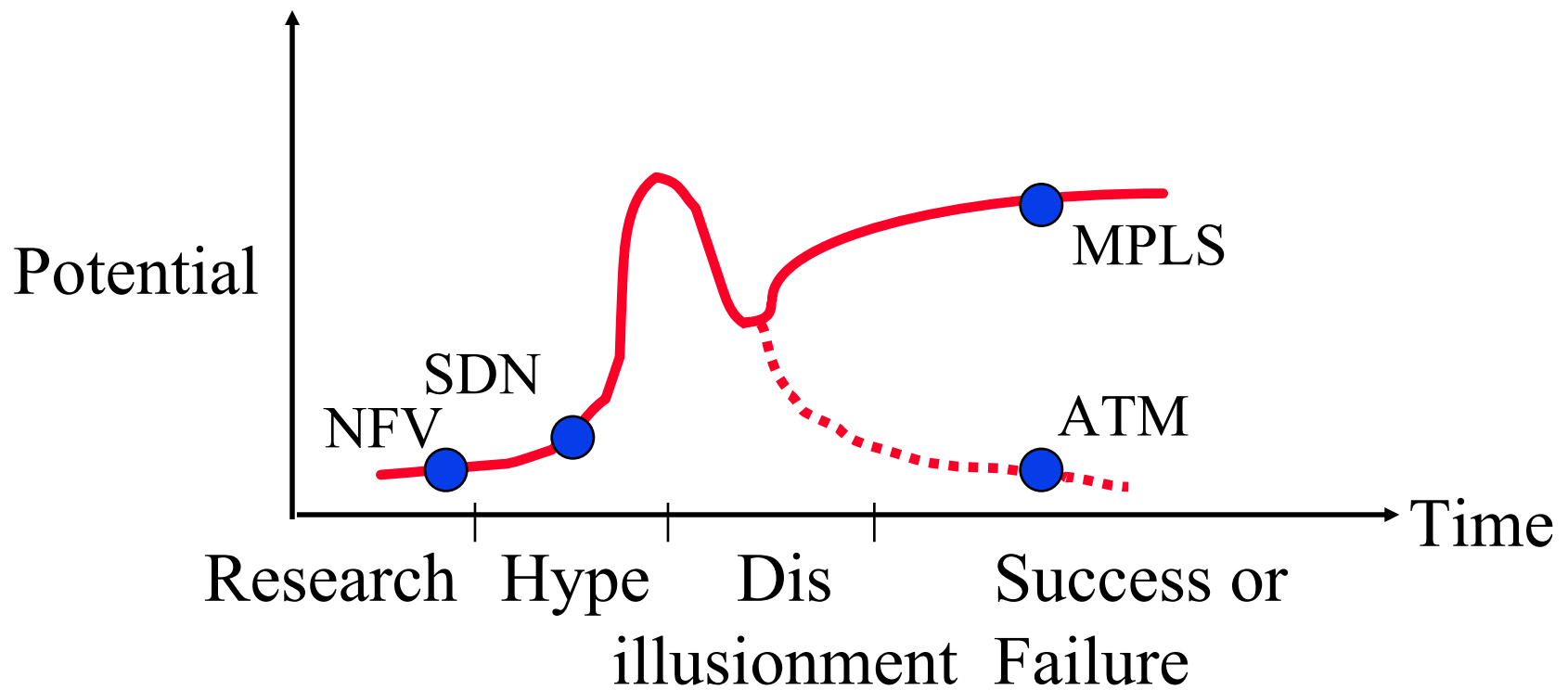
Before

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After

Life Cycles of Technologies

Potential

SDN

NFV

MPLS

ATM

Time

Research   Hype   Dis
                    illusionment

Success or
Failure

Industry Growth: Formula for Success

Innovators
⇒ Startups
⇒ Technology Differentiation
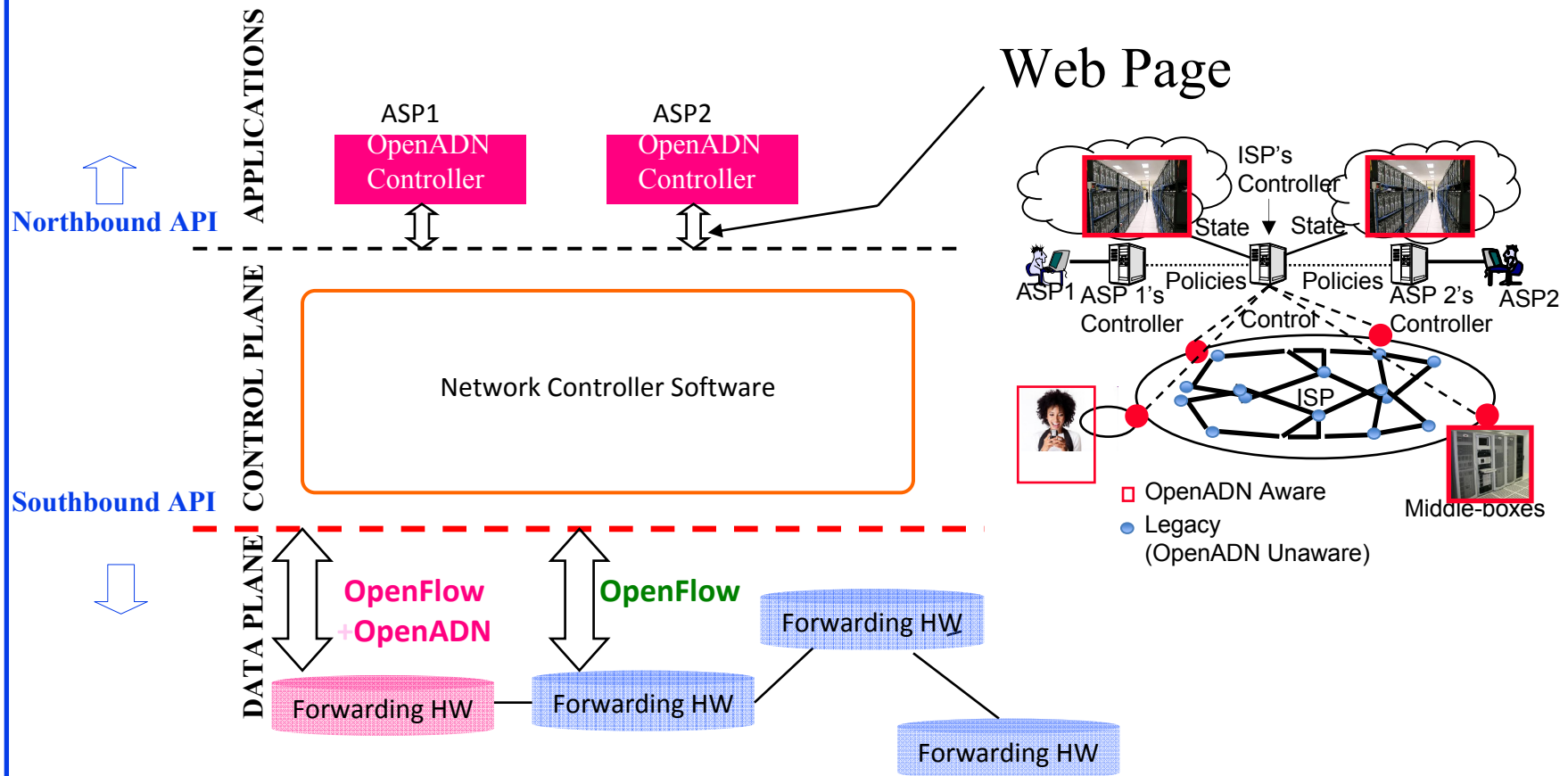
Big Companies Manufacturing
⇒ Price differentiation

Number of Companies

New Entrants | Consolidation | Stable Growth

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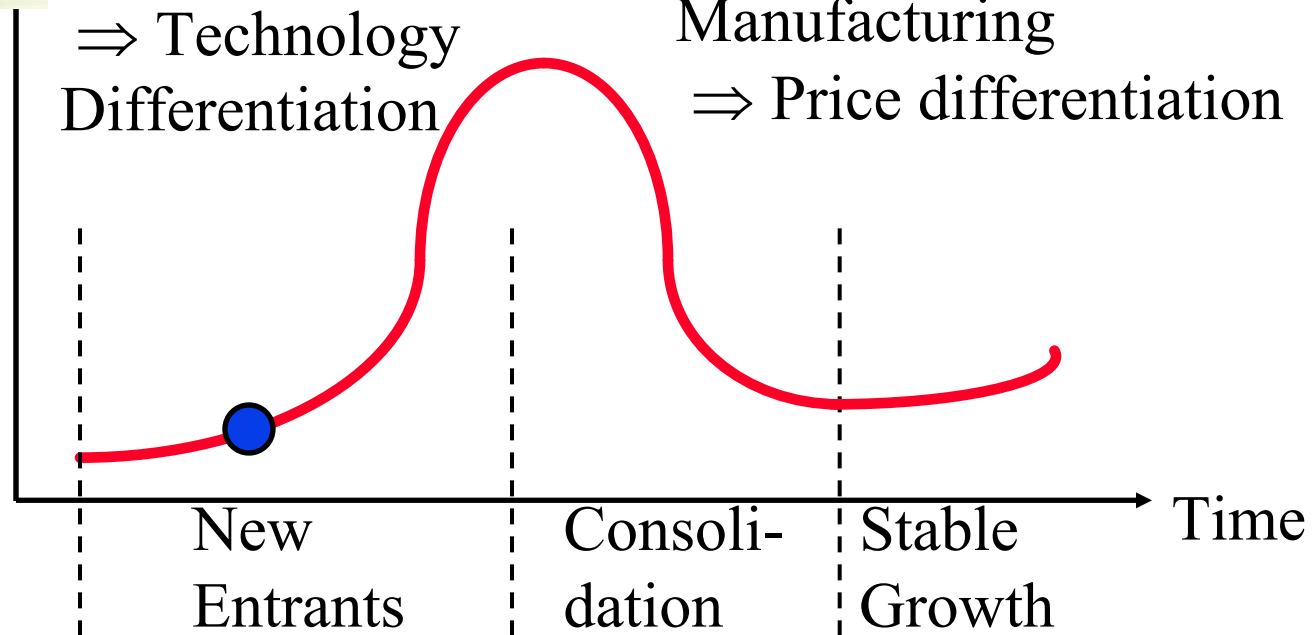
- ❑ Paradigm Shifts ⇒ Leadership Shift
- ❑ Old market leaders stick to old paradigm and loose
- ❑ Mini Computers→PC, Phone→Smart Phone, PC→Smart Phone

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OpenADN in SDN's Layered Abstractions

Web Page

APPLICATIONS

ASP1
OpenADN
Controller

ASP2
OpenADN
Controller

Northbound API

CONTROL PLANE

Network Controller Software

Southbound API

DATA PLANE

OpenFlow
+OpenADN

OpenFlow

Forwarding HW

Forwarding HW

Forwarding HW

Forwarding HW

ISP's
Controller
State   State

ASP1 ASP 1's   Policies Policies ASP 2's ASP2
Controller   Control   Controller

ISP

□ OpenADN Aware

Middle-boxes

● Legacy
(OpenADN Unaware)

❑ SDN provides standardized mechanisms for distribution of control information

❑ OpenADN aware devices use enhanced OpenFlow

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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.**

SDN and NFV in NKN

❏ National Knowledge Network should incorporate SDN and NFV components ⇒ Reduced cost, improved capacity, manageability, reliability, and fault tolerance

❏ Can be used inside institutions (data centers) or between institutions

❏ Can be used to dynamically control the utilization of core links Ease of management, fault tolerance, reliability, performance, cost

10Gb Links
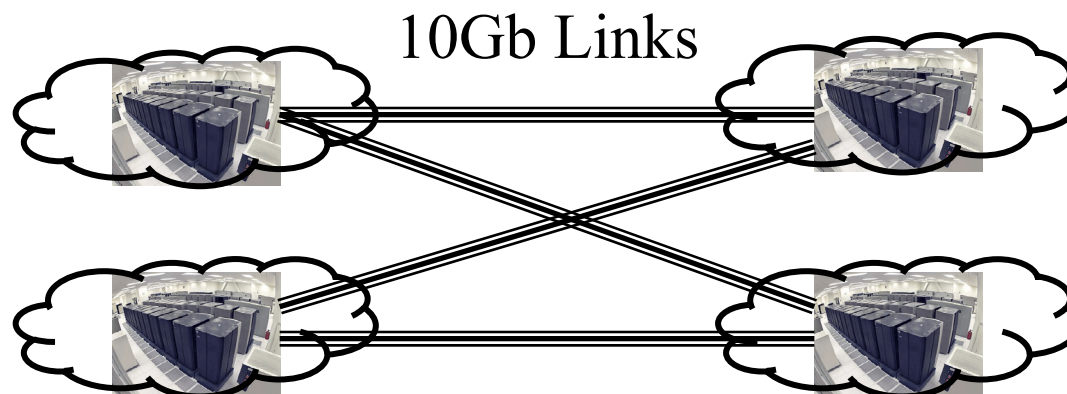
Rural Access

❑ Satellites: GEOs at 35,000 km
   Large antennas or low bandwidth ⇒ Not a solution

Balloons

- Google's Loon Project: June 2013
  30 balloons at 20 km height
  Canterbury, New Zealand
  Solar powered|

- Tethered balloons used in Afghanistan

- Good for disaster response

- May connect direct via WiFi or via relays on houses

Unmanned Aerial Vehicles (UAVs)

❑ Also known as Drones

❑ For experiments and research, several toy drones available for under $750
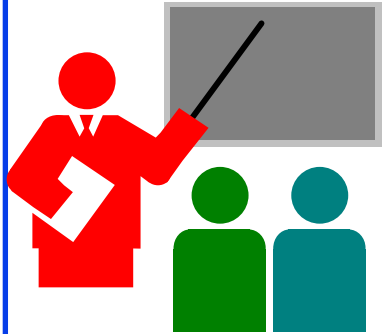

Nitroplanes.com $99

helipal.com $679   brookstone.com $300

Radioshack.com $300

Summary

1. Centralization of Control plane + Standardization of Southbound, Northbound, and East-west APIs $\Rightarrow$ Software Defined Networking (SDN)

2. NFV will allow large scale deployment of networking devices using standard hardware.

3. OpenADN enables delivery of applications using Northbound SDN API

4. New approaches to rural access via balloons and UAVs