Current Trends in Internet Evolution and a Framework for Application Delivery

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These slides and audio/video recordings of this talk are available on-line at:

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

1. Current trends in networking
2. Our research on next generation: open ADN
3. Software Defined Networks

Why to worry about Future Internet?

Billion dollar question!

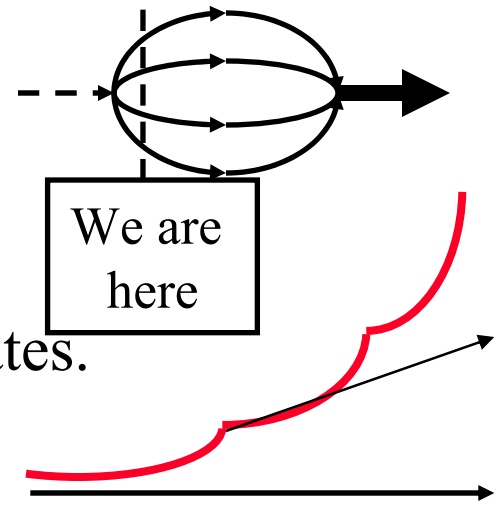
2012: Where are we now?

- At the knee of Mobile Internet age (paradigm shift)
  - Computing (IBM 360) ⇒ Mini-computing (PDP11) ⇒ Personal Computing (Desktop, PC+MAC) ⇒ Laptops ⇒ Netbooks ⇒ Smart Phones + Tablets
- Most valued companies in the stock market are generally those that lead the paradigm shift
  - Automotive (General Motors) ⇒ Electrical (GE, Edison Electric) ⇒ Networking (Cisco + 3Com in 80's) ⇒ Internet (Netscape + Yahoo in 90's) ⇒ Mobile Internet (Apple +MS+ Google, 2010's)
- Note: Apple ≠ PC (MAC) company (mobile device company)
  - Google ≠ search engine (mobile device company)
- Also Social Networking (Facebook), Internet Retail (Amazon)

5 Future Predictors

1. **Miniaturization**: Campus ⇒ Datacenter ⇒ Desktop ⇒ Laptop ⇒ Pocket ⇒ Multi-functional Pocket device
2. **Mobility**: Static ⇒ Mobile (1 km/hr) ⇒ Mobile (100 km/hr) ⇒ Mobile (600 km/hr)
3. **Distance**: PAN (5m) ⇒ LAN (500 m) ⇒ MAN (50 km) ⇒ WAN (500 km)
4. **Applications:** Defense ⇒ Industry ⇒ Personal
5. **Social Needs**: Energy, Environment, Health, Security

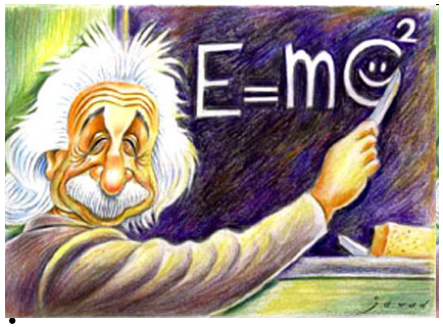
- Broadening and Aggregation: Research ⇒ Many Solutions ⇒ One Standard ⇒ General Public adoption, e.g., Ethernet
- Non-Linearity: Progress is not linear. It is exponential and bursty.
  Most predictions are linear ⇒ underestimates.



Trend: Moore's Law

- Computing Hardware is cheap
- Memory is plenty

⇒ Storage and computing (Intelligence) in the net



- Energy ⟷ Matter
- Space ⟷ Time
- Communication in Space ⟷ Communication in Time

Rural India

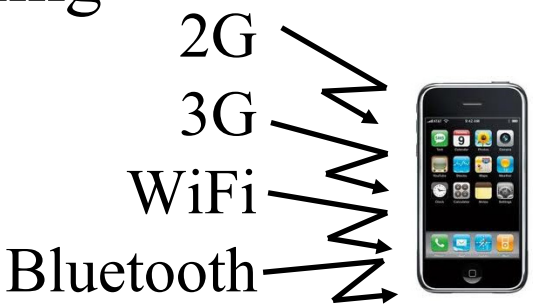
- Link
- Storage (USB, Caching,…)

Next Gen nets will use storage in networks, e.g., DTN, CCN

Trend: Multihoming + Mobility

- Centralized storage of info
- Anytime Anywhere computing
- Dynamically changing Locator
- User/Data/Host/Site/AS Multihoming
- User/Data/Host/Site Mobility

⇒ **ID/Locator Split**



Mobile Telephony already distinguishes ID vs. Locator
We need to bring this technology to IP.

Trend: Profusion of Services

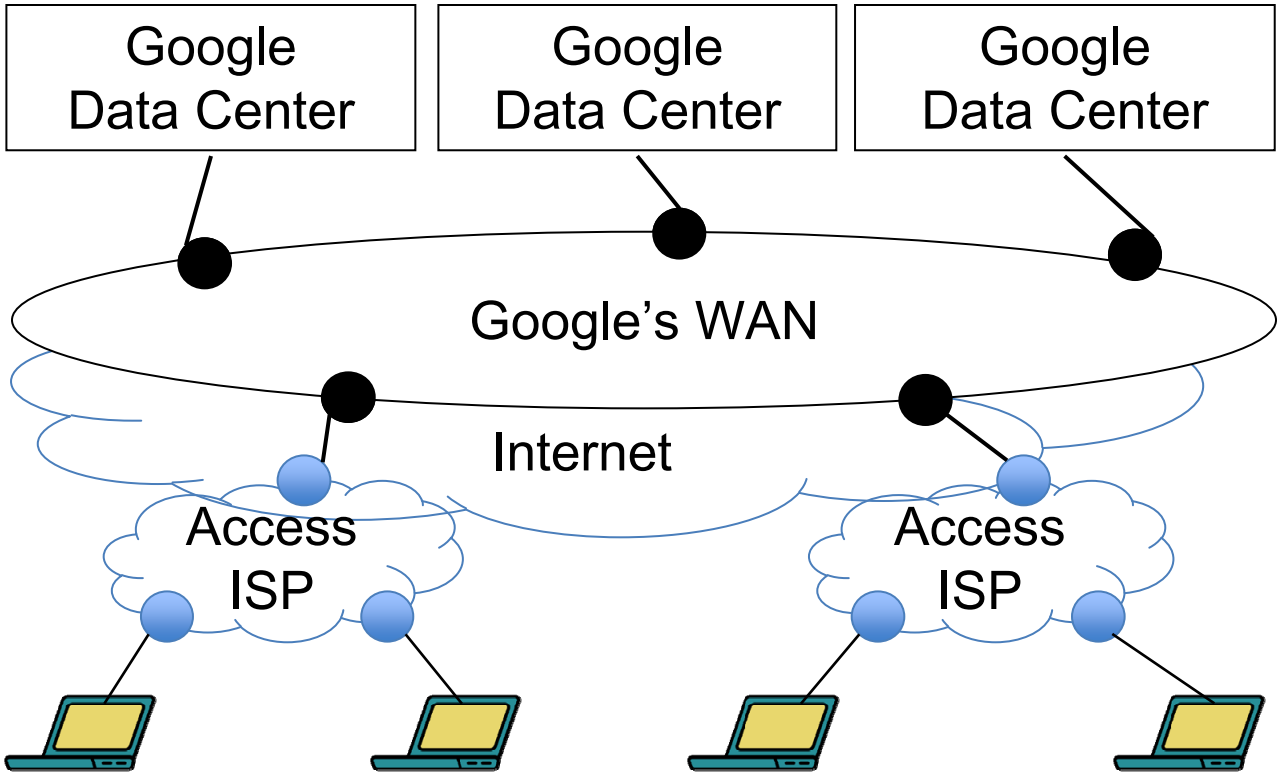
- Almost all top 50 Internet sites are services [Alexa]
- Smart Phones: iPhone, Android Apps
  ⇒ New globally distributed services, Games, …
  ⇒ More clouds, …

Networks need to support efficient service setup and delivery

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

Private Smart WANs

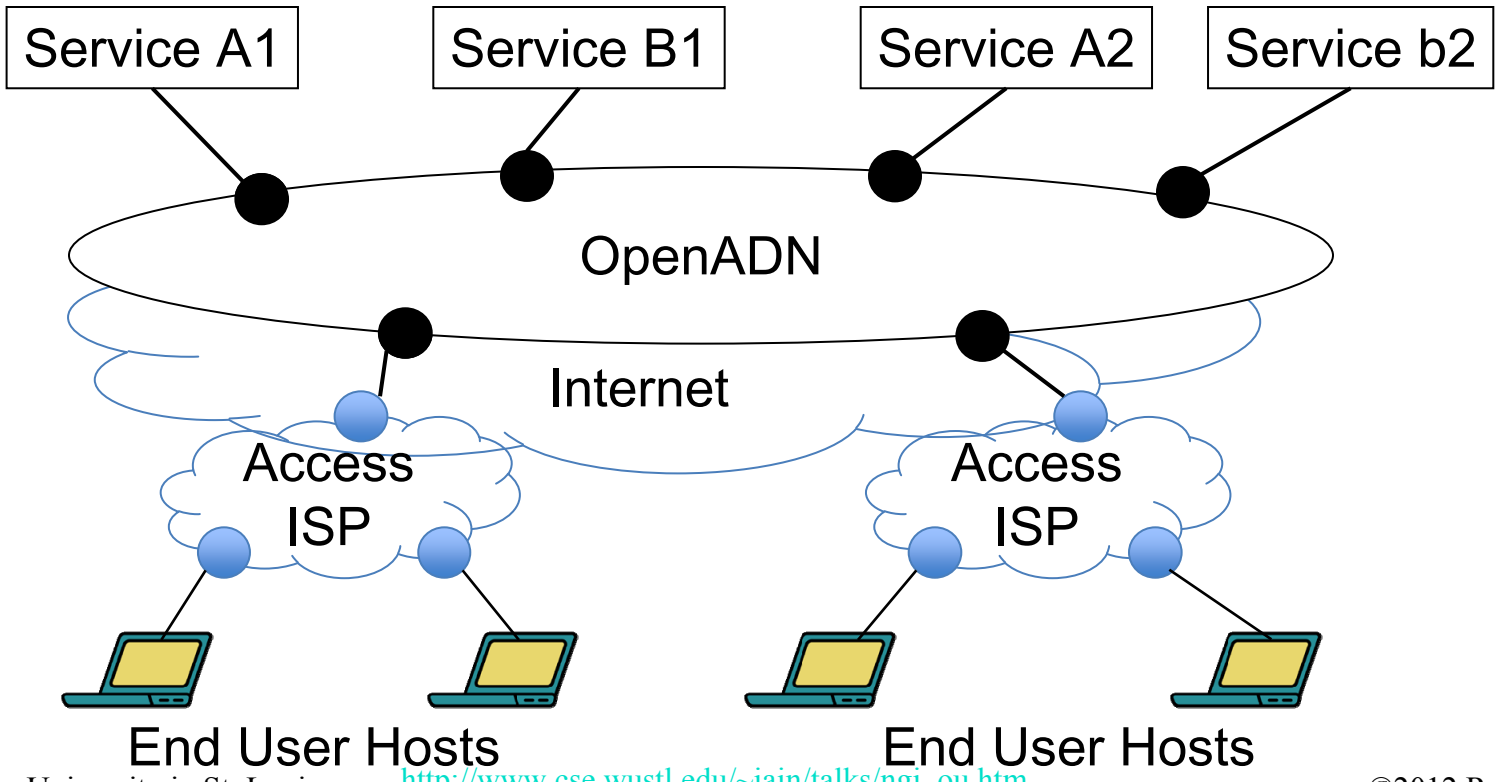
- Services totally avoid the Internet core ⇒ Many private WANs
- Google WAN, Akamai ⇒ Rules about how to connect users



Opportunity for ISPs to offer these types of WAN services

OpenADN

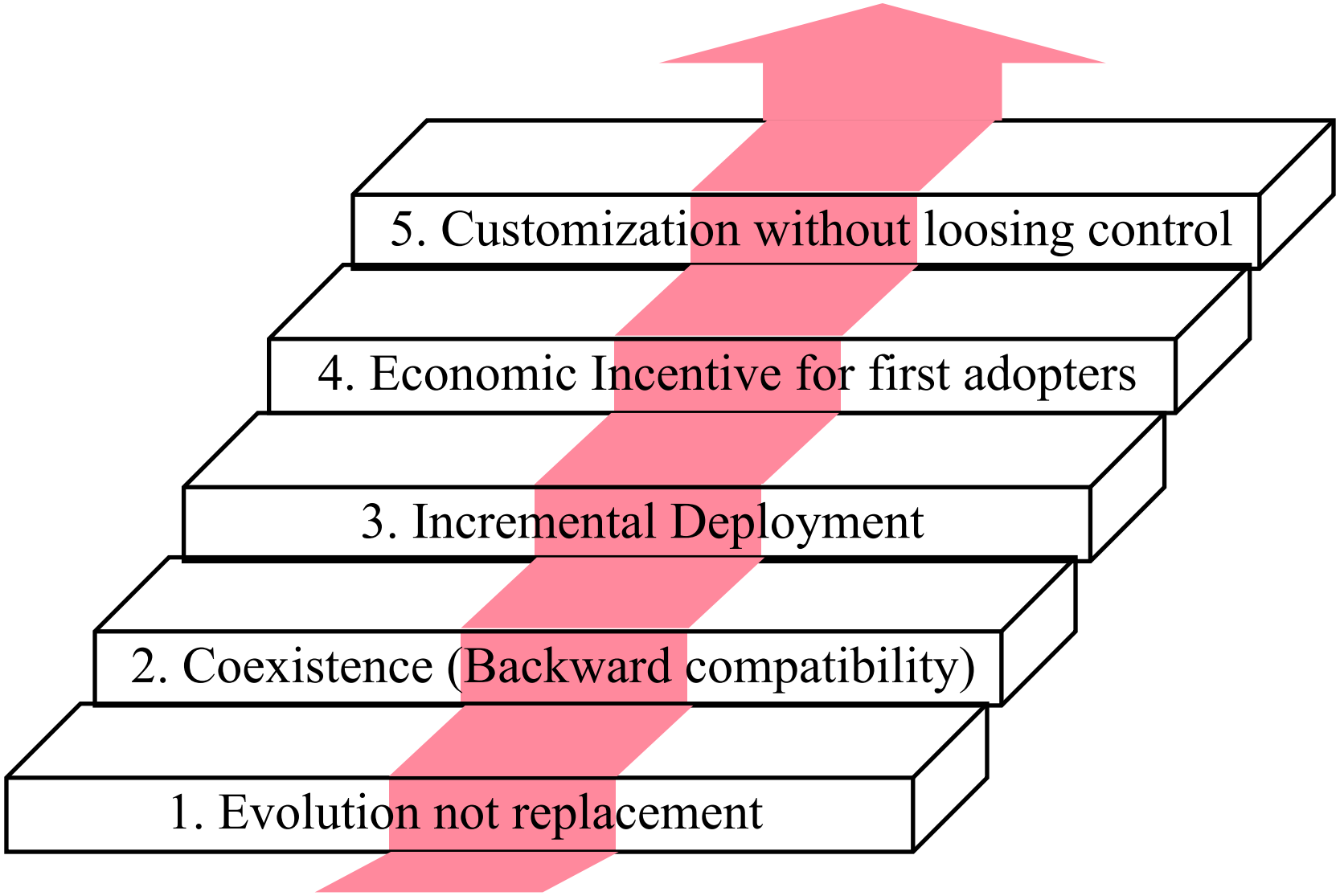
- High-Speed WAN for Application Service Delivery.
- Allows ASPs to quickly setup services



Ten Key Features that Services Need

1. **Replication**: Multiple datacenters appear as one
2. **Fault Tolerance**: Connect to B if A is down
3. **Load Balancing**: 50% to A, 50% to B
4. **Traffic Engineering**: 80% on Path A, 20% on Path B
5. **Flow based forwarding**: Movies, Storage Backup, …
   ATMoMPLS, TDMoMPLS, FRoMPLS, EoMPLS, …
   Packets in Access, Flows in Core
6. **Security**: Provenance, Authentication, Privacy, ...
7. **User Mobility**: Gaming/Video/… should not stop as the user moves
8. **Service composition**: Services using other services
9. **Customization**: Every service has different needs
10. **Dynamic Setup** ⇒ Networking as a Service

Five Arch Design Principles for Success



Networking: Failures vs Successes

- 1986: MAP/TOP (vs Ethernet)
- 1988: OSI (vs TCP/IP)
- 1991: DQDB
- 1994: CMIP (vs SNMP)
- 1995: FDDI (vs Ethernet)
- 1996: 100BASE-VG or AnyLan (vs Ethernet)
- 1997: ATM to Desktop (vs Ethernet)
- 1998: ATM Switches (vs IP routers)
- 1998: MPOA (vs MPLS)
- 1999: Token Rings (vs Ethernet)
- 2003: HomeRF (vs WiFi)
- 2007: Resilient Packet Ring (vs Carrier Ethernet)
- IntServ, DiffServ, …

Technology alone does not mean success.

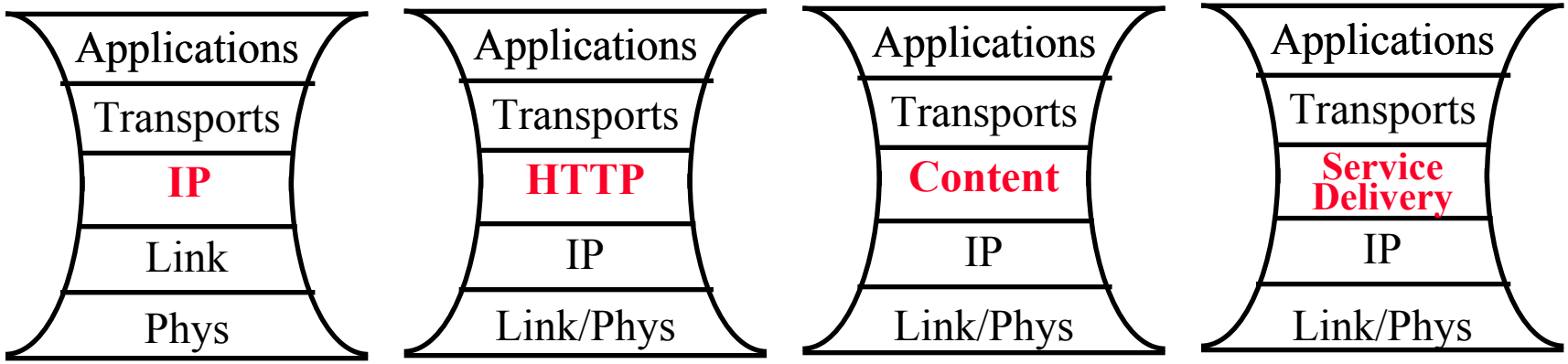
Key Features of openADN

1. Edge devices only.
   Core network can be current TCP/IP based or future SDN based
2. Coexistence (Backward compatibility): Old on New. New on Old
3. Incremental Deployment
4. Economic Incentive for first adopters

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

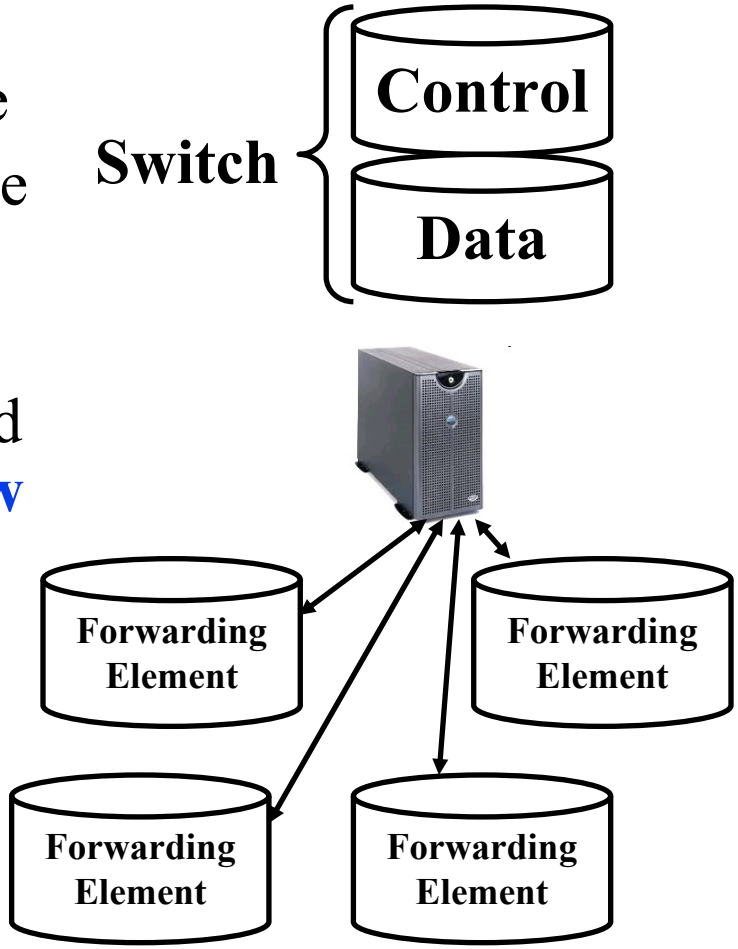
The Narrow Waist

- Everything as a service over service delivery narrow waist
- IP, HTTP, Content, Service delivery, …



Trend: Separation of Control and Data Planes

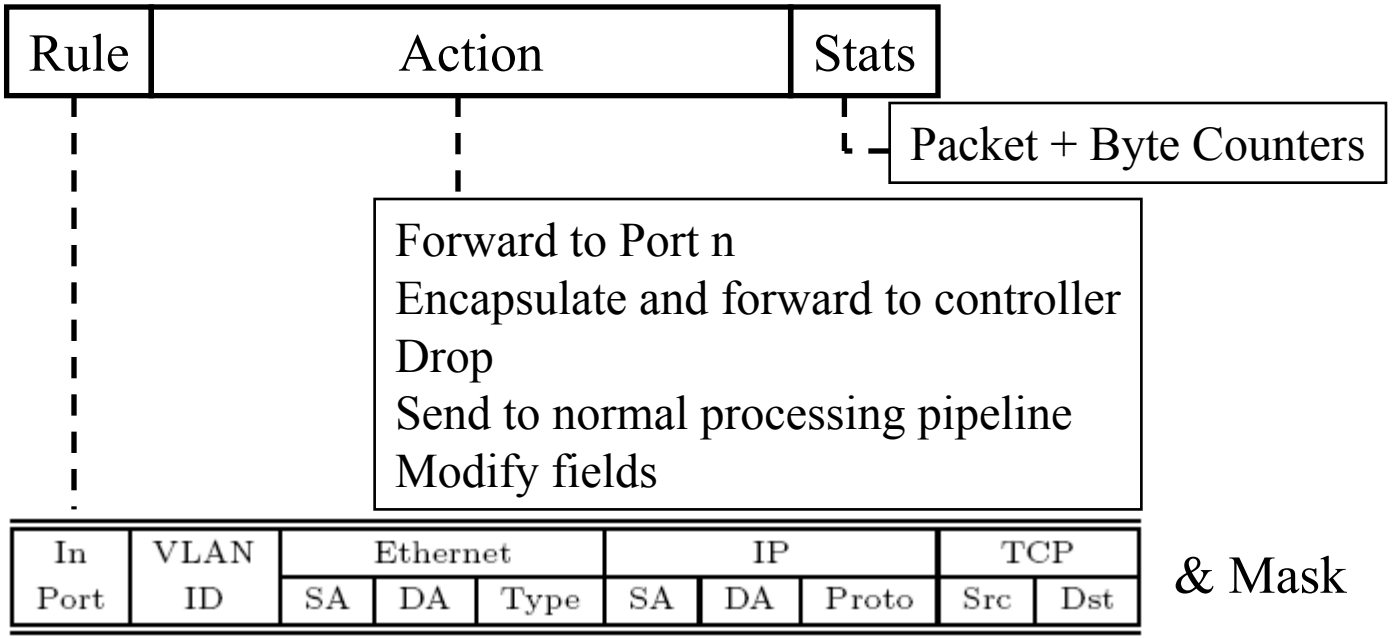
- Control = Prepare forwarding table
- Data Plane: Forward using the table
- Forwarding table is prepared by a central controller
- Protocol between the controller and the forwarding element: **OpenFlow**
- Centralized control of policies
- Switches are simple.
  Controller can be complex
  Can use powerful CPUs
- Lots of cheap switches
  = Good for large datacenters



Ref: [MCK08] ``OpenFlow: Enabling Innovation in Campus Networks," OpenFlow Whitepaper, March 2008
http://www.openflow.org/documents/openflow-wp-latest.pdf

OpenFlow (Cont)

- Three Components:
  - Flow table: How to identify and process a flow
  - Secure Channel: Between controller and the switch
  - Open Flow Protocol: Standard way for a controller to communicate with a switch



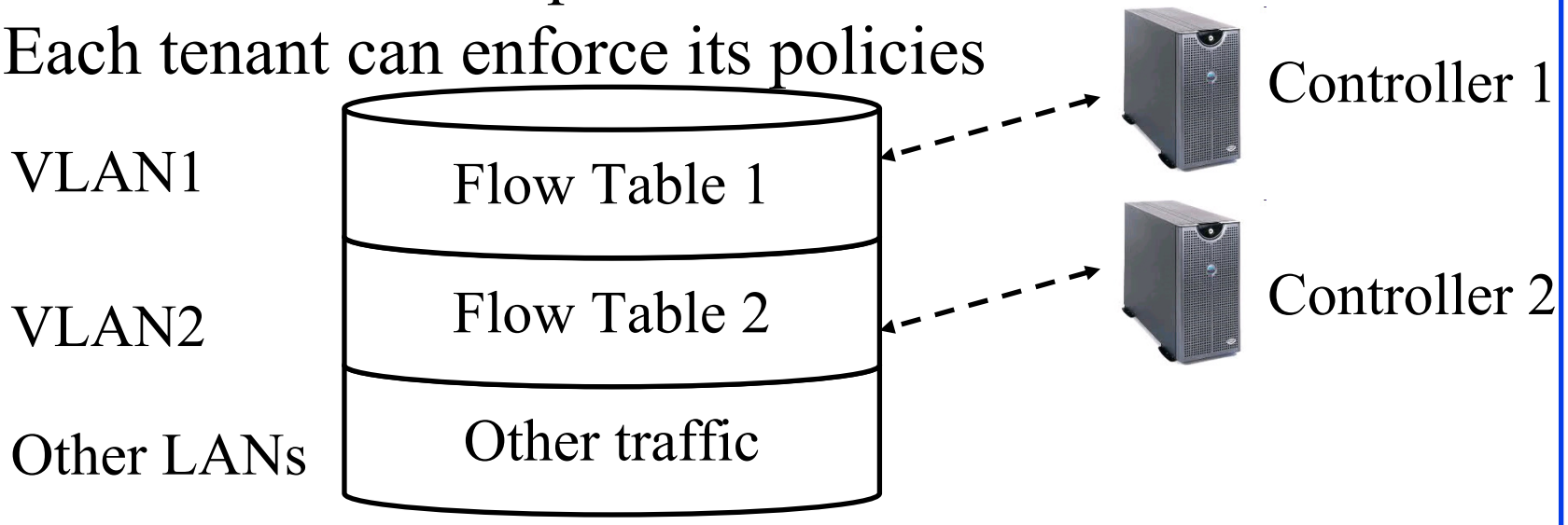
OpenFlow (Cont)

- Controller forwards the packets correctly as the mobile clients move
- Reference designs for Linux, Access points (OpenWRT), and NetFPGA (hardware)
- Allows both proactive (flow tables loaded before hand) and reactive (Flow entries loaded on demand)
- Allows wild card entries for aggregated flows
- Multiple controllers to avoid single point of failure: Rule Partitioning, Authority Partitioning
- Open Networking Foundation announced Open Switch Specification V1.2 on Jan 29, 2012: Includes IPv6 and experimenter extensions.

Ref: [MCK08], OpenFlow.org, OpenNetworking.org

Trend: Software Defined Networks

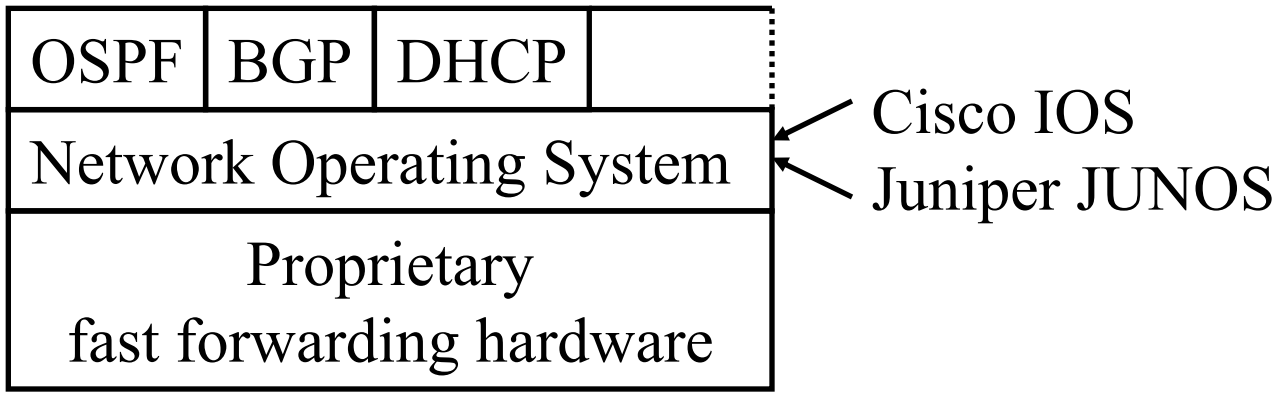
- Problem: Multiple tenants in the datacenter
- Solution: Use multiple controllers.
  Each tenant can enforce its policies



- Significant industry interest ⇒ Open Networking Foundation, https://www.opennetworking.org/

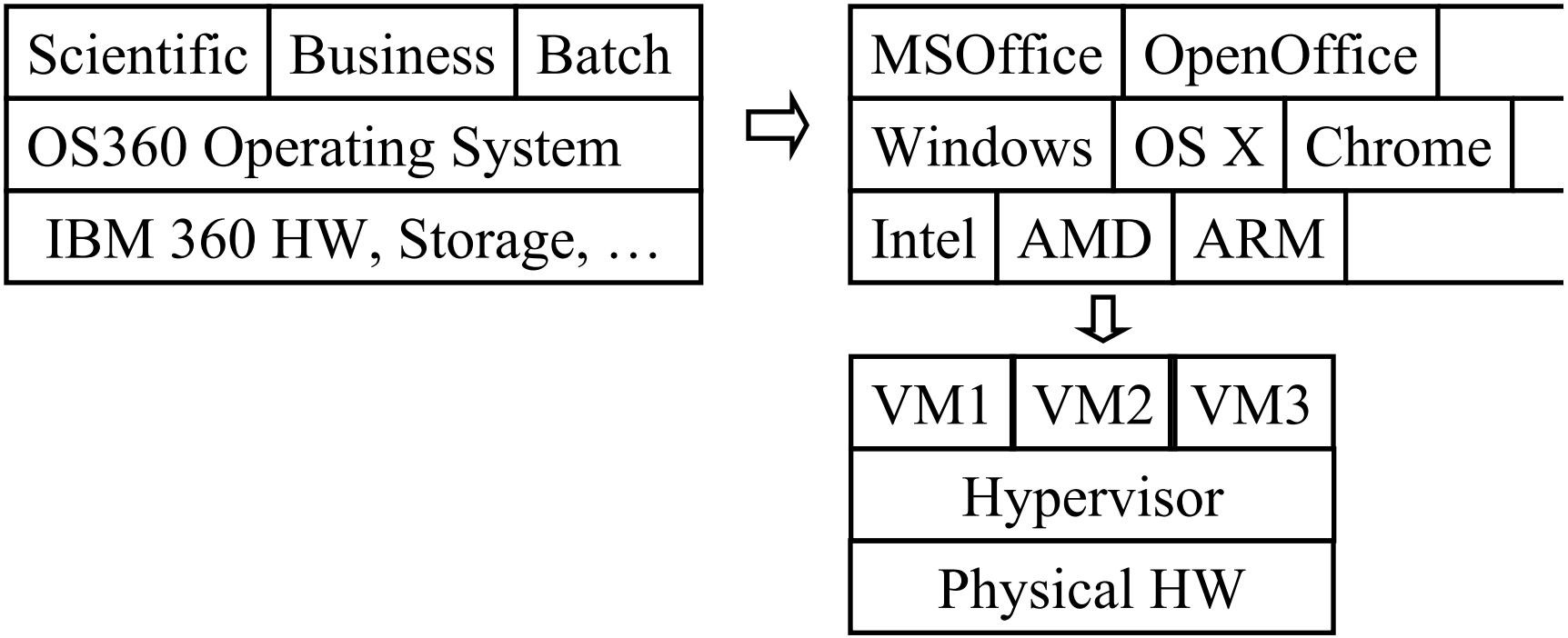
Problem: Complex Routers

- The routers are expensive because there is no standard implementation.
- Every vendor has its own hardware, operating/ management system, and proprietary protocol implementations.
- Similar to Mainframe era computers.
  No cross platform operating systems (e.g., Windows) or cross platform applications (java programs).

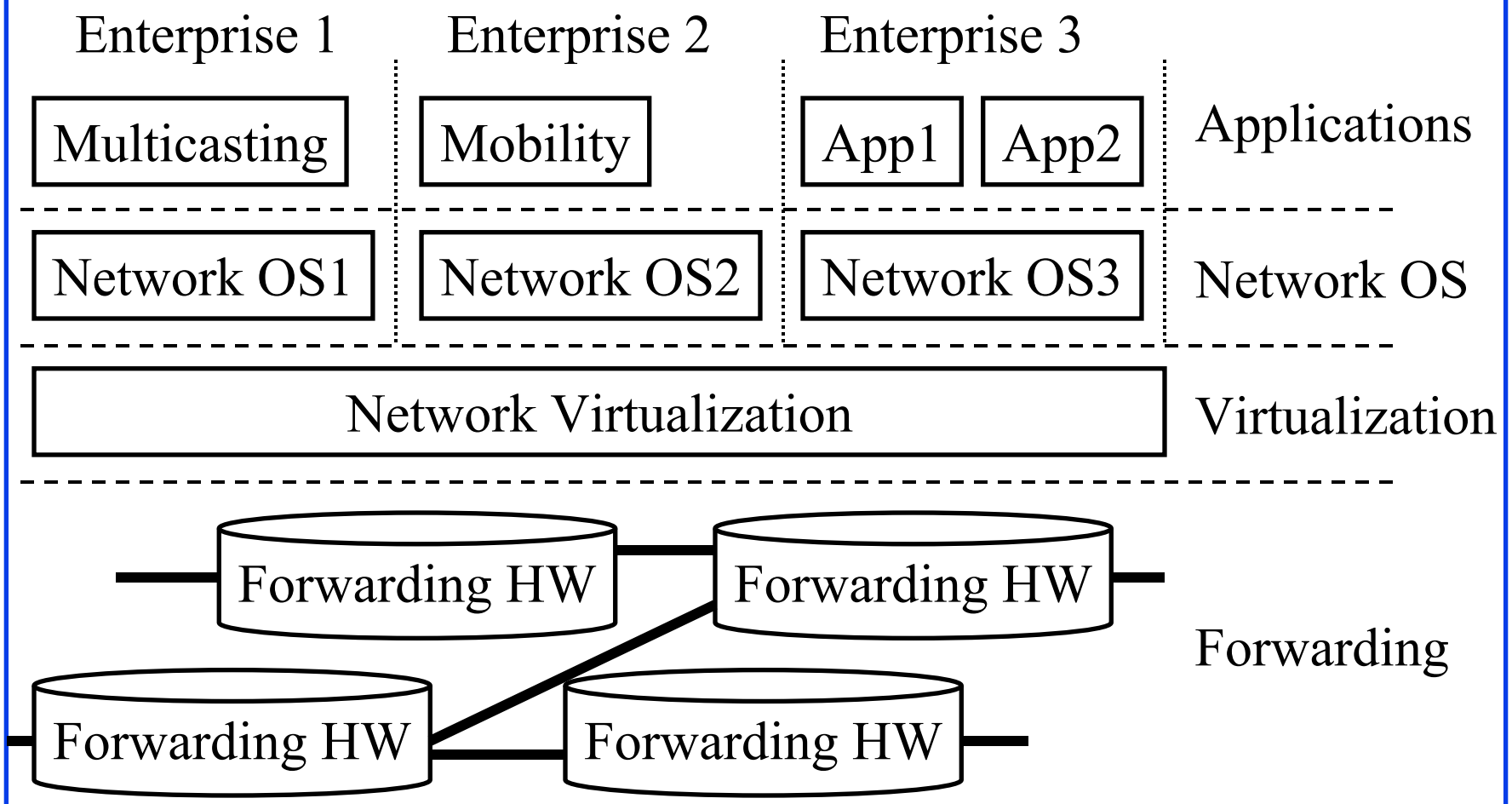


Solution: Divide, Simplify and Standardize

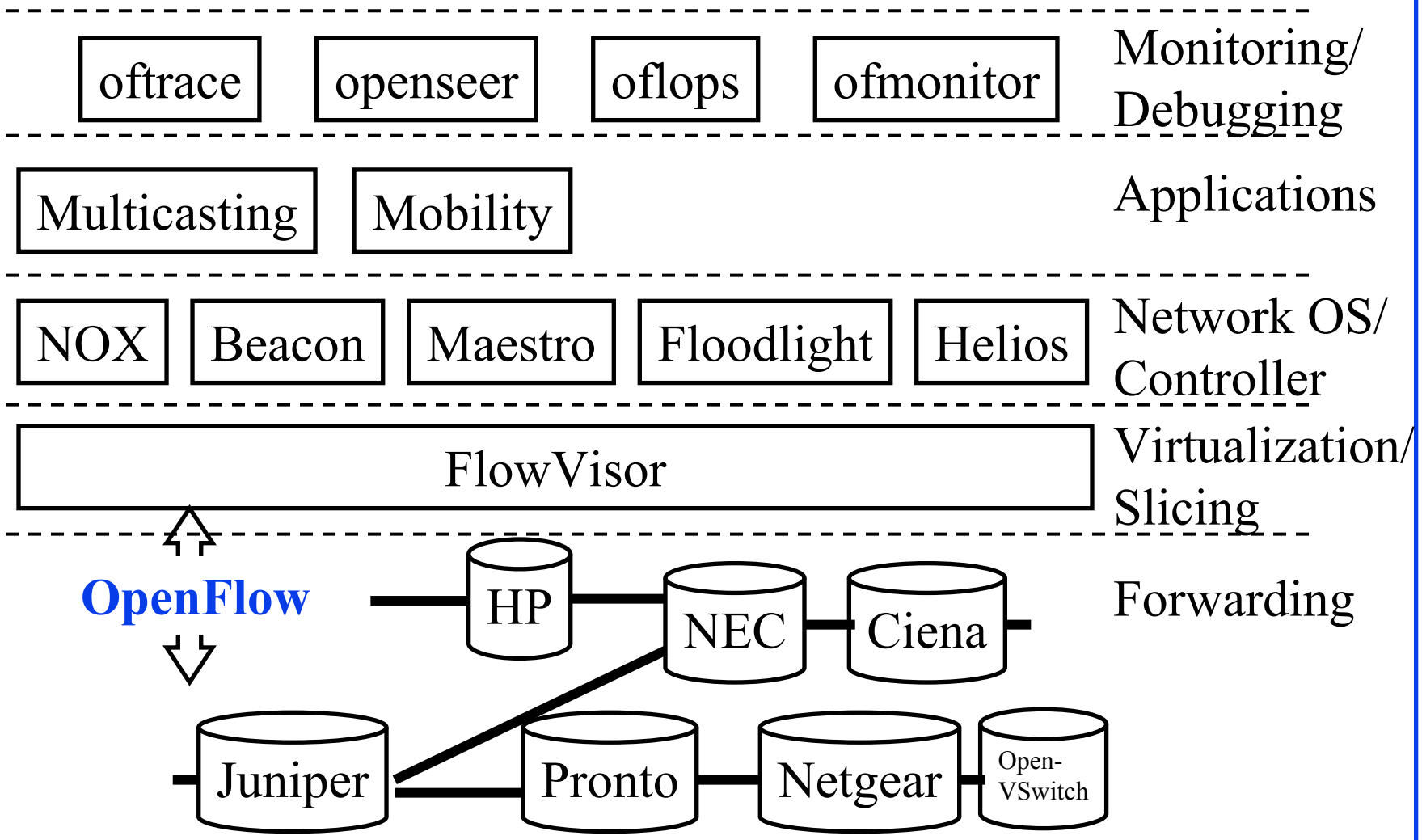
- Computing became cheaper because of clear division of hardware, operating system, and application boundaries with well defined APIs between them
- Virtualization ⇒ simple management + multi-tenant isolation



Multi-Tenant SDN Architecture



SDN Architecture Component Examples

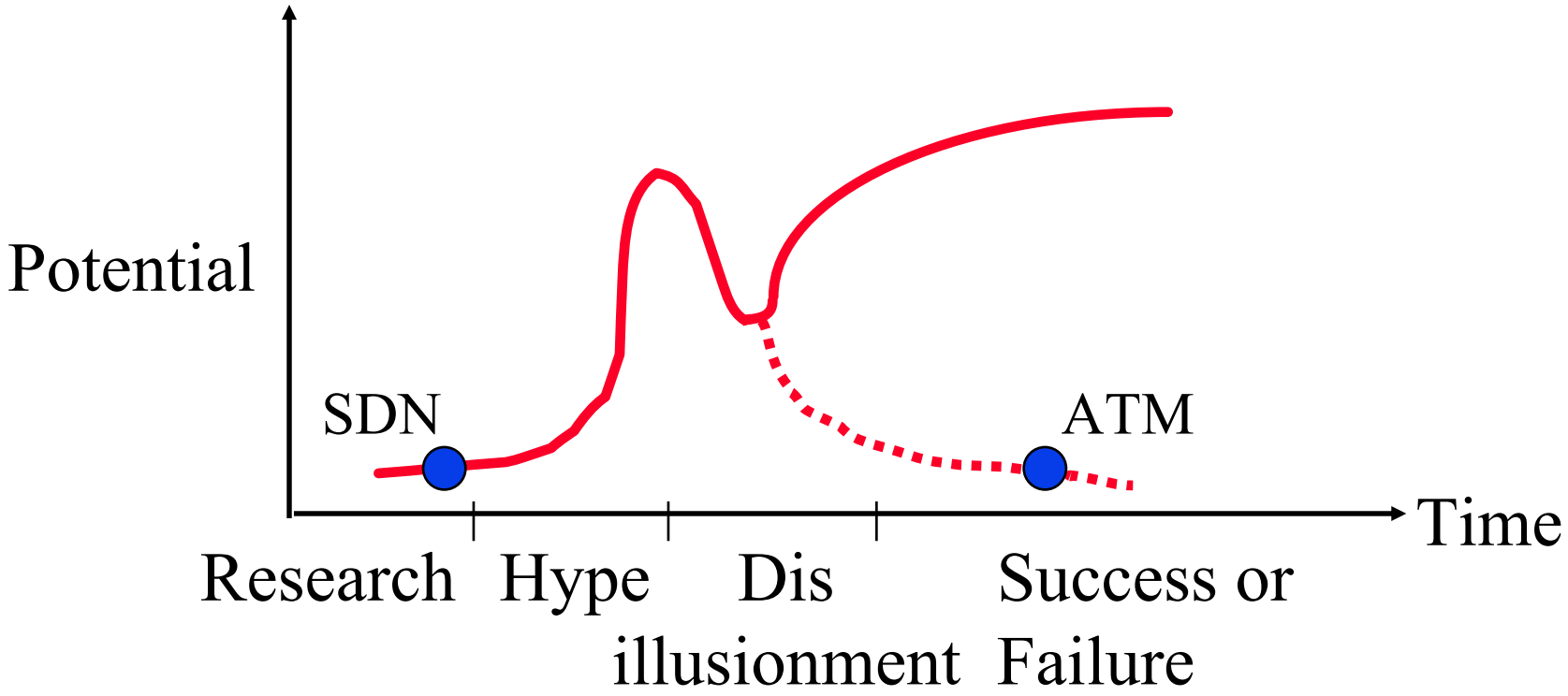


Ref: https://courses.soe.ucsc.edu/courses/cmpe259/Fall11/01/pages/lectures/srini-sdn.pdf

SDN Impact

- Why so much industry interest?
  - Commodity hardware
    ⇒ Lots of cheap forwarding engines ⇒ Low cost
  - Programmability ⇒ Customization
  - Sharing with Isolation ⇒ Networking utility
  - Those who buy routers, e.g., Google, Amazon, Docomo, DT will benefit significantly
- Opens up ways for new innovations
  - Dynamic topology control: Turn switches on/off depending upon the load and traffic locality
    ⇒"Energy proportional networking"

Life Cycles of Technologies



Industry Growth: Formula for Success

Innovators
⇒ Startups
⇒ Technology Differentiation

Big Companies
Manufacturing
⇒ Price differentiation

Number of Companies

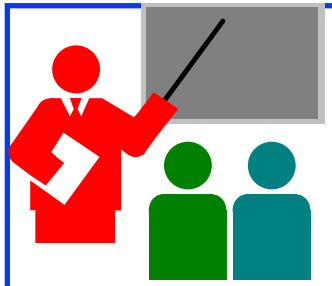
New Entrants

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



Summary

1. Peak of **mobile internet** paradigm shift
2. Miniaturization, Mobility, Distance, Applications, Social needs help predict the future
3. Profusion of **multi cloud-based applications** on the Internet. Application services need replication, fault tolerance, traffic engineering, security, …
4. **OpenADN** provides these features in a multi-cloud environment with backward compatibility, incremental deployment
5. Trend is towards simplifying and standardizing router interfaces ⇒ Software defined networking

Application Delivery: Opportunity for ISP's