Next Generation Internet: Architectures for Future Internet Evolution

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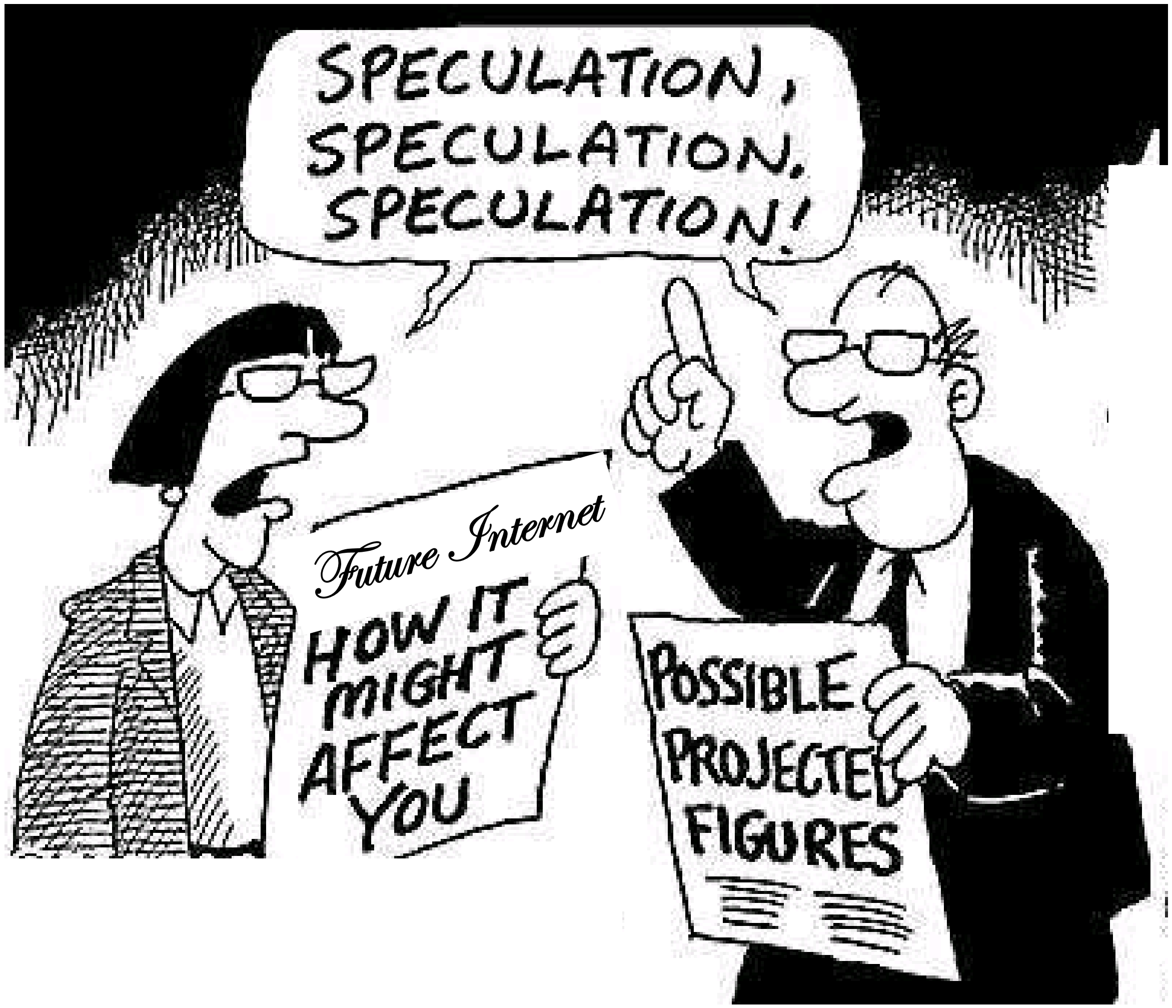
http://www.cse.wustl.edu/~jain/talks/icc12.htm

⚠ Warning



SPECULATION, SPECULATION, SPECULATION!
Future Internet
HOW IT MIGHT AFFECT YOU
POSSIBLE PROJECTED FIGURES

1. Future Internet Research
2. Current trends in networking
3. Software defined networks
4. Our research on next generation: openADN

Why worry about Future Internet?

Billion dollar question!

History of the Future

- In 2005 US National Science Foundation asked:
  How would you design Internet today? Clean slate design.
  - "Future Internet Design" (FIND): Architecture research
  - "Global Environment for Networking Innovations" (GENI): Testbed
- European Union: 7th Framework program
  Japan, China, Korea, Australia, …20+ countries
- April 2010: Future Internet Architecture (FIA): 4 Extra-Large Projects ⇒ Future Internet Assembly (FIA) in Europe
- Industry: Network Virtualization, Software Defined Networking

Ref: Jianli Pan, Subharthi Paul, and Raj Jain, "**A Survey of Research on Future Internet Architectures**," IEEE Comm. Magazine, Vol. 49, No. 7, July 2011, pp. 26-36, http://www1.cse.wustl.edu/~jain/papers/internet.htm
Future Internet http://en.wikipedia.org/wiki/Future_Internet

Key Problems with Current Internet

1. **Security**: Fundamental architecture design issue. Control +Data intermixed. Security is just one of the policies.

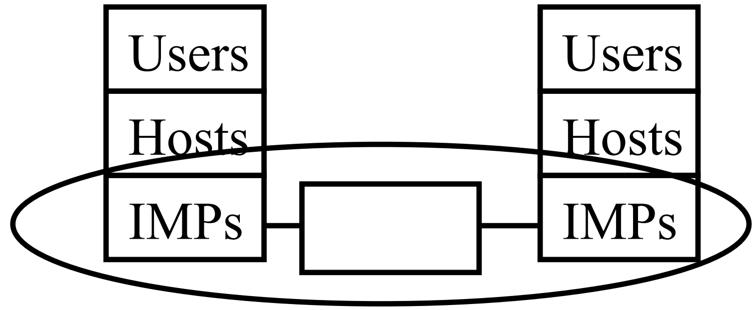
2. **Mobility**: Identity and location in one (IP Address)
   Makes mobility complex.

3. **Energy**: Assumes live and awake end-systems. Does not allow communication while sleeping. Many energy conscious systems today sleep.
4. More…

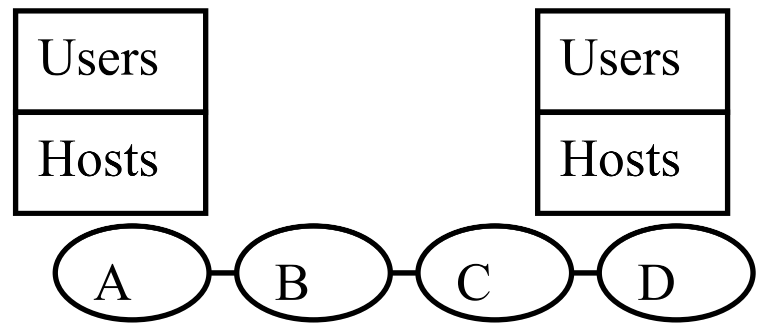
Ref: R. Jain, ``Internet 3.0: Ten Problems with Current Internet Architecture and Solutions for the Next Generation," Proceedings of Military Communications Conference (MILCOM 2006), Washington, DC, October 23-25, 2006

Internet Generations

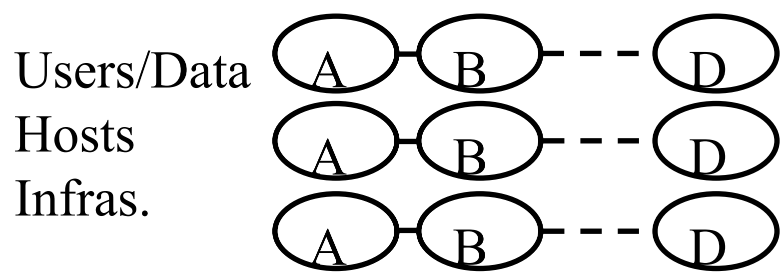
- **Internet 1.0** (1969 – 1989)
  - Single ownership ⇒ Trust
  - complete knowledge
  - Algorithmic optimality ⇒ RIP



- **Internet 2.0** (1989–2009) Commerce
  - Multiple ownership of infrastructure ⇒ Distrust, **Security**
  - No knowledge of internal topology and resources
  - ***Policy based*** routing ⇒ BGP



- **Internet 3.0** (2009–2029) Commerce
  - Users, Content, Host ownership
  - Security, Mobility, Energy
  - Clouds, Services



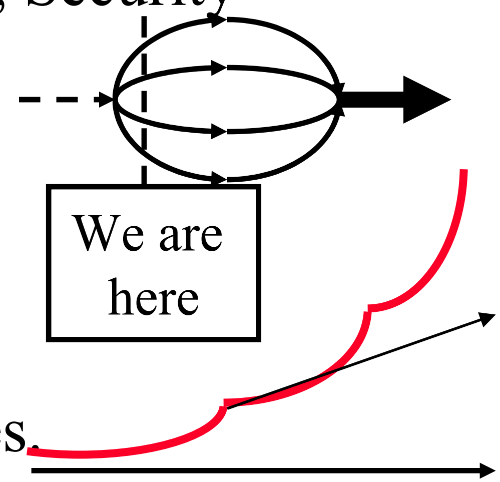
2012: Where are we now?

- 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
    Shift started on June 29, 2007 when iPhone was released.
- 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

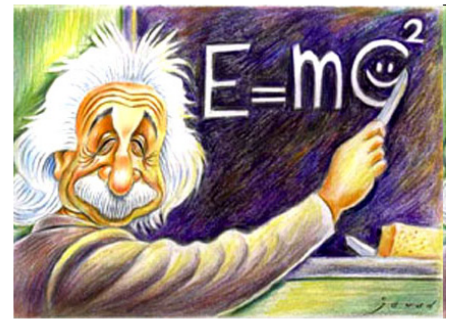
1. **Miniaturization**: Campus ⇒ Datacenter ⇒ Desktop ⇒ Laptop ⇒ Pocket ⇒ Multi-functional Pocket device
2. **Mobility**: Static ⇒ Mobile (1 km/hr) ⇒ Mobile (100 km/hr) ⇒ Mobile (600 km/hr)
3. **Distance**: PAN (5m) ⇒ LAN (500 m) ⇒ MAN (50 km) ⇒ WAN (500 km)
4. **Applications:** Defense ⇒ Industry ⇒ 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 1: Moore's Law

- Faster computers need faster networks
- More storage ⇒ Faster networks



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

Rural India

- Link
- Storage (USB, Caching,…)

Content Distribution may use storage in the edge, e.g., DTN, CCN

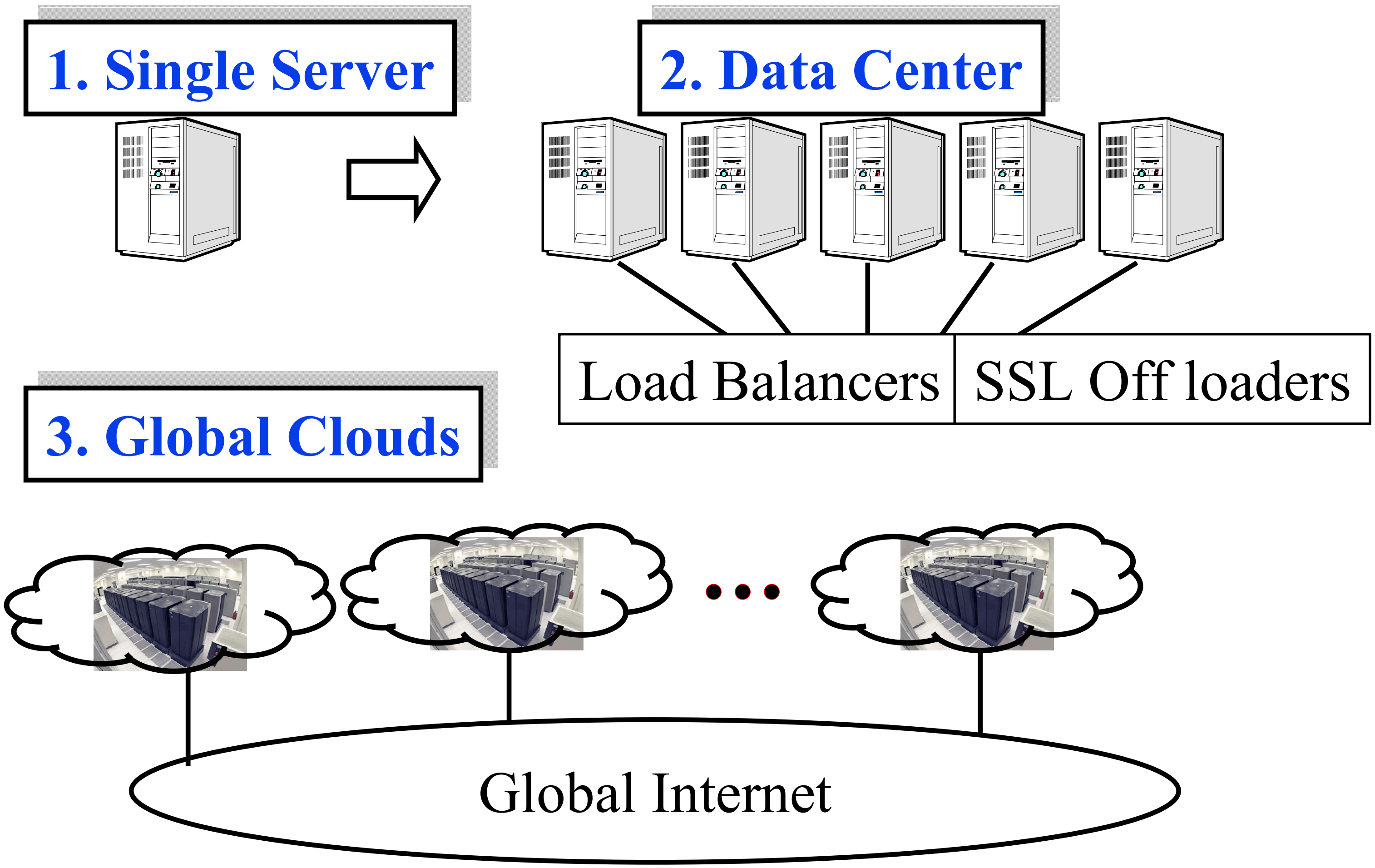
Trend 2: Explosion of Mobile Apps and Clouds

- All top 50 Internet sites are services [Alexa]
- 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)

Networks need to support efficient service setup and delivery

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

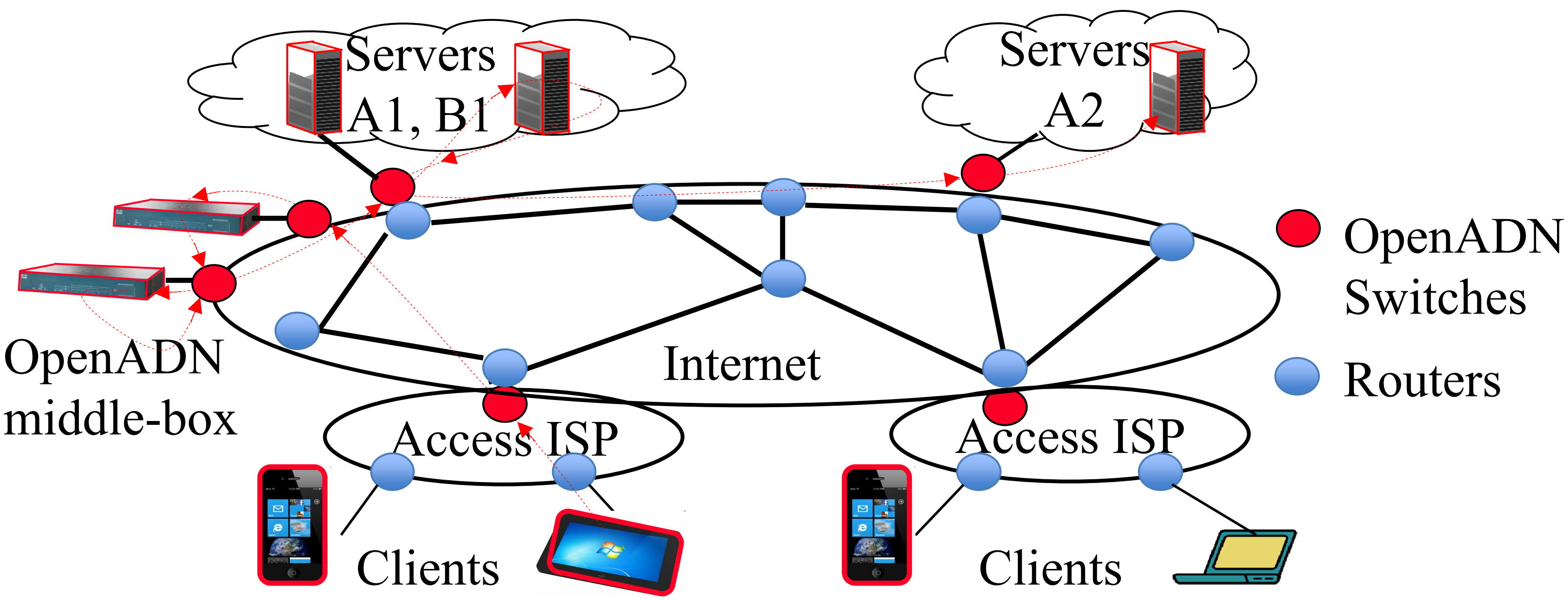
Service Center Evolution



Need to make the global Internet look like a data center

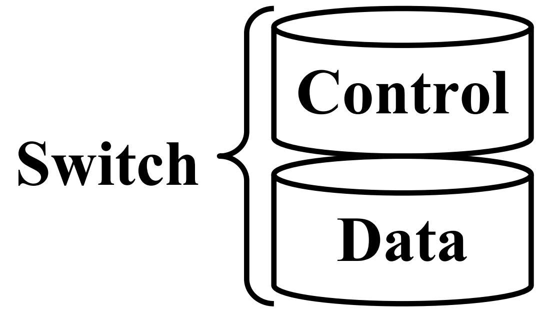
Our Solution: OpenADN

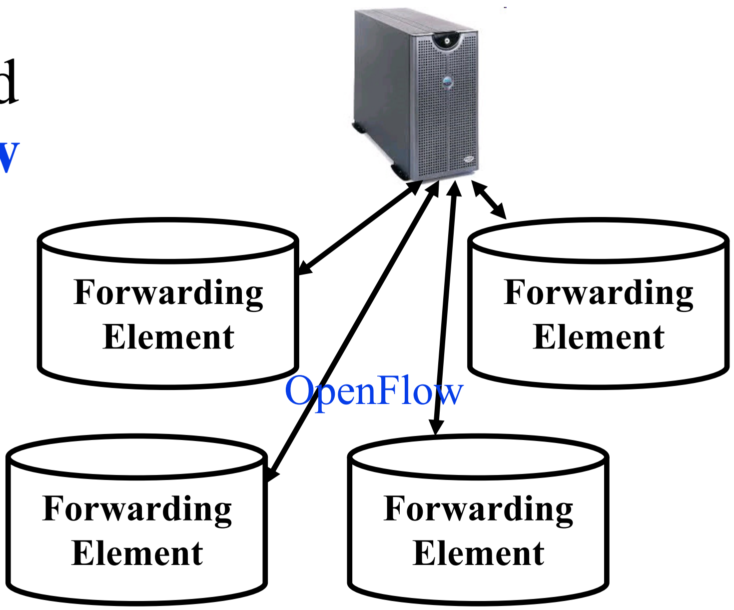
- Open Application Delivery Networking Platform
  Platform = OpenADN aware clients, servers, switches, and middle-boxes
- Allows Application Service Providers (ASPs) to quickly setup services on Internet using cloud computing



Step 1: Separation of Control and Data Planes

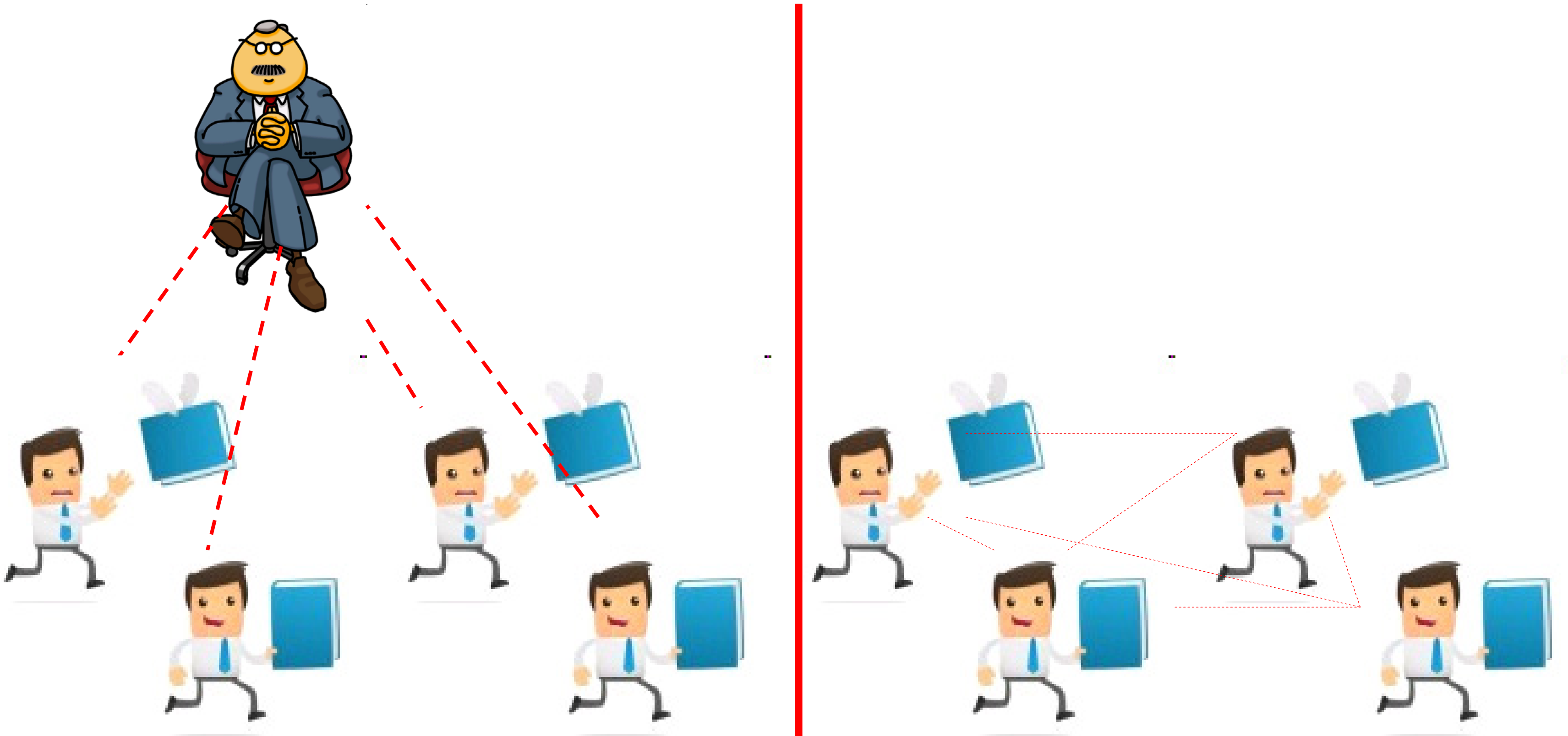
- Control = Prepare forwarding table
- Data Plane: Forward using the table
- Forwarding table is prepared by a central controller
- Protocol between the controller and the forwarding element: **OpenFlow**
- Centralized control of policies
- Switches are simple.
  Controller can be complex
  Can use powerful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

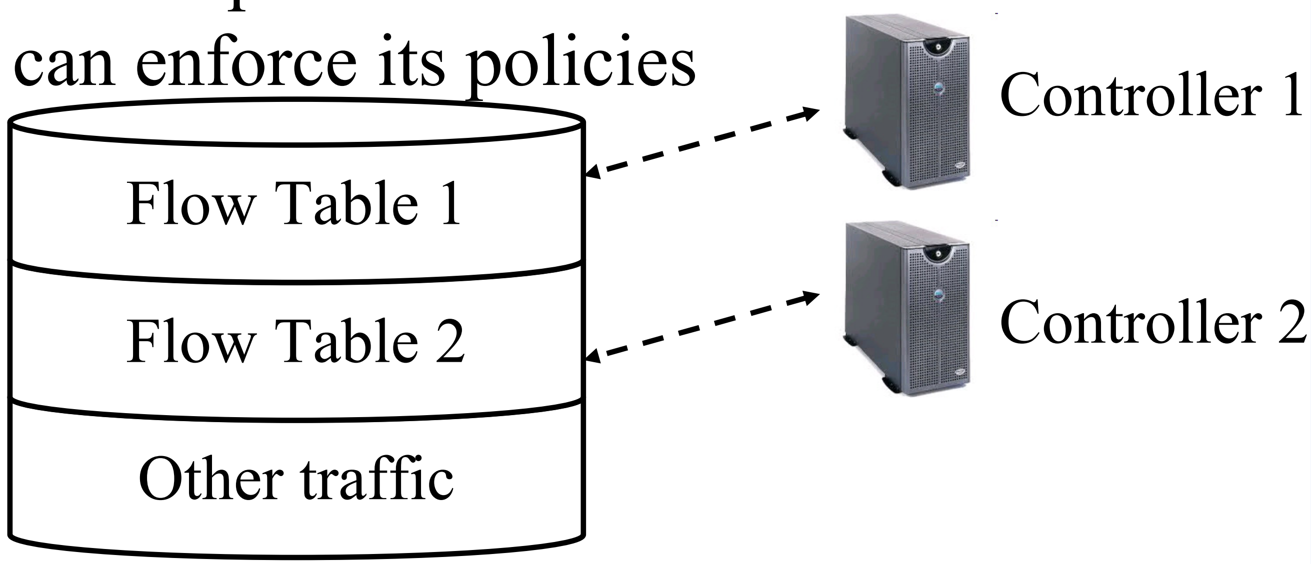
Centralized vs. Distributed



- Fully centralized is not scalable.
  Fully distributed is not manageable.
  ⇒ Hierarchy

Step 2: Multi-Tenants Clouds

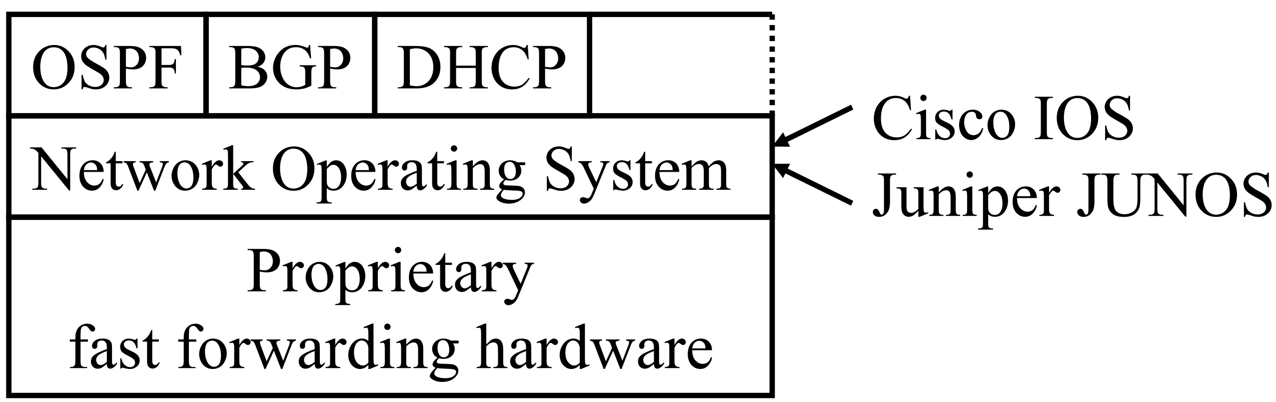
- Problem: Multiple tenants in the datacenter
- Solution: Use multiple controllers.
  Each tenant can enforce its policies



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

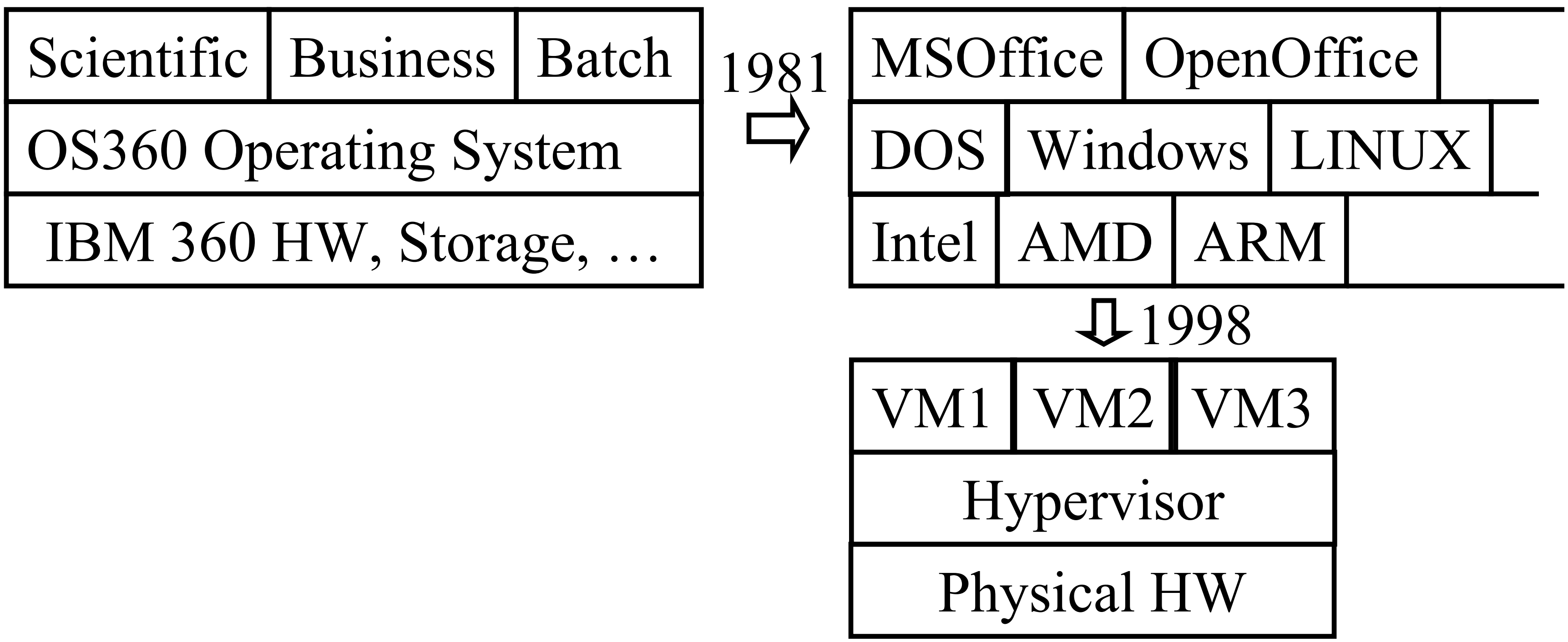
Step 3: Standardized Abstractions

- 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).



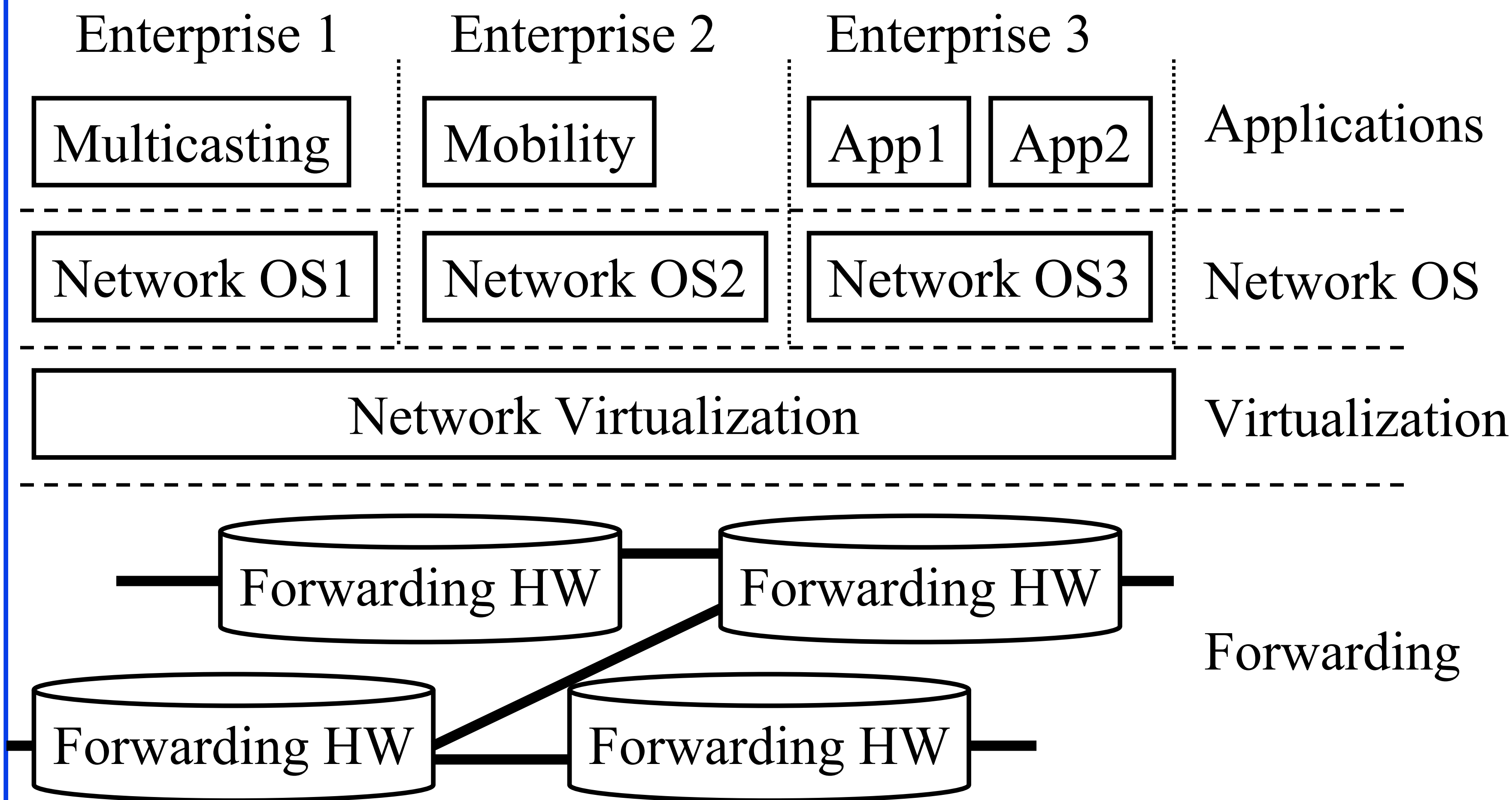
Example: PC Paradigm Shift

- 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



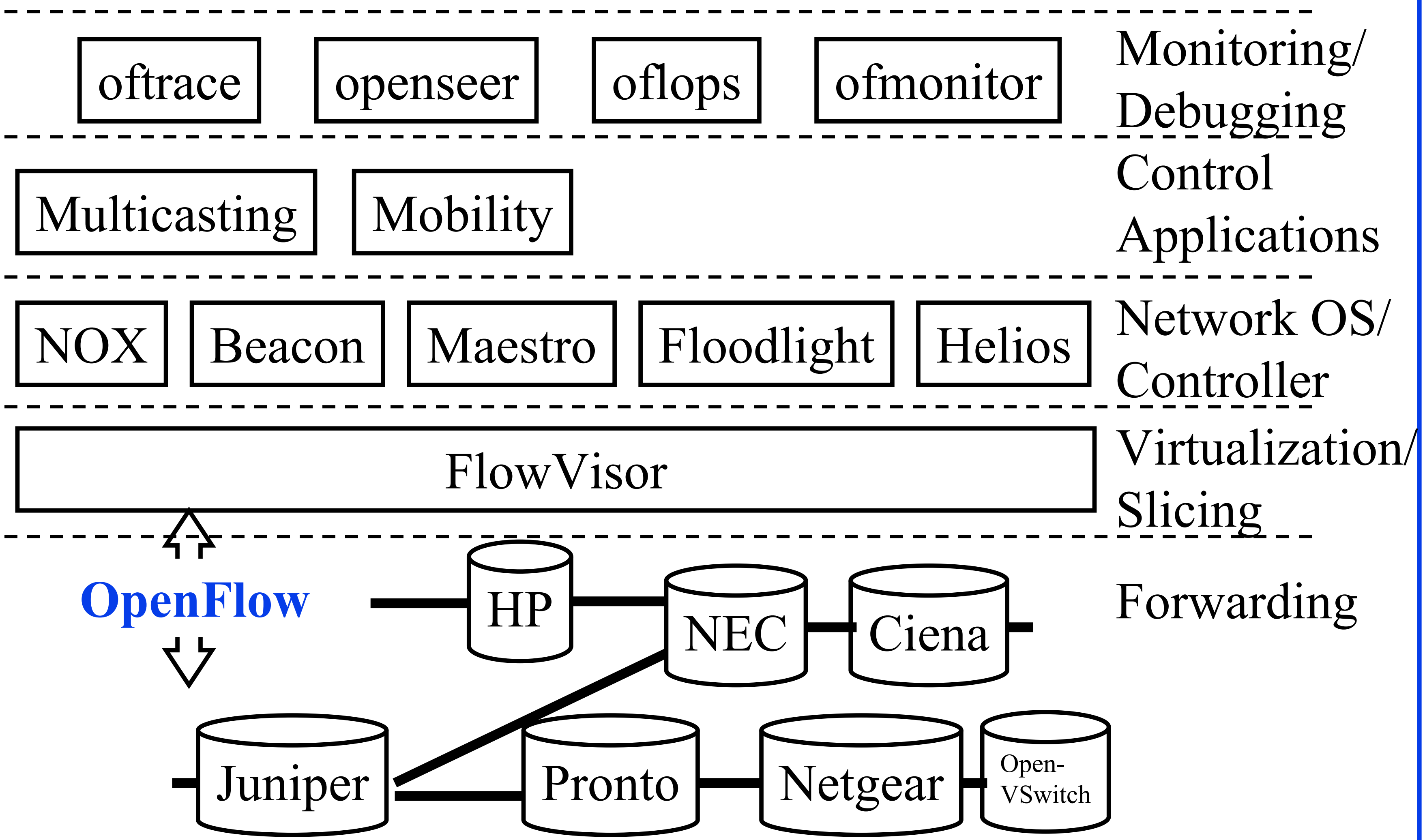
Software Defined Networking

- Layered abstractions with standardized APIs



Ref: http://www.itc23.com/.../K1_McKeown-ITC_Keynote_Sept_2011.pdf

SDN Architecture Component Examples

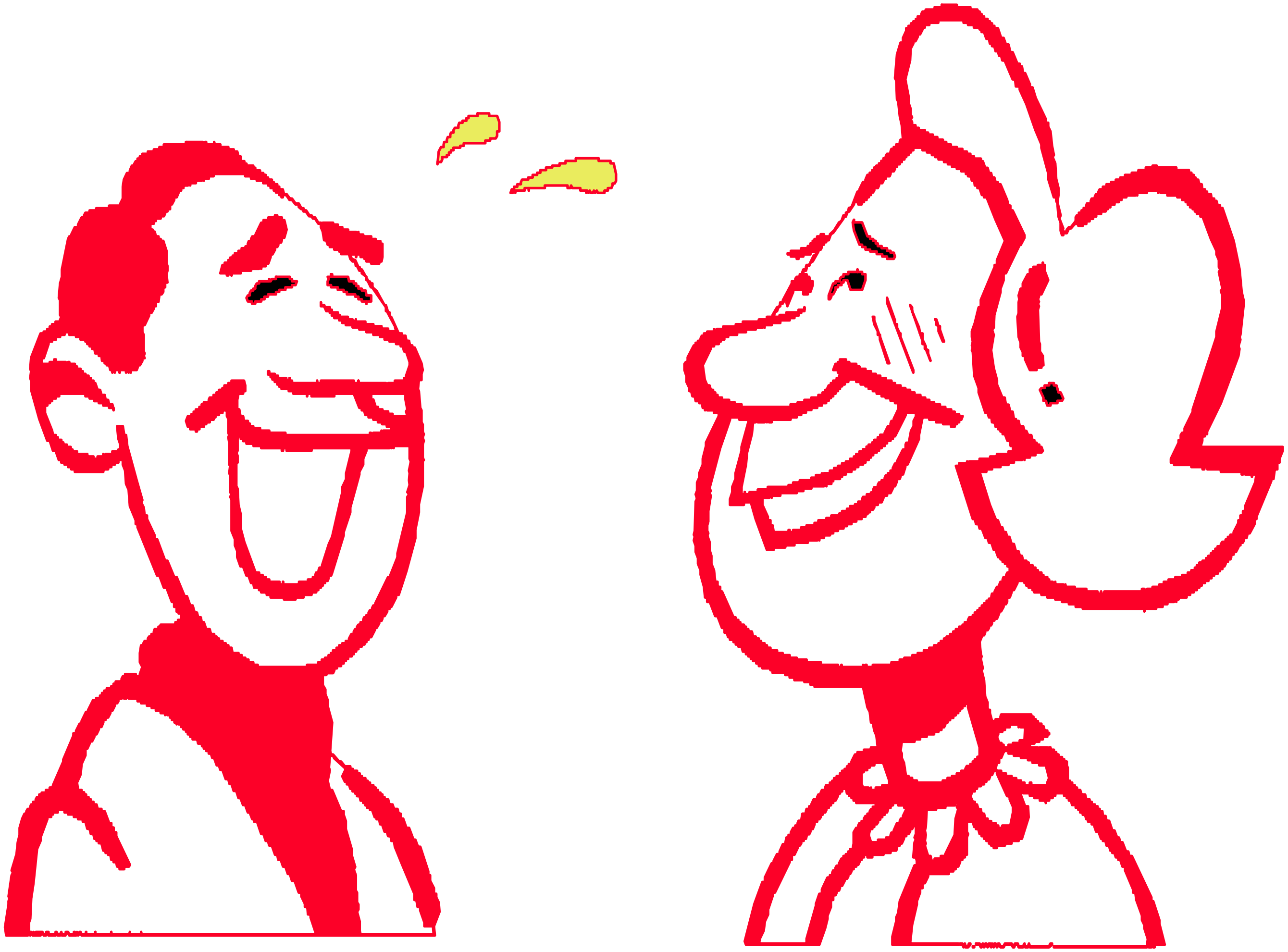


Ref: https://courses.soe.ucsc.edu/courses/cmpe259/Fall11/01/pages/lectures/srini-sdn.pdf

SDN Impact

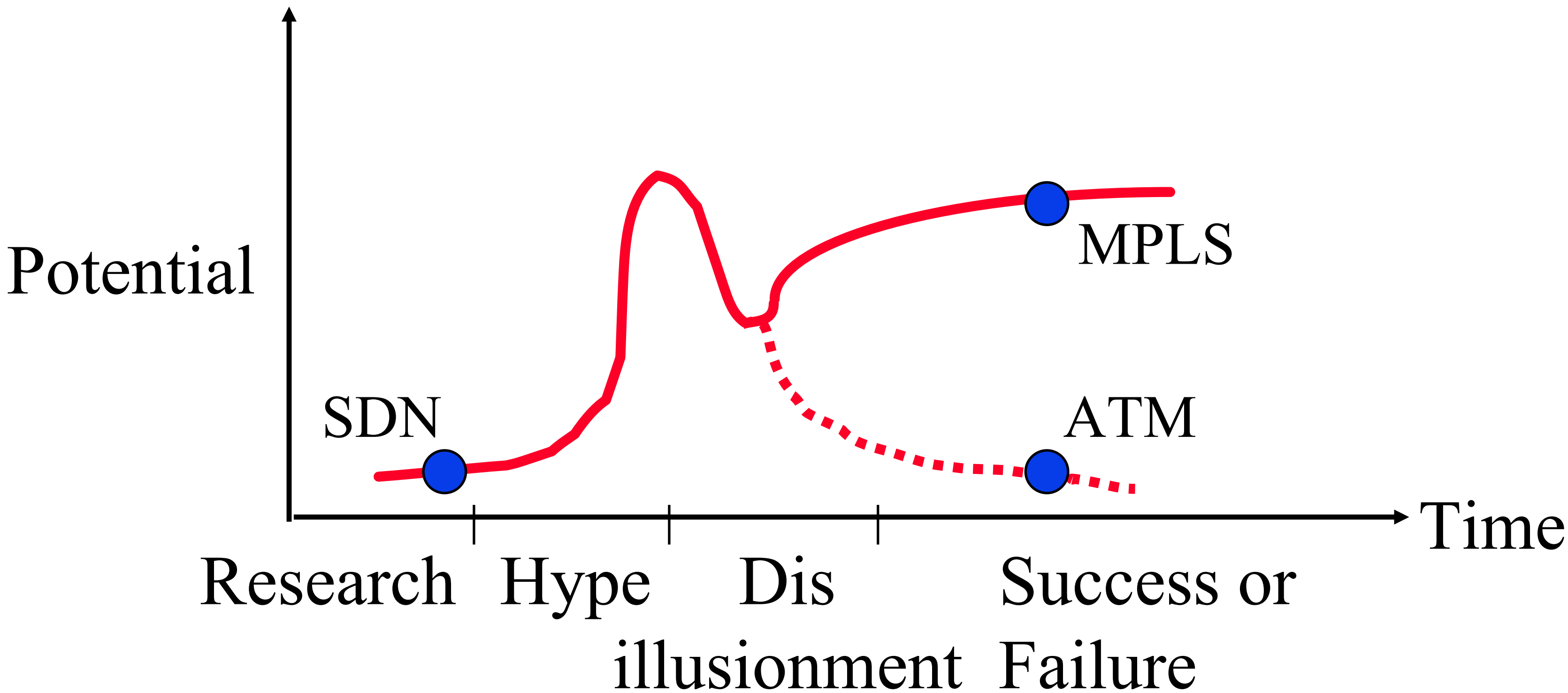
- Why so much industry interest?
  - Commodity hardware
    ⇒ Lots of cheap forwarding engines ⇒ Low cost
  - Programmability ⇒ Customization
  - Sharing with Isolation ⇒ Networking utility
  - Those who buy routers, e.g., Google, Amazon, Docomo, DT will benefit significantly
- Opens up ways for new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

Before



After

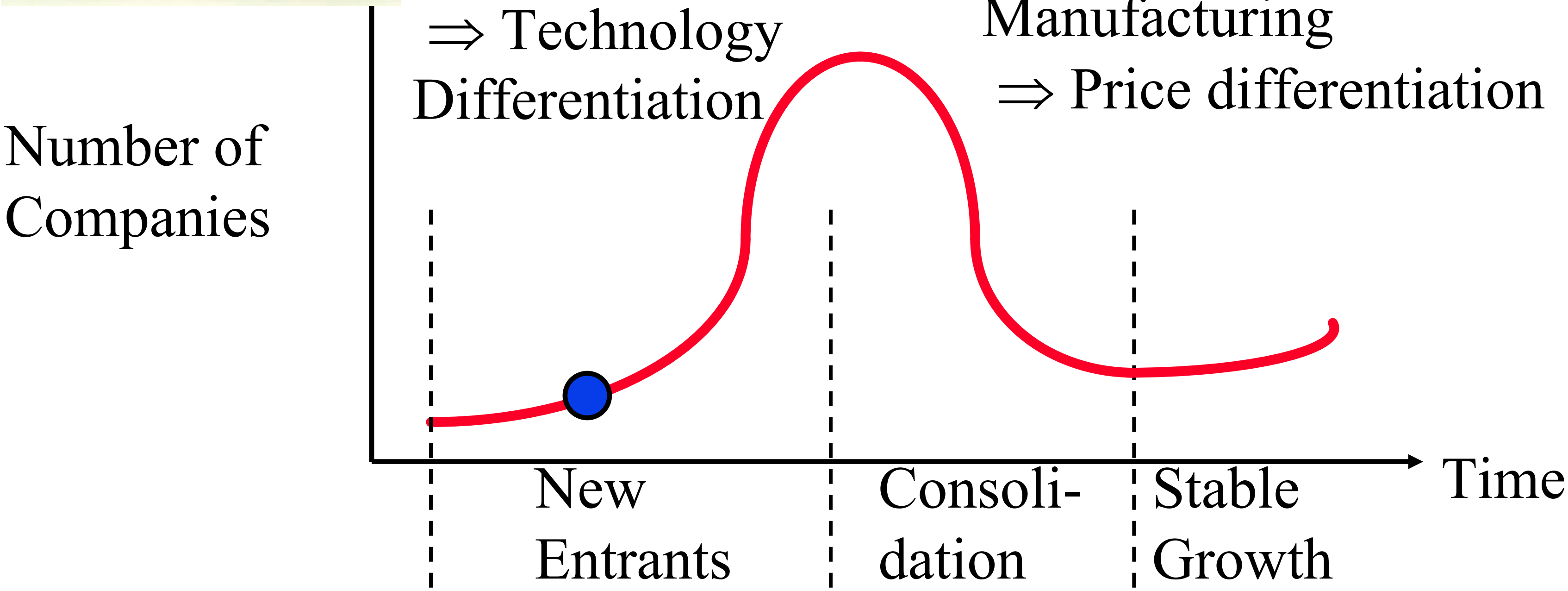
Life Cycles of Technologies



Industry Growth: Formula for Success

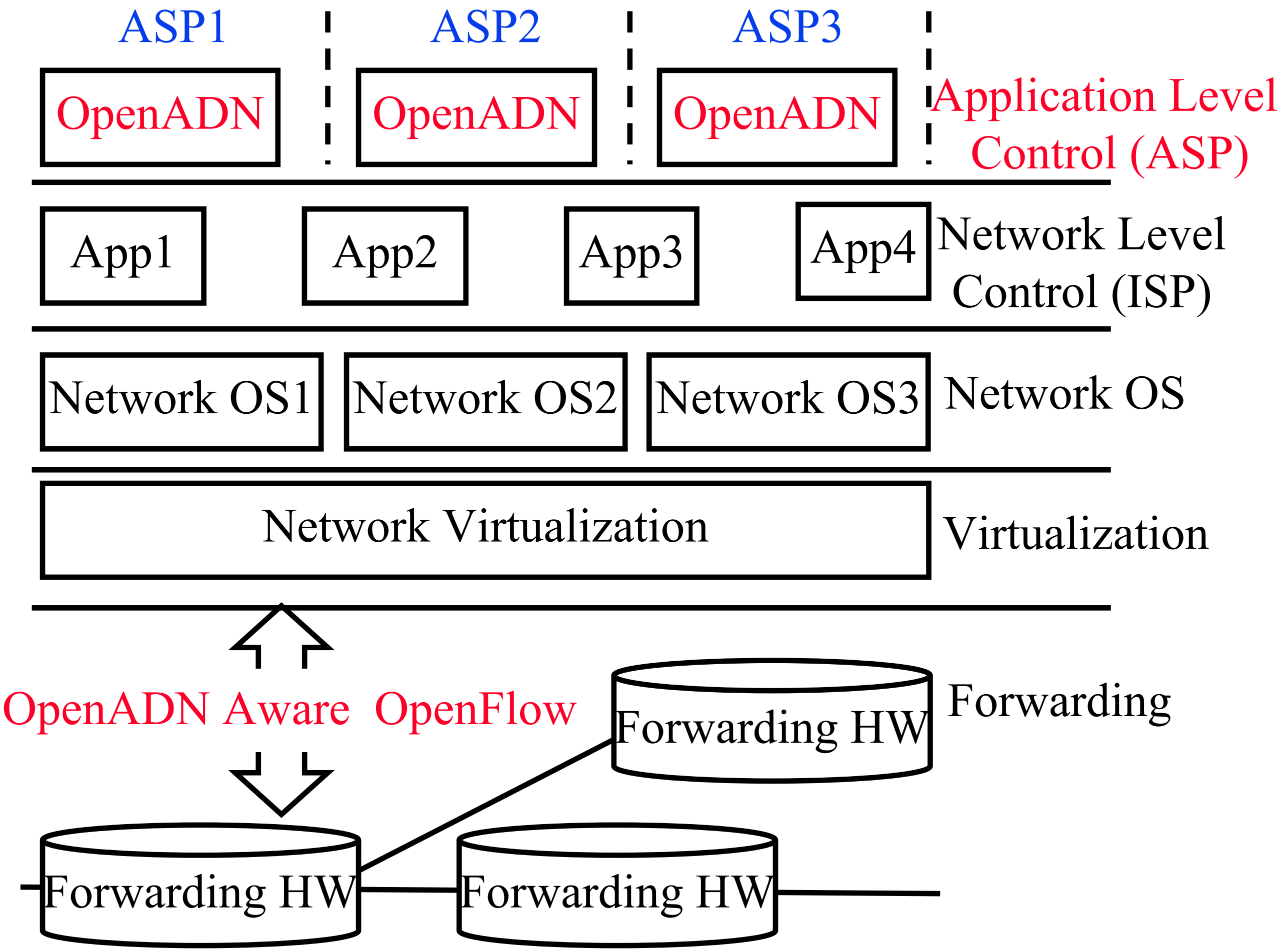
Innovators
⇒ Startups
⇒ Technology Differentiation

Big Companies
Manufacturing
⇒ Price differentiation



- 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 Abstraction

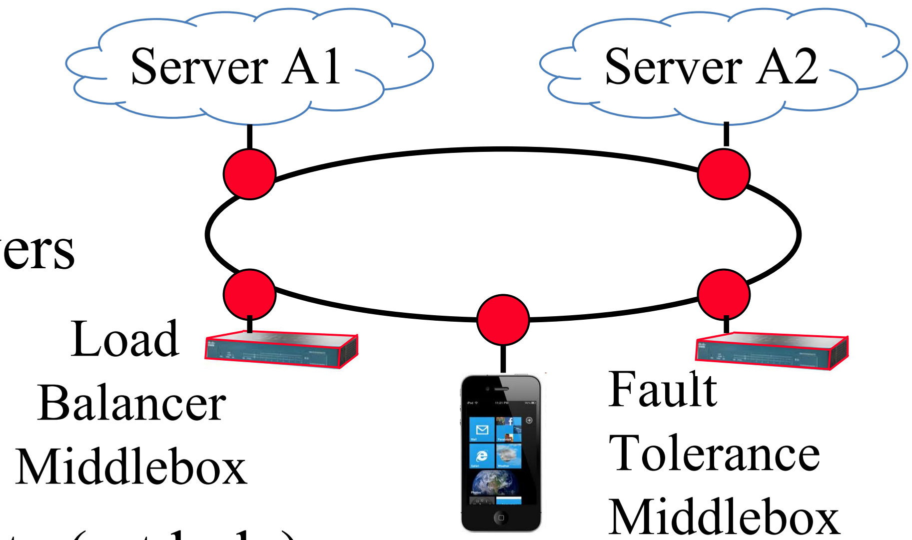


- SDN provides standardized mechanisms for distribution of control information

OpenADN Features

Message level:

- Server selection
- Load balancing between servers
- Fault tolerance
- Server mobility
- User Mobility
- Secure L5-L7 headers and data (rat hole)
- Middlebox services: Intrusion detection, Content based routers, application firewalls, …
  - Control plane and data plane MBs
- Middlebox traversal sequence
- Message level policies
- TCP Splicing



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

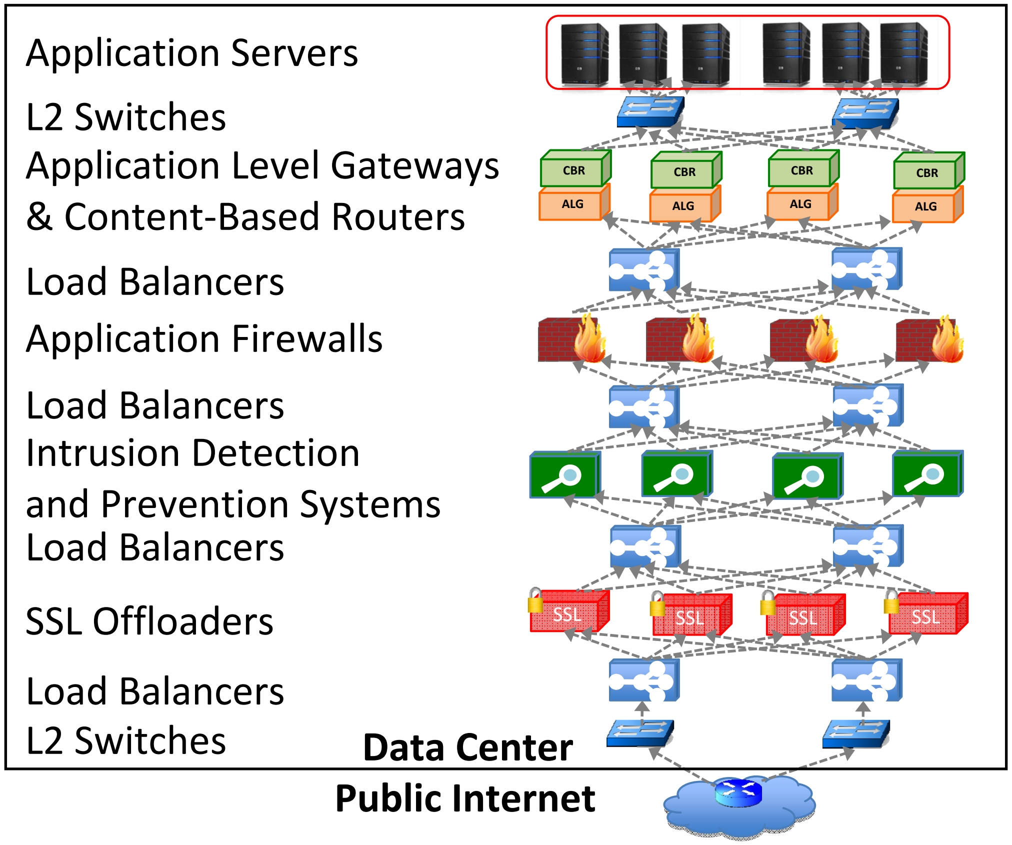
1. Edge devices only.
   Core network can be current TCP/IP based, OpenFlow or future SDN based
2. Coexistence (Backward compatibility):
   Old on New. New on Old
3. Incremental Deployment
4. Economic Incentive for first adopters
5. Resource owners (ISPs) keep complete control over their resources

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

Resource Control

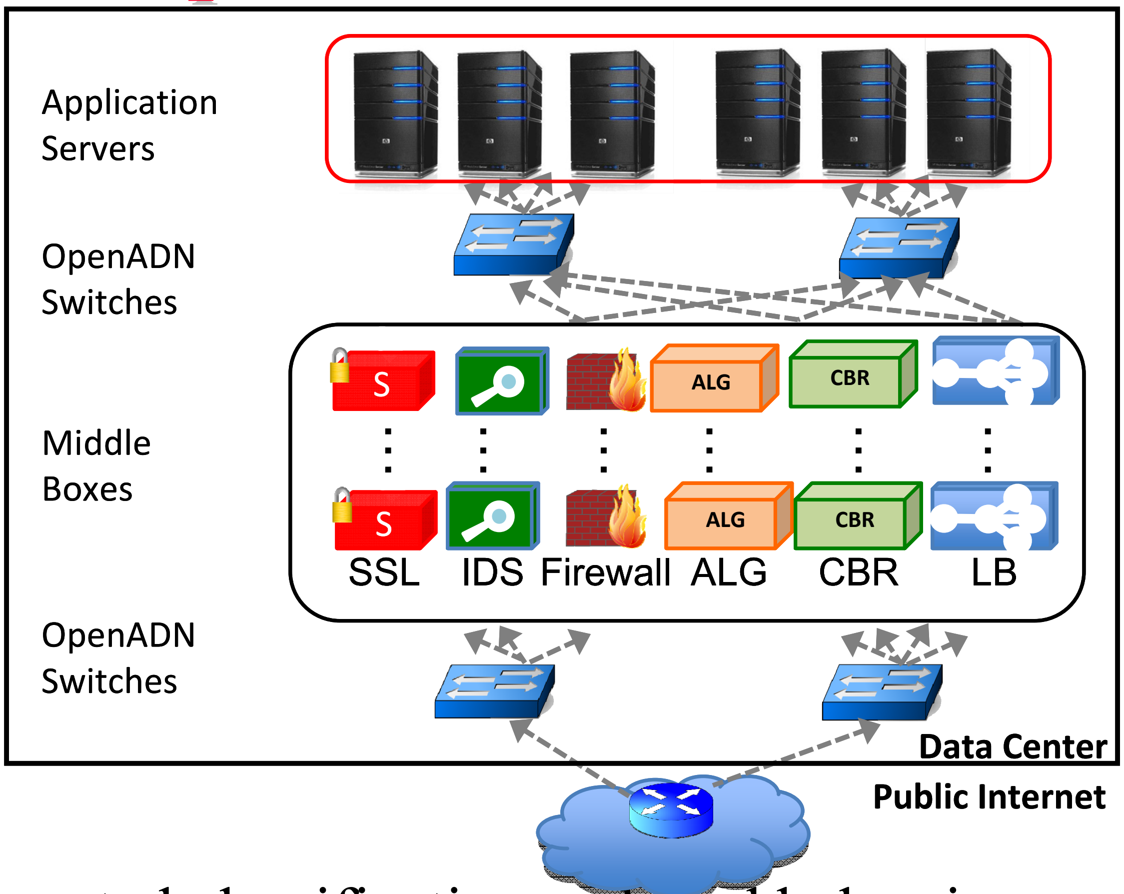
- ASPs keep complete control of their data.
  ISP does not have to look at the application headers or data to enforce application level policies
- ISPs keep complete control of their equipment.
  ASPs communicate their policies to ISP's control plane
- Middle boxes can be located anywhere on the global Internet (Of course, performance is best when they are close by)
- ISPs own OpenADN switches and offer them as a service
- ASPs or ISPs can own OpenADN middle boxes
- No changes to the core Internet

Data Center Applications

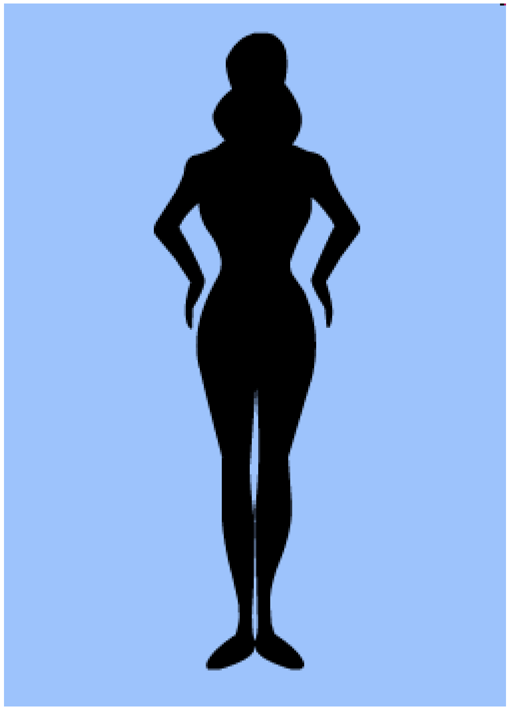


- Repeated classification and load balancing
- No application level control over MBs traversed
- Unnecessary traversals and reduced performance

OpenADN in Data Center

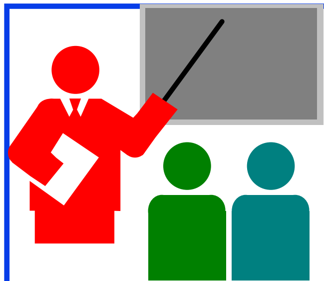


- No repeated classification and load balancing
- Application flow specific traversal through MBs
- Reduced number of appliances and increased performance



The Narrow Waist

Applications	Applications	Applications	Applications
Transports	Transports	Transports	Transports
IP	**HTTP**	**Content**	**Application Delivery**
Link	IP	IP	IP
Phys	Link/Phys	Link/Phys	Link/Phys



Summary

1. Peak of **mobile internet** paradigm shift
2. Miniaturization, Mobility, Distance, Applications, Social needs help predict the linear 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

Thank You! Merci!