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

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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


- *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
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, December 7, 2012,
http://www.cse.wustl.edu/~jain/talks/adn_iis.htm

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SDN Definition: 5 Innovations

1. Separation of Control and Data Plane
2. Flow Based Control
3. Centralization of Control Plane
4. Programmability of Control Plane
5. Standard API’s between Planes
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

<table>
<thead>
<tr>
<th>Match Fields</th>
<th>Priority</th>
<th>Counters</th>
<th>Instructions</th>
<th>Timeouts</th>
<th>Cookie</th>
</tr>
</thead>
</table>

Packet + Byte Counters

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

<table>
<thead>
<tr>
<th>In Port</th>
<th>VLAN ID</th>
<th>Ethernet SA</th>
<th>Ethernet DA</th>
<th>Ethernet Type</th>
<th>IP SA</th>
<th>IP DA</th>
<th>IP Proto</th>
<th>TCP Src</th>
<th>TCP Dst</th>
</tr>
</thead>
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3. Centralization of Control Plane

- Consistency
- Fast Response to changes
- Easy management of lots of devices
Centralized vs. Distributed

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

[Diagram showing the API between planes with Northbound, East-West, and Southbound APIs.]
SDN Impact

Why so much industry interest?
- Commodity hardware
  ⇒ Lots of cheap forwarding engines ⇒ Low cost
- Programmability ⇒ 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

1. Software implementation of network
2. Network Function Modules
3. Implementation in Virtual Machines
4. Thin Network OS
5. Standard API’s between Modules
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), …

Router =  

- DHCP
- NAT
- QoS
- Forwarding
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)


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

Potential

Research  Hype  Dis  Illusionment  Success or Failure

SDN  NFV  ATM  MPLS
Industry Growth: Formula for Success

- Paradigm Shifts \(\Rightarrow\) Leadership Shift
- Old market leaders stick to old paradigm and lose
- Mini Computers \(\rightarrow\) PC, Phone \(\rightarrow\) Smart Phone, PC \(\rightarrow\) Smart Phone
OpenADN in SDN’s Layered Abstractions

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

Northbound API

Southbound API

DATA PLANE

CONTROL PLANE

APPLICATIONS

ASP1

OpenADN Controller

ASP2

OpenADN Controller

Network Controller Software

Forwarding HW

Forwarding HW

Forwarding HW

ISP

Middle-boxes

ISP’s Controller

Policies

State

ASP 1’s Controller

Policies

Control

ASP 2’s Controller

Policies

State

ASP2

ASP 1’s

Controller

Web Page

SDN provides standardized mechanisms for distribution of control information

OpenADN aware devices use enhanced OpenFlow

Washington University in St. Louis

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

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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 \(\Rightarrow\) 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 ⇒ 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