OpenFlow / SDN: A New Approach to Networking

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A Quick Overview
“The Biggest Thing Since Ethernet: OpenFlow
New technology could disrupt the networking market, which for decades has relied on Ethernet and TCP/IP standards--and stalwart vendors like Cisco.”

InformationWeek, 10/17/2011
“The current Internet is at an impasse because new architectures cannot be deployed, or even adequately evaluated.”

“Overcoming the Internet Impasse through Virtualization,” L. Peterson, S. Shenker, J. Turner, Hotnets, 2004
OpenFlow/SDN: New Approach to Networking

Enable innovation in networking

Change Practice of Networking
Problem with Internet Infrastructure?

Routing, management, mobility management, access control, VPNs, ...

Vertically integrated, complex, closed, proprietary
Not suitable for experimental ideas

Million of lines of source code
6000+ RFCs

Billions of gates
Bloated
Power Hungry

Not good for network owners & users; Not good for researchers.
Problem: No Abstractions for Control Plane

- Addition of a new function to the network
  - Highly complex distributed system problem
- Networks too difficult to program and to reason about
  - No good abstractions and interfaces

Distributed Network Functions

State Distribution Mechanism

Not good for even network vendors
Software-Defined Network with Key Abstractions in the Control Plane

- Well-defined open API
  - Routing
  - TE
  - Mobility
- Open interface (OpenFlow) to Forwarding Abstraction: L1/L2/L3
- Separation of Data and Control Plane
- Network Map Abstraction
- Programmable Basestation

Network OS
Software Defined Network with Virtualization

- Abstract Network Model
- Network Virtualization
- Global Network View
- Network OS
Simple Example: Access Control

Abstract Network Model

Global Network View
Innovation/Research Enabled?
Nation-wide SDN Infrastructure

Part of NSF's GENI
Example Research Enabled

- Data center: energy conservation, routing, and management
- Seamless use of diverse wireless networks
- Network based load balancing
- Packet/circuit convergence, traffic engineering
- Simpler control plane for converged packet/circuit MPLS nets
- Slicing and remote control/management of home networks
- Distributed snap shot of VMs (by DOCOMO researchers)
- Inter-domain routing with pathlets (by UIUC)
- Redundant traffic elimination [for CDNs] (by Univ of Wisconsin)
- And many more ...

200+ OpenFlow/SDN deployments around the world!!
Videos of Demonstrations

These videos demonstrate different research experiments that build on top of OpenFlow. If you have similar videos that demonstrate your research and are interested in hosting them here, please contact Nikhil Handigol.
Industry Embracing SDN

Largest Network Providers/Operators
- BT
- Google
- Verizon
- INTERNET
- Level(3)
- Microsoft
- NTT docomo
- Amazon.com
- Facebook

Vendors and start-ups
- Broadcom
- Juniper Networks
- Ericsson
- HP
- NEC
- Ciena
- Dell
- Netgear
- Extreme Networks
- Arista
- Nicira
- Cisco
- Huawei
- IBM
- Big Switch Networks

Note: Level of interest and approach vary
Open Networking Foundation
http://opennetworking.org/

to continue standardization of OpenFlow and other SDN interfaces/APIs

Board of Directors
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SDN/OpenFlow Value Proposition

**Generic**

- Gives more control to network owners and operators
- Enables innovation in networking and development of new services
- Provides a more diverse choice of hardware and software
- Opportunity to build a more robust infrastructure

**Campus Specific**

- Proliferation of function specific appliances: increased CapEx & OpEx
- Legacy solutions not scaling: VLANs, access control…
OpenFlow/SDN Building Blocks Deployment on Stanford Campus
Enterprise Networking

Enterprise network operators want ...

- Firewall and Access Control
- Delegate management to departments
- Consolidate data and voice network
- Stretch VLANs across buildings and campus
- By-pass bottle-necks and check points for specific applications
- Host web service with load balancing
- Easy guest wireless access and security

And more ...
OpenFlow Components

- Monitoring/Debugging
- Applications
- Controllers
- Slicing software
- OpenFlow switches

FlowVisor: Virtualization or “Slicing” Layer

Isolated “slices”

Many controllers, or many versions

Simple Packet Forwarding Hardware

WiFi AP

Simple Packet Forwarding Hardware
OpenFlow Components

• Open Source Controllers
  Beacon, Maestro, NOX, RouteFlow, Trema, FloodLight

• Commercial Controllers
  BigSwitch, Nicira, NEC

• Hardware
  Juniper MX-Series, NEC IP8800, NEC WiMAX, HP Procurve 6600/5400/3500, Netgear 7324, IBM 5280 and 5820, Pronto 3240 and 3290, Ciena CoreDirector
Use Cases

• Network Administration
  – Guest Access (Wireless & Wired)
  – Campus Wireless
  – Data Center
  – Campus Back-bone Network
  – Delegated Management
• Residences
• Science Community
  – Connecting to other research communities
• Network Researchers
  – Shared Infrastructure
Initial Target Applications

- Firewall
- Load Balancing
- Wireless Guest Access
- Path/Bandwidth reservation and scheduling
Stanford's Network Today

- Approx. 12 Operational Zones
- Different appliance for each service
- Management complexity
  - Device oriented
  - Different interface for each appliance
- High CapEx and OpEx
- Vendor tie-in
- Bottle-necks
- VLANs, Spanning-Tree
Stanford's Network Tomorrow

- One or more controllers
- Allow for a mix of equipment
- Increased service offerings
- Delegated management
- Common interface
- Push service to the edge
Stanford Deployment
Proposed CENIC Openflow Topology

- UCSC
- Stanford
- UCB
- UCSF
- UCM
- UCD
- UC Med Ctr
- UCD
- Caltech
- NPS
- UCI
- UCLA
- UCR
- UCSD
- UCSB
- USC
- NLR/GENI OF switch Sunnyvale
- IN2/GENI OF switch Los Angeles
- NLR/FrameNet Sunnyvale
- IN2/ION Los Angeles
- NLR/FrameNet Los Angeles
- NLR/FrameNet El Paso
- HPR-L2 Switch Sunnyvale
- HPR-L2 Switch Sacramento
- HPR-L2 Switch Los Angeles
- Campus Access link with VLAN Translation (Campus OF VLAN) ← → X
- VLAN Translation X ← → A
- VLAN Translation A ← → 1750
- VLAN Translation B ← → 1750
- VLAN Translation C ← → 1750
- FrameNet Circuit/VLAN C

VLAN Translation X ← → B
VLAN Translation X ← → C
In Production...
Wireless (Experimental and Campus)
SNAC

• First roll out with OpenFlow 0.8.9
• Nicira + SNAC used as example controllers
• HP 5412 switches – early firmware releases
• Stable but proved less than ideal update mechanism
• Floor-based VLANs used to isolate tests
• OpenFlow 1.0 offered opportunity to examine newer solutions
BigSwitch Deployments

- Using KVM or ESX for VM appliance
- Near-final HP and other switch firmware
- OpenFlow native APs used to provide opt-in testing
- Both Test and Stanford-wide wireless VLANs exposed to OpenFlow network for verification
- Deployment team interactions were key
Controller View

OpenFlow Counter Stats

OpenFlow Message Stats
Flow Setup Rates

Flow Setup Rate

![Graphs showing flow setup rates over time and cumulative distribution functions (CDFs).](image-url)
Problem #1: Wireless Mesh

- Wireless mesh networks becoming common
- Hosts can have multiple valid attachment points to an OF network
- OF controller had to be enhanced to deal with not just host mobility, but multiple valid paths
Problem #2: Controller Plane Loop

- New packet-in results in a flowmod that is pushed from the controller to the switches
- Under heavy loads, one vendor's switch was too slow with flowmod insertions and routed output packet as another packet-in - Loop
- Lesson: Switch does not guarantee order of processing flowmod and packet-out
Problem #3: Unidirectional OF Link

- LLDP Packets in a VLAN not always recognized by some non-OF switches and were forwarded
- Unexpected switch behavior resulted in unidirectional OF links in the topology that controller could not yet handle: Net outage
- Lesson: Must handle unidirectional links between OF switches as different OF clusters
Problem #4: DHCP Relays

- Controller's attempt to understand relay-agents and forward packets to the correct end host
- Stanford and other networks tend to have multiple DHCP servers that are load balanced by the relays
- Optimization was premature, and it's best to maintain local relay-agents
Final Takeaways

• OpenFlow/SDN shows a lot of promise as a new paradigm for networking
• Network operators embracing it for their own reasons
  – Enable innovation and offer customized services
  – Reduce CapEx and OpEx
• Vendors are stepping up to meet customer demands
• Universities have an opportunity to lead
  – Deploy OpenFlow/SDN infrastructure; innovate services; reduce CapEx and OpEx
  – NSF willing to support the upgrade
  – Vendors willing to cooperate and help
Q&A