Enterprise
GENI

Nick McKeown
nickm@stanford.edu

Stanford OpenFlow team: Guido Appenzeller, Glen Gibb, David Underhill, David Erickson, Adam Covington, Brandon Heller, Rob Sherwood, Masayoshi Kobayashi, Guru Parulkar, Srinivasan Seetharaman, Yiannis Yiakoumis
Staged Approach

1. Define OpenFlow feature
2. Add OpenFlow to commercial switches and APs
3. Deploy at Stanford
4. Integrate with GENI Clearing House
5. Deploy on many college campus networks

6. We all create lots of open-source software so researchers can build on each other’s work

(We’re part-way into Stage 2)
OpenFlow Basics
Exploit the flow table in switches, routers, and chipsets

<table>
<thead>
<tr>
<th>Flow 1.</th>
<th>Rule (exact &amp; wildcard)</th>
<th>Action</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow 2.</td>
<td>Rule (exact &amp; wildcard)</td>
<td>Action</td>
<td>Statistics</td>
</tr>
<tr>
<td>Flow N.</td>
<td>Rule (exact &amp; wildcard)</td>
<td>Default Action</td>
<td>Statistics</td>
</tr>
</tbody>
</table>
OpenFlow Basics (2)

- **Rule** (exact & wildcard)
  - As *general* as possible
  - e.g. Port, VLAN ID, L2, L3, L4, …
  - As *wide* as possible

- **Action**
  - Small number of fixed actions
  - e.g. unicast, mcast, map-to-queue, drop
  - Extended via virtual ports
  - e.g. tunnels, encapsulate, encrypt

- **Statistics**
  - Count packets & bytes
  - Expiration time/count
OpenFlow Basics (3)

- Add/delete flow entries
- Encapsulated packets
- Controller discovery
OpenFlow Usage

Dedicated OpenFlow Network
Usage examples

Chip’s code:
- Static “VLANs”
- His own new routing protocol: unicast, multicast, multipath, load-balancing
- Network access control
- Home network manager
- Mobility manager
- Energy manager
- Packet processor (in controller)
- IPvChip
- Network measurement and visualization
- …
Enable Innovation in your Network.

OpenFlow is an open standard that allows you to run experimental protocols in production networks. It is in the process of being implemented by major switch vendors and used today by universities to deploy innovative networking technology in their campus networks.
Let’s see an example...
- Experimental feature on ProCurve 5400-series
- 144-ports of 1GE, hardware forwarding
- OpenFlow added by HP Labs and ProCurve group
- In 23 wiring closets in CS Building at Stanford
- Experimental feature on IP8800 series router
- 24-ports of 1GE, 2-ports of 10GE, hardware forwarding
- OpenFlow added by NEC team in Japan
- NEC announced plans for OpenFlow products
- Deployed at Stanford and in JGN2plus in Tokyo
Juniper

- OpenFlow added to Junos SDK
- First platform: MX-480 carrier class Ethernet
- 24-ports 10GE or 240-ports 1GE
- Hardware forwarding
- Deployed in Internet2 in NY and at Stanford

Umesh Krishnaswamy  Michaela Mezo  Parag Bajaria  James Kelly  Bobby Vandalore
Cisco

- Experimental feature on Catalyst 6509
- Software forwarding
- Deployed at Stanford

Pere Monclus  Sailesh Kumar  Flavio Bonomi
Nicira

- Created NOX controller
- Available at http://NOXrepo.org (GPL)
- Deployed at Stanford
Using Enterprise GENI for research
Step 1: Separate VLANs for Production and Research Traffic

- **Research VLANs**
- **Production VLANs**

**Normal L2/L3 Processing**

**Flow Table**

**Controller**
Step 2: Virtualize OpenFlow Switch
Virtualizing Control

- Aaron's Controller
- Heidi's Controller
- Craig's Controller

OpenFlow Switch

OpenFlow Hypervisor & Policy Control

OpenFlow Protocol
Virtualizing Control

Netadmin’s experiments

Multicast

http Load-balancer

OpenFlow Hypervisor & Policy Control

OpenFlow Protocol

OpenFlow Protocol

OpenFlow Switch

OpenFlow Switch

OpenFlow Switch

Netadmin’s experiments

Multicast

http Load-balancer

OpenFlow Hypervisor & Policy Control

OpenFlow Protocol

OpenFlow Protocol

OpenFlow Switch

OpenFlow Switch

OpenFlow Switch
Enterprise GENI

OpenFlow Hypervisor & Policy Control

GENI Clearing House

GENI Aggregate Manager

OpenFlow Protocol

OpenFlow Protocol

OpenFlow Protocol
Many Open Questions!

- Scalability of a controller
- Load-balancing over redundant controllers
- Federation, hierarchy and aggregation
- Protecting the controller against DDOS

Our goal is to enable the research community to explore all these questions
Thanks…

(It takes a village)
Internet2 Team

Chris Small

Matt Zekauskas
Installing Juniper MX-480 in NY
We plan trials in early 2009
5-6 college campuses

Contact us if you would like to take part
nickm@stanford.edu