OpenFlow Controllers and Tools

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These slides and audio/video recordings of this class lecture are at:

http://www.cse.wustl.edu/~jain/cse570-13/
Overview

1. OpenFlow Controllers
2. Software Routing Platform
3. OpenFlow Related Tools
OpenFlow Controllers

1. NOX
2. POX
3. SNAC
4. Beacon
5. Trema
6. Maestro
7. Floodlight

Many more…This is not a complete list.
NOX

- One of the first open source OpenFlow controllers
- Developed by Nicira and donated to research community in 2008
- Supported by ON.LAB at Stanford and by UC Berkeley and ICSI
- Provides a C++ API for OpenFlow 1.0
- Both a controller and a framework for developing OpenFlow applications
- Includes sample components for topology discovery, learning switch, network-wide switch
- Superseded by POX

Ref: http://www.noxrepo.org/forum/
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POX

- **Python**-based newer version of NOX.
- Platform for rapid development of network control software using Python
- OpenFlow controller plus a framework for interacting with OpenFlow switches, debugging, network virtualization, …
- Reusable components for path selection, topology discovery
- Supports the same GUI and visualization tools as NOX
- Runs on Linux, MACs, Windows and can be bundled with install-free PyPy runtime for easy deployment

Ref: [http://www.noxrepo.org/pox/about-pox/](http://www.noxrepo.org/pox/about-pox/)
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SNAC

- Open source OpenFlow controller with graphical user interface
- Uses a web-based policy manager to manage the network
- It is a module of NOX and requires appropriate version of NOX
- Allows programming NOX routing module’s policies without editing the code
- Allows admission control, shows network components, network usage, and events
- Reports many flow-level traffic details using REST API
- New hosts joining the network are automatically directed to SNAC for authentication

Ref: http://www.openflowhub.org/display/Snac/SNAC+Home
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Beacon

- Open source cross-platform modular OpenFlow controller implemented in **Java**
- Developed at Stanford University
- Java ⇒ Runs on many platforms including Android Phones and multi-core Linux servers
- Dynamic ⇒ Code bundles in Beacon can be started/stopped/refreshed/installed at runtime without disrupting other non-dependent bundles
- Uses Eclipse Integrated Development Environment

Ref: [https://openflow.stanford.edu/display/Beacon/Home](https://openflow.stanford.edu/display/Beacon/Home)
Onix

- Basic design framework of many OpenFlow Controllers
- *Distributed* Controller platform using a cluster of servers
- Multiple Onix instances synchronize their “Network information base (NIB)” similar to “Routing Information Base (RIB)”
- Network control logic is implemented on the top of Onix’s API
- Use in-memory database for state management


Trema

- Full-stack easy-to-use framework for developing OpenFlow controllers in **Ruby and C**
- Open source. Developed by NEC Research Lab.
- Modular extensible architecture
- Integrated development environment for testing and debugging

Ref: [http://github.com/trema/](http://github.com/trema/)
Ref: [http://trema.github.com/trema/](http://trema.github.com/trema/)
Maestro

- **Java based**: Portable to various operating systems and architectures
- Developed by Rice University and supported by NSF FIND program
- **Multi-threaded**: Provides parallelism within a single machine so that the controller is not a bottleneck
- Programming framework allows introducing new control functions

Ref: [https://code.google.com/p/maestro-platform/](https://code.google.com/p/maestro-platform/)
Washington University in St. Louis, [http://www.cse.wustl.edu/~jain/cse570-13/](http://www.cse.wustl.edu/~jain/cse570-13/)
Floodlight

- **Java** based OpenFlow controller based on Beacon runs within a JVM. Developers from Big Switch Networks
- **Indigo**: Software to make switch hardware OpenFlow compatible
- **Floodlight** is the core of Big Switch Controller from Big Switch Networks


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Floodlight (Cont)

- A number of real-world networking applications
  - **Neutron plug-in** for OpenStack cloud management system
  - **Static Flow Pusher**: Allows users to manually insert flows
  - **Circuit Pusher**: Creates permanent entries on all switches along the path
  - **Firewall**: Enforces access control list (ACL) rules on packets
  - **Big Virtual Switch**: Automates network provisioning for a large scale data centers. Includes provisioning, multi-tenant partitioning

Ref: http://www.projectfloodlight.org/floodlight/

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Open Source Routing Software

- **Bird Internet Routing Daemon (BIRD):**
  - TCP/IP routing daemon for Unix-like systems
  - Developed at Charles University, Prague
  - Provides BGP, RIP, OSPF for IPv4 and IPv6
  - Included in many Linux distributions
  - Used in several internet exchanges as a route server and has replaced Quagga because of its scalability issues

- **Quagga:** Includes OSPF, RIP, BGP, IS-IS on Unix-like OSs

- **eXensible Open Router Platform (XORP):**
  - Designed at ICSI in Berkeley
  - Supports OSPF, BGP, RIP, PIM, IGMP, OLSR
  - Generally replace by Quagga

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Key OpenFlow Related Software

- FlowVisor
- Mininet
- Ryu
- RouteFlow
FlowVisor

- Transparent Proxy between OpenFlow switches and multiple OpenFlow Controllers
- Creates network slices that can be managed by different controllers ⇒ Isolates slices from each other
- All control traffic goes through FlowVisor ⇒ Slight latency

Ref: https://github.com/OPENNETWORKINGLAB/flowvisor/wiki

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Mininet

- Widely used open source network emulation environment.
- Can simulate a number of end-hosts, switches, routers, links on a Linux
- Used for rapid prototyping of software define networks
- Built-in Open vSwitch, and a OpenFlow capable switch
- Command line launcher and Python API for creating networks of varying sizes, e.g., `mn --topo tree,depth=2,fanout=3`
- Useful diagnostic commands like `iperf`, `ping`, and other commands in a host, e.g., `mininet> h11 ifconfig -a`
- Mininet code for several popular commercial switches are available.

Ref: [https://github.com/mininet/mininet](https://github.com/mininet/mininet)

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Ryu

- Component-based framework that integrates with OpenStack and supports OpenFlow
- Provides software component with well defined API for network management and control applications
- Supports various versions of OpenFlow, OF-Config, Nicira extensions
- Developed by NTT laboratories
- Can easily setup a multi-node OpenStack environment using pre-configured Ryu VM image file

Ref: [http://osrg.github.io/ryu/](http://osrg.github.io/ryu/)
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RouteFlow

- Provides virtualized IP routing services over OpenFlow enabled hardware
- IP routing engines (e.g., Quagga) in the networking devices generate the forwarding information base (FIB) into the Linux IP tables using OSPF, BGP, etc.
- RouteFlow Client processes collect the IP and ARP tables and translate into OpenFlow tuples that are installed in the OpenFlow devices in the forwarding plane

Ref: https://sites.google.com/site/routeflow/home
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RouteFlow (Cont)

- Key components: RouteFlow Client, RouteFlow Server, and RouteFlow Proxy

Ref: https://sites.google.com/site/routeflow/home
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Other OpenFlow Related Projects

- **Avior**: Graphical user interface for floodlight network administration and testing. Can monitor Controllers, Switches, nodes, etc.

- **OFlops**: OpenFlow Operations Per Second (OFlops) measures various aspects of OpenFlow switch performance

- **Cbench**: Controller Benchmarker (Cbench) measures performance of controllers by generating packet-in events for new flows from a bunch of switches.

- **Twister**: Test automation framework to manage and drive test cases written in shell scripting languages. Supports TCL, Python, and Perl.

- **FortNOX**: An extension of NOX which automatically checks if new flow rules violate security policies

Summary

1. OpenFlow Controllers: NOX, SNAC, POX, BEACON, Floodlight, Trema, …
2. Software Routers: Quagga, BIRD, XORP
3. FlowVisor provides multi-tenancy and multi-controllers
4. Tools: Mininet, RouteFlow, Ryu, …
5. Other Tools: Testing, security, benchmarking, etc.
Reading List

- http://www.noxrepo.org/forum/
- http://www.noxrepo.org/pox/about-pox/
- http://www.openflowhub.org/display/Snac/SNAC+Home
- https://openflow.stanford.edu/display/Beacon/Home
- http://github.com/trema/
- http://trema.github.com/trema/
- http://www.projectfloodlight.org/floodlight/
- https://code.google.com/p/maestro-platform/
- https://github.com/mininet/mininet
- https://github.com/OPENNETWORKINGLAB/flowvisor/wiki?
- http://osrg.github.io/ryu/
- https://sites.google.com/site/routeflow/home
Reading List (Cont)

- [https://github.com/travelping/flower](https://github.com/travelping/flower)
- [https://github.com/Sovietaced/Avior](https://github.com/Sovietaced/Avior)
- [http://www.es.net/services/virtual-circuits-oscars](http://www.es.net/services/virtual-circuits-oscars)
- [http://github.com/Luxoft/Twister](http://github.com/Luxoft/Twister)
Acronyms

- ACL: Access control list
- API: Application Programming Interface
- BGP: Border Gateway Protocol
- BIRD: Bird Internet Routing Daemon
- FIB: Forwarding information base
- GUI: Graphical User Interface
- ICSI: International Computer Science Institute
- IGMP: Internet Group Management Protocol
- IP: Internet Protocol
- IPv4: Internet Protocol V4
- IPv6: Internet Protocol V6
- IS-IS: Intermediate System to Intermediate System
- JVM: Java Virtual Machine
- MAC: Mecia Access Control
- NIB: Network Information Base
### Acronyms (Cont)

- **NSF**: National Science Foundation
- **NTT**: Nippon Telegraph and Telephone
- **OF**: OpenFlow
- **OFlops**: OpenFlow Operations Per Second
- **OLSR**: Optimized Link State Routing
- **ON.LAB**: Open Networking Lab at Stanford
- **OS**: Operating System
- **OSPF**: Open Shortest Path First
- **PIM**: Protocol Independent Multicast
- **REST**: Representational State Transfer
- **RIB**: Routing Information Base
- **RIP**: Routing Information Protocol
- **SNAC**
- **TCL**: Tool Command Language
- **TCP**: Transmission Control Protocol
- **UC**: University of California
Acronyms (Cont)

- VM: Virtual Machine
- XORP: eXensible Open Router Platform