

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/>



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- ❑ Superseded by POX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

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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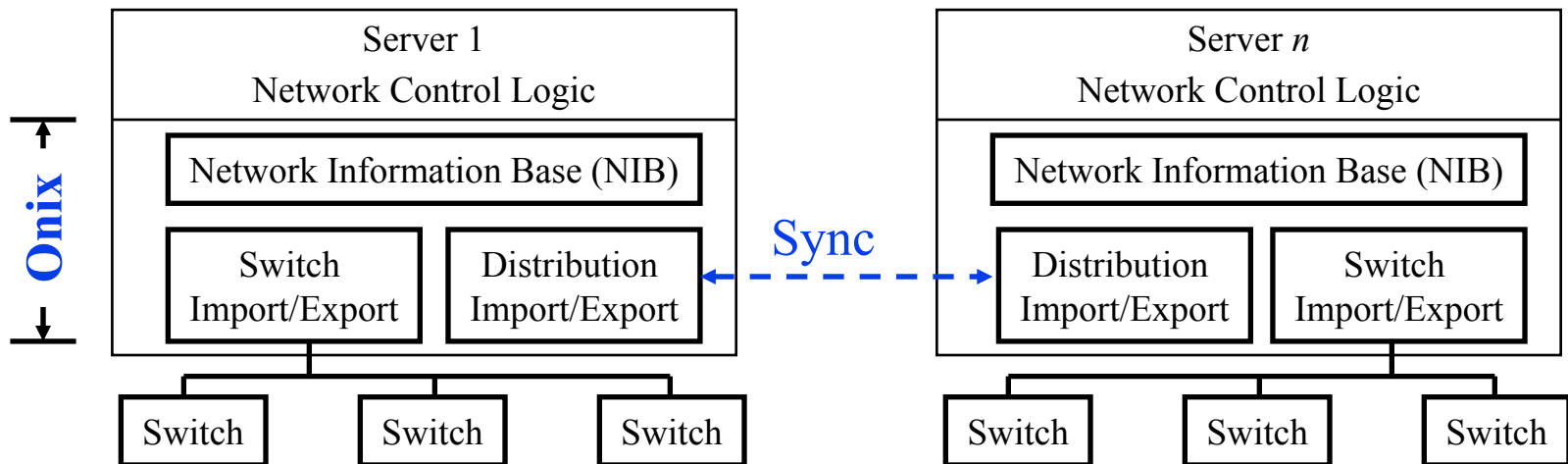
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Beacon

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

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



Ref: T. Koponen, et al., “Onix: A distributed Control Platform for Large Scale Production Networks,” OSDI 2010,
http://static.usenix.org/events/osdi10/tech/full_papers/Koponen.pdf

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/>

Ref: <http://trema.github.com/trema/>

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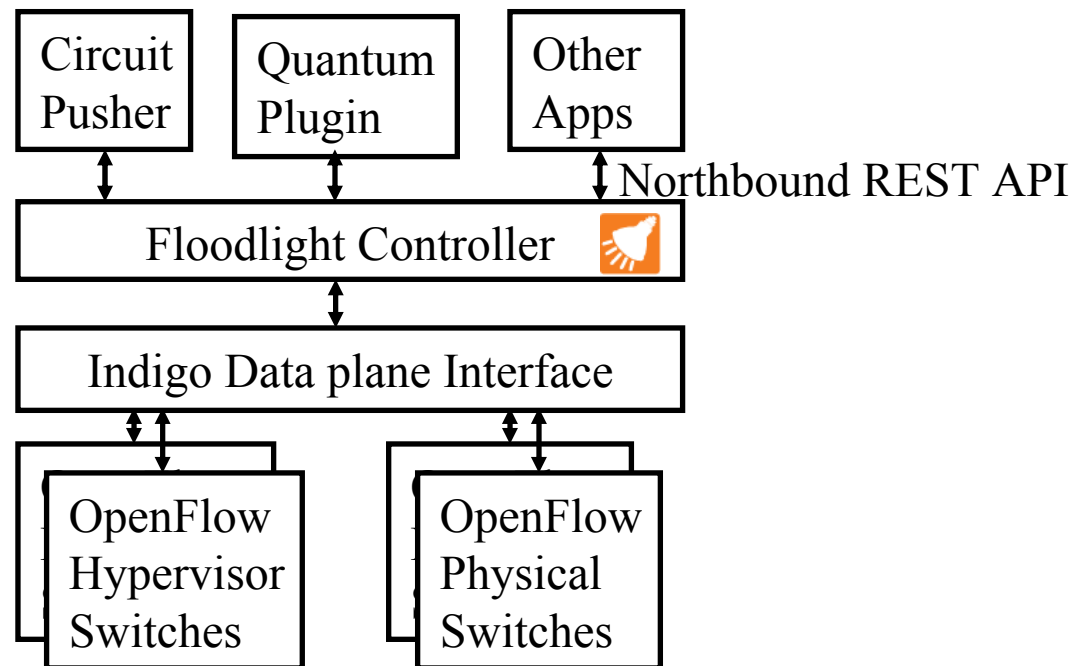
Maestro

- ❑ **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



Floodlight

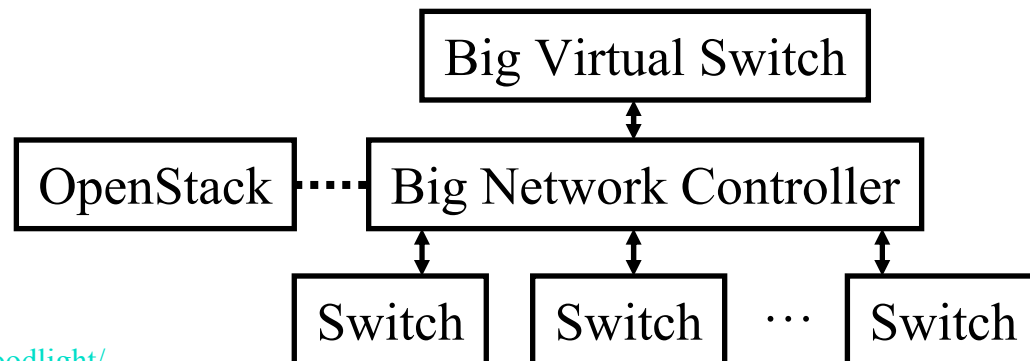
- ❑ **Java** based OpenFlow controller based on Beacon runs within a JVM. Developers from Big Switch Networks
- ❑ Indigo: Software to make switch hardware OpenFlow compatible
- ❑ Floodlight is the core of Big Switch Controller from Big Switch Networks



Ref: S. Azodolmolky, "Software Defined Networking with OpenFlow," Packt Publishing, October 2013, 152 pp., ISBN:978-1-84969-872-6 (Safari Book)

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



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 replaced by Quagga

Ref: http://en.wikipedia.org/wiki/Bird_Internet_routing_daemon

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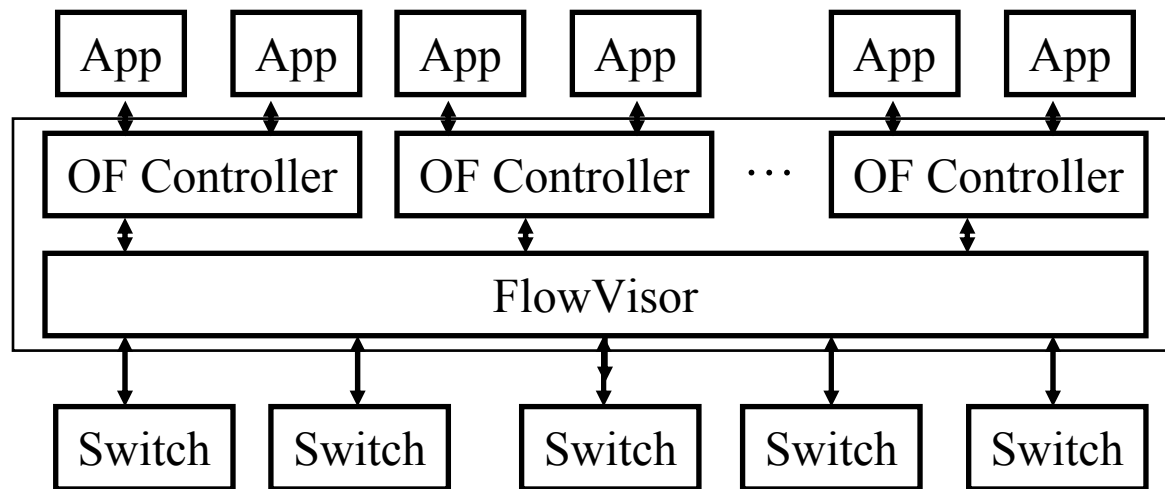
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Key OpenFlow Related Software

- ❑ FlowVisor
- ❑ Mininet
- ❑ Ryu
- ❑ RouteFlow

FlowVisor

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



Ref: <https://github.com/OPENNETWORKINGLAB/flowvisor/wiki?>

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Mininet

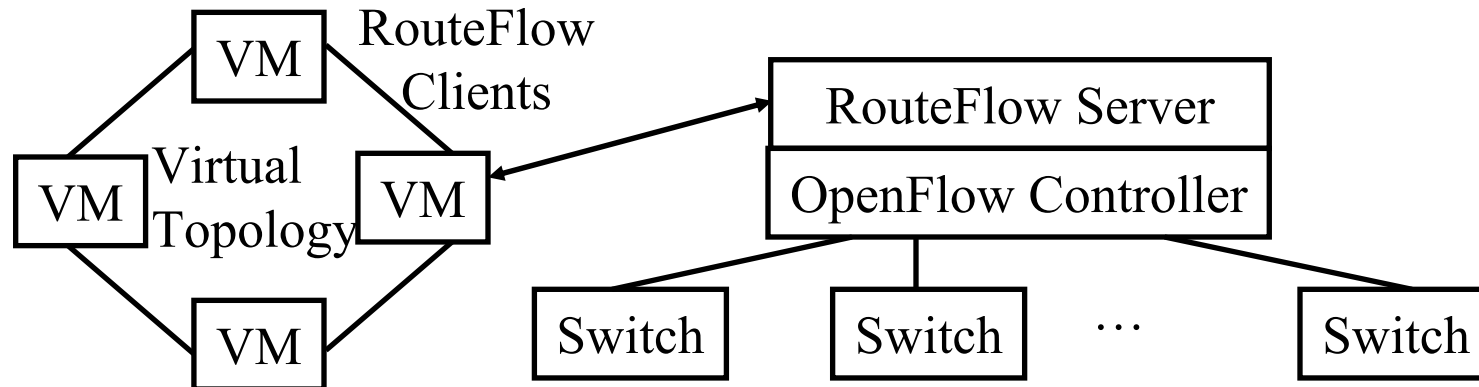
- ❑ Widely used open source network emulation environment.
- ❑ Can simulate a number of end-hosts, switches, routers, links on a Linux
- ❑ Used for rapid prototyping of software define networks
- ❑ Built-in Open vSwitch, and a OpenFlow capable switch
- ❑ Command line launcher and Python API for creating 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.

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

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>

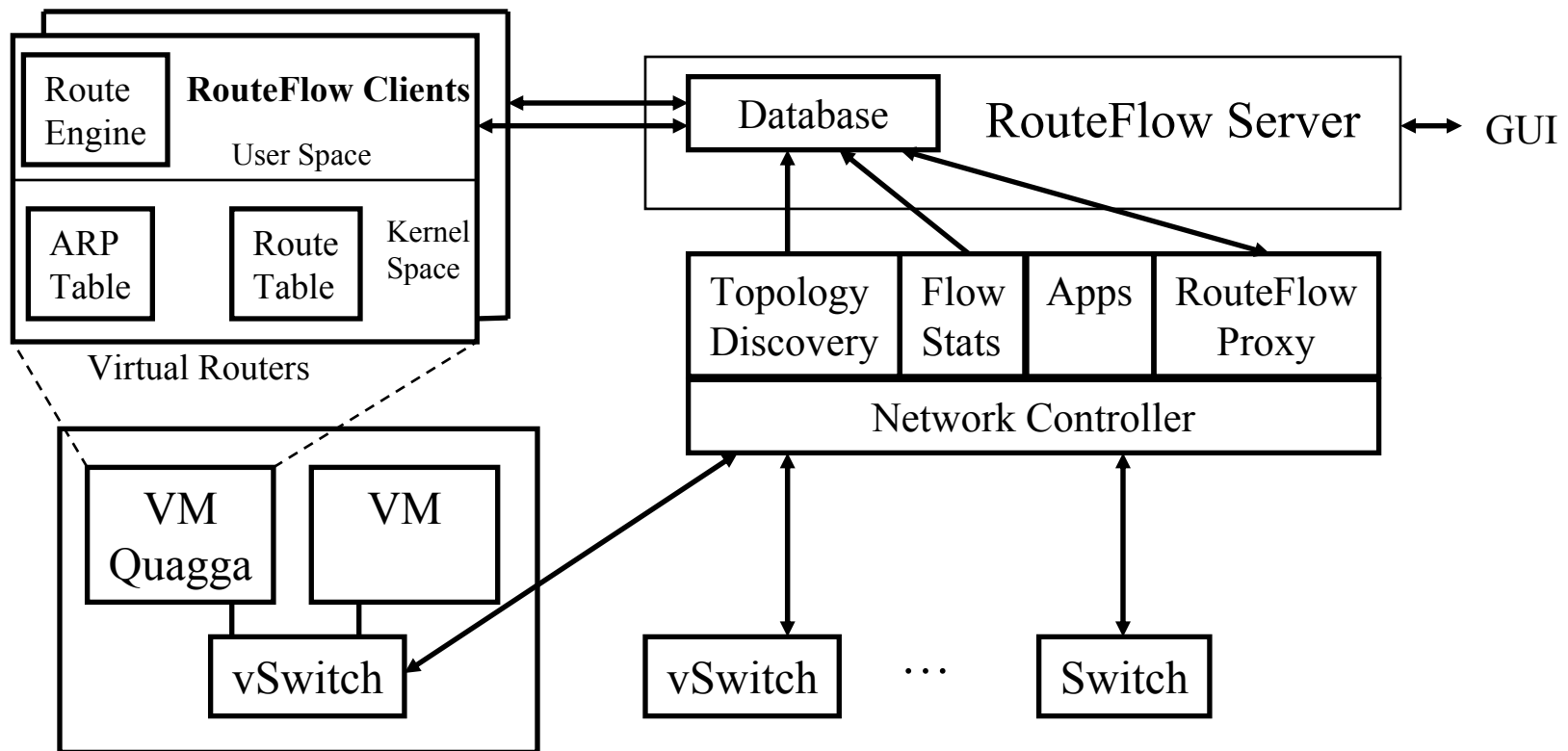
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RouteFlow (Cont)

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



Ref: <https://sites.google.com/site/routeflow/home>

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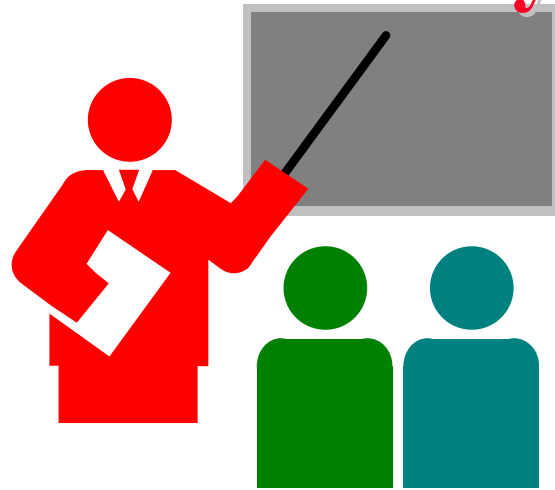
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Other OpenFlow Related Projects

- ❑ **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 Benchmark (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

Ref: <https://github.com/traveling/flower>, <https://github.com/Sovietaced/Avior>, <https://sites.google.com/site/routeflow/home>, <http://archive.openflow.org/wk/index.php/Oflops>, <http://www.es.net/services/virtual-circuits-oscars>, <http://github.com/Luxoft/Twister>, http://www.openflowsec.org/OpenFlow_Security/Home.html

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

- ❑ S. Azodolmolky, "Software Defined Networking with OpenFlow," Packt Publishing, October 2013, 152 pp., ISBN:978-1-84969-872-6 (Safari Book)
- ❑ T. Kooponen, et al., "Onix: A distributed Control Platform for Large Scale Production Networks," OSDI 2010,
http://static.usenix.org/events/osdi10/tech/full_papers/Kooponen.pdf
- ❑ <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)

- ❑ http://en.wikipedia.org/wiki/Bird_Internet_routing_daemon
- ❑ <https://github.com/traveling/flower>
- ❑ <https://github.com/Sovietaced/Avior>
- ❑ <http://archive.openflow.org/wk/index.php/Oflops>
- ❑ <http://www.es.net/services/virtual-circuits-oscars>
- ❑ <http://github.com/Luxoft/Twister>
- ❑ http://www.openflowsec.org/OpenFlow_Security/Home.html

Acronyms

- ❑ ACL Access control list
- ❑ API Application Programming Interface
- ❑ BGP Border Gateway Protocol
- ❑ 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 Media 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