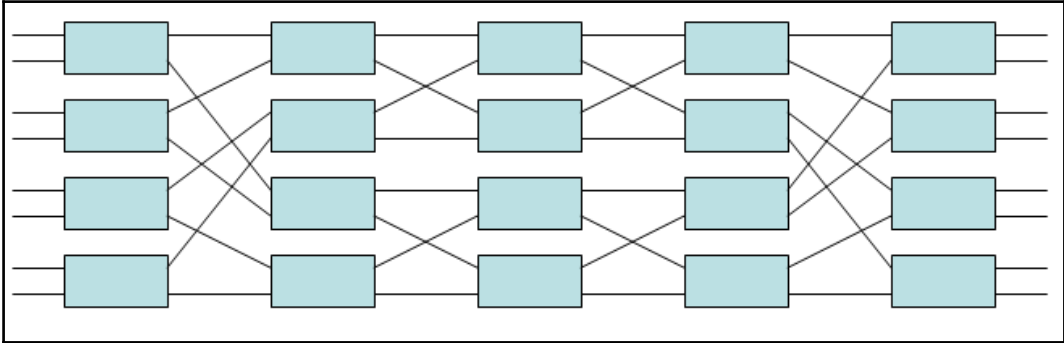
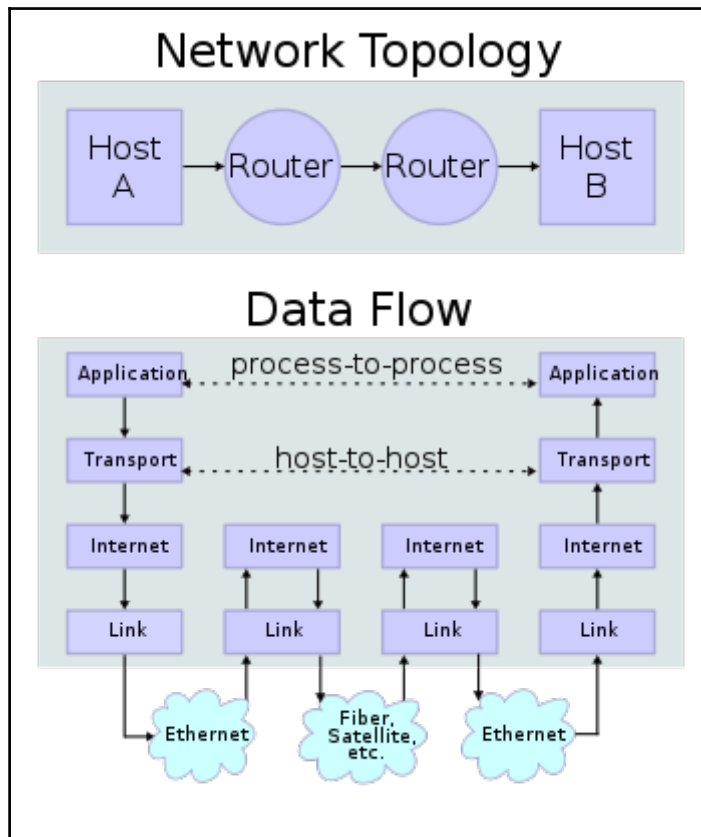


Chapter 1: Review of TCP/IP Protocol Suite and Python Language



OSI Model			
	Layer	Protocol data unit (PDU)	Function ^[3]
Host layers	7. Application	Data	High-level APIs, including resource sharing, remote file access
	6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5. Session		Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
	4. Transport	Segment (TCP) / Datagram (UDP)	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media layers	3. Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2. Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium



TCP Header																																	
Offsets	Octet	0				1				2				3																			
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Source port								Destination port																							
4	32	Sequence number																															
8	64	Acknowledgment number (if ACK set)																															
12	96	Data offset	Reserved 0 0 0			N S	C R	E E	U R	A K	P S	R S	S S	Y I	F N	Window Size																	
16	128	Checksum								Urgent pointer (if URG set)																							
20	160	Options (if data offset > 5. Padded at the end with "0" bytes if necessary.)																															
...																															

UDP Header																																	
Offsets	Octet	0				1				2				3																			
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Source port								Destination port																							
4	32	Length								Checksum																							

IPv4 Header Format																																	
Offsets	Octet	0				1				2				3																			
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version		IHL		DSCP		ECN		Total Length																							
4	32	Identification								Flags		Fragment Offset																					
8	64	Time To Live				Protocol				Header Checksum																							
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160																																
24	192																																
28	224																	Options (if IHL > 5)															
32	256																																

Fixed header format

<i>Offsets</i>	<i>Octet</i>	<i>0</i>				<i>1</i>								<i>2</i>								<i>3</i>											
<i>Octet</i>	<i>Bit</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>19</i>	<i>20</i>	<i>21</i>	<i>22</i>	<i>23</i>	<i>24</i>	<i>25</i>	<i>26</i>	<i>27</i>	<i>28</i>	<i>29</i>	<i>30</i>	<i>31</i>
<i>0</i>	<i>0</i>	<i>Version</i>				<i>Traffic Class</i>								<i>Flow Label</i>																			
<i>4</i>	<i>32</i>	<i>Payload Length</i>								<i>Next Header</i>								<i>Hop Limit</i>															
<i>8</i>	<i>64</i>	<i>Source Address</i>																															
<i>12</i>	<i>96</i>																																
<i>16</i>	<i>128</i>																																
<i>20</i>	<i>160</i>																																
<i>24</i>	<i>192</i>																																
<i>28</i>	<i>224</i>	<i>Destination Address</i>																															
<i>32</i>	<i>256</i>																																
<i>36</i>	<i>288</i>																																

Chapter 2: Low-Level Network Device Interactions

INTEROP Las Vegas

MAR 31-APR 4, 2014 EXPO: APR 1-3

1993

```
Router> enable
Router# configure terminal
Router(config)# enable secret cisco
Router(config)# ip route 0.0.0.0 0.0.0.0 20.2.2.3
Router(config)# interface ethernet0
Router(config-if)# ip address 10.1.1.1 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# interface serial0
Router(config-if)# ip address 20.2.2.2 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# router rip
Router(config-router)# network 10.0.0.0
Router(config-router)# network 20.0.0.0
Router(config-router)# exit
Router(config)# exit
Router# copy running-config startup-config
Router# disable
Router>
```

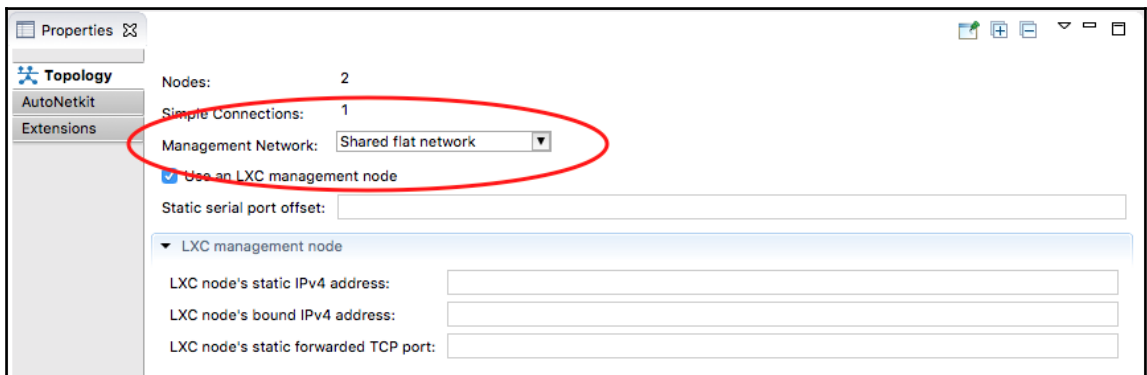
Terminal Protocol: **Telnet**

2013

```
Router> enable
Router# configure terminal
Router(config)# enable secret cisco
Router(config)# ip route 0.0.0.0 0.0.0.0 20.2.2.3
Router(config)# interface ethernet0
Router(config-if)# ip address 10.1.1.1 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# interface serial0
Router(config-if)# ip address 20.2.2.2 255.0.0.0
Router(config-if)# no shutdown
Router(config-if)# exit
Router(config)# router rip
Router(config-router)# network 10.0.0.0
Router(config-router)# network 20.0.0.0
Router(config-router)# exit
Router(config)# exit
Router# copy running-config startup-config
Router# disable
Router>
```

Terminal Protocol: **SSH**





Chapter2.virl | ansible.virl

vir:topology

iosv-1
192.168.0.1

iosv-2
192.168.0.2

Properties

Node

AutoNetkit

Configuration

Extensions

Name: iosv-1

Subtype: IOSv

IPv4: 192.168.0.1

IPv6:

Static Serial Ports

(C)onsole port:

(A)uxiliary port:

(M)onitor port:

(E)xtreme port:


VM Image: Browse...

VM Flavor: Browse...

Exclude node from simulation launch.

Other

Management interface static IPv4 address:


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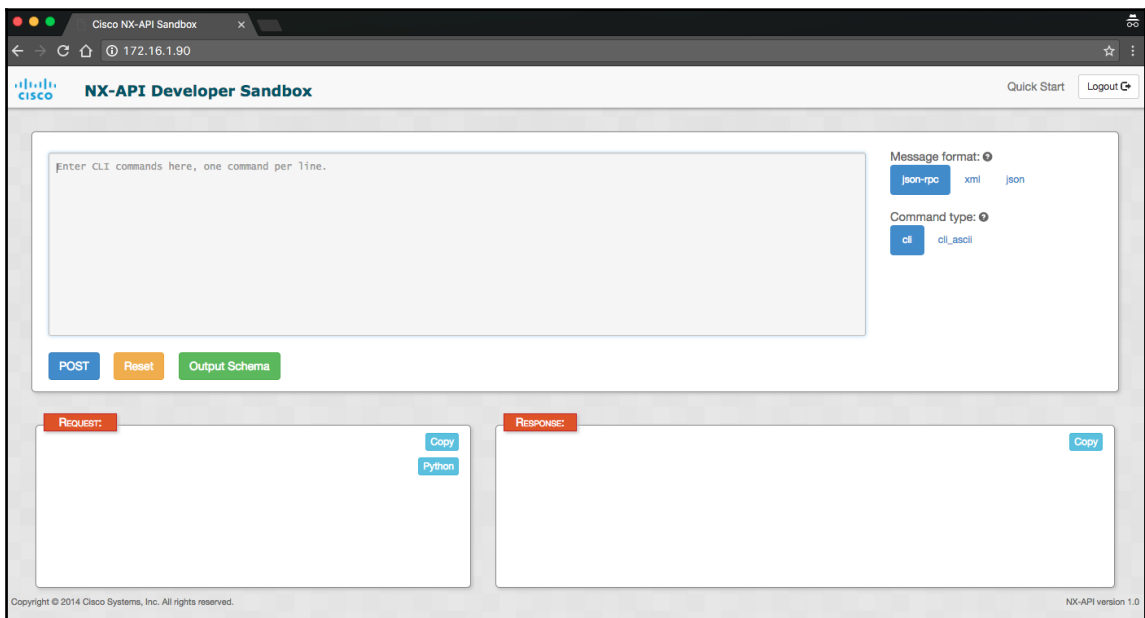
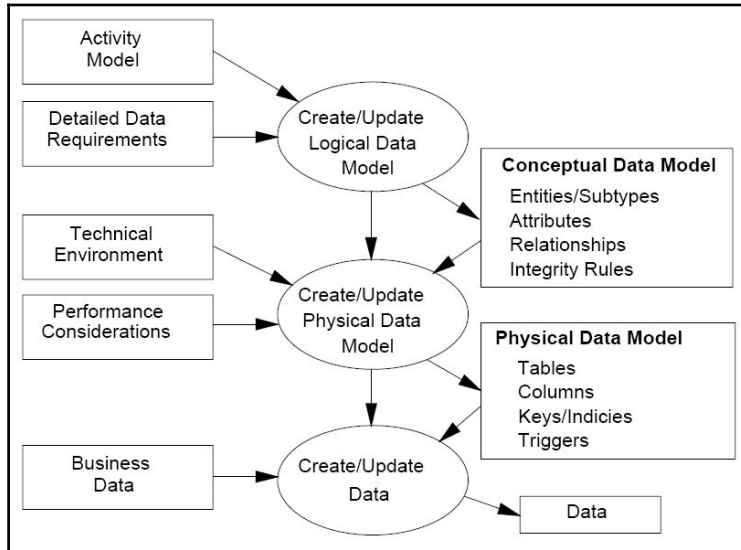
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Chapter 3: API and Intent-Driven Networking



Cisco NX-API Developer Sandbox

172.16.1.90

Quick Start Logout

show version

Message format: json-rpc xml json

Command type: cli cli_ascii

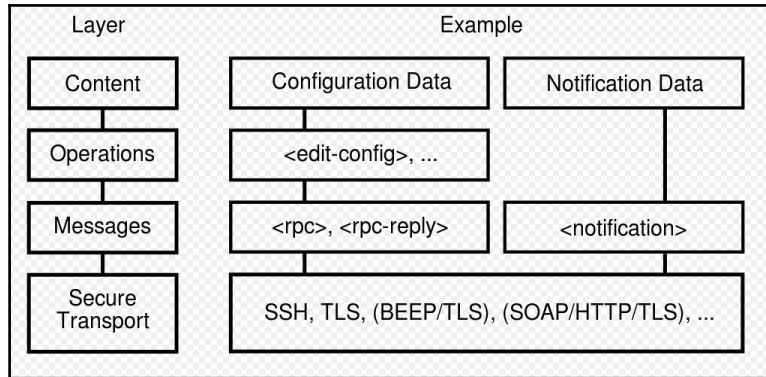
POST Reset Output Schema

REQUEST:

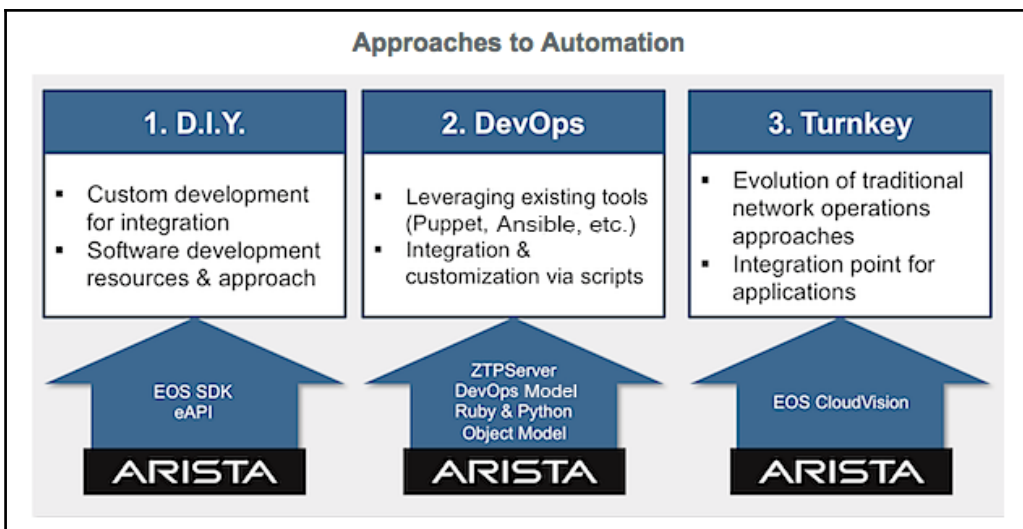
```
{
  "jsonrpc": "2.0",
  "method": "cli",
  "params": {
    "cmd": "show version",
    "version": 1.2
  },
  "id": 1
}
```

RESPONSE:

```
{
  "jsonrpc": "2.0",
  "result": {
    "body": {
      "header_str": "Cisco Nexus Operating System (NX-OS) Software\nTAC support: http://www.cisco.com/te
      "loader_ver_str": "N/A",
      "kickstart_ver_str": "7.2(0)D1(1) [build 7.2(0)ZD(0.120)]",
      "sys_ver_str": "7.2(0)D1(1) [build 7.2(0)ZD(0.120)]",
      "kick_file_name": "bootflash://titanium-d1-kickstart.7.2.0.ZD.0.120.bin",
      "kick_cpl_time": " 3/8/2015 1:00:00",
      "kick_tmstp": "03/08/2015 11:04:12",
      "isan_file_name": "bootflash://titanium-d1.7.2.0.ZD.0.120.bin",
      "isan_cpl_time": " 3/8/2015 1:00:00",
      "isan_tmstp": "03/08/2015 15:24:48"
    }
  }
}
```



Approaches to Automation



Not Secure https://192.168.199.158/explorer.html

ARISTA Command API Explorer Overview Command Documentation

Simple Request Script Editor

Simple eAPI request editor

This page lets you craft a single eAPI request, and explore the returned JSON. Note that this form creates real eAPI requests, so any configuration you perform will apply to this switch. Don't know where to start? Read the [API overview](#) or try one of these examples: [Check version](#), [Create an ACL](#), [Show virtual router](#), or [View running-config](#).

API Endpoint: Version:

Commands:

1	
---	--

Format: Timestamps: ID:

Request Viewer

1	"Enter commands above and click 'Submit POST request'"
---	--

Response Viewer

1	
---	--

API Endpoint

Version

Commands

1	show version
2	

Format

Timestamps

ID

Submit POST request

Request Viewer

```
1- {
2  "jsonrpc": "2.0",
3  "method": "runCmds",
4  "params": {
5    "format": "json",
6    "timestamps": false,
7  "cmds": [
8    "show version"
9  ],
10 "version": 1
11 },
12 "id": "EapiExplorer-1"
13 }
```

Response Viewer

```
1- {
2  "jsonrpc": "2.0",
3  "result": [
4  {
5    "modelName": "DCS-7050QX-32-F",
6    "internalVersion": "4.16.6M-3205780.4166M",
7    "systemMacAddress": "00:1c:73:38:4a:f1",
8    "serialNumber": "JPE13131723",
9    "memTotal": 3978148,
10   "bootupTimestamp": 1465964219.71,
11   "memFree": 257952,
12   "version": "4.16.6M",
13   "architecture": "i386",
14   "isIntlVersion": false,
15   "internalBuildId": "373dbd3c-60a7-4736-8d9e-bf5e7d207689",
16   "hardwareRevision": "00.00"
17  },
18 ],
19 "id": "EapiExplorer-1"
20 }
```

Chapter 4: The Python Automation Framework - Ansible Basics

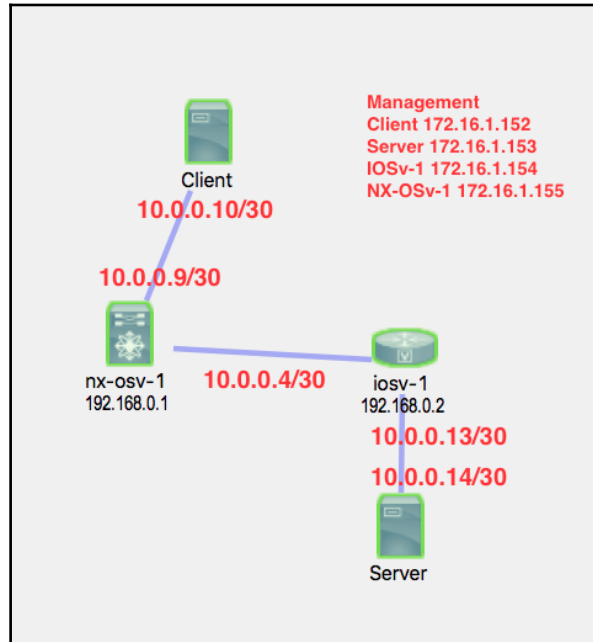
```
---
- hosts: 192.168.199.170
  tasks:
    - name: check disk usage
      shell: df > df_temp.txt
```

PLAYBOOK

PLAY

TASK

Chapter 6: Network Security with Python



Properties ⌵ Problems ⚠

Topology

AutoNetkit

Extensions

Nodes: 4

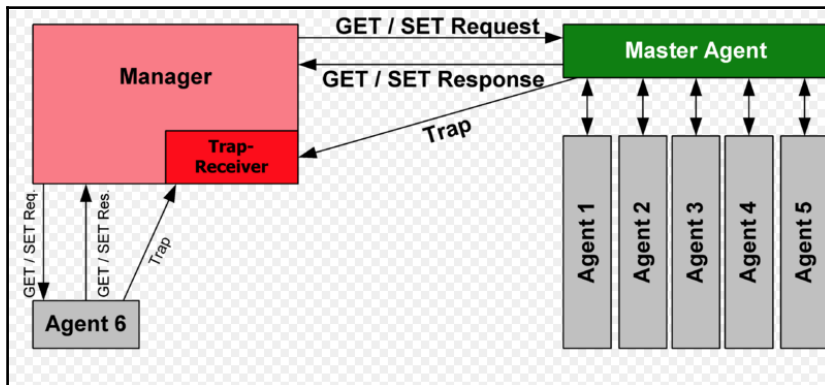
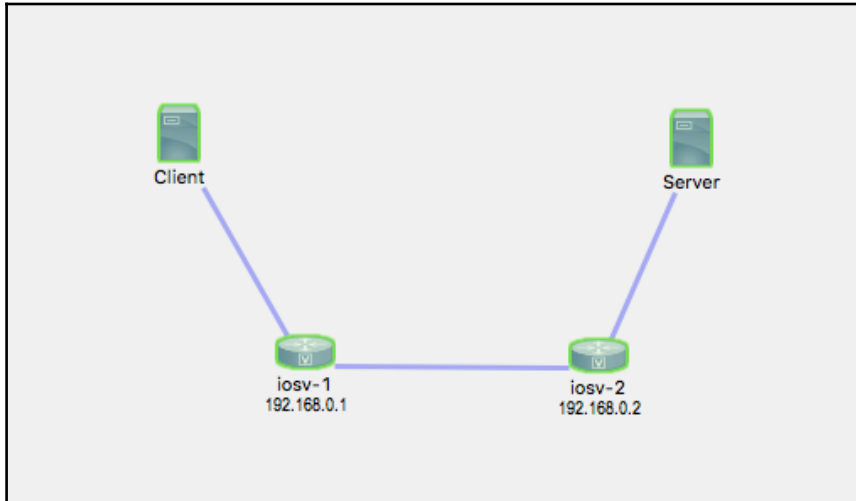
Simple Connections: 3

Management Network: Shared flat network

Use an LXC management node

Static serial port offset:

Chapter 7: Network Monitoring with Python - Part 1

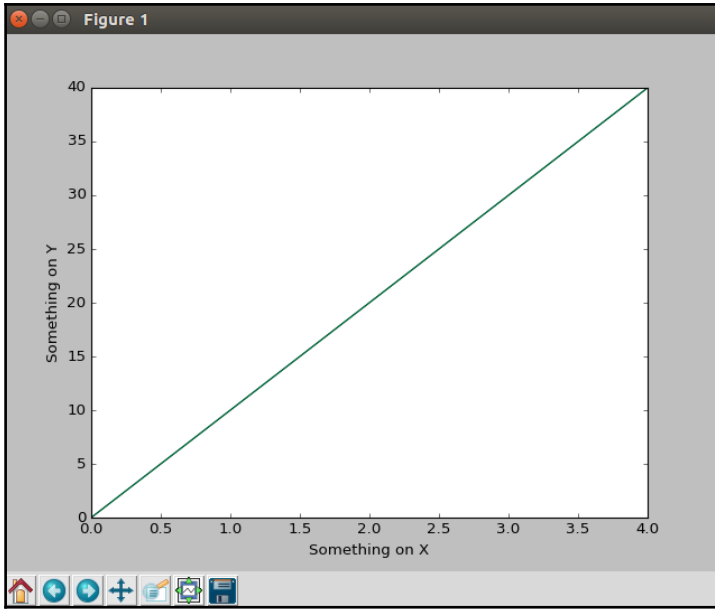


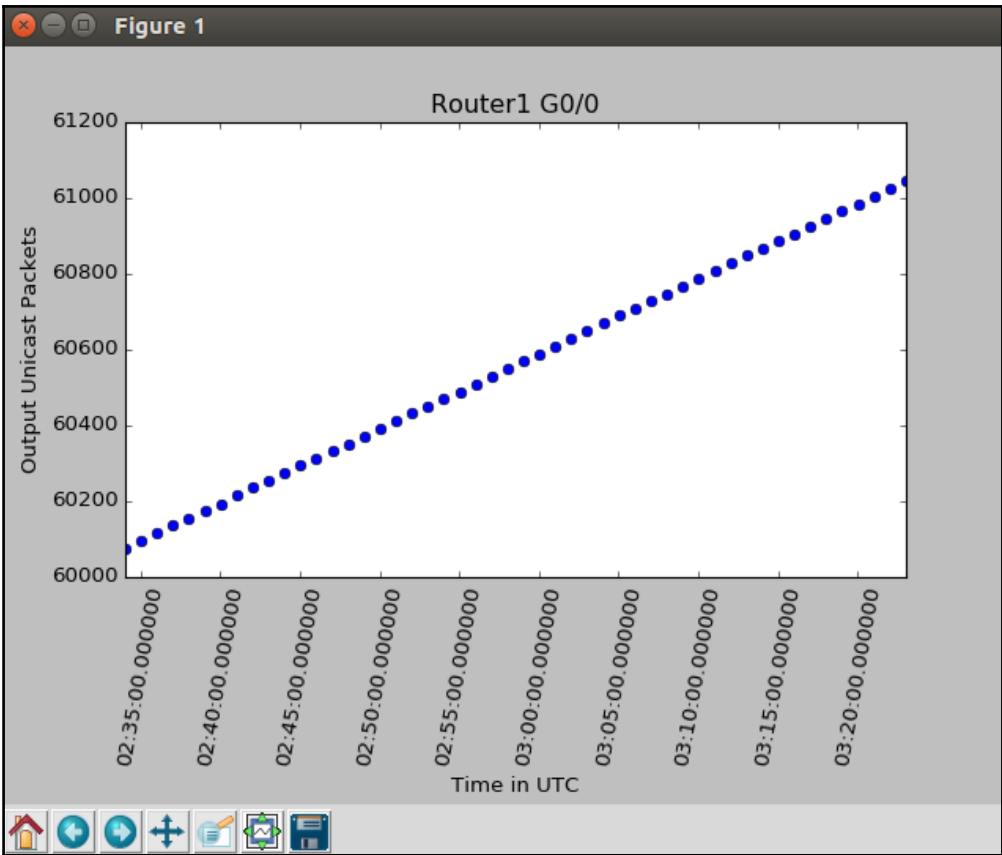
OID Tree

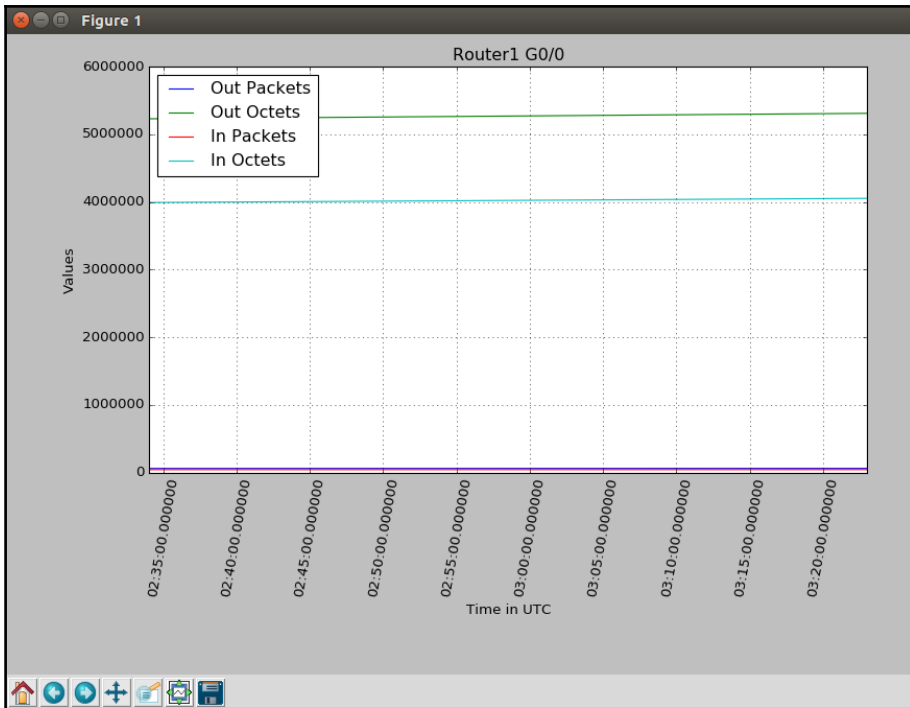
You are currently viewing your object with levels of hierarchy above your object.

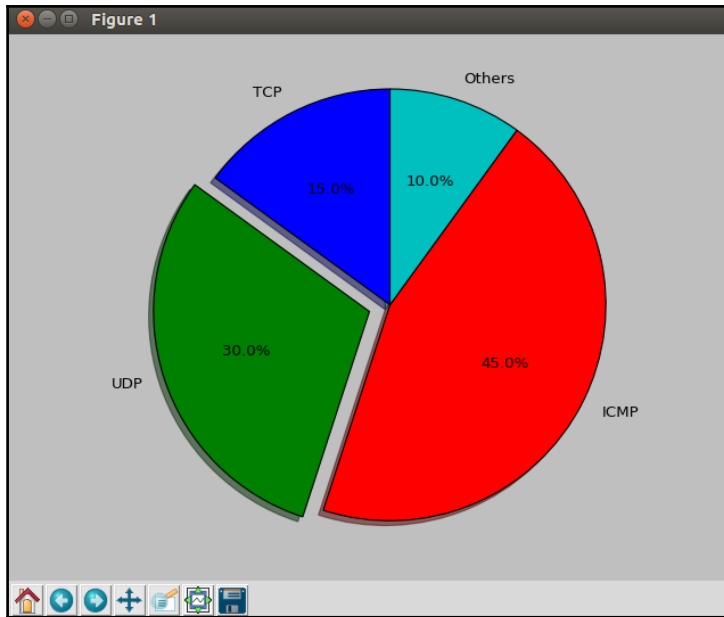
.iso (1) . org (3) . dod (6) . internet (1) . mgmt (2) . mib-2 (1)

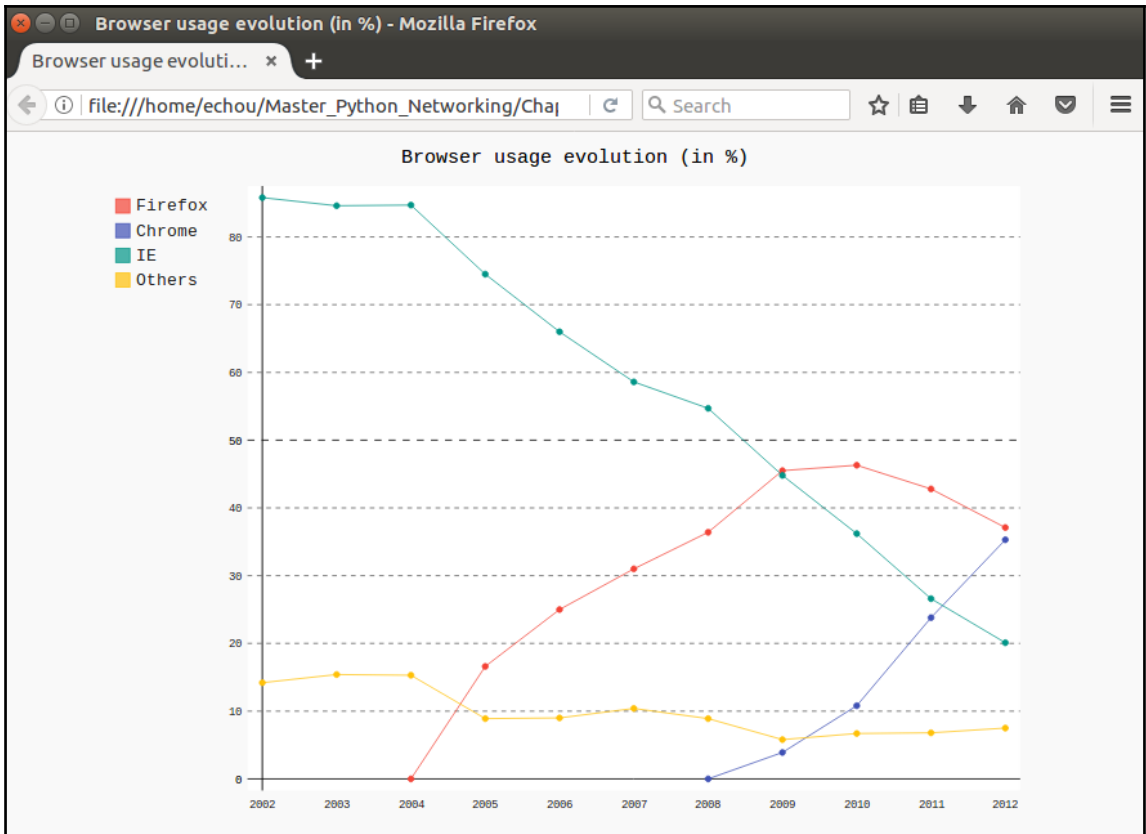
```
|
|-- interfaces (2)
|   |-- ifNumber (1)
|   |-- ifTable (2)
|       |-- ifEntry (1) object Details
|           |-- ifIndex (1)
|           |-- ifDescr (2)
|           |-- ifType (3)
|           |-- ifMtu (4)
|           |-- ifSpeed (5)
|           |-- ifPhysAddress (6)
|           |-- ifAdminStatus (7)
|           |-- ifOperStatus (8)
|           |-- ifLastChange (9)
|           |-- ifInOctets (10)
|           |-- ifInUcastPkts (11)
|           |-- ifInNUcastPkts (12)
|           |-- ifInDiscards (13)
|           |-- ifInErrors (14)
|           |-- ifInUnknownProtos (15)
|           |-- ifOutOctets (16)
|           |-- ifOutUcastPkts (17)
|           |-- ifOutNUcastPkts (18)
|           |-- ifOutDiscards (19)
|           |-- ifOutErrors (20)
|           |-- ifOutQLen (21)
|           |-- ifSpecific (22)
```

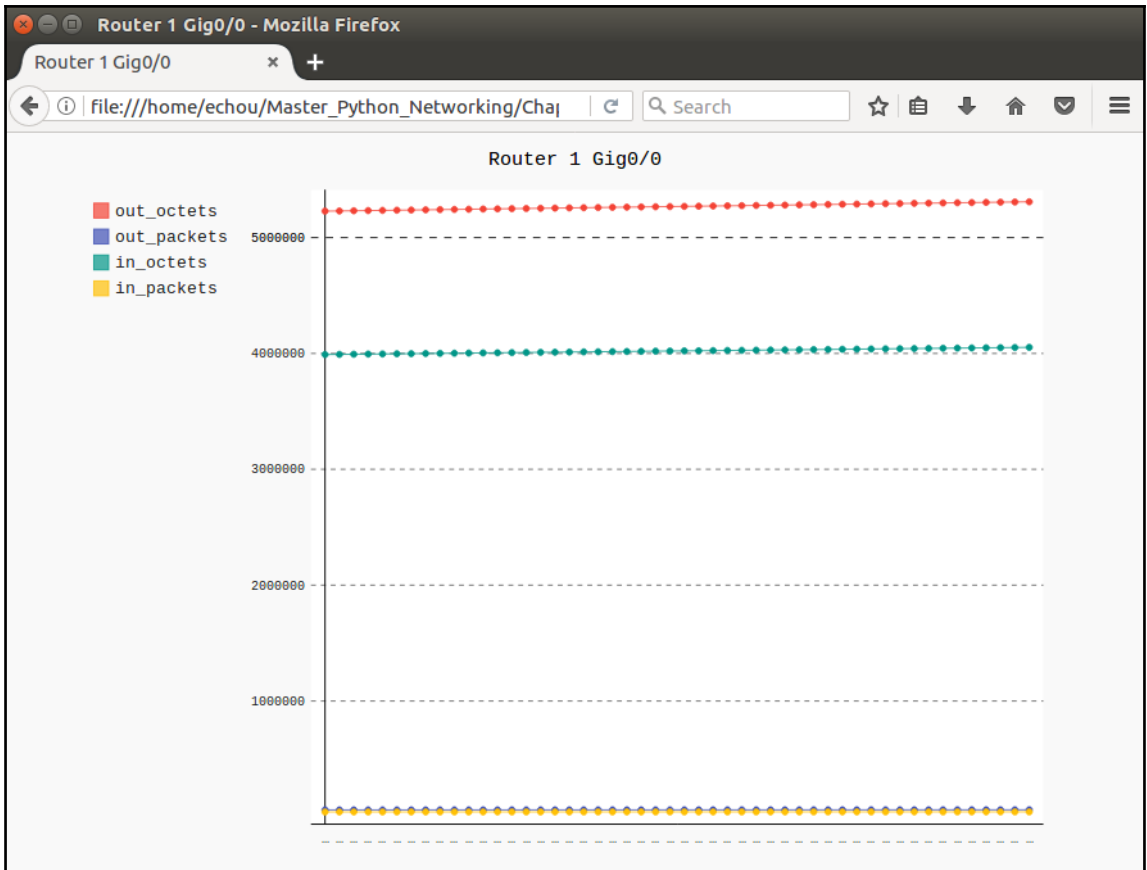


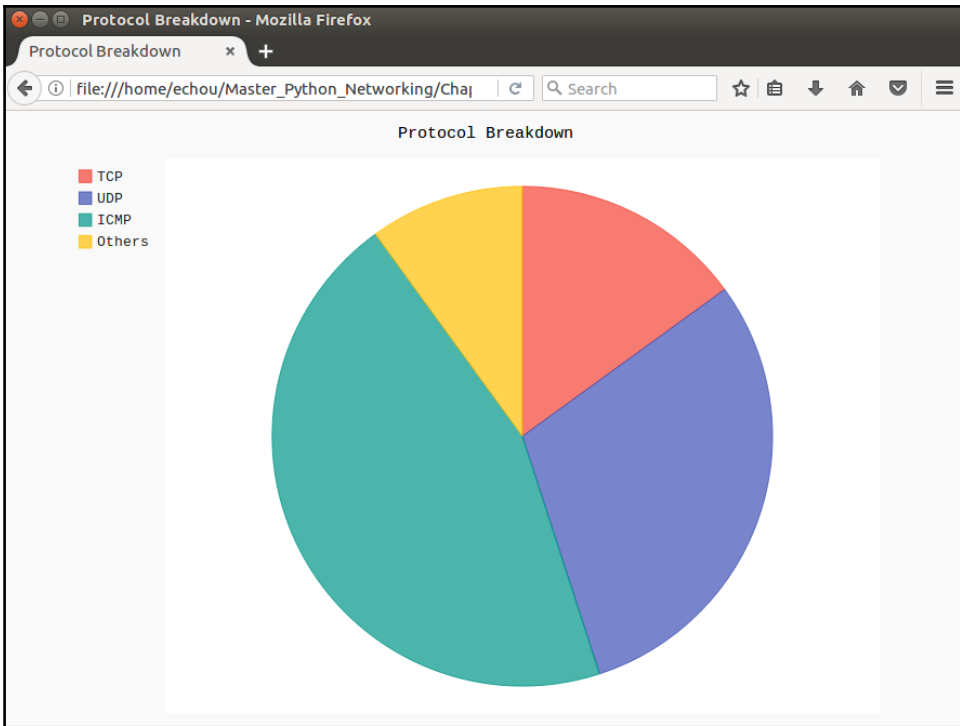












console graphs

Console -> Devices -> (Edit) Logged in as admin (Logout)

Device [new]

General Host Options

Description
Give this host a meaningful description.

Hostname
Fully qualified hostname or IP address for this device.

Host Template
Choose the Host Template to use to define the default Graph Templates and Data Queries associated with this Host.

Number of Collection Threads
The number of concurrent threads to use for polling this device. This applies to the Spine poller only.

Disable Host
Check this box to disable all checks for this host. Disable Host

Availability/Reachability Options

Downed Device Detection
The method Cacti will use to determine if a host is available for polling.
NOTE: It is recommended that, at a minimum, SNMP always be selected.

Ping Timeout Value
The timeout value to use for host ICMP and UDP ping. This host SNMP timeout value applies for SNMP pings.

Ping Retry Count
After an initial failure, the number of ping retries Cacti will attempt before failing.

SNMP Options

SNMP Version
Choose the SNMP version for this device.

SNMP Community
SNMP read community for this device.

SNMP Port
Enter the UDP port number to use for SNMP (default is 161).

SNMP Timeout
The maximum number of milliseconds Cacti will wait for an SNMP response (does not work with php-snmp support).

Maximum OID's Per Get Request
Specified the number of OID's that can be obtained in a single SNMP Get request.

Additional Options

Notes
Enter notes to this host.

IOSv-1 (172.16.1.189)**SNMP Information**

System: Cisco IOS Software, IOSv Software (VIOS-ADVENTERPRISEK9-M), Version
 /www.cisco.com/techsupport Copyright (c) 1986-2016 by Cisco Systems,
 Inc. Compiled Tue 22-Mar-16 16:19 by prod_rel_team
 Uptime: 26687354 (3 days, 2 hours, 7 minutes)
 Hostname: iosv-1.virt.info
 Location:
 Contact:

[*Create Graphs for this Host](#)
[*Data Source List](#)
[*Graph List](#)

New Graphs for [IOSv-1 (172.16.1.189) Cisco Router]

Host: Graph Types:

[*Edit this Host](#)
[*Create New Host](#)

Graph Templates**Graph Template Name**

Create: Cisco - CPU Usage

Create: SNMP - Generic OID Template

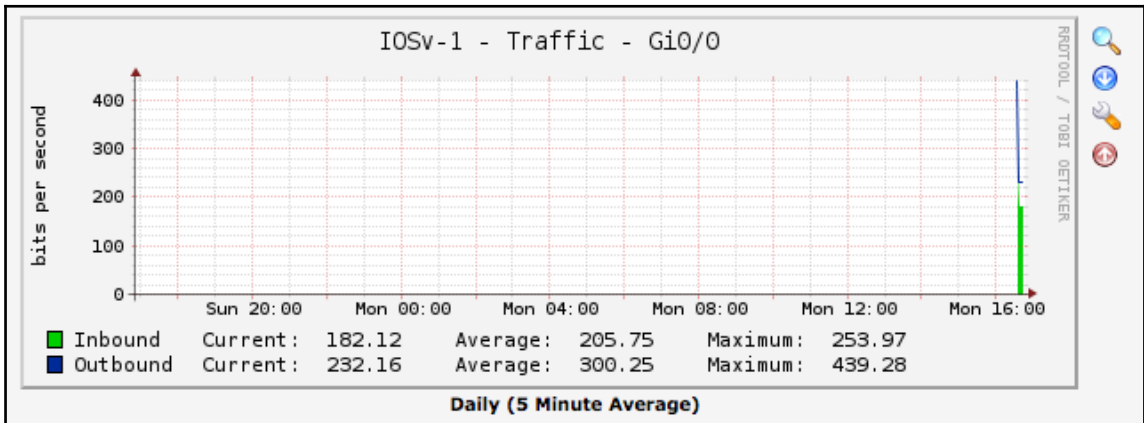
Create:

Data Query [SNMP - Interface Statistics]

Showing All Items

Index	Status	Description	Name (IF-MIB)	Alias (IF-MIB)	Type	Speed	High Speed	Hardware Address	IP Address
1	Up	GigabitEthernet0/0	Gi0/0	OOB Management	6	1000000000	1000	FA:16:3E:45:2B:47	172.16.1.189
2	Up	GigabitEthernet0/1	Gi0/1	to iosv-2	6	1000000000	1000	FA:16:3E:FD:FE:87	10.0.0.13
3	Up	GigabitEthernet0/2	Gi0/2	to Client	6	1000000000	1000	FA:16:3E:71:63:5B	10.0.0.6
4	Up	Null0	Nu0		1	4294967295	10000		
5	Up	Loopback0	Lo0	Loopback	24	4294967295	8000		192.168.0.1

L

Select a graph type: 

console
graphs

Console -> Data Input Methods -> (Edit)
Logged in as admin (Logout)

- Create
- New Graphs
- Management
- Graph Management
- Graph Trees
- Data Sources
- Devices
- Collection Methods
- Data Queries
- Data Input Methods**
- Templates
- Graph Templates
- Host Templates
- Data Templates
- Import/Export
- Import Templates
- Export Templates
- Configuration
- Settings
- Plugin Management
- Utilities
- System Utilities
- User Management
- Logout User

Save Successful.

Data Input Methods [edit: IOSv-1 SNMP Permit Count]

Name
Enter a meaningful name for this data input method.

Input Type
Choose the method you wish to use to collect data for this Data Input method.

Input String
The data that is sent to the script, which includes the complete path to the script and input sources in <> brackets.

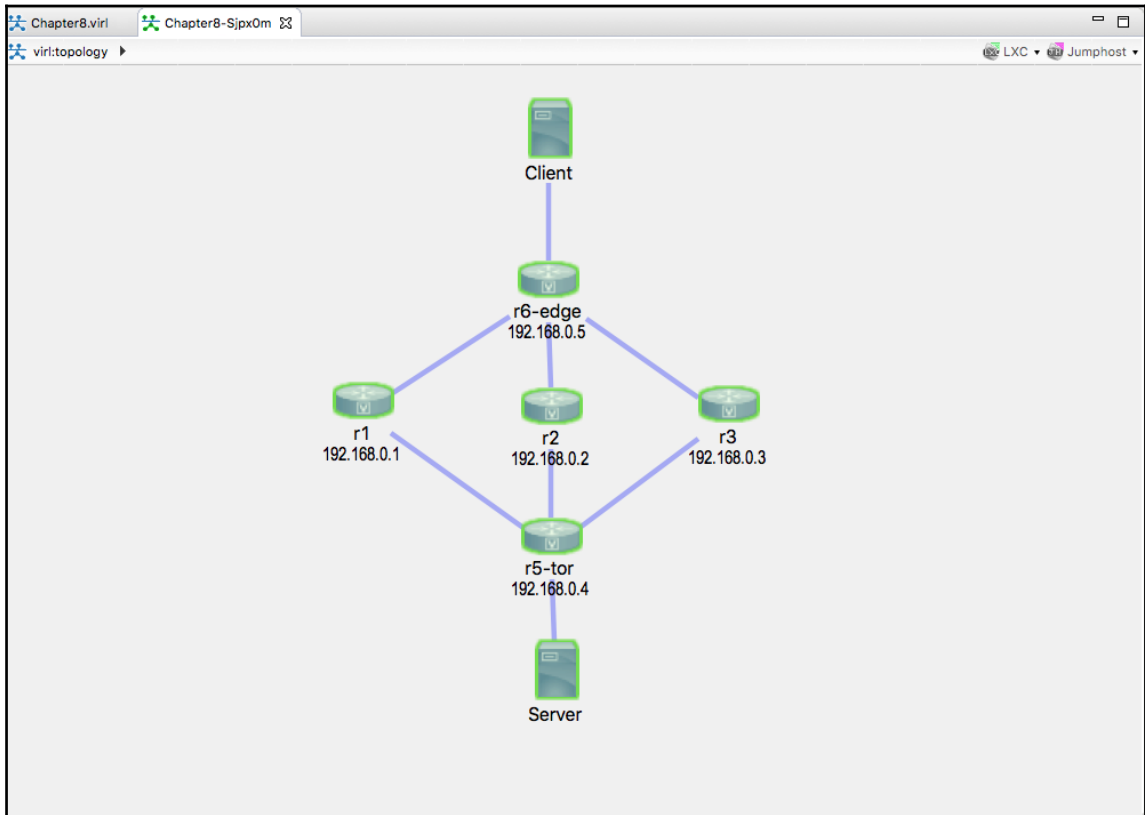
Input Fields

Name	Field Order	Friendly Name	
No Input Fields			

Output Fields

Name	Field Order	Friendly Name	Update RRA
SNMP Permit Count	0 (Not In Use)	SNMP Permit Count	Selected

Chapter 8: Network Monitoring with Python - Part 2



Properties Problems

Topology

AutoNetkit

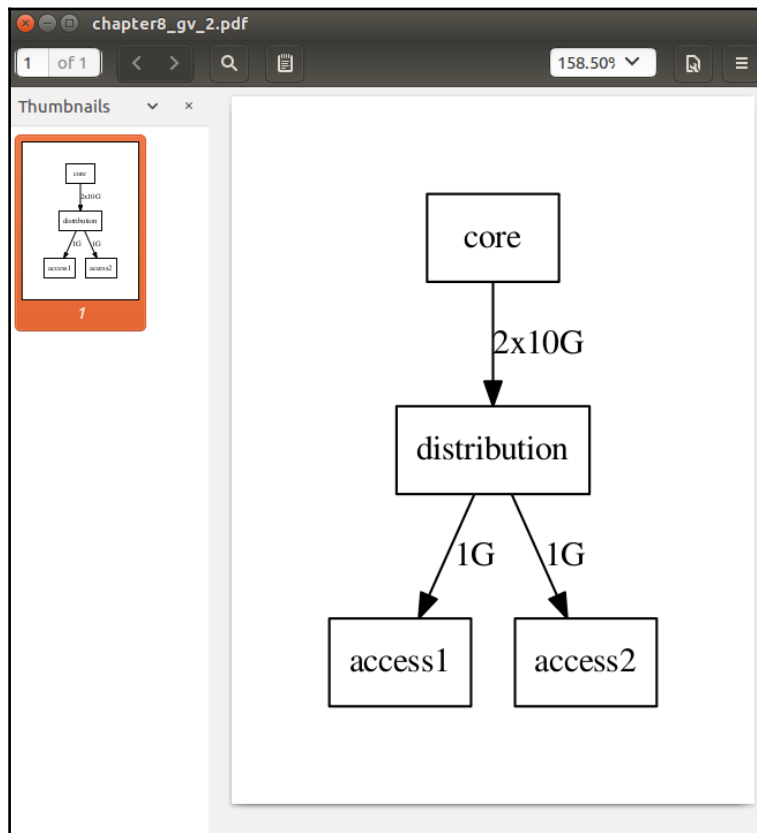
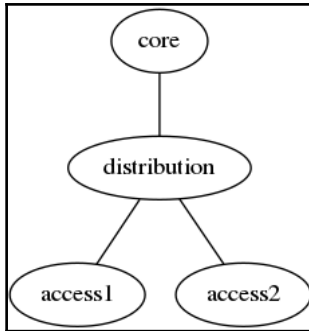
Extensions

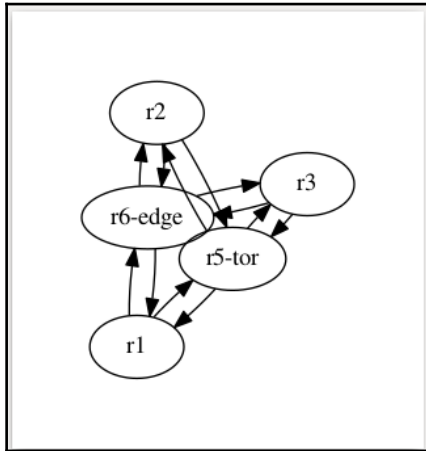
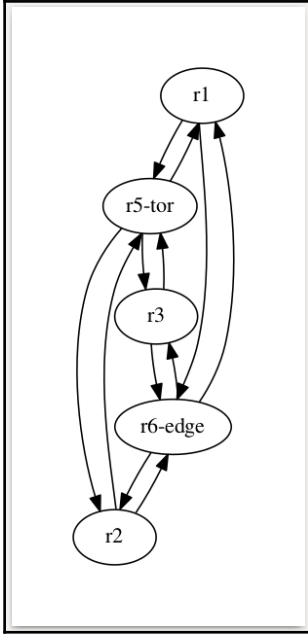
General

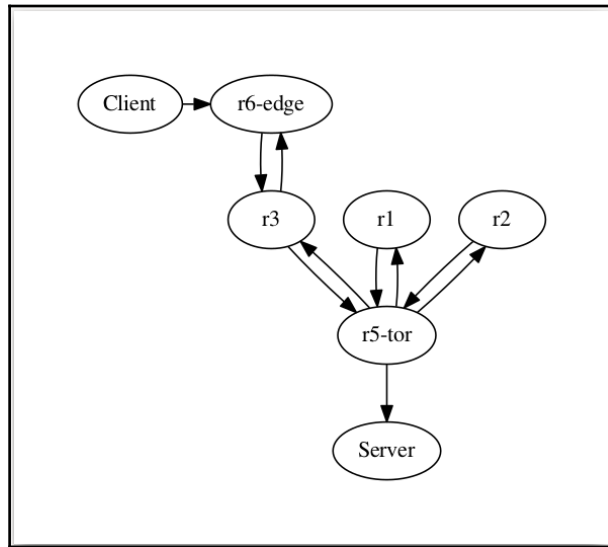
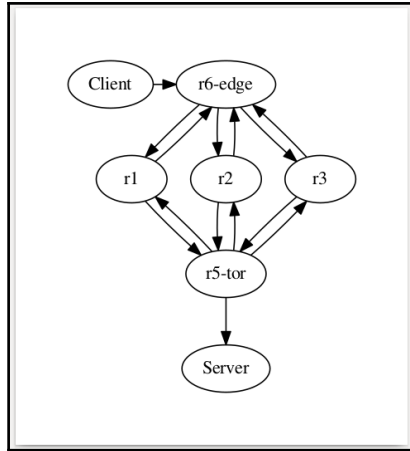
Enable CDP: Default

Enable OnePK: Default

Infrastructure Only: Default







ntop
web

(C) 1998-2012 - Luca Deri

About Summary All Protocols IP Utils Plugins Admin

Search ntop...

Local IP Traffic

Host	IP Address	Data Sent	Data Rcvd	Data Rcvd
172.16.1.1	172.16.1.1	716.7 KBytes	29.0 %	1.7 MBytes
172.16.1.173	172.16.1.173	1.0 MBytes	41.6 %	923.9 KBytes
172.16.1.215	172.16.1.215	0	0.0 %	362.1 KBytes
172.16.1.218	172.16.1.218	74.4 KBytes	3.0 %	10.1 KBytes
172.16.1.219	172.16.1.219	71.5 KBytes	2.9 %	10.0 KBytes
172.16.1.220	172.16.1.220	74.6 KBytes	3.0 %	10.7 KBytes
172.16.1.221	172.16.1.221	75.5 KBytes	3.1 %	10.8 KBytes
172.16.1.222	172.16.1.222	69.2 KBytes	2.8 %	12.5 KBytes
172.16.1.254	172.16.1.254	362.1 KBytes	14.6 %	0
Total Traffic		Data Sent	Data Rcvd	Used Bandwidth
2.7 MBytes		2.4 MBytes	3.0 MBytes	19.6 Kbit/s

ntop

(C) 1998-2012 - Luca Deri

About Summary All Protocols IP Utils Plugins Admin

Search ntop...

Top Talkers: Last Hour

Time Period	Top Senders	Top Receivers
1. Mon Mar 13 22:27:00 2017 Mon Mar 13 22:27:59 2017	172.16.1.173 11.8 Kbit/s	172.16.1.1 18.4 Kbit/s
	172.16.1.1 5.4 Kbit/s	172.16.1.173 6.8 Kbit/s
	172.16.1.254 2.6 Kbit/s	172.16.1.215 2.6 Kbit/s
		224.0.0.251 2.1 bit/s
2. Mon Mar 13 22:26:00 2017 Mon Mar 13 22:26:59 2017	172.16.1.173 10.6 Kbit/s	172.16.1.1 17.6 Kbit/s
	172.16.1.1 5.3 Kbit/s	172.16.1.173 6.7 Kbit/s
	172.16.1.254 2.6 Kbit/s	172.16.1.215 2.6 Kbit/s
	172.16.1.2 1.1 bit/s	224.0.0.251 3.0 bit/s
3. Mon Mar 13 22:25:00 2017 Mon Mar 13 22:25:59 2017	172.16.1.173 9.0 Kbit/s	172.16.1.1 16.4 Kbit/s
	172.16.1.1 5.2 Kbit/s	172.16.1.173 6.7 Kbit/s
	172.16.1.254 2.6 Kbit/s	172.16.1.215 2.6 Kbit/s
	172.16.1.221 547.5 bit/s	172.16.1.222 89.5 bit/s
4. Mon Mar 13 22:24:00 2017 Mon Mar 13 22:24:59 2017	172.16.1.173 9.2 Kbit/s	172.16.1.1 17.2 Kbit/s
	172.16.1.1 5.4 Kbit/s	172.16.1.173 5.0 Kbit/s
	172.16.1.254 2.6 Kbit/s	172.16.1.215 2.6 Kbit/s
	172.16.1.220 193.5 bit/s	172.16.1.221 35.7 bit/s
	172.16.1.219 184.5 bit/s	172.16.1.222 35.7 bit/s

Run time/Internal	
Web server URL	http://any:3000
GDBM version	GDBM version 1.8.3. 10/15/2002 (built Nov 16 2014 23:11:58)
Embedded Python	2.7.12 (default, Nov 19 2016, 06:48:10) [GCC 5.4.0 20160609]

Directory (search) order	
Data Files	<ul style="list-style-type: none"> ./usr/share/ntop ./usr/local/share/ntop
Config Files	<ul style="list-style-type: none"> ./usr/share/ntop ./usr/local/etc/ntop ./etc
Plugins	<ul style="list-style-type: none"> ./plugins ./usr/lib/ntop/plugins ./usr/local/lib/ntop/plugins


The screenshot shows the ntop web interface. At the top left is the ntop logo. Below it is a navigation menu with tabs: About, Summary, All Protocols, IP, Utils, Plugins, Admin. A dropdown menu is open under 'About', listing: What is ntop?, ntop blog, Credits, Make a Donation, ntop World, Online Documentation, Show Configuration, and Report a Problem. The 'Online Documentation' dropdown is further expanded to show: Man Page, Python ntop Engine, Help, FAQ, and Risk Flags. The 'Python ntop Engine' dropdown is also expanded to show: Python API and Tutorial. Below the navigation is a table with IP addresses:

172.16.1.215		
172.16.1.216	💡	🚩
	💡	

The screenshot shows a web browser window with the URL `172.16.1.173:3000/python/chapter8_ntop_1.py`. The ntop web interface is displayed, including the navigation menu and a search bar. The main content area shows the title "Mastering Python Networking" and a personalized greeting: "Hello, Eric" and "Ntop Information: 5.0.1 x86_64-pc-linux-gnu 2 days 22:54:55". At the bottom, there is a footer with technical details:

Report created on Thu Mar 16 21:00:31 2017 [ntop uptime: 2 days 22:54:55]
 Generated by ntop v5.0.1 (64 bit) [x86_64-pc-linux-gnu]
 © 1998-2012 by Luca Deri, built: Dec 8 2016 05:27:54.
 Listening on [ens34] for all packets (i.e. without a filtering expression)
 Web reports include only interface "ens34"
 172.16.1.1 -- [16/Mar/2017:21:00:31 -0700] "GET /python/chapter8_ntop_1.py HTTP/1.1" 200 10220 -- 48

← → ↻ 🏠 ⓘ 172.16.1.173:3000/python/chapter8_ntop_2.py




About Summary All Protocols IP Utils Plugins Admin

Mastering Python Networking

Here are my interfaces:
["ens34"]

Report created on Thu Mar 16 21:12:03 2017 [ntop uptime: 2 days 23:06:27]
Generated by ntop v.5.0.1 (64 bit) [x86_64-po-linux-gnu]
© 1998-2012 by Luca Deri, built: Dec 8 2015 05:27:54.
Listening on [ens34] for all packets (i.e. without a filtering expression)
Web reports include only interface "ens34"
172.16.1.1 -- [16/Mar/2017:21:12:03 -0700] "GET /python/chapter8_ntop_2.py HTTP/1.1" 200 10191 -- 24

← → ↻ 🏠 ⓘ 192.168.199.185:8008/html/index.html ☆ ⋮



Apps Agents Metrics Keys Flows Thresholds Events About

Software Version	2.0-1180
Host Name	pythonicNeteng
sFlow Rate	237 bits
License	Research and Evaluation License

The sFlow-RT analytics module incorporates InMon's asynchronous sFlow analysis technology (patent pending) to deliver real-time performance metrics through the [REST and JavaScript APIs](#). Visit [sFlow-RT.com](#) for documentation, software, and community support.

[Acknowledgements](#) lists third party software included in this package.

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← → ↻ 🏠 192.168.199.185:8008/agents/html ☆ ⋮

inMon sFlow-RT

Apps Agents Metrics Keys Flows Thresholds Events About

192.168.199.148 | 1.686

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Services ▾ Resource Groups ▾ ⚙

Eric Chou ▾ N. Virginia ▾ Support ▾

Dashboard

My domains

Modify the access policy for [REDACTED]

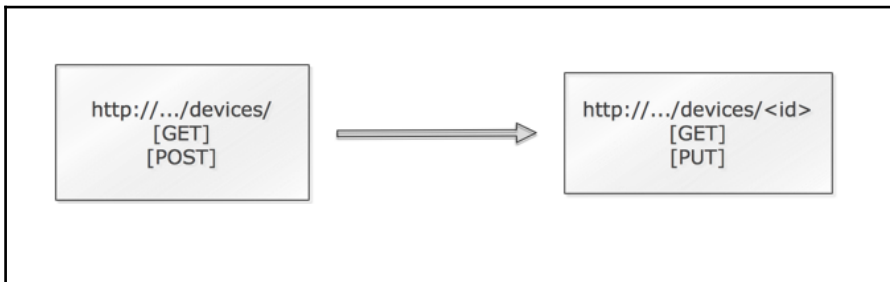
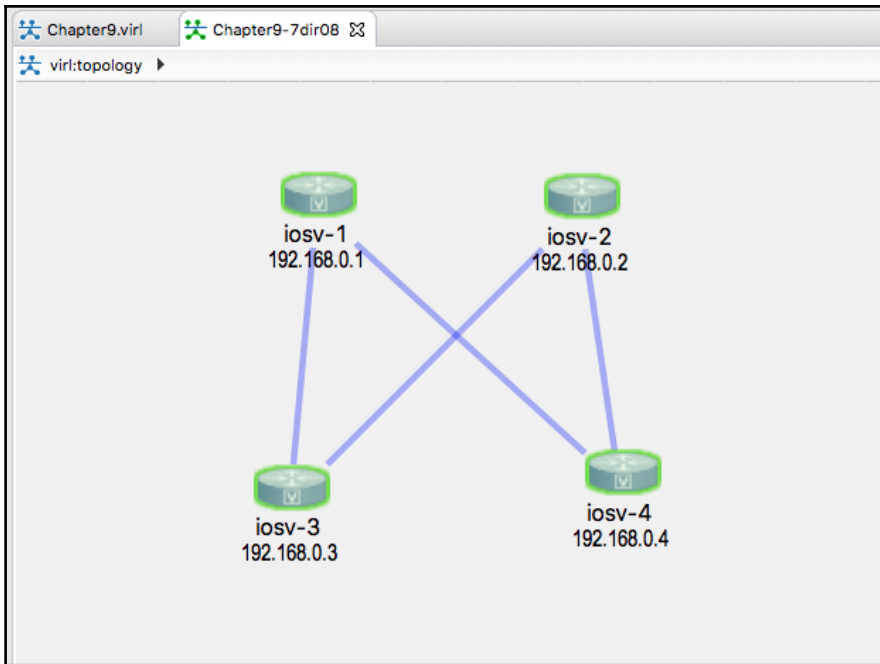
To allow or block access to the domain, select a policy template from the template selector or add one or more Identity and Access Management (IAM) policy statements in the **Edit the access policy** box.

Status **Active**

Set the domain access policy to

Add or edit the access policy

```
1 {
2   "Version": "2012-10-17",
3   "Statement": [
4     {
5       "Sid": "",
6       "Effect": "Allow",
7       "Principal": {
8         "AWS": "*"
9       },
10      "Action": "es:*",
11      "Resource": "arn:aws:es:us-east-1:[REDACTED]",
12      "Condition": {
13        "IpAddress": {
14          "aws:SourceIp": [
15            [REDACTED],
16            [REDACTED],
17            [REDACTED],
18            [REDACTED],
19            [REDACTED],
20            [REDACTED],
21            [REDACTED],
22            [REDACTED]
23          ]
24        }
25      }
26    }
27  ]
28 }
```

Chapter 10: OpenFlow Basics

The screenshot shows a web browser window with the URL `sdnhub.org/tutorials/sdn-tutorial-vm/`. The page features a dark navigation bar with the SDN Hub logo and menu items: TUTORIALS, RESOURCES, PROJECTS, EVENTS, and ABOUT. A red star icon highlights the current page title: "All-in-one SDN App Development Starter VM".

The main content area includes a paragraph: "Jumpstart your SDN development through our all-in-one pre-built tutorial VM, built for you by SDN Hub. This is a 64-bit Ubuntu 14.04 image (3GB) that has a number of SDN software and tools installed."

- SDN Controllers: [OpenDaylight](#), [ONOS](#) ^{new}, [RYU](#), [Floodlight](#), [Floodlight-OF1.3](#), [POX](#), and [Trema](#)
- Example code for a hub, L2 learning switch, traffic tap, and other applications
- [Open vSwitch 2.3.0](#) with support for Openflow 1.2, 1.3 and 1.4, and [LINC switch](#)
- [Mininet](#) to create and run example topologies
- [Pyretic](#)
- Wireshark 1.12.1 with native support for OpenFlow parsing
- JDK 1.8, Eclipse Luna, and Maven 3.3.3

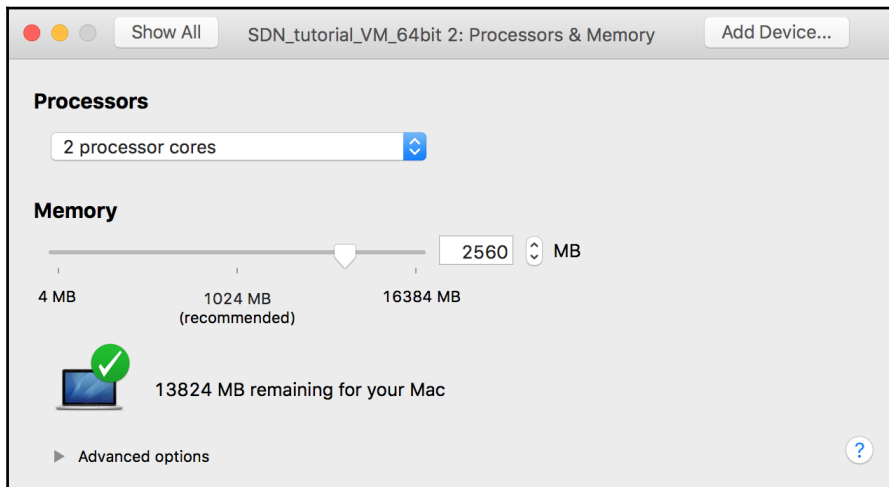
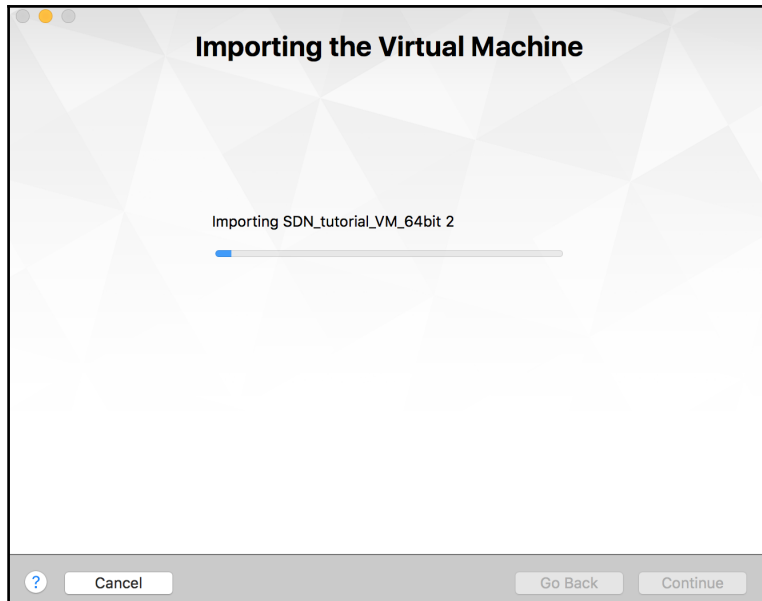
Download

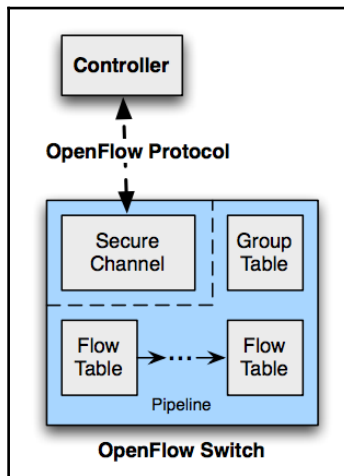
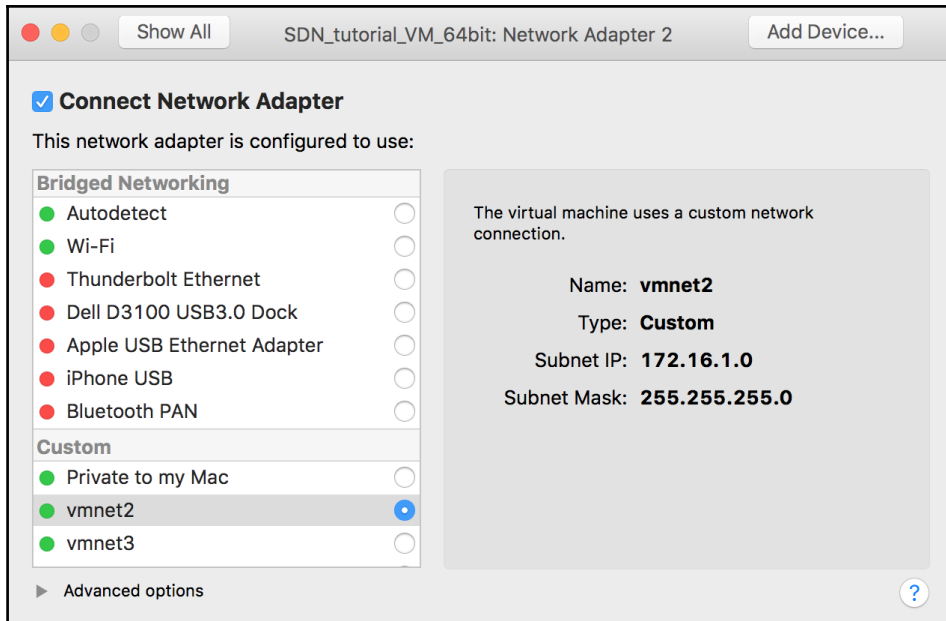
1. You can directly download the OVA file from our file server: [\[64-bit | 32-bit\]](#)

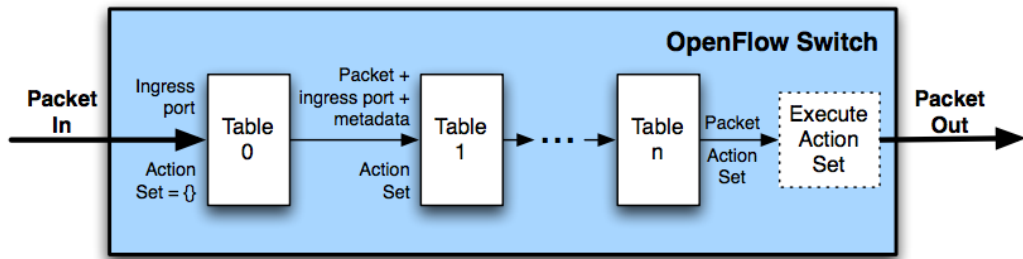
Instructions to use the VM

- Import the OVA (i.e., SDN Hub Tutorial VM) into Virtualbox or VMware Player and boot it. Feel free to change any of the VM attributes, but we highly recommend allocating at least 2 vCPUs and 2GB memory.
- In case the OVA (version 1.0) does not work on your VirtualBox or VMware player, unzip the OVA to extract the VMDK file. That file can be used to create a VM in your environment.
- Ensure you have connectivity to the Internet from the VM. If not, please ensure your Virtualbox/VMware network settings are correct for the VM's network adapter (should be in NAT mode).
- **Username and passwd are both "ubuntu"**
- You will need to open a **Terminal Emulator** to create and run network topologies using mininet. A link is placed right on the desktop.

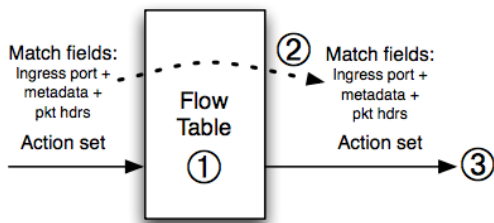
The right sidebar contains a search bar, a "RECENT POSTS" section with four entries (each with a right-pointing chevron), and a "POST ARCHIVES" section with a "Select Month" dropdown menu.







(a) Packets are matched against multiple tables in the pipeline



① Find highest-priority matching flow entry

② Apply instructions:

- i. Modify packet & update match fields (apply actions instruction)
- ii. Update action set (clear actions and/or write actions instructions)
- iii. Update metadata

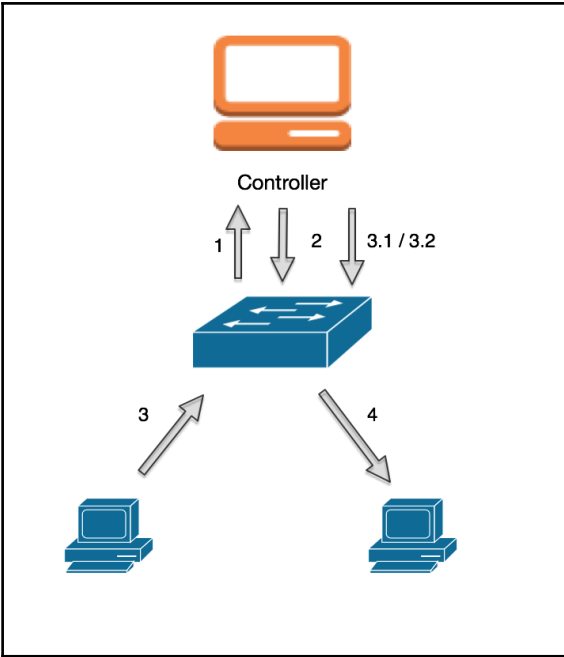
③ Send match data and action set to next table

(b) Per-table packet processing

```

/* OXM Flow match field types for OpenFlow basic class. */
enum oxm_ofb_match_fields {
    OFPXMT_OFB_IN_PORT          = 0, /* Switch input port. */
    OFPXMT_OFB_IN_PHY_PORT     = 1, /* Switch physical input port. */
    OFPXMT_OFB_METADATA        = 2, /* Metadata passed between tables. */
    OFPXMT_OFB_ETH_DST         = 3, /* Ethernet destination address. */
    OFPXMT_OFB_ETH_SRC         = 4, /* Ethernet source address. */
    OFPXMT_OFB_ETH_TYPE        = 5, /* Ethernet frame type. */
    OFPXMT_OFB_VLAN_VID        = 6, /* VLAN id. */
    OFPXMT_OFB_VLAN_PCP        = 7, /* VLAN priority. */
    OFPXMT_OFB_IP_DSCP         = 8, /* IP DSCP (6 bits in ToS field). */
    OFPXMT_OFB_IP_ECN          = 9, /* IP ECN (2 bits in ToS field). */
    OFPXMT_OFB_IP_PROTO        = 10, /* IP protocol. */
    OFPXMT_OFB_IPV4_SRC        = 11, /* IPv4 source address. */
    OFPXMT_OFB_IPV4_DST        = 12, /* IPv4 destination address. */
    OFPXMT_OFB_TCP_SRC         = 13, /* TCP source port. */
    OFPXMT_OFB_TCP_DST         = 14, /* TCP destination port. */
    OFPXMT_OFB_UDP_SRC         = 15, /* UDP source port. */
    OFPXMT_OFB_UDP_DST         = 16, /* UDP destination port. */
    OFPXMT_OFB_SCTP_SRC        = 17, /* SCTP source port. */
    OFPXMT_OFB_SCTP_DST        = 18, /* SCTP destination port. */
    OFPXMT_OFB_ICMPV4_TYPE     = 19, /* ICMP type. */
    OFPXMT_OFB_ICMPV4_CODE     = 20, /* ICMP code. */
    OFPXMT_OFB_ARP_OP          = 21, /* ARP opcode. */
    OFPXMT_OFB_ARP_SPA         = 22, /* ARP source IPv4 address. */
    OFPXMT_OFB_ARP_TPA         = 23, /* ARP target IPv4 address. */
    OFPXMT_OFB_ARP_SHA         = 24, /* ARP source hardware address. */
    OFPXMT_OFB_ARP_THA         = 25, /* ARP target hardware address. */
    OFPXMT_OFB_IPV6_SRC        = 26, /* IPv6 source address. */
    OFPXMT_OFB_IPV6_DST        = 27, /* IPv6 destination address. */
    OFPXMT_OFB_IPV6_FLABEL     = 28, /* IPv6 Flow Label */
    OFPXMT_OFB_ICMPV6_TYPE     = 29, /* ICMPv6 type. */
    OFPXMT_OFB_ICMPV6_CODE     = 30, /* ICMPv6 code. */
    OFPXMT_OFB_IPV6_ND_TARGET  = 31, /* Target address for ND. */
    OFPXMT_OFB_IPV6_ND_SLL     = 32, /* Source link-layer for ND. */
    OFPXMT_OFB_IPV6_ND_TLL     = 33, /* Target link-layer for ND. */
    OFPXMT_OFB_MPLS_LABEL      = 34, /* MPLS label. */
    OFPXMT_OFB_MPLS_TC         = 35, /* MPLS TC. */
    OFPXMT_OFB_MPLS_BOS        = 36, /* MPLS BoS bit. */
    OFPXMT_OFB_PBB_ISID        = 37, /* PBB I-SID. */
    OFPXMT_OFB_TUNNEL_ID       = 38, /* Logical Port Metadata. */
    OFPXMT_OFB_IPV6_EXTHDR     = 39, /* IPv6 Extension Header pseudo-field */
};

```



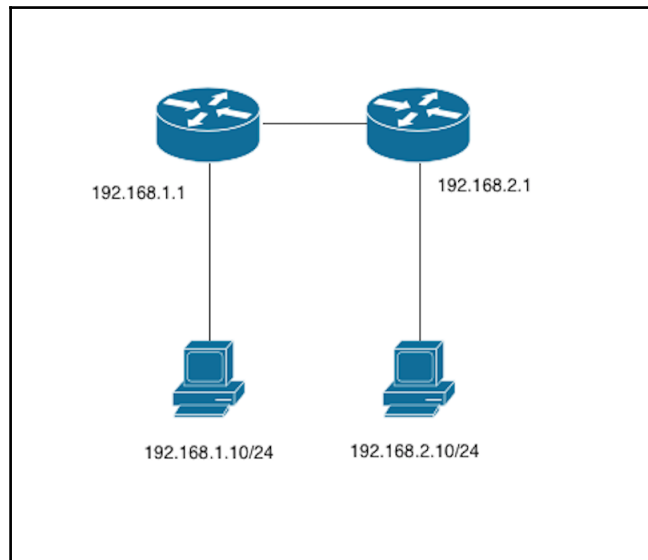
Chapter 11: Advanced OpenFlow Topics

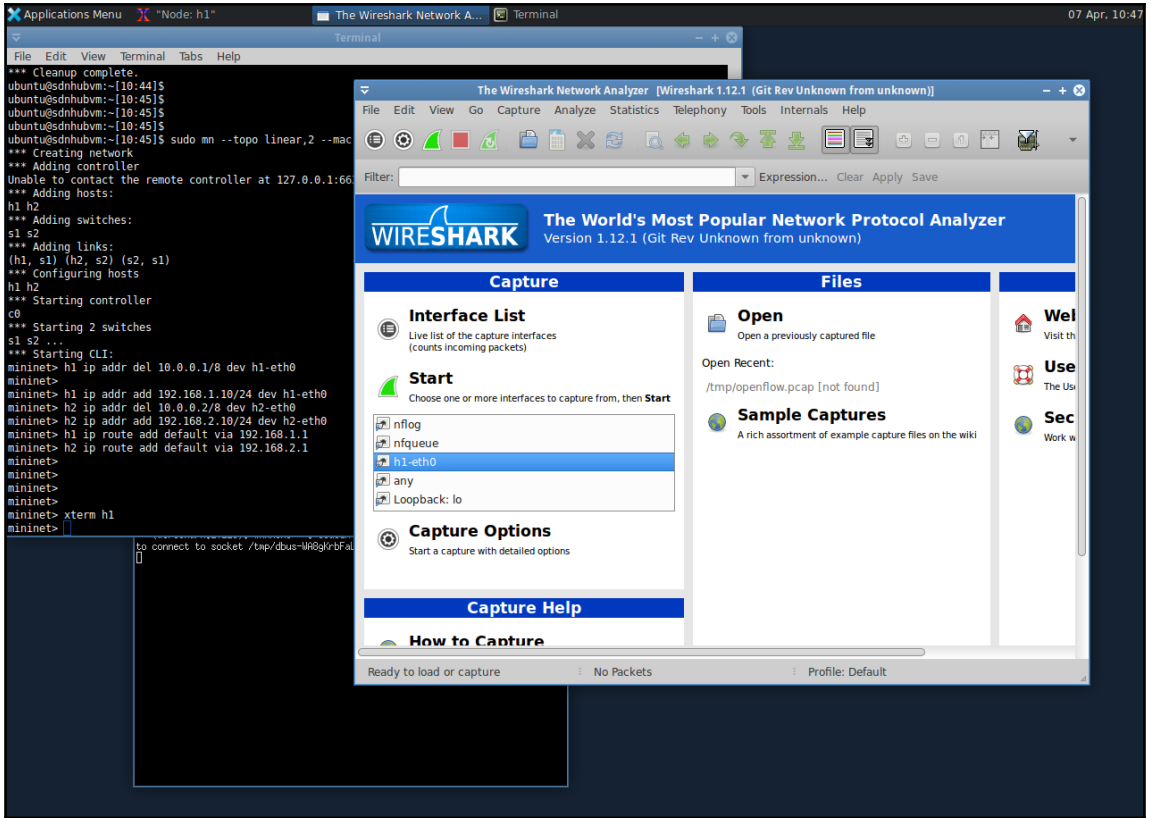
```
class ryu.controller.ofp_event.EventOFMsgBase(msg)
```

The base class of OpenFlow event class.

OpenFlow event classes have at least the following attributes.

Attribute	Description
msg	An object which describes the corresponding OpenFlow message.
msg.datapath	A ryu.controller.controller.Datapath instance which describes an OpenFlow switch from





20.003445000 00:00:00_00:00:02 00:00:00_00:00:01 ARP 60 192.168.1.1 is at 00:00:00:00:00:02

Frame 2: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0

Ethernet II, Src: 00:00:00_00:00:02 (00:00:00:00:00:02), Dst: 00:00:00_00:00:01 (00:00:00:00:00:01)

- Destination: 00:00:00_00:00:01 (00:00:00:00:00:01)
- Source: 00:00:00_00:00:02 (00:00:00:00:00:02)
 - Type: ARP (0x0806)
 - Padding: 00000000000000000000000000000000

Address Resolution Protocol (reply)

- Hardware type: Ethernet (1)
- Protocol type: IP (0x0800)
- Hardware size: 6
- Protocol size: 4
- Opcode: reply (2)
- Sender MAC address: 00:00:00_00:00:02 (00:00:00:00:00:02)
- Sender IP address: 192.168.1.1 (192.168.1.1)
- Target MAC address: 00:00:00_00:00:01 (00:00:00:00:00:01)
- Target IP address: 192.168.1.10 (192.168.1.10)

0000	00 00 00 00 00 01 00 00	00 00 00 02 08 06 00 01
0010	08 00 06 04 00 02 00 00	00 00 00 02 c0 a8 01 01
0020	00 00 00 00 00 01 c0 a8	01 0a 00 00 00 00 00 00
0030	00 00 00 00 00 00 00 00	00 00 00 00

Capturing from h1-eth0 [Wireshark 1.12.1 (Git Rev Unknown from unknown)]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	00:00:00_00:00:01	Broadcast	ARP	42	Who has 192.168.1.1?
2	0.003445000	00:00:00_00:00:02	00:00:00_00:00:01	ARP	60	192.168.1.1 is at 00:
3	0.003454000	192.168.1.10	192.168.2.10	ICMP	98	Echo (ping) request
4	0.006517000	192.168.2.10	192.168.1.10	ICMP	98	Echo (ping) reply
5	1.002884000	192.168.1.10	192.168.2.10	ICMP	98	Echo (ping) request
6	1.002945000	192.168.2.10	192.168.1.10	ICMP	98	Echo (ping) reply

▶ Frame 2: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0

▶ Ethernet II, Src: 00:00:00_00:00:02 (00:00:00:00:00:02), Dst: 00:00:00_00:00:01 (00:00:00:00:00:01)

▶ Address Resolution Protocol (reply)

```

0000 00 00 00 00 00 01 00 00 00 00 00 02 08 06 00 01 .....
0010 08 00 06 04 00 02 00 00 00 00 00 02 c0 a8 01 01 .....
0020 00 00 00 00 00 01 c0 a8 01 0a 00 00 00 00 00 00 .....
0030 00 00 00 00 00 00 00 00 00 00 00 00 .....

```

h1-eth0: <live capture in progress>... Packets: 6 · Display... Profile: Default

Capturing from h2-eth0 [Wireshark 1.12.1 (Git Rev Unknown from unknown)]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.1.10	192.168.2.10	ICMP	98	Echo (ping) request id=0x56c4, seq=1/256, ttl=64 (no response found!)
2	1.000149000	192.168.1.10	192.168.2.10	ICMP	98	Echo (ping) request id=0x56c4, seq=2/512, ttl=64 (no response found!)

Frame 1: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface 0

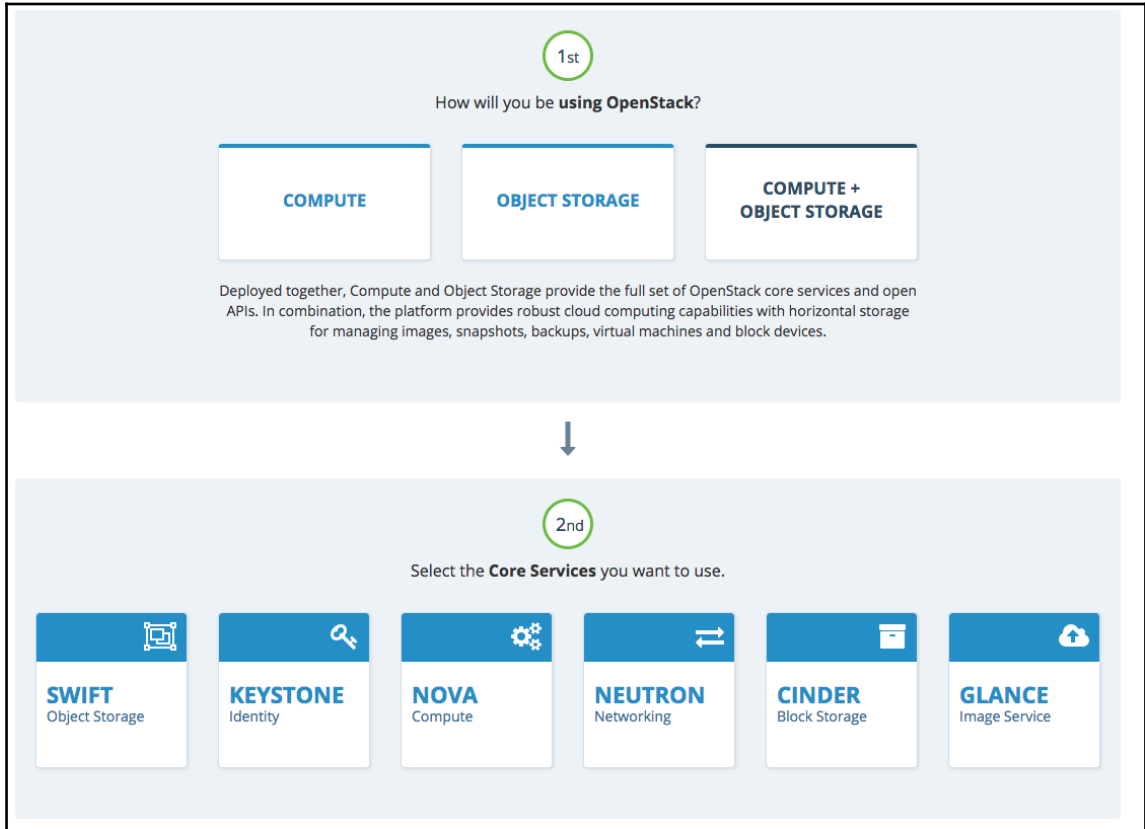
- Ethernet II, Src: 00:00:00:00:00:01 (00:00:00:00:00:01), Dst: 00:00:00:00:00:10 (00:00:00:00:00:10)
 - Destination: 00:00:00:00:00:10 (00:00:00:00:00:10)
 - Source: 00:00:00:00:00:01 (00:00:00:00:00:01)
 - Type: IP (0x0800)
- Internet Protocol Version 4, Src: 192.168.1.10 (192.168.1.10), Dst: 192.168.2.10 (192.168.2.10)
 - Type: 8 (Echo (ping) request)
 - Code: 0
 - Checksum: 0x05d3 [correct]
 - Identifier (BE): 22212 (0x56c4)
 - Identifier (LE): 50262 (0xc456)
 - Sequence number (BE): 1 (0x0001)
 - Sequence number (LE): 256 (0x0100)

```

0000  00 00 00 00 00 10 00 00 00 00 00 01 08 00 45 00  .....E.
0010  00 54 3b 04 40 00 40 01 7b 40 c0 a8 01 0a c0 a8  .T; @.@. {@.....
0020  02 0a 08 00 05 d3 56 c4 00 01 97 8c e7 58 00 00  ....V. ....X.
0030  00 00 58 af 05 00 00 00 00 00 10 11 12 13 14 15  ..X.....I*#%
0040  16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25  .....I*#%
0050  26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 32 33 34 35  6{()}+,-./012345
0060  36 37  .....
  
```

Frame (frame), 98 bytes Packets: 2 - Displayed: 2 (100.0%) Profile: Default

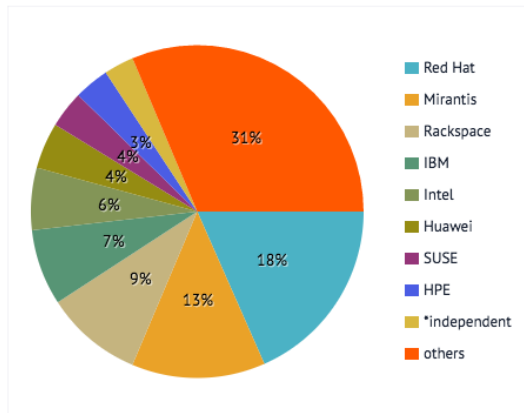
Chapter 12: OpenStack, OpenDaylight, and NFV



Optional Services (13 Results)

NAME	SERVICE	MATURITY ↕	AGE ↕	ADOPTION ↕	DETAILS
Horizon	Dashboard	6 of 8	5 Yrs	87 %	More Details
Ceilometer	Telemetry	1 of 8	4 Yrs	55 %	More Details
Heat	Orchestration	6 of 8	4 Yrs	67 %	More Details
Trove	Database	3 of 8	3 Yrs	13 %	More Details
Sahara	Elastic Map Reduce	3 of 8	3 Yrs	10 %	More Details
Ironic	Bare-Metal Provisioning	5 of 8	3 Yrs	21 %	More Details
Zaqar	Messaging Service	4 of 8	3 Yrs	4 %	More Details
Manila	Shared Filesystems	5 of 8	3 Yrs	14 %	More Details
Designate	DNS Service	3 of 8	3 Yrs	16 %	More Details
Barbican	Key Management	4 of 8	3 Yrs	9 %	More Details
Magnum	Containers	2 of 8	2 Yrs	11 %	More Details
Murano	Application Catalog	1 of 8	2 Yrs	11 %	More Details
Congress	Governance	1 of 8	2 Yrs	2 %	More Details

Contribution by companies



Show 10 entries

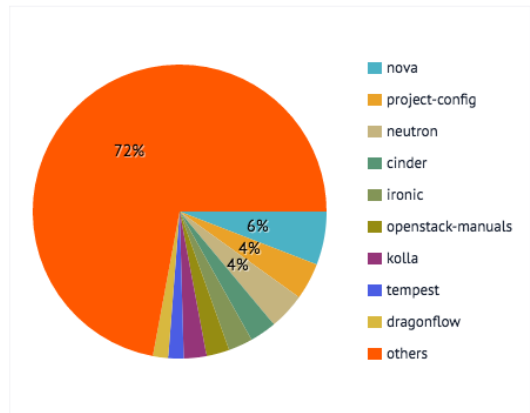
Search:

#	Company	Reviews
1	Red Hat	25741
2	Mirantis	18175
3	Rackspace	13226
4	IBM	10339
5	Intel	8459
6	Huawei	6271
7	SUSE	5018
8	HPE	4785
9	*independent	4059
9	99cloud	3656

Showing 1 to 10 of 174 entries

[First](#)
[Previous](#)
[1](#)
[2](#)
[3](#)
[4](#)
[5](#)
[Next](#)
[Last](#)

Contribution by modules



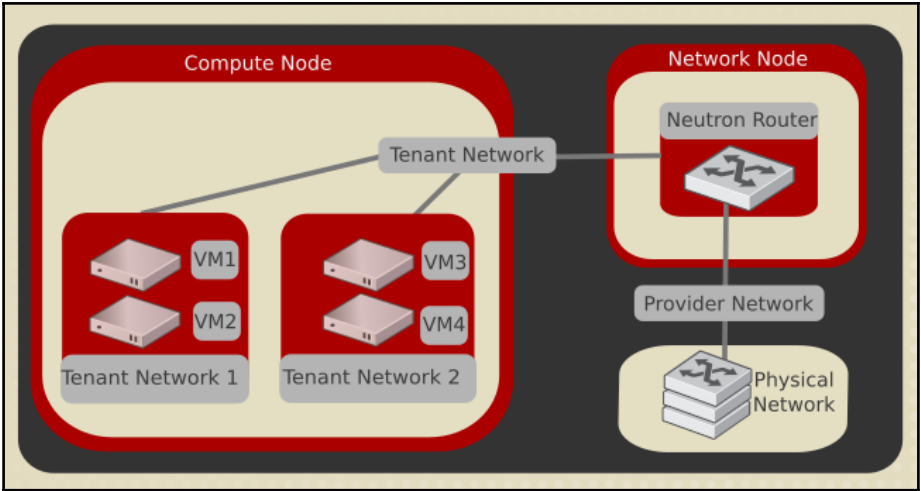
Show 10 entries

Search:

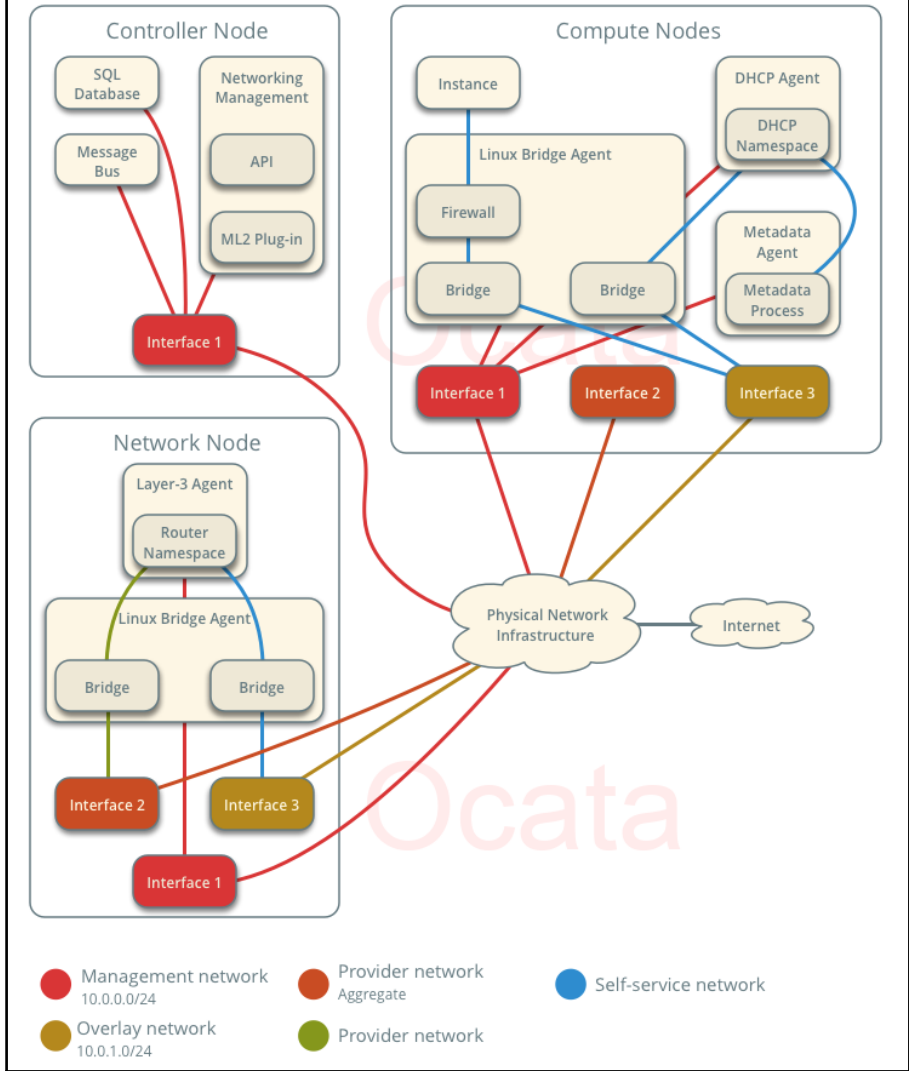
#	Module	Reviews
1	nova	8209
2	project-config	5658
3	neutron	5616
4	cinder	4107
5	ironic	3745
6	openstack-manuals	3537
7	kolla	3502
8	tempest	2371
9	dragonflow	2342
10	kolla-ansible	2230

Showing 1 to 10 of 882 entries

[First](#)
[Previous](#)
[1](#)
[2](#)
[3](#)
[4](#)
[5](#)
[Next](#)
[Last](#)

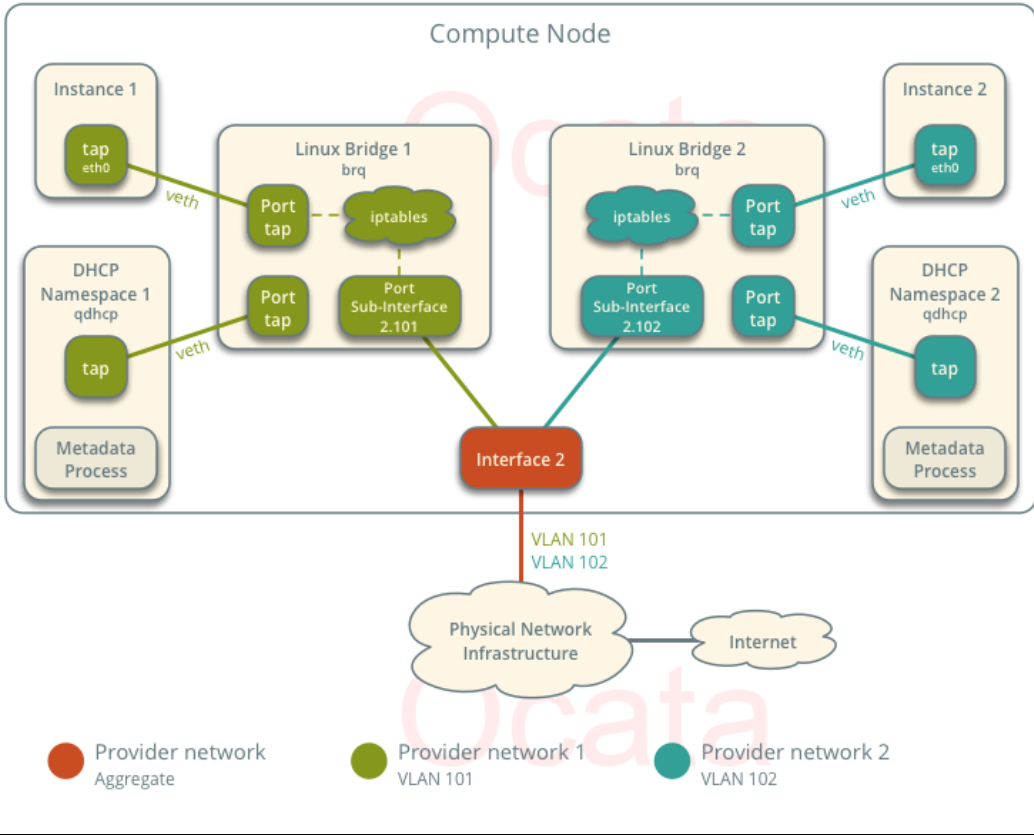


Linux Bridge - Self-service Networks Overview

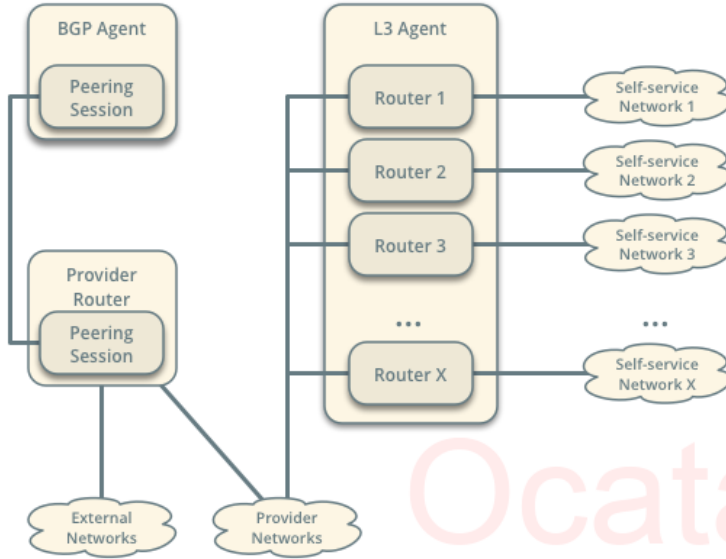


Linux Bridge - Provider Networks

Components and Connectivity



BGP Dynamic Routing Overview



openstack

Networks

Filter Q [+ Create Network](#) [x Delete Networks](#)

<input type="checkbox"/>	Name	Subnets Associated	Shared	Status	Admin State	Actions
<input type="checkbox"/>	Internal	192.168.37.0/24	No	Active	UP	Edit Network <input type="text"/>

Displaying 1 item

Project:

Compute:

Network:

Network Topology:

Networks:

Routers:

Object Store:

Identity:

openstack

Routers

Filter Q [+ Create Router \(Quota exceeded\)](#) [x Delete Routers](#)

<input type="checkbox"/>	Name	Status	External Network	Admin State	Actions
<input type="checkbox"/>	router1	Active	public	UP	Clear Gateway

Displaying 1 item

Project

Compute

Network

Network Topology

Networks

Routers

Object Store

Identity

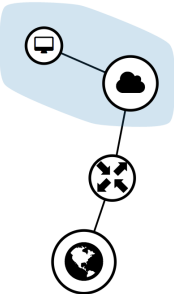
openstack

Network Topology

Resize the canvas by scrolling up/down with your mouse/trackpad on the topology. Pan around the canvas by clicking and dragging the space behind the topology.

Toggle labels Toggle Network Collapse

[Launch Instance](#) [+ Create Network](#) [+ Create Router \(Quota exceeded\)](#)



Network Topology

Networks

Routers

Object Store

Identity

The diagram shows a network topology with four nodes connected in a vertical chain. From top to bottom: a laptop icon (representing a host or instance), a cloud icon (representing a network or cloud), a router icon (a circle with four arrows pointing outwards), and a globe icon (representing an external network). A light blue shaded area highlights the top two nodes (laptop and cloud).

Manage Floating IP Associations



IP Address *

IP Address *

8.43.87.101



Select the IP address you wish to associate with the selected instance or port.

Port to be associated *

echou_u01: 192.168.37.3



Cancel

Associate

- Project ^
- Compute ^
- Overview
- Instances
- Volumes
- Images
- Access & Security
- Network v
- Object Store v
- Identity v

Instances

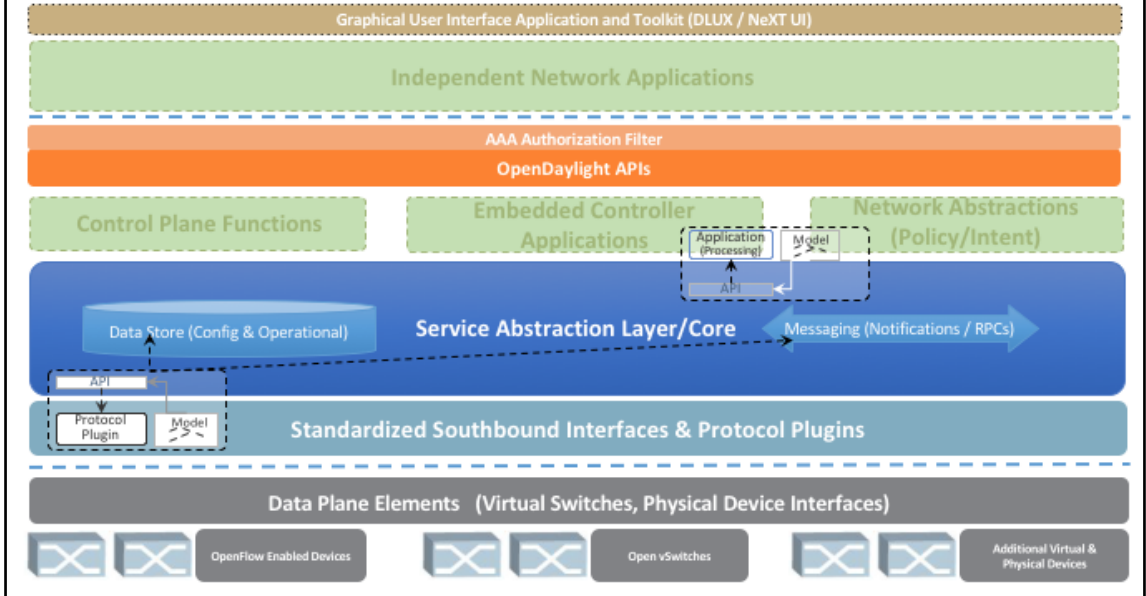
Instance Name

<input type="checkbox"/>	Instance Name	Image Name	IP Address	Size	Key Pair	Status	Availability Zone	Task	Power State	Time since created	Actions
<input type="checkbox"/>	echou_u01	Ubuntu16.04	Floating IPs: 192.168.37.3 8.43.87.101	m1.small	my_pub_key_01	Active	nova	None	Running	7 minutes	Create Snapshot v

Displaying 1 item




An Operational View of OpenDaylight



OpenDaylight Dlux x

Not Secure 172.16.1.174:8181/index.html#/login

Please Sign In



Username

Password

Remember Me

Login

The image shows a web browser window with the title 'OpenDaylight Dlux'. The address bar shows 'Not Secure 172.16.1.174:8181/index.html#/login'. The main content area has a header 'Please Sign In' and the OpenDaylight logo. Below the logo are two input fields for 'Username' and 'Password', a 'Remember Me' checkbox, and a large orange 'Login' button.

RestConf Documentation x

172.16.1.174:8181/apidoc/explorer/index.html

OpenDaylight RestConf API Documentation

[Controller Resources](#) [Mounted Resources](#)

Below are the list of APIs supported by the Controller.

XSQL(2014-06-26)	Show/Hide	List Operations	Expand Operations	Raw
aaa-authn-model(2014-10-29)	Show/Hide	List Operations	Expand Operations	Raw
config(2013-04-05)	Show/Hide	List Operations	Expand Operations	Raw
flow-capable-transaction(2015-03-04)	Show/Hide	List Operations	Expand Operations	Raw
flow-topology-discovery(2013-08-19)	Show/Hide	List Operations	Expand Operations	Raw
ietf-interfaces(2014-05-08)	Show/Hide	List Operations	Expand Operations	Raw
ietf-netconf(2011-06-01)	Show/Hide	List Operations	Expand Operations	Raw
ietf-netconf-monitoring(2010-10-04)	Show/Hide	List Operations	Expand Operations	Raw
lldp-speaker(2014-10-23)	Show/Hide	List Operations	Expand Operations	Raw
nc-notifications(2008-07-14)	Show/Hide	List Operations	Expand Operations	Raw
network-topology(2013-07-12)	Show/Hide	List Operations	Expand Operations	Raw

RestConf Documentation

172.16.1.174:8181/apidoc/explorer/index.html#!/network-topology(2013-07-12)

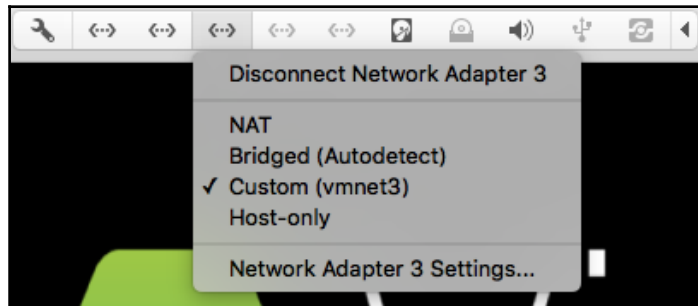
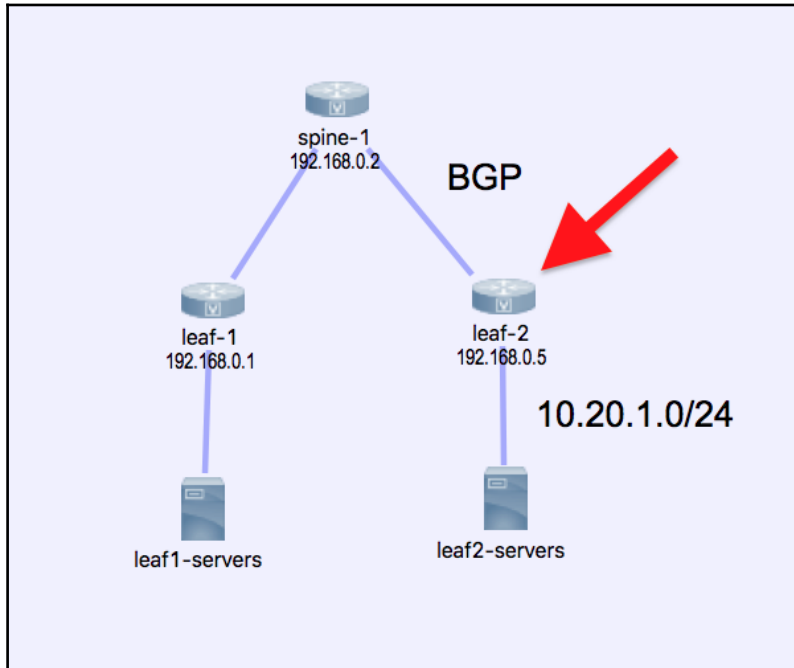
lldp-speaker(2014-10-23) [Show/Hide](#) [List Operations](#) [Expand Operations](#) [Raw](#)

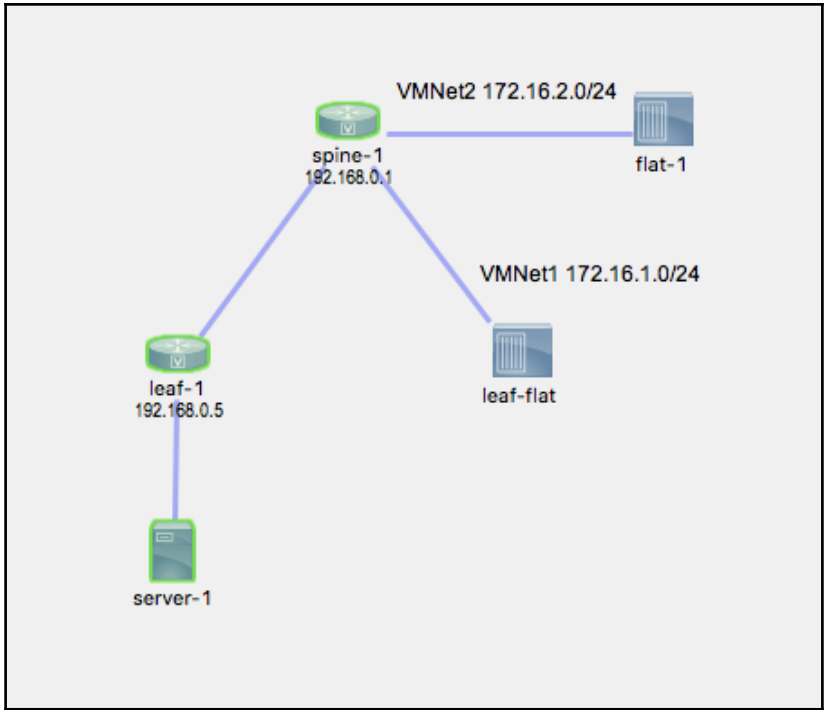
nc-notifications(2008-07-14) [Show/Hide](#) [List Operations](#) [Expand Operations](#) [Raw](#)

network-topology(2013-07-12) [Show/Hide](#) [List Operations](#) [Expand Operations](#) [Raw](#)

POST	/config/
GET	/config/network-topology:network-topology/
PUT	/config/network-topology:network-topology/
DELETE	/config/network-topology:network-topology/
POST	/config/network-topology:network-topology/
GET	/config/network-topology:network-topology/topology/{topology-id}/
PUT	/config/network-topology:network-topology/topology/{topology-id}/
DELETE	/config/network-topology:network-topology/topology/{topology-id}/
POST	/config/network-topology:network-topology/topology/{topology-id}/
GET	/config/network-topology:network-topology/topology/{topology-id}/topology-types/
PUT	/config/network-topology:network-topology/topology/{topology-id}/topology-types/
DELETE	/config/network-topology:network-topology/topology/{topology-id}/topology-types/
POST	/config/network-topology:network-topology/topology/{topology-id}/topology-types/

Chapter 13: Hybrid SDN



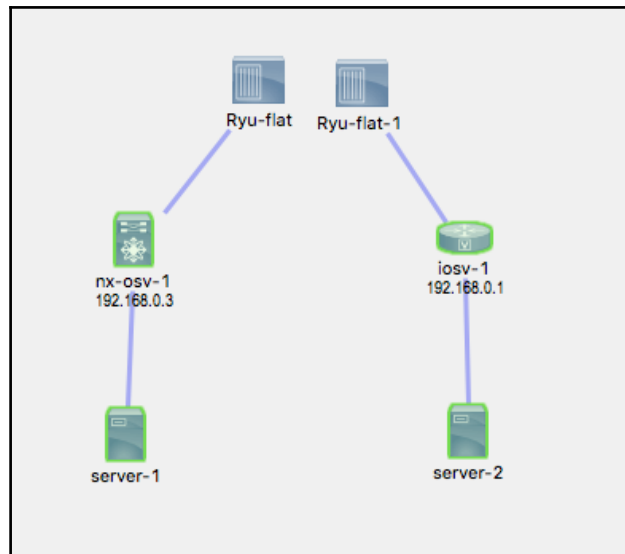


Neutron/DynamicRouting/BGPspeakersComparison

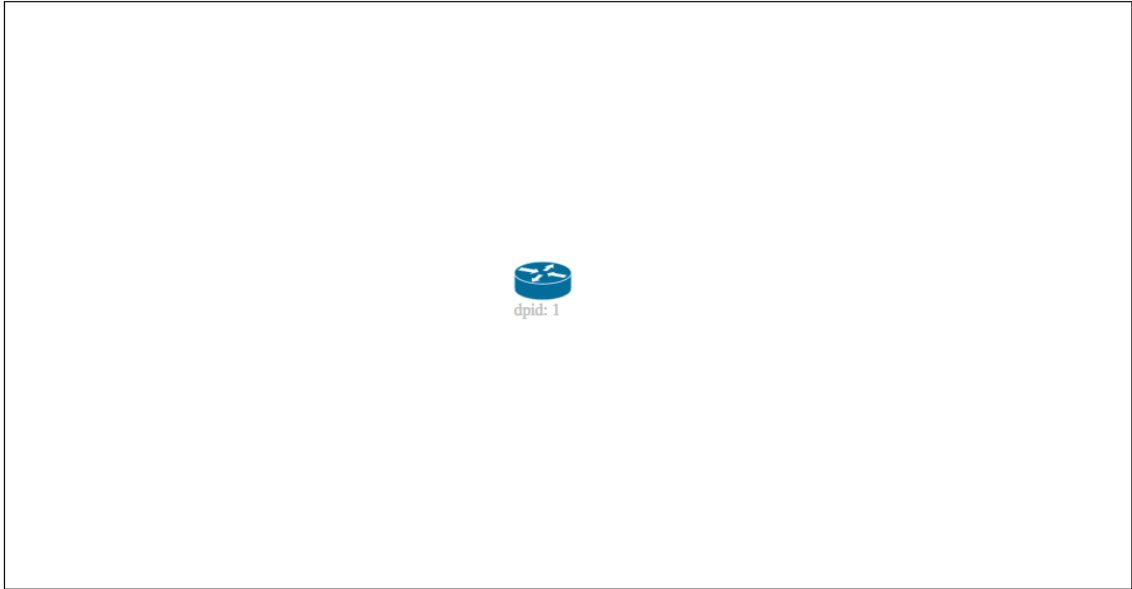
< [Neutron](#) | [DynamicRouting](#)

Comparison of BGP speakers for [bgp-dynamic-routing](#). Another potential user is [bgp-vpn](#).

	Ryu BGP	Quagga	BIRD	ExaBgp	BaGPipe
Protocol version	BGP-4	BGP-4	BGP-4	BGP-4	BGP-4
Implementation Language	Python	C	C	Python	Python
IPv4 advertisement	yes	yes	yes	yes	no (easily added)
IPv6 advertisement	yes	yes	yes	yes	no (easily added)
VPNv4 advertisement	yes				yes
VPNv6 advertisement	yes				not yet
RTC support (RFC4684)	yes	?	?	?	yes
IPv6 BGP peering	yes	yes	?	yes	could inherit from ExaBGP
32bit ASNs (RFC6793)	no	?	yes	yes	?
Standalone mode (run as a standalone process)	yes	yes	yes	yes	yes
Controlling API for Standalone mode	JSON RPC over WebSocket			stdin/out from subprocess	JSON RPC over HTTP
Library mode (run in an agent process)	yes (example reference)			yes	yes



Ryu Topology Viewer



- { "actions": ["OUTPUT:CONTROLLER"], "idle_timeout": 0, "cookie": 0, "packet_count": 0, "hard_timeout": 0, "byte_count": 0, "duration_sec": 11, "duration_nsec": 459000000, "priority": 65535, "length": 96, "flags": 0, "table_id": 0, "match": { "dl_type": 35020, "dl_dst": "01:80:c2:00:00:0e" } }

172.16.1.174:8080

Ryu Topology Viewer

```
graph TD; n1((dpid: 1)) --- n2((dpid: 2)); n1 --- n3((dpid: 3)); n2 --- n4((dpid: 4)); n2 --- n5((dpid: 5)); n2 --- n6((dpid: 6)); n2 --- n7((dpid: 7));
```

- { "actions": ["OUTPUT:CONTROLLER"], "idle_timeout": 0, "cookie": 0, "packet_count": 468, "hard_timeout": 0, "byte_count": 28080, "duration_sec": 474, "duration_nsec": 277000000, "priority": 65535, "length": 96, "flags": 0, "table_id": 0, "match": { "dl_type": 35020, "dl_dst": "01:80:c2:00:00:0e" } }

