

SDN DEMO PREP

Iteration 1

By

Kabiru Sanusi

Hands-on Python Net Apps

Description: Run, analyze, and interpret Python NetApps

Introduction: Clone the mininet GIT repo to your home dir, then the \${HOME}/mininet/custom directory should hold configuration files for custom mininets. See **topo-2sw-2host.py**, which loads the default minimal topology.

Commands Steps:

```
$ cd ${HOME}
$ git clone https://github.com/mininet/mininet
$ cd mininet
$ ls
$ cd custom
$ ls
$ sudo mn -custom topo-2sw-2host.py -topo mytopo
```

Output:

```
ks-sdn@ubuntu_server:~$
ks-sdn@ubuntu_server:~$ cd ${HOME}
ks-sdn@ubuntu_server:~$ git clone https://github.com/mininet/mininet
Cloning into 'mininet'...
remote: Enumerating objects: 10208, done.
remote: Counting objects: 100% (54/54), done.
remote: Compressing objects: 100% (38/38), done.
remote: Total 10208 (delta 22), reused 38 (delta 15), pack-reused 10154
Receiving objects: 100% (10208/10208), 3.23 MiB | 4.61 MiB/s, done.
Resolving deltas: 100% (6803/6803), done.
ks-sdn@ubuntu_server:~$ cd mininet
ks-sdn@ubuntu_server:~/mininet$ ls
bin          custom  doc      INSTALL  Makefile  mnexec.c  setup.py
CONTRIBUTORS  debian  examples LICENSE  mininet   README.md  util
ks-sdn@ubuntu_server:~/mininet$ cd custom
ks-sdn@ubuntu_server:~/mininet/custom$ ls
README  topo-2sw-2host.py
ks-sdn@ubuntu_server:~/mininet/custom$
```

```

*** Removing excess kernel datapaths
ns ax | egrep -o 'dp[0-9]+' | sed 's/dp/nl:/'
*** Removing OVS datapaths
ovs-vsctl --timeout=1 list-br
ovs-vsctl --timeout=1 list-br
*** Removing all links of the pattern foo-ethX
ip link show | egrep -o '([_\.[:alnum:]]+-eth[[:digit:]]+)'
ip link show
*** Killing stale mininet node processes
pkill -9 -f mininet:
*** Shutting down stale tunnels
pkill -9 -f Tunnel=Ethernet
pkill -9 -f .ssh/mn
rm -f ~/.ssh/mn/*
*** Cleanup complete.
ks-sdn@ubuntu_server:~/mininet/custom$ ls
README topo-2sw-2host.py
ks-sdn@ubuntu_server:~/mininet/custom$ sudo fuser -k 6653/tcp
6653/tcp:      1575
ks-sdn@ubuntu_server:~/mininet/custom$
ks-sdn@ubuntu_server:~/mininet/custom$ sudo mn --custom topo-2sw-2host.py --topo mytopo
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s3 s4
*** Adding links:
(h1, s3) (s3, s4) (s4, h2)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s3 s4 ...
*** Starting CLI:
mininet> _

```

```

*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s3 s4 ...
*** Starting CLI:
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
*** Results: 0% dropped (2/2 received)
mininet> net
h1 h1-eth0:s3-eth1
h2 h2-eth0:s4-eth2
s3 lo: s3-eth1:h1-eth0 s3-eth2:s4-eth1
s4 lo: s4-eth1:s3-eth2 s4-eth2:h2-eth0
c0
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=2521>
<Host h2: h2-eth0:10.0.0.2 pid=2523>
<OVSSwitch s3: lo:127.0.0.1,s3-eth1:None,s3-eth2:None pid=2528>
<OVSSwitch s4: lo:127.0.0.1,s4-eth1:None,s4-eth2:None pid=2531>
<OVSController c0: 127.0.0.1:6653 pid=2514>
mininet>
mininet> exit
*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s3 s4
*** Stopping 2 hosts
h1 h2
*** Done
completed in 147.584 seconds
ks-sdn@ubuntu_server:~/mininet/custom$

```

Note: Run the command below to kill tcp pocess running on port 6653 if it fails to create the topology

\$ sudo fuser -k 6653/tcp

Python Programming for Mininet

- Using an editor to enter Python statements:
- For the example, nano was used and the file saved as topox.py
- Save in the directory /home/<username>/mininet/custom/
- Run command :
 - **\$ sudo python topox.py**
- The image below shows the detail

```

File Machine View Input Devices Help
ks-sdn@sdn_server:~/mininet/custom$
ks-sdn@sdn_server:~/mininet/custom$ sudo nano topox.py

```

```
File Machine View Input Devices Help
GNU nano 2.9.3 topox.py

#!/usr/bin/python
from mininet.topo import Topo
from mininet.net import Mininet
from mininet.util import dumpNodeConnections
from mininet.log import setLogLevel
class SingleSwitchTopo(Topo):
    "Single switch connected to n hosts."
    def __init__(self, n=2, **opts):
        # Initialize topology and default options
        Topo.__init__(self, **opts)
        switch = self.addSwitch('s1')
        # Python's range (N) generates 0..N-1
        for h in range(n):
            host = self.addHost('h%s' % (h + 1))
            self.addLink(host, switch)

def simpleTest():
    "Create and test a simple network"
    topo = SingleSwitchTopo(n=4)
    net = Mininet(topo)
    net.start()
    print "Dumping host connections"
    dumpNodeConnections(net.hosts)
    print "Testing network connectivity"
    net.pingAll()
    net.stop()

if __name__ == '__main__':
    # Tell mininet to print useful information
    setLogLevel('info')
    simpleTest()

[ File 'topox.py' is unwritable ]
^G Get Help      ^O Write Out     ^W Where Is      ^K Cut Text      ^J Justify       ^C Cur Pos      M-U Undo
^X Exit          ^R Read File     ^\ Replace       ^U Uncut Text    ^T To Linter     _ Go To Line    M-E Redo
```

File Machine View Input Devices Help

GNU nano 2.9.3

topox.py

```
def simpleTest():
    "Create and test a simple network"
    topo = SingleSwitchTopo(n=4)
    net = Mininet(topo)
    net.start()
    print "Dumping host connections"
    dumpNodeConnections(net.hosts)
    print "Testing network connectivity"
    net.pingAll()
    net.stop()

if __name__ == '__main__':
    # Tell mininet to print useful information
    setLogLevel('info')
    simpleTest()
```

^G Get Help
^X Exit

^O Write Out
^R Read File

^W Where Is
^_ Replace

^K Cut Text
^U Uncut Text

^J Justify
^I To Linter

^C Cur Pos
^_ Go To Line

M-U Undo
M-E Redo

```
ks-sdn@ubuntu_server:~/mininet/custom$ sudo python topox.py
```

```
*** Creating network
```

```
*** Adding controller
```

```
*** Adding hosts:
```

```
h1 h2 h3 h4
```

```
*** Adding switches:
```

```
s1
```

```
*** Adding links:
```

```
(h1, s1) (h2, s1) (h3, s1) (h4, s1)
```

```
*** Configuring hosts
```

```
h1 h2 h3 h4
```

```
*** Starting controller
```

```
c0
```

```
*** Starting 1 switches
```

```
s1 ...
```

```
Dumping host connections
```

```
h1 h1-eth0:s1-eth1
```

```
h2 h2-eth0:s1-eth2
```

```
h3 h3-eth0:s1-eth3
```

```
h4 h4-eth0:s1-eth4
```

```
Testing network connectivity
```

```
*** Ping: testing ping reachability
```

```
h1 -> h2 h3 h4
```

```
h2 -> h1 h3 h4
```

```
h3 -> h1 h2 h4
```

```
h4 -> h1 h2 h3
```

```
*** Results: 0% dropped (12/12 received)
```

```
*** Stopping 1 controllers
```

```
c0
```

```
*** Stopping 4 links
```

```
....
```

```
*** Stopping 1 switches
```

```
s1
```

```
*** Stopping 4 hosts
```

```
h1 h2 h3 h4
```

```
*** Done
```

```
ks-sdn@ubuntu_server:~/mininet/custom$ _
```

```
#!/usr/local/bin/python
from mininet.topo import Topo
from mininet.net import Mininet
from mininet.util import dumpNodeConnections
from mininet.log import setLogLevel
class SingleSwitchTopo(Topo):
    "Single switch connected to n hosts."
    def __init__(self, n=2, **opts):
        # Initialize topology and defaults options
        Topo.__init__(self, **opts)
        switch = self.addSwitch('s1')

        # Python's range(N) generates 0..N-1
        for h in range(n):
            host = self.addHost('h%s' % (h + 1))
            self.addLink(host, switch)

def simpleTest():
    "Create and test a simple network"
    topo = SingleSwitchTopo(n=6)
    net = Mininet(topo)
    net.start()
    print "Dumping host connections"
    dumpNodeConnections(net.hosts)
    print "Testing network connectivity"
    net.pingAll()
    net.stop()

if __name__ == '__main__':
    # Tell mininet to print useful information
    setLogLevel('info')
    simpleTest()
```

[Read 33 lines]

^G Get Help
^X Exit

^O Write Out
^R Read File

^W Where Is
^_ Replace

^K Cut Text
^U Uncut Text

^J Justify
^T To Linter

^C Cur Pos
^_ Go To Line

M-U Undo
M-E Redo


```

h1 h2 h3 h4 h5 h6
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1) (h3, s1) (h4, s1) (h5, s1) (h6, s1)
*** Configuring hosts
h1 h2 h3 h4 h5 h6
*** Starting controller
c0
*** Starting 1 switches
s1 ...
Dumping host connections
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
h3 h3-eth0:s1-eth3
h4 h4-eth0:s1-eth4
h5 h5-eth0:s1-eth5
h6 h6-eth0:s1-eth6
Testing network connectivity
*** Ping: testing ping reachability
h1 -> h2 h3 h4 h5 h6
h2 -> h1 h3 h4 h5 h6
h3 -> h1 h2 h4 h5 h6
h4 -> h1 h2 h3 h5 h6
h5 -> h1 h2 h3 h4 h6
h6 -> h1 h2 h3 h4 h5
*** Results: 0% dropped (30/30 received)
*** Stopping 1 controllers
c0
*** Stopping 6 links
.....
*** Stopping 1 switches
s1
*** Stopping 6 hosts
h1 h2 h3 h4 h5 h6
*** Done
ks-sdn@ubuntu_server:~/mininet/custom$ _

```

Simple Python-based controller

- Installed RYU
 - The directory /ryu was removed completely with the linux command
 - **rm -rf ryu # this remove package installed in the previous iteration**
 - Then installed RYU from source code located at Github repo:
 - \$ cd ~
 - \$ git clone <https://github.com/faucetsdn/ryu.git>
 - \$ cd ryu
 - \$ python2 -m virtualenv v-ryu
 - \$ source v-ryu/bin/activate
 - (v-ryu)\$ pip install ovs==2.6.0 tinyrpc==0.9 paramiko
 - (v-ryu)\$ pip install .
- Start RYU with:
 - \$PYTHONPATH=. ./bin/ryu-manager -verbose ryu/app/simple_switch.py

```

Building wheel for ryu (setup.py) ... done
Created wheel for ryu: filename=ryu-4.34-py2-none-any.whl size=2203449 sha256=2f7eb7981d77160be5b4
32f816918a35478a294699ac12f06cd2599040bec04b
Stored in directory: /tmp/pip-ephem-wheel-cache-q0yHAG/wheels/0e/72/70/a20908bfdd7b14e5f93e58acca5
87d31e94b0a4cedbce29c30
Successfully built ryu
Installing collected packages: monotonic, greenlet, dnspython, eventlet, msgpack, contextlib2, typin
g, singledispatch, zipp, scandir, pathlib2, importlib-resources, netaddr, pbr, pytz, Babel, oslo.i18
n, stevedore, wrapt, funcsigns, debtcollector, rfc3986, certifi, urllib3, chardet, idna, requests, Py
YAML, oslo.config, pyparsing, packaging, repoze.lru, routes, tinypc, webob, ryu
Attempting uninstall: tinypc
Found existing installation: tinypc 0.9
Uninstalling tinypc-0.9:
Successfully uninstalled tinypc-0.9
Successfully installed Babel-2.9.1 PyYAML-5.4.1 certifi-2021.10.8 chardet-4.0.0 contextlib2-0.6.0.po
st1 debtcollector-1.22.0 dnspython-1.16.0 eventlet-0.31.1 funcsigns-1.0.2 greenlet-1.1.2 idna-2.10 im
portlib-resources-3.3.1 monotonic-1.6 msgpack-1.0.4 netaddr-0.8.0 oslo.config-7.0.0 oslo.i18n-3.25.1
packaging-20.9 pathlib2-2.3.7.post1 pbr-5.9.0 pyparsing-2.4.7 pytz-2022.1 repoze.lru-0.7 requests-2
.27.1 rfc3986-1.5.0 routes-2.5.1 ryu-4.34 scandir-1.10.0 singledispatch-3.7.0 stevedore-1.32.0 tinyp
c-1.0.4 typing-3.10.0.0 urllib3-1.26.9 webob-1.8.7 wrapt-1.14.1 zipp-1.2.0
(v-ryu) ks-sdn@sdn_server:~/ryu$ PYTHONPATH=. ./bin/ryu-manager --verbose ryu/app/simple_switch.py
Traceback (most recent call last):
  File "./bin/ryu-manager", line 18, in <module>
    from ryu.cmd.manager import main
  File "/home/ks-sdn/ryu/ryu/cmd/manager.py", line 33, in <module>
    from ryu.app import wsgi
  File "/home/ks-sdn/ryu/ryu/app/wsgi.py", line 23, in <module>
    from tinypc.server import RPCServer
  File "/home/ks-sdn/ryu/v-ryu/local/lib/python2.7/site-packages/tinypc/__init__.py", line 4, in <m
odule>
    from .protocols import *
  File "/home/ks-sdn/ryu/v-ryu/local/lib/python2.7/site-packages/tinypc/protocols/__init__.py", lin
e 15
    def __init__(self) -> None:
        ^
SyntaxError: invalid syntax
(v-ryu) ks-sdn@sdn_server:~/ryu$ _

```

- **Resolving the syntax error:**

- \$ sudo pip uninstall tinypc && sudo pip install tinypc==0.9.4
- Then Start RYU

```

Installing setuptools, pkg_resources, pip, wheel...sourcedone.
ks-sdn@sdn_server:~/ryu$ source v-ryu/bin/activate
(v-ryu) ks-sdn@sdn_server:~/ryu$ PYTHONPATH=. ./bin/ryu-manager --verbose ryu/app/simple_switch.py
loading app ryu/app/simple_switch.py
loading app ryu.controller.ofp_handler
instantiating app ryu.controller.ofp_handler of OFPHandler
instantiating app ryu/app/simple_switch.py of SimpleSwitch
BRICK SimpleSwitch
  CONSUMES EventOFPPacketIn
  CONSUMES EventOFPPortStatus
BRICK ofp_event
  PROVIDES EventOFPPacketIn TO {'SimpleSwitch': set(['main'])}
  PROVIDES EventOFPPortStatus TO {'SimpleSwitch': set(['main'])}
  CONSUMES EventOFPPortDescStatsReply
  CONSUMES EventOFPHello
  CONSUMES EventOFPErrormsg
  CONSUMES EventOFPEchoRequest
  CONSUMES EventOFPPortStatus
  CONSUMES EventOFPEchoReply
  CONSUMES EventOFPSwitchFeatures
hub: uncaught exception: Traceback (most recent call last):
  File "/home/ks-sdn/ryu/ryu/lib/hub.py", line 60, in _launch
    return func(*args, **kwargs)
  File "/home/ks-sdn/ryu/ryu/controller/controller.py", line 154, in __call__
    self.ofp_ssl_listen_port)
  File "/home/ks-sdn/ryu/ryu/controller/controller.py", line 206, in server_loop
    datapath_connection_factory)
  File "/home/ks-sdn/ryu/ryu/lib/hub.py", line 127, in __init__
    self.server = eventlet.listen(listen_info)
  File "/home/ks-sdn/ryu/v-ryu/local/lib/python2.7/site-packages/eventlet/convenience.py", line 78,
in listen
    sock.bind(addr)
  File "/usr/lib/python2.7/socket.py", line 228, in meth
    return getattr(self._sock,name)(*args)
error: [Errno 98] Address already in use

(v-ryu) ks-sdn@sdn_server:~/ryu$ _

```

- Resolving the Address already in use error above:
 - Run the modified statement with port 20000

```

File Machine View Input Devices Help
(v-ryu) ks-sdn@sdn_server:~/ryu$ PYTHONPATH=. ./bin/ryu-manager --verbose ryu/app/simple_switch.py -
-ofp-tcp-listen-port 20000

```

```

(v-ryu) ks-sdn@sdh_server:~/ryu$ PYTHONPATH=. ./bin/ryu-manager --verbose ryu/app/simple_switch.py -
-ofp-tcp-listen-port 20000
loading app ryu/app/simple_switch.py
loading app ryu.controller.ofp_handler
instantiating app ryu.controller.ofp_handler of OFPHandler
instantiating app ryu/app/simple_switch.py of SimpleSwitch
BRICK SimpleSwitch
  CONSUMES EventOFPPortStatus
  CONSUMES EventOFPPacketIn
BRICK ofp_event
  PROVIDES EventOFPPortStatus TO {'SimpleSwitch': set(['main'])}
  PROVIDES EventOFPPacketIn TO {'SimpleSwitch': set(['main'])}
  CONSUMES EventOFPHello
  CONSUMES EventOFPPortStatus
  CONSUMES EventOFPPortDescStatsReply
  CONSUMES EventOFPSwitchFeatures
  CONSUMES EventOFPErrormsg
  CONSUMES EventOFPEchoRequest
  CONSUMES EventOFPEchoReply

```

- Open Terminal 2:
 - Start Mininet network and test

File Machine View Input Devices Help

Ubuntu 18.04.6 LTS sdn_server tty2

sdn_server login: ks-sdn

Password:

Last login: Sun Jun 12 21:19:25 UTC 2022 on tty1

Welcome to Ubuntu 18.04.6 LTS (GNU/Linux 4.15.0-184-generic x86_64)

- * Documentation: <https://help.ubuntu.com>
- * Management: <https://landscape.canonical.com>
- * Support: <https://ubuntu.com/advantage>

System information as of Sun Jun 12 22:23:37 UTC 2022

System load:	0.0	Processes:	96
Usage of /:	43.2% of 18.91GB	Users logged in:	1
Memory usage:	12%	IP address for enp0s3:	192.168.1.54
Swap usage:	0%	IP address for docker0:	172.17.0.1

* Super-optimized for small spaces - read how we shrank the memory footprint of MicroK8s to make it the smallest full K8s around.

<https://ubuntu.com/blog/microk8s-memory-optimisation>

32 updates can be applied immediately.

To see these additional updates run: `apt list --upgradable`

New release '20.04.4 LTS' available.

Run 'do-release-upgrade' to upgrade to it.

ks-sdn@sdn_server:~\$ _

```

File Machine View Input Devices Help
ks-sdn@sdn_server:~$ sudo mn --topo single,3 --controller 'remote,ip=192.168.1.54,port=20000' --swit
ch ovsk,protocols=OpenFlow10
[sudo] password for ks-sdn:
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1) (h3, s1)
*** Configuring hosts
h1 h2 h3
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=2292>
<Host h2: h2-eth0:10.0.0.2 pid=2294>
<Host h3: h3-eth0:10.0.0.3 pid=2296>
<OVSSwitch{'protocols': 'OpenFlow10'} s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None,s1-eth3:None pid=2301>
<RemoteController{'ip': '192.168.1.54', 'port': 20000} c0: 192.168.1.54:20000 pid=2286>
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2 h3
h2 -> h1 h3
h3 -> h1 h2
*** Results: 0% dropped (6/6 received)
mininet>

```

- See the entries information on terminal 1:

```
File Machine View Input Devices Help
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:16 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:16 2
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port modified 2
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port modified 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:16 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
```

- Open Terminal 3:
 - To monitor RYU SDN controller OpenFlow connections

```
File Machine View Input Devices Help
Ubuntu 18.04.6 LTS sdn_server tty3
sdn_server login: ks-sdn
Password:
Last login: Sun Jun 12 22:23:37 UTC 2022 on tty2
Welcome to Ubuntu 18.04.6 LTS (GNU/Linux 4.15.0-184-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

System information as of Sun Jun 12 22:35:40 UTC 2022

System load:  0.0                Processes:            107
Usage of /:   43.2% of 18.91GB    Users logged in:     1
Memory usage: 14%                IP address for enp0s3: 192.168.1.54
Swap usage:   0%                IP address for docker0: 172.17.0.1

 * Super-optimized for small spaces - read how we shrank the memory
   footprint of MicroK8s to make it the smallest full K8s around.

   https://ubuntu.com/blog/microk8s-memory-optimisation

32 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

New release '20.04.4 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

ks-sdn@sdn_server:~$ _
```

```
File Machine View Input Devices Help
Every 2.0s: sudo netstat -tunlap | grep python          sdn_server: Sun Jun 12 22:38:54 2022
tcp        0      0 0.0.0.0:20000          0.0.0.0:*              LISTEN      2151/python
tcp        0      0 192.168.1.54:20000    192.168.1.54:47768     ESTABLISHED 2151/python
```

- See the entries information after stopping and cleanup of mininet network:


```
File Machine View Input Devices Help
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 b6:45:fd:1d:6b:d1 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 3e:8d:e4:09:2a:d3 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 ff:ff:ff:ff:ff:ff 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 ba:f7:12:b0:8d:25 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 3e:8d:e4:09:2a:d3 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 ba:f7:12:b0:8d:25 33:33:00:00:00:02 2
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 3e:8d:e4:09:2a:d3 33:33:00:00:00:02 3
EVENT ofp_event->SimpleSwitch EventOFPPacketIn
packet in 1 b6:45:fd:1d:6b:d1 33:33:00:00:00:02 1
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port modified 1
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port deleted 2
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port deleted 1
EVENT ofp_event->SimpleSwitch EventOFPPortStatus
port deleted 3
```

Simple RYU SDN BGP Topology

- This app is ran as root user
- `$ sudo su -`
- `# cd ryu`
- `# source v-ryu/bin/activate`
- `(v-ryu)# ryu-manager ryu/services/protocols/bgp/application.py -bgp-app-config-file ryu/services/protocols/bgp/bgp_sample_conf.py`
- The image shown below:

```

File Machine View Input Devices Help
ks-sdn@sdn_server:~$
ks-sdn@sdn_server:~$ sudo su
[sudo] password for ks-sdn:
root@sdn_server:/home/ks-sdn# cd ryu/
root@sdn_server:/home/ks-sdn/ryu# source v-ryu/bin/activate
(v-ryu) root@sdn_server:/home/ks-sdn/ryu# ryu-manager ryu/services/protocols/bgp/application.py --bg
p-app-config-file ryu/services/protocols/bgp/bgp_sample_conf.py

```

```

File Machine View Input Devices Help
fo': 100.0, 'as_number': 0}, 'traffic_action': {'action': 3}}]
API method flowspec.add_local called with args: {'rules': {'icmp_code': 6, 'tcp_flags': 'SYN+ACK & !=URGENT', 'fragment': 'LF | ==FF', 'dscp': '22 | 24', 'packet_len': 1000, 'icmp_type': 0, 'port': '80 | 8000', 'src_port': '>=8500 & <=9000', 'dst_prefix': '10.70.1.0/24', 'dst_port': '>9000 & <9050', 'ip_proto': 6, 'src_prefix': '172.18.0.0/24'}, 'flowspec_family': 'vpn4fs', 'route_dist': '65001:250', 'actions': {'redirect': {'local_administrator': 100, 'as_number': 10}, 'traffic_marking': {'dscp': 24}, 'traffic_rate': {'rate_info': 100.0, 'as_number': 0}, 'traffic_action': {'action': 3}}}
API method flowspec.add called with args: {'rules': {'icmp_code': 6, 'tcp_flags': 'SYN+ACK & !=URGENT', 'fragment': 'LF | ==FF', 'flow_label': 100, 'dscp': '22 | 24', 'packet_len': 1000, 'icmp_type': 0, 'port': '80 | 8000', 'src_port': '>=8500 & <=9000', 'dst_prefix': '2001::1/128/32', 'dst_port': '>9000 & <9050', 'next_header': 6, 'src_prefix': '3001::2/128'}, 'flowspec_family': 'ipv6fs', 'actions': {'redirect': {'local_administrator': 100, 'as_number': 10}, 'traffic_marking': {'dscp': 24}, 'traffic_rate': {'rate_info': 100.0, 'as_number': 0}, 'traffic_action': {'action': 3}}}
API method flowspec.add_local called with args: {'rules': {'icmp_code': 6, 'tcp_flags': 'SYN+ACK & !=URGENT', 'fragment': 'LF | ==FF', 'flow_label': 100, 'dscp': '22 | 24', 'packet_len': 1000, 'icmp_type': 0, 'port': '80 | 8000', 'src_port': '>=8500 & <=9000', 'dst_prefix': '2001::1/128/32', 'dst_port': '>9000 & <9050', 'next_header': 6, 'src_prefix': '3001::2/128'}, 'flowspec_family': 'vpn6fs', 'route_dist': '65001:300', 'actions': {'redirect': {'local_administrator': 100, 'as_number': 10}, 'traffic_marking': {'dscp': 24}, 'traffic_rate': {'rate_info': 100.0, 'as_number': 0}, 'traffic_action': {'action': 3}}}
API method flowspec.add_local called with args: {'rules': {'inner_vlan_id': '<3000', 'dst_mac': 'BE:EF:C0:FF:EE:DD', 'ether_type': 2048, 'llc_dsap': 66, 'inner_vlan_cos': '<=5', 'vlan_id': '>4000', 'llc_ssap': 66, 'vlan_cos': '>=3', 'llc_control': 100, 'snap': 74565, 'src_mac': '12:34:56:78:90:AB'}, 'flowspec_family': '12vpns', 'route_dist': '65001:350', 'actions': {'redirect': {'local_administrator': 100, 'as_number': 10}, 'traffic_rate': {'rate_info': 100.0, 'as_number': 0}, 'traffic_action': {'action': 3}, 'traffic_marking': {'dscp': 24}, 'tpid_action': {'tpid_2': 300, 'tpid_1': 200, 'actions': 49152}, 'vlan_action': {'cos_1': 3, 'vlan_1': 3000, 'vlan_2': 4000, 'cos_2': 2, 'actions_1': 192, 'actions_2': 32}}}
/home/ks-sdn/ryu/v-ryu/local/lib/python2.7/site-packages/paramiko/transport.py:33: CryptographyDeprecationWarning: Python 2 is no longer supported by the Python core team. Support for it is now deprecated in cryptography, and will be removed in the next release.
  from cryptography.hazmat.backends import default_backend
starting ssh server at localhost:4990
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True

```

- Open Terminal 2:
- Log (ssh) in at the RYU BGP instance:
 - \$ ssh localhost -p 4990
 - bgpd>show rib ?

- bgpd>show rib ipv4
- bgpd>quit

The image shows detail below:

```
File Machine View Input Devices Help
ks-sdn@sdn_server:~$
ks-sdn@sdn_server:~$ ssh localhost -p 4990
Hello, this is Ryu BGP speaker (version 4.34).

bgpd> show rib
rib <address-family> - show all routes for address family
rib all - show routes for all RIBs
bgpd> show rib ipv4
Status codes: * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete
  Network                Labels  Next Hop          Reason          Metric LocPrf Pa
th
  *> 10.10.1.0/24         None    0.0.0.0          Only Path              i
bgpd> quit
bgpd> bye.
Connection to localhost closed.
ks-sdn@sdn_server:~$
```

Finally, the image below shows the entries information of terminal 2 in terminal 1:

```
File  Machine  View  Input  Devices  Help
cationWarning: Python 2 is no longer supported by the Python core team. Support for it is now deprecated in cryptography, and will be removed in the next release.
  from cryptography.hazmat.backends import default_backend
starting ssh server at localhost:4990
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Connected (version 2.0, client OpenSSH_7.6p1)
Auth granted (none).
session start
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
session end
Disconnect (code 11): disconnected by user
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
Will try to reconnect to 172.17.0.3 after 30 secs: True
Will try to reconnect to 172.17.0.4 after 30 secs: True
Will try to reconnect to 172.17.0.2 after 30 secs: True
```