

BÁO CÁO THỰC HÀNH

Môn học: Công nghệ mạng khả lập trình

Buổi báo cáo: Lab 02

GVHD: Phan Xuân Thiện

Ngày thực hiện: 16/10/2025

THÔNG TIN CHUNG:

Lớp: NT541.Q11.2

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1. ĐÁNH GIÁ KHÁC:

Nội dung	Kết quả
Tổng thời gian thực hiện bài thực hành trung bình	1 ngày
Link Video thực hiện (nếu có)	
Ý kiến (nếu có) + Khó khăn + Đề xuất ...	
Điểm tự đánh giá	10

Phần bên dưới của báo cáo này là báo cáo chi tiết của nhóm thực hiện.

BÁO CÁO CHI TIẾT

I. Yêu cầu 1

1. Cài đặt SDN/OpenFlow Controller (remote controller). Dùng Ryu controller (python)

- Clone Github Repo source code Ryu Controller

```
khanh@ubuntu:~$ git clone https://github.com/faucetsdn/ryu.git
fatal: destination path 'ryu' already exists and is not an empty directory.
khanh@ubuntu:~$ rm -rf ryu/
khanh@ubuntu:~$ git clone https://github.com/faucetsdn/ryu.git
Cloning into 'ryu' ...
remote: Enumerating objects: 26506, done.
remote: Counting objects: 100% (4/4), done.
remote: Compressing objects: 100% (3/3), done.
Receiving objects: 16% (4274/26506), 1.90 MiB | 25.00 KiB/s
```

- Cài đặt Ryu Controller

```
khanh@ubuntu:~$ cd ryu
khanh@ubuntu:~/ryu$ pip install .
Processing /home/khanh/ryu
Requirement already satisfied: eventlet==0.31.1 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (0.31.1)
Requirement already satisfied: msgpack>=0.4.0 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (1.1.1)
Requirement already satisfied: netaddr in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (1.3.0)
Requirement already satisfied: oslo.config>=2.5.0 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (9.6.0)
Requirement already satisfied: ovs>=2.6.0 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (3.6.0)
Requirement already satisfied: packaging==20.9 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (20.9)
Requirement already satisfied: routes in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (2.5.1)
Requirement already satisfied: six>=1.4.0 in /usr/lib/python3/dist-packages (from ryu==4.34) (1.14.0)
Requirement already satisfied: tinypc==1.0.4 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (1.0.4)
Requirement already satisfied: webob>=1.2 in /home/khanh/.local/lib/python3.8/site-packages (from ryu==4.34) (1.8.9)
Requirement already satisfied: greenlet>=0.3 in /home/khanh/.local/lib/python3.8/site-packages (from eventlet==0.31.1->ryu==4.34) (3.1.1)
Requirement already satisfied: dnspython<2.0.0, >=1.15.0 in /home/khanh/.local/lib/python3.8/site-packages (from eventlet==0.31.1->ryu==4.34) (1.16.0)
Requirement already satisfied: requests>=2.18.0 in /usr/lib/python3/dist-packages (from oslo.config>=2.5.0->ryu==4.34) (2.22.0)
Building wheels for collected packages: ryu
  Building wheel for ryu (setup.py) ... done
  Created wheel for ryu: filename=ryu-4.34-py3-none-any.whl size=2203583 sha256=a8bacb58f3b66cb92d324bd410f30166ba1567e5bcafd549241f489c8636a649
  Stored in directory: /tmp/pip-ephem-wheel-cache-5qut6bja/wheels/f1/0a/b5/392102aa9e3e938501748f2296ebb89229cd1f14070fc6a81c
Successfully built ryu
Installing collected packages: ryu
  Attempting uninstall: ryu
    Found existing installation: ryu 4.34
    Uninstalling ryu-4.34:
      Successfully uninstalled ryu-4.34
Successfully installed ryu-4.34
khanh@ubuntu:~/ryu$
```

2. Tạo mạng OpenFlow bằng Mininet, kết nối với Ryu Controller

- Viết source code định nghĩa topology. Lưu file dưới tên topo.py

```

khanh@ubuntu:~/nt541/lab2$ cat topo.py
from mininet.topo import Topo
class MyTopo(Topo):
    def build(self):
        # Add hosts and switches
        h1 = self.addHost('h1')
        h2 = self.addHost('h2')
        h3 = self.addHost('h3')
        h4 = self.addHost('h4')

        s1 = self.addSwitch('s1')
        s2 = self.addSwitch('s2')
        s3 = self.addSwitch('s3')
        s4 = self.addSwitch('s4')

        # Add links
        self.addLink(h1, s1)
        self.addLink(h2, s2)
        self.addLink(h3, s3)
        self.addLink(h4, s4)

        self.addLink(s1, s2)
        self.addLink(s1, s3)
        self.addLink(s3, s4)
topos = {'mytopo': (lambda: MyTopo())}
khanh@ubuntu:~/nt541/lab2$

```

- Mở một terminal mới để chạy Ryu controller

```

khanhle@ubuntu:~$ ryu-manager ryu.app.simple_switch_13
loading app ryu.app.simple_switch_13
loading app ryu.controller.ofp_handler
instantiating app ryu.app.simple_switch_13 of SimpleSwitch13
instantiating app ryu.controller.ofp_handler of OFPHandler

```

- Ở terminal khác, tiến hành tạo mạng OpenFlow với Mininet, sử dụng lệnh:

"sudo mn --custom topo.py --topo mytopo --controller remote"

```

khanh@ubuntu:~/nt541/lab2$ sudo mn --custom topo.py --topo mytopo --controller remote
*** Creating network
*** Adding controller
Connecting to remote controller at 127.0.0.1:6653
*** Adding hosts:
h1 h2 h3 h4
*** Adding switches:
s1 s2 s3 s4
*** Adding links:
(h1, s1) (h2, s2) (h3, s3) (h4, s4) (s1, s2) (s1, s3) (s3, s4)
*** Configuring hosts
h1 h2 h3 h4
*** Starting controller
c0
*** Starting 4 switches
s1 s2 s3 s4 ...
*** Starting CLI:
mininet>

```

- Kiểm tra lại terminal Ryu controller, thấy rằng đã kết nối thành công



```
packet in 4 06:c4:a0:a4:a7:97 33:33:00:00:00:02 2
packet in 2 06:c4:a0:a4:a7:97 33:33:00:00:00:02 2
packet in 1 6e:d0:8e:48:91:4d 33:33:00:00:00:02 3
packet in 2 6e:d0:8e:48:91:4d 33:33:00:00:00:02 2
packet in 1 de:c8:34:9b:06:6c 33:33:00:00:00:02 2
packet in 1 4e:d7:eb:99:09:d2 33:33:00:00:00:02 1
packet in 2 7a:98:79:5b:0e:07 33:33:00:00:00:02 2
packet in 3 de:c8:34:9b:06:6c 33:33:00:00:00:02 2
packet in 3 4e:d7:eb:99:09:d2 33:33:00:00:00:02 2
packet in 2 4e:d7:eb:99:09:d2 33:33:00:00:00:02 2
packet in 4 de:c8:34:9b:06:6c 33:33:00:00:00:02 2
packet in 4 4e:d7:eb:99:09:d2 33:33:00:00:00:02 2
packet in 4 4a:59:6e:4f:db:a6 33:33:00:00:00:02 2
packet in 3 56:3e:a4:70:67:9f 33:33:00:00:00:02 3
packet in 1 56:3e:a4:70:67:9f 33:33:00:00:00:02 3
packet in 2 56:3e:a4:70:67:9f 33:33:00:00:00:02 2
packet in 4 4a:59:6e:4f:db:a6 33:33:00:00:00:fb 2
packet in 3 56:3e:a4:70:67:9f 33:33:00:00:00:fb 3
packet in 1 56:3e:a4:70:67:9f 33:33:00:00:00:fb 3
packet in 2 56:3e:a4:70:67:9f 33:33:00:00:00:fb 2
packet in 1 de:c8:34:9b:06:6c 33:33:00:00:00:fb 2
packet in 2 7a:98:79:5b:0e:07 33:33:00:00:00:fb 2
packet in 3 de:c8:34:9b:06:6c 33:33:00:00:00:fb 2
packet in 4 de:c8:34:9b:06:6c 33:33:00:00:00:fb 2
packet in 3 7e:99:b1:48:0b:6e 33:33:00:00:00:fb 2
packet in 4 7e:99:b1:48:0b:6e 33:33:00:00:00:fb 2
packet in 1 6e:d0:8e:48:91:4d 33:33:00:00:00:fb 3
packet in 2 6e:d0:8e:48:91:4d 33:33:00:00:00:fb 2
```

- Kiểm tra các node hiện có

```
mininet> nodes
available nodes are:
c0 h1 h2 h3 h4 s1 s2 s3 s4
mininet>
```

- Test ping h1 với h2 và h4

```
mininet> h1 ping h2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=10.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.357 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.075 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.068 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.095 ms
^C
--- 10.0.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4066ms
rtt min/avg/max/mdev = 0.068/2.278/10.797/4.260 ms
mininet> h1 ping h4
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.
64 bytes from 10.0.0.4: icmp_seq=1 ttl=64 time=9.61 ms
64 bytes from 10.0.0.4: icmp_seq=2 ttl=64 time=0.373 ms
64 bytes from 10.0.0.4: icmp_seq=3 ttl=64 time=0.080 ms
64 bytes from 10.0.0.4: icmp_seq=4 ttl=64 time=0.077 ms
64 bytes from 10.0.0.4: icmp_seq=5 ttl=64 time=0.082 ms
^C
--- 10.0.0.4 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4064ms
rtt min/avg/max/mdev = 0.077/2.044/9.608/3.783 ms
mininet>
```

3. Dùng Wireshark tiến hành bắt các gói tin OpenFlow (v1.3)

- OFP Hello: Thiết lập kết nối ban đầu giữa switch và controller

162	27.515049...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
264	29.684509...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
270	29.688991...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
275	29.690374...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
280	29.691386...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO

- OFP Features Request và OFP Features Reply: Cho phép controller lấy thông tin về switch

294	29.693279...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
287	29.693663...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
290	29.694250...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
293	29.694714...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
296	29.711596...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
297	29.714959...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
299	29.715938...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
300	29.717625...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
302	29.718864...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
303	29.720870...	127.0.0.1	127.0.0.1	OpenFlow	292 Type: OFPT_FEATURES_REPLY
305	29.721739...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
306	29.722074...	127.0.0.1	127.0.0.1	OpenFlow	292 Type: OFPT_FEATURES_REPLY

- OFP Echo Request và OFP Echo Reply: Kiểm tra kết nối giữa controller và switch

1	0.00000000...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2	0.00099620...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
3	0.00099929...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
4	0.0010168...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
5	0.0011744...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
6	0.0011815...	127.0.0.1	127.0.0.1	OpenFlow	68 42470 → 6653 [ACK] Seq=9 Ack=9 Win=86 Len=0 TSval=3379093212 TSecr=3379093212
7	0.0013208...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
8	0.0013315...	127.0.0.1	127.0.0.1	TCP	68 42510 → 6653 [ACK] Seq=9 Ack=9 Win=86 Len=0 TSval=3379093213 TSecr=3379093213
9	0.0013499...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
10	0.0013549...	127.0.0.1	127.0.0.1	TCP	68 42502 → 6653 [ACK] Seq=9 Ack=9 Win=86 Len=0 TSval=3379093213 TSecr=3379093213
11	0.0013707...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
12	0.0013748...	127.0.0.1	127.0.0.1	TCP	68 42486 → 6653 [ACK] Seq=9 Ack=9 Win=86 Len=0 TSval=3379093213 TSecr=3379093213
13	5.0013202...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
14	5.0020577...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
15	5.0020652...	127.0.0.1	127.0.0.1	TCP	68 42470 → 6653 [ACK] Seq=17 Ack=17 Win=86 Len=0 TSval=3379098213 TSecr=3379098213
16	5.0021405...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
17	5.0021622...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
18	5.0021820...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
19	5.0023051...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
20	5.0023705...	127.0.0.1	127.0.0.1	TCP	68 42502 → 6653 [ACK] Seq=17 Ack=17 Win=86 Len=0 TSval=3379098214 TSecr=3379098214

- OFP Packet In và OFP Packet Out: Gửi dữ liệu từ switch lên controller khi switch không biết cách xử lý và ngược lại

684	29.135585...	fe80::dc28:dfff...	ff02::2	OpenFlow	156 Type: OFPT_PACKET_IN
685	29.135976...	fe80::dc28:dfff...	ff02::2	OpenFlow	162 Type: OFPT_PACKET_OUT

- OFP Flow Mod: Là thông điệp điều khiển được Controller gửi xuống Switch nhằm cài đặt, cập nhật hoặc xóa các Flow Entry trong Flow Table của switch

207	12.106407...	127.0.0.1	127.0.0.1	OpenFlow	146 Type: OFPT_FLOW_MOD
208	12.106451...	ca:89:6a:47:1b::	fa:19:57:1a::	OpenFlow	132 Type: OFPT_PACKET_OUT
210	12.107109...	ca:89:6a:47:1b::	fa:19:57:1a::	OpenFlow	126 Type: OFPT_PACKET_IN
211	12.108048...	fa:19:57:1a::	Broadcast	OpenFlow	132 Type: OFPT_PACKET_OUT
212	12.108426...	127.0.0.1	127.0.0.1	OpenFlow	146 Type: OFPT_FLOW_MOD
213	12.108483...	ca:89:6a:47:1b::	fa:19:57:1a::	OpenFlow	132 Type: OFPT_PACKET_OUT
215	12.109101...	10.0.0.3	10.0.0.4	OpenFlow	182 Type: OFPT_PACKET_IN
216	12.109893...	127.0.0.1	127.0.0.1	OpenFlow	146 Type: OFPT_FLOW_MOD
217	12.109937...	10.0.0.3	10.0.0.4	OpenFlow	188 Type: OFPT_PACKET_OUT
219	12.110176...	10.0.0.3	10.0.0.4	OpenFlow	182 Type: OFPT_PACKET_IN

```

* Frame 207: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface lo, id 0
* Ethernet II, Src: 00:00:00:00:00:00 (00:00:00:00:00:00), Dst: 00:00:00:00:00:00 (00:00:00:00:00:00)
* Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
* Transmission Control Protocol, Src Port: 6653, Dst Port: 40256, Seq: 1297, Ack: 965, Len: 80
* OpenFlow 1.0
  000 0001 = Version: 1.0 (0x01)
  Type: OFPT_FLOW_MOD (14)
  Length: 80
  Transaction ID: 1023058018
  Wildcards: 4194290
  In port: 1
  Ethernet source address: ca:89:6a:47:1b:1b (ca:89:6a:47:1b:1b)
  Ethernet destination address: fa:19:57:1a:2e (fa:19:57:1a:2e)
  Input VLAN id: 0
  Input VLAN priority: 0
  Pad: 00
  D1 type: 0
  IP TOS: 0
  IP protocol: 0
  Pad: 0000
  Source Address: 0.0.0.0
  Destination Address: 0.0.0.0
  Source Port: 0
  Destination Port: 0
  Cookies: 0x0000000000000000
  Command: New Flow (0)
  Idle time-out: 0
  hard time-out: 0
  Priority: 32768
  Buffer Id: 0xffffffff
  Out port: 65535
  Flags: 1

```

4. Liệt kê, mô tả các trường thông tin chính trong mỗi loại thông điệp ở bước 3

- OFP Hello, OFP Features Request, OFP Echo Request, OFP Echo Reply:

- Version: Phiên bản của giao thức OpenFlow (1.0)
- Type: Loại thông điệp
- Length: Độ dài của thông điệp (8), riêng gói tin OFPT_PORT_STATUS có độ dài 64.
- Transaction ID: Mã để theo dõi yêu cầu và phản hồi

162	27.515049...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
264	29.684509...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
270	29.688991...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
275	29.690374...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
280	29.691386...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_HELLO
284	29.693279...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
287	29.693663...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
290	29.694250...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
293	29.694714...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
296	29.711596...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
297	29.714959...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
299	29.715938...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
300	29.717625...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
302	29.718864...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
303	29.720870...	127.0.0.1	127.0.0.1	OpenFlow	292 Type: OFPT_FEATURES_REPLY
305	29.721739...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS

▶ Frame 162: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 6653, Dst Port: 58492, Seq: 1, Ack: 1, Len: 8
 - OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_HELLO (0)
 Length: 8
 Transaction ID: 777930874

284	29.693279...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
287	29.693663...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
290	29.694250...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
293	29.694714...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_FEATURES_REQUEST
296	29.711596...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
297	29.714959...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
299	29.715938...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
300	29.717625...	127.0.0.1	127.0.0.1	OpenFlow	244 Type: OFPT_FEATURES_REPLY
302	29.718864...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS
303	29.720870...	127.0.0.1	127.0.0.1	OpenFlow	292 Type: OFPT_FEATURES_REPLY
305	29.721739...	127.0.0.1	127.0.0.1	OpenFlow	132 Type: OFPT_PORT_STATUS

▶ Frame 284: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 6653, Dst Port: 58498, Seq: 9, Ack: 9, Len: 8
 - OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_FEATURES_REQUEST (5)
 Length: 8
 Transaction ID: 389645511

2384	77.030180...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2385	77.030292...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2386	77.030982...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2388	77.031085...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2390	77.350204...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2391	77.350722...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2394	77.857508...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2395	77.857932...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2401	82.032658...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST

▶ Frame 2384: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 58522, Dst Port: 6653, Seq: 11323, Ack: 11529, Len: 8
 - OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_ECHO_REQUEST (2)
 Length: 8
 Transaction ID: 0

2386	77.030982...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2388	77.031085...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2390	77.350204...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2391	77.350722...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2394	77.857508...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST
2395	77.857932...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REPLY
2401	82.032658...	127.0.0.1	127.0.0.1	OpenFlow	76 Type: OFPT_ECHO_REQUEST

▶ Frame 2386: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 6653, Dst Port: 58524, Seq: 11529, Ack: 11331, Len: 8
 - OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_ECHO_REPLY (3)
 Length: 8
 Transaction ID: 0



305	29.721739...	127.0.0.1	127.0.0.1	OpenFlow	132	Type: OFPT_PORT_STATUS
306	29.722074...	127.0.0.1	127.0.0.1	OpenFlow	292	Type: OFPT_FEATURES_REPLY
312	29.889174...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
313	29.890174...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
317	29.890438...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
318	29.890961...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
322	29.891208...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN

▶ Frame 305: 132 bytes on wire (1056 bits), 132 bytes captured (1056 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 58524, Dst Port: 6653, Seq: 9, Ack: 17, Len: 64
 ▶ OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 ▶ Type: OFPT_PORT_STATUS (12)
 Length: 64
 Transaction ID: 0

- OFP Features Reply: Có các trường thông tin về switch

- N_tables: Số flow table mà switch hỗ trợ
- Capabilities: Các khả năng mà switch hỗ trợ
- Actions: Các hành động mà switch hỗ trợ
- Port: Thông tin các port của switch

303	29.720870...	127.0.0.1	127.0.0.1	OpenFlow	292	Type: OFPT_FEATURES_REPLY
305	29.721739...	127.0.0.1	127.0.0.1	OpenFlow	132	Type: OFPT_PORT_STATUS
306	29.722074...	127.0.0.1	127.0.0.1	OpenFlow	292	Type: OFPT_FEATURES_REPLY
312	29.889174...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
313	29.890174...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
317	29.890438...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
318	29.890961...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
322	29.891208...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
323	29.891497...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
331	29.953532...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
332	29.954410...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
338	29.954797...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
339	29.954822...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
340	29.955271...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
342	29.955297...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
348	29.955562...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
349	29.955913...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
356	30.049566...	::	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
357	30.050503...	::	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
373	30.208921...	::	ff02::1:ff43:12...	OpenFlow	172	Type: OFPT_PACKET_IN

▶ Frame 303: 292 bytes on wire (2336 bits), 292 bytes captured (2336 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 58522, Dst Port: 6653, Seq: 73, Ack: 17, Len: 224
 ▶ OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_FEATURES_REPLY (6)
 Length: 224
 Transaction ID: 3199340078
 ▶ Datapath unique ID: 0x0000000000000003
 n_buffers: 0
 n_tables: 254
 Pad: 000000
 ▶ capabilities: 0x000000c7
 1 = Flow statistics: True
 1 = Table statistics: True
 1 = Port statistics: True
 0... = Group statistics: False
 0... = Can reassemble IP fragments: False
 1... = Queue statistics: True
 0... = Switch will block looping ports: False
 ▶ actions: 0x000000ff
 1 = Output to switch port: True
 1 = Set the 802.1q VLAN id: True
 1 = Set the 802.1q priority: True
 1... = Strip the 802.1q header: True
 1... = Ethernet source address: True
 1... = Ethernet destination address: True
 1... = IP source address: True
 1... = IP destination address: True
 1... = IP ToS (DSCP field, 6 bits): True
 1... = TCP/UDP source port: True
 1... = TCP/UDP destination port: True
 1... = Output to queue: True
 ▶ Port data 1
 ▶ Port data 2

- OFP Packet In:

- In port: Cổng mà switch nhận gói tin.
- Reason: Lý do gói tin không được xử lý bởi flow rule trong flow table của switch.

322	29.891208...	::	ff02::1:ff5b:b6...	OpenFlow	172	Type: OFPT_PACKET_IN
323	29.891497...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
331	29.953532...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
332	29.954410...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
338	29.954797...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
339	29.954822...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
340	29.955271...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
342	29.955297...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
348	29.955562...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
349	29.955913...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
356	30.049566...	::	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
357	30.050503...	::	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
373	30.208921...	::	ff02::1:ff43:12...	OpenFlow	172	Type: OFPT_PACKET_IN

▶ Frame 322: 172 bytes on wire (1376 bits), 172 bytes captured (1376 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 58510, Dst Port: 6653, Seq: 249, Ack: 17, Len: 104
 ▶ OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_PACKET_IN (10)
 Length: 104
 Transaction ID: 0
 Buffer Id: 0xffffffff
 Total length: 86
 In port: 2
 Reason: No matching flow (table-miss flow entry) (0)
 Pad: 00
 ▶ Ethernet II, Src: 96:4b:71:5b:b6:bc (96:4b:71:5b:b6:bc), Dst: IPv6mcast_ff:5b:b6:bc (33:33:ff:5b:b6:bc)
 ▶ Internet Protocol Version 6, Src: ::, Dst: ff02::1:ff5b:b6bc
 ▶ Internet Control Message Protocol v6

- OFP Packet Out:

- Action type: Hành động thực hiện với gói tin
- Output port: Cổng mà switch sẽ gửi gói tin đến
- Max length: Độ dài tối đa

323	29.891497...	::	ff02::1:ff5b:b6...	OpenFlow	178	Type: OFPT_PACKET_OUT
331	29.953532...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
332	29.954410...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
338	29.954797...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
339	29.954822...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
340	29.955271...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
342	29.955297...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
348	29.955562...	fe80::7486:baff...	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
349	29.955913...	fe80::7486:baff...	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
356	30.049566...	::	ff02::16	OpenFlow	176	Type: OFPT_PACKET_IN
357	30.050503...	::	ff02::16	OpenFlow	182	Type: OFPT_PACKET_OUT
373	30.208921...	::	ff02::1:ff43:12...	OpenFlow	172	Type: OFPT_PACKET_IN

▶ Frame 323: 178 bytes on wire (1424 bits), 178 bytes captured (1424 bits) on interface any, id 0
 ▶ Linux cooked capture
 ▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 ▶ Transmission Control Protocol, Src Port: 6653, Dst Port: 58510, Seq: 17, Ack: 353, Len: 110
 ▶ OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_PACKET_OUT (13)
 Length: 110
 Transaction ID: 2876622058
 Buffer Id: 0xffffffff
 In port: 2
 Actions length: 8
 Actions type: Output to switch port (0)
 Action length: 8
 Output port: 65531
 Max length: 65509
 ▶ Ethernet II, Src: 96:4b:71:5b:b6:bc (96:4b:71:5b:b6:bc), Dst: IPv6mcast_ff:5b:b6:bc (33:33:ff:5b:b6:bc)
 ▶ Internet Protocol Version 6, Src: ::, Dst: ff02::1:ff5b:b6bc
 ▶ Internet Control Message Protocol v6

- OFP FlowMod:

- Thông tin chung của gói tin: version, type, length, transaction ID
- Các trường match fields bao gồm: wildcards, in_port, MAC nguồn, MAC đích, IP nguồn, IP đích, port nguồn, port đích ...

- Các trường thiết lập flow bao gồm: cookie, command, idle time-out, hard time-out, priority...

207	12.106487	127.0.0.1	127.0.0.1	OpenFlow	146	Type: OFPT_FLOW_MOD
208	12.106451	ca:89:6a:47:1b:...	fa:e1:19:57:1a:...	OpenFlow	132	Type: OFPT_PACKET_OUT
210	12.107109	ca:89:6a:47:1b:...	fa:e1:19:57:1a:...	OpenFlow	126	Type: OFPT_PACKET_IN
211	12.108048	fa:e1:19:57:1a:...	Broadcast	OpenFlow	132	Type: OFPT_PACKET_OUT
212	12.108426	127.0.0.1	127.0.0.1	OpenFlow	146	Type: OFPT_FLOW_MOD
213	12.108483	ca:89:6a:47:1b:...	fa:e1:19:57:1a:...	OpenFlow	132	Type: OFPT_PACKET_OUT
215	12.109101	10.0.0.3	10.0.0.4	OpenFlow	182	Type: OFPT_PACKET_IN
216	12.109893	127.0.0.1	127.0.0.1	OpenFlow	146	Type: OFPT_FLOW_MOD
217	12.109937	10.0.0.3	10.0.0.4	OpenFlow	188	Type: OFPT_PACKET_OUT
219	12.118176	10.0.0.3	10.0.0.4	OpenFlow	182	Type: OFPT_PACKET_IN

Frame 207: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface lo, id 0
 Ethernet II, Src: 00:00:00:00:00:00 (00:00:00:00:00:00), Dst: 00:00:00:00:00:00 (00:00:00:00:00:00)
 Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
 Transmission Control Protocol, Src Port: 6653, Dst Port: 48256, Seq: 1297, Ack: 965, Len: 80
 OpenFlow 1.0
 .000 0001 = Version: 1.0 (0x01)
 Type: OFPT_FLOW_MOD (14)
 Length: 80
 Transaction ID: 1023658018
 Wildcards: 4194290
 In port: 1
 Ethernet source address: ca:89:6a:47:1b:1b (ca:89:6a:47:1b:1b)
 Ethernet destination address: fa:e1:19:57:1a:2e (fa:e1:19:57:1a:2e)
 Input VLAN id: 0
 Input VLAN priority: 0
 Pad: 00
 D1 type: 0
 IP ToS: 0
 IP protocol: 0
 Pad: 0000
 Source Address: 0.0.0.0
 Destination Address: 0.0.0.0
 Source Port: 0
 Destination Port: 0
 Cookie: 0x0000000000000000
 Command: New Flow (0)
 Idle time-out: 0
 hard time-out: 0
 Priority: 32768
 Buffer Id: 0xffffffff
 Out port: 65535
 Flags: 1

II. Yêu cầu 2

1. Tiến hành cài đặt một loại OpenFlow virtual Switch (vd: Open vSwitch)

- Ở trên máy sẽ làm ovs, cài đặt Open vSwitch với command:

"sudo apt install openvswitch-switch"

```

khanh@khanh:~$ sudo apt install openvswitch-switch
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
openvswitch-switch is already the newest version (2.17.9-0ubuntu0.22.04.1).
0 upgraded, 0 newly installed, 0 to remove and 10 not upgraded.
khanh@khanh:~$
  
```

- Tạo một bridge interface có tên là labbridge

```

khanh@khanh:~$ sudo ovs-vsctl add-br labbridge
[sudo] password for khanh:
khanh@khanh:~$ sudo ovs-vsctl show
356107dd-67ae-408b-9b9a-922a276a5cfc
    Bridge labbridge
        Port labbridge
            Interface labbridge
                type: internal
    ovs_version: "2.17.9"
khanh@khanh:~$
  
```

- Tạo các virtual port vport1 và vport2

```
khanh@khanh:~$ sudo ip tuntap add mode tap vport1
khanh@khanh:~$ sudo ip tuntap add mode tap vport2
khanh@khanh:~$ sudo ipconfig vport1 up
khanh@khanh:~$ sudo ipconfig vport2 up
khanh@khanh:~$ ifconfig -a
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.160.147 netmask 255.255.255.0 broadcast 192.168.160.255
    inet6 fe80::56a7:a304:af49:3b3f prefixlen 64 scopeid 0x20<link>
    ether 00:0c:29:61:b2:24 txqueuelen 1000 (Ethernet)
    RX packets 218418 bytes 325350283 (325.3 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 14649 bytes 1033587 (1.0 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

labbridge: flags=4098<BROADCAST,MULTICAST> mtu 1500
    ether 62:99:59:ec:3f:43 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 272 bytes 28258 (28.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 272 bytes 28258 (28.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

ovs-system: flags=4098<BROADCAST,MULTICAST> mtu 1500
    ether 46:56:5c:b4:26:67 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

vport1: flags=4099<UP,BROADCAST,MULTICAST> mtu 1500
    ether aa:dd:c4:08:ef:c5 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

vport2: flags=4099<UP,BROADCAST,MULTICAST> mtu 1500
    ether 1a:1a:99:e6:de:a6 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

- Tiếp theo, thêm 2 port trên vào interface bridge labbridge

```
khanh@khanh:~$ sudo ovs-vsctl add-port labbridge vport1
khanh@khanh:~$ sudo ovs-vsctl add-port labbridge vport2
khanh@khanh:~$ sudo ovs-vsctl show
356107dd-67ae-408b-9b9a-922a276a5cfc
    Bridge labbridge
        Port vport1
            Interface vport1
        Port labbridge
            Interface labbridge
            type: internal
        Port vport2
            Interface vport2
    ovs_version: "2.17.9"
khanh@khanh:~$
```

2. Kết nối switch đã cài đặt với một Ryu controller và một số Host (≥ 2 host)

- Tiến hành tạo 2 máy ảo Ubuntu làm Host (một máy có IP .141, và một máy có IP .138)

The first terminal window shows the configuration of a host with IP 192.168.160.141. It lists network interfaces: br-da8db97d08ab, docker0, ens33, and lo, along with their IP addresses, netmasks, and broadcast addresses.

The second terminal window shows the configuration of a host with IP 192.168.160.138. It lists network interfaces: docker0, docker_gwbridge, ens33, and lo, along with their IP addresses, netmasks, and broadcast addresses.

- Trên máy ảo cài đặt Open vSwitch, kết nối Ryu controller tới với switch (192.168.160.148 là địa chỉ IP của máy Ryu controller)

The terminal window shows the configuration of Open vSwitch. It sets the controller to labbridge with IP 192.168.160.148 and port 6633. It also shows the status of the bridge and its interfaces.

- Kiểm tra kết nối ở máy Ryu controller, thấy rằng đã thành công

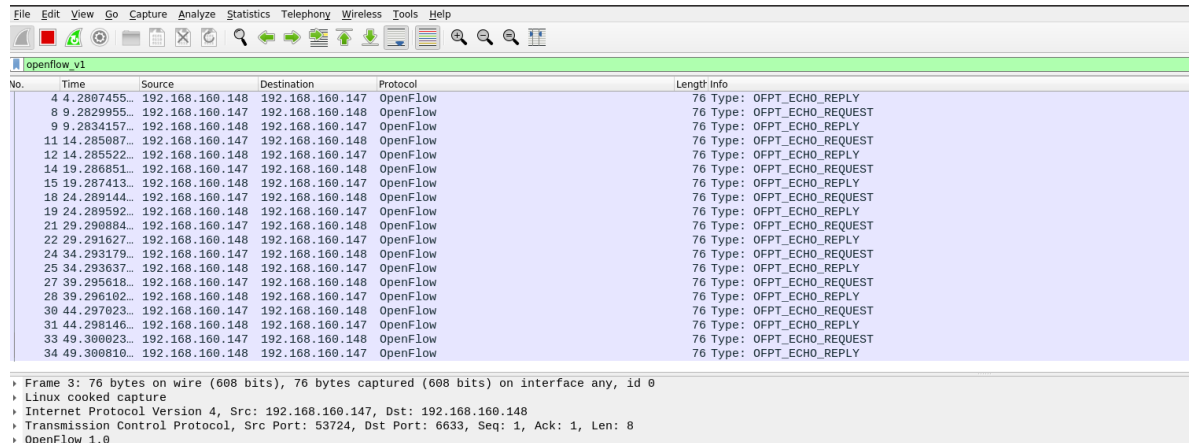
```

khanh@ubuntu:~$ ryu run ryu.app.simple_switch
loading app ryu.app.simple_switch
loading app ryu.controller.ofp_handler
instantiating app ryu.app.simple_switch of SimpleSwitch
instantiating app ryu.controller.ofp_handler of OFPHandler
packet in 108410778173251 00:23:20:8d:87:74 ff:ff:ff:ff:ff:ff 65534

```

3. Cài Wireshark và tiến hành các bước bắt gói tin trong yêu cầu 1, 2

- Bắt gói tin bằng Wireshark, thấy rằng Switch và Controller đang giao tiếp với nhau.



4. Test performance của mạng đã tạo ra

- Cho máy host 1 với địa chỉ IP .141 làm iperf server

```

khanhle@khanhle:~$ iperf3 -s
-----
Server listening on 5201
-----
Accepted connection from 192.168.160.138, port 54216
[ 5] local 192.168.160.141 port 5201 connected to 192.168.160.138 port 54218
[ ID] Interval           Transfer             Bitrate
[ 5] 0.00-1.00      sec    97.5 MBytes       818 Mbits/sec
[ 5] 1.00-2.00      sec   235 MBytes       1.97 Gbits/sec
[ 5] 2.00-3.00      sec   273 MBytes       2.29 Gbits/sec
[ 5] 3.00-4.00      sec   287 MBytes       2.41 Gbits/sec
[ 5] 4.00-5.00      sec   285 MBytes       2.39 Gbits/sec
[ 5] 5.00-6.00      sec   254 MBytes       2.13 Gbits/sec
[ 5] 6.00-7.00      sec   281 MBytes       2.36 Gbits/sec
[ 5] 7.00-8.00      sec   304 MBytes       2.55 Gbits/sec
[ 5] 8.00-9.00      sec   290 MBytes       2.43 Gbits/sec
[ 5] 9.00-10.00     sec   253 MBytes       2.12 Gbits/sec
[ 5] 10.00-10.07    sec   20.5 MBytes       2.48 Gbits/sec
-----
[ ID] Interval           Transfer             Bitrate
[ 5] 0.00-10.07     sec   2.52 GBytes       2.15 Gbits/sec
-----
Server listening on 5201
-----

```

- Cho máy host 2 với địa chỉ .138 làm iperf client. Kiểm tra hiệu năng của mạng đã tạo ra

```
khanhle@ubuntu:~$ iperf3 -c 192.168.160.141
Connecting to host 192.168.160.141, port 5201
[ 5] local 192.168.160.138 port 54218 connected to 192.168.160.141 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 5] 0.00-1.00    sec     110 MBytes  923 Mbits/sec   81  1.37 MBytes
[ 5] 1.00-2.00    sec     236 MBytes  1.98 Gbits/sec    0  1.51 MBytes
[ 5] 2.00-3.00    sec     274 MBytes  2.30 Gbits/sec    0  1.63 MBytes
[ 5] 3.00-4.00    sec     289 MBytes  2.42 Gbits/sec    0  1.73 MBytes
[ 5] 4.00-5.00    sec     284 MBytes  2.38 Gbits/sec    0  1.84 MBytes
[ 5] 5.00-6.00    sec     258 MBytes  2.16 Gbits/sec   11  1.43 MBytes
[ 5] 6.00-7.00    sec     282 MBytes  2.37 Gbits/sec    0  1.57 MBytes
[ 5] 7.00-8.00    sec     306 MBytes  2.57 Gbits/sec    0  1.70 MBytes
[ 5] 8.00-9.00    sec     288 MBytes  2.41 Gbits/sec    0  1.82 MBytes
[ 5] 9.00-10.00   sec     256 MBytes  2.15 Gbits/sec   19  1.42 MBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr
[ 5] 0.00-10.00   sec     2.52 GBytes  2.17 Gbits/sec  111
[ 5] 0.00-10.07   sec     2.52 GBytes  2.15 Gbits/sec
sender
receiver

iperf Done.
khanhle@ubuntu:~$
```

YÊU CẦU CHUNG

1) Đánh giá

- Chuẩn bị tốt các yêu cầu đặt ra trong bài thực hành.
- Sinh viên hiểu và tự thực hiện được bài thực hành, trả lời đầy đủ các yêu cầu đặt ra.
- Nộp báo cáo kết quả chi tiết những đã thực hiện, quan sát thấy và kèm ảnh chụp màn hình kết quả (nếu có); giải thích cho quan sát (nếu có).
- Sinh viên báo cáo kết quả thực hiện và nộp bài.

2) Báo cáo

- File **.PDF** hoặc **.docx**. Tập trung vào nội dung, giải thích.
 - Nội dung trình bày bằng Font chữ **Times New Romans/ hoặc font chữ của mẫu báo cáo này (UTM Avo)– cỡ chữ 13. Canh đều (Justify) cho văn bản. Canh giữa (Center) cho ảnh chụp.**
 - Đặt tên theo định dạng: LabX_MSSV1_MSSV2. (trong đó X là Thứ tự buổi Thực hành).
- Ví dụ: Lab01_21520001_21520002
- Nộp file báo cáo trên theo thời gian đã thống nhất tại courses.uit.edu.vn.

Bài sao chép, trễ, ... sẽ được xử lý tùy mức độ vi phạm.

HẾT