Lab 2 Report: SDN Simulation

** Please **fill in the report** and submit the **pdf** to NYUClasses*

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1. Objectives

- Fully understand the operation of Openflow and observe the operations
- Master the simulation tool mininet

2. Equipment Needs

- Computers
- Internet

3. Experiments

3.1 Basics

1. Install Ubuntu on your computer, you can install it on a VM using either VMWare player or VirtualBox:
   VMWare:
   https://my.vmware.com/web/vmware/free#desktop_end_user_computing/vmware_player/6_0
   VirtualBox:
   https://www.virtualbox.org/wiki/Downloads
   Ubuntu 16 or 18 is recommended! Ubuntu 20 might have some issues with python 2 and mininet!!
2. Follow the instructions to set up Mininet on your Ubuntu VM:
   http://mininet.org/download/
3. Perform basic simulations following these steps:
   http://mininet.org/walkthrough

3.2 Openflow

Part 1. Observe Openflow control messages:

1. Launch Mininet with default controller (**No "--controller remote" !**):

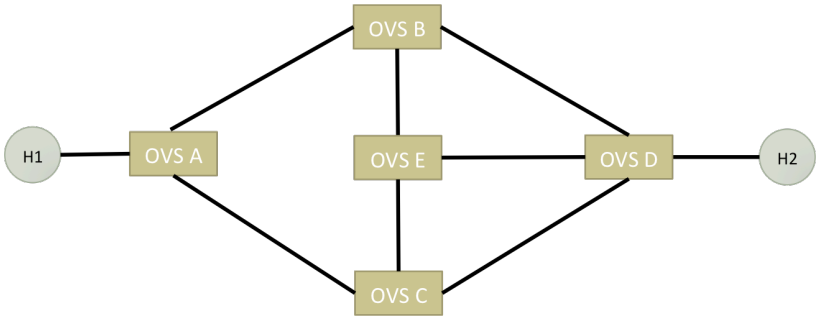
   $ sudo mn --custom ~/mininet/custom/topo-2sw-2host.py --topo mytopo

2. Install and open Wireshark in **Ubuntu**. Start listening to all the interfaces.

3. In Mininet:

mininet> pingall

You will see successful connections. Stop the Wireshark and find Openflow control flows. Fill in the table 4(a)



Part 2. Manually install flow entries in the OVS's

1. Use Mininet to create the topology above, where A, B, C, D, and E are all Openflow switches. (Remember to add **"--controller remote"** to disable default controller)
2. Enforce the following policies so that,
   a. Traffic from H1 ➔ H2
      i. HTTP traffic with d_port=80 follows path: A-B-D
      ii. other traffic follows path: A-C-E-D
   b. Traffic from H2 ➔ H1
      i. HTTP traffic with s_port=80, follow path: D-C-A
      ii. other traffic, follow path: D-B-E-C-A

   (i.e., you need to define a good match-action for the switches to achieve these.)

   c. verify your policies by,
      i. generating corresponding traffic (**using network debugging tools**)
      ii. capturing packets with Wireshark (listen to some switches' interfaces to see if the packets pass by)

   You can use OVS-OFCTL to manually install rules on switches (preferred method), or you can install a simple controller using RYU/POX/NOX/Beacon (Not recommended for lab 2 you'll do it in lab 3).

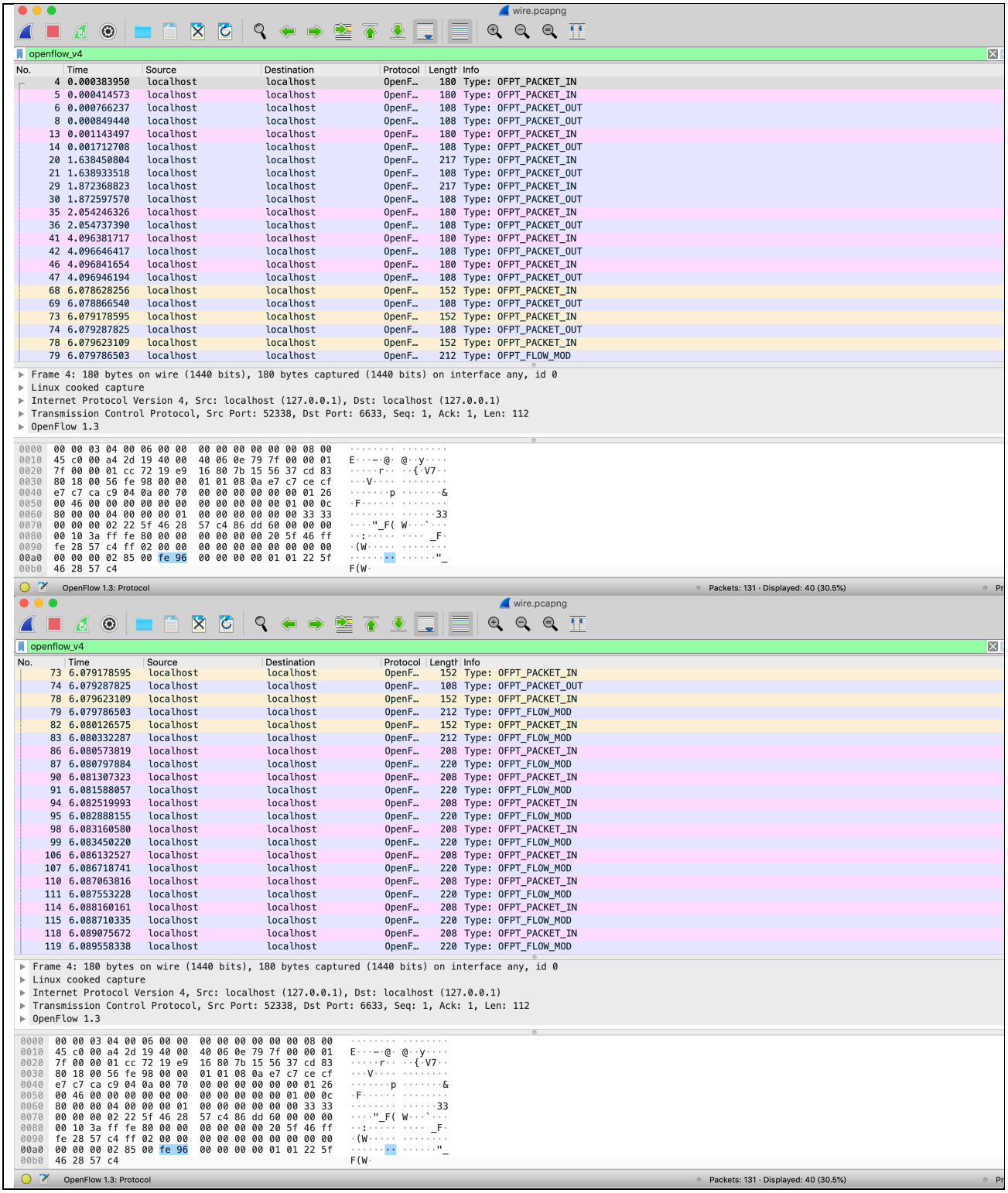
Part 3. Write a program that automatically creates a fat-tree with a given size N

1. Using mininet, create a 2-stage Fat Tree network using N-port switches, where N is a variable that should be an even number. (You don't need to check the connectivity, just create the topology.)

(Set N as a global variable in the topology (python) file)

4. Reports

(a) A screenshot of OpenFlow control messages you captured with WireShark.



(b)

Commands	Meaning of the commands
ovs-ofctl show s1	Show the current state of the openflow switch s1. Including the information of the flow table and ports.
ovs-ofctl dump-flows s1	Print all entries of flow which is in the table of switch that match flows.
ovs-ofctl add-flow s1 in_port=1,actions=output:2	Add flow entry to the table of switch. And also match the OpenFlow port is 1. Define the output as an action and the port number is 2.
ovs-ofctl add-flow s1 priority=500,in_port=1,dl_type=0x0800,nw_proto=6, actions=output:2	(what are the matches and what is the action?) Add flow entry to the table of switch. And also set the priority is 500 which means set the order of running flow order. Also match the OpenFlopw port is 1. Also al_type=0x0800 means to match all ethernet type 0x0800 which is IPv4 packets. And nw_proto=6 means to match all TCP packets. dl_type=0x0800,nw_proto=6 are the same as TCP. Also Define the output as an action and the port number is 2.
Question: What is "priority"? Why do we need "Priority"? What is the default priority if the priority is not given? 1. When traffic goes through from one host to another one. A wildcarded entry will match the priority to compare one to another. 2. Because there should be more than one flows to go through from one host to another. And then we need priority to set the highest priority. And the traffic will always go through the highest priority first. 3. Default priority: 32768	
Question: What is the default priority if the priority is not given? 32768	

(c) Output of mininet "net" command for both topologies (part 2 & part 3). (you can use any N for Fat-tree, ex: 4, 6, 8)

Part2:

```
mininet> net
h1 h1-eth1:s1-eth1
h2 h2-eth1:s5-eth4
s1 lo:  s1-eth1:h1-eth1 s1-eth2:s2-eth1 s1-eth3:s3-eth1
s2 lo:  s2-eth1:s1-eth2 s2-eth2:s4-eth1 s2-eth3:s5-eth1
s3 lo:  s3-eth1:s1-eth3 s3-eth2:s4-eth2 s3-eth3:s5-eth3
s4 lo:  s4-eth1:s2-eth2 s4-eth2:s3-eth2 s4-eth3:s5-eth2
s5 lo:  s5-eth1:s2-eth3 s5-eth2:s4-eth3 s5-eth3:s3-eth3 s5-eth4:h2-eth
c0
```

Part3:

```
mininet> net
host1 host1-eth0:switch1-eth1 host1-eth1:switch2-eth1 host1-eth2:switch3-eth1 host1-eth3:switch4-eth1 host1-eth4:switch5-eth1 host1-eth5:switch6-eth1
host2 host2-eth0:switch1-eth2 host2-eth1:switch2-eth2 host2-eth2:switch3-eth2 host2-eth3:switch4-eth2 host2-eth4:switch5-eth2 host2-eth5:switch6-eth2
host3 host3-eth0:switch1-eth3 host3-eth1:switch2-eth3 host3-eth2:switch3-eth3 host3-eth3:switch4-eth3 host3-eth4:switch5-eth3 host3-eth5:switch6-eth3
host4 host4-eth0:switch1-eth4 host4-eth1:switch2-eth4 host4-eth2:switch3-eth4 host4-eth3:switch4-eth4 host4-eth4:switch5-eth4 host4-eth5:switch6-eth4
host5 host5-eth0:switch1-eth5 host5-eth1:switch2-eth5 host5-eth2:switch3-eth5 host5-eth3:switch4-eth5 host5-eth4:switch5-eth5 host5-eth5:switch6-eth5
host6 host6-eth0:switch1-eth6 host6-eth1:switch2-eth6 host6-eth2:switch3-eth6 host6-eth3:switch4-eth6 host6-eth4:switch5-eth6 host6-eth5:switch6-eth6
host7 host7-eth0:switch1-eth7 host7-eth1:switch2-eth7 host7-eth2:switch3-eth7 host7-eth3:switch4-eth7 host7-eth4:switch5-eth7 host7-eth5:switch6-eth7
host8 host8-eth0:switch1-eth8 host8-eth1:switch2-eth8 host8-eth2:switch3-eth8 host8-eth3:switch4-eth8 host8-eth4:switch5-eth8 host8-eth5:switch6-eth8
host9 host9-eth0:switch1-eth9 host9-eth1:switch2-eth9 host9-eth2:switch3-eth9 host9-eth3:switch4-eth9 host9-eth4:switch5-eth9 host9-eth5:switch6-eth9
host10 host10-eth0:switch1-eth10 host10-eth1:switch2-eth10 host10-eth2:switch3-eth10 host10-eth3:switch4-eth10 host10-eth4:switch5-eth10 host10-eth5:switch6-eth10
host11 host11-eth0:switch1-eth11 host11-eth1:switch2-eth11 host11-eth2:switch3-eth11 host11-eth3:switch4-eth11 host11-eth4:switch5-eth11 host11-eth5:switch6-eth11
host12 host12-eth0:switch1-eth12 host12-eth1:switch2-eth12 host12-eth2:switch3-eth12 host12-eth3:switch4-eth12 host12-eth4:switch5-eth12 host12-eth5:switch6-eth12
host13 host13-eth0:switch1-eth13 host13-eth1:switch2-eth13 host13-eth2:switch3-eth13 host13-eth3:switch4-eth13 host13-eth4:switch5-eth13 host13-eth5:switch6-eth13
host14 host14-eth0:switch1-eth14 host14-eth1:switch2-eth14 host14-eth2:switch3-eth14 host14-eth3:switch4-eth14 host14-eth4:switch5-eth14 host14-eth5:switch6-eth14
host15 host15-eth0:switch1-eth15 host15-eth1:switch2-eth15 host15-eth2:switch3-eth15 host15-eth3:switch4-eth15 host15-eth4:switch5-eth15 host15-eth5:switch6-eth15
host16 host16-eth0:switch1-eth16 host16-eth1:switch2-eth16 host16-eth2:switch3-eth16 host16-eth3:switch4-eth16 host16-eth4:switch5-eth16 host16-eth5:switch6-eth16
host17 host17-eth0:switch1-eth17 host17-eth1:switch2-eth17 host17-eth2:switch3-eth17 host17-eth3:switch4-eth17 host17-eth4:switch5-eth17 host17-eth5:switch6-eth17
host18 host18-eth0:switch1-eth18 host18-eth1:switch2-eth18 host18-eth2:switch3-eth18 host18-eth3:switch4-eth18 host18-eth4:switch5-eth18 host18-eth5:switch6-eth18
core1 lo:  core1-eth1:switch1-eth19 core1-eth2:switch2-eth19 core1-eth3:switch3-eth19 core1-eth4:switch4-eth19 core1-eth5:switch5-eth19 core1-eth6:switch6-eth19
core2 lo:  core2-eth1:switch1-eth20 core2-eth2:switch2-eth20 core2-eth3:switch3-eth20 core2-eth4:switch4-eth20 core2-eth5:switch5-eth20 core2-eth6:switch6-eth20
core3 lo:  core3-eth1:switch1-eth21 core3-eth2:switch2-eth21 core3-eth3:switch3-eth21 core3-eth4:switch4-eth21 core3-eth5:switch5-eth21 core3-eth6:switch6-eth21
switch1 lo:  switch1-eth1:host1-eth0 switch1-eth2:host2-eth0 switch1-eth3:host3-eth0 switch1-eth4:host4-eth0 switch1-eth5:host5-eth0 switch1-eth6:host6-eth0 switch1-eth7:host7-eth0 switch1-eth8:h
 switch1-eth9:host9-eth0 switch1-eth10:host10-eth0 switch1-eth11:host11-eth0 switch1-eth12:host12-eth0 switch1-eth13:host13-eth0 switch1-eth14:host14-eth0 switch1-eth15:host15-eth0 switch1-eth16:
h0 switch1-eth17:host17-eth0 switch1-eth18:host18-eth0 switch1-eth19:core1-eth1 switch1-eth20:core2-eth1 switch1-eth21:core3-eth1
switch2 lo:  switch2-eth1:host1-eth1 switch2-eth2:host2-eth1 switch2-eth3:host3-eth1 switch2-eth4:host4-eth1 switch2-eth5:host5-eth1 switch2-eth6:host6-eth1 switch2-eth7:host7-eth1 switch2-eth8:h
 switch2-eth9:host9-eth1 switch2-eth10:host10-eth1 switch2-eth11:host11-eth1 switch2-eth12:host12-eth1 switch2-eth13:host13-eth1 switch2-eth14:host14-eth1 switch2-eth15:host15-eth1 switch2-eth16:
h1 switch2-eth17:host17-eth1 switch2-eth18:host18-eth1 switch2-eth19:core1-eth2 switch2-eth20:core2-eth2 switch2-eth21:core3-eth2
switch3 lo:  switch3-eth1:host1-eth2 switch3-eth2:host2-eth2 switch3-eth3:host3-eth2 switch3-eth4:host4-eth2 switch3-eth5:host5-eth2 switch3-eth6:host6-eth2 switch3-eth7:host7-eth2 switch3-eth8:h
 switch3-eth9:host9-eth2 switch3-eth10:host10-eth2 switch3-eth11:host11-eth2 switch3-eth12:host12-eth2 switch3-eth13:host13-eth2 switch3-eth14:host14-eth2 switch3-eth15:host15-eth2 switch3-eth16:
h2 switch3-eth17:host17-eth2 switch3-eth18:host18-eth2 switch3-eth19:core1-eth3 switch3-eth20:core2-eth3 switch3-eth21:core3-eth3
switch4 lo:  switch4-eth1:host1-eth3 switch4-eth2:host2-eth3 switch4-eth3:host3-eth3 switch4-eth4:host4-eth3 switch4-eth5:host5-eth3 switch4-eth6:host6-eth3 switch4-eth7:host7-eth3 switch4-eth8:h
 switch4-eth9:host9-eth3 switch4-eth10:host10-eth3 switch4-eth11:host11-eth3 switch4-eth12:host12-eth3 switch4-eth13:host13-eth3 switch4-eth14:host14-eth3 switch4-eth15:host15-eth3 switch4-eth16:
h3 switch4-eth17:host17-eth3 switch4-eth18:host18-eth3 switch4-eth19:core1-eth4 switch4-eth20:core2-eth4 switch4-eth21:core3-eth4
switch5 lo:  switch5-eth1:host1-eth4 switch5-eth2:host2-eth4 switch5-eth3:host3-eth4 switch5-eth4:host4-eth4 switch5-eth5:host5-eth4 switch5-eth6:host6-eth4 switch5-eth7:host7-eth4 switch5-eth8:h
 switch5-eth9:host9-eth4 switch5-eth10:host10-eth4 switch5-eth11:host11-eth4 switch5-eth12:host12-eth4 switch5-eth13:host13-eth4 switch5-eth14:host14-eth4 switch5-eth15:host15-eth4 switch5-eth16:
h4 switch5-eth17:host17-eth4 switch5-eth18:host18-eth4 switch5-eth19:core1-eth5 switch5-eth20:core2-eth5 switch5-eth21:core3-eth5
switch6 lo:  switch6-eth1:host1-eth5 switch6-eth2:host2-eth5 switch6-eth3:host3-eth5 switch6-eth4:host4-eth5 switch6-eth5:host5-eth5 switch6-eth6:host6-eth5 switch6-eth7:host7-eth5 switch6-eth8:h
 switch6-eth9:host9-eth5 switch6-eth10:host10-eth5 switch6-eth11:host11-eth5 switch6-eth12:host12-eth5 switch6-eth13:host13-eth5 switch6-eth14:host14-eth5 switch6-eth15:host15-eth5 switch6-eth16:
h5 switch6-eth17:host17-eth5 switch6-eth18:host18-eth5 switch6-eth19:core1-eth6 switch6-eth20:core2-eth6 switch6-eth21:core3-eth6
c0
mininet>
```

(d) The command you use to start your Mininet topology and the screen shot of the Mininet output while creating the networks.

Command you use to start your Mininet topology:
(Remember to add **"--controller remote"** to disable default controller; otherwise, you'll get zero for the following tasks.)

Part2:

```
sudo mn --custom topo-5sw-2host.py --topo mytopo --controller remote
```

```
sh6203@sh6203-VirtualBox:~$ sudo mn --custom topo-5sw-2host.py --topo mytopo --controlle
mote
*** Creating network
*** Adding controller
Unable to contact the remote controller at 127.0.0.1:6633
*** Adding hosts:
h1 h2
*** Adding switches:
s1 s2 s3 s4 s5
*** Adding links:
(h1, s1) (s1, s2) (s1, s3) (s2, s4) (s2, s5) (s3, s4) (s4, s5) (s5, h2) (s5, s3)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 5 switches
s1 s2 s3 s4 s5 ...
*** Starting CLI:
mininet>
```

Part3:

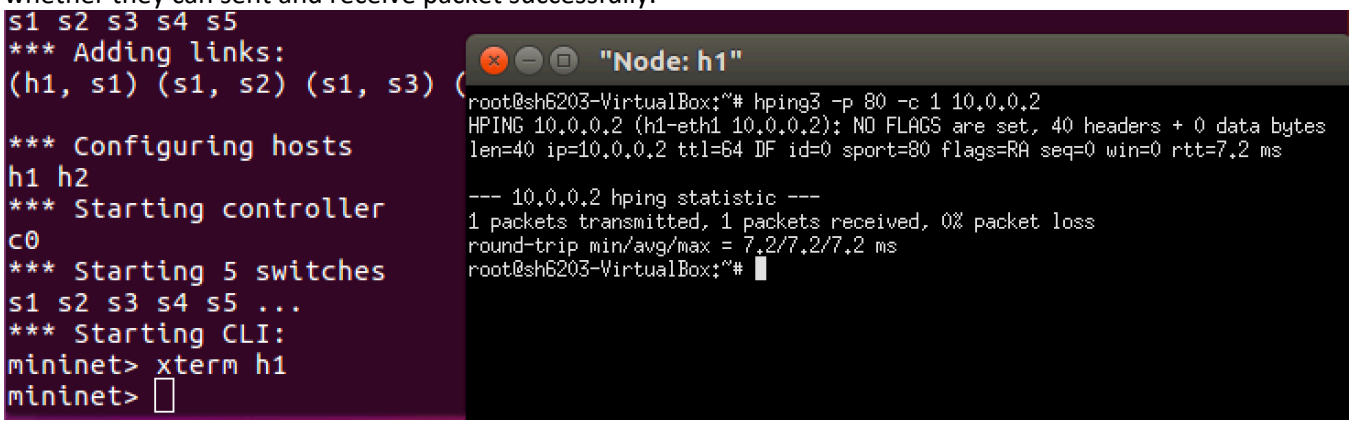
```
sh6203@sh6203-VirtualBox:~$ sudo mn --custom fatTree.py --topo mytopo --controller remote
[sudo] password for sh6203:
port number: 6
*** Creating network
*** Adding controller
Unable to contact the remote controller at 127.0.0.1:6633
*** Adding hosts:
host1 host2 host3 host4 host5 host6 host7 host8 host9 host10 host11 host12 host13 host14 host15 host16 host17 host18
*** Adding switches:
core1 core2 core3 switch1 switch2 switch3 switch4 switch5 switch6
*** Adding links:
(core1, switch1) (core1, switch2) (core1, switch3) (core1, switch4) (core1, switch5) (core1, switch6) (core2, switch1) (core2, switch2) (core2, switch3) (core2, switch4) (core2, switch5) (core2,
(core3, switch1) (core3, switch2) (core3, switch3) (core3, switch4) (core3, switch5) (core3, switch6) (host1, switch1) (host1, switch2) (host1, switch3) (host1, switch4) (host1, switch5) (host1,
(host2, switch1) (host2, switch2) (host2, switch3) (host2, switch4) (host2, switch5) (host2, switch6) (host3, switch1) (host3, switch2) (host3, switch3) (host3, switch4) (host3, switch5) (host3,
(host4, switch1) (host4, switch2) (host4, switch3) (host4, switch4) (host4, switch5) (host4, switch6) (host5, switch1) (host5, switch2) (host5, switch3) (host5, switch4) (host5, switch5) (host5,
(host6, switch1) (host6, switch2) (host6, switch3) (host6, switch4) (host6, switch5) (host6, switch6) (host7, switch1) (host7, switch2) (host7, switch3) (host7, switch4) (host7, switch5) (host7,
(host8, switch1) (host8, switch2) (host8, switch3) (host8, switch4) (host8, switch5) (host8, switch6) (host9, switch1) (host9, switch2) (host9, switch3) (host9, switch4) (host9, switch5) (host9,
(host10, switch1) (host10, switch2) (host10, switch3) (host10, switch4) (host10, switch5) (host10, switch6) (host11, switch1) (host11, switch2) (host11, switch3) (host11, switch4) (host11, switch
1, switch6) (host12, switch1) (host12, switch2) (host12, switch3) (host12, switch4) (host12, switch5) (host12, switch6) (host13, switch1) (host13, switch2) (host13, switch3) (host13, switch4) (ho
tch5) (host13, switch6) (host14, switch1) (host14, switch2) (host14, switch3) (host14, switch4) (host14, switch5) (host14, switch6) (host15, switch1) (host15, switch2) (host15, switch3) (host15,
(host15, switch5) (host15, switch6) (host16, switch1) (host16, switch2) (host16, switch3) (host16, switch4) (host16, switch5) (host16, switch6) (host17, switch1) (host17, switch2) (host17, switch
7, switch4) (host17, switch5) (host17, switch6) (host18, switch1) (host18, switch2) (host18, switch3) (host18, switch4) (host18, switch5) (host18, switch6)
*** Configuring hosts
host1 host2 host3 host4 host5 host6 host7 host8 host9 host10 host11 host12 host13 host14 host15 host16 host17 host18
*** Starting controller
c0
*** Starting 9 switches
core1 core2 core3 switch1 switch2 switch3 switch4 switch5 switch6 ...
*** Starting CLI:
```

(e) Briefly explain how you produce different traffic to verify whether the rules installed function correctly.
(Hint: Use the network debugging tool in lab 1)

After I finish different traffic, I use pingall to test wether I have finish correctly. And it shows

```
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
```

It can be from host1 to host2 and from host2 to host1, which means that my rules can be used to create flows. Also I use xterm h1 in mininet to open node h1. And use hping3 -p 80 -c 1 10.0.0.2 to hping host2. To check whether they can sent and receive packet successfully.



Here it shows 1 packets transmitted and 1 packets received. Also there are 0% packet loss. So the packet can trnasfered from the flow.

And also I use `sudo ovs-ofctl dump-flows s1, sudo ovs-ofctl dump-flows s2, sudo ovs-ofctl dump-flows s3, sudo ovs-ofctl dump-flows s4, sudo ovs-ofctl dump-flows s5,` to shows all the process information of my 5 switches, to see whether they are transfer the packetes correctly.

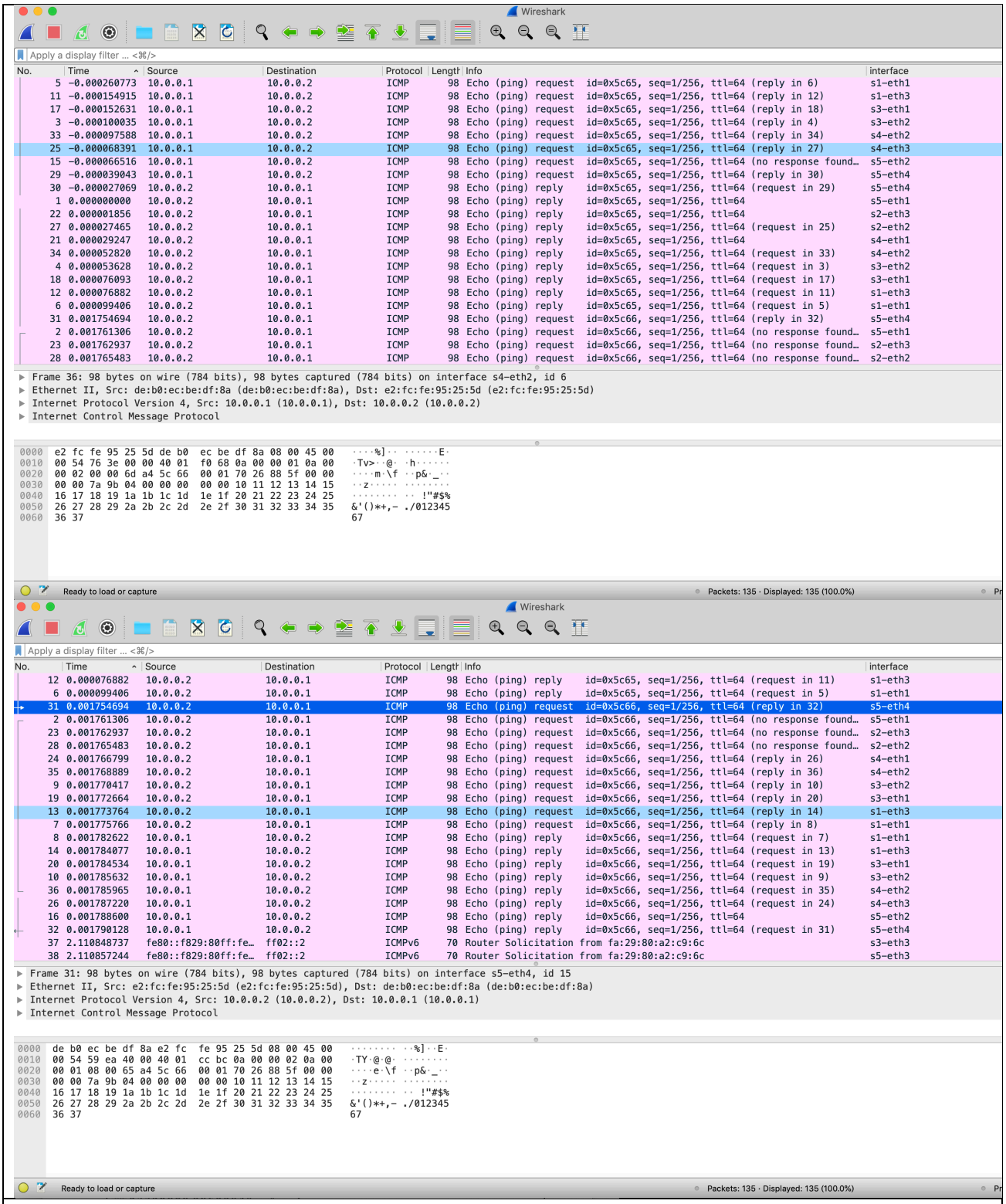
```
sh6203@sh6203-VirtualBox:~$ sudo ovs-ofctl dump-flows s1
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=250.745s, table=0, n_packets=1, n_bytes=54, idle_age=180, priority=100
,tcp,in_port=1,tp_dst=80 actions=output:2
 cookie=0x0, duration=250.678s, table=0, n_packets=1, n_bytes=54, idle_age=180, priority=100
,tcp,in_port=3,tp_src=80 actions=output:1
 cookie=0x0, duration=250.721s, table=0, n_packets=7, n_bytes=434, idle_age=5, priority=0,in
_port=1 actions=output:3
 cookie=0x0, duration=250.646s, table=0, n_packets=45, n_bytes=5754, idle_age=5, priority=0,
in_port=3 actions=output:1
sh6203@sh6203-VirtualBox:~$ sudo ovs-ofctl dump-flows s2
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=276.805s, table=0, n_packets=1, n_bytes=54, idle_age=206, priority=100
,tcp,in_port=1,tp_dst=80 actions=output:3
 cookie=0x0, duration=276.732s, table=0, n_packets=17, n_bytes=1799, idle_age=31, priority=0
,in_port=3 actions=output:2
sh6203@sh6203-VirtualBox:~$ sudo ovs-ofctl dump-flows s3
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=279.136s, table=0, n_packets=1, n_bytes=54, idle_age=208, priority=100
,tcp,in_port=3,tp_src=80 actions=output:1
 cookie=0x0, duration=279.165s, table=0, n_packets=17, n_bytes=1799, idle_age=33, priority=0
,in_port=1 actions=output:2
 cookie=0x0, duration=279.104s, table=0, n_packets=37, n_bytes=4529, idle_age=11, priority=0
,in_port=2 actions=output:1
```

```
sh6203@sh6203-VirtualBox:~$ sudo ovs-ofctl dump-flows s4
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=280.676s, table=0, n_packets=27, n_bytes=3164, idle_age=35, priority=0
,in_port=2 actions=output:3
 cookie=0x0, duration=280.627s, table=0, n_packets=27, n_bytes=3164, idle_age=35, priority=0
,in_port=1 actions=output:2

sh6203@sh6203-VirtualBox:~$ sudo ovs-ofctl dump-flows s5
NXST_FLOW reply (xid=0x4):
 cookie=0x0, duration=282.404s, table=0, n_packets=1, n_bytes=54, idle_age=212, priority=100
,tcp,in_port=1,tp_dst=80 actions=output:4
 cookie=0x0, duration=282.366s, table=0, n_packets=1, n_bytes=54, idle_age=212, priority=100
,tcp,in_port=4,tp_src=80 actions=output:3
 cookie=0x0, duration=282.373s, table=0, n_packets=37, n_bytes=4529, idle_age=14, priority=0
,in_port=2 actions=output:4
 cookie=0x0, duration=282.346s, table=0, n_packets=7, n_bytes=434, idle_age=49, priority=0,i
n_port=4 actions=output:1
```

It also shows my input port and output port.

(f) With the produced traffic, show the screenshots of Wireshark capture on different links (switch with interface) to verify the paths taken by different traffic are correct.



Here I use time to sort all of the traffic. And it shows the interface information here to show the traffic path. And from s1-s3-s4-s5 it shows the path A-C-E-D which is correct. And the interface flow is also correct from my code.

And then it flows from s5-s2-s4-s3-s1 which shows the path D-B-E-C-A. And the interface flow is also correct from my code.

(g) OVS-OFCTL commands used to install the rules on switches (part 2). (If you use a controller, upload your controller program)

https://drive.google.com/drive/folders/1b_DUz_p68Y0iaSuvJY1R6mCJe--drP_e?usp=sharing

(h) Also submit your custom topology files (.py files) for both topologies (part 2 & part 3) (do NOT paste code in report).

https://drive.google.com/drive/folders/1psW28jz1h-h6xcpX9sr6mbfYU6AP2Ygv?usp=sharing

We have zero tolerance to forged or fabricated data!! A single piece of forged/fabricated data would bring the total score down to zero.