Lab 2: SDN Simulation

Team member

Xinmei Jin （xj573)

Zhaoxi Chen (zc1134)

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
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

1. Use Mininet to create the topology below, where A, B, C, D, and E are all Openflow switches.
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
   c. verify your policies by,

i. generating corresponding traffic
ii. capturing packets with Wireshark

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 4).

3. 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.)

4. Reports

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

The test Topo we used is setted as follow.

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```
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
*** Results: 0% dropped (2/2 received)
mininet> h1 python -m SimpleHTTPServer 80 &
mininet> h2 wget -0 -h1
wget: invalid option -- '0'
wget: invalid option -- '1'
Usage: wget [OPTION]... [URL]...

Try `wget --help' for more options.
mininet> h2 wget -O - h1
--2018-02-23 10:12:45--  http://10.0.0.1/
Connecting to 10.0.0.1:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 354 [text/html]
Saving to: 'STDOUT'
-                   0%[                    ]       0  --.-KB/s    <!DOCTYPE html PUBLIC "-//W3C//DTD HTML 3.2 Final//EN"><html>
<title>Directory listing for /</title>
<body>
<h2>Directory listing for /</h2>
<hr>
<ul>
<li><a href="2017%20Fall/">2017 Fall/</a>
<li><a href="2018%20Spring/">2018 Spring/</a>
<li><a href="Basics/">Basics/</a>
<li><a href="DFA/">DFA/</a>
<li><a href="Ha/">Ha/</a>
</ul>
<hr>
</body>
</html>
-                   100%[===================>]     354  --.-KB/s    in 0s

2018-02-23 10:12:45 (51.0 MB/s) - written to stdout [354/354]

mininet> h1 kill %python
Serving HTTP on 0.0.0.0 port 80 ...
10.0.0.2 - - [23/Feb/2018 10:12:45] "GET / HTTP/1.1" 200 -
```

No.	Time	Source	Destination	Protocol	Length	Info
7	0.256451841	127.0.0.1	127.0.0.1	OpenFlow	108	Type: OFPT_PACKET_OUT
9	0.256544994	127.0.0.1	127.0.0.1	OpenFlow	108	Type: OFPT_PACKET_OUT
129	4.453028799	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
130	4.453297712	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
152	9.453041165	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
153	9.453196786	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
166	14.452554807	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
167	14.452896343	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
178	17.408233142	127.0.0.1	127.0.0.1	OpenFlow	180	Type: OFPT_PACKET_IN
179	17.408263456	127.0.0.1	127.0.0.1	OpenFlow	180	Type: OFPT_PACKET_IN
180	17.408477667	127.0.0.1	127.0.0.1	OpenFlow	108	Type: OFPT_PACKET_OUT
183	17.408585447	127.0.0.1	127.0.0.1	OpenFlow	108	Type: OFPT_PACKET_OUT
188	21.452827428	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
189	21.453171020	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
191	26.453498947	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
192	26.453794885	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
239	31.452810089	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
240	31.453121831	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
253	36.452773299	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
254	36.453094209	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
269	41.453020626	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
270	41.453356384	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
313	46.453043431	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REQUEST
314	46.453257841	127.0.0.1	127.0.0.1	OpenFlow	76	Type: OFPT_ECHO_REPLY
317	50.176431836	127.0.0.1	127.0.0.1	OpenFlow	180	Type: OFPT_PACKET_IN

```
▶ Frame 5: 180 bytes on wire (1440 bits), 180 bytes captured (1440 bits) on interface 0
▶ Linux cooked capture
▶ Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
▶ Transmission Control Protocol, Src Port: 39436, Dst Port: 6633, Seq: 1, Ack: 1, Len: 112
▶ OpenFlow 1.3
```

```
0000  00 00 03 04 00 06 00 00  00 00 00 00 00 00 08 00   ........ ........
0010  45 c0 00 a4 60 c7 40 00  40 06 da ca 7f 00 00 01   E...`.@. @.......
0020  7f 00 00 01 9a 0c 19 e9  a9 7d 9c 71 c0 d4 24 06   ........ .}.q..$.
0030  80 18 00 56 fe 98 00 00  01 01 08 0a 68 d1 98 5e   ...V.... ....h..^
0040  68 d1 89 84 04 0a 00 70  00 00 00 00 00 00 01 0a   h......p ........
0050  00 46 00 00 00 00 00 00  00 00 00 00 00 01 00 0c   .F...... ........
0060  80 00 00 04 00 00 00 02  00 00 00 00 00 00 33 33   ........ ......33
```

(b) Output of mininet “net” command for both topologies. (you can use any N for Fat-tree, ex: 4, 6, 8)

For network No.1:

```
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s4-eth4
s1 lo:  s1-eth1:h1-eth0 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-eth2
s4 lo:  s4-eth1:s2-eth2 s4-eth2:s3-eth2 s4-eth3:s5-eth3 s4-eth4:h2-eth0
s5 lo:  s5-eth1:s2-eth3 s5-eth2:s3-eth3 s5-eth3:s4-eth3
c0
```

For Fat Tree network:

N=4:

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```
mininet> net
host_1 host_1-eth0:down_s1-eth5 host_1-eth1:down_s2-eth5 host_1-eth2:down_s3-eth5 host_1-eth3:down_s4-eth5 host_1-eth4:down_s5-eth5 host_1-eth5:down_s6-eth5 host_1-eth6:d
own_s7-eth5 host_1-eth7:down_s8-eth5
host_2 host_2-eth0:down_s1-eth6 host_2-eth1:down_s2-eth6 host_2-eth2:down_s3-eth6 host_2-eth3:down_s4-eth6 host_2-eth4:down_s5-eth6 host_2-eth5:down_s6-eth6 host_2-eth6:d
own_s7-eth6 host_2-eth7:down_s8-eth6
host_3 host_3-eth0:down_s1-eth7 host_3-eth1:down_s2-eth7 host_3-eth2:down_s3-eth7 host_3-eth3:down_s4-eth7 host_3-eth4:down_s5-eth7 host_3-eth5:down_s6-eth7 host_3-eth6:d
own_s7-eth7 host_3-eth7:down_s8-eth7
host_4 host_4-eth0:down_s1-eth8 host_4-eth1:down_s2-eth8 host_4-eth2:down_s3-eth8 host_4-eth3:down_s4-eth8 host_4-eth4:down_s5-eth8 host_4-eth5:down_s6-eth8 host_4-eth6:d
own_s7-eth8 host_4-eth7:down_s8-eth8
host_5 host_5-eth0:down_s1-eth9 host_5-eth1:down_s2-eth9 host_5-eth2:down_s3-eth9 host_5-eth3:down_s4-eth9 host_5-eth4:down_s5-eth9 host_5-eth5:down_s6-eth9 host_5-eth6:d
own_s7-eth9 host_5-eth7:down_s8-eth9
host_6 host_6-eth0:down_s1-eth10 host_6-eth1:down_s2-eth10 host_6-eth2:down_s3-eth10 host_6-eth3:down_s4-eth10 host_6-eth4:down_s5-eth10 host_6-eth5:down_s6-eth10 host_6-
eth6:down_s7-eth10 host_6-eth7:down_s8-eth10
host_7 host_7-eth0:down_s1-eth11 host_7-eth1:down_s2-eth11 host_7-eth2:down_s3-eth11 host_7-eth3:down_s4-eth11 host_7-eth4:down_s5-eth11 host_7-eth5:down_s6-eth11 host_7-
eth6:down_s7-eth11 host_7-eth7:down_s8-eth11
host_8 host_8-eth0:down_s1-eth12 host_8-eth1:down_s2-eth12 host_8-eth2:down_s3-eth12 host_8-eth3:down_s4-eth12 host_8-eth4:down_s5-eth12 host_8-eth5:down_s6-eth12 host_8-
eth6:down_s7-eth12 host_8-eth7:down_s8-eth12
host_9 host_9-eth0:down_s1-eth13 host_9-eth1:down_s2-eth13 host_9-eth2:down_s3-eth13 host_9-eth3:down_s4-eth13 host_9-eth4:down_s5-eth13 host_9-eth5:down_s6-eth13 host_9-
eth6:down_s7-eth13 host_9-eth7:down_s8-eth13
host_10 host_10-eth0:down_s1-eth14 host_10-eth1:down_s2-eth14 host_10-eth2:down_s3-eth14 host_10-eth3:down_s4-eth14 host_10-eth4:down_s5-eth14 host_10-eth5:down_s6-eth14
host_10-eth6:down_s7-eth14 host_10-eth7:down_s8-eth14
host_11 host_11-eth0:down_s1-eth15 host_11-eth1:down_s2-eth15 host_11-eth2:down_s3-eth15 host_11-eth3:down_s4-eth15 host_11-eth4:down_s5-eth15 host_11-eth5:down_s6-eth15
host_11-eth6:down_s7-eth15 host_11-eth7:down_s8-eth15
host_12 host_12-eth0:down_s1-eth16 host_12-eth1:down_s2-eth16 host_12-eth2:down_s3-eth16 host_12-eth3:down_s4-eth16 host_12-eth4:down_s5-eth16 host_12-eth5:down_s6-eth16
host_12-eth6:down_s7-eth16 host_12-eth7:down_s8-eth16
host_13 host_13-eth0:down_s1-eth17 host_13-eth1:down_s2-eth17 host_13-eth2:down_s3-eth17 host_13-eth3:down_s4-eth17 host_13-eth4:down_s5-eth17 host_13-eth5:down_s6-eth17
host_13-eth6:down_s7-eth17 host_13-eth7:down_s8-eth17
host_14 host_14-eth0:down_s1-eth18 host_14-eth1:down_s2-eth18 host_14-eth2:down_s3-eth18 host_14-eth3:down_s4-eth18 host_14-eth4:down_s5-eth18 host_14-eth5:down_s6-eth18
host_14-eth6:down_s7-eth18 host_14-eth7:down_s8-eth18
host_15 host_15-eth0:down_s1-eth19 host_15-eth1:down_s2-eth19 host_15-eth2:down_s3-eth19 host_15-eth3:down_s4-eth19 host_15-eth4:down_s5-eth19 host_15-eth5:down_s6-eth19
host_15-eth6:down_s7-eth19 host_15-eth7:down_s8-eth19
host_16 host_16-eth0:down_s1-eth20 host_16-eth1:down_s2-eth20 host_16-eth2:down_s3-eth20 host_16-eth3:down_s4-eth20 host_16-eth4:down_s5-eth20 host_16-eth5:down_s6-eth20
host_16-eth6:down_s7-eth20 host_16-eth7:down_s8-eth20
host_17 host_17-eth0:down_s1-eth21 host_17-eth1:down_s2-eth21 host_17-eth2:down_s3-eth21 host_17-eth3:down_s4-eth21 host_17-eth4:down_s5-eth21 host_17-eth5:down_s6-eth21
host_17-eth6:down_s7-eth21 host_17-eth7:down_s8-eth21
host_18 host_18-eth0:down_s1-eth22 host_18-eth1:down_s2-eth22 host_18-eth2:down_s3-eth22 host_18-eth3:down_s4-eth22 host_18-eth4:down_s5-eth22 host_18-eth5:down_s6-eth22
host_18-eth6:down_s7-eth22 host_18-eth7:down_s8-eth22
host_19 host_19-eth0:down_s1-eth23 host_19-eth1:down_s2-eth23 host_19-eth2:down_s3-eth23 host_19-eth3:down_s4-eth23 host_19-eth4:down_s5-eth23 host_19-eth5:down_s6-eth23
host_19-eth6:down_s7-eth23 host_19-eth7:down_s8-eth23
host_20 host_20-eth0:down_s1-eth24 host_20-eth1:down_s2-eth24 host_20-eth2:down_s3-eth24 host_20-eth3:down_s4-eth24 host_20-eth4:down_s5-eth24 host_20-eth5:down_s6-eth24
host_20-eth6:down_s7-eth24 host_20-eth7:down_s8-eth24
host_21 host_21-eth0:down_s1-eth25 host_21-eth1:down_s2-eth25 host_21-eth2:down_s3-eth25 host_21-eth3:down_s4-eth25 host_21-eth4:down_s5-eth25 host_21-eth5:down_s6-eth25
host_21-eth6:down_s7-eth25 host_21-eth7:down_s8-eth25
```

```
host_22-eth6:down_s7-eth26 host_22-eth7:down_s8-eth26
host_23 host_23-eth0:down_s1-eth27 host_23-eth1:down_s2-eth27 host_23-eth2:down_s3-eth27 host_23-eth3:down_s4-eth27 host_23-eth4:down_s5-eth27 host_23-eth5:down_s6-eth27
host_23-eth6:down_s7-eth27 host_23-eth7:down_s8-eth27
host_24 host_24-eth0:down_s1-eth28 host_24-eth1:down_s2-eth28 host_24-eth2:down_s3-eth28 host_24-eth3:down_s4-eth28 host_24-eth4:down_s5-eth28 host_24-eth5:down_s6-eth28
host_24-eth6:down_s7-eth28 host_24-eth7:down_s8-eth28
host_25 host_25-eth0:down_s1-eth29 host_25-eth1:down_s2-eth29 host_25-eth2:down_s3-eth29 host_25-eth3:down_s4-eth29 host_25-eth4:down_s5-eth29 host_25-eth5:down_s6-eth29
host_25-eth6:down_s7-eth29 host_25-eth7:down_s8-eth29
host_26 host_26-eth0:down_s1-eth30 host_26-eth1:down_s2-eth30 host_26-eth2:down_s3-eth30 host_26-eth3:down_s4-eth30 host_26-eth4:down_s5-eth30 host_26-eth5:down_s6-eth30
host_26-eth6:down_s7-eth30 host_26-eth7:down_s8-eth30
host_27 host_27-eth0:down_s1-eth31 host_27-eth1:down_s2-eth31 host_27-eth2:down_s3-eth31 host_27-eth3:down_s4-eth31 host_27-eth4:down_s5-eth31 host_27-eth5:down_s6-eth31
host_27-eth6:down_s7-eth31 host_27-eth7:down_s8-eth31
host_28 host_28-eth0:down_s1-eth32 host_28-eth1:down_s2-eth32 host_28-eth2:down_s3-eth32 host_28-eth3:down_s4-eth32 host_28-eth4:down_s5-eth32 host_28-eth5:down_s6-eth32
host_28-eth6:down_s7-eth32 host_28-eth7:down_s8-eth32
host_29 host_29-eth0:down_s1-eth33 host_29-eth1:down_s2-eth33 host_29-eth2:down_s3-eth33 host_29-eth3:down_s4-eth33 host_29-eth4:down_s5-eth33 host_29-eth5:down_s6-eth33
host_29-eth6:down_s7-eth33 host_29-eth7:down_s8-eth33
host_30 host_30-eth0:down_s1-eth34 host_30-eth1:down_s2-eth34 host_30-eth2:down_s3-eth34 host_30-eth3:down_s4-eth34 host_30-eth4:down_s5-eth34 host_30-eth5:down_s6-eth34
host_30-eth6:down_s7-eth34 host_30-eth7:down_s8-eth34
host_31 host_31-eth0:down_s1-eth35 host_31-eth1:down_s2-eth35 host_31-eth2:down_s3-eth35 host_31-eth3:down_s4-eth35 host_31-eth4:down_s5-eth35 host_31-eth5:down_s6-eth35
host_31-eth6:down_s7-eth35 host_31-eth7:down_s8-eth35
host_32 host_32-eth0:down_s1-eth36 host_32-eth1:down_s2-eth36 host_32-eth2:down_s3-eth36 host_32-eth3:down_s4-eth36 host_32-eth4:down_s5-eth36 host_32-eth5:down_s6-eth36
host_32-eth6:down_s7-eth36 host_32-eth7:down_s8-eth36
down_s1 lo:  down_s1-eth1:top_s1-eth1 down_s1-eth2:top_s2-eth1 down_s1-eth3:top_s3-eth1 down_s1-eth4:top_s4-eth1 down_s1-eth5:host_1-eth0 down_s1-eth6:host_2-eth0 down_s1
-eth7:host_3-eth0 down_s1-eth8:host_4-eth0 down_s1-eth9:host_5-eth0 down_s1-eth10:host_6-eth0 down_s1-eth11:host_7-eth0 down_s1-eth12:host_8-eth0 down_s1-eth13:host_9-eth
0 down_s1-eth14:host_10-eth0 down_s1-eth15:host_11-eth0 down_s1-eth16:host_12-eth0 down_s1-eth17:host_13-eth0 down_s1-eth18:host_14-eth0 down_s1-eth19:host_15-eth0 down_s
1-eth20:host_16-eth0 down_s1-eth21:host_17-eth0 down_s1-eth22:host_18-eth0 down_s1-eth23:host_19-eth0 down_s1-eth24:host_20-eth0 down_s1-eth25:host_21-eth0 down_s1-eth26:
host_22-eth0 down_s1-eth27:host_23-eth0 down_s1-eth28:host_24-eth0 down_s1-eth29:host_25-eth0 down_s1-eth30:host_26-eth0 down_s1-eth31:host_27-eth0 down_s1-eth32:host_28-
eth0 down_s1-eth33:host_29-eth0 down_s1-eth34:host_30-eth0 down_s1-eth35:host_31-eth0 down_s1-eth36:host_32-eth0
down_s2 lo:  down_s2-eth1:top_s1-eth2 down_s2-eth2:top_s2-eth2 down_s2-eth3:top_s3-eth2 down_s2-eth4:top_s4-eth2 down_s2-eth5:host_1-eth1 down_s2-eth6:host_2-eth1 down_s2
-eth7:host_3-eth1 down_s2-eth8:host_4-eth1 down_s2-eth9:host_5-eth1 down_s2-eth10:host_6-eth1 down_s2-eth11:host_7-eth1 down_s2-eth12:host_8-eth1 down_s2-eth13:host_9-eth
1 down_s2-eth14:host_10-eth1 down_s2-eth15:host_11-eth1 down_s2-eth16:host_12-eth1 down_s2-eth17:host_13-eth1 down_s2-eth18:host_14-eth1 down_s2-eth19:host_15-eth1 down_s
2-eth20:host_16-eth1 down_s2-eth21:host_17-eth1 down_s2-eth22:host_18-eth1 down_s2-eth23:host_19-eth1 down_s2-eth24:host_20-eth1 down_s2-eth25:host_21-eth1 down_s2-eth26:
host_22-eth1 down_s2-eth27:host_23-eth1 down_s2-eth28:host_24-eth1 down_s2-eth29:host_25-eth1 down_s2-eth30:host_26-eth1 down_s2-eth31:host_27-eth1 down_s2-eth32:host_28-
eth1 down_s2-eth33:host_29-eth1 down_s2-eth34:host_30-eth1 down_s2-eth35:host_31-eth1 down_s2-eth36:host_32-eth1
down_s3 lo:  down_s3-eth1:top_s1-eth3 down_s3-eth2:top_s2-eth3 down_s3-eth3:top_s3-eth3 down_s3-eth4:top_s4-eth3 down_s3-eth5:host_1-eth2 down_s3-eth6:host_2-eth2 down_s3
-eth7:host_3-eth2 down_s3-eth8:host_4-eth2 down_s3-eth9:host_5-eth2 down_s3-eth10:host_6-eth2 down_s3-eth11:host_7-eth2 down_s3-eth12:host_8-eth2 down_s3-eth13:host_9-eth
2 down_s3-eth14:host_10-eth2 down_s3-eth15:host_11-eth2 down_s3-eth16:host_12-eth2 down_s3-eth17:host_13-eth2 down_s3-eth18:host_14-eth2 down_s3-eth19:host_15-eth2 down_s
3-eth20:host_16-eth2 down_s3-eth21:host_17-eth2 down_s3-eth22:host_18-eth2 down_s3-eth23:host_19-eth2 down_s3-eth24:host_20-eth2 down_s3-eth25:host_21-eth2 down_s3-eth26:
host_22-eth2 down_s3-eth27:host_23-eth2 down_s3-eth28:host_24-eth2 down_s3-eth29:host_25-eth2 down_s3-eth30:host_26-eth2 down_s3-eth31:host_27-eth2 down_s3-eth32:host_28-
eth2 down_s3-eth33:host_29-eth2 down_s3-eth34:host_30-eth2 down_s3-eth35:host_31-eth2 down_s3-eth36:host_32-eth2
down_s4 lo:  down_s4-eth1:top_s1-eth4 down_s4-eth2:top_s2-eth4 down_s4-eth3:top_s3-eth4 down_s4-eth4:top_s4-eth4 down_s4-eth5:host_1-eth3 down_s4-eth6:host_2-eth3 down_s4
-eth7:host_3-eth3 down_s4-eth8:host_4-eth3 down_s4-eth9:host_5-eth3 down_s4-eth10:host_6-eth3 down_s4-eth11:host_7-eth3 down_s4-eth12:host_8-eth3 down_s4-eth13:host_9-eth
3 down_s4-eth14:host_10-eth3 down_s4-eth15:host_11-eth3 down_s4-eth16:host_12-eth3 down_s4-eth17:host_13-eth3 down_s4-eth18:host_14-eth3 down_s4-eth19:host_15-eth3 down_s
4-eth20:host_16-eth3 down_s4-eth21:host_17-eth3 down_s4-eth22:host_18-eth3 down_s4-eth23:host_19-eth3 down_s4-eth24:host_20-eth3 down_s4-eth25:host_21-eth3 down_s4-eth26:
host_22-eth3 down_s4-eth27:host_23-eth3 down_s4-eth28:host_24-eth3 down_s4-eth29:host_25-eth3 down_s4-eth30:host_26-eth3 down_s4-eth31:host_27-eth3 down_s4-eth32:host_28-
```

```
2 down_s3-eth14:host_10-eth2 down_s3-eth15:host_11-eth2 down_s3-eth16:host_12-eth2 down_s3-eth17:host_13-eth2 down_s3-eth18:host_14-eth2 down_s3-eth19:host_15-eth2 down_s
3-eth20:host_16-eth2 down_s3-eth21:host_17-eth2 down_s3-eth22:host_18-eth2 down_s3-eth23:host_19-eth2 down_s3-eth24:host_20-eth2 down_s3-eth25:host_21-eth2 down_s3-eth26:
host_22-eth2 down_s3-eth27:host_23-eth2 down_s3-eth28:host_24-eth2 down_s3-eth29:host_25-eth2 down_s3-eth30:host_26-eth2 down_s3-eth31:host_27-eth2 down_s3-eth32:host_28-
eth2 down_s3-eth33:host_29-eth2 down_s3-eth34:host_30-eth2 down_s3-eth35:host_31-eth2 down_s3-eth36:host_32-eth2
down_s4 lo:  down_s4-eth1:top_s1-eth4 down_s4-eth2:top_s2-eth4 down_s4-eth3:top_s3-eth4 down_s4-eth4:top_s4-eth4 down_s4-eth5:host_1-eth3 down_s4-eth6:host_2-eth3 down_s4
-eth7:host_3-eth3 down_s4-eth8:host_4-eth3 down_s4-eth9:host_5-eth3 down_s4-eth10:host_6-eth3 down_s4-eth11:host_7-eth3 down_s4-eth12:host_8-eth3 down_s4-eth13:host_9-eth
3 down_s4-eth14:host_10-eth3 down_s4-eth15:host_11-eth3 down_s4-eth16:host_12-eth3 down_s4-eth17:host_13-eth3 down_s4-eth18:host_14-eth3 down_s4-eth19:host_15-eth3 down_s
4-eth20:host_16-eth3 down_s4-eth21:host_17-eth3 down_s4-eth22:host_18-eth3 down_s4-eth23:host_19-eth3 down_s4-eth24:host_20-eth3 down_s4-eth25:host_21-eth3 down_s4-eth26:
host_22-eth3 down_s4-eth27:host_23-eth3 down_s4-eth28:host_24-eth3 down_s4-eth29:host_25-eth3 down_s4-eth30:host_26-eth3 down_s4-eth31:host_27-eth3 down_s4-eth32:host_28-
eth3 down_s4-eth33:host_29-eth3 down_s4-eth34:host_30-eth3 down_s4-eth35:host_31-eth3 down_s4-eth36:host_32-eth3
down_s5 lo:  down_s5-eth1:top_s1-eth5 down_s5-eth2:top_s2-eth5 down_s5-eth3:top_s3-eth5 down_s5-eth4:top_s4-eth5 down_s5-eth5:host_1-eth4 down_s5-eth6:host_2-eth4 down_s5
-eth7:host_3-eth4 down_s5-eth8:host_4-eth4 down_s5-eth9:host_5-eth4 down_s5-eth10:host_6-eth4 down_s5-eth11:host_7-eth4 down_s5-eth12:host_8-eth4 down_s5-eth13:host_9-eth
4 down_s5-eth14:host_10-eth4 down_s5-eth15:host_11-eth4 down_s5-eth16:host_12-eth4 down_s5-eth17:host_13-eth4 down_s5-eth18:host_14-eth4 down_s5-eth19:host_15-eth4 down_s
5-eth20:host_16-eth4 down_s5-eth21:host_17-eth4 down_s5-eth22:host_18-eth4 down_s5-eth23:host_19-eth4 down_s5-eth24:host_20-eth4 down_s5-eth25:host_21-eth4 down_s5-eth26:
host_22-eth4 down_s5-eth27:host_23-eth4 down_s5-eth28:host_24-eth4 down_s5-eth29:host_25-eth4 down_s5-eth30:host_26-eth4 down_s5-eth31:host_27-eth4 down_s5-eth32:host_28-
eth4 down_s5-eth33:host_29-eth4 down_s5-eth34:host_30-eth4 down_s5-eth35:host_31-eth4 down_s5-eth36:host_32-eth4
down_s6 lo:  down_s6-eth1:top_s1-eth6 down_s6-eth2:top_s2-eth6 down_s6-eth3:top_s3-eth6 down_s6-eth4:top_s4-eth6 down_s6-eth5:host_1-eth5 down_s6-eth6:host_2-eth5 down_s6
-eth7:host_3-eth5 down_s6-eth8:host_4-eth5 down_s6-eth9:host_5-eth5 down_s6-eth10:host_6-eth5 down_s6-eth11:host_7-eth5 down_s6-eth12:host_8-eth5 down_s6-eth13:host_9-eth
5 down_s6-eth14:host_10-eth5 down_s6-eth15:host_11-eth5 down_s6-eth16:host_12-eth5 down_s6-eth17:host_13-eth5 down_s6-eth18:host_14-eth5 down_s6-eth19:host_15-eth5 down_s
6-eth20:host_16-eth5 down_s6-eth21:host_17-eth5 down_s6-eth22:host_18-eth5 down_s6-eth23:host_19-eth5 down_s6-eth24:host_20-eth5 down_s6-eth25:host_21-eth5 down_s6-eth26:
host_22-eth5 down_s6-eth27:host_23-eth5 down_s6-eth28:host_24-eth5 down_s6-eth29:host_25-eth5 down_s6-eth30:host_26-eth5 down_s6-eth31:host_27-eth5 down_s6-eth32:host_28-
eth5 down_s6-eth33:host_29-eth5 down_s6-eth34:host_30-eth5 down_s6-eth35:host_31-eth5 down_s6-eth36:host_32-eth5
down_s7 lo:  down_s7-eth1:top_s1-eth7 down_s7-eth2:top_s2-eth7 down_s7-eth3:top_s3-eth7 down_s7-eth4:top_s4-eth7 down_s7-eth5:host_1-eth6 down_s7-eth6:host_2-eth6 down_s7
-eth7:host_3-eth6 down_s7-eth8:host_4-eth6 down_s7-eth9:host_5-eth6 down_s7-eth10:host_6-eth6 down_s7-eth11:host_7-eth6 down_s7-eth12:host_8-eth6 down_s7-eth13:host_9-eth
6 down_s7-eth14:host_10-eth6 down_s7-eth15:host_11-eth6 down_s7-eth16:host_12-eth6 down_s7-eth17:host_13-eth6 down_s7-eth18:host_14-eth6 down_s7-eth19:host_15-eth6 down_s
7-eth20:host_16-eth6 down_s7-eth21:host_17-eth6 down_s7-eth22:host_18-eth6 down_s7-eth23:host_19-eth6 down_s7-eth24:host_20-eth6 down_s7-eth25:host_21-eth6 down_s7-eth26:
host_22-eth6 down_s7-eth27:host_23-eth6 down_s7-eth28:host_24-eth6 down_s7-eth29:host_25-eth6 down_s7-eth30:host_26-eth6 down_s7-eth31:host_27-eth6 down_s7-eth32:host_28-
eth6 down_s7-eth33:host_29-eth6 down_s7-eth34:host_30-eth6 down_s7-eth35:host_31-eth6 down_s7-eth36:host_32-eth6
down_s8 lo:  down_s8-eth1:top_s1-eth8 down_s8-eth2:top_s2-eth8 down_s8-eth3:top_s3-eth8 down_s8-eth4:top_s4-eth8 down_s8-eth5:host_1-eth7 down_s8-eth6:host_2-eth7 down_s8
-eth7:host_3-eth7 down_s8-eth8:host_4-eth7 down_s8-eth9:host_5-eth7 down_s8-eth10:host_6-eth7 down_s8-eth11:host_7-eth7 down_s8-eth12:host_8-eth7 down_s8-eth13:host_9-eth
7 down_s8-eth14:host_10-eth7 down_s8-eth15:host_11-eth7 down_s8-eth16:host_12-eth7 down_s8-eth17:host_13-eth7 down_s8-eth18:host_14-eth7 down_s8-eth19:host_15-eth7 down_s
8-eth20:host_16-eth7 down_s8-eth21:host_17-eth7 down_s8-eth22:host_18-eth7 down_s8-eth23:host_19-eth7 down_s8-eth24:host_20-eth7 down_s8-eth25:host_21-eth7 down_s8-eth26:
host_22-eth7 down_s8-eth27:host_23-eth7 down_s8-eth28:host_24-eth7 down_s8-eth29:host_25-eth7 down_s8-eth30:host_26-eth7 down_s8-eth31:host_27-eth7 down_s8-eth32:host_28-
eth7 down_s8-eth33:host_29-eth7 down_s8-eth34:host_30-eth7 down_s8-eth35:host_31-eth7 down_s8-eth36:host_32-eth7
top_s1 lo:  top_s1-eth1:down_s1-eth1 top_s1-eth2:down_s2-eth1 top_s1-eth3:down_s3-eth1 top_s1-eth4:down_s4-eth1 top_s1-eth5:down_s5-eth1 top_s1-eth6:down_s6-eth1 top_s1-e
th7:down_s7-eth1 top_s1-eth8:down_s8-eth1
top_s2 lo:  top_s2-eth1:down_s1-eth2 top_s2-eth2:down_s2-eth2 top_s2-eth3:down_s3-eth2 top_s2-eth4:down_s4-eth2 top_s2-eth5:down_s5-eth2 top_s2-eth6:down_s6-eth2 top_s2-e
th7:down_s7-eth2 top_s2-eth8:down_s8-eth2
top_s3 lo:  top_s3-eth1:down_s1-eth3 top_s3-eth2:down_s2-eth3 top_s3-eth3:down_s3-eth3 top_s3-eth4:down_s4-eth3 top_s3-eth5:down_s5-eth3 top_s3-eth6:down_s6-eth3 top_s3-e
th7:down_s7-eth3 top_s3-eth8:down_s8-eth3
top_s4 lo:  top_s4-eth1:down_s1-eth4 top_s4-eth2:down_s2-eth4 top_s4-eth3:down_s3-eth4 top_s4-eth4:down_s4-eth4 top_s4-eth5:down_s5-eth4 top_s4-eth6:down_s6-eth4 top_s4-e
th7:down_s7-eth4 top_s4-eth8:down_s8-eth4
c0
mininet>
```

(c) Mininet output while creating the networks

For network No.1:

```
zhaoxi@zhaoxi-TWJ:~/Documents/NYUStudy$ sudo mn --custom /home/zhaoxi/mytopo.py --topo mytopo --controller remote
*** 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) (s3, s5) (s4, h2) (s4, s5)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 5 switches
s1 s2 s3 s4 s5 ...
*** Starting CLI:
```

For Fat Tree network:

N = 4

```
zhaoxi@zhaoxi-TWJ:~/Documents/NYUStudy$ sudo mn --custom /home/zhaoxi/fattree.py --topo mytopo --controller remote
*** Creating network
*** Adding controller
Unable to contact the remote controller at 127.0.0.1:6633
*** Adding hosts:
host_1 host_2 host_3 host_4 host_5 host_6 host_7 host_8 host_9 host_10 host_11 host_12 host_13 host_14 host_15 host_16 host_17 host_18 host_19 host_20 host_21 host_22 hos
t_23 host_24 host_25 host_26 host_27 host_28 host_29 host_30 host_31 host_32
*** Adding switches:
down_s1 down_s2 down_s3 down_s4 down_s5 down_s6 down_s7 down_s8 top_s1 top_s2 top_s3 top_s4
*** Adding links:
(down_s1, host_1) (down_s1, host_2) (down_s1, host_3) (down_s1, host_4) (down_s1, host_5) (down_s1, host_6) (down_s1, host_7) (down_s1, host_8) (down_s1, host_9) (down_s1
, host_10) (down_s1, host_11) (down_s1, host_12) (down_s1, host_13) (down_s1, host_14) (down_s1, host_15) (down_s1, host_16) (down_s1, host_17) (down_s1, host_18) (down_s
1, host_19) (down_s1, host_20) (down_s1, host_21) (down_s1, host_22) (down_s1, host_23) (down_s1, host_24) (down_s1, host_25) (down_s1, host_26) (down_s1, host_27) (down_
s1, host_28) (down_s1, host_29) (down_s1, host_30) (down_s1, host_31) (down_s1, host_32) (down_s2, host_1) (down_s2, host_2) (down_s2, host_3) (down_s2, host_4) (down_s2,
 host_5) (down_s2, host_6) (down_s2, host_7) (down_s2, host_8) (down_s2, host_9) (down_s2, host_10) (down_s2, host_11) (down_s2, host_12) (down_s2, host_13) (down_s2, hos
t_14) (down_s2, host_15) (down_s2, host_16) (down_s2, host_17) (down_s2, host_18) (down_s2, host_19) (down_s2, host_20) (down_s2, host_21) (down_s2, host_22) (down_s2, ho
st_23) (down_s2, host_24) (down_s2, host_25) (down_s2, host_26) (down_s2, host_27) (down_s2, host_28) (down_s2, host_29) (down_s2, host_30) (down_s2, host_31) (down_s2, h
ost_32) (down_s3, host_1) (down_s3, host_2) (down_s3, host_3) (down_s3, host_4) (down_s3, host_5) (down_s3, host_6) (down_s3, host_7) (down_s3, host_8) (down_s3, host_9)
(down_s3, host_10) (down_s3, host_11) (down_s3, host_12) (down_s3, host_13) (down_s3, host_14) (down_s3, host_15) (down_s3, host_16) (down_s3, host_17) (down_s3, host_18)
 (down_s3, host_19) (down_s3, host_20) (down_s3, host_21) (down_s3, host_22) (down_s3, host_23) (down_s3, host_24) (down_s3, host_25) (down_s3, host_26) (down_s3, host_27
) (down_s3, host_28) (down_s3, host_29) (down_s3, host_30) (down_s3, host_31) (down_s3, host_32) (down_s4, host_1) (down_s4, host_2) (down_s4, host_3) (down_s4, host_4) (
down_s4, host_5) (down_s4, host_6) (down_s4, host_7) (down_s4, host_8) (down_s4, host_9) (down_s4, host_10) (down_s4, host_11) (down_s4, host_12) (down_s4, host_13) (down
_s4, host_14) (down_s4, host_15) (down_s4, host_16) (down_s4, host_17) (down_s4, host_18) (down_s4, host_19) (down_s4, host_20) (down_s4, host_21) (down_s4, host_22) (dow
n_s4, host_23) (down_s4, host_24) (down_s4, host_25) (down_s4, host_26) (down_s4, host_27) (down_s4, host_28) (down_s4, host_29) (down_s4, host_30) (down_s4, host_31) (do
wn_s4, host_32) (down_s5, host_1) (down_s5, host_2) (down_s5, host_3) (down_s5, host_4) (down_s5, host_5) (down_s5, host_6) (down_s5, host_7) (down_s5, host_8) (down_s5,
host_9) (down_s5, host_10) (down_s5, host_11) (down_s5, host_12) (down_s5, host_13) (down_s5, host_14) (down_s5, host_15) (down_s5, host_16) (down_s5, host_17) (down_s5,
host_18) (down_s5, host_19) (down_s5, host_20) (down_s5, host_21) (down_s5, host_22) (down_s5, host_23) (down_s5, host_24) (down_s5, host_25) (down_s5, host_26) (down_s5,
 host_27) (down_s5, host_28) (down_s5, host_29) (down_s5, host_30) (down_s5, host_31) (down_s5, host_32) (down_s6, host_1) (down_s6, host_2) (down_s6, host_3) (down_s6, h
ost_4) (down_s6, host_5) (down_s6, host_6) (down_s6, host_7) (down_s6, host_8) (down_s6, host_9) (down_s6, host_10) (down_s6, host_11) (down_s6, host_12) (down_s6, host_1
3) (down_s6, host_14) (down_s6, host_15) (down_s6, host_16) (down_s6, host_17) (down_s6, host_18) (down_s6, host_19) (down_s6, host_20) (down_s6, host_21) (down_s6, host_
22) (down_s6, host_23) (down_s6, host_24) (down_s6, host_25) (down_s6, host_26) (down_s6, host_27) (down_s6, host_28) (down_s6, host_29) (down_s6, host_30) (down_s6, host
_31) (down_s6, host_32) (down_s7, host_1) (down_s7, host_2) (down_s7, host_3) (down_s7, host_4) (down_s7, host_5) (down_s7, host_6) (down_s7, host_7) (down_s7, host_8) (d
own_s7, host_9) (down_s7, host_10) (down_s7, host_11) (down_s7, host_12) (down_s7, host_13) (down_s7, host_14) (down_s7, host_15) (down_s7, host_16) (down_s7, host_17) (d
own_s7, host_18) (down_s7, host_19) (down_s7, host_20) (down_s7, host_21) (down_s7, host_22) (down_s7, host_23) (down_s7, host_24) (down_s7, host_25) (down_s7, host_26) (
down_s7, host_27) (down_s7, host_28) (down_s7, host_29) (down_s7, host_30) (down_s7, host_31) (down_s7, host_32) (down_s8, host_1) (down_s8, host_2) (down_s8, host_3) (do
wn_s8, host_4) (down_s8, host_5) (down_s8, host_6) (down_s8, host_7) (down_s8, host_8) (down_s8, host_9) (down_s8, host_10) (down_s8, host_11) (down_s8, host_12) (down_s8
, host_13) (down_s8, host_14) (down_s8, host_15) (down_s8, host_16) (down_s8, host_17) (down_s8, host_18) (down_s8, host_19) (down_s8, host_20) (down_s8, host_21) (down_s
8, host_22) (down_s8, host_23) (down_s8, host_24) (down_s8, host_25) (down_s8, host_26) (down_s8, host_27) (down_s8, host_28) (down_s8, host_29) (down_s8, host_30) (down_
s8, host_31) (down_s8, host_32) (top_s1, down_s1) (top_s1, down_s2) (top_s1, down_s3) (top_s1, down_s4) (top_s1, down_s5) (top_s1, down_s6) (top_s1, down_s7) (top_s1, dow
n_s8) (top_s2, down_s1) (top_s2, down_s2) (top_s2, down_s3) (top_s2, down_s4) (top_s2, down_s5) (top_s2, down_s6) (top_s2, down_s7) (top_s2, down_s8) (top_s3, down_s1) (t
op_s3, down_s2) (top_s3, down_s3) (top_s3, down_s4) (top_s3, down_s5) (top_s3, down_s6) (top_s3, down_s7) (top_s3, down_s8) (top_s4, down_s1) (top_s4, down_s2) (top_s4, d
own_s3) (top_s4, down_s4) (top_s4, down_s5) (top_s4, down_s6) (top_s4, down_s7) (top_s4, down_s8)
*** Configuring hosts
host_1 host_2 host_3 host_4 host_5 host_6 host_7 host_8 host_9 host_10 host_11 host_12 host_13 host_14 host_15 host_16 host_17 host_18 host_19 host_20 host_21 host_22 hos
```

(d) Briefly explain how you produce different traffic to verify whether the rules installed function correctly.

a. Use pingall instruction.

Monitor S2_eth2(S1-->S2-->S4...).there should be ICMP and ARP packet.
Monitor S4. there should be no packets.

b. Use these instructions to run a simple web server and client:

mininet> h1 python -m SimpleHTTPServer 80 &
mininet> h2 wget -O - h1

Monitor S3. there should be no packets.
Others should has corresponding packets.

(e) 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.

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s2-eth2 pingall

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s4-pingall

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HTTP

S3

h1 python -m SimpleHTTPServer 80 &

h2 wget -O - h1

HTTP

S2

h1 python -m SimpleHTTPServer 80 &

h2 wget -O - h2

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

For network No.1:

```
mininet> sh ovs-ofctl add-flow s1 priority=500,in_port=1,dl_type=0x0800,nw_proto=6,actions=output:2
mininet> sh ovs-ofctl add-flow s2 priority=500,in_port=1,dl_type=0x0800,nw_proto=6,actions=output:2
mininet> sh ovs-ofctl add-flow s4 priority=500,in_port=1,dl_type=0x0800,nw_proto=6,actions=output:4
mininet>
mininet> sh ovs-ofctl add-flow s1 in_port=1,actions=output:3
mininet> sh ovs-ofctl add-flow s3 in_port=1,actions=output:3
mininet> sh ovs-ofctl add-flow s5 in_port=2,actions=output:3
mininet> sh ovs-ofctl add-flow s4 in_port=3,actions=output:4
mininet>
mininet> sh ovs-ofctl add-flow s4 priority=500,in_port=4,dl_type=0x0800,nw_proto=6,actions=output:2
mininet> sh ovs-ofctl add-flow s3 priority=500,in_port=2,dl_type=0x0800,nw_proto=6,actions=output:1
mininet> sh ovs-ofctl add-flow s1 priority=500,in_port=3,dl_type=0x0800,nw_proto=6,actions=output:1
mininet>
mininet> sh ovs-ofctl add-flow s4 in_port=4,actions=output:1
mininet> sh ovs-ofctl add-flow s2 in_port=2,actions=output:3
mininet> sh ovs-ofctl add-flow s5 in_port=1,actions=output:2
mininet> sh ovs-ofctl add-flow s3 in_port=3,actions=output:1
mininet> sh ovs-ofctl add-flow s1 in_port=3,actions=output:1
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
*** Results: 0% dropped (2/2 received)
```

(g) Also submit your custom topology files (.py files) for both topologies (do NOT paste code in report). **We have zero tolerance to forged or fabricated data!!** A single piece of forged/fabricated data would bring the total score down to zero.