Lab 1

Layer 2 Forwarding &
MAC Learning

Deadline: 2022/03/01 (Tue) 23:59

Outline

- Objective
- Experiment Environment
- Mininet
- Packet Analysis Tools
- Lab Requirements

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Objective

- Network Emulation Environment Setup
- Familiar with packet analysis tools
- Layer 2 Concept Recap
  - Packet Forwarding and MAC Learning

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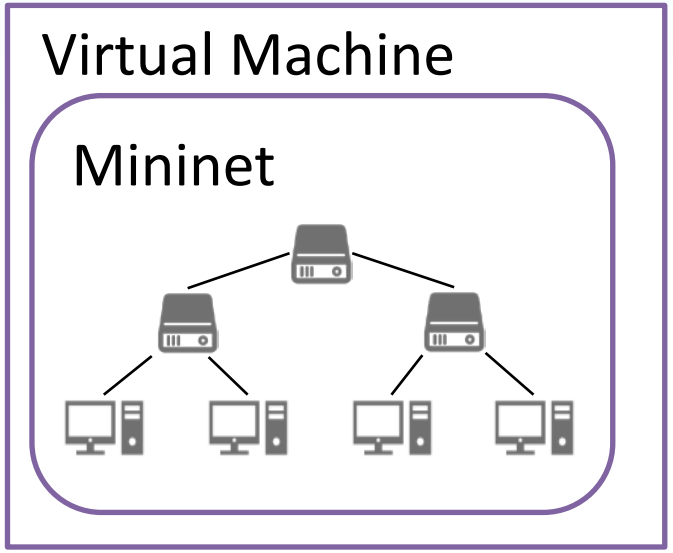
Experiment Environment

- Oracle VM VirtualBox:
  - Developed by Oracle Corporation
  - A free and open-source hosted hypervisor
- Ubuntu 18.04: Open-source operating system
- Mininet: a *network emulator*
  - A virtual test bed and development environment for SDN
  - Can easily creates a network of virtual hosts, switches, and links
- Packet Analysis Tools: Wireshark, tcpdump

Experiment Environment

- A Virtual Machine with Ubuntu desktop 18.04 LTS

- **Min** Hardware requirements
  - 2 Cores (or 2 CPUs)
  - 4G RAM
  - 20G HDD



- For more installation detail, please refer to:
  - **Environment_Setup.pdf**

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  - Overview and Installation
  - Basic Usage
- Packet Analysis Tools
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Mininet Overview and Installation

- Mininet: Emulate a network on your computer
  - Provide Python API for building custom network
  - Provide simple built-in topology with CLI commands

- Installation:

```
$ sudo apt install mininet
```

  - sudo: execute command as root permission
  - apt: advanced package tool to manage applications

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    - Method 1:Built-in Topology
    - Method 2:Custom Topology
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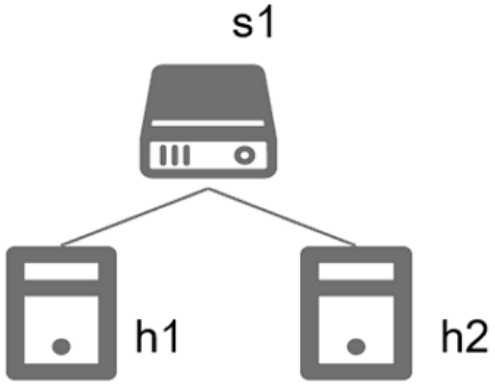
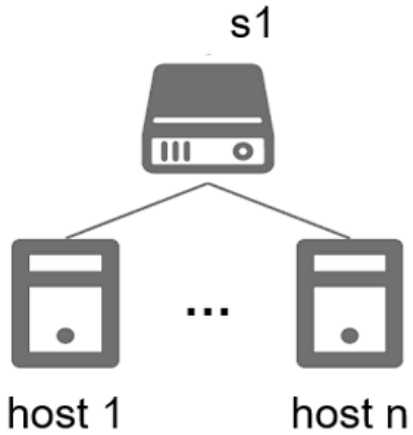
Method 1: Built-in Topology (1/2)

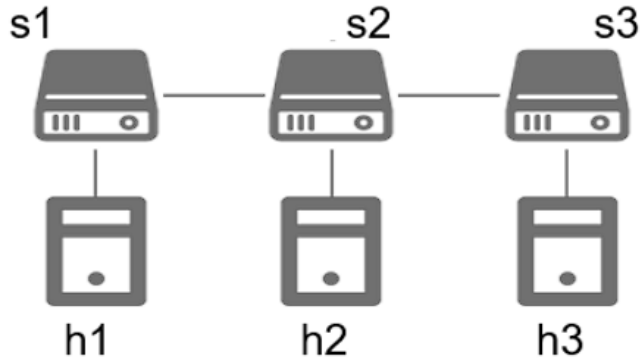
- Five built-in topologies
  - Minimal (Default)
  - Single
  - Linear
  - Torus
  - Tree



▲ Minimal



▲ Single



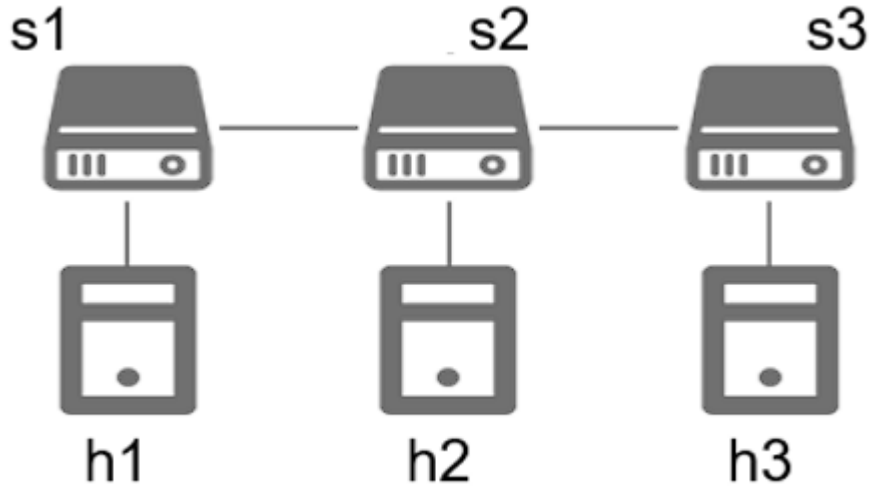
▲ Linear

Method 1: Built-in Topology (2/2)

- Example: Create a linear topology with 3 switch

```
$ sudo mn --topo=linear,3
```

  - "--topo" specifies the topology
  - By default, each switch has a host




```
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s2) (h3, s3) (s2, s1) (s3, s2)
*** Configuring hosts
h1 h2 h3
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3 ...
*** Starting CLI:
mininet>
```

```
mininet> exit (exit mininet CLI)
```

Clear Your Experiment Environment

- Note:
  - Make sure to clean up the environment of Mininet after every time you exit Mininet CLI

```
$ sudo mn -c            # clean and exit
```

  - A "cleanup" command to get rid of junk (interfaces, processes, files in /tmp, etc.) which might be left around by Mininet or Linux

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    - Method 1:Build-in Topology
    - Method 2:Custom Topology
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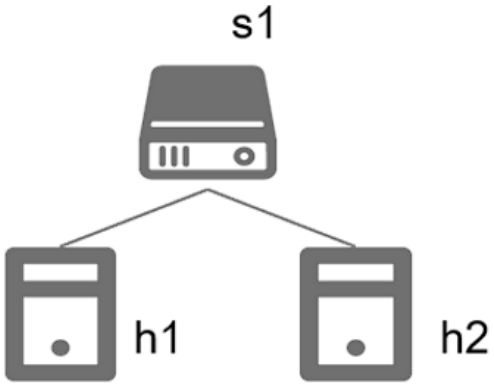
Method 2: Custom Topology

- Write a Python script
  - Example: Tree of Depth 1



sample.py

```
#! /usr/bin/python
import time
from mininet.topo import Topo
from mininet.net import Mininet
from mininet.node import Node, Switch
from mininet.cli import CLI

def topology():
    net = Mininet()

    #add nodes and links
    h1 = net.addHost('h1')
    h2 = net.addHost('h2')
    s1 = net.addSwitch('s1',failMode = 'standalone')
    net.addLink('h1','s1')
    net.addLink('h2','s1')

    net.start()
    CLI(net)  #enter mininet CLI
    net.stop()
if __name__ == '__main__':
    topology()
```

- Execute your python script

```
$ sudo python sample.py
```

Mininet Basic commands (1/2)

- Show all nodes (Hosts and Network Devices)

```
mininet> nodes
```

- Show all links between nodes

```
mininet> links
```

- Test the reachability of a pair of hosts (e.g. h1 and h2)

```
mininet> h1 ping h2
```

- Do an all-pairs “ping”

```
mininet> pingall
```

Mininet Basic commands (2/2)

- Run command on a node

```
mininet> <node name> [command]
```

- Show network interface configuration of a node

```
mininet> h1 ifconfig
```

- Start an xterm CLI panel of a node (e.g., h1 panel)

```
mininet> h1 xterm &
```

- Exit mininet

```
mininet> exit
```

- Always clear network topology before you start

```
$ sudo mn -c
```

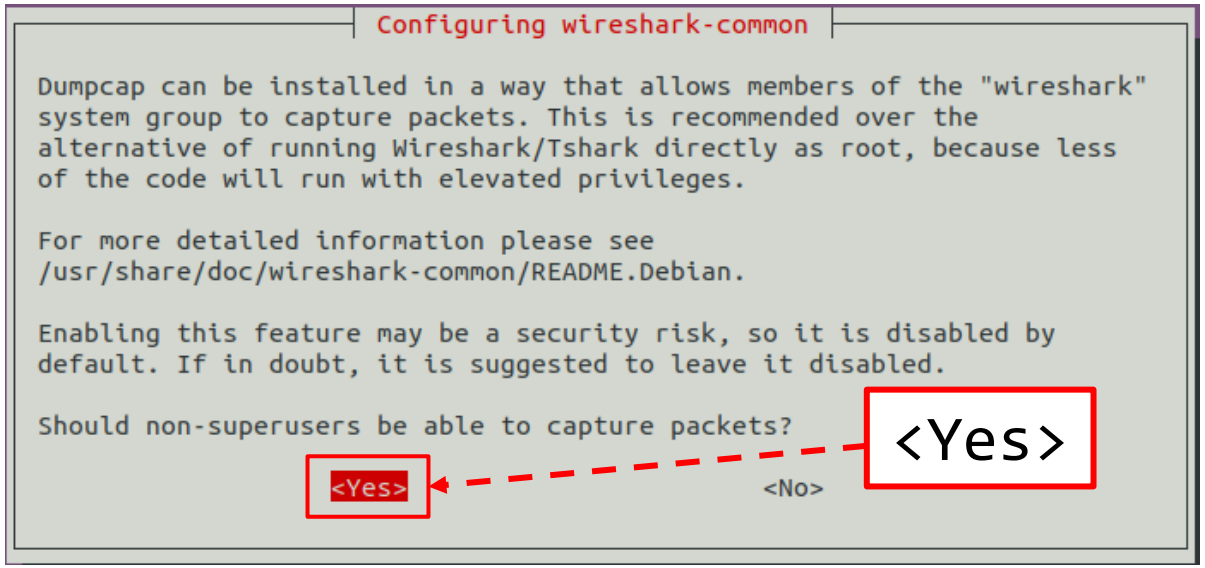
Outline

- Objective
- Experiment Environment
- Mininet
- Packet Analysis Tools
  - Wireshark
  - tcpdump
- Lab Requirements

Wireshark (1/6)

- A free and open-source GUI packet analyzer
  - Installation:

```
$ sudo apt install wireshark
```

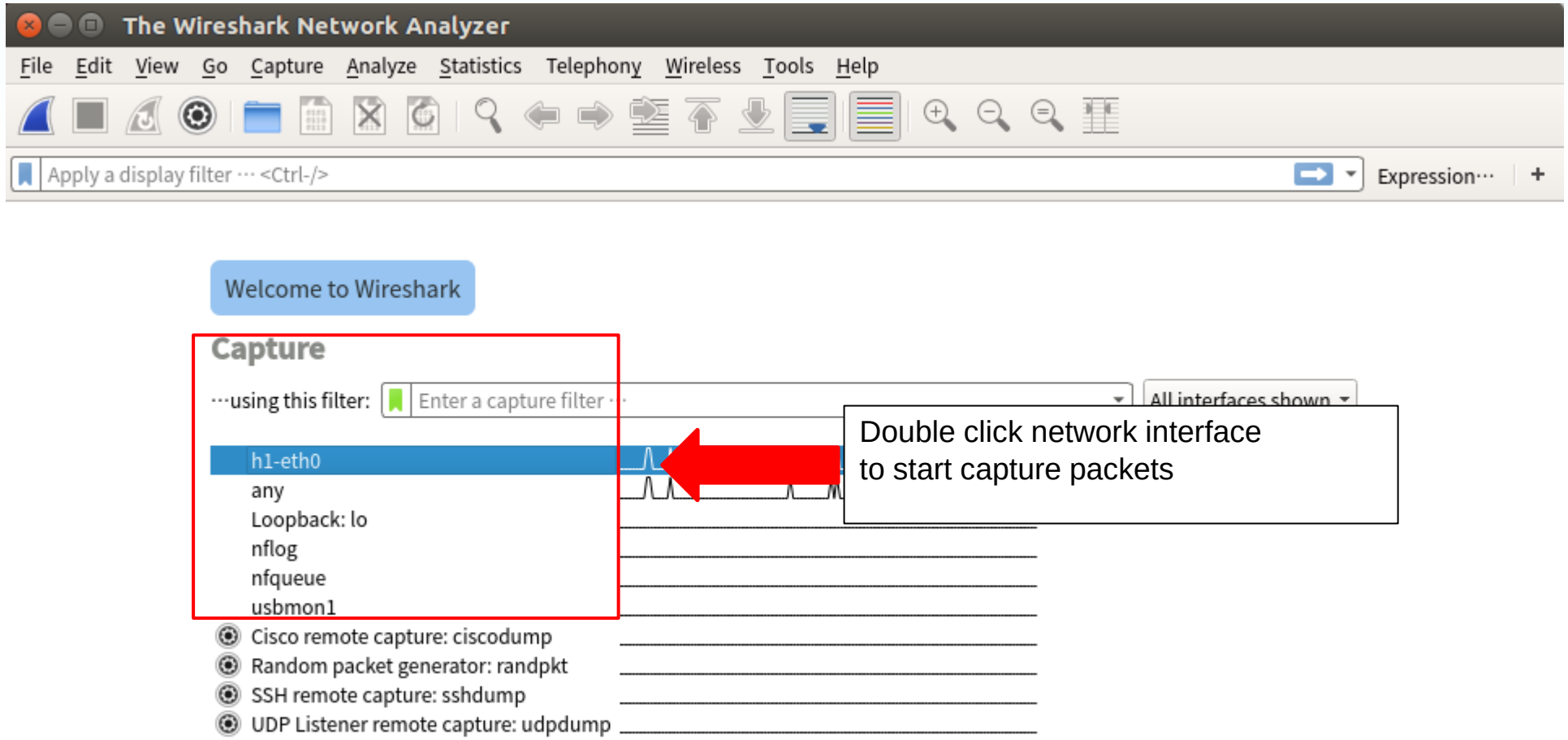


  - Run:

```
$ sudo wireshark
```

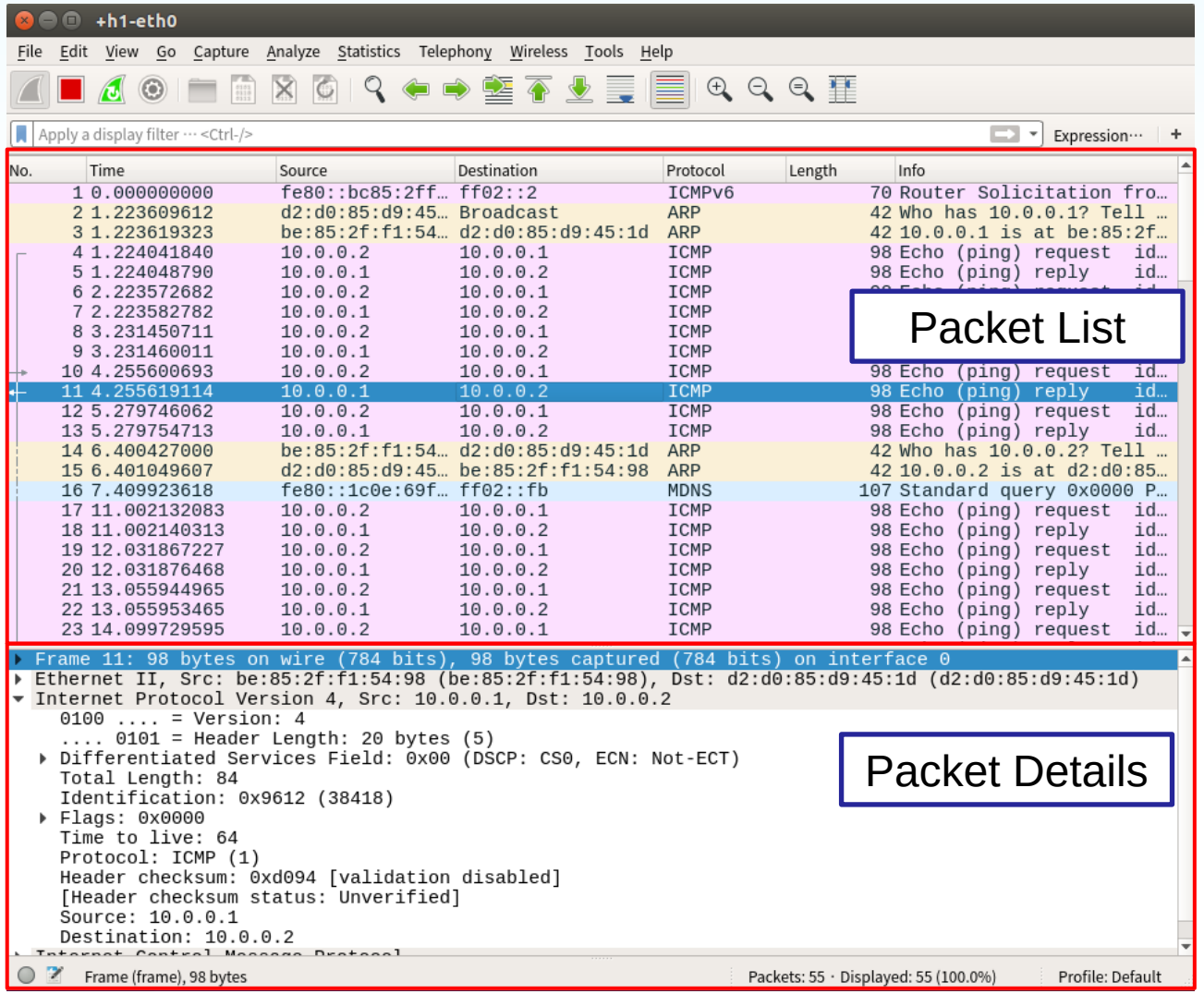
Wireshark (2/6)

- Wireshark GUI



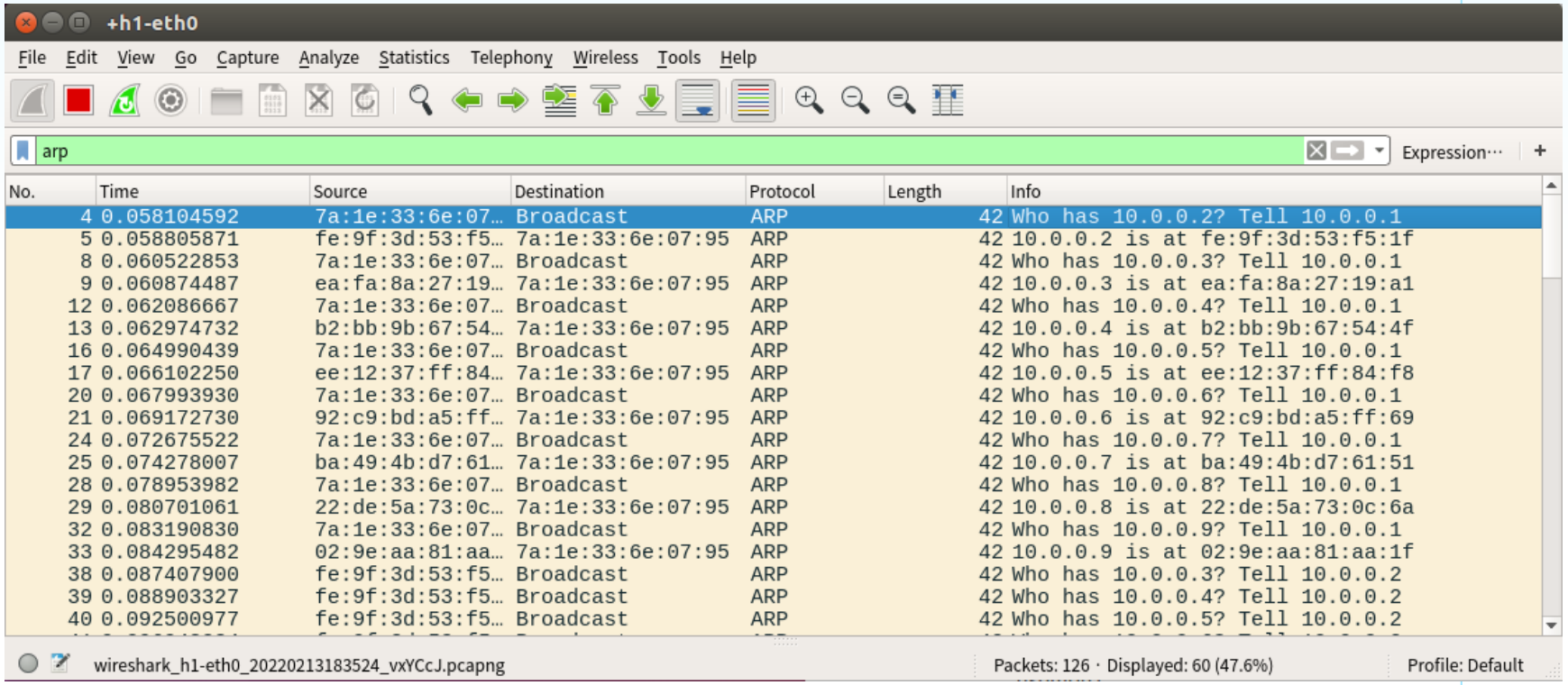
Wireshark (3/6)

- GUI panels

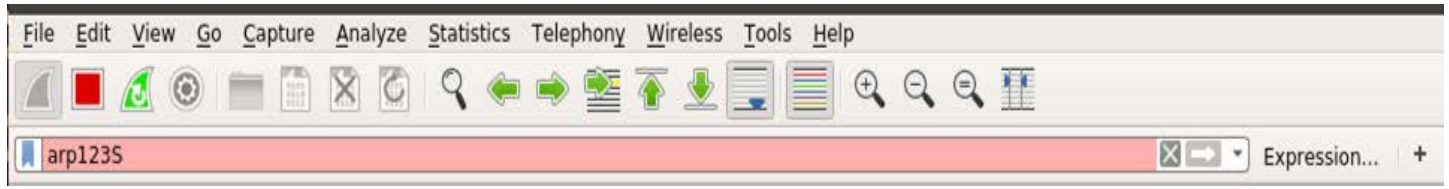


Wireshark (4/6)

- Packet filter
  - Valid Filter

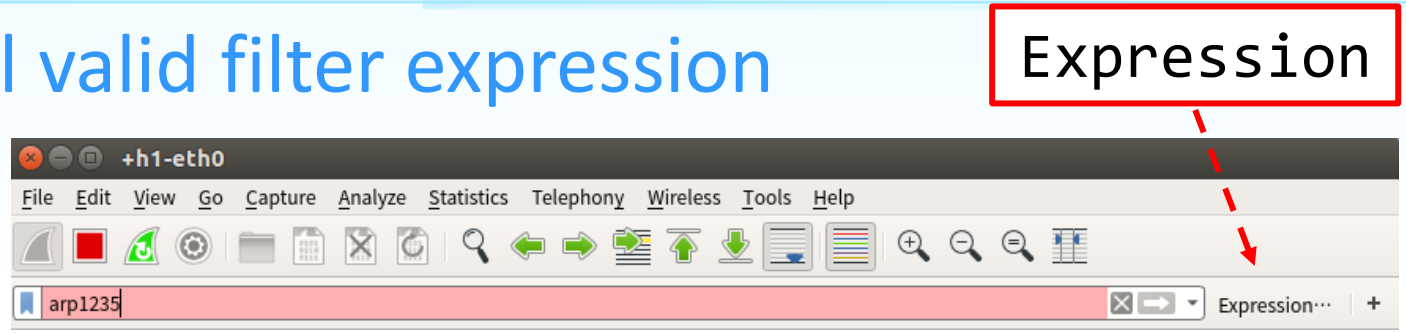


  - Invalid Filter

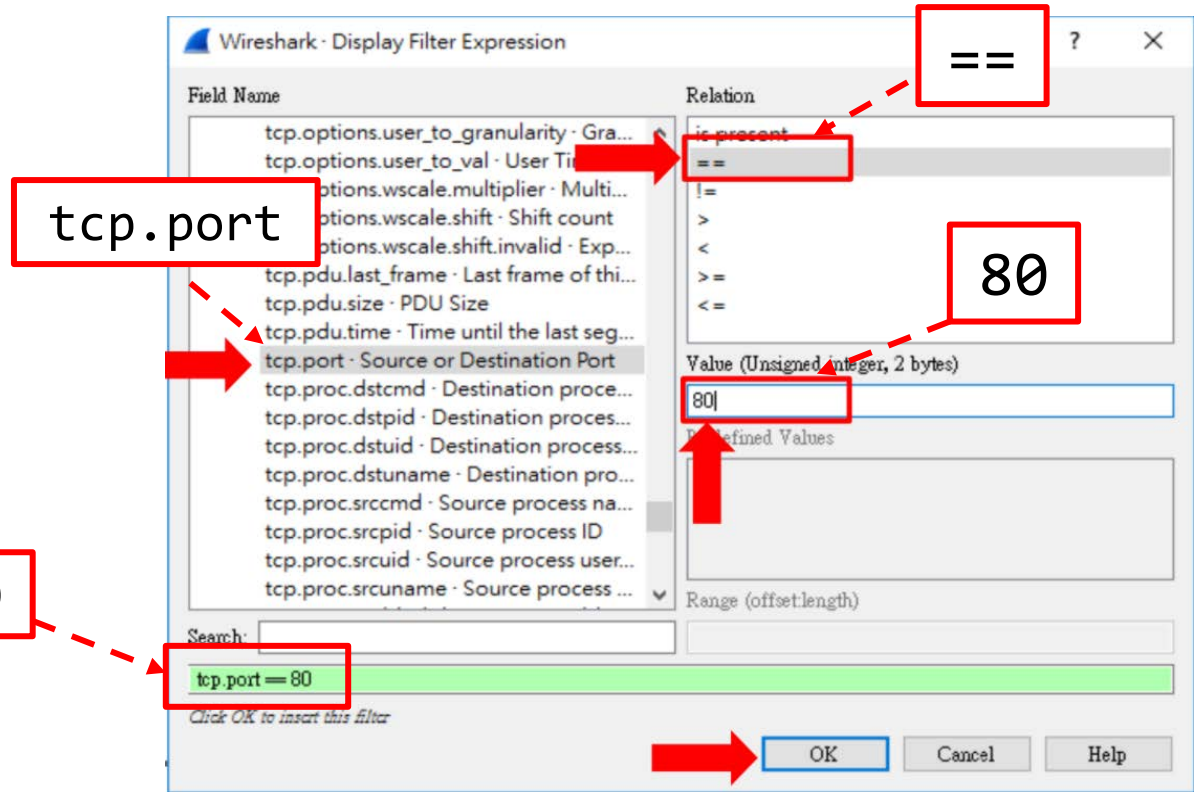


Wireshark (5/6)

- How to obtain all valid filter expression
  - Click expression



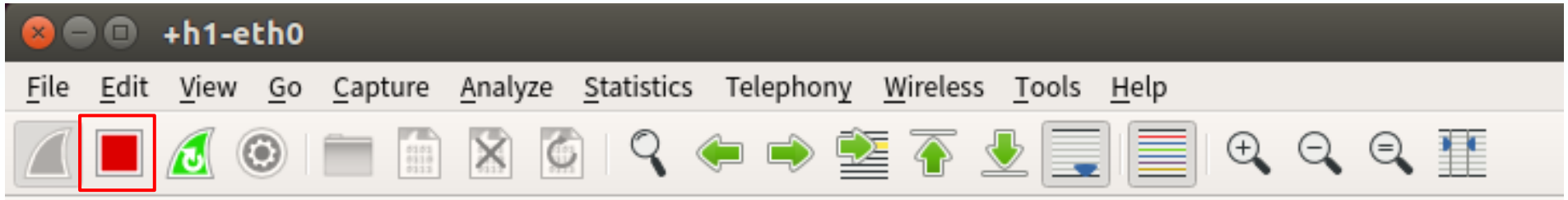
  - Example:
    - Filter all tcp port 80



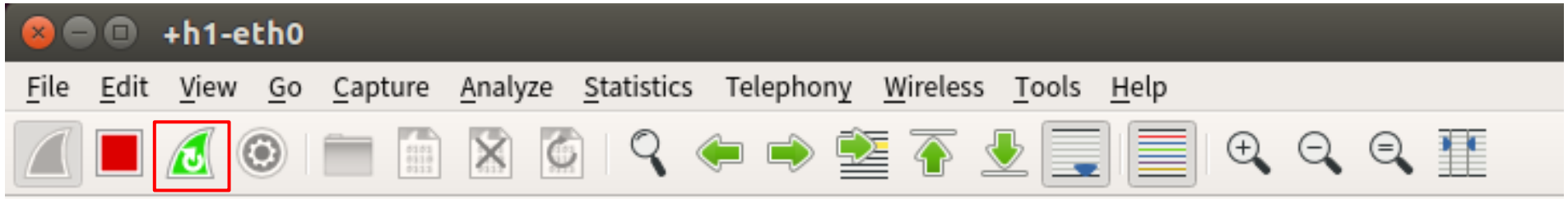
tcp.port == 80

Wireshark (6/6)

- Stop capturing



- Restart capturing



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- Packet Analysis Tools
  - Wireshark
  - tcpdump
- Lab Requirements

tcpdump (1/3)

- A packet analyzer runs under CLI
  - Works on most Unix-like operating systems
  - Use *libpcap.c* library to capture packets

- Installation

```
$ sudo apt install tcpdump -y
```

- Run

```
$ sudo tcpdump [option]
```

tcpdump (2/3)

- Example

```
winlab@server172:~$ sudo tcpdump -i ens11f0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on ens11f0, link-type EN10MB (Ethernet), capture size 262144 bytes
08:40:02.873698 02:eb:6b:52:03:fb (oui Unknown) > Broadcast, ethertype Unknown (
0x8942), length 135:
        0x0000:  0207 0418 0f76 fb12 6a04 0202 3106 0200  .....v..j...1...
        0x0010:  78fe 12a4 2305 014f 4e4f 5320 4469 7363  x...#..ONOS.Disc
        0x0020:  6f76 6572 79fe 17a4 2305 026f 663a 3030  overy...#..of:00
```

  - -i: choose an interface
- Man page of tcpdump
  - https://www.tcpdump.org/manpages/tcpdump.1.html

tcpdump (3/3)

- How to know what interfaces are on the host

```
winlab@server172: ~
winlab@server172:~$ ifconfig
enp8s0    Link encap:Ethernet  HWaddr 8c:ea:1b:30:da:01
          inet addr:140.113.131.172  Bcast:140.113.131.191  Mask:255.255.255.192
          inet6 addr: fe80::8eea:1bff:fe30:da01/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:75055400 errors:0 dropped:28 overruns:0 frame:0
          TX packets:2803394 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:5310400469 (5.3 GB)  TX bytes:181265732 (181.2 MB)
          Memory:c7500000-c75fffff

ens11f0   Link encap:Ethernet  HWaddr 8c:ea:1b:30:da:6f
          inet addr:192.168.168.2  Bcast:192.168.168.255  Mask:255.255.255.0
          inet6 addr: fe80::8eea:1bff:fe30:da6f/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1758006 errors:0 dropped:1757674 overruns:0 frame:0
          TX packets:4541 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:237316142 (237.3 MB)  TX bytes:307630 (307.6 KB)
```

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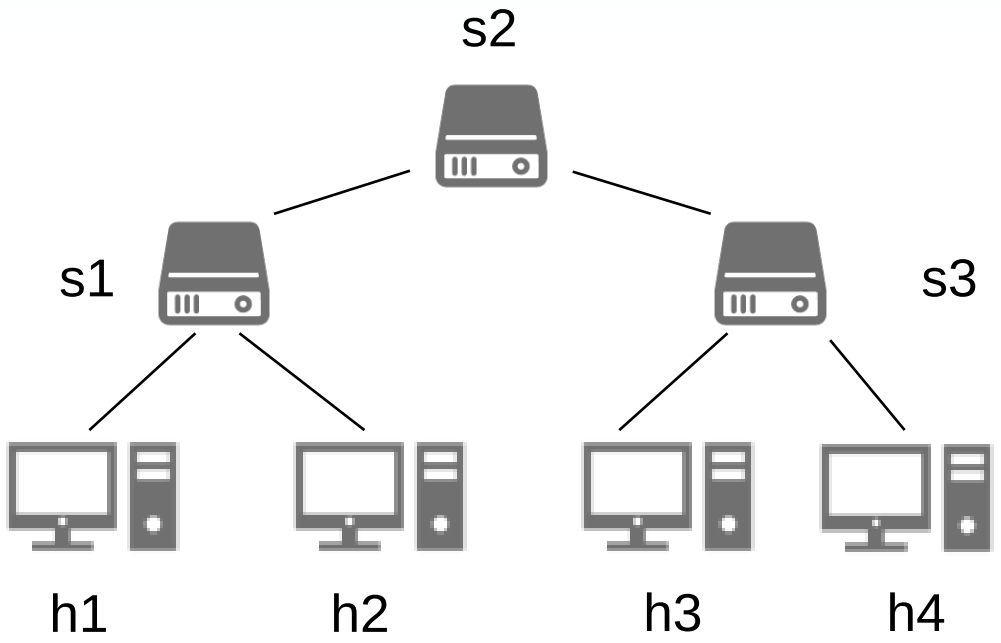
  - Part1: A Tree Topology
  - Part2: A Leaf-Spine Topology
  - About Submission

Part1: A Tree Topology (1/4)

- Edit a Python script to build the following topology

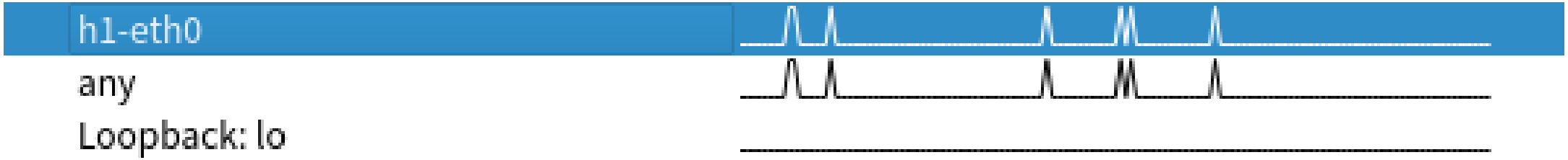


Part1: A Tree Topology (2/4)

- Run part1 python script
- Run wireshark at node h1

```
mininet> h1 wireshark &
```

- Capture packets on h1-eth0



Part1: A Tree Topology (3/4)

- Invoke another terminal
- Flush s1~s3 MAC address table
  - Mininet switch may contain previous MAC information records

```
$ sudo ovs-appctl fdb/flush s1
```

- Observe s1 MAC address table

```
$ sudo ovs-appctl fdb/show s1
```

- Do ping action

```
mininet> h1 ping h4 -c 5
```

  - -c: send given number ICMP packets
- Observe s1 MAC address table again

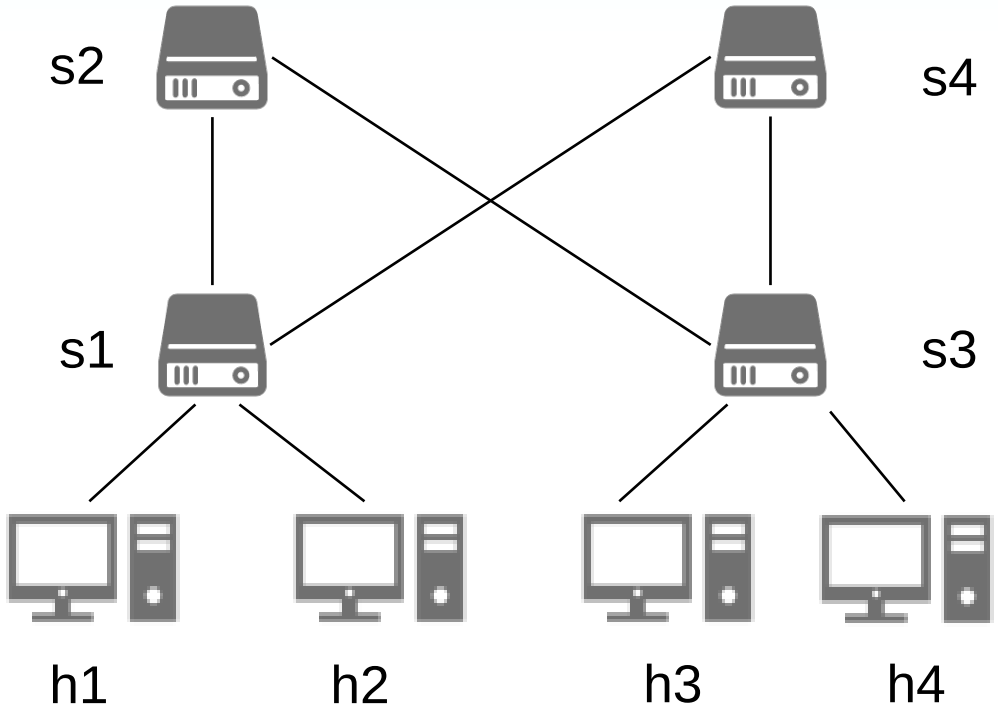
```
$ sudo ovs-appctl fdb/show s1
```

Part1: A Tree Topology (4/4)

- Answer questions
  1. Flush all switch tables and take screenshots to show the switch tables of all switches. (5%)
     - After h1 ping h4
  2. How does h4 knows h1's MAC address? Take screenshot on Wireshark to verify your answers. (10%)
  3. How does h1 knows h4's MAC address? Take screenshot on Wireshark to verify your answers. (10%)
  4. Why does the first ping have a longer delay? (10%)
  5. Show the switch tables and identify the entries that constitute the path of Ping. (10%)

Part2: A Leaf-Spine Topology (1/5)

- Edit a Python script to build the following topology

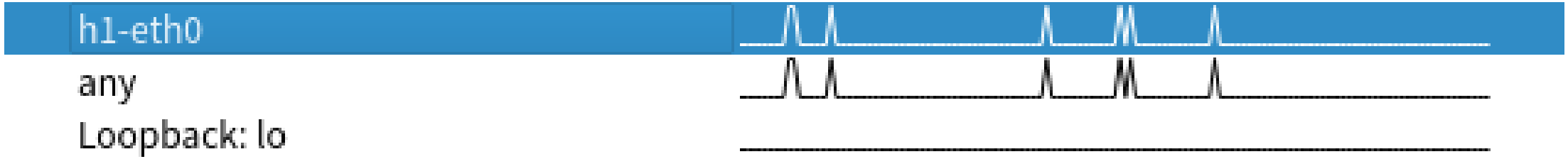


Part2: A Leaf-Spine Topology (2/5)

- Run part2 python script
- Run wireshark at node h1

```
mininet> h1 wireshark &
```

- Capture packets on h1-eth0



Part2: A Leaf-Spine Topology (3/5)

- Invoke another terminal
- Flush s1~s4 MAC address table
  - Mininet switch may contain previous MAC information records

```
$ sudo ovs-appctl fdb/flush s1
```

- Run ping on h1

```
mininet> h1 ping h4 -c 5
```

  - -c: send given number ICMP packets

Part2: A Leaf-Spine Topology (4/5)

- Enable STP on all switches (s1~s4)

```
$ sudo ovs-vsctl set bridge s1 stp-enable=true
```

  - Commands may take few minutes.

- Run ping on h1

```
mininet> h1 ping h4 -c 5
```

Part2: A Leaf-Spine Topology (5/5)

- Answer questions
  1. Can h1 ping h4 successfully before enabling STP? Take screenshots to justify your answer. (10%)
  2. Can h1 ping h4 successfully after STP enabled? Take screenshots to justify your answer. (10%)
  3. Show s1 MAC tables before and after enables STP and explain the differences. (10%)
  4. What have you observed and learned from this lab? (5%)

About Submission

- Files
  - Two Python scripts:
    - lab1_part1_<studentID>.py (10%)
    - lab1_part2_<studentID>.py (10%)
  - A report: lab1_<studentID>.pdf (80%)
    - Part1 and Part2 Question Answers
- Submission
  - Zip Python scripts and the report into a zip file
    - Named: lab1_<studentID>.zip
  - Wrong file name or format subjects to 10 points deduction

References

- Introduction to Mininet
  - https://github.com/mininet/mininet/wiki/Introduction-to-Mininet
- Mininet Python API
  - http://mininet.org/api/annotated.html
- Manpage for Linux command
  - netstat
    - http://manpages.ubuntu.com/manpages/trusty/man8/netstat.8.html
  - mn
    - http://manpages.ubuntu.com/manpages/bionic/man1/mn.1.html

Q & A