

## Assignment-02

## CS 433 Computer Networks (2023-24)

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I)

- a) The code is attached with this repository. A mininet includes three inter-connected subnets each with a router and two hosts.

Here's a brief explanation of the key components and implementation:

1. **Custom Router Class (LinuxRouter):**

- Inherits from the Mininet Node class.
- Overrides the config method to enable IP forwarding on the router.
- Overrides the terminate method to disable IP forwarding when terminating.

2. **Topology Class (NetworkTopo):**

- Inherits from the Mininet Topo class.
- Defines the network topology, including routers, switches, and links between them.
- Configures IP addresses for router interfaces.

3. **Topology Building (build method in NetworkTopo):**

- Adds three routers (r1, r2, r3) with specific IP addresses.
- Adds three switches (s1, s2, s3).
- Establishes links between routers and switches.
- Configures point-to-point links between routers (r1-eth2 to r2-eth2, r2-eth3 to r3-eth2, r3-eth3 to r1-eth3).
- Adds hosts (h1 to h6) and connects them to switches with assigned IP addresses and default routes.

4. **Mininet Initialization and Startup (run function):**

- Creates an instance of the NetworkTopo topology.
- Initializes Mininet with the specified topology.
- Starts the Mininet network.

5. **Packet Capture and Static Routes (run function):**

- Enables packet capture on specific interfaces of r1.
- Configures static routes on routers to ensure proper routing between subnets.

6. **CLI Interaction (CLI(net) in run` function):**

- Opens the Mininet Command Line Interface (CLI) for user interaction.

7. **Routing Table Display and Modification (run function):**

- Displays the initial routing tables for routers (r1, r2, r3).
- Modifies default routes for specific traffic.
- Displays the updated routing tables.

8. **Packet Capture Cleanup (run function):**

- Stops the packet capture on r1 before exiting.

9. **Mininet Cleanup (run function):**

- Stops the Mininet network.

10. **Script Execution Check ('if name == 'main':):**

- Ensures that the script is executed when run directly and not when imported as a

module.

```
tcp 0 0 127.0.0.1:34640 127.0.0.1:6653 TIME_WAIT
vboxuser@Ubuntu:~$ sudo /bin/python3 /home/vboxuser/Desktop/Q1.py
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 r1 r2 r3
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s2) (h5, s3) (h6, s3) (r1, r2) (r2, r3) (r3, r1) (s1, r1) (s2, r2) (s3, r3)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 r1 r2 r3
*** Starting controller
c0
*** Starting 3 switches
s1 s2 s3 ...
*** Waiting for switches to connect
s1 s2 s3
* Routing Table for Router r1:
Kernel IP routing table
Destination Gateway Genmask Flags Metric Ref Use Iface
10.0.0.0 192.168.6.1 255.0.0.0 UG 0 0 0 r1-eth3
172.16.0.0 192.168.4.2 255.240.0.0 UG 0 0 0 r1-eth2
192.168.1.0 0.0.0.0 255.255.255.0 U 0 0 0 r1-eth1
192.168.4.0 0.0.0.0 255.255.255.252 U 0 0 0 r1-eth2
192.168.6.0 0.0.0.0 255.255.255.252 U 0 0 0 r1-eth3
* Routing Table for Router r2:
Kernel IP routing table
Destination Gateway Genmask Flags Metric Ref Use Iface
10.0.0.0 192.168.5.2 255.0.0.0 UG 0 0 0 r2-eth3
172.16.0.0 0.0.0.0 255.240.0.0 U 0 0 0 r2-eth1
192.168.1.0 192.168.4.1 255.255.255.0 UG 0 0 0 r2-eth2
192.168.4.0 0.0.0.0 255.255.255.252 U 0 0 0 r2-eth2
192.168.5.0 0.0.0.0 255.255.255.252 U 0 0 0 r2-eth3
* Routing Table for Router r3:
Kernel IP routing table
Destination Gateway Genmask Flags Metric Ref Use Iface
10.0.0.0 0.0.0.0 255.0.0.0 U 0 0 0 r3-eth1

mininet> h1 ping -c 3 h6
PING 10.0.0.101 (10.0.0.101) 56(84) bytes of data.
64 bytes from 10.0.0.101: icmp_seq=1 ttl=62 time=5.03 ms
64 bytes from 10.0.0.101: icmp_seq=2 ttl=62 time=0.602 ms
64 bytes from 10.0.0.101: icmp_seq=3 ttl=62 time=0.218 ms

--- 10.0.0.101 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2030ms
rtt min/avg/max/mdev = 0.218/1.951/5.033/2.184 ms
mininet> h1 ping -c h4
ping: invalid argument: '172.16.0.101'
mininet> h1 ping -c 3 h4
PING 172.16.0.101 (172.16.0.101) 56(84) bytes of data.
64 bytes from 172.16.0.101: icmp_seq=1 ttl=62 time=3.73 ms
64 bytes from 172.16.0.101: icmp_seq=2 ttl=62 time=0.954 ms
64 bytes from 172.16.0.101: icmp_seq=3 ttl=62 time=0.098 ms

--- 172.16.0.101 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2090ms
rtt min/avg/max/mdev = 0.098/1.594/3.732/1.551 ms
mininet> h1 ping -c 3 h2
PING 192.168.1.101 (192.168.1.101) 56(84) bytes of data.
64 bytes from 192.168.1.101: icmp_seq=1 ttl=64 time=3.05 ms
64 bytes from 192.168.1.101: icmp_seq=2 ttl=64 time=0.425 ms
64 bytes from 192.168.1.101: icmp_seq=3 ttl=64 time=0.086 ms

--- 192.168.1.101 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2153ms
rtt min/avg/max/mdev = 0.086/1.185/3.046/1.322 ms
mininet>
```

b) WireShark output for the packets captured on router 1:

The image shows a Wireshark packet capture window titled "Capturing from s1-eth2". The interface includes a menu bar (File, Edit, View, Go, Capture, Analyze, Statistics, Telephony, Wireless, Tools, Help) and a toolbar with various icons for packet capture and analysis. A display filter bar at the top shows "Apply a display filter ... <Ctrl-/>".

The main packet list displays 10 captured packets, all of which are ICMP Echo (ping) messages. The packets alternate between being requests and replies between the source IP 10.0.0.101 and the destination IP 192.168.1.100. Each packet is 98 bytes long.

No.	Time	Source	Destination	Protocol	Length	Info
2	0.000062487	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
3	1.003441790	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
4	1.003523273	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
5	2.061198698	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
6	2.061288165	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
7	3.084973237	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
8	3.085060951	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
9	4.107174384	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
10	4.107239796	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0

Below the packet list, the details pane for the selected packet (No. 1) is expanded, showing the following layers:

- Frame 1: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface s1-eth2, id 0
- Ethernet II, Src: 52:4d:56:2d:dc:5e (52:4d:56:2d:dc:5e), Dst: aa:d7:2a:6d:bf:40 (aa:d7:2a:6d:bf:40)
- Internet Protocol Version 4, Src: 192.168.1.100, Dst: 10.0.0.101
- Internet Control Message Protocol

The packet bytes pane at the bottom shows the raw data in hexadecimal and ASCII. The ASCII column contains the text: ".\*m.@RM V-^..E..Tv.@.@. ....d..e....>. ..=.0e...f.... !"#\$\$%&'()\*+,- ./01234567".

The status bar at the bottom indicates "s1-eth2: <live capture in progress>", "Packets: 12 · Displayed: 12 (100.0%)", and "Profile: Default".

Capturing from s1-eth1

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
2	0.000095349	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
3	1.023869136	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
4	1.023930221	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
5	2.067956647	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
6	2.068002343	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
7	3.076095440	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0
8	3.076161243	10.0.0.101	192.168.1.100	ICMP	98	Echo (ping) reply id=0
9	4.095763444	192.168.1.100	10.0.0.101	ICMP	98	Echo (ping) request id=0

Frame 1: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface s1-eth1, id 0  
 Ethernet II, Src: 52:4d:56:2d:dc:5e (52:4d:56:2d:dc:5e), Dst: aa:d7:2a:6d:bf:40 (aa:d7:2a:6d:bf:40)  
 Internet Protocol Version 4, Src: 192.168.1.100, Dst: 10.0.0.101  
 Internet Control Message Protocol

```

0000  aa d7 2a 6d bf 40 52 4d 56 2d dc 5e 08 00 45 00  ..*m.@RM V-..^..E-
0010  00 54 8c 4a 40 00 40 01 e1 ed c0 a8 01 64 0a 00  .T.J@.@. ....d..
0020  00 65 08 00 df 22 3e c7 00 37 68 2e 4f 65 00 00  .e...">..7h.Oe..
0030  00 00 59 78 0a 00 00 00 00 00 10 11 12 13 14 15  .Yx.....
0040  16 17 18 19 1a 1b 1c 1d 1e 1f 20 21 22 23 24 25  . .... !"#$$%
0050  26 27 28 29 2a 2b 2c 2d 2e 2f 30 31 32 33 34 35  &'()*+,-./012345
0060  36 37 67
  
```

s1-eth1: <live capture in progress> Packets: 10 · Displayed: 10 (100.0%) Profile: Default

Capturing from s1-eth3

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/>

No.	Time	Source	Destination	Protocol	Length	Info
-----	------	--------	-------------	----------	--------	------

s1-eth3: <live capture in progress> No Packets Profile: Default

...using this filter:  All interfaces shown

- enp0s3
- s1-eth2
- s1-eth3
- s2-eth2
- s2-eth3
- s3-eth2
- s3-eth3
- s1-eth1
- s2-eth1
- s3-eth1
- any
- Loopback: lo
- bluetooth-monitor
- nflog
- nfqueue
- dbus-system
- dbus-session
- ovs-system
- s1
- s3
- s2

Address: fe80::80e4:b3ff:feef:fcfe  
No capture filter

c)

```
# Vary the default route for h1 to h6 traffic via different routers
net['r1'].cmd('ip route del 10.0.0.0/8 via 192.168.6.1')
net['r1'].cmd('ip route add 10.0.0.0/8 via 192.168.4.2')
net['r3'].cmd('ip route del 192.168.1.0/24 via 192.168.6.2')
net['r3'].cmd('ip route add 192.168.1.0/24 via 192.168.5.1')
```

Code snippet for varying the default route

```
* Updated Routing Table for Router r1:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         192.168.4.2     255.0.0.0        UG    0      0      0 r1-eth2
172.16.0.0       192.168.4.2     255.240.0.0      UG    0      0      0 r1-eth2
192.168.1.0      0.0.0.0         255.255.255.0    U      0      0      0 r1-eth1
192.168.4.0      0.0.0.0         255.255.255.252  U      0      0      0 r1-eth2
192.168.6.0      0.0.0.0         255.255.255.252  U      0      0      0 r1-eth3

* Updated Routing Table for Router r2:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         192.168.5.2     255.0.0.0        UG    0      0      0 r2-eth3
172.16.0.0       0.0.0.0         255.240.0.0      U      0      0      0 r2-eth1
192.168.1.0      192.168.4.1     255.255.255.0    UG    0      0      0 r2-eth2
192.168.4.0      0.0.0.0         255.255.255.252  U      0      0      0 r2-eth2
192.168.5.0      0.0.0.0         255.255.255.252  U      0      0      0 r2-eth3

* Updated Routing Table for Router r3:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         0.0.0.0         255.0.0.0        U      0      0      0 r3-eth1
172.16.0.0       192.168.5.1     255.240.0.0      UG    0      0      0 r3-eth2
192.168.1.0      192.168.5.1     255.255.255.0    UG    0      0      0 r3-eth2
192.168.5.0      0.0.0.0         255.255.255.252  U      0      0      0 r3-eth2
192.168.6.0      0.0.0.0         255.255.255.252  U      0      0      0 r3-eth3

*** Starting CLI:
```

```
mininet> h1 ping -c 3 h6
PING 10.0.0.101 (10.0.0.101) 56(84) bytes of data:
64 bytes from 10.0.0.101: icmp_seq=1 ttl=61 time=4.50 ms
64 bytes from 10.0.0.101: icmp_seq=2 ttl=61 time=1.42 ms
64 bytes from 10.0.0.101: icmp_seq=3 ttl=61 time=0.108 ms

--- 10.0.0.101 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2008ms
rtt min/avg/max/mdev = 0.108/2.008/4.501/1.841 ms
```

```

Edit Selection View Go Run Terminal Help

"Node: h6"
root@Ubuntu:/home/vboxuser# iperf -s
-----
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 10.0.0.101 port 5001 connected with 192.168.1.100 port 54386
[ ID] Interval      Transfer    Bandwidth
[ 1] 0.0000-9.9990 sec  20.8 GBytes  17.8 Gbits/sec
[

"Node: h1"
root@Ubuntu:/home/vboxuser# iperf -c 10.0.0.101
-----
Client connecting to 10.0.0.101, TCP port 5001
TCP window size: 85.3 KByte (default)
-----
[ 1] local 192.168.1.100 port 54386 connected with 10.0.0.101 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 1] 0.0000-10.0142 sec  20.8 GBytes  17.8 Gbits/sec
root@Ubuntu:/home/vboxuser#

```

d)

```

* Updated Routing Table for Router r1:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         192.168.4.2     255.0.0.0        UG      0      0      0 r1-eth2
172.16.0.0       192.168.4.2     255.240.0.0      UG      0      0      0 r1-eth2
192.168.1.0      0.0.0.0         255.255.255.0    U       0      0      0 r1-eth1
192.168.4.0      0.0.0.0         255.255.255.252  U       0      0      0 r1-eth2
192.168.6.0      0.0.0.0         255.255.255.252  U       0      0      0 r1-eth3

* Updated Routing Table for Router r2:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         192.168.5.2     255.0.0.0        UG      0      0      0 r2-eth3
172.16.0.0       0.0.0.0         255.240.0.0      U       0      0      0 r2-eth1
192.168.1.0      192.168.4.1     255.255.255.0    UG      0      0      0 r2-eth2
192.168.4.0      0.0.0.0         255.255.255.252  U       0      0      0 r2-eth2
192.168.5.0      0.0.0.0         255.255.255.252  U       0      0      0 r2-eth3

* Updated Routing Table for Router r3:
Kernel IP routing table
Destination      Gateway          Genmask          Flags Metric Ref    Use Iface
10.0.0.0         0.0.0.0         255.0.0.0        U       0      0      0 r3-eth1
172.16.0.0       192.168.5.1     255.240.0.0      UG      0      0      0 r3-eth2
192.168.1.0      192.168.5.1     255.255.255.0    UG      0      0      0 r3-eth2
192.168.5.0      0.0.0.0         255.255.255.252  U       0      0      0 r3-eth2
192.168.6.0      0.0.0.0         255.255.255.252  U       0      0      0 r3-eth3

```

\* Routing Table for Router r1:

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.0.0	192.168.6.1	255.0.0.0	UG	0	0	0	r1-eth3
172.16.0.0	192.168.4.2	255.240.0.0	UG	0	0	0	r1-eth2
192.168.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r1-eth1
192.168.4.0	0.0.0.0	255.255.255.252	U	0	0	0	r1-eth2
192.168.6.0	0.0.0.0	255.255.255.252	U	0	0	0	r1-eth3

\* Routing Table for Router r2:

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.0.0	192.168.5.2	255.0.0.0	UG	0	0	0	r2-eth3
172.16.0.0	0.0.0.0	255.240.0.0	U	0	0	0	r2-eth1
192.168.1.0	192.168.4.1	255.255.255.0	UG	0	0	0	r2-eth2
192.168.4.0	0.0.0.0	255.255.255.252	U	0	0	0	r2-eth2
192.168.5.0	0.0.0.0	255.255.255.252	U	0	0	0	r2-eth3

\* Routing Table for Router r3:

Kernel IP routing table

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
10.0.0.0	0.0.0.0	255.0.0.0	U	0	0	0	r3-eth1
172.16.0.0	192.168.5.1	255.240.0.0	UG	0	0	0	r3-eth2
192.168.1.0	192.168.6.2	255.255.255.0	UG	0	0	0	r3-eth3
192.168.5.0	0.0.0.0	255.255.255.252	U	0	0	0	r3-eth2
192.168.6.0	0.0.0.0	255.255.255.252	U	0	0	0	r3-eth3

\* Updated Routing Table for Router r1: