50.020 Network Security Lab 5 Firewall Exploration Writeup

Task 1 - Implementing Simple Firewall (Optional)

- Is optional and was not attempted.

Summary of iptables tables

1. `filter` table: used for packet filtering
   - `INPUT` chain
   - `FORWARD` chain
   - `OUTPUT` chain
2. `nat` table: used for network address translation, modified network addresses
   - `PREROUTING` chain
   - `INPUT` chain
   - `OUTPUT` chain
   - `POSTROUTING` chain
3. `mangle` table: used for packet content modification
   - `PREROUTING` chain: enforced at `NF_IP_PRE_ROUTING` hook
   - `INPUT` chain: enforced at `NF_INET_LOCAL_IN` hook
   - `FORWARD` chain: enforced at `NF_INET_FORWARD` hook
   - `OUTPUT` chain: enforced at `NF_INET_LOCAL_OUT` hook
   - `POSTROUTING` chain: enforced at `NF_IP_POST_ROUTING` hook

iptable command line interface

- ```
  iptables -t <table> -<operation> <chain> <rule> -j <target>

  // List all the rules in a table (without line number)
  iptables -t <table> -L -n

  // List all the rules in a table (with line number)
  iptables -t <table> -L -n --line-numbers

  // Delete a rule in a table by specifying the line number
  iptables -t <table> -D <chain> <line-number>

  // Drop all packets that satisfy a certain <rule>
  iptables -t <table> -A <chain> <rule> -j DROP
  ```

Task 2 - Experimenting with stateless firewall

Task 2.A: Protecting the router

- In the router container, I run the following commands as per the instructions in the assignment:
  -
  ```

```
iptables -A INPUT -p icmp --icmp-type echo-request -j ACCEPT
iptables -A OUTPUT -p icmp --icmp-type echo-reply -j ACCEPT
iptables -P OUTPUT DROP
iptables -P INPUT DROP
```

```
root@3a83319fa079:/# iptables -A INPUT -p icmp --icmp-type echo-request -j ACCEPT
root@3a83319fa079:/# iptables -A OUTPUT -p icmp --icmp-type echo-reply -j ACCEPT
root@3a83319fa079:/# iptables -P OUTPUT DROP
root@3a83319fa079:/# iptables -P INPUT DROP
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy DROP)
target     prot opt source               destination
ACCEPT     icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 8

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy DROP)
target     prot opt source               destination
ACCEPT     icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 0
root@3a83319fa079:/#
```

- Then I try to ping the router (`10.9.0.11`) from the hostA container hosted on `10.9.0.5` .

```
root@e20fb81e8eb5:/# ping 10.9.0.11
PING 10.9.0.11 (10.9.0.11) 56(84) bytes of data.
64 bytes from 10.9.0.11: icmp_seq=1 ttl=64 time=1.92 ms
64 bytes from 10.9.0.11: icmp_seq=2 ttl=64 time=0.144 ms
64 bytes from 10.9.0.11: icmp_seq=3 ttl=64 time=0.164 ms
64 bytes from 10.9.0.11: icmp_seq=4 ttl=64 time=0.128 ms
64 bytes from 10.9.0.11: icmp_seq=5 ttl=64 time=0.162 ms
64 bytes from 10.9.0.11: icmp_seq=6 ttl=64 time=0.097 ms
^C
--- 10.9.0.11 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5096ms
rtt min/avg/max/mdev = 0.097/0.435/1.916/0.662 ms
root@e20fb81e8eb5:/#
```

  - We see that the ping is successful, which is expected since we have allowed ICMP echo-request and echo-reply packets in the iptables rules.

- Then I try to telnet to the router (`10.9.0.11`) from the hostA container hosted on `10.9.0.5` .

```
root@e20fb81e8eb5:/# telnet 10.9.0.11
Trying 10.9.0.11...
telnet: Unable to connect to remote host: Connection timed out
root@e20fb81e8eb5:/#
```

  - We see that the telnet attempt times out, which is expected since we have set the default policy for INPUT and OUTPUT chains to DROP, and we have not allowed any TCP packets in the iptables rules.

- Then I clean up the iptables rules as per the assignment instructions

```
iptables -F
iptables -P INPUT ACCEPT
iptables -P OUTPUT ACCEPT
```

```
root@3a83319fa079:/# iptables -F
root@3a83319fa079:/# iptables -P OUTPUT ACCEPT
root@3a83319fa079:/# iptables -P INPUT ACCEPT
```

```
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@3a83319fa079:/#
```

Task 2.B: Protecting internal network

- We want to setup rules to achieve this outcome:
  i. Outside host cannot ping internal hosts.
  ii. Outside host can ping router.
  iii. Internal hosts can ping outside host.
  iv. All other packets between internal network and external network should be blocked.
- First we use `ip addr` to check the interfaces of the internal and external networks.
  - ```
    root@3a83319fa079:/# ip addr
    1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
        link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
        inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
        inet6 ::1/128 scope host
        valid_lft forever preferred_lft forever
    2: eth0@if34: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP group default
        link/ether 46:61:6c:8c:db:f6 brd ff:ff:ff:ff:ff:ff link-netnsid 0
        inet 192.168.60.11/24 brd 192.168.60.255 scope global eth0
        valid_lft forever preferred_lft forever
    3: eth1@if36: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP group default
        link/ether d2:54:23:ad:a5:ad brd ff:ff:ff:ff:ff:ff link-netnsid 0
        inet 10.9.0.11/24 brd 10.9.0.255 scope global eth1
        valid_lft forever preferred_lft forever
    ```
  - we see that `eth0` is the internal network interface with IP `192.168.60.11`
  - we see that `eth1` is the external network interface with IP `10.9.0.11`
- To achieve the desired outcome, we need to setup the following iptables rules on the router container:
  i. By default, drop all packets in the FORWARD chain.
    - `iptables -P FORWARD DROP`
  ii. In the FORWARD chain, drop all icmp echo-request packets coming from external network interface `eth1` .
    - `iptables -A FORWARD -i eth1 -p icmp --icmp-type echo-request -j DROP`
  iii. In the FORWARD chain, allow all icmp echo-request packets coming from internal network interface `eth0` .
    - `iptables -A FORWARD -i eth0 -p icmp --icmp-type echo-request -j ACCEPT`
  iv. In the FORWARD chain, allow all icmp echo-reply packets from external network interface `eth1` .
    - `iptables -A FORWARD -i eth1 -p icmp --icmp-type echo-reply -j ACCEPT`
- ```
  root@3a83319fa079:/# iptables -P FORWARD DROP
  root@3a83319fa079:/# iptables -A FORWARD -i eth1 -p icmp --icmp-type echo-request -j DROP
  root@3a83319fa079:/# iptables -A FORWARD -i eth0 -p icmp --icmp-type echo-request -j ACCEPT
  ```

```
root@3a83319fa079:/# iptables -A FORWARD -i eth1 -p icmp --icmp-type echo-reply -j ACCEPT
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy DROP)
target     prot opt source               destination
DROP       icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 8
ACCEPT     icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 8
ACCEPT     icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 0

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@3a83319fa079:/#
```

- Then we test the rules:
  i. From external network hostA (`10.9.0.5`), we try to ping internal host1 (`192.168.60.5`).
  - ```
    root@e20fb81e8eb5:/# ping 192.168.60.5
    PING 192.168.60.5 (192.168.60.5) 56(84) bytes of data.
    ^C
    --- 192.168.60.5 ping statistics ---
    53 packets transmitted, 0 received, 100% packet loss, time 53241ms
    ```
  - We see that all the ping attempts fail and results in 100% packet loss, which is expected since we have dropped all icmp echo-request packets from external network in the FORWARD chain.

  ii. From external network hostA (`10.9.0.5`), we try to ping the router (`10.9.0.11`).
  - ```
    root@e20fb81e8eb5:/# ping 10.9.0.11
    PING 10.9.0.11 (10.9.0.11) 56(84) bytes of data.
    64 bytes from 10.9.0.11: icmp_seq=1 ttl=64 time=0.817 ms
    64 bytes from 10.9.0.11: icmp_seq=2 ttl=64 time=0.310 ms
    64 bytes from 10.9.0.11: icmp_seq=3 ttl=64 time=0.219 ms
    64 bytes from 10.9.0.11: icmp_seq=4 ttl=64 time=0.134 ms
    64 bytes from 10.9.0.11: icmp_seq=5 ttl=64 time=0.154 ms
    64 bytes from 10.9.0.11: icmp_seq=6 ttl=64 time=0.064 ms
    ^C
    --- 10.9.0.11 ping statistics ---
    6 packets transmitted, 6 received, 0% packet loss, time 5082ms
    rtt min/avg/max/mdev = 0.064/0.283/0.817/0.250 ms
    ```
  - We see that the ping is successful, which is expected since we have not blocked any icmp packets to the router in the INPUT chain.

  iii. From internal host1 (`192.168.60.5`), we try to ping external hostA (`10.9.0.5`).
  - ```
    root@a73822c4f6a0:/# ping 10.9.0.5
    PING 10.9.0.5 (10.9.0.5) 56(84) bytes of data.
    64 bytes from 10.9.0.5: icmp_seq=1 ttl=63 time=2.14 ms
    64 bytes from 10.9.0.5: icmp_seq=2 ttl=63 time=0.231 ms
    64 bytes from 10.9.0.5: icmp_seq=3 ttl=63 time=0.191 ms
    64 bytes from 10.9.0.5: icmp_seq=4 ttl=63 time=0.086 ms
    64 bytes from 10.9.0.5: icmp_seq=5 ttl=63 time=0.126 ms
    64 bytes from 10.9.0.5: icmp_seq=6 ttl=63 time=0.108 ms
    ^C
    --- 10.9.0.5 ping statistics ---
    6 packets transmitted, 6 received, 0% packet loss, time 5090ms
    rtt min/avg/max/mdev = 0.086/0.479/2.135/0.742 ms
    ```
  - We see that the ping is successful, which is expected since we have allowed icmp echo-request and echo-reply packets from internal network in the FORWARD chain.

  iv. We try to telnet from internal host1 (`192.168.60.5`) to external hostA (`10.9.0.5`), which sends a TCP SYN packet.
  - ```
    root@a73822c4f6a0:/# telnet 10.9.0.5
    Trying 10.9.0.5...
    telnet: Unable to connect to remote host: Connection timed out
    ```
  - We see that the telnet attempt times out, which is expected since we have set the default policy for FORWARD chain to DROP, and we have not allowed any TCP packets in the iptables rules.

  v. We try to telnet from external hostA (`10.9.0.5`) to internal host1 (`192.168.60.5`), which sends a TCP SYN packet.
  - ```
    root@e20fb81e8eb5:/# telnet 192.168.60.5
    Trying 192.168.60.5...
    telnet: Unable to connect to remote host: Connection timed out
    ```
    ```

- We see that the telnet attempt times out, which is expected since we have set the default policy for FORWARD chain to DROP, and we have not allowed any TCP packets in the iptables rules.

- With this, we have successfully setup the iptables rules to achieve the desired outcome.
- cleaning up the iptables rules as per the assignment instructions

```
iptables -F
iptables -P FORWARD ACCEPT
```

Task 2.C: Protecting Internal Servers

- The assignment requires us to setup these rules:
  i. Outside hosts can only access host1's telnet server on `192.168.60.5/23`, not the other internal hosts' servers.
  ii. Outside hosts cannot access all other internal servers.
  iii. Internal hosts can access all internal servers.
  iv. Internal hosts cannot access external servers.
  v. Connection tracking mechanism is not allowed.
- To achieve the desired outcome, we need to setup the following rules on the router's FORWARD chain:
  i. By default, drop all packets in the FORWARD chain.
    - `iptables -P FORWARD DROP`
  ii. In the FORWARD chain, allow all TCP packets to internal host1's telnet server on `192.168.60.5/23` from external network interface `eth1`.
    - `iptables -A FORWARD -i eth1 -p tcp -d 192.168.60.5 --dport 23 -j ACCEPT`
  iii. In the FORWARD chain, allow all TCP packets from internal host1's telnet server on `192.168.60.5/23` to all internal network servers on interface `eth0`.
    - `iptables -A FORWARD -i eth0 -p tcp -s 192.168.60.5 --sport 23 -j ACCEPT`

```
root@3a83319fa079:/# iptables -P FORWARD DROP
root@3a83319fa079:/# iptables -A FORWARD -i eth1 -p tcp -d 192.168.60.5 --dport 23 -j ACCEPT
root@3a83319fa079:/# iptables -A FORWARD -i eth0 -p tcp -s 192.168.60.5 --sport 23 -j ACCEPT
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy DROP)
target     prot opt source               destination
ACCEPT     tcp  --  0.0.0.0/0            192.168.60.5         tcp dpt:23
ACCEPT     tcp  --  192.168.60.5         0.0.0.0/0            tcp spt:23

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@3a83319fa079:/#
```

- Note that requirement 3 is automatically satisfied since all internal hosts are in the same subnet `192.168.60.0/24`, their traffic will not go through the router, so no iptables rules are needed on the router for internal hosts to access internal servers.

- Then we test the rules:
  i. Outside hosts can only access host1's telnet server on `192.168.60.5/23`
    - From external hostA (`10.9.0.5`), we try to telnet internal host1 (`192.168.60.5`).
    -

```
root@e20fb81e8eb5:/# telnet 192.168.60.5
Trying 192.168.60.5...
Connected to 192.168.60.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
a73822c4f6a0 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage
```

```
This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.
```

- We see that the telnet is successful, which is expected since we have allowed TCP packets to internal host1's telnet server from external network in the FORWARD chain.

ii. Outside hosts cannot access all other internal servers.

- From external hostA (`10.9.0.5`), we try to telnet internal host2 (`192.168.60.6`).

```
root@e20fb81e8eb5:/# telnet 192.168.60.6
Trying 192.168.60.6...
telnet: Unable to connect to remote host: Connection timed out
```

  - We see that the telnet attempt times out, which is expected since we have not allowed any TCP packets to internal host2's telnet server from external network in the FORWARD chain.

- From external hostA (`10.9.0.5`), we try to telnet internal host3 (`192.168.60.7`).

```
root@e20fb81e8eb5:/# telnet 192.168.60.7
Trying 192.168.60.7...
telnet: Unable to connect to remote host: Connection timed out
```

  - We see that the telnet attempt times out, which is expected since we have not allowed any TCP packets to internal host3's telnet server from external network in the FORWARD chain.

iii. Internal hosts can access all internal servers.

- From internal host1 (`192.168.60.5`), we try to telnet internal host2 (`192.168.60.6`).

```
root@a73822c4f6a0:/# telnet 192.168.60.6
Trying 192.168.60.6...
Connected to 192.168.60.6.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
ace3c5d78bcb login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.
```

- From internal host1 (`192.168.60.5`), we try to telnet internal host3 (`192.168.60.7`).

```
root@a73822c4f6a0:/# telnet 192.168.60.7
Trying 192.168.60.7...
Connected to 192.168.60.7.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
545617a8c239 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.
```

```
To restore this content, you can run the 'unminimize' command.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.
```

- From internal host2 (`192.168.60.6`), we try to telnet internal host3 (`192.168.60.7`).

```
root@ace3c5d78bcb:/# telnet 192.168.60.7
Trying 192.168.60.7...
Connected to 192.168.60.7.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
545617a8c239 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 08:04:40 UTC 2025 from host1-192.168.60.5.net-192.168.60.0 on pts/1
```

- From internal host2 (`192.168.60.6`), we try to telnet internal host1 (`192.168.60.5`).

```
root@ace3c5d78bcb:/# telnet 192.168.60.5
Trying 192.168.60.5...
Connected to 192.168.60.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
a73822c4f6a0 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 07:14:21 UTC 2025 from 10.9.0.5 on pts/2
```

- From internal host3 (`192.168.60.7`), we try to telnet internal host1 (`192.168.60.5`).

```
root@545617a8c239:/# telnet 192.168.60.5
Trying 192.168.60.5...
Connected to 192.168.60.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
a73822c4f6a0 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 08:07:29 UTC 2025 from host2-192.168.60.6.net-192.168.60.0 on pts/2
```

- From internal host3 (`192.168.60.7`), we try to telnet internal host2 (`192.168.60.6`).

```
root@545617a8c239:/# telnet 192.168.60.6
Trying 192.168.60.6...
Connected to 192.168.60.6.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
ace3c5d78bcb login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)
```

```
 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 08:03:32 UTC 2025 from host1-192.168.60.5.net-192.168.60.0 on pts/1
```

- We see that all the telnet attempts between internal hosts are successful, which is expected since internal hosts are in the same subnet and their traffic does not go through the router and the iptables rules do not affect them.

iv. Internal hosts cannot access external servers.

- From internal host1 (`192.168.60.5`), we try to telnet external hostA (`10.9.0.5`).

```
root@a73822c4f6a0:/# telnet 10.9.0.5
Trying 10.9.0.5...
telnet: Unable to connect to remote host: Connection timed out
```

- From internal host2 (`192.168.60.6`), we try to telnet external hostA (`10.9.0.5`).

```
root@ace3c5d78bcb:/# telnet 10.9.0.5
Trying 10.9.0.5...
telnet: Unable to connect to remote host: Connection timed out
```

- From internal host3 (`192.168.60.7`), we try to telnet external hostA (`10.9.0.5`).

```
root@545617a8c239:/# telnet 10.9.0.5
Trying 10.9.0.5...
telnet: Unable to connect to remote host: Connection timed out
```

- We see that the telnet attempt times out, which is expected since we have set the default policy for FORWARD chain to DROP, and we have not allowed any TCP packets from internal network to external network in the FORWARD chain.

v. Connection tracking mechanism is not allowed.

- We have not used any connection tracking mechanism in our iptables rules, so this requirement is satisfied.

- With this, we have successfully setup the iptables rules to achieve the desired outcome.
- cleaning up the iptables rules as per the assignment instructions

```
iptables -F
iptables -P FORWARD ACCEPT
```

Task 3 - Connection tracking and stateful firewall

Task 3.A: Experimenting with connection tracking

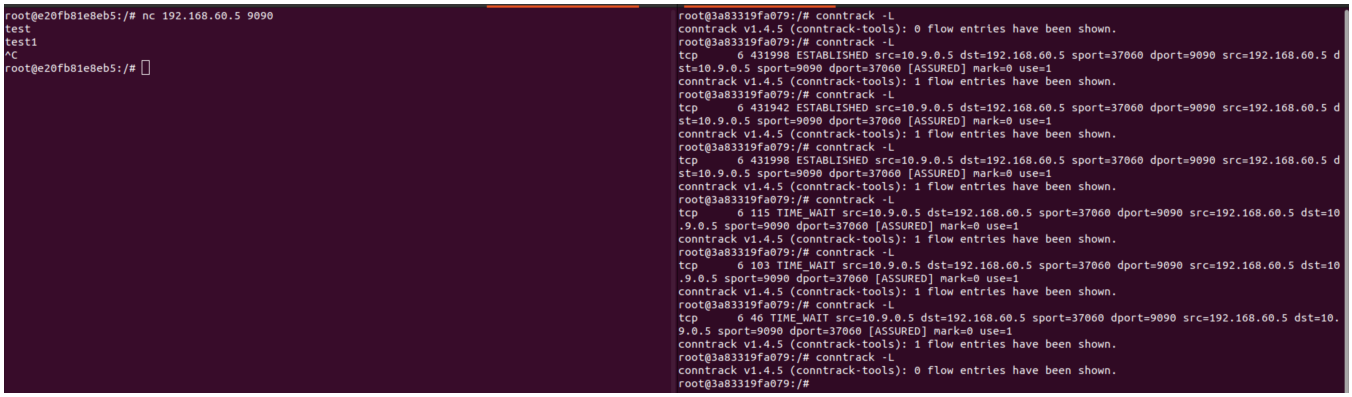
- To test for ICMP connection tracking, we run the ping commands to `192.168.60.5` from `10.9.0.5` as per the instructions in the assignment, then on the router, we check the connection tracking table using `conntrack -L` .

```
root@e20fb81e8eb5:/# ping 192.168.60.5
PING 192.168.60.5 (192.168.60.5) 56(84) bytes of data.
64 bytes from 192.168.60.5: icmp_seq=1 ttl=63 time=0.662 ms
64 bytes from 192.168.60.5: icmp_seq=2 ttl=63 time=0.118 ms
64 bytes from 192.168.60.5: icmp_seq=3 ttl=63 time=0.112 ms
64 bytes from 192.168.60.5: icmp_seq=4 ttl=63 time=0.186 ms
64 bytes from 192.168.60.5: icmp_seq=5 ttl=63 time=0.184 ms
64 bytes from 192.168.60.5: icmp_seq=6 ttl=63 time=0.115 ms
^C
--- 192.168.60.5 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5125ms
rtt min/avg/max/mdev = 0.112/0.229/0.662/0.195 ms
root@e20fb81e8eb5:/#
```

```
root@3a83319fa079:/# conntrack -L
conntrack v1.4.5 (conntrack-tools): 0 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
icmp     1 29 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=6 src=192.168.60.5 dst=10.9.0.5 type=0 c
ode=0 id=6 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
icmp     1 27 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=6 src=192.168.60.5 dst=10.9.0.5 type=0 c
ode=0 id=6 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
icmp     1 10 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=6 src=192.168.60.5 dst=10.9.0.5 type=0 c
ode=0 id=6 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
icmp     1 2 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=6 src=192.168.60.5 dst=10.9.0.5 type=0 co
de=0 id=6 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
icmp     1 0 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=6 src=192.168.60.5 dst=10.9.0.5 type=0 co
de=0 id=6 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@3a83319fa079:/# conntrack -L
conntrack v1.4.5 (conntrack-tools): 0 flow entries have been shown.
root@3a83319fa079:/#
```

- We see that before the ping commands, there are no entries in the connection tracking table.
- During the ping commands, we see that there are entries in the connection tracking table for the ICMP packets between `10.9.0.5` and `192.168.60.5` .
- After the ping commands, we see that the entries in the connection tracking table for the ICMP packets between `10.9.0.5` and `192.168.60.5` are still present, indicating that the connection tracking mechanism is still tracking the state of the ICMP

connection.
    - When repeatedly running the `conntrack -L` command, we see that the 3rd value in the entry changes from 29 to 0, then after 0 the entry is removed, indicating that the connection tracking mechanism has a timeout for the ICMP connection state after 30 seconds of inactivity.
- To test for UDP connection tracking, we run the `nc -lu 9090` on internal host1 (`192.168.60.5`) and then run netcat on external hostA (`10.9.0.5`) to send a UDP packet to internal host1.
    - 

    - We see that before sending the UDP packet, there are no entries in the connection tracking table.
    - After sending the UDP packet, we see that there are entries in the connection tracking table for the UDP packets between `10.9.0.5` and `192.168.60.5` .
    - When repeatedly running the `conntrack -L` command, we see that the 3rd value in the entry changes from 29 to 0, then after 0 the entry is removed, indicating that the connection tracking mechanism has a timeout for the UDP connection state after 30 seconds of inactivity.
    - Every time we send a new UDP packet from external hostA to internal host1, if the connection tracking entry has expired, a new entry is created in the connection tracking table, if the connection tracking entry is still present, the existing entry is refreshed for another 30 seconds with the new timestamp.
- To test for TCP connection tracking, we run the `nc -l 9090` on internal host1 (`192.168.60.5`) and then run netcat on external hostA (`10.9.0.5`) to send a TCP packet to internal host1.
    - 

    - We see that before sending the TCP packet, there are no entries in the connection tracking table.
    - After sending the TCP packet, we see that there are entries in the connection tracking table for the TCP packets between `10.9.0.5` and `192.168.60.5` .
    - The entries in the connection tracking table for TCP connections do not expire after 30 seconds of inactivity like ICMP and UDP connections. Instead, they remain in the table for a long time while the connection is still established, 432000 seconds (5 days) after the last packet is seen.
    - When the TCP connection is closed (by sending a FIN packet), the connection tracking entry is marked as `TIME_WAIT` state, and it will be removed from the connection tracking table after 120 seconds of inactivity.

Task 3.B: Setting up a stateful firewall

- As outlined by the assignment, we are to implement the same set of rules as in Task 2.C, but now with additional rule that allows internal hosts to access external servers using connection tracking mechanism.
- We recall `eth0` is the internal network interface, and `eth1` is the external network interface.

- These is the outcome we have to achieve:
  i. Outside hosts can only access host1's telnet server on `192.168.60.5/23`, not the other internal hosts' servers.
  ii. Outside hosts cannot access all other internal servers.
  iii. Internal hosts can access all internal servers.
  iv. Internal hosts can access external servers.
- To achieve the desired outcome, we need to setup the following rules on the router's FORWARD chain:
  i. By default, drop all packets in the FORWARD chain.
    - `iptables -P FORWARD DROP`
  ii. In the FORWARD chain, allow SYN TCP packets to internal host1's telnet server on `192.168.60.5/23`, from external network interface `eth1`.
    - `iptables -A FORWARD -i eth1 -p tcp -d 192.168.60.5 --dport 23 --syn -m conntrack --ctstate NEW -j ACCEPT`
  iii. In the FORWARD chain, allow SYN TCP packets from internal hosts to external servers, from internal network interface `eth0`.
    - `iptables -A FORWARD -i eth0 -p tcp --syn -m conntrack --ctstate NEW -j ACCEPT`
  iv. In the FORWARD chain, allow all established and related packets.
    - `iptables -A FORWARD -m conntrack --ctstate ESTABLISHED,RELATED -j ACCEPT`
- We setup the iptables rules as shown:

```
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy DROP)
target     prot opt source               destination
ACCEPT     tcp  --  0.0.0.0/0            192.168.60.5         tcp dpt:23 flags:0x17/0x02 ctstate NEW
ACCEPT     tcp  --  0.0.0.0/0            0.0.0.0/0            tcp flags:0x17/0x02 ctstate NEW
ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0            ctstate RELATED,ESTABLISHED

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

- Then we test the rules:
  i. Outside hosts can only access host1's telnet server on `192.168.60.5/23`, not the other internal hosts' servers.
    - From external hostA (`10.9.0.5`), we can successfully connect to host1's telnet server on `192.168.60.5:23`.

```
root@e20fb81e8eb5:/# telnet 192.168.60.5
Trying 192.168.60.5...
Connected to 192.168.60.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
a73822c4f6a0 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 08:09:02 UTC 2025 from host3-192.168.60.7.net-192.168.60.0 on pts/2
seed@a73822c4f6a0:~$
```

    - We see that the telnet is successful, which is expected since we have allowed SYN TCP packets to internal host1's telnet server from external network in the FORWARD chain, then after the connection is established, the ESTABLISHED packets are allowed by the last rule through the connection tracking mechanism.
  ii. Outside hosts cannot access all other internal servers.
    - From external hostA (`10.9.0.5`), we cannot connect to host2's telnet server on `192.168.60.6:23`.

```
root@e20fb81e8eb5:/# telnet 192.168.60.6
Trying 192.168.60.6...
telnet: Unable to connect to remote host: Connection timed out
```

    - From external hostA (`10.9.0.5`), we cannot connect to host3's telnet server on `192.168.60.7:23`.

```
root@e20fb81e8eb5:/# telnet 192.168.60.7
Trying 192.168.60.7...
```

```
telnet: Unable to connect to remote host: Connection timed out
```

- We see that the telnet attempts time out, which is expected since we have not allowed any SYN TCP packets to internal host2 and host3's telnet servers from external network in the FORWARD chain.

iii. Internal hosts can access all internal servers.

- From internal host1 (`192.168.60.5`), we can connect to host2's telnet server on `192.168.60.6:23` .
  - ```
    root@a73822c4f6a0:/# telnet 192.168.60.6
    Trying 192.168.60.6...
    Connected to 192.168.60.6.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    ace3c5d78bcb login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
     * Management:     https://landscape.canonical.com
     * Support:        https://ubuntu.com/advantage

    This system has been minimized by removing packages and content that are
    not required on a system that users do not log into.

    To restore this content, you can run the 'unminimize' command.
    Last login: Wed Oct 29 08:09:39 UTC 2025 from host3-192.168.60.7.net-192.168.60.0 on pts/2
    ```
- From internal host1 (`192.168.60.5`), we can connect to host3's telnet server on `192.168.60.7:23` .
  - ```
    root@a73822c4f6a0:/# telnet 192.168.60.7
    Trying 192.168.60.7...
    Connected to 192.168.60.7.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    545617a8c239 login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
     * Management:     https://landscape.canonical.com
     * Support:        https://ubuntu.com/advantage

    This system has been minimized by removing packages and content that are
    not required on a system that users do not log into.

    To restore this content, you can run the 'unminimize' command.
    Last login: Wed Oct 29 08:06:31 UTC 2025 from host2-192.168.60.6.net-192.168.60.0 on pts/1
    ```
- From internal host2 (`192.168.60.6`), we can connect to host1's telnet server on `192.168.60.5:23` .
  - ```
    root@ace3c5d78bcb:/# telnet 192.168.60.5
    Trying 192.168.60.5...
    Connected to 192.168.60.5.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    a73822c4f6a0 login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
     * Management:     https://landscape.canonical.com
     * Support:        https://ubuntu.com/advantage

    This system has been minimized by removing packages and content that are
    not required on a system that users do not log into.

    To restore this content, you can run the 'unminimize' command.
    Last login: Wed Oct 29 09:33:52 UTC 2025 from 10.9.0.5 on pts/2
    seed@a73822c4f6a0:~$
    ```
- From internal host2 (`192.168.60.6`), we can connect to host3's telnet server on `192.168.60.7:23` .
  - ```
    root@ace3c5d78bcb:/# telnet 192.168.60.7
    Trying 192.168.60.7...
    Connected to 192.168.60.7.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    545617a8c239 login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
    ```

```
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 09:39:05 UTC 2025 from host1-192.168.60.5.net-192.168.60.0 on pts/2
seed@545617a8c239:~$
```

- From internal host3 (`192.168.60.7`), we can connect to host1's telnet server on `192.168.60.5:23` .

```
root@545617a8c239:/# telnet 192.168.60.5
Trying 192.168.60.5...
Connected to 192.168.60.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
a73822c4f6a0 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 09:39:39 UTC 2025 from host2-192.168.60.6.net-192.168.60.0 on pts/2
seed@a73822c4f6a0:~$
```

- From internal host3 (`192.168.60.7`), we can connect to host2's telnet server on `192.168.60.6:23` .

```
root@545617a8c239:/# telnet 192.168.60.6
Trying 192.168.60.6...
Connected to 192.168.60.6.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
ace3c5d78bcb login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Wed Oct 29 09:38:18 UTC 2025 from host1-192.168.60.5.net-192.168.60.0 on pts/2
seed@ace3c5d78bcb:~$
```

- We see that all the telnet attempts between internal hosts are successful, which is expected since internal hosts are in the same subnet and their traffic does not go through the router and the iptables rules do not affect them.

iv. Internal hosts can access external servers.

- From internal host1 (`192.168.60.5`), we can connect to an telnet server on external hostA (`10.9.0.5`).

```
root@a73822c4f6a0:/# telnet 10.9.0.5
Trying 10.9.0.5...
Connected to 10.9.0.5.
Escape character is '^]'.
Ubuntu 20.04.6 LTS
e20fb81e8eb5 login: seed
Password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
```

```
individual files in /usr/share/doc/*/copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

seed@e20fb81e8eb5:~$
```

- From internal host2 (`192.168.60.6`), we can connect to an telnet server on external hostA (`10.9.0.5`).
  - ```
    root@ace3c5d78bcb:/# telnet 10.9.0.5
    Trying 10.9.0.5...
    Connected to 10.9.0.5.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    e20fb81e8eb5 login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
     * Management:     https://landscape.canonical.com
     * Support:        https://ubuntu.com/advantage

    This system has been minimized by removing packages and content that are
    not required on a system that users do not log into.

    To restore this content, you can run the 'unminimize' command.
    Last login: Wed Oct 29 09:43:49 UTC 2025 from 192.168.60.5 on pts/3
    ```
- From internal host3 (`192.168.60.7`), we can connect to an telnet server on external hostA (`10.9.0.5`).
  - ```
    root@545617a8c239:/# telnet 10.9.0.5
    Trying 10.9.0.5...
    Connected to 10.9.0.5.
    Escape character is '^]'.
    Ubuntu 20.04.6 LTS
    e20fb81e8eb5 login: seed
    Password:
    Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.15.0-160-generic aarch64)

     * Documentation:  https://help.ubuntu.com
     * Management:     https://landscape.canonical.com
     * Support:        https://ubuntu.com/advantage

    This system has been minimized by removing packages and content that are
    not required on a system that users do not log into.

    To restore this content, you can run the 'unminimize' command.
    Last login: Wed Oct 29 09:45:33 UTC 2025 from 192.168.60.6 on pts/3
    ```
- We see that the telnet attempts are successful, which is expected since we have allowed SYN TCP packets from internal network on `eth0` to external network on `eth1` in the FORWARD chain, then after the connection is established, the ESTABLISHED packets are allowed by the last rule through the connection tracking mechanism.

- We can achieve the same result with a stateless firewall using the following iptable rules:

```
iptables -P FORWARD DROP
# Allow external → host1 telnet (SYN)
iptables -A FORWARD -i eth1 -p tcp -d 192.168.60.5 --dport 23 --syn -j ACCEPT
# Allow host1 telnet → external (return traffic: SYN-ACK, ACK, data, FIN)
iptables -A FORWARD -i eth0 -p tcp -s 192.168.60.5 --sport 23 -j ACCEPT
# Allow external → host1 telnet (ACK, data, FIN for established connection)
iptables -A FORWARD -i eth1 -p tcp -d 192.168.60.5 --dport 23 -j ACCEPT

# Allow internal → external (NEW connections)
iptables -A FORWARD -i eth0 -o eth1 -p tcp --syn -j ACCEPT
# Allow external → internal (return traffic)
iptables -A FORWARD -i eth1 -o eth0 -p tcp -j ACCEPT
```

- The advantage of using a stateful firewall:
  i. **Simpler rules** - Fewer rules needed, more concise
  ii. **Better security** - Automatically tracks connection state, only allows legitimate return traffic
  iii. **Protection against spoofing** - Can't just send packets with arbitrary source ports; they must belong to actual established

connections

iv. **Handles complex protocols** - RELATED state helps with protocols like FTP that open secondary connections

v. **Easier to maintain** - Adding new services requires fewer rules

- The disadvantage of using a stateful firewall:
  i. **Memory overhead** - Must maintain connection tracking table in kernel memory
  ii. **Performance impact** - CPU cycles needed to track every connection
  iii. **Scalability issues** - Connection table can fill up on high-traffic routers
  iv. **DoS vulnerability** - Attackers can exhaust connection tracking table with SYN floods
  v. **State complexity** - State can desynchronize (e.g., router reboot loses all connection state)
- The advantages of using a stateless firewall:
  i. **No memory overhead** - Doesn't need to track connections
  ii. **Better performance** - Faster packet processing (just match rules)
  iii. **Better scalability** - Can handle more simultaneous connections
  iv. **No state synchronization issues** - Router reboot doesn't break existing connections
  v. **More predictable** - Each packet evaluated independently
- The disadvantages of using a stateless firewall:
  i. **Weaker security** - Must allow broad return traffic (any packet from sport 23)
    - Attacker could craft packets with `--sport 23` to bypass firewall
    - Example: External attacker could send packets claiming to be from port 23 to any internal port
  ii. **More complex rules** - Need explicit rules for both directions of traffic
  iii. **Harder to maintain** - Each service needs multiple rules (outbound SYN, inbound return, etc.)
  iv. **Can't handle asymmetric routing well** - Must allow any return traffic matching source/dest ports
  v. **Vulnerable to port scanning** - Easier for attackers to probe for open ports
- With this, we have successfully setup the iptables rules to achieve the desired outcome using a stateful firewall.
- cleaning up the iptables rules as per the assignment instructions

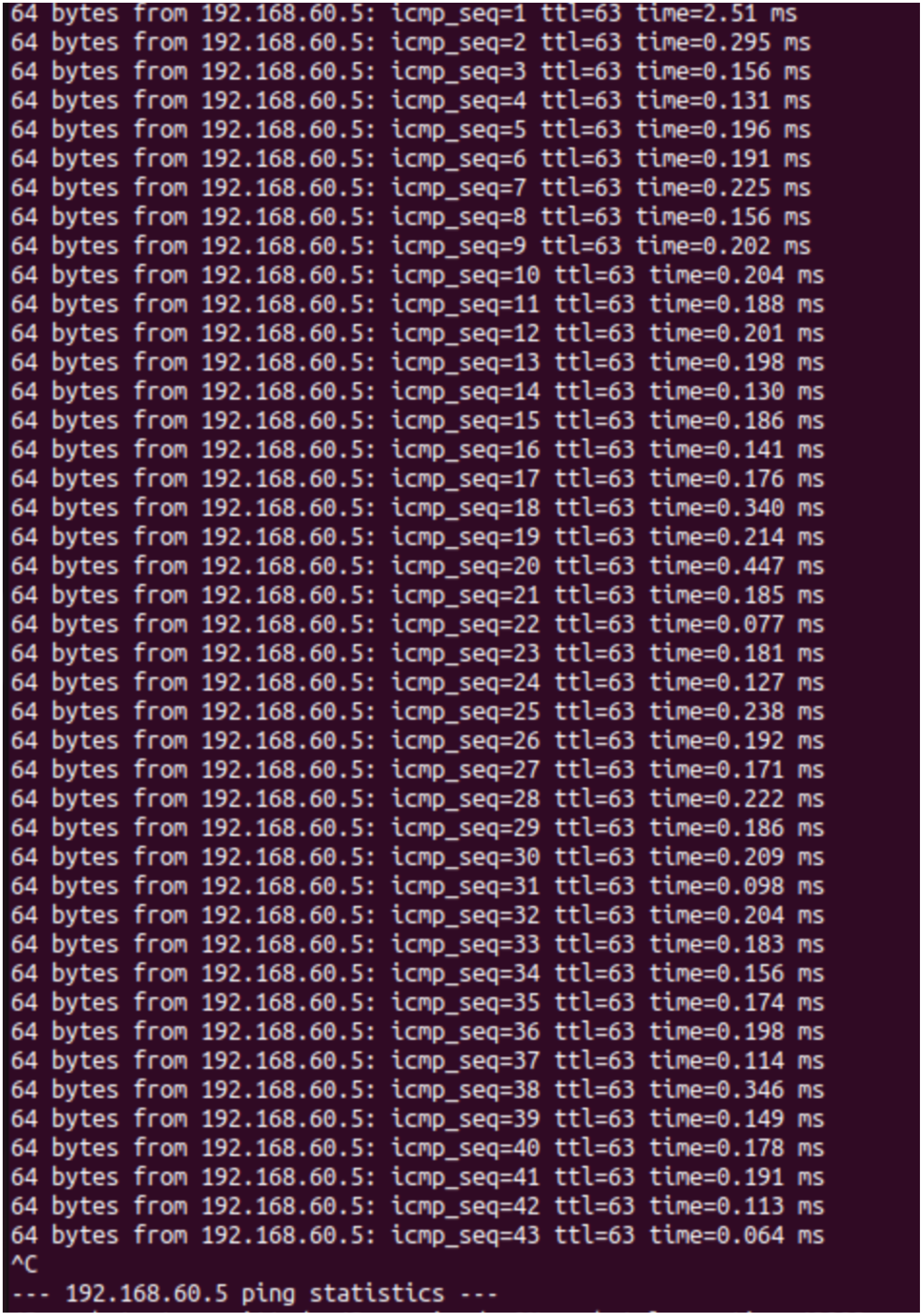
```
iptables -F
iptables -P FORWARD ACCEPT
```

Task 4 - Limiting Network Traffic

1. Based on the instructions in the assignment, we run the following commands first
   - `iptables -A FORWARD -s 10.9.0.5 -m limit --limit 10/minute --limit-burst 5 -j ACCEPT`
   - ```
     root@3a83319fa079:/# iptables -A FORWARD -s 10.9.0.5 -m limit \
     > --limit 10/minute --limit-burst 5 -j ACCEPT
     root@3a83319fa079:/# iptable -L -n
     bash: iptable: command not found
     root@3a83319fa079:/# iptables -L -n
     Chain INPUT (policy ACCEPT)
     target     prot opt source               destination

     Chain FORWARD (policy ACCEPT)
     target     prot opt source               destination
     ACCEPT     all  --  10.9.0.5             0.0.0.0/0            limit: avg 10/min burst 5

     Chain OUTPUT (policy ACCEPT)
     target     prot opt source               destination
     root@3a83319fa079:/#
     ```
2. Then we run a ping host1 (`192.168.60.5`) from hostA (`10.9.0.5`)
   - ```
     root@e20fb81e8eb5:/# ping 192.168.60.5
     PING 192.168.60.5 (192.168.60.5) 56(84) bytes of data.
     ```


64 bytes from 192.168.60.5: icmp_seq=1 ttl=63 time=2.51 ms
64 bytes from 192.168.60.5: icmp_seq=2 ttl=63 time=0.295 ms
64 bytes from 192.168.60.5: icmp_seq=3 ttl=63 time=0.156 ms
64 bytes from 192.168.60.5: icmp_seq=4 ttl=63 time=0.131 ms
64 bytes from 192.168.60.5: icmp_seq=5 ttl=63 time=0.196 ms
64 bytes from 192.168.60.5: icmp_seq=6 ttl=63 time=0.191 ms
64 bytes from 192.168.60.5: icmp_seq=7 ttl=63 time=0.225 ms
64 bytes from 192.168.60.5: icmp_seq=8 ttl=63 time=0.156 ms
64 bytes from 192.168.60.5: icmp_seq=9 ttl=63 time=0.202 ms
64 bytes from 192.168.60.5: icmp_seq=10 ttl=63 time=0.204 ms
64 bytes from 192.168.60.5: icmp_seq=11 ttl=63 time=0.188 ms
64 bytes from 192.168.60.5: icmp_seq=12 ttl=63 time=0.201 ms
64 bytes from 192.168.60.5: icmp_seq=13 ttl=63 time=0.198 ms
64 bytes from 192.168.60.5: icmp_seq=14 ttl=63 time=0.130 ms
64 bytes from 192.168.60.5: icmp_seq=15 ttl=63 time=0.186 ms
64 bytes from 192.168.60.5: icmp_seq=16 ttl=63 time=0.141 ms
64 bytes from 192.168.60.5: icmp_seq=17 ttl=63 time=0.176 ms
64 bytes from 192.168.60.5: icmp_seq=18 ttl=63 time=0.340 ms
64 bytes from 192.168.60.5: icmp_seq=19 ttl=63 time=0.214 ms
64 bytes from 192.168.60.5: icmp_seq=20 ttl=63 time=0.447 ms
64 bytes from 192.168.60.5: icmp_seq=21 ttl=63 time=0.185 ms
64 bytes from 192.168.60.5: icmp_seq=22 ttl=63 time=0.077 ms
64 bytes from 192.168.60.5: icmp_seq=23 ttl=63 time=0.181 ms
64 bytes from 192.168.60.5: icmp_seq=24 ttl=63 time=0.127 ms
64 bytes from 192.168.60.5: icmp_seq=25 ttl=63 time=0.238 ms
64 bytes from 192.168.60.5: icmp_seq=26 ttl=63 time=0.192 ms
64 bytes from 192.168.60.5: icmp_seq=27 ttl=63 time=0.171 ms
64 bytes from 192.168.60.5: icmp_seq=28 ttl=63 time=0.222 ms
64 bytes from 192.168.60.5: icmp_seq=29 ttl=63 time=0.186 ms
64 bytes from 192.168.60.5: icmp_seq=30 ttl=63 time=0.209 ms
64 bytes from 192.168.60.5: icmp_seq=31 ttl=63 time=0.098 ms
64 bytes from 192.168.60.5: icmp_seq=32 ttl=63 time=0.204 ms
64 bytes from 192.168.60.5: icmp_seq=33 ttl=63 time=0.183 ms
64 bytes from 192.168.60.5: icmp_seq=34 ttl=63 time=0.156 ms
64 bytes from 192.168.60.5: icmp_seq=35 ttl=63 time=0.174 ms
64 bytes from 192.168.60.5: icmp_seq=36 ttl=63 time=0.198 ms
64 bytes from 192.168.60.5: icmp_seq=37 ttl=63 time=0.114 ms
64 bytes from 192.168.60.5: icmp_seq=38 ttl=63 time=0.346 ms
64 bytes from 192.168.60.5: icmp_seq=39 ttl=63 time=0.149 ms
64 bytes from 192.168.60.5: icmp_seq=40 ttl=63 time=0.178 ms
64 bytes from 192.168.60.5: icmp_seq=41 ttl=63 time=0.191 ms
64 bytes from 192.168.60.5: icmp_seq=42 ttl=63 time=0.113 ms
64 bytes from 192.168.60.5: icmp_seq=43 ttl=63 time=0.064 ms
^C
--- 192.168.60.5 ping statistics ---

```
43 packets transmitted, 43 received, 0% packet loss, time 42982ms
rtt min/avg/max/mdev = 0.064/0.242/2.506/0.355 ms
root@e20fb81e8eb5:/#
```

- We see that the ping is successful and sequential pings are received and replied to, even past the rate limit.
- This is likely because the default policy of the FORWARD chain was set to ACCEPT, so all packets, even those exceeding the rate limit, are accepted by default.

3. Then we add rule 2 as per the assignment instructions

- `iptables -A FORWARD -s 10.9.0.5 -j DROP`

-

```
root@3a83319fa079:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination
ACCEPT     all  --  10.9.0.5            0.0.0.0/0            limit: avg 10/min burst 5
DROP       all  --  10.9.0.5            0.0.0.0/0

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@3a83319fa079:/#
```

4. Then we run a ping host1 (`192.168.60.5`) from hostA (`10.9.0.5`) again

- ```
  root@e20fb81e8eb5:/# ping 192.168.60.5
  PING 192.168.60.5 (192.168.60.5) 56(84) bytes of data.
  64 bytes from 192.168.60.5: icmp_seq=1 ttl=63 time=1.12 ms
  64 bytes from 192.168.60.5: icmp_seq=2 ttl=63 time=0.160 ms
  64 bytes from 192.168.60.5: icmp_seq=3 ttl=63 time=0.177 ms
  64 bytes from 192.168.60.5: icmp_seq=4 ttl=63 time=0.109 ms
  64 bytes from 192.168.60.5: icmp_seq=5 ttl=63 time=0.189 ms
  64 bytes from 192.168.60.5: icmp_seq=7 ttl=63 time=0.208 ms
  64 bytes from 192.168.60.5: icmp_seq=13 ttl=63 time=0.218 ms
  64 bytes from 192.168.60.5: icmp_seq=19 ttl=63 time=0.628 ms
  64 bytes from 192.168.60.5: icmp_seq=25 ttl=63 time=0.195 ms
  64 bytes from 192.168.60.5: icmp_seq=31 ttl=63 time=0.220 ms
  64 bytes from 192.168.60.5: icmp_seq=37 ttl=63 time=0.186 ms
  64 bytes from 192.168.60.5: icmp_seq=43 ttl=63 time=0.393 ms
  64 bytes from 192.168.60.5: icmp_seq=48 ttl=63 time=0.214 ms
  64 bytes from 192.168.60.5: icmp_seq=54 ttl=63 time=0.195 ms
  64 bytes from 192.168.60.5: icmp_seq=60 ttl=63 time=0.210 ms
  64 bytes from 192.168.60.5: icmp_seq=66 ttl=63 time=0.200 ms
  64 bytes from 192.168.60.5: icmp_seq=72 ttl=63 time=0.193 ms
  ^C
  --- 192.168.60.5 ping statistics ---
  77 packets transmitted, 17 received, 77.9221% packet loss, time 77768ms
  rtt min/avg/max/mdev = 0.109/0.283/1.122/0.238 ms
  root@e20fb81e8eb5:/#
  ```
- This time we see that the ping requests if the first 5 pings are replied to sequentially and none are dropped, since the rule allows a burst of 5 packets.
- After the first 5 pings, subsequent pings are dropped as expected, since they exceed the rate limit of 10 pings per minute, and we implemented rule 2 to drop all other packets from `10.9.0.5` that are exceeding the rate limit.

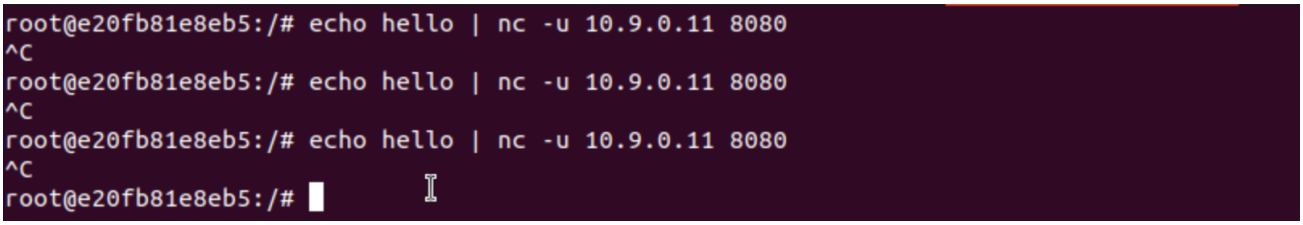
5. Yes the 2nd rule is necessary to enforce the rate limiting effectively.
   - The first rule alone only specifies the rate limit but does not drop packets that exceed the limit.
   - Without the second rule, packets exceeding the limit would still be accepted by default if the default policy is ACCEPT.
  ```

- The second rule ensures that any packets from `10.9.0.5` that exceed the rate limit are dropped.

Task 5 - Load Balancing

- As instructed by the assignment, we first start the netcat server on all three internal hosts on port 8080 using the following command:
  - `nc -luk 8080`
- Then we setup the iptables rules on the router to achieve load balancing using the nth mode with the following commands such that incoming UDP traffic on port 8080 is distributed evenly among the three internal hosts:

```
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode nth --every 3 --packet 0 -j DNAT --to
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode nth --every 2 --packet 0 -j DNAT --to
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode nth --every 1 --packet 0 -j DNAT --to
```

  - Then when we use the `echo hello | nc -u 10.9.0.11 8080` command from external hostA (`10.9.0.5`) 3 times, we see that the UDP packets are distributed evenly among the three internal hosts as shown as each internal host receives one packet each in a round-robin fashion:
    - 

  - Host 1 (`192.168.60.5`) receives the 1st packet
    - 

  - Host 2 (`192.168.60.6`) receives the 2nd packet,
    - 

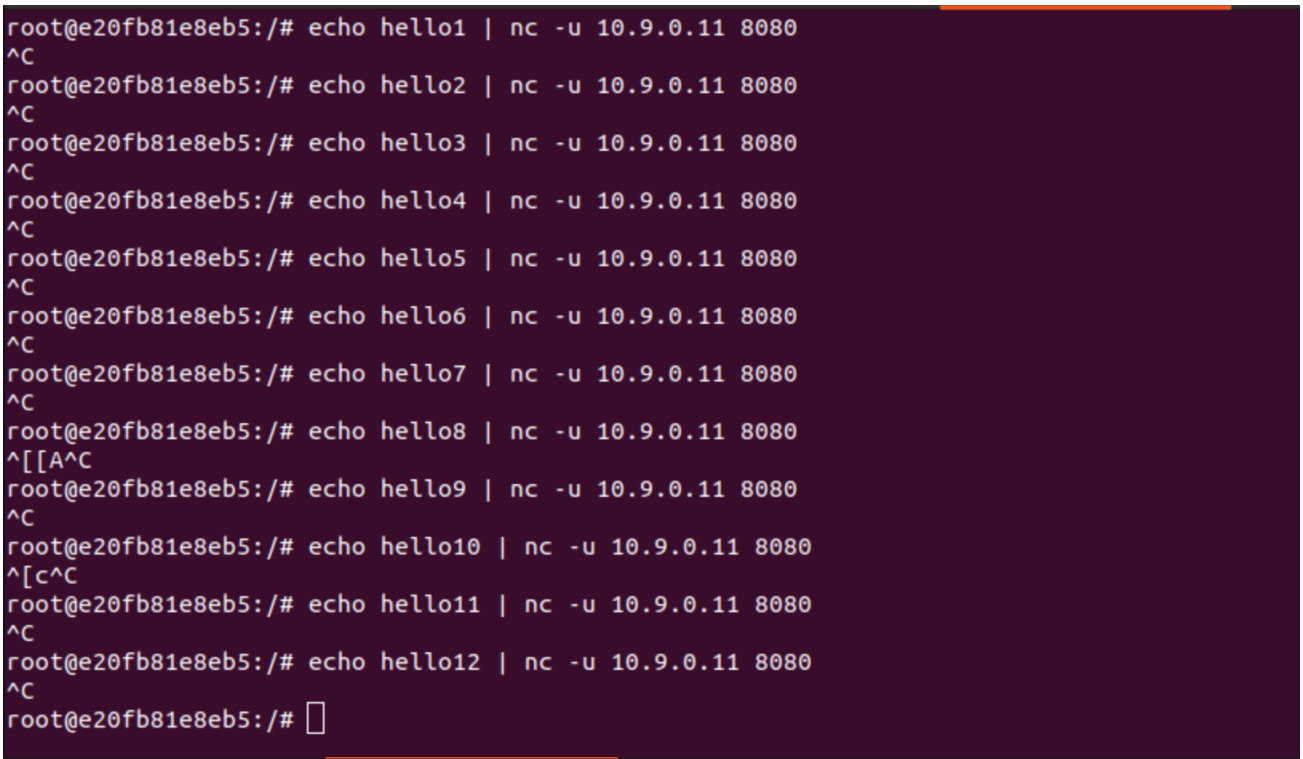
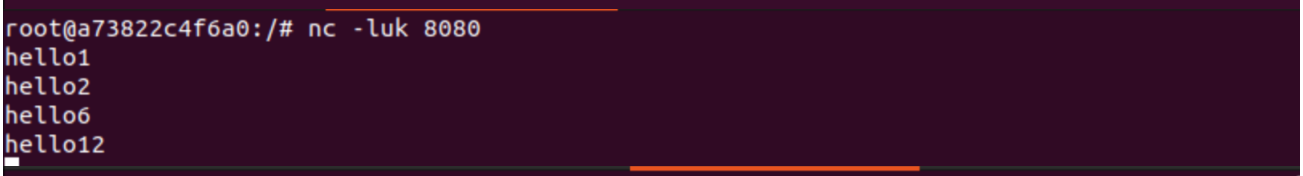
  - Host 3 (`192.168.60.7`) receives the 3rd packet.
    - 

  - This works because as the `statistic` module processes each incoming packet, it uses the `--every` parameter to determine the frequency of packets that match each rule and each rule is evaluated in order.
    - The first rule uses `--every 3` to match every 1/3 packets to be sent to host1, leaving the remaining 2/3 packets to be evaluated by the next rules.
    - The second rule uses `--every 2` to match every 1/2 of the remaining packets (which is 1/3 of the original packets) to be sent to host2, leaving the remaining 1/3 packets to be evaluated by the last rule.
    - The last rule uses `--every 1` to match all remaining packets (which is 1/3 of the original packets) to be sent to host3.
  - With this, we have successfully setup load balancing using iptables to distribute incoming UDP traffic on port 8080 evenly among the three internal hosts.
  - cleaning up the iptables rules as per the assignment instructions

```
iptables -t nat -F
```

- Then now we want to use the random mode to achieve the same load balancing effect.
  - We setup the iptable rules on the router using the following commands:

```
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode random --probability 0.333 -j DNA
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode random --probability 0.5 -j DNAT
iptables -t nat -A PREROUTING -p udp --dport 8080 -m statistic --mode random --probability 1 -j DNAT --
```

- Then when we use the `echo hello | nc -u 10.9.0.11 8080` command from external hostA (`10.9.0.5`) 12 times, we see that the UDP packets are distributed roughly evenly among the three internal hosts, where Host 1 receives 4 packets, Host 2 receives 5 packets, and Host 3 receives 3 packets:
  - 
    ```
    root@e20fb81e8eb5:/# echo hello1 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello2 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello3 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello4 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello5 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello6 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello7 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello8 | nc -u 10.9.0.11 8080
    ^[[A^C
    root@e20fb81e8eb5:/# echo hello9 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello10 | nc -u 10.9.0.11 8080
    ^[c^C
    root@e20fb81e8eb5:/# echo hello11 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/# echo hello12 | nc -u 10.9.0.11 8080
    ^C
    root@e20fb81e8eb5:/#
    ```
  - 
    ```
    root@a73822c4f6a0:/# nc -luk 8080
    hello1
    hello2
    hello6
    hello12
    ```
  - 
    ```
    root@ace3c5d78bcb:/# nc -luk 8080
    hello7
    hello8
    hello9
    hello10
    hello11
    ```
  - 
    ```
    root@545617a8c239:/# nc -luk 8080
    hello3
    hello4
    hello5
    ```
- This works because as the `statistic` module processes each incoming packet, it uses the `--probability` parameter to determine the likelihood of packets that match each rule and each rule is evaluated in order.
  - The first rule uses `--probability 0.333` to match approximately 1/3 of the packets to be sent to host1, leaving the remaining packets to be evaluated by the next rules.
  - The second rule uses `--probability 0.5` to match approximately 1/2 of the remaining packets (which is approximately 1/3 of the original packets) to be sent to host2, leaving the remaining packets to be evaluated by the last rule.
  - The last rule uses `--probability 1` to match all remaining packets (which is approximately 1/3 of the original packets) to be sent to host3.
- With this, we have successfully setup load balancing using iptables in random mode to distribute incoming UDP traffic on port 8080 roughly evenly among the three internal hosts.