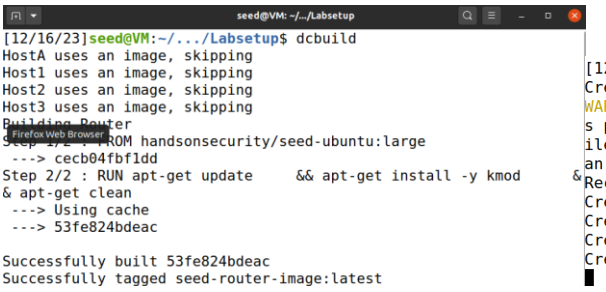
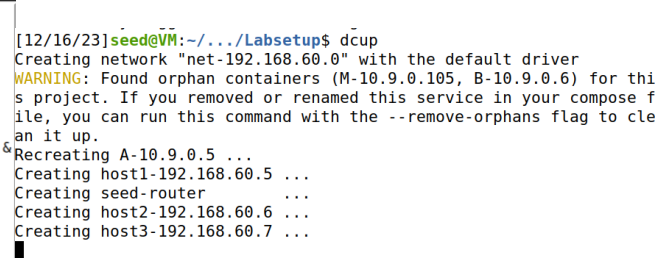
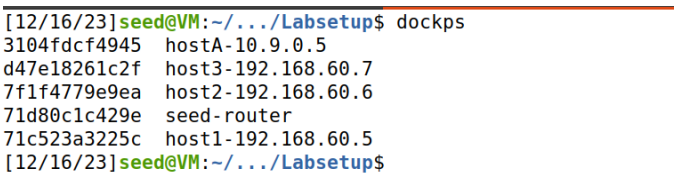
Lab 6-Firewall

The setup files from seed labs were downloaded and the docker containers were built and run.







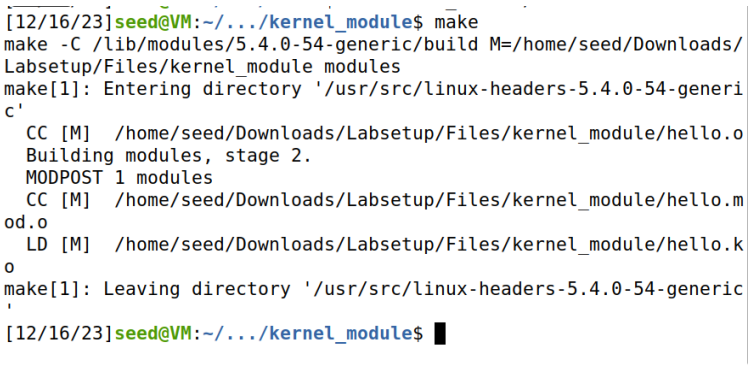
Task 1: Implementing a Simple Firewall

The goal of this lab is to implement a packet-filtering firewall that inspects incoming and outgoing packets, enforcing administrator-defined policies within the Linux kernel. Traditionally, kernel modification and rebuilding were required for such implementations, but modern Linux systems offer alternatives, namely Loadable Kernel Modules (LKMs) and Netfilter.

1.1 implementing a simple kernel module in hello.ko

1. Created Makefile:

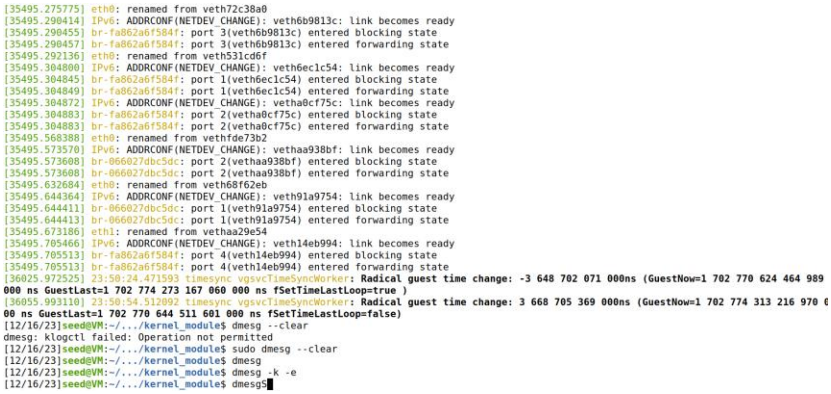
Developed a Makefile to compile the LKM, using the provided Makefile template (included in the lab setup files).



After running the make file we can see that the kernel module is built.

Cleared out the messages in kernel module using dmesg

```
[12/16/23]seed@VM:~/.../kernel_module$ sudo dmesg --clear
[12/16/23]seed@VM:~/.../kernel_module$ dmesg
[12/16/23]seed@VM:~/.../kernel_module$ dmesg -k -e
[12/16/23]seed@VM:~/.../kernel_module$ dmesg
```



Then the module is checked to capture messages by writing them with below command

```
[12/16/23]seed@VM:~/.../kernel_module$ dmesg -k -w
```

2. Compiled and Loaded:

The following commands were used to ensure proper running of kernel module:

1. On running hello.ko the kernel should output hello world message as shown below:

```
video                  49152  0
[12/16/23]seed@VM:~/.../kernel_module$ sudo insmod hello.ko
[12/16/23]seed@VM:~/.../kernel_module$ dmesg -k -w
[37561.853691] Hello World!
[12/16/23]seed@VM:~/.../kernel_module$ lsmod | grep -i hello
hello                  16384  0
[12/16/23]seed@VM:~/.../kernel_module$
```

2. To remove it from the module and then check the messages printed the following commands were used:

```
[12/16/23]seed@VM:~/.../kernel_module$ sudo  rmmod hello
[12/16/23]seed@VM:~/.../kernel_module$ dmesg

[37561.853691] Hello World!
[37789.753326] Bye-bye World!.
[12/16/23]seed@VM:~/.../kernel_module$
[12/16/23]seed@VM:~/.../kernel_module$ S
```

Results:

Upon loading the module, "Hello World!" was printed to the system logs.
After removing the module, "Bye-bye World!" was printed.
Verified module presence with `lsmod | grep hello`.
Viewed detailed module information with `modinfo hello.ko`.

1.2 Implement simple firewall using Netfilter

1. Hooking in Netfilter

```
[12/16/23]seed@VM:~/.../packet_filter$ ping www.example.com
PING www.example.com (93.184.216.34) 56(84) bytes of data.
64 bytes from 93.184.216.34 (93.184.216.34): icmp_seq=1 ttl=49 time
=23.5 ms
64 bytes from 93.184.216.34 (93.184.216.34): icmp_seq=2 ttl=49 time
=6.17 ms
64 bytes from 93.184.216.34 (93.184.216.34): icmp_seq=3 ttl=49 time
=13.8 ms
^C
--- www.example.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2012ms
rtt min/avg/max/mdev = 6.170/14.513/23.523/7.099 ms
[12/16/23]seed@VM:~/.../packet_filter$
```

```
[12/16/23]seed@VM:~/.../packet_filter$ dig @8.8.8.8 www.example.com

; <<>> DiG 9.16.1-Ubuntu <<>> @8.8.8.8 www.example.com
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 58291
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONA
L: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;www.example.com.               IN      A

;; ANSWER SECTION:
www.example.com.        16090   IN      A       93.184.216.34

;; Query time: 8 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Sat Dec 16 21:18:04 EST 2023
;; MSG SIZE  rcvd: 60

[12/16/23]seed@VM:~/.../packet_filter$
```

Able to ping example.com

```
[12/16/23]seed@VM:~/.../packet_filter$ make
make -C /lib/modules/5.4.0-54-generic/build M=/home/seed/Downloads/
Labsetup/Files/packet_filter modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-54-generi
c'
  CC [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedFil
ter.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedFil
ter.mod.o
  LD [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedFil
ter.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-54-generic
'
[12/16/23]seed@VM:~/.../packet_filter$
```

Lookout for registering filters indicating the module is built properly

```
[12/16/23]seed@VM:~/.../packet_filter$ ls
Makefile        seedFilter.c    seedFilter.mod.c
modules.order   seedFilter.ko   seedFilter.mod.o
Module.symvers  seedFilter.mod  seedFilter.o
[12/16/23]seed@VM:~/.../packet_filter$ sudo insmod seedFilter.ko
[12/16/23]seed@VM:~/.../packet_filter$ lsmod | grep -i seed
seedFilter             16384  0
[12/16/23]seed@VM:~/.../packet_filter$ dmesg -k -w
[37561.853691] Hello World!
[37789.753326] Bye-bye World!.
[40589.576298] Hello World!
[40609.523746] Bye-bye World!.
[41392.759077] Registering filters.
[41398.140768] *** LOCAL_OUT
[41398.140864]     10.0.2.15  --> 91.189.91.157 (UDP)
[41408.145093] *** LOCAL_OUT
```

```
[12/16/23]seed@VM:~/.../packet_filter$ dig @8.8.8.8 www.example.com

; <<>> DiG 9.16.1-Ubuntu <<>> @8.8.8.8 www.example.com
; (1 server found)
;; global options: +cmd
;; connection timed out; no servers could be reached
```

seed@VM: ~/.../packet_filter

seed@VM: ~/.../Labsetup | seed@VM: ~/.../packet_filter | seed@VM: ~/.../kernel_module

```
[41637.154349] *** Dropping 8.8.8.8 (UDP), port 53
[41638.234928] *** LOCAL_OUT
[41638.234931]     10.0.2.15  --> 91.189.91.157 (UDP)
[41641.047796] *** LOCAL_OUT
[41641.047801]     127.0.0.1  --> 127.0.0.53 (UDP)
[41641.054600] *** LOCAL_OUT
[41641.054603]     10.0.2.15  --> 128.122.0.71 (UDP)
[41641.069777] *** LOCAL_OUT
[41641.069779]     127.0.0.53  --> 127.0.0.1 (UDP)
[41642.143827] *** LOCAL_OUT
[41642.143830]     10.0.2.15  --> 8.8.8.8 (UDP)
[41642.143848] *** Dropping 8.8.8.8 (UDP), port 53
[41647.148452] *** LOCAL_OUT
[41647.148454]     10.0.2.15  --> 8.8.8.8 (UDP)
[41647.148468] *** Dropping 8.8.8.8 (UDP), port 53
[41648.240844] *** LOCAL_OUT
[41648.240846]     10.0.2.15  --> 91.189.91.157 (UDP)
[41658.256736] *** LOCAL_OUT
[41658.256784]     10.0.2.15  --> 91.189.91.157 (UDP)
```

```
[12/16/23]seed@VM:~/.../packet_filter$ sudo rmmod seedFilter
[12/16/23]seed@VM:~/.../packet_filter$
```

seed@VM: ~/.../kernel_module

seed@VM: ~/.../Labsetup | seed@VM: ~/.../packet_filter | seed@VM: ~/.../kernel_module

```
[41678.257979]     10.0.2.15  --> 91.189.91.157 (UDP)
[41688.259106] *** LOCAL_OUT
[41688.259108]     10.0.2.15  --> 91.189.91.157 (UDP)
[41698.264070] *** LOCAL_OUT
[41698.264073]     10.0.2.15  --> 91.189.91.157 (UDP)
[41708.265694] *** LOCAL_OUT
[41708.265696]     10.0.2.15  --> 91.189.91.157 (UDP)
[41718.266395] *** LOCAL_OUT
[41718.266399]     10.0.2.15  --> 91.189.91.157 (UDP)
[41728.295048] *** LOCAL_OUT
[41728.295050]     10.0.2.15  --> 91.189.91.157 (UDP)
[41738.297121] *** LOCAL_OUT
[41738.297123]     10.0.2.15  --> 91.189.91.157 (UDP)
[41748.299722] *** LOCAL_OUT
[41748.299723]     10.0.2.15  --> 91.189.91.157 (UDP)
[41758.302009] *** LOCAL_OUT
[41758.302012]     10.0.2.15  --> 91.189.91.157 (UDP)
[41768.303037] *** LOCAL_OUT
[41768.303039]     10.0.2.15  --> 91.189.91.157 (UDP)
[41771.250530] The filters are being removed.
```

SeedFilters are being removed from the module.

Contents from seedFilter were copied to seedPrint file and worked with the file for next steps.

All hook functions are written from the structure and in the seedFilter file are 5 are added at necessary function parameters and all the hook functions are implemented using make function as shown in the images:

```
// NF_INET_PRE_ROUTING
   hook1.hook = printInfo;
   hook1.hooknum = NF_INET_PRE_ROUTING;
   hook1.pf = PF_INET;
   hook1.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook1);
// NF_INET_LOCAL_IN
   hook2.hook = printInfo;
   hook2.hooknum = NF_INET_LOCAL_IN;
   hook2.pf = PF_INET;
   hook2.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook2);
// NF_INET_FORWARD
   hook3.hook = printInfo;
   hook3.hooknum = NF_INET_FORWARD;
   hook3.pf = PF_INET;
   hook3.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook3);
// NF_INET_LOCAL_OUT
   hook4.hook = printInfo;
   hook4.hooknum = NF_INET_LOCAL_OUT;
   hook4.pf = PF_INET;
   hook4.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook4);
// NF_INET_POST_ROUTING
   hook5.hook = printInfo;
   hook5.hooknum = NF_INET_POST_ROUTING;
   hook5.pf = PF_INET;
   hook5.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook5);

   return 0;
}

void removeFilter(void) {
   printk(KERN_INFO "The filters are being removed.\n");
   nf_unregister_net_hook(&init_net, &hook1);
   nf_unregister_net_hook(&init_net, &hook2);
   nf_unregister_net_hook(&init_net, &hook3);
   nf_unregister_net_hook(&init_net, &hook4);
   nf_unregister_net_hook(&init_net, &hook5);
}
```

```
[12/16/23]seed@VM:~/.../packet_filter$ make
make -C /lib/modules/5.4.0-54-generic/build M=/home/seed/Downloads/Labsetup/File
s/packet_filter modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-54-generic'
  Building modules, stage 2.
  MODPOST 0 modules
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-54-generic'
```

Modules were built and loaded into the kernel module which can be seen from kernel messages:

```
[12/16/23]seed@VM:~/.../packet_filter$ make
make -C /lib/modules/5.4.0-54-generic/build M=/home/seed/Downloads/Labsetup/File
s/packet_filter modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-54-generic'
  Building modules, stage 2.
  MODPOST 1 modules
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-54-generic'
[12/16/23]seed@VM:~/.../packet_filter$ sudo insmod seedPrint.ko
[12/16/23]seed@VM:~/.../packet_filter$ SS
[43930.964474] seedPrint: Registering filters.
[43938.943237] *** LOCAL_OUT
[43938.943241]     10.0.2.15  --> 91.189.91.157 (UDP)
```

We can cross verify using dig on 8.8.8.8 example.com

```
[12/16/23]seed@VM:~/.../packet_filter$ dig @8.8.8.8 www.example.com

; <<>> DiG 9.16.1-Ubuntu <<>> @8.8.8.8 www.example.com
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 48205
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;www.example.com.               IN      A

;; ANSWER SECTION:
www.example.com.        18843   IN      A       93.184.216.34

;; Query time: 8 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Sat Dec 16 22:05:22 EST 2023
;; MSG SIZE  rcvd: 60

[12/16/23]seed@VM:~/.../packet_filter$
```

```
seed@VM: ~/.../kernel_module
seed@VM: ~/.../Labsetup   seed@VM: ~/.../packet_filter   seed@VM: ~/...
[44065.044172]     127.0.0.1  --> 127.0.0.1 (UDP)
[44065.044183] *** POST_ROUTING
[44065.044209]     127.0.0.1  --> 127.0.0.1 (UDP)
[44065.044223] *** PRE_ROUTING
[44065.044223]     127.0.0.1  --> 127.0.0.1 (UDP)
[44065.044225] *** LOCAL_IN
[44065.044225]     127.0.0.1  --> 127.0.0.1 (UDP)
[44065.071683] *** LOCAL_OUT
[44065.071685]     10.0.2.15  --> 8.8.8.8 (UDP)
[44065.071697] *** POST_ROUTING
[44065.071697]     10.0.2.15  --> 8.8.8.8 (UDP)
[44065.080281] *** PRE_ROUTING
[44065.080283]     8.8.8.8  --> 10.0.2.15 (UDP)
[44065.080297] *** LOCAL_IN
[44065.080297]     8.8.8.8  --> 10.0.2.15 (UDP)
[44068.975050] *** LOCAL_OUT
[44068.975054]     10.0.2.15  --> 91.189.91.157 (UDP)
[44068.975069] *** POST_ROUTING
[44068.975070]     10.0.2.15  --> 91.189.91.157 (UDP)
[44068.985336] *** PRE_ROUTING
[44068.985338]     91.189.91.157  --> 10.0.2.15 (UDP)
```

2.Once the seedPrint.ko module is built on checking that terminal we see different hooks are invoked at different intervals:

```
[43930.964474] seedPrint: Registering filters.
[43938.943237] *** LOCAL_OUT
[43938.943241]     10.0.2.15  --> 91.189.91.157 (UDP)
[43938.943255] *** POST_ROUTING
[43938.943256]     10.0.2.15  --> 91.189.91.157 (UDP)
[43938.956217] *** PRE_ROUTING
[43938.956220]     91.189.91.157  --> 10.0.2.15 (UDP)
[43938.956235] *** LOCAL_IN
[43938.956236]     91.189.91.157  --> 10.0.2.15 (UDP)
[43948.955099] *** LOCAL_OUT
[43948.955103]     10.0.2.15  --> 91.189.91.157 (UDP)
[43948.955123] *** POST_ROUTING
[43948.955124]     10.0.2.15  --> 91.189.91.157 (UDP)
[43948.968293] *** PRE_ROUTING
[43948.968338]     91.189.91.157  --> 10.0.2.15 (UDP)
[43948.968360] *** LOCAL_IN
[43948.968361]     91.189.91.157  --> 10.0.2.15 (UDP)
[43952.289920] *** LOCAL_OUT
[43952.289926]     10.0.2.15  --> 128.122.0.71 (UDP)
[43952.289949] *** POST_ROUTING
[43952.289950]     10.0.2.15  --> 128.122.0.71 (UDP)
[43952.313820] *** PRE_ROUTING
[43952.314386]     128.122.0.71  --> 10.0.2.15 (UDP)
[43952.314595] *** LOCAL_IN
[43952.314783]     128.122.0.71  --> 10.0.2.15 (UDP)
[43952.441360] *** LOCAL_OUT
[43952.441365]     10.0.2.15  --> 35.224.170.84 (TCP)
[43952.442472] *** POST_ROUTING
[43952.442476]     10.0.2.15  --> 35.224.170.84 (TCP)
[43952.485013] *** PRE_ROUTING
[43952.485016]     35.224.170.84  --> 10.0.2.15 (TCP)
```

On clearly understanding the process we find that:

1. NF_INET_PRE_ROUTING:
   Invoked just before routing. It can be used to alter the packet before any routing decisions are made.
2. NF_INET_LOCAL_IN:
   Invoked for packets destined to the local machine. It is called after routing, just before the packet is delivered to the local socket.
3. NF_INET_FORWARD:
   Invoked for packets that are being forwarded to another destination. It occurs after routing and before the packet is forwarded.
4. NF_INET_LOCAL_OUT:
   Invoked for locally generated packets before routing. It allows modification of locally generated packets before they are sent out.
5. NF_INET_POST_ROUTING:

Invoked after the routing decision has been made and before the packet is sent out. It allows modification of the packet before it leaves the system.

3. Ping from hostA to 10.9.0.1 ip addressed to VM

```
[12/16/23]seed@VM:~/.../packet_filter$ docksh hostA-10.9.0.5
root@3104fdcf4945:/# ping 10.9.0.1 -c 2
PING 10.9.0.1 (10.9.0.1) 56(84) bytes of data.
64 bytes from 10.9.0.1: icmp_seq=1 ttl=64 time=15.5 ms
64 bytes from 10.9.0.1: icmp_seq=2 ttl=64 time=0.083 ms

--- 10.9.0.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1003ms
rtt min/avg/max/mdev = 0.083/7.813/15.543/7.730 ms
root@3104fdcf4945:/#
```

```
root@3104fdcf4945:/# ping 10.9.0.1 -c 2
PING 10.9.0.1 (10.9.0.1) 56(84) bytes of data.
64 bytes from 10.9.0.1: icmp_seq=1 ttl=64 time=15.5 ms
64 bytes from 10.9.0.1: icmp_seq=2 ttl=64 time=0.083 ms

--- 10.9.0.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1003ms
rtt min/avg/max/mdev = 0.083/7.813/15.543/7.730 ms
root@3104fdcf4945:/# telnet 10.9.0.1
Trying 10.9.0.1...
Connected to 10.9.0.1.
Escape character is '^]'.
Ubuntu 20.04.1 LTS
VM login: seed
Password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-54-generic x86_64)

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

32 updates can be installed immediately.
32 of these updates are security updates.
To see these additional updates run: apt list --upgradable


The list of available updates is more than a week old.
To check for new updates run: sudo apt update
Your Hardware Enablement Stack (HWE) is supported until April 2025.
Last login: Tue Nov 14 14:30:02 EST 2023 on tty3
[12/16/23]seed@VM:~$
```

Now we will make seedBlock.c and start working with the file to check which hook functions are working:

```c
//blocking UDP to 8.8.8.8:53
unsigned int blockUDP(void *priv, struct sk_buff *skb,
                      const struct nf_hook_state *state)
{
   struct iphdr *iph;
   struct udphdr *udph;

   u16  port   = 53;
   char ip[16] = "8.8.8.8";
   u32  ip_addr;

   if (!skb) return NF_ACCEPT;

   iph = ip_hdr(skb);
   // Convert the IPv4 address from dotted decimal to 32-bit binary
   in4_pton(ip, -1, (u8 *)&ip_addr, '\0', NULL);

   if (iph->protocol == IPPROTO_UDP) {
       udph = udp_hdr(skb);
       if (iph->daddr == ip_addr && ntohs(udph->dest) == port){
            printk(KERN_WARNING "*** Dropping %pI4 (UDP), port %d\n", &(iph->daddr), port);
            return NF_DROP;
        }
   }
   return NF_ACCEPT;
}
```

```c
//blocking ping to vm: 10.9.0.1
unsigned int blockICMP(void *priv, struct sk_buff *skb,
                       const struct nf_hook_state *state)
{
   struct iphdr *iph;
   struct icmphdr *icmph;

   //u16  port   = 53;
   char ip[16] = "10.9.0.1";
   u32  ip_addr;

   if (!skb) return NF_ACCEPT;

   iph = ip_hdr(skb);
   // Convert the IPv4 address from dotted decimal to 32-bit binary
   in4_pton(ip, -1, (u8 *)&ip_addr, '\0', NULL);

   if (iph->protocol == IPPROTO_ICMP) {
       icmph = icmp_hdr(skb);
       if (iph->daddr == ip_addr && icmph->type == ICMP_ECHO){
            printk(KERN_WARNING "*** Dropping %pI4 (ICMP) \n", &(iph->daddr));
            return NF_DROP;
        }
   }
   return NF_ACCEPT;
}


//blocking telnet to VM: 10.9.0.1:23
unsigned int blockTelnet(void *priv, struct sk_buff *skb,
                         const struct nf_hook_state *state)
{
   struct iphdr *iph;
   struct tcphdr *tcph;

   u16  port   = 23;//telnet
   char ip[16] = "10.9.0.1";
   u32  ip_addr;

   if (!skb) return NF_ACCEPT;

   iph = ip_hdr(skb);
   // Convert the IPv4 address from dotted decimal to 32-bit binary
   in4_pton(ip, -1, (u8 *)&ip_addr, '\0', NULL);

   if (iph->protocol == IPPROTO_TCP) {
       tcph = tcp_hdr(skb);
       if (iph->daddr == ip_addr && ntohs(tcph->dest) == port){
            printk(KERN_WARNING "*** Dropping %pI4 (Telnet), port %d\n", &(iph->daddr), port);
            return NF_DROP;
        }
   }
   return NF_ACCEPT;
}
```

As we see each hook function is invoked at mentioned time instances.

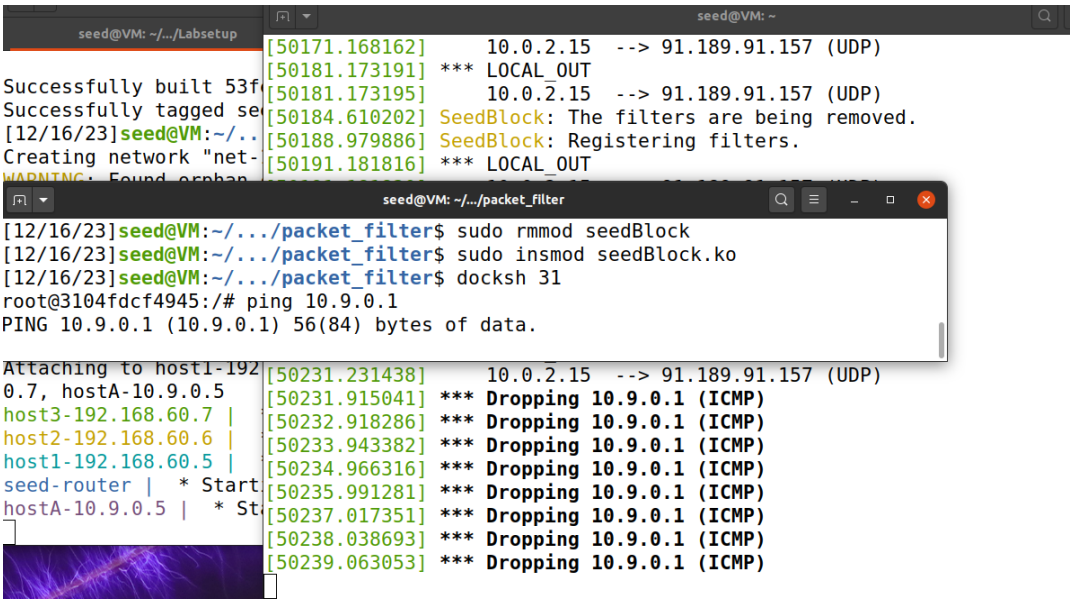
```c
int registerFilter(void) {
   printk(KERN_INFO "Registering filters.\n");

   hook1.hook = printInfo;
   hook1.hooknum = NF_INET_LOCAL_OUT;
   hook1.pf = PF_INET;
   hook1.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook1);

   hook2.hook = blockUDP;
   hook2.hooknum = NF_INET_POST_ROUTING;
   hook2.pf = PF_INET;
   hook2.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook2);

   hook3.hook = blockICMP;
   hook3.hooknum = NF_INET_PRE_ROUTING;
   hook3.pf = PF_INET;
   hook3.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook3);

   hook4.hook = blockTelent;
   hook4.hooknum = NF_INET_PRE_ROUTING;
   hook4.pf = PF_INET;
   hook4.priority = NF_IP_PRI_FIRST;
   nf_register_net_hook(&init_net, &hook4);

   return 0;
```

```
void removeFilter(void) {
   printk(KERN_INFO "The filters are being removed.\n");
   nf_unregister_net_hook(&init_net, &hook1);
   nf_unregister_net_hook(&init_net, &hook2);
   nf_unregister_net_hook(&init_net, &hook3);
   nf_unregister_net_hook(&init_net, &hook4);
}
```

Now that hook files are built using the make command seedBlock.ko is created which is loaded onto the kernel with the insmod command.

```
[12/16/23]seed@VM:~/.../packet_filter$ make
make -C /lib/modules/5.4.0-54-generic/build M=/home/seed/Downloads/Labsetup/File
s/packet_filter modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-54-generic'
  CC [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedBlock.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedBlock.mod.o
  LD [M]  /home/seed/Downloads/Labsetup/Files/packet_filter/seedBlock.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-54-generic'
[12/16/23]seed@VM:~/.../packet_filter$ sudo insmod seedBlock.ko
[12/16/23]seed@VM:~/.../packet_filter$
[49391.016674] SeedBlock: Registering filters.
[49400.401165] *** LOCAL_OUT
```

On pinging VM from host -A since it is blocked the ping is dropped as shown below:



Task-2

Task 2.1

On pinging router from host A is successful

```
[12/17/23]seed@VM:~$ docksh 31
root@3104fdcf4945:/# ping 10.9.0.11 -c 2
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=25.0 ms
64 bytes from 10.9.0.11: icmp_seq=2 ttl=64 time=0.089 ms

--- 10.9.0.11 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1004ms
rtt min/avg/max/mdev = 0.089/12.537/24.986/12.448 ms
root@3104fdcf4945:/#
```

Tenet connection host a to router also works

```
root@3104fdcf4945:/# telnet 10.9.0.11
Trying 10.9.0.11...
Connected to 10.9.0.11.
Escape character is '^]'.
Ubuntu 20.04.1 LTS
71d80c1c429e login: seed
Password:
root@71d80c1c429e:/# iptables -A INPUT -p icmp --icmp-type echo-request -j ACCEPT
root@71d80c1c429e:/# iptables -t filter -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination
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 8

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
ACCEPT     icmp --  0.0.0.0/0            0.0.0.0/0            icmptype 0
root@71d80c1c429e:/#
root@71d80c1c429e:/# iptables -P OUTPUT DROP
root@71d80c1c429e:/# iptables -P INPUT DROP
root@71d80c1c429e:/# iptables -t filter -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
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 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@71d80c1c429e:/#
```

Now if we ping the router or try a telnet connection it doesn't work.

```
root@3104fdcf4945:/# telnet 10.9.0.11
Trying 10.9.0.11...
```

Task 2.2

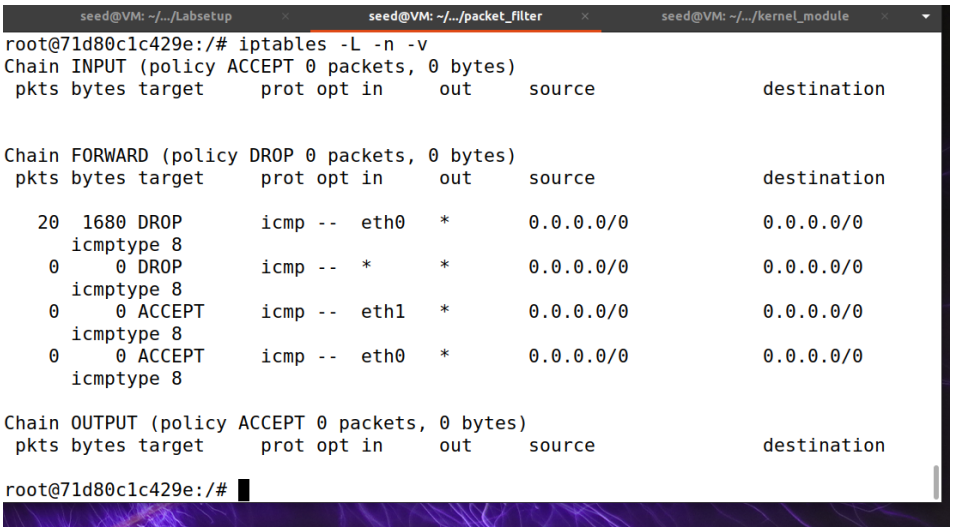
The docker containers are restarted before starting next step using docker restart<container id>. After running iptables -A FORWARD -i eth0 -p icmp --icmp-type echo-request -j DROP

```
root@71d80c1c429e:/# iptables -A FORWARD -i eth0 -p icmp --icmp-type echo-request -
j DROP
root@71d80c1c429e:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

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

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@71d80c1c429e:/#
```

So we can see now that the ping host A to 10.9.0.11 is working and to 192.168.60.5 is not working as shown below:

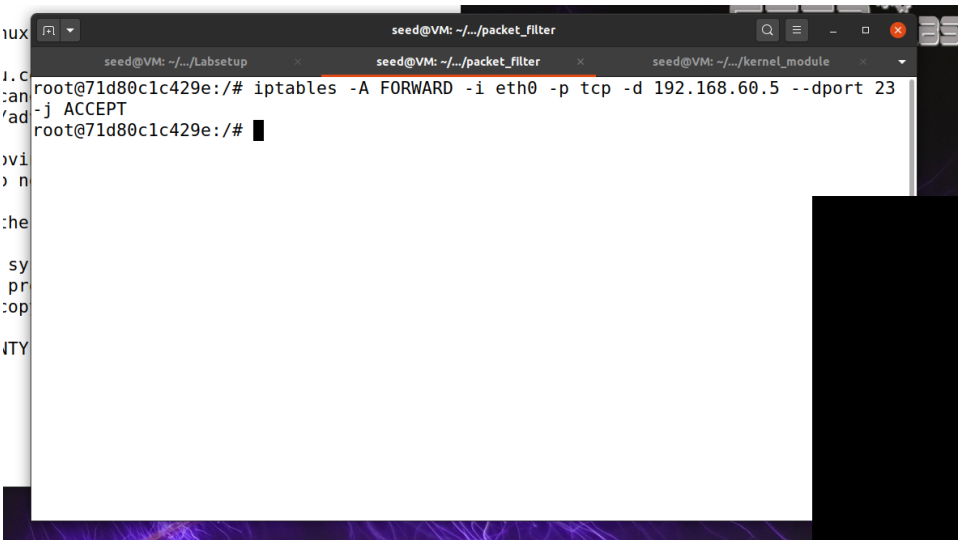
```
root@3104fdcf4945:/# ping 10.9.0.11
PING 10.9.0.11 (10.9.0.11) 56(84) bytes of data.
64 bytes from 10.9.0.11: icmp_seq=1 ttl=64 time=8.91 ms
64 bytes from 10.9.0.11: icmp_seq=2 ttl=64 time=0.105 ms
64 bytes from 10.9.0.11: icmp_seq=3 ttl=64 time=0.103 ms
64 bytes from 10.9.0.11: icmp_seq=4 ttl=64 time=0.107 ms
64 bytes from 10.9.0.11: icmp_seq=5 ttl=64 time=0.106 ms
64 bytes from 10.9.0.11: icmp_seq=6 ttl=64 time=0.106 ms
64 bytes from 10.9.0.11: icmp_seq=7 ttl=64 time=0.092 ms
^C
--- 10.9.0.11 ping statistics ---
7 packets transmitted, 7 received, 0% packet loss, time 6085ms
rtt min/avg/max/mdev = 0.092/1.360/8.907/3.080 ms
root@3104fdcf4945:/# 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 ---
20 packets transmitted, 0 received, 100% packet loss, time 19456ms
```

Here is the detailed view of iptables after it is set to ACCEPT from VMs both eth0 and eth1 And running iptables -L -n, we can see that it ACCEPTS all three.

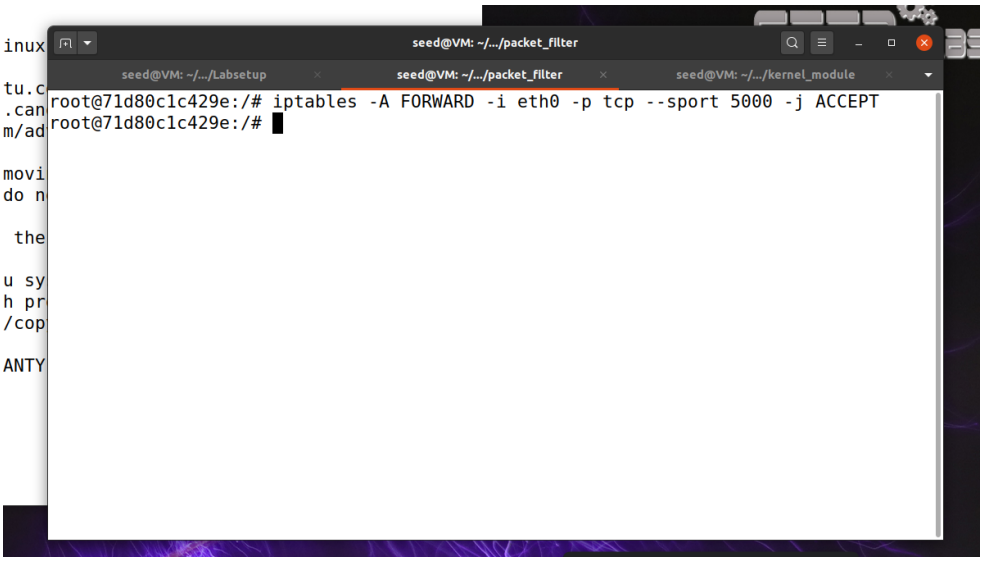


Task 2.3

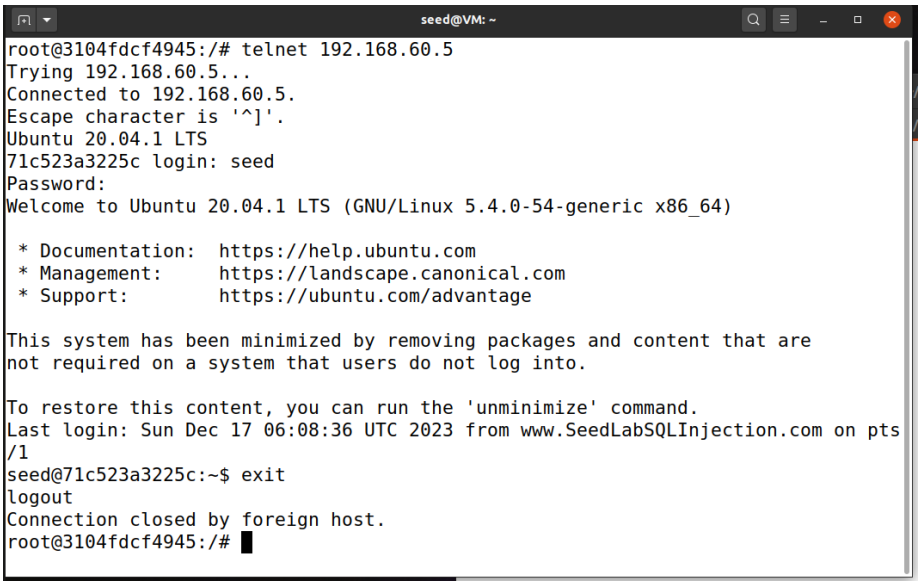
running iptables -A FORWARD -i eth0 -d 192.168.60.5 -p -tcp –dport 23 -j ACCEPT to make sure all internal hosts run on telnet server listening to port 23 and outside hosts can only have access to server on 192.168.60.5



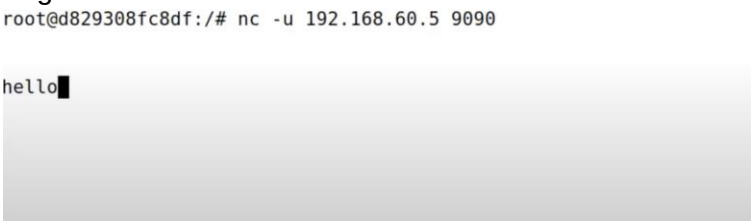
The command given in the document is run as shown below:

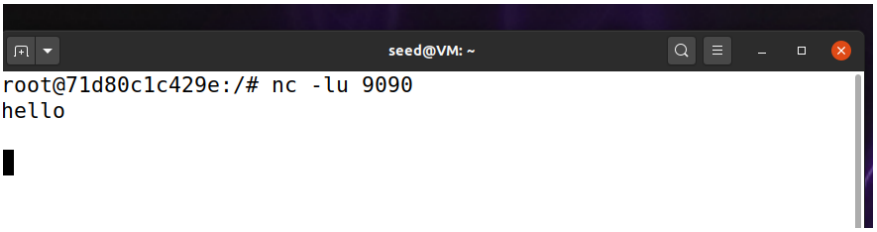


And we can see that the telnet to VN eth1 is working from Host A

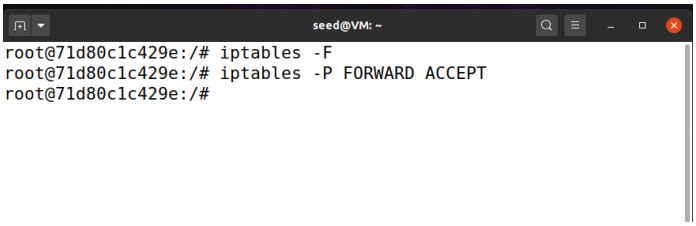


Sending Hello by using nc -u 192.168.60.5 9090






```
root@3104fdcf4945:/# nc -u 192.168.60.5 9090
^C
root@3104fdcf4945:/# nc -ltv 9090
Listening on 0.0.0.0 9090
root@3104fdcf4945:/#
```



Task 3: Connection Tracking and Stateful Firewall

3.1 ICMP experiment:

Run the following command and check the connection tracking information on the router. Describe your observation. How long is the ICMP connection state be kept?

We will send out ICMP packets to host machine 192.168.60.5 using ping command. Since we need it to continuously send packets. We will run it in the background by adding & charecter as shown in the picture below.
ICMP Experiment: Execute the provided command and examine the connection tracking details on the router. Provide a description of your observations. Determine the duration for which the ICMP connection state is retained.

To achieve this, initiate the transmission of ICMP packets to the host machine at IP address 192.168.60.5 using the ping command. Given the need for continuous packet transmission, run the command in the background by appending the "&" character, as depicted in the image below.

Subsequently, execute the `conntrack -L` command to monitor the number of active connections.

Then we execute Conntrack -L command to track how many connections are active.

```
root@a1a904431131:/# conntrack -L
icmp     1 29 src=10.9.0.5 dst=192.168.60.5 type=8 code=0 id=65 src=192.168.60.5 dst=10.9.0.5 type
=0 code=0 id=65 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
root@a1a904431131:/#
```

From the above picture we can see that. 1 flow entry is active and it is sending ICMP packets.

Now our task is to end the ping job and observe for how long the Conntrack will hold the status even after termination of the job.

```
root@243fff5590bf:/# conntrack -L
icmp     1 23 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=20 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=20 mark=0 use=1
icmp     1 29 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=18 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=18 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 2 flow entries have been shown.
[1]+  Terminated              ping 192.168.60.5 &> /dev/null
root@243fff5590bf:/# conntrack -L
icmp     1 16 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=20 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=20 mark=0 use=1
icmp     1 29 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=18 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=18 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 2 flow entries have been shown.
root@243fff5590bf:/# conntrack -L
icmp     1 5 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=20 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=20 mark=0 use=1
icmp     1 29 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=18 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=18 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 2 flow entries have been shown.
root@243fff5590bf:/# conntrack -L
icmp     1 29 src=192.168.60.11 dst=192.168.60.5 type=8 code=0 id=18 src=192.168.60.5 dst=192.168.60.11 type=0 code=0 id=18 mark=0 use=1
conntrack v1.4.5 (conntrack-tools): 1 flow entries have been shown.
```

In the provided screenshot, we observe that upon executing the `jobs` command, a running ping job is visible in the background. This is also evident when we use the `Conntrack` command.

Executing `kill %1` terminates the ping job, and we promptly run the `Conntrack -L` command multiple times to assess the duration for which the state is retained.

Based on our observation, the state persists for approximately 8 seconds. In the end, it is noticeable that the count of flow streams decreases by one.

UDP experiment: Run the following command and check the connection tracking information on the router. Describe your observation. How long is the UDP connection state be kept?

In order to send out UDP packets. Lets login to host 192.168.60.5 and initiate a Netcat connection.

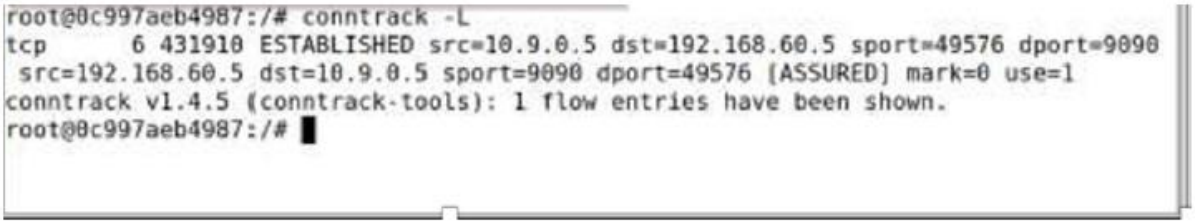
```
root@ubuntu-seed-labs:~# docker exec -it 833fe3104c4a /bin/bash
root@833fe3104c4a:/# nc -lu 9090
```

Now lets login to external host A on 10.9.0.5 and connect to Netcat server on 192.168.60.5 and try sending some UDP packets. This can be done by typing something on the terminal.

Same text will be reflected on the host machine as well.

If we execute the Conntrack -L command now, We can observe a flow stream of UDP packets.

Let's end the Netcat server connection and observe Conntrack as to how long the connection state is retained.
By executing the Conntrack -L command again and again, we can get a rough estimate of how long it will store the state.

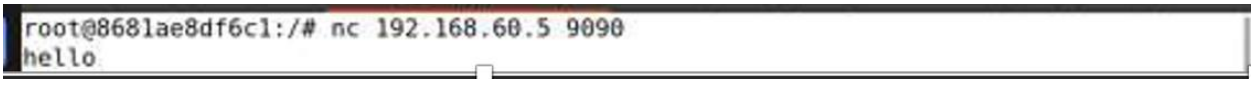


Based on the above observation. We can say that Conntrack stores the state for roughly 8 to 10 seconds.

TCP experiment: Run the following command and check the connection tracking information on the router. Describe your observation. How long is the TCP connection state be kept?

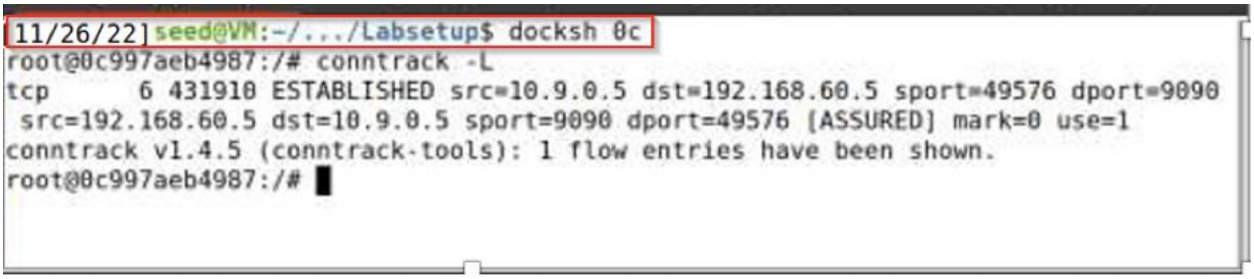
To send TCP packets between two hosts. Lets initiate Netcat TCP server on host 192.168.60.5

Now from host 10.9.0.5 we will connect to the TCP server to send out TCP packets.



As seen in the above pictures, The TCP packets have been successfully received by the Server.

Lets Observe Conntrack for the Flow stream information.

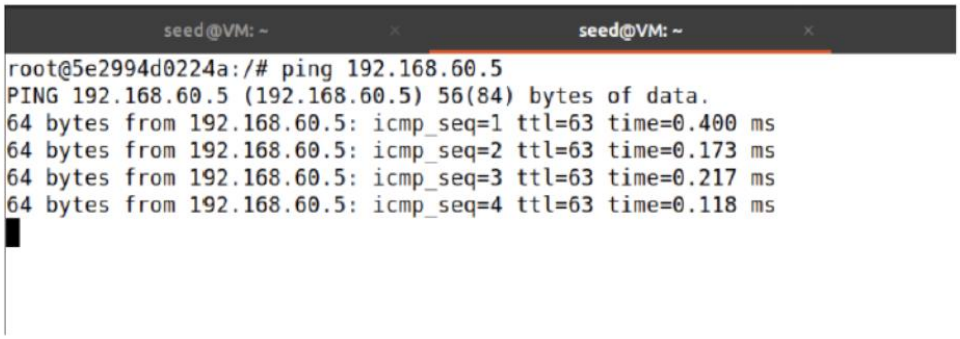


In the above image, we can see that the status of TCP packets are ESTABLISHED. Meaning the TCP handshake was successful and the connection is formed and retained for data transfer.

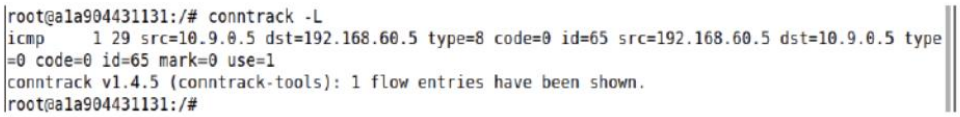
To check how long the state will be held by Conntrack, we have to end the TCP connection from both the sides and Observe the Conntrack Results.

ICMP EXPERIMENT:

Ping 192.168.60.5 from 10.9.0.5

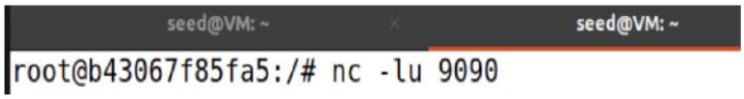


The ICMP connection status is kept in the connection table for 29 seconds. Because ICMP is connectionless, the state is saved in a shorter timescale, hence we don't see a connection state in the table.



UDP EXPERIMENT:

On 192.168.60.5 container I started the netcat server



In 10.9.0.5 container

#nc – u 192.168.60.5 9090

Once we ended the TCP connection. We can see the status of TCP packets now changed to TIME_WAIT from ESTABLISHED. It will wait for 113s seconds before discarding the state. As time goes we can observe this timer count getting decreased and finally becoming Zero. that is when the connection state is discarded from Conntrack.

3.2 : Setting Up a Stateful Firewall

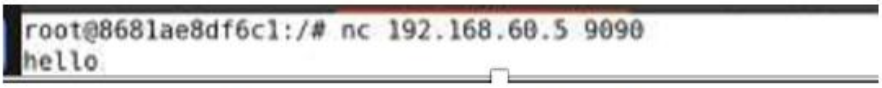
A Netcat TCP server is initiated in the External server Hoest A.

Here in the 192.168.60.5 container can see hello is displayed in the 10.9.0.5 container.

The connection table saves the state of the UDP connection for 33 seconds. Because UDP is a connectionless protocol, the duration in which the state is saved is shorter, and there is no connection state in the table.

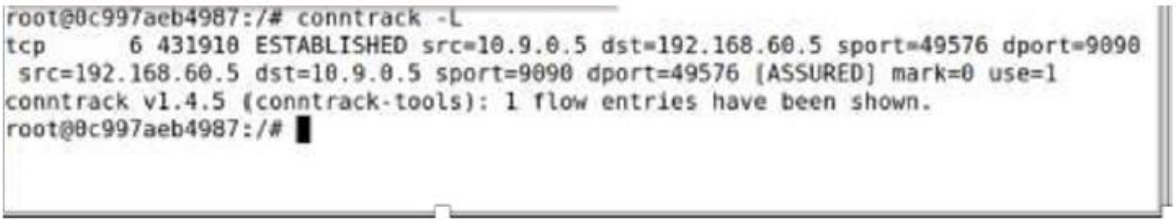
TCP EXPERIMENT:

On 192.168.60.5 container I started the netcat TCP server



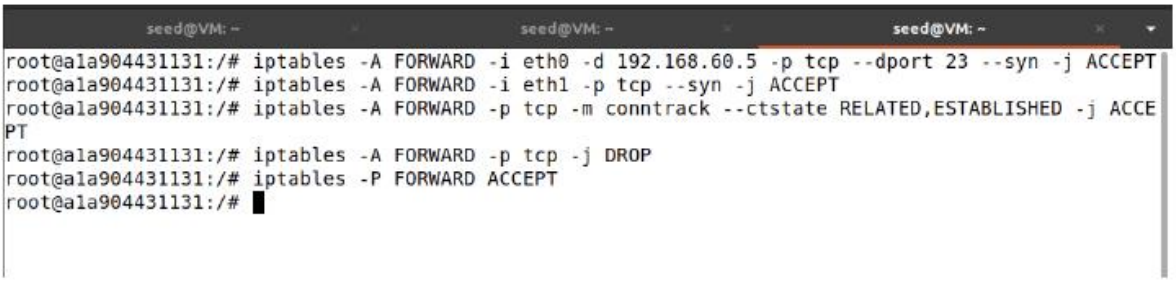
Here in the 192.168.60.5 container, hello is displayed in the 10.9.0.5 container.

The state of the TCP connection is kept for **431910** seconds. Because TCP is a connection-oriented protocol, we keep the connection state for a longer period of time. As soon as the TCP connection is established, we see the state as ESTABLISHED.



5 Task 3.B: Setting Up a Stateful Firewall

Running the following commands on seed-router

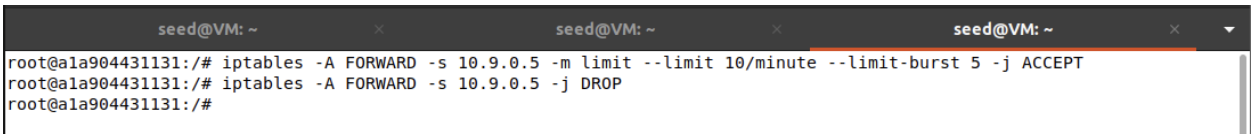


In the above image, From internal host 1. We are connecting to the Netcat server hosted on external host A.
The connection was established successfully and all the input given on the client is reflected on the server.
This completes testing of all the scenarios of the Firewall.

In the end. Lets go ahead and clear all the rules.

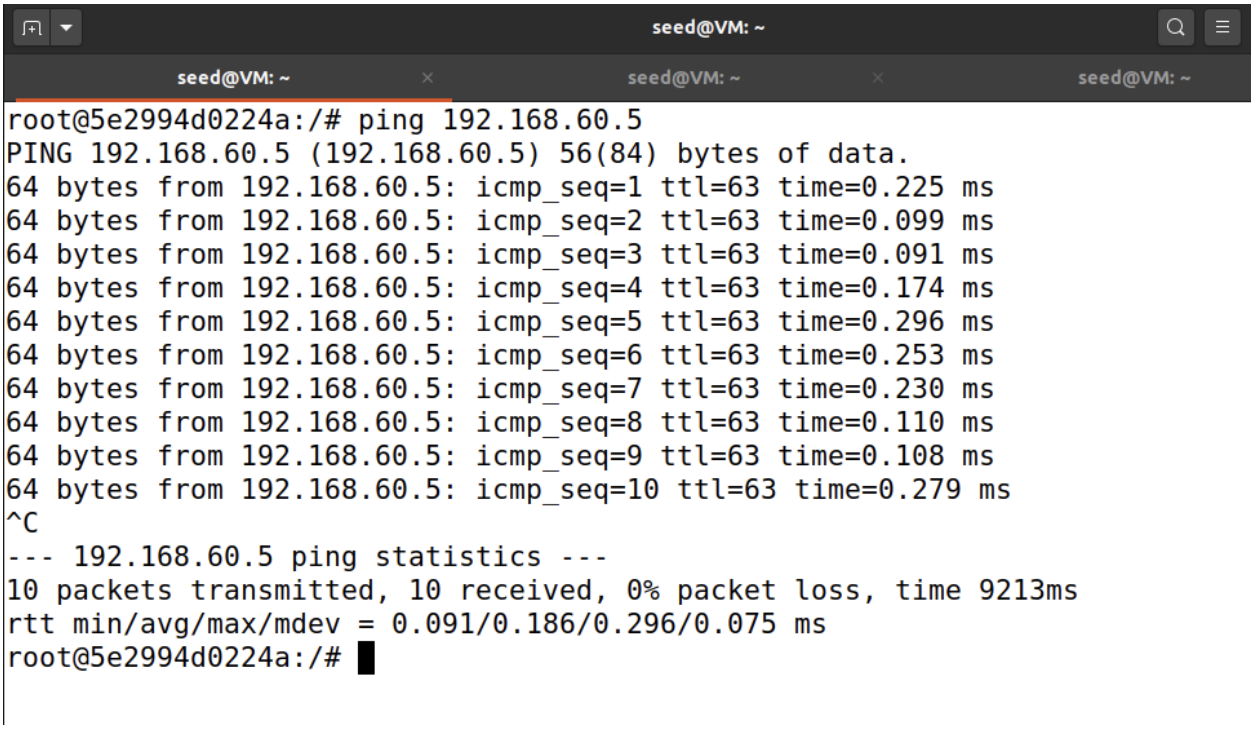
Task 4: Limiting Network Traffic

In this task, we will use **limit** module to limit how many packets from 10.9.0.5 are allowed to get into the internal network.



The above command restricts traffic at IP 10.9.0.5 and only allows 10 packets per minute. Our task is to find out if this rule is enough on its own to restrict the packet flow.

In order to test that. Lets ping 192.168.60.5 from 10.0.0.5

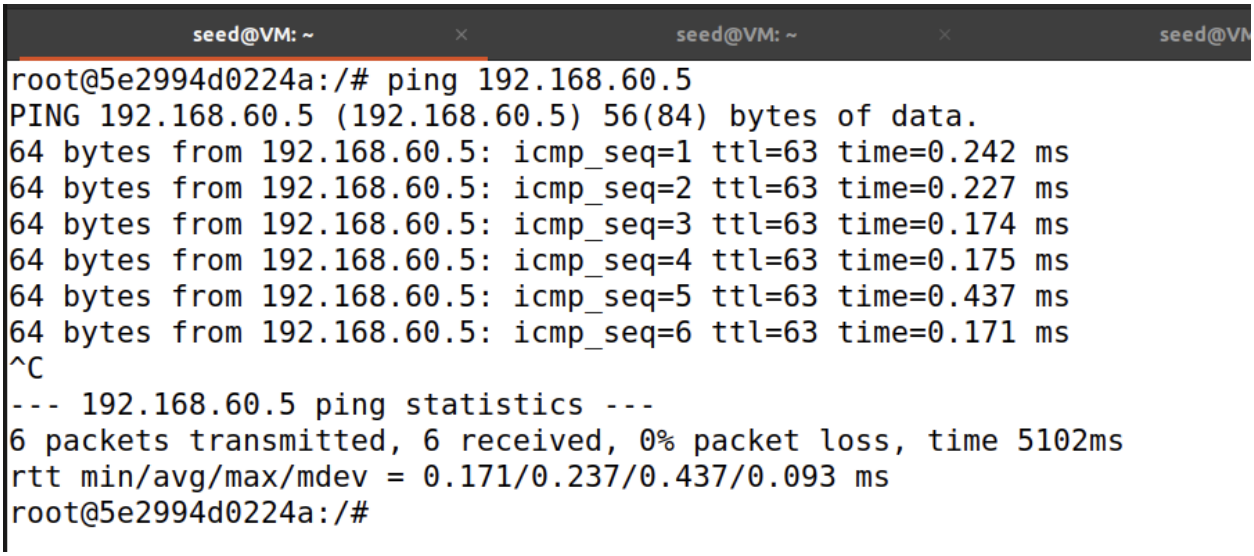


From what we observe from the above image. Every packet is going through. This is because whichever packets did not pass the filter is still going through because we do not have a second

rule to drop such packets which did not pass first filter.

Lets add a second filter to drop packets.

After this lets test it by pinging 192.168.60.5 from 10.0.0.5



This time we can observe 73.4694 % packet loss. This is because all the packets which didn't go through the first rule are dropped in the second rule. Now the filter is successfully limiting the packet count.

Task-5

Initially the server is started on the three hosts : 192.168.60.5, 192.168.60.6, and 192.168.60.7 and it is set to accept UDP datagrams from multiple hosts.

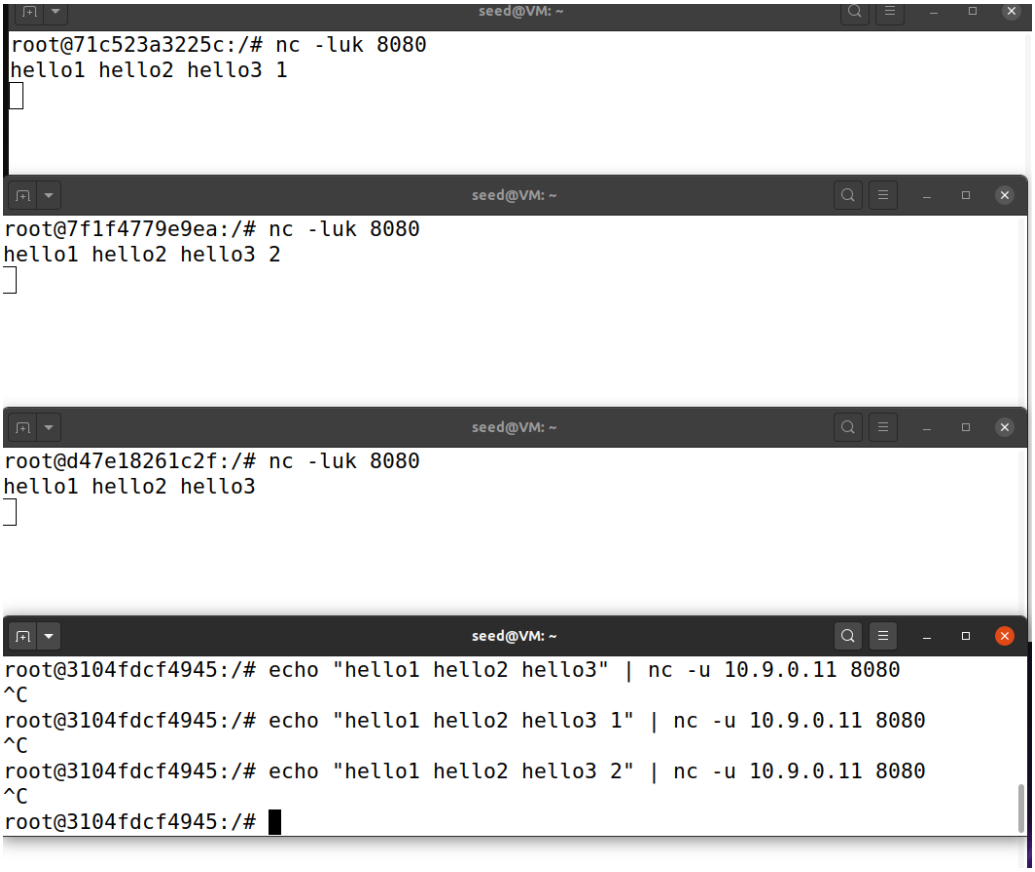
Packets from router are sent to host 1

WE SEE THAT HELLO IS captured in host 1 and not in any other dockers.

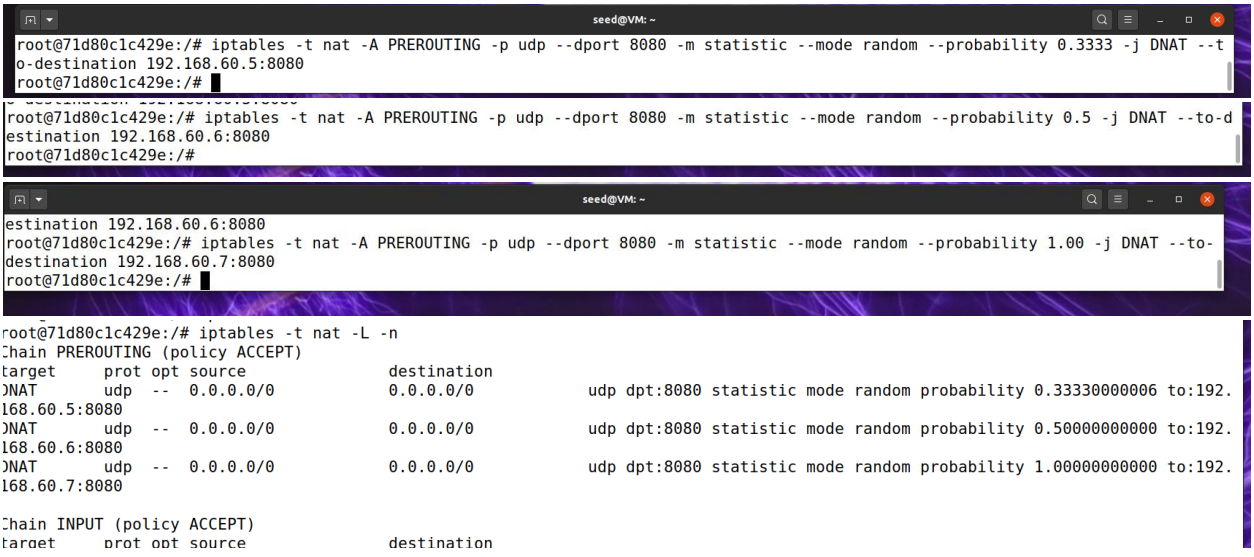
Sending every 3 packets to host 1,2,3.

```
root@71d80c1c429e:/# iptables -t nat -L -n
Chain PREROUTING (policy ACCEPT)
target     prot opt source               destination
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode nth every 3 to:192.168.60.5:8080
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode nth every 3 packet 2 to:192.168.60.7:808
0
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode nth every 3 packet 1 to:192.168.60.6:808
0
```

We can see the policy with 3 DNAT udp packets in the pre routing. Now sending the udp packets from host to router port 8080 as follows:

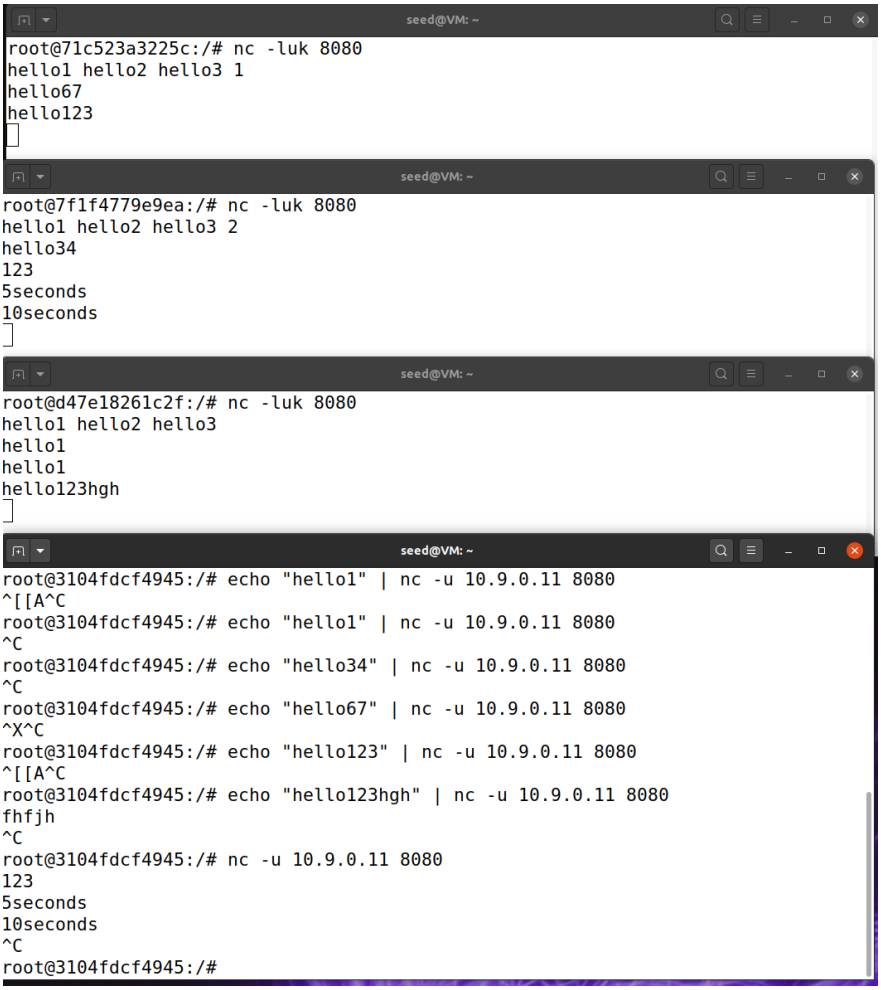


We can see that after each 2 seconds the packet sent are equally distributed among host 1 2 3.




```
root@71d80c1c429e:/# iptables -t nat -L -n
Chain PREROUTING (policy ACCEPT)
target     prot opt source               destination
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode random probability 0.33330000006 to:192.
168.60.5:8080
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode random probability 0.50000000000 to:192.
168.60.6:8080
DNAT       udp  --  0.0.0.0/0            0.0.0.0/0            udp dpt:8080 statistic mode random probability 1.00000000000 to:192.
168.60.7:8080

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

For random mode, the packets don't run as expected for short packets.



For long packets or over long periods of time the packets behave statistically to the rules.

Conclusion for Task 5

- Round-Robin Load Balancing with nth Mode:
  1. The nth mode employs a round-robin strategy, choosing every third packet in the sequence.
  2. The designated packet, identified as packet 0, undergoes modification, altering its destination IP address and port to 192.168.60.5:8080.
  3. This rule guarantees that one in every three UDP packets directed to the router's 8080 port is rerouted to 192.168.60.5.

Conclusion:

In conclusion, the exploration of network security in this lab encompassed various aspects of firewall implementation and configuration using iptables. Tasks involved the development of stateless and stateful firewall rules, connection tracking mechanisms, and the application of advanced iptables modules. Through ICMP, UDP, and TCP

experiments, students gained practical insights into the intricacies of connection tracking and stateful packet filtering.

The tasks not only reinforced the fundamental concepts of firewall construction but also delved into nuanced scenarios, such as protecting internal networks, controlling access to servers, and implementing packet rate limiting. The utilization of iptables modules like 'limit' and 'statistic' showcased the versatility of iptables in enforcing network traffic restrictions.

Moreover, the exploration of load balancing techniques demonstrated the multifaceted applications of iptables beyond traditional firewall functionalities. By manipulating packet routing based on load balancing policies, students learned to distribute network traffic effectively among multiple servers.

In retrospect, the lab provided a comprehensive hands-on experience for network security students, enabling them to apply theoretical knowledge in a practical setting. The tasks covered a spectrum of firewall-related topics, empowering students to implement robust security measures, optimize network traffic, and critically analyze the advantages and disadvantages of different approaches. Overall, this lab contributed significantly to enhancing the students' proficiency in network security and iptables utilization.