Team:

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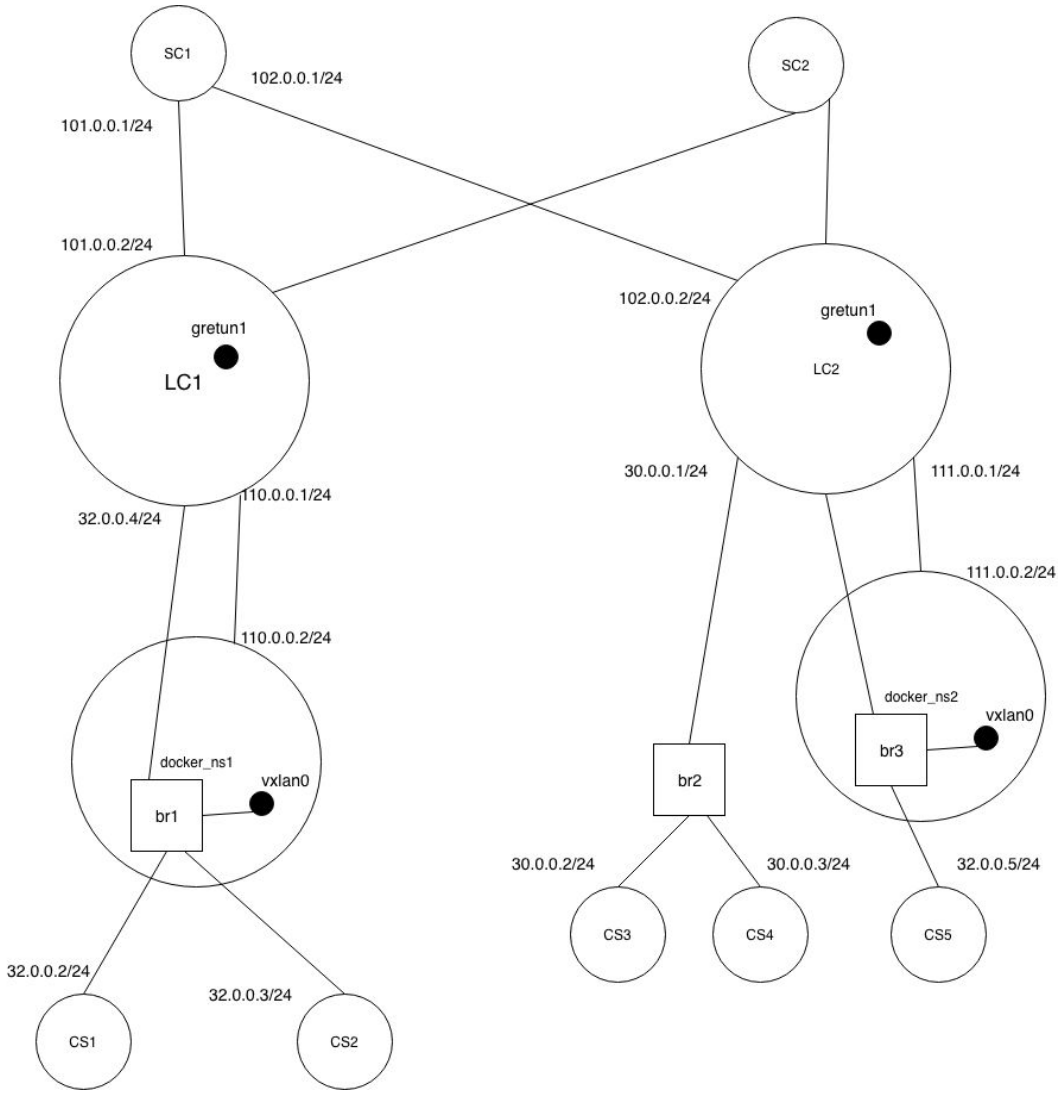
Staging Server IP			VM IP		
152.14.83.156	ece792	EcE792net!	192.168.124.15	ece792	EcE792net!

Problem 1:

Architecture Setup:



Screenshot for topology setup:

- Docker containers

Configuration:

docker_ns2 interfaces:

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# ifconfig
br3_dockerns Link encap:Ethernet  HWaddr 2e:f6:71:c5:c0:bd
          inet6 addr: fe80::2cf6:71ff:fec5:c0bd/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1450  Metric:1
          RX packets:3120 errors:0 dropped:0 overruns:0 frame:0
          TX packets:72 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:99788 (99.7 KB)  TX bytes:5136 (5.1 KB)

br3_vif1  Link encap:Ethernet  HWaddr 2e:f6:71:c5:c0:bd
          inet6 addr: fe80::2cf6:71ff:fec5:c0bd/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:2933 errors:0 dropped:0 overruns:0 frame:0
          TX packets:680 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:134538 (134.5 KB)  TX bytes:51836 (51.8 KB)

br3_vif3  Link encap:Ethernet  HWaddr 6e:5f:2f:6c:36:83
          inet6 addr: fe80::6c5f:2fff:fe6c:3683/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:87 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3201 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:6354 (6.3 KB)  TX bytes:149434 (149.4 KB)

lc2ns2vif1 Link encap:Ethernet  HWaddr c2:6b:7a:4f:bc:20
          inet addr:111.0.0.2  Bcast:111.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::c06b:7aff:fe4f:bc20/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:176 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2728 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:17314 (17.3 KB)  TX bytes:214548 (214.5 KB)

vxlan0    Link encap:Ethernet  HWaddr e6:c0:81:d9:32:04
          inet6 addr: fe80::e4c0:81ff:fed9:3204/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1450  Metric:1
          RX packets:89 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1135 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:7196 (7.1 KB)  TX bytes:37000 (37.0 KB)
```

- **docker_ns2 route:**

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         111.0.0.1       0.0.0.0         UG    0      0        0 lc2ns2vif1
111.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 lc2ns2vif1
```

- **TCPDUMP at docker_ns2 after VXLAN encap:**

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# tcpdump -i lc2ns2vif1
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on lc2ns2vif1, link-type EN10MB (Ethernet), capture size 262144 bytes
01:32:25.951862 IP 111.0.0.2.48078 > 110.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42
IP 32.0.0.5 > 32.0.0.2: ICMP echo request, id 104, seq 469, length 64
01:32:25.952014 IP 110.0.0.2.48078 > 111.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42
IP 32.0.0.2 > 32.0.0.5: ICMP echo reply, id 104, seq 469, length 64
```

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LC2 Container:

LC2 container Interfaces:

```
gretun1   Link encap:UNSPEC  HWaddr 66-00-00-02-00-00-00-00-00-00-00-00-00-00-00-00
          inet6 addr: fe80::200:5efe:6600:2/64 Scope:Link
          UP POINTOPOINT RUNNING NOARP  MTU:1476  Metric:1
          RX packets:1175 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2893 errors:35 dropped:0 overruns:0 carrier:35
          collisions:0 txqueuelen:1000
          RX bytes:154002 (154.0 KB)  TX bytes:289688 (289.6 KB)

lc2ns2vif2 Link encap:Ethernet  HWaddr e6:6a:63:e2:c6:ed
          inet addr:111.0.0.1  Bcast:111.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::e46a:63ff:fee2:c6ed/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:3991 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1318 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:386582 (386.5 KB)  TX bytes:176722 (176.7 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:275 errors:0 dropped:0 overruns:0 frame:0
          TX packets:275 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:14652 (14.6 KB)  TX bytes:14652 (14.6 KB)

sc1lc2vif2 Link encap:Ethernet  HWaddr 22:05:83:d1:41:41
          inet addr:102.0.0.2  Bcast:102.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::2005:83ff:fed1:4141/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1384 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3232 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:211611 (211.6 KB)  TX bytes:421041 (421.0 KB)

sc2lc2vif2 Link encap:Ethernet  HWaddr 5a:7e:d5:0e:5e:6b
          inet addr:104.0.0.2  Bcast:104.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::587e:d5ff:fe0e:5e6b/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:18 errors:0 dropped:0 overruns:0 frame:0
          TX packets:18 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1356 (1.3 KB)  TX bytes:1356 (1.3 KB)
```

LC2 container route

```
root@2b18e0e58f86:/# route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         102.0.0.1       0.0.0.0         UG    0      0        0 sc1lc2vif2
30.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 br3dockervif4
32.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 br3_vif4
40.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 br2dockervif4
102.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 sc1lc2vif2
104.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 sc2lc2vif2
110.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 gretun1
111.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 lc2ns2vif2
172.17.0.0      0.0.0.0         255.255.0.0     U     0      0        0 eth0
```

- **TCPDUMP at LC2 after GRE encap:**

```
root@2b18e0e58f86:/# /usr/bin/tcpdump -i sc1lc2vif2
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on sc1lc2vif2, link-type EN10MB (Ethernet), capture size 262144 bytes
06:42:47.332148 IP 102.0.0.2 > 101.0.0.2: GREv0, length 138: IP 111.0.0.2.48078 > 110.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42
IP 32.0.0.5 > 32.0.0.2: ICMP echo request, id 104, seq 1076, length 64
06:42:47.332710 IP 102.0.0.2.56865 > 192.168.124.1.53: 41526+ PTR? 2.0.0.101.in-addr.arpa. (40)
06:42:47.332824 IP 101.0.0.2 > 102.0.0.2: GREv0, length 138: IP 110.0.0.2.48078 > 111.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42
IP 32.0.0.2 > 32.0.0.5: ICMP echo reply, id 104, seq 1076, length 64
```

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LC11 tcpdump capture

```
root@637c45c6e8e0:/# /usr/bin/tcpdump -i gretun1
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on gretun1, link-type LINUX_SLL (Linux cooked), capture size 262144 bytes
^C06:36:16.228214 IP 111.0.0.2.48078 > 110.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42

IP 32.0.0.5 > 32.0.0.2: ICMP echo request, id 104, seq 694, length 64

1 packet captured
226 packets received by filter
219 packets dropped by kernel
```

```
root@637c45c6e8e0:/# route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         101.0.0.1       0.0.0.0         UG    0      0        0 sc1lc1vif2
32.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 lc1br1vif1
101.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 sc1lc1vif2
110.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 lc1ns1vif1
111.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 gretun1
172.17.0.0      0.0.0.0         255.255.0.0     U     0      0        0 eth0
root@637c45c6e8e0:/#
```

Lc11 ifconfig

```
root@637c45c6e8e0:/# ifconfig
eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:0b
          inet addr:172.17.0.11  Bcast:0.0.0.0  Mask:255.255.0.0
          inet6 addr: fe80::42:acff:fe11:b/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:15764 errors:0 dropped:0 overruns:0 frame:0
          TX packets:11339 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:30019493 (30.0 MB)  TX bytes:972344 (972.3 KB)

gretun1   Link encap:UNSPEC  HWaddr 65-00-00-02-00-00-00-00-00-00-00-00-00-00-00-00
          inet6 addr: fe80::200:5efe:6500:2/64 Scope:Link
          UP POINTOPOINT RUNNING NOARP  MTU:1476  Metric:1
          RX packets:1413 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1273 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:178702 (178.7 KB)  TX bytes:167668 (167.6 KB)

lc1br1vif1 Link encap:Ethernet  HWaddr 0e:d5:20:a6:0c:bb
          inet addr:32.0.0.4  Bcast:32.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::cd5:20ff:fea6:cbb/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:18 errors:0 dropped:0 overruns:0 frame:0
          TX packets:24 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1340 (1.3 KB)  TX bytes:1872 (1.8 KB)

lc1ns1vif1 Link encap:Ethernet  HWaddr 5a:cf:64:28:e0:dc
          inet addr:110.0.0.1  Bcast:110.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::58cf:64ff:fe28:e0dc/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1417 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1501 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:193810 (193.8 KB)  TX bytes:202856 (202.8 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
```

Docker_ns1 tcpdump captures

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# tcpdump -i vxlan0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on vxlan0, link-type EN10MB (Ethernet), capture size 262144 bytes
^C01:42:05.375996 IP 32.0.0.5 > 32.0.0.2: ICMP echo request, id 104, seq 1035, length 64

1 packet captured
112 packets received by filter
105 packets dropped by kernel
root@ece792-Standard-PC-i440FX-PIIX-1996:~# tcpdump -i lc1ns1vif2
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on lc1ns1vif2, link-type EN10MB (Ethernet), capture size 262144 bytes
^C
01:43:16.000040 IP 111.0.0.2.48078 > 110.0.0.2.4789: VXLAN, flags [I] (0x08), vni 42
IP 32.0.0.5 > 32.0.0.2: ICMP echo request, id 104, seq 1104, length 64

1 packet captured
259 packets received by filter
252 packets dropped by kernel
```

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         110.0.0.1       0.0.0.0         UG    0      0        0 lc1ns1vif2
110.0.0.0       0.0.0.0         255.255.255.0   U     0      0        0 lc1ns1vif2
root@ece792-Standard-PC-i440FX-PIIX-1996:~#
```

Interfaces

```
root@ece792-Standard-PC-i440FX-PIIX-1996:~# ifconfig
br1_dockerns Link encap:Ethernet  HWaddr 1e:4e:70:57:63:2f
          inet6 addr: fe80::c88e:b1ff:fea0:f137/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1450  Metric:1
          RX packets:2116 errors:0 dropped:0 overruns:0 frame:0
          TX packets:75 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:74464 (74.4 KB)  TX bytes:5386 (5.3 KB)

br1_vif1  Link encap:Ethernet  HWaddr 1e:4e:70:57:63:2f
          inet6 addr: fe80::1c4e:70ff:fe57:632f/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:2960 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3356 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:196012 (196.0 KB)  TX bytes:227188 (227.1 KB)

br1_vif3  Link encap:Ethernet  HWaddr ba:7e:20:f0:4b:3a
          inet6 addr: fe80::b87e:20ff:fef0:4b3a/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:72 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2166 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:5136 (5.1 KB)  TX bytes:107968 (107.9 KB)

lc1br1vif2 Link encap:Ethernet  HWaddr be:f1:ae:81:f3:01
          inet6 addr: fe80::bcf1:aeff:fe81:f301/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:24 errors:0 dropped:0 overruns:0 frame:0
          TX packets:18 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1872 (1.8 KB)  TX bytes:1340 (1.3 KB)

lc1ns1vif2 Link encap:Ethernet  HWaddr 32:be:2a:f1:9a:08
          inet addr:110.0.0.2  Bcast:110.0.0.255  Mask:255.255.255.0
          inet6 addr: fe80::30be:2aff:fef1:9a08/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1434 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1350 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
```

1(a) VXLAN Namespace configuration

We are assuming over here that, bridge1 and bridge3 networks are in the different subnet.

Topology Diagram:

Namespace: docker_ns1

- Interfaces configuration:
-
- Routes inside the namespace which is only going to hypervisor

Commands used to setup above topology:

```
Commands:
docker build -t basic_ubuntu .

//Create container from existing image:
//docker create -t -i basic_ubuntu co

To start container from existing image:
docker run --name ubuntu_container1 --privileged  --rm -i -t basic_ubuntu
bash
or
docker run -it --name <container_name> <image_name>
docker run --name lc2 --privileged --rm -i -t ubuntu_netw

Execute command inside container in interactive mode:
docker exec -it ubuntu_container1 bash

Exit : ctrl p+q

sudo ./vethpairs.sh br1_dockerns cs2 br1_vif3 br1_vif4 32.0.0.3/24
sudo ./vethpairs.sh <bridge_name> <container_name> <vethpair_interface1>
<vethpair_interface2>  <ip address>

docker network create bridge1-net

ip link add br1dockervif3 type veth peer name br1dockervif4
sudo brctl addif br1_docker br1dockervif3
docker inspect --format '{{.State.Pid}}' cs1
sudo ip link set netns 22469 dev br1dockervif2

VXLAN:
VXLAN Tunnel Datapath
Add default route in namespace
Hypervisor Config:
Namespace: docker_ns2
```

```
sudo ip link add name vxlan0 type vxlan id 42 dev lc2ns2vif1 local
111.0.0.2 remote 110.0.0.2 dstport 4789
sudo ip link set dev vxlan0 up
sudo brctl addif br3_dockerns vxlan0

Namespace: docker_ns1
sudo ip link add name vxlan0 type vxlan id 42 dev lc1ns1vif2 remote
111.0.0.2 dstport 4789
sudo ip link set dev vxlan0 up
sudo brctl addif br1_dockerns vxlan0

Guest Configuration:
sudo ip route add 192.168.12.0/24 dev eth0
sudo ip route add 192.168.11.0/24 dev eth0


GRE tunnel

Hypervisor Config:
sudo ip route add 192.168.12.0/24 via 192.168.123.66
sudo ip route add 192.168.11.0/24 via 192.168.123.123
```

1(b) Automation:

README:
Input: input.csv as mentioned in repo
It is assumed that two leaf containers, lc11 and lc2 are setup and sc1 and sc2 are setup.
As mentioned, lc11 and lc2 are connected with gre tunnel as configured in above step.

sudo python netw_funcs.py

Ansible scripts are created reusable and hierarchical.
So it is called from python code and also called from another ansible-scripts.

L2 Automation:

```
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~/linux_netw_hw/hw4$ docker ps
CONTAINER ID        IMAGE               COMMAND             CREATED             STATUS              PORTS               NAMES
6c87482b6e3d        ubuntu_netw         "sleep infinity"    8 minutes ago       Up 8 minutes                            CS22
d5d5bf00b771        ubuntu_netw         "sleep infinity"    8 minutes ago       Up 8 minutes                            CS21
```

L3 Bridge Automation:

```
TASK [Interface prefix] ************************************************************
ok: [localhost]

TASK [Create veth pair for bridge and container] ********************************
changed: [localhost]

TASK [Attach brvif2 to bridge] *************************************************
changed: [localhost]

TASK [Make the bridge interface up] ********************************************
changed: [localhost]

TASK [Make the brvif2 up] ******************************************************
changed: [localhost]

TASK [Fetch container process ID] **********************************************
changed: [localhost]

TASK [Attach brvif1 to container] **********************************************
changed: [localhost]

TASK [Make the interface running] **********************************************
changed: [localhost]

TASK [Attach brvif1 to container] **********************************************
changed: [localhost]

TASK [Remove previous default route to default network] ************************
changed: [localhost]

TASK [Add  default route to new netowrk created] *******************************
changed: [localhost]

PLAY RECAP *********************************************************************
localhost                  : ok=53   changed=42   unreachable=0    failed=0
```

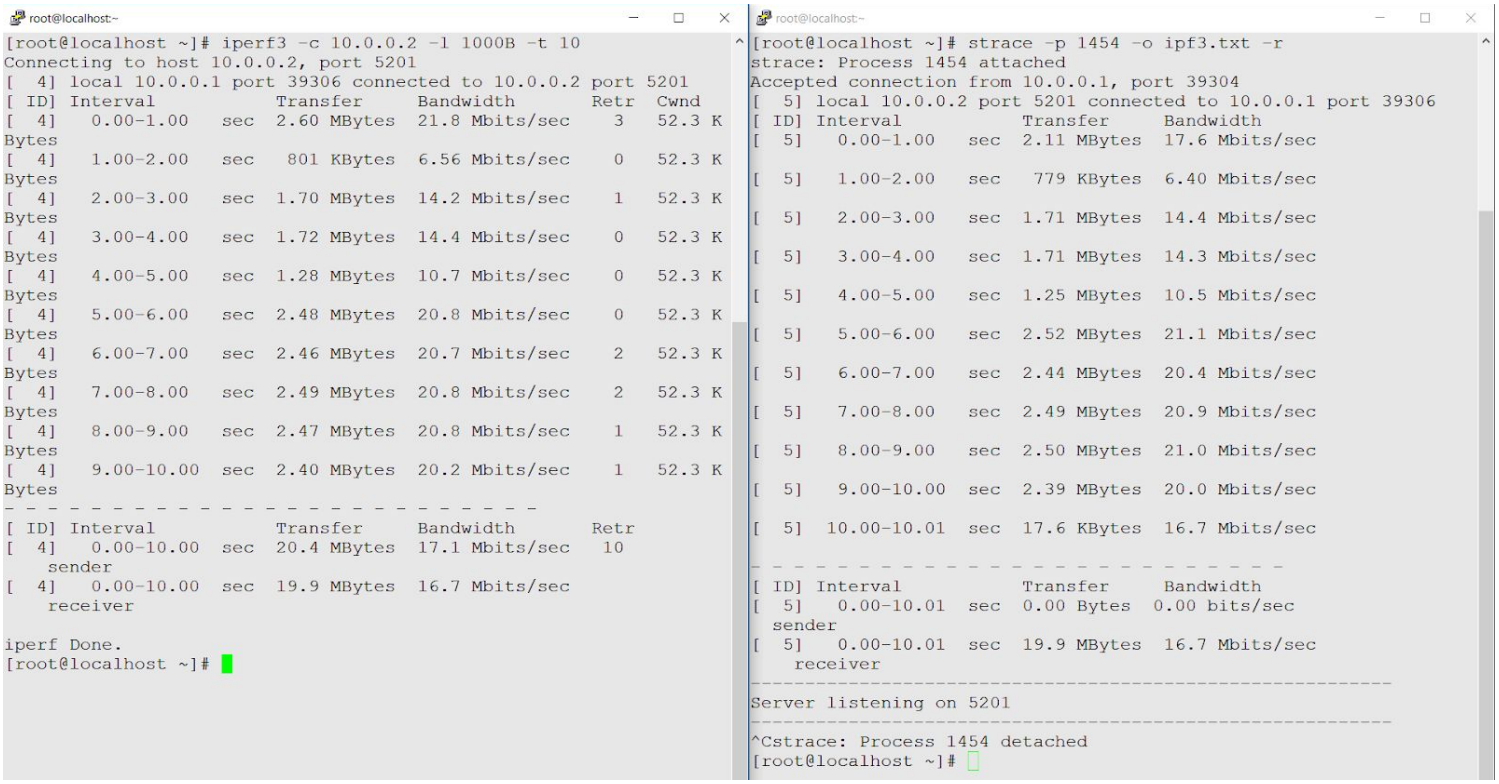
Similar results for another types as we put in .csv files. The code is robust to won't create duplicated docker containers and created using docker container modules of Ansible.

Problem 2:

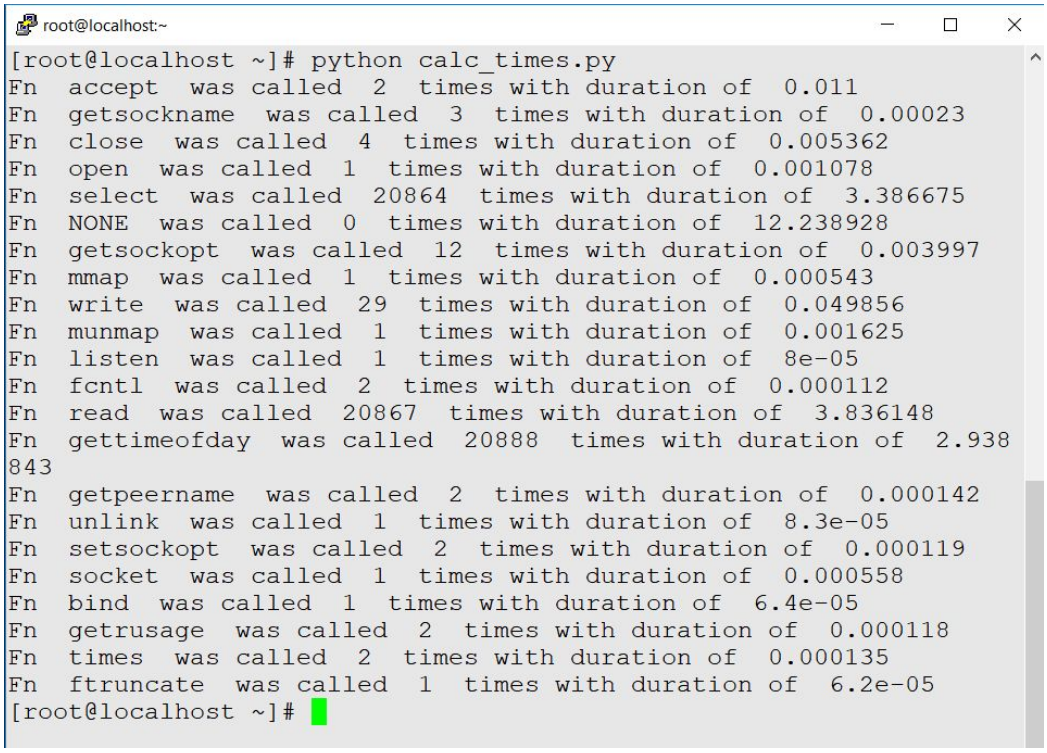
1) We have configured 2 VMs (iperf_test1 and iperf_test2) with 5 GB (VMs larger than 5GB had issues booting as we did not shutdown all VMs in our setup, we needed some for the project) memory and have performed the tests.

```
12:55:27.700882 IP 10.0.0.1.39292 > 10.0.0.2.5201: Flags [P.], seq 348:349, ack
233, win 237, options [nop,nop,TS val 243959 ecr 142076], length 1
12:55:27.707435 IP 10.0.0.1.39292 > 10.0.0.2.5201: Flags [F.], seq 349, ack 233,
 win 237, options [nop,nop,TS val 243965 ecr 142076], length 0
12:55:27.724389 IP 10.0.0.2.5201 > 10.0.0.1.39292: Flags [F.], seq 233, ack 350,
 win 235, options [nop,nop,TS val 142101 ecr 243959], length 0
12:55:27.725480 IP 10.0.0.1.39292 > 10.0.0.2.5201: Flags [.], ack 234, win 237,
options [nop,nop,TS val 243983 ecr 142101], length 0
^C
3405 packets captured
3415 packets received by filter
10 packets dropped by kernel
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ brctl show iperf_br
bridge name     bridge id               STP enabled     interfaces
iperf_br                8000.fe54001dda1e       no              vnet0
                                                        vnet6
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ virsh domifaddr iperf_test1
 Name       MAC address          Protocol     Address
-------------------------------------------------------------------------------
 vnet1      52:54:00:93:82:42    ipv4         192.168.122.80/24

ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ virsh domifaddr iperf_test2
 Name       MAC address          Protocol     Address
-------------------------------------------------------------------------------
 vnet9      52:54:00:3a:b0:ff    ipv4         192.168.122.132/24

ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ virsh domiflist iperf_test1
Interface  Type       Source     Model       MAC
-------------------------------------------------------
vnet0      bridge     iperf_br   virtio      52:54:00:91:e4:43
vnet1      network    default    virtio      52:54:00:93:82:42

ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ virsh domiflist iperf_test2
Interface  Type       Source     Model       MAC
-------------------------------------------------------
vnet6      bridge     iperf_net  virtio      52:54:00:1d:da:1e
vnet9      network    default    virtio      52:54:00:3a:b0:ff
```

The above screenshot displays the interfaces and their ip addresses.The interfaces in the iperf_net have been assigned 10.0.0.1 on iperf_test1 and 10.0.0.2 on iperf_test2. The first lines show the tcpdump when iperf is executing on the VMs.



The screenshot above displays the results of performing iperf on the VMs. On the left, strace has been attached to the iperf server executing in the background using “strace -o ipf3.txt -r -p <pid>”. We obtain a log of the function calls made by the server. The throughput also decreases slightly when this is done.



On parsing the log file using a python script we observe that 20,867 calls were made to the read and select function calls, both of which are used to select and read data from socket file descriptors, in 10 seconds. The NONE function is the initial wait time before iperf client connects, so we can ignore it.The client is sending 1000 bytes in each packet. On trying to calculate throughput from this:
20,867 * 8 (converting to bits) * 1000 (length) / 10 * 1000 * 1000
16.693 Mbps which is close to the observed throughput of 16.7Mbps

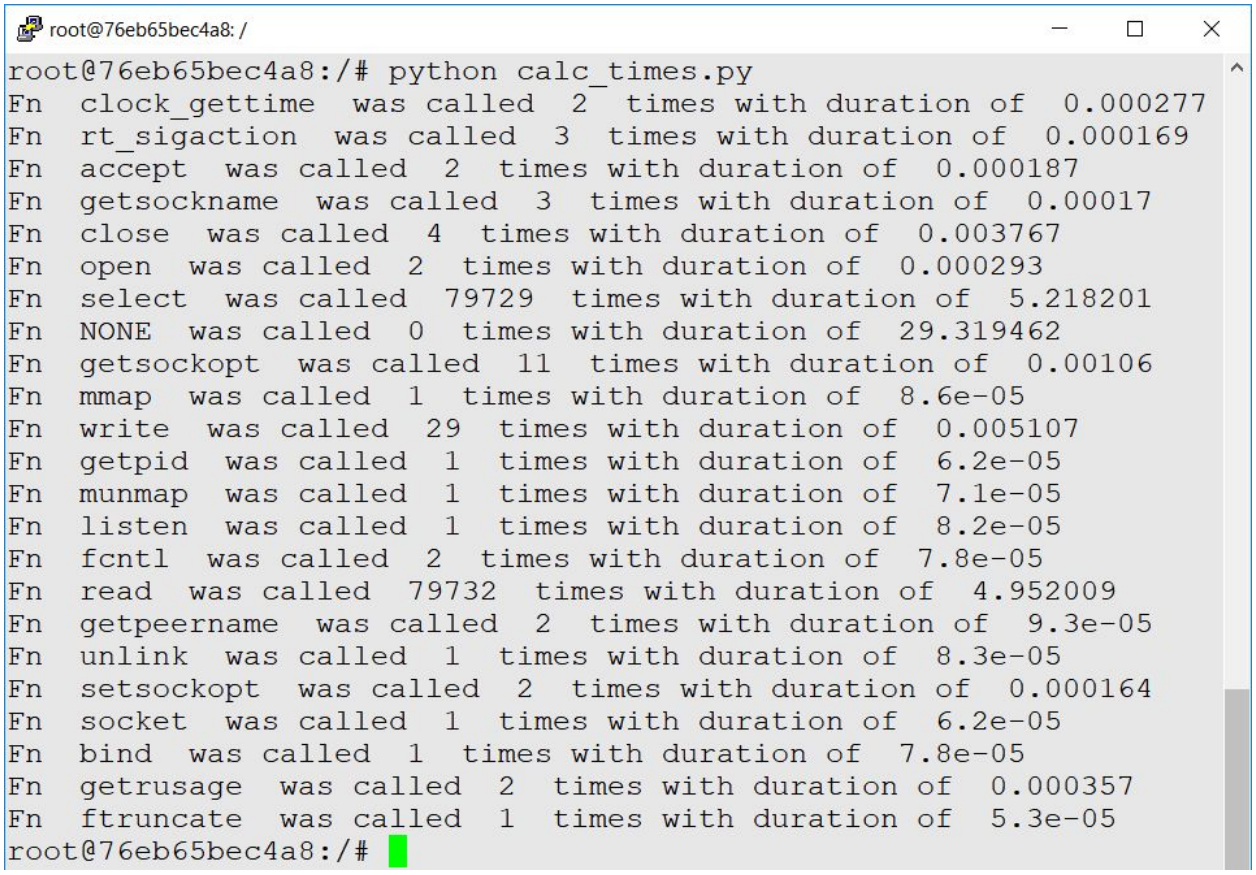
2) Repeating the same on containers we obtain:

```
13:29:44.347982 IP 20.0.0.2.41784 > 20.0.0.1.5201: Flags [.], ack 205, win 237, options [nop,nop,TS val 666951826 ecr 1290619714], l
ength 0
13:29:44.348439 IP 20.0.0.2.41784 > 20.0.0.1.5201: Flags [P.], seq 294:295, ack 205, win 237, options [nop,nop,TS val 666951826 ecr
1290619714], length 1
13:29:44.348893 IP 20.0.0.2.41784 > 20.0.0.1.5201: Flags [F.], seq 295, ack 205, win 237, options [nop,nop,TS val 666951826 ecr 1290
619714], length 0
13:29:44.349285 IP 20.0.0.1.5201 > 20.0.0.2.41784: Flags [F.], seq 205, ack 296, win 235, options [nop,nop,TS val 1290619714 ecr 666
951826], length 0
13:29:44.349338 IP 20.0.0.2.41784 > 20.0.0.1.5201: Flags [.], ack 206, win 237, options [nop,nop,TS val 666951826 ecr 1290619714], l
ength 0
13:29:44.639851 IP6 fe80::be:7cff:fe37:ca90 > ip6-allrouters: ICMP6, router solicitation, length 16
13:29:44.639857 IP6 fe80::b44b:22ff:fe8a:de93 > ip6-allrouters: ICMP6, router solicitation, length 16
^C
4441 packets captured
4511 packets received by filter
70 packets dropped by kernel
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$ brctl show iperf_br
bridge name     bridge id               STP enabled     interfaces
iperf_br                8000.928197a0a7f3       no              cslvif2
                                                        cs2vif2
ece792@ece792-Standard-PC-i440FX-PIIX-1996:~$
```

The above screenshot displays the other ends of interfaces connected to the container. These have been connected to an L2 bridge.

```
root@76eb65bec4a8:/# iperf3 -s &
[1] 103
root@76eb65bec4a8:/# -----------------------------------------------
--------------
Server listening on 5201
-----------------------------------------------------------


root@76eb65bec4a8:/# strace -o ipf3.txt -r -p 103
strace: Process 103 attached
Accepted connection from 20.0.0.2, port 41784
[  5] local 20.0.0.1 port 5201 connected to 20.0.0.2 port 41786
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  8.12 MBytes  68.1 Mbits/sec

[  5]   1.00-2.00   sec  7.54 MBytes  63.3 Mbits/sec

[  5]   2.00-3.00   sec  7.79 MBytes  65.4 Mbits/sec

[  5]   3.00-4.00   sec  7.60 MBytes  63.8 Mbits/sec

[  5]   4.00-5.00   sec  7.24 MBytes  60.7 Mbits/sec

[  5]   5.00-6.00   sec  7.44 MBytes  62.4 Mbits/sec

[  5]   6.00-7.00   sec  7.54 MBytes  63.2 Mbits/sec

[  5]   7.00-8.00   sec  7.43 MBytes  62.3 Mbits/sec

[  5]   8.00-9.00   sec  7.51 MBytes  63.0 Mbits/sec

[  5]   9.00-10.00  sec  7.51 MBytes  63.0 Mbits/sec

[  5]  10.00-10.04  sec   317 KBytes  60.7 Mbits/sec

- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  5]   0.00-10.04  sec  76.9 MBytes  64.2 Mbits/sec    0
    sender
[  5]   0.00-10.04  sec  76.0 MBytes  63.5 Mbits/sec
```

```
root@cc1815e3b658:/# iperf -c 20.0.0.1 -l 1000B -t 10
bash: iperf: command not found
root@cc1815e3b658:/# iperf3 -c 20.0.0.1 -l 1000B -t 10
Connecting to host 20.0.0.1, port 5201
[  4] local 20.0.0.2 port 41786 connected to 20.0.0.1 port 5201
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  9.09 MBytes  76.2 Mbits/sec    0    140 K
Bytes
[  4]   1.00-2.00   sec  7.79 MBytes  65.4 Mbits/sec    0    147 K
Bytes
[  4]   2.00-3.00   sec  7.71 MBytes  64.6 Mbits/sec    0    147 K
Bytes
[  4]   3.00-4.00   sec  7.46 MBytes  62.6 Mbits/sec    0    147 K
Bytes
[  4]   4.00-5.00   sec  7.21 MBytes  60.5 Mbits/sec    0    147 K
Bytes
[  4]   5.00-6.00   sec  7.54 MBytes  63.3 Mbits/sec    0    154 K
Bytes
[  4]   6.00-7.00   sec  7.71 MBytes  64.6 Mbits/sec    0    154 K
Bytes
[  4]   7.00-8.00   sec  7.21 MBytes  60.5 Mbits/sec    0    154 K
Bytes
[  4]   8.00-9.00   sec  7.71 MBytes  64.6 Mbits/sec    0    154 K
Bytes
[  4]   9.00-10.00  sec  7.46 MBytes  62.6 Mbits/sec    0    154 K
Bytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-10.00  sec  76.9 MBytes  64.5 Mbits/sec    0
    sender
[  4]   0.00-10.00  sec  76.0 MBytes  63.8 Mbits/sec
    receiver

iperf Done.
root@cc1815e3b658:/#
```



On trying to calculate throughput from this:
79,729 * 8 (converting to bits) * 1000 (length) / 10 * 1000 * 1000
63.78 which is close to the observed throughput of 63.8 Mbps

We observe that for a packet size 1000B, the throughput of containers is ~4x that of VMs.

3) No, the container and VM performance tests are not similar, we can observe that the containers perform better and provide higher throughput compared to the VMs. The function call which gets executed the maximum number of times are select and read function calls. On calculating the time it takes for containers and VMs to perform this.
Container: 4.952/79732 ~ 0.0000621
VM: 3.836/20867 ~ 0.000184
It takes around ~3x times more for the VM to perform this function call compared to containers. There are other functions such as accept, open, close and socket which take ~1/5th - 1/10th of the time to execute on containers than they take on VMs, we believe they too are contributing factors to the higher throughput in the containers. Apart from these VMs also execute gettimeofday which takes up ~30% of the total execution time.

4)
All the outputs are attached in folder iperfoutputs

PacketSize	Throughput
200B	14.9MBits/sec
400B	27.0MBits/Sec
800B	57.4MBits/sec
1600B	104.0MBits/sec
3200B	217.0MBits/sec
6400B	414.0MBits/sec

On parsing the output of strace we obtain the following:
For 200 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_200b.op
Fn  clock_gettime  was called  2  times with duration of  0.000106
Fn  rt_sigaction  was called  3  times with duration of  0.000382
Fn  accept  was called  2  times with duration of  0.000213
Fn  getsockname  was called  3  times with duration of  0.000249
Fn  close  was called  4  times with duration of  0.008961
Fn  open  was called  1  times with duration of  0.000249
Fn  select  was called  89525  times with duration of  5.406206
Fn  NONE  was called  0  times with duration of  46.770093
Fn  getsockopt  was called  11  times with duration of  0.000865
Fn  mmap  was called  1  times with duration of  0.000118
Fn  write  was called  29  times with duration of  0.007106
Fn  munmap  was called  1  times with duration of  0.000102
Fn  listen  was called  1  times with duration of  4.7e-05
Fn  fcntl  was called  2  times with duration of  0.00012
Fn  read  was called  89528  times with duration of  4.760557
Fn  getpeername  was called  2  times with duration of  0.000186
Fn  unlink  was called  1  times with duration of  0.00011
Fn  setsockopt  was called  2  times with duration of  9.9e-05
Fn  socket  was called  1  times with duration of  6.3e-05
Fn  bind  was called  1  times with duration of  5.7e-05
Fn  getrusage  was called  2  times with duration of  0.000114
Fn  ftruncate  was called  1  times with duration of  8e-05
root@76eb65bec4a8:/#
```

For 200 Bytes with network filter, though it is not an accurate representation of the execution time for the network functions as many other functions called between are skipped. But we can infer that setsockopt, socket, bind, accept…. are network function calls.

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_net_200b.op
Fn  setsockopt  was called  2  times with duration of  0.000233
Fn  NONE  was called  0  times with duration of  0.0
Fn  socket  was called  1  times with duration of  0.000147
Fn  bind  was called  1  times with duration of  0.000109
Fn  accept  was called  2  times with duration of  0.043109
Fn  getsockname  was called  3  times with duration of  1.000761
Fn  getpeername  was called  2  times with duration of  0.000292
Fn  listen  was called  1  times with duration of  0
Fn  getsockopt  was called  11  times with duration of  9.134872
```

For 400 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_400b.op
Fn  clock_gettime  was called  2  times with duration of  0.000114
Fn  rt_sigaction  was called  3  times with duration of  0.000198
Fn  accept  was called  2  times with duration of  0.000187
Fn  getsockname  was called  3  times with duration of  0.0003
Fn  close  was called  4  times with duration of  0.000935
Fn  open  was called  1  times with duration of  0.000244
Fn  select  was called  85131  times with duration of  5.386883
Fn  NONE  was called  0  times with duration of  3.287122
Fn  getsockopt  was called  11  times with duration of  0.000887
Fn  mmap  was called  1  times with duration of  0.000177
Fn  write  was called  29  times with duration of  0.002736
Fn  munmap  was called  1  times with duration of  7.1e-05
Fn  listen  was called  1  times with duration of  4.8e-05
Fn  fcntl  was called  2  times with duration of  0.000146
Fn  read  was called  85134  times with duration of  4.783249
Fn  getpeername  was called  2  times with duration of  0.00019
Fn  unlink  was called  1  times with duration of  0.000158
Fn  setsockopt  was called  2  times with duration of  0.000121
Fn  socket  was called  1  times with duration of  5.9e-05
Fn  bind  was called  1  times with duration of  6.4e-05
Fn  getrusage  was called  2  times with duration of  0.000104
Fn  ftruncate  was called  1  times with duration of  0.000115
```

For 800 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_800b.op
Fn  clock_gettime  was called  2  times with duration of  0.000133
Fn  rt_sigaction  was called  3  times with duration of  0.000183
Fn  accept  was called  2  times with duration of  0.000275
Fn  getsockname  was called  3  times with duration of  0.000265
Fn  close  was called  4  times with duration of  0.000697
Fn  open  was called  1  times with duration of  0.000457
Fn  select  was called  88510  times with duration of  5.384462
Fn  NONE  was called  0  times with duration of  1.404665
Fn  getsockopt  was called  11  times with duration of  0.000832
Fn  mmap  was called  1  times with duration of  0.00011
Fn  write  was called  29  times with duration of  0.002748
Fn  munmap  was called  1  times with duration of  7e-05
Fn  listen  was called  1  times with duration of  4.5e-05
Fn  fcntl  was called  2  times with duration of  0.000131
Fn  read  was called  88513  times with duration of  4.787201
Fn  getpeername  was called  2  times with duration of  0.000212
Fn  unlink  was called  1  times with duration of  9.8e-05
Fn  setsockopt  was called  2  times with duration of  0.000101
Fn  socket  was called  1  times with duration of  7.2e-05
Fn  bind  was called  1  times with duration of  6e-05
Fn  getrusage  was called  2  times with duration of  0.000118
Fn  ftruncate  was called  1  times with duration of  7.8e-05
root@76eb65bec4a8:/#
```

For 1600 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_1600b.op
Fn  clock_gettime  was called  2  times with duration of  9.5e-05
Fn  rt_sigaction  was called  3  times with duration of  0.000187
Fn  accept  was called  2  times with duration of  0.00027
Fn  getsockname  was called  3  times with duration of  0.000212
Fn  close  was called  4  times with duration of  0.000677
Fn  open  was called  1  times with duration of  0.000277
Fn  select  was called  80921  times with duration of  5.325972
Fn  NONE  was called  0  times with duration of  7.417033
Fn  getsockopt  was called  11  times with duration of  0.000886
Fn  mmap  was called  1  times with duration of  0.00011
Fn  write  was called  29  times with duration of  0.002704
Fn  munmap  was called  1  times with duration of  5.2e-05
Fn  listen  was called  1  times with duration of  4.5e-05
Fn  fcntl  was called  2  times with duration of  9.2e-05
Fn  read  was called  80924  times with duration of  4.846145
Fn  getpeername  was called  2  times with duration of  0.000153
Fn  unlink  was called  1  times with duration of  0.000312
Fn  setsockopt  was called  2  times with duration of  9.1e-05
Fn  socket  was called  1  times with duration of  5.6e-05
Fn  bind  was called  1  times with duration of  5.1e-05
Fn  getrusage  was called  2  times with duration of  0.0001
Fn  ftruncate  was called  1  times with duration of  6.3e-05
root@76eb65bec4a8:/#
```

For 3200 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_3200b.op
Fn  clock_gettime  was called  2  times with duration of  6.9e-05
Fn  rt_sigaction  was called  3  times with duration of  0.000135
Fn  accept  was called  2  times with duration of  0.000193
Fn  getsockname  was called  3  times with duration of  0.000228
Fn  close  was called  4  times with duration of  0.000301
Fn  open  was called  1  times with duration of  0.00017
Fn  select  was called  84341  times with duration of  5.251252
Fn  NONE  was called  0  times with duration of  4.818501
Fn  getsockopt  was called  11  times with duration of  0.000844
Fn  mmap  was called  1  times with duration of  0.000125
Fn  write  was called  29  times with duration of  0.002595
Fn  munmap  was called  1  times with duration of  5.3e-05
Fn  listen  was called  1  times with duration of  3.2e-05
Fn  fcntl  was called  2  times with duration of  9.9e-05
Fn  read  was called  84344  times with duration of  4.921138
Fn  getpeername  was called  2  times with duration of  0.000166
Fn  unlink  was called  1  times with duration of  0.00025
Fn  setsockopt  was called  2  times with duration of  0.000168
Fn  socket  was called  1  times with duration of  4.4e-05
Fn  bind  was called  1  times with duration of  4.1e-05
Fn  getrusage  was called  2  times with duration of  6.9e-05
Fn  ftruncate  was called  1  times with duration of  8.8e-05
root@76eb65bec4a8:/#
```

For 6400 Bytes

```
root@76eb65bec4a8:/# cat /ntw_ops/trace_6400b.op
Fn  clock_gettime  was called  2  times with duration of  9.6e-05
Fn  rt_sigaction  was called  3  times with duration of  0.000158
Fn  accept  was called  2  times with duration of  0.000201
Fn  getsockname  was called  3  times with duration of  0.00071
Fn  close  was called  4  times with duration of  0.000452
Fn  open  was called  1  times with duration of  0.000279
Fn  select  was called  80657  times with duration of  5.148772
Fn  NONE  was called  0  times with duration of  2.009921
Fn  getsockopt  was called  11  times with duration of  0.000837
Fn  mmap  was called  1  times with duration of  0.000341
Fn  write  was called  29  times with duration of  0.003826
Fn  munmap  was called  1  times with duration of  5.2e-05
Fn  listen  was called  1  times with duration of  4.8e-05
Fn  fcntl  was called  2  times with duration of  0.000164
Fn  read  was called  80660  times with duration of  5.017708
Fn  getpeername  was called  2  times with duration of  0.00027
Fn  unlink  was called  1  times with duration of  0.000138
Fn  setsockopt  was called  2  times with duration of  9.1e-05
Fn  socket  was called  1  times with duration of  5.6e-05
Fn  bind  was called  1  times with duration of  7.5e-05
Fn  getrusage  was called  2  times with duration of  9.9e-05
Fn  ftruncate  was called  1  times with duration of  7.7e-05
```

From these screenshots, we can observe that time execution time for socket, getpeername, setsockopt, open, close and other network related function calls doesn't change/increase with

an increase in packet size. From this, we can infer that network function calls aren’t affected by the increase in packet size.

Problem 3:

kubectl not being configured with networking plugin so far and we are still learning. We will keep trying and submit later. Sorry for the inconvenience. Thank you.

Reference Links:

- https://www.howtoforge.com/tutorial/ubuntu-docker/
-
- https://askubuntu.com/questions/477551/how-can-i-use-docker-without-sudo
- https://docs.docker.com/network/overlay-standalone.swarm/#set-up-a-key-value-store
-
- https://stackoverflow.com/questions/31907117/how-to-connect-docker-containers-without-a-bridge
- https://wiki.ubuntu.com/Strace
- https://jvns.ca/blog/2017/03/19/getting-started-with-ftrace/
- https://stackoverflow.com/questions/30663245/tcpdump-reports-error-in-docker-container-thats-started-with-privileged
-