Project Report

1. Show the configuration commands you made on each node to provide Internet connectivity for hosts and briefly explain the purpose of the commands

(a)BRG1 and BRG2

```
#gre(BRG1)
sudo modprobe fou
docker exec -it BRG1 ip fou add port 33333 ipproto 47
docker exec -it BRG1 ip link add gretap type gretap remote 140.113.0.2 local 172.27.0.2 encap fou
key 1 encap-sport 33333 encap-dport 55555
docker exec -it BRG1 ip link set gretap up
docker exec -it BRG1 ip link add br1 type bridge
docker exec -it BRG1 brctl addif br1 Veth5up
docker exec -it BRG1 brctl addif br1 gretap
docker exec -it BRG1 ip link set br1 up

#gre(BRG2)
sudo modprobe fou
docker exec -it BRG2 ip fou add port 33332 ipproto 47
docker exec -it BRG2 ip link add gretap type gretap remote 140.113.0.2 local 172.27.0.3 encap fou
key 2 encap-sport 33332 encap-dport 55554
docker exec -it BRG2 ip link set gretap up
docker exec -it BRG2 ip link add br2 type bridge
docker exec -it BRG2 brctl addif br2 Veth7up
docker exec -it BRG2 brctl addif br2 gretap
docker exec -it BRG2 ip link set br2 up
```

Ans:

1. Do GRE configuration in BRG1(BRG2), including setting source and destination ip address and port(statically).
2. Set up GRE tunnel.
3. Build bridge inside BRG1(BRG2) and add link(gretap and Veth, which is between BRG1 and H1) to bridge.
4. Set up bridge to connect BRGr.

(b)BRGr

Ans:

```
docker run -it -d --cap-add=NET_ADMIN --name BRGr -v /home/potatofarm/Desktop/main:/main --
net=none --privileged ubuntu-new
```

1. Put main(dynamic update GRE tunnel) file into container BRGr.

```
#gateway
docker exec -it BRGr route add -net 140.114.0.0/16 gw 140.113.0.1
```

2. Set routing rules to send packet which is 140.114. … to Router at left.

```
docker exec -d BRGr ./main
```

3. Execute main file to build GRE tunnel to connect BRG1(BRG2) and H1(H2).

(c)Edge Router

Ans:

```
docker run -it -d --cap-add=NET_ADMIN --name Edge -v /home/potatofarm/Desktop/dhcpd.conf:/
dhcpd.conf --net=none --privileged ubuntu-new
```

1. Put dhcpd.conf file into container.

```
#DHCP(Edge)
sudo iptables -P FORWARD ACCEPT
docker exec -it Edge touch /var/lib/dhcp/dhcpd.leases
docker exec -it Edge /usr/sbin/dhcpd Veth3up -cf ./dhcpd.conf
```

2. Create a directory for DHCP to run, and execute dhcpd.conf to create DHCP server on Veth(between Edge router and br0).

```
#NAT(Edge)
docker exec -it Edge iptables -t nat -A POSTROUTING -s 172.27.0.0/16 -o Veth2left -j MASQUERADE
```

```
potatofarm@potatofarm-VirtualBox:~/Desktop$ docker exec -it Edge iptables -t nat -L
 -n -v
Chain PREROUTING (policy ACCEPT 22 packets, 3490 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain INPUT (policy ACCEPT 16 packets, 2374 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain OUTPUT (policy ACCEPT 4 packets, 276 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain POSTROUTING (policy ACCEPT 4 packets, 276 bytes)
 pkts bytes target     prot opt in     out     source               destination
    2   756 MASQUERADE  all  --  *      Veth2left  172.27.0.0/16        0.0.0.0/0
```

3. Do NAT to translate 172.27. … to proper ip address(MASQUERADE)(to GWr).

(d)GWr
Ans:

```
#DHCP(GWr)
sudo iptables -P FORWARD ACCEPT
sudo touch /var/lib/dhcp/dhcpd.leases
sudo /usr/sbin/dhcpd Veth0right -cf ./dhcpd-GWr.conf
```

1. Create a directory for DHCP to run, and execute dhcpd.conf to create DHCP server on Veth(between GWr and BRGr)

```
#NAT(GWr)
sudo iptables -t nat -A POSTROUTING -s 20.0.0.0/8 -o enp0s3 -j MASQUERADE
```

```
Chain POSTROUTING (policy ACCEPT 817 packets, 63622 bytes)
 pkts bytes target     prot opt in     out     source               destination

    0     0 MASQUERADE  all  --  *      !docker0  172.17.0.0/16        0.0.0.0/0

    0     0 MASQUERADE  all  --  *      enp0s3  172.27.0.0/16         0.0.0.0/0

    0     0 MASQUERADE  all  --  *      enp0s3  172.27.0.0/16         0.0.0.0/0

    7   588 MASQUERADE  all  --  *      enp0s3  20.0.0.0/8           0.0.0.0/0

    0     0 MASQUERADE  all  --  *      enp0s3  20.0.0.0/8           0.0.0.0/0

    0     0 MASQUERADE  all  --  *      enp0s3  20.0.0.0/8           0.0.0.0/0
```

2. Do NAT to translate 20.0.0. … to proper ip address(MASQUERADE)(to VM).

2.Show interfaces list on node BRGr and BRG1, 2

Ans:

(1)BRGr

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRGr ifconfig
GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 06:52:36:df:25:6f  txqueuelen 1000  (Ethernet)
        RX packets 7  bytes 1026 (1.0 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 80  bytes 7070 (7.0 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

GRE2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 3e:ec:59:de:c9:13  txqueuelen 1000  (Ethernet)
        RX packets 8  bytes 1124 (1.1 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 75  bytes 6362 (6.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

Veth0left: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether fa:c1:91:76:dd:87  txqueuelen 1000  (Ethernet)
        RX packets 125  bytes 14912 (14.9 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 17  bytes 2258 (2.2 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

Veth1right: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 140.113.0.2  netmask 255.255.0.0  broadcast 0.0.0.0
        ether be:a6:5b:64:b8:07  txqueuelen 1000  (Ethernet)
        RX packets 148  bytes 20858 (20.8 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 188  bytes 26250 (26.2 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 06:52:36:df:25:6f  txqueuelen 1000  (Ethernet)
        RX packets 62  bytes 5906 (5.9 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2  bytes 108 (108.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

(2)BRG1

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRG1 ifconfig
Veth4down: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.27.0.2  netmask 255.255.255.192  broadcast 172.27.0.63
        ether ae:d1:7d:5f:8e:04  txqueuelen 1000  (Ethernet)
        RX packets 124  bytes 19352 (19.3 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 21  bytes 3408 (3.4 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

Veth5up: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether 32:4d:22:93:a7:65  txqueuelen 1000  (Ethernet)
        RX packets 9  bytes 1710 (1.7 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 26  bytes 3768 (3.7 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 32:4d:22:93:a7:65  txqueuelen 1000  (Ethernet)
        RX packets 22  bytes 3736 (3.7 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2  bytes 108 (108.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
gretap: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether d6:43:77:4e:5e:8c  txqueuelen 1000  (Ethernet)
        RX packets 24  bytes 3660 (3.6 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 11  bytes 1664 (1.6 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

(3)BRG2

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRG2 ifconfig
Veth6down: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.27.0.3  netmask 255.255.255.192  broadcast 172.27.0.63
        ether 2a:9d:46:f9:c8:f9  txqueuelen 1000  (Ethernet)
        RX packets 120  bytes 18490 (18.4 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 21  bytes 3514 (3.5 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

Veth7up: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether fe:9f:4a:85:39:3a  txqueuelen 1000  (Ethernet)
        RX packets 10  bytes 1808 (1.8 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 23  bytes 3098 (3.0 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 42:a7:ad:a0:c6:e7  txqueuelen 1000  (Ethernet)
        RX packets 18  bytes 3024 (3.0 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2  bytes 108 (108.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

gretap: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 42:a7:ad:a0:c6:e7  txqueuelen 1000  (Ethernet)
        RX packets 21  bytes 2990 (2.9 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 12  bytes 1748 (1.7 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

3.Capture packets and take screenshots on node

(1)BRG1 input(h1 ping 8.8.8.8)

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRG1 tcpdump -i Veth5up -XX
-n
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on Veth5up, link-type EN10MB (Ethernet), capture size 262144 bytes
13:47:42.529271 IP 20.0.0.10 > 8.8.8.8: ICMP echo request, id 68, seq 10, length
 64
        0x0000:  4a91 edf7 11c7 0280 9c34 b149 0800 4500  J........4.I..E.
        0x0010:  0054 d100 4000 4001 458f 1400 000a 0808  .T..@.@.E.......
        0x0020:  0808 0800 496c 0044 000a fefe 8f60 0000  ....Il.D.....`..
        0x0030:  0000 5913 0800 0000 0000 1011 1213 1415  ..Y.............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ..........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(2)BRG1 output(h1 ping 8.8.8.8)

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRG1 tcpdump -i Veth4down -X
X -n
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on Veth4down, link-type EN10MB (Ethernet), capture size 262144 bytes
13:46:02.481616 IP 172.27.0.2.33333 > 140.113.0.2.55555: UDP, length 106
        0x0000:  4663 b2a9 3a31 aed1 7d5f 8e04 0800 4500  Fc..:1..}_....E.
        0x0010:  0086 5197 4000 4011 b03f ac1b 0002 8c71  ..Q.@.@..?.....q
        0x0020:  0002 8235 d903 0072 0000 2000 6558 0000  ...5...r.... eX..
        0x0030:  0001 4a91 edf7 11c7 0280 9c34 b149 0800  ..J........4.I..
        0x0040:  4500 0054 9fe9 4000 4001 76a6 1400 000a  E..T..@.@.v.....
        0x0050:  0808 0808 0800 ec35 003e 0001 9afe 8f60  .......5.>.....`
        0x0060:  0000 0000 1b59 0700 0000 0000 1011 1213  .....Y..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............!"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(3)BRG1 input(DNS server reply)

```
14:44:50.315558 IP 140.113.0.2.55555 > 172.27.0.2.33333: UDP, length 106
        0x0000:  aed1 7d5f 8e04 4663 b2a9 3a31 0800 4500  ..}_..Fc..:1..E.
        0x0010:  0086 27dd 4000 3b11 def9 8c71 0002 ac1b  ..'.@.;....q....
        0x0020:  0002 d903 8235 0072 0000 2000 6558 0000  .....5.r.... eX..
        0x0030:  0001 0280 9c34 b149 4a91 edf7 11c7 0800  .....4.IJ.......
        0x0040:  4500 0054 2f9c 4000 3d01 e9f3 0808 0808  E..T/.@.=.......
        0x0050:  1400 000a 0000 871e 0077 0005 620c 9060  .........w..b..`
        0x0060:  0000 0000 c325 0400 0000 0000 1011 1213  .....%..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............!"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(4)BRG1 output(DNS server reply)

```
14:49:30.004346 IP 8.8.8.8 > 20.0.0.10: ICMP echo reply, id 126, seq 4, length 6
4
        0x0000:  0280 9c34 b149 4a91 edf7 11c7 0800 4500  ...4.IJ.......E.
        0x0010:  0054 3046 4000 3d01 e949 0808 0808 1400  .T0F@.=..I......
        0x0020:  000a 0000 6afe 007e 0004 790d 9060 0000  ....j..~..y..`..
        0x0030:  0000 bd3e 0f00 0000 0000 1011 1213 1415  ...>............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ..........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

When leaving BRG1 to GRE tunnel, packets will be added Outer Mac, Outer IP and UDP header.

(5)Access router input(h1 ping 8.8.8.8)

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it Router tcpdump -i Veth1left
-XX -n
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on Veth1left, link-type EN10MB (Ethernet), capture size 262144 bytes
14:40:39.879266 IP 140.114.0.1.33333 > 140.113.0.2.55555: UDP, length 106
        0x0000:  bea6 5b64 b807 32fa 619e 3584 0800 4500  ..[d..2.a.5...E.
        0x0010:  0086 d1fb 4000 3e11 5185 8c72 0001 8c71  ....@.>.Q..r...q
        0x0020:  0002 8235 d903 0072 0000 2000 6558 0000  ...5...r.... eX..
        0x0030:  0001 4a91 edf7 11c7 0280 9c34 b149 0800  ..J........4.I..
        0x0040:  4500 0054 772b 4000 4001 9f64 1400 000a  E..Tw+@.@..d....
        0x0050:  0808 0808 0800 1fe7 006f 0001 670b 9060  .........o..g..`
        0x0060:  0000 0000 146a 0d00 0000 0000 1011 1213  .....j..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(6)Access router output(h1 ping 8.8.8.8)

```
14:51:28.371132 IP 140.114.0.1.33333 > 140.113.0.2.55555: UDP, length 106
        0x0000:  4e0b bc6c c310 7247 5989 35e9 0800 4500  N..l..rGY.5...E.
        0x0010:  0086 aaf6 4000 3f11 778a 8c72 0001 8c71  ....@.?.w..r...q
        0x0020:  0002 8235 d903 0072 0000 2000 6558 0000  ...5...r.... eX..
        0x0030:  0001 4a91 edf7 11c7 0280 9c34 b149 0800  ..J........4.I..
        0x0040:  4500 0054 4743 4000 4001 cf4c 1400 000a  E..TGC@.@..L....
        0x0050:  0808 0808 0800 5086 008c 0003 f00d 9060  ......P........`
        0x0060:  0000 0000 62a9 0500 0000 0000 1011 1213  ....b...........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(7)Access router input(DNS server reply)

```
14:40:39.879373 IP 140.113.0.2.55554 > 140.114.0.1.33332: UDP, length 106
        0x0000:  32fa 619e 3584 bea6 5b64 b807 0800 4500  2.a.5...[d....E.
        0x0010:  0086 9f83 4000 4011 81fd 8c71 0002 8c72  ....@.@....q...r
        0x0020:  0001 d902 8234 0072 0000 2000 6558 0000  .....4.r.... eX..
        0x0030:  0002 4a91 edf7 11c7 0280 9c34 b149 0800  ..J........4.I..
        0x0040:  4500 0054 772b 4000 4001 9f64 1400 000a  E..Tw+@.@..d....
        0x0050:  0808 0808 0800 1fe7 006f 0001 670b 9060  .........o..g..`
        0x0060:  0000 0000 146a 0d00 0000 0000 1011 1213  .....j..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(8)Access router output(DNS server reply)

```
14:51:28.377505 IP 140.113.0.2.55555 > 140.114.0.1.33333: UDP, length 106
        0x0000:  7247 5989 35e9 4e0b bc6c c310 0800 4500  rGY.5.N..l....E.
        0x0010:  0086 a1fa 4000 3c11 8386 8c71 0002 8c72  ....@.<....q...r
        0x0020:  0001 d903 8235 0072 0000 2000 6558 0000  .....5.r.... eX..
        0x0030:  0001 0280 9c34 b149 4a91 edf7 11c7 0800  .....4.IJ.......
        0x0040:  4500 0054 30a3 4000 3d01 e8ec 0808 0808  E..T0.@.=.......
        0x0050:  1400 000a 0000 5886 008c 0003 f00d 9060  ......X........`
        0x0060:  0000 0000 62a9 0500 0000 0000 1011 1213  ....b...........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

No big change, but port might change due to GRE tunnel.

|——|

(9)BRGr input(h1 ping 8.8.8.8)

```
15:01:31.284832 IP 140.114.0.1.33333 > 140.113.0.2.55555: UDP, length 106
        0x0000:  bea6 5b64 b807 32fa 619e 3584 0800 4500  ..[d..2.a.5...E.
        0x0010:  0086 dd24 4000 3e11 465c 8c72 0001 8c71  ...$@.>.F\.r...q
        0x0020:  0002 8235 d903 0072 0000 2000 6558 0000  ...5...r.... eX..
        0x0030:  0001 4a91 edf7 11c7 0280 9c34 b149 0800  ..J........4.I..
        0x0040:  4500 0054 b77a 4000 4001 5f15 1400 000a  E..T.z@.@._.....
        0x0050:  0808 0808 0800 07c4 009e 0002 4b10 9060  ............K..`
        0x0060:  0000 0000 5158 0400 0000 0000 1011 1213  ....QX..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  ............ !"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

(10)BRGr output(h1 ping 8.8.8.8)

```
15:00:21.882018 IP 20.0.0.10 > 8.8.8.8: ICMP echo request, id 152, seq 6, length
 64
        0x0000:  4a91 edf7 11c7 0280 9c34 b149 0800 4500  J........4.I..E.
        0x0010:  0054 b41a 4000 4001 6275 1400 000a 0808  .T..@.@.bu......
        0x0020:  0808 0800 36b3 0098 0006 0510 9060 0000  ....6........`..
        0x0030:  0000 5f6b 0d00 0000 0000 1011 1213 1415  .._k............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ............ !"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(11)BRGr input(DNS server reply)

```
15:00:20.889702 IP 8.8.8.8 > 20.0.0.10: ICMP echo reply, id 152, seq 5, length 6
4
        0x0000:  0280 9c34 b149 4a91 edf7 11c7 0800 4500  ...4.IJ.......E.
        0x0010:  0054 3208 4000 3d01 e787 0808 0808 1400  .T2.@.=.........
        0x0020:  000a 0000 26bb 0098 0005 0410 9060 0000  ....&........`..
        0x0030:  0000 7864 0d00 0000 0000 1011 1213 1415  ..xd............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ............ !"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(12)BRGr output(DNS server reply)

```
15:01:31.339933 IP 140.113.0.2.55555 > 140.114.0.1.33333: UDP, length 106
        0x0000:  32fa 619e 3584 bea6 5b64 b807 0800 4500  2.a.5...[d....E.
        0x0010:  0086 d913 4000 3d11 4b6d 8c71 0002 8c72  ....@.=.Km.q...r
        0x0020:  0001 d903 8235 0072 0000 2000 6558 0000  .....5.r....eX..
        0x0030:  0001 0280 9c34 b149 4a91 edf7 11c7 0800  .....4.IJ.......
        0x0040:  4500 0054 3238 4000 3d01 e757 0808 0808  E..T28@.=..W....
        0x0050:  1400 000a 0000 0fc4 009e 0002 4b10 9060  ............K..`
        0x0060:  0000 0000 5158 0400 0000 0000 1011 1213  ....QX..........
        0x0070:  1415 1617 1819 1a1b 1c1d 1e1f 2021 2223  .............!"#
        0x0080:  2425 2627 2829 2a2b 2c2d 2e2f 3031 3233  $%&'()*+,-./0123
        0x0090:  3435 3637                                4567
```

Packets are leaving BRGr, meaning they are not in GRE tunnel anymore. Need to decapsulate additional header to send to GWr.

|——|

(13)GWr input(h1 ping 8.8.8.8)

```
23:06:45.508385 IP 20.0.0.10 > 8.8.8.8: ICMP echo request, id 166, seq 4, length
 64
        0x0000:  4a91 edf7 11c7 0280 9c34 b149 0800 4500  J........4.I..E.
        0x0010:  0054 3f1f 4000 4001 d770 1400 000a 0808  .T?.@.@..p......
        0x0020:  0808 0800 a44f 00a6 0004 8511 9060 0000  .....O.......`..
        0x0030:  0000 77c1 0700 0000 0000 1011 1213 1415  ..w.............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ...........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(14)GWr output(h1 ping 8.8.8.8)

```
23:09:14.612840 IP 10.0.2.15 > 8.8.8.8: ICMP echo request, id 174, seq 4, length
 64
        0x0000:  5254 0012 3502 0800 27b1 5395 0800 4500  RT..5...'.S...E.
        0x0010:  0054 a9c4 4000 3f01 75c6 0a00 020f 0808  .T..@.?.u.......
        0x0020:  0808 0800 32af 00ae 0004 1a12 9060 0000  ....2........`..
        0x0030:  0000 5259 0900 0000 0000 1011 1213 1415  ..RY............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ...........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(15)GWr input(DNS server reply)

```
23:09:14.669402 IP 8.8.8.8 > 10.0.2.15: ICMP echo reply, id 174, seq 4, length 6
4
        0x0000:  0800 27b1 5395 5254 0012 3502 0800 4500  ..'.S.RT..5...E.
        0x0010:  0054 3329 4000 3e01 ed61 0808 0808 0a00  .T3)@.>..a......
        0x0020:  020f 0000 3aaf 00ae 0004 1a12 9060 0000  ....:........`..
        0x0030:  0000 5259 0900 0000 0000 1011 1213 1415  ..RY............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ...........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

(16)GWr output(DNS server reply)

```
23:06:45.543899 IP 8.8.8.8 > 20.0.0.10: ICMP echo reply, id 166, seq 4, length 6
4
        0x0000:  0280 9c34 b149 4a91 edf7 11c7 0800 4500  ...4.IJ.......E.
        0x0010:  0054 32e3 4000 3d01 e6ac 0808 0808 1400  .T2.@.=.........
        0x0020:  000a 0000 ac4f 00a6 0004 8511 9060 0000  .....O.......`..
        0x0030:  0000 77c1 0700 0000 0000 1011 1213 1415  ..w.............
        0x0040:  1617 1819 1a1b 1c1d 1e1f 2021 2223 2425  ...........!"#$%
        0x0050:  2627 2829 2a2b 2c2d 2e2f 3031 3233 3435  &'()*+,-./012345
        0x0060:  3637                                     67
```

source ip and destination ip might change due to NAT translation on GWr.

4.BRGr will receive ping responses from Google DNS. Briefly describe how BRGr determines the GRE interface to tunnel the response packets back to BRG1.
Ans:

```
potatofarm@potatofarm-VirtualBox:~$ docker exec -it BRGr brctl showmacs br1
port no mac addr                is local?       ageing timer
  2     06:52:36:df:25:6f       yes                0.00
  2     06:52:36:df:25:6f       yes                0.00
  3     3e:ec:59:de:c9:13       yes                0.00
  3     3e:ec:59:de:c9:13       yes                0.00
  1     fa:c1:91:76:dd:87       yes                0.00
  1     fa:c1:91:76:dd:87       yes                0.00
```

```
br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1464
        ether 06:52:36:df:25:6f  txqueuelen 1000  (Ethernet)
        RX packets 80  bytes 7070 (7.0 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2  bytes 108 (108.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

When packet sending, BRGr knows the port of a packet, and could use port to find MAC address. BRGr would determine destination through MAC address, and learn the information using MAC learning.