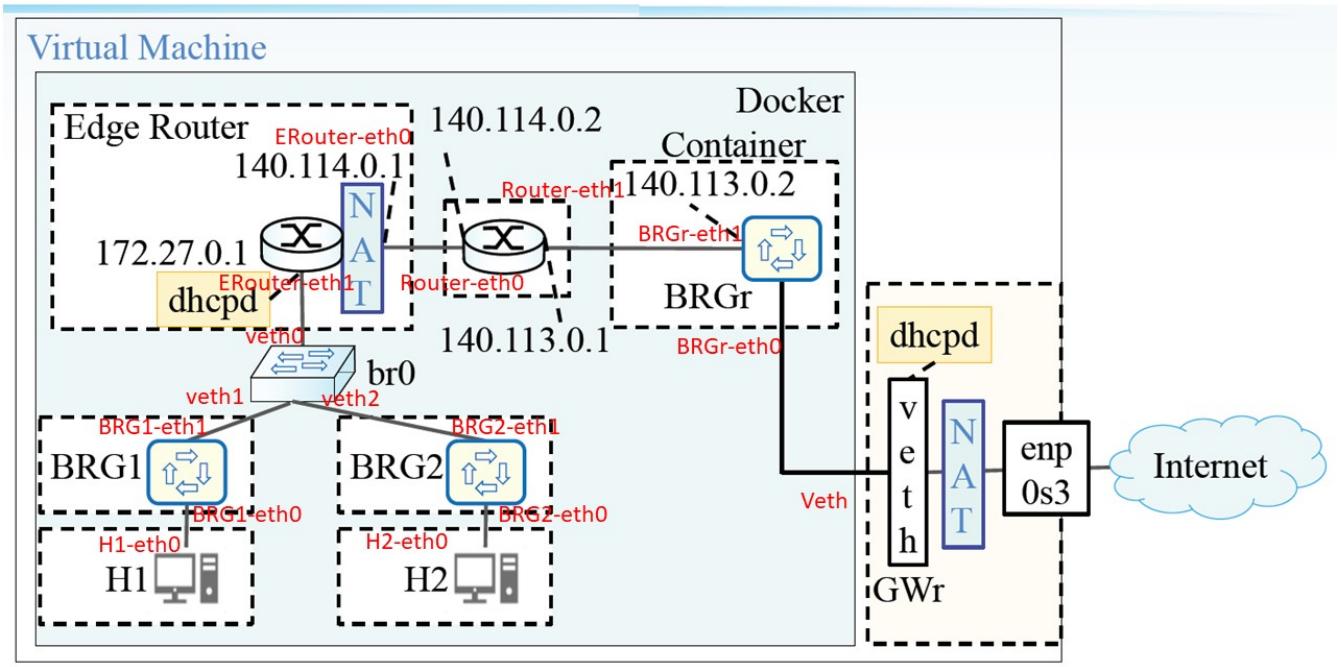
NS Project Report

Topology:



1. configuration commands:
   A. BRG1: GRE over UDP (statically):

```
server_ip=$(ifconfig | sed -n '9p' | awk '{print $2;}')
ip fou add port 30000 ipproto 47
ip link add GRE1 type gretap remote 140.113.0.2 local $server_ip key 1 encap fou encap-sport 30000 encap-dport 50000
ip link set GRE1 up
ip link add br1 type bridge
brctl addif br1 BRG1-eth0
brctl addif br1 GRE1
ip link set br1 up
```

由上到下:

i. 用 ifconfig 拿到自己 ip
ii. 設定 fou 的 port 和 ipproto 47 (gre)
iii. 設定通道 GRE1，remote 填 BRGr-eth1 ip、local 填自己 ip、key 填 1 (BRG2 那條填 2，區別用)、sport 填 i 設定的 port、dport 填 BRGr-eth1 那端的 port。
iv. 建立 GRE1
v. 設定 bridge br1，並加入 BRG1-eth0 和通道 GRE1 兩個 interface，然後將其 set up。

   B. BRGr: GRE over UDP (dynamically):

```
string cmd = "ip fou add port "+ dst_port +" ipproto 47";
system(cmd.c_str());
cmd = "ip link add GRE" + to_string(tunnel_cnt) + " type gretap remote " + string(sourceIp) + " local 140.113.0.2 key "+ to_string(tunnel_cnt) +" encap fou encap-sport "+ dst_port +" encap-dport "+ src_port;
system(cmd.c_str());
cmd = "ip link set GRE" + to_string(tunnel_cnt) + " up";
system(cmd.c_str());
if(tunnel_cnt == 1){
    system("ip link add br1 type bridge");
    system("brctl addif br1 BRGr-eth0");
}
cmd = "brctl addif br1 GRE" + to_string(tunnel_cnt);
system(cmd.c_str());
if(tunnel_cnt == 1){
    system("ip link set br1 up");
}
cout<<"\nCreate tunnel " << string(sourceIp) << ":" << src_port << " to " << "140.113.0.2:" << dst_port << endl;
tunnel_cnt++;

//update filter
string temp = filter;
filter = temp + " and not port " + dst_port;
const char* filter_exp = filter.c_str();
if (pcap_compile(descr, &fp, filter_exp, 0, net) == -1) {
  fprintf(stderr, "Couldn't parse filter %s: %s\n", filter_exp, pcap_geterr(descr));
  return;
}

if (pcap_setfilter(descr, &fp) == -1) {
  fprintf(stderr, "Couldn't install filter %s: %s\n", filter_exp, pcap_geterr(descr));
  return;
}
```

和上題 A 的指令類似，只是將 ip 和 port 的地方換成 parse 出來的結果。而因為對 BRG1 來說 BRGr 是 tunnel 的另一端，因此 encap-sport 和 encap-dport 那邊要相反。超過一條 tunnel 的話，bridge br1 不用重複建。而底下為 dynamic update filter 的部分，建過 tunnel 的 port 就不再 parse 封包。

C. Edge Router:

DHCP for BRG1, BRG2:

```
sudo docker exec -it EdgeRouter ip addr add 172.27.0.1/24 dev ERouter-eth1
```

設定 Edge Router interface 的 ip。

```
sudo docker cp dhcpd_edge.conf EdgeRouter:/dhcpd.conf
sudo docker exec -it EdgeRouter touch /var/lib/dhcp/dhcpd.leases
sudo docker exec -it EdgeRouter /usr/sbin/dhcpd 4 -pf /run/dhcp-server-dhcpd.pid -cf ./dhcpd.conf ERouter-eth1
```

將 dhcpd_edge.conf 複製進 Edge Router 並創立 leases 檔，再將 dhcp server run 在 ERouter-eth1 上。

```
subnet 172.27.0.0 netmask 255.255.255.0 {
        range 172.27.0.2 172.27.0.254;
        option routers 172.27.0.1;
        option subnet-mask 255.255.255.0;
}
```

dhcpd_edge.conf。

NAT rules for BRG1 (show NAT tables to justify your answer):

```
sudo docker exec -it EdgeRouter iptables -t nat -A POSTROUTING -o ERouter-eth0 -j MASQUERADE
```

設定 ERouter-eth0 為 nat 的 output interface。

```
root@4c8ecf339eda: /
yucheng@ubuntu:~/Desktop$ docker attach EdgeRouter
root@4c8ecf339eda:/# iptables -t nat -nvL
Chain PREROUTING (policy ACCEPT 21 packets, 3380 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain INPUT (policy ACCEPT 14 packets, 2224 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain OUTPUT (policy ACCEPT 3 packets, 125 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain POSTROUTING (policy ACCEPT 3 packets, 125 bytes)
 pkts bytes target     prot opt in     out     source               destination
    2   756 MASQUERADE  all  --  *      ERouter-eth0  0.0.0.0/0            0.0.0.0/0
root@4c8ecf339eda:/#
```

NAT tables in Edge Router。

D. GWr:

DHCP for hosts:

```
sudo ip link add BRGr-eth0 type veth peer name Veth
```

建立 veth pair。BRGr-eth0 放入 BRGr 裡，Veth 留在本機端。

```
sudo ip link set dev Veth up
```

set up Veth。

```
sudo /usr/sbin/dhcpd 4 -pf /run/dhcp-server-dhcpd.pid -cf ./dhcpd.conf Veth
```

run server program on Veth。

```
subnet 20.0.0.0 netmask 255.0.0.0 {
        range 20.0.0.2 20.0.0.100;
        option routers 20.0.0.1;
        option subnet-mask 255.0.0.0;
        option domain-name-servers 8.8.8.8;
}
```

dhcpd.conf。

NAT rules for hosts (show NAT tables to justify your answer):

```
sudo iptables -t nat -A POSTROUTING -s 20.0.0.0/8 -j MASQUERADE
```

設定來自 20.0.0.0/8 的 ip 要經過 nat 到外網。

```
yucheng@ubuntu: ~/Desktop
yucheng@ubuntu:~/Desktop$ sudo iptables -t nat -nvL
Chain PREROUTING (policy ACCEPT 32 packets, 5825 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain INPUT (policy ACCEPT 9 packets, 2705 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain OUTPUT (policy ACCEPT 126 packets, 11533 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain POSTROUTING (policy ACCEPT 128 packets, 13088 bytes)
 pkts bytes target     prot opt in     out     source               destination
    9   629 MASQUERADE  all  --  *      *       20.0.0.0/8           0.0.0.0/0

Chain DOCKER (0 references)
 pkts bytes target     prot opt in     out     source               destination
yucheng@ubuntu:~/Desktop$
```

NAT tables in host。

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

BRGr:

```
yucheng@ubuntu:~$ docker attach BRGr
root@ef695e0d4345:/# ifconfig
BRGr-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether 8e:2c:36:a1:02:69  txqueuelen 1000  (Ethernet)
        RX packets 70  bytes 8350 (8.3 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 14  bytes 1964 (1.9 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

BRGr-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 140.113.0.2  netmask 255.255.255.0  broadcast 0.0.0.0
        ether c2:36:9c:e9:8d:5c  txqueuelen 1000  (Ethernet)
        RX packets 73  bytes 11615 (11.6 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 87  bytes 12556 (12.5 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 56:10:c8:66:82:dc  txqueuelen 1000  (Ethernet)
        RX packets 6  bytes 928 (928.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 38  bytes 3766 (3.7 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

GRE2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether da:51:60:60:35:29  txqueuelen 1000  (Ethernet)
        RX packets 6  bytes 928 (928.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 35  bytes 3530 (3.5 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 56:10:c8:66:82:dc  txqueuelen 1000  (Ethernet)
        RX packets 33  bytes 3526 (3.5 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
```

BRG1:

```
yucheng@ubuntu:~$ docker attach BRG1
root@9052eee0da36:/# ifconfig
BRG1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether b6:a2:7f:80:d4:2b  txqueuelen 1000  (Ethernet)
        RX packets 6  bytes 928 (928.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 16  bytes 2110 (2.1 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

BRG1-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.27.0.2  netmask 255.255.255.0  broadcast 172.27.0.255
        ether 22:f1:82:25:8d:65  txqueuelen 1000  (Ethernet)
        RX packets 95  bytes 12028 (12.0 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 17  bytes 2434 (2.4 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 06:5c:a1:1b:a5:ab  txqueuelen 1000  (Ethernet)
        RX packets 14  bytes 2002 (2.0 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 8  bytes 924 (924.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 06:5c:a1:1b:a5:ab  txqueuelen 1000  (Ethernet)
        RX packets 11  bytes 1646 (1.6 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

root@9052eee0da36:/#
```

BRG2:

```
yucheng@ubuntu:~$ docker attach BRG2
root@815a6fc2a584:/# ifconfig
BRG2-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        ether 7a:d3:dc:26:9a:e5  txqueuelen 1000  (Ethernet)
        RX packets 6  bytes 928 (928.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 12  bytes 1342 (1.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

BRG2-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.27.0.3  netmask 255.255.255.0  broadcast 172.27.0.255
        ether aa:5d:7b:f9:02:d8  txqueuelen 1000  (Ethernet)
        RX packets 91  bytes 11410 (11.4 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 16  bytes 2392 (2.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

GRE2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 6a:92:94:c1:e3:60  txqueuelen 1000  (Ethernet)
        RX packets 10  bytes 1234 (1.2 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 8  bytes 924 (924.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

br1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1450
        ether 6a:92:94:c1:e3:60  txqueuelen 1000  (Ethernet)
        RX packets 7  bytes 934 (934.0 B)
        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

root@815a6fc2a584:/#
```

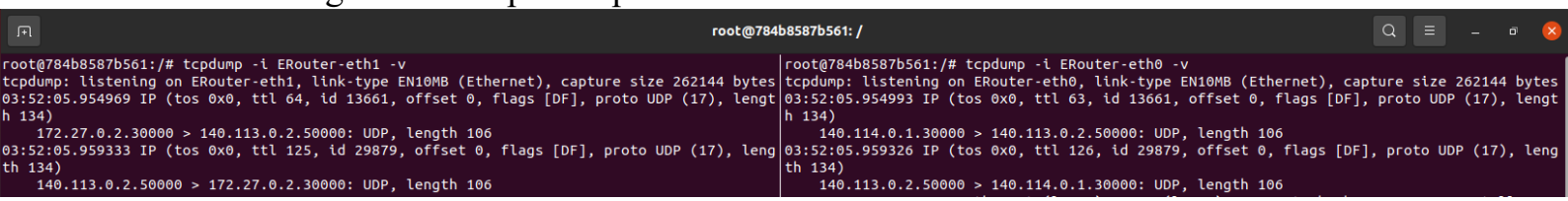
h1 ping google DNS server 8.8.8.8:

```
yucheng@ubuntu:~/Desktop$ docker attach H1
root@d9cdbe8a79f6:/# dhclient H1-eth0
mv: cannot move '/etc/resolv.conf.dhclient-new.24' to '/etc/resolv.conf': Device or resource busy
root@d9cdbe8a79f6:/# ifconfig
H1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 20.0.0.2  netmask 255.0.0.0  broadcast 20.255.255.255
        ether 56:66:5d:d8:2a:3d  txqueuelen 1000  (Ethernet)
        RX packets 7  bytes 938 (938.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 4  bytes 788 (788.0 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

root@d9cdbe8a79f6:/# ping 8.8.8.8 -c1
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=127 time=3.68 ms

--- 8.8.8.8 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 3.688/3.688/3.688/0.000 ms
root@d9cdbe8a79f6:/#
```

3. Capture packets and take screenshots on node:
   BRG1 input/output:

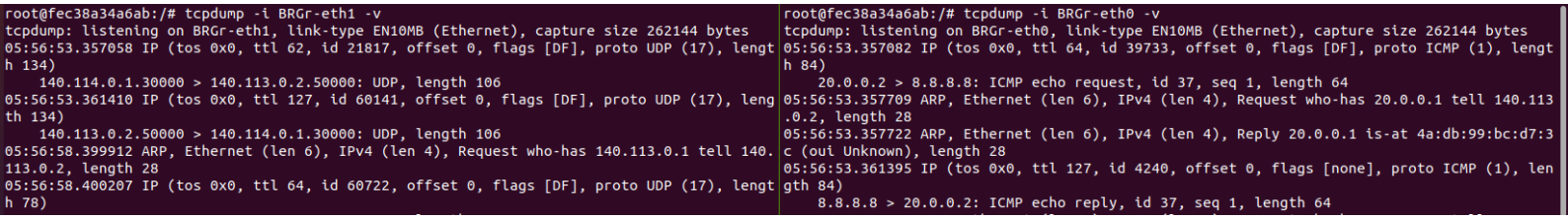
從 h1 送出、BRG1-eth0 收到的 icmp request，src ip 是 h1 的 ip 20.0.0.2，dst ip 是 8.8.8.8；從 BRG1-eth1 送出的 src ip 是 BRG1-eth1 的 ip 172.27.0.2、port 30000，dst ip 是 BRGr-eth1 的 ip 140.113.0.2、port 50000。因為這裡走的是一個 gre fou tunnel，它的 src、dst 就分別是通道兩端的端口。而回來的 icmp reply 也是同理。

Edge Router input/output:



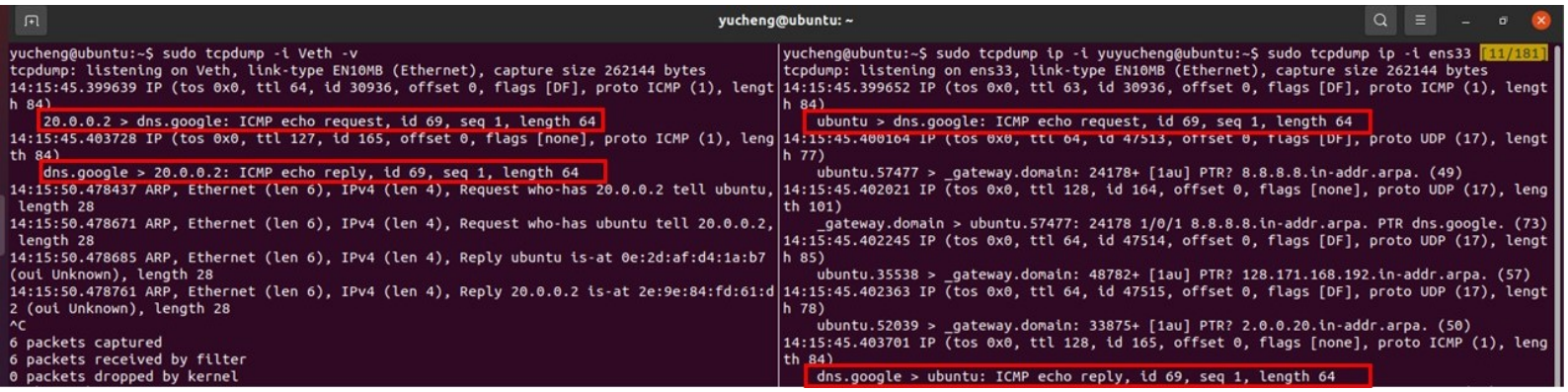
而 Edge Router 負責實際轉送 tunnel 封包。ERouter-eth1 的 src、dst 和上圖 BRG1-eth1 一樣；而 ERouter-eth0 的 dst 一樣，但 src ip 部分變成了 ERouter-eth0 自己本身的 ip 140.114.0.1。這裡要經過一個 nat，由自己的 ip:port 對應 dst 的 ip:port。而反向也是同理。

BRGr input/output:



BRGr-eth1 的 src、dst 和上圖 ERouter-eth0 一樣；而 BRGr-eth0 是對應 BRG1-eth0 的 tunnel 的另一端，它會將 tunnel 的 header 解開，還原出原本的 src、dst。因此它的 src、dst 和 BRG1-eth0 一樣。反向同理。

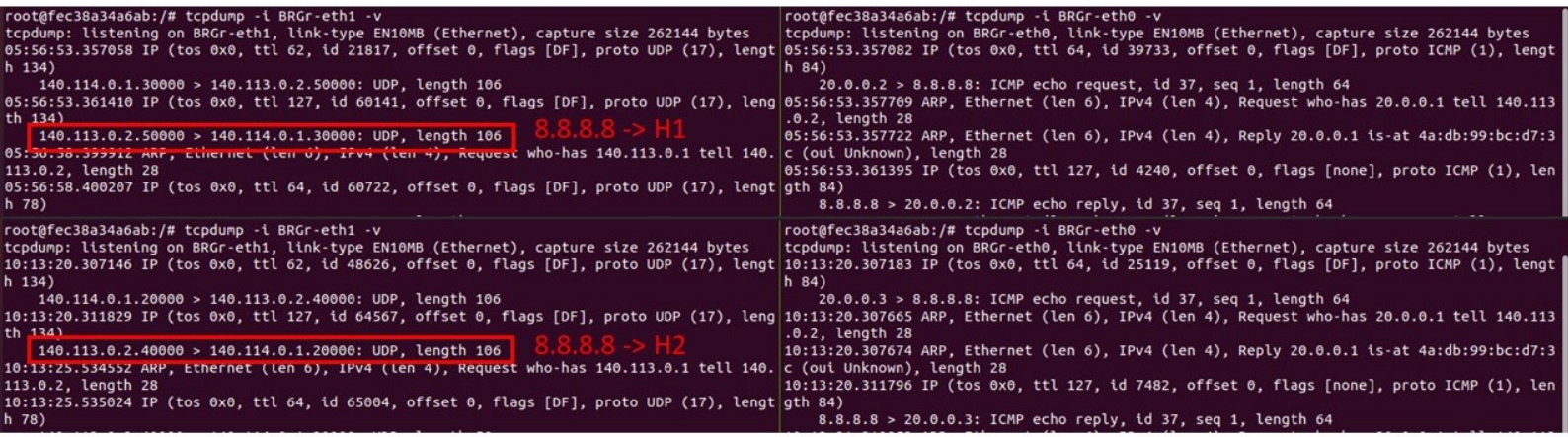
GWr input/output:



GWr 會將 icmp request 封包穿過 nat 送到外網。Veth 收到的封包 src 是 H1 的 20.0.0.2，dst 是 8.8.8.8；穿過 nat 後，由本機的 ubuntu ip 送到 dns.google。反向同理。

4. How BRGr determines the GRE interface to tunnel the response packets back to BRG1:

   比較 H1 和 H2 的 ping reply:



由上圖可以發現，雖然由於 nat 的關係，兩者的 src ip 和 dst ip 是一樣的，但其 port 不一樣。而 BRGr 就是透過這點來分辨要走哪個 GRE interface。若是 50000 => 30000，則走 GRE1，經過 tunnel 送到 BRG1 回到 H1；若是 40000=>20000，則走 GRE2，經過 tunnel 送到 BRG2 回到 H2。指令上用 key 可以區別兩個通道。