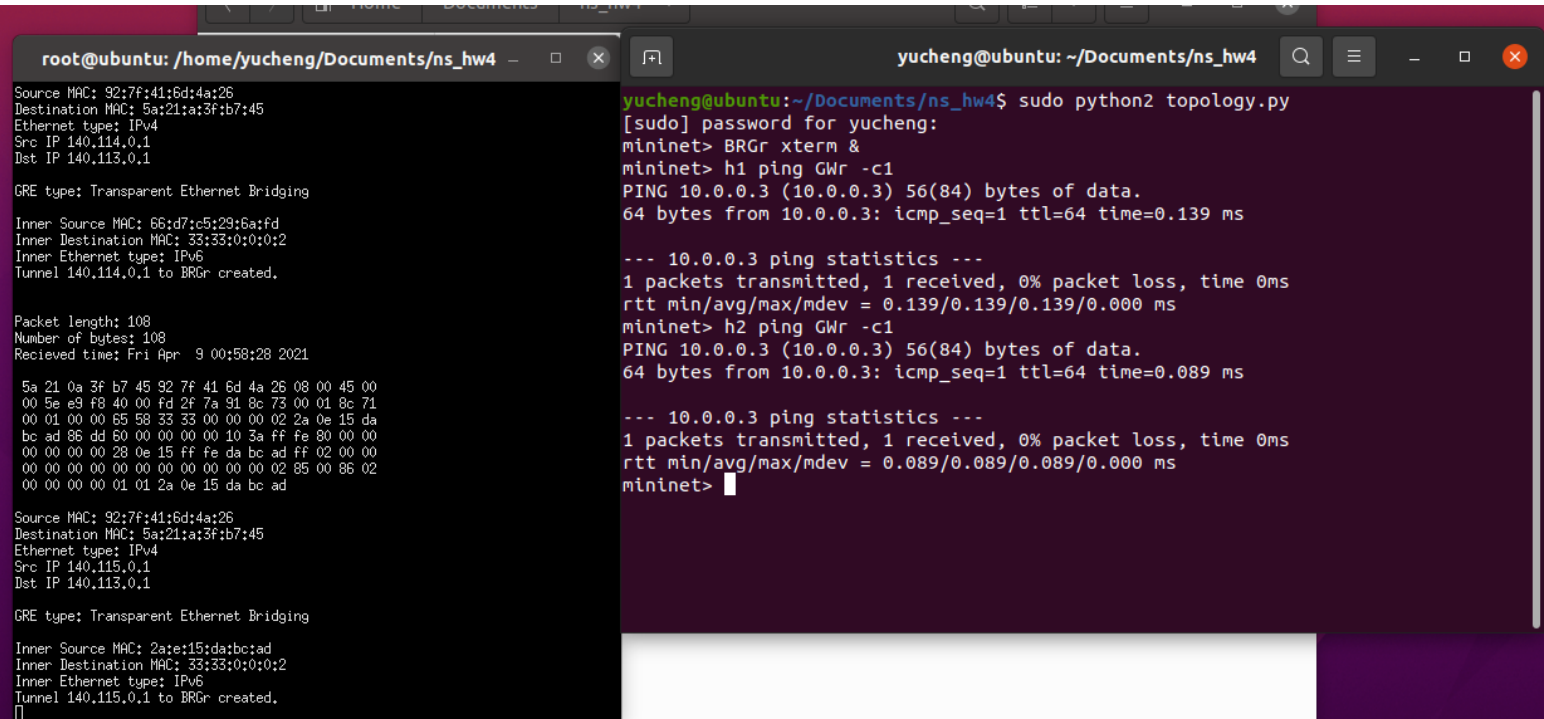


NS Lab4 Report

1. ping result:



The screenshot shows two terminal windows. The left window, titled 'root@ubuntu: /home/yucheng/Documents/ns_hw4', displays the output of a network configuration script. It shows the creation of a GRE tunnel between two hosts, including details like source/destination MACs, IP addresses, and packet statistics. The right window, titled 'yucheng@ubuntu: ~/Documents/ns_hw4', shows the execution of 'sudo python2 topology.py' and subsequent ping commands. The output shows successful ping results for 10.0.0.3, with 0% packet loss and a time of 0.139 ms.

```
root@ubuntu: /home/yucheng/Documents/ns_hw4
Source MAC: 92:7f:41:6d:4a:26
Destination MAC: 5a:21:a:3f:b7:45
Ethernet type: IPv4
Src IP 140.114.0.1
Dst IP 140.113.0.1

GRE type: Transparent Ethernet Bridging

Inner Source MAC: 66:d7:c5:29:6a:fd
Inner Destination MAC: 33:33:0:0:0:2
Inner Ethernet type: IPv6
Tunnel 140.114.0.1 to BRGr created.

Packet length: 108
Number of bytes: 108
Received time: Fri Apr 9 00:58:28 2021

5a 21 0a 3f b7 45 92 7f 41 6d 4a 26 08 00 45 00
00 5e e9 f8 40 00 fd 2f 7a 91 8c 73 00 01 8c 71
00 01 00 00 65 58 33 33 00 00 00 02 2a 0e 15 da
bc ad 85 dd 60 00 00 00 10 3a ff fe 80 00 00
00 00 00 00 28 0e 15 ff fe da bc ad ff 02 00 00
00 00 00 00 00 00 00 00 00 02 85 00 85 02
00 00 00 00 01 01 2a 0e 15 da bc ad

Source MAC: 92:7f:41:6d:4a:26
Destination MAC: 5a:21:a:3f:b7:45
Ethernet type: IPv4
Src IP 140.115.0.1
Dst IP 140.113.0.1

GRE type: Transparent Ethernet Bridging

Inner Source MAC: 2a:e:15:da:bc:ad
Inner Destination MAC: 33:33:0:0:0:2
Inner Ethernet type: IPv6
Tunnel 140.115.0.1 to BRGr created.

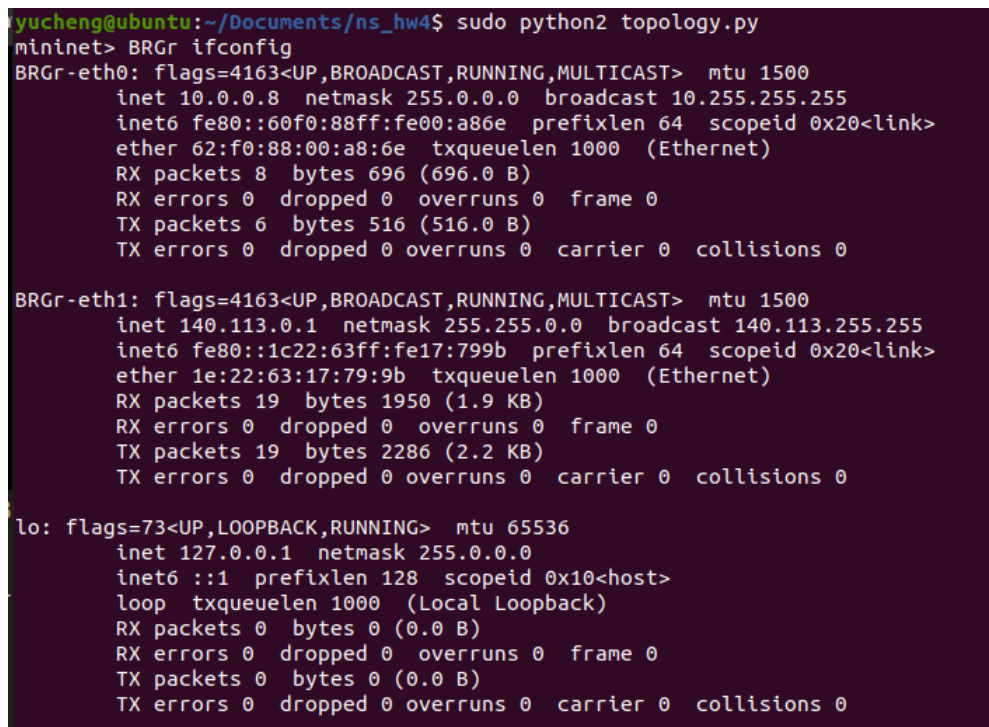
yucheng@ubuntu: ~/Documents/ns_hw4$ sudo python2 topology.py
[sudo] password for yucheng:
mininet> BRGr xterm &
mininet> h1 ping GWr -c1
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.139 ms

--- 10.0.0.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.139/0.139/0.139/0.000 ms
mininet> h2 ping GWr -c1
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.089 ms

--- 10.0.0.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.089/0.089/0.089/0.000 ms
mininet>
```

2. show all interfaces:

before tunnel create (ping failed):



The screenshot shows a terminal window titled 'yucheng@ubuntu: ~/Documents/ns_hw4' displaying the output of 'sudo python2 topology.py'. The output shows the configuration of three network interfaces: BRGr-eth0, BRGr-eth1, and lo. BRGr-eth0 is configured with IP 10.0.0.8, netmask 255.0.0.0, and broadcast 10.255.255.255. BRGr-eth1 is configured with IP 140.113.0.1, netmask 255.255.0.0, and broadcast 140.113.255.255. lo is configured with IP 127.0.0.1, netmask 255.0.0.0, and broadcast 127.0.0.1.

```
yucheng@ubuntu: ~/Documents/ns_hw4$ sudo python2 topology.py
mininet> BRGr ifconfig
BRGr-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.8 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 8 bytes 696 (696.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 6 bytes 516 (516.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

BRGr-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 140.113.0.1 netmask 255.255.0.0 broadcast 140.113.255.255
    inet6 fe80::1c22:63ff:fe17:799b prefixlen 64 scopeid 0x20<link>
    ether 1e:22:63:17:79:9b txqueuelen 1000 (Ethernet)
    RX packets 19 bytes 1950 (1.9 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 19 bytes 2286 (2.2 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
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    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
```

after tunnel created (ping success):

```
mininet> BRGr ifconfig
BRGr-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.8 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 976 (976.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 32 bytes 2480 (2.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

BRGr-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 140.113.0.1 netmask 255.255.0.0 broadcast 140.113.255.255
    inet6 fe80::1c22:63ff:fe17:799b prefixlen 64 scopeid 0x20<link>
    ether 1e:22:63:17:79:9b txqueuelen 1000 (Ethernet)
    RX packets 62 bytes 6580 (6.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 91 bytes 10348 (10.3 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

GRE0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::f854:2bff:fe9b:8e91 prefixlen 64 scopeid 0x20<link>
    ether fa:54:2b:9b:8e:91 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 29 bytes 1864 (1.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::cc84:1eff:fec4:9c14 prefixlen 64 scopeid 0x20<link>
    ether ce:84:1e:c4:9c:14 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 20 bytes 1256 (1.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

br0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 672 (672.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 12 bytes 984 (984.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
```

3. Interconnection diagram:

```

mininet> BRGr ifconfig
BRGr-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.8 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 976 (976.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 32 bytes 2480 (2.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

BRGr-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 140.113.0.1 netmask 255.255.0.0 broadcast 140.113.255.255
    inet6 fe80::1c22:63ff:fe17:799b prefixlen 64 scopeid 0x20<link>
    ether 1e:22:63:17:79:9b txqueuelen 1000 (Ethernet)
    RX packets 62 bytes 6580 (6.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 91 bytes 10348 (10.3 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

GRE0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::f854:2bff:fe9b:8e91 prefixlen 64 scopeid 0x20<link>
    ether fa:54:2b:9b:8e:91 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 29 bytes 1864 (1.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

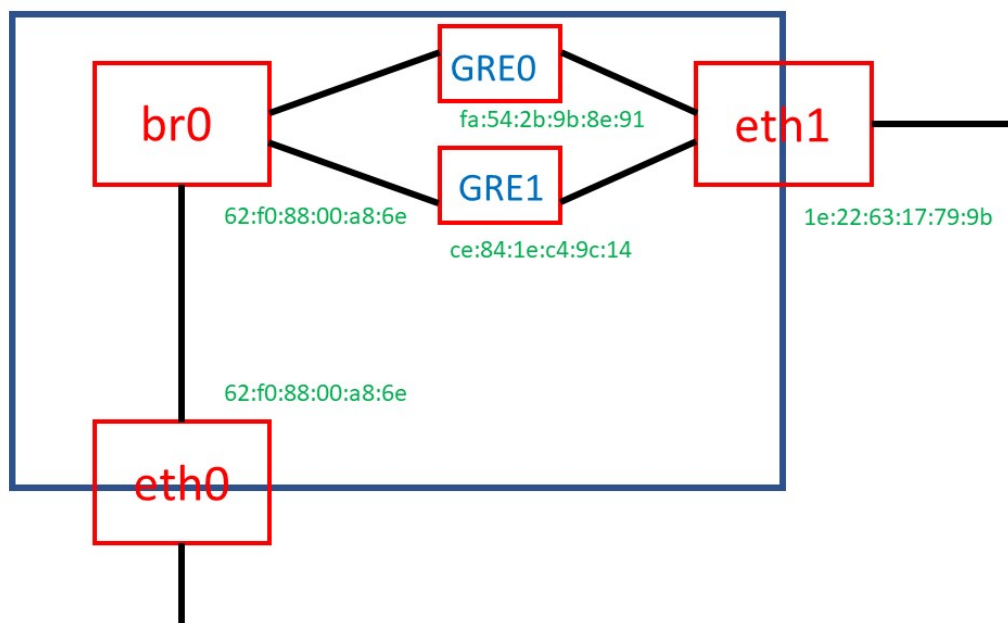
GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::cc84:1eff:fec4:9c14 prefixlen 64 scopeid 0x20<link>
    ether ce:84:1e:c4:9c:14 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 20 bytes 1256 (1.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

br0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 672 (672.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 12 bytes 984 (984.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536

```

BRGr



在 tunnel 還沒建立前，interfaces 如上題圖一，只有 eth0 和 eth1 這兩個 physical interface。而 tunnel 建立後，增加了 br0、GRE0、GRE1 這三個 logical interface，路徑圖由上圖所示。br0 是一個 linux bridge，而 GRE0、GRE1 是扮演 gretap 的角色。封包會依 host 不同而選擇走不同的 tunnel，下題會有更詳細的說明。

4. BRGr determines gretap:

```
mlnlnet> BRGr ifconfig
BRGr-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.8 netmask 255.0.0.0 broadcast 10.255.255.255
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 976 (976.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 32 bytes 2480 (2.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

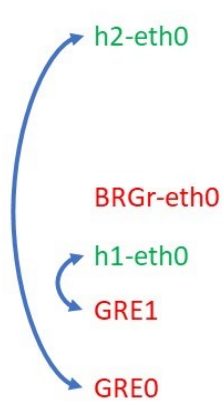
BRGr-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 140.113.0.1 netmask 255.255.0.0 broadcast 140.113.255.255
    inet6 fe80::1c22:63ff:fe17:799b prefixlen 64 scopeid 0x20<link>
    ether 1e:22:63:17:79:9b txqueuelen 1000 (Ethernet)
    RX packets 62 bytes 6580 (6.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 91 bytes 10348 (10.3 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

GRE0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::f854:2bff:fe9b:8e91 prefixlen 64 scopeid 0x20<link>
    ether fa:54:2b:9b:8e:91 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 29 bytes 1864 (1.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

GRE1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::cc84:1eff:fec4:9c14 prefixlen 64 scopeid 0x20<link>
    ether ce:84:1e:c4:9c:14 txqueuelen 1000 (Ethernet)
    RX packets 5 bytes 350 (350.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 20 bytes 1256 (1.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

br0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1462
    inet6 fe80::60f0:88ff:fe00:a86e prefixlen 64 scopeid 0x20<link>
    ether 62:f0:88:00:a8:6e txqueuelen 1000 (Ethernet)
    RX packets 12 bytes 672 (672.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 12 bytes 984 (984.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
```

```

root@ubuntu:/home/yucheng/Documents/ns_hw4# brctl showmacs br0
port no mac addr is local? ageing timer
  3 12:c0:92:9f:f3:5a no 85.48
  2 12:fb:f7:8d:2a:e7 no 18.41
  1 16:b5:0c:42:8b:6a no 18.41
  2 4a:be:ff:ff:1d:cc no 71.15
  3 5e:43:f7:c1:e9:55 no 77.29
  1 62:f0:88:00:a8:6e yes 0.00
  1 62:f0:88:00:a8:6e yes 0.00
  3 7a:e3:74:2f:d7:44 no 23.79
  3 ce:84:1e:c4:9c:14 yes 0.00
  3 ce:84:1e:c4:9c:14 yes 0.00
  2 fa:54:2b:9b:8e:91 yes 0.00
  2 fa:54:2b:9b:8e:91 yes 0.00
root@ubuntu:/home/yucheng/Documents/ns_hw4#

```

port	no	mac addr	is local?	ageing timer
3		12:c0:92:9f:f3:5a	no	85.48
2		12:fb:f7:8d:2a:e7	no	18.41
1		16:b5:0c:42:8b:6a	no	18.41
2		4a:be:ff:ff:1d:cc	no	71.15
3		5e:43:f7:c1:e9:55	no	77.29
1		62:f0:88:00:a8:6e	yes	0.00
1		62:f0:88:00:a8:6e	yes	0.00
3		7a:e3:74:2f:d7:44	no	23.79
3		ce:84:1e:c4:9c:14	yes	0.00
3		ce:84:1e:c4:9c:14	yes	0.00
2		fa:54:2b:9b:8e:91	yes	0.00
2		fa:54:2b:9b:8e:91	yes	0.00

BRGr 裡的 bridge br0 會做 MAC learning，將 h1、h2 的 MAC Address 存進自己的 MAC Address table。如上圖所示，若要傳送封包給 h1，就去 lookup MAC Address table，就知道要走 port 3，也就是 GRE1；h2 同理，走 port 2，也就是 GRE0。

5. h1 aware of GRE tunnel:

```
mininet> h1 ping GWr -c1
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.141 ms

--- 10.0.0.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.141/0.141/0.141/0.000 ms

root@ubuntu: /home/yucheng/Documents/ns_hw4 - □ ×

root@ubuntu:/home/yucheng/Documents/ns_hw4# tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on h1-eth0, link-type EN10MB (Ethernet), capture size 262144 bytes

02:51:30.536432 IP 10.0.0.1 > 10.0.0.3: ICMP echo request, id 5502, seq 1, length 64
02:51:30.536541 IP 10.0.0.3 > 10.0.0.1: ICMP echo reply, id 5502, seq 1, length 64
^C
2 packets captured
2 packets received by filter
0 packets dropped by kernel
root@ubuntu:/home/yucheng/Documents/ns_hw4#
```

由上圖可見，h1 並不會知道自己跟 GWr 其實並不在同一個 LAN。

他們的 ip 都是 10.0.0 開頭的，因此以 h1 的角度來看，GWr 跟他是在

在同一個 LAN。但實際上是透過 tunnel 將他們連在一起的。