1. Question 1

1.1: Without Fragmenting

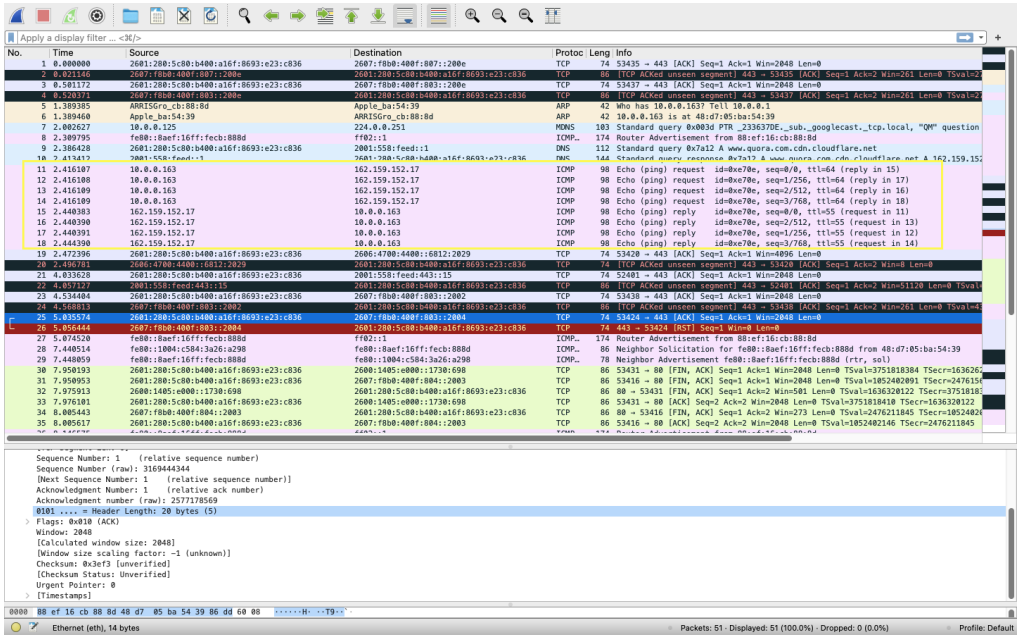
Different IP fragments created will using command ping www.quora.com -l 2000 is as follows from Wireshark using 4 ICMP packets:

Terminal Window:

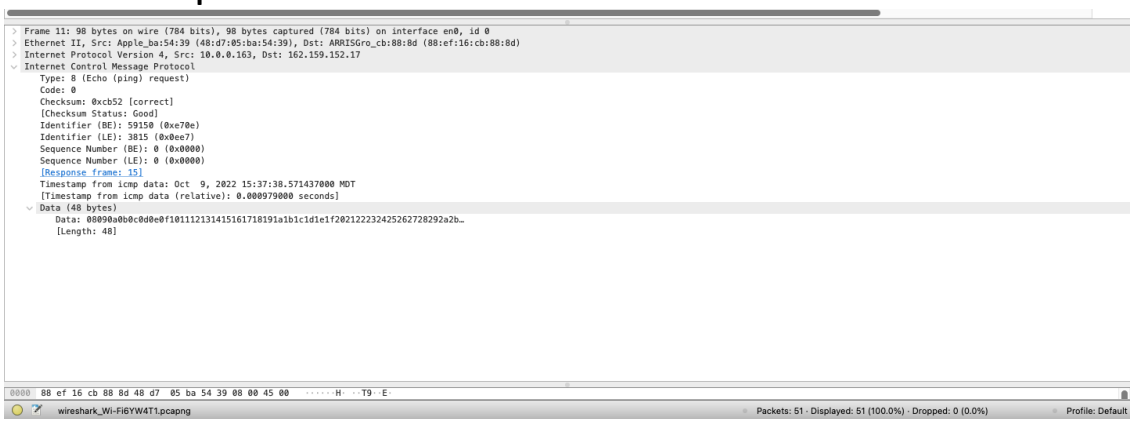
```
Last login: Sat Oct  8 23:57:38 on ttys000
[kiran@Kirans-MacBook-Air ~ % su
[Password:
[sh-3.2# ping www.quora.com -l 1700 -c 4
PING www.quora.com.cdn.cloudflare.net (162.159.152.17): 56 data bytes
64 bytes from 162.159.152.17: icmp_seq=0 ttl=55 time=22.989 ms
64 bytes from 162.159.152.17: icmp_seq=1 ttl=55 time=32.239 ms
64 bytes from 162.159.152.17: icmp_seq=2 ttl=55 time=35.738 ms
64 bytes from 162.159.152.17: icmp_seq=3 ttl=55 time=35.752 ms

--- www.quora.com.cdn.cloudflare.net ping statistics ---
4 packets transmitted, 4 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 22.989/31.679/35.752/5.218 ms
sh-3.2#
```

Wireshark Window:

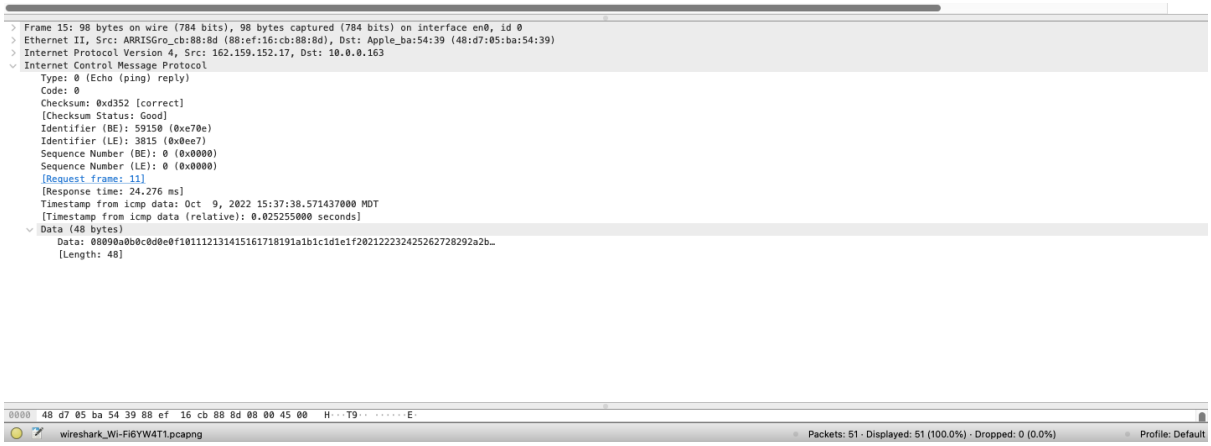
Figure below shows 4 echo request and 4 reply packets



ICMP Echo Request Packet



ICMP Echo Reply Packet

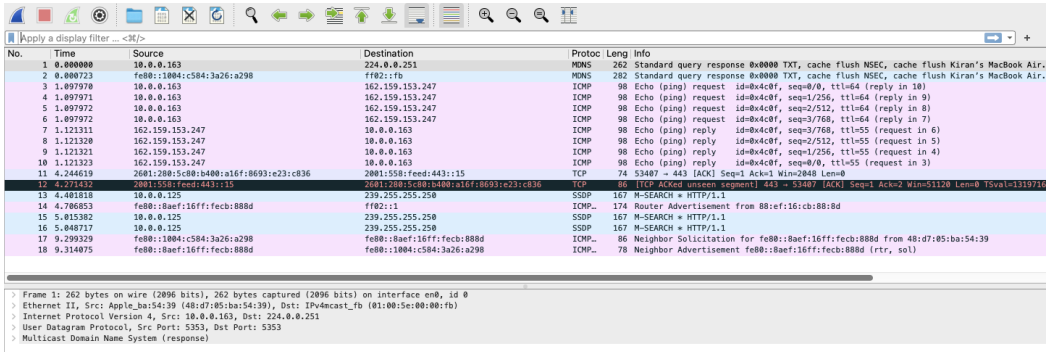


1.2 With Fragmenting

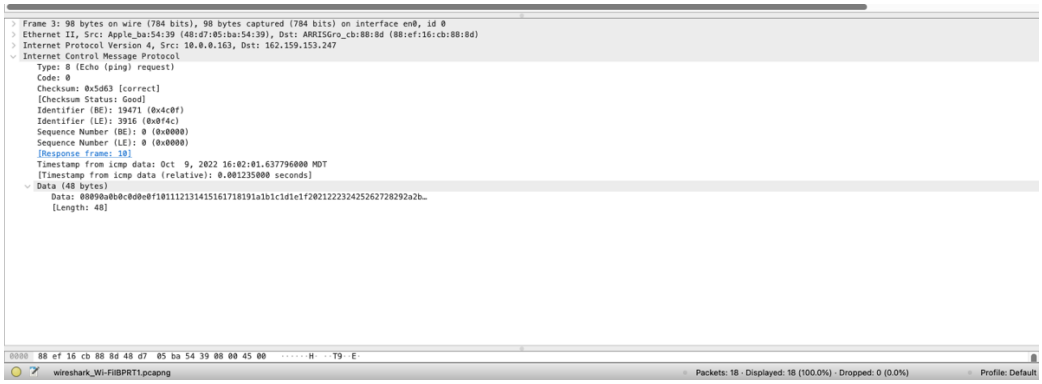
Terminal Window:

```
sh-3.2# ping -l 50 www.quora.com -f -c 4
PING www.quora.com.cdn.cloudflare.net (162.159.153.247): 56 data bytes
....Request timeout for icmp_seq 2

--- www.quora.com.cdn.cloudflare.net ping statistics ---
4 packets transmitted, 1 packets received, 75.0% packet loss
round-trip min/avg/max/stddev = 25.560/25.560/25.560/0.000 ms
sh-3.2#
```

Wireshark Window:



ICMP Echo Request Packet



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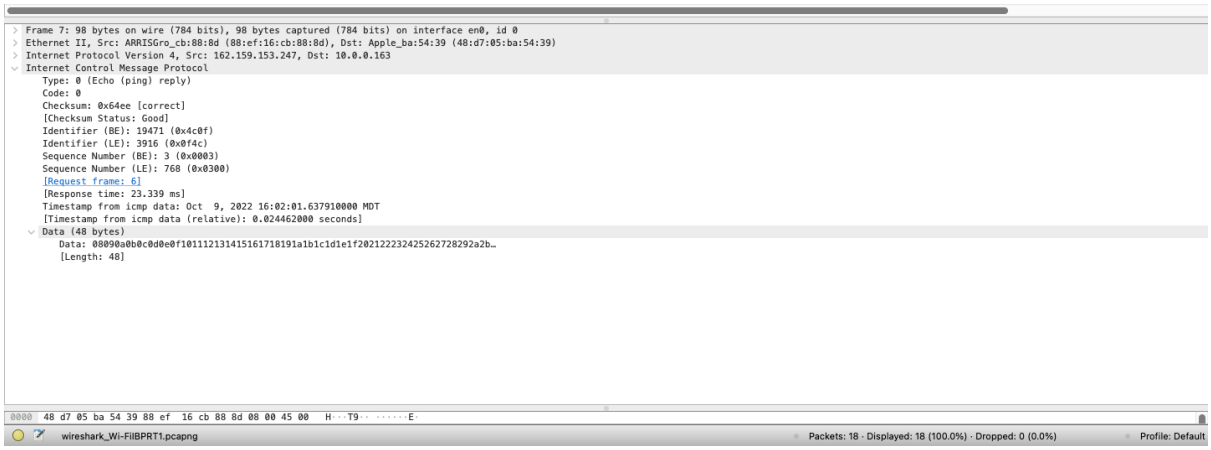
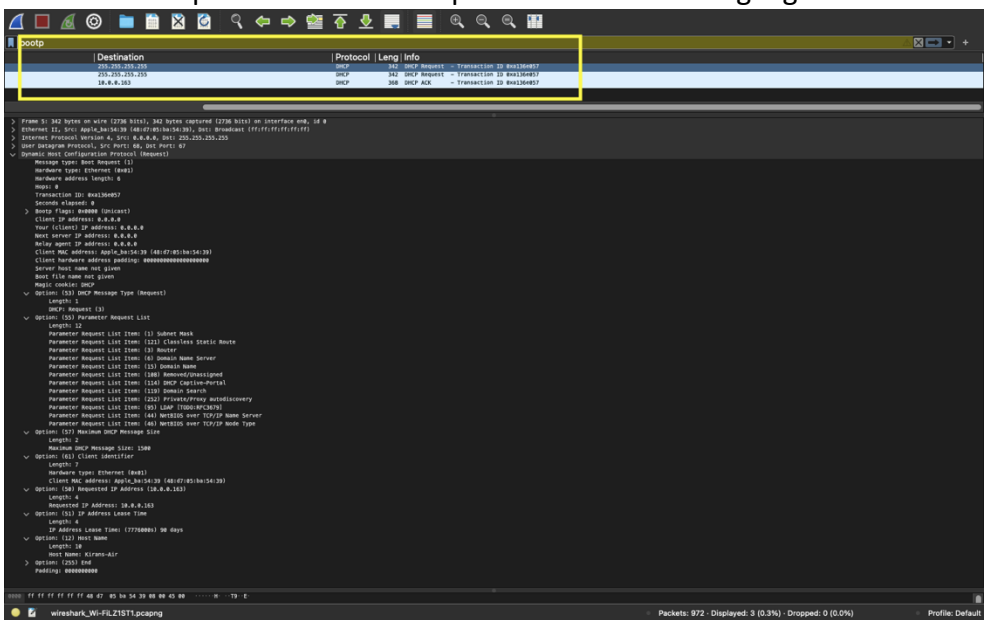
ICMP Echo Replay Packet



2. Question 2

2.1 DHCP DORA

Figure below shows the DCP DORA process used while pinging www.google.com from terminal. Two packets for DHCP Rqst and DHCP ACK is highlighted below:



DHCP packets contains fields such as Hardware type, Message type, Hardware Address length, Hops, Opcode, Transaction ID's, Message Type, Options for Parameter Request List, Boot file name, Server Name and lastly IP and MAC addresses of client and server.

Hardware type defines type of DHCP packet response or request. Hardware address length field shows byte length of physical address. Hops fields highlights the hop in counts. Transaction ID is number used to identify DCHP DORA process info invokes by system. Flags field used as an indicator to indicate weather message is broadcast or unicast. Gateway IP indicates gateway IP address from LAN to local server. Client hardware field shows MAC address of the DHCP client. Options field which is a 8 to 214 bytes in length highlights DHCP message type. Two parameters inside options indicates type and length of data. DHCP packet header contains multiple fields for client and server IP and MAC addresses indication as well as gateway IP addresses too.

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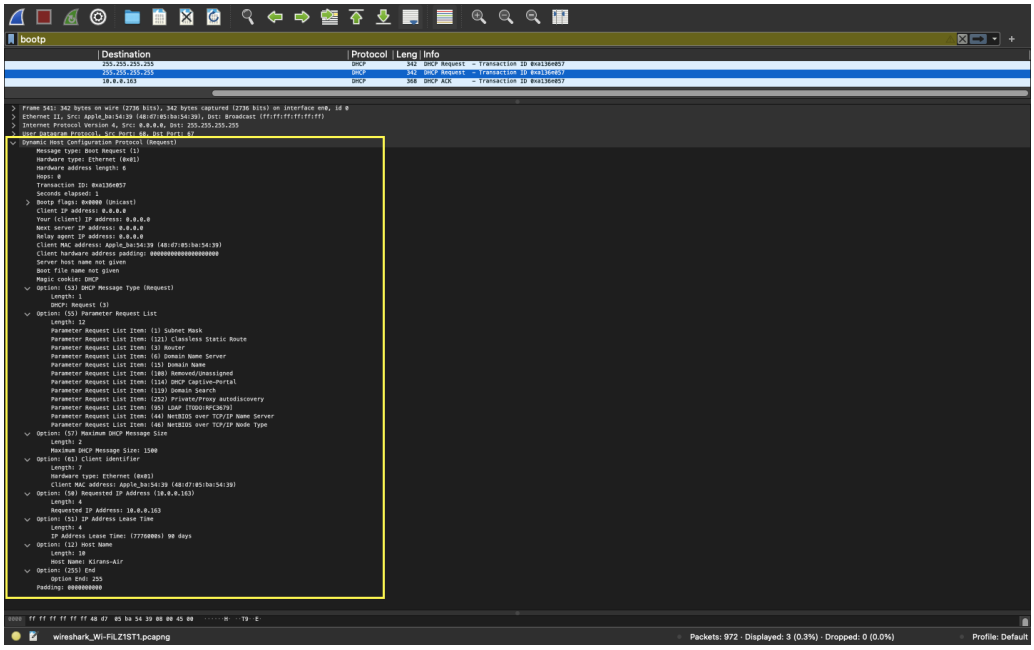
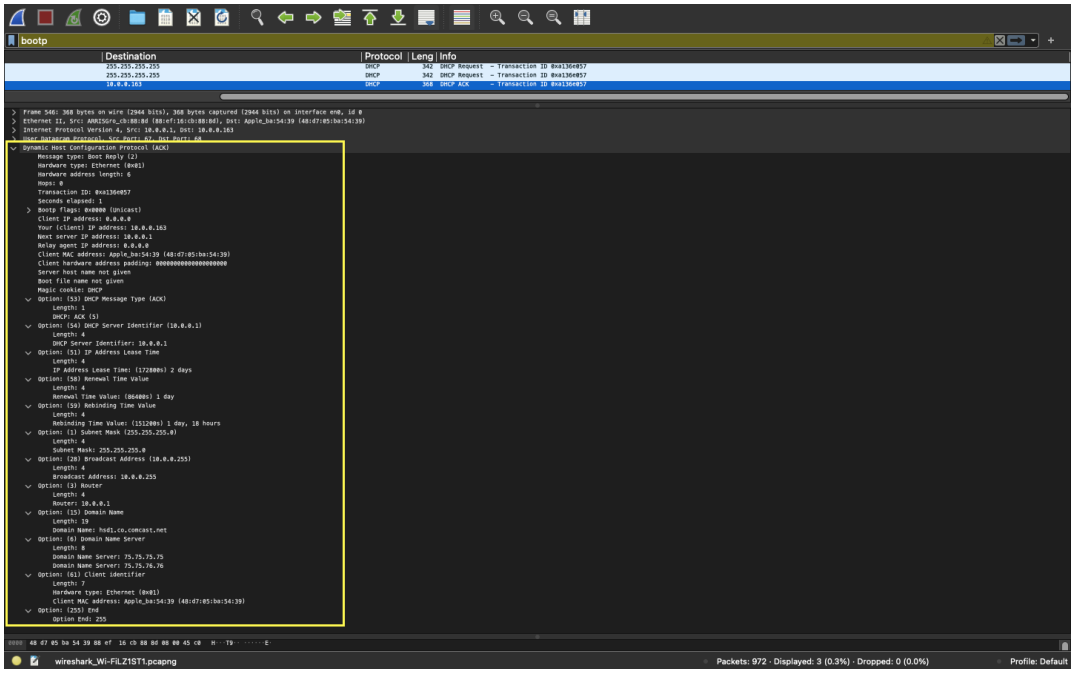
DHCP Request Packet:

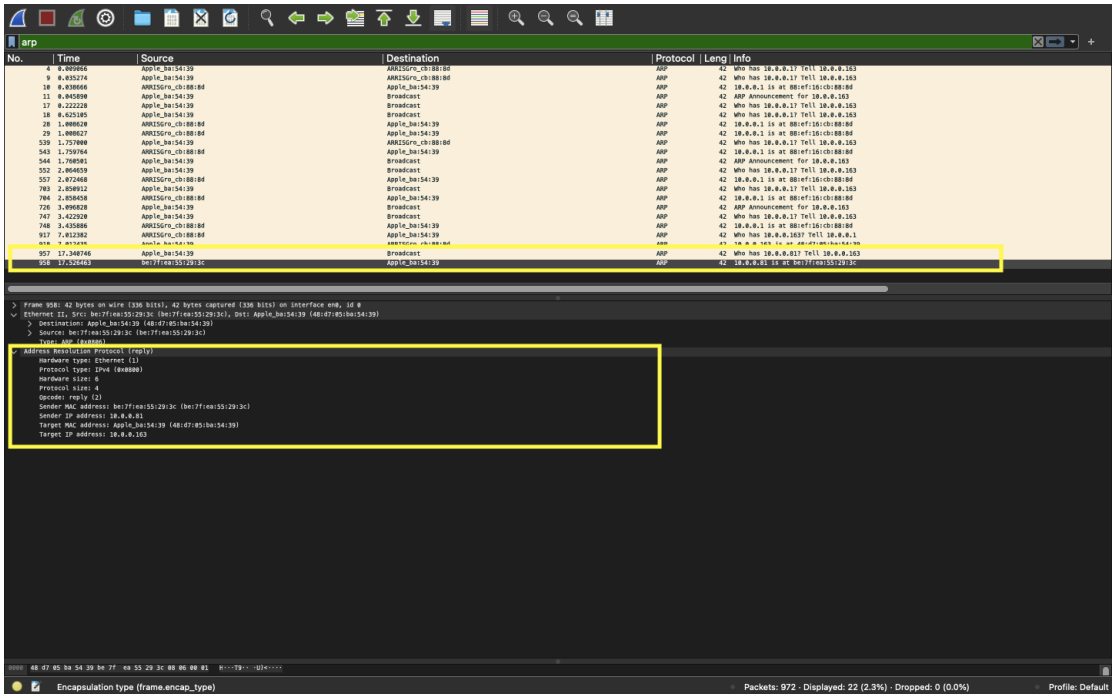


DHCP ACK Packet:



2.2 ARP Request and Response:

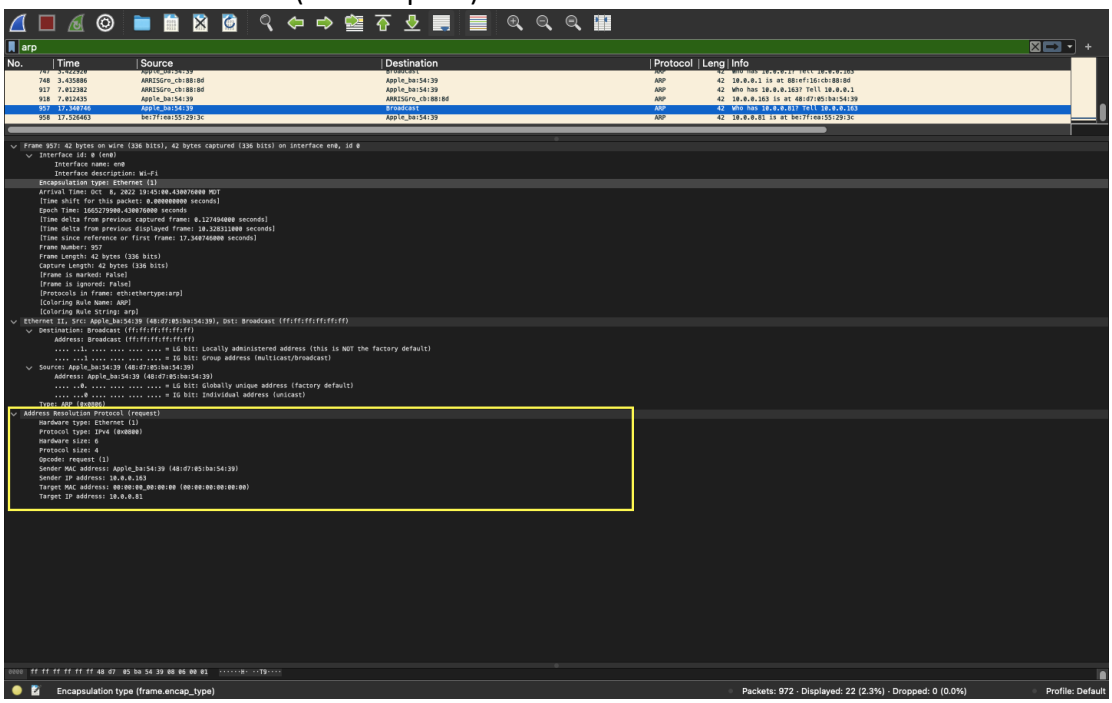
The figure below shoes the ARP broadcast and ARP reply packets.



ARP packet contains fields as Hardware Type, prototype type, hardware length, protocol length, operation bit and sender and receiver address.

Hardware type field tells the local network type which is ethernet in this case. Protocol type defines type of protocol used. Hardware size reflects length of physical address in byte. Protocol length indicates length of IP address in bytes. Opcode defines ARP packet type which is 1 in case of Request and 2 in case of reply. MAC and IP address of sender & receiver are also highlighted in ARP packets.

ARP Broadcast Packet (ARP Request):



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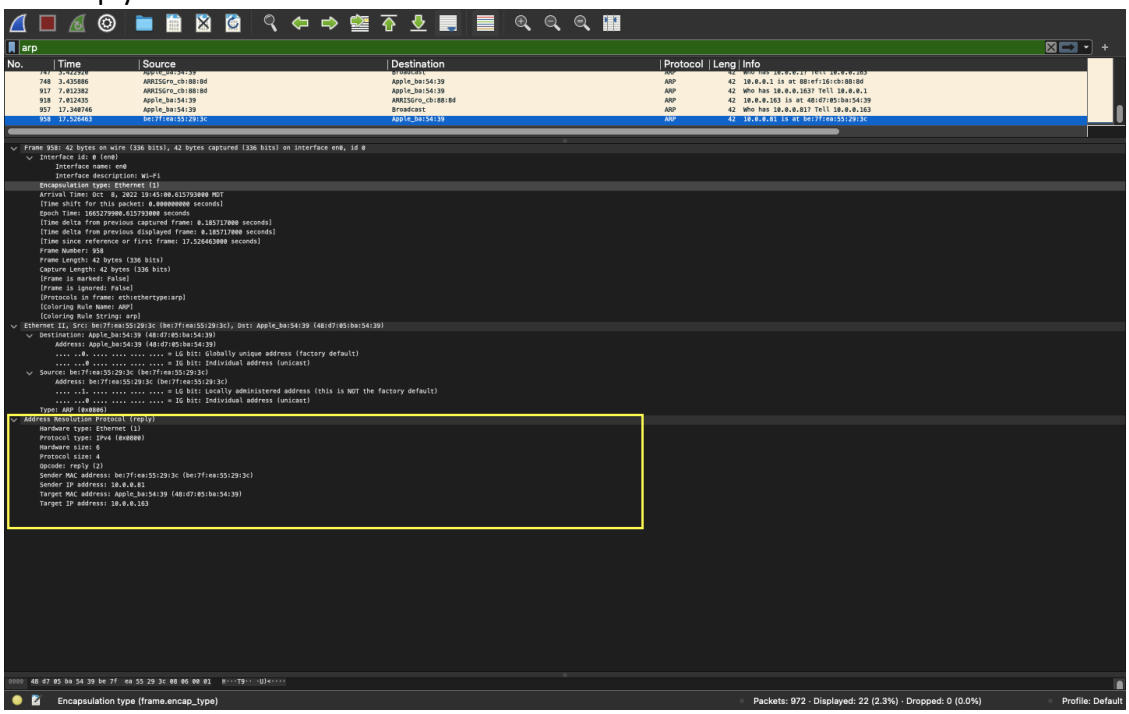
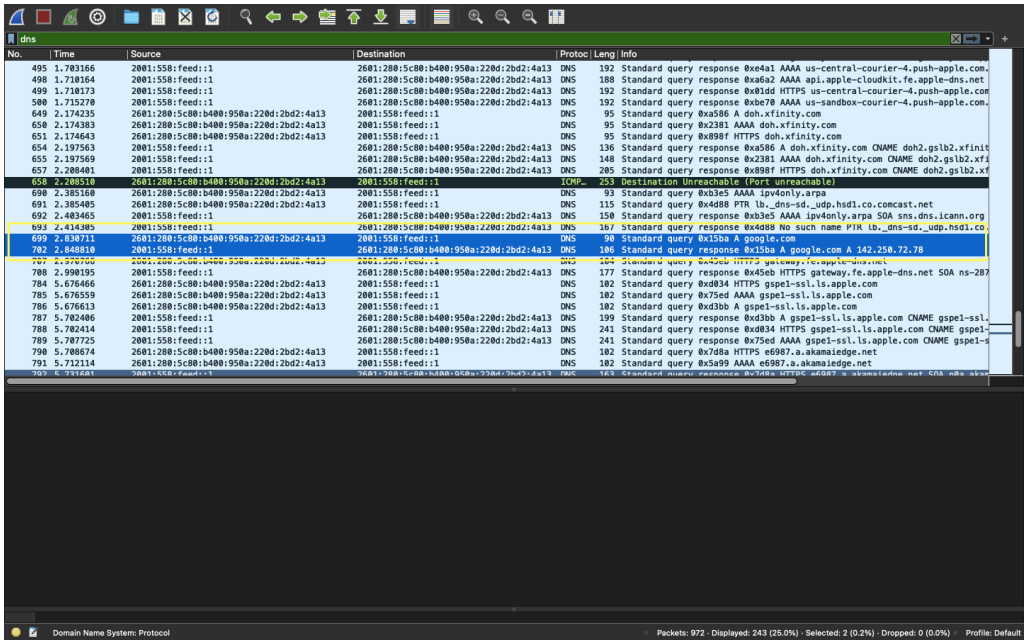
ARP Reply Packet:



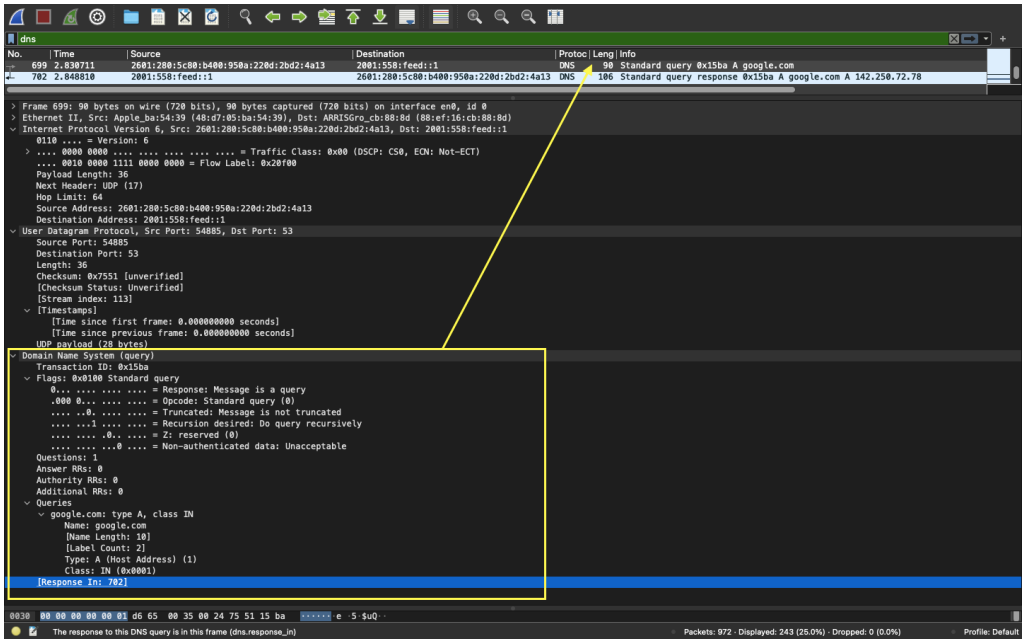
2.3: DNS Query



DNS packets contains fields such as ID, Query/Response Flags, Opcode, Answer/Authority/Additional RR's, Query and Response Fields.

DNS ID is usually created by server requesting query. Query Response flags distinguishes between the QR and also indicates bits for truncated and recursion message. Response codes (RR's) three reserved bits defined with value zero acting as a response for the server reply indicating if the query is answered correctly.

DNS Standard Query:



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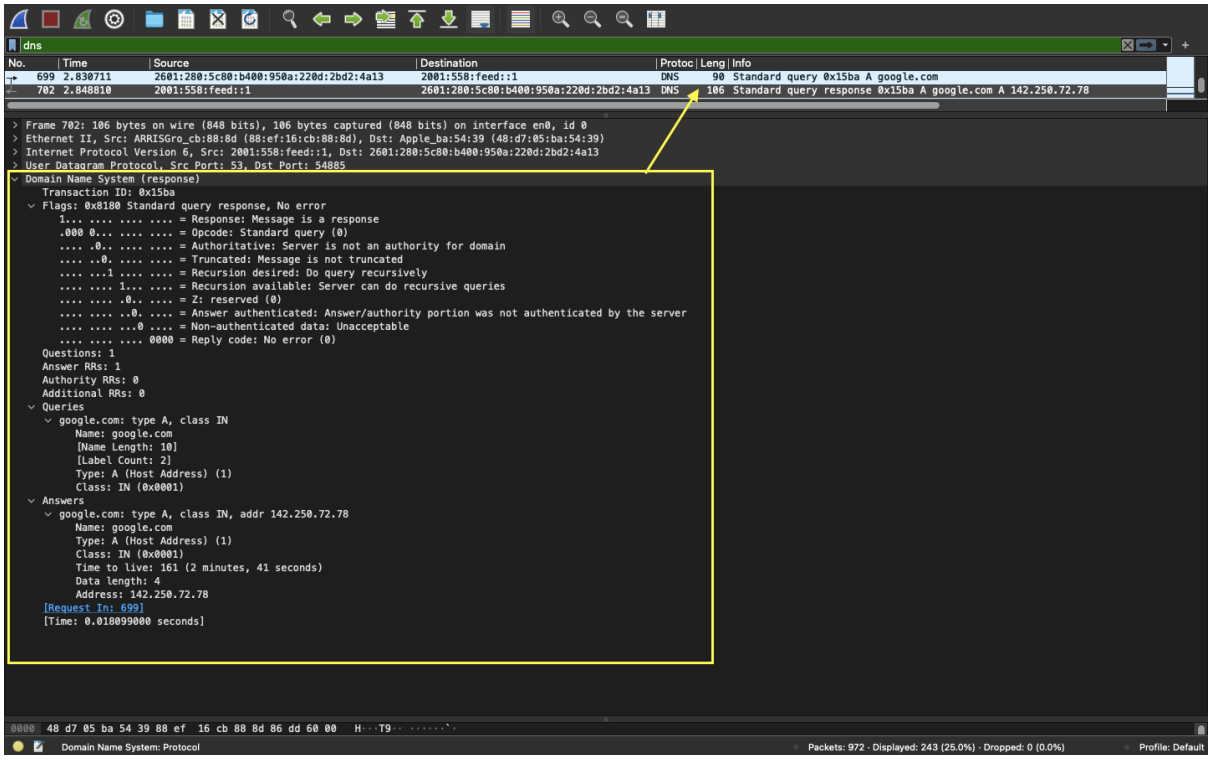
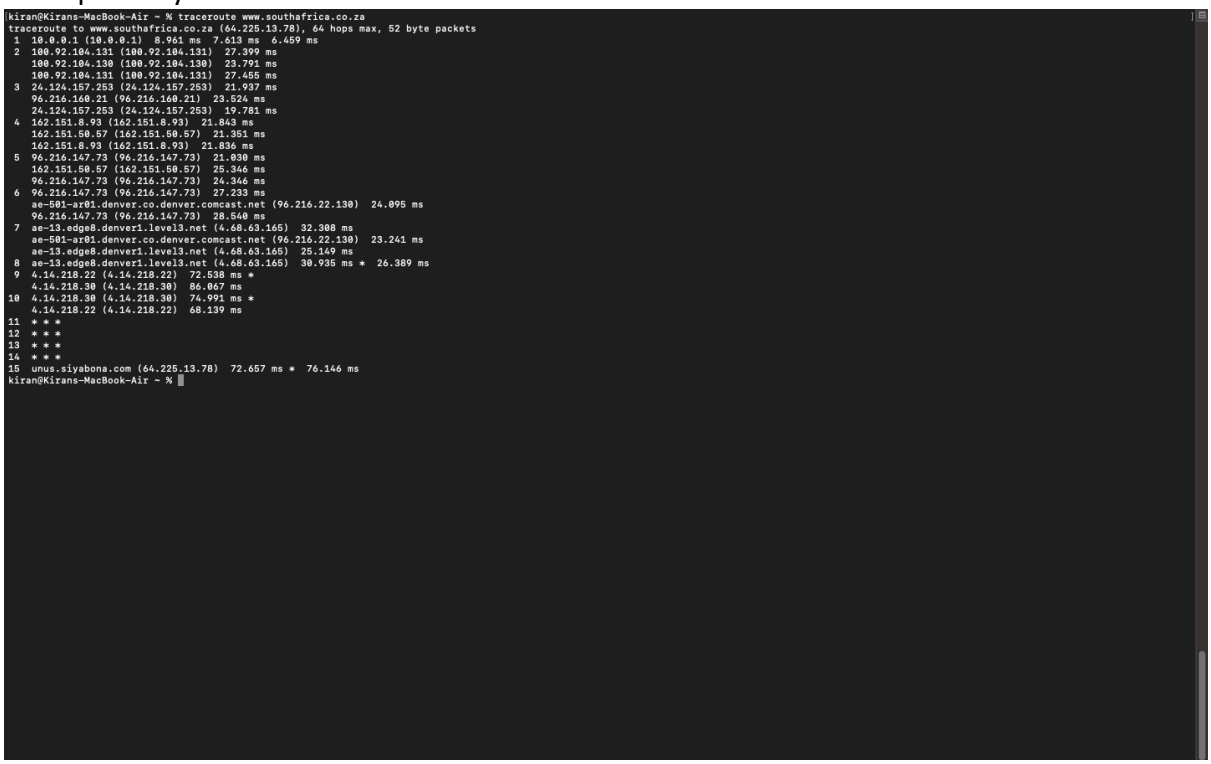
DNS Standard Response:



Question 3:

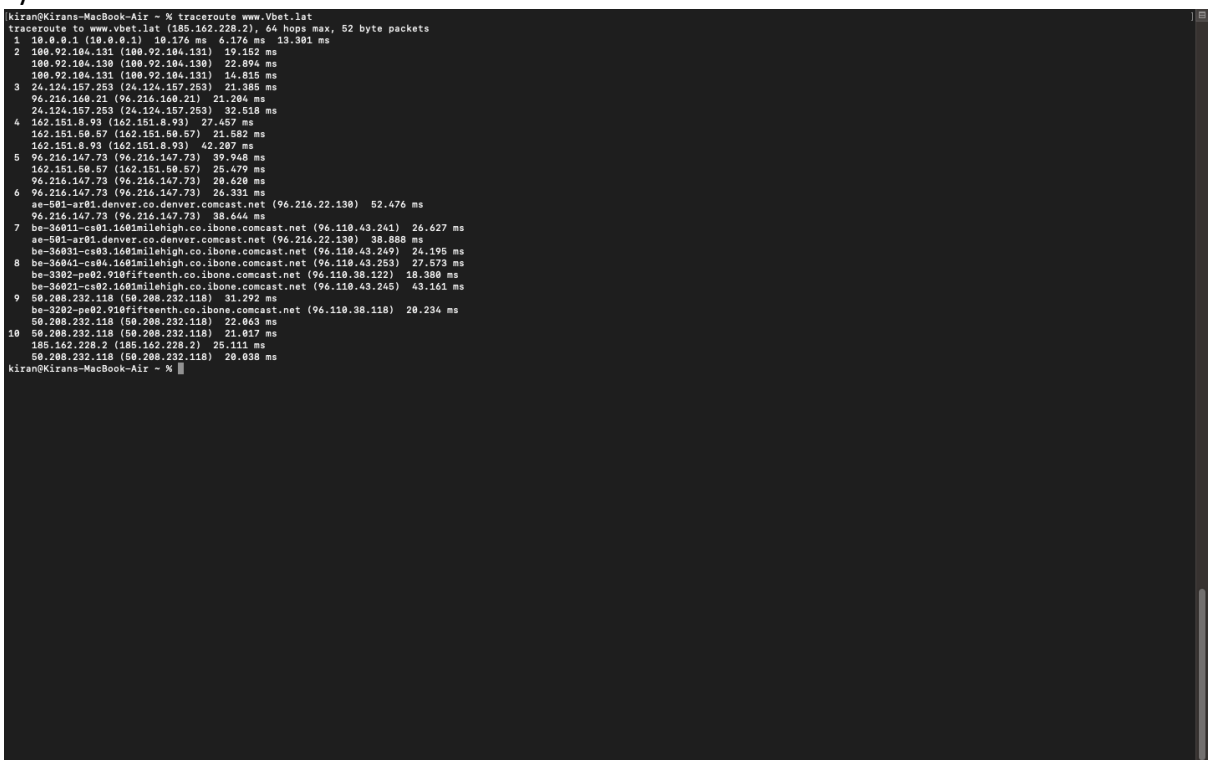
3.1 South Africa

The figure below shows that for website with.co.za domain (www.southafrica.co.za) it took 15 hops for system to route.



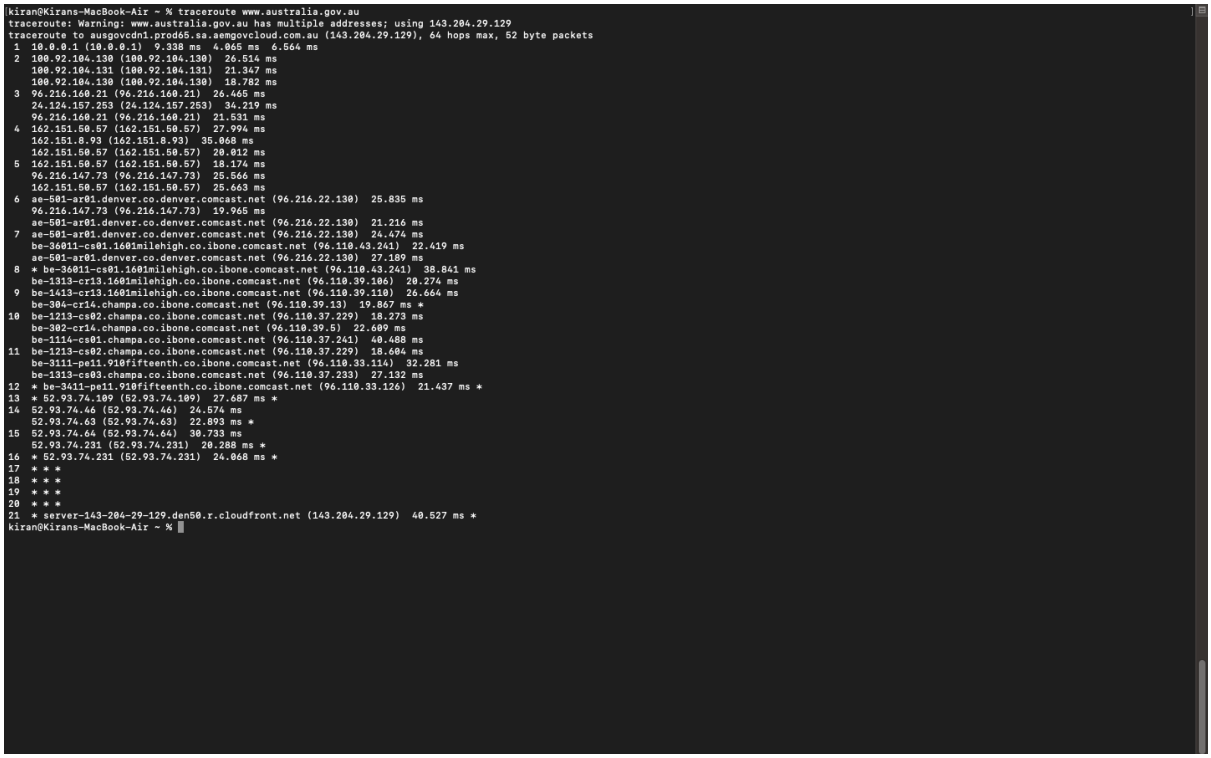
3.2: South America

The figure below shows that for website with. lat domain (www. Vbet.lat) it took 10 hops for system to route.



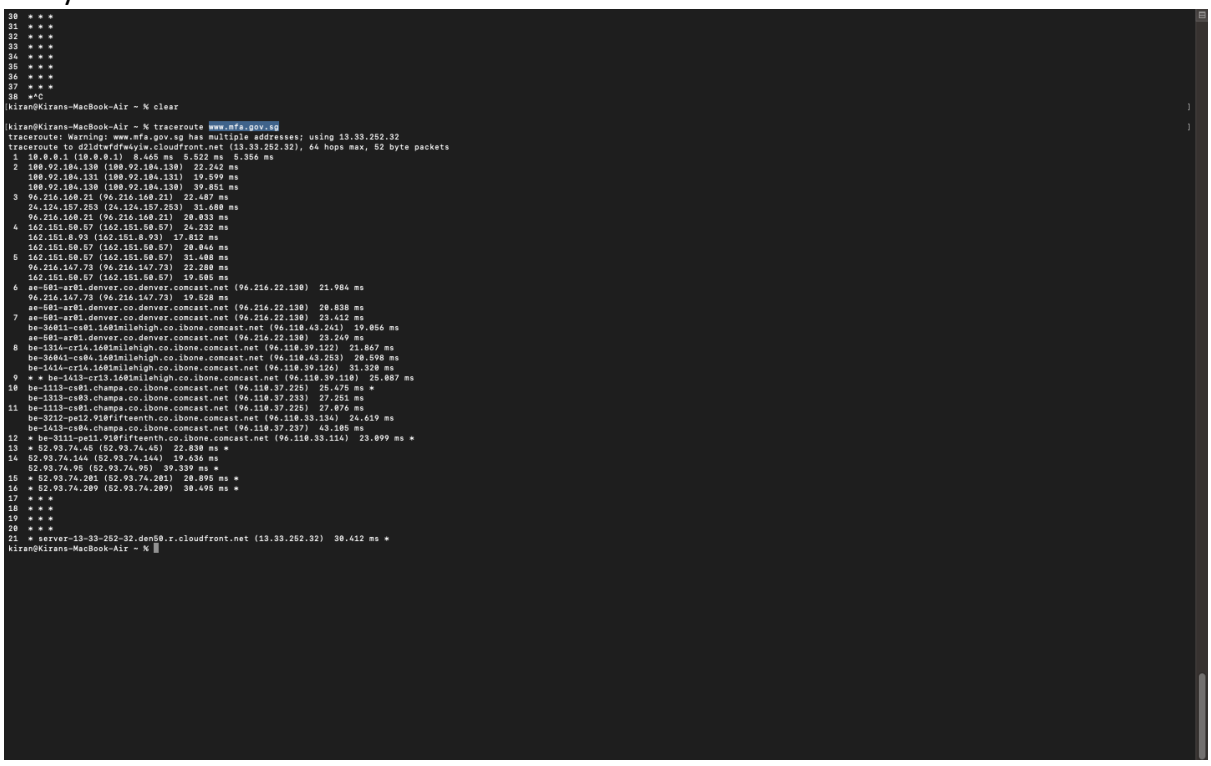
3.3: Australia

The figure below shows that for website with .au domain (www.australia.gov.au/) it took 21 hops for system to route.



3.4: Singapore

The figure below shows that for website with .sg domain (`www.mfa.gov.sg`) it took 16 hops for system to route.



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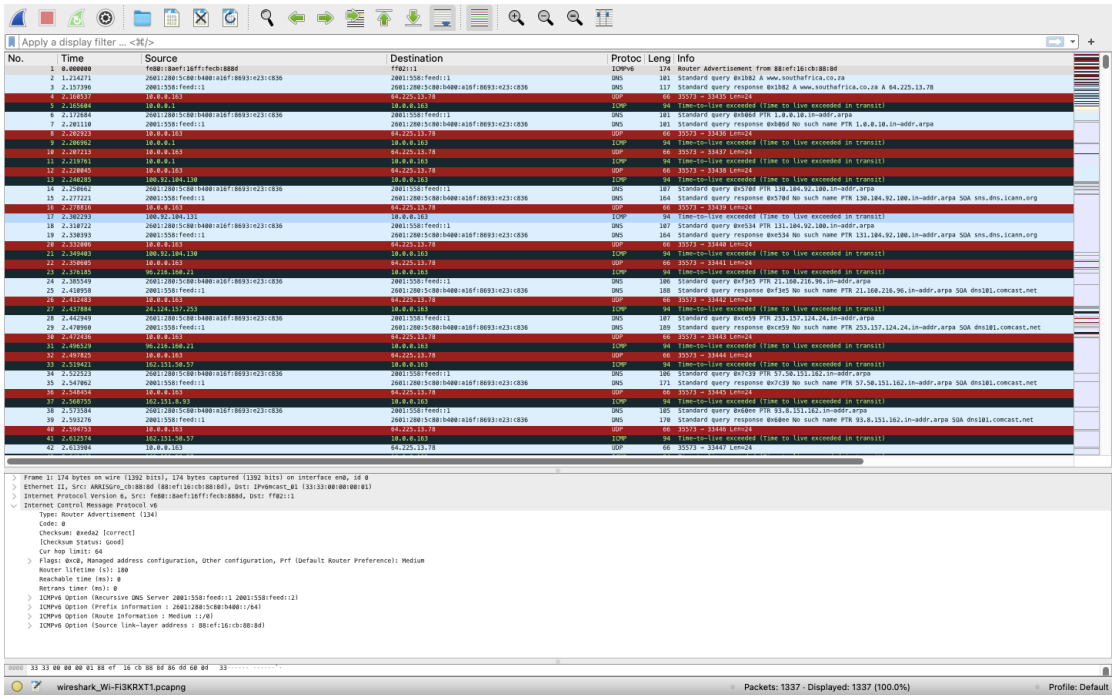
Question 4

Traceroute for the website www.southafrica.co.za :

```
sh-3.2# traceroute www.southafrica.co.za
traceroute to www.southafrica.co.za (64.225.13.78), 64 hops max, 52 byte packets
 1  10.0.0.1 (10.0.0.1)  7.350 ms  4.288 ms  12.795 ms
 2  100.92.104.130 (100.92.104.130)  21.130 ms
    100.92.104.131 (100.92.104.131)  24.441 ms
    100.92.104.130 (100.92.104.130)  17.623 ms
 3  96.216.160.21 (96.216.160.21)  26.543 ms
    24.124.157.253 (24.124.157.253)  26.358 ms
    96.216.160.21 (96.216.160.21)  24.351 ms
 4  162.151.50.57 (162.151.50.57)  22.277 ms
    162.151.8.93 (162.151.8.93)  21.271 ms
    162.151.50.57 (162.151.50.57)  18.085 ms
 5  162.151.50.57 (162.151.50.57)  27.767 ms
    96.216.147.73 (96.216.147.73)  21.615 ms
    162.151.50.57 (162.151.50.57)  22.436 ms
 6  ae-501-ar01.denver.co.denver.comcast.net (96.216.22.130)  27.317 ms
    96.216.147.73 (96.216.147.73)  20.724 ms
    ae-501-ar01.denver.co.denver.comcast.net (96.216.22.130)  27.023 ms
 7  ae-501-ar01.denver.co.denver.comcast.net (96.216.22.130)  17.174 ms
    ae-13.edge8.denver1.level3.net (4.68.63.165)  23.964 ms
    ae-501-ar01.denver.co.denver.comcast.net (96.216.22.130)  22.981 ms
 8  * ae-13.edge8.denver1.level3.net (4.68.63.165)  301.691 ms *
 9  * 4.14.218.30 (4.14.218.30)  76.016 ms *
10  * 4.14.218.30 (4.14.218.30)  65.223 ms *
11  * * *
12  * * *
13  * * *
14  * * *
15  * unus.siyabona.com (64.225.13.78)  62.866 ms *
sh-3.2#
```

The Wireshark mapping with UDP and TCMP packets for each hop as shown below:



The table below shows the UDP frame data with TTL fields and port no used. The data field showed for each frame is a data of 24 bytes payload.

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Hop	Destination Address	Time to Live	Destination Port No	Data/Message Recieved
1	10.0.0.1	1	33435	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
2	100.92.104.130 100.92.104.131 100.92.104.130	2	33438	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
3	96.216.160.21 24.124.157.253 96.216.160.21	3	33441	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
4	162.151.50.57 162.151.8.93 162.151.50.57	4	33444	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
5	162.151.50.57 96.216.147.73 162.151.50.57	5	33447	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
6	96.216.22.130	6	33450	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
7	96.216.22.130	7	33453	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
8	4.68.63.165	8	33457	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)
9	64.225.13.78	9	33461	00000000000000000000000000000000 000000000000000000 (24 Byte UDP Payload)

5: Question 5

5.1: Using Century Link Looking Glass

5.1.1 Africa to Denver

From Johannesburg to CU Denver Public IP:
The data hoped from Johannesburg, New York, Denver and Back to CU Boulder.

JOHANNESBURG SOUTHAFRICA Traceroute results for: 128.138.0.0 (128.138.0.0)

Tracing route to 128.138.0.0 1 ae1.3511.edge2.NewYork6.level3.net (4.69.209.78) 250ms 251ms 253ms
2 Lumen-level3-NewYork6.Level3.net (4.68.110.154) 250ms 250ms 253ms
3 dvr-edge-13.inet.qwest.net (67.14.24.89) 287ms 286ms 286ms
4 205.171.45.118 (205.171.45.118) 287ms 287ms 287ms
5 compmx-tcommx-b.colorado.edu (128.138.81.221) 290ms 287ms 287ms
6 0.0.0.0 (0.0.0.0) * * *
7 0.0.0.0 (0.0.0.0) * * *
8 0.0.0.0 (0.0.0.0) * * *
9 0.0.0.0 (0.0.0.0) * * *
10 0.0.0.0 (0.0.0.0) * * *
11 0.0.0.0 (0.0.0.0) * * *
12 0.0.0.0 (0.0.0.0) * * *
13 0.0.0.0 (0.0.0.0) * * *
14 0.0.0.0 (0.0.0.0) * * *
15 0.0.0.0 (0.0.0.0) * * *
16 0.0.0.0 (0.0.0.0) * * *
17 0.0.0.0 (0.0.0.0) * * *
18 0.0.0.0 (0.0.0.0) * * *
19 0.0.0.0 (0.0.0.0) * * *
20 0.0.0.0 (0.0.0.0) * * *
21 0.0.0.0 (0.0.0.0) * * *
22 0.0.0.0 (0.0.0.0) * * *
23 0.0.0.0 (0.0.0.0) * * *
24 0.0.0.0 (0.0.0.0) * * *
25 0.0.0.0 (0.0.0.0) * * *
26 0.0.0.0 (0.0.0.0) * * *
27 0.0.0.0 (0.0.0.0) * * *
28 0.0.0.0 (0.0.0.0) * * *
29 0.0.0.0 (0.0.0.0) * * *
30 0.0.0.0 (0.0.0.0) * * *

5.1.2 South America to Denver

From Sao Paulo, Brazil to CU Denver Public IP:
The data hoped from Sao Paulo, New York, Denver and Back to CU Boulder.

SAOPAOLO BRAZIL Traceroute results for: 128.138.0.0 (128.138.0.0)

Tracing route to 128.138.0.0 1 * * *
2 ge-2-1-4.chi11.ip.tiscali.net (4.68.110.146) 107ms 109ms 107ms
3 dvr-edge-13.inet.qwest.net (67.14.24.93) 155ms 150ms 152ms
4 205.171.45.118 (205.171.45.118) 151ms 153ms 152ms
5 compmx-tcommx-b.colorado.edu (128.138.81.221) 168ms 154ms 151ms
6 * * *
7 * * *
8 * * *
9 * * *
10 * * *
11 * * *
12 * * *
13 * * *
14 * * *
15 * * *
16 * * *
17 * * *
18 * * *
19 * * *
20 * * *
21 * * *
22 * * *

5.1.3 Australia to Denver

From Australia to CU Denver Public IP:
The data hoped from Sydney, Seattle, Denver and Back to CU Boulder.

SYDNEY Traceroute results for: 128.138.0.0 (128.138.0.0)

Tracing route to 128.138.0.0 1 0.0.0.0 (0.0.0.0) * ae1.3502.ear3.Seattle1.level3.net (4.69.203.165) 173ms 173ms
2 Lumen-level3-Seattle1.Level3.net (4.68.110.174) 176ms 173ms 173ms
3 dvr-edge-13.inet.qwest.net (67.14.24.89) 200ms 200ms 201ms
4 205.171.45.118 (205.171.45.118) 201ms 201ms 201ms
5 compmx-tcommx-b.colorado.edu (128.138.81.221) 201ms 201ms 201ms
6 0.0.0.0 (0.0.0.0) * * *
7 0.0.0.0 (0.0.0.0) * * *
8 0.0.0.0 (0.0.0.0) * * *
9 0.0.0.0 (0.0.0.0) * * *
10 0.0.0.0 (0.0.0.0) * * *
11 0.0.0.0 (0.0.0.0) * * *
12 0.0.0.0 (0.0.0.0) * * *
13 0.0.0.0 (0.0.0.0) * * *
14 0.0.0.0 (0.0.0.0) * * *
15 0.0.0.0 (0.0.0.0) * * *
16 0.0.0.0 (0.0.0.0) * * *
17 0.0.0.0 (0.0.0.0) * * *
18 0.0.0.0 (0.0.0.0) * * *
19 0.0.0.0 (0.0.0.0) * * *
20 0.0.0.0 (0.0.0.0) * * *
21 0.0.0.0 (0.0.0.0) * * *
22 0.0.0.0 (0.0.0.0) * * *

5.1.4 Singapore to Denver

From Singapore to CU Denver Public IP:

The data hoped from Singapore, Seattle, Denver and Back to CU Boulder.

SINGAPORE Traceroute results for: 128.138.0.0 (128.138.0.0)

Tracing route to 128.138.0.0 1 ae2.3602.ear3.Seattle1.level3.net (4.69.203.169) 158ms 158ms 0.0.0.0 (0.0.0.0) *
2 Lumen-level3-Seattle1.Level3.net (4.68.110.174) 153ms 153ms 158ms
3 dvr-edge-13.inet.qwest.net (67.14.24.89) 185ms 186ms 190ms
4 205.171.45.118 (205.171.45.118) 186ms 186ms 181ms
5 compmx-tcommx-b.colorado.edu (128.138.81.221) 191ms 186ms 186ms
6 0.0.0.0 (0.0.0.0) * * *
7 0.0.0.0 (0.0.0.0) * * *
8 0.0.0.0 (0.0.0.0) * * *
9 0.0.0.0 (0.0.0.0) * * *
10 0.0.0.0 (0.0.0.0) * * *
11 0.0.0.0 (0.0.0.0) * * *
12 0.0.0.0 (0.0.0.0) * * *
13 0.0.0.0 (0.0.0.0) * * *
14 0.0.0.0 (0.0.0.0) * * *
15 0.0.0.0 (0.0.0.0) * * *
16 0.0.0.0 (0.0.0.0) * * *
17 0.0.0.0 (0.0.0.0) * * *
18 0.0.0.0 (0.0.0.0) * * *
19 0.0.0.0 (0.0.0.0) * * *
20 0.0.0.0 (0.0.0.0) * * *
21 0.0.0.0 (0.0.0.0) * * *
22 0.0.0.0 (0.0.0.0) * * *

5.2: Using Cogentco Looking Glass

5.2.1 Africa to Denver

From Johannesburg to CU Denver Public IP:
Data hoped from Johannesburg, London, Ney York, Chicago, Kansas and back to Denver as seen below.

```
traceroute to 128.138.0.0 (128.138.0.0), 30 hops max, 60 byte packets
 1  gi0-0-0-17.20.agr11.jnb01.atlas.cogentco.com (206.185.255.1)  0.860 ms  0.902 ms
 2  be2355.ccr51.jnb01.atlas.cogentco.com (154.54.43.37)  0.453 ms  0.608 ms
 3  be2385.ccr21.lon01.atlas.cogentco.com (154.54.40.93)  167.473 ms  167.500 ms
 4  ldn-b3-link.ip.twelve99.net (62.115.9.28)  175.473 ms  175.459 ms
 5  ldn-bb1-link.ip.twelve99.net (62.115.120.74)  193.591 ms  185.840 ms
 6  nyk-bb2-link.ip.twelve99.net (62.115.113.20)  247.507 ms nyk-bb1-link.ip.twelve99.net (62.115.112.244)  253.
 7  chi-b24-link.ip.twelve99.net (62.115.118.151)  253.220 ms  253.123 ms
 8  kanc-b2-link.ip.twelve99.net (62.115.125.153)  292.441 ms kanc-b2-link.ip.twelve99.net (213.155.130.177)  28
 9  kanc-bb2-link.ip.twelve99.net (62.115.138.74)  285.439 ms  272.566 ms
10  den-b3-link.ip.twelve99.net (62.115.139.205)  263.369 ms *
11  frontrange-ic328309-den-b1.ip.twelve99-cust.net (62.115.63.79)  303.176 ms  296.564 ms
12  core-1200-ptr.frgp.net (192.43.217.169)  276.917 ms  266.077 ms
13  ucb-i1-frgp.colorado.edu (198.59.55.9)  264.843 ms  285.529 ms
14  * *
15  * *
16  * *
17  * *
18  * *
```

5.1.2 South America to Denver

From Sao Paulo, Brazil to CU Denver Public IP:
The data hoped from Sao Paulo, New York, Denver and Back to CU Boulder.

```
traceroute to 128.138.0.0 (128.138.0.0), 30 hops max, 60 byte packets
 1  gi100-0-0-43.51.ccr31.sao01.atlas.cogentco.com (209.14.255.1)  0.741 ms  0.785 ms
 2  be2531.ccr31.jfk10.atlas.cogentco.com (154.54.88.1)  109.880 ms  110.772 ms
 3  be2073.ccr31.jfk05.atlas.cogentco.com (154.54.0.229)  109.208 ms  109.300 ms
 4  ae-24.edge2.NewYork6.Level3.net (4.68.110.89)  109.697 ms  109.687 ms
 5  Lumen-level3-NewYork6.Level3.net (4.68.110.154)  108.706 ms  109.669 ms
 6  dvr-edge-13.inet.qwest.net (67.14.24.89)  149.770 ms  149.759 ms
 7  205.171.45.118 (205.171.45.118)  150.023 ms  151.028 ms
 8  compmx-tcommx-b.colorado.edu (128.138.81.221)  149.181 ms  150.155 ms
 9  * *
10  * *
11  * *
12  * *
13  * *
14  * *
15  * *
16  * *
17  * *
18  * *
```

5.2.3 Australia to Denver

From Sydney, Australia to CU Denver Public IP:
The data hoped from Sydney, Portland, Seattle, San Jose, Denver and Back to CU Boulder.

```
traceroute to 128.138.0.0 (128.138.0.0), 30 hops max, 60 byte packets
 1  te0-3-1-17.32.ccr51.syd01.atlas.cogentco.com (206.149.255.1)  0.478 ms  0.477 ms
 2  be2237.ccr51.pdx02.atlas.cogentco.com (154.54.45.121)  133.585 ms  133.574 ms
 3  be2216.ccr21.pdx01.atlas.cogentco.com (154.54.31.157)  134.188 ms  134.125 ms
 4  be2670.ccr22.sea02.atlas.cogentco.com (154.54.42.149)  137.373 ms  137.710 ms
 5  sea-b2-link.telia.net (62.115.187.136)  137.302 ms  137.252 ms
 6  sjo-b23-link.ip.twelve99.net (62.115.118.169)  154.660 ms  154.527 ms
 7  den-b1-link.ip.twelve99.net (213.155.133.170)  175.913 ms  175.870 ms
 8  den-b3-link.ip.twelve99.net (62.115.139.248)  173.729 ms  173.581 ms
 9  frontrange-ic328309-den-b1.ip.twelve99-cust.net (62.115.63.79)  175.764 ms  173.686 ms
10  core-1200-ptr.frgp.net (192.43.217.169)  175.461 ms  173.553 ms
11  ucb-i1-frgp.colorado.edu (198.59.55.9)  176.402 ms  176.525 ms
12  * *
13  * *
14  * *
15  * *
16  * *
17  * *
18  * *
```

5.2.4 Singapore to Denver

From Singapore to CU Denver Public IP:

The data hoped from Singapore, Los Angeles, San Jose, San Francisco, Seattle, San Jose, Denver and Back to CU Boulder.

```
traceroute to 128.138.0.0 (128.138.0.0), 30 hops max, 60 byte packets
 1  gi0-0-0-19.215.nr11.b019922-0.sin01.atlas.cogentco.com (66.250.250.201)  1.012 ms  0.995 ms
 2  te0-0-0-33.nr01.b019922-0.sin01.atlas.cogentco.com (154.24.75.133)  1.286 ms te0-0-0-19.nr01.b019922-0.sin01
 3  te0-0-0-23.agr02.sin01.atlas.cogentco.com (154.24.61.77)  1.501 ms te0-0-0-23.agr01.sin01.atlas.cogentco.com
 4  be2080.ccr31.sin01.atlas.cogentco.com (154.54.88.17)  1.394 ms  1.458 ms
 5  be2913.ccr41.lax04.atlas.cogentco.com (154.54.27.54)  202.533 ms  202.532 ms
 6  be3271.ccr41.lax01.atlas.cogentco.com (154.54.42.101)  210.028 ms be3360.ccr42.lax01.atlas.cogentco.com (154
 7  be3176.ccr21.sjc01.atlas.cogentco.com (154.54.31.190)  198.411 ms be3177.ccr22.sjc01.atlas.cogentco.com (154
 8  be3179.ccr22.sfo01.atlas.cogentco.com (154.54.43.149)  198.146 ms be3178.ccr21.sfo01.atlas.cogentco.com (154
 9  be2077.ccr22.sea02.atlas.cogentco.com (154.54.0.242)  209.607 ms  202.007 ms
10  sea-b2-link.telia.net (62.115.187.136)  209.217 ms  223.381 ms
11  sjo-b23-link.ip.twelve99.net (62.115.118.169)  203.881 ms  204.352 ms
12  den-b1-link.ip.twelve99.net (213.155.133.170)  230.473 ms  224.686 ms
13  den-b3-link.ip.twelve99.net (62.115.139.248)  221.890 ms  221.824 ms
14  frontrange-ic328309-den-b1.ip.twelve99-cust.net (62.115.63.79)  227.303 ms  230.066 ms
15  core-1200-ptr.frgp.net (192.43.217.169)  233.698 ms  231.750 ms
16  ucb-i1-frgp.colorado.edu (198.59.55.9)  235.080 ms  231.052 ms
17  * *
18  * *
```