Lab 01 Report

```
Lines in this font represent terminal commands and terminal output.
```
Lines beginning with `$` are the terminal commands that were run.

Lines in this font are the answers to the questions.

EXERCISE 1

1.
```
$ nslookup www.google.com
  Server:  129.94.242.2
  Address: 129.94.242.2#53

  Non-authoritative answer:
  Name:  www.google.com
  Address:  216.58.199.36
```

   The IP Address of Google is 216.58.199.36. Google uses multiple IP Addresses for load balancing, such that multiple servers have multiple IP Addresses to connect to based on traffic intensity and geographical location.

2.
```
$ nslookup 127.0.0.1
  Server:  129.94.242.2
  Address: 129.94.242.2#53

  1.0.0.127.in-addr.arpa name = localhost.
```

   The name of the IP Address 127.0.0.1 is localhost, it refers to the machine you are currently using, and is known as the loopback address. It allows you to point your software at your current computer without having to visit external routers over the network to find your current computer.

EXERCISE 2

`$ ping -c 3 www.cse.unsw.edu.au` – Reachable by ping.

```
$ ping -c 3 www.getfittest.com.au
ping:  unknown host www.getfittest.com.au
```
Unreachable by ping. Unreachable by Web Browser as well, indicating that the host does not exist. The domain name does not have an IP Address associated with it.

`$ ping -c 3 www.mit.edu.au` – Reachable by ping.

`$ ping -c 3 www.intel.com.au` – Reachable by ping.

`$ ping -c 3 www.tpg.com.au` – Reachable by ping.

```
$ ping -c 3 www.hola.hp
ping:  unknown host www.hola.hp
```
Unreachable by ping. Unreachable by Web Browser as well, indicating that the host does not exist. The domain name does not have an IP Address associated with it.

```
$ ping -c 3 www.amazon.com
```
– Reachable by ping.

```
$ ping -c 3 www.tsinghua.edu.cn
```
– Reachable by ping.

```
$ ping -c 3 www.kremlin.ru
PING www.kremlin.ru (95.173.136.70) 56(84) bytes of data.
--- www.kremlin.ru ping statistics ---
3 packets transmitted, 0 received, 100% packet loss, time 2039ms
```
All packets are dropped by the host, indicated by the 100% packet loss. This usually indicates that the firewall of the host is set to drop all icmp ping requests. We can reasonably assume this is true, and thus the host is reachable, just not responding to the ping request. Using a Web Browser, we can reach the host.

```
$ ping -c 3 8.8.8.8
```
– Reachable by ping.

EXERCISE 3

1.
```
$ traceroute www.columbia.edu
traceroute to www.columbia.edu (128.59.105.24), 30 hops max, 60 byte packets
1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.094 ms 0.084 ms 0.101 ms
2 129.94.39.17 (129.94.39.17) 0.991 ms 0.976 ms 1.016 ms
3 libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.495 ms
ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35) 1.588 ms 1.408 ms
4 libcr1-po-5.gw.unsw.edu.au (149.171.255.165) 1.185 ms ombcr1-po-5.gw.unsw.edu.au
(149.171.255.197) 1.300 ms 1.286 ms
5 unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.321 ms 1.340 ms
unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101) 1.365 ms
6 138.44.5.0 (138.44.5.0) 1.525 ms 1.438 ms 1.436 ms
7 et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149) 2.453 ms 2.271 ms 2.251 ms
8 et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99) 95.186 ms 95.289 ms 95.225 ms
9 et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201) 146.762 ms 146.727 ms 146.695 ms
10 abilene-1-lo-jmb-706.sttlwa.pacificwave.net (207.231.240.8) 146.980 ms 146.960 ms 146.690 ms
11 et-4-0-0.4079.rtsw.miss2.net.internet2.edu (162.252.70.0) 157.787 ms 157.753 ms 157.799 ms
12 et-4-0-0.4079.rtsw.minn.net.internet2.edu (162.252.70.58) 180.814 ms 180.673 ms 180.538 ms
13 et-1-1-5.4079.rtsw.eqch.net.internet2.edu (162.252.70.106) 188.527 ms 189.856 ms 189.722 ms
14 162.252.70.163 (162.252.70.163) 188.541 ms 188.907 ms 190.028 ms
15 ae-1.4079.rtsw.clev.net.internet2.edu (162.252.70.130) 197.265 ms 197.291 ms 197.272 ms
16 buf-9208-I2-CLEV.nysernet.net (199.109.11.33) 201.413 ms 201.520 ms 201.438 ms
17 syr-9208-buf-9208.nysernet.net (199.109.7.193) 204.777 ms 204.869 ms 204.894 ms
18 nyc-9208-syr-9208.nysernet.net (199.109.7.162) 210.574 ms 210.862 ms 210.536 ms
19 columbia.nyc-9208.nysernet.net (199.109.4.14) 210.400 ms 210.535 ms 210.529 ms
20 cc-core-1-x-nyser32-gw-1.net.columbia.edu (128.59.255.5) 210.635 ms 210.853 ms 210.796 ms
21 cc-conc-1-x-cc-core-1.net.columbia.edu (128.59.255.210) 210.775 ms 210.808 ms 210.737 ms
22 neurotheory.columbia.edu (128.59.105.24) 210.617 ms 210.844 ms 210.733 ms
```

There are 22 routers between the CSE computer and the destination host. 5 routers are a part of the UNSW network, routers 1-5. Considering the time taken for pings to reach the router and return, we can identify the point that the packets cross the Pacific. The time taken to ping router 8 (95 ms) compared with the time taken to ping router 7 (2.3 ms) indicates a

large distance crossed beteen those two routers. Furthermore, the time taken to ping router 9 (147 ms) compared to the time taken to ping router 8 (95 ms) is still a significant change, although not as large a difference as between routers 7 and 8. This large difference in times indicates that the packets cross the Pacific Ocean between routers 7 and 9, with router 8 being an intermediary hop about two-thirds the way across the Pacific. Looking at a map, this lines up with router 8 being on Haiwaii, which is situated about two-thirds of the way from Australia to mainland US.

2. (a)
```
$ traceroute www.ucla.edu
traceroute to www.ucla.edu (164.67.228.152), 30 hops max, 60 byte packets
1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.135 ms 0.107 ms 0.122 ms
2 129.94.39.17 (129.94.39.17) 1.075 ms 1.051 ms 1.022 ms
3 libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.858 ms 1.842 ms
ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35) 1.625 ms
4 libcr1-po-5.gw.unsw.edu.au (149.171.255.165) 1.216 ms ombcr1-po-6.gw.unsw.edu.au
(149.171.255.169) 1.294 ms ombcr1-po-5.gw.unsw.edu.au (149.171.255.197) 1.275 ms
5 unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101) 1.367 ms 1.507 ms 1.490 ms
6 138.44.5.0 (138.44.5.0) 1.896 ms 1.664 ms 1.640 ms
7 et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149) 2.605 ms 2.367 ms 2.378 ms
8 et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99) 95.319 ms 95.343 ms 95.338 ms
9 et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201) 146.855 ms 146.784 ms 146.705 ms
10 cenichpr-1-is-jmb-778.snvaca.pacificwave.net (207.231.245.129) 163.168 ms 163.259 ms
163.166 ms
11 hpr-lax-hpr3--svl-hpr3-100ge.cenic.net (137.164.25.73) 171.067 ms 171.110 ms 171.108 ms
12 * * *
13 bd11f1.anderson--cr00f2.csb1.ucla.net (169.232.4.4) 173.503 ms
bd11f1.anderson--cr001.anderson.ucla.net (169.232.4.6) 171.511 ms
bd11f1.anderson--cr00f2.csb1.ucla.net (169.232.4.4) 171.549 ms
14 cr00f2.csb1--dr00f2.csb1.ucla.net (169.232.4.53) 171.438 ms 171.522 ms
cr00f1.anderson--dr00f2.csb1.ucla.net (169.232.4.55) 171.535 ms
```

(b)
```
$ traceroute www.u-tokyo.ac.jp
traceroute to www.u-tokyo.ac.jp (210.152.243.234), 30 hops max, 60 byte packets
1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.108 ms 0.089 ms 0.112 ms
2 129.94.39.17 (129.94.39.17) 1.101 ms 1.066 ms 1.052 ms
3 ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35) 1.544 ms
libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.655 ms 1.634 ms
4 ombcr1-po-6.gw.unsw.edu.au (149.171.255.169) 1.244 ms libcr1-po-5.gw.unsw.edu.au
(149.171.255.165) 1.239 ms libcr1-po-6.gw.unsw.edu.au (149.171.255.201) 1.254 ms
5 unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.269 ms 1.404 ms 1.377 ms
6 138.44.5.0 (138.44.5.0) 1.527 ms 1.467 ms 1.625 ms
7 et-0-3-0.pe1.bkvl.nsw.aarnet.net.au (113.197.15.147) 1.959 ms 1.904 ms 1.919 ms
8 ge-4_0_0.bb1.a.pao.aarnet.net.au (202.158.194.177) 156.213 ms 156.130 ms 156.315 ms
9 paloalto0.iij.net (198.32.176.24) 158.160 ms 158.202 ms 158.020 ms
10 osk004bb01.IIJ.Net (58.138.88.189) 271.335 ms 271.205 ms osk004bb00.IIJ.Net (58.138.88.185)
288.958 ms
11 osk004ix51.IIJ.Net (58.138.106.130) 279.662 ms osk004ix51.IIJ.Net (58.138.106.126)
288.581 ms osk004ix51.IIJ.Net (58.138.106.130) 279.720 ms
12 210.130.135.130 (210.130.135.130) 288.548 ms 288.458 ms 288.451 ms
```

```
13 124.83.228.58 (124.83.228.58) 292.545 ms 345.384 ms 345.344 ms

14 124.83.252.178 (124.83.252.178) 277.117 ms 277.035 ms 277.010 ms

15 158.205.134.26 (158.205.134.26) 285.702 ms 285.791 ms 285.694 ms
```

(c)
```
$ traceroute www.lancaster.ac.uk

traceroute to www.lancaster.ac.uk (148.88.65.80), 30 hops max, 60 byte packets

1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.146 ms 0.122 ms 0.102 ms

2 129.94.39.17 (129.94.39.17) 1.101 ms 1.066 ms 1.056 ms

3 libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.747 ms 1.693 ms

ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35) 1.352 ms

4 ombcr1-po-6.gw.unsw.edu.au (149.171.255.169) 34.273 ms

ombcr1-po-5.gw.unsw.edu.au (149.171.255.197) 34.232 ms 34.279 ms

5 unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.380 ms

unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101) 1.262 ms 1.294 ms

6 138.44.5.0 (138.44.5.0) 1.442 ms 1.415 ms 1.515 ms

7 et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149) 2.521 ms 2.247 ms 2.187 ms

8 et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99) 95.228 ms 95.276 ms 95.312 ms

9 et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201) 146.683 ms 146.667 ms 146.610 ms

10 abilene-1-lo-jmb-706.sttlwa.pacificwave.net (207.231.240.8) 146.845 ms 146.756 ms 146.713 ms

11 et-4-0-0.4079.rtsw.miss2.net.internet2.edu (162.252.70.0) 158.187 ms 158.458 ms 158.147 ms

12 et-4-0-0.4079.rtsw.minn.net.internet2.edu (162.252.70.58) 180.600 ms 180.848 ms 180.620 ms

13 et-1-1-5.4079.rtsw.eqch.net.internet2.edu (162.252.70.106) 188.590 ms 188.796 ms 188.571 ms

14 162.252.70.163 (162.252.70.163) 189.182 ms 189.217 ms 197.162 ms

15 ae-1.4079.rtsw.clev.net.internet2.edu (162.252.70.130) 198.321 ms 198.084 ms 198.200 ms

16 et-2-0-0.4079.rtsw.ashb.net.internet2.edu (162.252.70.54) 205.072 ms 206.060 ms 205.944 ms

17 ae-2.4079.rtsw.wash.net.internet2.edu (162.252.70.136) 206.244 ms 205.340 ms 205.310 ms

18 internet2-gw.mx1.lon.uk.geant.net (62.40.124.44) 280.398 ms 280.364 ms 280.379 ms

19 janet-gw.mx1.lon.uk.geant.net (62.40.124.198) 280.625 ms 280.737 ms 283.460 ms

20 ae29.londpg-sbr2.ja.net (146.97.33.2) 300.343 ms 299.030 ms 298.981 ms

21 ae31.erdiss-sbr2.ja.net (146.97.33.22) 284.975 ms 284.773 ms 284.754 ms

22 ae29.manckh-sbr2.ja.net (146.97.33.42) 286.605 ms 286.655 ms 286.659 ms

23 ae24.lanclu-rbr1.ja.net (146.97.38.58) 288.977 ms 288.832 ms 288.898 ms

24 lancaster-university.ja.net (194.81.46.2) 305.054 ms 304.661 ms 304.051 ms

25 * * *

26 ismx-issrx.rtr.lancs.ac.uk (148.88.255.17) 290.729 ms 290.703 ms 290.655 ms

27 dc.iss.srv.rtrcloud.lancs.ac.uk (148.88.253.3) 305.025 ms 302.714 ms 302.355 ms

28 www.lancs.ac.uk (148.88.65.80) 290.579 ms !X 290.952 ms !X 290.519 ms !X
```

All three paths to the destination hosts diverge at router 6, with IP Address 138.44.5.0. Using the whois command, router 6 is managed by Australian Academic and Research Network. This router is probably linked to ingoing and outgoing connections from/to Australian university and academic networks. This router is used by UNSW, but not necessarily owned by UNSW, or a part of the UNSW Network.

The distance from Sydney to California is roughly 12000km, and has 14 routers in the path. The distance from Sydney to Tokyo is roughly 7000km, and has 15 routers in the path. The distance from Sydney to Lancaster is roughly 17000km, and has 28 routers in the path. This does not show any simple proporionality relationship between the number of hop routers and the geographical distance.

4

There are many hops within the UNSW network, however to cross the Pacific Ocean, only one intermediary hop was required. This also demonstrates that there is NOT a proporionality relationship between the number of routers and the physical distance traversed.

3. (a) From www.speedtest.sg/tr.php to my machine.

```
traceroute to 129.94.242.53 (129.94.242.53), 30 hops max, 60 byte packets
1 ge2-8.r01.sin01.ne.com.sg (202.150.221.169) 0.156 ms 0.178 ms 0.184 ms
2 10.11.33.30 (10.11.33.30) 0.252 ms 0.262 ms 0.272 ms
3 10.11.33.74 (10.11.33.74) 0.722 ms 0.730 ms 0.735 ms
4 aarnet.sgix.sg (103.16.102.67) 225.643 ms 225.702 ms 225.682 ms
5 xe-3-0-3.pe1.brwy.nsw.aarnet.net.au (113.197.15.206) 232.785 ms 232.829 ms 232.803 ms
6 138.44.5.1 (138.44.5.1) 225.853 ms 225.959 ms 225.852 ms
7 libcr1-te-1-5.gw.unsw.edu.au (149.171.255.102) 225.944 ms 225.955 ms 226.067 ms
8 ombudnex1-po-1.gw.unsw.edu.au (149.171.255.202) 236.584 ms 236.601 ms libudnex1-po-1.gw.unsw.edu.au
(149.171.255.166) 224.150 ms
9 ufw1-ae-1-3154.gw.unsw.edu.au (149.171.253.36) 236.534 ms 236.470 ms 236.488 ms
10 129.94.39.23 (129.94.39.23) 224.734 ms 224.759 ms 224.886 ms
```

From my machine to www.speedtest.sg.

```
$ traceroute www.speedtest.sg
traceroute to www.speedtest.com.sg (202.150.221.170), 30 hops max, 60 byte packets
1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.131 ms 0.106 ms 0.091 ms
2 129.94.39.17 (129.94.39.17) 1.115 ms 1.086 ms 1.074 ms
3 libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.619 ms ombudnex1-vl-3154.gw.unsw.edu.au
(149.171.253.35) 1.944 ms 2.749 ms
4 libcr1-po-6.gw.unsw.edu.au (149.171.255.201) 1.275 ms ombcr1-po-6.gw.unsw.edu.au (149.171.255.169)
1.256 ms 1.264 ms
5 unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.348 ms 1.384 ms 1.306 ms
6 138.44.5.0 (138.44.5.0) 1.456 ms 1.401 ms 1.418 ms
7 et-0-3-0.pe1.alxd.nsw.aarnet.net.au (113.197.15.153) 2.055 ms 1.871 ms 2.011 ms
8 xe-0-2-1-204.pe1.wnpa.alxd.aarnet.net.au (113.197.15.183) 24.354 ms 24.344 ms
xe-0-0-3.pe1.wnpa.akl.aarnet.net.au (113.197.15.67) 24.322 ms
9 et-0-1-0.200.pe1.tkpa.akl.aarnet.net.au (113.197.15.69) 24.684 ms 24.728 ms 24.708 ms
10 xe-0-2-6.bdr1.a.lax.aarnet.net.au (202.158.194.173) 148.076 ms 148.187 ms 148.036 ms
11 singtel.as7473.any2ix.coresite.com (206.72.210.63) 148.247 ms 148.160 ms 148.160 ms
12 203.208.151.181 (203.208.151.181) 317.311 ms 203.208.171.9 (203.208.171.9) 320.224 ms 203.208.172.173
(203.208.172.173) 148.316 ms
13 203.208.177.110 (203.208.177.110) 236.757 ms 224.933 ms 203.208.151.233 (203.208.151.233)
308.023 ms
14 202-150-221-170.rev.ne.com.sg (202.150.221.170) 237.043 ms 203.208.182.45 (203.208.182.45) 334.005
ms 202-150-221-170.rev.ne.com.sg (202.150.221.170) 224.793 ms
```

(b) From www.telstra.net/cgi-bin/trace to my machine.

```
1 gigabitethernet3-3.exi2.melbourne.telstra.net (203.50.77.53) 0.247 ms 0.223 ms 0.242 ms

2 bundle-ether3-100.win-core10.melbourne.telstra.net (203.50.80.129) 1.118 ms 1.862 ms 1.868 ms

3 bundle-ether12.ken-core10.sydney.telstra.net (203.50.11.122) 12.738 ms 12.356 ms 12.987 ms

4 bundle-ether1.ken-edge901.sydney.telstra.net (203.50.11.95) 12.112 ms 13.229 ms 11.862 ms

5 aarnet6.lnk.telstra.net (139.130.0.78) 11.609 ms 11.607 ms 11.609 ms

6 ge-6-0-0.bb1.a.syd.aarnet.net.au (202.158.202.17) 11.862 ms 11.729 ms 11.737 ms

7 ae9.pe2.brwy.nsw.aarnet.net.au (113.197.15.56) 11.985 ms 12.103 ms 11.986 ms

8 et-3-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.146) 12.111 ms 12.107 ms 12.111 ms

9 138.44.5.1 (138.44.5.1) 12.360 ms 12.356 ms 12.362 ms

10 libcr1-te-1-5.gw.unsw.edu.au (149.171.255.102) 12.360 ms 12.357 ms 12.361 ms

11 libudnex1-po-1.gw.unsw.edu.au (149.171.255.166) 12.615 ms 12.608 ms 12.608 ms

12 ufw1-ae-1-3154.gw.unsw.edu.au (149.171.253.36) 13.110 ms 13.106 ms 12.986 ms

13 129.94.39.23 (129.94.39.23) 13.236 ms 13.232 ms 13.237 ms
```

From my machine to www.telstra.net/cgi-bin/trace.

```
$ traceroute www.telstra.net
traceroute to www.telstra.net (203.50.5.178), 30 hops max, 60 byte packets
1 cserouter1-server.cse.unsw.EDU.AU (129.94.242.251) 0.127 ms 0.115 ms 0.097 ms
2 129.94.39.17 (129.94.39.17) 1.087 ms 1.050 ms 1.028 ms
3 libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.824 ms ombudnex1-vl-3154.gw.unsw.edu.au
(149.171.253.35) 1.577 ms libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34) 1.630 ms
4 libcr1-po-5.gw.unsw.edu.au (149.171.255.165) 1.364 ms libcr1-po-6.gw.unsw.edu.au
(149.171.255.201) 1.417 ms ombcr1-po-5.gw.unsw.edu.au (149.171.255.197) 1.219 ms
5 unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.324 ms unswbr1-te-1-9.gw.unsw.edu.au
(149.171.255.101) 1.312 ms unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105) 1.363 ms
6 138.44.5.0 (138.44.5.0) 1.394 ms 1.497 ms 1.488 ms
7 et-0-3-0.pe1.alxd.nsw.aarnet.net.au (113.197.15.153) 14.045 ms 13.378 ms 13.360 ms
8 ae9.bb1.b.syd.aarnet.net.au (113.197.15.65) 1.997 ms 1.916 ms 1.990 ms
9 gigabitethernet1-1.pe1.b.syd.aarnet.net.au (202.158.202.18) 1.974 ms 2.017 ms 1.948 ms
10 gigabitethernet3-11.ken37.sydney.telstra.net (139.130.0.77) 4.281 ms 2.484 ms 2.585 ms
11 bundle-ether2.chw-edge901.sydney.telstra.net (203.50.11.103) 2.694 ms
bundle-ether13.ken-core10.sydney.telstra.net (203.50.11.94) 4.275 ms 4.235 ms
12 bundle-ether10.win-core10.melbourne.telstra.net (203.50.11.123) 14.828 ms 14.791 ms
bundle-ether13.chw-core10.sydney.telstra.net (203.50.11.98) 3.355 ms
13 203.50.6.40 (203.50.6.40) 15.601 ms bundle-ether8.exi-core10.melbourne.telstra.net
(203.50.11.125) 16.358 ms 203.50.6.40 (203.50.6.40) 15.584 ms
14 bundle-ether2.exi-ncprouter101.melbourne.telstra.net (203.50.11.209) 15.560 ms 15.043 ms
15.384 ms
15 www.telstra.net (203.50.5.178) 14.374 ms 14.663 ms 15.047 ms
```

The IP Address of www.speedtest.sg is 202.150.221.170, and the IP Address of www.telstra.net is 203.50.5.178. The reverse and forward paths share a good amount of routers, but do have a few variations. For the routers that are shared between the two paths, they do not have the same IP Addresses, although in most cases they differ by 1 number in the very last section of the IP Address, ie, 149.171.255.165 for the forward direction and 149.171.255.166 for the reverse direction. This is due to multiple servers at the hop, some that manage outbound traffic, and some that manage inbound traffic, to share, and distribute the load.
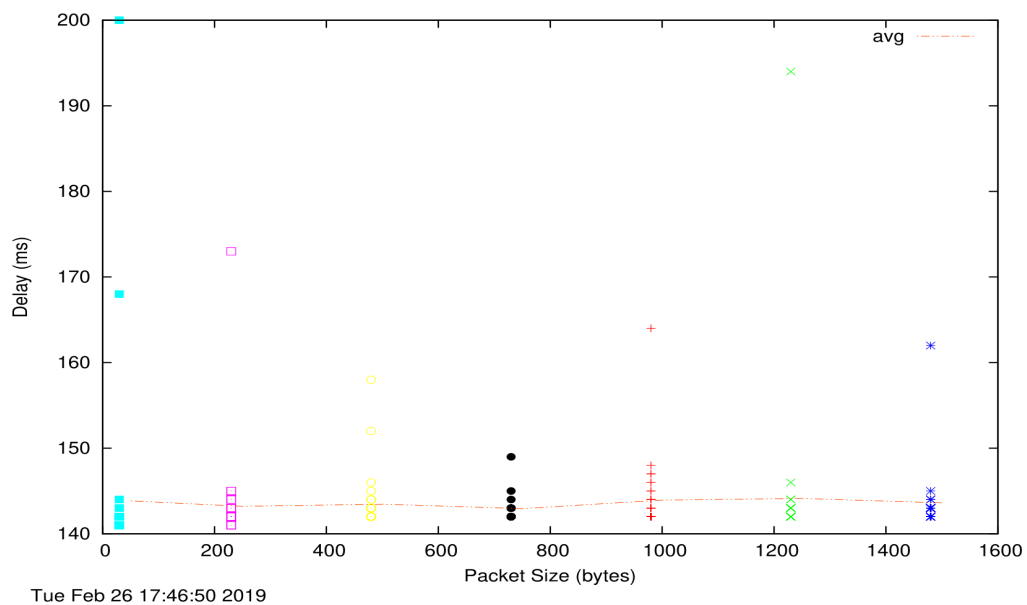
EXERCISE 4

Figure 1: Delay of www.nus.edu.sg vs Packet Number
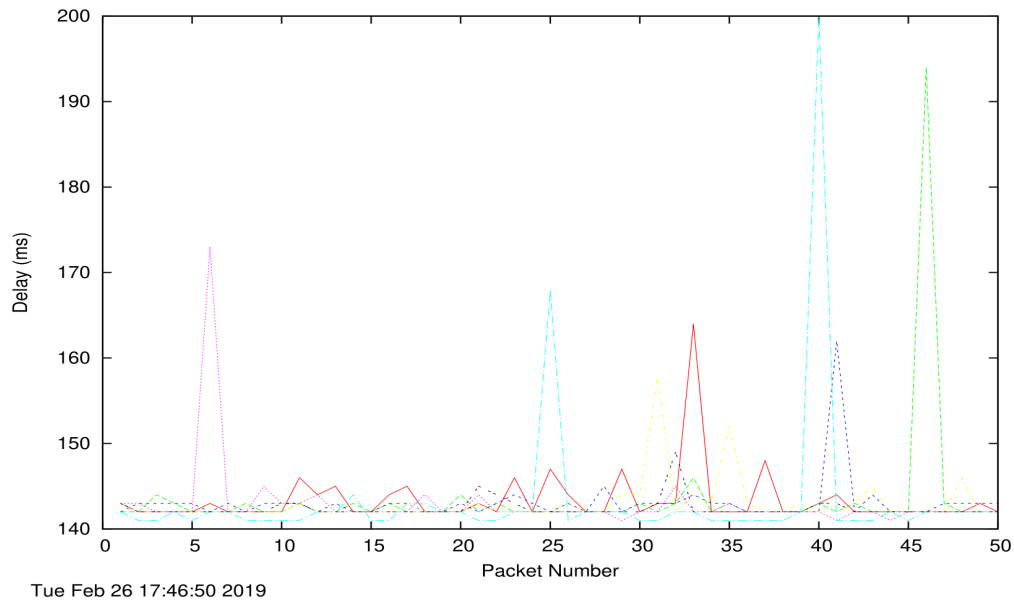
Figure 2: Scatter of www.nus.edu.sg vs Packet Size

Figure 3: Delay of www.tu-berlin.de vs Packet Number
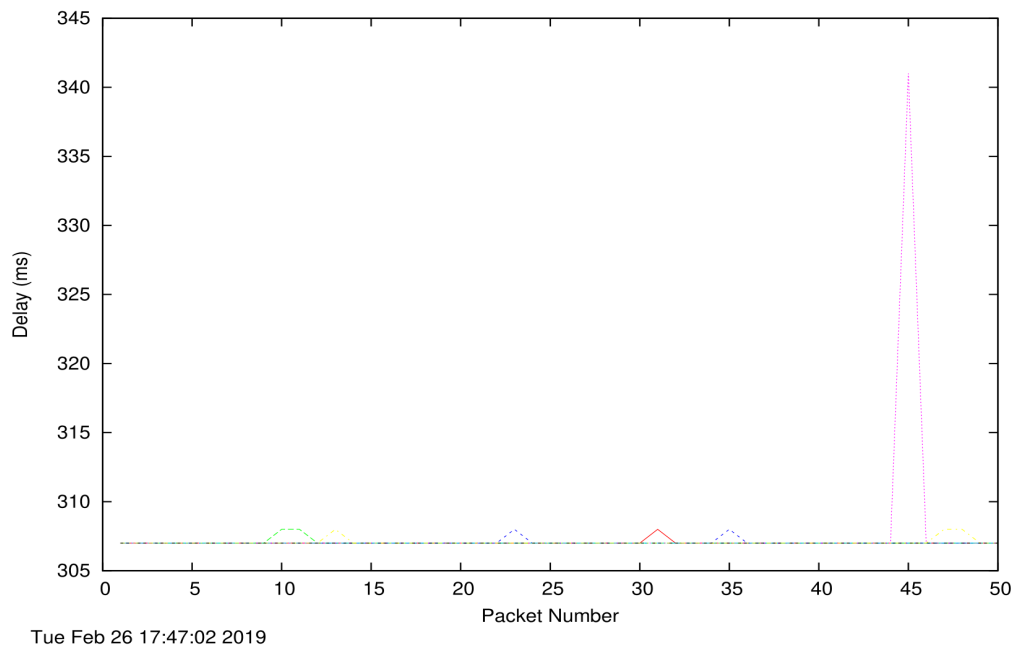
Figure 4: Scatter of www.tu-berlin.de vs Packet Size
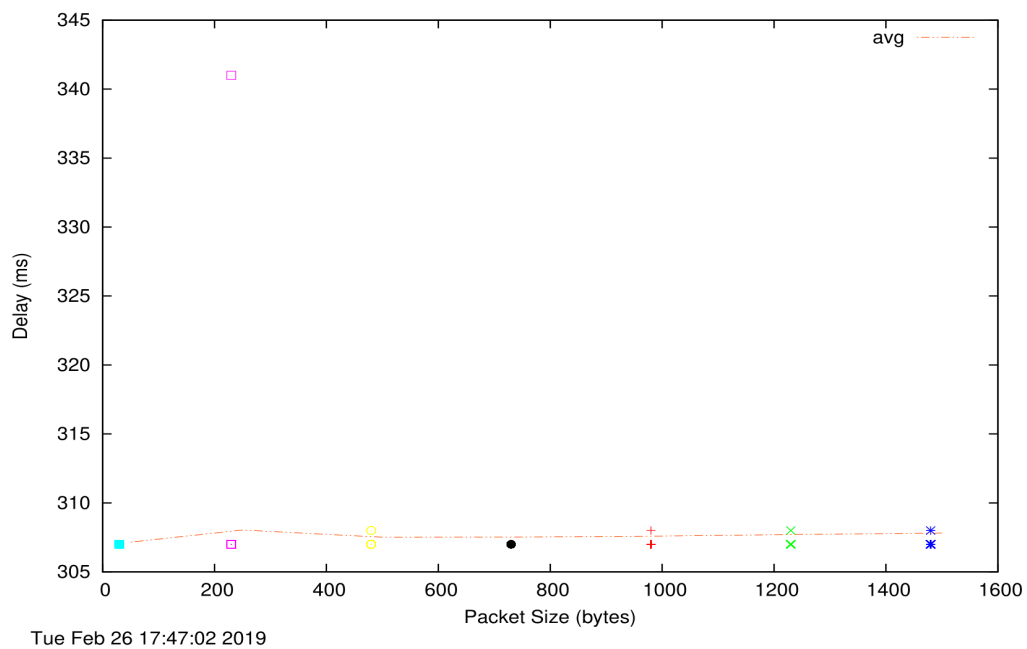
Figure 5: Delay of www.uq.edu.au vs Packet Number
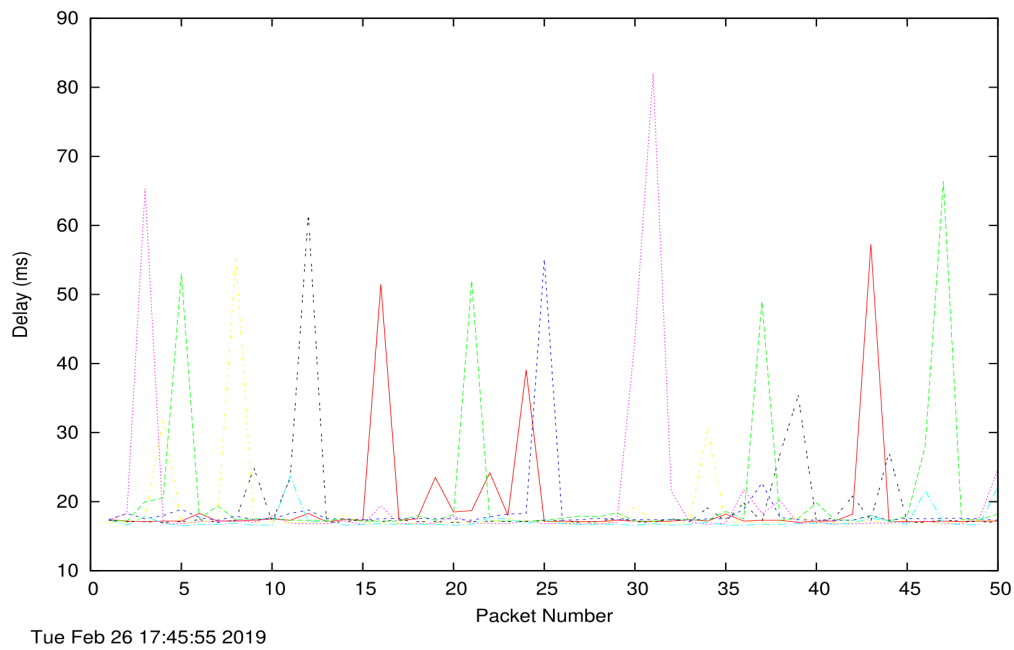
Figure 6: Scatter of www.uq.edu.au vs Packet Size
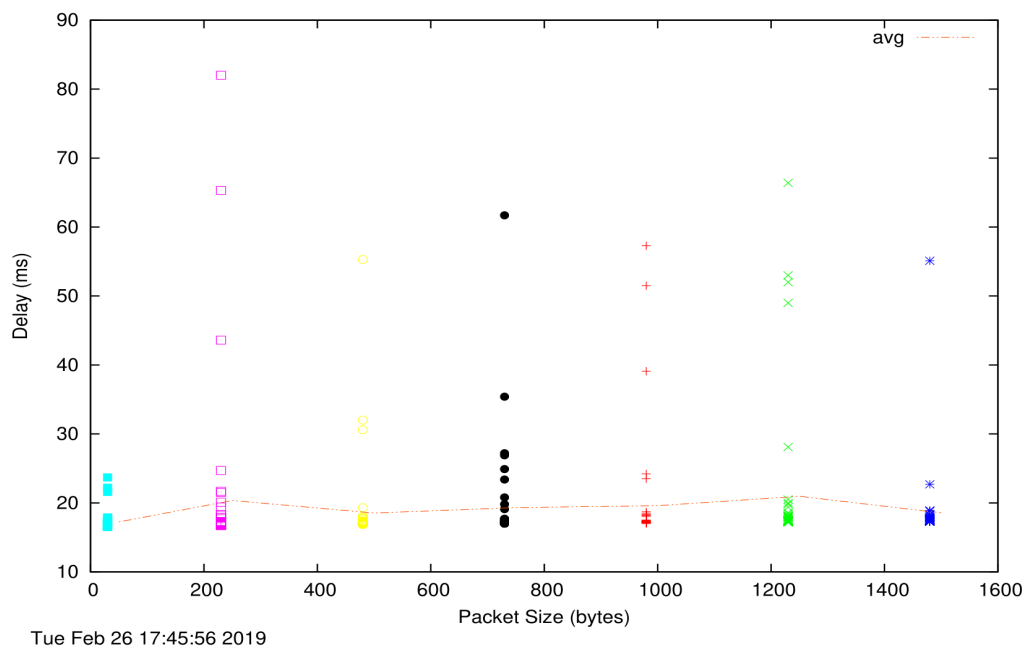
9

Above are the plots from Exercise 4 provided by the `runping.sh` and `plot.sh` scripts.

1. Assume the speed of light is 3×10^8m/s.

   - **University of Queenland:** Distance from UNSW is 730km. Time taken to traverse at the speed of light is 0.0024 seconds.
   - **National University of Singapore:** Distance from UNSW is 6300km. Time taken to traverse at the speed of light is 0.021 seconds
   - **Techniste Universitat Berlin:** Distance from UNSW is 16100km. Time taken to traverse at the speed of light is 0.054 seconds

Figure 7: Minimum Ping RTT / Minimum Time vs Distance
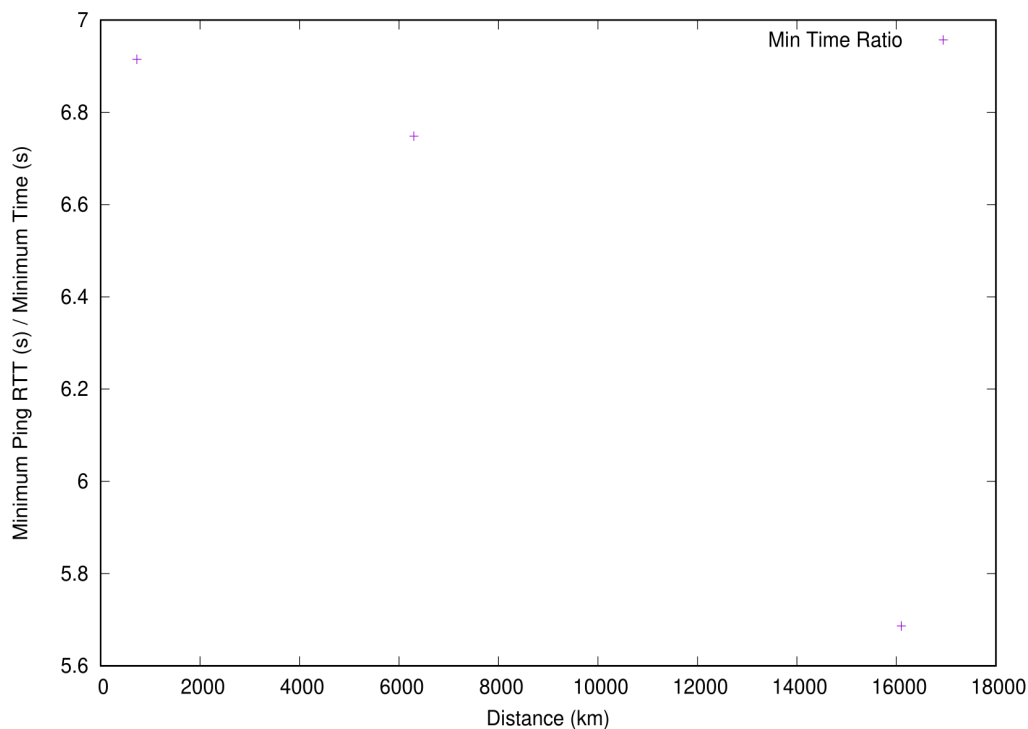
The y-axis values are greater than $2 \times T$, where T is the time taken for the shortest distance at the speed of light, for the following reasons. Firstly, the path from the start host to the destination host is not 'as the crow flies', and so will take a longer path, and hence take longer than $2 \times T$, even if the packet was travelling at the speed of light. Secondly, the physical links are a mix of coaxial, fibre optics and other communication mediums, none of which are able to allow the packets to travel at the speed of light, and so the packet will take longer than $2 \times T$, even if the packet was travelling the most direct route.

2. For the hosts www.uq.edu.au and www.nus.edu.sg, the delay varies signifcantly over time, especially for the host www.uq.edu.au, indicated in Figures 1 and 5 by the spikes at varying intervals across the plot. Conversely, for the www.tu-berlin.de host, the delay over time is very stable, with only 1 siginificant spike at the very end, as shown in Figure 3. However, it cannot be said that this will always be the case for the www.tu-berlin.de host. The variation in delay over time is due to the queueing delay, ie, the load on the router/host, which varies over time. This is the only delay that is affected by time, as propagation, transmission, and processing delays are all independent of time. Particular hosts may have larger spikes as other traffic may be accessing the routers/host at the same time we are pinging it.

3. We will consider each of the delays separately.

   - **Processing Delay:** This delay is related to the packet header size and is not affected by the packet size.

   - **Queueing Delay:** This delay is closely linked to the transmission delay, and arrival rate of packets. Packets have to wait for the time it takes to transmit those packets ahead of it, ie their transmission delay, which is dependent on packet size. However, a packet's queueing delay is not dependent on its own size, but the size of the packets in front of it in the queue, and the rate at which they all arrived.

   - **Transmission Delay:** This delay is directly proportional to the size of the packet, as a packet's size determines how long the router takes to transmit the entire packet into the physical link.

   - **Propagation Delay:** This delay is dependent on the distance a bit in the packet travels, and at what speed the bit can travel, which is limited by the medium the packet is transmitted in. It is unrelated to the size of the packet.