Exercise 1: nslookup

1.

```
MacPro:~ macpro$ nslookup www.google.com
Server:         10.0.0.138
Address:        10.0.0.138#53

Non-authoritative answer:
Name:   www.google.com
Address: 216.58.200.100
```

Because this website is used on multiple servers, and each server running on a different end system, and each end system has a different IP address.

2.

```
MacPro:~ macpro$ nslookup 127.0.0.1
Server:         10.0.0.138
Address:        10.0.0.138#53

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

127.0.0.1 is the loopback address, known as localhost. It can be used by the machine to send a packet to itself. It is a non-routable IP address and localhost is often used for testing purpose.

Exercise 2: Using ping to test host reachability

1. www.cse.unsw.edu.au **reachable.**
2. www.getfittest.com.au **unreachable, unknown host.**
3. www.mit.edu **reachable.**
4. www.intel.com.au **reachable.**
5. www.tpg.com.au **reachable**.
6. www.hola.hp **unreachable, unknown host.**
7. www.amazon.com **reachable**.
8. www.tsinghua.edu.cn **reachable.**
9. www.kremlin.ru **unreachable(lost all packets). This is maybe because some organisations prohibit their website reached by ping.**
10. 8.8.8.8 **reachable.**
11. www.getfittest.com.au & www.hola.hp also are unreachable from the web browser.
    Because their IP addresses do not exist.
    But www.kremlin.ru is reachable from the web browser.

Exercise 3: Use traceroute to understand network topology

Q1:

```
weill % 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)  0.114 ms  0.116 ms  0.100 ms
 2  129.94.39.17 (129.94.39.17)  1.010 ms  0.990 ms  1.009 ms
 3  libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34)  1.563 ms  1.969 ms  1.726 ms
 4  libcr1-po-5.gw.unsw.edu.au (149.171.255.165)  1.134 ms ombcr1-po-5.gw.unsw.edu.au (149.171.255.197)  1.195 ms  1.212 ms
 5  unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101)  1.331 ms  1.223 ms  1.231 ms
 6  138.44.5.0 (138.44.5.0)  1.376 ms  1.420 ms  1.346 ms
 7  et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.546 ms  2.388 ms  2.403 ms
 8  et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.310 ms  95.273 ms  95.349 ms
 9  et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201)  146.659 ms  146.750 ms  146.727 ms
10  abilene-1-lo-jmb-706.sttlwa.pacificwave.net (207.231.240.8)  146.807 ms  146.836 ms  146.846 ms
11  et-4-0-0.4079.rtsw.miss2.net.internet2.edu (162.252.70.0)  157.683 ms  157.652 ms  157.710 ms
12  et-4-0-0.4079.rtsw.minn.net.internet2.edu (162.252.70.58)  180.724 ms  180.807 ms  180.914 ms
13  et-1-1-5.4079.rtsw.eqch.net.internet2.edu (162.252.70.106)  188.852 ms  188.711 ms  188.695 ms
14  162.252.70.163 (162.252.70.163)  195.756 ms  188.655 ms  188.869 ms
15  ae-1.4079.rtsw.clev.net.internet2.edu (162.252.70.130)  197.151 ms  198.746 ms  197.096 ms
16  buf-9208-I2-CLEV.nysernet.net (199.109.11.33)  201.397 ms  201.632 ms  201.526 ms
17  syr-9208-buf-9208.nysernet.net (199.109.7.193)  204.662 ms  204.615 ms  204.599 ms
18  nyc-9208-syr-9208.nysernet.net (199.109.7.162)  210.466 ms  210.276 ms  210.901 ms
19  columbia.nyc-9208.nysernet.net (199.109.4.14)  210.524 ms  210.531 ms  210.514 ms
20  cc-core-1-x-nyser32-gw-1.net.columbia.edu (128.59.255.5)  210.906 ms  210.914 ms  210.635 ms
21  cc-conc-1-x-cc-core-1.net.columbia.edu (128.59.255.210)  210.863 ms  210.688 ms  210.818 ms
22  exeas.org (128.59.105.24)  210.577 ms  210.558 ms  210.561 ms
```

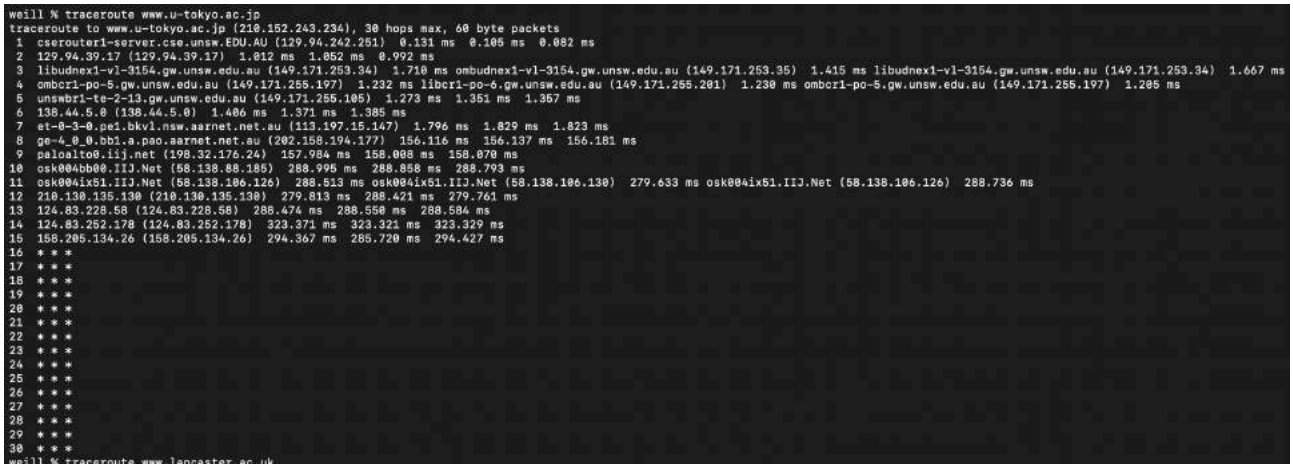
There are 21 routers between my workstation and www.columbia.edu. The first 5 routers along the path are part of the UNSW network based on their hostnames. Between 7th router and 10th router, packets cross the Pacific Ocean.

Q2:

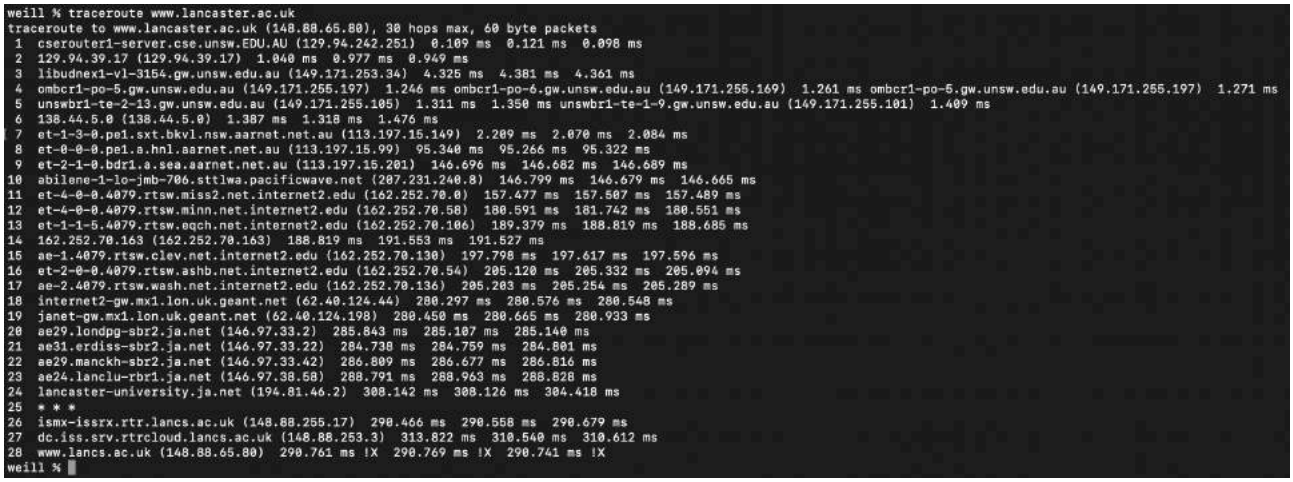
1. www.ucla.edu

```
weill % 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)  0.131 ms  0.109 ms  0.086 ms
 2  129.94.39.17 (129.94.39.17)  1.016 ms  1.001 ms  0.999 ms
 3  ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35)  115.258 ms  115.245 ms  115.223 ms
 4  libcr1-po-6.gw.unsw.edu.au (149.171.255.201)  1.209 ms libcr1-po-5.gw.unsw.edu.au (149.171.255.165)  1.212 ms ombcr1-po-5.gw.unsw.edu.au (149.171.255.197)  1.265 ms
 5  unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101)  1.252 ms unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105)  1.267 ms  1.271 ms
 6  138.44.5.0 (138.44.5.0)  1.403 ms  1.403 ms  1.414 ms
 7  et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.331 ms  2.220 ms  2.206 ms
 8  et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.273 ms  95.294 ms  95.354 ms
 9  et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201)  146.739 ms  146.717 ms  146.662 ms
10  cenichpr-1-is-jmb-778.snvaca.pacificwave.net (207.231.245.129)  163.237 ms  163.194 ms  163.225 ms
11  hpr-lax-hpr3--svl-hpr3-100ge.cenic.net (137.164.25.73)  171.074 ms  171.068 ms  170.998 ms
12  * * *
13  bd11f1.anderson--cr001.anderson.ucla.net (169.232.4.6)  171.513 ms  171.431 ms bd11f1.anderson--cr00f2.csb1.ucla.net (169.232.4.4)  171.498 ms
14  cr00f2.csb1--dr00f2.csb1.ucla.net (169.232.4.53)  171.420 ms  171.583 ms  171.501 ms
15  * * *
16  * * *
17  * * *
18  * * *
19  * * *
20  * * *
21  * * *
22  * * *
23  * * *
24  * * *
25  * * *
26  * * *
27  * * *
28  * * *
29  * * *
30  * * *
weill %
```

2. www.u-tokyo.ac.jp



3. www.lancaster.ac.uk



All 3 paths have same first 7 hops. The 3 paths differ in the next hop(**8th hop**) following the 138.44.5.0 router. The Los Angeles(ucla) and Lancaster paths also have a same 8th hop router (113.197.15.99). For all 3 paths, this 8th router belongs to the AARNET network.

No, he number of hops on each path is not proportional to the physical distance. The path to Tokyo (closer to Sydney than Los Angeles) has about 15 hops while to Los Angeles only has 14 hops.

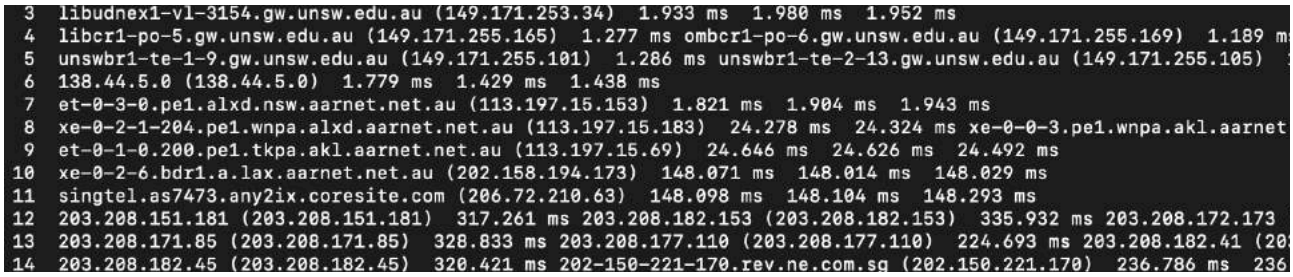
Q3:

My IP address: 129.94.242.2

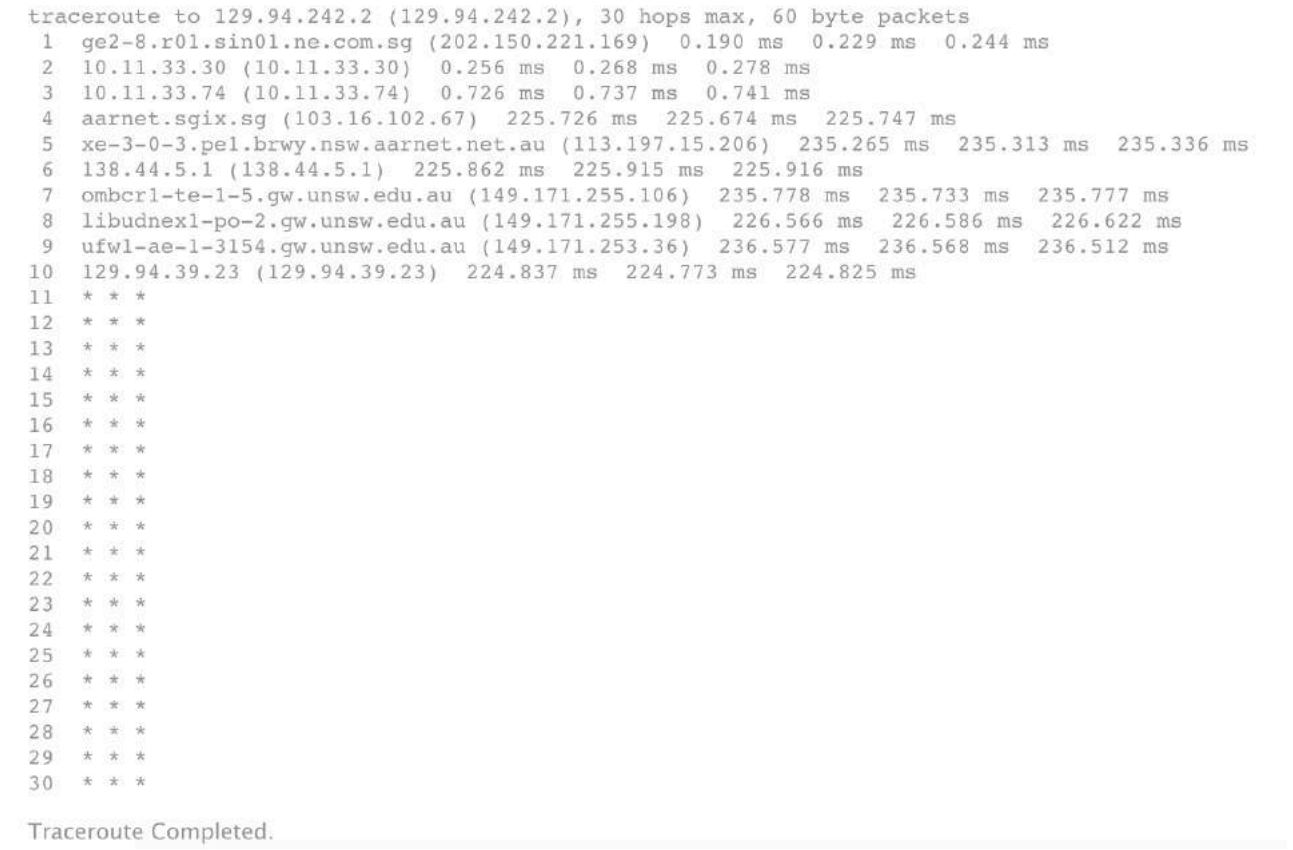
www.speedtest.com.sg IP address: 202.150.221.170

www.telstra.net IP address: 203.50.5.178

Traceroute my machine to www.speedtest.com.sg:

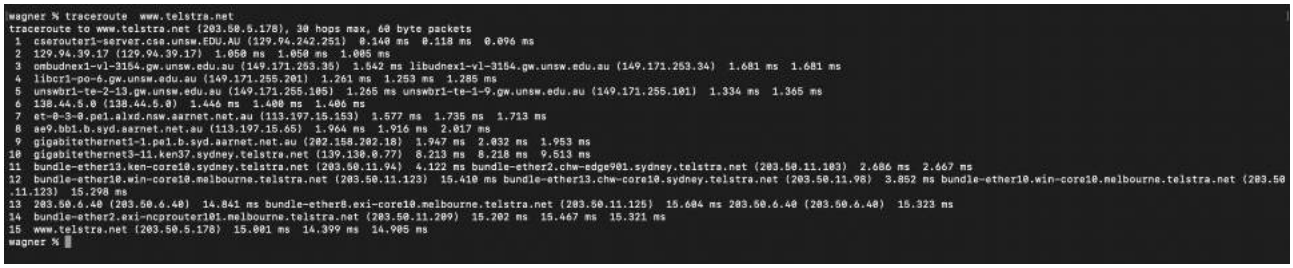


Traceroute www.speedtest.com.sg to my machine:



In this case, the forward and reverse paths are very different. The path from my machine to speedtest.com.sg appears to go through routers in Auckland (113.197.15.69) and LA (202.158.194.173) whereas the path from speedtest.com.sg to my machine appears to go through south Australia(113.197.15.206) and then arrive at Sydney.

Traceroute my machine to www.telstra.net:



Traceroute www.telstra.net to my machine:

```
 1  gigabitethernet3-3.exi2.melbourne.telstra.net (203.50.77.53)  0.339 ms  0.222 ms  0.244 ms
 2  bundle-ether3-100.win-core10.melbourne.telstra.net (203.50.80.129)  2.493 ms  1.487 ms  2.245 ms
 3  bundle-ether12.ken-core10.sydney.telstra.net (203.50.11.122)  12.737 ms  12.231 ms  12.988 ms
 4  bundle-ether1.ken-edge901.sydney.telstra.net (203.50.11.95)  11.989 ms  12.105 ms  11.988 ms
 5  aarnet6.lnk.telstra.net (139.130.0.78)  11.614 ms  11.607 ms  11.613 ms
 6  ge-6-0-0.bb1.a.syd.aarnet.net.au (202.158.202.17)  11.864 ms  11.732 ms  11.739 ms
 7  ae9.pe2.brwy.nsw.aarnet.net.au (113.197.15.56)  11.988 ms  12.107 ms  11.988 ms
 8  et-3-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.146)  12.115 ms  12.107 ms  12.116 ms
 9  138.44.5.1 (138.44.5.1)  12.361 ms  12.357 ms  12.360 ms
10  libcr1-te-1-5.gw.unsw.edu.au (149.171.255.102)  12.363 ms  12.356 ms  12.362 ms
11  libudnex1-po-1.gw.unsw.edu.au (149.171.255.166)  12.613 ms
12  ufw1-ae-1-3154.gw.unsw.edu.au (149.171.253.36)  29.977 ms  28.599 ms  31.726 ms
13  129.94.39.23 (129.94.39.23)  44.843 ms  49.960 ms  44.095 ms
```

In this case, the reverse path does not go through the same routers as the forward path. But in many conditions, although when both the forward and the reverse path cross the same router, it is possible that different IP addresses are used. The reason is that the names in the traceroute output are the names of the router interfaces and not of routers. So, both IP addresses indeed belong to the same route but have been allocated to different interfaces of it.

Exercise 4: Use ping to gain insights into network performance

./runping.sh www.abc.net

```
wagner % ./runping.sh www.abc.net

ping -s 22 -c 50 -i 1 www.abc.net > www.abc.net-p50
ping -s 222 -c 50 -i 1 www.abc.net > www.abc.net-p250
ping -s 472 -c 50 -i 1 www.abc.net > www.abc.net-p500
ping -s 722 -c 50 -i 1 www.abc.net > www.abc.net-p750
ping -s 972 -c 50 -i 1 www.abc.net > www.abc.net-p1000
ping -s 1222 -c 50 -i 1 www.abc.net > www.abc.net-p1250
ping -s 1472 -c 50 -i 1 www.abc.net > www.abc.net-p1500
```

(i) www.uq.edu.au

```
wagner % ./runping.sh www.uq.edu.au

ping -s 22 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p50
ping -s 222 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p250
ping -s 472 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p500
ping -s 722 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p750
ping -s 972 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p1000
ping -s 1222 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p1250
ping -s 1472 -c 50 -i 1 www.uq.edu.au > www.uq.edu.au-p1500
```

(ii) www.nus.edu.sg

```
wagner % ./runping.sh www.nus.edu.sg

ping -s 22 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p50
ping -s 222 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p250
ping -s 472 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p500
ping -s 722 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p750
ping -s 972 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p1000
ping -s 1222 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p1250
ping -s 1472 -c 50 -i 1 www.nus.edu.sg > www.nus.edu.sg-p1500
```

(iii) www.tu-berlin.de

```
[wagner % ./runping.sh www.tu-berlin.de

ping -s 22 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p50
ping -s 222 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p250
ping -s 472 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p500
ping -s 722 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p750
ping -s 972 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p1000
ping -s 1222 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p1250
ping -s 1472 -c 50 -i 1 www.tu-berlin.de > www.tu-berlin.de-p1500
```

Q1.

Distance between UNSW and the 3 destinations (based on flight path between them) are: **Brisbane: 735km, Singapore: 6310km, Berlin: 16,099.**

The shortest possible time that a packet will take to reach these 3 destinations are:

(assuming propagation speed: 3 x 10^8 m/s)

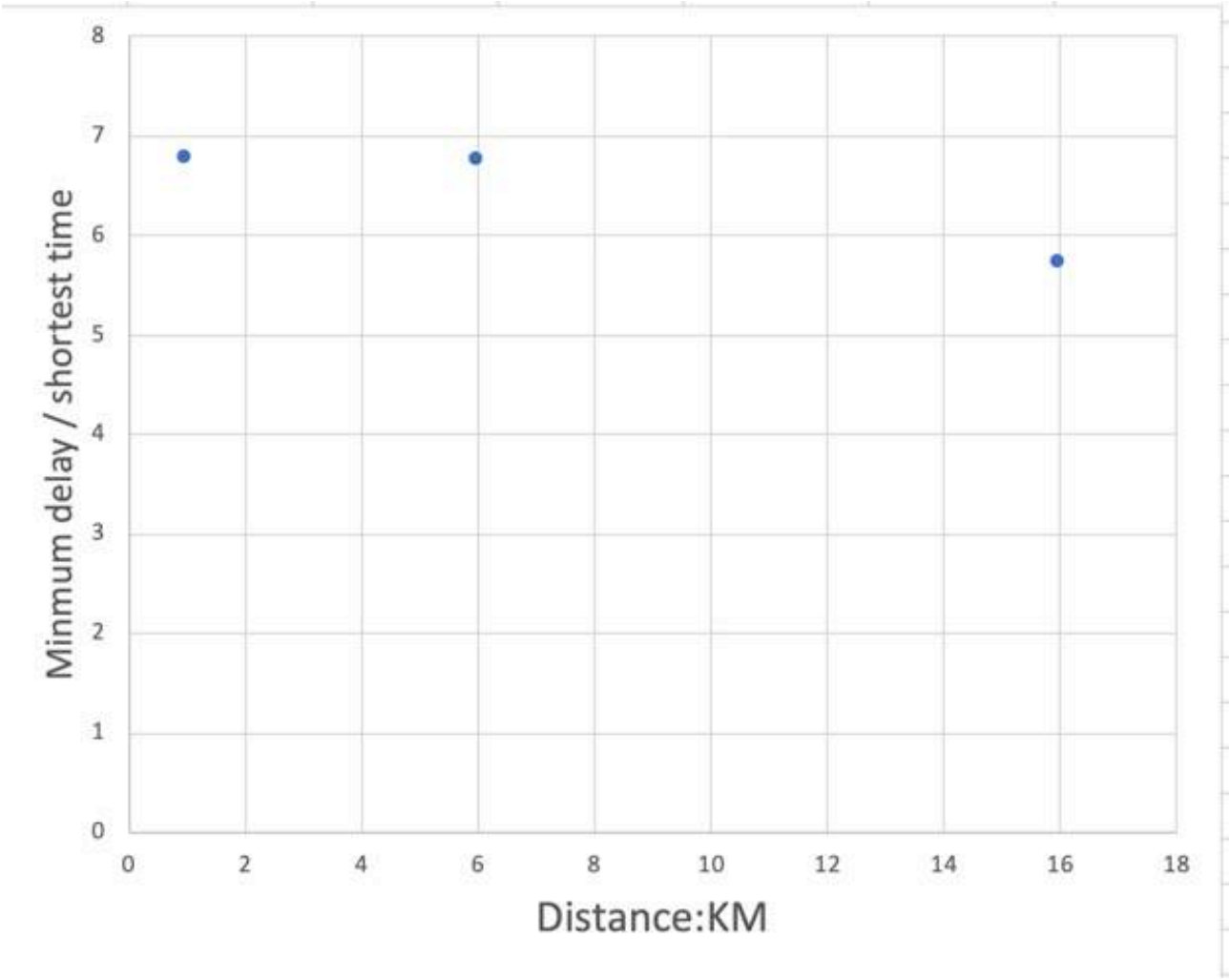
Brisbane: 2.45ms, Singapore: 21ms, Berlin: 53.66ms

The minimum RTT (for 50 byte packets) to these 3 destinations from the corresponding *avg.txt files are:

Brisbane: 16.580ms, Singapore: 141.836ms, Berlin: 307.059ms

The ratios of the minimum RTT to the minimum propagation delay for these 3 destinations are: **Brisbane: 6.77, Singapore: 6.75, Berlin: 5.72.**

The following graph shows the relations between this ratio and distance.



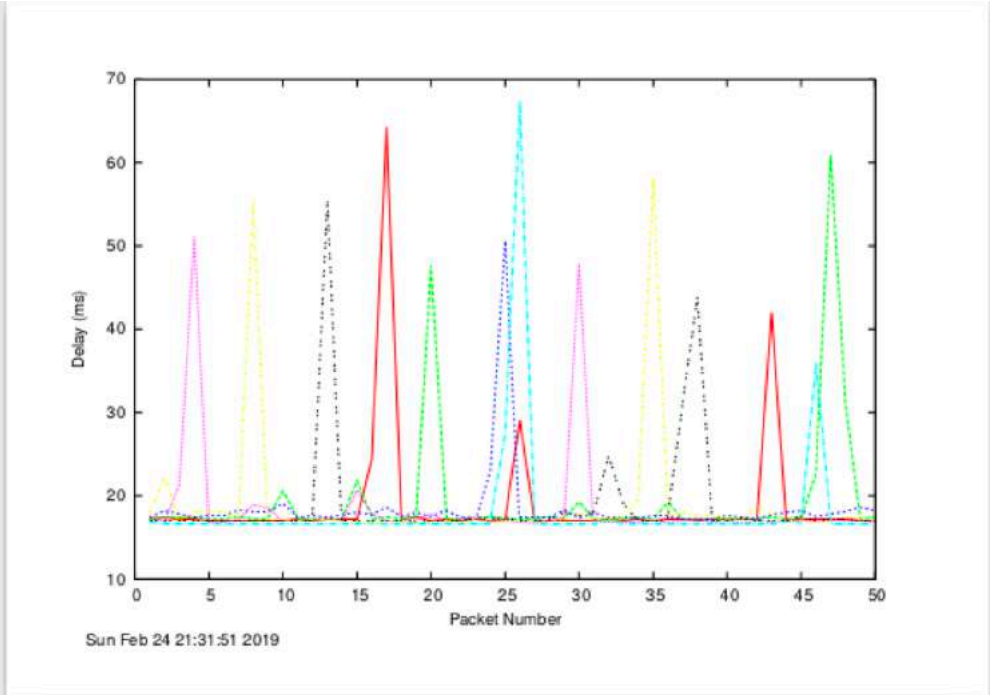
Reasons for this ratio is always > 2. As following:

1. speed of light should be take into account for transmission delays.
2. Routing method(ISP-level) may result in paths are not the shortest hop paths.
3. It is impossible for packets to travel at the full speed of light in real medium.

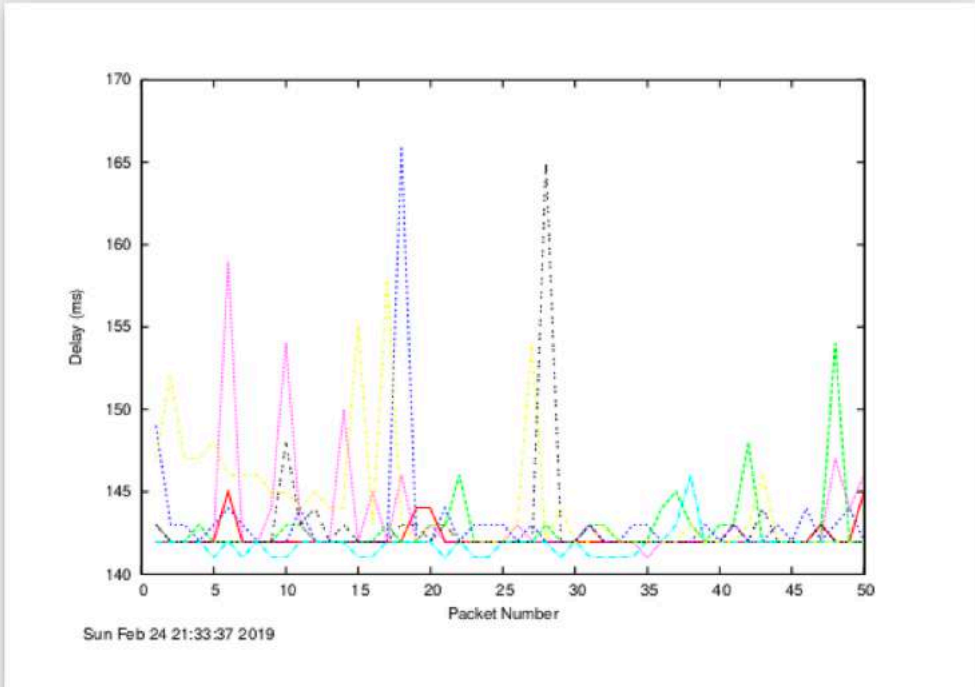
Q2:

Each of the following plots (destination_delay.pdf) show the delay of consecutive packets of same size:

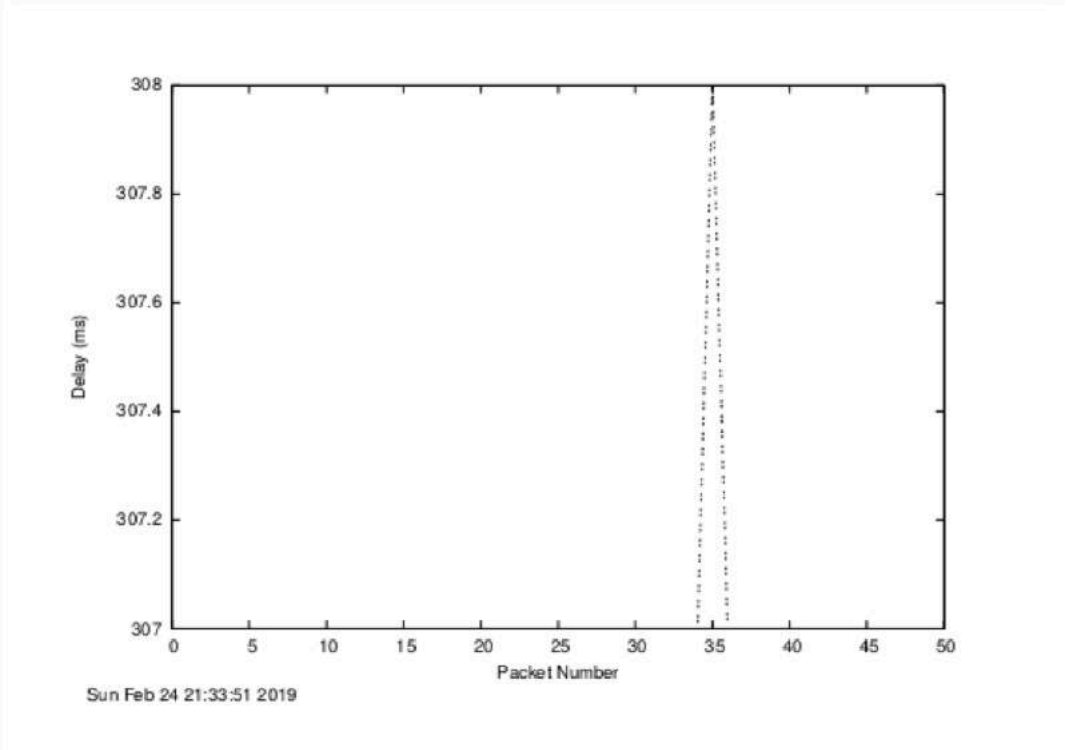
www.uq.edu.au



www.nus.edu.sg



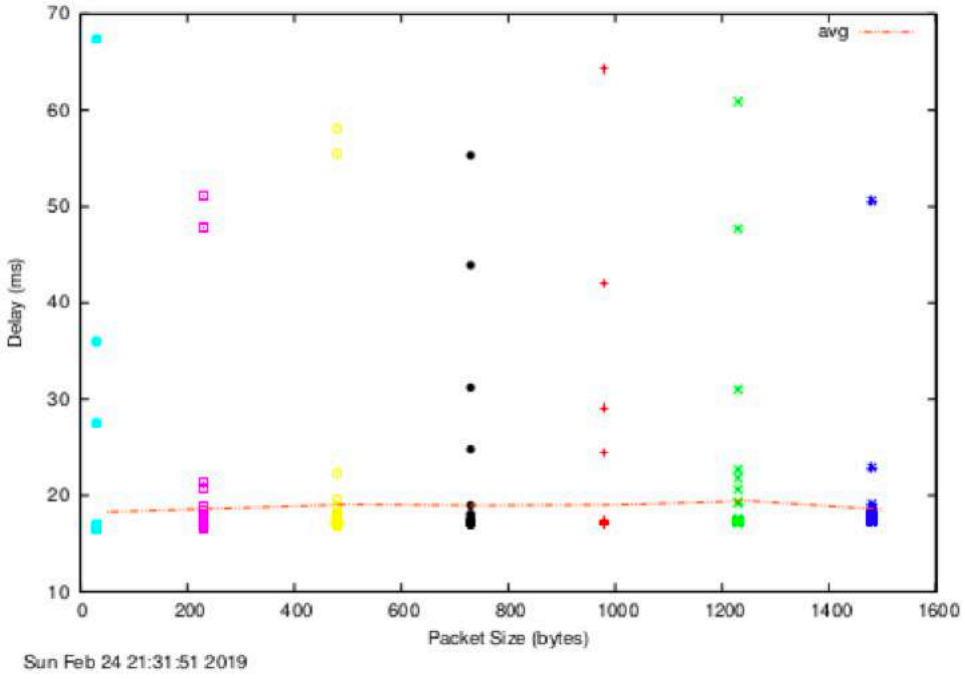
www.tu-berlin.de



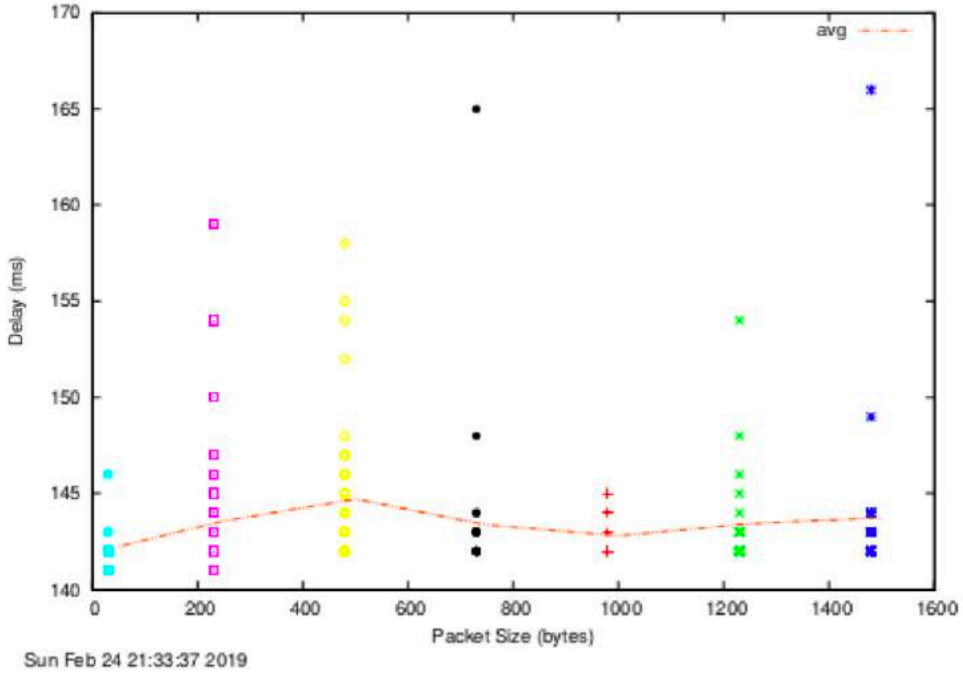
For these 3 destinations, the delay randomly varies over time. This is mostly due to the variability of processing and queuing delays. The degree of variability is related to the quality of the end–to–end path.

The following plots (destination_scatter.pdf) show the various measurements of delay as a scatter plot for different packet sizes.

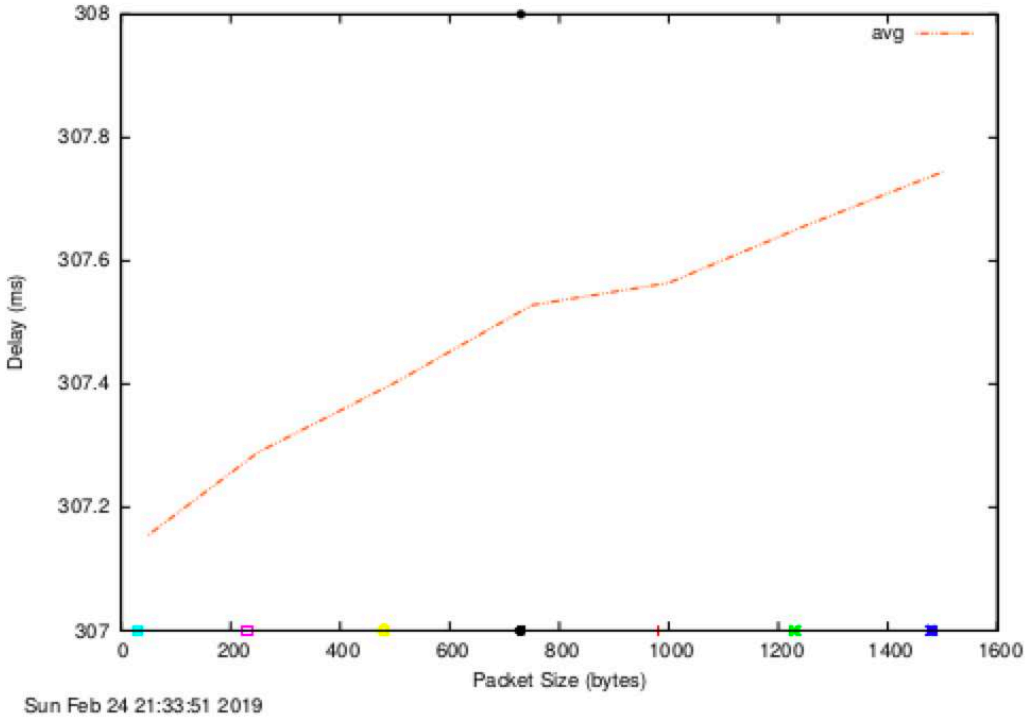
www.uq.edu.au



www.nus.edu.sg



www.tu-berlin.de



For www.tu-berlin.de, the delay depends on the size of the packets. Because the transmission delay for larger packets is greater which will increase the overall delay.
However, his trend is not obvious for www.uq.edu.au and www.nus.edu.sg. The average delay does not seem to vary much for different packet sizes.

The reasons are:

a) the destination is far away, and therefore the propagation delay (independent from the packet size) is significantly higher than the transmission delay (dependent on the packet size)

b) there is high congestion in the network, so the queueing delay may take up a significant part of the total delay.

Q3.

Depend on the packet size : transmission delay.

Not depend on the packet size: processing delay, queuing delay, propagation delay.

The transmission delay is almost completely depend on the packet size.

The processing delay depend on the header packet size.

The queuing delay depends on the congestion in the network.

The propagation delay depends on the link.