Exercise 1: nslookup

1. IP address of www.google.com is 172.217.25.164. Two IP addresses are supplied as output as one IP address is the IP address of the local machine/host making the nslookup request and the other IP address is the corresponding IP address of google.com.

2. Name of the given IP address is local host. The local host IP address is different to a regular IP address as all computers use the address as their own and devices cannot communicate with one another using the local host IP address unlike other IP addresses.

Exercise 2:

www.cse.unsw.edu.au reachable
www.getfittest.com.au unknown host (also not reachable from browser as host name does not exist)
www.mit.edu reachable
www.intel.com.au reachable
www.tpg.com.au reachable
www.hola.hp not reachable unknown host (also not reachable from browser as host name does not exist)
www.amazon.com reachable
www.tsinghua.edu.cn reachable
www.kremlin.ru - packets transmitted but not received, with 100% packet loss (the host name exists as the corresponding IP address can be found with nslookup, but is only accessible through the browser on my personal machine and not the browser on the CSE machines. I speculate the 100% packet loss may have something to do with a firewall that is possibly blocking communication with my local machine)
8.8.8.8 reachable

Exercise 3:

Question 1.
a) There are 23 routers between the workstation and www.columbia.edu (as can be seen in the image below).

```
vx3 % 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)  0.106 ms  0.080 ms  0.071 ms
 2  129.94.39.17 (129.94.39.17)  1.026 ms  0.996 ms  1.042 ms
 3  libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34)  2.153 ms  1.867 ms  1.838 ms
 4  libcr1-po-5.gw.unsw.edu.au (149.171.255.165)  1.208 ms ombcr1-po-5.gw.unsw.edu.au (149.171.255.197)  1.330 ms  1.278 ms
 5  unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101)  1.398 ms unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105)  1.408 ms unswb
r1-te-1-9.gw.unsw.edu.au (149.171.255.101)  1.209 ms
 6  138.44.5.0 (138.44.5.0)  1.653 ms  1.387 ms  1.368 ms
 7  et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.211 ms  2.330 ms  2.332 ms
 8  et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.254 ms  95.255 ms  95.295 ms
 9  et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201)  146.716 ms  146.673 ms  146.614 ms
10  abilene-1-lo-jmb-706.sttlwa.pacificwave.net (207.231.240.8)  146.822 ms  146.959 ms  146.902 ms
11  et-4-0-0.4079.rtsw.miss2.net.internet2.edu (162.252.70.0)  157.792 ms  157.666 ms  157.682 ms
12  et-4-0-0.4079.rtsw.minn.net.internet2.edu (162.252.70.58)  181.068 ms  180.812 ms  180.766 ms
13  et-1-1-5.4079.rtsw.eqch.net.internet2.edu (162.252.70.106)  188.698 ms  189.493 ms  189.447 ms
14  162.252.70.163 (162.252.70.163)  221.899 ms  188.646 ms  188.635 ms
15  ae-1.4079.rtsw.clev.net.internet2.edu (162.252.70.130)  197.158 ms  197.116 ms  197.021 ms
16  buf-9208-I2-CLEV.nysernet.net (199.109.11.33)  201.413 ms  201.532 ms  201.480 ms
17  syr-9208-buf-9208.nysernet.net (199.109.7.193)  204.709 ms  204.805 ms  204.689 ms
18  nyc-9208-syr-9208.nysernet.net (199.109.7.162)  210.389 ms  210.493 ms  210.787 ms
19  columbia.nyc-9208.nysernet.net (199.109.4.14)  210.629 ms  210.532 ms  210.413 ms
20  nyser111-gw-1-x-nyser32-gw-1.net.columbia.edu (128.59.255.10)  210.773 ms  210.727 ms  210.698 ms
21  phi-core-1-x-nyser111-gw-1.net.columbia.edu (128.59.255.13)  244.485 ms  239.804 ms  229.177 ms
22  cc-conc-1-x-phi-core-1.net.columbia.edu (128.59.255.214)  210.868 ms  210.828 ms  210.761 ms
23  ci.columbia.edu (128.59.105.24)  210.457 ms  210.611 ms  210.516 ms
```

b) 4 of these routers are part of the UNSW network (router 1, 3, 4 and 5).
c) Between the 7th and 8th router packets cross the Pacific Ocean. This can be deduced as there is a large ping time difference between the two, as shown below:

```
--- 113.197.15.149 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 1.864/1.889/1.914/0.025 ms
vx3 % ping 113.197.15.201
PING 113.197.15.201 (113.197.15.201) 56(84) bytes of data.
64 bytes from 113.197.15.201: icmp_req=1 ttl=56 time=146 ms
64 bytes from 113.197.15.201: icmp_req=2 ttl=56 time=146 ms
64 bytes from 113.197.15.201: icmp_req=3 ttl=56 time=146 ms
^C
--- 113.197.15.201 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 146.535/146.548/146.563/0.011 ms
```

Question 2

NOTE: I refer to “divergence” as the last router in common two paths have
a) The paths between www.ucla.edu and www.u-tokyo.ac.jp diverge at the 5th router unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101). Refer to images below, where the 6th router in the path from the local machine to www.u-tokyo.ac.jp is obscured, whereas the 6th router in the path from the local machine to www.ucla.edu has its information visible. This means that the 6th router in these two paths must be different, as otherwise they would both be obscured, or both have the same information displayed.

```
vx3 % 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)  0.080 ms  0.082 ms  0.087 ms
 2  129.94.39.17 (129.94.39.17)  0.995 ms  0.990 ms  0.971 ms
 3  ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35)  12.816 ms libudnex1-
vl-3154.gw.unsw.edu.au (149.171.253.34)  4.538 ms ombudnex1-vl-3154.gw.unsw.edu.au
(149.171.253.35)  12.762 ms
 4  ombcr1-po-5.gw.unsw.edu.au (149.171.255.197)  1.323 ms libcr1-po-6.gw.unsw.edu.au
(149.171.255.201)  18.518 ms ombcr1-po-6.gw.unsw.edu.au (149.171.255.169)  1.319 ms
 5  unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105)  1.291 ms  1.354 ms unswbr1-
te-1-9.gw.unsw.edu.au (149.171.255.101)  1.244 ms
 6  138.44.5.0 (138.44.5.0)  1.424 ms  1.426 ms  1.384 ms
 7  et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.221 ms  2.475 ms  2.471 ms
 8  et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.139 ms  95.224 ms  95.162 ms
 9  et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201)  146.694 ms  146.697 ms  146.660 ms
10  cenichpr-1-is-jmb-778.snvaca.pacificwave.net (207.231.245.129)  163.172 ms * *
11  * * *
12  * * *
13  bd11f1.anderson--cr00f2.csb1.ucla.net (169.232.4.4)  171.527 ms bd11f1.anderson--
cr001.anderson.ucla.net (169.232.4.6)  171.490 ms *
14  * cr00f1.anderson--dr00f2.csb1.ucla.net (169.232.4.55)  171.588 ms cr00f2.csb1--
dr00f2.csb1.ucla.net (169.232.4.53)  171.612 ms
15  * * *
```

```
vx3 % 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)  0.092 ms * *
 2  129.94.39.17 (129.94.39.17)  1.067 ms * *
 3  * libudnex1-vl-3154.gw.unsw.edu.au (149.171.253.34)  8.313 ms  8.273 ms
 4  * * ombcr1-po-6.gw.unsw.edu.au (149.171.255.169)  49.759 ms
 5  * unswbr1-te-1-9.gw.unsw.edu.au (149.171.255.101)  1.268 ms  1.275 ms
 6  * * *
 7  * * et-0-3-0.pe1.bkvl.nsw.aarnet.net.au (113.197.15.147)  2.016 ms
 8  ge-4_0_0.bb1.a.pao.aarnet.net.au (202.158.194.177)  156.192 ms  156.196 ms  156.273 ms
 9  paloalto0.iij.net (198.32.176.24)  158.120 ms  157.961 ms  158.017 ms
10  osk004bb01.IIJ.Net (58.138.88.189)  271.353 ms  271.290 ms  271.340 ms
11  osk004ix51.IIJ.Net (58.138.106.130)  270.993 ms osk004ix51.IIJ.Net (58.138.106.126)
288.420 ms  288.537 ms
12  210.130.135.130 (210.130.135.130)  288.664 ms  288.558 ms  279.825 ms
13  124.83.228.58 (124.83.228.58)  271.144 ms  279.877 ms  272.768 ms
14  124.83.252.178 (124.83.252.178)  277.385 ms *  277.148 ms
15  158.205.134.26 (158.205.134.26)  285.712 ms  294.433 ms  294.417 ms
16  * * *
```

The paths between www.ucla.edu and www.lancaster.ac.uk diverge at the 8th router et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99). Refer to the images below, where the 9th router from the local machine www.lancaster.ac.uk is obscured, whereas the 9th router from the local machine to www.ucla.edu is visible. For reasons outlined above, these two routers

must be different and so the last point in common the two paths have must be the 8th router (their point of divergence).

```
vx3 % 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)  0.080 ms  0.082 ms  0.087 ms
 2  129.94.39.17 (129.94.39.17)  0.995 ms  0.990 ms  0.971 ms
 3  ombudnex1-vl-3154.gw.unsw.edu.au (149.171.253.35)  12.816 ms libudnex1-
vl-3154.gw.unsw.edu.au (149.171.253.34)  4.538 ms ombudnex1-vl-3154.gw.unsw.edu.au
(149.171.253.35)  12.762 ms
 4  ombcr1-po-5.gw.unsw.edu.au (149.171.255.197)  1.323 ms libcr1-po-6.gw.unsw.edu.au
(149.171.255.201)  18.518 ms ombcr1-po-6.gw.unsw.edu.au (149.171.255.169)  1.319 ms
 5  unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105)  1.291 ms  1.354 ms unswbr1-
te-1-9.gw.unsw.edu.au (149.171.255.101)  1.244 ms
 6  138.44.5.0 (138.44.5.0)  1.424 ms  1.426 ms  1.384 ms
 7  et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.221 ms  2.475 ms  2.471 ms
 8  et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.139 ms  95.224 ms  95.162 ms
 9  et-2-1-0.bdr1.a.sea.aarnet.net.au (113.197.15.201)  146.694 ms  146.697 ms  146.660 ms
10  cenichpr-1-is-jmb-778.snvaca.pacificwave.net (207.231.245.129)  163.172 ms * *
11  * * *
12  * * *
13  bd11f1.anderson--cr00f2.csb1.ucla.net (169.232.4.4)  171.527 ms bd11f1.anderson--
cr001.anderson.ucla.net (169.232.4.6)  171.490 ms *
14  * cr00f1.anderson--dr00f2.csb1.ucla.net (169.232.4.55)  171.588 ms cr00f2.csb1--
dr00f2.csb1.ucla.net (169.232.4.53)  171.612 ms
15  * * *
16  * * *
```

```
vx3 % 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)  0.129 ms  0.110 ms  0.087 ms
 2  129.94.39.17 (129.94.39.17)  1.124 ms  1.117 ms  1.106 ms
 3  * * *
 4  ombcr1-po-6.gw.unsw.edu.au (149.171.255.169)  1.299 ms * *
 5  unswbr1-te-2-13.gw.unsw.edu.au (149.171.255.105)  1.355 ms  1.322 ms unswbr1-
te-1-9.gw.unsw.edu.au (149.171.255.101)  1.383 ms
 6  * 138.44.5.0 (138.44.5.0)  1.416 ms *
 7  * et-1-3-0.pe1.sxt.bkvl.nsw.aarnet.net.au (113.197.15.149)  2.114 ms  2.111 ms
 8  * et-0-0-0.pe1.a.hnl.aarnet.net.au (113.197.15.99)  95.232 ms *
 9  * * *
10  abilene-1-lo-jmb-706.sttlwa.pacificwave.net (207.231.240.8)  146.884 ms  146.875 ms *
11  * * et-4-0-0.4079.rtsw.miss2.net.internet2.edu (162.252.70.0)  157.569 ms
12  * * et-4-0-0.4079.rtsw.minn.net.internet2.edu (162.252.70.58)  180.773 ms
13  * * *
14  162.252.70.163 (162.252.70.163)  188.673 ms *  188.677 ms
15  * * *
16  * * *
17  ae-2.4079.rtsw.wash.net.internet2.edu (162.252.70.136)  205.322 ms  205.498 ms  205.554
ms
```

b) Additional information for the first router where www.ucla.edu and www.u-tokyo.ac.jp diverge is the organisation is UNSW. Additional information for the second router where www.ucla.edu and www.lancester.ac.uk diverge is the organisation is AARNet Network Operations Centre.

c) www.ucla.edu (164.67.228.152) is located in Los Angeles (30 jumps). U-tokyo.ac.jp (210.152.243.234) is located in Japan (30 jumps), and www.lancaster.ac.uk is located in the UK near Blackpool (28 jumps). Assuming the we take the shortest possible route (from this point onwards, referred to as ***d***) from the host machine to the final destinations, the number of jumps is not proportional to ***d*** (refer to image below). For example, the value of ***d*** between the local machine and Japan is the smallest of all 3 shortest possible distance routes, but Japan has the equal highest number of jumps (30 jumps). This could be possibly because the routes from the local machine to each final destination are not necessarily the shortest possible distance route and might be more inefficient (e.g. to get to Japan from Australia, maybe the route is from Australia to Europe and then Europe to Japan).

Question 3

a) The IP address of the selected external traceroute servers are 202.150.221.170. (www.speedtest.com) and 203.50.5.178 (www.telstra.net). The IP address of the local machine is 129.94.242.2

b) The reverse paths do not go through all the same routers as the forward path. This is clear as all the ith routers in the forwards path are not identical to the n-ith routers in the reverse path (where n = # of routers and i is an element of [1...n]). Additionally, the reverse & forward paths between www.telstra.net and the local machine have a different number of routers, so it is clear these cannot be the same paths. Some routers in the reverse and forward paths, however have very similar host names & IP addresses (refer to image below). As an IP address uniquely identifies a router, the routers with similar IP addresses cannot be the same but possibly belong to the same company.

```
 7  et-0-3-0.pe1.alxd.nsw.aarnet.net.au (113.197.15.153)
33 ms  1.571 ms  1.549 ms
```

```
8  et-3-1-0.pe1.brwy.nsw.aarnet.net.au (113.197.15.146)  12.111 ms  12.103 ms  12.112
```

Exercise 4:

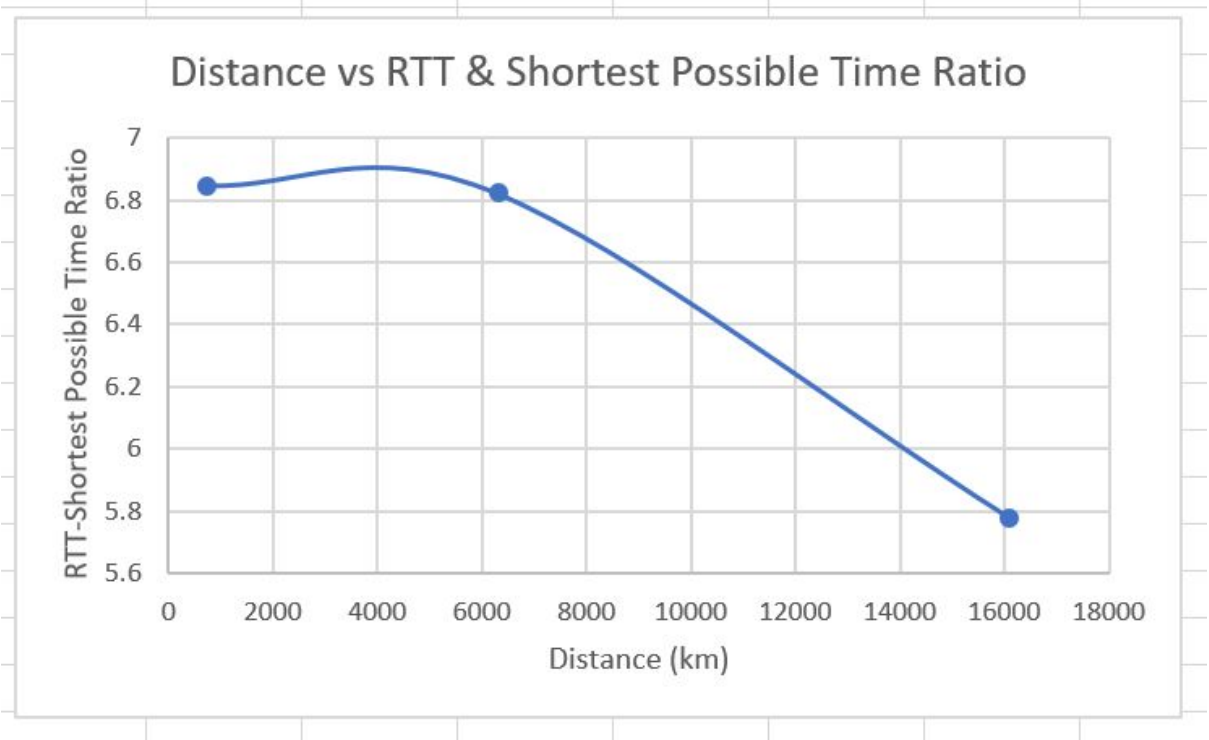
Question

a) Plotting the required graph:
Shortest possible distances from Sydney to the 3 cities:
Brisbane - 730km, Singapore 6,302km, Berlin 16,084km

Shortest possible time (assuming packets travel at speed of light - 3*10^8) - calculations below:
(730*10^3)/(3*10^8)=2.43333333ms
(6302*10^3)/(3*10^8) = 21.0066667ms
(16,084*10^3)/(3*10^8)=53.6133333ms

RTT values (using 50 byte packets and the average time data collated using the shellscript)
Brisbane RTT: 16.6613
Singapore: 143.323ms
Berlin: 307.203ms

Ratio between minimum delay (RTT - using 50 byte packets) and shortest possible time T:
Brisbane 16.6613/2.433333 = 6.84751336
Singapore 143.323/21.0066667= 6.82276047
Berlin 307.203/53.1633333 = 5.77847514



b) Can you think of at least two reasons the y-axis values that you plot are greater than 2?

First reason - distance:

The route taken to get from the local machine to the overseas location may not necessarily be the route with the shortest possible distance. For example, instead of packets travelling 16,084km directly from Sydney to Berlin (like a hypotenuse), they might travel first across through Africa and then to Europe (more in the shape of an reflected “L”). As the distance packets travel on these inefficient routes will be greater than the shortest possible distance between two cities, the RTT value will be greater than 2T (where T is the shortest possible time).

Second reason - processing and transmission delays:

Even though packets propagate at the speed of light in the communication links, they will undergo considerable processing and transmission delays at the routers. As each route from the local machine to the end destination consists of 20+ routers, these delays will accumulate considerably. This forms another reason that the RTT value is greater than 2T.

Question 2:

The delay to the destinations (for same-sized packets) vary over time. This is most likely due to the fact that network congestion varies at certain points in time. Higher levels of network congestion will result in longer queueing delays and vice versa, which explains why the delay to each destinations are not constant over time.

Question 3:

Transmission delay depends on packet size.
Processing delay depends on the size of the header, so processing delay would only be affected by packet size if a change in packet size results in an increase in the header size.
The others do not depend on packet size.