Computer Networks

Assignment 1 – Network Engineering

1. Network Transport Times

a)

1. mel1.speedtest.telstra.net

```
benjamin@benjamin-FX503VM:~$ traceroute mel1.speedtest.telstra.net
traceroute to mel1.speedtest.telstra.net (139.130.3.66), 30 hops max, 60 byte packets
 1  192.168.1.254 (192.168.1.254)  3.545 ms  5.234 ms  6.980 ms
 2  85-220-64-1.dsl.dynamic.simnet.is (85.220.64.1)  23.747 ms  26.111 ms  26.870 ms
 3  teledesign-plc.demarc.cogentco.com (149.6.148.46)  69.690 ms  70.579 ms  75.403 ms
 4  te0-4-0-11.rcr21.b023101-0.lon13.atlas.cogentco.com (149.6.148.45)  75.115 ms  75.971 ms  76.693 ms
 5  be2350.ccr42.lon13.atlas.cogentco.com (130.117.51.137)  77.970 ms be2348.ccr41.lon13.atlas.cogentco.com (130.117.51.73)  78.225 ms be2350.ccr42.lon13.atlas.cogentco.com (130.117.51.137)  79.887 ms
 6  be2490.ccr42.jfk02.atlas.cogentco.com (154.54.42.85)  135.891 ms be2317.ccr41.jfk02.atlas.cogentco.com (154.54.30.185)  113.645 ms  116.052 ms
 7  be3496.ccr31.jfk10.atlas.cogentco.com (154.54.0.142)  113.735 ms be3495.ccr31.jfk10.atlas.cogentco.com (66.28.4.182)  115.071 ms be3496.ccr31.jfk10.atlas.cogentco.com (154.54.0.142)  115.450 ms
 8  sprint.jfk10.atlas.cogentco.com (154.54.12.22)  119.639 ms  117.770 ms  204.076 ms
 9  sl-crs2-akr-be21.sprintlink.net (144.232.22.66)  205.049 ms  204.983 ms  204.979 ms
10  sl-crs2-chi-be2.sprintlink.net (144.232.18.7)  204.948 ms  204.918 ms  204.889 ms
11  sl-crs2-oma-be4.sprintlink.net (144.232.22.75)  204.865 ms  204.818 ms  204.793 ms
12  sl-crs2-oro-be7.sprintlink.net (144.232.15.167)  204.773 ms  204.749 ms  204.707 ms
13  sl-crs2-stk-be2.sprintlink.net (144.232.15.239)  204.655 ms  204.625 ms  204.553 ms
14  sl-crs2-sj-be3.sprintlink.net (144.232.22.178)  204.588 ms  204.868 ms  204.803 ms
15  sl-mst50-pa-ae15-0.sprintlink.net (144.232.15.61)  204.775 ms  204.756 ms  204.732 ms
16  sl-telst8-879421-0.sprintlink.net (144.228.111.186)  204.620 ms sl-telst8-879425-0.sprintlink.net (144.228.110.114)  204.621 ms  204.566 ms
17  i-92.paix-core02.telstraglobal.net (202.84.247.42)  204.579 ms  204.524 ms  204.495 ms
18  i-37.sydo-core03.telstraglobal.net (202.84.247.46)  409.014 ms  408.973 ms  408.913 ms
19  bundle-ether3.oxf-gw11.sydney.telstra.net (203.50.13.97)  408.415 ms  408.778 ms  316.981 ms
20  bundle-ether1.chw-core10.sydney.telstra.net (203.50.6.92)  324.128 ms  323.035 ms  324.032 ms
21  bundle-ether8.exi-core10.melbourne.telstra.net (203.50.11.125)  333.858 ms  334.311 ms  336.219 ms
22  bundle-ether1.lon-edge901.melbourne.telstra.net (203.50.11.108)  334.870 ms  335.694 ms  333.134 ms
23  telstr1270.lnk.telstra.net (139.130.3.66)  332.348 ms !X  376.175 ms !X  376.071 ms !X
benjamin@benjamin-FX503VM:~$
```

<u>Australia:</u>
bundle-ether8.exi-core10.melbourne.telstra.net (203.50.11.125) 333.858 ms 334.311 ms 336.219 ms

```
benjamin@benjamin-FX503VM:~$ geoiplookup 203.50.11.125
GeoIP Country Edition: AU, Australia
benjamin@benjamin-FX503VM:~$
```

2. 103.242.70.4

```
benjamin@benjamin-FX503VM:~$ traceroute 103.242.70.4
traceroute to 103.242.70.4 (103.242.70.4), 30 hops max, 60 byte packets
 1  192.168.1.254 (192.168.1.254)  2.853 ms  3.682 ms  5.426 ms
 2  85-220-64-1.dsl.dynamic.simnet.is (85.220.64.1)  22.673 ms  24.876 ms  26.310 ms
 3  siminn-linx-gw-1.isholf.is (195.66.225.26)  68.075 ms  68.361 ms  72.164 ms
 4  40ge1-3.core1.lon2.he.net (195.66.224.21)  73.115 ms  74.348 ms  76.142 ms
 5  100ge13-2.core1.nyc4.he.net (72.52.92.166)  134.272 ms  134.636 ms  135.294 ms
 6  100ge8-1.core1.sjc2.he.net (184.105.81.218)  198.467 ms  173.754 ms  174.689 ms
 7  10ge4-4.core1.sjc1.he.net (72.52.92.117)  177.735 ms * 100ge13-2.core1.sjc1.he.net (184.105.65.113)  188.877 ms
 8  * * *
 9  be100.bdr04.sjc01.ca.us.vocus.network (114.31.199.33)  306.424 ms * be101.bdr03.lax01.ca.us.vocus.network (114.31.199.35)  307.639 ms
10  be103.cor01.lax01.ca.us.vocus.network (114.31.199.49)  303.555 ms  450.476 ms be101.bdr04.lax01.ca.us.vocus.network (114.31.199.39)  451.124 ms
11  be200.cor01.alb01.akl.nz.vocus.network (114.31.202.44)  451.044 ms be200.bdr01.akl03.akl.nz.vocus.network (114.31.199.73)  451.054 ms  451.029 ms
12  be101.bdr04.alb01.akl.nz.vocus.network (114.31.202.41)  450.987 ms  450.971 ms  450.929 ms
13  ip-59.87.45.175.VOCUS.net.au (175.45.87.59)  385.448 ms  385.363 ms be50.cor01.alb01.akl.nz.vocus.network (114.31.202.86)  385.330 ms
14  * * *
15  ns1.att.wlg.telesmart.co.nz (103.242.70.4)  508.550 ms  508.820 ms  508.751 ms
benjamin@benjamin-FX503VM:~$
```

New-Zealand:

ip-59.87.45.175.VOCUS.net.au (175.45.87.59) 385.448 ms 385.363 ms
be50.cor01.alb01.akl.nz.vocus.network (114.31.202.86) 385.330 ms

```
benjamin@benjamin-FX503VM:~$ geoiplookup 175.45.87.59
GeoIP Country Edition: NZ, New Zealand
benjamin@benjamin-FX503VM:~$
```

```
benjamin@benjamin-FX503VM:~$ geoiplookup 114.31.202.86
GeoIP Country Edition: NZ, New Zealand
benjamin@benjamin-FX503VM:~$
```

b)

If there is no response for a traceroute within a 5 second timeout interval, a *** is printed for that probe (first * = Time To Live (TTL), second * = address of the gateway, third * = round trip time of each probe). → Host is blocked (can't find the IP address)

Reference:
https://serverfault.com/questions/334029/what-does-mean-when-traceroute

c)

1. mel1.speedtest.telstra.net

```
benjamin@benjamin-FX503VM:~$ ping mel1.speedtest.telstra.net
PING mel1.speedtest.telstra.net (139.130.3.66) 56(84) bytes of data.
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=1 ttl=49 time=602 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=2 ttl=49 time=523 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=3 ttl=49 time=445 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=4 ttl=49 time=366 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=5 ttl=49 time=571 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=6 ttl=49 time=331 ms
64 bytes from telstr1270.lnk.telstra.net (139.130.3.66): icmp_seq=7 ttl=49 time=438 ms
^C
--- mel1.speedtest.telstra.net ping statistics ---
7 packets transmitted, 7 received, 0% packet loss, time 6001ms
rtt min/avg/max/mdev = 330.613/467.930/602.039/94.413 ms
benjamin@benjamin-FX503VM:~$
```

Round Trip Time (RTT) : **467.930 ms** on average

2. per1.speedtest.telstra.net

```
benjamin@benjamin-FX503VM:~$ ping per1.speedtest.telstra.net
PING per1.speedtest.telstra.net (203.43.60.161) 56(84) bytes of data.
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=1 ttl=49 time=393 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=2 ttl=49 time=619 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=3 ttl=49 time=541 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=4 ttl=49 time=462 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=5 ttl=49 time=690 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=6 ttl=49 time=612 ms
64 bytes from per1.speedtest.telstra.net (203.43.60.161): icmp_seq=7 ttl=49 time=533 ms
^C
--- per1.speedtest.telstra.net ping statistics ---
7 packets transmitted, 7 received, 0% packet loss, time 6003ms
rtt min/avg/max/mdev = 392.719/550.203/690.064/93.417 ms
benjamin@benjamin-FX503VM:~$
```

Round Trip Time (RTT) : **550.203 ms** on average

d)

Speed of light in a vacuum = 300,000,000 m/s
Core index of a fraction (fibre-optic cable) in Australia = 1.50

Accordingly, light in glass travels at:
300,000,000 / 1.5 = 200,000,000 m/s

Packet from Iceland to Melbourne (RTT) : 468 ms
Packet from Iceland to Perth (RTT) : 550 ms

Packet travelling between Melbourne and Perth (RTT):
550 – 468 = 82 ms round trip time (41 ms one-way approximately)
41 ms = 0.041 sec

Distance between Perth and Melbourne:
Speed = Distance / Time
200,000,000 m/s = Distance / 0.041 s
Distance = 200,000,000 * 0.041 = 8,200,000 m
= **8,200 km**

Reference:
https://en.wikipedia.org/wiki/Speed_of_light

e)

1. Seems to be located in the regions of **Ireland**, according to the average RTT (round trip time) given:

Ping to: www.ru.is

Checkpoint	Result	min. rtt	avg. rtt	max. rtt	IP
Ireland - Dublin (iedub03)	OK	0.381	0.572	1.976	54.171.81.101
United Kingdom - Cardiff (gbcar01)	OK	12.535	12.679	12.944	54.171.81.101
United Kingdom - London (gblon03)	OK	12.622	12.844	13.616	54.171.81.101
United Kingdom - Edinburgh (gbedi01)	OK	13.492	13.641	14.336	54.72.68.210
Netherlands - Eemshaven (nleem01)	OK	18.658	18.778	19.130	54.72.68.210
Belgium - St. Ghislain (bestg01)	OK	18.984	19.195	19.872	54.72.68.210
France - Paris (frpar05)	OK	22.261	22.309	22.340	54.171.81.101

2. Seems to be located near the regions off Spain, France, Switzerland, Germany, and USA with regards to the average RTT given…

Ping to: www.mit.edu

Checkpoint	Result	min. rtt	avg. rtt	max. rtt	IP
Spain - Madrid (esmad03)	OK	0.256	0.339	0.419	23.14.138.46
France - Paris (frpar05)	OK	0.561	0.582	0.622	104.126.243.244
United States - Los Angeles (uslax03)	OK	0.757	0.855	1341	184.30.185.198
Switzerland - Zurich (chzrh02)	OK	0.779	0.869	1399	2.19.78.25
United States - Los Angeles (uslax04)	OK	0.762	0.886	1615	184.30.185.198
United States - Ashburn (usabn09)	OK	0.826	0.954	1426	23.6.64.128
Germany - Frankfurt (defra05)	OK	0.889	0.978	1361	104.125.30.202
Denmark - Copenhagen (dkcph03)	OK	1018	1032	1060	23.78.45.119

3. Content Delivery Network (CDN), which routes requests to the nearest cached hosted version on the CDN's network of servers.

Reference:
https://webmasters.stackexchange.com/questions/49707/how-to-host-a-website-in-multiple-countries-for-fast-response-times

2. Network Throughput

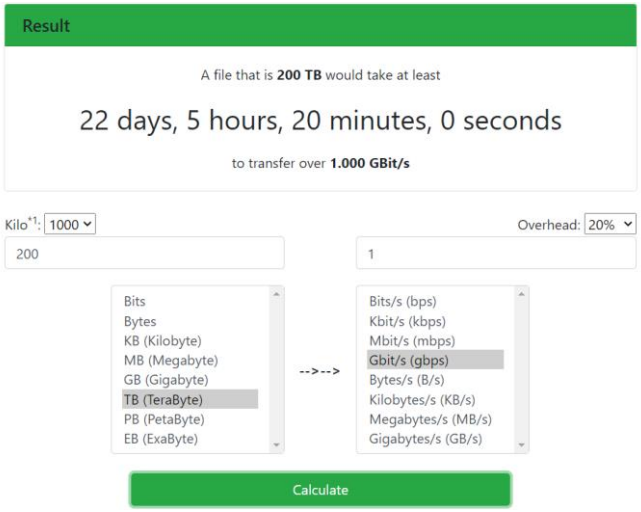
a)

Dataset = 200 TB → 200,000 GB
20% protocol overhead → 200,000 GB * 1.2 = 240,000 GB

1 Gbps connection → 0.125 GB/s

240,000 / 0.125 = 1,920,000 seconds
= 32,000 minutes
= 533.33 hours
= 22.22 days OR
22 days and 5 hours (approximately)

Verification by online calculator:



References:
https://piazza.com/class/kdrds5srlf6sr?cid=170
https://techinternets.com/copy_calc

b)

Ignoring time to read and write the tape….

Kef Airport : 3 hours
Flight time : 3 hours
Oslo : 1 hour

Total : 7 hours

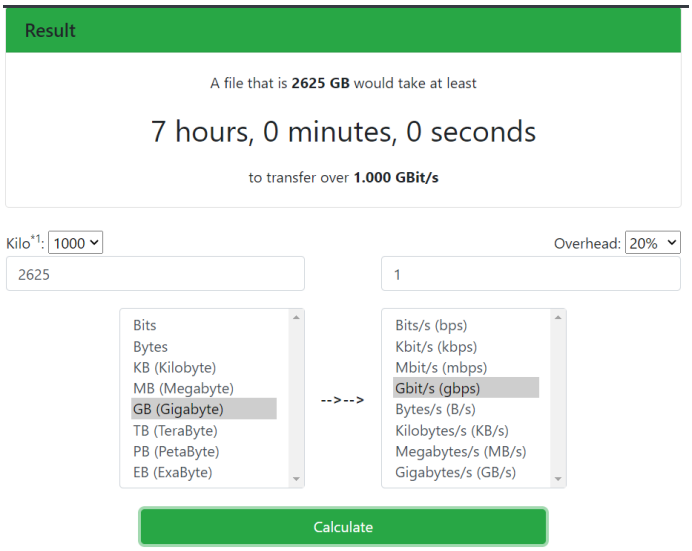
The break-even-point to send data over network, rather than by tape, is therefore:

7 hours = 420 minutes = 25,200 seconds
Connection speed: 1Gpbs → 0.125GB/s

25,200 sec = Data sent / 0.125 GB/s
Data sent = 25,200 * 0.125 = 3,150 GB

With 20% overhead (network link), data sent will be:
3,150 / 1.2 = 2,625.0 GB = **2.625 TB** over a 7 hour period

Verification by online calculator:



Reference:
https://techinternets.com/copy_calc
https://piazza.com/class/kdrds5srlf6sr?cid=170
https://piazza.com/class/kdrds5srlf6sr?cid=169

c)

Maximum writing and reading speed for a tape : 900 MB/s
To read/write 12TB with maximum reading/writing speed being 900 MB/s :

12 TB = 12,000 GB
12,000 GB = 12,000,000 MB

12,000,000 / 900 = 13,333.33 seconds
= 222.22 minutes
= 3.704 hours (approximately) per tape

Given that the 200TB of data is not compressed on disk (source: "***…can hold 12 TB[2] (30 TB at 2.5:1 compression)***"), you would need 7 tapes in total to transfer the data (200TB / 2.5 compression ratio = 80TB / 12TB per tape = 6.67 tapes (rounded up to 7 tapes)).

So, the total time (including reading/writing the compressed data tapes) would be:
7 hours + ((3.704 hours * 2 times) * 7 tapes) = **58.856 hours**

Note:
If data is already compressed and consists of 200TB of data, then you would need 17 tapes in total to transfer the data (200 / 12 = 16.67). This would lead to approximately 133 hours in total time for transferring the data.

References:
https://piazza.com/class/kdrds5srlf6sr?cid=170
https://piazza.com/class/kdrds5srlf6sr?cid=182
https://en.wikipedia.org/wiki/Linear_Tape-Open

d)

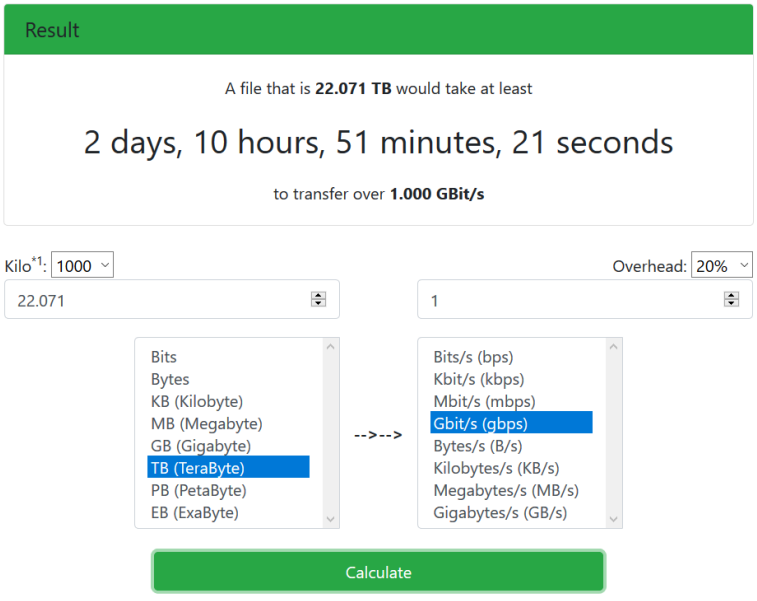
Time it takes to send 200TB (80TB when compressed) of data via airplane to Oslo (Norway), including reading/writing the tapes:
58.856 hours (2 days, 10 hours, 51 minutes)

58.856 hours = 3,531.36 minutes = 211,881.6 seconds
Connection speed: 1Gpbs → 0.125 GB/s

211,811.6 sec = Data sent / 0.125 GB/s
Data sent = 211,881.6 * 0.125 = 26,485.2 GB

With 20% overhead in network link transfer, data sent will be:
26,485.2 / 1.2 = 22,071 GB = **22.071 TB** over a 58.586 hour period
(new break-even-point).

If more data is needed to be sent, you would be quicker to use the tapes via airline carriage. Verification by online calculator:



Reference:
https://techinternets.com/copy_calc
https://piazza.com/class/kdrds5srlf6sr?cid=170
https://piazza.com/class/kdrds5srlf6sr?cid=169

3. Network Engineering

a)

To guarantee that each and every customer has access to 1Gb at any time, meaning that they could all be wanting access to their full capacity at the same exact time, then ISP could provision **50 customers** over a 50Gb link. However, with doing so each customer will have to pay a higher fee for this kind of service.

b)

50 Gb link costs ISK 5,000,000 per month.
Profit included to cover overheads : ISK 5,000,000 * 1.25 = ISK 6,250,000
Charge per customer: ISK 10,000

For each 10Gb link, the smallest number of customers to still make given profit target therefore is:

ISK 6,250,000 / ISK 10,000 = 625 customers for a 50Gb link
50 Gb link / 10Gb link = 5 links of 10Gb each
625 total customers / 5 links = **125 customers** for each 10Gb link

Reference:
https://piazza.com/class/kdrds5srlf6sr?cid=171

c)

625 customers per 50Gb link:
50 Gb / 625 = **0.08 Gb (or 80 Mb)**

If all the customers are maximizing their network connection simultaneously (internet gets slower while high demand is occurring, therefore the very slow bandwidth in this particular case).

d)

Customer who would want a guaranteed 10GB link at all time (80Gb), would have to cover the cost of 125 customers per 10Gb link eight times in total.

So, the total cost would be (given the cost per customer is ISK 10,000):
ISK 10,000 * 125 customers * 8 links = **10,000,000 ISK** per month

Reference:
https://piazza.com/class/kdrds5srlf6sr?cid=152
https://piazza.com/class/kdrds5srlf6sr?cid=177

e)

Average usage per customer: 20%
1Gb access guaranteed during usage (illusion), assuming that usage of customers are evenly distributed over the day.

Given that each customer is only active 20% of the time, and are evenly distributed over the day, means that the ISP can (or gambles on that they can) maintain **250 customers** over a 50Gb link (50 customers / 0.2).

In regards to the gambling part mentioned here above, it could/would occur that the usage of customers come and goes in bursts (as happens in real life), meaning that packets may be lost and/or the speed of the network slows down when such bursts occur – resulting in unsatisfied and annoyed customers. 😊

So, the ISP is essentially gambling on that all of their customers are not using all of their bandwidth at the same time (but only 20% as is given in this example), keeping all customers happy/satisfied with the service provided.

f)

I would try and maximize the links of the ISP to the fullest, without affecting the service provided to each customer. This can be done, as most businesses operate during the day-time on weekdays, while household customers are using the network more during after working hours (in the evening and on weekends).

And if some customers (households and/or businesses) are willing to pay more to be guaranteed a certain bandwidth at any time, the cost would be greater and also fewer customers for each link – thereby, always maximizing the profit of the Internet Service Provider (ISP).

Bonus Question

Fastest Slowest

Question 1 – Part A & C

mel1.speedtest.telstra.net

Round Trip Time (RTT) in milliseconds (ms)

	Iceland – USA *	USA – Australia	Iceland – Australia
01:00:00 PM	162,57	282,66	445,23
03:00:00 PM	164,463	145,31	309,773
05:00:00 PM	162,901	239,465	402,366
07:00:00 PM	203,43	410,811	614,241

** Traceroute should have been through London, but it routes through USA instead.*

Question 1 – Part C

per1.speedtest.telstra.net

Round Trip Time (RTT) in milliseconds (ms)

	Iceland – USA *	USA – Australia	Iceland – Australia
01:00:00 PM	175,113	181,899	357,012
03:00:00 PM	345,982	74,561	420,543
05:00:00 PM	163,398	210,034	373,432
07:00:00 PM	198,884	219,497	418,381

** Traceroute should have been through London, but it routes through USA instead.*

Question 1 – Part A

103.242.70.4

Round Trip Time (RTT) in milliseconds (ms)

	Iceland – London	London – New Zealand	Iceland – New Zealand
01:00:00 PM	69,681	242,827	312,508
03:00:00 PM	61,956	490,438	552,394
05:00:00 PM	73,032	543,336	616,368
07:00:00 PM	68,13	545,689	613,819

In the tables here above, it is shown the time it takes to send data from Iceland to Australia (or New Zealand). Top table is between Iceland and Melbourne (Australia), middle table is Iceland and Perth (Australia), and bottom table is Iceland and New Zealand.

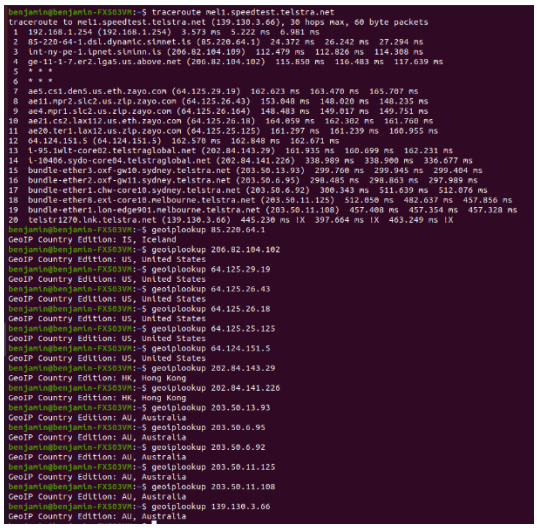
The fastest time to send traffic is shown in light-green colour, and the slowest time to send traffic is shown in yellow colour.

As shown, the fastest time to send to Melbourne is in the midday, around 15:00 o'clock (03:00 PM), and the slowest time to send traffic is in the evening time or around 19:00 o'clock (07:00 PM).

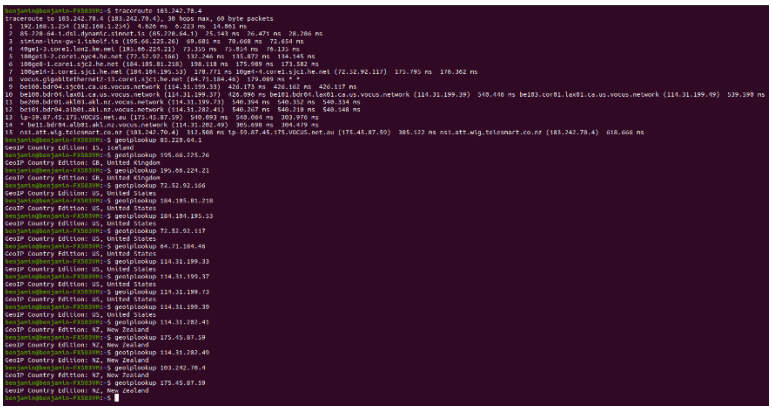
In regards to sending traffic to Perth in Australia, the fastest time is early in the midday or around 13:00 o'clock (01:00 PM). The slowest time is on the other hand around midday or at 15:00 o'clock (03:00 PM) – in contrast with sending data to Melbourne, which is very interesting to see.

There is also a note to mention, where as in the assignment description we where suppose to locate the time from Iceland to London, and from London to Australia. However, as can be seen in the pictures here below, when sending data from Iceland to Australia the route goes through the United States of America (not the UK) – which may or may not lead to some skewness in the end results.

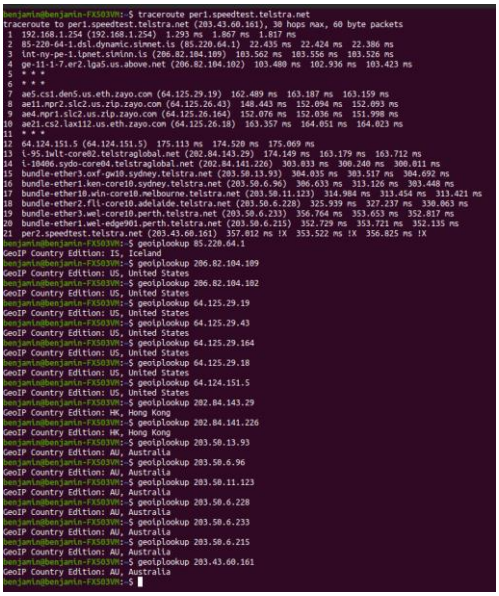
The congestion that is occurring, that may slow down the traffic in these examples, is due too the amount of burden that is happening at different time spells around the world in regards to internet speed. That is, when there is a lot of people and/or businesses using their bandwidth capacities, then the speed slows down because the packets being sent are cueing up to be processed in orderly manner. The more this amount of people that are using their bandwidth of the ISP, the more likelier it is that packages become lost (which does not happen in these particular cases, but do occur).



Traceroute for Iceland – USA - China – Australia (Melbourne)



Traceroute for Iceland – UK – USA – New Zealand



Traceroute for Iceland – USA – China – Australia (Perth)

Name: Benjamín Aage Birgisson
TA Name: Benedikt Hólm Þórðarson
Time Taken: 12.0 hrs
Estimated time: 10 hrs