Assignmnet3

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Section2

Ans 2.1

Looking at Fig 1 and Fig 2

```
chendeMacBook-Pro:~ chen$ traceroute -nw1 cis.unimelb.edu.au
traceroute to cis.unimelb.edu.au (128.250.106.72), 64 hops max, 52 byte packets
 1  172.16.11.1  3.416 ms  0.757 ms  2.840 ms
 2  10.1.1.1  1.663 ms  6.809 ms  6.144 ms
 3  115.70.163.154  2.219 ms  10.972 ms  1.585 ms
 4  218.100.78.33  2.563 ms  1.717 ms  4.082 ms
 5  113.197.15.138  2.835 ms  2.547 ms  6.369 ms
 6  138.44.64.73  12.161 ms  8.568 ms  4.107 ms
 7  * * *
 8  * * *
 9  * * *
10  * * *
11  * * *
12  * * *
13  128.250.106.72  4.661 ms !Z  2.140 ms !Z  1.972 ms !Z
```

Figure 1:

```
chendeMacBook-Pro:~ chen$ traceroute -w1 cis.unimelb.edu.au
traceroute to cis.unimelb.edu.au (128.250.106.72), 64 hops max, 52 byte packets
 1  172.16.11.1 (172.16.11.1)  13.085 ms  2.141 ms  7.258 ms
 2  10.1.1.1 (10.1.1.1)  6.857 ms  1.235 ms  1.142 ms
 3  154.163.70.115.static.exetel.com.au (115.70.163.154)  1.738 ms  7.574 ms  1.566 ms
 4  as7575.vic.ix.asn.au (218.100.78.33)  1.898 ms  3.980 ms  1.957 ms
 5  ae5.vic-wmlb-pe1.aarnet.net.au (113.197.15.138)  10.276 ms  1.819 ms  1.995 ms
 6  138.44.64.73 (138.44.64.73)  2.940 ms  4.100 ms  1.851 ms
 7  * * *
 8  * * *
 9  * * *
10  * * *
11  * * *
12  * * *
13  4000v-eng-web-departments-l.eng.unimelb.edu.au (128.250.106.72)  4.147 ms !Z  6.436 ms !Z  11.653
 ms !Z
```

Figure 2:

Fig 1 is the result of traceroute -nw1 cis.unimelb.edu.au, Fig 2 is the result without "n". If "n" was not typed, in the second column of each hop line is the host name and the IP address (if the IP address does not have a symbolical host name, it would output IP address twice). "-n" means printing hop IP addresses numerically rather than symbolically and numerically.

"w" set the time to wait for a response to a probe (default 5 seconds). Here we set "w1" with means waiting 1 second. We can find that in figure 1 the longest waiting time is 12.161ms which is less than 1 s, so we did not see * * * in this line.

Ans 2.2

Looking at the result achieved in section 2.2 of the appendix

For easy to observe, the tail of each traceroute is printed and followed by the host name.

Use "https://www.iplocation.net" to find IP locations.

Use "https://www.freemaptools.com/how-far-is-it-between.htm" to find distances.

Looking at the data 1 of the appendix and figure 3

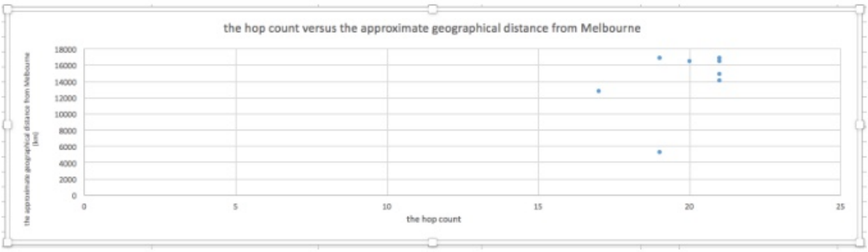

Figure 3:

The hop count versus the approximate geographical distance from Melbourne seems positively related even though it is not too obvious. We can find that three large European countries France, Germany and Russia has same hop counts. Indonesia has less hop count compared to European countries. Usually longer distance means more routers required. The router paths to Europe usually go through Indonesia, so Indonesia has less hop count compared to European countries.

Section3

Ans 3.1

Jitter is the standard deviation in the packet arrival times.

Delay is how long it takes for the packet to travel across the network from one node to another.

Real-time applications, such as telephony and videoconferencing, have strict delay requirements and strict jitter requirements.

Long delay means one user's photographs and voice reaches the other users much later than the cases that they are face to face in reality. It is unacceptable for real time applications.

If using videoconferencing over the network that make all frames delay by exactly 1 seconds which means the jitter is 0, the harm is not too strict. The users can accept it because it looks like a slow play. But if the delay varies randomly between 0.2 and 1 seconds, the videos and the voices received by the users would be speed-freak unless the application hides the jitter.

Ans 3.2

Looking at the section 3.2 Results bash script and 3.2 output, data 1of the appendix and figure 4 and figure 5

The average round-trip delay is the third column and the jitter is the fifth column.

It is worth to mention that jitter is calculated from the stddev in the output of ping in 3.2 output of the appendix.

"Ping" calculate the stddev as $stddev = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$

jitter is $\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i^2 - 2x_i\bar{x} + \bar{x}^2)} = \sqrt{\frac{1}{N-1}(\sum_{i=1}^{N}(x_i^2) - n \times \bar{x}^2)}$

They are calculated at the section 3.2 Results bash script .

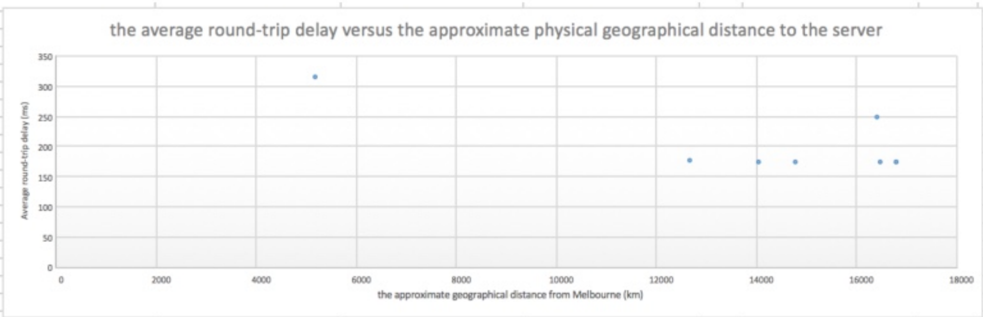

Figure 4:

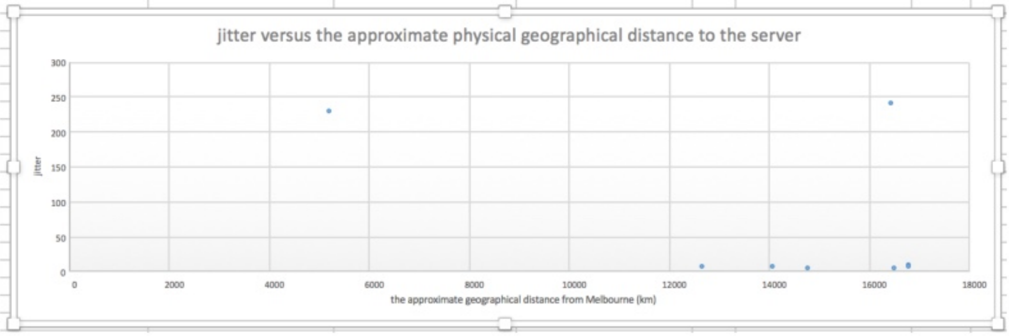

Figure 5:

Ans 3.3

Theoretically, the average round-trip delay versus the approximate geographical distance from Melbourne could be positively related, longer distance implies longer propagation delay. But it does not means longer distance must have longer delay time. Other factors like the router path, speed of signals also influence it. The results have large errors that they are not positive related obviously.

The jitter versus the approximate geographical distance from Melbourne could be positively related theoretically. Longer distance implies more materials and mediums used during the trip which implies more changes to use different mediums like Coaxial Cable, Single-mode Fiber, Multi-mode Optic Cable, and their speed of signals could be different based on temperatures, humidities, etc. Therefore, longer distance implies higher probability to change the old propagative time, the variance could be higher. The results have large errors that they are not positive related obviously.

Section4

Ans 4.1

Bandwidth-delay product $= totalavailablebandwidth \times roundtriptime$

It would be the amount of data stored at the receiver in time it takes to send a segment and receive an acknowledgement.

If there is a connection sending data from Perth to Melbourne at 10 Mbps with a round-trip time of 1 second. It has high bandwidth-delay product of 10 Mbit. This 10 Mbit data will be stored at the receiver in time it takes to send a segment and receive an acknowledgement.

Large bandwidth-delay product requires larger sliding windows and more buffering for the sliding windows.

Usually the bandwidth cannot be fully utilized. The throughput efficiency reflects the utilization rate of bandwidth. Generally, large delay implies greater throughput efficiency. The relation ship between the throughput efficiency and bandwidth-delay product could relative with bandwidth and delay.

Ans 4.2

As I cannot connect to iperf.comneonext.de and iperf.scottlinux.com by iperf or iperf3, I use iperf.volia.net and ping.online.net to replace them.

Looking at the Section 4.2 Results of the appendix and data 1 of the appendix.

Three set of measurements measuring the bandwidth of the public iperf hosts are in the printed line of the Section 4.2 Results and the mean bandwidth for each host is in the second column of data 1.

Ans 4.3

Looking at the Fig 6, Fig 7 and data 1 of the appendix and Section 4.3 Speedtest of the appendix.

The bandwidth-delay product is the forth column in data1.

Fig 6 is the bar chart for each host in standard scale. Fig 6 is the bar chart for each host using a logarithmic scale.

As the logarithmic scales are pretty stable, there does not exist obvious outliers. All of the data stored at the receiver in time it takes to send a segment and receive an acknowledgement is in the level of 0.5 Mbits to 5 Mbit.

Compared with the upload speed 56.34 Mbit/s of my actual internet link speed in Section 4.2 Speedtest of the appendix, all bandwidths are really small.

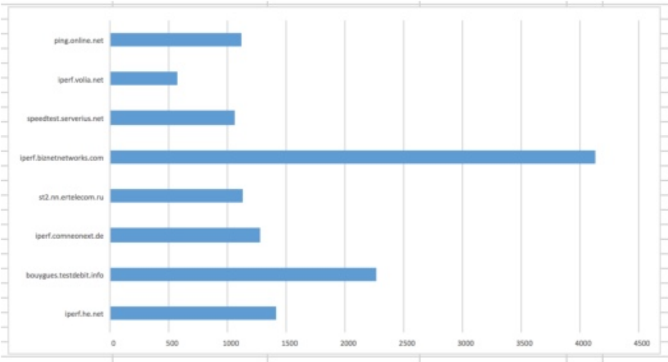

Figure 6:

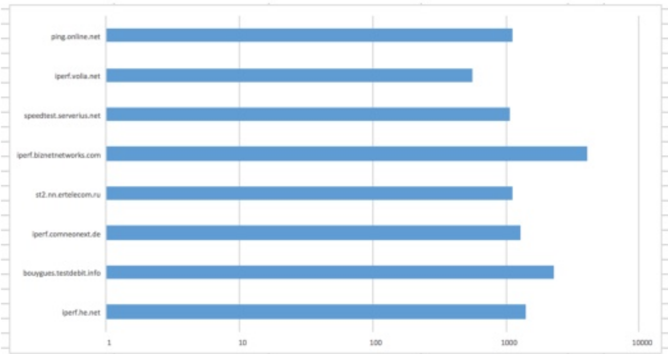

Figure 7:

Ans 4.4

Looking at the Fig 8.

There are not enough data that the errors have large influence. There does not exist obvious outliers.

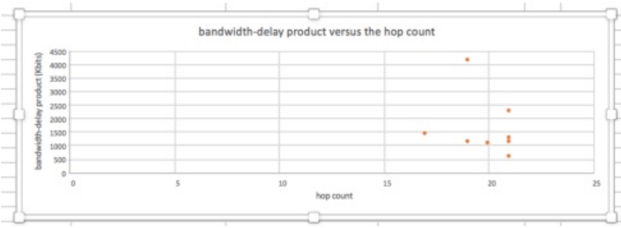

Figure 8:

There does not exist obviously correlations. If we can control all other factors, the bandwidth-delay product could be positive related to the hop count, but there are too many noisy factors.

Ans 4.5

As I cannot connect to iperf.comneonext.de and iperf.scottlinux.com by iperf or iperf3, I use iperf.volia.net and ping.online.net to replace them. We concentrated on addresses "iperf.he.net
bouygues.testdebit.info
iperf.comneonext.de st2.nn.ertelecom.ru
iperf.biznetnetworks.com speedtest.serverius.net iperf.volia.net
ping.online.net".
The commands and bash scripts for section 2 and 3 are in appedix: The commands for section 4 are:
iperf -c iperf.he.net
iperf3 -c bouygues.testdebit.info -p 5209
iperf -c iperf.comneonext.de
iperf -c st2.nn.ertelecom.ru
iperf3 -c iperf.biznetnetworks.com
iperf -c speedtest.serverius.net
iperf -c iperf.volia.net
iperf -c ping.online.net
Homebrew on Mac can install iperf and iperf3 easily.
"https://iperf.fr/iperf-servers.php" helped to find ports and addresses which can work with iperf.
"https://www.iplocation.net" helped to find IP locations. "https://www.freemaptools.com/how-far-is-it-between.htm" helped to find distances.
Excel is used to store data and plot charts.

Appendix

1. data 1

hostname	Average Bandwidth (Mbits/sec)	Average round-trip delay (ms)	bandwidth-delay product (Kbits)	jitter	Distance From Melbourne (km)	hop count	City
iperf.he.net	8.09	174.269	1409.83621	4.9848	12692	17	California Fremont
bouygues.testdebit.info	13.2	171.944	2269.6608	6.84	16819	21	Ile-de-France Meudon
iperf.comneonext.de	5.2	245.333	1275.7316	239.66	16451	21	Nordrhein-Westfalen Koeln
st2.nn.ertelecom.ru	6.51	172.659	1124.01009	6.101	14075	21	Nizhegorodskay a oblast' Nizhniy Novgorod
iperf.biznetnetworks.com	13.21	312.458	4127.57018	228.31	5218	19	Jakarta Raya Jakarta
speedtest.serverius.net	6.22	170.807	1062.41954	2.99	16507	20	Flevoland Dronten
iperf.volia.net	3.3	171.587	566.2371	4.4012	14796	21	Kyiv Kiev
ping.online.net	6.46	172.96	1117.3216	6.8279	16810	19	Ile-de-France Paris

2. Section 2.2 Results:

   bash script:

```
#!/bin/bash
addresslist=("iperf.he.net" "bouygues.testdebit.info" "iperf.comneonext.de" "st2.nn.ertelecom.ru"
    "iperf.biznetnetworks.com" "speedtest.serverius.net" "iperf.volia.net" "ping.online.net")
for ((i=0; i<${#addresslist[@]}; i++)); do
    addedline=$(traceroute -I -nw1 ${addresslist[$i]})
    echo "${addedline:(-130)}""      ${addresslist[$i]}"
done
```

   output:

```
chendeMacBook-Pro:bash_script chen$ bash twopoint2.sh
traceroute to 9000.mtu.he.net (216.218.227.10), 64 hops max, 72 byte packets
8.045 ms  166.631 ms  167.822 ms
16  72.52.92.109  176.738 ms  209.262 ms  254.444 ms
17  216.218.227.10  166.932 ms *  272.210 ms      iperf.he.net
traceroute to bouygues.testdebit.info (89.84.1.222), 64 hops max, 72 byte packet
s
  325.075 ms  408.033 ms
20  89.89.101.141  541.824 ms  502.300 ms  395.624 ms
21  89.84.1.222  316.674 ms  400.186 ms  402.601 ms      bouygues.testdebit.info
traceroute to iperf.comneonext.de (85.25.140.156), 64 hops max, 72 byte packets
09.523 ms  409.134 ms
20  217.118.23.131  410.725 ms  414.651 ms  403.779 ms
21  85.25.140.156  376.447 ms  442.524 ms  409.981 ms      iperf.comneonext.de
traceroute to st2.nn.ertelecom.ru (91.144.184.232), 64 hops max, 72 byte packets
405.728 ms
19  91.144.185.249  409.543 ms  407.462 ms  411.788 ms
20  * * *
21  91.144.184.232  466.622 ms  414.130 ms  417.211 ms      st2.nn.ertelecom.ru
traceroute to iperf.biznetnetworks.com (117.102.109.186), 64 hops max, 72 byte p
ackets
312 ms  409.195 ms
18  182.253.187.106  429.054 ms  389.980 ms  410.065 ms
19  117.102.109.186  414.757 ms  404.086 ms  409.582 ms      iperf.biznetnetwork
s.com
traceroute to speedtest.serverius.net (178.21.16.76), 64 hops max, 72 byte packe
ts
ms  409.694 ms
18  * * *
19  178.21.17.18  367.782 ms  409.815 ms  405.622 ms
20  178.21.16.76  418.131 ms  405.067 ms  414.402 ms      speedtest.serverius.ne
t
traceroute to speedtest.volia.net (82.144.193.18), 64 hops max, 72 byte packets
ms  357.723 ms
19  * * *
20  77.120.1.30  452.454 ms  369.267 ms  384.815 ms
21  82.144.193.18  354.949 ms  344.822 ms  367.886 ms      iperf.volia.net
traceroute to ping.online.net (62.210.18.40), 64 hops max, 72 byte packets
s  393.278 ms
17  * * *
18  195.154.1.107  369.778 ms  410.847 ms  410.301 ms
19  62.210.18.40  409.338 ms  407.713 ms  424.246 ms      ping.online.net
```

3. Section 3.2 Results:

   bash script:

```bash
#!/bin/bash
addresslist=("iperf.he.net" "bouygues.testdebit.info" "iperf.comneonext.de" "st2.nn.ertelecom.ru" "iperf.biznetnetworks.com"
    "speedtest.serverius.net" "iperf.volia.net" "ping.online.net")
for ((i=0; i<${#addresslist[@]}; i++)); do
    echo "Result of Ping  ${addresslist[$i]}   "
    ping -c4 iperf.he.net > tempfile.txt
    for ((j=0; j<2; j++)); do
        ping -c4 iperf.he.net >> tempfile.txt
    done
    cat tempfile.txt
    echo "-------------statistical results--------------------------------"
    awk '$1 == 64 {sum += substr($7,6); sumsquare += substr($7,6)*substr($7,6)} END {average=sum/
        12;jitter=sqrt((sumsquare-12*average*average)/11);print "average is " average " ms", " jitter is " jitter}' ./tempfile.txt
    echo "----------------------------------------------------------------"
    echo "***********************************************************************"
done
```

   3.2 output: