Department of Electronic and Telecommunication Engineering

University of Moratuwa

Practical Session 1

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This report is submitted as a partial fulfillment of the module

EN2150 – Communication Network Engineering

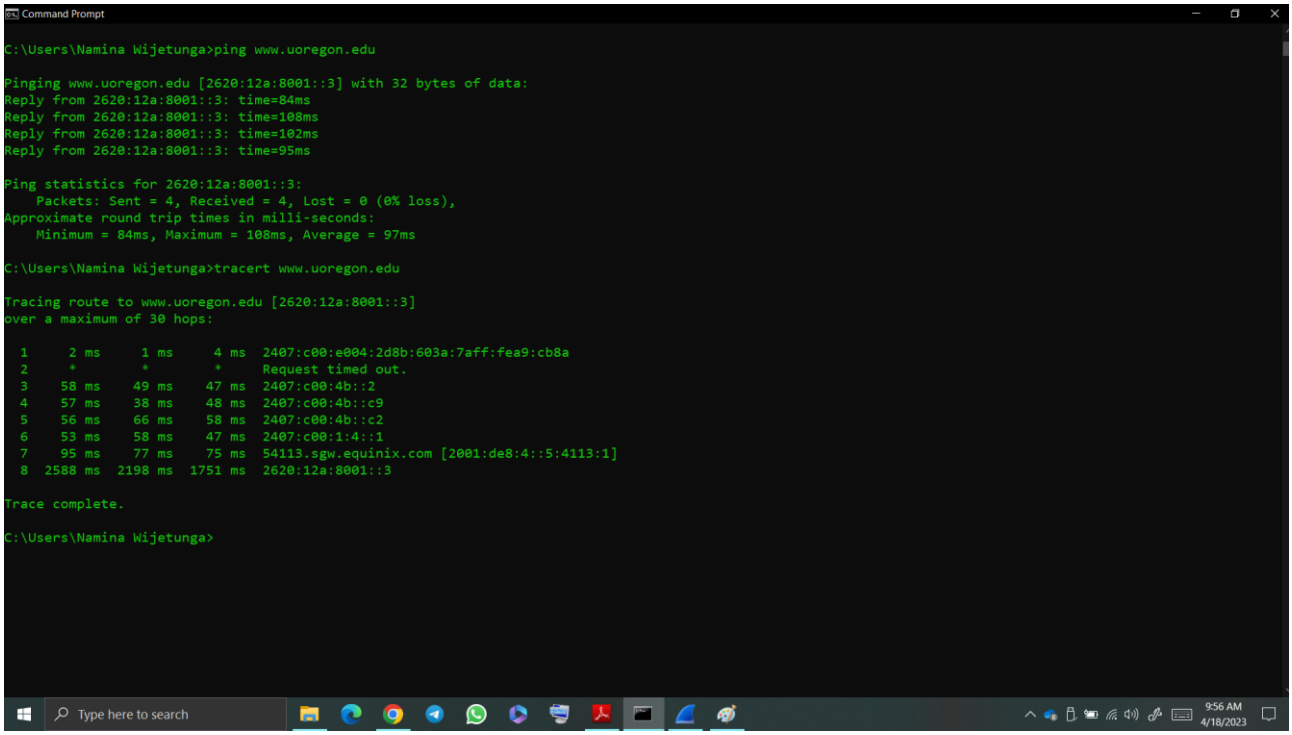
24nd of March 2023

Question (1) - What is a hierarchical network? Networks aggregating at different levels

b) Activate Wireshark packet capture and perform the following:

I. Access each of the following web pages and then Ping and Traceroute to the same web pages. Copy the results to a file for later analysis.

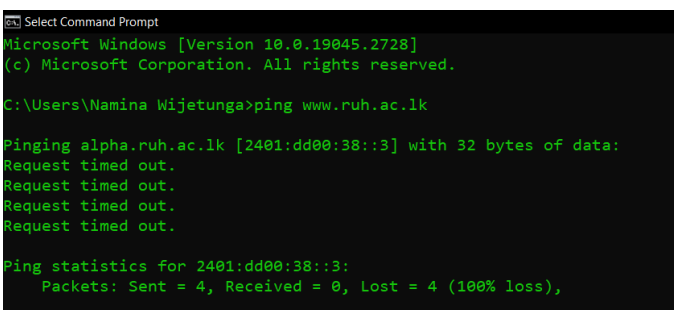
- **www.uoregon.edu**

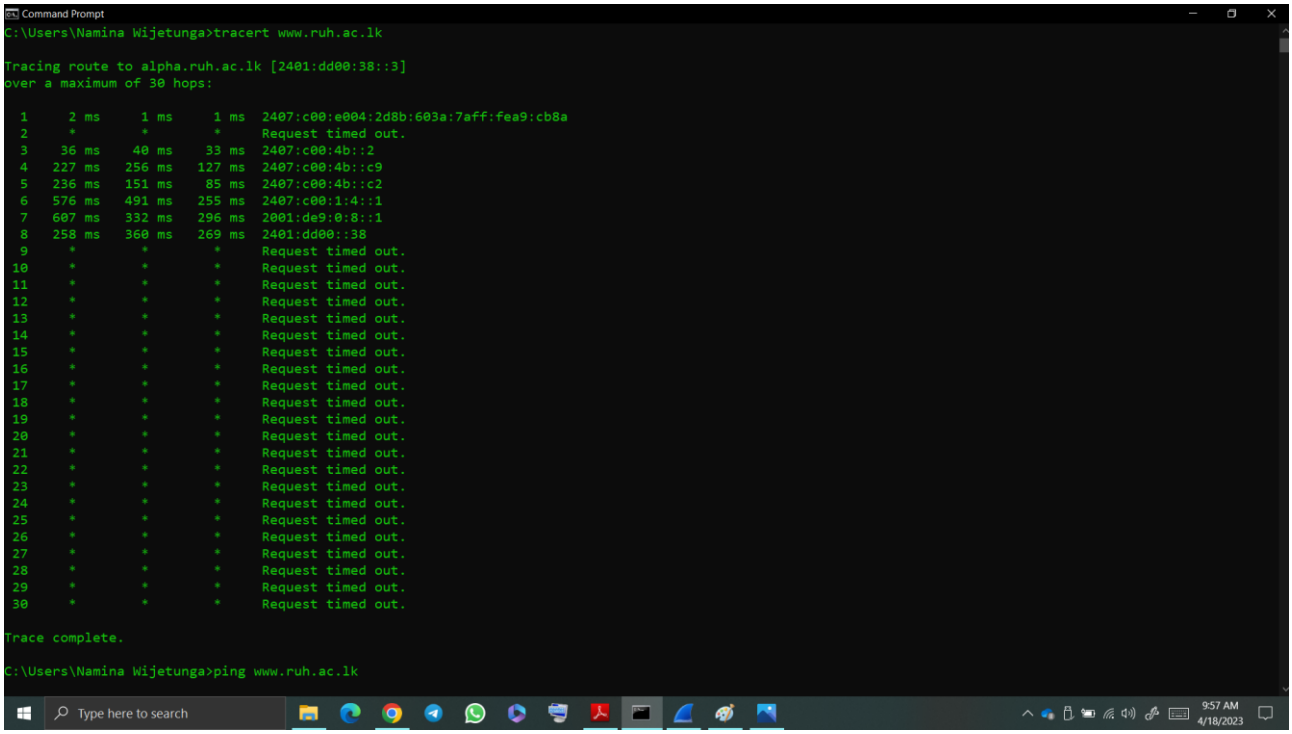


Using the IP address geolocator,

1. 2407:c00:e004:2d8b:603a:7aff:fea9:cb8a - Jaffna, Sri Lanka - Mobitel Pvt Ltd
2. 2407:c00:4b::2 - Colombo, Sri Lanka - Mobitel Pvt Ltd
3. 2407:c00:4b::c9 - Colombo, Sri Lanka - Mobitel Pvt Ltd
4. 2407:c00:4b::c2 - Colombo, Sri Lanka - Mobitel Pvt Ltd
5. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
6. 2001:de8:4::5:4113:1 - Tokyo, Japan - Equinix Asia Pacific Pte Ltd
7. 2620:12a:8001::3 - San Francisco, USA - Pantheon

- **www.ruh.ac.lk**





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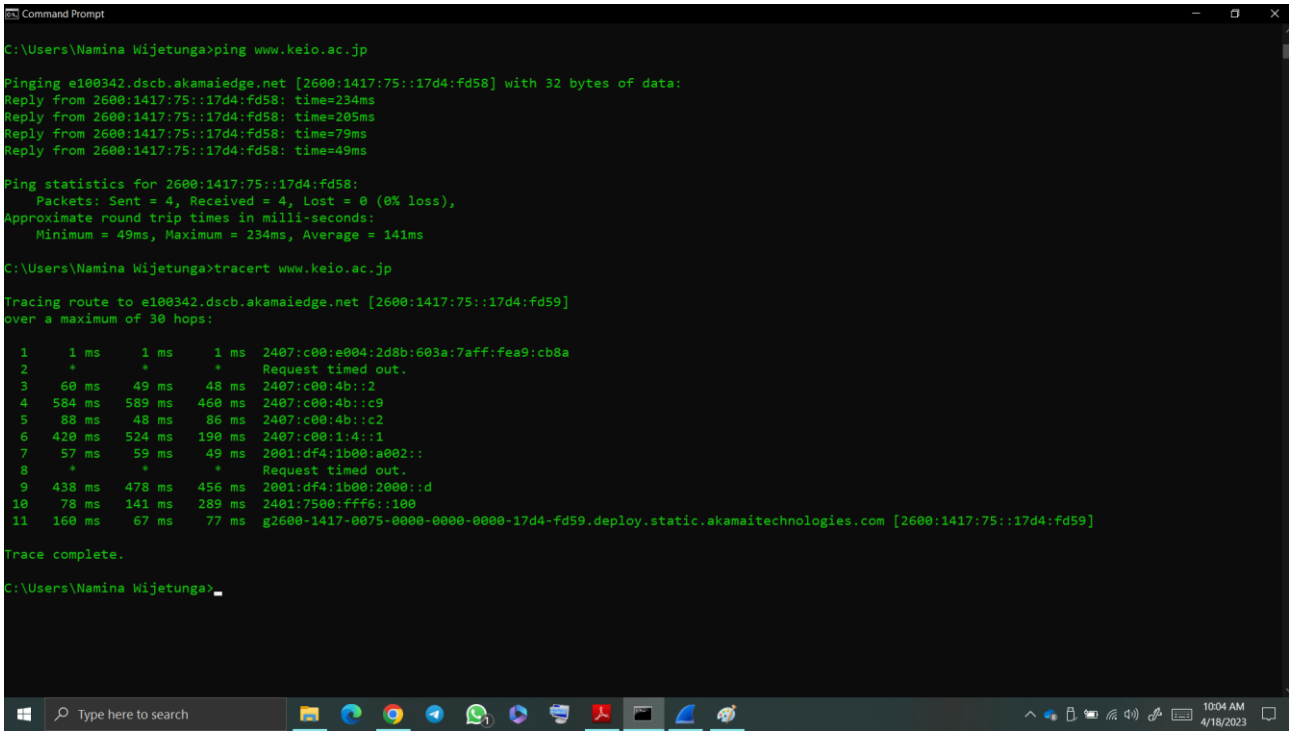
5. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
6. 2001:de9:0:8::1 - Colombo, Sri Lanka - Sri Lanka Telecom PLC
7. 2401:dd00::38 - Colombo, Sri Lanka - Lanka Education and Research Network

- **www.keio.ac.jp**



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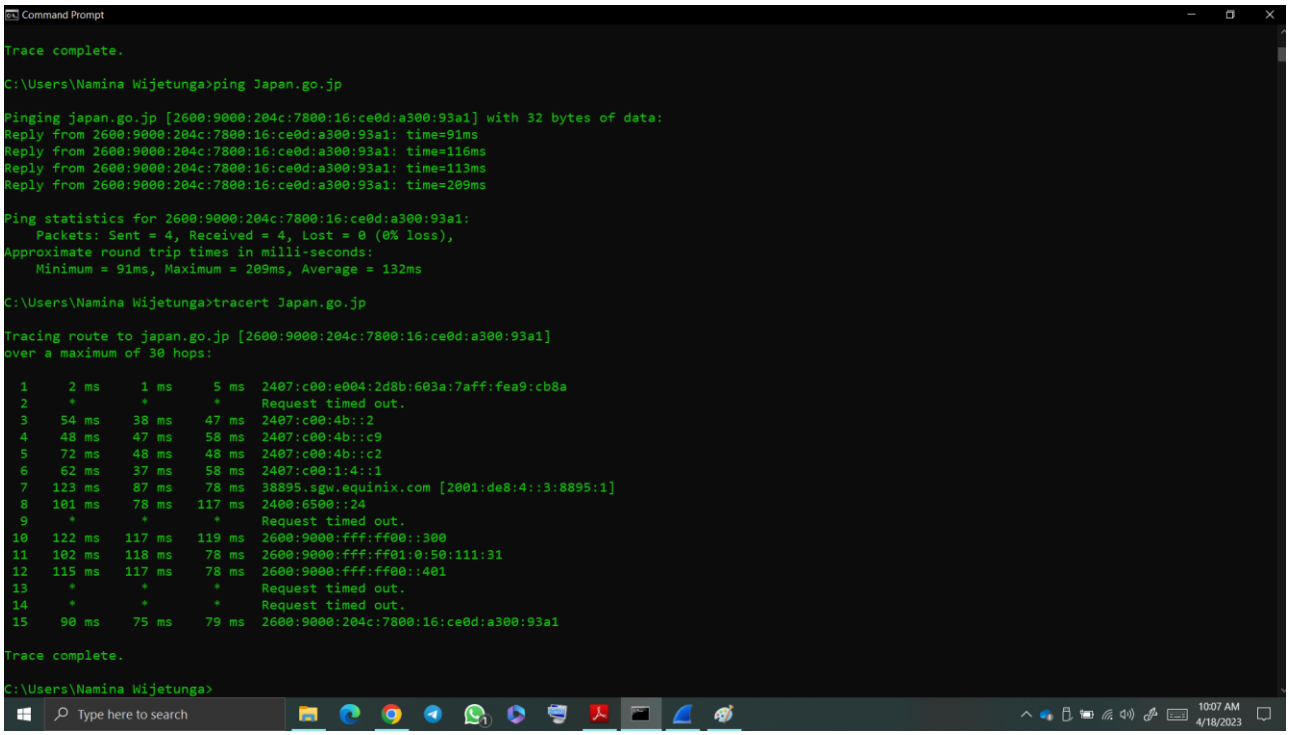
4. 2407:c00:4b::c2 - Colombo, Sri Lanka - Mobitel Pvt Ltd
5. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
6. 2001:df4:1b00:a002:: - Colombo, Sri Lanka - Sri Lanka Telecom PLC
7. 2001:df4:1b00:2000::d - Colombo, Sri Lanka - Sri Lanka Telecom PLC
8. 2401:7500:fff6::100 - Mumbai, India - Web Werks India Pvt. Ltd.
9. 2600:1417:75::17d4:fd59 - Mumbai, India - Akamai Technologies Inc.

- **Japan.go.jp**



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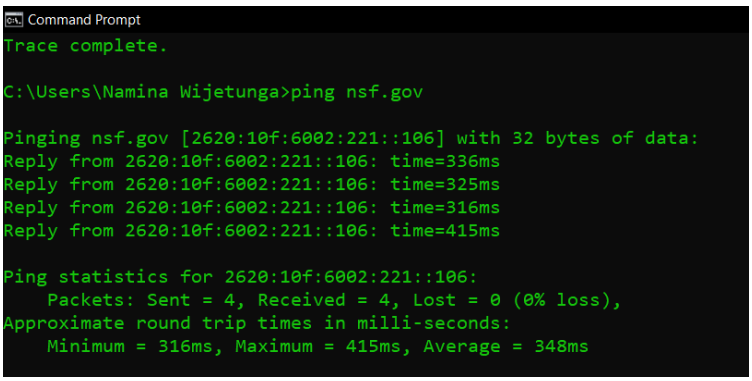
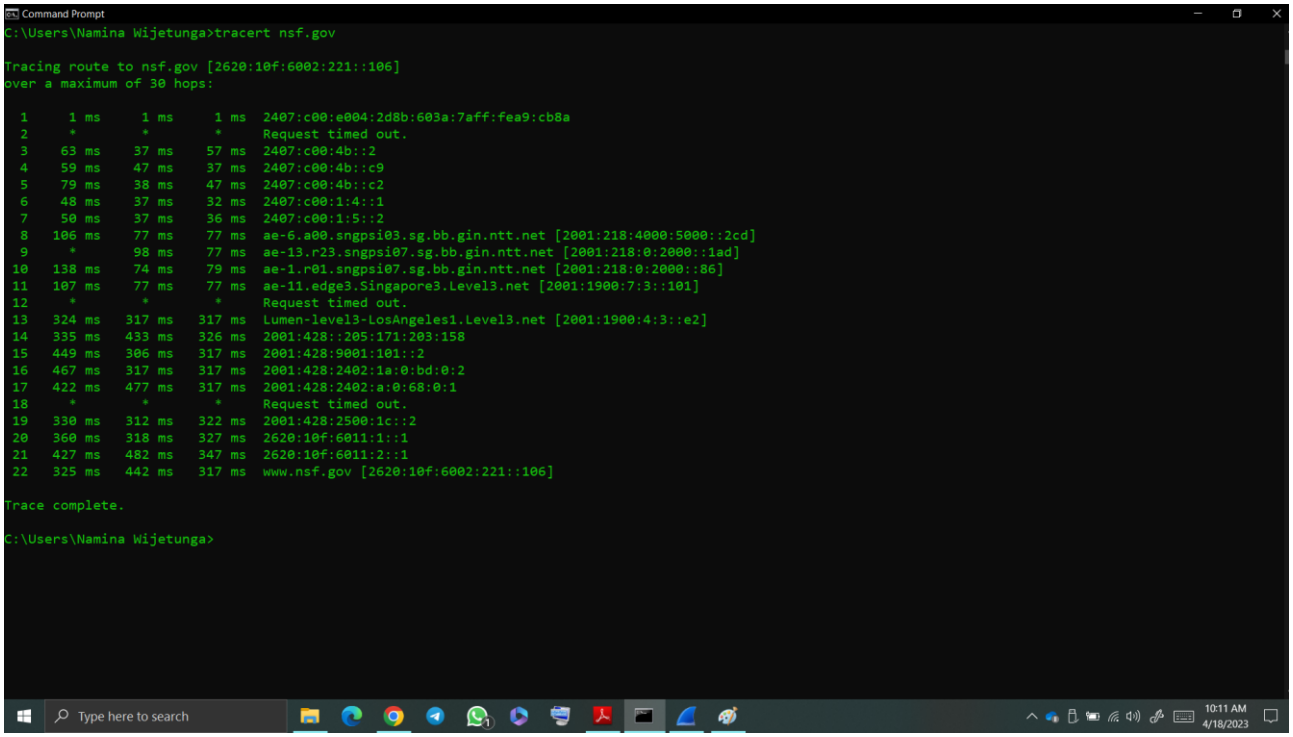
5. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
6. 2001:de8:4::3:8895:1 - Singapore - Equinix Japan
7. 2400:6500::24 - Singapore - Amazon Asia-Pacific Resources Private Limited
8. 2600:9000:fff:ff00::300 - Washington, USA - Amazon.com Inc.
9. 2600:9000:fff:ff01:0:50:111:31 - Washington, USA - Amazon.com Inc.
10. 2600:9000:fff:ff00::401 - Washington, USA - Amazon.com Inc.

11. 2600:9000:204c:7800:16:ce0d:a300:93a1 - Washington, USA - Amazon.com Inc.

- **nsf.gov**





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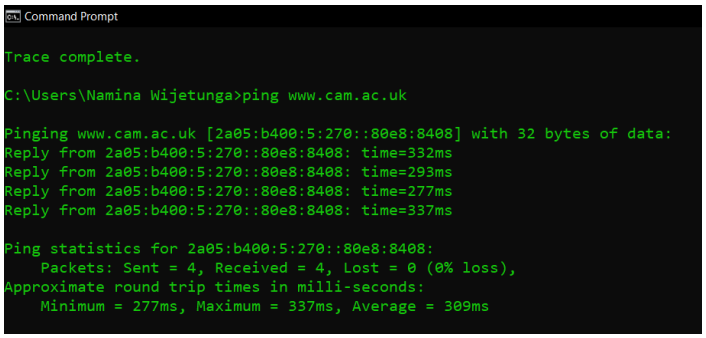
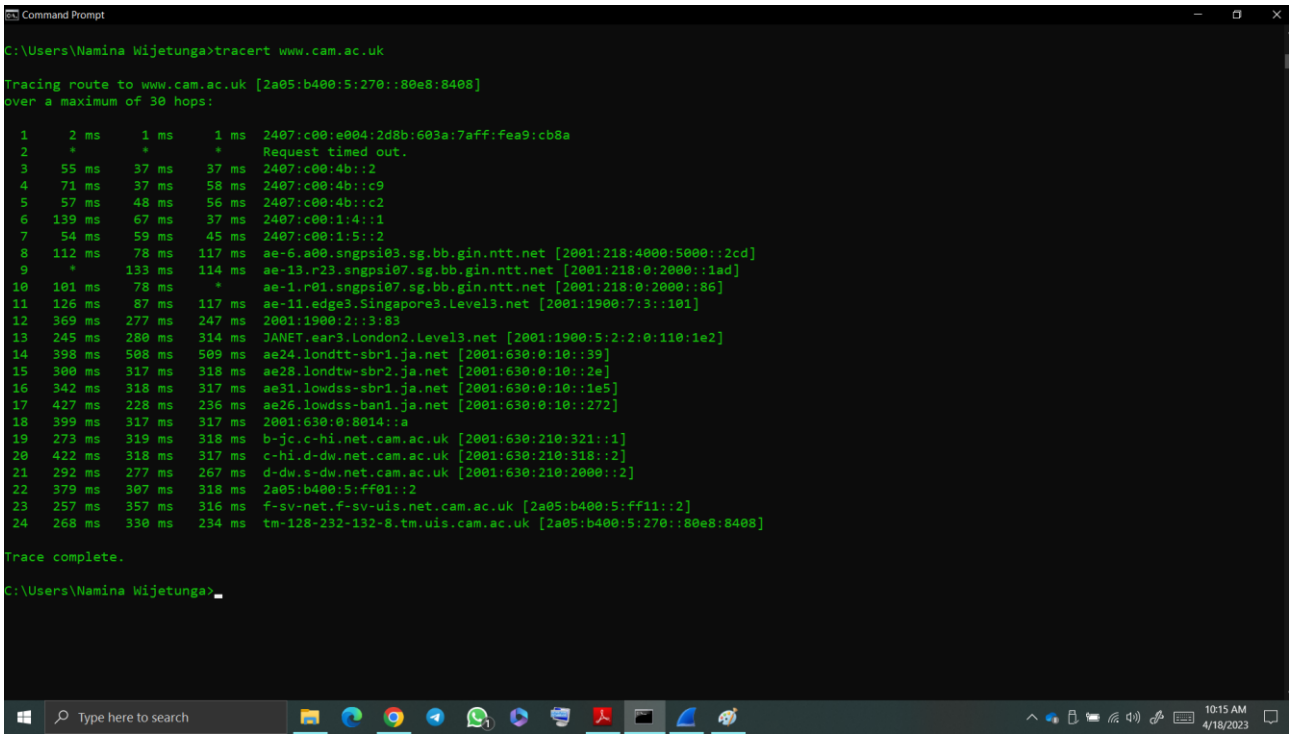
4. 2407:c00:4b::c2 - Colombo, Sri Lanka - Mobitel Pvt Ltd
5. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
6. 2407:c00:1:5::2 - Colombo, Sri Lanka - Mobitel Pvt Ltd
7. 2001:218:4000:5000::2cd - Tokyo, Japan - NTT Ltd Japan Corporation
8. 2001:218:0:2000::1ad - Tokyo, Japan - NTT Ltd Japan Corporation
9. 2001:218:0:2000::86 - Singapore - NTT Ltd Japan Corporation
10. 2001:1900:7:3::101 - California, USA - Level 3 Communications Inc.
11. 2001:1900:4:3::e2 - New York, USA - Level 3 Communications Inc

12. 2001:428::205:171:203:158 - California, USA - CenturyLink Communications LLC
13. 2001:428:9001:101::2 - Washington, USA - CenturyLink Communications LLC
14. 2001:428:2402:1a:0:bd:0:2 - Louisiana, USA - CenturyLink Communications LLC
15. 2001:428:2402:a:0:68:0:1 - Louisiana, USA - CenturyLink Communications LLC
16. 2001:428:2500:1c::2 - New York, USA - CenturyLink Communications LLC
17. 2620:10f:6011:1::1 - Virginia, USA - National Science Foundation
18. 2620:10f:6011:2::1 - Virginia, USA - National Science Foundation
19. 2620:10f:6002:221::106 - Virginia, USA - National Science Foundation

- **www.cam.ac.uk**





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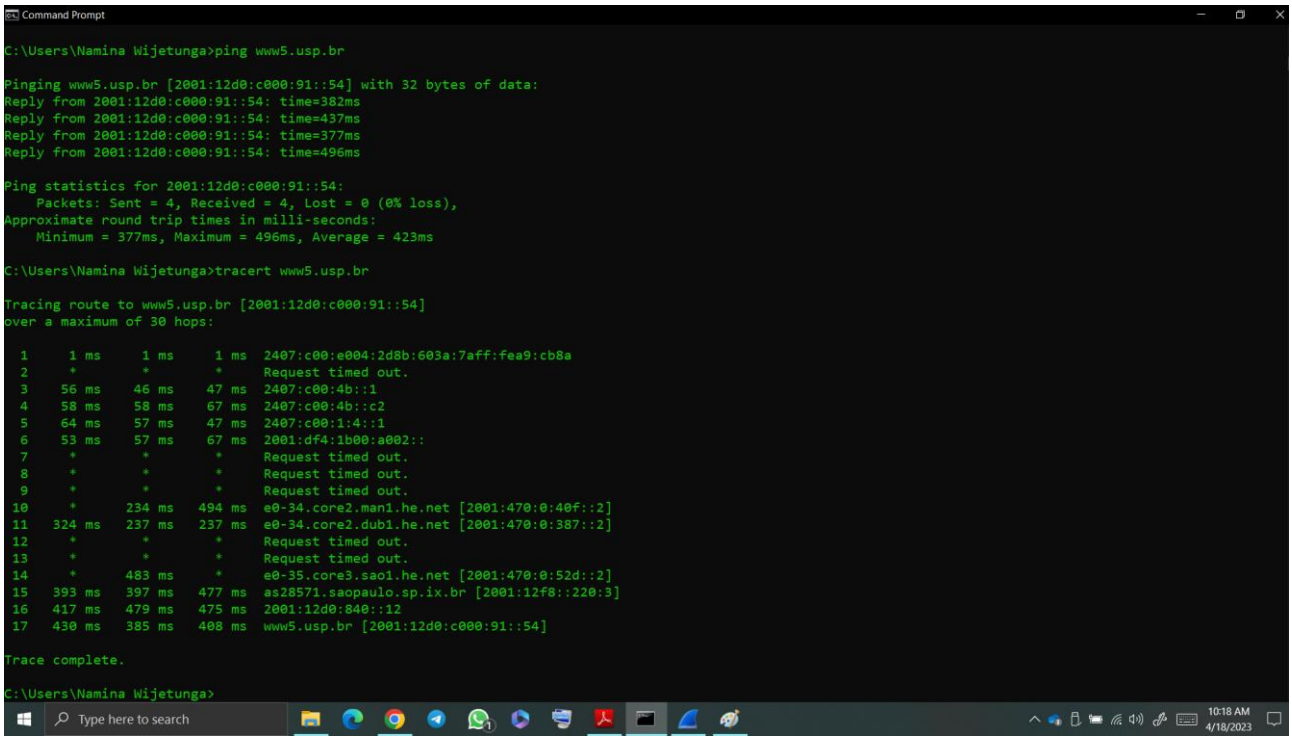
10. 2001:1900:7:3::101 - California, USA - Level 3 Communications Inc
11. 2001:1900:2::3:83 - California, USA - Level 3 Communications Inc
12. 2001:1900:5:2:2:0:110:1e2 - Louisiana, USA - Level 3 Communications Inc
13. 2001:630:0:10::39 - London, UK - JISC Services Limited
14. 2001:630:0:10::2e - London, UK - JISC Services Limited
15. 2001:630:0:10::1e5 - London, UK - JISC Services Limited
16. 2001:630:0:10::272 - London, UK - JISC Services Limited
17. 2001:630:0:8014::a - London, UK - JISC Services Limited
18. 2001:630:210:321::1 - Cambridge, UK - JISC Services Limited
19. 2001:630:210:318::2 - Cambridge, UK - JISC Services Limited
20. 2001:630:210:2000::2 - Cambridge, UK - JISC Services Limited
21. 2a05:b400:5:ff01::2 - Cambridge, UK - The Chancellor Masters & Scholars of the University of Cambridge
22. 2a05:b400:5:ff11::2 - Cambridge, UK - The Chancellor Masters & Scholars of the University of Cambridge
23. 2a05:b400:5:270::80e8:8408 - Cambridge, UK - The Chancellor Masters & Scholars of the University of Cambridge

- **www5.usp.br**



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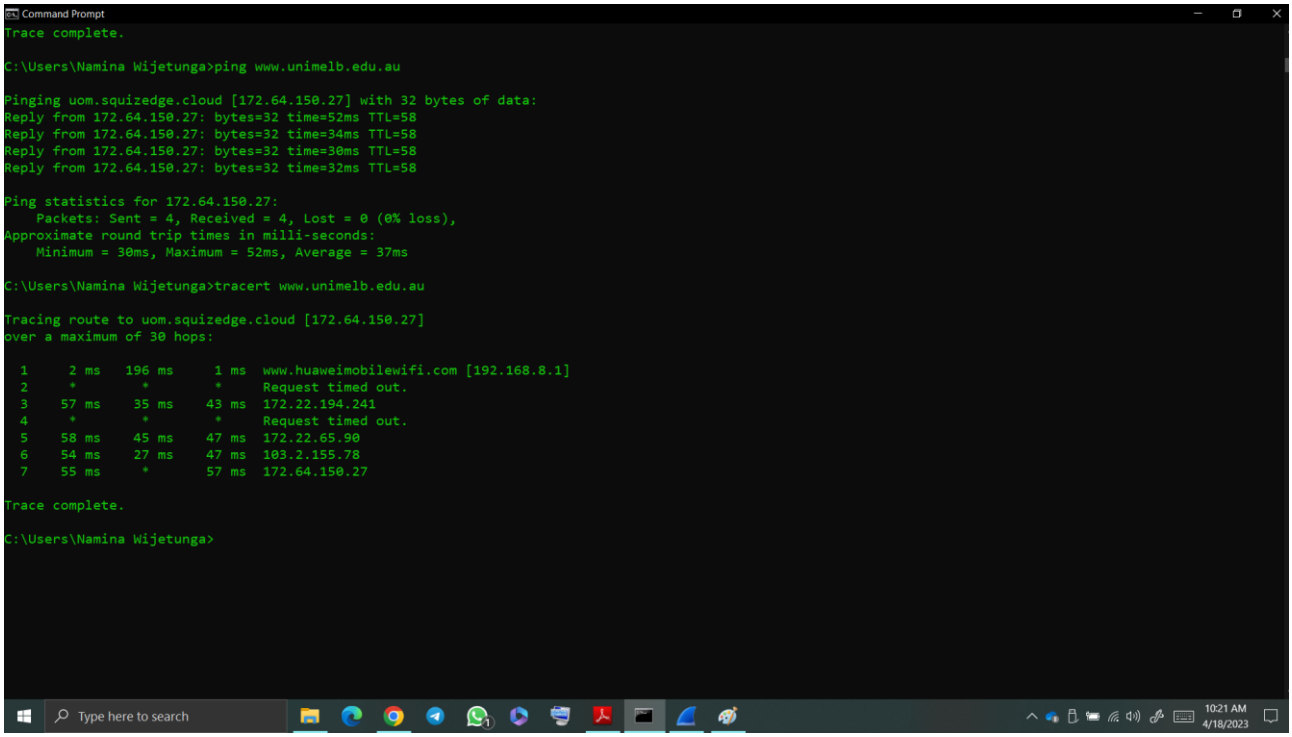
4. 2407:c00:1:4::1 - Colombo, Sri Lanka - Mobitel Pvt Ltd
5. 2001:df4:1b00:a002:: - Colombo, Sri Lanka - Sri Lanka Telecom PLC
6. 2001:470:0:40f::2 - California, USA - Hurricane Electric LLC
7. 2001:470:0:387::2 - California, USA - Hurricane Electric LLC
8. 2001:470:0:52d::2 - California, USA - Hurricane Electric LLC
9. 2001:12f8::220:3 - São Paulo, Brazil - Núcleo de Inf. e Coord. do Ponto BR - NIC.BR
10. 2001:12d0:840::12 - São Paulo, Brazil - Universidade De SAO Paulo
11. 2001:12d0:c000:91::54 - São Paulo, Brazil - Universidade De SAO Paulo

- **www.unimelb.edu.au**



Using the IP address geolocator,

1. 192.168.8.1
2. 172.22.194.241
3. 172.22.65.90
4. 103.2.155.78
5. 172.64.150.27

No information about the location could be obtained.

II. Analysing what happens during web page loading, ping and traceroute by observing the packet details in each of the Layers Within Wireshark captured packets

- Web page loading

  The protocols involved in loading a web page include HTTP (Hypertext Transfer Protocol), TCP (Transmission Control Protocol), and DNS (Domain Name System).

  The browser first needs to find the IP address of the web server hosting the website that want to access. It sends a DNS request to a DNS server to translate the domain name in the URL into an IP address.

  Once the browser has the IP address, it establishes a TCP connection with the web server. This involves a three-way handshake process where the browser and server exchange messages to confirm that they can communicate with each other. The browser then sends an HTTP request to the server asking for the web page content. The server responds with an HTTP response that includes the requested web page content.

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- Ping -

  When the ping packet is sent, it contains a header with information about the sender, recipient, and the packet itself. The recipient device receives the packet, processes it, and sends a response packet back to the sender, indicating that it has received the packet and how long it took to process.

- Traceroute -

  Traceroute program sends a series of packets with incrementally increasing time-to-live (TTL) values. The TTL value is decremented each time the packet passes through a router, and if the TTL reaches 0, the router drops the packet and sends an ICMP (Internet Control Message Protocol) error message back to the sender.
  It records the information from the ICMP messages and displays it in a table or graph, showing the path that the packets took from the source to the destination.

III. Why do you get "* * *" instead of IP addresses for some steps in traceroute?

  Explanation -

  This occurs when the network device that is responsible for the ongoing hop does not respond to the traceroute request. It can

happen due hardware issues of the network device, the network devices being too busy to respond, or the network device can be programmed so that the ICMP requests in can handle are limited. Therefore, some ICP requests can be dropped.

c) What does the PING indicate?

Explanation - PING indicates the connectivity between the sending and receiving devices of a network and determine the latency, or time delay, of the connection.

I. **Theoretical round trip time** to each from the current location

Theoretical Round Trip Time = $\frac{\text{Distance}}{\text{Speed of Light}}$ x 2

The location where the practical was conducted was Trincomalee, Sri Lanka. Assume that the speed of light in a vacuum is 299,792.458 km/s.

- **www.ruh.ac.lk**

  Approximate distance to University of Ruhuna from Trincomalee - 399 km

  Theoretical Round Trip Time - 2.6618 ms

- **www.uoregon.edu**

  Approximate distance to University of Oregon from Trincomalee - 15,414 km

  Theoretical Round Trip Time - 102.8311 ms

- **www.keio.ac.jp**

  Approximate distance to Keio University from Trincomalee - 5,945 km

  Theoretical Round Trip Time - 39.6608 ms

- **Japan.go.jp**

  Approximate distance to Tokyo from Trincomalee - 6,620 km

  Theoretical Round Trip Time - 44.1639 ms

- **nsf.gov**

  Approximate distance to National Science Foundation, Virginia from Trincomalee - 14,900 km

  Theoretical Round Trip Time - 99.4021 ms

- **www.cam.ac.uk**

  Approximate distance to University of Cambridge from Trincomalee - 9,385 km

  Theoretical Round Trip Time - 62.0998 ms

- **www5.usp.br**

  Approximate distance to University of San Paulo, Brazil from Trincomalee - 18,065 km

  Theoretical Round Trip Time - 120.5167 ms

- **www.unimelb.edu.au**

  Approximate distance to University of Melbourne from Trincomalee - 6,875 km

  Theoretical Round Trip Time - 45.8651 ms

II. Comparison of the Theoretical Round Trip Time and the measured Ping Time

	Theoretical round trip time (in milliseconds)	Measured average ping time (in milliseconds)
www.ruh.ac.lk	2.6618	Request timed out
www.uoregon.edu	102.8311	97
www.keio.ac.jp	39.6608	141
Japan.go.jp	44.1639	132
nsf.gov	99.4021	348
www.cam.ac.uk	62.0998	309
www5.usp.br	120.5167	423
www.unimelb.edu.au	45.8651	37

Explanation -

- The actual route travelled by the packets is not a straight line and they are undergoing so many processes on the way to the destination.
- More the number of devices they have to go through (Examples such as switches, routers) more processes will happen, and more processing delays will encounter.
- Additionally, the speed of light inside the fibre is less than the speed of light inside a vacuum which will take more time to reach the destination.

III. Can you identify sub-components that contribute to PING time?

- Quality of the ISP.
- Speed of the Internet connection.
- Firewall configuration.

- Geographical location.
- Bandwidth.

Question (2) - Why is bandwidth (throughput) important?

Explanation -

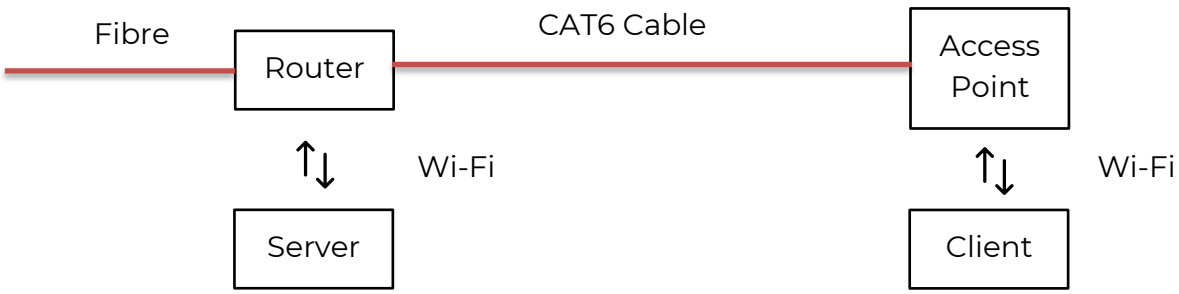
- Bandwidth is a measure of the amount of data that can be transmitted over a network in a given time period.
- Higher the bandwidth, more data can be transmitted, and it is important when multiple devices are trying to access the same Wi-Fi or Hotspot.
- It will reduce the latency which will reduce the response time for a given request.
- But increasing the bandwidth causes the cost of the network to increase as well.
- Therefore, it is important to manage the bandwidth when designing a efficient and a user friendly network.

<u>Performing iperf3 bandwidth test</u>

- **During Off-Peak Traffic Time**

  I. At Home

  - **Client & Server Connected to The Same Network**



IP Address - 192.168.1.8

IP Address - 192.168.4.240

```
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 192.168.1.7, port 6902
[  5] local 192.168.1.8 port 5201 connected to 192.168.1.7 port 6903
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  8.20 MBytes  68.8 Mbits/sec
[  5]   1.00-2.00   sec  8.79 MBytes  73.7 Mbits/sec
[  5]   2.00-3.00   sec  8.29 MBytes  69.5 Mbits/sec
[  5]   3.00-4.00   sec  7.56 MBytes  63.4 Mbits/sec
[  5]   4.00-5.00   sec  7.19 MBytes  60.3 Mbits/sec
[  5]   5.00-6.00   sec  7.92 MBytes  66.4 Mbits/sec
[  5]   6.00-7.00   sec  8.17 MBytes  68.5 Mbits/sec
[  5]   7.00-8.01   sec  7.91 MBytes  65.8 Mbits/sec
[  5]   8.01-9.00   sec  8.36 MBytes  70.7 Mbits/sec
[  5]   9.00-10.00  sec  8.49 MBytes  71.2 Mbits/sec
[  5]  10.00-10.07  sec   478 KBytes  60.2 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-10.07  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-10.07  sec  81.3 MBytes  67.8 Mbits/sec                receiver
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
```

Results at the Server

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3.exe -c 192.168.1.8
Connecting to host 192.168.1.8, port 5201
[  4] local 192.168.1.7 port 6903 connected to 192.168.1.8 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec  8.75 MBytes  73.1 Mbits/sec
[  4]   1.00-2.00   sec  8.75 MBytes  73.6 Mbits/sec
[  4]   2.00-3.01   sec  8.12 MBytes  67.8 Mbits/sec
[  4]   3.01-4.01   sec  7.62 MBytes  63.9 Mbits/sec
[  4]   4.01-5.00   sec  7.25 MBytes  61.2 Mbits/sec
[  4]   5.00-6.00   sec  7.88 MBytes  66.0 Mbits/sec
[  4]   6.00-7.01   sec  8.25 MBytes  68.8 Mbits/sec
[  4]   7.01-8.01   sec  7.88 MBytes  66.1 Mbits/sec
[  4]   8.01-9.00   sec  8.38 MBytes  70.6 Mbits/sec
[  4]   9.00-10.00  sec  8.50 MBytes  71.4 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.00  sec  81.4 MBytes  68.3 Mbits/sec                sender
[  4]   0.00-10.00  sec  81.3 MBytes  68.2 Mbits/sec                receiver

iperf Done.

C:\Users\Namina Wijetunga\Downloads\A>
```

Results at the Client

- **Public Servers**

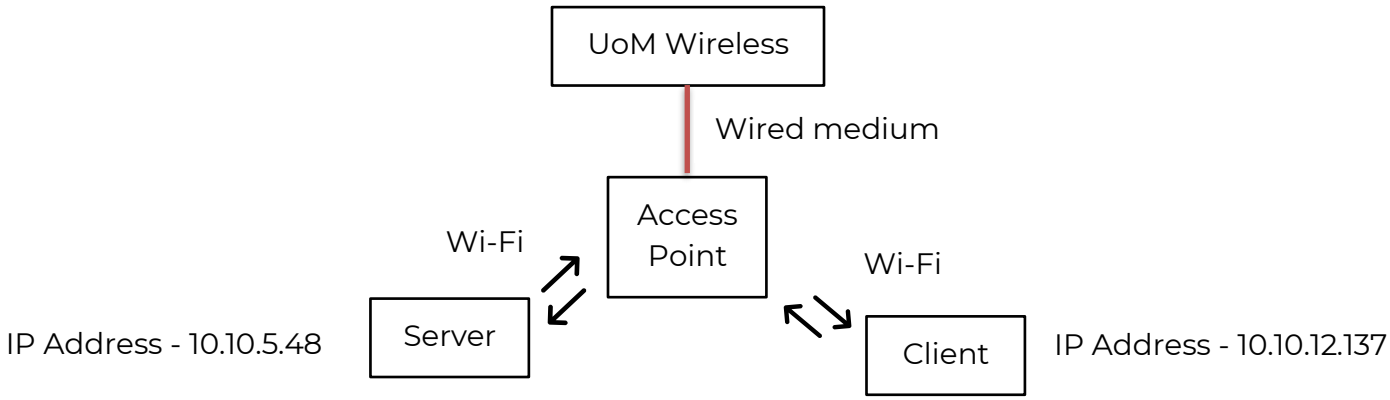
```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.astra.in.ua -p 5203
Connecting to host iperf.astra.in.ua, port 5203
[  4] local 192.168.4.240 port 11941 connected to 193.93.216.52 port 5203
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec   512 KBytes  4.20 Mbits/sec
[  4]   2.01-3.00   sec  1.00 MBytes  8.43 Mbits/sec
[  4]   3.00-4.01   sec   768 KBytes  6.25 Mbits/sec
[  4]   4.01-5.01   sec   640 KBytes  5.25 Mbits/sec
[  4]   5.01-6.01   sec   640 KBytes  5.24 Mbits/sec
[  4]   6.01-7.00   sec   512 KBytes  4.22 Mbits/sec
[  4]   7.00-8.01   sec   640 KBytes  5.18 Mbits/sec
[  4]   8.01-9.01   sec   640 KBytes  5.28 Mbits/sec
[  4]   9.01-10.01  sec   640 KBytes  5.24 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  6.12 MBytes  5.13 Mbits/sec                  sender
[  4]   0.00-10.01  sec  6.11 MBytes  5.13 Mbits/sec                  receiver

iperf Done.

C:\Users\Namina Wijetunga\Downloads\A>
```

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5203
Connecting to host iperf.biznetnetworks.com, port 5203
[  4] local 192.168.4.240 port 11850 connected to 117.102.109.186 port 5203
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   2.01-3.01   sec   640 KBytes  5.25 Mbits/sec
[  4]   3.01-4.00   sec   512 KBytes  4.20 Mbits/sec
[  4]   4.00-5.02   sec   384 KBytes  3.11 Mbits/sec
[  4]   5.02-6.01   sec   512 KBytes  4.22 Mbits/sec
[  4]   6.01-7.01   sec   640 KBytes  5.25 Mbits/sec
[  4]   7.01-8.01   sec   512 KBytes  4.19 Mbits/sec
[  4]   8.01-9.01   sec   512 KBytes  4.20 Mbits/sec
[  4]   9.01-10.01  sec   640 KBytes  5.24 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  4.75 MBytes  3.98 Mbits/sec                  sender
[  4]   0.00-10.01  sec  4.67 MBytes  3.92 Mbits/sec                  receiver

iperf Done.
```

```
Command Prompt
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c speedtest.uztelecom.uz -p 5203
Connecting to host speedtest.uztelecom.uz, port 5203
[  4] local 192.168.4.240 port 11906 connected to 195.69.189.215 port 5203
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   384 KBytes  3.13 Mbits/sec
[  4]   1.01-2.01   sec  1.00 MBytes  8.34 Mbits/sec
[  4]   2.01-3.01   sec  1.00 MBytes  8.39 Mbits/sec
[  4]   3.01-4.00   sec  1.12 MBytes  9.51 Mbits/sec
[  4]   4.00-5.00   sec   768 KBytes  6.30 Mbits/sec
[  4]   5.00-6.01   sec   256 KBytes  2.07 Mbits/sec
[  4]   6.01-7.01   sec   256 KBytes  2.11 Mbits/sec
[  4]   7.01-8.01   sec   128 KBytes  1.05 Mbits/sec
[  4]   8.01-9.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   9.00-10.00  sec   256 KBytes  2.10 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.00  sec  5.38 MBytes  4.51 Mbits/sec                  sender
[  4]   0.00-10.00  sec  5.27 MBytes  4.42 Mbits/sec                  receiver

iperf Done.
```

II. At University of Moratuwa

- **Client & Server Connected to The Same Network**




```
C:\Windows\System32\cmd.exe - iperf3.exe  -s
------------------------------------------------------------
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-10.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-10.04  sec  12.1 MBytes  10.1 Mbits/sec                  receiver
------------------------------------------------------------
Server listening on 5201
------------------------------------------------------------
Accepted connection from 10.10.12.137, port 12583
[  5] local 10.10.5.48 port 5201 connected to 10.10.12.137 port 12584
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.01   sec  3.26 MBytes  27.2 Mbits/sec
[  5]   1.01-2.01   sec  3.60 MBytes  30.2 Mbits/sec
[  5]   2.01-3.00   sec  2.10 MBytes  17.7 Mbits/sec
[  5]   3.00-4.01   sec  3.09 MBytes  25.8 Mbits/sec
[  5]   4.01-5.00   sec  3.53 MBytes  29.8 Mbits/sec
[  5]   5.00-6.00   sec  3.48 MBytes  29.1 Mbits/sec
[  5]   6.00-7.00   sec  4.00 MBytes  33.7 Mbits/sec
[  5]   7.00-8.00   sec  4.05 MBytes  34.0 Mbits/sec
[  5]   8.00-9.00   sec  3.45 MBytes  28.8 Mbits/sec
[  5]   9.00-10.00  sec  3.81 MBytes  32.0 Mbits/sec
[  5]  10.00-10.05  sec   133 KBytes  23.1 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-10.05  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-10.05  sec  34.5 MBytes  28.8 Mbits/sec                  receiver
------------------------------------------------------------
Server listening on 5201
------------------------------------------------------------
```

Results at the Server

```
Command Prompt
C:\Users\Namina Wijetunga\Downloads\A>iperf3.exe -c 10.10.5.48
Connecting to host 10.10.5.48, port 5201
[  4] local 10.10.12.137 port 12584 connected to 10.10.5.48 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec  3.50 MBytes  29.3 Mbits/sec
[  4]   1.00-2.01   sec  3.50 MBytes  29.3 Mbits/sec
[  4]   2.01-3.00   sec  2.25 MBytes  18.9 Mbits/sec
[  4]   3.00-4.01   sec  3.00 MBytes  25.1 Mbits/sec
[  4]   4.01-5.01   sec  3.62 MBytes  30.4 Mbits/sec
[  4]   5.01-6.01   sec  3.50 MBytes  29.3 Mbits/sec
[  4]   6.01-7.00   sec  3.88 MBytes  32.8 Mbits/sec
[  4]   7.00-8.00   sec  4.12 MBytes  34.6 Mbits/sec
[  4]   8.00-9.00   sec  3.38 MBytes  28.3 Mbits/sec
[  4]   9.00-10.01  sec  3.75 MBytes  31.3 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  34.5 MBytes  28.9 Mbits/sec                  sender
[  4]   0.00-10.01  sec  34.5 MBytes  28.9 Mbits/sec                  receiver

iperf Done.

C:\Users\Namina Wijetunga\Downloads\A>0
```

Results at the Client

- **Public Servers**

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.astra.in.ua -p 5202
Connecting to host iperf.astra.in.ua, port 5202
[  4] local 2401:dd00:10:20:c08b:ea52:6a5e:9755 port 4673 connected to 2a10:2f40:1::aa port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.09 Mbits/sec
[  4]   1.01-2.00   sec   128 KBytes  1.05 Mbits/sec
[  4]   2.00-3.02   sec   384 KBytes  3.10 Mbits/sec
[  4]   3.02-4.00   sec   640 KBytes  5.32 Mbits/sec
[  4]   4.00-5.01   sec   640 KBytes  5.20 Mbits/sec
[  4]   5.01-6.00   sec   768 KBytes  6.33 Mbits/sec
[  4]   6.00-7.01   sec   768 KBytes  6.22 Mbits/sec
[  4]   7.01-8.01   sec   512 KBytes  4.21 Mbits/sec
[  4]   8.01-9.00   sec   512 KBytes  4.22 Mbits/sec
[  4]   9.00-10.00  sec   384 KBytes  3.16 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.00  sec  4.88 MBytes  4.09 Mbits/sec                  sender
[  4]   0.00-10.00  sec  4.87 MBytes  4.09 Mbits/sec                  receiver

iperf Done.

C:\Users\Namina Wijetunga\Downloads\A>
```

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c speedtest.uztelecom.uz -p 5202
Connecting to host speedtest.uztelecom.uz, port 5202
[  4] local 2401:dd00:10:20:c08b:ea52:6a5e:9755 port 4653 connected to 2a05:45c7:f000:100::215 port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec   512 KBytes  4.21 Mbits/sec
[  4]   2.01-3.01   sec   896 KBytes  7.30 Mbits/sec
[  4]   3.01-4.01   sec   640 KBytes  5.27 Mbits/sec
[  4]   4.01-5.00   sec   896 KBytes  7.37 Mbits/sec
[  4]   5.00-6.00   sec   512 KBytes  4.20 Mbits/sec
[  4]   6.00-7.01   sec   768 KBytes  6.23 Mbits/sec
[  4]   7.01-8.00   sec   896 KBytes  7.39 Mbits/sec
[  4]   8.00-9.01   sec   768 KBytes  6.25 Mbits/sec
[  4]   9.01-10.01  sec   640 KBytes  5.26 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  6.62 MBytes  5.55 Mbits/sec                  sender
[  4]   0.00-10.01  sec  6.62 MBytes  5.55 Mbits/sec                  receiver

iperf Done.
```

- **During Peak Traffic Time**

I. At Home

▪ Client & Server Connected to The Same Network

Command Prompt - iperf3.exe -s

```
C:\Users\Asus\Downloads\A>iperf3.exe -s
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 192.168.1.7, port 6896
[  5] local 192.168.1.8 port 5201 connected to 192.168.1.7 port 6897
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  4.89 MBytes  41.1 Mbits/sec
[  5]   1.00-2.00   sec  6.09 MBytes  51.0 Mbits/sec
[  5]   2.00-3.00   sec  7.26 MBytes  61.0 Mbits/sec
[  5]   3.00-4.00   sec  8.08 MBytes  67.8 Mbits/sec
[  5]   4.00-5.00   sec  8.55 MBytes  71.7 Mbits/sec
[  5]   5.00-6.00   sec  8.54 MBytes  71.6 Mbits/sec
[  5]   6.00-7.00   sec  8.25 MBytes  69.3 Mbits/sec
[  5]   7.00-8.00   sec  8.09 MBytes  67.7 Mbits/sec
[  5]   8.00-9.00   sec  8.39 MBytes  70.3 Mbits/sec
[  5]   9.00-10.00  sec  8.37 MBytes  70.4 Mbits/sec
[  5]  10.00-10.04  sec   364 KBytes  69.1 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-10.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-10.04  sec  76.9 MBytes  64.2 Mbits/sec                receiver
-----------------------------------------------------------
```

Results at the Server

Command Prompt

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3.exe -c 192.168.1.8
Connecting to host 192.168.1.8, port 5201
[  4] local 192.168.1.7 port 6897 connected to 192.168.1.8 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec  5.12 MBytes  42.6 Mbits/sec
[  4]   1.01-2.01   sec  6.25 MBytes  52.7 Mbits/sec
[  4]   2.01-3.01   sec  7.25 MBytes  60.8 Mbits/sec
[  4]   3.01-4.01   sec  8.00 MBytes  67.1 Mbits/sec
[  4]   4.01-5.01   sec  8.50 MBytes  71.3 Mbits/sec
[  4]   5.01-6.00   sec  8.62 MBytes  72.6 Mbits/sec
[  4]   6.00-7.00   sec  8.25 MBytes  69.5 Mbits/sec
[  4]   7.00-8.01   sec  8.00 MBytes  66.6 Mbits/sec
[  4]   8.01-9.01   sec  8.38 MBytes  70.3 Mbits/sec
[  4]   9.01-10.00  sec  8.50 MBytes  71.7 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.00  sec  76.9 MBytes  64.5 Mbits/sec                  sender
[  4]   0.00-10.00  sec  76.9 MBytes  64.5 Mbits/sec                  receiver

iperf Done.
```

Results at the Client

▪ Public Servers

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.astra.in.ua -p 5202
Connecting to host iperf.astra.in.ua, port 5202
[  4] local 192.168.4.240 port 7208 connected to 193.93.216.52 port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   2.01-3.01   sec   640 KBytes  5.22 Mbits/sec
[  4]   3.01-4.00   sec   512 KBytes  4.23 Mbits/sec
[  4]   4.00-5.00   sec   640 KBytes  5.26 Mbits/sec
[  4]   5.00-6.01   sec   640 KBytes  5.19 Mbits/sec
[  4]   6.01-7.01   sec   384 KBytes  3.16 Mbits/sec
[  4]   7.01-8.01   sec   512 KBytes  4.20 Mbits/sec
[  4]   8.01-9.00   sec   512 KBytes  4.21 Mbits/sec
[  4]   9.00-10.01  sec   512 KBytes  4.15 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  4.75 MBytes  3.98 Mbits/sec                  sender
[  4]   0.00-10.01  sec  4.72 MBytes  3.96 Mbits/sec                  receiver

iperf Done.
```

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5202
Connecting to host iperf.biznetnetworks.com, port 5202
[  4] local 192.168.4.240 port 7096 connected to 117.102.109.186 port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   1.00-2.01   sec   128 KBytes  1.04 Mbits/sec
[  4]   2.01-3.01   sec   256 KBytes  2.09 Mbits/sec
[  4]   3.01-4.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   4.01-5.01   sec   384 KBytes  3.14 Mbits/sec
[  4]   5.01-6.00   sec   256 KBytes  2.12 Mbits/sec
[  4]   6.00-7.01   sec   128 KBytes  1.04 Mbits/sec
[  4]   7.01-8.01   sec   384 KBytes  3.12 Mbits/sec
[  4]   8.01-9.00   sec   128 KBytes  1.06 Mbits/sec
[  4]   9.00-10.01  sec   256 KBytes  2.07 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  2.38 MBytes  1.99 Mbits/sec                  sender
[  4]   0.00-10.01  sec  2.18 MBytes  1.83 Mbits/sec                  receiver

iperf Done.
```

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c speedtest.uztelecom.uz -p 5202
iperf3: error - the server is busy running a test. try again later

C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c speedtest.uztelecom.uz -p 5202
Connecting to host speedtest.uztelecom.uz, port 5202
[  4] local 192.168.4.240 port 7306 connected to 195.69.189.215 port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.07 Mbits/sec
[  4]   1.01-2.00   sec   640 KBytes  5.29 Mbits/sec
[  4]   2.00-3.01   sec   896 KBytes  7.27 Mbits/sec
[  4]   3.01-4.01   sec   640 KBytes  5.23 Mbits/sec
[  4]   4.01-5.00   sec   768 KBytes  6.34 Mbits/sec
[  4]   5.00-6.00   sec   640 KBytes  5.25 Mbits/sec
[  4]   6.00-7.00   sec   384 KBytes  3.15 Mbits/sec
[  4]   7.00-8.00   sec   512 KBytes  4.20 Mbits/sec
[  4]   8.00-9.01   sec   384 KBytes  3.10 Mbits/sec
[  4]   9.01-10.01  sec   512 KBytes  4.20 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  5.50 MBytes  4.61 Mbits/sec                  sender
[  4]   0.00-10.01  sec  5.44 MBytes  4.56 Mbits/sec                  receiver

iperf Done.
```

II. At University of Moratuwa

- **Client & Server Connected to The Same Network**

```
C:\Windows\System32\cmd.exe - iperf3.exe  -s
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 10.10.12.137, port 11327
[  5] local 10.10.5.48 port 5201 connected to 10.10.12.137 port 11328
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec   190 KBytes  1.55 Mbits/sec
[  5]   1.00-2.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   2.01-3.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   3.01-4.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   4.01-5.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   5.01-6.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   6.01-7.01   sec  0.00 Bytes  0.00 bits/sec
[  5]   7.01-8.01   sec   200 KBytes  1.64 Mbits/sec
[  5]   8.01-9.00   sec  0.00 Bytes  0.00 bits/sec
[  5]   9.00-10.01  sec  0.00 Bytes  0.00 bits/sec
[  5]  10.01-11.01  sec  0.00 Bytes  0.00 bits/sec
[  5]  11.01-12.00  sec  0.00 Bytes  0.00 bits/sec
[  5]  12.00-12.45  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-12.45  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-12.45  sec   390 KBytes   257 Kbits/sec                  receiver
-----------------------------------------------------------
```

Results at the Client

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3.exe -c 10.10.5.48
Connecting to host 10.10.5.48, port 5201
[  4] local 10.10.12.137 port 11328 connected to 10.10.5.48 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   384 KBytes  3.12 Mbits/sec
[  4]   1.01-2.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   2.01-3.00   sec  0.00 Bytes  0.00 bits/sec
[  4]   3.00-4.00   sec  0.00 Bytes  0.00 bits/sec
[  4]   4.00-5.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   5.01-6.00   sec  0.00 Bytes  0.00 bits/sec
[  4]   6.00-7.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   7.01-8.00   sec   256 KBytes  2.11 Mbits/sec
[  4]   8.00-9.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   9.01-10.00  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.00  sec   640 KBytes   524 Kbits/sec                  sender
[  4]   0.00-10.00  sec   390 KBytes   319 Kbits/sec                  receiver
```

Results at the Server

- **Public Servers**

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c speedtest.uztelecom.uz -p 5202
Connecting to host speedtest.uztelecom.uz, port 5202
[  4] local 2401:dd00:10:20:cdab:ea2b:1d81:580d port 13668 connected to 2a05:45c7:f000:100::215 port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec   256 KBytes  2.09 Mbits/sec
[  4]   1.00-2.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   2.01-3.00   sec  0.00 Bytes  0.00 bits/sec
[  4]   3.00-4.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   4.01-5.00   sec  0.00 Bytes  0.00 bits/sec
[  4]   5.00-6.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   6.01-7.00   sec   512 KBytes  4.24 Mbits/sec
[  4]   7.00-8.01   sec   128 KBytes  1.04 Mbits/sec
[  4]   8.01-9.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   9.01-10.01  sec   256 KBytes  2.09 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.01  sec  1.12 MBytes   943 Kbits/sec                  sender
[  4]   0.00-10.01  sec  1.12 MBytes   943 Kbits/sec                  receiver

iperf Done.
```

```
C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.astra.in.ua -p 5202
Connecting to host iperf.astra.in.ua, port 5202
[  4] local 2401:dd00:10:20:cdab:ea2b:1d81:580d port 13716 connected to 2a10:2f40:1::aa port 5202
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   2.01-3.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   3.01-4.01   sec  0.00 Bytes  0.00 bits/sec
[  4]   4.01-5.00   sec   128 KBytes  1.06 Mbits/sec
[  4]   5.00-6.01   sec   256 KBytes  2.07 Mbits/sec
[  4]   6.01-7.00   sec   512 KBytes  4.23 Mbits/sec
[  4]   7.00-8.01   sec   640 KBytes  5.20 Mbits/sec
[  4]   8.01-9.01   sec   640 KBytes  5.24 Mbits/sec
[  4]   9.01-10.02  sec   640 KBytes  5.23 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-10.02  sec  3.00 MBytes  2.51 Mbits/sec                  sender
[  4]   0.00-10.02  sec  3.00 MBytes  2.51 Mbits/sec                  receiver

iperf Done.
```

```
Command Prompt
  -T, --title str           prefix every output line with this string
  --get-server-output       get results from server
  --udp-counters-64bit      use 64-bit counters in UDP test packets

[KMG] indicates options that support a K/M/G suffix for kilo-, mega-, or giga-

iperf3 homepage at: http://software.es.net/iperf/
Report bugs to:     https://github.com/esnet/iperf

C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5202
iperf3: error - unable to connect to server: Connection timed out

C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5203
iperf3: error - unable to connect to server: Connection timed out

C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5203
iperf3: error - unable to connect to server: Connection timed out

C:\Users\Namina Wijetunga\Downloads\A>iperf3 -c iperf.biznetnetworks.com -p 5202
iperf3: error - unable to connect to server: Connection timed out
```

Observations and Comments:

- The bandwidth of the client and server which are connected to the same network is higher than the bandwidth of the public server and the remote client.
- The bandwidth during the peak traffic time is much lesser than the bandwidth during the off-peak traffic time.
- When connected to the network at University of Moratuwa during the peak traffic time, for some public servers, the connection timed out which the reason being too many users in the network trying to access the network at same time.

Question (3) - Why is latency important?

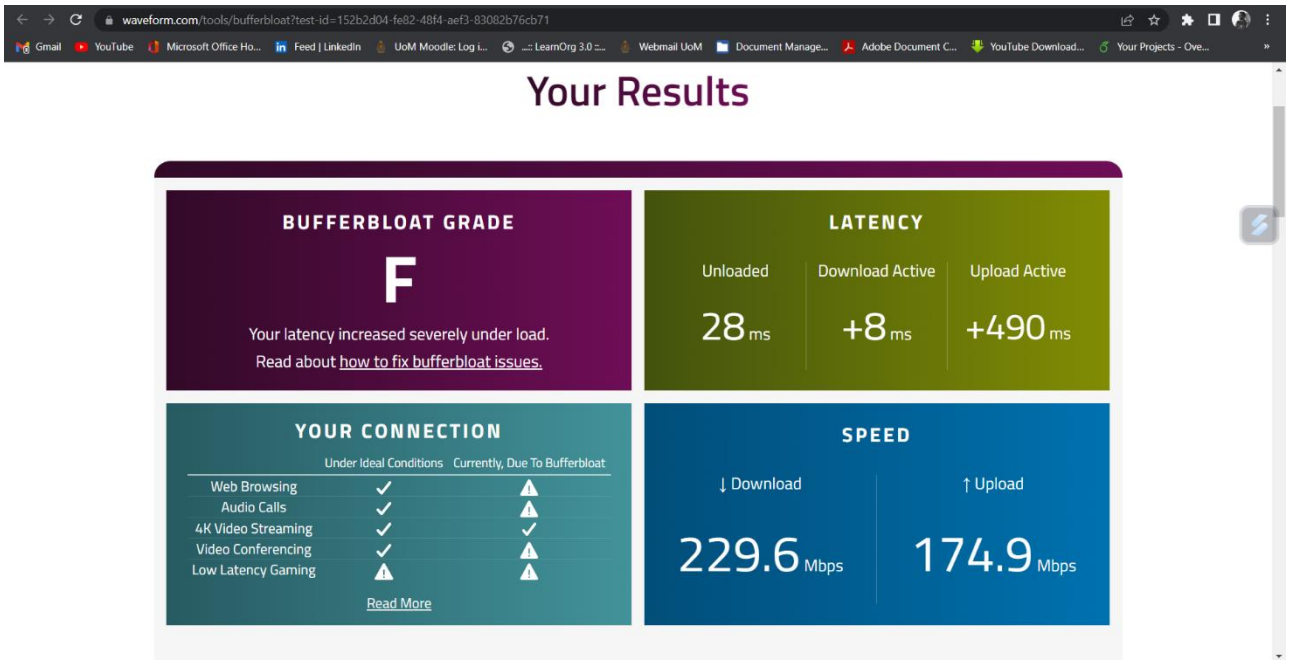
Explanation -

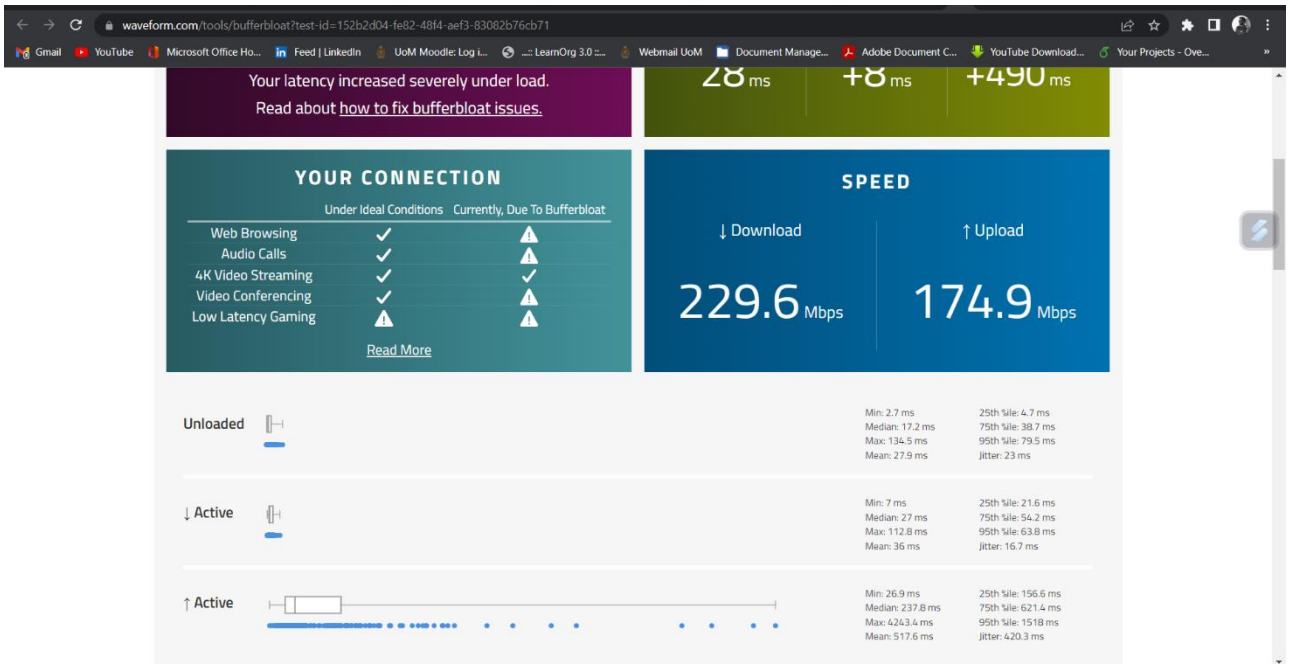
- User experience: In applications that require real-time interaction, such as online gaming or video conferencing, even small amounts of latency can have a noticeable impact on the user experience. Latency can cause delays in voice or video transmission, making conversations or gameplay feel sluggish or unresponsive.
- Network performance: Latency can also affect the overall performance of a network. High latency can lead to slow data transfer rates, packet loss, and network congestion, which can impact the ability of users to access and use network resources.
- Financial transactions: In financial applications, such as trading platforms, even a small delay in data transmission can have significant financial consequences. Latency can impact the accuracy of stock prices and transaction times, which can result in lost profits or other financial impacts.
- Cloud computing: Many cloud-based applications and services rely on low-latency network connections to provide fast and responsive performance. High latency can impact the performance of these applications and make them feel slow or unresponsive.
- SEO: Latency also plays a role in website search engine optimization (SEO). Search engines such as Google consider website speed and responsiveness as part of their ranking algorithms, which means that websites with lower latency are likely to perform better in search results.

Performing Bufferbloat latency test,

- **During Off-Peak Traffic Time**

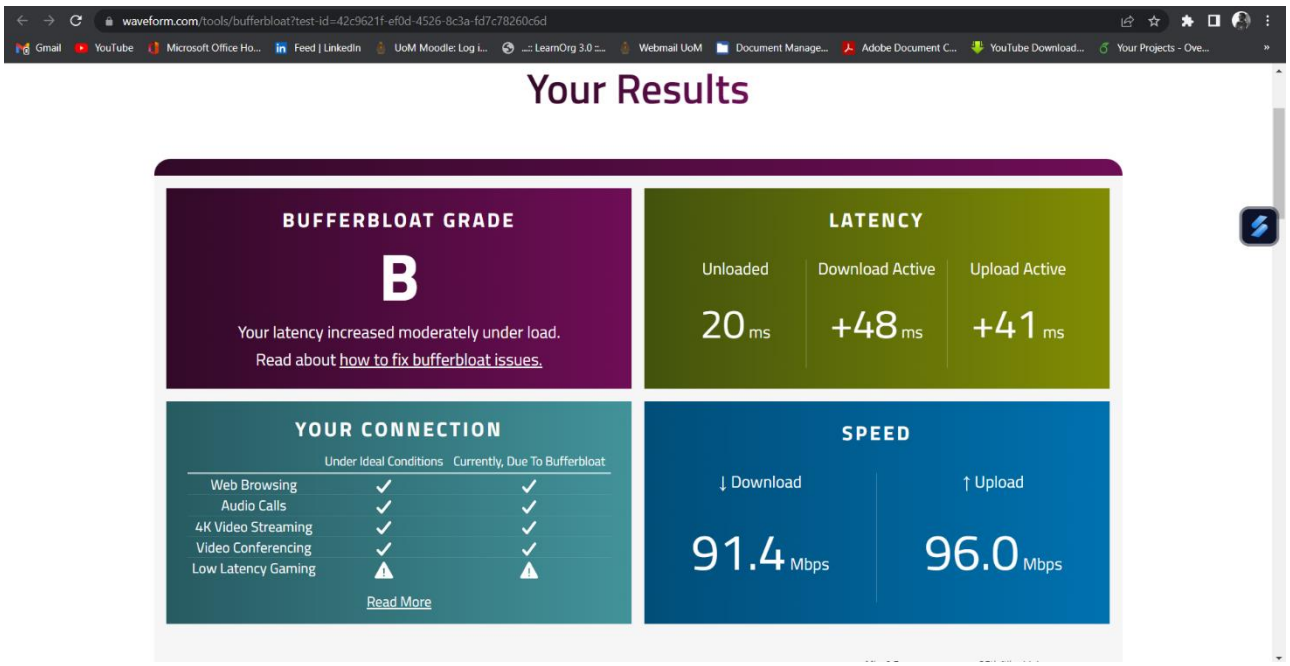
  I. At University of Moratuwa

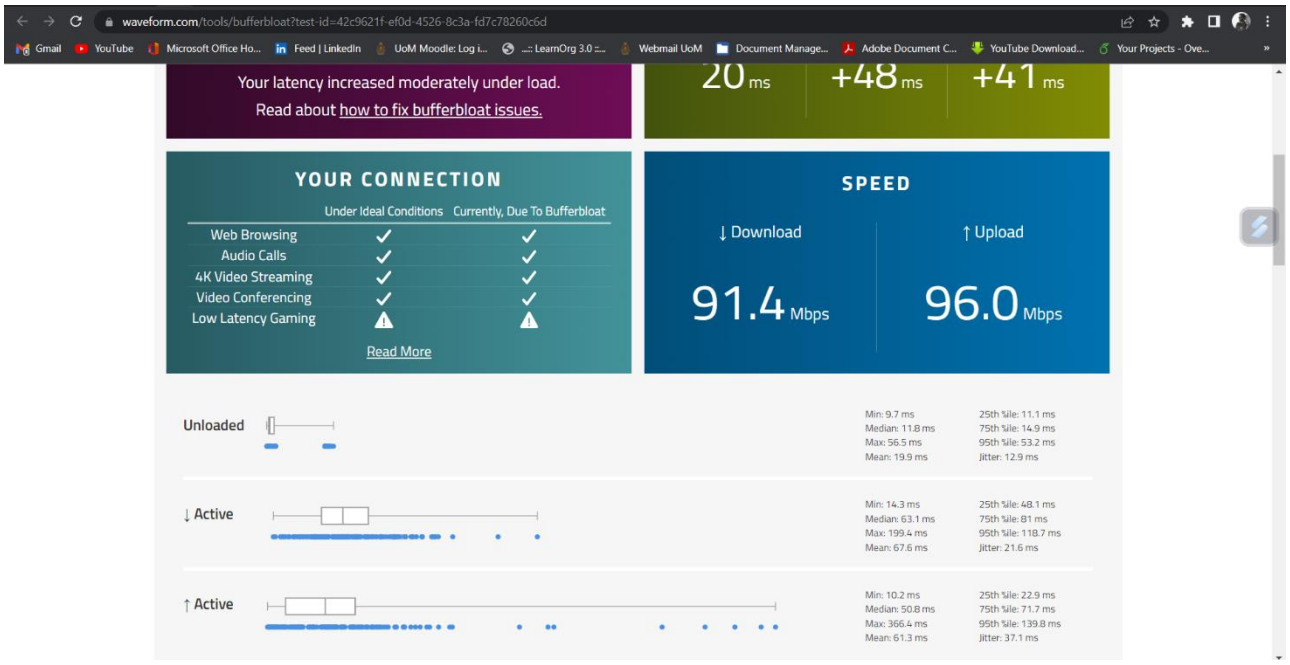




https://www.waveform.com/tools/bufferbloat?test-id=152b2d04-fe82-48f4-aef3-83082b76cb71

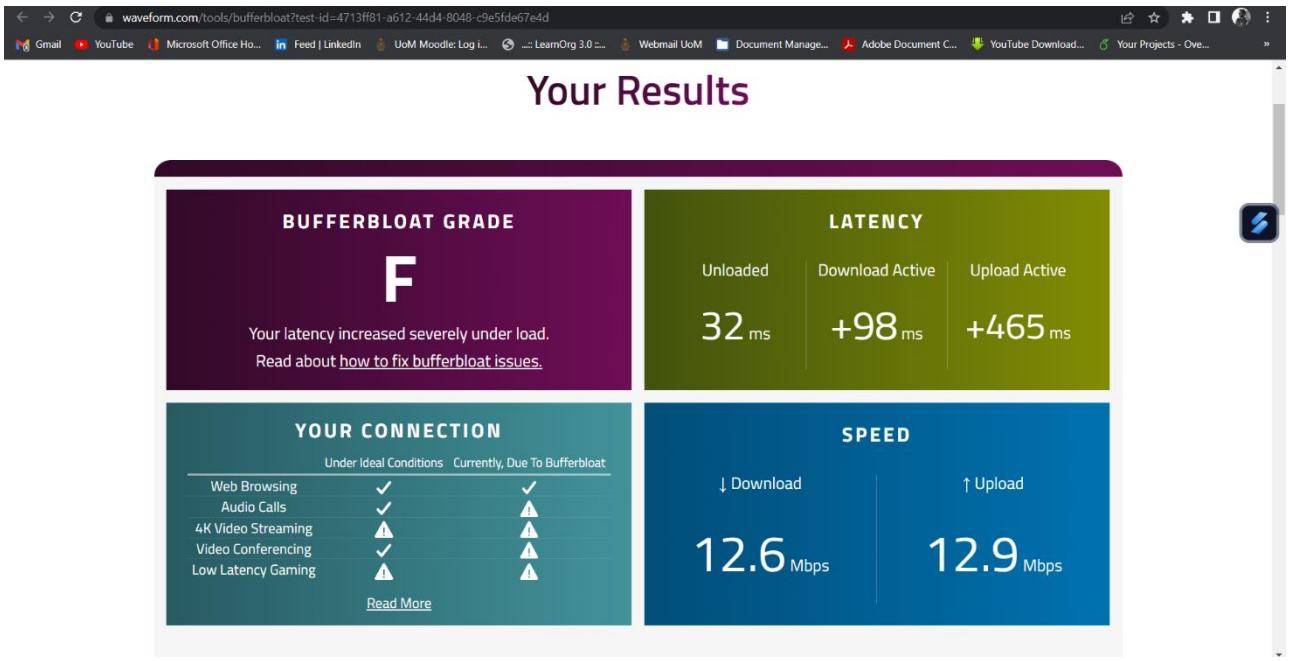
II. At Home Using Wi-Fi

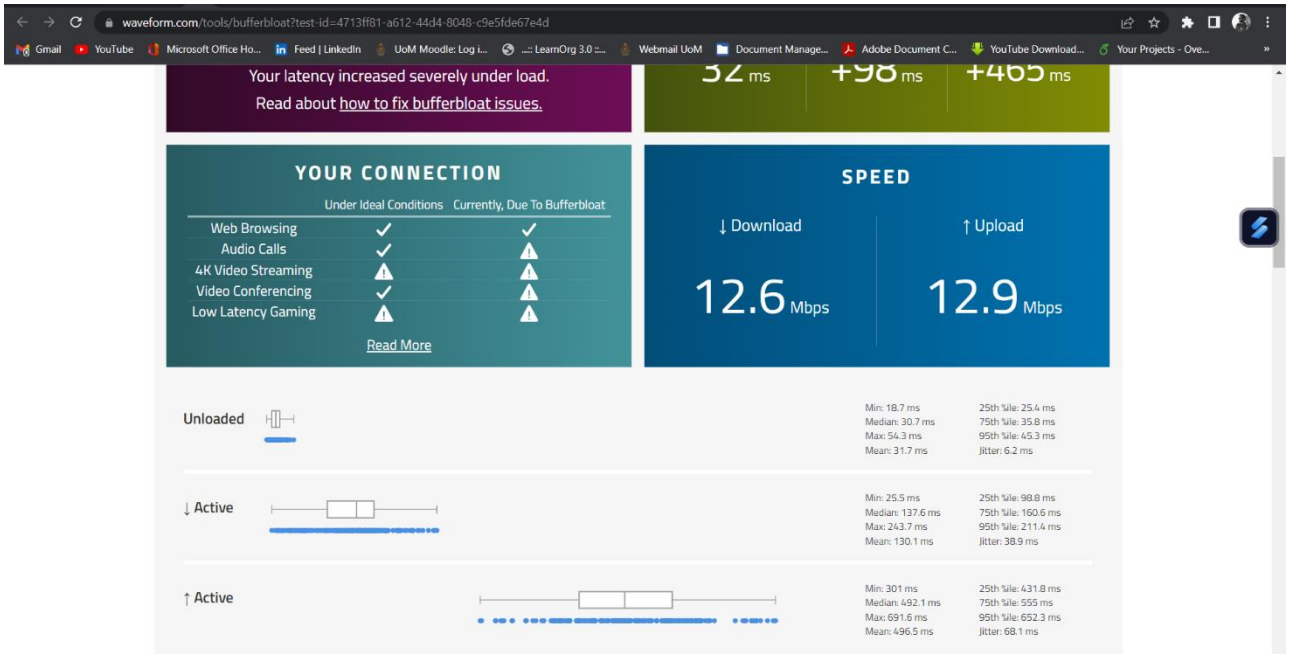




https://www.waveform.com/tools/bufferbloat?test-id=42c9621f-ef0d-4526-8c3a-fd7c78260c6d

III. At Home Using Cellular Data

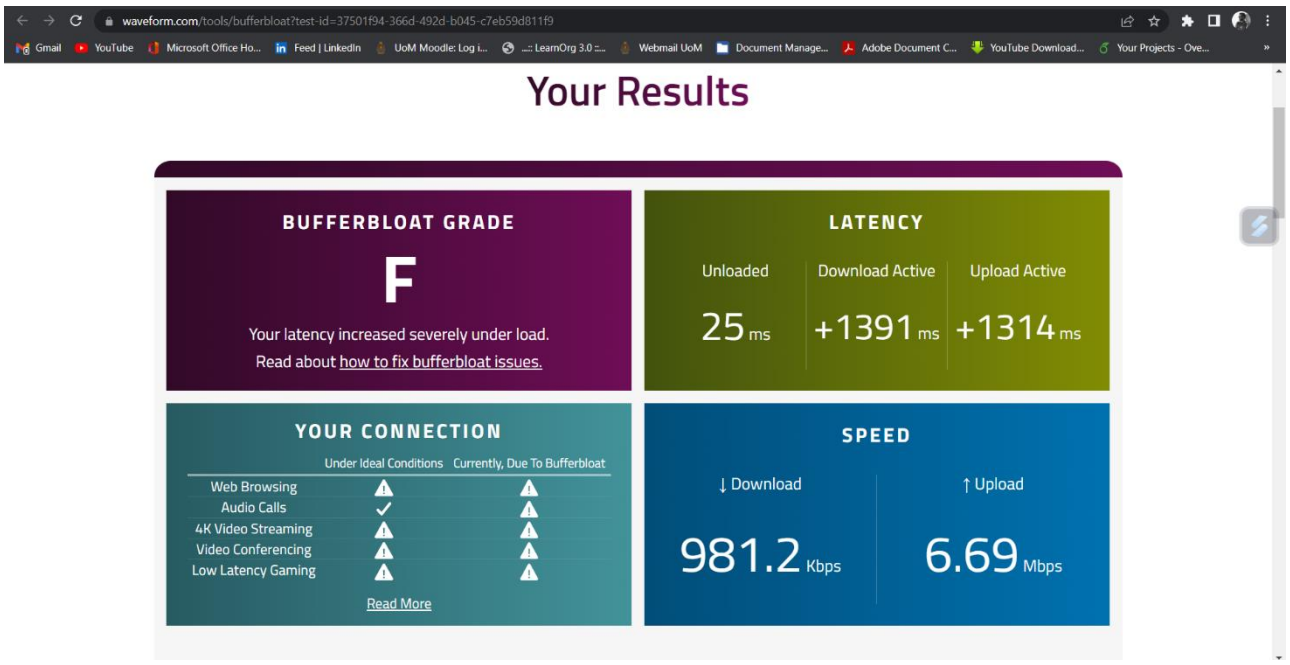


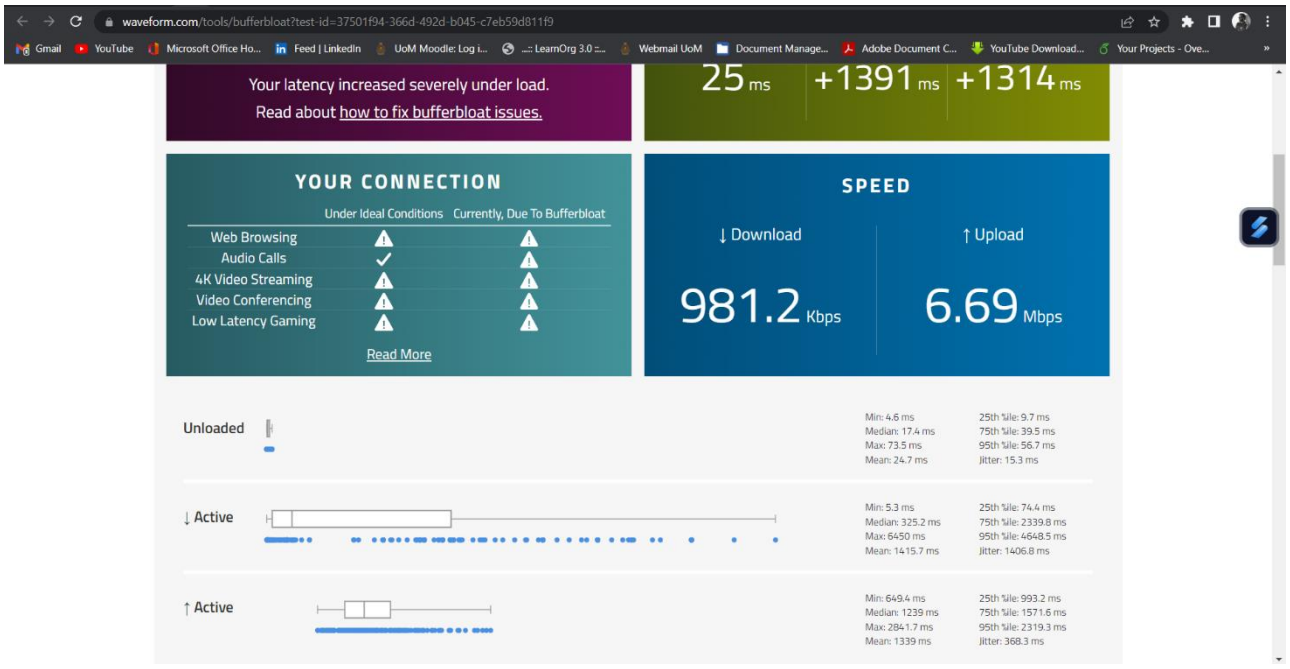


https://www.waveform.com/tools/bufferbloat?test-id=4713ff81-a612-44d4-8048-c9e5fde67e4d

- **During Peak Traffic Time**

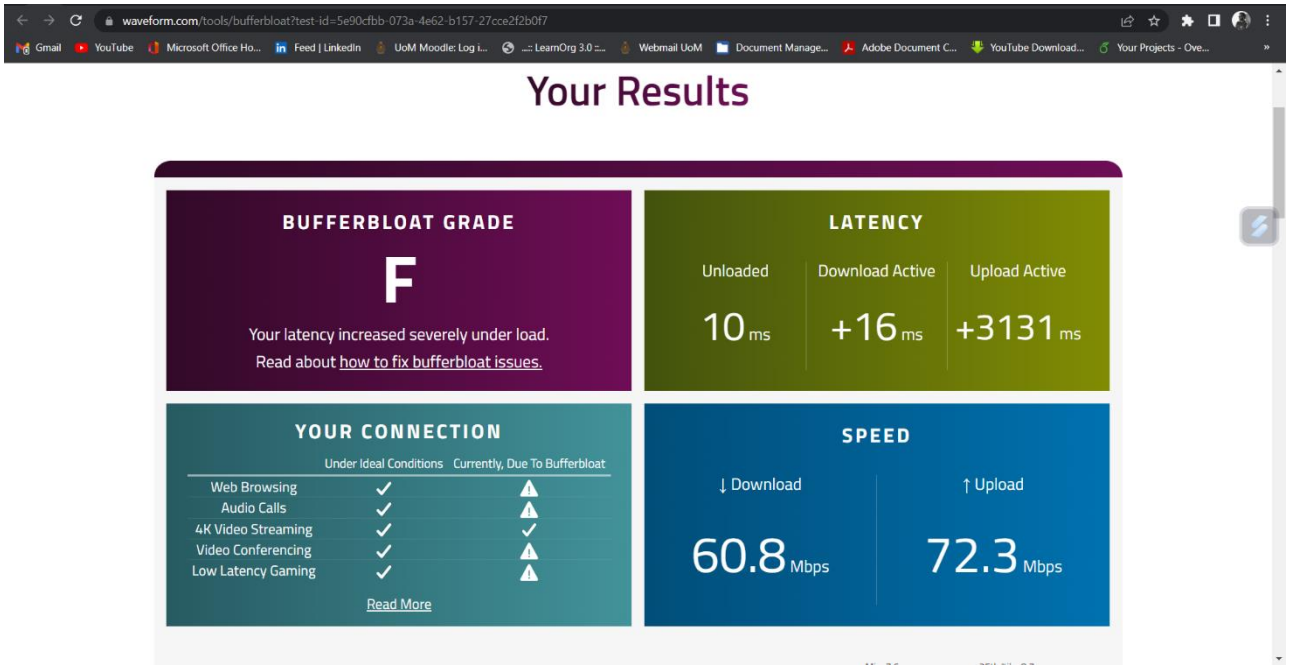
    I. **At University of Moratuwa**

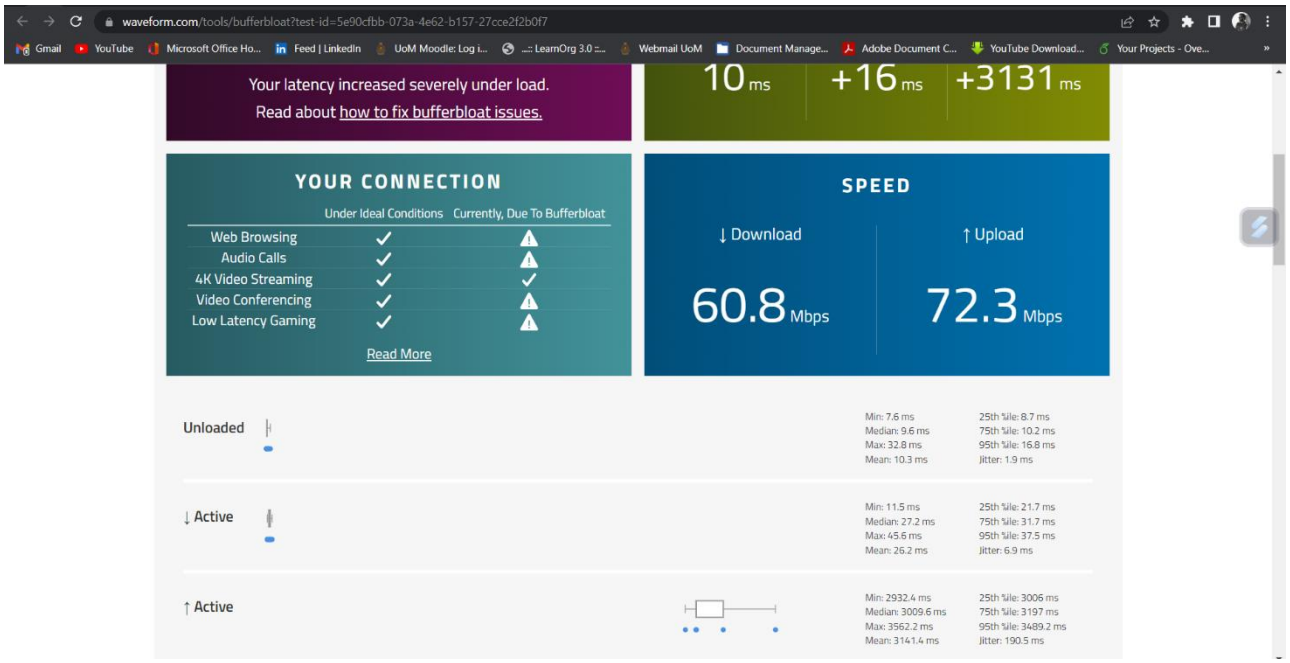




https://www.waveform.com/tools/bufferbloat?test-id=37501f94-366d-492d-b045-c7eb59d811f9

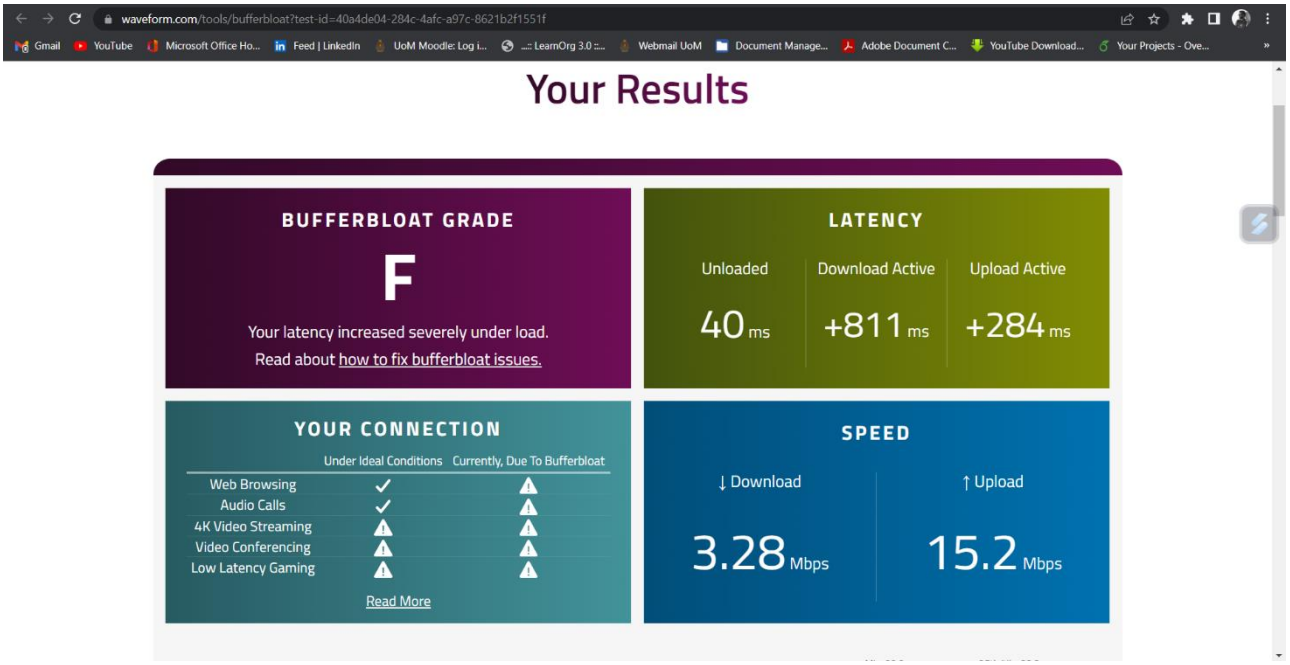
II. At Home Using Wi-Fi

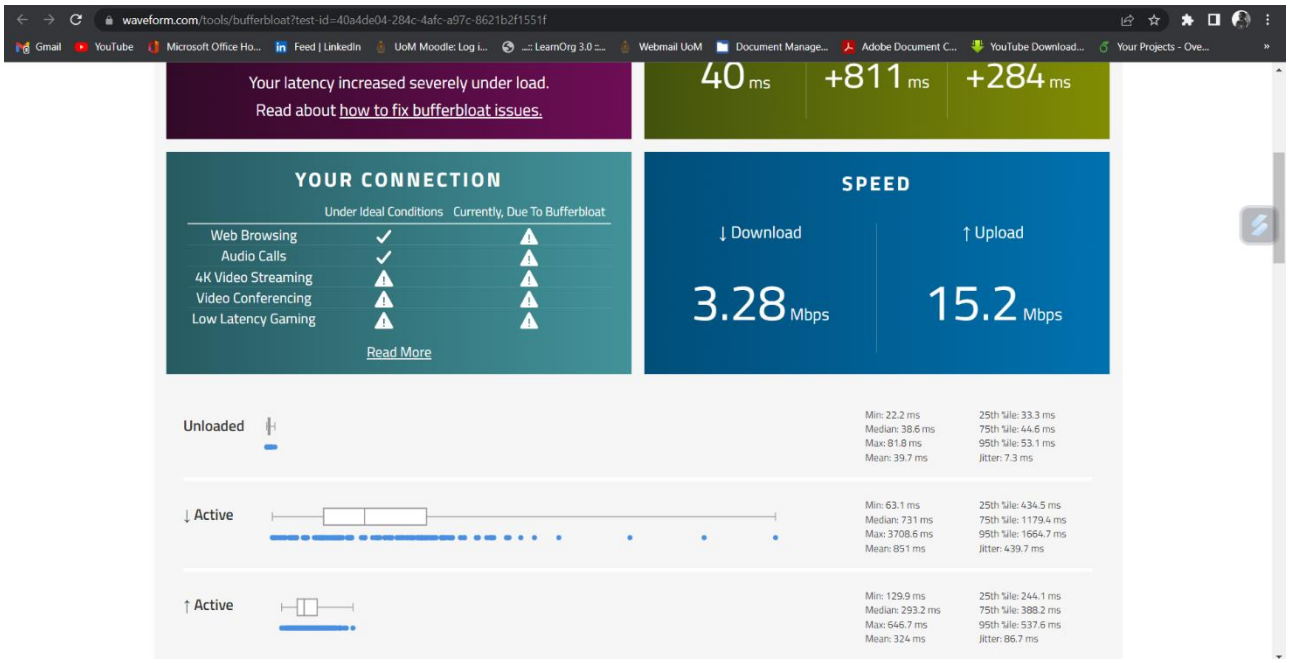




https://www.waveform.com/tools/bufferbloat?test-id=5e90cfbb-073a-4e62-b157-27cce2f2b0f7

III. **At Home Using Cellular Data**





https://www.waveform.com/tools/bufferbloat?test-id=40a4de04-284c-4afc-a97c-8621b2f1551f