Assignment 1

Aarunish Sinha - 2018CS10321

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0.1 Network Analysis

0.1.1 Running *traceroute*

traceroute version - 1.4a12+Darwin
OS - macOS 10.15.7

traceroute, by default, enforeces IPv4. In order to force traceroute to use IPv6, use *traceroute*6 $<$ *hostname* $>$.
While running *traceroute* on *www.iitd.ac.in*, ISP starts blocking packets on the path to *www.iitd.ac.in* network. So, a different destination(*www.google.com*) is used for network analysis.

0.1.2 Findings

The destination IP address, as recorded, for *www.google.com* is: 216.58.200.164
Some private IP addresses found on the path are:
172.26.103.196
172.26.103.210
172.26.103.211
192.168.85.56
192.168.85.52
192.168.85.57
192.168.85.53
172.26.40.64
172.16.16.11
172.16.88.169
172.26.12.228
172.26.12.226
172.16.4.199
172.16.2.48
172.16.2.46

The second router in the path, for which $ttl = 2$, does not reply to the traceroute requests.
On running *traceroute* again on *www.google.com*, different destination IP addresses were obtained: 172.217.167.19 and 209.85.252.65

0.1.3 Maximum packet size

Any packet with a size more the 65507 *bytes* is too large and cannot be sent by *ping*.
For *www.google.com*, a packet size greater than 68 *bytes* results in 100% packet loss.

0.2

0.3 Internet Architecture

Whois Analysis:

Traceroute to *www.utah.edu* from Mobile Network(India):

172.20.10.1	End-point Device
10.72.43.19	PRIVATE-ADDRESS-BBLK-RFC1918-IANA-RESERVED
172.16.84.191	PRIVATE-ADDRESS-BBLK-RFC1918-IANA-RESERVED
172.26.124.5	PRIVATE-ADDRESS-BBLK-RFC1918-IANA-RESERVED
49.45.4.251	RELIANCEJIO-IN
49.45.4.103	RELIANCEJIO-IN
49.45.4.81	RELIANCEJIO-IN
4.68.62.138	LVLT-ORG-4-8 (Level 3 Parent) LA US
67.14.134.74	CenturyLink Communications LA US
67.128.147.214	CenturyLink Communications LA US
140.197.252.104	Utah Education Network UT US
140.197.252.76	Utah Education Network UT US
140.197.253.139	Utah Education Network UT US
199.104.93.117	Utah Education Network UT US
155.99.130.59	University of Utah UT US
155.99.130.10	University of Utah UT US
155.99.132.3	University of Utah UT US
155.98.186.21	Destination

We can see that the traffic gets into the local ISPs like Reliance Jio in India and CenturyLink Communications in US, transits to an intermediate ISPs like Utah Education Network and finally into the destination domains.

0.3.1 Number of Hops:

Web Servers	Mobile Network (India)	USA	Greece
www.utah.edu	29	20	25
www.uct.ac.za	Max Hops Limit (64): Exceeded	Max Hops Limit (30): Exceeded	Max Hops Limit (30): Exceeded
www.iitd.ac.in	Max Hops Limit (64): Exceeded	Max Hops Limit (30): Exceeded	Max Hops Limit (30): Exceeded
www.google.com	11	9	9
www.facebook.com	12	14	8

The number of hops between nodes in the same continent is less than the number of hops between nodes in different continents. For example, in the case of *www.utah.edu* number of hops is least in USA(North America) as compared to India(Asia) or Greece(Europe).
The number of hops required to reach Google or Facebook is similar in all the three countries and also the number of hops is required is also less. Since, Google and Facebook have peered with the local ISPs of various countries, mirroring their websites in multiple places for fast access.

0.3.2 Latencies (in ms):

Web Servers	Mobile Network (India)	USA	Greece
www.utah.edu	584.236	51.989	171.277
www.uct.ac.za	NA(* * *)	NA(* * *)	NA(* * *)
www.iitd.ac.in	NA(* * *)	NA(* * *)	NA(* * *)
www.google.com	83.827	3.845	28.821
www.facebook.com	46.378	39.734	29.139

For *www.utah.edu* the latency increases as the number of hops increase. This is because as the number of routers increase in the network path, the total delay i.e. queuing delay, transmission delay, etc also increases.
Although latency seems to be related to the number of hops, a direct proportionality cannot be inferred from the observed data. The trend is not strictly followed in case of Google and Facebook web servers. This could be due the fact that even if two packets traverse the same path, due to the unbounded delay nature of the internet, they may take very different amounts of time for reaching their destination.

0.3.3 Destination IP addresses:

Web Servers	Mobile Network (India)	USA	Greece
www.utah.edu	155.98.186.21	155.98.186.21	155.98.186.21
www.uct.ac.za	137.158.154.230	137.158.154.230	137.158.154.230
www.iitd.ac.in	103.27.9.24	103.27.9.24	103.27.9.24
www.google.com	172.217.167.196	172.217.12.196	216.58.205.68
www.facebook.com	157.240.198.35	157.240.19.35	31.13.84.36

Destination servers resolved to the same IP address irrespective from where traceroute to them is run - *www.utah.edu*, *www.uct.ac.za* and *www.iitd.ac.in*. Since, Google and Facebook have their websites hosted at multiple data centers, it is attempted that nearest IP address is returned.

0.3.4 Route Length for Multiple IP addresses of the same web server:

Mobile Network(India) routes *www.google.com* to 172.217.167.196
Princeton(USA) routes *www.google.com* to 172.217.12.196
Greece routes *www.google.com* to 216.58.205.68

It takes **9** hops from Priceton(USA) to 172.217.12.196:
1 core-87-router (128.112.128.2) 0.774 ms 0.869 ms 0.935 ms
2 rtr-border-hpcrc-router.princeton.edu (128.112.12.110) 1.480 ms 1.211 ms 1.320 ms
3 rtr-border-87-router.princeton.edu (204.153.48.49) 15.909 ms 1.948 ms 1.705 ms
4 ve1205.core2.nyc4.he.net (216.66.49.73) 3.147 ms 3.130 ms 3.079 ms
5 100ge15-1.core1.nyc4.he.net (184.104.195.169) 3.125 ms 3.199 ms 2.965 ms
6 core1-0-0-8.lga.net.google.com (198.32.118.39) 4.400 ms 3.353 ms 3.113 ms
7 108.170.248.65 (108.170.248.65) 3.804 ms
108.170.248.1 (108.170.248.1) 4.959 ms
108.170.248.65 (108.170.248.65) 3.865 ms
8 172.253.69.211 (172.253.69.211) 3.830 ms
172.253.70.13 (172.253.70.13) 3.782 ms
172.253.69.211 (172.253.69.211) 3.789 ms
9 lga25s63-in-f4.1e100.net (172.217.12.196) 3.826 ms 3.755 ms 3.955 ms

It takes **15** hops from Princeton(USA) to 216.58.205.68:
1 core-87-router (128.112.128.2) 1.463 ms 0.833 ms 0.903 ms
2 rtr-border-hpcrc-router.princeton.edu (128.112.12.110) 19.237 ms 18.037 ms 1.443 ms
3 rtr-border-87-router.princeton.edu (204.153.48.49) 2.000 ms 1.850 ms 1.883 ms
4 ve1205.core2.nyc4.he.net (216.66.49.73) 3.023 ms 5.700 ms 3.036 ms
5 100ge15-1.core1.nyc4.he.net (184.104.195.169) 3.315 ms 3.378 ms 3.143 ms
6 core1-0-0-8.lga.net.google.com (198.32.118.39) 3.369 ms 3.028 ms 3.058 ms
7 108.170.248.20 (108.170.248.20) 4.655 ms 4.436 ms
108.170.248.84 (108.170.248.84) 4.375 ms
8 108.170.227.151 (108.170.227.151) 4.549 ms
108.170.227.148 (108.170.227.148) 4.421 ms
108.170.227.151 (108.170.227.151) 4.962 ms
9 172.253.65.167 (172.253.65.167) 71.836 ms * *
10 209.85.245.230 (209.85.245.230) 77.609 ms 76.808 ms 76.928 ms
11 *
209.85.142.97 (209.85.142.97) 84.180 ms
209.85.244.159 (209.85.244.159) 105.033 ms
12 72.14.233.133 (72.14.233.133) 91.215 ms
72.14.235.39 (72.14.235.39) 91.033 ms
72.14.234.21 (72.14.234.21) 91.545 ms

13 108.170.245.65 (108.170.245.65) 92.147 ms 92.264 ms 92.509 ms
14 216.239.42.11 (216.239.42.11) 91.278 ms 132.118 ms
216.239.42.9 (216.239.42.9) 90.893 ms
15 mil04s25-in-f68.1e100.net (216.58.205.68) 90.499 ms 90.316 ms 90.993 ms

It takes **19** hops from Princeton(USA) to 172.217.167.196:
1 core-87-router (128.112.128.2) 1.545 ms 0.718 ms 0.558 ms
2 rtr-border-87-router.princeton.edu (128.112.12.78) 1.617 ms 1.032 ms 1.471 ms
3 ve1205.core2.nyc4.he.net (216.66.49.73) 2.696 ms 2.614 ms 2.661 ms
4 100ge15-1.core1.nyc4.he.net (184.104.195.169) 2.648 ms 2.444 ms 2.487 ms
5 core1-0-0-8.lga.net.google.com (198.32.118.39) 2.818 ms 2.758 ms 2.814 ms
6 108.170.248.99 (108.170.248.99) 3.523 ms
108.170.248.20 (108.170.248.20) 4.368 ms 4.274 ms
7 209.85.255.52 (209.85.255.52) 4.063 ms
209.85.254.239 (209.85.254.239) 4.682 ms 4.755 ms
8 216.239.59.0 (216.239.59.0) 46.730 ms * 27.480 ms
9 209.85.247.5 (209.85.247.5) 31.172 ms
172.253.76.22 (172.253.76.22) 31.372 ms
142.250.231.184 (142.250.231.184) 38.097 ms
10 142.250.235.25 (142.250.235.25) 33.148 ms
142.250.235.163 (142.250.235.163) 38.668 ms
142.250.235.167 (142.250.235.167) 38.396 ms
11 *
142.250.236.43 (142.250.236.43) 49.262 ms
209.85.247.43 (209.85.247.43) 43.303 ms
12 *
209.85.250.5 (209.85.250.5) 66.179 ms 65.156 ms
13 142.250.232.155 (142.250.232.155) 146.921 ms *
172.253.79.55 (172.253.79.55) 146.412 ms
14 209.85.248.4 (209.85.248.4) 260.260 ms * 212.341 ms
15 172.253.74.52 (172.253.74.52) 242.228 ms
142.250.63.168 (142.250.63.168) 243.025 ms
142.250.63.170 (142.250.63.170) 243.372 ms
16 108.170.225.88 (108.170.225.88) 282.887 ms
72.14.239.58 (72.14.239.58) 280.742 ms
216.239.58.4 (216.239.58.4) 281.083 ms
17 108.170.251.113 (108.170.251.113) 282.375 ms 281.270 ms
108.170.251.97 (108.170.251.97) 279.870 ms
18 209.85.252.65 (209.85.252.65) 278.769 ms
209.85.252.71 (209.85.252.71) 281.126 ms 281.228 ms
19 del03s18-in-f4.1e100.net (172.217.167.196) 279.816 ms 280.535 ms 281.274 ms

As we can see that the number of hops increases as we connect to Google's Server in Greece and India compared to when we connect to Google's Server in the USA. The farther the server geographically, the larger the number of hops

required to reach the destination IP address.

0.3.5 Country without a local Data Center of Facebook/Google:

traceroute *www.google.com* from Czech Republic: traceroute to www.google.com (172.217.23.196), 30 hops max, 60 byte packets
1 10ge-dc.cbr1.silesnet.net (78.157.167.1) [AS43709] 2.065 ms 2.368 ms 2.646 ms
2 10ge-b1.ces1.silesnet.net (78.157.167.197) [AS43709] 0.141 ms 0.144 ms 0.139 ms
3 10ge-ib.ces2.silesnet.net (78.157.167.194) [AS43709] 0.708 ms 0.755 ms 1.095 ms
4 10ge-google.prg.silesnet.net (78.157.167.254) [AS43709] 6.852 ms 6.851 ms 6.892 ms
5 108.170.245.49 (108.170.245.49) [AS15169] 6.729 ms
108.170.245.33 (108.170.245.33) [AS15169] 6.828 ms 6.823 ms
6 108.170.238.161 (108.170.238.161) [AS15169] 6.762 ms 6.732 ms
108.170.238.159 (108.170.238.159) [AS15169] 6.772 ms
7 prg03s05-in-f196.1e100.net (172.217.23.196) [AS15169] 6.716 ms 6.522 ms 6.523 ms
7 prg03s05-in-f196.1e100.net (172.217.23.196) [AS15169] 6.716 ms 6.522 ms 6.523 ms

The IP address 172.217.23.196 is of the Google Mountain View Server, in the USA. Thus, Czech Republic does not has it's local ISPs directly peered with google.