1 Network Analysis

1.1 Subpart a

The ISP was blocking packets on www.iitd.ac.in so I used www.google.com instead.

Terminal Output :
manupriya@manupriya-Vostro-3583: $ traceroute www.google.com
traceroute to www.google.com (142.250.67.196), 64 hops max
1 192.168.1.1 1.983ms 1.758ms 1.722ms
2 122.160.220.236 83.292ms 125.17.145.29 66.589ms 124.677ms
3 125.18.20.101 131.762ms 182.79.154.71 64.558ms *
4 182.79.217.89 101.858ms 142.250.161.56 66.494ms 128.547ms
5 142.250.161.56 157.928ms 10.23.221.158 103.653ms 126.153ms
6 * 74.125.243.97 143.978ms 103.212ms
7 142.250.46.130 204.067ms 204.436ms 74.125.244.195 110.108ms
8 108.170.251.108 197.976ms 72.14.233.107 125.752ms 128.457ms
9 142.250.63.116 73.757ms 216.239.62.154 182.162ms 206.089ms
10 72.14.233.106 204.830ms 72.14.234.234 203.037ms 204.621ms
11 108.170.248.177 95.924ms 142.250.235.11 211.666ms 204.265ms
12 142.250.235.11 102.847ms 142.250.67.196 203.960ms 123.798ms

Ip address for www.google.com :- 142.250.67.196

Ip addresses seen on the path were :-
192.168.1.1 (my system)
122.160.220.236
125.17.145.29
125.18.20.101
182.79.154.71
182.79.217.89
142.250.161.56
142.250.161.56
10.23.221.158
74.125.243.97
142.250.46.130
74.125.244.195
108.170.251.108
72.14.233.107
142.250.63.116
216.239.62.154
72.14.233.106
72.14.234.234
108.170.248.177
142.250.235.11
142.250.235.11
142.250.67.196 (destination)

1.2 Subpart b

The characteristic differences between ipv4 and ipv6 are :
1. IPv4 is 32-Bit IP address whereas IPv6 is a 128-Bit IP address.
2. IPv4 is a numeric addressing method whereas IPv6 is an alphanumeric addressing method.
3. IPv4 binary bits are separated by a dot(.) whereas IPv6 binary bits are separated by a colon(:).

There were not any ipv6 addresses obtained while tracerouting to www.google.com from my system
The private ip addresses noticed were : 192.168.1.1 and 10.23.221.158
To force the use of ipv4, the following command is given :
traceroute 4 www.google.com
Using this, the output is :

manupriya@manupriya-Vostro-3583: $ traceroute 4 www.google.com
traceroute to www.google.com (216.58.200.196), 64 hops max
1 192.168.1.1 3.152ms 2.163ms 1.871ms
2 122.160.220.236 133.611ms 125.17.145.29 131.227ms *
3 125.17.145.29 96.807ms 182.79.154.73 69.490ms 68.418ms
4 182.79.217.89 69.455ms 142.250.161.56 68.503ms 69.218ms
5 142.250.161.56 69.185ms * 87.894ms
6 * 216.58.200.196 98.779ms 69.898ms

One private IP address was noticed : 192.168.1.1
There was 1 missing router along the path shown as a '*'.

1.3 Subpart c

The maximum size of ping packets I am able to send is 1464 bytes to www.google.com

2 Replicating Traceroute

Please find the python script in the zip file
To run : python3 ass1.py

3 Internet Architecture

3.1 Subpart a

Number of Hops			
Website	Princeton(North America)	Greece(Europe)	Terminal(Asia)
www.utah.edu	20	25	21
www.uct.ac.za	11	17	12
vayu.iitd.ac.in	16	18	14
www.google.com	9	9	8
www.facebook.com	14	8	7

www.uct.ac.za was not reachable, so I have taken the last reachable address (154.114.124.1) as the destination and calculated hops only upto that.
We notice that to reach a node in Utah, we require less hops(20) from Princeton compared to Greece and my terminal, which are not in North America. In case of vayu.iitd.ac.in also, less hops are required from my system node compared to Princeton and Greece. So, the statement "number of hops between nodes in the same continent is lower than the number of hops between nodes in different continentsïs true.
Google and Facebook have peering with local ISP's in different continents, so the inter-continental distance is not really significant for communicating with these web servers.

Google and Facebook require considerably less number of hops to reach them compared to other websites because they are very big companies and can afford a direct link to their server from the local ISP's in different continents. This peering reduces the number of hops required to reach the destination

3.2 Subpart b

Latency			
Website	Princeton(North America)	Greece(Europe)	Terminal(Asia)
www.utah.edu	52.125	170.089	304.960
www.uct.ac.za	200.725*	218.112*	482.34*
vayu.iitd.ac.in	260.113	222.744	12.720
www.google.com	3.866	26.544	33.691
www.facebook.com	39.763	27.583	11.945

* : the web server could not be traced within the max number of hops permitted from the tracerouter so this is the time till the last reachable address (154.114.124.1)

We do notice that more the number of hops, more is the latency between the web server and the traceroute source. This is logical because any packet encounters queueing, transmission, propagation and node processing delays on its path from source to destination. The more number of hops, that implies more number of nodes in the path and hence the queueing delay significantly adds up from all the nodes causing more latency.

3.3 Subpart c

www.utah.edu, www.uct.ac.za and vayu.iitd.ac.in web servers have the same IP address irrespective of the traceroute source. www.google.com and www.facebook.com have different ip addresses when the traceroute source is in different continents.
Example for Google : Princeton(172.217.11.36) and Greece(172.217.23.196) and My terminal(172.217.166.36)

These 2 web servers (Google and Facebook) are resolved to different IP addresses when queried from different parts of the world because they are very big companies and can afford direct connection/peering with some local ISP's in different continents and do not rely on the different tiers of ISP's to deliver their content. Whereas these standard tiers (from Local to Regional to Tier 1 then downward again) are used by the other web servers.

A CDN (Content Delivery Network) is a highly-distributed platform of servers that helps minimize delays in loading web page content by reducing the physical distance between the server and the user. This helps users around the world view the same high-quality content without slow loading times. Google and Facebook have several servers and datacentres which are used for delivery of content to requests in local ISP's. Hence, a request from Princeton and a request from Delhi will be directed along different paths and destination by the CDN. This leads to different ip addresses of same web server.

3.4 Subpart d

YES, while tracing from the same source, paths are different to different IP addresses for the same web server ie Google or Facebook.

Every traceroute source takes the smallest path to www.google.com when it automatically chooses an IP address for this web server on its own. If some other IP address is given to my terminal system (for example 172.217.23.196 from the Greece tracerouting server), it takes longer path and more number of hops to reach the same destination which is www.google.com.

So if I do traceroutes from the same starting point (say X) to different IP addresses I found for the same web-server (from different traceroute sources), the paths are different. The paths for IP addresses from the other sources are longer than the path from particular source X.

3.5 Subpart e

From all the traceroute source servers in the list, it is possible to reach www.google.com and www.facebook.com in less than 10 hops with small latency. Also, checking all the ip addresses on the path, the routers are either located in the same country or at Google and Facebook servers located in different continents. That means, there is a direct connection from local ISP's to Google and Facebook servers. So, Google and Facebook are peered with local ISP's of USA, India, Greece, Canada, Sweden, Germany and Czech Republic situated in different continents.

There is a country ”Malta”(http://traceroute.fmc.lu/) in Europe and while tracerouting we observe :
1. For Google :

traceroute to www.google.com (216.58.206.4), 30 hops max, 60 byte packets
1 80.92.66.3 (80.92.66.3) 0.361 ms 0.572 ms 80.92.66.2 (80.92.66.2) 0.456 ms
2 80-92-83-193.ip.dclux.com (80.92.83.193) 0.441 ms 0.499 ms 0.498 ms
3 xe-9-2-2.bar1.Brussels1.Level3.net (212.3.232.169) 17.188 ms 213.135.251.128 (213.135.251.128) 1.169 ms xe-9-2-2.bar1.Brussels1.Level3.net (212.3.232.169) 17.181 ms
4 213.135.251.127 (213.135.251.127) 1.793 ms ae-1-3102.ear4.Amsterdam1.Level3.net (4.69.158.202) 15.830 ms 213.135.251.127 (213.135.251.127) 1.456 ms
5 72.14.215.89 (72.14.215.89) 5.205 ms Google-level3-100G.Amsterdam1.Level3.net (4.68.75.110) 16.502 ms 16.484 ms
6 108.170.251.193 (108.170.251.193) 13.915 ms 108.170.252.65 (108.170.252.65) 15.330 ms *
7 216.239.56.151 (216.239.56.151) 13.821 ms 216.239.56.149 (216.239.56.149) 5.275 ms 216.239.56.151 (216.239.56.151) 13.918 ms
8 fra16s20-in-f4.1e100.net (216.58.206.4) 5.178 ms 209.85.244.159 (209.85.244.159) 14.451 ms fra16s20-in-f4.1e100.net (216.58.206.4) 14.003 ms

We notice that routers in Belgium (212.3.232.169) and Neatherlands (4.68.75.110) are intermediary in the path. So Malta’s local ISP is not directly peered with Google.

2. For Facebook :

traceroute to www.facebook.com (69.171.250.35), 30 hops max, 60 byte packets
1 80.92.66.3 (80.92.66.3) 59.275 ms 59.484 ms 80.92.66.2 (80.92.66.2) 0.370 ms
2 80-92-83-199.ip.dclux.com (80.92.83.199) 0.430 ms 0.428 ms 0.428 ms
3 xe-9-2-2.bar1.Brussels1.Level3.net (212.3.232.169) 13.514 ms 213.135.251.128 (213.135.251.128) 1.177 ms 1.129 ms
4 80.249.212.175 (80.249.212.175) 7.996 ms 8.128 ms 8.125 ms
5 4.14.96.26 (4.14.96.26) 97.317 ms 96.308 ms po131.asw02.ams2.tfbnw.net (31.13.29.72) 7.509 ms
6 po231.psw01.ams4.tfbnw.net (129.134.47.215) 7.603 ms po226.psw04.ams4.tfbnw.net (129.134.48.101) 7.825 ms po104.psw03.iad3.tfbnw.net (31.13.28.31) 96.206 ms
7 173.252.67.79 (173.252.67.79) 7.703 ms 173.252.67.23 (173.252.67.23) 96.224 ms 173.252.67.161 (173.252.67.161) 96.162 ms
8 edge-star-mini-shv-01-any2.facebook.com (69.171.250.35) 96.183 ms 96.173 ms 96.168 ms

We notice that routers in Belgium (212.3.232.169) and Poland (129.134.47.215) are intermediary in the path. So Malta’s local ISP is not directly peered with Facebook.