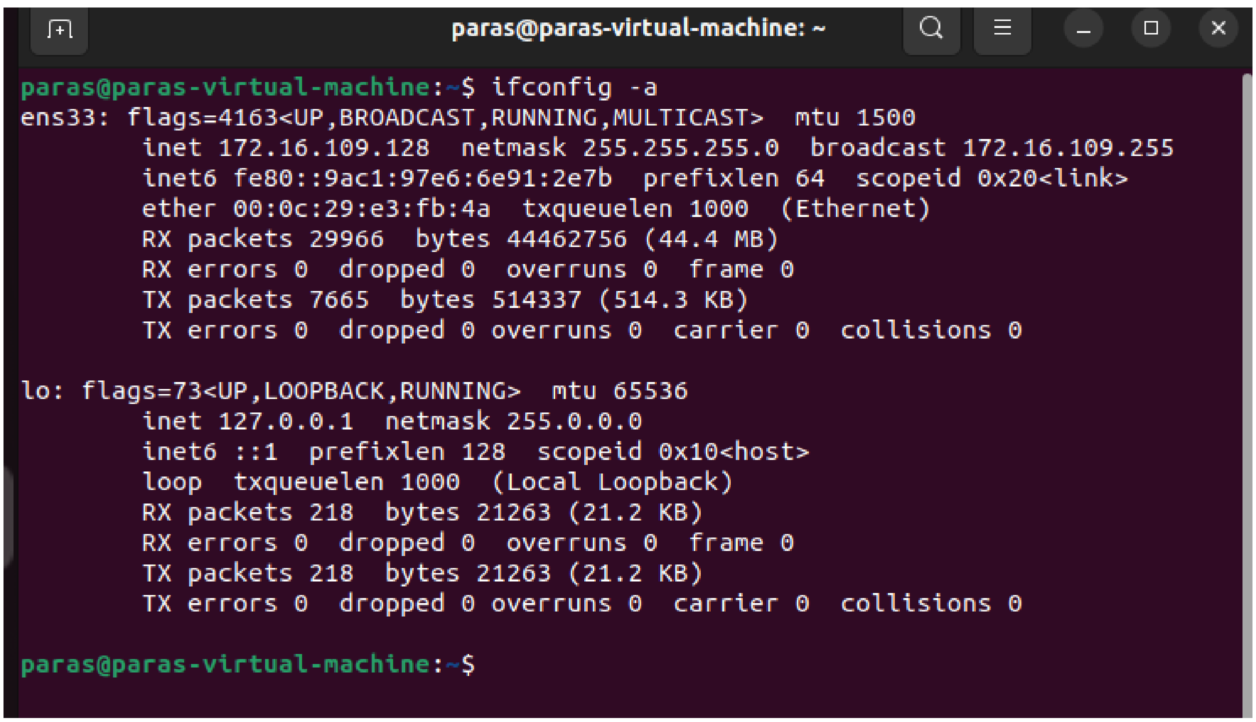
Indraprastha Institute of Information Technology Delhi (IIITD)

ASSIGNMENT-1

Name-PARAS DHIMAN || Roll no-2021482

Computer Networks - CSE232

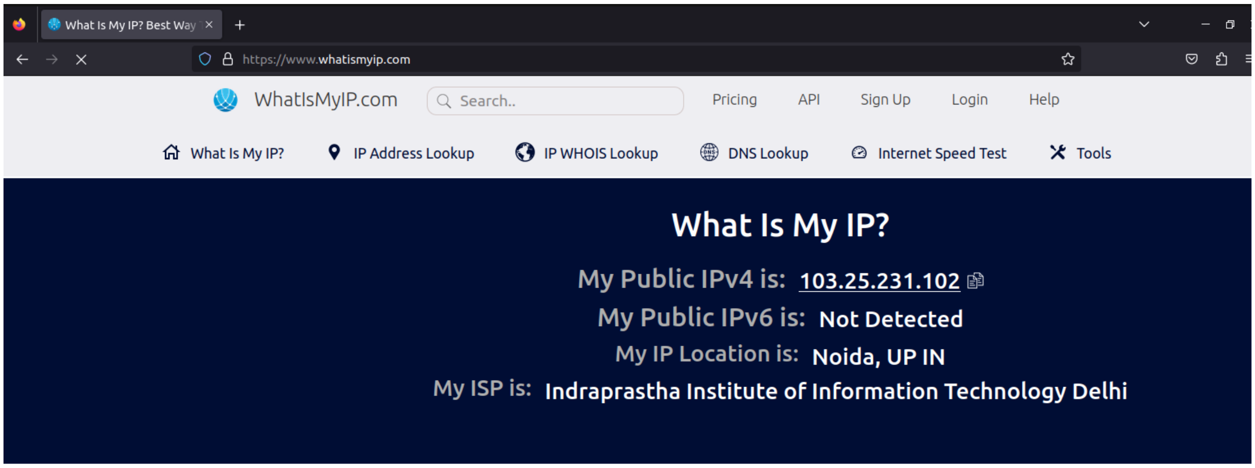
Question 1:



```
paras@paras-virtual-machine: ~
paras@paras-virtual-machine:~$ ifconfig -a
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 172.16.109.128  netmask 255.255.255.0  broadcast 172.16.109.255
        inet6 fe80::9ac1:97e6:6e91:2e7b  prefixlen 64  scopeid 0x20<link>
        ether 00:0c:29:e3:fb:4a  txqueuelen 1000  (Ethernet)
        RX packets 29966  bytes 44462756 (44.4 MB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 7665  bytes 514337 (514.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 218  bytes 21263 (21.2 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 218  bytes 21263 (21.2 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

paras@paras-virtual-machine:~$
```



IP Address Linux = 172.16.109.128
IP Address From Browser = 103.25.231.102
The IP address are shown different Because:

1. The IP address shown by ifconfig is the internal IP address assigned to the machine on the local network. The IP address shown on whatismyip.com is my public IP address assigned, i.e., assigned by the Internet Service Provider (ISP).
2. These two addresses differ because our router is a gateway between the local network and the internet. When we connect to the internet, the router assigns our device a local IP address (internal IP) used for communication within the home network. When data leaves the local network and goes onto the internet, it is sent from the router using the public IP address provided by the ISP.
3. This setup helps manage and secure devices within my local network while allowing multiple devices to share a public IP address.

Question 2:

A.

```
> exit

paras@paras-virtual-machine:~$ nslookup
> set type=ns
> google.in
;; communications error to 127.0.0.53#53: timed out
Server:         127.0.0.53
Address:        127.0.0.53#53

Non-authoritative answer:
google.in       nameserver = ns2.google.com.
google.in       nameserver = ns3.google.com.
google.in       nameserver = ns1.google.com.
google.in       nameserver = ns4.google.com.

Authoritative answers can be found from:
ns2.google.com  internet address = 216.239.34.10
ns2.google.com  has AAAA address 2001:4860:4802:34::a
ns4.google.com  internet address = 216.239.38.10
ns1.google.com  has AAAA address 2001:4860:4802:32::a
ns1.google.com  internet address = 216.239.32.10
ns3.google.com  internet address = 216.239.36.10
> set type=A
> server ns1.google.com
Default server: ns1.google.com
Address: 216.239.32.10#53
Default server: ns1.google.com
Address: 2001:4860:4802:32::a#53
> server ns2.google.com
Default server: ns2.google.com
Address: 216.239.34.10#53
Default server: ns2.google.com
Address: 2001:4860:4802:34::a#53
>
```

An authoritative DNS lookup is used to retrieve accurate and official DNS information for a specific domain directly from the authoritative DNS servers
On Linux opened up the Terminal then typed
>nslookup
>type = ns(name server)
>google.in
This command instructs nslookup to query the authoritative DNS servers for the domain "google in" to retrieve the name server (NS) records.Then we see list of authoritative DNS servers associated with the domain "google.in." These servers are responsible for providing the DNS information for the domain.
So to query a specific authoritative DNS server directly,we can use the following command (replace authoritative_server_ip with the actual IP address of the authoritative server):
Copy code
nslookup google.in authoritative_server_ip
can set the
>type=A(i.e. specifying type address then name the
>sever = ns1.google.com)
Authoritative DNS servers provide the official and accurate DNS information for a domain. DNS servers use this information to resolve domain names into IP addresses.

B.

```
paras@paras-HP-Laptop-15s-du1xxx:~$ nslookup -debug stackexchange.com
Server:         127.0.0.53
Address:        127.0.0.53#53

------------
    QUESTIONS:
        stackexchange.com, type = A, class = IN
    ANSWERS:
    ->  stackexchange.com
        internet address = 151.101.129.69
        ttl = 147
    ->  stackexchange.com
        internet address = 151.101.65.69
        ttl = 147
    ->  stackexchange.com
        internet address = 151.101.193.69
        ttl = 147
    ->  stackexchange.com
        internet address = 151.101.1.69
        ttl = 147
    AUTHORITY RECORDS:
    ADDITIONAL RECORDS:
------------
Non-authoritative answer:
Name:   stackexchange.com
Address: 151.101.129.69
Name:   stackexchange.com
Address: 151.101.65.69
Name:   stackexchange.com
Address: 151.101.193.69
Name:   stackexchange.com
Address: 151.101.1.69
------------
    QUESTIONS:
        stackexchange.com, type = AAAA, class = IN
    ANSWERS:
    AUTHORITY RECORDS:
    ->  stackexchange.com
        origin = ns-1832.awsdns-37.co.uk
        mail addr = awsdns-hostmaster.amazon.com
        serial = 1
        refresh = 7200
        retry = 900
        expire = 1209600
        minimum = 86400
        ttl = 82
    ADDITIONAL RECORDS:
------------
```

- The Time to Live (TTL) value in the context of DNS refers to the duration for which resolvers, including the local DNS server, cache DNS information. It specifies how long the resolved IP address for a domain name should be stored in the cache before it is considered stale and needs to be refreshed from the authoritative DNS server.
- The DNS record has a TTL value of 82 seconds for stackexchange.com, which means that the local DNS server will store the resolved IP address for that domain in its cache for 82 seconds. During this time, any requests for that domain will be answered using the cached IP address. After the TTL period expires, the local DNS server will consider the cached information outdated and request updated information from the authoritative DNS server.
- In summary, the TTL value indicates the duration in seconds for which a DNS entry is valid in the cache of the local DNS server. Once the TTL expires, the local DNS server

will no longer use the cached information and seek fresh data from the authoritative DNS server.

Question 3:

A.

```
paras@paras-HP-Laptop-15s-du1xxx:~$ traceroute google.in
traceroute to google.in (142.250.193.228), 30 hops max, 60 byte packets
 1  192.168.64.254 (192.168.64.254)  16.782 ms  16.685 ms  16.796 ms
 2  auth.iiitd.edu.in (192.168.1.99)  10.860 ms  10.832 ms  10.805 ms
 3  103.25.231.1 (103.25.231.1)  8.914 ms  8.884 ms  8.841 ms
 4  * * *
 5  10.119.234.162 (10.119.234.162)  8.702 ms  8.670 ms  11.491 ms
 6  72.14.195.56 (72.14.195.56)  43.187 ms 72.14.194.160 (72.14.194.160)  34.226 ms  34.140 ms
 7  74.125.244.193 (74.125.244.193)  32.240 ms 74.125.243.97 (74.125.243.97)  34.056 ms  34.018 ms
 8  142.251.54.101 (142.251.54.101)  30.615 ms  30.529 ms 142.251.54.99 (142.251.54.99)  30.475 ms
 9  del11s18-in-f4.1e100.net (142.250.193.228)  31.511 ms  8.569 ms  8.480 ms
paras@paras-HP-Laptop-15s-du1xxx:~$
```

Average latency = Average RTT / 2

1. 192.168.64.254:
   - Latencies: 16.782 ms, 16.685 ms, 16.796 ms
   - Average Latency = (16.782 + 16.685 + 16.796) / 3 ≈ 16.754 ms / 2 = 8.377 ms
2. auth.iiitd.edu.in (192.168.1.99):
   - Latencies: 10.860 ms, 10.832 ms, 10.805 ms
   - Average Latency = (10.860 + 10.832 + 10.805) / 3 ≈ 10.832 ms / 2 = 5.416 ms
3. 103.25.231.1:
   - Latencies: 8.914 ms, 8.884 ms, 8.841 ms
   - Average Latency = (8.914 + 8.884 + 8.841) / 3 ≈ 8.880 ms / 2 = 4.440 ms

(No response from this host)

4. 10.119.234.162:
   - Latencies: 8.702 ms, 8.670 ms, 11.491 ms
   - Average Latency = (8.702 + 8.670 + 11.491) / 3 ≈ 9.954 ms / 2 = 4.977 ms
5. 72.14.195.56:
   - Latencies: 43.187 ms, 34.226 ms, 34.140 ms
   - Average Latency = (43.187 + 34.226 + 34.140) / 3 ≈ 37.184 ms / 2 = 18.592 ms
6. 74.125.244.193:
   - Latencies: 32.240 ms, 34.056 ms, 34.018 ms
   - Average Latency = (32.240 + 34.056 + 34.018) / 3 ≈ 33.771 ms / 2 = 16.8855 ms
7. 142.251.54.101:
   - Latencies: 30.615 ms, 30.529 ms, 30.475 ms
   - Average Latency = (30.615 + 30.529 + 30.475) / 3 ≈ 30.540 ms / 2 = 15.270 ms
8. del11s18-in-f4.1e100.net (142.250.193.228):
   - Latencies: 31.511 ms, 8.569 ms, 8.480 ms
   - Average Latency = (31.511 + 8.569 + 8.480) / 3 ≈ 16.853 ms / 2 = 8.4265 ms

Total Average latency will be = (Sum of all average latencies) / Number of hosts with valid latencies

= 8.377 ms + 5.416 ms + 4.440 ms + 4.977 ms + 18.592 ms + 16.8855 ms + 15.270 ms + 8.4265 ms / 9

= 82.384 / 9 = 9.1537 ms

There are total 9 hops in the traceroute output.

B.

```
paras@paras-HP-Laptop-15s-du1xxx:~$ ping google.in -c 50
PING google.in (142.250.192.196) 56(84) bytes of data.
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=1 ttl=118 time=7.05 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=2 ttl=118 time=6.81 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=3 ttl=118 time=28.9 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=4 ttl=118 time=6.52 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=5 ttl=118 time=9.26 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=6 ttl=118 time=6.77 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=7 ttl=118 time=7.82 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=8 ttl=118 time=6.69 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=9 ttl=118 time=6.74 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=10 ttl=118 time=13.7 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=11 ttl=118 time=17.3 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=12 ttl=118 time=23.5 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=13 ttl=118 time=6.46 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=14 ttl=118 time=12.4 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=15 ttl=118 time=6.04 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=16 ttl=118 time=9.87 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=17 ttl=118 time=25.0 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=18 ttl=118 time=8.72 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=19 ttl=118 time=18.8 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=20 ttl=118 time=6.19 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=21 ttl=118 time=11.9 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=22 ttl=118 time=6.57 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=23 ttl=118 time=6.55 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=24 ttl=118 time=6.71 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=25 ttl=118 time=12.0 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=26 ttl=118 time=20.3 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=27 ttl=118 time=6.67 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=28 ttl=118 time=6.63 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=29 ttl=118 time=7.16 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=30 ttl=118 time=25.1 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=31 ttl=118 time=7.41 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=32 ttl=118 time=6.67 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=33 ttl=118 time=7.97 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=34 ttl=118 time=12.2 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=35 ttl=118 time=23.9 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=36 ttl=118 time=53.4 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=37 ttl=118 time=6.84 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=38 ttl=118 time=6.35 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=39 ttl=118 time=9.41 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=40 ttl=118 time=6.41 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=41 ttl=118 time=7.89 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=42 ttl=118 time=14.5 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=43 ttl=118 time=6.68 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=44 ttl=118 time=15.8 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=45 ttl=118 time=6.37 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=46 ttl=118 time=8.86 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=47 ttl=118 time=6.41 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=48 ttl=118 time=6.70 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=49 ttl=118 time=35.5 ms
64 bytes from del11s12-in-f4.1e100.net (142.250.192.196): icmp_seq=50 ttl=118 time=6.51 ms

--- google.in ping statistics ---
50 packets transmitted, 50 received, 0% packet loss, time 49081ms
rtt min/avg/max/mdev = 6.044/11.997/53.356/9.101 ms
paras@paras-HP-Laptop-15s-du1xxx:~$
```

calculate the average latency for each host using the provided latency values and formula:

Average Latency = (Sum of Latencies) / (Number of Latency Measurements)

For hosts with multiple responses, consider each response as a separate latency measurement. If a host didn't respond, exclude it from the average latency calculation.

- Minimum Round-Trip Time (RTT): 6.044 ms
- Average Round-Trip Time (RTT): 11.997 ms
- Maximum Round-Trip Time (RTT): 53.356 ms
- Mean Deviation of RTT (mdev): 9.101 ms

The average latency, which is the average round-trip time (RTT), is approximately 11.997 ms.

C.

a. Total Average Latency from Traceroute: 82.384 ms b. Average Latency from Ping Test: 11.997 ms

The calculated total average latency from traceroute (a) is 9.1537 ms, while the average latency from the ping test (b) is 11.997 ms. These two values are different.

The reason for this discrepancy is that traceroute and ping measure latency in slightly different ways:

- Traceroute measures the time it takes for packets to travel from the computer to each intermediate host along the path. It doesn't necessarily represent the total end-to-end latency to the final destination.
- Ping measures the round-trip time (RTT) for packets to travel from the computer to the destination and back. It gives a more direct measurement of the latency to the final destination.

Additionally, traceroute involves multiple network hops, and latencies can vary due to routing changes, network congestion, and other factors. Ping, on the other hand, measures the RTT to the destination directly without necessarily following the same path as traceroute.

In summary, while the values don't match exactly, they provide insights into different aspects of latency along the network path. Traceroute shows the latency to each intermediate host, and ping shows the latency to the final destination. The differences can be attributed to the different measurement methods and network conditions.

Here, it is varying much but yes it may vary certainly in different cases.

D.

a. Maximum Ping Latency among Intermediate Hosts: 37.184 ms (from host 72.14.195.56) b. Maximum Round-Trip Time (RTT) from Ping Test: 53.356 ms

In this comparison, the maximum ping latency (a) is 37.184 ms, while the maximum RTT from the ping test (b) is 53.356 ms. Again, these two values are different.

The reasons for this difference are similar to the previous explanation:

- Traceroute's intermediate host latency measurement (a) represents the time taken for packets to travel between the computer and each intermediate host. The maximum latency among these hosts is 37.184 ms.
- Ping's maximum RTT measurement (b) represents the time taken for packets to travel from the computer to the destination and back. It's possible that the route taken for ping is different from that taken for traceroute, and the round-trip time can be affected by various factors along the path.

In summary, the difference between the maximum ping latency and the maximum RTT can be attributed to the varying paths, network conditions, and other factors affecting the measurements. While they don't match exactly, they provide insights into different aspects of latency and network perform;ance.

Some of the factors can be :

1. **Routing Variability:** Different paths due to congestion, policies, load balancing, and network complexity.
2. **Network Conditions:** Rapid changes in network components causing latency fluctuations.
3. **Load Balancing:** Varying packet paths through load-distributed servers or data centers.
4. **Packet Prioritization:** Differing routes based on traffic type priorities.
5. **Network Topology:** Complex interconnections leading to latency variations.
6. **Peering Agreements:** ISP agreements influencing route choices and differences in paths.

E.

Multiple entries for a single hop in the traceroute command typically indicate that there are multiple routers or devices at that hop that are responding to the traceroute packets. This phenomenon can occur due to various reasons, including:

1. **Load Balancing:** Some networks employ load balancing techniques where incoming traffic is distributed across multiple routers or paths. Traceroute packets may be distributed among these routers, resulting in multiple responses for a single hop.

2. **Parallel Paths:** In complex network architectures, packets can take parallel paths to reach the same hop. Each path may be associated with a different router, leading to multiple responses.
3. **Packet Handling:** Some routers or devices might respond to traceroute packets more than once due to certain configurations, packet processing, or software behavior.
4. **Redundancy:** Redundant network links or routers can result in multiple responses from different components at the same hop.
5. **Firewalls and Filters:** Some network security devices or firewalls can modify packets, causing traceroute packets to take different paths and receive responses from different routers.
6. **Varying Response Times:** Even if there's a single router at a hop, it might respond multiple times due to varying response times for different packets.

In essence, multiple entries for a single hop in traceroute indicate that there are multiple devices or paths involved in routing packets to that hop. This complexity in routing can be due to network design, optimization, redundancy, and other factors.

F.

```
paras@paras-HP-Laptop-15s-du1xxx:~$ ping stanford.edu -c 50
PING stanford.edu (171.67.215.200) 56(84) bytes of data.
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=1 ttl=231 time=328 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=2 ttl=231 time=330 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=3 ttl=231 time=345 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=4 ttl=231 time=378 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=5 ttl=231 time=328 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=6 ttl=231 time=330 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=7 ttl=231 time=328 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=8 ttl=231 time=349 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=9 ttl=231 time=376 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=10 ttl=231 time=333 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=11 ttl=231 time=329 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=12 ttl=231 time=344 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=13 ttl=231 time=368 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=14 ttl=231 time=365 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=15 ttl=231 time=328 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=16 ttl=231 time=326 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=17 ttl=231 time=345 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=18 ttl=231 time=359 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=19 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=20 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=21 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=22 ttl=231 time=350 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=23 ttl=231 time=377 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=24 ttl=231 time=326 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=25 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=26 ttl=231 time=346 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=27 ttl=231 time=367 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=28 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=29 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=30 ttl=231 time=326 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=31 ttl=231 time=355 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=32 ttl=231 time=367 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=33 ttl=231 time=333 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=34 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=35 ttl=231 time=333 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=36 ttl=231 time=373 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=37 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=38 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=39 ttl=231 time=337 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=40 ttl=231 time=389 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=41 ttl=231 time=388 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=42 ttl=231 time=326 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=43 ttl=231 time=330 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=44 ttl=231 time=341 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=45 ttl=231 time=368 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=46 ttl=231 time=328 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=47 ttl=231 time=327 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=48 ttl=231 time=336 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=49 ttl=231 time=368 ms
64 bytes from web.stanford.edu (171.67.215.200): icmp_seq=50 ttl=231 time=364 ms

--- stanford.edu ping statistics ---
50 packets transmitted, 50 received, 0% packet loss, time 49063ms
rtt min/avg/max/mdev = 325.961/343.729/388.905/19.455 ms
paras@paras-HP-Laptop-15s-du1xxx:~$
```

calculate the average latency for each host using the provided latency values and formula:

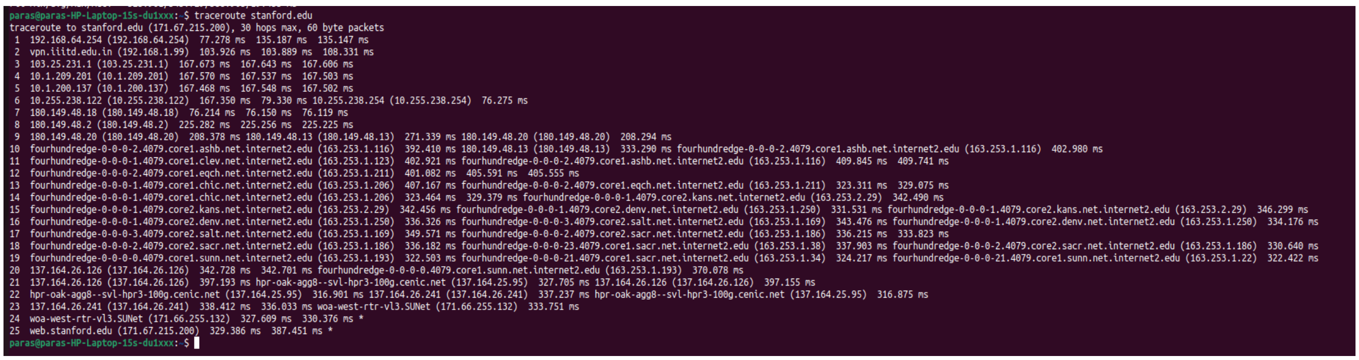
Average Latency = (Sum of Latencies) / (Number of Latency Measurements)

For hosts with multiple responses, consider each response as a separate latency measurement. If a host didn't respond, exclude it from the average latency calculation.

- Minimum Round-Trip Time (RTT): 325.961 ms
- Average Round-Trip Time (RTT): 343.729 ms
- Maximum Round-Trip Time (RTT): 388.905 ms
- Mean Deviation of RTT (mdev): 19.455 ms

The average latency, which is the average round-trip time (RTT), is approximately 343.729 ms.

G.



```
paras@paras-HP-Laptop-15s-du1xxx:~$ traceroute stanford.edu
traceroute to stanford.edu (171.67.215.200), 30 hops max, 60 byte packets
 1  192.168.64.254 (192.168.64.254)  77.278 ms  135.187 ms  135.147 ms
 2  vpn.iiitd.edu.in (192.168.1.99)  103.926 ms  103.889 ms  108.331 ms
 3  103.25.231.1 (103.25.231.1)  167.673 ms  167.643 ms  167.606 ms
 4  10.1.209.201 (10.1.209.201)  167.570 ms  167.537 ms  167.503 ms
 5  10.1.200.137 (10.1.200.137)  167.468 ms  167.548 ms  167.502 ms
 6  10.255.238.122 (10.255.238.122)  167.350 ms  79.330 ms 10.255.238.254 (10.255.238.254)  76.275 ms
 7  180.149.48.18 (180.149.48.18)  76.214 ms  76.150 ms  76.119 ms
 8  180.149.48.2 (180.149.48.2)  225.282 ms  225.256 ms  225.225 ms
 9  180.149.48.20 (180.149.48.20)  208.378 ms 180.149.48.13 (180.149.48.13)  271.339 ms 180.149.48.20 (180.149.48.20)  208.294 ms
10  fourhundredge-0-0-0-2.4079.core1.ashb.net.internet2.edu (163.253.1.116)  392.410 ms 180.149.48.13 (180.149.48.13)  333.290 ms fourhundredge-0-0-0-2.4079.core1.ashb.net.internet2.edu (163.253.1.116)  402.980 ms
11  fourhundredge-0-0-0-1.4079.core1.clev.net.internet2.edu (163.253.1.123)  402.921 ms fourhundredge-0-0-0-2.4079.core1.ashb.net.internet2.edu (163.253.1.116)  409.845 ms  409.741 ms
12  fourhundredge-0-0-0-2.4079.core1.eqch.net.internet2.edu (163.253.1.211)  401.082 ms  405.591 ms  405.555 ms
13  fourhundredge-0-0-0-1.4079.core1.chic.net.internet2.edu (163.253.1.206)  407.167 ms fourhundredge-0-0-0-2.4079.core1.eqch.net.internet2.edu (163.253.1.211)  323.311 ms  329.075 ms
14  fourhundredge-0-0-0-1.4079.core1.chic.net.internet2.edu (163.253.1.206)  323.464 ms  329.379 ms fourhundredge-0-0-0-1.4079.core2.kans.net.internet2.edu (163.253.2.29)  342.490 ms
15  fourhundredge-0-0-0-1.4079.core2.kans.net.internet2.edu (163.253.2.29)  342.456 ms fourhundredge-0-0-0-1.4079.core2.denv.net.internet2.edu (163.253.1.250)  331.531 ms fourhundredge-0-0-0-1.4079.core2.kans.net.internet2.edu (163.253.2.29)  346.299 ms
16  fourhundredge-0-0-0-1.4079.core2.denv.net.internet2.edu (163.253.1.250)  336.326 ms fourhundredge-0-0-0-3.4079.core2.salt.net.internet2.edu (163.253.1.169)  343.476 ms fourhundredge-0-0-0-1.4079.core2.denv.net.internet2.edu (163.253.1.250)  334.176 ms
17  fourhundredge-0-0-0-3.4079.core2.salt.net.internet2.edu (163.253.1.169)  349.571 ms fourhundredge-0-0-0-2.4079.core2.sacr.net.internet2.edu (163.253.1.186)  336.215 ms  333.823 ms
18  fourhundredge-0-0-0-2.4079.core2.sacr.net.internet2.edu (163.253.1.186)  336.182 ms fourhundredge-0-0-0-23.4079.core1.sacr.net.internet2.edu (163.253.1.38)  337.903 ms fourhundredge-0-0-0-2.4079.core2.sacr.net.internet2.edu (163.253.1.186)  330.640 ms
19  fourhundredge-0-0-0-0.4079.core1.sunn.net.internet2.edu (163.253.1.193)  322.503 ms fourhundredge-0-0-0-21.4079.core1.sacr.net.internet2.edu (163.253.1.34)  324.217 ms fourhundredge-0-0-0-21.4079.core1.sunn.net.internet2.edu (163.253.1.22)  322.422 ms
20  137.164.26.126 (137.164.26.126)  342.728 ms  342.701 ms fourhundredge-0-0-0-0.4079.core1.sunn.net.internet2.edu (163.253.1.193)  370.078 ms
21  137.164.26.126 (137.164.26.126)  397.193 ms hpr-oak-agg8--svl-hpr3-100g.cenic.net (137.164.25.95)  327.705 ms 137.164.26.126 (137.164.26.126)  397.155 ms
22  hpr-oak-agg8--svl-hpr3-100g.cenic.net (137.164.25.95)  316.901 ms 137.164.26.241 (137.164.26.241)  337.237 ms hpr-oak-agg8--svl-hpr3-100g.cenic.net (137.164.25.95)  316.875 ms
23  137.164.26.241 (137.164.26.241)  338.412 ms  336.033 ms woa-west-rtr-vl3.SUNet (171.66.255.132)  333.751 ms
24  woa-west-rtr-vl3.SUNet (171.66.255.132)  327.609 ms  330.376 ms *
25  web.stanford.edu (171.67.215.200)  329.386 ms  387.451 ms *
paras@paras-HP-Laptop-15s-du1xxx:~$
```

The number of hops between the traceroute results of "google.in" and "stanford.edu" is different:

- For "google.in": 9 hops
- For "stanford.edu": 25 hops

This indicates that the two destinations ("google.in" and "stanford.edu") are reached through different network paths with varying numbers of intermediate routers or network devices. The difference in the number of hops can be attributed to the complex and dynamic nature of the internet's routing infrastructure, as well as the diverse paths that packets can take based on network conditions and routing policies

H.

1. **Routing Path Variability:** Different routes due to network congestion and routing policies result in varying latency for each destination.
2. **Network Infrastructure:** Additional intermediate networks, like Internet2, introduce extra hops and potential delays to "stanford.edu."
3. **Peering Agreements:** Varying partnerships between networks influence the efficiency of data transmission, affecting latency.

4. **Dynamic Network Conditions:** Rapid changes in network load, congestion, and routing can lead to fluctuations in latency.
5. **Server Load and Location:** Server workload and geographical distance contribute to differences in response time.
6. **Load Balancing:** Load distribution among servers can cause different packets to take distinct paths, influencing latency.
7. **Packet Prioritization:** Varied priority levels for different types of traffic can lead to different routing decisions, affecting latency.

In summary, the significant latency difference between the "google.in" and "stanford.edu" traceroutes can be attributed to variations in network infrastructure, routing paths, network conditions, server locations, and peering agreements. These factors can lead to different levels of congestion, processing delays, and efficiency in data transmission along the paths, ultimately resulting in the observed latency disparities.

Question 4:

```
paras@paras-virtual-machine:~$ sudo tc qdisc add dev lo root netem loss 100%
[sudo] password for paras:
paras@paras-virtual-machine:~$ ping -c 5 127.0.0.1
PING 127.0.0.1 (127.0.0.1) 56(84) bytes of data.

--- 127.0.0.1 ping statistics ---
5 packets transmitted, 0 received, 100% packet loss, time 4075ms

paras@paras-virtual-machine:~$ sudo tc qdisc del dev lo root netem
paras@paras-virtual-machine:~$
```

NetEm is an enhancement of the Linux traffic control facilities that allow adding delay, packet loss, duplication, and other characteristics to packets outgoing from a selected network interface.
Sudo: This command is used to run the subsequent command as the superuser (root), granting administrative privileges to the following command.

1. tc: This is the Linux command to manipulate network traffic control settings.
2. qdisc: Stands for "Queueing Discipline," a mechanism to control how packets are queued and scheduled for transmission.
3. add dev lo root netem loss 100%: This part of the command adds a network emulation rule to the loopback (lo) device, simulating network conditions using the netem module. Here's what each part means:
    - dev lo: Specifies the network device. In this case, it's the loopback device (lo), which is used for local communications.

- root: Specifies the root queuing discipline, meaning this rule applies at the root level.
- netem: Specifies the type of queuing discipline, in this case, network emulation.
- loss 100%: This sets the packet loss rate to 100%, effectively simulating complete packet loss.

1. ping -c 5 127.0.0.1: This command runs the ping command with the following options:
   - -c 5: Specifies to send 5 ping packets.
   - 127.0.0.1: The IP address of localhost.
1. sudo tc qdisc del dev lo root netem: This command removes the network emulation rule that was added to the loopback (lo) device, effectively reverting the network conditions to normal.

This sequence of commands is used to simulate a network condition with 100% packet loss using the tc tool, run a ping command to 127.0.0.1 (localhost) in that simulated environment, and then remove the simulation to return the network conditions to normal.
Reference link:https://man7.org/linux/man-pages/man8/tc-netem.8.html
https://wiki.linuxfoundation.org/networking/netem

Question 5:

Running the telnet command perform an get request on a webpage hosted at 192.168.24.12

```
paras@paras-virtual-machine:~$ telnet 192.168.24.12 9900
Trying 192.168.24.12...
Connected to 192.168.24.12.
Escape character is '^]'.
GET /secret HTTP/1.1
Host: google.in

HTTP/1.1 200 OK
Content-Type: text/plain
ip: 192.168.88.148
X-secret: U2FsdGVkX19zW9I83NZPdPkEMddI6/oAFrZA5XlYdHylFc7+hjSgvSU5oRAglvw8
Date: Thu, 17 Aug 2023 17:30:28 GMT
Connection: keep-alive
Keep-Alive: timeout=5
Content-Length: 8

Success
Connection closed by foreign host.
```

The specific service or application associated with port 9900 would determine what happens if the connection is successful.

Telnet communications are not encrypted, so any data transmitted can be intercepted in plain text. For secure remote access, protocols like SSH are recommended.

By this I gained insight into how web browsers communicate with servers to retrieve webpage content. This hands-on approach helped me to understand the underlying interactions that occur when accessing a webpage.

Question 6:

Sending an email using the SMTP server:

```
paras@paras-HP-Laptop-15s-du1xxx:~$ telnet 192.168.24.12 smtp
Trying 192.168.24.12...
Connected to 192.168.24.12.
Escape character is '^]'.
220 Welcome to CSE232 Mail Server
helo cse232.com
250 xeon01-rs-iiitd.iiitd.edu.in
mail to: 21482@cse232.com
501 5.5.4 Syntax: MAIL FROM:<address>
mail from:21482@cse232.com
250 2.1.0 Ok
rcpt to:21482@cse232.com
250 2.1.5 Ok
data
354 End data with <CR><LF>.<CR><LF>
Subject: test

This is a test message.
.
250 2.0.0 Ok: queued as 159786F64585
QUIT
221 2.0.0 Bye
Connection closed by foreign host.
paras@paras-HP-Laptop-15s-du1xxx:~$ telnet 192.168.24.12 smtp
Trying 192.168.24.12...
Connected to 192.168.24.12.
Escape character is '^]'.
220 Welcome to CSE232 Mail Server
helo cse232.com
250 xeon01-rs-iiitd.iiitd.edu.in
mail from:21482@cse232.com
250 2.1.0 Ok
rcpt to:21207@cse232.com
250 2.1.5 Ok
data
354 End data with <CR><LF>.<CR><LF>
Subject: test2

This is a test message srimant.
.
250 2.0.0 Ok: queued as 27C386F64586
QUIT
221 2.0.0 Bye
Connection closed by foreign host.
paras@paras-HP-Laptop-15s-du1xxx:~$
```

Checking my inbox from web browser for mails received from other students:

```
192.168.24.12:9901/U2FsdGVkX1%2Bgnyx777

From 21482@cse232.com  Fri Aug 18 00:34:31 2023
Return-Path: <21482@cse232.com>
X-Original-To: 21482@cse232.com
Delivered-To: 21482@cse232.com
Received: from cse232.com (unknown [192.168.88.148])
        by xeon01-rs-iiitd.iiitd.edu.in (Postfix) with SMTP id 159786F64585
        for <21482@cse232.com>; Fri, 18 Aug 2023 00:32:03 +0530 (IST)
Subject: test

This is a test message.

From 21207@cse232.com  Fri Aug 18 00:39:23 2023
Return-Path: <21207@cse232.com>
X-Original-To: 21482@cse232.com
Delivered-To: 21482@cse232.com
Received: from cse232.com (unknown [192.168.45.23])
        by xeon01-rs-iiitd.iiitd.edu.in (Postfix) with SMTP id 205E16F64585
        for <21482@cse232.com>; Fri, 18 Aug 2023 00:37:29 +0530 (IST)
Subject: cnnnnnnnnnnnnnn

Hey Paras!
Best of luck for your CN Assignment 1!
```

The mail Received by my friend:

```
From 21207@cse232.com  Fri Aug 18 00:24:15 2023
Return-Path: <21207@cse232.com>
X-Original-To: 21207@cse232.com
Delivered-To: 21207@cse232.com
Received: from cse231.com (unknown [192.168.45.23])
        by xeon01-rs-iiitd.iiitd.edu.in (Postfix) with SMTP id 2972C6F64585
        for <21207@cse232.com>; Fri, 18 Aug 2023 00:22:27 +0530 (IST)
SUBJECT: Test

Hey there!

From 21482@cse232.com  Fri Aug 18 00:38:51 2023
Return-Path: <21482@cse232.com>
X-Original-To: 21207@cse232.com
Delivered-To: 21207@cse232.com
Received: from cse232.com (unknown [192.168.88.148])
        by xeon01-rs-iiitd.iiitd.edu.in (Postfix) with SMTP id 27C386F64586
        for <21207@cse232.com>; Fri, 18 Aug 2023 00:37:43 +0530 (IST)
Subject: test2

This is a test message srimant.
```