R2 Analysis

1. Number of probes per “ttl” in each trace file

From inspecting all five Group-1 `.pcap` files, each TTL value is probed three times:

- `group1-trace1.pcap`: 3 probes per TTL
- `group1-trace2.pcap`: 3 probes per TTL
- `group1-trace3.pcap`: 3 probes per TTL
- `group1-trace4.pcap`: 3 probes per TTL
- `group1-trace5.pcap`: 3 probes per TTL

So, all Group-1 traces use 3 probes per TTL.

2. Is the sequence of intermediate routers the same in different trace files?

No.

The first part of the path is identical, but the later hops differ between traces.

Common prefix (first 11 hops in all five traces):

`142.104.68.167 → 142.104.68.1 → 192.168.9.5 → 192.168.10.1 →`

`192.168.8.6 → 142.104.252.37 → 142.104.252.246 → 207.23.244.242 →`

`206.12.3.17 → 199.212.24.64 → 206.81.80.17`

3. If the sequence is different, list the difference and explain why Hops where differences occur (across the 5 traces):

- **Hop 12:** `74.125.37.91` or `72.14.237.123`

- **Hop 13:** `209.85.250.59`, `74.125.37.91`, or `72.14.237.123`
- **Hop 14:** `209.85.245.65`, `209.85.250.121`, `209.85.249.153`, `209.85.249.109`, or `72.14.237.123`
- **Hop 15:** `209.85.247.61`, `209.85.250.57`, `209.85.246.219`, or `209.85.249.155`
- **Hop 16:** `209.85.246.219`, `209.85.250.123`, `209.85.249.153`, or `209.85.247.63`

Explanation

These differences are consistent with load balancing (e.g. ECMP) in the core network.

- Routers have multiple equal cost paths toward 8.8.8.8.
- They choose the outgoing link by hashing packet fields (source/destination IP, ports, etc.).
- Different traceroute probes (even within the same run, and across different runs) can be sent over different next hops, so the visible route changes at later hops while still going to the same destination.

So, the route variations in Group 1 are best explained by per-flow/per-probe load balancing rather than real topology changes.

Group 2

1. Number of probes per “ttl” in each trace file

Again, each TTL value is probed three times in all Group-2 traces:

- `group2-trace1.pcap`: 3 probes per TTL
- `group2-trace2.pcap`: 3 probes per TTL
- `group2-trace3.pcap`: 3 probes per TTL

- `group2-trace4.pcap`: 3 probes per TTL
- `group2-trace5.pcap`: 3 probes per TTL

So, all Group-2 traces also use 3 probes per TTL.

2. Is the sequence of intermediate routers the same in different trace files?

Yes.

All five Group-2 traces follow the exact same 8-hop route:

`192.168.0.1 → 24.108.0.1 → 64.59.161.197 → 66.163.72.26 → 66.163.68.18 → 72.14.221.102 → 108.170.245.113 → 209.85.249.249`

Because the sequence of intermediate routers is the same, we proceed to build the RTT comparison table as requested.

3. RTT comparison table and maximum-delay hop

To determine which hop incurs the maximum additional delay, we examine the increase in RTT between consecutive hops for all five traceroute attempts.

TTL	Trace 1	Trace 2	Trace 3	Trace 4	Trace 5
1	3.3ms	2.7ms	7.9ms	3.4ms	1.7ms
2	15.8ms	17.1ms	11.8ms	13.2ms	16.2ms
3	18.9ms	20.1ms	22.6ms	21.7ms	21.6ms
4	22.8ms	19.4ms	19.5ms	19.8ms	18.6ms
5	26.5ms	21.6ms	20.3ms	35.8ms	20.7ms
6	24.3ms	20.0ms	21.8ms	22.7ms	43.5ms
7	18.4ms	51.7ms	22.8ms	18.3ms	26.9ms
8	23.0ms	108.7ms	20.6ms	24.6ms	25.6ms

Across all traces, Hop 2 consistently causes the largest increase in round-trip time. Hop 2 is the first router inside the ISP's network, after the user's local gateway (Hop 1). This hop often corresponds to:

A long-distance physical link (e.g., fiber from the household router to the ISP POP).

A heavily-loaded aggregation router.

A point where traffic shaping, congestion, or queueing is significant.

A hop where the propagation delay sharply increases compared to the LAN.