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	3329.7ms	2710.7ms	7854.0ms	3415.3ms	1745.7ms
2	15811.7ms	17118.3ms	11835.3ms	13245.0ms	16153.7ms
3	18869.3ms	20096.7ms	22579.3ms	21672.3ms	21601.7ms
4	22843.0ms	19420.0ms	19460.3ms	19754.7ms	18558.3ms
5	26502.0ms	21555.3ms	20321.3ms	35771.3ms	20717.0ms
6	24263.7ms	19982.3ms	21849.7ms	22674.7ms	43472.0ms
7	18408.0ms	51658.0ms	22763.3ms	18337.3ms	26921.3ms
8	22970.7ms	-224262.3ms	20592.0ms	24574.3ms	25623.3ms

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.