Group 1 Analysis

1. Number of probes per TTL in each trace file

All five trace files in Group 1 use **3 probes per TTL**. This was determined by analyzing the UDP packets sent with each TTL value. For example, packets with TTL=1 used destination ports 33434, 33435, and 33436 (three consecutive ports), confirming three probes per TTL.

2. Is the sequence of intermediate routers the same?

No, the sequence is different.

While the first 11 hops are identical across all five traces, differences appear starting at hop 12 (TTL=12) and continue through hop 13 (TTL=13). The common prefix for all traces is:

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. Differences and Explanation

The differences occur at the following hops:

Hop (TTL)	Routers Observed	Frequency
12 (TTL=12)	74.125.37.91	3 out of 5 traces
	72.14.237.123	2 out of 5 traces
13 (TTL=13)	74.125.37.91	1 out of 5 traces
	72.14.237.123	3 out of 5 traces
	209.85.250.59	1 out of 5 traces

Explanation:

These differences are caused by **load balancing** (specifically ECMP - Equal Cost Multi-Path routing). At hop 11 (TTL=11), the router has multiple equal-cost paths to the destination and uses a hash function on packet header fields (source IP, destination IP, source port, destination port) to select which next-hop router to use. Since each traceroute probe uses a different source port (33434, 33435, 33436, etc.), different probes can take different paths through the network.

This is a common traffic engineering technique used to distribute load across multiple routers and links, improving network performance and reliability.

Group 2 Analysis

1. Number of probes per TTL in each trace file

All five trace files in Group 2 use **3 probes per TTL**, consistent with Group 1.

2. Is the sequence of intermediate routers the same?

Yes, the sequence is identical in all five traces.

All Group 2 traces follow the 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

3. RTT Comparison Table

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

4. Maximum Delay Analysis

To determine which hop incurs the maximum additional delay, I calculated the RTT increase between consecutive hops by averaging across all five traces.

Hop-by-hop RTT increases (averaged across all traces):

From Hop	To Hop	Average RTT Increase
1	2	+12.1 ms
2	3	+4.1 ms
3	4	-1.0 ms
4	5	+5.5 ms
5	6	-0.4 ms
6	7	+3.8 ms
7	8	+7.4 ms

Conclusion: Hop 2 (router 24.108.0.1) incurs the maximum delay increase of approximately **12.1 ms**.

Explanation: Hop 2 represents the transition from the local home network (192.168.0.1) to the Internet Service Provider's network (24.108.0.1). This large delay increase is typical and can be attributed to:
• Physical distance from the home gateway to the ISP's point-of-presence (POP)
• Aggregation and processing at the ISP's edge router

- Potential congestion or rate limiting at the customer-ISP boundary
- Cable modem or DSL equipment processing delays

This is a common bottleneck in residential internet connections, where the 'last mile' link between the customer and ISP often has higher latency than the backbone network links.