Question 1: Internet Delay

Every time a packet is received at the router, it is time-stamped (TA). It is also time-stamped when it is about to leave link K and arrive at the next hop (TB). Note that this would be a difficult measurement to actually perform!

When 5 packets of size 500 bytes are transmitted through the link K, TB–TA is measured to be 10 ms, 2.8 ms, 2.4 ms, 4 ms, and 5.5 ms. When 5 packets of size 1000 bytes are transmitted through the link K, TB–TA is measured to be 11.0 ms, 10 ms, 2.8 ms, 3.0 ms, and 5.5 ms. Assume that processing delay at the router is negligible.

What is the average queuing delay experienced by the 1000-byte packets?

The average queuing delay experienced by the 1000 byte packets can be measured by subtracting 2.8 (the lowest runtime of all 5 samples) to each measured sample and dividing the total by 5. When we take (11.0 - 2.8) + (10 - 2.8) + (2.8 - 2.8) + (3.0 - 2.8) + (5.5 - 2.8) → 18.3 / 5 → 3.66 ms.

What are reasonable estimates of transmission and propagation delays that will be experienced by a packet of size 600 bytes sent through the link K?

Reasonable estimates of transmission and propagation delays that will be experienced by a packet of size 600 bytes sent through the link K is

Transmission time T = length(size) / B where B is the bandwidth.

Propagation time is the bits to travel from sender to the receiver - usually represented by C (as a constant for propagation delay). TB - TA = T + P. (transmission time plus propagation time).

So 2.8 (TB - TA) = (1000 / B) + C and 2.4 = (500/B) + C

2.8B = 1000 + BC and 2.4B = 500 + BC; //multiplying both sides by B

2.8B - 2.4B = (1000 + BC) - (500 + BC) //subtracting both expressions

0.4B = 500; // solving for B

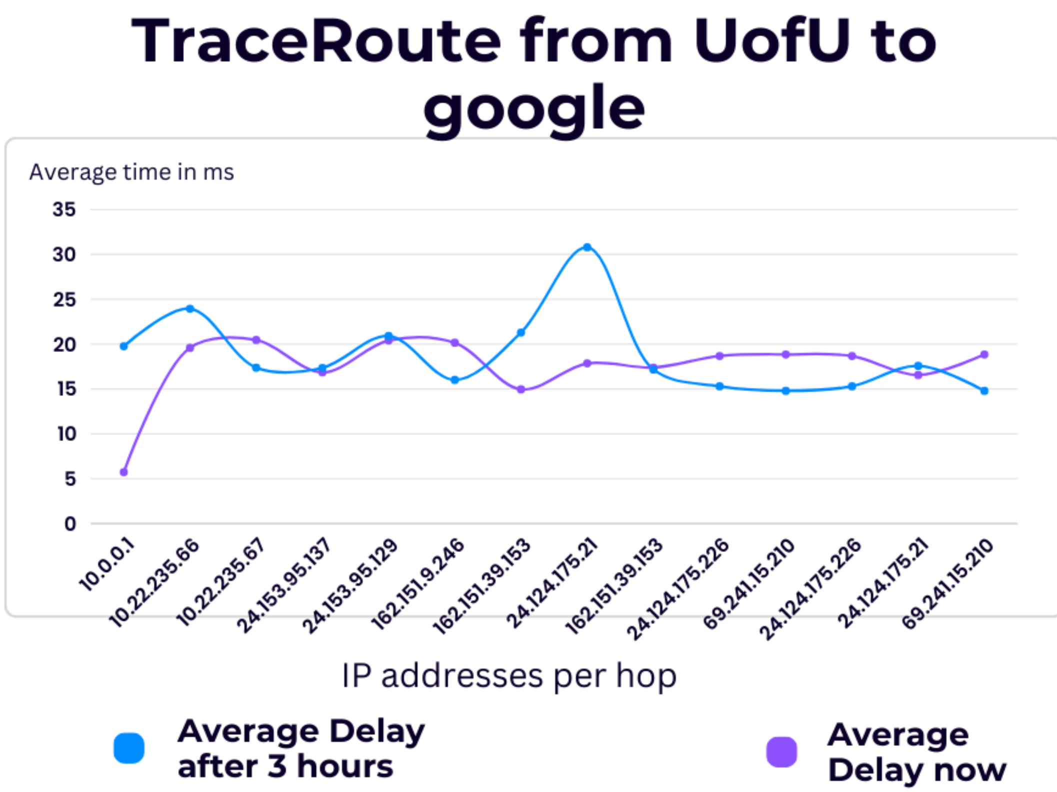
B = 500 / 0.4 = 1250.

2.4 = 500 / 1250 + C → 2.4 = 0.4 + C → C = 2.0 //solving for C

The transmission and propagation delay for a size of 600 would be x = 600 / 1250 = 0.48 ms and 2 ms for propagation time delay since it's a constant.

Question 2: Traceroute

Part A:



To deal with incomplete data, the program that parsed the collected data only parsed complete data; if the time for example was missing then it does not get counted. When calculating the average delay; instead of dividing per 3 each hop; the program kept track of how many IP addresses per hop and divided the total of that per the count.

Part B: Suppose one of the three `traceroute` delay values between the source and a given router hop turns out to be unusually high. **What are two possible causes for this unusually high delay?**

Two possible causes for this unusual high delays can be due to network congestion and packet loss. Network congestion happens when the network segment or specific router is congested; when the traffic flow through the network exceeds its maximum capacity; usually the congestion is temporary. Packet loss happens when some packets are dropped due to overwhelmed routers or network links since traceroute relies on receiving responses from each hop.

Question 3: Ping

Average delay output for the collected data: 24.057954732510282 ms from 243 packets transmitted, 243 packets received, 0.0% packet loss round-trip min/avg/max/stddev = 15.395/39.453/618.315/71.202 ms.