

Router Buffer Data Analysis

This page provides different sort of data analysis using ping and traceroute data.

Goals

To find the minimum buffer size along a network path.
To utilise existing measurements if they already exist.

Non-goals (at this time)

To determine where the bottleneck queue size exists in a network path.
To deploy new measurement infrastructures.

Delays:

There are three types of delays a packet can have during its transmission from source to destination.

Yee: We don't care about how long it takes for each hop to send data etc. we only care about the goals specified above.

1. Propagation delay (P_d): A time required to send a single bit from one hop to another along the path.
2. Transmission delay (T_d): A time required to transmit whole packet from a hop along the outgoing link.
3. Queuing delay (Q_d): A time required by the packet to wait in the buffer before being ready for transmission into an outgoing link.

Yee: Maybe specify:

1. Propagation Delay (T_p): The time it takes for a packet to transfer across the network path when the queuing and transmission delays are zero.
1. Transmission Delay (T_d): The time it takes for a packet to be processed and transferred through the network nodes.
1. Queuing Delay (T_q): Variation in the end-to-end delay because the packet had to be serviced by devices due to queuing.

There may be many nodes along the network path, each contributing to the transmission and queuing delays.

As such, the one way latency along a network path is composed of

$$T = T_p + T_d + T_q$$

Bearing in mind that the transmission and queuing delays may be at both ends of the peer link, for a single hop, we have

$$T_i = T_p + T_{di} + T_{di+1} + T_{qi} + T_{qi+1}$$

And the complete end-to-end one way latency is defined as

$$T = \sum_i^n T_i$$

where n is the total number of nodes along a route.

Total delay is the sum of all P_d , T_d and Q_d along the path. Round trip time (RTT) is equal to $2 * \text{total delay}$, if the reverse path takes the same route and delays. *Note: P_d is normally taken as 0, compared to other delays.* Cannot ignore P_d on long distance links, i.e. it is $1 \text{ ms} \sim 100 \text{ km}$ so for 1000 km we have 10 ms and to Pakistan (say $10,000 \text{ km}$) it is 1000 ms . For fast long distance links one can probably ignore T_d since if the packet is say $100 \text{ Bytes} \sim 1000 \text{ bits}$, it takes 1 ms ($1000 \text{ bits} / 1 * 10^6 \text{ bps}$) to clock from the NIC to the wires at 1 Mbit/s , 10 usec at 100 Mbits/s and 0.1 us at 10 Gbits/s .

Let's say, we have to find minimum buffer sizes along the path. Practically, it is very difficult to measure the exact buffer size of each hop along the path. We can somehow easily estimate the queuing delay along the path using ping and traceroute tools. From queuing delay, we can estimate congestion, buffer overflow, incoming and outgoing data rate. If we take the difference of incoming and outgoing data rate that will give us the queue occupancy. From queue occupancy, we can roughly estimate the buffer size of that specific router. In the following sections, I am going to explain how we can measure the average queuing delay using ping, and queuing delay at each and every hop along the path using traceroute.

Ping and Delays:

In a network world, ping basically helps us to measure round trip time (RTT) from source to destination using ICMP Echo Messages. It doesn't provide, what path the packet takes to each router and the no. of routers the packet have traversed. Normally network engineers provide the no. of attempts e.g. 10 in PingER for each probe. From these 10 attempts, they measure four or five different metrics. Min RTT, Max RTT, Avg RTT, Packet loss and sometimes the standard deviation of the RTTs. Using these metrics, we can measure the average queuing delay along the whole path by subtracting MaxRTT from MinRTT.

Let L = size of the packet and, R = data rate of the whole path.

Average Q_d = $\text{MaxRTT} - \text{MinRTT}$.
Average T_d = L/R

It is practically, impossible to get a very good estimate of Queuing delay at each hop along the path using ping. Yee: Why???

Traceroute and Delays:

The default traceroute basically provides us with following metrics:

1. No. of hops from source to destination
2. IP and names of hops.
3. Three times measured RTTs from source to each hop along the path. There is an option to change three to another number.

In my own personal point of view, we can measure a good estimate of buffer size at each hop using traceroute measurement. The following sections describe the steps to figure out estimate of buffer size at each hop.

Lets say we have two hops(R1, R2) between source A and destination B. Traceroute measure three different RTTs from A to R1 and R2 respectively. and let's denote those RTTs by (RTT1(1), RTT1(2), RTT1(3)) for R1 and (RTT2(1), RTT2(2), RTT2(3)) for R2.

Now get the max and min RTT from the two sets separately. and denote it minRTT1, maxRTT1 for R1 and minRTT2 and maxRTT2 for R2.

If we disregard the variability of the RTTs it is simple to find queuing delay at R1 which is:

Queuing Delay at R1 (Qd1) = maxRTT1 - minRTT1

As the packet goes, the latency from A to R2 is mainly affected by the queuing delay of R1. Hence we need to subtract the queuing delay at R1 from the difference of maxRTT2 and minRTT2.

Queuing Delay at R2 (Qd2) = maxRTT2 - minRTT2 - Qd1

Hence, Queuing Delay of nth hop router (Rn) is given below:

$$Qdn = (maxRTTn - minRTTn) - \sum_{i=1}^{n-1} (Qdi)$$

In fact queuing delay is variable, and three RTTs are not enough to measure a good estimate of queuing delay. In this case, we need to measure the analysis of like around 10-100 RTTs to get a sufficient good estimate of queuing delay. The more RTTs we have in a set for a router, the better estimate we can fetch.

Once we have the queuing delay from source to router A, we can easily find the transmission delay. Once we have transmission delay we can figure out the Incoming data rate of that router.

We know that RTT from A to R1 = 2(PdA + Td1 + Qd1), lets consider Pd, is 0 compared to Td and Qd then

RTT from A to R1 = 2(Td1 + Qd1)

Td1 = RTT/2 - Qd1

RTT from A to R2 = 2(Td1 + Qd1) + 2(Td2 + Qd2)
= 2(Td1 + Td2 + Qd1 + Qd2)

Td2 = RTT/2 - Td1 - Qd1 - Qd2

In order to get a good estimate of Td we calculate the average RTT for each hop avgRTT1 = avg(RTT1, RTT2, RTT3) for router R1.

Hence the transmission delay for nth hop is given below:

Td1 = avgRTT1/2 - Qd1

Tdn = avgRTTn/2 - \sum_{i=1}^{n-1} (Tdi) - \sum_{i=1}^n (Qdi)

In order to find queue occupancy, we need to know the incoming and outgoing link data rate.

Queue Occupancy (Qo) = incoming rate - outgoing rate

Now the incoming rate of R1 is Td1 and outgoing rate of R1 is Td2. So,

Qo1 = Td1 - Td2

Qo2 = Td2 - Td3

Qon = Tdn - Tdn+1

If n is the last hop then, Tdn+1 provides the transmission rate of last hop to set the whole packet on wire towards intended destination.

I am still working on figuring out the estimate of buffer size at each router, using the above calculated metrics.