

- 1) What is network congestion? What causes it?

In the simplest terms, network congestion is the increase in end-to-end delay due to high bandwidth utilization at some point in the network. It is caused by end systems sending data faster than the network is capable of handling (those darned routers!).

- 2) What are some consequences of a congested network?

Packets are dropped, delayed, or routed through a non-optimal path. Because of this, sending hosts will attempt to retransmit (if using TCP), which causes an increase in network congestion. If this were to continue, there would be a congestion collapse (essentially a network super-slow-down).

- 3) Given a nodal delay of 3 ms when there is no traffic on the network (i.e., when usage = 0%).

- a. What is the effective delay when network usage is 25%? **4 ms**
- b. What is the effective delay when network usage is 75%? **12 ms**
- c. What is the effective delay when network usage is 90%? **30 ms**
- d. What is the effective delay when network usage is 99%? **300 ms**
- e. What do these numbers illustrate about the given equation? **It is very idealized, and not very useful in practice – but useful in understanding the basic principles involved.**

- 4) What is the goal of congestion control? What, in general, is used to do this?

To optimizing network utilization, such that a high throughput is ensured, with the restriction that we utilization is not pushed so high that delay and packetloss become major factors. This is accomplished by attempting to detect and avoid congestion, and if congestion is un-avoidable, the sender should reduce their data output.

- 5) A host starts a TCP transmission with an EstimatedRTT of 50ms (from the “handshake”). The host then sends 3 packets and records the RTT for each:

SampleRTT1 = 30 ms SampleRTT2 = 40 ms SampleRTT3 = 20 ms

(NOTE: SampleRTT1 is the “oldest”; SampleRTT3 is the most recent.)

Using an exponential weighted moving average with a weight of 0.4 given to the most recent sample, what is the EstimatedRTT for packet #4 (nearest .1 ms)? **32.72 ms**

$$0.6 * 50 + 0.4 * 30 = 42$$

$$0.6 * 42 + 0.4 * 40 = 41.2$$

$$0.6 * 41.2 + 0.4 * 20 = 32.72$$

6) How is TCP's timeout interval set?

$$\text{TimeoutInterval} = \text{EstimatedRTT} + 4 * \text{DevRTT}$$

EstimatedRTT is a exponential weighted moving average based on recent and past sampled round trip time values.

$$\text{EstimatedRTT}_n = (1 - \alpha)\text{EstimatedRTT}_{n-1} + (\alpha)\text{SampleRTT}_{new}$$

DevRTT is a factor which increases when the most recent sampled round trip time is different from the most recent estimated round trip time. It is another exponential weighted moving average, strongly weighted toward the most recent deviation value.

$$\text{DevRTT}_n = (1 - \beta)\text{DevRTT}_{n-1} + \beta(\text{SampleRTT}_{new} - \text{EstimatedRTT}_{n-1})$$