National University of Singapore
School of Computing
CS5229: Advanced Computer Networks
Semester I, 2021/2022

Lecture 1 Training
End-to-End Argument

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In Lecture 1, we briefly discussed the end-to-end argument in system design and mentioned that there were trade offs.

In this question, we will investigate the impact of these trade offs on practical metrics that we care about. In particular, you are to determine the flow completion time (FCT, time between the first packet sent from the server to the last packet received at the receiver) and round-trip times (RTT) for different network scenarios.

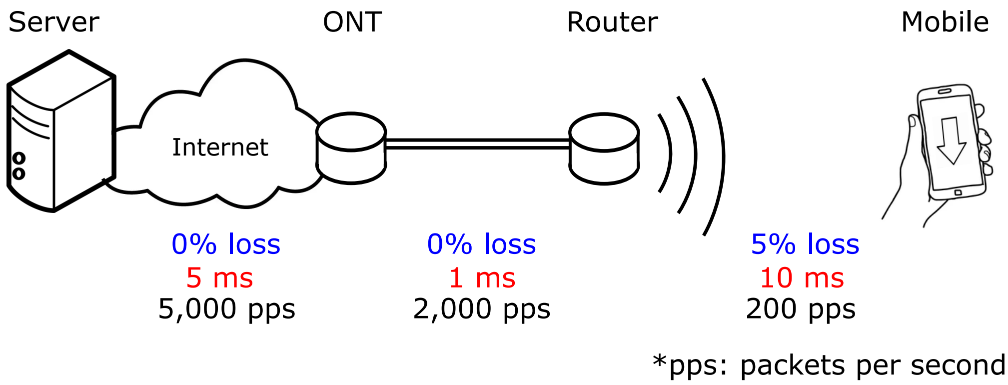

Figure 1: Simple wireless network.

Consider the network in Figure 1. Suppose the mobile end host wants to download a file consisting of 1,000 packets from the server. Each wired/wireless link in this topology has some loss rate, one-way delay, and bandwidth (in packets per second) associated with it (specified in Figure 1).

For simplicity, you can assume that there are no other competing flows in the network and that both retransmitted packets or acknowledgement packets will suffer no loss. All nodes in the network use the NACK-like retransmission policy described in Figure 2.

Basically, the packets will contain a sequence number and the receiver assumes that there is no reordering, so if it detects a skipped sequence number, it will immediately inform the sender of this missing packet via a NACK. The sender will retransmit the missing packet once it receives the NACK.

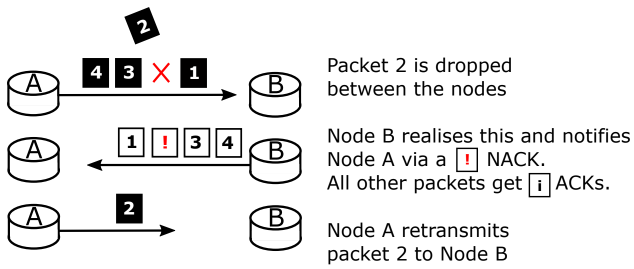

Figure 2: Retransmission policy

Given this information, answer the following questions on Coursemology:

1. What is the RTT and FCT if the loss rate at the wireless link is zero?
2. What is the expected ($E(x)$) RTT and FCT for downloading the 1,000 packet file when the loss rate at the wireless link 5%, for each of the following scenarios:
   (a) **Only** end-to-end retransmission are allowed
   (b) Link re-transmissions are allowed in the wireless link between the Router and the Mobile

You are not expected to do any complex modelling or mathematical computations to derive the above answers. In networking, we often do back-of-the-envelope calculations allow us to check that our experiments are yielding results that are within expectation.

Solutions

1. The FCT is the sum of the transmission time (time taken to put packet on the wire), plus the propogation time (time taken for the packets to travel to the receiver). Since the bottleneck bandwidth for this connection is 200 pps, we will use this bandwidth to calculate the transmission time. We will use the path's one-way delay to calculate the propogation delay.
   FCT = transmission time + propogation time=$\frac{1000}{200} + (0.005 + 0.001 + 0.010)$ = **5.016 s**

   The RTT, or the *round-trip time* of a connection is simply twice the one-way delay:
   RTT = $2 \times (5 + 1 + 10) =$ **32 ms**
2. With packet losses (5%)
   (a) *end-to-end retransmits:* 5% packet loss means the sender sends a total of 1,050 packets instead of 1,000 packets. Plugging in these values in the equation used earlier we get,
   FCT =$\frac{1050}{200} + (0.005 + 0.001 + 0.010)$ = **5.266 s**
   An end-to-end retransmission will have no effect on the RTT.
   Therefore, $E(\textbf{RTT}) =$ **32 ms**

   (b) *link-level retransmits:* Following the same logic as before,
   FCT =$\frac{1050}{200} + (0.005 + 0.001 + 0.010)$ = **5.266 s**

   Note: You might be tempted to think that because the retransmits are happening at the link-level instead of end-to-end, the FCT is should be smaller because the RTT of path traversed by the retransmitted packets is smaller. But the length of this traversed path (which shows up as propogation delay in the FCT equation) only determines how quickly your *first* packet can reach the receiver. After that the FCT is dominated by the transmission delay because the packets travel in a stream. This delay only depends on the bottleneck bandwidth and **not** the RTT of the path.

However, link-level retransmissions **will** have an effect on the RTT. Since the end host is blind to the link-level retransmission, the retransmission will show up as extra delay in the ACK for the lost packet. Since we know how many packets are lost and how much extra delay these retransmission will cause, we can calculate the RTT as follows:
$E(\textbf{RTT}) = 32 \times 0.95 + (32 + \textbf{20}) \times 0.05 = \textbf{33 ms}$
Here, the extra 20 ms is for the NACK to travel from the Mobile to the Router, and the retransmitted packet to travel from the Router to the Mobile.