Module 2 – Sample delay calculations

1. This is Problem 8 at the end of Chapter 1 in the book, Page 70.

Consider two hosts A and B, connected by a single link of transmission rate R bps. Suppose that the two hosts are separated by \( m \) meters and that the propagation speed along the link is \( s \) meters/sec. Host A needs to send a single packet of size \( L \) bits to host B.

a) What is the propagation delay, \( d_{\text{prop}} \)?
   Ans: \( d_{\text{prop}} = \frac{m \text{ meters}}{s \text{ meters/ sec}} = \frac{m}{s} \text{ sec} \)

b) The transmission time of the packet, \( d_{\text{trans}} \) is:
   Ans: \( d_{\text{trans}} = \frac{L \text{ bits}}{R \text{ bits/ sec}} = \frac{L}{R} \text{ sec} \)

c) Ignoring processing and queuing delays, obtain an expression for end-to-end delay:
   Ans: The last bit gets pushed out of A’s interface in \( \frac{L}{R} \text{ sec} \); this bit takes \( \frac{m}{s} \) sec to reach B. So the total end-to-end delay is: \( \frac{L}{R} + \frac{m}{s} \) sec.

d) If A begins transmission at \( t = 0 \), at \( t = d_{\text{trans}} \), where is the last bit of the packet?
   Ans: The last bit has already reached host B, assuming \( \frac{m}{s} (= d_{\text{trans}}) \) is much less than \( \frac{L}{R} (= d_{\text{prop}}) \).

2. In the network above, the transmission delay for a single 54Kbyte packet that A needs to transmit to B is:
   Ans: \( \frac{L}{R} \times 54 \times 10^3 \times 8 \text{ sec} \)

3. Suppose two hosts A and B are separated by 10,000 kilometers and connected by a single direct link with \( R = 1 \text{ Mbps} \). Assume the propagation speed is \( 2.5 \times 10^8 \text{ meters/ sec} \).

   a) The “Bandwidth-delay product” of a link is defined as \( R \times d_{\text{prop}} \). Calculate the bandwidth-delay product for this link:
   Ans: \( d_{\text{prop}} = \frac{10,000 \text{ km} \times 1000 \text{ meters/km}}{2.5 \times 10^8 \text{ meters/ sec}} = \frac{1}{25} \text{ sec} \); \( R = 1 \text{ Mbps} \); So
   Bandwidth-delay product = \( \frac{1}{25} \text{ sec} \times 10^6 \text{ bits/ sec} = 4 \times 10^4 \text{ bits} \)

   b) What is the maximum number of bits on the link at any given time?
   A first bit takes \( \frac{1}{25} \text{ sec} \) to reach B once it leaves A. During this time, how many
bits have been injected into the wire by A? \(\frac{1}{25} \times 10^6 \text{bits/sec} = 4 \times 10^4 = 40,000 \text{ bits.}\) So the maximum number of bits on the link at any given time is 40,000. Thus Bandwidth-delay product is the maximum number of bits on the link at any given time.

4. Consider a router that has a finite buffer at its outbound link. Suppose that the link has \(R = 1.5 \text{ Mbps} \) transmission rate and that a packet contains 6400 bits. If 1000 such packet arrive simultaneously at the router, what is the average queuing delay for the 1000 packets?

Ans: The queuing delay for the first packet is 0; the second packet has to wait till the first one is completely transmitted, which takes \(\frac{6400}{1.5 \times 10^6} \text{ sec.}\) The waiting time for the third packet will be \(2 \times \frac{6400}{1.5 \times 10^6} \text{ sec,}\) since it gets sent only after the first two are sent. Arguing similarly, the last packet has to wait \(999 \times \frac{6400}{1.5 \times 10^6} \text{ sec.}\)

So the average delay is the average of these delays:

\[
\frac{\left( \frac{6400}{1.5 \times 10^6} + 2 \times \frac{6400}{1.5 \times 10^6} + 3 \times \frac{6400}{1.5 \times 10^6} + \ldots + 999 \times \frac{6400}{1.5 \times 10^6} \right)}{999} \text{ sec} = \frac{1+2+3+\ldots+999}{999} \times \frac{6400}{1.5 \times 10^6} = 500 \times \frac{6400}{1.5 \times 10^6} \simeq 2.13 \text{ sec.}
\]