Homework 1 – Solutions

P2. Equation 1.1 gives a formula for the end-to-end delay of sending one packet of length *L* over *N* links of transmission rate *R*. Generalize this formula for sending *P* such packets back-to-back over the *N* links.

P2 Solution: At time N*(L/R) the first packet has reached the destination, the second packet is stored in the last router, the third packet is stored in the next-to-last router, etc. At time N*(L/R) + L/R, the second packet has reached the destination, the third packet is stored in the last router, etc. Continuing with this logic, we see that at time N*(L/R) + (P-1)*(L/R) = (N+P-1)*(L/R) all packets have reached the destination.

P6. This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate *R* bps. Suppose that the two hosts are separated by *m* meters, and suppose the propagation speed along the link is *s* meters/sec. Host A is to send a packet of size *L* bits to Host B.

a) Express the propagation delay, d_{prop}, in terms of *m* and *s*.
b) Determine the transmission time of the packet, d_{trans}, in terms of *L* and *R*.
c) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.
d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?
e) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?
f) Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?
g) Suppose $s = 2.5 \cdot 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance *m* so that d_{prop} equals d_{trans}.

P6 Solution:

a) $d_{prop} = m/s$ seconds.
b) $d_{trans} = L/R$ seconds.
c) $d_{end-to-end} = (m/s + L/R)$ seconds.
d) The bit is just leaving Host A.
e) The first bit is in the link and has not reached Host B.
f) The first bit has reached Host B.
g) $m = \frac{L}{R}s = \frac{120}{56 \times 10^3}\left(2.5 \times 10^8\right) = 536$ km.

P15. Let *a* denote the rate of packets arriving at a link in packets/sec, and let *µ* denote the link's transmission rate in packets/sec. Based on the formula for the total delay (i.e., the queuing delay plus the transmission delay) derived in the previous problem, derive a formula for the total delay in terms of *a* and *µ*.

P15. Solution:

(From P14 a) The transmission delay is L/R. The total delay is $\frac{IL}{R(1-I)} + \frac{L}{R} = \frac{L/R}{1-I}$

$\boldsymbol{\mu = R/L}$ packets per second. The inverse is L/R or transmission delay.

Total delay $= \frac{L/R}{1-I} = \frac{L/R}{1-aL/R} = \frac{1/\mu}{1-a/\mu} = \frac{1}{\mu - a}$.

R22. List five tasks that a layer can perform. Is it possible that one (or more) of these tasks could be performed by two (or more) layers?

R22 Solution:

Five generic tasks are error control, flow control, segmentation and reassembly, multiplexing, and connection setup. Yes, these tasks can be duplicated at different layers. For example, error control is often provided at more than one layer.