Problem 1

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?

a. $d_{prop} = m/s$ seconds

b. $d_{trans} = L/R$ seconds

c. $d_{end-to-end} = d_{prop} + d_{trans} = (m/s + L/R)$ seconds

d. The last 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.

Problem 2

Using the same scenario as in Problem 1, suppose $m = 10,000$ kilometers, $R = 1$ Mbps, and $s = 2.0 \times 10^8$ meters/sec. (Please show your work. *Hint:* Each part of this question builds on the previous part.)

a. Calculate the bandwidth-delay product, $R \times d_{prop}$.

b. Consider sending a file of 200,000 bits from Host A to Host B. Suppose the file is sent continuously as one big message. What is the maximum number of bits that will be in the link at any time? How about sending a smaller file of 10,000 bits?

c. Provide an interpretation of the bandwidth-delay product – what does it represent?

d. What is the width (in meters) of a bit in the link? Is it longer than a football field (which is about 100 meters long)?

Problem 2 continued on next page. . .

a. $R = 1$ Mbs = 1,000,000 bps
m = 10,000 km = 10,000,000 m
$d_{prop} = m/s$
$d_{prop} = 10,000,000$ m / (2.0×10^8) m/sec = 0.05 seconds
$R \times d_{prop} = 1,000,000$ bps $\times$ 0.05 secs = 50,000 bits

b. Each bit will be in the link for d_{prop} seconds. The link can send R bits at once. Thus, a maximum of $R \times d_{prop} = 50,000$ bits can be in the link. $200,000 > 50,000$, so the link will reach its maximum capacity of 50,000 bits. For the 10,000 bits file, the maximum number of bits in the link is 10,000.

c. The bandwidth-delay product represents the maximum number of bits that can fit in the link.

d. We can find the width of a bit by dividing the length of the link by the maximum number of bits that it can fit:

width $= m/(R \times d_{prop})$ = 10,000,000 m / 50,000 bits = 200 meters per bit

Yes, the width of a bit is longer than a football field.

Problem 3

Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS look-up is necessary to obtain the IP address. Suppose that your host must contact n DNS servers before receiving the needed IP address from DNS; the successive visits incur RTTs of RTT_1, ..., RTT_n (don't worry about the details of how DNS works). Further suppose that the Web page associated with the link is a small HTML file, consisting only of references to three very small objects on the same server. Let RTT_0 denote the RTT between the local host and the server containing the object. Neglecting transmission times, how much time elapses (in terms of RTT_0, RTT_1, ..., RTT_n) from when you click on the link until your host receives all of the objects, if you are using:

a. Nonpersistent HTTP with no parallel TCP connections?

b. Nonpersistent HTTP with parallel connections?

c. Persistent HTTP with pipelining?

a. DNS RTTs + HTML RTTs (with TCP handshake) + 3 object RTTs (with TCP handshakes)
$= (RTT_1 + ... + RTT_n) + 2RTT_0 + 3 \times 2RTT_0$
$= 8RTT_0 + (RTT_1 + ... + RTT_n)$

b. DNS RTTs + HTML RTTs (with TCP handshake) + parallel object RTTs (with TCP handshakes)
$= (RTT_1 + ... + RTT_n) + 2RTT_0 + 2RTT_0$
$= 4RTT_0 + (RTT_1 + ... + RTT_n)$

c. DNS RTTs + HTML RTTs (with TCP handshake) + RTT for all referenced objects
$= (RTT_1 + ... + RTT_n) + 2RTT_0 + RTT_0$
$= 3RTT_0 + (RTT_1 + ... + RTT_n)$