CHAPTER 1

Packet-Switched Networks

1.1. Total distance = $\ell = 2(\sqrt{3,000^2 + 10,000^2}) = 20{,}880.61$ km.

Speed of light = $c = 2.3 \times 10^8$ m/s.

(a) proagation delay= $t_p = \frac{\ell}{c} = \frac{20,880.61 \text{ km}}{2.3\times10^8 \text{ m/s}} = 90.8 \text{ ms}$

(b) Number of bits in transit during the propagation delay

$= (90.8 \text{ ms}) \times (100\times10^6 \text{ b/s})$

$= 9.08 \text{ Mb}$

(c) 10 bytes = 80 bits

2.5 bytes = 20 bits, then:

$$T = t_f(\text{transfer time, data}) + t_f(\text{transfer time, ACK}) + t_p(\text{data}) + t_p(\text{ACK})$$

$$= \frac{80\text{b} + 20\text{b}}{100\times10^6 \text{ b/s}} + 2\times 90.8\text{ms} = 181.7 \text{ ms}$$

1.2. Total distance = $\ell = 2(\sqrt{(30/1000)^2 + 10,000^2}) \approx 20{,}000$ km.

Speed of light = $c = 2.3 \times 10^8$ m/s.

(a) $t_p = \frac{\ell}{c} = \frac{20,000 \text{ km}}{2.3\times10^8 \text{ m/s}} = 87 \text{ ms}$

(b) 100 Mb/s $\times$ 0.087 s = 8.7 Mb

(c) Data : $\frac{(10\ \text{B})\times 8\ \text{b}}{100\ \text{Mb/s}} + t_p = 0.79\ \mu s\ + 0.087\ \text{s}$

Ack: $\frac{(2.5\ \text{B})\times 8\,\text{b}}{100\ \text{Mb/s}} + t_p = 0.19\ \mu\text{s} + 0.087\ \text{s}$

Total time $\approx 1\mu$s (transfer) $+ 0.173$ s (prop.)

1.3. Assuming the speed of transmission at 2.3×10^8 :

(a) Total Delay: $D = (n_h - 1)t_p + [n_p + (n_h - 2)]t_f + n_h t_r$

(b) $t_{p1} = \frac{50\ \text{miles} \times 1600\ \text{m/miles}}{2.3\ \times 10^8\ \text{m/s}} = 0.35\ \text{ms}$

$t_{p2} = \frac{400\ \text{miles} \times 1600\ \text{m/miles}}{2.3 \times 10^8\ \text{m/s}} = 2.8\ \text{ms}$

The packet of size 10,000 bytes includes the header of size 40 bytes. Therefore:

$\text{Number of packets} = n_p = \frac{200\text{MB}}{10,000\text{B} - 40\text{B}} = 20,080.$

$t_f = \frac{10,000\ \text{B/pockets} \times 8\ \text{b/B}}{100\ \text{Mb/s}} = 0.8\ \text{ms/packets}$

$D = [(2-1)0.35 + (3-1)2.8] + [20,080 + (5-2)]0.8 + 5\times 0.2\times 10^3 \approx 16.66\ \text{s}$

Note that for this exercise we assumed the processing time is provided per packet (and not collectively for all packets. Thus we multiplied the last term by 5)

1.4.

$D_p = [n_p + (n_h - 2)]t_{f1} + n_h t_{r1} + (n_h - 1)t_p$

$D_c = 3\big([1 + (n_h - 2)]t_{f2} + n_h t_{r2} + (n_h - 1)t_p\big)$

$D_t = D_p + D_c = 4(n_h - 1)t_p + (n_p + n_h - 2)t_{f1} + 3(n_h - 1)t_{f2} + n_h(t_{r1} + 3t_{r2})$

1.5.

$\text{Number of packets} = n_p = \frac{200\text{MB}}{10,000\text{B} - 40\text{B}} = 20,080.$

$D_t = D_p + D_c$

$t_{p1} = \frac{50\ \text{miles}\times 1600\ \text{m/miles}}{2.3\times 10^8\ \text{m/s}} = 0.35\ \text{ms}$

$$t_{p2} = \frac{400 \text{ miles} \times 1600 \text{ m/miles}}{2.3 \times 10^8 \text{ m/s}} = 2.8 \text{ ms}$$

(a) Here, t_r is defined as the processing time for each packet. Therefore, $t_r = 0.2$. Also, $n_p = 1$

$$d_{\text{conn-req}} = d_{\text{conn-accep}}$$
$$= (n_h - 1)t_p + [n_p + (n_h - 2)]\, t_f + n_h t_r$$
$$= [(2-1)0.35 + (3-1)2.8] \text{ ms} + [1 + (5-2)]\frac{500 \text{ b/packet}}{100 \text{ mb/s}} + 1 \times 0.2 \text{ s} \approx 0.2 \text{ s}$$

We notice here that the large processing delay has dominated.

(b) $d_{\text{conn-release}} \approx 0.2$ s

(c) Since t_r is defined as the processing time for each packet, then $t_r = 20,080 \times 0.2 = 4,016$ s. Here, for the same reason as above, the large total processing delay has dominated.

$$D_p \approx n_h t_r = 5 \times 4,016 = 20,090 \text{ s}$$
$$D_c = d_{\text{conn-req}} + d_{\text{conn-accep}} + d_{\text{conn-release}} = 0.2 + 0.2 + 0.2 = 0.6$$

$$D_t = D_p + D_c = 20,090 + 0.2 \times 3 = 20,090.6 \text{ s}$$

This result is a clear indication of traffic congestion

1.6.

$s = 10^9$ b/s

$n_h = 10$ nodes

$t_r = 0.1$s

10,000 B of data is broken up to two chunks leading to two packets:

Packet1 size = 9,960 (data) + 40 (header) = 10,000 B

Packet2 size = 2,040 (data) + 40 (header) = 2,080 B

Transfer delay:

For data packets, $P1$ (Packet1) and $P2$ (Packet2):

$$t_{f1-P1} = \frac{10,000 \text{ B} \times 8 \text{ b/B}}{10^9 \text{ b/s}} = 8 \times 10^{-5} \text{ s}$$

$$t_{f1-P2} = \frac{2,080 \text{ B} \times 8 \text{ b/B}}{10^9 \text{ b/s}} = 16.64 \times 10^{-6} \text{ s}$$

For signaling packets:

t_{f2} = transfer times for control packets= $\frac{500\,\text{b}}{10^9\ \text{b/s}} = 5\times10^{-7}$ s

Propagation delay:

$$t_p = \frac{\ell}{c} = \frac{500\ \text{miles} \times 1.61\times10^3\ \text{m}}{2.3\times10^8\ \text{m/s}} = 3.5\times10^{-3}\ \text{s}$$

(a) request + accept time:

$$t_1 + t_2 = 2\big([n_p + (n_h - 2)]\, t_{f2} + (n_h - 1)\, t_p + n_h t_r]\big) = 2.06\,\text{s}$$

(b) $t_3 = \frac{1}{2}(t_1 + t_2) = 1.03\,\text{s}$

(c) In the timing chart, we assume that packets are transmitted in the order of their sizes starting with the longest (P_1 appears first and then $P2$ in the timing chart). Therefore, $P1$ is dominant over $P2$ when parallel transmission over nodes happen. So for transfer time, we have a situation in which $n_p + (n_h - 2) - 1$ of Pls and one last $P2$ are calculated:

$$D_p = [n_p + (n_h - 2) - 1]t_{f1-P1} + (1)t_{f1-P2} + n_h t_r + +(\text{n}_h - 1)t_p$$
$$= 1.5 \times 10 - 4\ \text{s} + 1\ \text{s} + 3.15 \times 10 - 2\ \text{s} = 1.031\ \text{s}$$

$$D_c = t_1 + t_2 + t_3 = 3.09\ \text{s}$$

$$\text{D}_t = \text{D}_p + \text{D}_c = 1.03 + 3.09 = 4.1\ \text{s}$$

1.7. See Figure 1.1