Solutions to Select Exercises

CHAPTER 1

4. We will count the transfer as completed when the last data bit arrives at its destination

(a) 1.5 MB $=$ 12582912 bits. 2 initial RTTs (160 ms) $+$ 12,582,912/10,000,000 bps (transmit) $+$ RTT/2 (propagation) $\approx$ 1.458 seconds.

(b) Number of packets required $=$ 1.5 MB/1KB $=$ 1536. To the above we add the time for 1535 RTTs (the number of RTTs between when packet 1 arrives and packet 1536 arrives), for a total of $1.458 + 122.8 = 124.258$ seconds.

(c) Dividing the 1536 packets by 20 gives 76.8. This will take 76.5 RTTs (half an RTT for the first batch to arrive, plus 76 RTTs between the first batch and the 77th partial batch), plus the initial 2 RTTs, for 6.28 seconds.

(d) Right after the handshaking is done we send one packet. One RTT after the handshaking we send two packets. At n RTTs past the initial handshaking we have sent $1 + 2 + 4 + \cdots + 2^n = 2^{n+1} - 1$ packets. At $n = 10$ we have thus been able to send all 1536 packets; the last batch arrives 0.5 RTT later. Total time is $2 + 10.5$ RTTs, or 1 second.

6. Propagation delay is 50×10^3 m/(2×10^8 m/s) $=$ 250 μs. 800 bits / 250 μs is 3.2 Mbps. For 512-byte packets, this rises to 16.4 Mbps.

14. **(a)** Propagation delay on the link is $(55 \times 10^9)/(3 \times 10^8) = 184$ seconds. Thus, the RTT is 368 seconds.

(b) The delay $\times$ bandwidth product for the link is $184 \times 128 \times 10^3 = 2.81$ MB.

(c) After a picture is taken, it must be transmitted on the link and be completely propagated before Mission Control can interpret it. Transmit delay for 5 MB of data is 41,943,040 bits/$128 \times 10^3 = 328$ seconds. Thus, the total time required is transmit delay + propagation delay $= 328 + 184 = 512$ seconds.

17. **(a)** For each link, it takes 1 Gbps / 5 kb = 5 μs to transmit the packet on the link, after which it takes an additional 10 μs for the last bit to propagate across the link. Thus, for a LAN with only one switch that starts forwarding only after receiving the whole packet, the total transfer delay is two transmit delays + two propagation delays = 30 μs.

(b) For three switched and thus four links, the total delay is four transmit delays + four propagation delays = 60 μs.

(c) For cut-through, a switch need only decode the first 128 bits before beginning to forward. This takes 128 ns. This delay replaces the switch transmit delays in the previous answer for a total delay of one transmit delay + three cut-through decoding delays + four propagation delays = 45.384 μs.

27. **(a)** $1920 \times 1080 \times 24 \times 30 = 1,492,992,000 \approx$ 1.5 Gbps.

(b) $8 \times 8000 = 64$ Kbps.

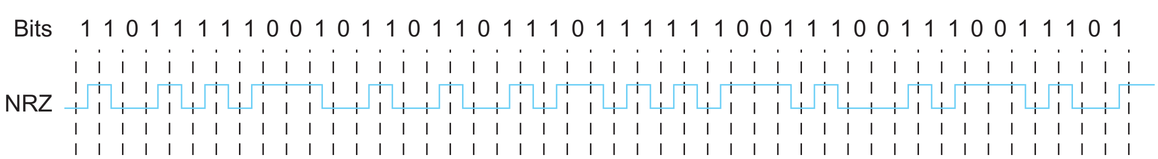
(c) $260 \times 50 = 13$ Kbps.

(d) $24 \times 88,200 = 216,800 \approx$ 2.1 Mbps.

CHAPTER 2

3. The 4B/5B encoding of the given bit sequence is the following:

11011 11100 10110 11011 10111 11100 11100 11101



7. Let $_\wedge$ mark each position where a stuffed 0 bit was removed. There was one error where the sever consecutive 1s are detected (err) At the end of the bit sequence, the end of frame was detected (eof).

01101011111$_\wedge$10100111111$\underline{1}_{err}$0 110 $\underline{\mathbf{01111110}}_{eof}$

19. **(a)** We take the message 1011 0010 0100 1011, append 8 zeros and divide by 1 0000 0111 $(x^8 + x^2 + x^1 + 1)$. The remainder