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.

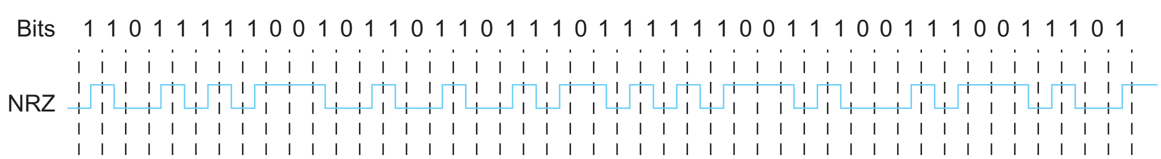
(c) $260 \times 50 = 13$ Kbps.

(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{\mathbf{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 is 1001 0011. We transmit the original message with this remainder appended, resulting in 1011 0010 0100 0011 1001 0011.

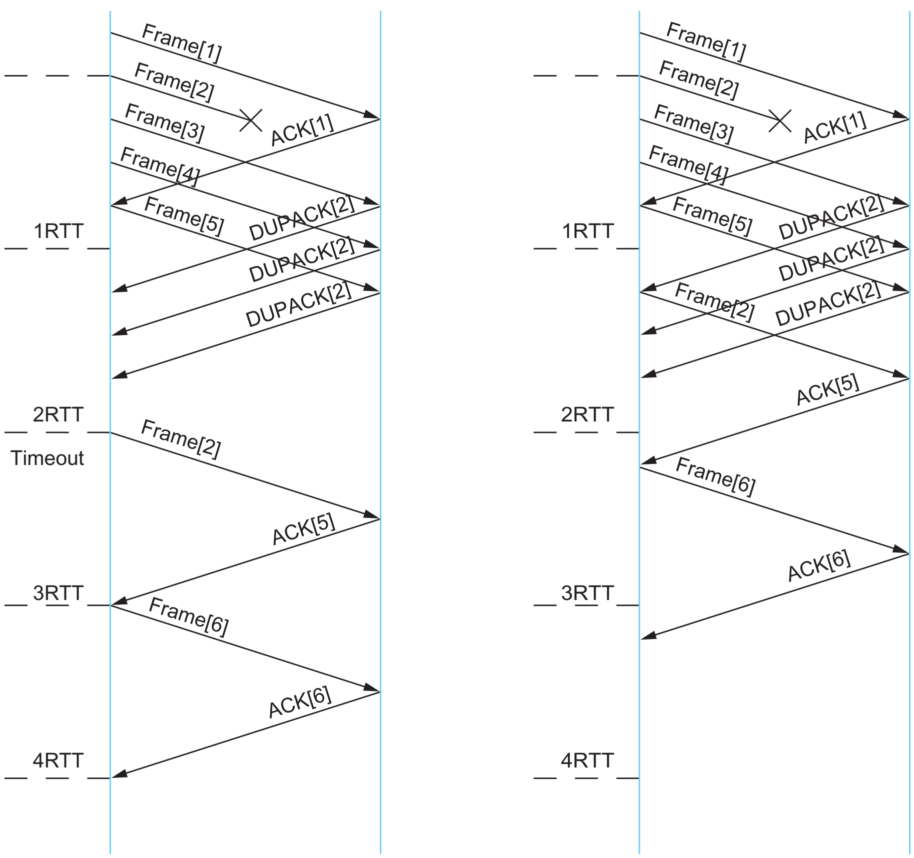
(b) Inverting the first bit gives 0011 0010 0100 1011 1001 0011. Dividing by 1 0000 0111 $(x^8 + x^2 + x^1 + 1)$ gives a a remainder of 1011 0110.

25. One-way latency of the link is 100 ms. (Bandwidth)×(roundtrip delay) is about 125 pps × 0.2 sec, or 25 packets. SWS should be this large.

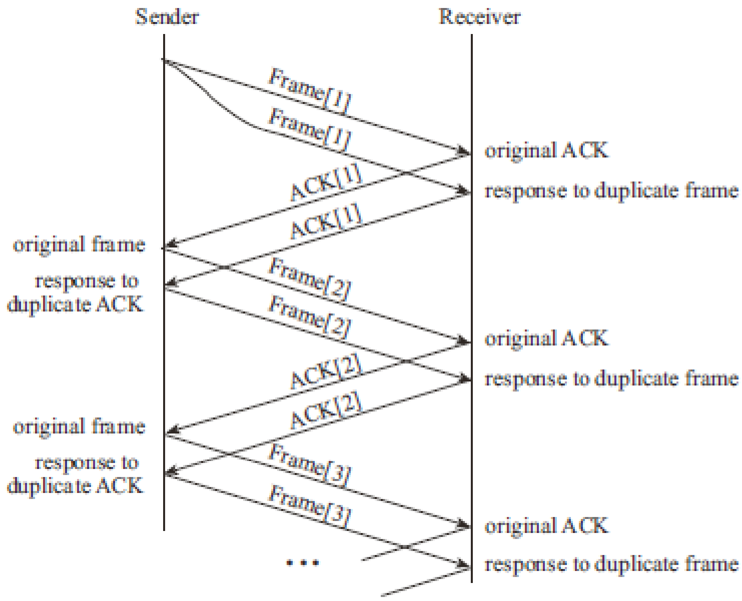
(a) If RWS = 1, the necessary sequence number space is 26. Therefore, 5 bits are needed.

(b) If RWS = SWS, the sequence number space must cover twice the SWS, or up to 50. Therefore, 6 bits are needed.

32. The figure that follows gives the timeline for the first case. The second case reduces the total transaction time by roughly 1 RTT.



28. (a) The duplications below continue until the end of the transmission.



(b) To trigger the sorcerer's apprentice phenomenon, a duplicate data frame must cross somewhere in the network with the previous ACK for that frame. If both sender and receiver adopt a resend-on-timeout strategy, *with the same timeout interval*, and an ACK is lost, then both sender and receiver will indeed retransmit at about the same time. Whether these retransmissions are synchronized enough that they cross in the network depends on other factors; it helps to have some modest latency delay or else slow hosts. With the right conditions, however, the sorcerer's apprentice phenomenon can be reliably reproduced.