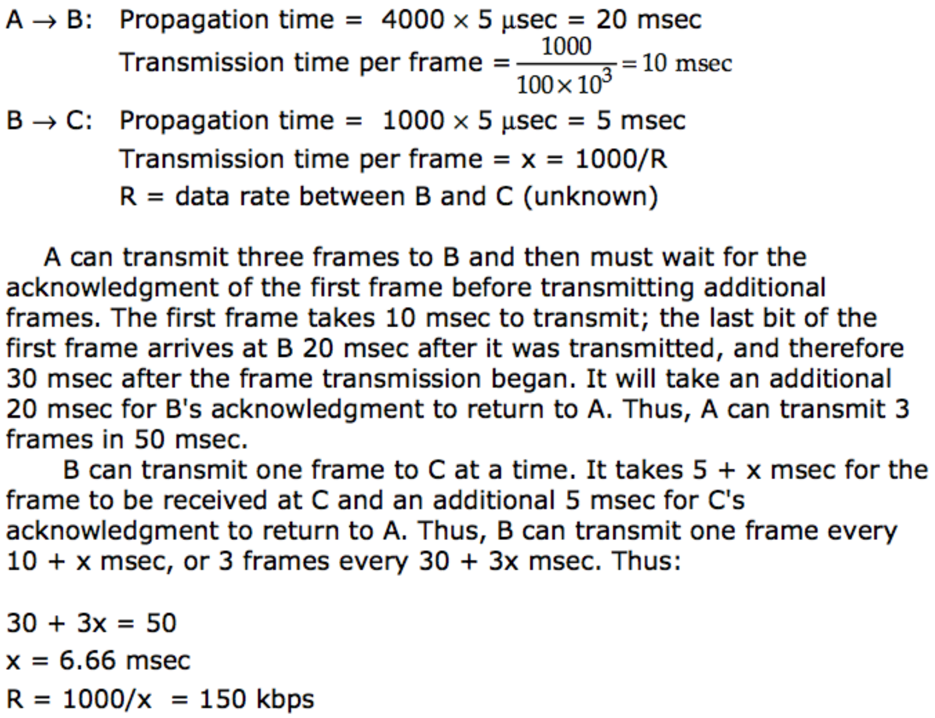
Homework+Lab 6: Solution.

Homework Problems

1. Stallings Problem 7.3.

   Answer:



A → B: Propagation time = 4000×5 μsec = 20 msec

Transmission time per frame = $\frac{1000}{100 \times 10^3} = 10$ msec

B → C: Propagation time = 1000×5 μsec = 5 msec

Transmission time per frame = x = 1000/R

R = data rate between B and C (unknown)

A can transmit three frames to B and then must wait for the acknowledgment of the first frame before transmitting additional frames. The first frame takes 10 msec to transmit; the last bit of the first frame arrives at B 20 msec after it was transmitted, and therefore 30 msec after the frame transmission began. It will take an additional 20 msec for B's acknowledgment to return to A. Thus, A can transmit 3 frames in 50 msec.

B can transmit one frame to C at a time. It takes 5 + x msec for the frame to be received at C and an additional 5 msec for C's acknowledgment to return to A. Thus, B can transmit one frame every 10 + x msec, or 3 frames every 30 + 3x msec. Thus:

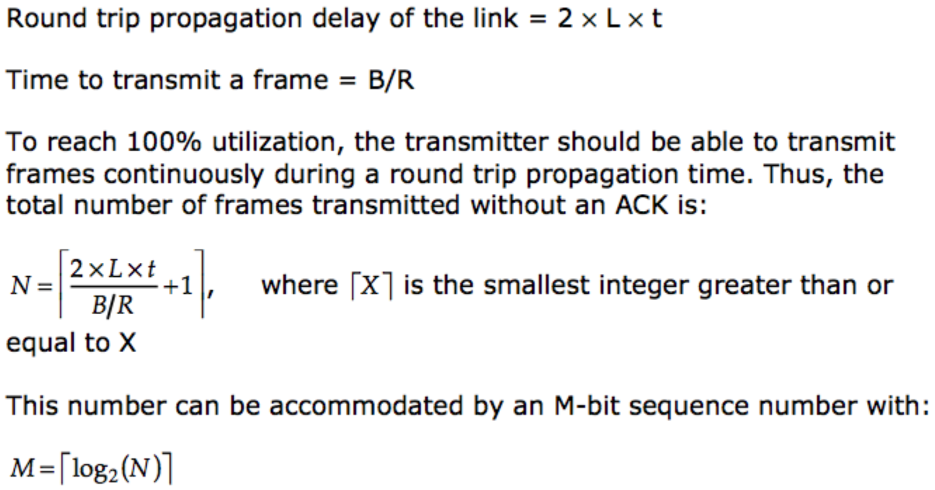
30 + 3x = 50

x = 6.66 msec

R = 1000/x = 150 kbps

2. Stallings Problem 7.4.

   Answer:



Round trip propagation delay of the link = 2 × L × t

Time to transmit a frame = B/R

To reach 100% utilization, the transmitter should be able to transmit frames continuously during a round trip propagation time. Thus, the total number of frames transmitted without an ACK is:

$N = \left\lceil \frac{2 \times L \times t}{B/R} + 1 \right\rceil$, where $\lceil X \rceil$ is the smallest integer greater than or equal to X

This number can be accommodated by an M-bit sequence number with:

$M = \lceil \log_2(N) \rceil$

3. Stallings Problem 16.11.

Answer: We can compute the a parameter as

$$a = \frac{t_{\text{prop}}}{t_{\text{frame}}} = \frac{80}{L}$$

and the link utilization follows as

$$U = \frac{1}{1+2a} = \frac{1}{1+160/L} \geq 0.5$$

which is satisfied if and only if $L \geq 160$. Therefore, an efficiency of at least 50% requires a frame size of at least 160 bits.

4. Stallings Problem 16.12.

   Answer: We can compute the a parameter as

$$a = \frac{t_{\text{prop}}}{t_{\text{frame}}} = 270$$

and the link utilization for part (a) follows as

$$U = \frac{1}{1+2a} = \frac{1}{1+540} \approx 0.002.$$

For part (b), with $W = 7$ the link utilization is

$$U = \frac{W}{1+2a} = \frac{7}{1+540} \approx 0.013.$$

For part (c) with $W = 127$ the link utilization is

$$U = \frac{W}{1+2a} = \frac{127}{1+540} \approx 0.23.$$

For part (d) with $W = 255$ the link utilization is

$$U = \frac{W}{1+2a} = \frac{255}{1+540} \approx 0.47.$$

5. Suppose that

$$\begin{aligned} t_{\text{frame}} &= \text{1.000 millisecond (time to transmit one frame)} \\ t_{\text{prop}} &= \text{1.500 milliseconds (propagation time of medium, same in both directions)} \end{aligned}$$

with ACK and processing times is assumed to be negligible. The total time to deliver n frames starts at the beginning of the transmission of the first frame and finishes at the end of the receipt of the acknowledgement.

   (a) Suppose that no frames or acknowledgments are lost or damaged. Compute the amount of time required to deliver 10 frames to the receiver if the sender and receiver use **stop-and-wait** error control.

   Answer: Using stop-and-wait, the total time is

$$T = n(t_{\text{frame}} + t_{\text{prop}} + t_{\text{proc}} + t_{\text{ack}} + t_{\text{prop}} + t_{\text{proc}}) = n \times 4 \text{ ms}.$$

   Since no frames/ACKs are damaged or lost, this will require a total of 40 ms to deliver $n = 10$ frames.

(b) Suppose that no frames or acknowledgments are lost or damaged. Compute the amount of time required to deliver 10 frames to the receiver if the sender and receiver use **Go-Back-N** error control with a window size of 4 frames (the sender will wait to transmit more frames if there are 4 unacknowledged frames outstanding). Assume that the receiver sends an RR (receive ready) acknowledgment for every correctly received frame and that the sender/receiver have a full-duplex link.

Answer: Note that $a = \frac{t_{\text{prop}}}{t_{\text{frame}}} = 1.5$. Also note that $W \geq 2a + 1 = 4$, hence we have a link utilization here of $U = 1$. Hence the transmitter can transmit all $n = 10$ frames without pausing and the total time is

$$T = nt_{\text{frame}} + t_{\text{prop}} + t_{\text{proc}} + t_{\text{ack}} + t_{\text{prop}} + t_{\text{proc}} = 13 \text{ ms}$$

since no frames/ACKs were damaged or lost.

(c) Now we consider the case where an acknowledgment (ACK or RR) for a frame has been lost. The sender's timeout period is given as 6 milliseconds and begins at the completion of the transmitted frame. Compute the amount of time required to deliver 10 frames to the receiver, given that the acknowledgement RR5 is lost (recall the first frame is labeled frame 0), if the sender and receiver use **stop-and-wait** error control.

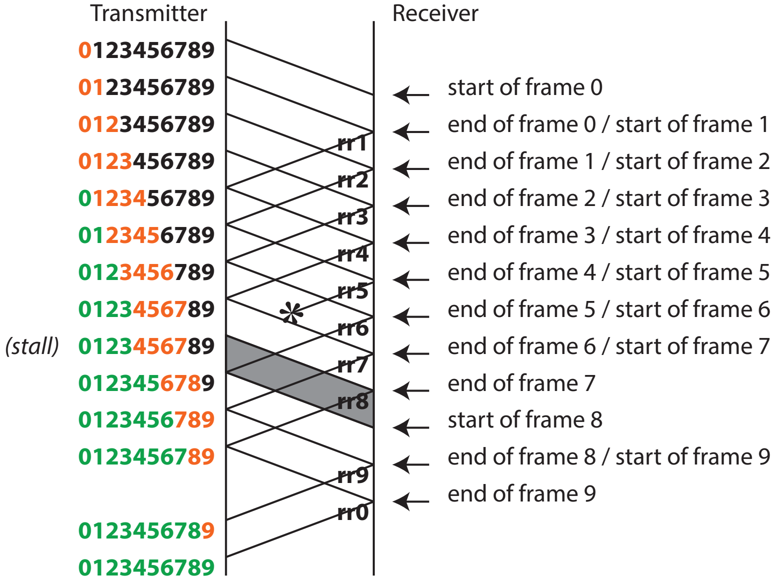
Answer: For stop-and-wait it doesn't matter which frame was lost. For the 9 frames that were delivered without problems, each will take 4.01 ms as shown in part (a). For the frame where the ACK was lost, the total time is

$$T_{\text{lostack}} = t_{\text{frame}} + t_{\text{timeout}} + t_{\text{frame}} + t_{\text{prop}} + t_{\text{proc}} + t_{\text{ack}} + t_{\text{prop}} + t_{\text{proc}}) = 11.01 \text{ ms.}$$

Hence the total time is $9 \times 4 + 11 = 47$ ms.

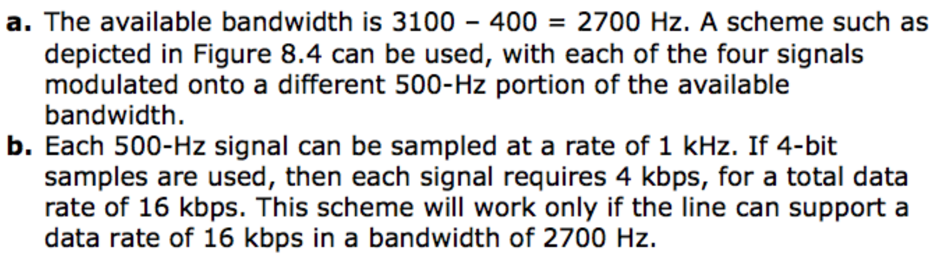
(d) Under the same assumptions, compute the amount of time required to deliver 10 frames to the receiver, given that the acknowledgement RR5 is lost (recall the first frame is labeled frame 0), if the sender and receiver use **Go-Back-N** error control with a window size of 4 frames (the sender will wait to transmit more frames if there are 4 unacknowledged frames outstanding). Assume that the receiver sends an RR (receive ready) acknowledgment for every correctly received frame and that the sender/receiver have a full-duplex link.

Answer: By inspecting the timing diagram below, one can see that if the RR for frame 5 is lost, this causes a stall such that frame 9 can not be immediately sent. Upon the reception of the RR for frame 6, since RRs are cumulative, this RR allows frame 9 to be sent. The overall effect is to add 1 ms to the case when we had no errors, hence the total time is 14 ms.



6. Stallings Problem 8.1.

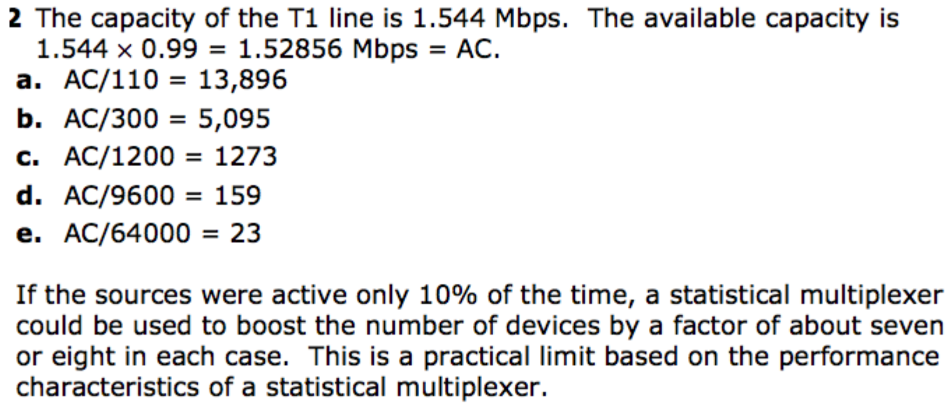
   Answer:



a. The available bandwidth is 3100 – 400 = 2700 Hz. A scheme such as depicted in Figure 8.4 can be used, with each of the four signals modulated onto a different 500-Hz portion of the available bandwidth.

b. Each 500-Hz signal can be sampled at a rate of 1 kHz. If 4-bit samples are used, then each signal requires 4 kbps, for a total data rate of 16 kbps. This scheme will work only if the line can support a data rate of 16 kbps in a bandwidth of 2700 Hz.

7. Stallings Problem 8.12.



2 The capacity of the T1 line is 1.544 Mbps. The available capacity is 1.544 × 0.99 = 1.52856 Mbps = AC.

a. AC/110 = 13,896

b. AC/300 = 5,095

c. AC/1200 = 1273

d. AC/9600 = 159

e. AC/64000 = 23

If the sources were active only 10% of the time, a statistical multiplexer could be used to boost the number of devices by a factor of about seven or eight in each case. This is a practical limit based on the performance characteristics of a statistical multiplexer.

8. Stallings Problem 8.13.

   Answer: Synchronous TDM: 9600 bps × 10 = 96 kbps. Statistical TDM: 9600 bps × 10 × 0.5/0.8 = 60 kbps.