Problems: Flow and multiplexing

1. How does Go-back-N ARQ differ from Selective Repeat ARQ?

2. What is piggybacking?

3. What does the ACK number mean for Stop-and-wait, Go-back-n and Selective repeat ARQ?

4. A Go-back-N ARQ uses a window of size 15. How many bits are needed to define the sequence number

5. A Selective Repeat ARQ is using 7 bits to represent the sequence numbers. What is the size of the window?

6. A computer is using a sliding window of size 7. Complete the following sequence numbers for 20 frames: $0, 1, 2, \ldots, X, 0, 1, 2, \ldots$.

   (a) Go-Back-N

   (b) Selective Repeat

7. Draw the sender and receiver windows for a system using Go-back-N ARQ, where a 3 bit field is used and given the following:

   (a) Frame 0 is sent; Frame 0 is acknowledged.

   (b) Frames 1 and 2 are sent; Frames 1 and 2 are acknowledged.

   (c) Frames 3, 4, and 5 are sent; Frames 3 and 4 is acknowledged; Timer for Frame 5 expires.

   (d) Frames 5, 6, and 7 are sent; Frames 5 through 7 are acknowledged.

8. Repeat Exercise 7., using Selective Repeat ARQ.

9. How does ARQ correct an error in the flow control?

10. How are a lost acknowledgment and a lost frame handled at the sender site?

11. In Go-back-N ARQ, the size of the sender window must be less than 2^m, where m is the number of bits used for the representation of sequence numbers. Show in an example, by drawing a message sequence, why the size of the sender window must be less than 2^m.

12. How is the bandwidth-delay product related to the system efficiency and size of window?

13. Assume that three connections are multiplexed with FDM on a link that has a total bandwidth of 7900 Hz. What is the maximal bandwidth for each connection if there must be a 200 Hz guard band between the channels?

14. Assume that 100 connections are multiplexed with Synchronous TDM and each connection requires 14.4 kbps

    (a) What is the minimum required bit rate on the link?

    (b) Assume that only 70 connections transfer data at the same time. How much of the bandwidth will be unused?

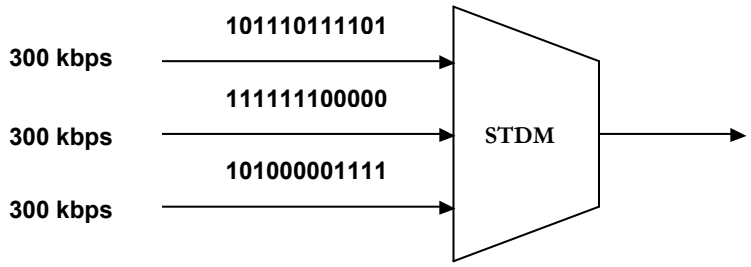
15. The figure below shows a multiplexer for Synchronous TDM. Assume that a frame consists of 3 time slots, that each time slot contains 3 bits, and that each frame starts with a framing bit, alternating between 0 and 1. Answer the following questions:

    (a) What is the bit sequence on the outgoing link?

    (b) What is the bit rate on the outgoing link?

    (c) What is the duration of a bit on the outgoing link?

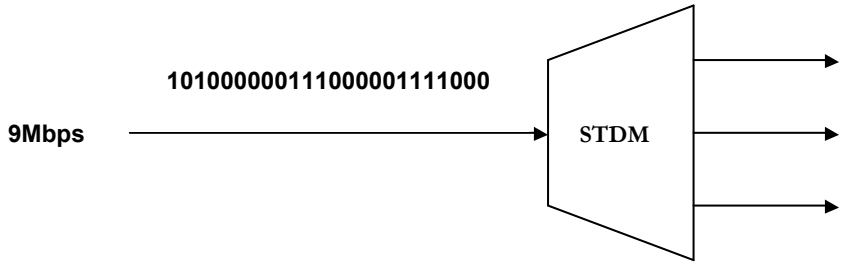
    (d) What is the duration of a frame on the outgoing link?



16. The figure below shows a demultiplexer for Synchronous TDM. Assume that each frame consists of 3 time slots, that each time slot contains 4 bits, and that there are no framing bits. Answer the questions below.

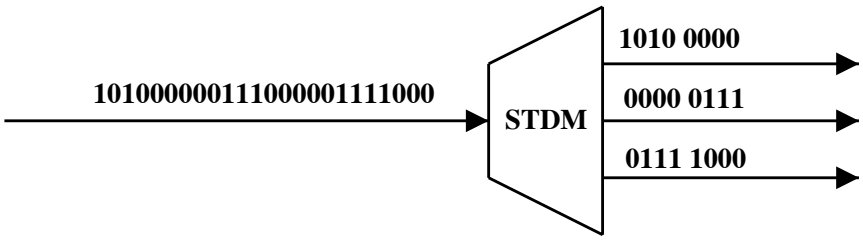
    (a) What are the bit sequences on the outgoing links?

    (b) What are the bit rates for each outgoing links?

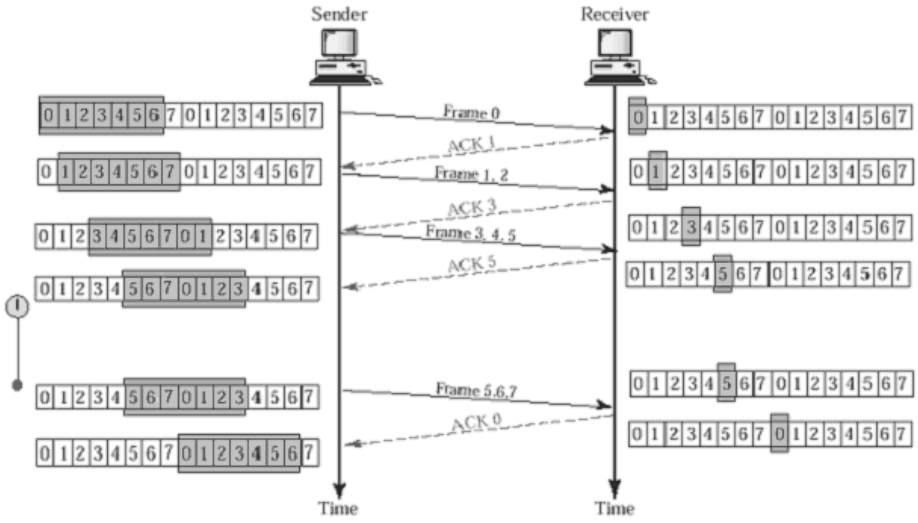


Solutions: Flow and multiplexing

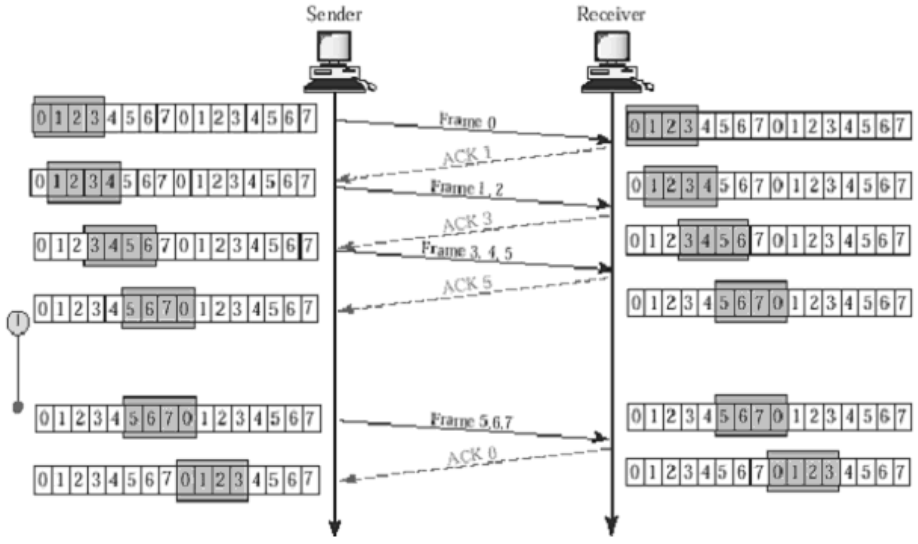
1. In Go-Back-N ARQ, if time-out expires for frame $n-k$, and the sender is currently sending frame n, frames $n-k, n-k+1, \ldots, n-1, n$ have to be retransmitted. In Selective Repeat ARQ on the other hand, the receiver indicates what frame that should be retransmitted.
2. To include acknowledgement for one frame in the data frame of another frame.
3. **Stop-and-wait:** Expected number of next frame.
   Go-back-n: Ack n means ack of frames $0, \ldots, n-1$, and that frame n is awaited.
   Selective repeat: Ack n means ack of frames $0, \ldots, n-1$, and that frame n is awaited.
4. $2^m - 1 = 15,\ m = 4$
5. $\frac{2^7}{2} = 64$
6. 01234567012345670123
7. See Figure 1 a).
8. See Figure 1 b).
9. Specified frames are retransmitted.
10. By time-out.
11. If, for example, we choose $m = 2$, and a window size of 4, the following can happen. Assume that all acknowledgements are lost, and the frame 0 timeout expires. Then, the sender retransmits frame 0. But the receiver, which has received frames 0,1,2, and 3, is now expecting a new frame 0. So when the retransmitted frame 0 arrives, it is uncorrectly assumed to be a new frame.
12. The bandwidth-delay product is a measure of the number of bits we can send out of our system while waiting for news from the receiver. A high bandwidth-delay product imposes a large window.
13. 2500Hz
14. (a) 1.44 Mbps
    (b) 30
15. (a) 101111101 1 000111110 0 001100111 1 111000101 0 $\rightarrow$
    (b) 1 Mbps, 1 frame == 10 bits
    (c) 1 μs
    (d) 10 μs, 1 frame == 10 bits
16. (a)



    (b) 3 Mbps



a)



b)

Figure 1: a) Exercise 7., b) Exercise 8..