11.1 Flow and Error Control

Flow Control

Error Control
Flow control refers to a set of procedures used to restrict the amount of data that the sender can send before waiting for acknowledgment.

Note:

Error control in the data link layer is based on automatic repeat request, which is the retransmission of data.
11.2 Stop-and-Wait ARQ

Operation

Bidirectional Transmission
11.2 Stop-and-Wait ARQ, lost frame

Time-out

11.3 Stop-and-Wait ARQ, lost ACK frame

Time-out
Note:

In Stop-and-Wait ARQ, numbering frames prevents the retaining of duplicate frames.

11.4 Stop-and-Wait ARQ, delayed ACK
Note:

Numbered acknowledgments are needed if an acknowledgment is delayed and the next frame is lost.
11.3 Go-Back-N ARQ

Sequence Number

Sender and Receiver Sliding Window

Control Variables and Timers

Acknowledgment

Resending Frames

Operation

11.6 Sender sliding window

Window size = 7

a. Before sliding

b. After sliding two frames
11.7 Receiver sliding window

- a. Before sliding
- b. After sliding

11.8 Control variables

- a. Sender window
- b. Receiver window
11.9  Go-Back-N ARQ, normal operation

11.10  Go-Back-N ARQ, lost frame
11.11 Go-Back-N ARQ: sender window size

In Go-Back-N ARQ, the size of the sender window must be less than $2^m$; the size of the receiver window is always 1.

Note:
11.4 Selective-Repeat ARQ

Sender and Receiver Windows

Operation

Sender Window Size

Bidirectional Transmission

Pipelining

11.12 Selective Repeat ARQ, sender and receiver windows
11.13 Selective Repeat ARQ, lost frame

In Selective Repeat ARQ, the size of the sender and receiver window must be at most one-half of $2^m$. 

Note:
Example 1

In a Stop-and-Wait ARQ system, the bandwidth of the line is 1 Mbps, and 1 bit takes 20 ms to make a round trip. What is the bandwidth-delay product? If the system data frames are 1000 bits in length, what is the utilization percentage of the link?

Solution

The bandwidth-delay product is

\[ 1 \times 10^6 \times 20 \times 10^{-3} = 20,000 \text{ bits} \]

The system can send 20,000 bits during the time it takes for the data to go from the sender to the receiver and then back again. However, the system sends only 1000 bits. We can say that the link utilization is only 1000/20,000, or 5%. For this reason, for a link with high bandwidth or long delay, use of Stop-and-Wait ARQ wastes the capacity of the link.
Example 2

What is the utilization percentage of the link in Example 1 if the link uses Go-Back-N ARQ with a 15-frame sequence?

Solution

The bandwidth-delay product is still 20,000. The system can send up to 15 frames or 15,000 bits during a round trip. This means the utilization is 15,000/20,000, or 75 percent. Of course, if there are damaged frames, the utilization percentage is much less because frames have to be resent.