FLOW CONTROL

Flow Control

- important design issue that occurs in the data link layer (and higher layers as well)
- what to do with a sender that systematically wants to transmit frames

FLOW AND ERROR CONTROL

The most important responsibilities of the data link layer are flow control and error control. Collectively, these functions are known as data link control.

Note

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

11.4

12-B Status from UGC

Note

Error control in the data link layer is based on automatic repeat request, which is the retransmission of data.

11.5

11-3 PROTOCOLS

Now let us see how the data link layer can combine framing, flow control, and error control to achieve the delivery of data from one node to another. The protocols are normally implemented in software by using one of the common programming languages. To make our discussions language-free, we have written in pseudocode a version of each protocol that concentrates mostly on the procedure instead of delving into the details of language rules.

11.6

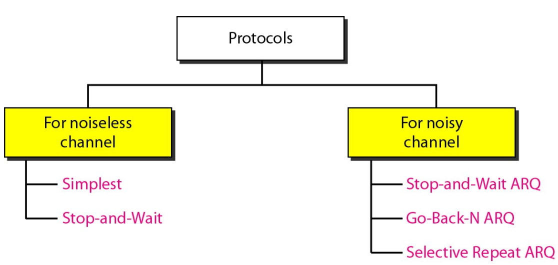


Figure 11.5 *Taxonomy of protocols discussed in this chapter*

11.7

11-4 NOISELESS CHANNELS

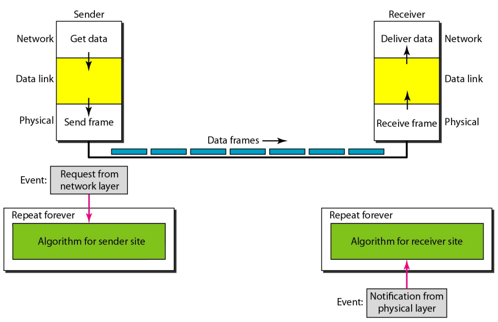
Let us first assume we have an ideal channel in which no frames are lost, duplicated, or corrupted. We introduce two protocols for this type of channel.

Topics discussed in this section:

Simplest Protocol
Stop-and-Wait Protocol

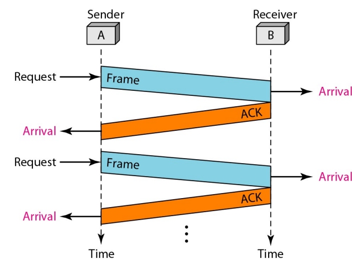
11.8

Figure 11.6 *The design of the simplest protocol with no flow or error control*



11.9

Figure 11.9 *Flow diagram for Example 11.2*



11.10

11-5 NOISY CHANNELS

Although the Stop-and-Wait Protocol gives us an idea of how to add flow control to its predecessor, noiseless channels are nonexistent. We discuss three protocols in this section that use error control.

Topics discussed in this section:

Stop-and-Wait Automatic Repeat Request
Go-Back-N Automatic Repeat Request
Selective Repeat Automatic Repeat Request

11.11

STOP-AND-WAIT ARQ

- *It has the following features:*

- The sending device keeps a copy of the last frame transmitted until it receives an acknowledgment for that frame.
- Keeping a copy allows the sender to retransmit lost or damaged frames until they are received correctly.

- For identification purposes, both data frames and acknowledgment (ACK) frames are numbered alternately 0 and 1.
- A data 0 frame is acknowledged by an ACK 1 frame, indicating that the receiver has received data frame 0 and is now expecting data frame 1.
- This numbering allows for identification of data frames in case of duplicate transmission.

- A damaged or lost frame is treated in the same manner by the receiver.
- ***Discards and no acknowledgement***

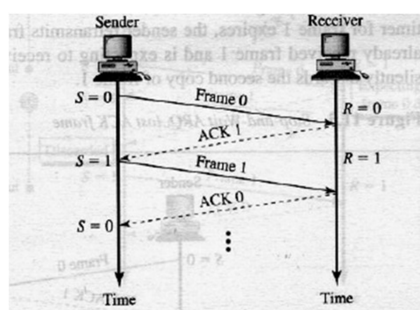
- The sender has a control variable.
- **S, that holds the number of the recently sent frame (0 or 1).**
- The receiver has a control variable,
- **Call *R*, that holds the number of the next frame expected (0 or 1).**

- **The sender starts a timer when it sends a frame.**
- *sender assumes that the frame was lost or damaged and resends it if timeout*.

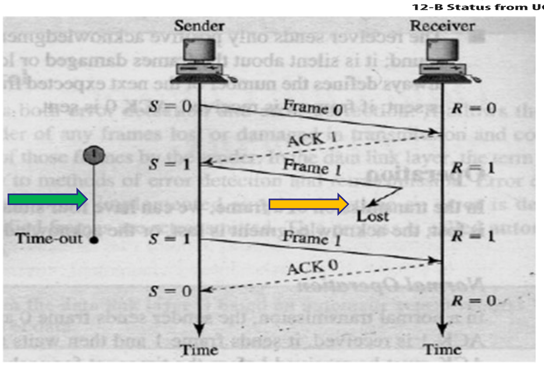
- The receiver sends only positive acknowledgment for frames received safe and sound; it is silent about the frames damaged or lost.
- The acknowledgment number always defines the number of the next expected frame. *If frame 0 is received, ACK 1 is sent; if frame 1is received, ACK 0 is sent.*

Operation

- *Normal Operation*



Lost or Damaged Frame



Link Utilization

U = 1/(1+2a),

a = Propagation time / transmission time

11.18

In stop and wait protocol , If the packet size is 1 KB and propagation time is 15ms the channel capacity is 10^9 bits / sec then find : transmission time and channel utilization

Transmission time $(1\times1024\times8)/10^9$ =8 micro seconds

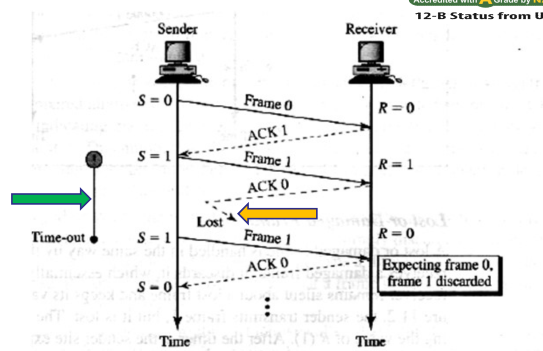
Channel utilization =1/1+2(15000/8)

=1/3751×100

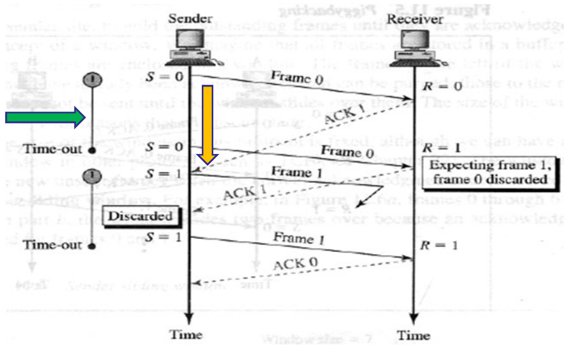
=0.0266%

11.19

Lost Acknowledgment



Delayed Acknowledgment



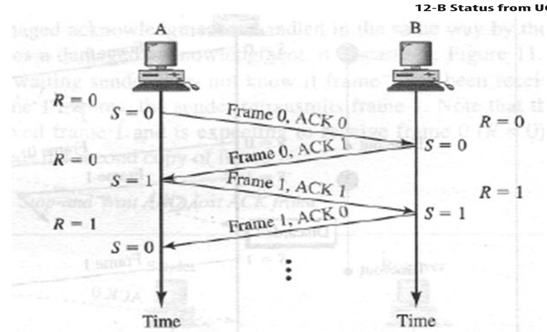
Bidirectional Transmission

- The stop-and-wait mechanism we have discussed is unidirectional. However, we can have bidirectional transmission
- If the two parties have two separate channels for full duplex transmission or share the same channel for half-duplex transmission. In this case, each party needs both S and *R* variables to track frames sent and expected.

Piggybacking

- Combine a data frame with an acknowledgment.

Piggybacking



GO-BACK-N ARQ

- In Stop-and-Wait ARQ, at any point in time for a sender, there is only one frame,
- The outstanding frame, that is sent and waiting to be acknowledged.
- This is not a good use of the transmission medium.
- *To improve the efficiency, multiple frames should be in transition while waiting for acknowledgment.*

Two protocols use this concept:

- Go-Back-N ARQ
- Selective Repeat ARQ.

These procedures requires additional features to be added to Stop-and-Wait ARQ.

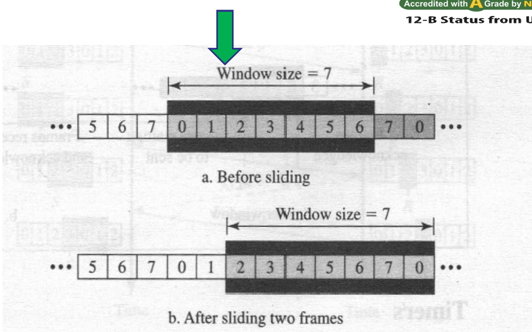
Sequence Numbers

- Frames from a sending station are numbered sequentially. However, because we need to include the sequence number of each frame in the header, we need to set a limit. If the header of the frame allows *m* bits for the sequence number, the sequence numbers
  - Range from 0 to $2^m - 1$.
- 0,1,2,3,4,5,6,7, 0, 1,2,3,4,5,6,7, 0, 1, ...

Sender Sliding Window

- At the sender site, to hold the outstanding frames until they are acknowledged, we use the concept of a window. We imagine that all frames are stored in a buffer. The outstanding frames are enclosed in a window. The frames to the left of the window are those that have already been acknowledged and can be purged;
- The size of the window is at most $2^m - 1$ for reasons .

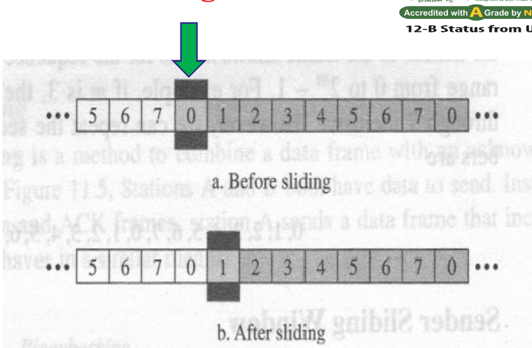
Sender sliding window



Receiver Sliding Window

- **The size of the window at the receiver site in this protocol is always 1.**
- The receiver is always looking for a specific frame to arrive in a specific order. Any frame arriving out of order is discarded and needs to be resent.

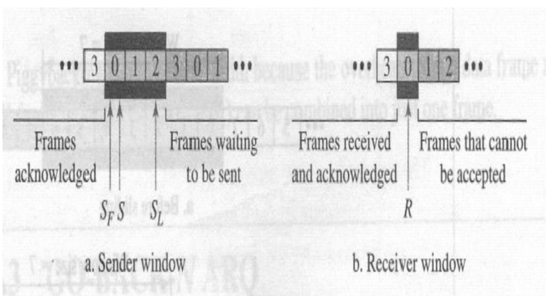
Receiver Sliding Window



Control Variables

- **The sender has three variables, S, *SF*, and SL**
- S holds the sequence number of the recently sent frame;
- *SF* holds the sequence number of the first frame in the window.
- S*L* holds the sequence number of the last frame in the window.
- The size of the window is *W*, where
  - **W= SL - SF+ 1.**

Control variables



Acknowledgment

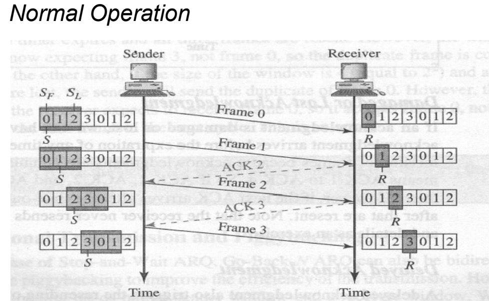
- The receiver sends positive acknowledgments if a frame has arrived safe and sound and in order. If a frame is damaged or is received out of order, the receiver is silent and will discard all subsequent frames until it receives the one it is expecting.

Resending Frame

- When a frame is damaged, the sender goes back and sends a set of frames starting from the damaged one up to the last one sent.

Operation

- *Normal Operation*



Go-Back-NARQ, lost frame

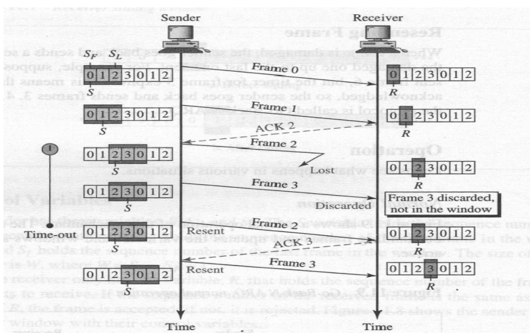
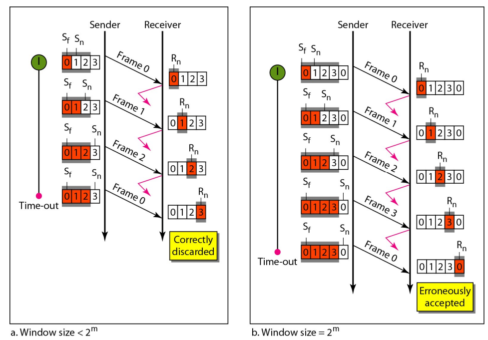


Figure 11.15 *Window size for Go-Back-N ARQ*



In Stop and wait protocol every 4th packet is lost and we need to send total 10 packets so how many transmission it took to send all the packets?

Consider the sliding window flow-control protocol operating between a sender and a receiver over a full-duplex error-free link. Assume the following:
The time taken for processing the data frame by the receiver is negligible.
The time taken for processing the acknowledgement frame by the sender is negligible.
The sender has infinite number of frames available for transmission.
The size of the data frame is 2,000 bits and the size of the acknowledgement frame is 10 bits.
The link data rate in each direction is 1 Mbps (= 106 bits per second).
One way propagation delay of the link is 100 milliseconds.
The minimum value of the sender\'s window size in terms of the number of frames, (rounded to the nearest integer) needed to achieve a link utilization of 50% is_____________.
(A)51
(B)50
(C)25
(D)52

GATE 2021

Suppose that the stop-and-wait protocol is used on a link with a bit rate of 64 kilobits per second and 20 milliseconds propagation delay. Assume that the transmission time for the acknowledgement and the processing time at nodes are negligible. Then the minimum frame size in bytes to achieve a link utilization of at least 50% is ________.

GATE 2015

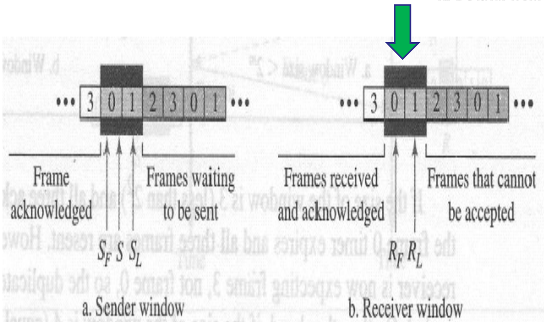
SELECTIVE REPEAT ARQ

12-B Status from UGC

- **Go-Back-N ARQ simplifies the process at the receiver site.**
- **The receiver keeps track of only one variable, and there is no need to buffer out-of-order frames; they are simply discarded.**
- ***However, this protocol is very inefficient for a noisy link.***
- This resending uses up the bandwidth and slows down the transmission.

Sender and Receiver Windows

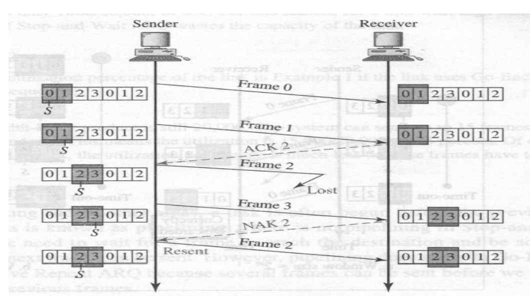
12-B Status from UGC



Operation

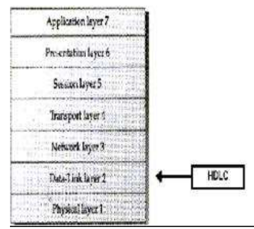
12-B Status from UGC

Selective Repeat ARQ. Lost frame



HDLC

- High-Level Data Link Control , is a bit oriented, switched and non-switched protocol. It is a data link control protocol, and falls within layer 2, the Data Link Layer, of the Open Systems Interface (OSI) model



- HDLC is a protocol developed by the International Organization for Standardization (ISO). It falls under the ISO standards ISO 3309 and ISO 4335. It has found itself being used throughout the world. It has been so widely implemented because it supports both half duplex and full duplex communication lines, point to point (peer to peer) and multi-point networks, and switched or non-switched channels.

This technical overview will be concerned with the following aspects of HDLC:

- Stations and Configurations
- Operational Modes
- Non-Operational Modes
- Frame Structure
- Commands and Responses
- HDLC Subsets (SDLC and LAPB)

HDLC STATIONS AND CONFIGURATIONS

- HDLC specifies the following three types of stations for data link control:
- Primary Station
- Secondary Station
- Combined Station

PRIMARY STATION

- Within a network using HDLC as it's data link protocol, if a configuration is used in which there is a primary station, it is used as the controlling station on the link. It has the responsibility of controlling all other stations on the link (usually secondary stations). Despite this important aspect of being on the link, the primary station is also responsible for the organization of data flow on the link. It also takes care of error recovery at the data link level (layer 2 of the OSI model).

SECONDARY STATION

- If the data link protocol being used is HDLC, and a primary station is present, a secondary station must also be present on the data link. The secondary station is under the control of the primary station. It has no ability, or direct responsibility for controlling the link. It is only activated when requested by the primary station. It only responds to the primary station. The secondary station's frames are called responses. It can only send response frames when requested by the primary station.

COMBINED STATION

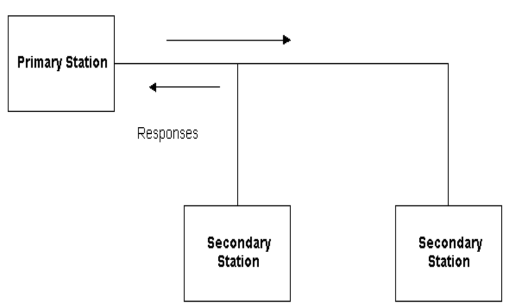
- A combined station is a combination of a primary and secondary station. On the link, all combined stations are able to send and receive commands and responses without any permission from any other stations on the link. Each combined station is in full control of itself, and does not rely on any other stations on the link. No other stations can control any combined station.

HDLC also defines three types of configurations for the three types of stations

- Unbalanced Configuration
- Balanced Configuration
- Symmetrical Configuration

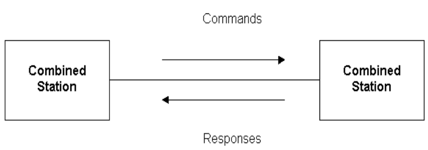
UNBALANCED CONFIGURATION

- The unbalanced configuration in an HDLC link consists of a primary station and one or more secondary stations. The unbalanced occurs because one stations controls the other stations. In a unbalanced configurations, any of the following can be used:
- Full - Duplex or Half - Duplex operation
- Point to Point or Multi-point networks



BALANCED CONFIGURATION

- The balanced configuration in an HDLC link consists of two or more combined stations. Each of the stations have equal and complimentary responsibility compared to each other. Balanced configurations can used only the following:
- Full - Duplex or Half - Duplex operation
- Point to Point networks



SYMMETRICAL CONFIGURATION

- This third type of configuration is not widely in use today. It consists of two independent point to point, unbalanced station configurations. In this configurations, each station has a primary and secondary status. Each station is logically considered as two stations

HDLC Operational Modes

- HDLC offers three different modes of operation. These three modes of operations are:
- Normal Response Mode (NRM)
- Asynchronous Response Mode (ARM)
- Asynchronous Balanced Mode (ABM)

Normal Response Mode

- This is the mode in which the primary station initiates transfers to the secondary station. The secondary station can only transmit a response when, and only when, it is instructed to do so by the primary station. In other words, the secondary station must receive explicit permission from the primary station to transfer a response. After receiving permission from the primary station, the secondary station initiates it's transmission. This transmission from the secondary station to the primary station may be much more than just an acknowledgment of a frame. It may in fact be more than one information frame. Once the last frame is transmitted by the secondary station, it must wait once again from explicit permission to transfer anything, from the primary station. Normal Response Mode is only used within an unbalanced configuration

Asynchronous Response Mode

- In this mode, the primary station doesn't initiate transfers to the secondary station. In fact, the secondary station does not have to wait to receive explicit permission from the primary station to transfer any frames. The frames may be more than just acknowledgment frames. They may contain data, or control information regarding the status of the secondary station. This mode can reduce overhead on the link, as no frames need to be transferred in order to give the secondary station permission to initiate a transfer. However some limitations do exist. Due to the fact that this mode is Asynchronous, the secondary station must wait until it detects and idle channel before it can transfer any frames. This is when the ARM link is operating at half-duplex. If the ARM link is operating at full-duplex, the secondary station can transmit at any time. In this mode, the primary station still retains responsibility for error recovery, link setup, and link disconnection

Asynchronous Balanced Mode

- This mode uses combined stations. There is no need for permission on the part of any station in this mode. This is because combined stations do not require any sort of instructions to perform any task on the link.

- Normal Response Mode is used most frequently in multi-point lines, where the primary station controls the link. Asynchronous Response Mode is better for point to point links, as it reduces overhead. Asynchronous Balanced Mode is not used widely today.

HDLC Frame Structure

- HDLC uses the term "frame" to indicate an entity of data (or a protocol data unit) transmitted from one station to another..

Field Name	Size(in bits)
Flag Field(F)	8 bits
Address Field(A)	8 bits
Control Field(C)	8 or 16 bits
Information Field(I)	Variable; Not used in some frames
Frame Check Sequence(FCS)	16 or 32 bits
Closing Flag Field(F)	8 bits

THE FLAG FIELD

- Every frame on the link must begin and end with a flag sequence field (F). Stations attached to the data link must continually listen for a flag sequence. The flag sequence is an octet looking like 01111110. Flags are continuously transmitted on the link between frames to keep the link active.

THE ADDRESS FIELD

- The address field (A) identifies the primary or secondary stations involvement in the frame transmission or reception. Each station on the link has a unique address. In an unbalanced configuration, the A field in both commands and responses refers to the secondary station. In a balanced configuration, the command frame contains the destination station address and the response frame has the sending station's address.

THE CONTROL FIELD

- HDLC uses the control field (C) to determine how to control the communications process. This field contains the commands, responses and sequences numbers used to maintain the data flow accountability of the link, defines the functions of the frame and initiates the logic to control the movement of traffic between sending and receiving stations. There three control field formats

- **Information Transfer Format**
  The frame is used to transmit end-user data between two devices.
- **Supervisory Format**
  The control field performs control functions such as acknowledgment of frames, requests for re-transmission, and requests for temporary suspension of frames being transmitted. Its use depends on the operational mode being used.
- **Unnumbered Format**
  This control field format is also used for control purposes. It is used to perform link initialization, link disconnection and other link control functions.

THE POLL/FINAL BIT(P/F)

- The 5th bit position in the control field is called the poll/final bit, or p/f bit. It can only be recognized when it is set to 1. If it is set to 0, it is ignored. The poll/final bit is used to provide dialogue between the primary station and secondary station. The primary station uses P=1 to acquire a status response from the secondary station. The P bit signifies a poll. The secondary station responds to the P bit by transmitting a data or status frame to the primary station with the P/F bit set to F=1. The F bit can also be used to signal the end of a transmission from the secondary station under Normal Response Mode.

THE INFORMATION FIELD

- This field is not always in a HDLC frame. It is only present when the Information Transfer Format is being used in the control field. The information field contains the actually data the sender is transmitting to the receiver.

THE FRAME CHECK SEQUENCE FIELD

- This field contains a 16 bit, or 32 bit cyclic redundancy check. It is used for error detection