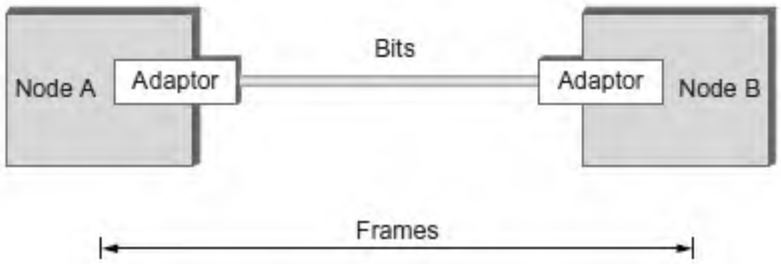
Data Link Layer – Framing – Flow control – Error control – Data-Link Layer Protocols – HDLC –PPP - Media Access Control – Ethernet Basics – CSMA/CD – Virtual LAN – Wireless LAN (802.11) - Physical Layer: Data and Signals - Performance – Transmission media- Switching – Circuit Switching.

2.1 Data Link Layer

- In the OSI model, the data link layer is the 2nd layer from the bottom.
- It is responsible for **transmitting frames from one node to next node**.
- The main responsibility of the Data Link Layer is to transfer the datagram across an individual link.
- An important characteristic of a Data Link Layer is that datagram can be handled by different link layer protocols on different links in a path.
- The other responsibilities of this layer are
  1. **Framing -** Divides the stream of bits received into data units called frames.
  2. **Physical addressing** – If frames are to be distributed to different systems on the same network, data link layer adds a header to the frame to define the sender and receiver.
  3. **Flow control-** If the rate at which the data are absorbed by the receiver is less than the rate produced in the sender ,the Data link layer imposes a flow control mechanism.
  4. **Error control-** Used for detecting and retransmitting damaged or lost frames and to prevent duplication of frames. This is achieved through a trailer added at the end of the frame.
  5. **Medium Access control -** Used to determine which device has control over the link at any given time.

5.2 FRAMING

- The data-link layer packs the bits of a message into frames, so that each frame is distinguishable from another.



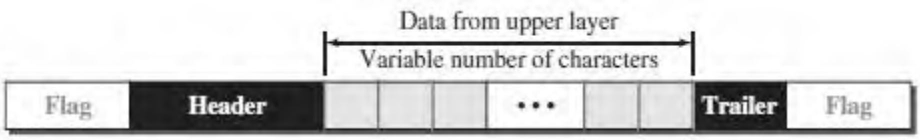
- Although the whole message could be packed in one frame, that is not normally done.
- One reason is that a frame can be very large, making flow and error control very inefficient.

Frame Size

- Frames can be of fixed or variable size.
- Frames of fixed size are called cells. In fixed-size framing, there is no need for defining the boundaries of the frames; the size itself can be used as a delimiter.
- In variable-size framing, we need a way to define the end of one frame and the beginning of the next. Two approaches were used for this purpose: a character-oriented approach and a bit-oriented approach.

Character-Oriented Framing

- In character-oriented (or byte-oriented) framing, data to be carried are 8-bit characters.
- To separate one frame from the next, an 8-bit (1-byte) flag is added at the beginning and the end of a frame.
- The flag, composed of protocol-dependent special characters, signals the start or end of a frame.



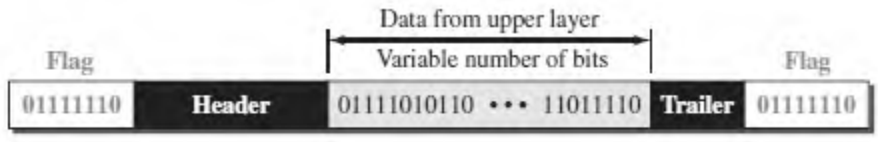
Bit-Oriented Framing

- In bit-oriented framing, the data section of a frame is a sequence of bits to be interpreted by the upper layer as text, graphic, audio, video, and so on.

➢ In addition to headers and trailers), we still need a delimiter to separate one frame from the other.

➢ Most protocols use a special 8-bit pattern flag, 01111110, as the delimiter to define the beginning and the end of the frame

➢ If the flag pattern appears in the data, the receiver must be informed that this is not the end of the frame.



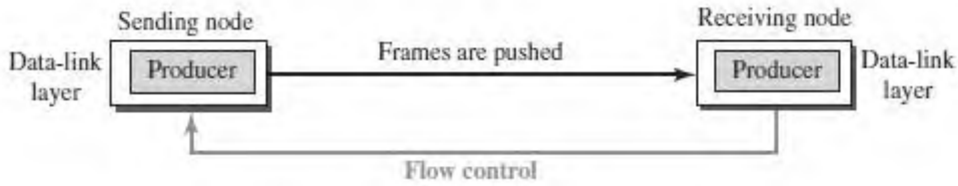
5.3 FLOW CONTROL

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

➢ The receiving device has limited speed and limited memory to store the data.

➢ Therefore, the receiving device must be able to inform the sending device to stop the transmission temporarily before the limits are reached.

➢ It requires a buffer, a block of memory for storing the information until they are processed.



Two methods have been developed to control the flow of data:

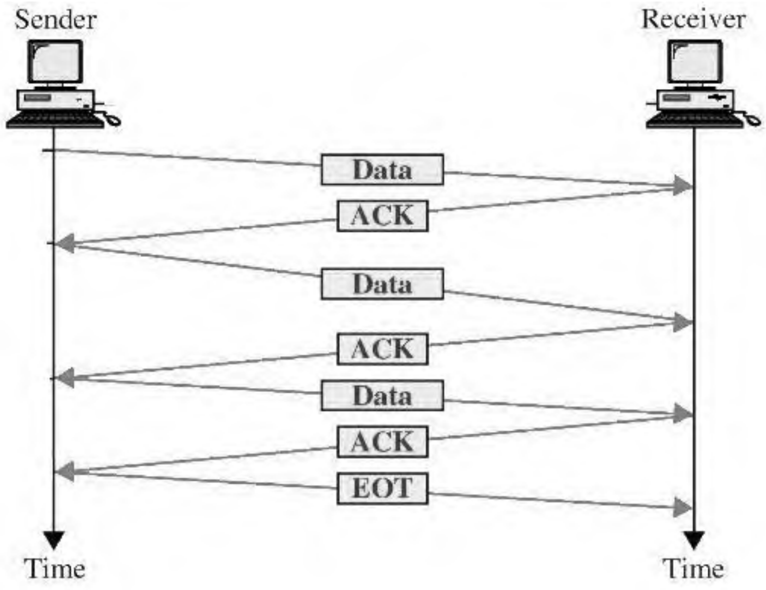
1. Stop-and-Wait
2. Sliding Window

STOP-AND-WAIT

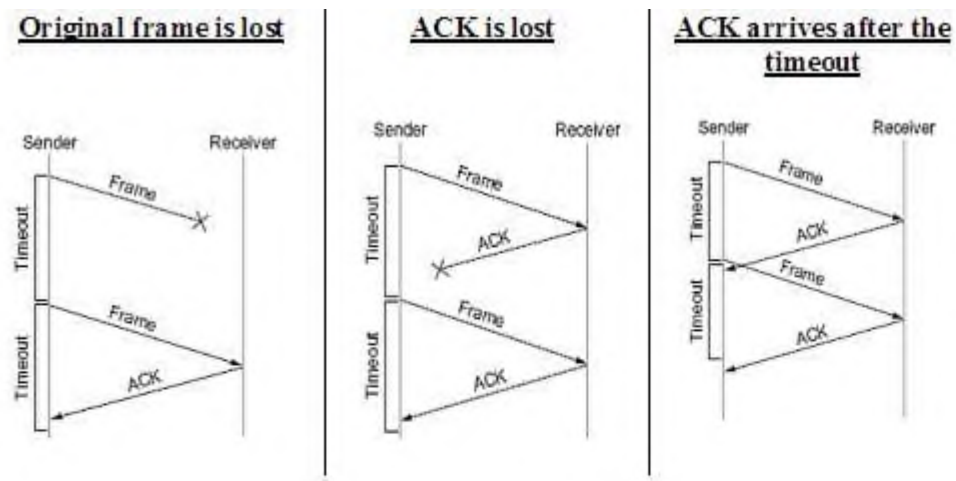
➢ The simplest scheme is the stop-and-wait algorithm.

➢ In the Stop-and-wait method, the sender waits for an acknowledgement after every frame it sends.

- When acknowledgement is received, then only next frame is sent.
- The process of alternately sending and waiting of a frame continues until the sender transmits the EOT (End of transmission) frame.



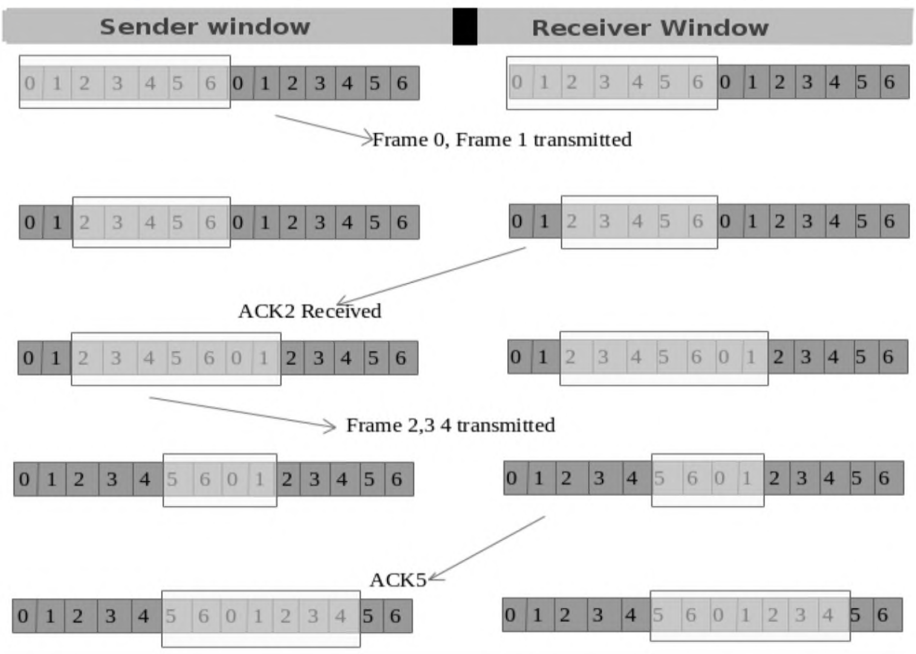
- If the acknowledgement is not received within the allotted time, then the sender assumes that the frame is lost during the transmission, so it will retransmit the frame.
- The acknowledgement may not arrive because of the following three scenarios :
    1. Original frame is lost
    2. ACK is lost
    3. ACK arrives after the timeout



SLIDING WINDOW

- The Sliding Window is a method of flow control in which a sender can transmit the several frames before getting an acknowledgement.
- In Sliding Window Control, multiple frames can be sent one after the another due to which capacity of the communication channel can be utilized efficiently.
- A single ACK acknowledge multiple frames.
- Sliding Window refers to imaginary boxes at both the sender and receiver end.
- The window can hold the frames at either end, and it provides the upper limit on the number of frames that can be transmitted before the acknowledgement.
- Frames can be acknowledged even when the window is not completely filled.
- The window has a specific size in which they are numbered as modulo-n means that they are numbered from 0 to n-1.
- For example, if n = 8, the frames are numbered from 0,1,2,3,4,5,6,7,0,1,2,3,4,5,6,7,0,1........
- The size of the window is represented as n-1. Therefore, maximum n-1 frames can be sent before acknowledgement.
- When the receiver sends the ACK, it includes the number of the next frame that it wants to receive.
- For example, to acknowledge the string of frames ending with frame number 4, the receiver will send the ACK containing the number 5.
- When the sender sees the ACK with the number 5, it got to know that the frames from 0 through 4 have been received.

Example of Sliding Window



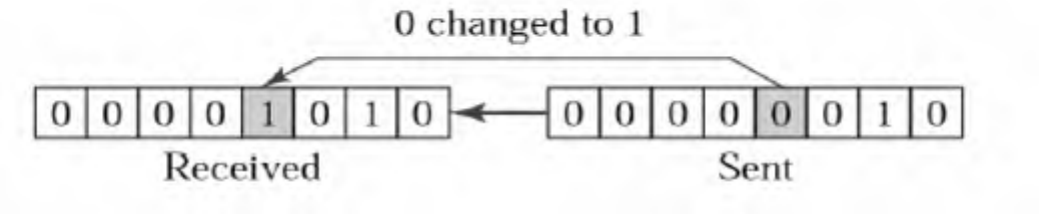
5.4 ERROR CONTROL

Data can be corrupted during transmission. For reliable communication, errors must be detected and corrected. Error Control is a technique of error detection and retransmission.

TYPES OF ERRORS

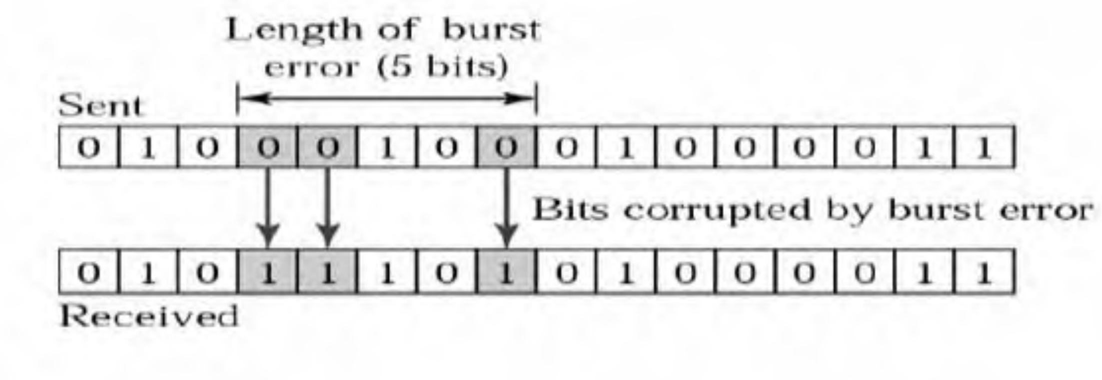
SINGLE-BIT ERROR

The term Single-bit error means that only one bit of a given data unit (such as byte, character, data unit or packet) is changed from 1 to 0 or from 0 to 1.



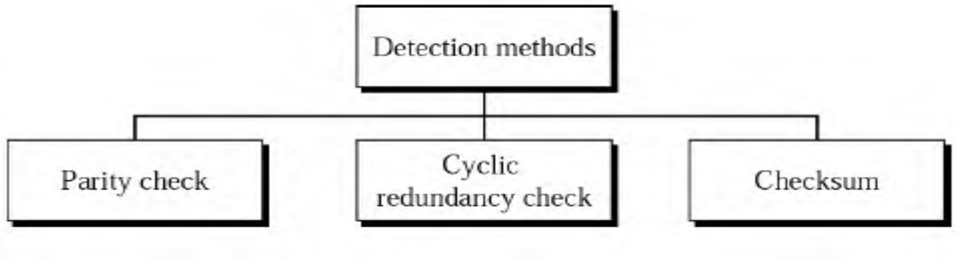
BURST ERROR

The term Burst Error means that two or more bits in the data unit have changed from 1 to 0 or from 0 to 1.



ERROR DETECTION TECHNIQUES / METHODS

The basic idea behind any error detection scheme is to add additional information to a frame that can be used to determine if errors have been introduced.



PARITY CHECK

- One bit, called parity bit is added to every data unit so that the total number of 1's in the data unit becomes even (or) odd.
- The source then transmits this data via a link, and bits are checked and verified at the destination.
- Data is considered accurate if the number of bits (even or odd) matches the number transmitted from the source.
- This techniques is the most common and least complex method.

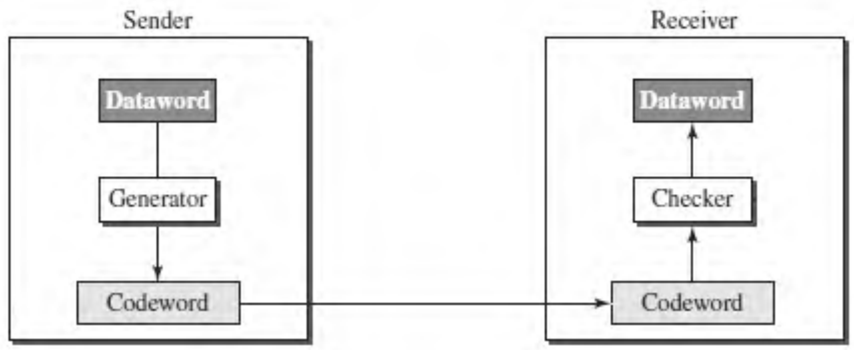
1. ***Even parity*** – Maintain even number of 1s
 E.g., 1011 → 1011 **1**
2. ***Odd parity*** – Maintain odd number of 1s
 E.g., 1011 → 1011 **0**

CYCLIC REDUNDANCY CHECK

- Cyclic codes refers to encoding messages by adding a fixed-length check value.
- CRCs are popular because they are simple to implement, easy to analyze mathematically and particularly good at detecting common errors caused in transmission channels.

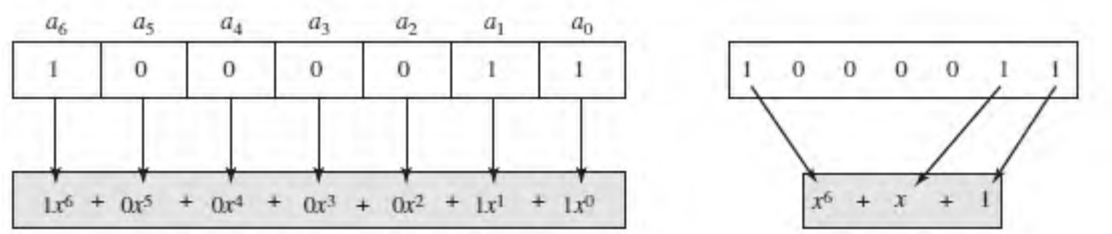
Steps Involved :

- Consider the original message (dataword) as M(x) consisting of 'k' bits and the divisor as C(x) consists of 'n+1' bits.
- The original message M(x) is appended by 'n' bits of zero's. Let us call this zero-extended message as T(x).
- Divide T(x) by C(x) and find the remainder.
- The division operation is performed using XOR operation.
- The resultant remainder is appended to the original message M(x) as CRC and sent by the sender(codeword).



Polynomials

- A pattern of 0s and 1s can be represented as a **polynomial** with coefficients of 0 and 1.
- The power of each term shows the position of the bit; the coefficient shows the value of the bit.

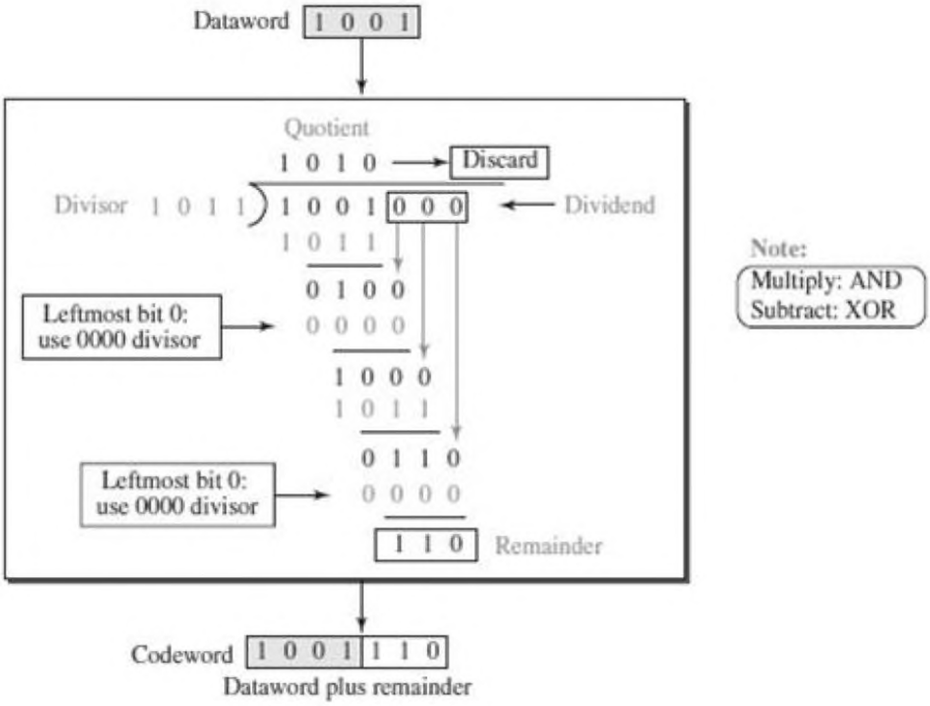


a. Binary pattern and polynomial b. Short form

Example 1:

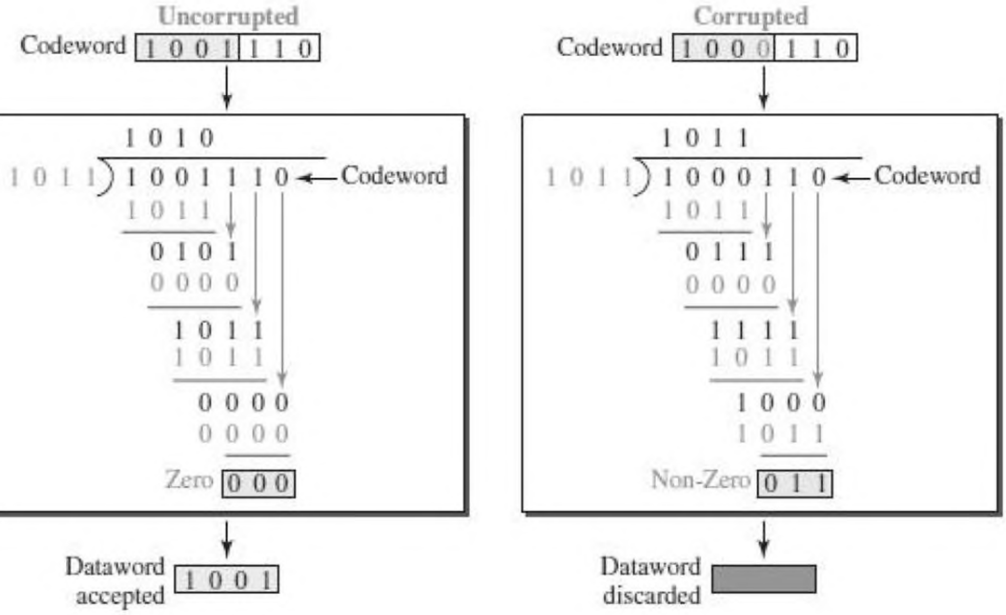
- Consider the Dataword / Message M(x) = 1001
- Divisor C(x) = 1011 (n+1=4)
- Appending 'n' zeros to the original Message M(x).
- The resultant messages is called T(x) = 1001 **000.** (here n=3)
- Divide T(x) by the divisor C(x) using XOR operation.

Sender Side :



Receiver Side:

(For Both Case – Without Error and With Error)

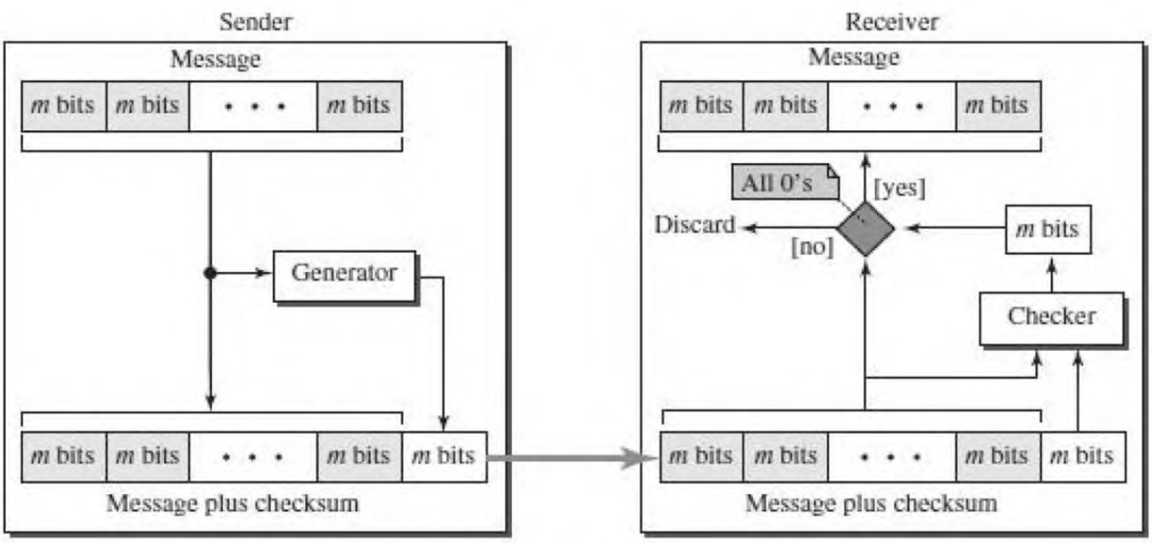


CHECKSUM

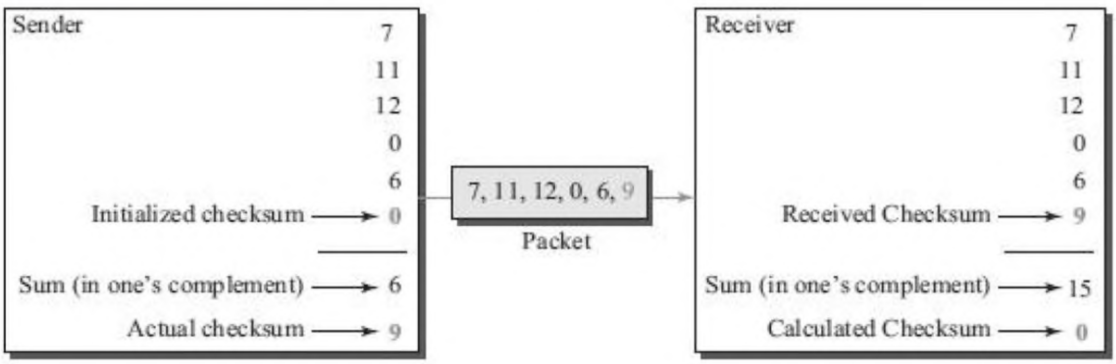
- Checksum is a calculated value that is used to determine the integrity of data.

Procedure to calculate the traditional checksum

Sender	*Receiver*
1. The message is divided into 16-bit words.	1. The message and the checksum are received.
2. The value of the checksum word is initially set to zero.	2. The message is divided into 16-bit words.
3. All words including the checksum are added using one's complement addition.	3. All words are added using one's complement addition.
4. The sum is complemented and becomes the checksum.	4. The sum is complemented and becomes the new checksum.
5. The checksum is sent with the data.	5. If the value of the checksum is 0, the message is accepted; otherwise, it is rejected.



Example : Let the message to be transmitted be 7,11,12,0,6.



ERROR CONTROL

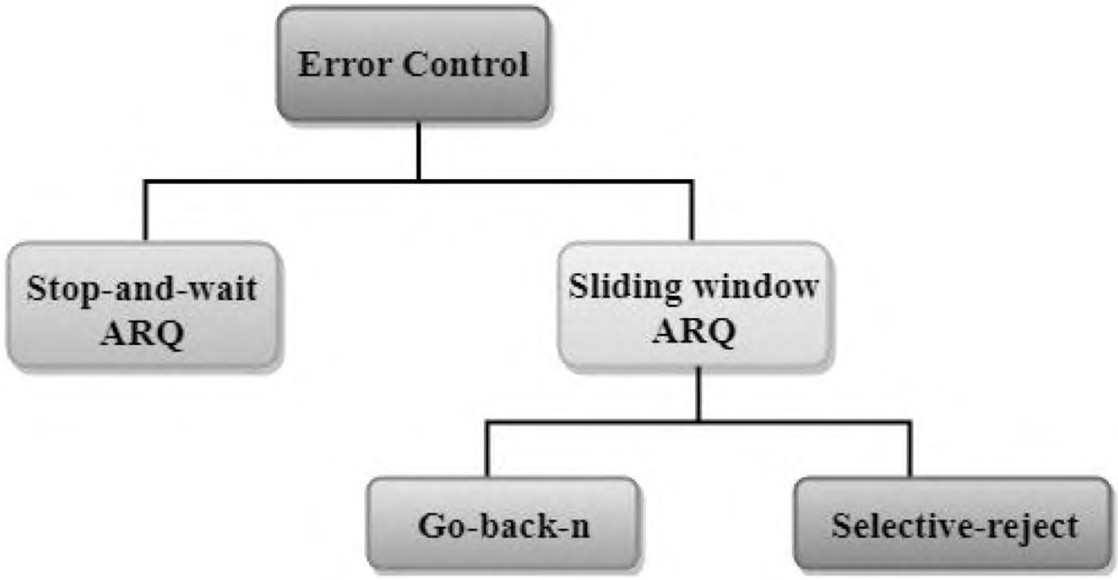
- Error control includes both error detection and error correction.
- Whenever an error is detected, specified frames are retransmitted
- It allows the receiver to inform the sender if a frame is lost or damaged during transmission and coordinates the retransmission of those frames by the sender.
- Includes the following actions:

Error detection

1. Positive Acknowledgement (**ACK**): if the frame arrived with no errors
2. Negative Acknowledgement (**NAK**): if the frame arrived with errors
3. Retransmissions after **Timeou**t: Frame is retransmitted after certain amount of time if no acknowledgement was received

- Error control in the data link layer is based on automatic repeat request (ARQ).

Categories of Error Control

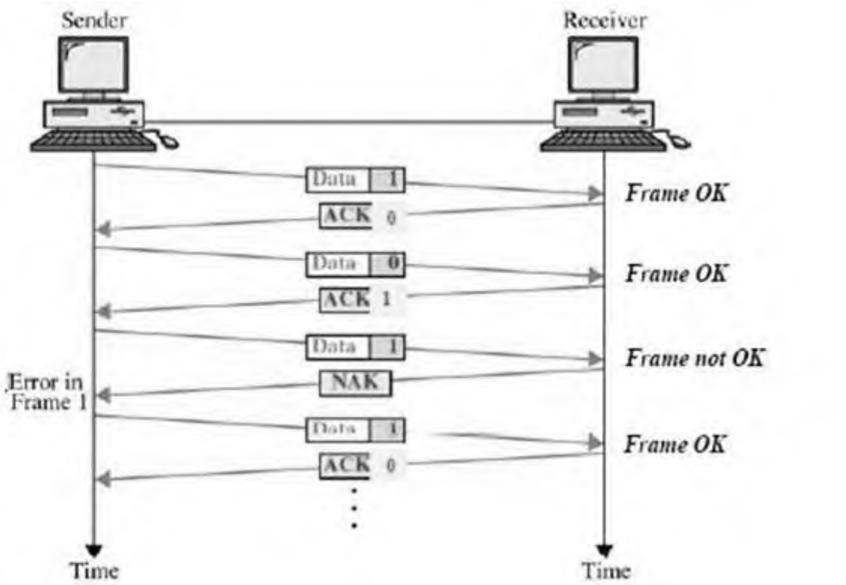


STOP-AND-WAIT ARQ

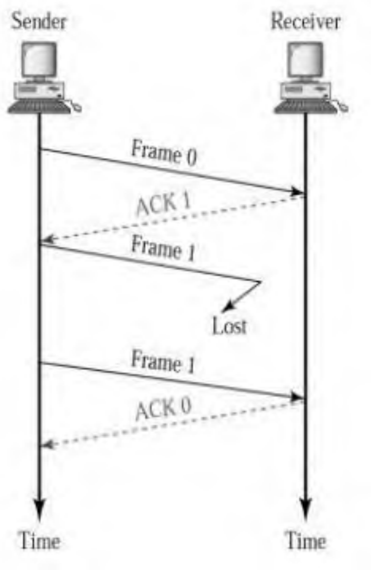
- Stop-and-wait ARQ is a technique used to retransmit the data in case of damaged or lost frames.
- This technique works on the principle that the sender will not transmit the next frame until it receives the acknowledgement of the last transmitted frame.

Two possibilities of the retransmission in Stop and Wait ARQ:

Damaged Frame: When the receiver receives a damaged frame(i.e., the frame contains an error), then it returns the NAK frame. For example, when the frame DATA 1 is sent, and then the receiver sends the ACK 0 frame means that the data 1 has arrived correctly. The sender transmits the next frame: DATA 0. It reaches undamaged, and the receiver returns ACK 1.The sender transmits the third frame: DATA 1. The receiver reports an error and returns the NAK frame. The sender retransmits the DATA 1 frame.



Lost Frame: Sender is equipped with the timer and starts when the frame is transmitted. Sometimes the frame has not arrived at the receiving end so that it cannot be acknowledged either positively or negatively. The sender waits for acknowledgement until the timer goes off. If the timer goes off, it retransmits the last transmitted frame.



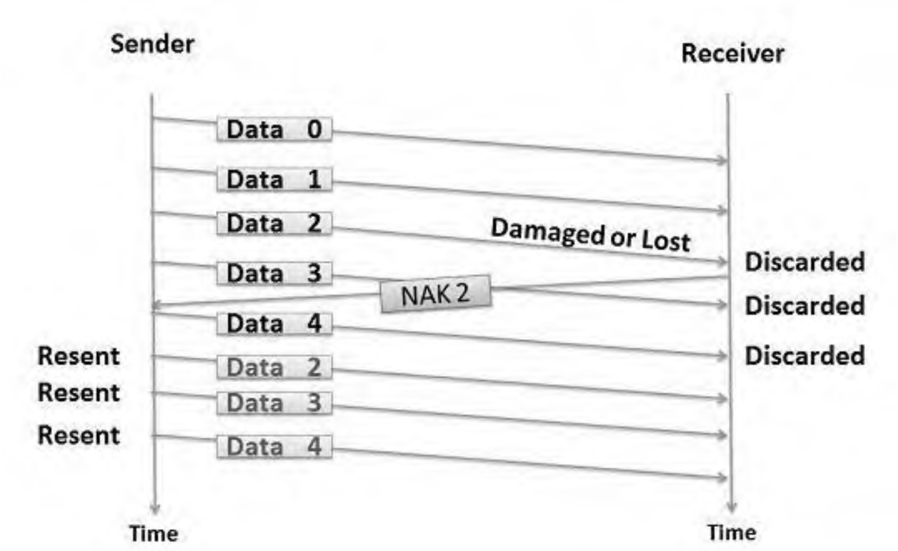
SLIDING WINDOW ARQ

Sliding Window ARQ is a technique used for continuous transmission error control.

Two protocols used in sliding window ARQ:

1.GO-BACK-N ARQ

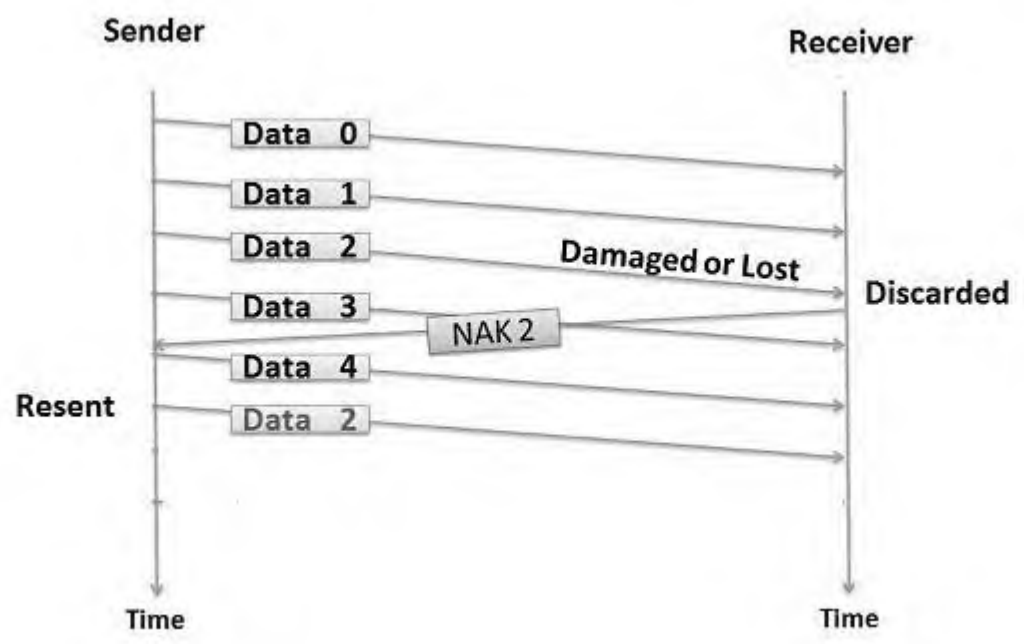
In Go-Back-N ARQ protocol, if one frame is lost or damaged, then it retransmits all the frames after which it does not receive the positive ACK



- In the above figure, three frames (Data 0,1,2) have been transmitted before an error discovered in the third frame.
- The receiver discovers the error in Data 2 frame, so it returns the NAK 2 frame.
- All the frames including the damaged frame (Data 2,3,4) are discarded as it is transmitted after the damaged frame.
- Therefore, the sender retransmits the frames (Data2,3,4).

SELECTIVE-REJECT(REPEAT) ARQ

- Selective-Reject ARQ technique is more efficient than Go-Back-n ARQ.
- In this technique, only those frames are retransmitted for which negative acknowledgement (NAK) has been received.
- The receiver storage buffer keeps all the damaged frames on hold until the frame in error is correctly received.
- The receiver must have an appropriate logic for reinserting the frames in a correct order.
- The sender must consist of a searching mechanism that selects only the requested frame for retransmission.



- In the above figure, three frames (Data 0,1,2) have been transmitted before an error discovered in the third frame.
- The receiver discovers the error in Data 2 frame, so it returns the NAK 2 frame.
- The damaged frame only (Data 2) is discarded.
- The other subsequent frames (Data 3,4) are accepted.
- Therefore, the sender retransmits only the damaged frame (Data2).