The Data Link Layer is responsible for delivering frames of information over a single link .

- Handles transmission errors and regulates the flow of data.
- It deals with the problem of having fast transmitter and slow receiver.
- it deals with how to control the access to the shared channel.

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At sender side:

- breaks data into frames.
- Transmits the frames sequent.

At receiver side:

- Confirms receiving frames by sending acknowledgment.

Services to the Network Layer(Three)

- **Unacknowledged connectionless service:**
  Good in real-time traffic and LAN.
- **Acknowledged connectionless service:**
  useful in wireless systems.
- **Acknowledged connection-oriented service:**
  used in routing.

Framing

To detect or correct errors. the data link layer breaks the bit stream up into discrete frames and computes the checksum for each frame.

Relationship between packets and frames

Link layer accepts **packets** from the network layer, and encapsulates them into **frames** that it sends using the physical layer.

Framing Methods

used to mark the start and end of each frame.

- Byte count.
  begins with a count of the number of bytes in it.
- byte stuffing.
  occurrences of flags in the data must be stuffed.
- bit stuffing.
  at sender, after five 1's in the data, a 0 is added.
  at receive, a 0 after five 1's is deleted.

Error Control

repairs frames that are received in error.

- errors detected at the receiver.
- retransmit the unacknowledged.
- Timer protects against lost acknowledgements.

Flow Control

Prevents a fast transmitter to slow receiver.

- Receiver gives feedback on the data it can accept.

Lecture 2
Error Control

Detection Methods

- Parity Check.
- Cyclic Redundancy Check (CRC).
- Checksum.

Corrections Methods

- Retransmission.
- Forward Error Correction.
- Burst Error Correction.

Types of Errors

- Single-bit error.
  only 1 bit has changed.
- Burst error.
  2 or more bits have changed.

Redundancy

adding extra bits for detecting errors at the destination.

datawords : block that have m bits.
codewords : datawords + Redundancy.

parity check

Simple parity check can detect all single-bit errors. It can detect burs errors only if the total number of errors is odd for even parity

Two-dimensional parity-check code

block of bits is divided into rows and a redundant row of bits is added to the whole block.

Lecture 3
Error Detection and Correction using Hamming Code

Hamming Code

- Provide for FEC using a “Block Parity”.
- Allows correction of single bit errors.

- This is accomplished by using more than one parity bit.

Hamming Code:

- Increases overhead in data transmitted.
- Increases overhead in processing time.

Lecture 4
Error Detection using Cyclic codes

Cyclic codes

If Codeword is cyclically shifted, the result is another Codeword.

Type of Cyclic codes:

- Cyclic Redundancy Check
- Checksum.

Binary Division

This procedure is very useful to us in calculating CRC syndromes.
If the carry is 0 then Dataword is **accepted**, otherwise Dataword is **Discarded**.

polynomial generator

Lecture 5
Checksum

Checksum is an error detection method.

Sender steps:

1. unit is divided into k sections, each of n bits.
2. All sections are added using one's complement to get the sum.
3. The sum is complemented and becomes the checksum.
4. checksum is sent with the data.

Receiver steps:

1. unit is divided into k sections, each of n bits.
2. All sections are added using one's complement to get the sum.
3. The sum is complemented.
4. If the result is zero, the data are **accepted**: otherwise, **rejected**.

Lecture 6
Flow Control

The most important responsibilities of the data link layer are flow control and 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.

Protocols

For noisy channel:

- Stop-and-wait ARQ
- Go-back-N ARQ
- Selective Repeat ARQ

Stop-and-wait ARQ

The sender will send frame and keeps a a copy of it . if sender receive ACK will delete the copy and send the next frame and so on.

Cases of operations:

- Normal operation.
  The sender will not send the next data until it get ACK.
- The frame is lost.
- The ACK is lost.
- The ACK is delayed.

Lecture 7
Go-back-N

name of Go-back-N

when the frame is damaged the sender goes back and resends a set of frames starting from the last one acknowledged; the number of retransmitted frames is N.

Pipelining

One task begins before the other one ends.

Sequence numbers

- Sent frames are numbered sequentially
- Sequence number is stored in the header
- sequence number goes from 0 to 2^m-1

Sliding Window Protocols

- to hold the unacknowledged outstanding frames
- In Go-back-N ARQ the receiver window size always 1

Control variables

- S : holds the sequence number of the recently sent frame.
- S_F : holds sequence number of the first frame in the window.
- S_L : holds sequence number of the last frame in the window.
- R : sequence number of the frame expected to be received.

Cases of operations:

- Normal operation.
  ACK1–not necessary if ACK2 is sent.
- damaged or lost frame.
  Damaged frames are discarded.
- sender window size.
  if window size = 2^m then Erroneously will accepted.
  m is the size of the sequence number.

Lecture 8
Selective Repeat

- The window size is reduced to one half of 2^m.
- Both the transmitter and the receiver have the same window size.
- Receiver expects frames within the range of the sequence numbers.

Cases of operations:

- Lost frame.
- Sender window size.
  if window size > 2^{m-1} then Erroneously will accepted.