**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 2m-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.
* SF : holds sequence number of the first frame in the window.
* SL : 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 = 2m 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 2m.
* 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 > 2m-1 then Erroneously will accepted.