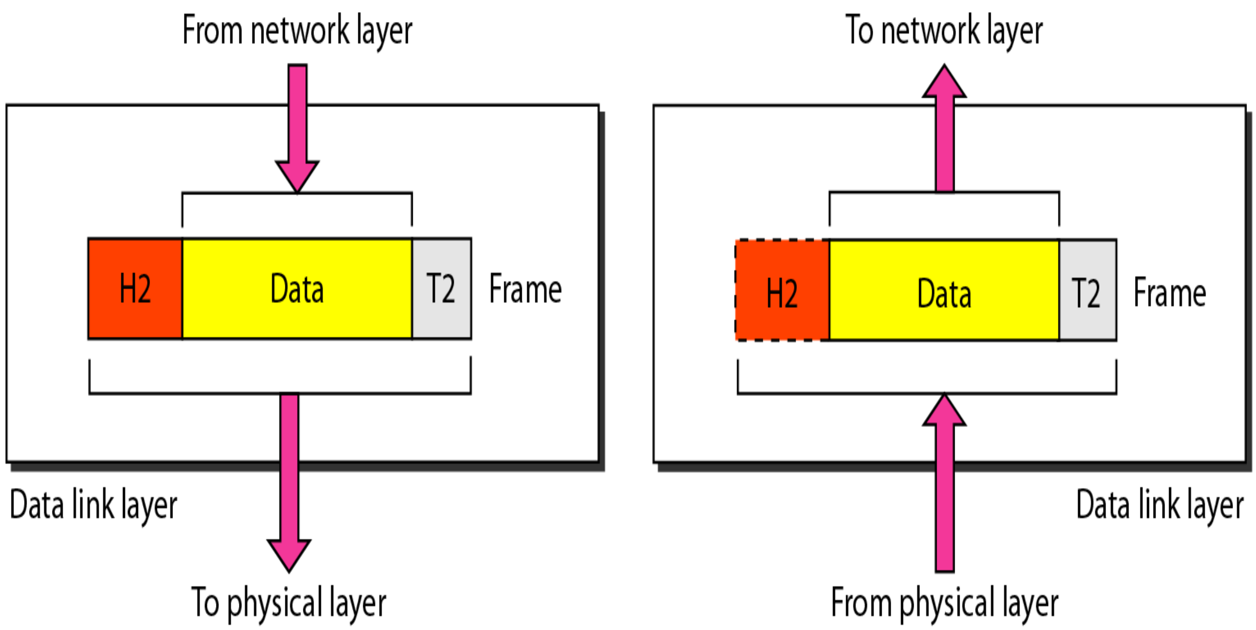
Chapter 5

Data Link Layer and Physical Layer

Data Link Layer is second layer of OSI Layered Model. This layer is one of the most complicated layers and has complex functionalities and liabilities. Data link layer hides the details of underlying hardware and represents itself to upper layer as the medium to communicate.

Data link layer works between two hosts which are directly connected in some sense. This direct connection could be point to point or broadcast. Systems on broadcast network are said to be on same link. The work of data link layer tends to get more complex when it is dealing with multiple hosts on single collision domain.

Data link layer is responsible for converting data stream to signals bit by bit and to send that over the underlying hardware. At the receiving end, Data link layer picks up data from hardware which are in the form of electrical signals, assembles them in a recognizable frame format, and hands over to upper layer.



Data link layer has two sub-layers:

Logical Link Control (LLC) sublayer provides the logic for the data link. Thus, it controls the synchronization, flow control, and error checking functions of the data link layer.

- It deals with protocols, flow-control, and error control

Media Access Control (MAC) sublayer provides control for accessing the transmission medium. It is responsible for moving data packets from one network interface card (NIC) to another, across a shared transmission medium. Physical addressing is handled at the MAC sublayer. MAC is also handled at this layer.

- It deals with actual control of media

Functionality of Data-link Layer

Data link layer does many tasks on behalf of upper layer. These are:

- **Framing**
  Data-link layer takes packets from Network Layer and encapsulates them into Frames.Then, it sends each frame bit-by-bit on the hardware. At receiver' end, data link layer picks up signals from hardware and assembles them into frames.
- **Addressing**
  Data-link layer provides layer-2 hardware addressing mechanism. Hardware address is assumed to be unique on the link. It is encoded into hardware at the time of manufacturing.
- **Synchronization**
  When data frames are sent on the link, both machines must be synchronized in order to transfer to take place.
- **Error Control**
  Sometimes signals may have encountered problem in transition and the bits are flipped. These errors are detected and attempted to recover actual data bits. It also provides error reporting mechanism to the sender.
- **Flow Control**
  Stations on same link may have different speed or capacity. Data-link layer ensures flow control that enables both machine to exchange data on same speed.

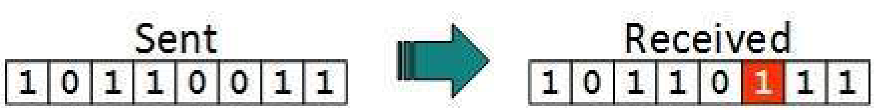
There are many reasons such as noise, cross-talk etc., which may help data to get corrupted during transmission. The upper layers work on some generalized view of network architecture and are not aware of actual hardware data processing. Hence, the upper layers expect error-free transmission between the systems. Most of the applications would not function expectedly if they receive erroneous data. Applications such as voice and video may not be that affected and with some errors they may still function well.

Data-link layer uses some error control mechanism to ensure that frames (data bit streams) are transmitted with certain level of accuracy. But to understand how errors is controlled, it is essential to know what types of errors may occur.

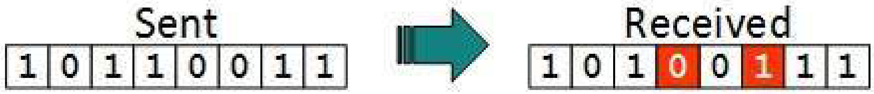
Types of Errors

There may be three types of errors:

- **Single bit error**

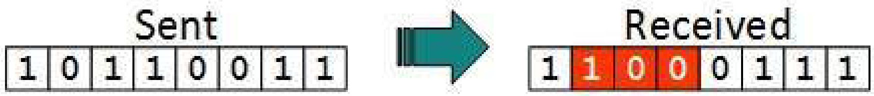
  

  In a frame, there is only one bit, anywhere though, which is corrupt.
- **Multiple bits error**



Frame is received with more than one bits in corrupted state.

- **Burst error**



Frame contains more than1 consecutive bits corrupted.

Error control mechanism may involve two possible ways:

- Error detection
- Error correction

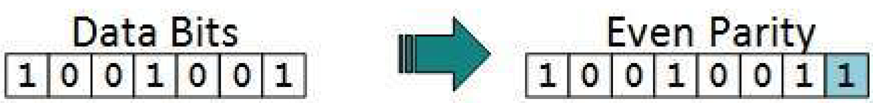
Error Detection

Errors in the received frames are detected by means of Parity Check and Cyclic Redundancy Check (CRC). In both cases, few extra bits are sent along with actual data to confirm that bits received at other end are same as they were sent. If the counter-check at receiver' end fails, the bits are *considered corrupted.*

Parity Check

One extra bit is sent along with the original bits to make number of 1s either even in case of even parity, or odd in case of odd parity.

The sender while creating a frame counts the number of 1s in it. For example, if even parity is used and number of 1s is even then one bit with value 0 is added. This way number of 1s remains even.If the number of 1s is odd, to make it even a bit with value 1 is added.

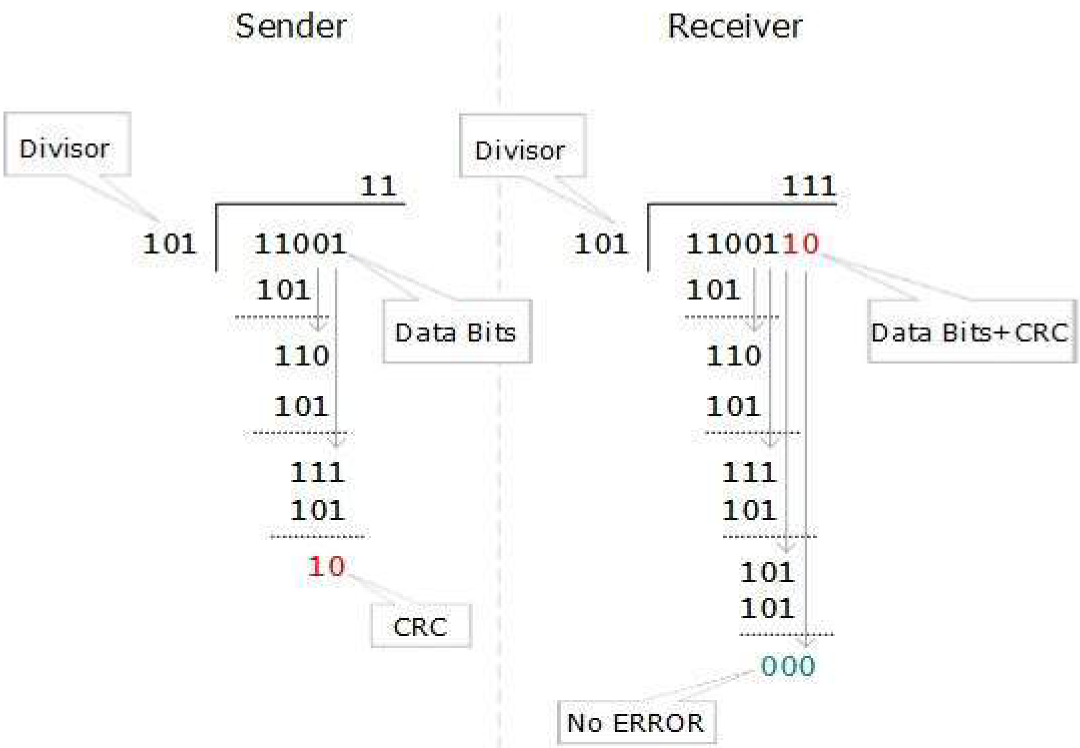


The receiver simply counts the number of 1s in a frame. If the count of 1s is even and even parity is used, the frame is considered to be not-corrupted and is accepted. If the count of 1s is odd and odd parity is used, the frame is still not corrupted.

If a single bit flips in transit, the receiver can detect it by counting the number of 1s. But when more than one bits are erro neous, then it is very hard for the receiver to detect the error.

Cyclic Redundancy Check (CRC)

CRC is a different approach to detect if the received frame contains valid data. This technique involves binary division of the data bits being sent. The divisor is generated using polynomials. The sender performs a division operation on the bits being sent and calculates the remainder. Before sending the actual bits, the sender adds the remainder at the end of the actual bits. Actual data bits plus the remainder is called a codeword. The sender transmits data bits as codewords.



At the other end, the receiver performs division operation on codewords using the same CRC divisor. If the remainder contains all zeros the data bits are accepted, otherwise it is considered as there some data corruption occurred in transit.

Error Correction

In the digital world, error correction can be done in two ways:

- **Backward Error Correction** When the receiver detects an error in the data received, it requests back the sender to retransmit the data unit.
- **Forward Error Correction** When the receiver detects some error in the data received, it executes error-correcting code, which helps it to auto-recover and to correct some kinds of errors.

The first one, Backward Error Correction, is simple and can only be efficiently used where retransmitting is not expensive. For example, fiber optics. But in case of wireless transmission retransmitting may cost too much. In the latter case, Forward Error Correction is used.

To correct the error in data frame, the receiver must know exactly which bit in the frame is corrupted. To locate the bit in error, redundant bits are used as parity bits for error detection.For example, we take ASCII words (7 bits data), then there could be 8 kind of information we need: first seven bits to tell us which bit is error and one more bit to tell that there is no error.

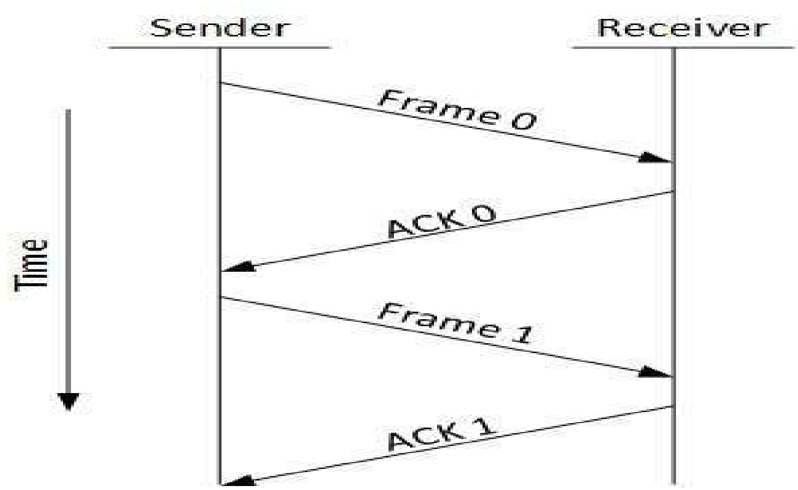
Data-link layer is responsible for implementation of point-to-point flow and error control mechanism.

Flow Control

When a data frame (Layer-2 data) is sent from one host to another over a single medium, it is required that the sender and receiver should work at the same speed. That is, sender sends at a speed on which the receiver can process and accept the data. What if the speed (hardware/software) of the sender or receiver differs? If sender is sending too fast the receiver may be overloaded, (swamped) and data may be lost.

Two types of mechanisms can be deployed to control the flow:

- **Stop and Wait**
  This flow control mechanism forces the sender after transmitting a data frame to stop and wait until the acknowledgement of the data-frame sent is received.



- **Sliding Window**
  In this flow control mechanism, both sender and receiver agree on the number of data-frames after which the acknowledgement should be sent. As we learnt, stop and wait flow control mechanism wastes resources, this protocol tries to make use of underlying resources as much as possible.

Error Control

When data-frame is transmitted, there is a probability that data-frame may be lost in the transit or it is received corrupted. In both cases, the receiver does not receive the correct data-frame and sender does not know anything about any loss.In such case, both sender and receiver are equipped with some protocols which helps them to detect transit errors such as loss of data-frame. Hence, either the sender retransmits the data-frame or the receiver may request to resend the previous data-frame.

Requirements for error control mechanism:

- **Error detection** - The sender and receiver, either both or any, must ascertain that there is some error in the transit.
- **Positive ACK** - When the receiver receives a correct frame, it should acknowledge it.
- **Negative ACK** - When the receiver receives a damaged frame or a duplicate frame, it sends a NACK back to the sender and the sender must retransmit the correct frame.
- **Retransmission:** The sender maintains a clock and sets a timeout period. If an acknowledgement of a data-frame previously transmitted does not arrive before the timeout the sender retransmits the frame, thinking that the frame or it's acknowledgement is lost in transit.

Framing

Framing is a point-to-point connection between two computers or devices consists of a wire in which data is transmitted as a stream of bits. However, these bits must be framed into discernible blocks of information. Framing is a function of the data link layer. It provides a way for a sender to transmit a set of bits that are meaningful to the receiver. Ethernet, token ring, frame relay, and other data link layer technologies have their own frame structures. Frames have headers that contain information such as error-checking codes.

At the data link layer, it extracts the message from the sender and provides it to the receiver by providing the sender's and receiver's addresses. The advantage of using frames is that data is broken up into recoverable chunks that can easily be checked for corruption.

Multiple Access Protocol

Multiple access protocols are a set of protocols operating in the Medium Access Control sublayer (MAC sublayer) of the Open Systems Interconnection (OSI) model. These protocols allow a number of nodes or users to access a shared network channel. Several data streams originating from several nodes are transferred through the multi-point transmission channel.

The objectives of multiple access protocols are optimization of transmission time, minimization of collisions and avoidance of crosstalks.

MAC Address

A media access control address (MAC address) is a unique identifier assigned to a network interface controller (NIC) for use as a network address in communications within a network segment.

To find MAC Address on computer

Windows

1. Press both the Windows Key and the R key simultaneously.
2. Type *ncpa.cpl* into the search box and press ENTER.
3. Right-click your Local Area Connection or Wi-Fi Connection (depending on how you are connected) and select Status.
4. Click Details and the Physical Address is your MAC Address.

Responsibility of Data Link Layer

The data link layer is responsible for multiplexing data streams, data frame detection, medium access, and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.

Physical Layer

The physical layer is the first and lowest layer of the Open System Interconnection Model (OSI Model.)

The physical layer (also known as layer 1) deals with bit-level transmission between different devices and supports electrical or mechanical interfaces connecting to the physical medium for synchronized communication.

This layer plays with most of the network's physical connections—wireless transmission, cabling, cabling standards and types, connectors and types, network interface cards, and more —as per network requirements.

Physical Layer is the bottom-most layer in the **Open System Interconnection (OSI) Model** which is a physical and electrical representation of the system. It consists of various network components such as power plugs, connectors, receivers, cable types, etc. Physical Layer sends data bits from one device(s) (like a computer) to another device(s). Physical Layer defines the types of encoding (that is how the 0's and 1's are encoded in a signal). Physical Layer is responsible for the communication of the unstructured raw data streams over a physical medium.

Functions Performed by Physical Layer :

Following are some important and basic functions that are performed by the Physical Layer of the OSI Model –

- ✓ Physical Layer maintains the data rate (how many bits a sender can send per second).
- ✓ It performs Synchronization of bits.
- ✓ It helps in Transmission Medium decision (direction of data transfer).
- ✓ It helps in Physical Topology (Mesh, Star, Bus, Ring) decision (Topology through which we can connect the devices with each other).
- ✓ It helps in providing Physical Medium and Interface decisions.
- ✓ It provides two types of configuration Point to Point configuration and Multi-

Point configuration.
- ✓ It provides an interface between devices (like PC's or computers) and transmission medium.
- ✓ It has a protocol data unit in bits.
- ✓ Hubs, Ethernet, etc. device is used in this layer.
- ✓ This layer comes under the category of Hardware Layers (since the hardware layer is responsible for all the physical connection establishment and processing too).
- ✓ It provides an important aspect called Modulation, which is the process of converting the data into radio waves by adding the information to an electrical or optical nerve signal.
- ✓ It also provides Switching mechanism wherein data packets can be forward from one port (sender port) to the leading destination port.
- ✓

The physical layer provides the following services:

- Modulates the process of converting a signal from one form to another so that it can be physically transmitted over a communication channel.
- Bit-by-bit delivery.
- Line coding, which allows data to be sent by hardware devices that are optimized for digital communications that may have discreet timing on the transmission link.
- Bit synchronization for synchronous serial communications.
- Start-stop signaling and flow control in asynchronous serial communication.
- Circuit switching and multiplexing hardware control of multiplexed digital signals.
- Carrier sensing and collision detection, whereby the physical layer detects carrier availability and avoids the congestion problems caused by undeliverable packets.
- Signal equalization to ensure reliable connections and facilitate multiplexing.
- Forward error correction/channel coding such as error correction code.