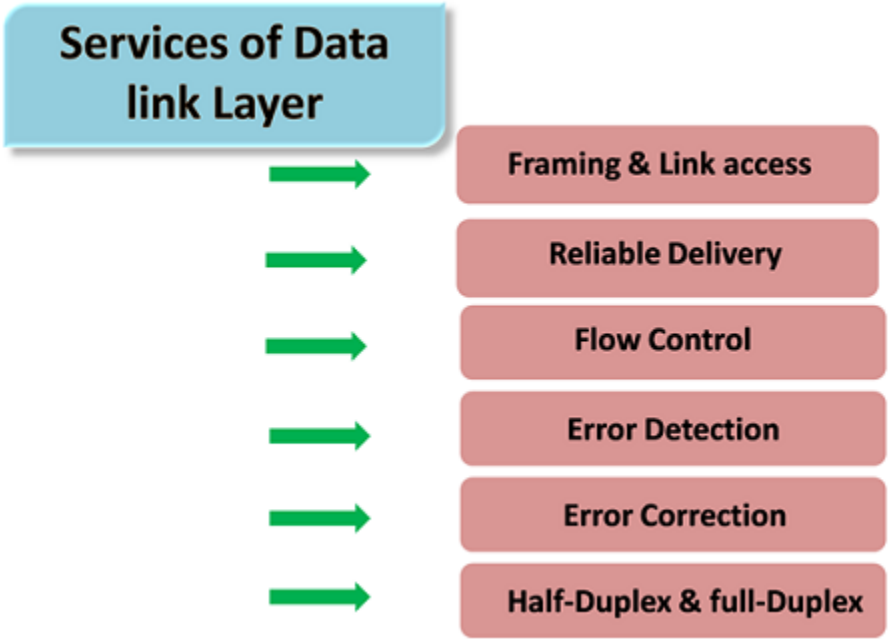
Data Link Layer

- In the OSI model, the data link layer is a 4th layer from the top and 2nd layer from the bottom.
- The communication channel that connects the adjacent nodes is known as links, and in order to move the datagram from source to the destination, the datagram must be moved across an individual link.
- The main responsibility of the Data Link Layer is to transfer the datagram across an individual link.
- The Data link layer protocol defines the format of the packet exchanged across the nodes as well as the actions such as Error detection, retransmission, flow control, and random access.
- The Data Link Layer protocols are Ethernet, token ring, FDDI and PPP.
- 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. For example, the datagram is handled by Ethernet on the first link, PPP on the second link.

Following services are provided by the Data Link Layer:



- **Framing & Link access:** Data Link Layer protocols encapsulate each network frame within a Link layer frame before the transmission across the link. A frame consists of a

data field in which network layer datagram is inserted and a number of data fields. It specifies the structure of the frame as well as a channel access protocol by which frame is to be transmitted over the link.

- **Reliable delivery:** Data Link Layer provides a reliable delivery service, i.e., transmits the network layer datagram without any error. A reliable delivery service is accomplished with transmissions and acknowledgements. A data link layer mainly provides the reliable delivery service over the links as they have higher error rates and they can be corrected locally, link at which an error occurs rather than forcing to retransmit the data.
- **Flow control:** A receiving node can receive the frames at a faster rate than it can process the frame. Without flow control, the receiver's buffer can overflow, and frames can get lost. To overcome this problem, the data link layer uses the flow control to prevent the sending node on one side of the link from overwhelming the receiving node on another side of the link.
- **Error detection:** Errors can be introduced by signal attenuation and noise. Data Link Layer protocol provides a mechanism to detect one or more errors. This is achieved by adding error detection bits in the frame and then receiving node can perform an error check.
- **Error correction:** Error correction is similar to the Error detection, except that receiving node not only detect the errors but also determine where the errors have occurred in the frame.
- **Half-Duplex & Full-Duplex:** In a Full-Duplex mode, both the nodes can transmit the data at the same time. In a Half-Duplex mode, only one node can transmit the data at the same time.

Where Is Link Layer Implemented?

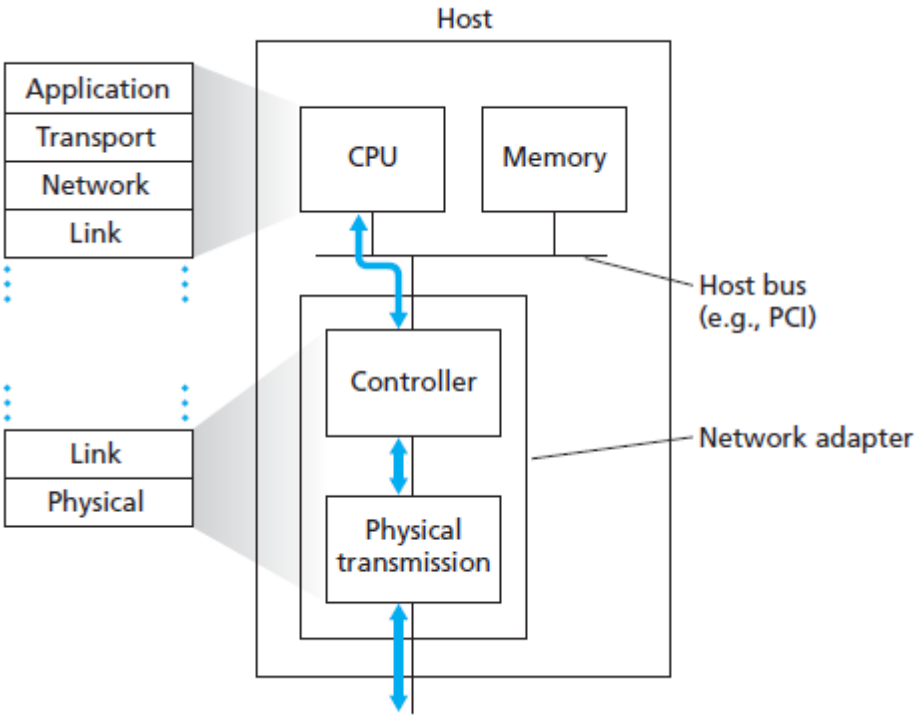
For the most part, the **link layer is implemented** in a network adapter, also sometimes known as a Network Interface Card (NIC).
At the heart of the network adapter is the link layer controller, usually a single, special purpose chip that implements many of the link layer services (framing, link access, error detection etc.). Thus, much of a link layer controller's functionality is implemented in hardware.

For example, Intel's 8254x controller implements the Ethernet protocols, the Atheros AR5006 controller implements the 802.11 WiFi protocols.

Until the late 1990s most network adapters were physically separate cards (such as PCMCIA card or a plug-in card fitting into a PC's PCI card slot) but increasingly, network adapters are being integrated onto the host's motherboard – a so called LAN-on-motherboard configuration.

On the sending side, the controller takes a datagram that has been created and stored in host memory by the higher layers of the protocol stack, encapsulates the datagram in a link layer frame (filling in the frame's various fields), and then transmits the fame into the communication link, following the link access protocol. On the receiving side, a controller receivers the entire frame, and extracts the network layer datagram. If the link layer performs error detection , then it is the sending controller that sets the error detection bits in the frame header and it is the receiving controller that performs the error detection.

The figure below show a network adapter attaching to a host's bus (e.g. a PCI or PCI-X bus), where it looks much like any other I/O device to the other host components.



The above figure also shows that while most of the link layer is implemented in hardware, part of the link layer is implemented in software that runs on the host's CPU.

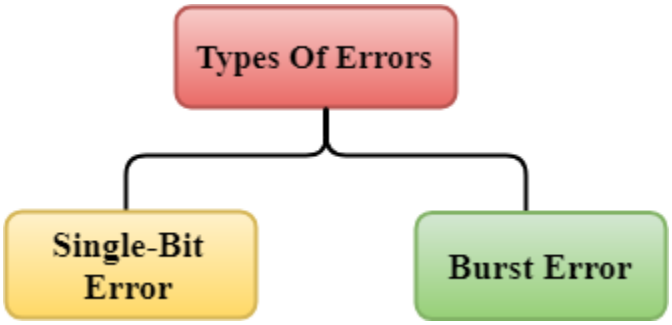
The software components of the link layer implement higher-level link layer functionality such as assembling link layer addressing information and activating the controller hardware.

On the receiving side, link layer software responds to controller interrupts (e.g. due to the receipt of one or more frames), handling error conditions and passing a datagram up to the network layer. Thus, the link layer is a combination of hardware and software – the place in the protocol stack where software meets hardware.

Error Detection

When data is transmitted from one device to another device, the system does not guarantee whether the data received by the device is identical to the data transmitted by another device. An Error is a situation when the message received at the receiver end is not identical to the message transmitted.

Types Of Errors

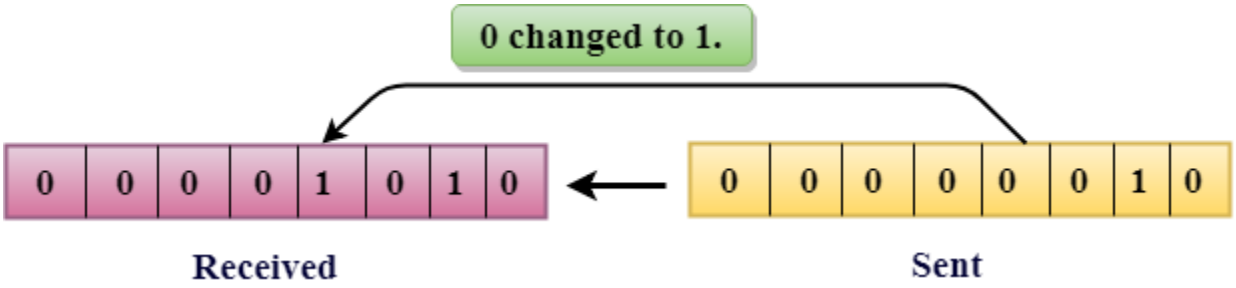


Errors can be classified into two categories:

- Single-Bit Error
- Burst Error

Single-Bit Error:

The only one bit of a given data unit is changed from 1 to 0 or from 0 to 1.



In the above figure, the message which is sent is corrupted as single-bit, i.e., 0 bit is changed to 1.

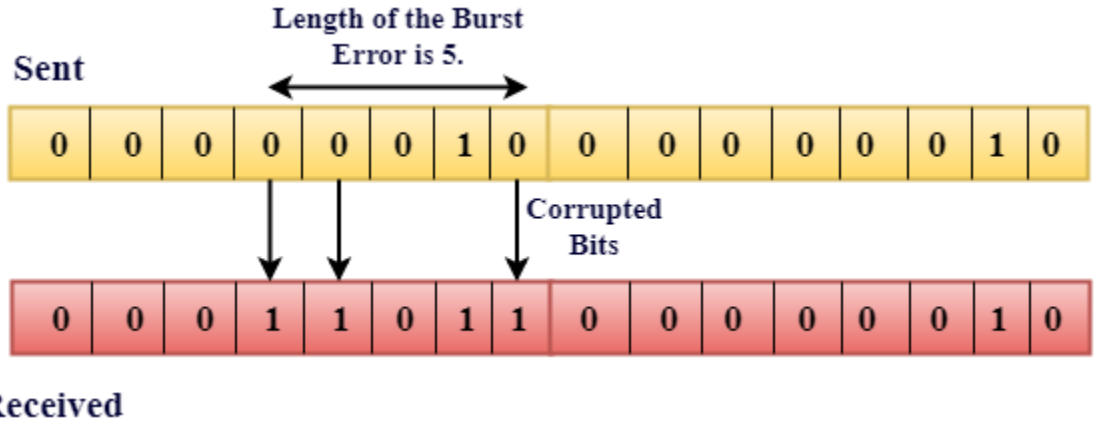
Single-Bit Error does not appear more likely in Serial Data Transmission. For example, Sender sends the data at 10 Mbps, this means that the bit lasts only for 1 ?s and for a single-bit error to occurred, a noise must be more than 1 ?s.

Single-Bit Error mainly occurs in Parallel Data Transmission. For example, if eight wires are used to send the eight bits of a byte, if one of the wire is noisy, then single-bit is corrupted per byte.

Burst Error:

The two or more bits are changed from 0 to 1 or from 1 to 0 is known as Burst Error.

The Burst Error is determined from the first corrupted bit to the last corrupted bit.



The duration of noise in Burst Error is more than the duration of noise in Single-Bit.

Burst Errors are most likely to occurr in Serial Data Transmission.

The number of affected bits depends on the duration of the noise and data rate.

Error Detecting Techniques:

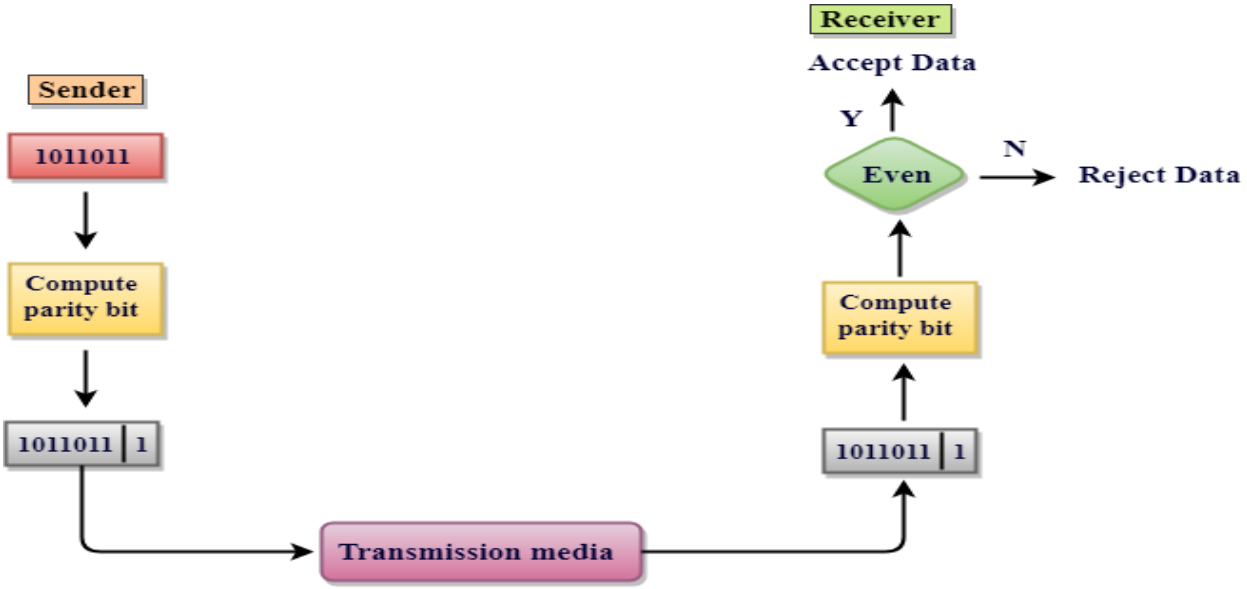
The most popular Error Detecting Techniques are:

- Single parity check
- Two-dimensional parity check
- Checksum
- Cyclic redundancy check

Single Parity Check

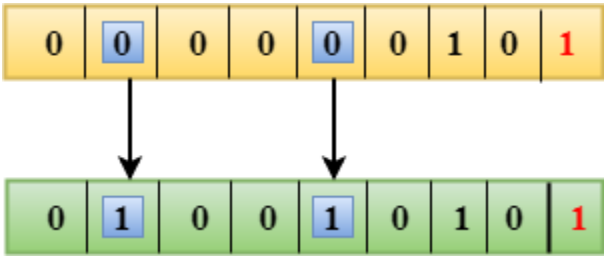
- Single Parity checking is the simple mechanism and inexpensive to detect the errors.
- In this technique, a redundant bit is also known as a parity bit which is appended at the end of the data unit so that the number of 1s becomes even. Therefore, the total number of transmitted bits would be 9 bits.
- If the number of 1s bits is odd, then parity bit 1 is appended and if the number of 1s bits is even, then parity bit 0 is appended at the end of the data unit.
- At the receiving end, the parity bit is calculated from the received data bits and compared with the received parity bit.

- This technique generates the total number of 1s even, so it is known as even-parity checking.



Drawbacks Of Single Parity Checking

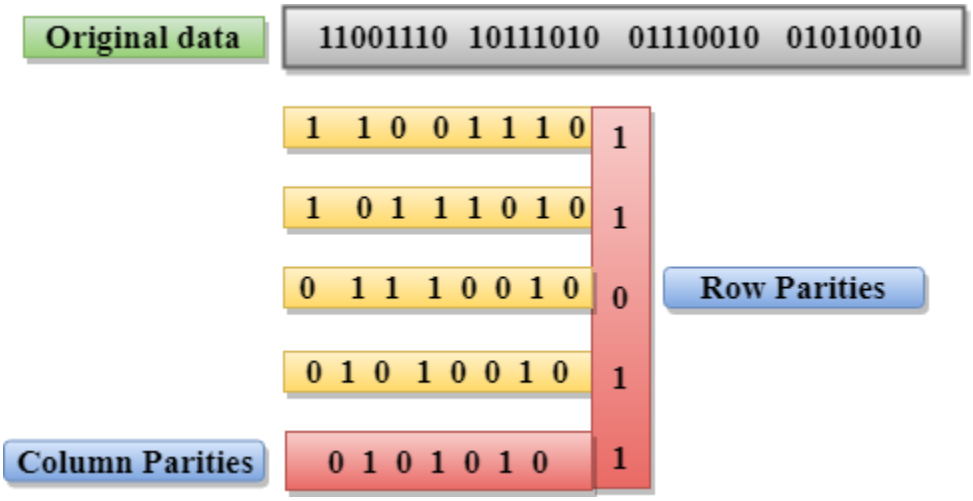
- It can only detect single-bit errors which are very rare.
- If two bits are interchanged, then it cannot detect the errors.



Two-Dimensional Parity Check

- Performance can be improved by using **Two-Dimensional Parity Check** which organizes the data in the form of a table.
- Parity check bits are computed for each row, which is equivalent to the single-parity check.
- In Two-Dimensional Parity check, a block of bits is divided into rows, and the redundant row of bits is added to the whole block.

- At the receiving end, the parity bits are compared with the parity bits computed from the received data.



Drawbacks Of 2D Parity Check

- If two bits in one data unit are corrupted and two bits exactly the same position in another data unit are also corrupted, then 2D Parity checker will not be able to detect the error.
- This technique cannot be used to detect the 4-bit errors or more in some cases.

Checksum

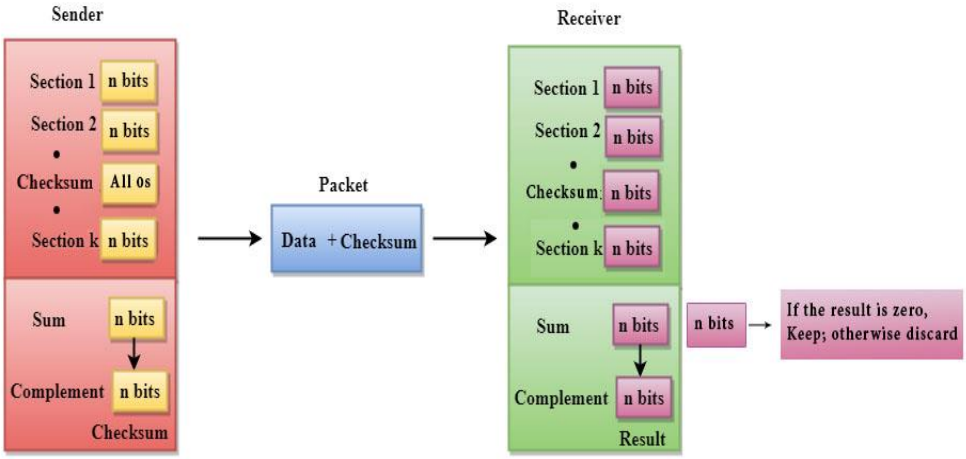
A Checksum is an error detection technique based on the concept of redundancy.

It is divided into two parts:

Checksum Generator

A Checksum is generated at the sending side. Checksum generator subdivides the data into equal segments of n bits each, and all these segments are added together by using one's complement arithmetic. The sum is complemented and appended to the original data, known as checksum field. The extended data is transmitted across the network.

Suppose L is the total sum of the data segments, then the checksum would be ?L



1. The Sender follows the given steps:
2. The block unit is divided into k sections, and each of n bits.
3. All the k sections are added together by using one's complement to get the sum.
4. The sum is complemented and it becomes the checksum field.
5. The original data and checksum field are sent across the network.

Checksum Checker

A Checksum is verified at the receiving side. The receiver subdivides the incoming data into equal segments of n bits each, and all these segments are added together, and then this sum is complemented. If the complement of the sum is zero, then the data is accepted otherwise data is rejected.

1. The Receiver follows the given steps:
2. The block unit is divided into k sections and each of n bits.
3. All the k sections are added together by using one's complement algorithm to get the su m.
4. The sum is complemented.
5. If the result of the sum is zero, then the data is accepted otherwise the data is discarded.

Cyclic Redundancy Check (CRC)

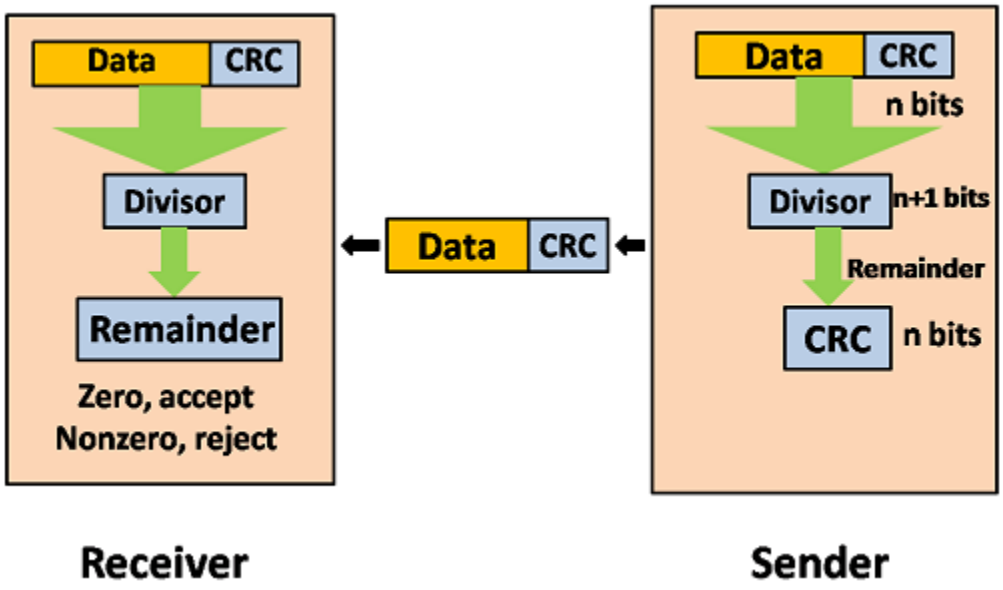
CRC is a redundancy error technique used to determine the error.

Following are the steps used in CRC for error detection:

- In CRC technique, a string of n 0s is appended to the data unit, and this n number is less than the number of bits in a predetermined number, known as division which is n+1 bits.
- Secondly, the newly extended data is divided by a divisor using a process is known as binary division. The remainder generated from this division is known as CRC remainder.
- Thirdly, the CRC remainder replaces the appended 0s at the end of the original data. This newly generated unit is sent to the receiver.
- The receiver receives the data followed by the CRC remainder. The receiver will treat this whole unit as a single unit, and it is divided by the same divisor that was used to find the CRC remainder.

If the resultant of this division is zero which means that it has no error, and the data is accepted.

If the resultant of this division is not zero which means that the data consists of an error. Therefore, the data is discarded.



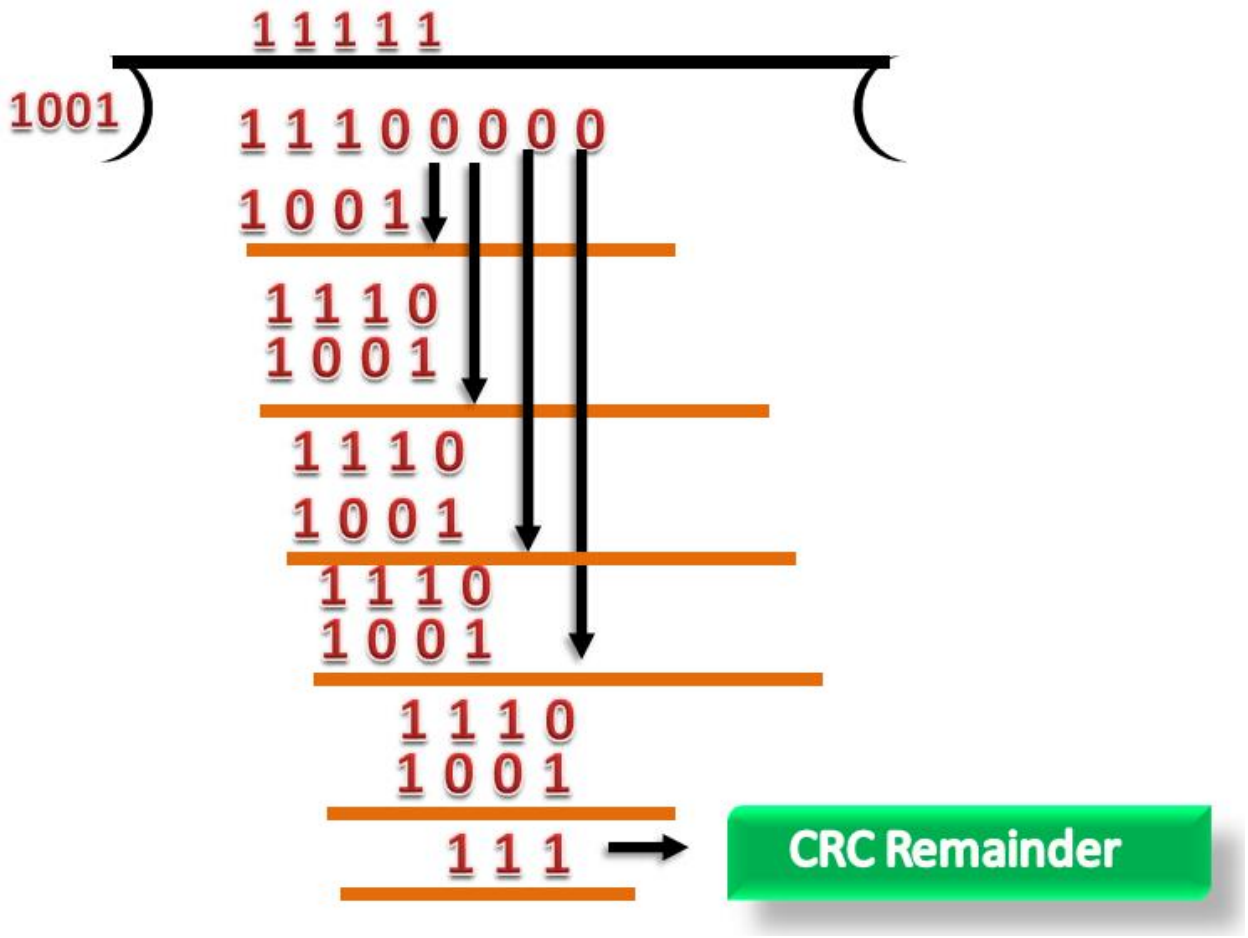
Let's understand this concept through an example:

Suppose the original data is 11100 and divisor is 1001.

CRC Generator

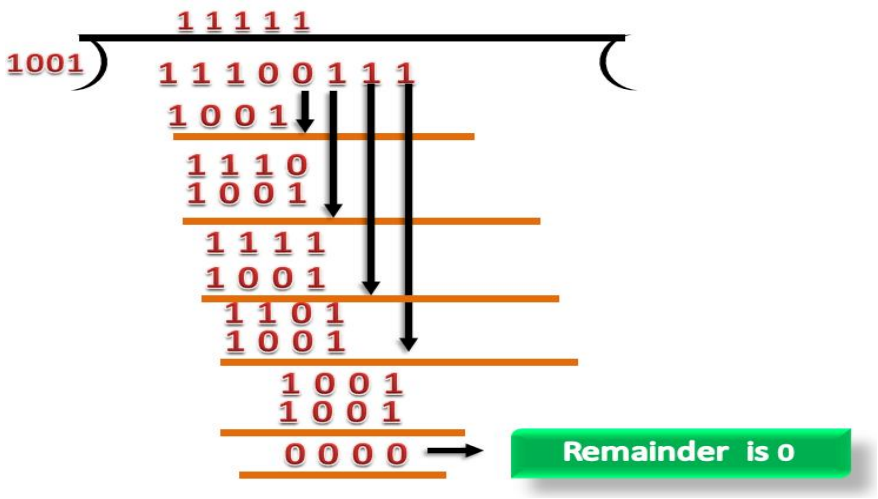
- A CRC generator uses a modulo-2 division. Firstly, three zeroes are appended at the end of the data as the length of the divisor is 4 and we know that the length of the string 0s to be appended is always one less than the length of the divisor.

- Now, the string becomes 11100000, and the resultant string is divided by the divisor 1001.
- The remainder generated from the binary division is known as CRC remainder. The generated value of the CRC remainder is 111.
- CRC remainder replaces the appended string of 0s at the end of the data unit, and the final string would be 11100111 which is sent across the network.



CRC Checker

- The functionality of the CRC checker is similar to the CRC generator.
- When the string 11100111 is received at the receiving end, then CRC checker performs the modulo-2 division.
- A string is divided by the same divisor, i.e., 1001.
- In this case, CRC checker generates the remainder of zero. Therefore, the data is accepted.



Multiple access protocol- ALOHA, CSMA, CSMA/CA and CSMA/CD

Data Link Layer

The data link layer is used in a computer network to transmit the data between two devices or nodes. It divides the layer into parts such as **data link control** and the **multiple access resolution/protocol**. The upper layer has the responsibility to flow control and the error control in the data link layer, and hence it is termed as **logical of data link control**. Whereas the lower sub-layer is used to handle and reduce the collision or multiple access on a channel. Hence it is termed as **media access control** or the multiple access resolutions.

Data Link Control

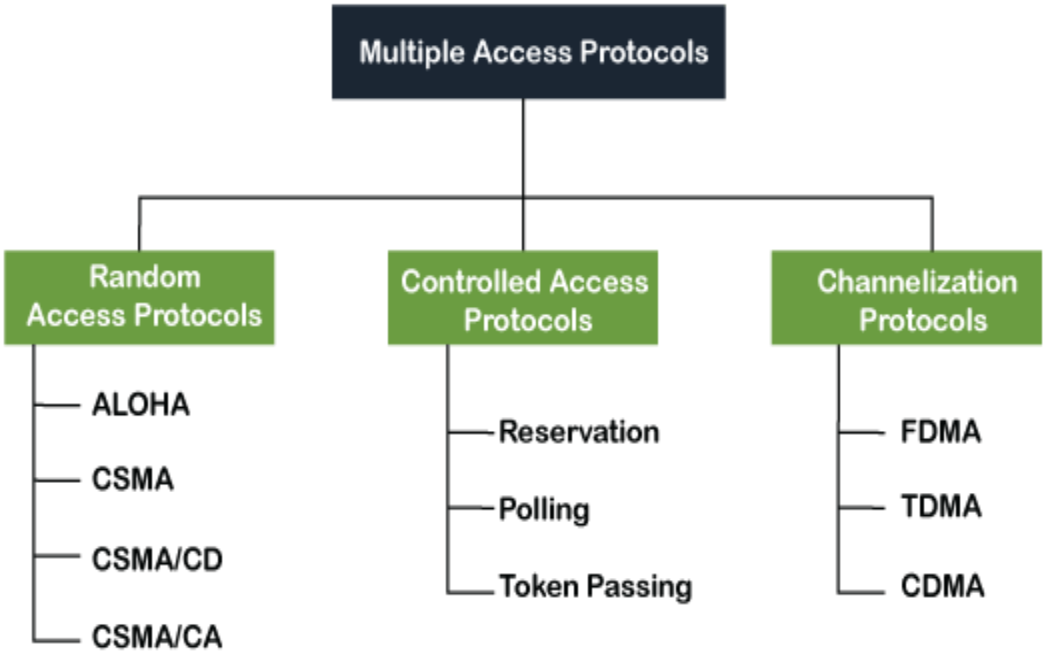
A data link control is a reliable channel for transmitting data over a dedicated link using various techniques such as framing, error control and flow control of data packets in the computer network.

What is a multiple access protocol?

When a sender and receiver have a dedicated link to transmit data packets, the data link control is enough to handle the channel. Suppose there is no dedicated path to communicate or transfer the data between two devices. In that case, multiple stations access the channel and simultaneously transmits the data over the channel. It may create collision and cross talk. Hence, the multiple access protocol is required to reduce the collision and avoid crosstalk between the channels.

For example, suppose that there is a classroom full of students. When a teacher asks a question, all the students (small channels) in the class start answering the question at the same time (transferring the data simultaneously). All the students respond at the same time due to which data is overlap or data lost. Therefore it is the responsibility of a teacher (multiple access protocol) to manage the students and make them one answer.

Following are the types of multiple access protocol that is subdivided into the different process as:



A. Random Access Protocol

In this protocol, all the station has the equal priority to send the data over a channel. In random access protocol, one or more stations cannot depend on another station nor any station control another station. Depending on the channel's state (idle or busy), each station transmits the data frame. However, if more than one station sends the data over a channel, there may be a collision or data conflict. Due to the collision, the data frame packets may be lost or changed. And hence, it does not receive by the receiver end.

Following are the different methods of random-access protocols for broadcasting frames on the channel.

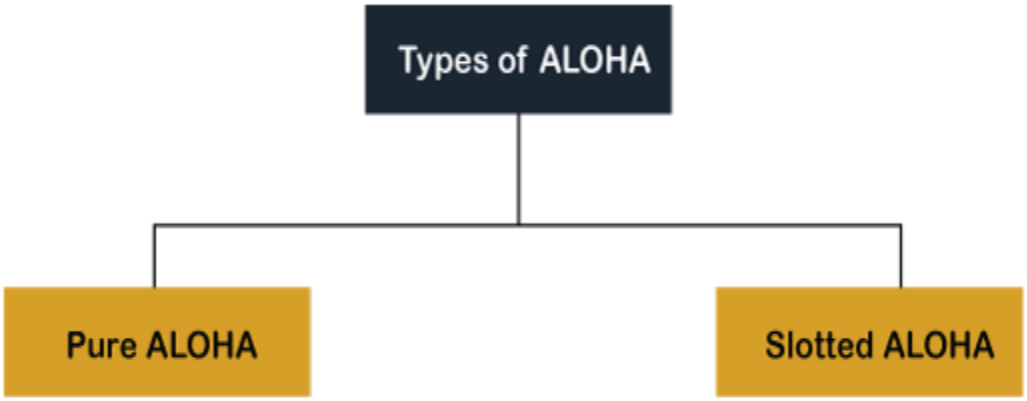
- Aloha
- CSMA
- CSMA/CD
- CSMA/CA

ALOHA Random Access Protocol

It is designed for wireless LAN (Local Area Network) but can also be used in a shared medium to transmit data. Using this method, any station can transmit data across a network simultaneously when a data frameset is available for transmission.

Aloha Rules

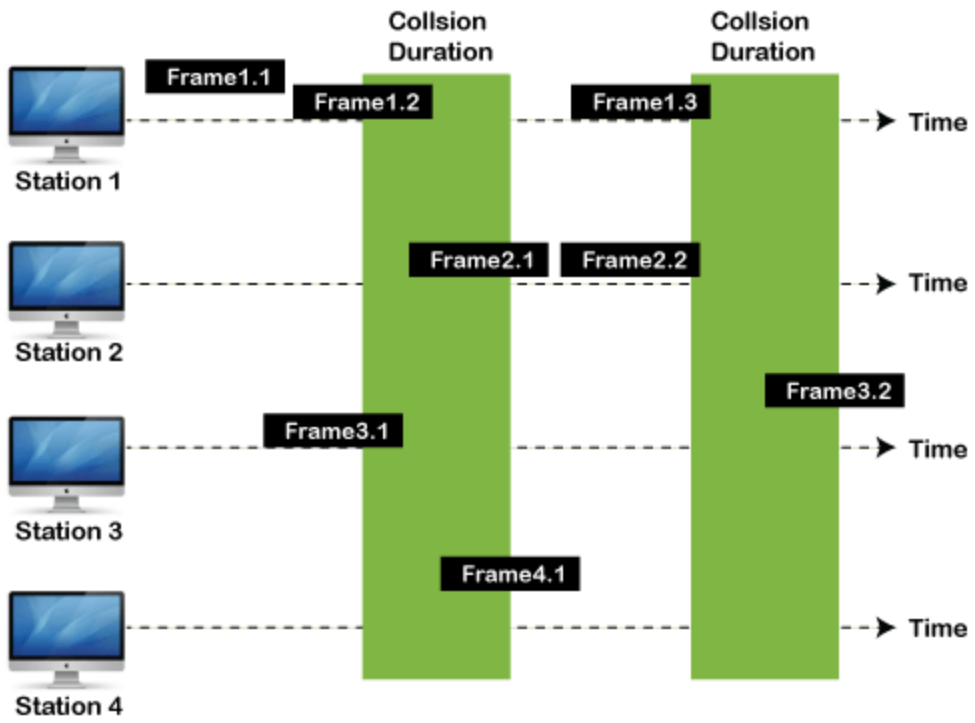
1. Any station can transmit data to a channel at any time.
2. It does not require any carrier sensing.
3. Collision and data frames may be lost during the transmission of data through multiple stations.
4. Acknowledgment of the frames exists in Aloha. Hence, there is no collision detection.
5. It requires retransmission of data after some random amount of time.



Pure Aloha

Whenever data is available for sending over a channel at stations, we use Pure Aloha. In pure Aloha, when each station transmits data to a channel without checking whether the channel is idle or not, the chances of collision may occur, and the data frame can be lost. When any station transmits the data frame to a channel, the pure Aloha waits for the receiver's acknowledgment. If it does not acknowledge the receiver end within the specified time, the station waits for a random amount of time, called the backoff time (Tb). And the station may assume the frame has been lost or destroyed. Therefore, it retransmits the frame until all the data are successfully transmitted to the receiver.

1. The total vulnerable time of pure Aloha is 2 * Tfr.
2. Maximum throughput occurs when G = 1/ 2 that is 18.4%.
3. Successful transmission of data frame is S = G * e ^ - 2 G.



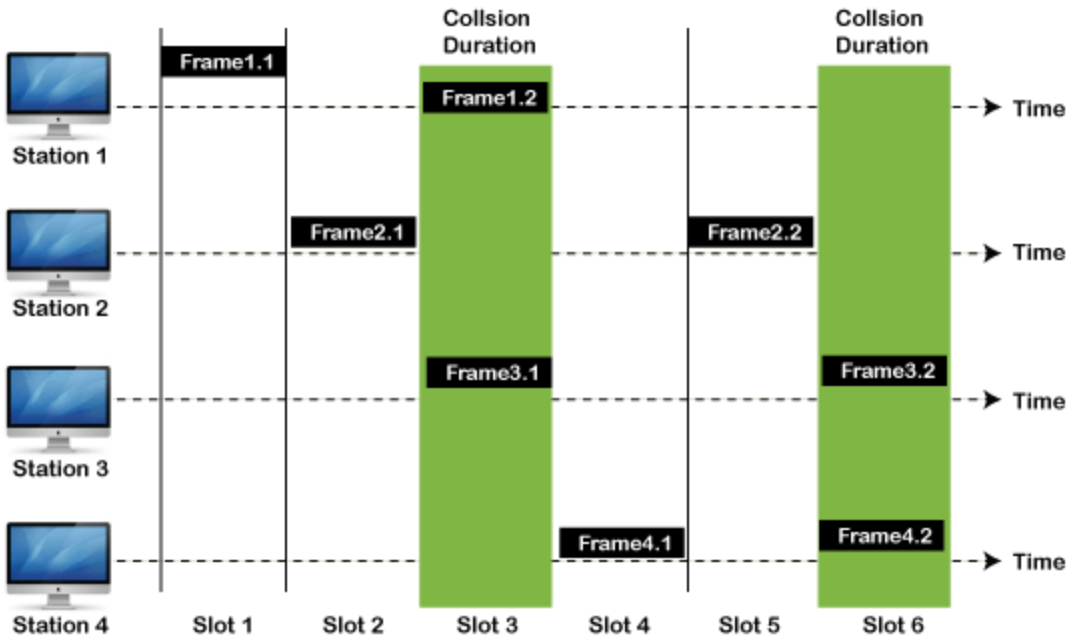
Frames in Pure ALOHA

As we can see in the figure above, there are four stations for accessing a shared channel and transmitting data frames. Some frames collide because most stations send their frames at the same time. Only two frames, frame 1.1 and frame 2.2, are successfully transmitted to the receiver end. At the same time, other frames are lost or destroyed. Whenever two frames fall on a shared channel simultaneously, collisions can occur, and both will suffer damage. If the new frame's first bit enters the channel before finishing the last bit of the second frame. Both frames are completely finished, and both stations must retransmit the data frame.

Slotted Aloha

The slotted Aloha is designed to overcome the pure Aloha's efficiency because pure Aloha has a very high possibility of frame hitting. In slotted Aloha, the shared channel is divided into a fixed time interval called **slots**. So that, if a station wants to send a frame to a shared channel, the frame can only be sent at the beginning of the slot, and only one frame is allowed to be sent to each slot. And if the stations are unable to send data to the beginning of the slot, the station will have to wait until the beginning of the slot for the next time. However, the possibility of a collision remains when trying to send a frame at the beginning of two or more station time slot.

1. Maximum throughput occurs in the slotted Aloha when G = 1 that is 37%.
2. The probability of successfully transmitting the data frame in the slotted Aloha is S = G * e ^ - 2 G.
3. The total vulnerable time required in slotted Aloha is Tfr.



Frames in Slotted ALOHA

CSMA (Carrier Sense Multiple Access)

It is a **carrier sense multiple access** based on media access protocol to sense the traffic on a channel (idle or busy) before transmitting the data. It means that if the channel is idle, the station can send data to the channel. Otherwise, it must wait until the channel becomes idle. Hence, it reduces the chances of a collision on a transmission medium.

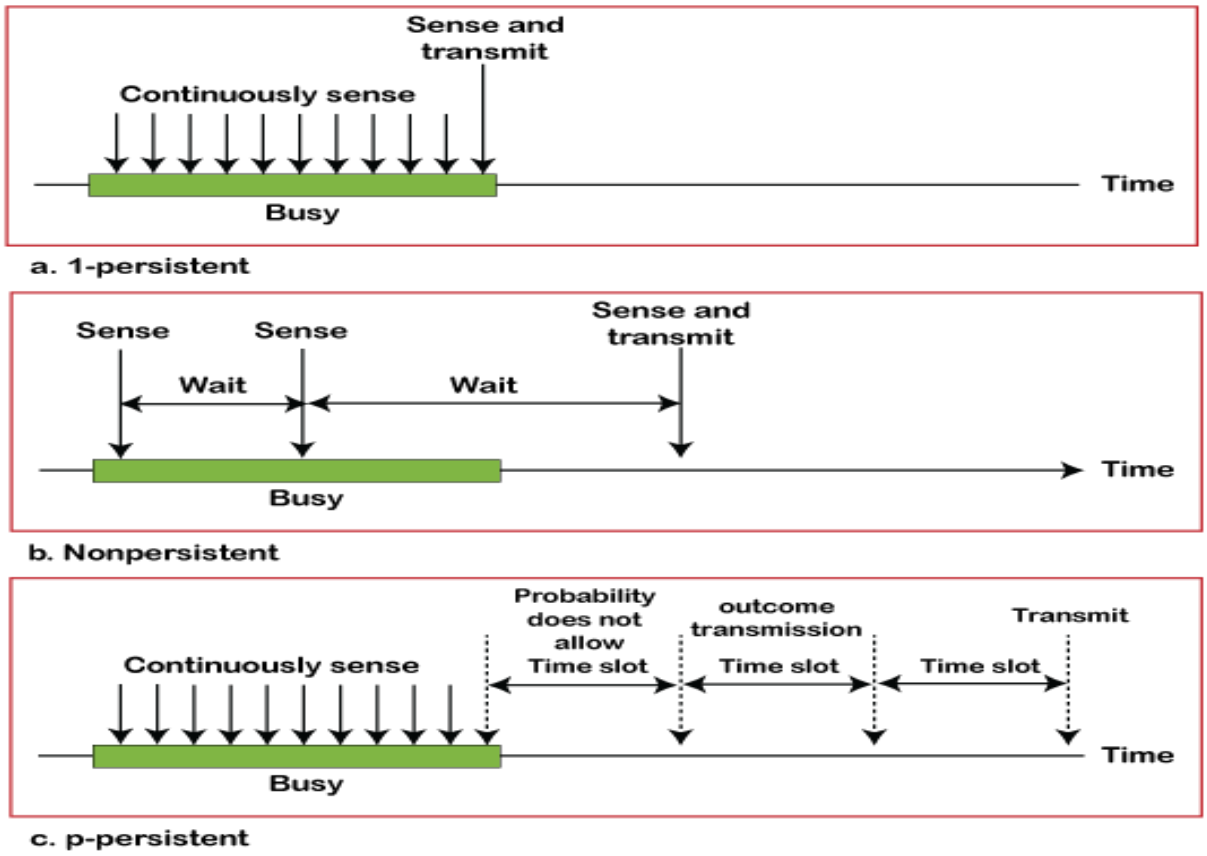
CSMA Access Modes

1-Persistent: In the 1-Persistent mode of CSMA that defines each node, first sense the shared channel and if the channel is idle, it immediately sends the data. Else it must wait and keep track of the status of the channel to be idle and broadcast the frame unconditionally as soon as the channel is idle.

Non-Persistent: It is the access mode of CSMA that defines before transmitting the data, each node must sense the channel, and if the channel is inactive, it immediately sends the data. Otherwise, the station must wait for a random time (not continuously), and when the channel is found to be idle, it transmits the frames.

P-Persistent: It is the combination of 1-Persistent and Non-persistent modes. The P-Persistent mode defines that each node senses the channel, and if the channel is inactive, it sends a frame with a **P** probability. If the data is not transmitted, it waits for a (**q = 1-p probability**) random time and resumes the frame with the next time slot.

O- Persistent: It is an O-persistent method that defines the superiority of the station before the transmission of the frame on the shared channel. If it is found that the channel is inactive, each station waits for its turn to retransmit the data.



CSMA/ CD

It is a **carrier sense multiple access/ collision detection** network protocol to transmit data frames. The CSMA/CD protocol works with a medium access control layer. Therefore, it first senses the shared channel before broadcasting the frames, and if the channel is idle, it transmits a frame to check whether the transmission was successful. If the frame is successfully received, the station sends another frame. If any collision is detected in the CSMA/CD, the station sends a jam/ stop signal to the shared channel to terminate data transmission. After that, it waits for a random time before sending a frame to a channel.

CSMA/ CA

It is a **carrier sense multiple access/collision avoidance** network protocol for carrier transmission of data frames. It is a protocol that works with a medium access control layer. When a data frame is sent to a channel, it receives an acknowledgment to check whether the channel is clear. If the station receives only a single (own) acknowledgments, that means the data frame has been successfully transmitted to the receiver. But if it gets two signals (its own and one more in which

the collision of frames), a collision of the frame occurs in the shared channel. Detects the collision of the frame when a sender receives an acknowledgment signal.

Following are the methods used in the CSMA/ CA to avoid the collision:

Interframe space: In this method, the station waits for the channel to become idle, and if it gets the channel is idle, it does not immediately send the data. Instead of this, it waits for some time, and this time period is called the **Interframe** space or IFS. However, the IFS time is often used to define the priority of the station.

Contention window: In the Contention window, the total time is divided into different slots. When the station/ sender is ready to transmit the data frame, it chooses a random slot number of slots as **wait time**. If the channel is still busy, it does not restart the entire process, except that it restarts the timer only to send data packets when the channel is inactive.

Acknowledgment: In the acknowledgment method, the sender station sends the data frame to the shared channel if the acknowledgment is not received ahead of time.

B. Controlled Access Protocol

It is a method of reducing data frame collision on a shared channel. In the controlled access method, each station interacts and decides to send a data frame by a particular station approved by all other stations. It means that a single station cannot send the data frames unless all other stations are not approved. It has three types of controlled access: **Reservation, Polling**, and **Token Passing**.

C. Channelization Protocols

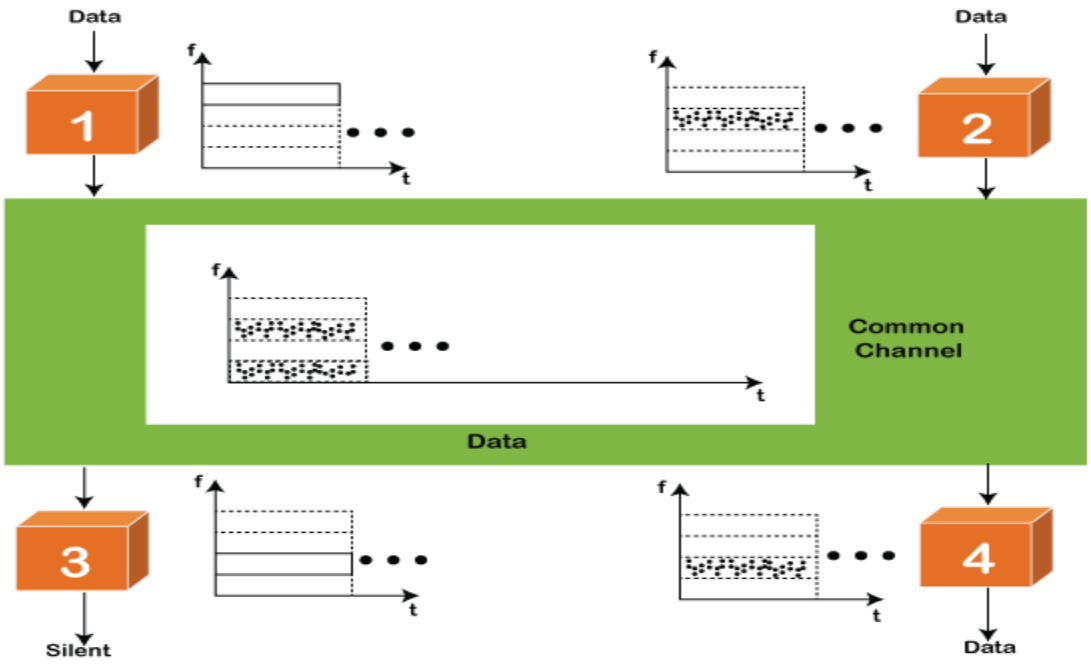
It is a channelization protocol that allows the total usable bandwidth in a shared channel to be shared across multiple stations based on their time, distance and codes. It can access all the stations at the same time to send the data frames to the channel.

Following are the various methods to access the channel based on their time, distance and codes:

1. FDMA (Frequency Division Multiple Access)
2. TDMA (Time Division Multiple Access)
3. CDMA (Code Division Multiple Access)

FDMA

It is a frequency division multiple access (**FDMA**) method used to divide the available bandwidth into equal bands so that multiple users can send data through a different frequency to the subchannel. Each station is reserved with a particular band to prevent the crosstalk between the channels and interferences of stations.



TDMA

Time Division Multiple Access (**TDMA**) is a channel access method. It allows the same frequency bandwidth to be shared across multiple stations. And to avoid collisions in the shared channel, it divides the channel into different frequency slots that allocate stations to transmit the data frames. The same **frequency** bandwidth into the shared channel by dividing the signal into various time slots to transmit it. However, TDMA has an overhead of synchronization that specifies each station's time slot by adding synchronization bits to each slot.

CDMA

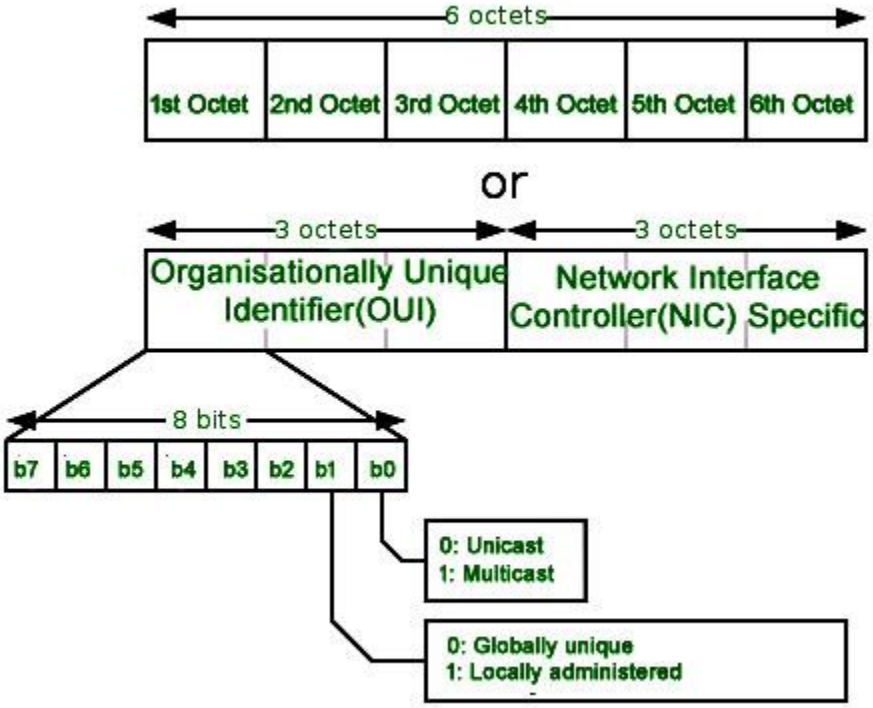
The code division multiple access (CDMA) is a channel access method. In CDMA, all stations can simultaneously send the data over the same channel. It means that it allows each station to transmit the data frames with full frequency on the shared channel at all times. It does not require the division of bandwidth on a shared channel based on time slots. If multiple stations send data to a channel simultaneously, their data frames are separated by a unique code sequence. Each station has a different unique code for transmitting the data over a shared channel. For example, there are multiple users in a room that are continuously speaking. Data is received by the users if only two-person interact with each other using the same language. Similarly, in the network, if different stations communicate with each other simultaneously with different code language.

Media Access Control (MAC) Address –

MAC Addresses are unique **48-bits** hardware number of a computer, which is embedded into a network card (known as a **Network Interface Card**) during the time of manufacturing. MAC Address is also known as the **Physical Address** of a network device. In IEEE 802 standard, Data Link Layer is divided into two sublayers –

1. Logical Link Control(LLC) Sublayer
2. Media Access Control(MAC) Sublayer

MAC address is used by the Media Access Control (MAC) sublayer of the Data-Link Layer. MAC Address is worldwide unique since millions of network devices exist and we need to uniquely identify each.



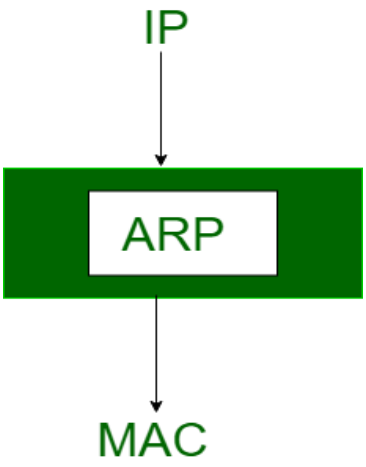
Characteristics of MAC address:

Media Access Control address (MAC address) is a unique identifier assigned to most network adapters or network interface cards (NICs) by the manufacturer for identification and used in the Media Access Control protocol sub-layer.
An Ethernet MAC address is a 48-bit binary value expressed as 12 hexadecimal digits (4 bits per hexadecimal digit). MAC addresses are in a flat structure and thus they are not routable on the Internet. Serial interfaces do not use MAC addresses. It does NOT contain a network and host portion with the address. It is used to deliver the frame to the destination device.

How Address Resolution Protocol (ARP) works?

Most of the computer programs/applications use **logical address (IP address)** to send/receive messages, however, the actual communication happens over the **physical address (MAC address)** i.e from layer 2 of the OSI model. So our mission is to get the destination MAC address which helps in communicating with other devices. This is where ARP comes into the picture, its

functionality is to translate IP address to physical addresses.



The acronym ARP stands for **Address Resolution Protocol** which is one of the most important protocols of the Network layer in the OSI model.
Note: ARP finds the hardware address, also known as Media Access Control (MAC) address, of a host from its known IP address.

Let's look at how ARP works.

Imagine a device that wants to communicate with the other over the internet. What ARP does? Does it broadcast a packet to all the devices of the source network.
The devices of the network peel the header of the data link layer from the **protocol data unit (PDU)** called frame and transfer the packet to the network layer (layer 3 of OSI) where the network ID of the packet is validated with the destination IP's network ID of the packet and if it's equal then it responds to the source with the MAC address of the destination, else the packet reaches the gateway of the network and broadcasts packet to the devices it is connected with and validates their network ID
The above process continues till the second last network device in the path reaches the destination where it gets validated and ARP, in turn, responds with the destination MAC address.

ARP: ARP stands for (**Address Resolution Protocol**). It is responsible to find the hardware address of a host from a known IP address. There are three basic **ARP** terms.
The important terms associated with **ARP** are:
(i) Reverse ARP

(ii) Proxy ARP

(iii) Inverse ARP

1. **ARP Cache:** After resolving the MAC address, the ARP sends it to the source where it is stored in a table for future reference. The subsequent communications can use the MAC address from the table
2. **ARP Cache Timeout:** It indicates the time for which the MAC address in the ARP cache can reside
3. **ARP request:** This is nothing but broadcasting a packet over the network to validate whether we came across the destination MAC address or not.
    1. The physical address of the sender.
    2. The IP address of the sender.
    3. The physical address of the receiver is FF:FF:FF:FF:FF:FF or 1's.
    4. The IP address of the receiver
4. **ARP response/reply:** It is the MAC address response that the source receives from the destination which aids in further communication of the data.

Ethernet at the Data-Link Layer

At the data link layer, Ethernet specifies what the data should look like, including the header and trailer. The protocol is defined by IEEE 802.3 and divides the data link layer into two sublayers: the Logical Link Control (LLC) sublayer and the Media Access Control (MAC) sublayer.

The MAC Sublayer

802.3 specifies a sublayer within Ethernet called the Ethernet Media Access Control sublayer. This acts as an interface between the physical layer and the higher-level services of a network interface.

Ethernet Frame vs Ethernet Packet

Technically 802.3 defines both a Media Access Control (MAC) frame and a MAC packet.

An Ethernet MAC frame includes a destination address, source address, length/type, payload plus padding and finally a frame check sequence (FCS).

An Ethernet MAC Packet encapsulates the MAC frame, adding a preamble and a 'start of frame' delimiter.

Most texts (and engineers) will use 'frame' or 'Ethernet frame' to refer to the complete 'Ethernet Packet' from the preamble to the FCS. When people refer to a packet, they will almost always be referring to an IP packet at the internet layer.

The most common form of an Ethernet PDU is summarised below.

Ethernet Shared Media compared to Point to Point links

Historically, LANs could use 'shared media' which meant that layer 2 devices called hubs were used to connect devices on the network. Hubs simply repeated the signals received on one port out of all the other ports which meant that the total bandwidth was *shared* across the whole network. This means that if different devices transmit data at the same time, the electrical signals may 'collide'.

Modern networks use switches at layer two. Switches are more advanced than hubs and treat each port as a separate, *point to point* link. This means that bandwidth is no longer shared across the whole LAN. Therefore the switch acts as a boundary to prevent collisions from happening across the network.

Ethernet Fields

Ethernet Header

Preamble

Length: 7 bytes (56 bits)

The Ethernet Preamble is a series of alternating ‘1s’ and ‘0s’ which enables a receiver to synchronise with the transmitter.

Start of Frame Delimiter

Length: 1 byte (8 bits)

The start of frame delimiter indicates to the receiver the end of the preamble and therefore the beginning of the other Ethernet header content.

Destination Address

The MAC address of the intended recipient, or recipients of the frame.

Source Address

The MAC address of the sender.

Type / Length

In modern networks, this field is used for the EtherType which indicates what type of data is encapsulated. For example, a value of 0x0800 would mean that the frame encapsulates IP data. The IEEE maintains the official registry of available EtherTypes.

Ethernet Payload / Layer 3 Data / Client Data

Payload

Data from a higher layer which is being encapsulated. This is most often an IPv4 or IPv6 packet. To fit in a typical frame, the maximum length of the packet is 1500 bytes. Therefore, we say that the layer 3 Maximum Transmission Unit (MTU) is 1500 bytes for Ethernet.

Padding

Because the minimum length of a payload is 46 bytes, if the payload is less than that then padding is added.

Ethernet Trailer

Frame Check Sequence (FCS)

The Ethernet FCS is a cyclic redundancy check which allows the recipient to check whether the data has been corrupted.

Ethernet Addresses

Ethernet frames include a source and a destination Media Access Control (MAC) address. Generally, each interface on a network will have a MAC address – whether it's a port on a switch, a network interface card (NIC) in a computer or a WiFi chip in a phone. There are also special addresses for sending frames to multiple recipients.

All MAC addresses are 48 bits (6 bytes) long and are typically represented using hexadecimal (hex) notation. If the first bit of the destination address is 0, the address is a unicast address which means that it is intended for a single recipient. If the first bit is 1 then the address indicates a group address.

Unicast MAC Addresses

Messages being sent to a single device use a unicast or individual address. It is important that each device on a network has a unique Ethernet address so that frames get sent to the correct device. To ensure this, all ethernet hardware is assigned a globally unique MAC address for each interface by the manufacturer.

Consequently, MAC addresses are also called burned-in addresses (BIA).

Some operating systems, or software make it possible to alter the MAC address of a given interface. This can be done for privacy reasons, network requirements (for example, networking with virtual machines) or for more nefarious purposes.

Unicast addresses are formed of two equal parts: an Organizationally Unique Identifier for the manufacturer and an interface specific identifier.

Organizationally Unique Identifier (OUI)

Length: 24 bits (3 bytes)

Every vendor of Ethernet equipment should have their own unique OUI which has been assigned by the IEEE.

Vendor Assigned, Interface Specific Identifier

Length: 24 bits (3 bytes)

The vendor is responsible for assigning the last 24 bits which should an identifier unique to that manufacturer so that no two devices have the same address.

Group Addresses

Other MAC addresses may be associated with none or more devices on a network.

Multicast MAC Addresses

Multicast addresses may be used to send messages to a specific group of devices on a network. The details of operation must be configured at a higher layer. For example, the Cisco Discovery Protocol (CDP) uses multicast addresses.

Broadcast Addresses

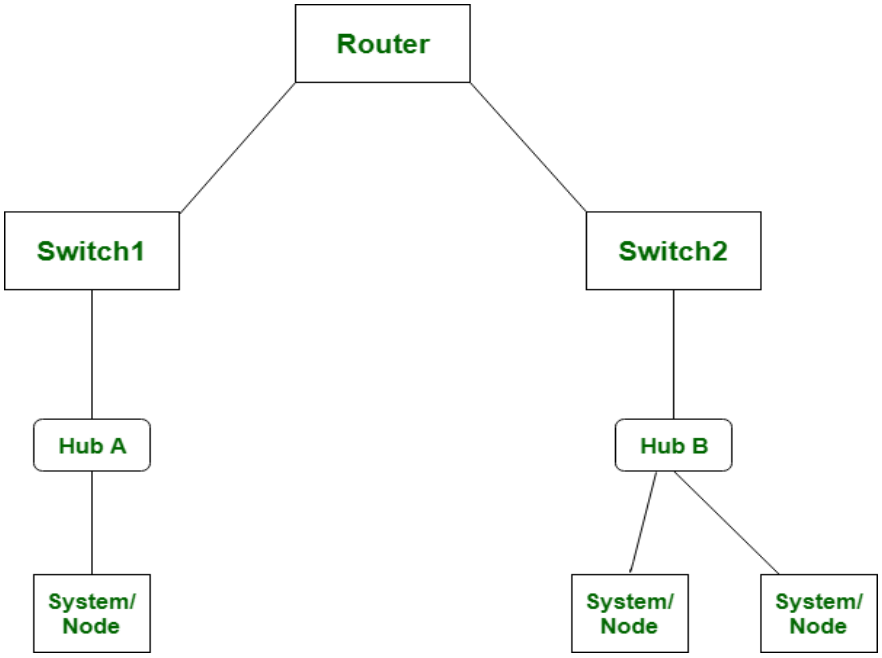
The broadcast address is used to send a frame to all devices on the local area network. The broadcast address has all bits set to '1' which is FF:FF:FF:FF:FF:FF in hex.

Difference between Router and Switch

Both **Router** and **Switch** are the connecting devices in networking. A router is employed to settle on the littlest path for a packet to achieve its destination.

Prerequisite -

The main objective of router is to connect various networks simultaneously and it works in the network layer, whereas the main objective of switch is to connect various devices simultaneously and it works in the data link layer.



Let us see the difference between router and switch:

Router	Switch
The main objective of router is to connect various networks simultaneously.	While the main objective of switch is to connect various devices simultaneously.
It works in network layer.	While it works in data link layer.
Router is used by LAN as well as MAN.	While switch is used by only LAN.
Through the router, data is sent in the form of packets.	While through switch data is sent in the form of frame.
There is less collision taking place in the router.	While there is no collision taking place in full duplex switch.
Router is compatible with NAT.	While it is not compatible with NAT.
The types of routing are: Adaptive and Non-adaptive routing.	The types of switching are: Circuit, Packet, and Message Switching.

Virtual LAN (VLAN)

Virtual LAN (VLAN) is a concept in which we can divide the devices logically on layer 2 (data link layer). Generally, layer 3 devices divide broadcast domain but broadcast domain can be divided by switches using the concept of VLAN.

A broadcast domain is a network segment in which if a device broadcast a packet then all the devices in the same broadcast domain will receive it. The devices in the same broadcast domain will receive all the broadcast packets but it is limited to switches only as routers don't forward out the broadcast packet. To forward out the packets to different VLAN (from one VLAN to another) or broadcast domain, inter Vlan routing is needed. Through VLAN, different small-size sub-networks are created which are comparatively easy to handle.

Types of connections in VLAN –
There are three ways to connect devices on a VLAN, the type of connections are based on the connected devices i.e. whether they are VLAN-aware(A device that understands VLAN formats and VLAN membership) or VLAN-unaware(A device that doesn't understand VLAN format and VLAN membership).

1. **Trunk Link –**
   All connected devices to a trunk link must be VLAN-aware. All frames on this should have a special header attached to it called tagged frames.
2. **Access link –**
   It connects VLAN-unaware devices to a VLAN-aware bridge. All frames on the access link must be untagged.
3. **Hybrid link –**
   It is a combination of the Trunk link and Access link. Here both VLAN-unaware and VLAN-aware devices are attached and it can have both tagged and untagged frames.

Advantages –

- **Performance –**
  The network traffic is full of broadcast and multicast. VLAN reduces the need to send such traffic to unnecessary destinations. e.g.-If the traffic is intended for 2 users but as 10 devices are present in the same broadcast domain, therefore, all will receive the traffic i.e. wastage of bandwidth but if we make VLANs, then the broadcast or multicast packet will go to the intended users only.
- **Formation of virtual groups –**
  As there are different departments in every organization namely sales, finance etc., VLANs can be very useful in order to group the devices logically according to their departments.
- **Security –**
  In the same network, sensitive data can be broadcast which can be accessed by the outsider but by creating VLAN, we can control broadcast domains, set up firewalls, restrict access. Also, VLANs can be used to inform the network manager of an intrusion. Hence, VLANs greatly enhance network security.
- **Flexibility –**
  VLAN provide flexibility to add, remove the number of host we want.

- **Cost reduction –**
  VLANs can be used to create broadcast domains which eliminate the need for expensive routers.
  By using Vlan, the number of small size broadcast domain can be increased which are easy to handle as compared to a bigger broadcast domain.