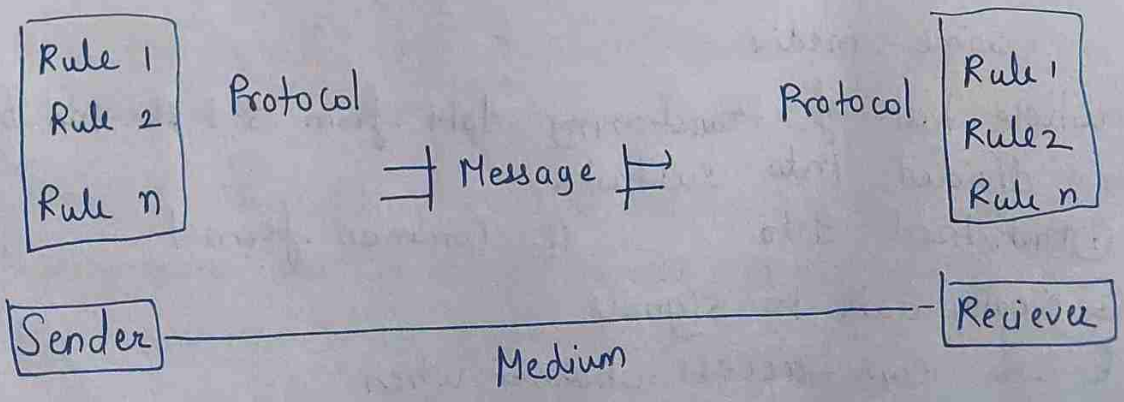
Introduction:

- Data communication are the exchange of data between two devices via some form of transmission media
- For data communication to occur, the communicating devices must be a part of communication system made up of a combination of hardware and software
- The effectiveness of data communication system depends on four fundamental characteristics
  1. delivery - Must deliver to the correct destination
  2. Accuracy : deliver the data accurately
  3. Timeliness - deliver data in a timely manner. Data deliver late are useless
  4. Jitter : Jitter refers to the variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets.

     Example: let us assume that video packets are sent every 30 ms. If some of the packets arrive with 30-ms delay and others with 40-ms delay, an uneven quality in the video is the result

- A data communication system has five components



Message: The message is the information (data) to be communicated

Sender: The sender is the device that sends the data message

Reciever: The reciever is the device that recieves the message

Transmission media: The transmission medium is the physical path by which a message travels from sender to reciever
(Twisted pair wire, coaxial cable)

Protocol: A protol is a set of rules that govern data communication. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating

Importance

- H/W cost decreases - more and more computer was installed in different part of the world
- Need was to transfer data between them
- Tape devices, floppy disks were used but not efficient
- So there was need to ~~instatted~~ transfer data through some media
- whole task of transferring data from S to R can be divided into subtasks

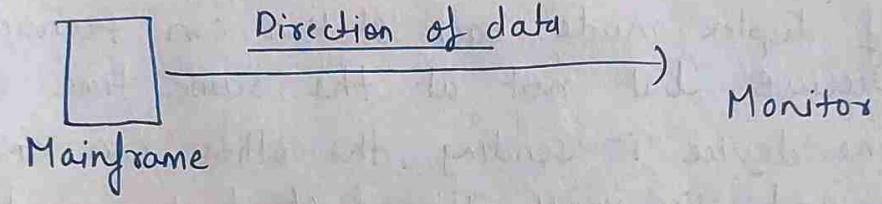
① Packetized data ② Common format
② Binary data to signals
③ who can access channel when

- Hence we need a network model which can handle all the issues related to data transfer
- Network model has layers which can perform few subtasks
  - ⊙ OSI
  - ⊙ IP / TCP

Modes of transmission

Communication between two devices can be simplex, half duplex or full duplex

① Simplex



In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit, the other can only recieve. The simplex mode can use the entire capacity of the channel to send data in one direction

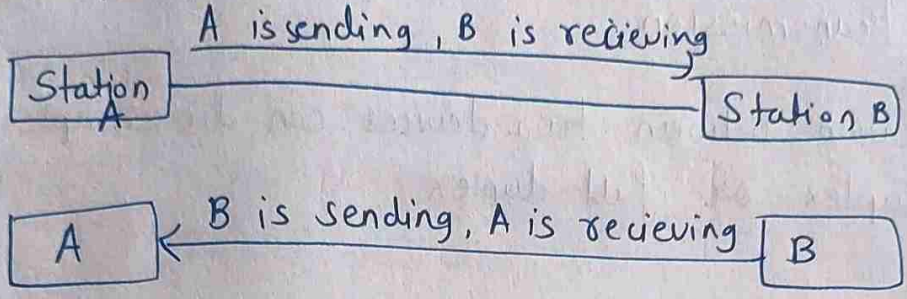
Advantages

- Simplex mode is the easiest and most reliable mode of communication
- It is the most cost effective mode, as it only requires one communication ~~model~~ channel
- There is no need for co-ordination between the transmitting and recieving devices, which simplifies the communication process

Disdvantages

- Only one way communication is possible
- There is no way to verify if the transmitted data has been recieved correctly

2) Half Duplex Mode



In half duplex mode each station can transmit and recieve, but not at the same time

When one device is sending, the other can only recieve and vice versa. The half duplex mode is used in cases where there is no need for communication in both directions at the same time.

The entire capacity of the channel can be utilized for each direction

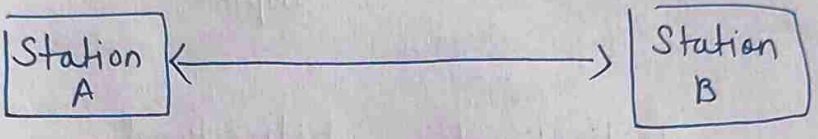
Advantages

- Half duplex mode allows for bidirectional communication, which is useful in situations where devices need to send and recieve data
- It is more efficient than simplex mode, as the channel can be used for both transmission and reception
- Half duplex is less expensive than full duplex mode, as it only requires one communication channel

Disadvantages

- Half duplex mode is less reliable than full duplex mode as both devices cannot transmit at the same time
- There is a delay between transmission and reception, which can cause problems in some application
- There is a need for co-ordination between the transmitting and recieving devices, which can complicate the communication process

Full duplex mode



In full duplex mode, both station can transmit and recieve simultaneously. Full duplex mode is used when the communication in both direction is required all the time. The capacity of channel must be divided between the two direction

Channel capacity = 2 * bandwidth x propogation delay

Advantages:

- Full duplex mode allows for simultaneous bidirectional communication, which is ideal for real time application such as video conferencing or online gaming.
- It is the most efficient mode of communication, as both devices can transmit and recieve data simultaneously
- Full duplex mode provides a high level of reliability and accuracy, as there is no need for error correction mechanisms

Disadvantages

- Most expensive mode, as it requires two communication channels.
- It is more complex than simplex and half-duplex modes
- Full duplex may not be suitable for all applications, as it requires a high level of bandwidth.

* Difference

Parameters	Simplex	Half duplex	Full duplex
Direction of communication	Unidirectional	bidirectional but one at a time	bidirectional communication simultaneously
Sender and Reciever	Sender can send but that sender can't recieve data	Sender can send and also recieve the data but one at a time	Sender can send the data and also recieve the data simult.
Channel usage	Usage of one channel for transmission of data	one channel	two channel
Performance	provides less performance than half & full duplex	provides less performance than full duplex	provides better performance than half and simple duplex

Bandwidth utilization	utilizes the maximum of a single bandwidth	lesser utilization of single bandwidth at the time of transmission	doubles the utilization of transmission bandwidth
Suitable for	Suitable for those transmission when there is requirement of full bandwidth for delivering data	sending data in both directions, but not at the same time	sending and recieving data simultaneously in both directions
Examples	keyboard and monitor	Walkie-Talkies	Telephone

Data transmission Concepts

Bandwidth: maximum rate at which data transfer occurs across any particular path of the network.

It is basically a measure of the amount of data that can be sent and recieved at any instance of time

Difference b/w range of frequencies

Data rate: It is defined as the amount of data transmitted during a specified period over a network

It is the speed at which data is transferred from one device to another or between a peripheral device and the computer

Speed of data transmission

Latency : It is the time ~~interval~~ needed when you have given input to the system and the total time period it takes to give output ~~to~~

Protocols And Standards

A protocol is a set of rules that govern data communication. A protocol defines what is communicated, how it is communicated and when it is communicated. The Key elements of protocol are

① Syntax : The term syntax refers to the structure or format of the data, meaning the order in which they are directed

② Semantics : refers to the meaning of each section of bits

③ Timing : refers to two characteristics
(i) when data should be sent and how fast they can be sent

* Standards are essential in creating and maintaining an open and competetive market for equipment manufacturers

Standards provides guidelines to manufacturers, vendors, government agencies

Data communication standard fall into two categories

① De facto (by fact):
Standards that have not been approved by an organized body but have been adopted as

Standards through widespread use are de facto standards

② De jure (by law)

Those standards that have been legislated by an officially recognized body are de jure standards

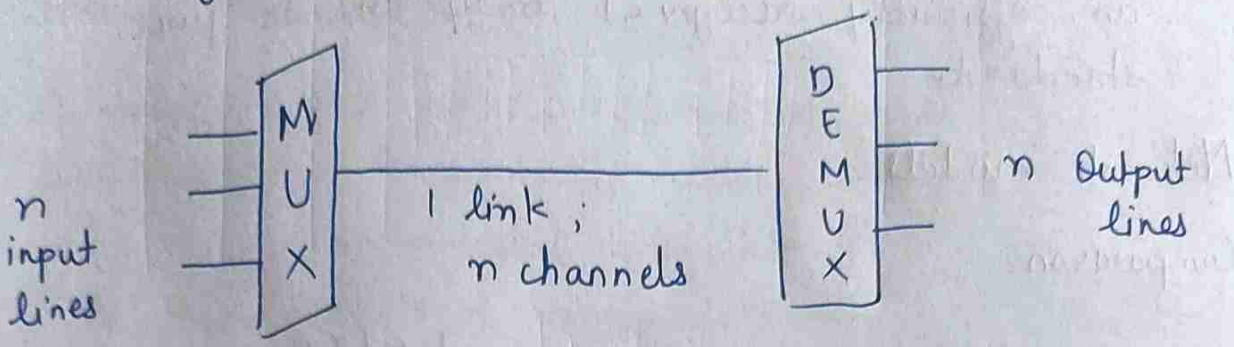
Network models

Comparison

	OSI	TCP/IP
1.	7 layers	4 layers
2.	Model was first defined befor implementation of takes	Model defined after protocol were implemented
3.	OSI model based on three concept i.e service, interface and protocol	TCP/IP did not originally distinguish b/w service, interface and protocol.
4.	OSI model gives guarantee of reliable delivery of packet	does not always guarantee the reliable delivery of packet
5.	OSI does not support internet working	TCP/IP support
6.	Steict layering	loosely layered.
7	Support connectionless and connection-oriented communication in network layer	Support only connection-oriented communication in transport layer

Multiplexing

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link



Types

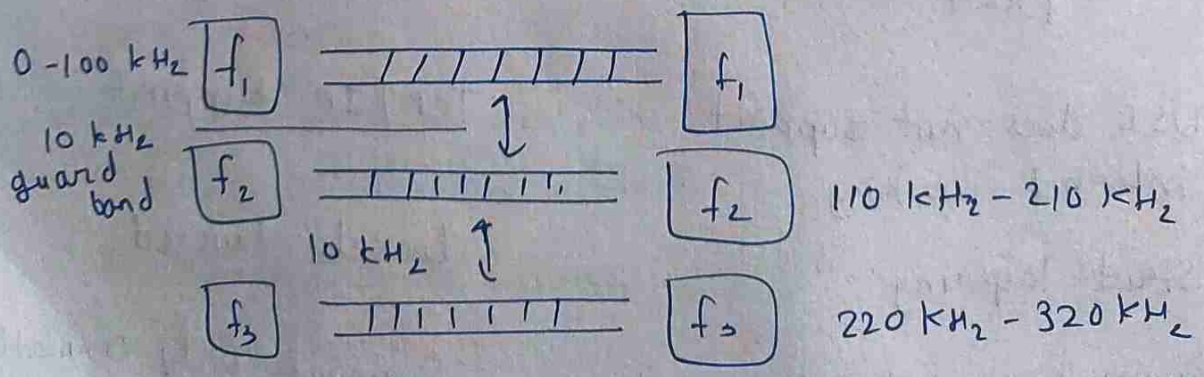
- Frequency [FDM) division multiplexing (Analog)
- Wavelength (WDM) Division multiplexing (Analog)
- Time (TDM) Division multiplexing (Digital)

* Multiplexing is done at physical layer

① FDM

Link is divided on the basis of frequency

It is used to transmit analog signals

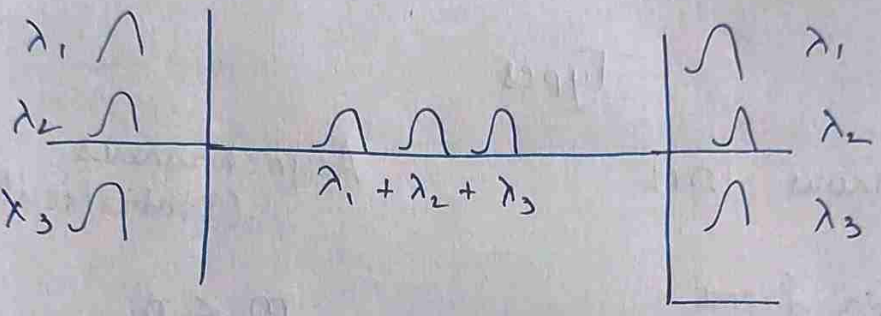


WDM

WDM is same as FDM, except that the multiplexing and demultiplexing involve optical signals transmitted through fibre optic channels

It is ~~used to~~ designed to use the high-data rate capability of fibre-optic cable

Prisms are used here



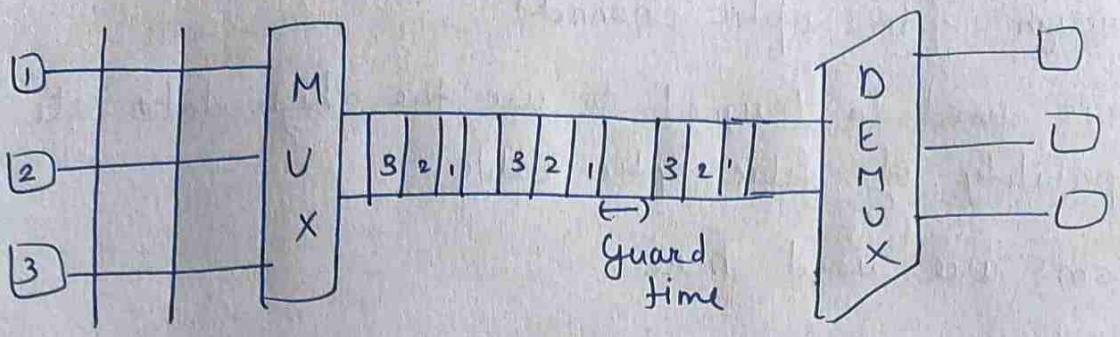
WDM is an analog multiplexing technique to combine optical signals

TDM

- In TDM technique channel is decided on the basis of time i.e for particular time period station is allowed to used entire bandwidth of link
- It is used for digital signals
- 2 Assumption
  1. Each station transmit data at same data rate say 'x'
  2. Data flow of each connection is divided into fix and equal size parts called data unit

Data unit can be one bit or byte or group of characters

Data is transmitted in the form of frames via link. Each frame is made of 'm' slots and each slot carry one data unit.



Types

Synchronous TDM

(m) No. of slots in frame = no. of stations (n)

$m = n$

If station doesn't want to send data then its corresponding slots will be empty

Asynchronous (Statistical TDM)

$m < n$

If at any instant of time more than 'm' stations want to send data than we have backlogs

Time needed to send data unit by sender is transmission time

$$T.T = \frac{\text{size of data unit}}{\text{B.W of link}}$$

T_p - propogation time

1 st bit of data unit need T_p time to reach reciever

Entire data unit reach recievers in $T_p + TT$ time

Cycle time is $T_p + TT$

Useful time is $T.T$

$$\eta = T.T \,/\, T_p + T_T$$

Error detection

Parity check

- parity is extra bit
  1. even parity
     if no. of 1's are even
  2. odd parity
     if number of ones are odd

Example:

(i) Even parity

1010111_ (no. of one's are 5 so add one)

10101111

(ii) Odd parity

(a) 1010111_

10101110

(b) 1010

10101

CRC:

Given a data word of length 'n'

Divisor of length 'k'

Append 'k-1' 0's after D.W

C.W = DW appended by Reminder

```
10011 | 11010110110000
        10011
        -----
        01001
         10011
         -----
         00010
           10011
           -----
           00100
             10011
             -----
             00111
```

11010110111110

Polynomial eqn

$x^4 + x + 1 \quad - \quad x^4 + 0x^3 + 0x^2 + x^1 + 1$

bit = 10011

A bit string 10011101 is transmitted using standard CRC method and the polynomial is $x^3 + 1$

$x^3 + 1$

$1x^3 + 0x^2 + 0x^1 + x^0 = 1001$

Sender side

```
1001 | 10011101000
       1001
       ----
       00001101
          1001
          ----
          01000
           1001
           ----
            100
```

Actual

10011101100

Reciever side

```
1001 | 10011101100
       1001
       ----
        1101
        1001
        ----
         1001
         1001
         ----
          000
```

As remainder is all zero.
Data recieved has no error

D·W 100100
Key - 1101

Sender side

```
1101 | 100100 000
       1101
       ----
        1000
        1101
        ----
         1010
         1101
         ----
          0111 0
           1101
           ----
            1100
            1101
            ----
             001
```

Reciever side

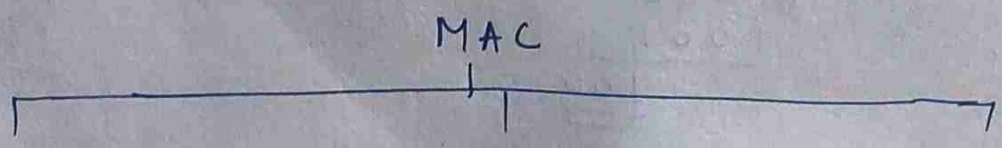
```
1101 | 100100001
       1101
       ----
        1000
        1101
        ----
         1010
         1101
         ----
          1110
          1101
          ----
           1101
           1101
           ----
            0000
```

Remainder is 000
∴ No error

* if divisor is of n bit then remainder should be of n-1 bit

MAC (Media/Multiple Access protocol)

Data link protocol → { LLC, MAC }



Random Access Protocols	Control Access	Channelization Access
Aloha	• Polling	FDMA
CSMA	• Token passing	TDMA
CSMA/CD	• Reservation	CDMA
CSMA/CA		

If there is a dedicated link between the sender and the reciever then data link control layer is sufficient, however it there is no dedicated link present then multiple stations can access the channel simultaneously

Hence multiple access protocols are required to decrease collision and avoid crosstalk

① Random Access protocol

- In this, each station has the right to the medium without being controlled by any other reason
- If more than one station tries to send, there is an access conflict (COLLISION) and the frames will be either destroyed or modified

① ALOHA: A simple and unco-ordinated protocol where devices send data whenever they have data to transmit. If a collision occurs they wait a random amount of time before retransmitting

② Carrier Sense Multiple Access (CSMA)
Device sense the channel before transmitting.
If channel is busy, they wait until it's free to transmit.

③ CSMA/CD (Collision detection)
If collision occurs, the device stop transmitting and retires after a random delay

④ CSMA/CA (Collision Avoidance)
tries to avoid them by sending a warning before actual data transmission

② Control Access Protocols

- Regulates access to a shared communication medium ensuring that multiple users or devices can transmit data efficiently and without interference.

① Polling: A central controller asks each device ~~tot~~ one by one if they need to send data. Devices only transmit when polled.

② Token passing: A token circulates between device in a network. Only the device that holds the token can transmit, preventing ~~o~~ collisions

③ Channelized Access Protocol

Divides the communication medium into distinct channels, allowing multiple users or devices to communicate simultaneously without interference.

① FDMA: frequency division multiple access:

Divided into separate frequency bands and each device is assigned a unique frequency for transmission.

② TDMA [Time

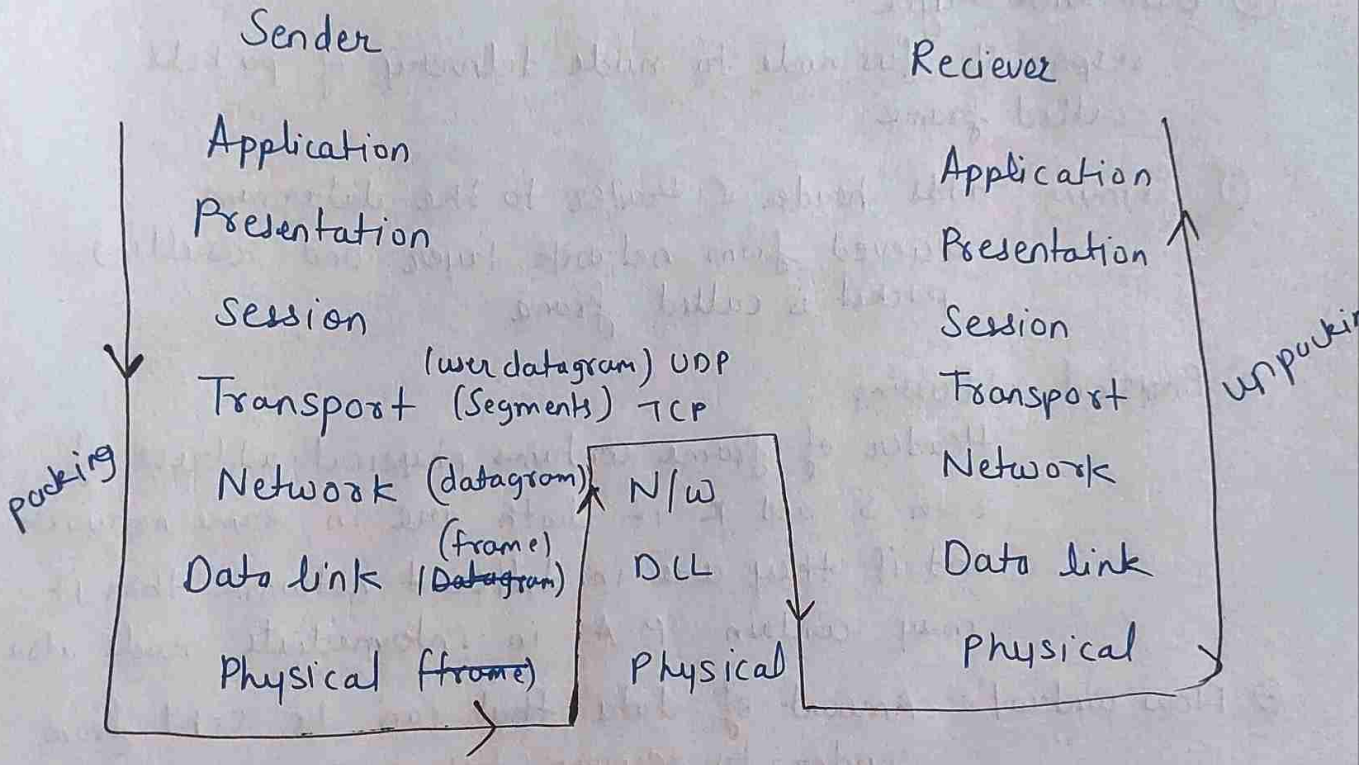
divided into time slots and each device is assigned a specific time slot for transmission.

③ CDMA [Code

devices share the same frequency spectrum but each device is assigned a unique code to distinguish its transmission from other

OSI model (Open System interconnected)

- This model was standardized by I-S O
  (International Organization for standardization)
- Open system here means that 2 system can communicate regardless of their underlying architecture
- OSI model has 7 layer



① Physical, data link and Network are known as network support layer as they mainly deals with physical aspects of moving data from one device to another

② Transport layer is used for end to end delivery of msg

③ Session, presentation, application are known as user support layer as they deals with concept of interoperability

1.9.2 Functions of OSI Layers

1. Physical Layer

- Physical layer is the lowest layer of the OSI model. Physical layer co-ordinates the functions required to transmit a bit stream over a communication channel. It deals with electrical and mechanical specifications of interface and transmission media. It also deals with procedures and functions required for transmission.
- The position of physical layer with transmission medium and the next layer (data link layer) is shown in Fig. 1.9.2

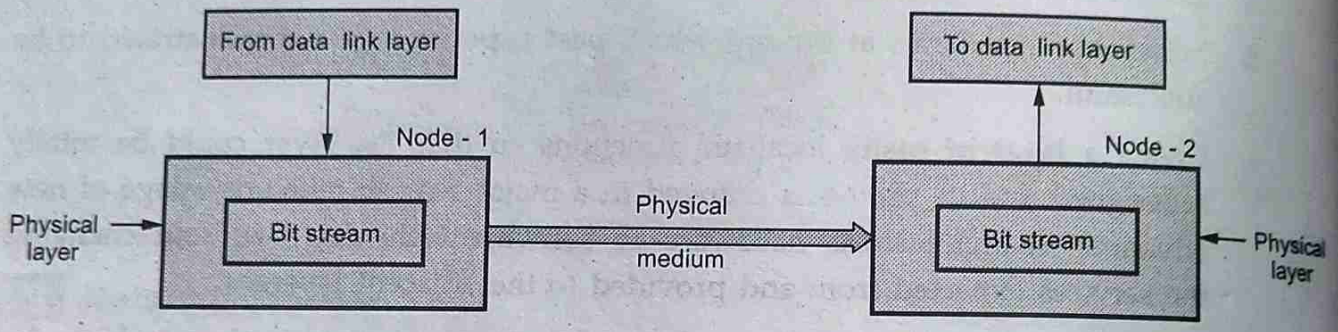


Fig. 1.9.2 Physical layer

Functions of Physical Layer

i) Physical characteristics of interfaces and media : The design issue of physical layer considers the characteristics of interface between devices and transmission media.

ii) Representation of bits : Physical layer encodes the bit stream into electrical or optical signal.

iii) Data rate : The physical layer defines the duration of a bit which is called as data rate or transmission rate.

iv) Synchronization of bits : The transmission rate and receiving rate must be same. This is done by synchronizing clocks at sender and receiver. Physical layer performs this function.

2. Data Link Layer

- The data link layer is responsible for transmitting frames from one node to the next. It transforms the physical layer to a reliable link making it an error free link to upper layer. Fig. 1.9.3 shows data link layer. (Refer Fig. 1.9.3 on next page)

Functions of Data Link Layer

i) Framing : The frames received from network layer is divided into manageable data units called frames.

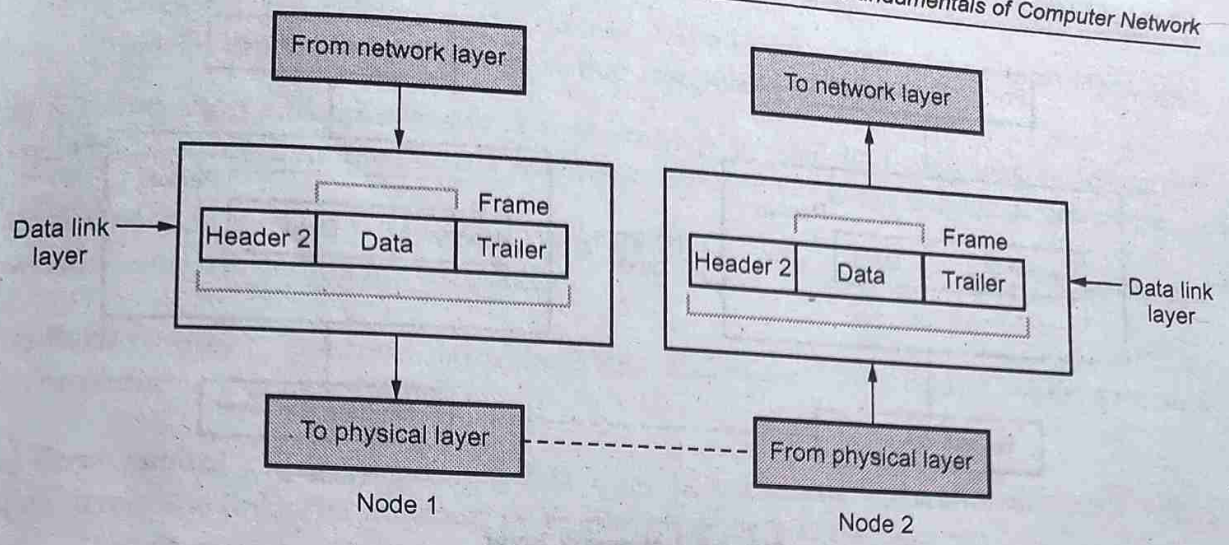


Fig. 1.9.3 Data link layer

ii) Physical addressing : When frames are to be sent to different LANs, the data link layer adds a header to the frame to define sender or receiver.

iii) Flow control : When the rate of the data transmitted and rate of data reception by receiver is not same, some data may be lost. The data link layer imposes a flow control mechanism to prevent overwhelming the receiver.

iv) Error control : Data link layer incorporates reliability to the physical layer by adding mechanism to detect and retransmit damaged or lost frames.

v) Access control : When multiple devices are connected to same link, the data link layer determines which device has control over link.

3. Network Layer

- The network layer is responsible for the delivery of packets from the source to destination. Fig. 1.9.4 shows network layer. (Refer Fig. 1.9.4 on next page)

Functions of Network Layer

i) Logical addressing : Data link layer implements physical addressing. When a packet passes network boundary, an addressing system is needed to distinguish source and destination, network layer performs these function. The network layer adds a header to the packet of upper layer includes the logical addresses of sender and receiver.

ii) Routing : Network layer route or switch the packets to its final destination in an internetwork.

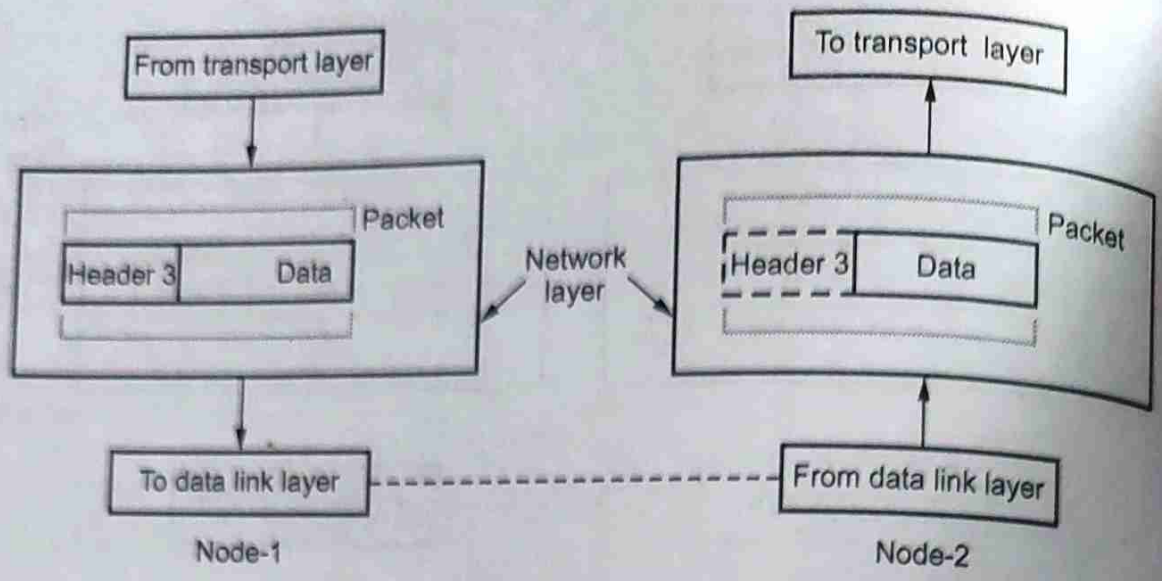


Fig. 1.9.4 Network layer

4. Transport Layer

- The transport layer is responsible for delivery of message from one process to another. The network does the host to destination delivery of individual packets considering it as independent packet. But transport layer ensures that the whole message arrives intact and in order with error control and process control. Fig. 1.9.5 shows transport layer.

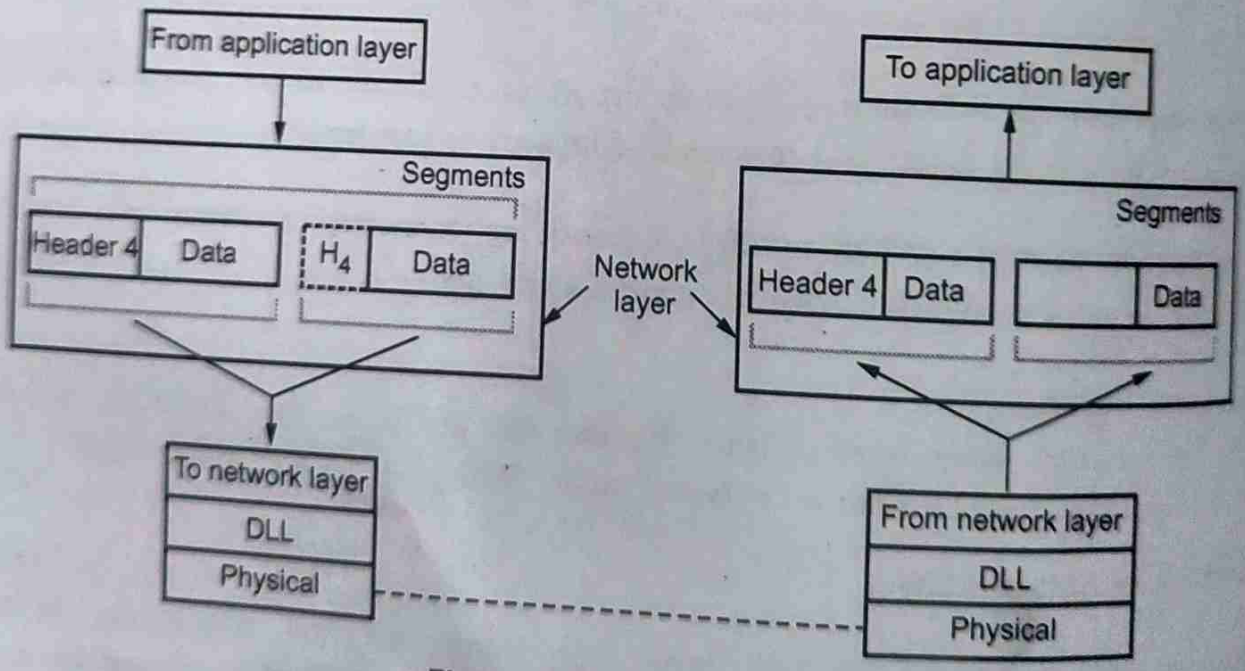


Fig. 1.9.5 Transport layer

Functions of Transport Layer

i) Port addressing : Computer performs several operations simultaneously. Process-to-process delivery means specific process of one computer must be delivered to specific process on other computer. The transport layer header therefore include port address.

- Network layer delivers packet to the desired computer and transport layer, gets message to the correct process on that computer.

ii) Segmentation and reassembly : A message is divided into segments, each segment contains a sequence number which enables transport layer to reassemble at destination.

iii) Connection control : Transport layer performs connectionless or connection oriented services with the destination machine.

iv) Flow control : Transport layer performs end-to-end flow control while data link layer performs it across the link.

v) Error control : Error control at this layer is performed on end-to-end basis rather than across the link. The transport layer ensures error free transmission.

5. Session Layer

- The session layer is network dialog controller i.e. it establishes and synchronizes the interaction between communication system. Fig. 1.9.6 shows session layer.

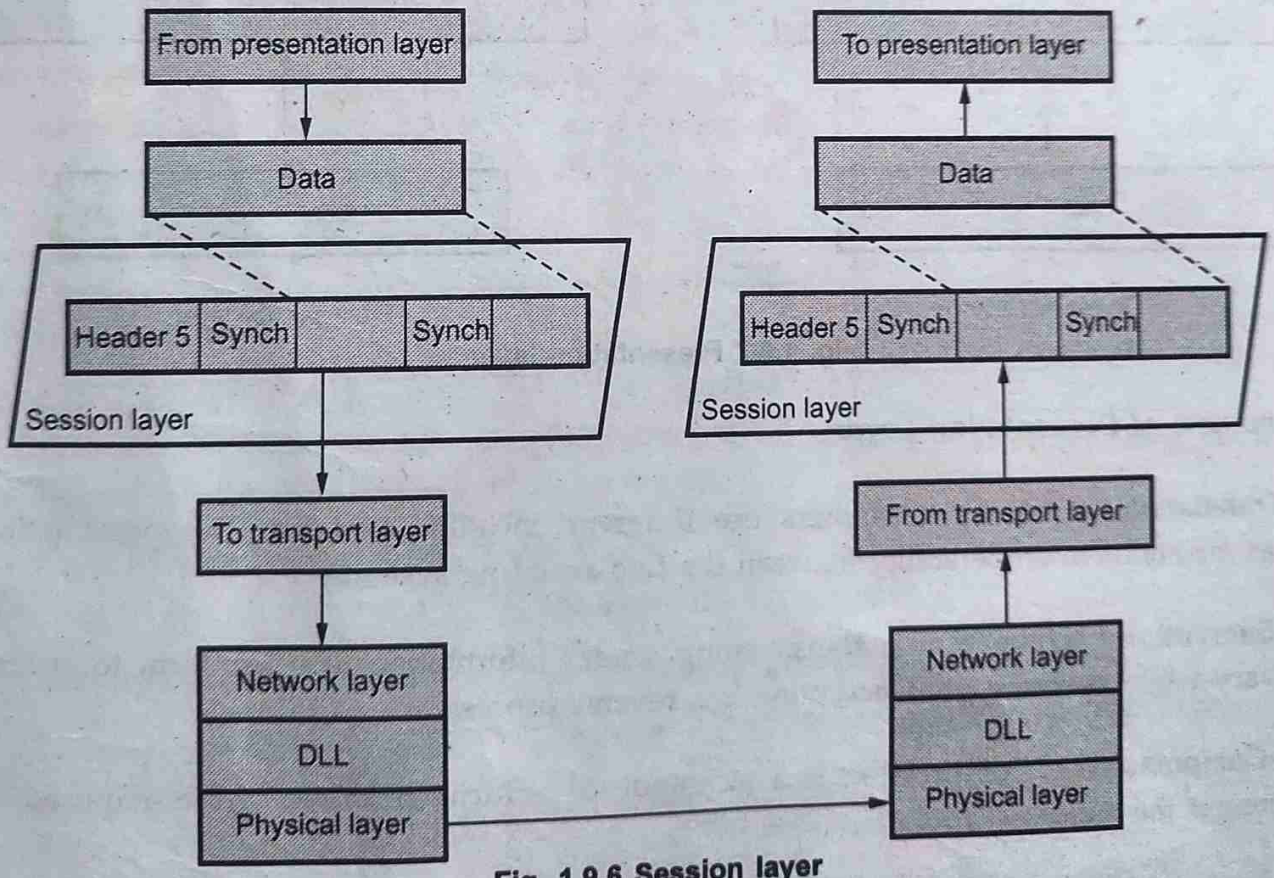


Fig. 1.9.6 Session layer

Functions of Session Layer

i) Dialog control : Communication between two processes take place in either half duplex or full-duplex mode. The session layer manages dialog control for this communication

ii) Synchronization : Session layer adds synchronization points into stream of data.

6. Presentation Layer

- The presentation layer deals with syntax and semantics of the information being exchanged. Fig. 1.9.7 shows presentation layer.

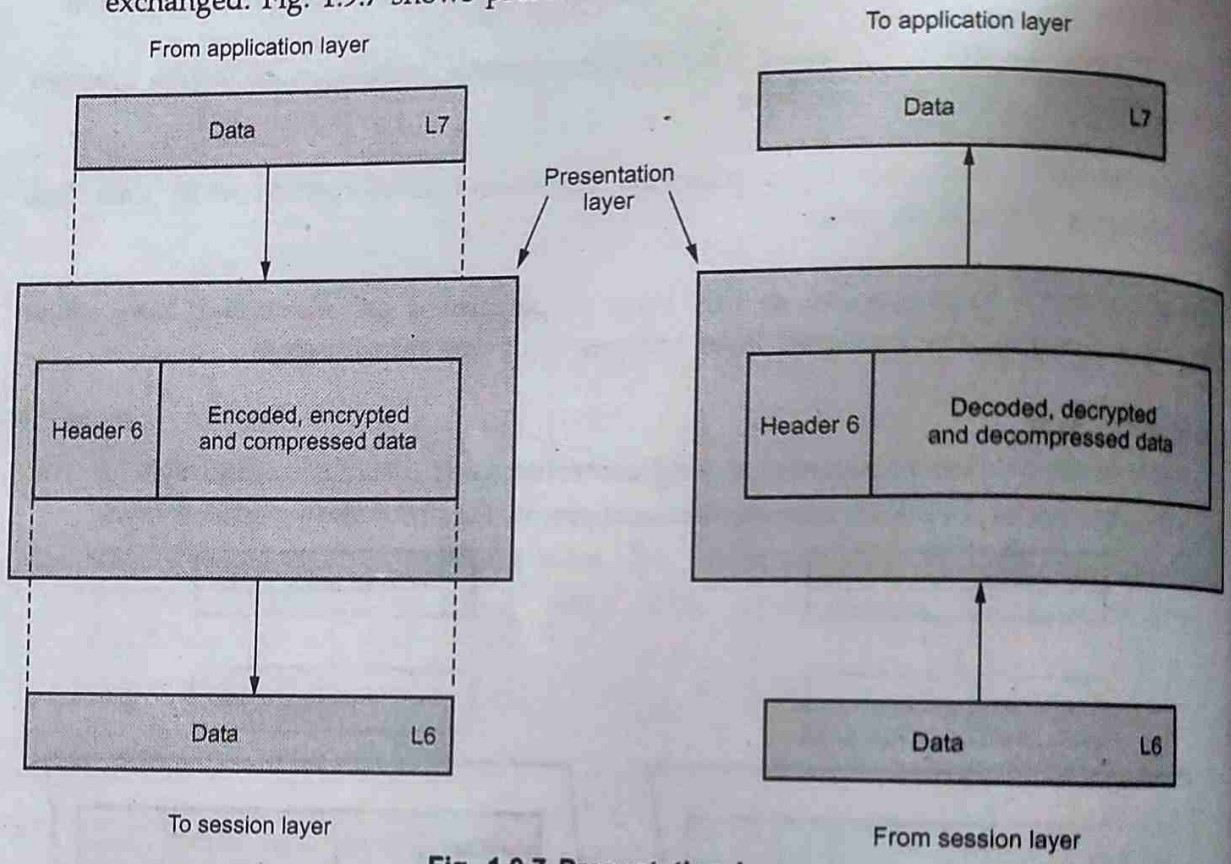


Fig. 1.9.7 Presentation layer

Functions of Presentation Layer

i) Translation : Different computers use different encoding systems. The presentation layer maintains interoperability between the two encoding systems.

ii) Encryption : Encryption is transforming sender information to other form to ensure privacy while transmission. Decryption is a reverse process.

iii) Compression : Compression is a technique of reducing number of bits required to represent the data.

7. Application Layer

- Application layer is responsible for accessing the network by user. It provides user interfaces and other supporting services such as e-mail, remote file access, file transfer, sharing database, message handling (X.400), directory services (X.500).

Functions of Application Layer

i) Network virtual terminal : It is a software version of physical terminal that allows a user to log onto a remote host.

ii) File Transfer, Access and Management (FTAM) : FTAM allows user to access files in remote hosts, to retrieve files and to manage files in remote computer.

iii) Mail services : E-mail forwarding, storage are the services under this category.

iv) Directory services : Directory services include access for global information and distributed database.

1.9.3 TCP/IP Model

- The internet architecture, which is also sometimes called the TCP/IP architecture after its two main protocols.
- TCP/IP stands for Transmission Control Protocol / Internet Protocol.
- The TCP/IP reference model is a set of protocols that allow communication across multiple diverse networks.
- TCP/IP is normally considered to be a four layer system. Layers of TCP/IP are Application layer, Transport layer, Internet layer, Host to network layer.
- Host to network layer is also called physical and data link layer.
- The application layer in TCP/IP can be equated with the combination of session, presentation, application layer of the OSI reference model.

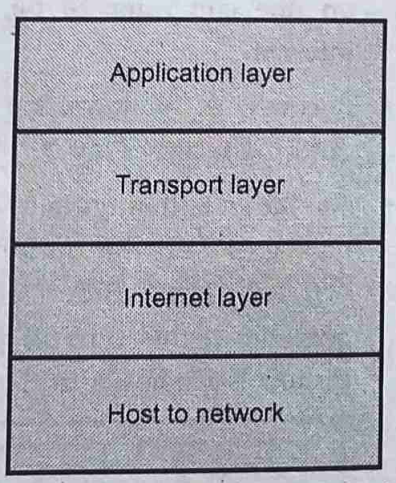


Fig. 1.9.8 TCP/IP reference model

- Fig. 1.9.8 shows TCP/IP reference model.
- TCP/IP defines two protocol at transport layer : TCP and UDP.
- **User Datagram Protocol (UDP)** is connectionless protocol.
- UDP is used for application that requires quick but necessarily reliable delivery.
- Internet layer also called **network layer.** Internet layer handles communication from one machine to the other. Routing of packet takes place in internet layer.
- TCP/IP does not define any specific protocol in host to network layer. This layer is responsible for accpeting and transmitting IP datagrams. This layer normally includes the device driver in the operating system.

- Detailed function of each layer is given below.
  1. **Application layer :** Application layer includes all process and services that use the transport layer to deliver data. The most widely known application protocols are : TELNET, File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP) and Simple Network Management Protocol (SNMP). TELNET is the Network Terminal Protocol, which provides remote login over the network. FTP is used for interactive file transfer. SMTP delivers the electronic mail.
  2. **Transport layer :** Application programs send data to the transport layer protocols TCP and UDP. An application is designed to choose either TCP or UDP based on the services it needs.
- The transport layer provides peer entities on the source and destination hosts to carry on a conversation. Both ends protocol is defined in this layer.
- TCP is reliable connection oriented protocol that allows a byte stream originating on one computer to be delivered without error or any other computer in the internet.
- It converts the incoming byte stream into discrete message and passes each one onto the internet layer.
- At the destination side, the receiving TCP reassembles the received data or messages into the output format. TCP also handles flow control. It synchronizes between fast sender and slow receiver. UDP is a connectionless protocol. Sometimes this type of protocol is used for prompt delivery. The relation of the protocols is shown in the Fig. 1.9.9.

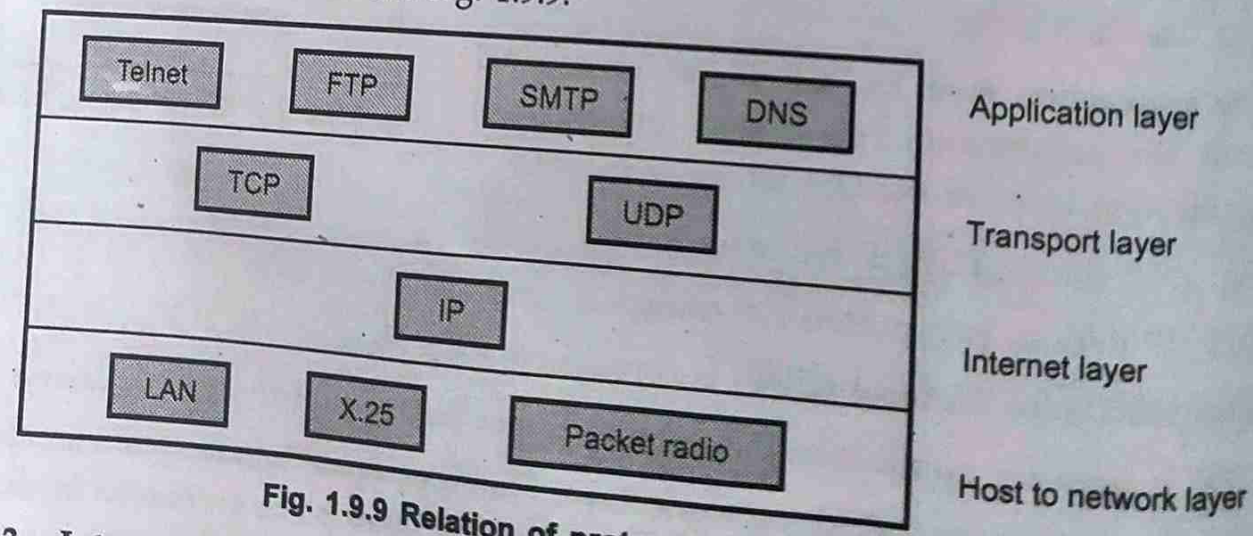


Fig. 1.9.9 Relation of protocol in TCP/IP model

3. **Internet layer :** The Internet network level protocol (IP, ARP, ICMP) handle machine to machine communications.

These protocols provide for transmission and reception of transport requests and handle network level control. The TCP/IP internet layer moves data from one host to another; even if the hosts are on different networks.

- The primary protocol used to move data is the Internet Protocol (IP), which provides the following services :
  a. **Addressing :** Determining the route to deliver data to the destination host.
  b. **Fragmentation :** Breaking the messages into pieces if an intervening network cannot handle a large message.
- It provides a connectionless method of delivering data from one host to another. It does not guarantee delivery and does not provide sequencing of datagrams. It attaches a header to datagram that includes source address and the destination address, both of which are unique internet addresses.

4. **Host to network :** This layer is also called network interface layer. This layer is same as **physical and data link layer** of **OSI model**. **Host to network layer cannot define any protocol.** It is responsible for accpeting and transmitting IP datagrams. This layer may consist of a device driver in the operating system and the corresponding network interface card in the machine.