1 Computer Network Basics

1.1 INTRODUCTION

Fig.1.1 Data Communication System

"Hello world", which is data here, needs to be transmitted from the Sender to Receiver, this transmission of data involves some set of protocols (will be discussed in the next chapters) and this flow of data in a system is called "Data Communication System".

Components of data communication system:
Sender:
One who sends data

Data:
It is a huge subject in itself, but we limit it to the context/information which needs to be transmitted from sender to receiver (in the above diagram **"Hello World"** is a data).

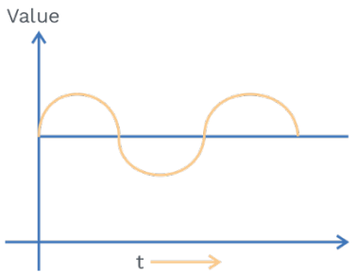
Medium:
Data passes through a medium which can be wireless or wired (Twisted pair, Coaxial cable or Optical fiber etc.)

Receiver:
One who receives data.

Protocol:
Set of rules that governs transmission of data.

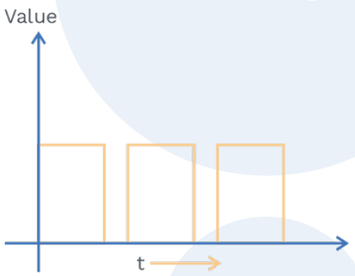
Lets understand Data and Medium a bit more:
1) Data:
For transmission of data, it must be transformed into electromagnetic signals.

Signal can be classified in analog and digital form.



Analog signal:
Data is represented in continuous waveforms.

Digital signal:
Data is represented in discrete form (0's or 1's/High or low).



Note:

Signals always varies with respect to time or frequency.

$$(\text{time} = \frac{1}{\text{frequency}}).$$

Baseband signal: Typically uses digital signals.
Broadband signal: Typically uses analog signals.

2) Medium:
Transmission medium is a channel through which data can be sent or received.

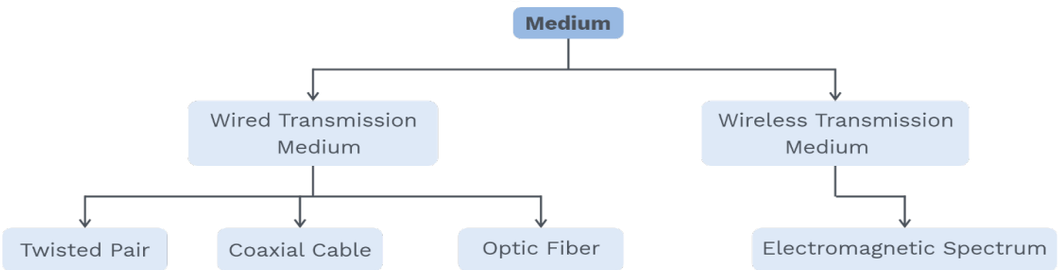


Fig. 1.2 Flow Chart Representing Types of Transmission Medium

Twisted pair:

Do you know the RJ - 45 connector?

Yes, the port on your laptop or CPU for RJ-45, it contains twisted-pair cables for Ethernet connection. It is also known as CAT 5 cables.

Fig. 1.3 Diagram of Twisted Pair

- In twisted-pair cables, two wires twisted together in a helix fashion.
- It has low cost transmission.
- It can carry both analog and digital signals.
- More the thickness of wire, more is the bandwidth.

Why twisted wires, why not normal wires !!

Normal wires will generate the magnetic field, which interferes with the signal, when the wires gets twisted, the magnetic field around the wires get disrupted.

Rack Your Brain

Where twisted wires are used !!

Coaxial cable:

It has a copper wire as a core, surrounded by insulating materials, which further surrounded by the braided outer conductor, which is further surrounded by a plastic sheath.

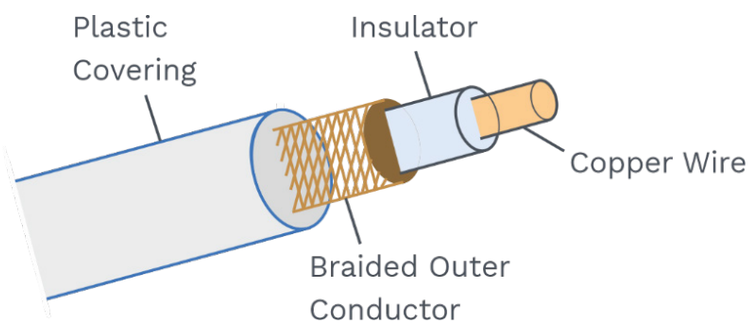


Fig. 1.4 Structure of Coaxial Cable

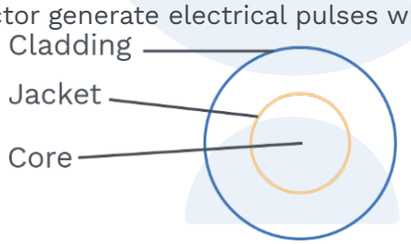
- It has better features than twisted pair because of its shielding.
- It has excellent noise immunity and high bandwidth.
- Here also, more the length of the cable, more the bandwidth.

Rack Your Brain

Why coaxial cables are used !!

Fiber Optics:

- It sends information using lights instead of electrons. Light travels from the core, a layer which surrounds the core is called cladding.
- Fiber optics consist of the light source, transmission medium and detector.
- Light pulse indicates 1 and absence of pulse indicates 0, the medium is thin, fiberglass and detector generate electrical pulses when light falls on it.



- Error rates are less because it does not affect by electromagnetic interference.
- It is thin and lightweight.
- Data rates are very high.
- They are good for security reasons because they are difficult to tap.

How many types of fibre exist !!

2 types are there – Single-mode fibre and multimode fibre.

In single-mode: Light travels in Single Path,
high cost,
can be used in 10 to 100 Km,
data rates are high (in Tb/s),

In multimode: Light travels in many paths,
low cost,
can be used in 2000 metres,
data rates are low (in Gb/s).

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If you have to run a network which ranges from 1400 metres and have a data rate as 1 Gb/s? Which fibre should you choose !!

Till now we have seen wired medium, now let us see wireless transmission medium:

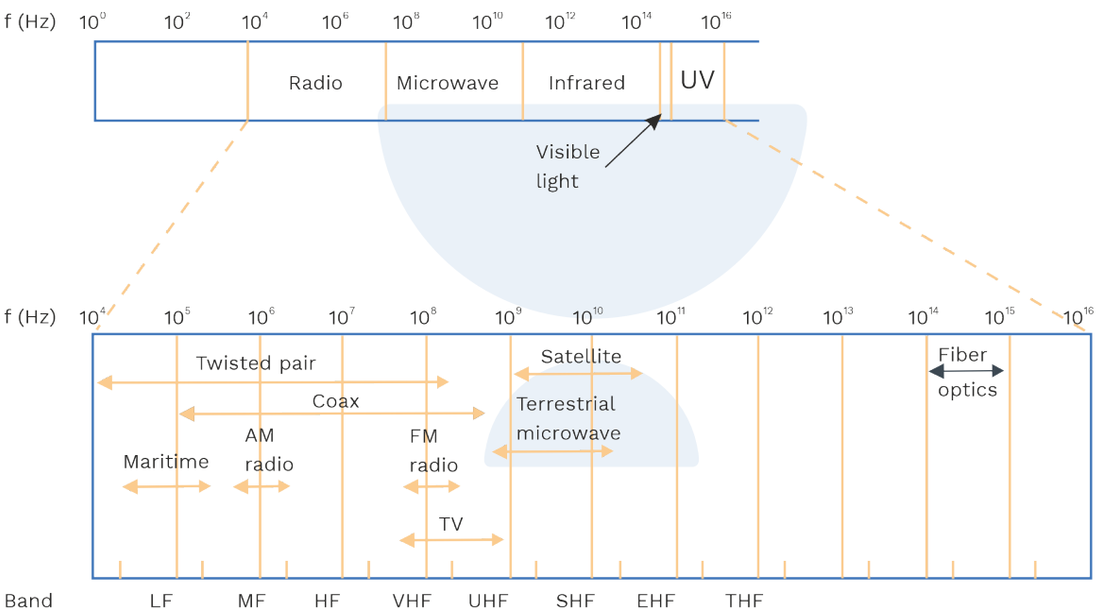


Fig. 1.5 EM Spectrum and Uses in Communication

Waves which can be used for transmitting information are radio, micro, infrared and some portion of visible light as they can be modulated and amplified easily. UV, X and gamma rays do not propagate through the buildings; hence not used for transmission frequently.

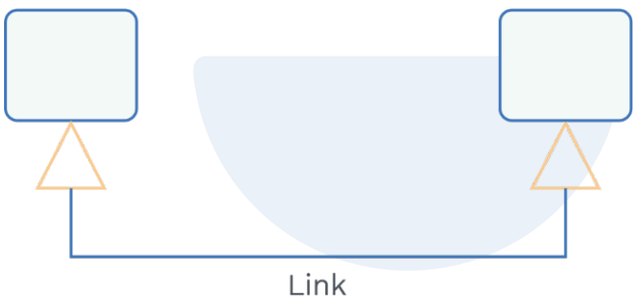
Note:

Data flow can be categorized in simplex mode, half duplex mode and full duplex mode.

Simplex mode: Only one of the two devices can send the data, hence the entire channel is used for transmission, example: radio station.

Half-Duplex mode: Any of the two devices can send or receive the data but not at the same time; here entire channel is used for transmission or receiving of data, example: Walkie Talkies.
Full-Duplex mode: Both devices can send and receive data simultaneously, hence the entire is used for two purposes simultaneously which increases the efficiency of the channel, for example: Telephone networks.

Topologies and its types:
Link:
Device connected through link



Topology:
Many links from topology, basically it is a representation of the physical and logical structure.

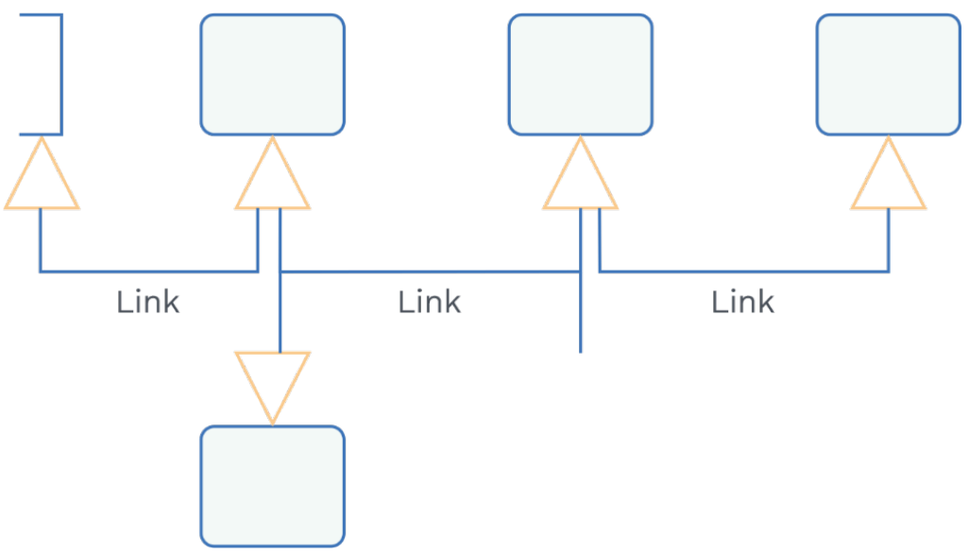


Fig. 1.6 Structure of Topology

Topology types:

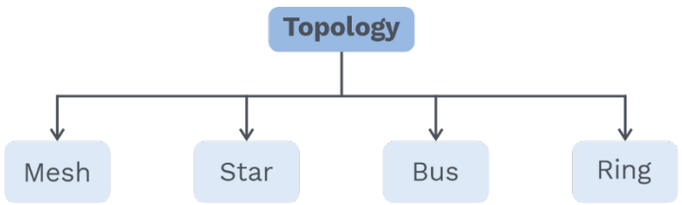


Fig. 1.7 Types of Network Topology

Bus topology:

- All the nodes are connected to a shared cable.
- There will be no central node.
- One long cable act as a back-bone of this network.
- For n devices, only 1 link is required.

Advantage:

- Installation is easy, used for small networks, fewer cables are required.

Disadvantage:

- Can be used with limited nodes; cable length is also limited.

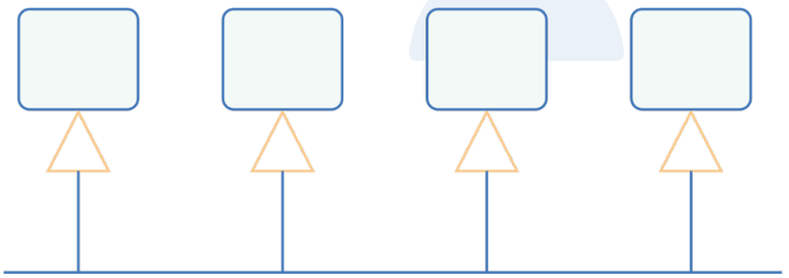


Fig. 1.8 A Bus Topology

Star topology:

- Each device has a point to point link through a central node (hub or switch) that may act as controller.
- There is a central node which acts as an exchange medium.
- Devices are not directly connected with each other.
- For n devices, n links are required.

Advantage:

- Easy to manage when faults occurs, installation is easy, easy to expand.

Disadvantage:

- Require more cable than the bus, if the central node gets down, then all nodes get down.

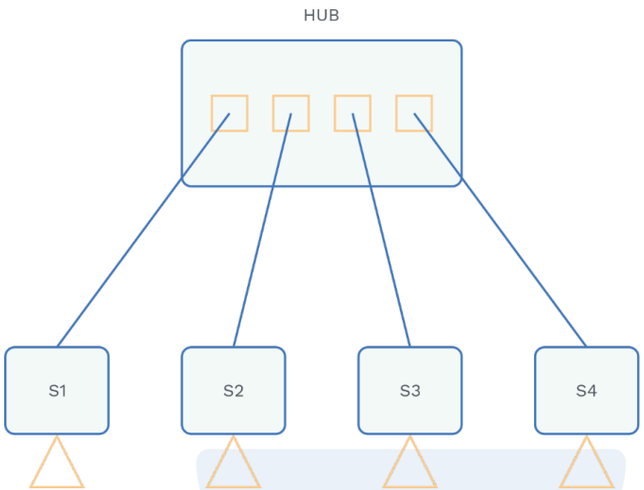


Fig. 1.9 A Star Topology

Ring Topology:

- Each device has a point to point connection only with two devices that are on either side of a device.
- If any device fails, the entire network gets down.
- Each device in a ring has a repeater.
- Message travel in a single direction.
- If n nodes are present, then n physical links.

Advantages:

- Using token, each device gets a fair chance to send a message.
- Easy to install, good for long-distance.

Disadvantage:

- If nodes get moved, it affects the performance.
- If a node gets down, entire network gets down.

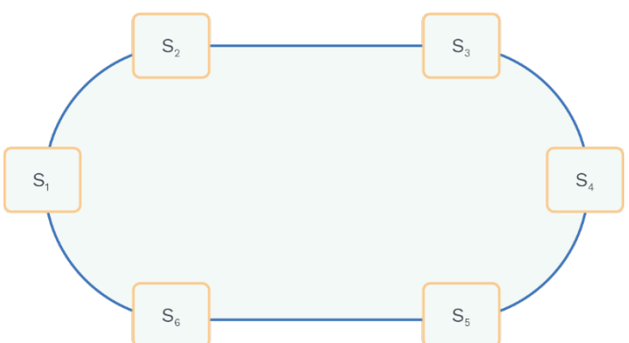


Fig. 1.10 A Ring Topology

Mesh Topology:

- Every device has a point to point link with every other device.
- Message can travel in any direction.
- If n devices are present, then (n – 1) ports must be present on each device.
- And total number of physical links is n(n–1)/2.

Advantage:

- If one node gets down, still message can flow through other paths.
- Fault detection is easy because of the dedicated link.

Disadvantage:

- Installation is not easy.
- Expensive as more number of cables is used.
- There is a possibility of a redundant path.

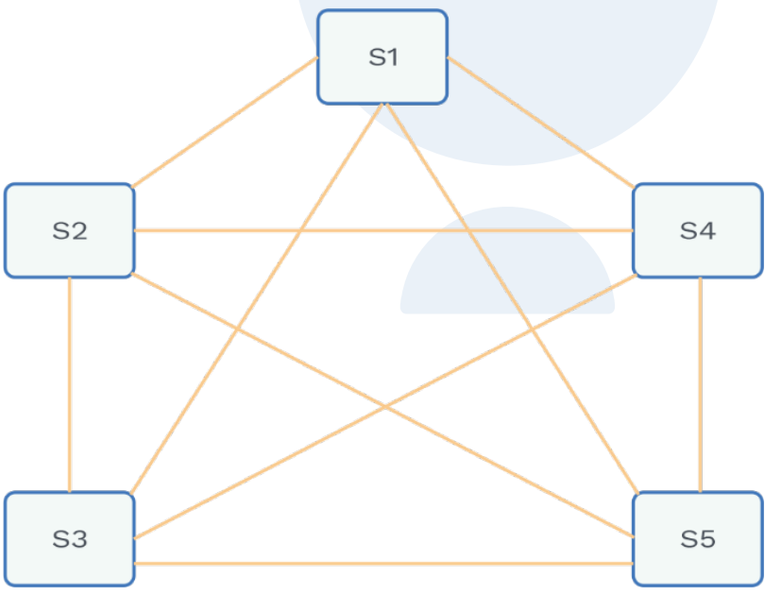


Fig. 1.11 A Mesh Topology

Rack Your Brain

a) In a mesh system, if the number of devices are 10, how many physical links must be present?

b) In a ring system, if the number of devices are 5, how many physical links must be there?

Tree Topology:

- Collection of star topology in hierarchical level.
- More devices can be added now as the network can grow by connecting one central hub to another hub.

Advantage:

- Easy to expand, Isolation of different network is possible.

Disadvantage:

- If the central hub is down, the entire network goes down.
- Cost is high because more number of cables will be required.

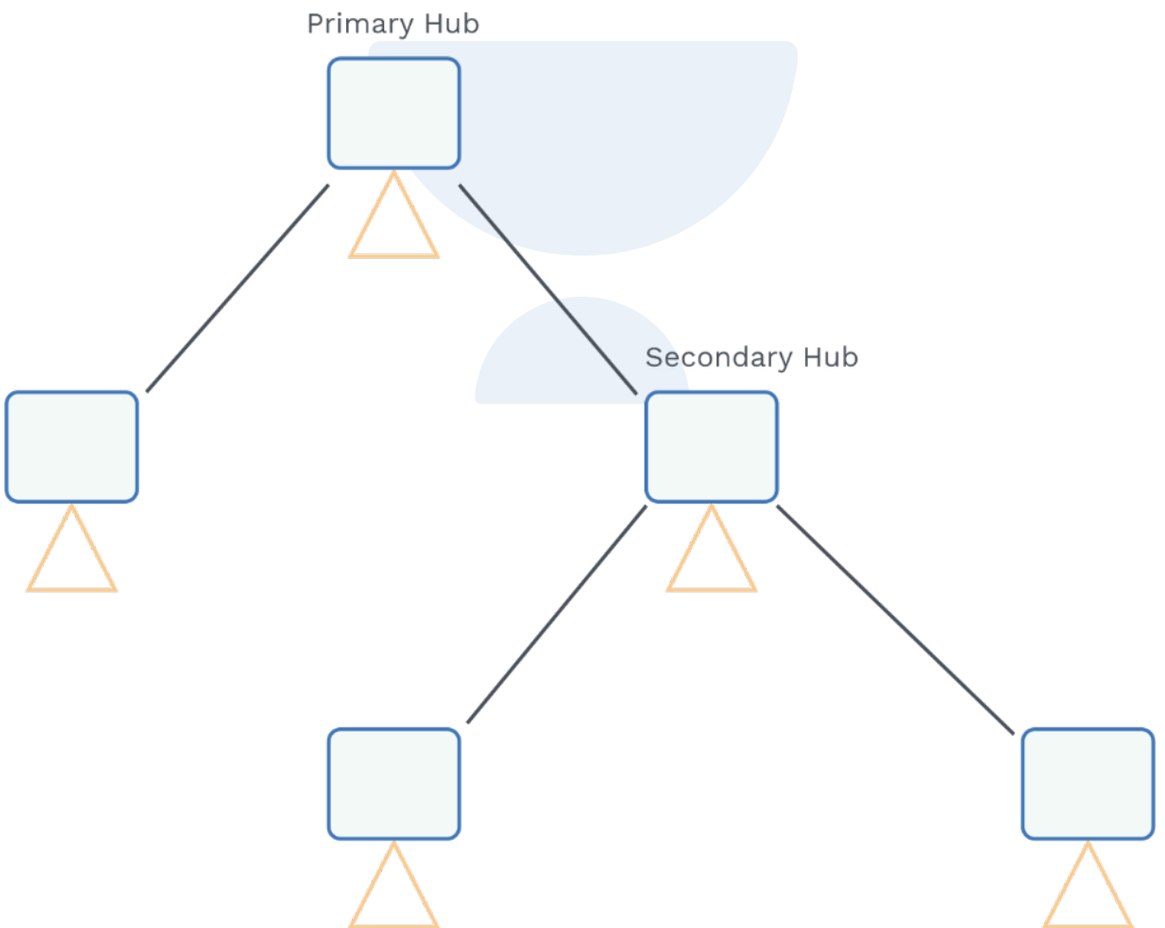


Fig. 1.12 A Tree Topology

1.2 NETWORK TYPES

Interprocessor distance	Processors located in same	Example
1m	Square meter	Personal area network
10 m	Room	Local Area Network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Fig. 1.13 Classification of Network

PAN (Personal Area Network):
- Range of Person, your bluetooth works in PAN.
- Works for short range.

LAN (Local Area Network):
- Range of buildings, privately owned networks.
- Wireless LAN such as WiFi.
- Wired LAN such as Ethernet.

MAN (Metropolitan Area Network):
- Ranges of cities, your cable television networks.
- Connection of Multiple LAN's.

WAN (Wide Area Network):
- Ranges of countries, your telephone network works in WAN.
- Works for a very large range.

OSI Model:

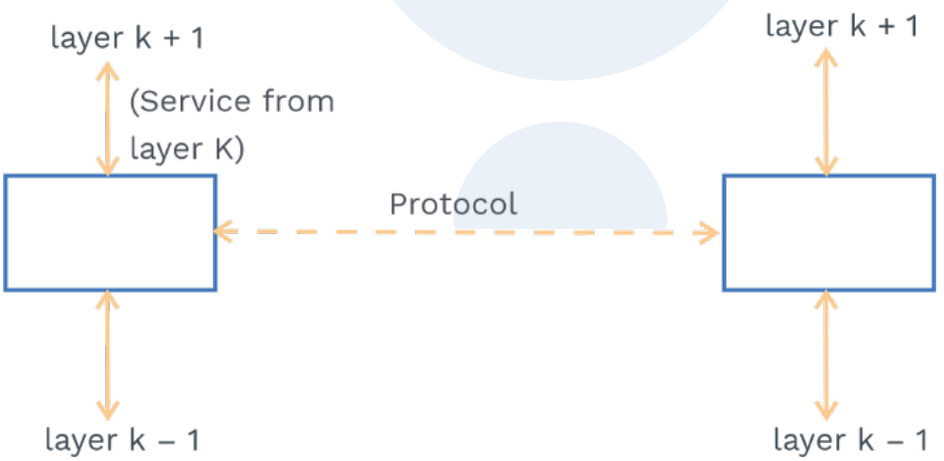
- International Organization of Standardization (ISO): proposed an open systems interconnection (OSI) model, which allows two systems to communicate irrespective of their architecture.
- The aim of the OSI model: To represent how to provide communication between the dissimilar systems without making any changes to the logic of the underlying software and hardware.
- OSI model is a 7 layered architecture.

Protocol Layering:

A list of protocols used by the system in which one protocol is used in each layer is called protocol layering or protocol stack.

Relationship between Service and Protocol:

Service and protocol both are different; one can understand service is a high-level function and protocol is a detail of a function.



Each layer's boundaries are decided in such a way that there should be a minimum flow of information between each layer.

Note:

OSI model has been widely used but the protocols "used in OSI" have been forgotten.

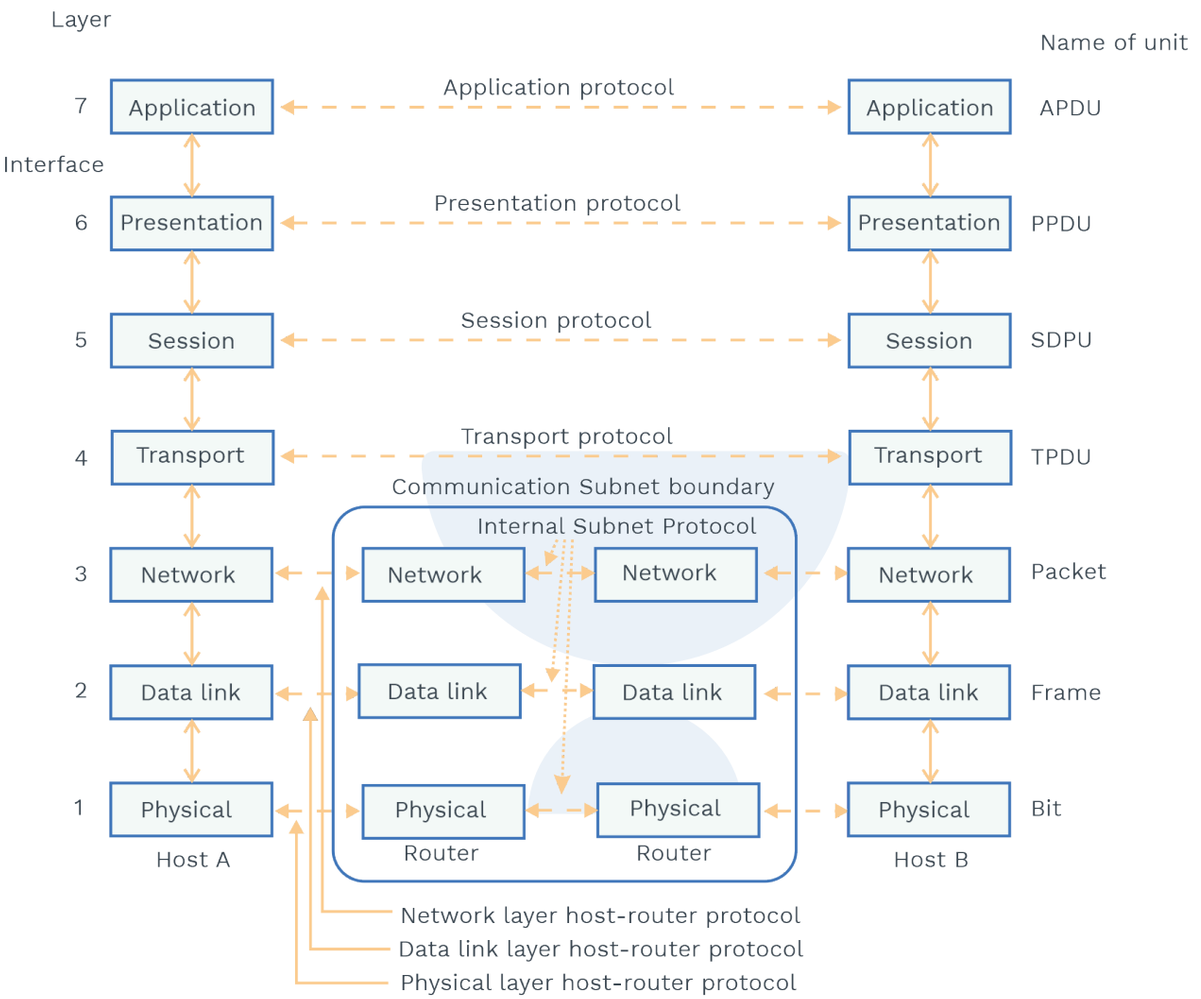
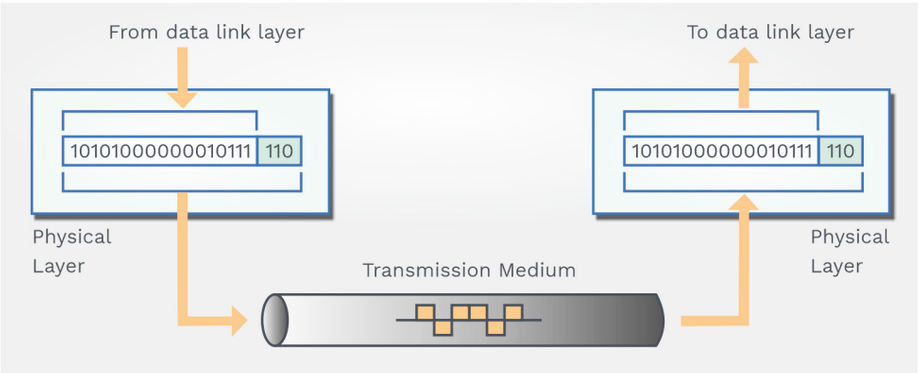


Fig. 1.14 The OSI Model

Before discussing each layer we must keep in mind that portion of the packet at stage x-1 contains the whole packet of stage x. Stage x – 1 thinks that the packet which is coming from stage x is one unit. One can say it follows the encapsulation technique.

Physical layer:

- It deals with the interface between the devices and the transmission medium.



- It deals with the transmission of raw bit through transmitting media the Sender and Receiver must send or receive bit at the same rate and must be synchronized.
- It also deals with physical topology and transmission modes.

Rack Your Brain

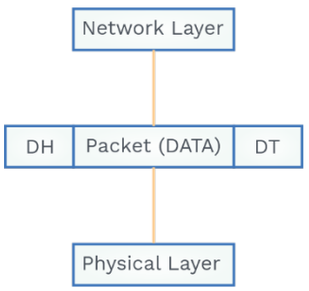
a) Name some physical topology.
b) Name some transmission mode.

Data Link Layer:
It makes a frame move from one node to the next node.

- It makes data from the physical layer error-free and sends to the network layer.
- It deals with **framing** (the process of division of data unit from network layer into manageable streams called frames).
- It deals with **physical addressing** (adding a physical address **i.e. MAC address,** so that frame could reach the destination network)
- If rates are mismatched between nodes, then the data link layer provides a flow control mechanism.
- Data link layer also see whom to give access if two or more device is connected to a link at a given time.

Rack Your Brain

Above 5 points are Error Control, Framing, Physical Addressing, Flow Control and Access Control, respectively.



Network layer:
It deals with the delivery of packets from source host to destination host.

- **Logical addressing:** Data link layer solves address issues locally, but the network layer provides a logical address (IP address) in order to reach from Source to destination when the packet reaches the destination network.
- **Network layer do routing**: Several networks is interconnected with each other through the router, and it is the responsibility of the network layer to route the packet to the destination.

Transport layer:
It is the responsibility of the transport layer to deliver the message from the source process to the destination process.

- It does **segmentation** (splitting message from application layer into segments) and **reassembly** (intact the message correctly on receiving the destination).
- It deals with port addresses in order to reach the service of the process called **port addressing.**
- Transport layer also determines service provided to the session layer, it may be connection-oriented or connectionless services.
- **Flow control:** At transport layer, flow control is done from end to end.
- **Error correction:** It is usually done by retransmission if any error occurs.

Rack Your Brain

a) You have seen how transport layers perform error control, think about how data links perform error control.
b) At the transport layer if flow control is end to end, at the data link layer, it is?

Session layer:
It is the responsibility of a session layer to establish a session (dialog control and synchronization) between sender and the receiver.

- **Dialog control:** Between a link, it keeps an eye whose turn is now on the link for sending the data.
- **Synchronization:** It adds a checkpoint if the sender is sending a huge file, **eg:** Sending a file of 1GB, it will add a checkpoint after 100KB so that if any file gets lost, it will be easily recovered.

Presentation layer:

It deals with compression, translation and encryption.

- **Translation:** It deals with the conversion of bits before sending a message.
- **Encryption:** it deals with an encoded messages before sending; encryption is done for security reason.
- **Compression:** While sending a multimedia file, it compresses the file for smooth transmission.

Application layer:

- It deals with a variety of protocols which is useful for common clients.
- The protocols are HTTP, FTP, DNS, SMTP. (We will discuss this in application layer chapter.)

TCP/IP Model:

- Protocols which are associated with the OSI model are not used in today's world, although the OSI model is still in use as it works as a framework for other models because of its generalized structure.
- If not OSI protocol, then whose protocols are we using now?
  TCP/IP model
- Below is a diagram of the TCP/IP model, which is similar to the OSI model. Have a look at the difference between the two.

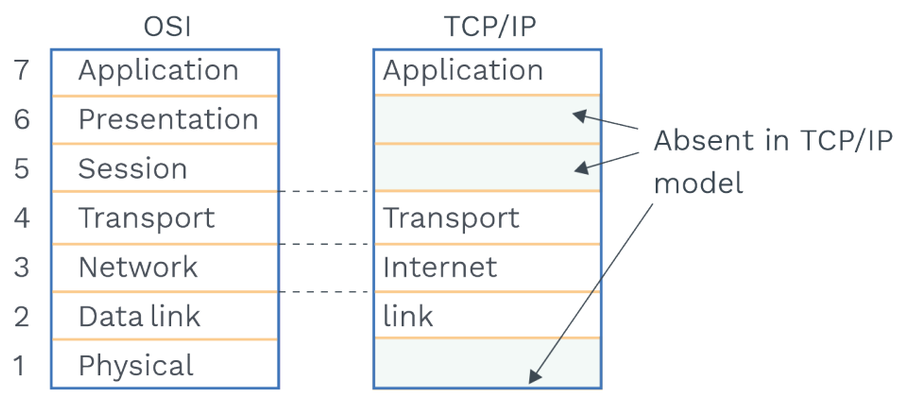


Fig. 1.15 Comparison Between OSI Model and TCP/IP Model

Have you noticed presentation, session and physical layer are absent in TCP/IP?

OSI MODEL	TCP/IP MODEL
This model is popularly used, but protocol associated with this model is now obselete	This model is not used, but protocol associated with this model is used frequently
Both model uses layered architecture Both model process data in the form of packet	

Key similarities between OSI and TCP model:

- For communication process both are using layered architecture and each layer is specific to its task in both models.
- Both models follow the encapsulation, hiding the implementation details at each layer.
- Both follow the stack independent protocol technique.
- Both model has implemented end to end communication upto the transport layer.

Key differences between OSI and TCP model:

- One major difference is between layers OSI model has 7 layers whereas TCP/IP has 4 layers.
- In the OSI model, the transport layer provides connection-oriented services, but the TCP/IP model transport layer can make choices between connection or connectionless services.

  Protocols used in TCP have been shown in the given diagram:

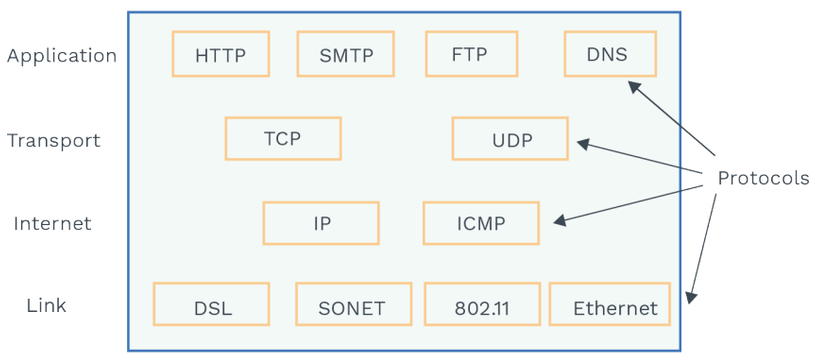
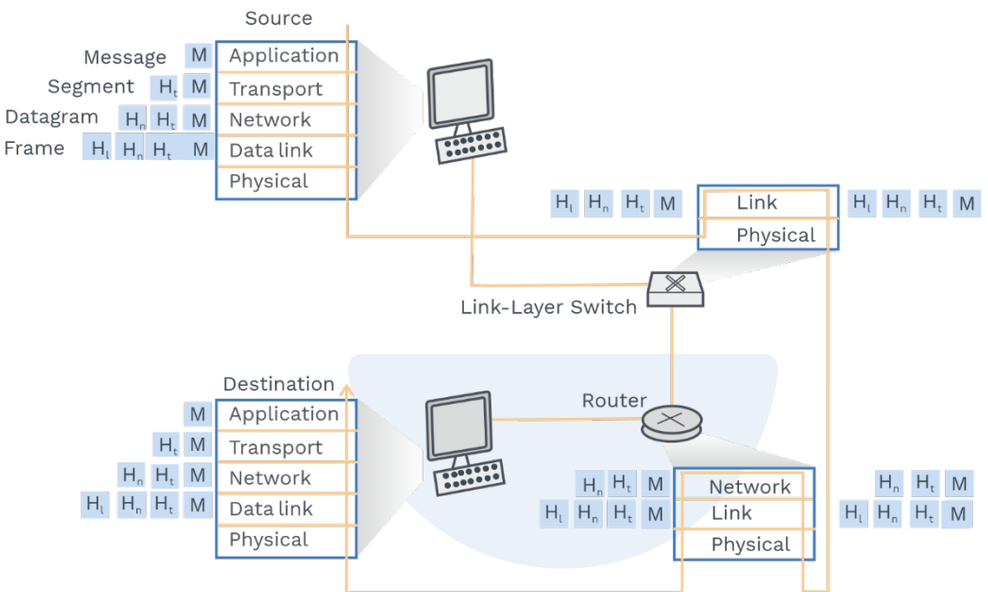


Fig. 1.16 Protocols Used in TCP Model

Let us see How these layer work in short (We will go deep of each layer later but let's have a taste)



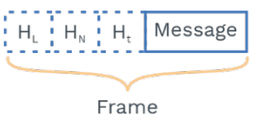
- At Source message starts travelling from the application layer.
- Transport layer receives the message and adds H_t (Transport layer header).
- The transport layer segment then passes to the network layer, and the network layer adds a network layer header to it.

Note

a) You may ask where this header gets acknowledged?
At the received side of the transport layer.

b) Is there any name given to this message at the transport layer?
Yes, we called it as segment.

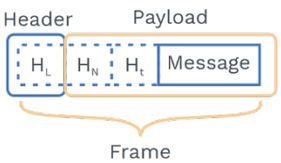
- Network layers send this datagram to the data link layer, which adds a data link layer header. Do you think there is any name at the data link layer also!! Frame



- At every layer, packet is having two fields:
  1) Header field
  2) Payload field

What is a Payload Field?

Payload field at layer k is the packet which is coming from k-1 layer !!
For example, at the data link layer, see the diagram below:

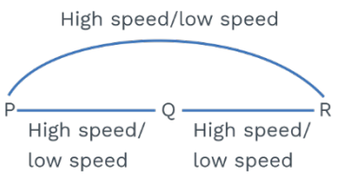


- From the link layer, it goes to the switch or bridges, which sees till the physical address (MAC) of the packet and forwards it to the destination node.
- Let us say the packet is in a different network; now packet has to pass with the router, which can see till the IP address of the packet and map to its destination address.
- Finally, packet reaches its destination host, where each layer by seeing their header and acknowledges the packet.

PRACTICE QUESTIONS

Q1 **3 routers are connected in a network, between each pair of router network, administrators can add 2 lines (high speed line or low line) If it takes 10ms to inspect each topology. How long would it take to inspect all of them?**

Sol:



No. of lines are PQ, QR, PR.
Each line is having 2 choices.
So, total number of topology possible is 2x2x2 = 8
10 ms for each to inspect; hence 0.08 sec. to inspect all.

Q2 **One advantage and one disadvantage of layered architecture?**

Sol: Advantage: Can be managed easily.

Disadvantage: Delays are more compared to single layer architecture.

Q3 **Difference between message streams and Byte streams?**

Sol: In message streams, packets have separate boundaries, but in byte streams, packets is considered as a single unit.

Q4 **Assume at in OSI model algorithms (protocol) used at layer k are changes, what will be the effect at layer K i (i = 1,2,3)?**

Sol: There will be no effect, now can you think why? Because each algorithm is associated with its layer only in OSI model, there will be no effect on other layers.

Q5 **Follow up with the question in d, what if services at layer k has changed, will it affect layer K i (i = 1,2,3)?**

Sol: We might need to modify services at upper layer because each layer is giving services to the upper layer.

Previous Years' Question

Q) In the following pairs of OSI protocol layer/sub–layer and its functionality, the INCORRECT pair is :

a) Network layer – Routing
b) Data link layer – Bit synchronization
c) Medium access control sublayer – Channel sharing
d) Transport layer – end to end sharing

Sol: b)

Physical layer – Bit synchronization

Chapter summary:

- The seven-layer OSI model provides guidelines for the development of universally compatible networking protocols:
- **Network support layers** : Physical, Data Link and Network Layer.
- **User support layers** : Session, Presentation and Application layer.
- **Physical layer** : Delivery of bit streams over physical layer.
- **Data Link layer** : Node to node delivery of data.
- **Network layer** : Source to destination delivery.
- **Transport layer** : Process to process delivery.
- **Application layer** : Enables user to access network.
- TCP/IP is a four- layer hierarchical protocol suite.
- Level of address used in TCP/IP.
- Data link layer uses physical address use in LAN or WAN.
- IP address uses logical address used to identify host.
- Port address identify a process on a host.

For N devices:

- 1 link is required for bus topology.
- N link is required for ring topology.
- N link is required for star topology.
- N(N-1)/2 link is required in mesh topology.
- Twisted air cable, coaxial cable, and optical fiber are the most popular types of guided media.
- Unguided media transport electromagnetic waves without the use of a physical conductor.