1. Introduction

Q.3.4.1.1 State important characteristics of data communications.
Answer: Inportant characteristics of data communications include the following.
Delivery: System must deliver data to the correct destination.
Accuracy: Data needs to be delivered accurately.
Timeliness: Data needs to be delivered without significant delay.
Jitter: It refers to the variation in packet arrival time. An uneven delay in packet arrival leads to a poor quality of signal received by the destination.

Q.3.4.1.2 What are nodes in a network?
Answer: A network is a set of devices, called nodes, connected by communication links. A physical node is an electronic device that is attached to a network, and is capable of creating, receiving, or transmitting information over a communication channel. A physical node may be either a data communication equipment or a data terminal equipment. Some examples of data communication equipment are modem, hub, bridge and switch. A digital telephone handset, printer and host computer are examples of data terminal equipment.

Q.3.4.1.3 Discuss criteria for measuring effectiveness of a network.
Answer: There are many ways one could measure the effectiveness of a network. Some issues regarding the network criteria are performance, reliability and security.
The performance of a network can be measured by criteria such as transit time and response time. The time required for a message to travel from the source to the destination is called transit time. The time elapsed between an inquiry and the response given by the system is known as response time.
The reliability of a network can be measured by criteria such as the frequency of failure, the time it takes a link to recover from a failure, and the network's robustness in a catastrophe.
The security of a network includes many issues such as
* protecting data from unauthorized access
* protecting data from damage and development
* implementing policies and procedures for recovery from breaches and

data losses.

Q.3.4.1.4 Compare and contrast point-to-point connection with multipoint connection.
Answer: We discuss a few contrasting points between these two types of connection.
∘ A point-to-point connection provides a dedicated link between two devices. A multipoint connection is one in which more than two specific devices share a single link.
∘ In case of point-to-point connection, the entire capacity of the link is reserved for transmission between those two devices. In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. When the channel is shared spatially, several devices can use the same channel simultaneously. In case of timeshared connection, each user uses the entire channel for a small amount of time.

Q.3.4.1.5 What is full-duplex mode of communication? How does it differ from half-duplex mode of communication?
Answer: In a full-duplex mode, both the stations can transmit and receive signals simultaneously. One common example of full-duplex communication is a talk between two people over a telephone line, where both can talk and listen at the same time. This implies that the capacity of the channel must be divided between the two directions.
In half-duplex mode, each station can either transmit or receive signals. In other words, a station cannot both transmit and receive signals simultaneously. When one device is sending, the other can only receive, and vice versa. In this case, the entire capacity of the channel can be utilized for each direction.

Q.3.4.1.6 What is mesh topology? Assume that there are six devices arranged in a mesh topology. How many cables are needed?
Answer: In this topology, there is a dedicated point-to-point link bewteen a pair of devices. A dedicated link carries traffic only between the two devices that it connects.
One can have $\binom{6}{2}$ pairs from 6 devices. Then the number of cables required is $\binom{6}{2} = \frac{6(6-1)}{2} = 15$.

Q.3.4.1.7 Explain the notion of hybrid topology. Give an example using a neat diagram.
Answer: A hybrid topology is a combination of atleast two basic topolo-

gies. Fig. 1.1 is an example of hybrid topology, where the backbone is a star topology. It connects three series of stations and each series contains four stations connected by a bus topology.

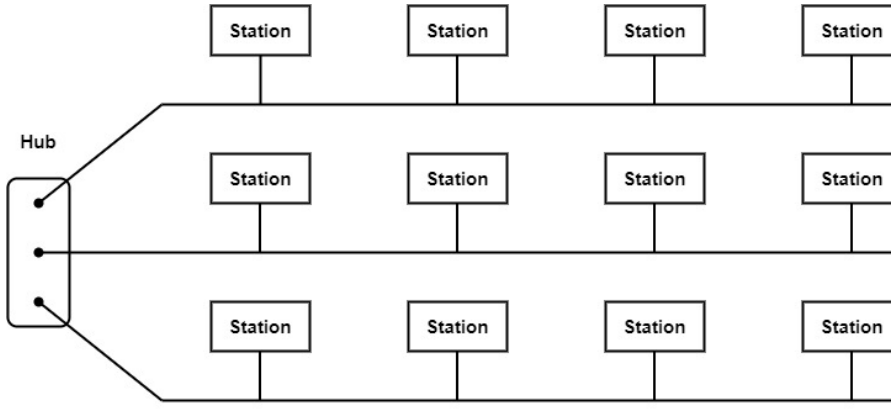

Figure 1.1: A hybrid topology having a star backbone, connecting three bus networks

Q.3.4.1.8 Discuss characteristics of local area networks.
Answer: A local area network (LAN) is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building. Some characteristics of LAN are stated below:
◦ Ethernet and Wi-Fi are the two most common technologies used for local area networks.
◦ A given LAN will use only one type of transmission medium.
◦ The common LAN topologies are bus, ring, star and mesh.
◦ LANs can maintain connections with other LANs via leased lines, leased services, or across the Internet using virtual private network technologies.
◦ LANs provide a reliable data transfer. A typical speed of an ethernet LAN is 100 megabits per second.
◦ A LAN usually has low cost of installation, expansion and maintenance. An installation of LAN is relatively simple.

Q.3.4.1.9 What is the difference between a host and an end system? List different types of end systems.

2. Models of Network

Q.3.4.2.1 What are the principles applied to arrive at the OSI model?
Answer: OSI stands for open systems interconnection. The OSI model has seven layers, each of which has a different level of abstraction and performs a well-defined function. The principles that were applied to arrive at the seven layers are given as follows:
◦ A layer should be created when there is a need of different layer.
◦ Each layer should perform a well-defined function.
◦ The function of each layer should be chosen with an eye toward defining standardized protocols.
◦ The layer boundaries should be chosen so that it can minimize the information flow across the interfaces.
◦ The number of layers should be large enough that distinct functions need not be put together in the same layer out of necessary, and small enough so that the architecture does not become too heavy.

Q.3.4.2.2 Choose the correct option:
Between machines, layer x on one machine communicates with layer y on another machine.
(i) $x < y$, (ii) $x = y$, (iii) $x > y$, (iv) no restriction on x and y
Answer: (ii)

Q.3.4.2.3 Discuss the nature of layers in the OSI model in terms of harware and software implementations.
Answer: The lowest layer of OSI model, i.e., physical layer, is implemented mostly in hardware. The upper layers are almost always implemented in software. But, the lower layers, except the physical layer, are implemented in a combination of hardware and software.

Q.3.4.2.4 State the characteristics and functions performed by the physical layer in OSI model.
Answer: We first discuss some characteristics of the physical layer.
□ Physical Layer defines electrical and physical specifications for devices. The physical layer defines the relationship between a device and a transmission medium, such as a copper or optical cable. This includes the layout of pins, voltages, cable specifications, hubs, repeaters, network adapters, host bus adapters (used in storage area networks) and more

items.
□ The physical layer data consists of a stream of bits without any interpretation. For the purpose of transmition, bits must be encoded into signals - electrical or optical.
□ At the physical layer, the devices are connected to the media. In a point-to-point configuration, two devices are connected through a dedicated link. In a multi-point configuration, a link is shared among several devices.
□ The connection pattern of devices is an important issue, and it is called topology of the network. For example, the devices may be connected through a central device. This is known as star topology.
□ The physical layer also concerned with the direction of transmission between two devices. There are three modes of transmission: simplex, half-duplex, or full-duplex. The simplex mode is a one-way communication. In half-duplex mode, two devices can send and receive, but not at the same time. In full-duplex mode, two devices can send and receive at the same time.
The major functions and services performed by the physical layer are given here.
1) Establishment and termination of a connection to a communication medium
2) Participation in the process whereby the communication resources are effectively shared among multiple users
3) Modulation, or conversion between the representation of digital data in user equipment and the corresponding signals transmitted over a communication channel
4) The sender and receiver clocks must be synchronized.

Q.3.4.2.5 What are the functions performed at the data link layer?
Answer: The main task of the data link layer is to transform a raw transmission facility into a line that appears free of undetected transmission errors to the network layer. It accomplishes this task by having the sender break up the input data into data frames and transmit the frames sequentially. If the service is reliable, the receiver confirms correct receipt of each frame by sending back an acknowledgement frame.
The functions of data link layer are given below:
◦ *Framing*: Frames are formed from the streams of bits received from the network layer. A frame is a manageable unit of data.
◦ *Physical addressing*: The data link layer adds a header to the frame in order to define physical address of the sender and / or receiver of the

frame, if the frames are to be distributed to different systems on the network.
◦ *Flow control*: A flow control mechanism prevents traffic jam at the receiver side, if the receiver is slower than the sender.
◦ *Error control*: Error control is achieved by adding a trailer at the end of the frame. Duplication of frames are also prevented by using this mechanism. Data link layer adds mechanism to prevent duplication of frames.
◦ *Access control*: Protocols of this layer determine which of the devices has control over the link at a given time, when two or more devices are connected to the same link.

Q.3.4.2.6 What is the objective of network layer of OSI model? State its responsibilities.
Answer: The network layer controls the operation of the subnet. The objective of this layer is to deliver packets from the source to destination across multiple links and / or networks.
The responsibilities of network layer include the following:
• It translates logical network address into physical address.
• Routers and gateways operate in the network layer. A mechanism is provided by network layer for routing the packets to final destination.
• Connection services are provided including network layer flow control, network layer error control and packet sequence control.
• It can break larger packets into small packets, if required.

Q.3.4.2.7 State the responsibility of transport layer. Discuss its functions.
Answer: A process is an application program running on a host. The transport layer achieves process-to-process delivery of the entire message. Functions performed by the transport layer are given below.
▷ *Addressing of service-point*: The transport layer header includes the service-point address or port address for source-to-destination delivery. The transport layer gets the entire message to the correct process of the desination computer.
▷ *Segmentation and reassembly*: A message is divided into segments. Each segment contains sequence number, which enables this layer in reassembling the message. Message is reassembled correctly upon arrival at the destination and replaces packets which were lost in transmission.
▷ *Connection control*: In case of a connectionless communication, a transport layer treats each segment as an independent packet and delivers

3. Preliminary Concepts

Q.3.4.3.1 Fill in the blank.
An important function of physical layer is move data in the form of —— through transmission media.
Answer: electromagnetic signals

Q.3.4.3.2 Compare and contrast analog data with digital data.
Answer: Analog data are continuous. They take continuous values. But digital data have discrete states. So, they take discrete values.
Data are stored in computer memory in the form of 0s and 1s. They can be converted to a digital signal or modulated into an analog signal for transmission across a medium.
Sounds made by a human voice are analog in nature. They take continuous values. When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal.

Q.3.4.3.3 Differentiate between analog signal and digital signal.
Answer: An analog signal assumes in the form of a wave. The signal has infinite levels over a period of time. A digital signal, on the other hand, can have only a limited number of defined values.
An analog signal can be expressed using a continuous curve in the X-Y plane, where the strength of a signal is given by its Y-value, at a particular time, given by its X-value. A digital signal, on the other hand, can be represented by a bar chart over a time period. In case of a binary digital signal, high values are represented by 1s, and low values are represented by 0s.

Q.3.4.3.4 Explain the following terms: period, frequency, high frequency, low frequency.
Answer: Period of a periodic signal refers to the amount of time, in seconds, a signal needs to complete one cycle. Frequency refers to the number of periods in one second. In general, frequency is the rate of change of a signal with respect to time. Let the duration of a period represented by T, may be different for each signal but it is constant for any given periodic signal.
Let $g(t)$ be a periodic function of t. The period is the smallest value of

T satisfying $g(t+T) = g(t)$ for all t. Frequency (f) of signal has unit hertz. One hertz is equal to one cycle per second. Now, $f = \frac{1}{T}$.
Frequency is the rate of change with respect to time. Then high frequency refers to a change in a short span of time, and thus, a change over a long span of time yields low frequency.

Q.3.4.3.5 Certain application requires power frequency 100 Hz. Express the period of this sine wave in nanoseconds.
Answer: We have $T = \frac{1}{f} = \frac{1}{100} = 0.01$ s
$= 0.01 \times 10^3$ ms $= 10 \times 10^3 \mu$s $= 10^4 \times 10^3$ns $= 10^7$ns

Q.3.4.3.6 The period of a signal is 10^3ms. Find the frequency in Gigahertz.
Answer: We have $f = \frac{1}{T}$.
Now, $T = 10^3$ms $= 10^3 \times 10^{-3}$s $= 1$ s
$f = \frac{1}{T} = \frac{1}{1}$ Hz $= 1$ Hz $= 1 \times 10^{-3}$ KHz
$= 10^{-3} \times 10^{-3}$ MHz $= 10^{-6} \times 10^{-3}$ GHz $= 10^{-9}$ GHz

Q.3.4.3.7 Discuss the notion of phase of a waveform.
Answer: It describes the position of a waveform relative to time 0. If we think of the wave as something that can be shifted backward or forward along the time axis, a phase describes the amount of that shift. It indicates the status of the first cycle.
Phase is measured in degrees or radians, and we have the relationship: $180^\circ = \pi$ radian. Consider a sine wave with a phase of 0° starts at time 0 with a zero amplitude. A phase shift of 360° corresponds to a shift, either forward or backward, of a complete period.

Q.3.4.3.8 How does a phase be expressed in terms of shift or offset?
Answer: This can be explained using the following examples.
1. A sine wave with a phase of 0° has not been shifted.
2. A sine wave with a phase of 45° has been shifted to the left by $\frac{45}{360}$ i.e., $\frac{1}{8}$ of a cycle. In this case, the signal does not exist before time 0.
3. A sine wave with a phase of 180° has been shifted to the left by $\frac{180}{360}$ i.e., $\frac{1}{2}$ of a cycle. In this case, the signal does not exist before time 0.

Q.3.4.3.9 A sine wave has offset of $\frac{1}{12}$ of a cycle. Calculate its phase in degrees and radians.
Answer: 1 complete cycle $= 360^\circ$.
Then phase in degrees $= \frac{1}{12} \times 360^\circ = 30^\circ$

Phase in radians $= 30 \times \frac{\pi}{180}$ rad $= \frac{22}{7\times 6}$ rad $= 0.5238$ rad

Q.3.4.3.10 Fill in the blank.
Consider a signal that does not change over time. Then the frequency of the signal is ——.
Answer: zero

Q.3.4.3.11 What is wavelength? Give the expression of wavelength for sinusoidal waves.
Answer: The wavelength is the spatial period of a periodic wave, i.e., the distance over which the wave's shape repeats. It is the distance between consecutive corresponding points of the same phase on the wave, such as two adjacent crests, troughs, or zero crossings, and is a characteristic of both traveling waves and standing waves, as well as other spatial wave patterns. The inverse of the wavelength is called the spatial frequency.
The wavelength of a sine wave, λ, can be measured between any two points with the same phase, such as between crests (on top), or troughs (on bottom), or corresponding zero crossings as shown in Fig. 3.1.

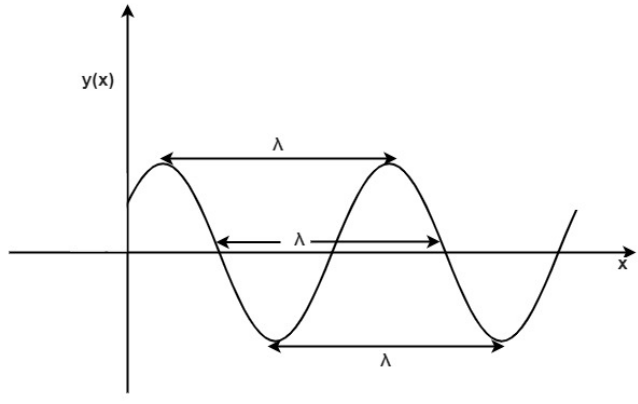

Figure 3.1: Wavelength of a sinusoidal wave

In linear media, any wave pattern can be described in terms of the independent propagation of sinusoidal components. The wavelength, λ, of a sinusoidal waveform traveling at constant speed v is given by

$$\lambda = \frac{v}{f}$$

where, v is called the phase speed (magnitude of the phase velocity) of the wave and f is the wave's frequency.