

HEME OF VALUATION

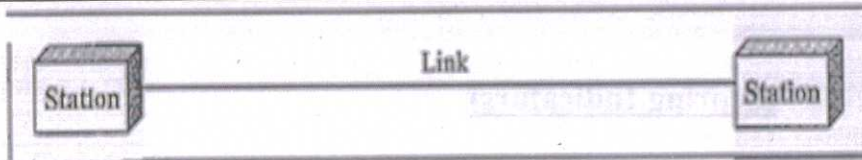
(Scoring Indicators)

Revision: 2015

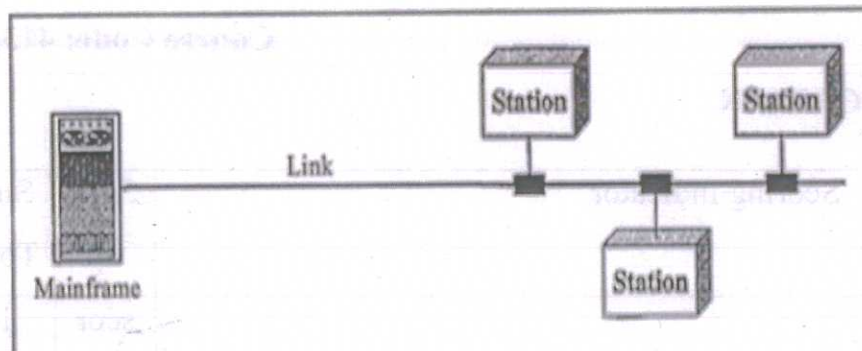
Course Code: 4132

Course Title: DATA COMMUNICATION

Qst. No	Scoring Indicator	Split up score	Sub Total	Total
<u>PART A</u>				
I(i)	Delivery, accuracy, timeliness, and jitter.	2	2	10
I(ii)	Baseband transmission means sending a digital signal over a channel without changing the digital signal to an analog signal	2	2	
I(iii)	Twisted pair cable, coaxial cable, fiber optic cable	2	2	
I(iv)	The Hamming distance between two words (of the same size) is the number of differences between the corresponding bits.	2	2	
I(v)	The range of frequencies contained in a composite signal is its bandwidth..	2	2	
<u>PART B</u>				
II(i)	<p>A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices. Most point-to-point connections use an actual length of wire or cable to connect the two ends</p> <p>Multipoint- A multipoint (also called multi drop) connection is one in which more than two specific devices share a single link .In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a spatially shared connection.</p>	2fig + 4Exp	6	



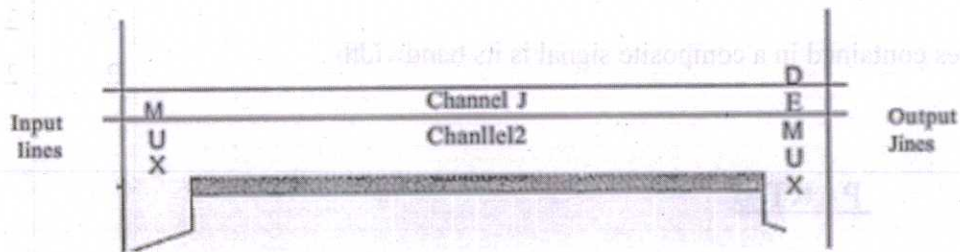
a. Point-to-point



II(ii)

Frequency-Division Multiplexing is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted. In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal. These bandwidth ranges are the channels through which the various signals travel. Channels can be separated by strips of unused bandwidth-guard bands-to prevent signals from overlapping.

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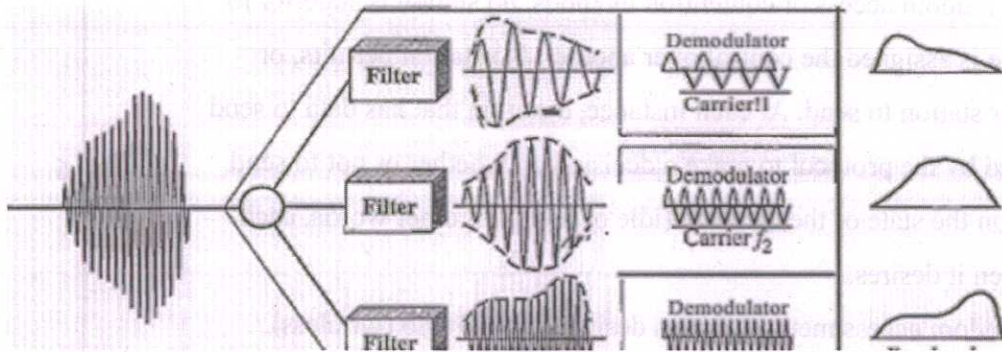
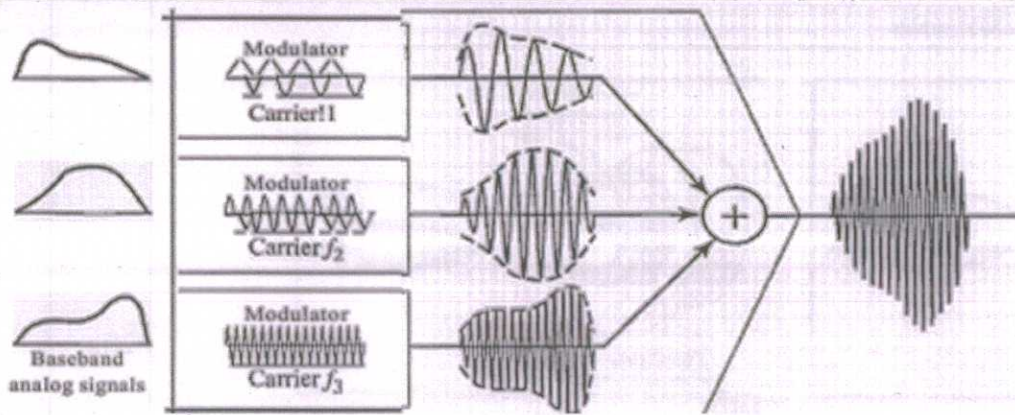


Multiplexing process- Each source generates a signal of a similar frequency range. Inside the multiplexer, these similar signals modulates different carrier frequencies ($f_1, f_2, \text{ and } f_n$). The resulting modulated signals are then combined into a single composite signal that is sent out over a media link that has enough bandwidth to accommodate it.

2

Demultiplexing Process The demultiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals. The individual signals are then passed to a demodulator that separates them from their carriers and passes them to the output lines

6



2

II(iii)

.A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together



One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two. In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.

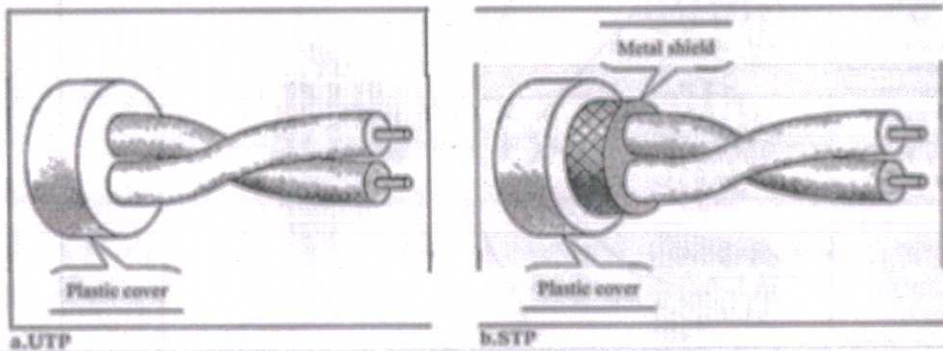
Unshielded Versus Shielded Twisted-Pair Cable The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP). IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP). STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors. Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.

4

expl

6

Figure 7.4 UTP and STP cables



II(iv)

2fig

RANDOMACCESS In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits, or does not permit, another station to send. At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send. This decision depends on the state of the medium (idle or busy). In other words, each station can transmit when it desires.

6

ALOHA, the earliest random access method, It was designed for a radio (wireless) LAN, but it can be used on any shared medium. The medium is shared between the stations. When a station sends data, another station may attempt to do so at the same time. The data from the two stations collide and become garbled

Pure ALOHA

The original ALOHA protocol is called pure ALOHA. This is a simple, but elegant protocol. The idea is that each station sends a frame whenever it has a frame to send. However, since there is only one channel to share, there is the possibility of collision between frames from different stations.

2

Slotted ALOHA

Pure ALOHA has a vulnerable time of $2 \times T_{fr}$. This is so because there is no rule that defines when the station can send. A station may send soon after another station has started or soon before another station has finished. Slotted ALOHA was invented to improve the efficiency of pure ALOHA. In slotted ALOHA we divide the time into slots of T_{fr} s and force the station to send only at the beginning of the time slot.

6

Carrier Sense Multiple Access (CSMA)

To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed. The chance of collision can be reduced if a station senses the medium before trying to use it. Carrier sense multiple access (CSMA) requires that each station first listen to the medium before sending. CSMA can reduce the possibility of collision, but it cannot eliminate it.

2

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

II(v)

The CSMA method does not specify the procedure following a collision. Carrier senses multiple access with collision detection (CSMA/CD) augments the algorithm to handle the collision.

In this method, a station monitors the medium after it sends a frame to see if the transmission was successful. If so, the station is finished. If, however, there is a collision, the frame is sent again.

At time t_1 , station A has executed its persistence procedure and starts sending the bits of its frame. At time t_2 , station C has not yet sensed the first bit sent by A. Station C executes its persistence procedure and starts sending .

The collision occurs sometime after time t_2' Station C detects a collision at time t_3 when it receives the first bit of A's frame. Station C immediately aborts transmission. Station A detects collision at time t_4 when it receives the first bit of C's frame; it also immediately aborts transmission

The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another.

There are four basic topologies possible: mesh, star, bus, and ring

Mesh- every device has a dedicated point-to-point link to every other device. The term dedicated means that the link carries traffic only between the two devices it connects.

To find the number of physical links in a fully connected mesh network with n nodes, we first consider that each node must be connected to every other node. Node 1 must be connected to $n - 1$ nodes, node 2 must be connected to $n - 1$ nodes, and finally node n must be connected to $n - 1$ nodes.

Advantages over other network topologies.

eliminating the traffic problems that can occur when links must be shared by multiple devices

A mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system.

There is the advantage of privacy or security. When every, message travels along a dedicated line, only the intended recipient sees it.

point-to-point links make fault identification and fault isolation easy.

The main disadvantages of a mesh are related to the amount of cabling and the number of I/O ports

installation and reconnection are difficult.

the sheer bulk of the wiring can be greater than the available space

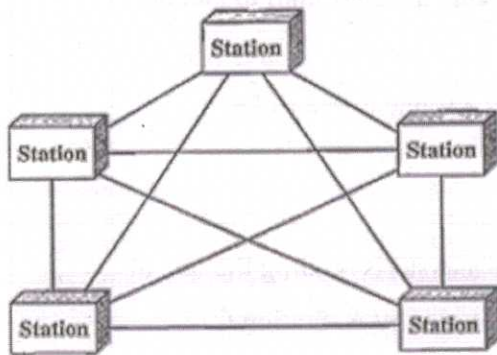
the hardware required to connect each link (I/O ports and cable) can be prohibitively expensive. Egs-telephone regional offices in which each regional office needs to be

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2+2+
2

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connected to every other regional office.



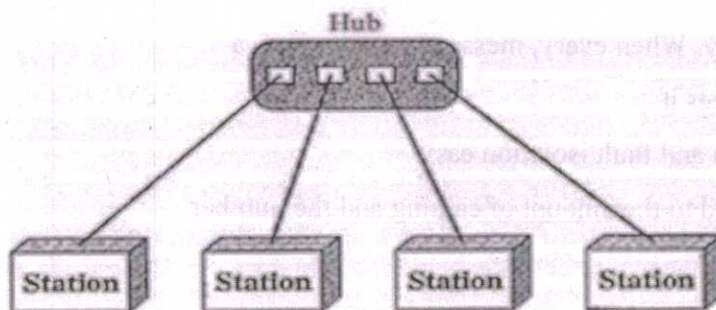
Star Topology- each device has a dedicated point-to-point link only to a central controller, usually called a hub. The devices are not directly linked to one another. a star topology does not allow direct traffic between devices. The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device

A star topology is less expensive than a mesh topology. In a star, each device needs only one link and one I/O port to connect it to any number of others. This factor also makes it easy to install and reconfigure. Far less cabling needs to be housed, and additions, moves, and deletions involve only one connection: between that device and the hub.

If one link fails, only that link is affected. All other links remain active. This factor also lends itself to easy fault identification and fault isolation.

disadvantage of a star topology is the dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead.

The star topology is used in local-area networks (LANs), High-speed LANs often use a star topology with a central hub.



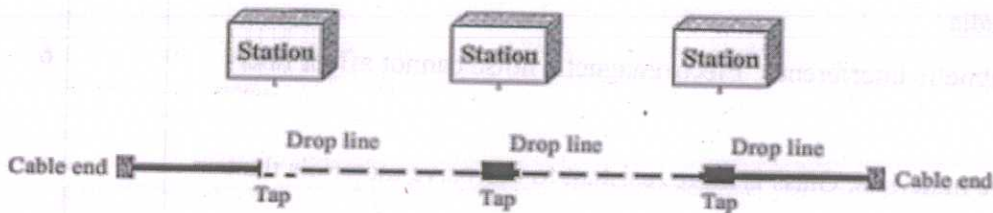
Bus topology- is multipoint. One long cable acts as a backbone to link all the devices in a network

Nodes are connected to the bus cable by drop lines and taps. A drop line is a connection

running between the device and the main cable. A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core. As a signal travels along the backbone, some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it travels farther and farther. For this reason there is a limit on the number of taps a bus can support and on the distance between those taps.

Advantages - ease of installation.

Disadvantages include difficult reconnection and fault isolation. It can therefore be difficult to add new devices.



II(vi)

Periodic analog signals can be classified as simple or composite.

A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals.

A composite periodic analog signal is composed of multiple sine waves.

Sine Wave- is the most fundamental form of a periodic analog signal. Each cycle consists of a single arc above the time axis followed by a single arc below it.

A sine wave can be represented by three parameters: the peak amplitude, the frequency, and the phase.

Peak Amplitude -is the absolute value of its highest intensity, proportional to the energy it carries. For electric signals, peak amplitude is normally measured in volts.

Frequency refers to the number of periods in 1 s. Note that period and frequency are just one characteristic defined in two ways. Period is the inverse of frequency, and frequency is the inverse of period, as the following formulas show. $f=1/T$ and $T=1/f$

Phase The term phase describes the position of the waveform relative to time 0. If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift.

Wavelength is another characteristic of a signal traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium.

The time-domain plot shows changes in signal amplitude with respect to time (it is an

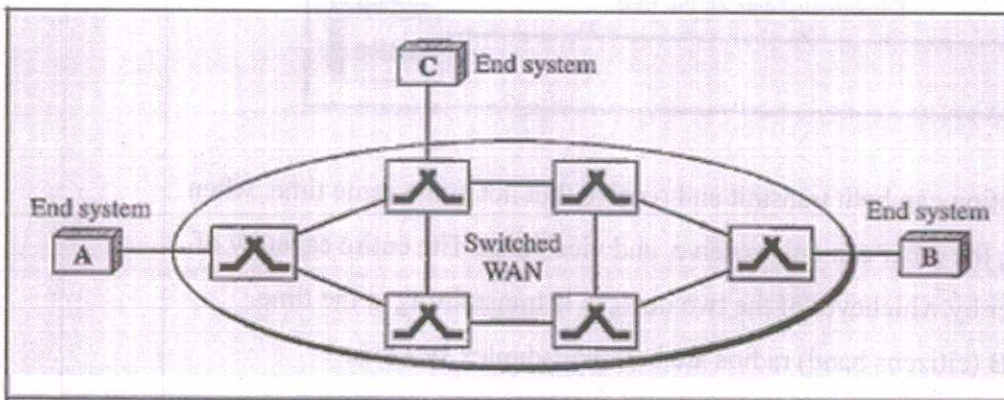
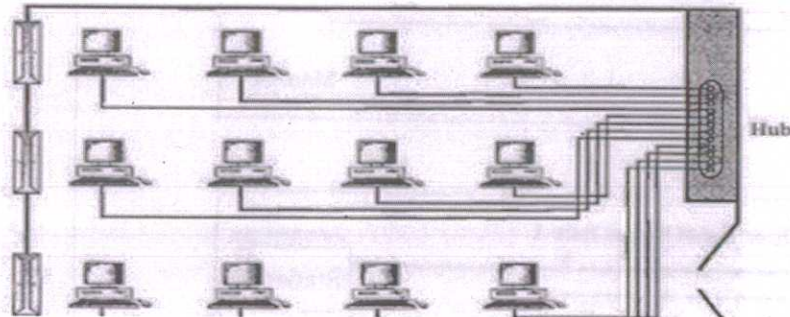
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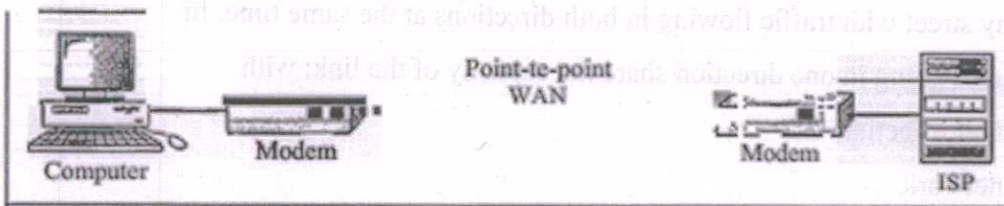
<p>II(vii))</p>	<p>amplitude-versus-time plot). Phase is not explicitly shown on a time domain plot. A frequency-domain plot is concerned with only the peak value and the frequency. Changes of amplitude during one period are not shown Composite Signals - A composite signal is made of many simple sine waves. A single-frequency sine wave is not useful in data communications; we need to send a composite signal, a signal made of many simple sine waves. Advantages Fiber-optic cable Higher bandwidth. Less signal attenuation. Fiber-optic transmission distance is significantly greater than that of other guided media Immunity to electromagnetic interference. Electromagnetic noise cannot affect fiber-optic cables. Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper. Light weight. Fiber-optic cables are much lighter than copper cables. * Greater immunity to tapping. Disadvantages - Installation and maintenance. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere. Unidirectional light propagation. -Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed. Cost. The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified</p>	<p>3+3</p>	<p>6</p>
<p>III(a)</p>	<p>The category into which a network falls is determined by its size. A LAN normally covers an area less than 2 mi; a WAN can be worldwide. Networks of a size in between are normally referred to as metropolitan area networks and span tens of miles. LAN- is usually privately owned and links the devices in a single office, building, or campus . Depending on the needs of an organization and the type of technology used, a LAN can be as simple as two PCs and a printer in someone's home office; or it can extend throughout a company and include audio and video peripherals. Currently, LAN size is limited to a few kilo meters. A wide area network (WAN) provides long-distance transmission of data, image, audio, and video information over large geographic areas that may comprise a country, a continent, or even the whole world The switched WAN connects the end systems, which usually comprise a router</p>	<p>4+3+3</p>	<p>10</p>

(internetworking connecting device) that connects to another LAN or WAN.

The point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an Internet service provider (ISP). This type of WAN is often used to provide Internet access



a. Switched WAN



b. Point-to-point WAN

Metropolitan Area Networks is a network with a size between a LAN and a WAN. It normally covers the area inside a town or a city. It is designed for customers who need a high-speed connectivity, normally to the Internet, and have endpoints spread over a city or part of city

Examples- the telephone company network that can provide a high-speed DSL line to the customer.

III(b) cable TV network that originally was designed for cable TV

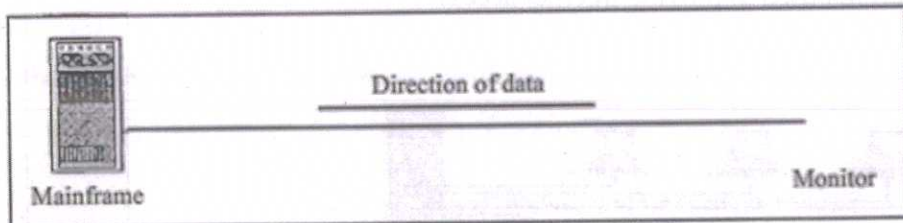
Communication between two devices can be simplex, half-duplex, or full-duplex .

In simplex mode, the communication is unidirectional, as on a one-way street. Only

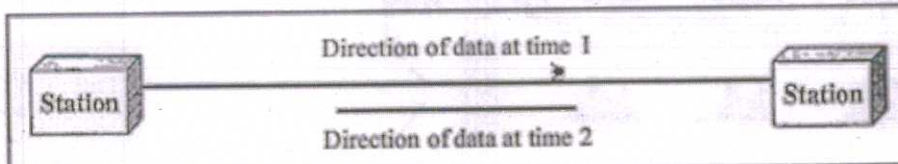
one of the two devices on a link can transmit; the other can only receive .Keyboards and traditional monitors are examples of simplex devices.

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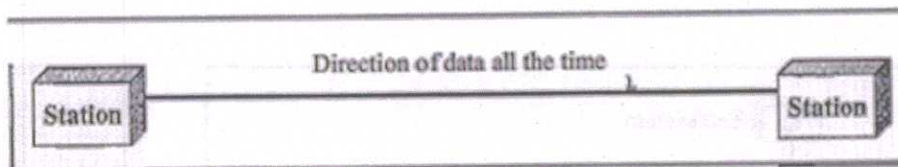
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a. Simplex



b. Half-duplex



c. Full-duplex

Half-Duplex- each station can both transmit and receive, but not at the same time. when one device is sending, the other can only receive, and vice versa. The entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.

Walkie-talkies and CB (citizens band) radios are both half-duplex systems.

Full-Duplex -both stations can transmit and receive simultaneously .The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time. In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction.

Example- telephone network.

The physical layer is also concerned with the following:

Physical characteristics of interfaces and medium.

Representation of bits. The physical layer data consists of a stream of bits

Data rate

Synchronization of bits

Line configuration

Physical topology

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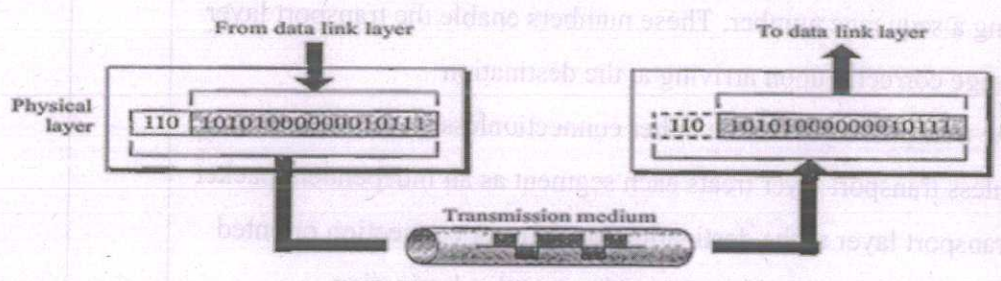
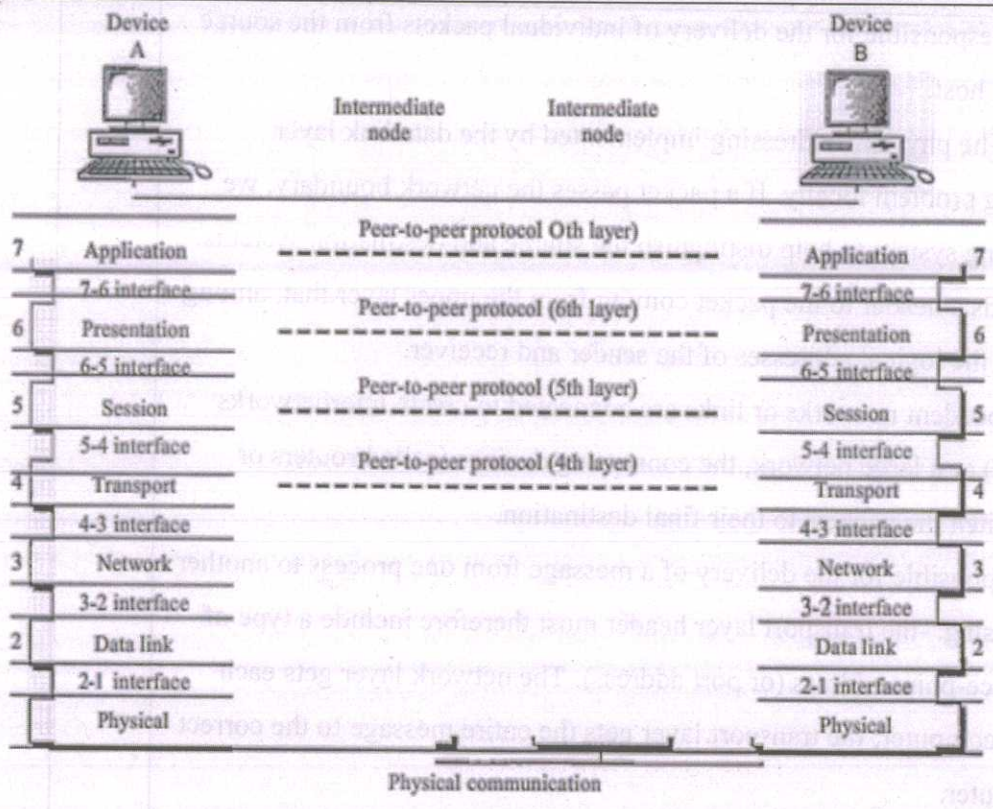
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IV



The physical layer is responsible for movements of individual bits from one node to the next

Data Link Layer

Physical addressing. If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver .

Flow control. If the rate at which the data are absorbed by the receiver is less than the rate at which data are produced in the sender, the data link layer imposes a flow control mechanism to avoid overwhelming the receiver.

Error control. The data link layer adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames. It also uses a mechanism to recognize duplicate frames. Error control is normally achieved through a trailer added to the end of the frame.

Access control. When two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Logical addressing. The physical addressing implemented by the data link layer handles the addressing problem locally. If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems. The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender and receiver.

Routing. When independent networks or links are connected to create internetworks (network of networks) or a large network, the connecting devices (called routers or switches) route or switch the packets to their final destination.

Transport layer is responsible for the delivery of a message from one process to another.

Service-point addressing. -the transport layer header must therefore include a type of address called a service-point address (or port address). The network layer gets each packet to the correct computer; the transport layer gets the entire message to the correct process on that computer.

Segmentation and reassembly. A message is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination

Connection control-The transport layer can be either connectionless or connection oriented. A connectionless transport layer treats each segment as an independent packet and delivers it to the transport layer at the destination machine. A connection oriented transport layer makes a connection with the transport layer at the destination

The session layer is responsible for dialog control and synchronization.

Dialog control- The session layer allows two systems to enter into a dialog. It allows the communication between two processes to take place in either half-duplex or full-duplex (two ways at a time) mode.

Synchronization. The session layer allows a process to add checkpoints, or synchronization points, to a stream of data.

The presentation layer is responsible for translation, compression, and encryption.

The application layer is responsible for providing services to the user.

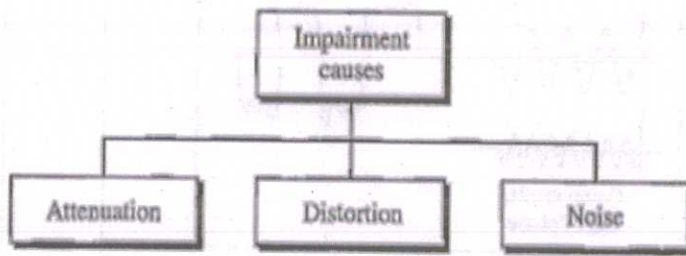
Network virtual terminal. A network virtual terminal is a software version of a physical terminal, and it allows a user to log on to a remote host

File transfer, access, and management. This application allows a user to access files in a remote host (to make changes or read data), to retrieve files from a remote computer for use in the local computer, and to manage or control files in a remote computer locally.

Mail services.

V(a)

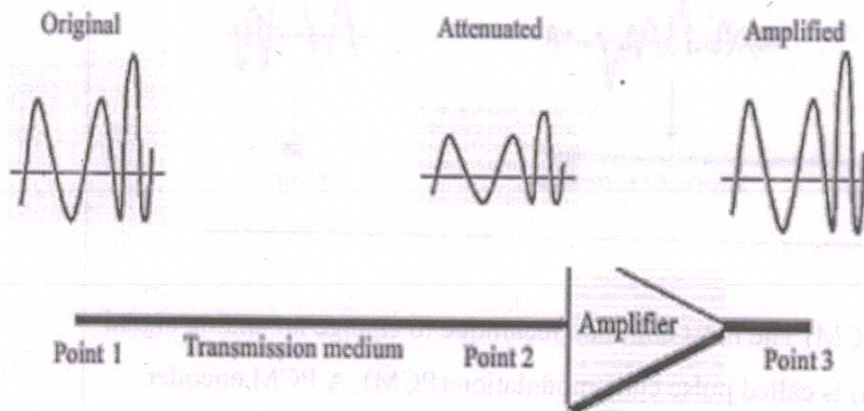
Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment



2fig+
2+2+
2

8

Attenuation Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium.



Distortion means that the signal changes its form or shape. Distortion can occur in a composite signal made of different frequencies. Each signal component has its own propagation speed (see the next section) through a medium and, therefore, its own delay in arriving at the final destination. Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.

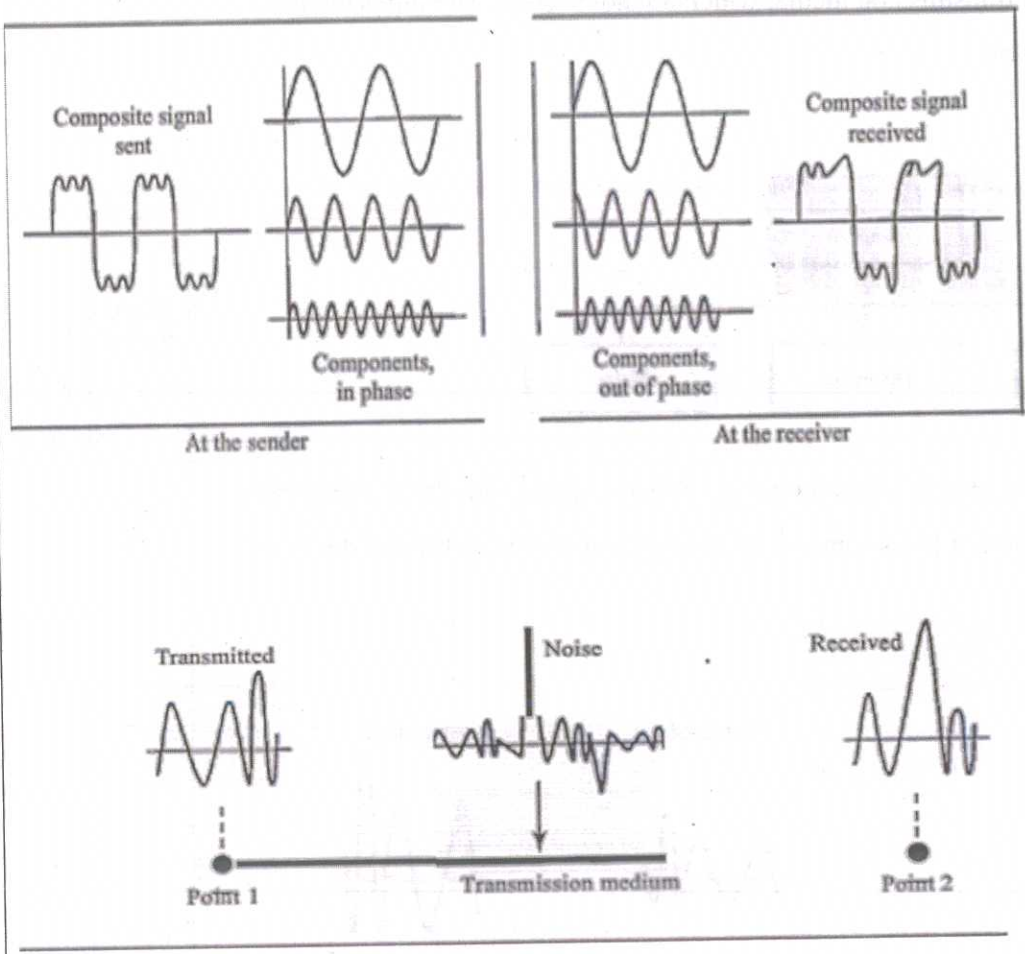
Noise- Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.

Thermal noise is the random motion of electrons in a wire which creates an extra signal not originally sent by the transmitter.

Induced noise comes from sources such as motors and appliances.

Crosstalk is the effect of one wire on the other.

Impulse noise is a spike (a signal with high energy in a very short time) that comes from power lines, lightning, and so on



V(b)

Pulse Code Modulation (PCM) The most common technique to change an analog signal to digital data (digitization) is called pulse code modulation (PCM). A PCM encoder has three processes.

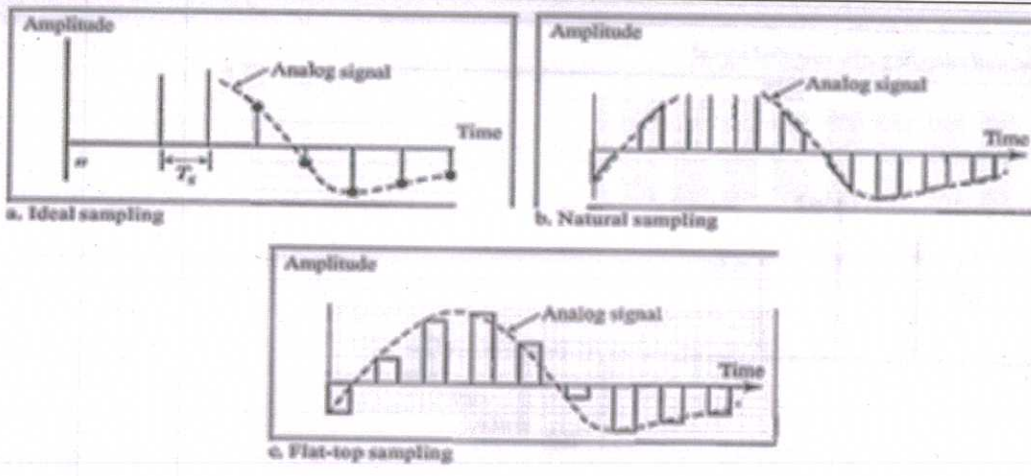
1. The analog signal is sampled.
2. The sampled signal is quantized
3. The quantized values are encoded as streams of bits.

The first step in PCM is sampling. The analog signal is sampled every T_s s, where T_s is the sample interval or period. The inverse of the sampling interval is called the sampling rate or sampling frequency.

There are three sampling methods-ideal, natural, and flat-top-as shown in Figure 4.22. In ideal sampling, pulses from the analog signal are sampled. This is an ideal sampling method and cannot be easily implemented.

In natural sampling, a high-speed switch is turned on for only the small period of time when the sampling occurs. The result is a sequence of samples that retains the shape of the analog signal. The most common sampling method, called sample and hold, however, creates flat-top samples by using a circuit.

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expl



Quantization The result of sampling is a series of pulses with amplitude values between the maximum and minimum amplitudes of the signal. The set of amplitudes can be infinite with non-integral values between the two limits. These values cannot be used in the encoding process. The following are the steps in quantization: 1. We assume that the original analog signal has instantaneous amplitudes between V_{min} and V_{max} .

2. We divide the range into L zones, each of height Δ (delta).

$$\Delta = \frac{V_{max} - V_{min}}{L}$$

3. We assign quantized values of 0 to $L - 1$ to the midpoint of each zone.

4. We approximate the value of the sample amplitude to the quantized values.

The quantization process selects the quantization value from the middle of each zone.

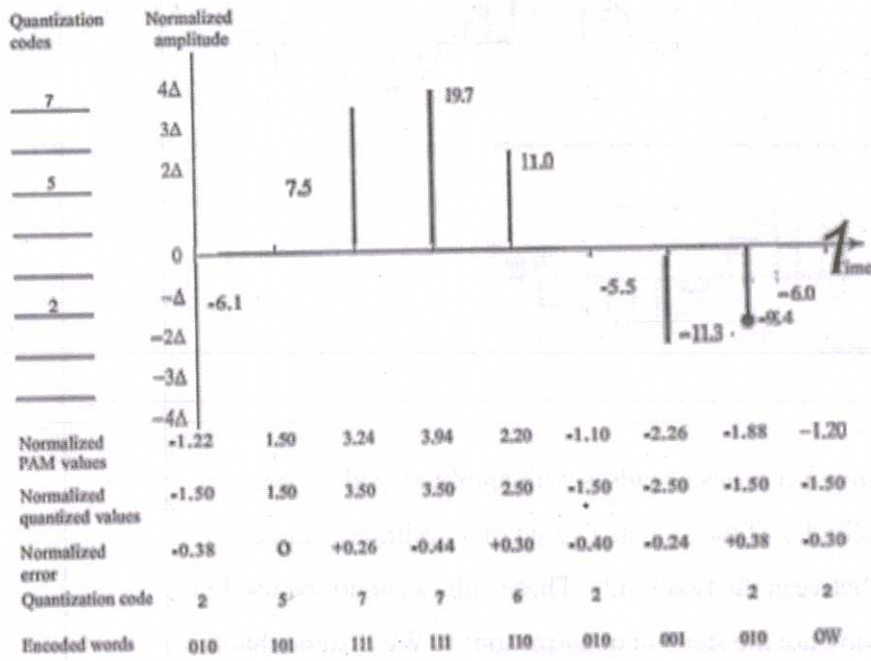
This means that the normalized quantized values (second row) are different from the normalized amplitudes. The difference is called the normalized error (third row).

The fourth row is the quantization code for each sample based on the quantization levels at the left of the graph. The encoded words (fifth row) are the final products of the conversion.

Encoding- The last step in PCM is encoding. After each sample is quantized and the number of bits per sample is decided, each sample can be changed to an $\log_2 L$ -bit code word. In Figure 4.26 the encoded words are shown in the last row. A quantization code of 2 is encoded as 010; 5 is encoded as 101; and so on. Note that the number of bits for each sample is determined from the number of quantization levels. If the number of quantization levels is L , the number of bits is $\log_2 L$. In our example L is 8 and $\log_2 L$ is therefore 3.

Example-

Figure 4.26 Quantization and encoding of a sampled signal

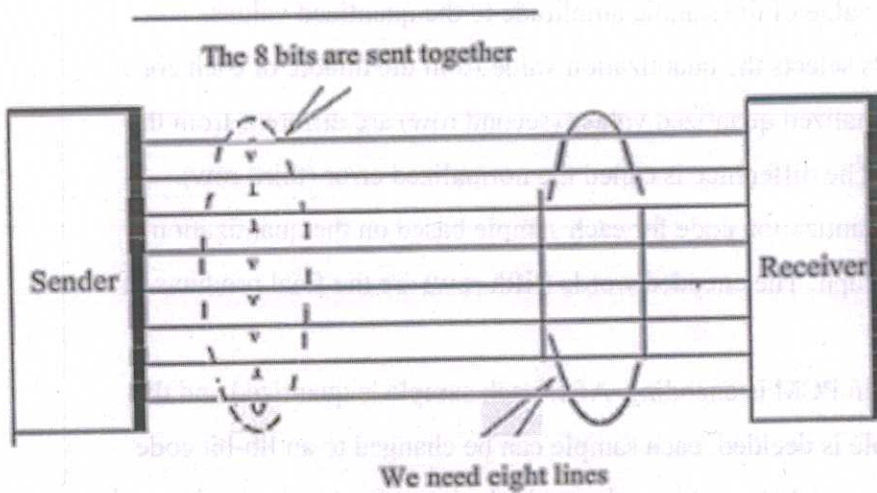


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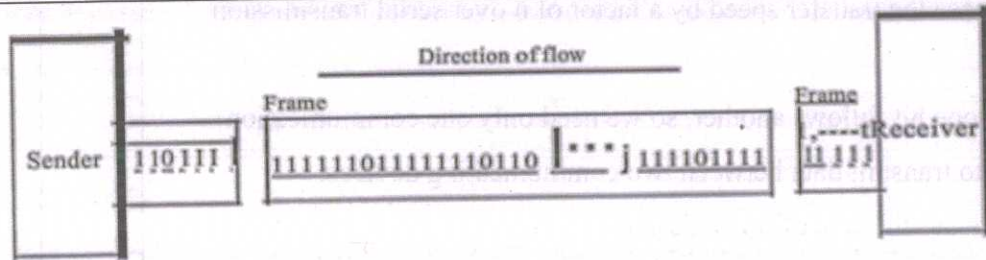
The transmission of binary data across a link can be accomplished in either parallel or serial mode. In parallel mode, multiple bits are sent with each clock tick. In serial mode, 1 bit is sent with each clock tick. While there is only one way to send parallel data, there are three subclasses of serial transmission: asynchronous, synchronous, and isochronous.

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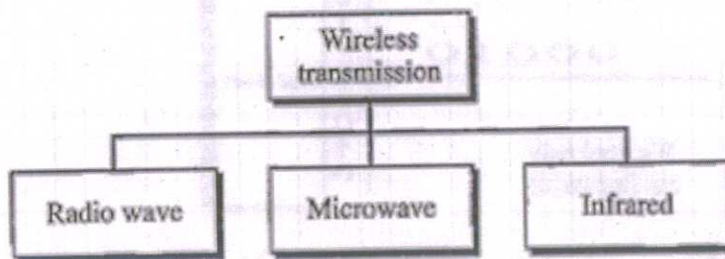
Parallel Transmission Binary data, consisting of 1s and 0s, may be organized into groups of n bits each. By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission. The mechanism for parallel transmission is a conceptually simple one: Use n wires to send n bits at one time. That way each bit has its own wire, and all n bits of one group can be transmitted with each clock tick from one device to another. The advantage of parallel transmission is speed. All else being equal, parallel



VII

The advantage of synchronous transmission is speed.

This type of communication is often referred to as wireless communication. Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them



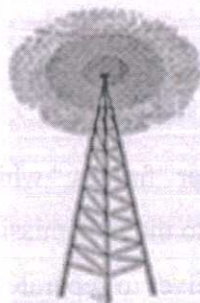
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1. Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves; waves ranging in frequencies between 1 and 300 GHz are called microwaves. However, the behavior of the waves, rather than the frequencies, is a better criterion for classification. Radio waves, for the most part, are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna. The omnidirectional property has a disadvantage, too. The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

Omnidirectional Antenna Radio waves use omnidirectional antennas that send out signals in all directions

Omnidirectional antenna



Applications- The omnidirectional characteristics of radio waves make them useful for

multicasting, in which there is one sender but many receivers

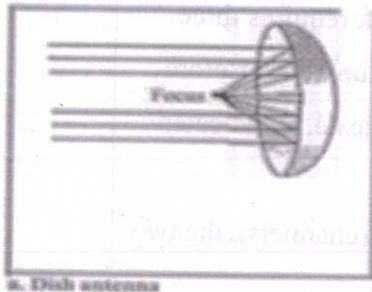
Microwaves Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas. The following describes some characteristics of microwave propagation:

Microwave propagation is line-of-sight.

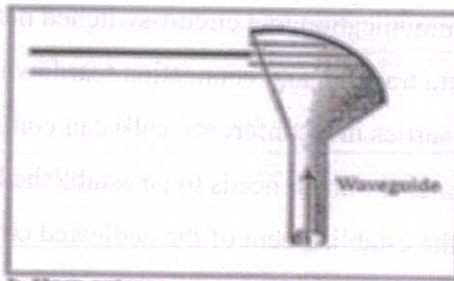
Very high-frequency microwaves cannot penetrate walls.

Use of certain portions of the band requires permission from authorities.

Unidirectional Antenna Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications: the parabolic dish and the horn.



a. Dish antenna



b. Horn antenna

Applications Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed

Infrared Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls.

Example- infrared remote control

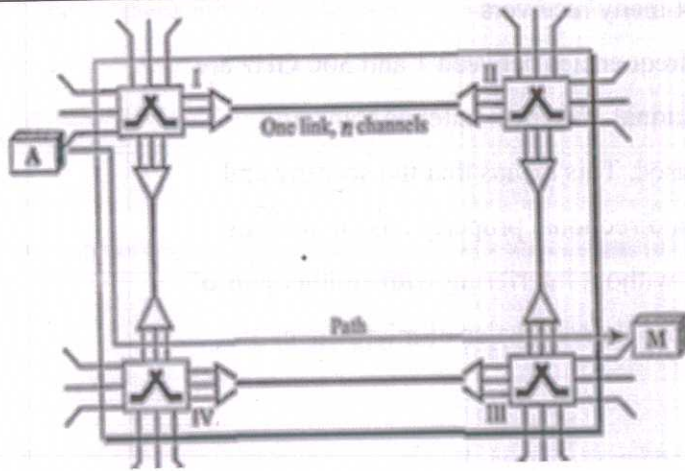
Applications-established standards for using these signals for communication between devices such as keyboards, mice, PCs, and printers.

A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links.

However, each connection uses only one dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM. The end systems, such as computers or telephones, are directly connected to a switch.

3
fig+5

8



When end system A needs to communicate with end system M, system A needs to request a connection to M that must be accepted by all switches as well as by M itself. This is called the setup phase; a circuit (channel) is reserved on each link, and the combination of circuits or channels defines the dedicated path. After the dedicated path made of connected circuits (channels) is established, data transfer can take place. After all data have been transferred, the circuits are torn down.

Three Phases The actual communication in a circuit-switched network requires three phases: connection setup, data transfer, and connection teardown. **Setup Phase** Before the two parties (or multiple parties in a conference call) can communicate, a dedicated circuit (combination of channels in links) needs to be established.

Data Transfer Phase After the establishment of the dedicated circuit (channels), the two parties can transfer data.

Teardown Phase When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

VIII(b)
)

VIRTUAL-CIRCUIT NETWORKS A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both. 1. As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.

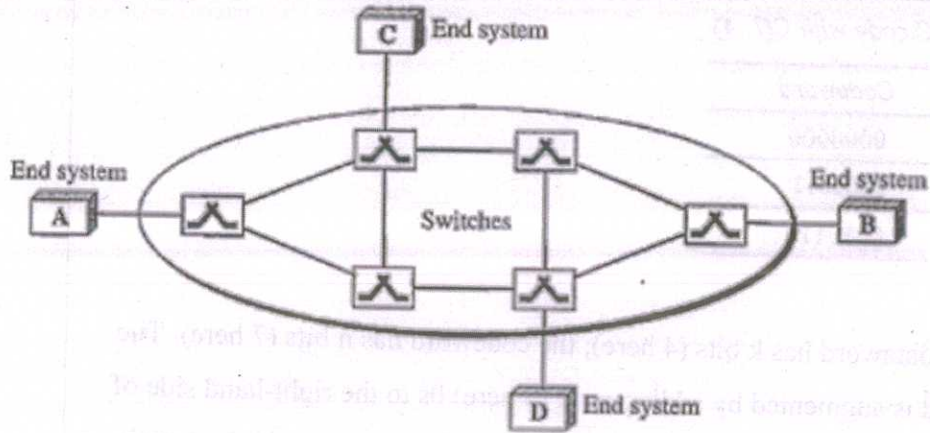
2. Resources can be allocated during the setup phase, as in a circuit-switched network, or on demand, as in a datagram network.

3. As in a datagram network, data are packetized and each packet carries an address in the header.

4. As in a circuit-switched network, all packets follow the same path established during the connection.

5. A virtual-circuit network is normally implemented in the data link layer, while a circuit-switched network is implemented in the physical layer and a datagram network in the network layer.

3
fig+4



Addressing In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).

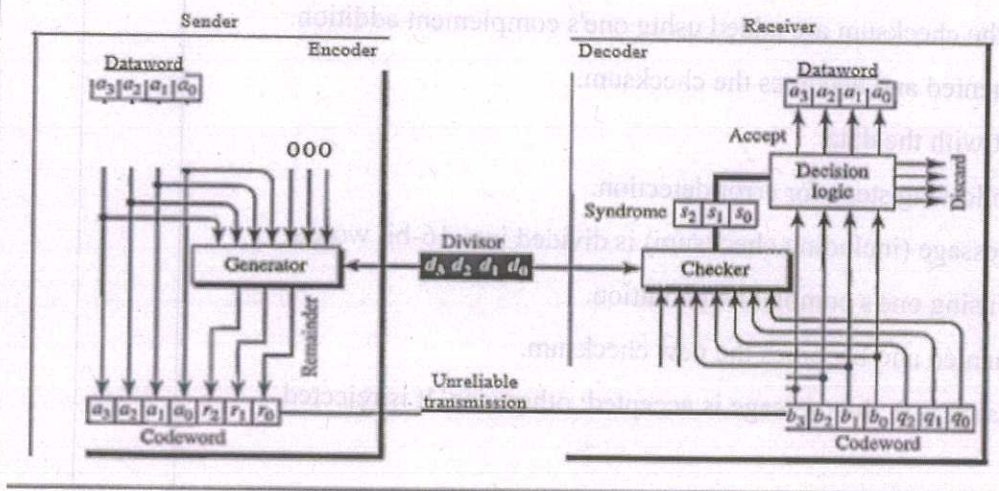
Global Addressing A source or a destination needs to have a global address—an address that can be unique in the scope of the network or internationally if the network is part of an international network.

Virtual-Circuit Identifier The identifier that is actually used for data transfer is called the virtual-circuit identifier (Vel). A vel, unlike a global address, is a small number that has only switch scope.

IX(a) Cyclic codes are special linear block codes with one extra property. In a cyclic code, if a codeword is cyclically shifted (rotated), the result is another codeword.

a category of cyclic codes called the cyclic redundancy check (CRC) that is used in networks such as LANs and WANs.

Figure 10.14 CRC encoder and decoder



4
fig+6

10

Table 10.6 A CRC code with $C(7, 4)$

Dataword	Codeword
0000	0000000
0001	0001011
0010	0010110

In the encoder, the dataword has k bits (4 here); the codeword has n bits (7 here). The size of the dataword is augmented by adding $n - k$ (3 here) 0s to the right-hand side of the word. The n -bit result is fed into the generator. The generator uses a divisor of size $n - k + 1$ (4 here), predefined and agreed upon. The generator divides the augmented dataword by the divisor (modulo-2 division). The quotient of the division is discarded; the remainder (r_{2r1r0}) is appended to the dataword to create the codeword. The decoder receives the possibly corrupted codeword. A copy of all n bits is fed to the checker which is a replica of the generator. The remainder produced by the checker is a syndrome of $n - k$ (3 here) bits, which is fed to the decision logic analyzer. The analyzer has a simple function. If the syndrome bits are all as, the 4 leftmost bits of the codeword are accepted as the dataword (interpreted as no error); otherwise, the 4 bits are discarded (error).

IX(b) The checksum is used in the Internet by several protocols although not at the data link layer

the Internet has been using a 16-bit checksum. The sender calculates the checksum by following these steps.

1. The message is divided into 16-bit words.
2. The value of the checksum word is set to 0.
3. All words including the checksum are added using one's complement addition.
4. The sum is complemented and becomes the checksum.
5. The checksum is sent with the data.

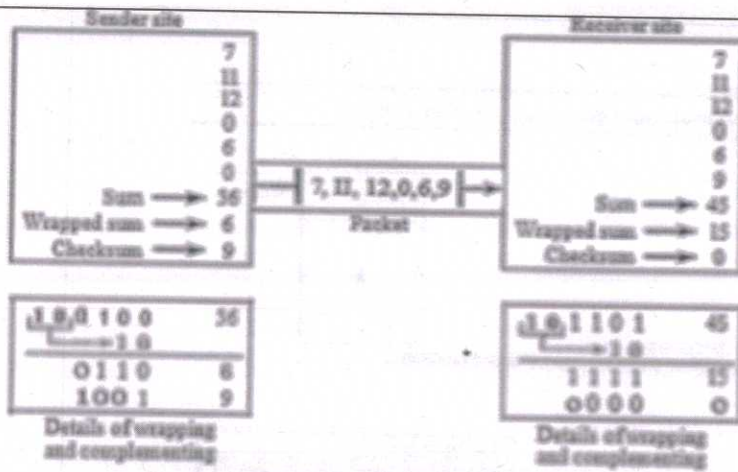
The receiver uses the following steps for error detection.

1. The message (including checksum) is divided into 16-bit words.
2. All words are added using one's complement addition.
3. The sum is complemented and becomes the new checksum.
4. If the value of checksum is 0, the message is accepted; otherwise, it is rejected.

Example-

5

5



two protocols for this type of channel. The first is a protocol that does not use flow control; the second is the one that does. Of course, neither has error control because we have assumed that the channel is a perfect noiseless channel.

Simplest Protocol - is one that has no flow or error control.

it is a unidirectional protocol in which data frames are traveling in only one direction- from the sender to receiver. We assume that the receiver can immediately handle any frame it receives with a processing time that is small enough to be negligible. The data link layer of the receiver immediately removes the header from the frame and hands the data packet to its network layer, which can also accept the packet immediately

Design

There is no need for flow control in this scheme.

The data link layer at the sender site gets data from its network layer, makes a frame out of the data, and sends it. The data link layer at the receiver site receives a frame from its physical layer, extracts data from the frame, and delivers the data to its network layer.

The data link layers of the sender and receiver provide transmission services for their network layers

. The procedure at the sender site is constantly running; there is no action until there is a request from the network layer.

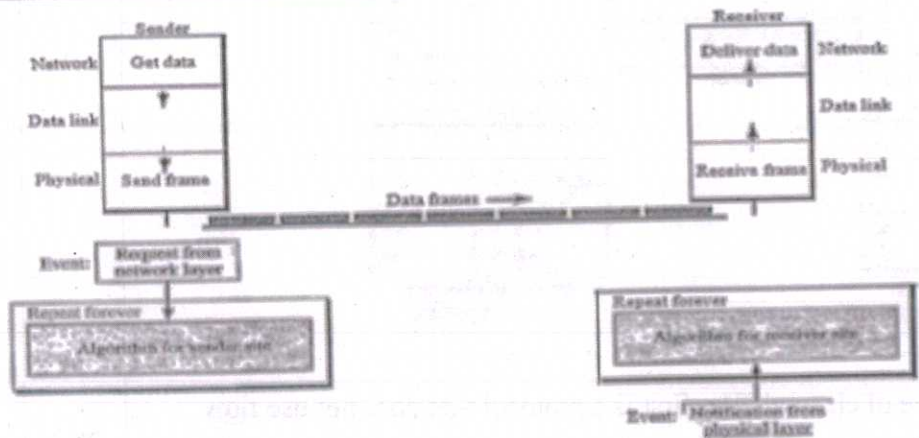
Algorithm 11.1. Sender-site algorithm for the simplest protocol

```

1 while (true) // Repeat forever
2 {
3   WaitForEvent() // Sleep until an event occurs
4   if(Event(RequestToSend)) // There is a packet to send
5   {
6     GetData()
7     MakeFrame()
8     SendFrame() // Send the frame
9   }
10 }

```

Figure 11.6 The design of the simplest protocol with no flow or error control



Algorithm 11.1 Sender-site algorithm for the simplest protocol

```

1 while (true) // Repeat forever
2 {
3   WaitForEvent() // Sleep until an event occurs
4   if(Event(RequestToSend)) // There is a packet to send
5   {
6     GetData()
7     MakeFrame()
8     SendFrame() // Send the frame
9   }
10 }

```

Algorithm 11.2 Receiver-site algorithm for the simplest protocol

```

1 while(true) // Repeat forever
2 {
3   WaitForEvent() // Sleep until an event occurs
4   if(Event(ArrivalNotification)) // Data frame arrived
5   {
6     ReceiveFrame()
7     ExtractData()
8     DeliverData() // Deliver data to network layer
9   }
10 }

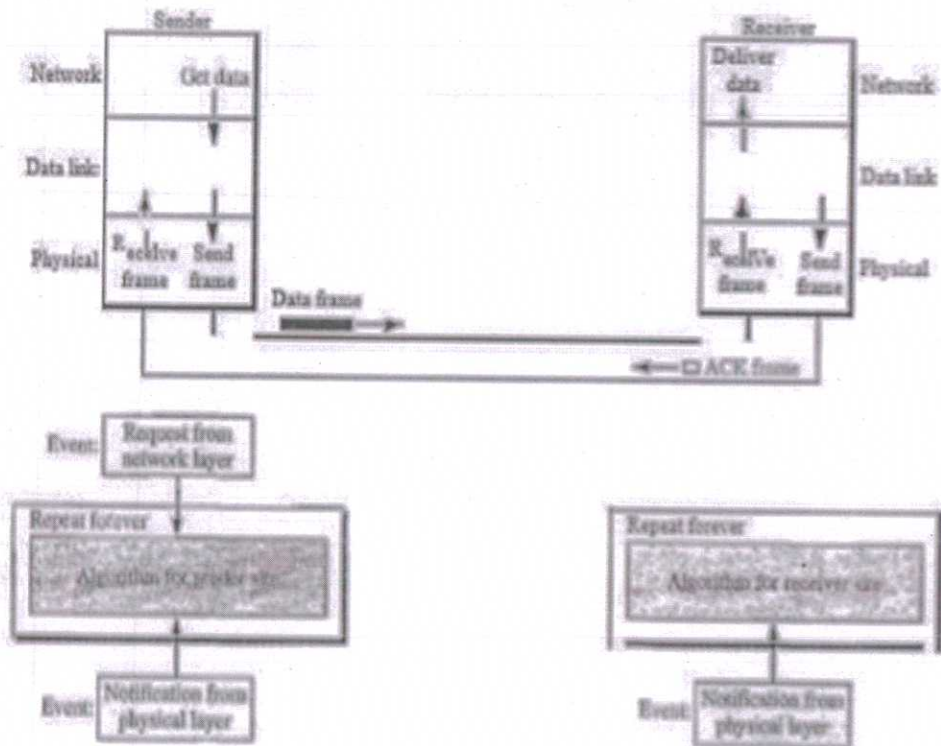
```

Stop-and-Wait Protocol

If data frames arrive at the receiver site faster than they can be processed, the frames must be stored until their use. Normally, the receiver does not have enough storage space, especially if it is receiving data from many sources. This may result in either the

discarding of frames or denial of service. To prevent the receiver from becoming overwhelmed with frames, we somehow need to tell the sender to slow down. There must be feedback from the receiver to the sender. The protocol we discuss now is called the Stop-and-Wait Protocol because the sender sends one frame, stops until it receives confirmation from the receiver (okay to go ahead), and then sends the next frame.

Design



Algorithm 11.3 Sender-site algorithm for Stop-and-Wait Protocol

```

1 while (true)                                //Repeat forever
2 canSend = true                               //Allow the first frame to go
3 {
4   WaitForEvent()                             // Sleep until an event occurs
5   if(Event (RequestToSend) AND canSend)
6   {
7     GetData();
8     MakeFrame();
9     SendFrame()                             //Send the data frame
10    canSend = false;                         //cannot send until ACK arrives
11  }
12  WaitForEvent()                             // Sleep until an event occurs
13  if(Event(ArrivalNotification) // An ACK has arrived
14  {
15    ReceiveFrame();                          //Receive the ACK frame
16    canSend = true;
17  }
18 }

```

Algorithm 11.4 Receiver-site algorithm for Stop-and-Wait Protocol

```
1 while (true) //Repeat forever
2 {
3   WaitForEvent(); // Sleep until an event occurs
4   if(Event(ArrivalNotification)) //Data frame arrives
5   {
6     ReceiveFrame();
7     ExtractData();
8     Deliver(data); //Deliver data to network layer
9     SendFrame(); //Send an ACK frame
10  }
11 }
```