Guided Media

Guided Media, which are those that provide a conduit from one device to another, include twisted pair cable, co-axial cable and fiber optics cable.

1. Twisted pair Cable

![Twisted-pair cable](image)
Structure - One wire is used to carry signals to the receiver and the other wire is used only as the ground reference. The receiver uses the difference between the two. 

Wires are twisted in order to avoid interference due to crosstalk which may affect differently to both wires if they were parallel.

a. **UTP** – Un-shielded twisted pair  
b. **STP** – Shielded twisted pair

**Figure 7.4** *UTP and STP cables*

Performance – With increase in transmission frequency, attenuation increases.
Connectors

Applications – Telephone lines carrying voice and data channels. LANs such as 10Base-T or 100Base-T

2. Co-axial Cable

Co-axial cable carries higher frequency ranges than those in twisted pair cable.

Structure – Coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid or combination of the two.
Connectors

**Figure 7.7**  *Coaxial cable*

**Figure 7.8**  *BNC connectors*

**Performance** – Coaxial cable has higher bandwidth but the signal weakens quickly and requires a frequent use of repeaters.
Applications – Widely used in analog telephone networks, later adopted into digital telephone networks. Cable TVs, traditional Ethernet LANs.

3. Fiber optic Cable

A fiber optic cable is made up of plastic or glass and transmits signals in the form of light. It uses the property of total internal reflection of light for transmission inside the medium.

Propagation Modes
Diagrammatic Representation of various modes of propagation of signals

Figure 7.12  Propagation modes

Figure 7.13  Modes

a. Multimode, step index

b. Multimode, graded index

c. Single mode
**Multimode Step-Index Fiber** – Density of core remains constant from the center to the edges. At the interface of the core and the cladding, there is an abrupt change to lower density which alters the angle of beam’s motion. “Suddenness of change”

**Multimode Graded-Index Fiber** – It has varying densities thus leading to less distortion in signal. Density is highest at the centre of the core and decreases gradually to its lowest at the edge.

**Single Mode** – Highly focused source of light that limits beams to a small range of angles, all close to the horizontal.

**Cable Structure** – The outer jacket is made of either PVC or Teflon. Inside the jacket are Kevlar strands to strengthen the cable. Below is a plastic coating to cushion the fiber. The fiber is at the center of the cable it consists of cladding and core.

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**Figure 7.14** Fiber construction

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**Connectors**
Performance – Attenuation is flatter than in the case of twisted-pair or coaxial cable. The performance is such that less number of repeaters are required.

Applications – some Cable TVs, broadband services, Ethernet LANs like 100Base-FX network or 1000Base-X network.

Question 2  
[Asi Baka - 1641015]  
Explain the types of guided and unguided media with suitable diagrams.
**Guided media**

Which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. A signal traveling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transports signals in the form of light.

- **Twisted-Pair Cable**

  This cable is the most commonly used and is cheaper than others. It is lightweight, cheap, can be installed easily, and they support many different types of network.
A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together. One of these wires is used to carry signals to the receiver, and the other is used only as 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. If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources. This results in a difference at the receiver.

**Twisted Pair is of two types:**

- **Unshielded Twisted Pair (UTP):** It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of two conductors usually copper, each with its own color plastic insulator. Identification is the reason behind colored plastic insulation.

  **Advantage:**
  - Installation is easy
  - Flexible
  - Cheap
  - It has high speed capacity,
  - 100 meter limit
  - Higher grades of UTP are used in LAN technologies like Ethernet.

  **Disadvantage:**
  - Bandwidth is low when compared with Coaxial Cable
  - Provides less protection from interference.
- **Shielded Twisted Pair (STP):** This cable has a metal foil or braided-mesh covering which encases each pair of insulated conductors. Electromagnetic noise penetration is prevented by metal casing. Shielding also eliminates crosstalk. It has same attenuation as unshielded twisted pair. It is faster the unshielded and coaxial cable. It is more expensive than coaxial and unshielded twisted pair.

*Advantage:*
- Easy to install
- Performance is adequate
- Can be used for Analog or Digital transmission
- Increases the signaling rate
- Higher capacity than unshielded twisted pair
- Eliminates crosstalk

*Disadvantage:*
- Difficult to manufacture
- Heavy
Coaxial Cable

Coaxial is called by this name because it contains two conductors that are parallel to each other. Copper is used in this as center conductor which can be a solid wire or a standard one. It is surrounded by PVC installation, a sheath which is encased in an outer conductor of metal foil, braid or both.
Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.

**Advantage:**
- Bandwidth is high
- Used in long distance telephone lines.
- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- The can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

**Disadvantage:**
- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.
- If the shield is imperfect, it can lead to grounded loop.
• **Fiber-Optic Cable**

Optical fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it.

![Fiber-Optic Cable Diagram](image)

**Propagation Modes**
Current technology supports two modes (Multimode and Single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics. Multimode can be implemented in two forms: Step-index and Graded-index.

- **Multimode**: Multimode is so named because multiple beams from a light source move through the core in different paths. How these beams move within the cable depends on the structure of the core.
  - In multimode *step-index fiber*, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding.
  - In multimode *graded-index fiber*, this distortion gets decreases through the cable. The word index here refers to the index of refraction. This index of refraction is related to the density. A graded-index fiber, therefore, is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge.
- **Single Mode**: Single mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The single-mode fiber itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density.
**Advantage:**

- Higher bandwidth
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials
- Light weight
- Greater immunity to tapping

**Disadvantage:**

- Installation and maintenance
- Unidirectional light propagation
- High Cost

**Unguided media**
Unguided medium transport electromagnetic waves without using a physical conductor. 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.

**Ground Propagation:** In this, radio waves travel through the lowest portion of the atmosphere, hugging the Earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet.
**Sky Propagation:** In this, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to Earth. This type of transmission allows for greater distances with lower output power.

**Line-of-sight Propagation:** in this type, very high-frequency signals are transmitted in straight lines directly from antenna to antenna.

We can divide wireless transmission into three broad groups:

- **Radio Waves**
  Electromagnetic waves ranging in frequencies between 3 KHz and 1 GHz are normally called radio waves.
Radio waves 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 send waves that can be received by any receiving antenna. The omnidirectional property has disadvantage, too. The waves transmitted by one antenna are susceptible to interference by another antenna that may send signal using the same frequency or band.

Radio waves, particularly with those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communication inside or outside a building.

- **Micro Waves**

Electromagnetic waves having frequencies between 1 and 300 GHz are called micro waves. Micro waves are unidirectional. When an antenna transmits microwaves, 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.

Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications: Parabolic Dish and Horn.
Advantage:
- Used for long distance telephone communication
- Carries 1000's of voice channels at the same time

Disadvantages:
- It is Very costly

• Infrared Waves

Infrared waves, with frequencies from 300 GHz to 400 THz, can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another, a short-
When we use infrared remote control, we do not interfere with the use of the remote by our neighbors. However, this same characteristic makes infrared signals useless for long-range communication. In addition, we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.

Question 3
[Bebin Samuel - 1641017]
Explain line coding schemes, its classification, its types and subtypes with valid example and clear figures.
The Line Coding schemes are categorized as shown in the following figure:

I. Unipolar Scheme:
In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

NRZ (Non-Return-to-Zero): Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0. It is called NRZ because the signal does not return to zero at the middle of the bit. The following figure shows a unipolar NRZ scheme.

![NRZ Scheme Diagram]

Compared with its polar counterpart, the normalized power (power needed to send 1 bit per unit line resistance) is double that for polar NRZ. For this reason, this scheme is normally not used in data communications today.

**II. Polar Schemes**

In polar schemes, the voltages are on the both sides of the time axis. For example, the voltage level for 0 can be positive and the voltage level for 1 can be negative.

a). Non-Return-to-Zero (NRZ):
In polar NRZ encoding, we use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-L and NRZ-I, as shown in the following Figure. The figure also shows the value of $r$, the average baud rate, and the bandwidth.

In the first variation, NRZ-L (NRZ-Level), the level of the voltage determines the value of the bit. In the second variation, NRZ-I (NRZ-Invert), the change or lack of change in the level of the voltage determines the value of the bit. If there is no change, the bit is 0; if there is a change, the bit is 1.

**b). Return to Zero (RZ):**

The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. One solution is the return-to-zero (RZ) scheme, which uses three values: positive, negative, and zero. In RZ, the signal changes not between bits but during the bit. In the following figure, we see that the signal goes to 0 in the middle of each bit. It remains there until the beginning of the next bit.
c). Biphase Manchester and Differential Manchester:

The idea of RZ (transition at the middle of the bit) and the idea of NRZ-L are combined into the Manchester scheme.

In Manchester encoding, the duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization.

Differential Manchester, on the other hand, combines the ideas of RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition; if the next bit is 1, there is none. The following figure shows both Manchester and differential Manchester encoding.
The Manchester scheme overcomes several problems associated with NRZ-L, and differential Manchester overcomes several problems associated with NRZ-I. First, there is no baseline wandering. There is no DC component because each bit has a positive and negative voltage contribution. The only drawback is the signal rate. The signal rate for Manchester and differential Manchester is double that for NRZ. The reason is that there is always one transition at the middle of the bit and maybe one transition at the end of each bit.

III. Bipolar Schemes

In bipolar encoding (sometimes called multilevel binary), there are three voltage levels, positive, negative, and zero. The voltage level for one data element is at
zero, while the voltage level for the other element alternates between positive and negative.

AMI and Pseudoternary: The following figure shows two variations of bipolar encoding: AMI and pseudo ternary.

A common bipolar encoding scheme is called bipolar alternate mark inversion (AMI). In alternate mark inversion, a neutral zero voltage represents binary 0. Binary 1s are represented by alternating positive and negative voltages.

A variation of AMI encoding is called Pseudoternary in which the 1 bit is encoded as a zero voltage and the 0 bit is encoded as alternating positive and negative voltages.

The bipolar scheme was developed as an alternative to NRZ. The bipolar scheme has the same signal rate as NRZ, but there is no DC component. The NRZ scheme has most of its energy concentrated near zero frequency, which makes it unsuitable for transmission over channels with poor performance around this frequency. The concentration of the energy in bipolar encoding is around frequency N/2.
IV. Multilevel Schemes:

The desire to increase the data speed or decrease the required bandwidth has resulted in the creation of many schemes. The goal is to increase the number of bits per baud by encoding a pattern of m data elements into a pattern of n signal elements. We only have two types of data elements (0s and 1s), which means that a group of m data elements can produce a combination of $2^m$ data patterns.

We can have different types of signal elements by allowing different signal levels. If we have $L$ different levels, then we can produce $L^n$ combinations of signal patterns.

If $2^m = L^n$, then each data pattern is encoded into one signal pattern. If $2^m < L^n$, data patterns occupy only a subset of signal patterns. The subset can be carefully designed to prevent baseline wandering, to provide synchronization, and to detect errors that occurred during data transmission. Data encoding is not possible if $2^m > L^n$ because some of the data patterns cannot be encoded.

The code designers have classified these types of coding as mBnL, where m is the length of the binary pattern, B means binary data, n is the length of the signal pattern, and L is the number of levels in the signaling. A letter is often used in place of L: B(binary) for $L=2$, T (ternary) for $L=3$, and Q (quaternary) for $L=4$. Note that the first two letters define the data pattern, and the second two define the signal pattern.

a). 2BIQ:

The first mBnL scheme we discuss, two binary, one quaternary (2BIQ), uses data patterns of size 2 and encodes the 2-bit patterns as one signal element belonging to a four-level signal.
In this type of encoding \( m = 2, n = 1, \) and \( L = 4 \) (quaternary). The following figure shows an example of a 2B1Q signal.

<table>
<thead>
<tr>
<th>Previous level: positive</th>
<th>Previous level: negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next bits</td>
<td>Next level</td>
</tr>
<tr>
<td>00</td>
<td>+1</td>
</tr>
<tr>
<td>01</td>
<td>+3</td>
</tr>
<tr>
<td>10</td>
<td>-1</td>
</tr>
<tr>
<td>11</td>
<td>-3</td>
</tr>
</tbody>
</table>

The average signal rate of 2B1Q is \( S = N/4 \). This means that using 2B1Q, we can send data 2 times faster than by using NRZ-L. However, 2B IQ uses four different signal levels, which means the receiver has to discern four different thresholds. The reduced bandwidth comes with a price. There are no redundant signal patterns in this scheme because \( 2^2 = 4 \).
b). 8B6T:

A very interesting scheme is eight binary, six ternary (8B6T). The idea is to encode a pattern of 8 bits as a pattern of 6 signal elements, where the signal has three levels (ternary). In this type of scheme, we can have $2^8=256$ different data patterns and data patterns and $3^6=729$ different signal patterns.

There are $729 - 256 = 473$ redundant signal elements that provide synchronization and error detection. Part of the redundancy is also used to provide DC balance. Each signal pattern has a weight of 0 or +1 DC values. This means that there is no pattern with the weight -1. To make the whole stream DC-balanced, the sender keeps track of the weight. If two groups of weight 1 are encountered one after another, the first one is sent as is, while the next one is totally inverted to give a weight of -1. The following figure shows an example of three data patterns encoded as three signal patterns.

The three possible signal levels are represented as -, 0, and +. The first 8-bit pattern 00010001 is encoded as the signal pattern -0-0++ with weight 0; the second 8-bit pattern 010 10011 is encoded as - + - + + 0 with weight +1. The third bit pattern should be encoded as + - - + 0 + with weight +1. To create DC balance, the sender inverts the actual signal. The receiver can easily recognize that this is an inverted pattern because the weight is -1. The pattern is inverted before decoding.
The last signaling scheme we discuss in this category is called four dimensional five-level pulse amplitude modulation (4D-PAM5). The 4D means that data is sent over four wires at the same time. It uses five voltage levels, such as -2, -1, 0, 1, and 2.

However, one level, level 0, is used only for forward error detection. If we assume that the code is just one-dimensional, the four levels create something similar to 8B4Q. In other words, an 8-bit word is translated to a signal element of four different levels. The worst signal rate for this imaginary one-dimensional version is \( N \times \frac{4}{8} \), or \( N/2 \).

The technique is designed to send data over four channels (four wires). This means the signal rate can be reduced to \( N/8 \), a significant achievement. All 8 bits can be fed into a wire simultaneously and sent by using one signal element. The point here
is that the four signal elements comprising one signal group are sent simultaneously in a four-dimensional setting.

The following figure shows the imaginary one-dimensional and the actual four-dimensional implementation. Gigabit LANs use this technique to send 1-Gbps data over four copper cables that can handle 125 Mbaud. This scheme has a lot of redundancy in the signal pattern because 28 data patterns are matched to $44 = 256$ signal patterns. The extra signal patterns can be used for other purposes such as error detection.

![Diagram of Multiline Transmission: MLT-3](image)

V. Multiline Transmission: MLT-3:
NRZ-I and differential Manchester are classified as differential encoding but use two transition rules to encode binary data (no inversion, inversion). If we have a signal with more than two levels, we can design a differential encoding scheme with more
than two transition rules. MLT-3 is one of them. The multiline transmission, three level (MLT-3) scheme uses three levels (+V, 0 and -V) and three transition rules to move between the levels.

1. If the next bit is 0, there is no transition.
2. If the next bit is 1 and the current level is not 0, the next level is 0.
3. If the next bit is 1 and the current level is 0, the next level is the opposite of the last nonzero level.

The behavior of MLT-3 can best be described by the state diagram shown in the following figure. The three voltage levels (-V, 0, and +V) are shown by three states (ovals). The transition from one state (level) to another is shown by the connecting lines. The following figure also shows two examples of an MLT-3 signal.
The signal rate is the same as that for NRZ-I, but with greater complexity (three levels and complex transition rules). It turns out that the shape of the signal in this scheme helps to reduce the required bandwidth. Let us look at the worst-case scenario, a sequence of Is. In this case, the signal element pattern +VO - VO is repeated every 4 bits.

A non-periodic signal has changed to a periodic signal with the period equal to 4 times the bit duration. This worst-case situation can be simulated as an analog signal with a frequency one-fourth of the bit rate. In other words, the signal rate for MLT-3 is one-fourth the bit rate. This makes MLT-3 a suitable choice when we need to send 100 Mbps on a copper wire that cannot support more than 32 MHz (frequencies above this level create electromagnetic emissions).

**Question 4**  
[Ashwin George - 1641014]
Explain physical description and application of Microwave, Broadcast Radio and Fiber optics.

Microwave:

Physical description:

- Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall.
- The curvature of the earth as well as other blocking obstacles do not allow two short towers to communicate by using microwaves. Repeaters are often needed for long distance communication.
- Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore wider sub bands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

Applications:

Microwaves, due to their unidirectional properties, are very useful when unicast (one to-one) communication is needed between the sender and the receiver. They are used in cellular phones, satellite networks, and wireless LANs.
Broadcast radio:

Physical description:

- 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.

- Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.

- Radio waves, particularly those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, for example, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communication to just inside or outside a building.

- The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band. When this band is divided into subbands, the subbands are also narrow, leading to a low data rate for digital communications.
Applications:

The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers. AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

Fiber optics:

Physical description:

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- Light travels in a straight line as long as it is moving through a single uniform substance. If a ray of light traveling through one substance suddenly enters another substance of a different density, the ray changes direction.
- If the angle of incidence $I$ (the angle the ray makes with the line perpendicular to the interface between the two substances) is less than the critical angle, the ray refracts and moves closer to the surface. If the angle of incidence is equal to the critical angle, the light bends along the interface. If the angle is greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser

Applications:

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective.
Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network. Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises. This is a cost-effective configuration since the narrow bandwidth requirement at the user end does not justify the use of optical fiber.

Question 5 [Christopher Mossa Bagorro - 1641018]
Provide the classification of Transmission media. Explain in detail each one of them.

Question 6 [Anshul Agarwal - 1641011]
Define Transmission Media.
Transmission Media – A transmission medium is broadly defined as anything that can carry information from a source to a destination.

Figure 7.1 Transmission medium and physical layer

Question 7 [Ashwin George - 1641014]
What is Synchronization?
Synchronization is a process that involves coordinating the execution of multiple threads to ensure a desired outcome without corrupting the shared data and preventing any occurrence of deadlocks and race conditions.
Synchronization also occurs between network nodes to ensure that data streams are received and transmitted correctly, and to prevent data collision.

**Question 8**

[Ashutosh Singh - 1641013]

**Define carrier signal and explain its role in analog transmission.**

1. In analog transmission, the sending device produces a high-frequency signal that acts as a base for the information signal. This base signal is called the carrier signal or carrier frequency. It is a constant frequency signal.
2. The carrier frequency is chosen so that it is compatible with the transmission medium.
3. The receiving device must be tuned into the frequency of this carrier signal.
4. Digital information changes one or more characteristics of the carrier signal (e.g., amplitude, frequency, or phase). This digital information is the input signal or modulating signal.
5. This type of modification is called modulation or shift keying. The resultant signal is called a modulated signal.

**Question 9**

[Ashutosh Singh - 1641013]

**What is the relationship between period and frequency?**

Frequency, \( f \), is how many cycles of an oscillation occur per second and is measured in cycles per second or hertz (Hz). The period of a wave, \( T \), is the amount of time it takes a wave to vibrate one full cycle. These two terms are inversely proportional to each other: \( f = 1/T \) and \( T = 1/f \).

**Question 10**

[Asi Baka - 1641015]

**Define Line coding.**
Line coding is a process of converting digital data to digital signal. We assume that data, in the form of text, number, graphical images, audio, or video are stored in computer memory as sequences of bits. Line coding converts a sequence of bits to a digital signal. At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

**Question 11**  
[Christopher Mossa Bagorro - 1641018]  
What is NRZ? Explain its types.

**Question 12**  
[Bebin Samuel - 1641017]  
Discuss AMI and pseudoternary with example.  
AMI is a bipolar encoding system where neutral (zero) voltage represents binary 0 and alternating positive and negative voltages represents binary 1.
**Question 13**  
*Anshul Agarwal - 1641011*  
**What is throughput?**  
The throughput is a measure of how fast we can actually send data through a network.  
A link may have a bandwidth of B bps, but we can only send T bps through this link with T always less than B.  
The throughput is an actual measurement of how fast we can send data.

**Question 14**  
*Apisit Dhupatemiya - 1641012*  
**Define Computer Network.**  
A computer network is a set of computers connected together for the purpose of sharing resources. The most common resource shared today is connection to the Internet. Other shared resources can include a printer or a file server. The Internet itself can be considered a computer network.

**Question 15**  
*Aniruddho Majumer - 1641010*  
**What is a bit interval?**  
Data can be represented by a digital signal. For example a 1 can be encoded as a positive voltage and a 0 can be encoded as a zero voltage. The bit interval is the time required to send one single bit. This means that the bit rate is number of bits sent in one second, usually expressed in bits per seconds (bps)
Question 16  [Aniruddho Majumer - 1641010]
What is scrambling?
Scrambling is a way to avoid long sequences of 0s and 1s in the original stream so that baseline wandering can be avoided. We modify the encoding technique to include scrambling. Note that scrambling as opposed to block coding is done at the same time as encoding. The system needs to insert the required pulses on the defined scrambling rules. Two common scrambling techniques are B8ZS and HDB3.

Question 17  [Christopher Mossa Bagorro - 1641018]
What is Quantization and Delta Modulation?

Question 18  [Asi Baka - 1641015]
What is frequency and amplitude?
Frequency

- Frequency refer to the number of period in 1 second.
- Frequency is the inverse of period. As the following formula:

\[ f = \frac{1}{T} \]

- Frequency is the rate of change with respect to time. Change in short span time means high frequency. Change over long span of time means low frequency.

Amplitude

Amplitude of a signal is the absolute of its highest intensity, proportional to the energy it carried. For electric signal, amplitude is normally measured in volts.

Question 19  
[Apisit Dhupatemiya - 1641012]
What is bandwidth?
The range of frequencies contained in a composite signal is its bandwidth. The bandwidth is normally a difference between two numbers.

Example: if a composite signal contains frequencies between 1000 and 5000, its bandwidth is 5000 – 1000, or 4000.

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Question 20  
[Ashutosh Singh - 1641013]
What is meant by self synchronization?
It’s a process to adjust one’s period to that of an average of the group while in process of establishing consistency among data from a source to a target data storage and vice versa and the continuous harmonization of the data over time.
Question 21  [Ashwin George - 1641014]
Define bauds.
Baud was the prevalent measure for data transmission speed until replaced by a more accurate term, bps (bits per second). One baud is one electronic state change per second. Since a single state change can involve more than a single bit of data, the bps unit of measurement has replaced it as a better expression of data transmission speed.

Question 22  [Christopher Mossa Bagorro - 1641018]
Let us consider a signal is carrying data in which one data element is encoded as one signal element (r = 1). If the bit rate is 100 kbps. What is the average value of the baud rate if c is between 0 and 1?

Question 23  [Bebin Samuel - 1641017]
If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700 and 900 Hz, what is the bandwidth?
Maximum Frequency - Minimum Frequency = 900-100 = 800 Hz

Question 24  [Aniruddho Majumer - 1641010]
Illustrate about PSK, ASK and FSK.
Amplitude Shift Keying

In amplitude shift keying, the amplitude of the carrier signal is varied to create signal elements. Both frequency and phase remain constant while the amplitude changes.
**Figure 5.3  Binary amplitude shift keying**

[Diagram showing binary amplitude shift keying with amplitude, bit rate, and time elements]

**Frequency Shift Keying**

In frequency shift keying, the frequency of the carrier signal is varied to represent data. The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes. Both peak amplitude and phase remain constant for all signal elements.
Phase Shift Keying

In phase shift keying, the phase of the carrier is varied to represent two or more different signal elements. Both peak amplitude and frequency remain constant as the phase changes. Today, PSK is more common than ASK or FSK. However, we will see shortly that QAM, which combines ASK and PSK, is the dominant method of digital-to-analog modulation.
Question 25  
[Bebin Samuel - 1641017]
Differentiate between Parallel Transmission and Serial Transmission Modes

**Figure 4.31  Data transmission and modes**

Parallel Transmission
Mechanism – Use n wires to send n bits at one time

Advantage

1. **Speed** – Increases by a factor of ‘n’ over serial transmission

Disadvantage

1. **Cost** – It requires ‘n’ communication lines just to transmit the data stream. Therefore it is expensive, hence limited to shorter distances.

Serial Transmission
**Advantage** – Cost effective than parallel transmission hence can be used for long distance transmission

**Disadvantage** – Slower than parallel transmission

1. **Asynchronous Transmission** – In this type, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte. There may be a gap between each byte. Asynchronous here means “asynchronous at the byte level,” but the bits are still synchronised; their durations are the same.
2. **Synchronous Transmission** – In this type, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits. The bit streams are combined into longer “frames” which may have multiple bytes.

**Figure 4.34**  *Asynchronous transmission*

Timing is very important because the accuracy of the received information is completely dependent on the ability of the receiving device to keep an accurate count of bits as they come in.

**Figure 4.35**  *Synchronous transmission*

**Advantage** – Speed, as there are no extra bits
Isochronous – In real time video or audio, in which uneven delays between frames are not acceptable, synchronous transmission fails. For this to be flawless there needs to be synchronisation in the entire bit stream. The isochronous transmission guarantees that the data arrive at a fixed-rate.

Question 26

[Asi Baka - 1641015]

What is the principle of refraction? Write a short note on Fiber optics. Clearly state its types, advantages and disadvantages.

A fundamental optical parameter one should have an idea about, while studying fiber optics is **Refractive index**. By definition, “The ratio of the speed of light in a vacuum to that in matter is the index of refraction n of the material.” It is represented as

\[
n = \frac{c}{v}
\]

Where,

\[
c = \text{the speed of light in free space} = 3 \times 10^8 \text{ m/s}
\]

\[
v = \text{the speed of light in di-electric or non-conducting material}
\]

Generally, for a travelling light ray, **reflection** takes place when \( n_2 < n_1 \). The bent of light ray at the interface is the result of difference in the speed of light in two materials that have different refractive indices. The relationship between these angles at the interface can be termed as **Snell’s law**. It is represented as

\[
n_1 \sin \phi_1 = n_2 \sin \phi_2
\]

Where,

\[
\phi_1 \text{ is the angle of incidence}
\]

\[
\phi_2 \text{ is the refracted angle}
\]

\[
n_1 \text{ and } n_2 \text{ are the refractive indices of two materials}
\]
For an optically dense material, if the reflection takes place within the same material, then such a phenomenon is called as internal reflection. The incident angle and refracted angle are shown in the following figure.

If the angle of incidence $\phi_1$ is much larger, then the refracted angle $\phi_2$ at a point becomes $\frac{\pi}{2}$. Further refraction is not possible beyond this point. Hence, such a point is called as Critical angle $\phi_c$. When the incident angle $\phi_1$ is greater than the critical angle, the condition for total internal reflection is satisfied.
The following figure shows these terms clearly.

![Diagram of light ray](image)

A light ray, if passed into a glass, at such condition, it is totally reflected back into the glass with no light escaping from the surface of the glass.

Optical fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it.

**Applications of Fiber Optics**
- Used in telephone systems
- Used in sub-marine cable networks
- Used in data link for computer networks, CATV Systems
- Used in CCTV surveillance cameras
- Used for connecting fire, police, and other emergency services.
- Used in hospitals, schools, and traffic management systems.
They have many industrial uses and also used for in heavy duty constructions.

**Types of Optical Fibers**

Depending upon the material composition of the core, there are two types of fibers used commonly. They are

- *Step-index fiber* – the refractive index of the core is uniform throughout and undergoes an abrupt change (or step) at the cladding boundary.
- *Graded-index fiber* – the core refractive index is made to vary as a function of the radial distance from the center of the fiber.

Both of these are further divided into –

- *Single-mode fiber* – these are excited with laser.
- *Multi-mode fiber* – these are excited with LED.

**Functional Advantages:**

- The transmission bandwidth of the fiber optic cables is higher than the metal cables.
- The amount of data transmission is higher in fiber optic cables.
- The power loss is very low and hence helpful in long-distance transmissions.
- Fiber optic cables provide high security and cannot be tapped.
- Fiber optic cables are the most secure way for data transmission.
- Fiber optic cables are immune to electromagnetic interference.
- These are not affected by electrical noise.

**Physical Advantages:**

- The capacity of these cables is much higher than copper wire cables.
- Though the capacity is higher, the size of the cable doesn’t increase like it does in copper wire cabling system.
- The space occupied by these cables is much less.
- The weight of these FOC cables is much lighter than the copper ones.
- Since these cables are dielectric, no spark hazards are present.
- These cables are more corrosion resistant than copper cables, as they are bent easily and are flexible.
- The raw material for the manufacture of fiber optic cables is glass, which is cheaper than copper.
- Fiber optic cables last longer than copper cables.

Disadvantages:
- Though fiber optic cables last longer, the installation cost is high.
- The number of repeaters are to be increased with distance.
- They are fragile if not enclosed in a plastic sheath. Hence, more protection is needed than copper ones.

Question 27

[Ashutosh Singh - 1641013]

Draw the graph of the NRZ-L and NRZ-I scheme using each of the following data streams, assuming that the last signal level has been positive. From the graphs, calculate the bandwidth for this scheme using the average number of changes in the signal level. a) 01010101 b) 00110011
<table>
<thead>
<tr>
<th>BASIS FOR COMPARISON</th>
<th>SERIAL TRANSMISSION</th>
<th>PARALLEL TRANSMISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meaning</strong></td>
<td>Data flows in bi-direction, bit by bit</td>
<td>Multiple lines are used to send data i.e. 8 bits or 1 byte at a time</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Economical</td>
<td>Expensive</td>
</tr>
<tr>
<td><strong>Bits transferred at 1 clock pulse</strong></td>
<td>1 bit</td>
<td>8 bits or 1 byte</td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Used for long distance communication. Eg, Computer to computer</td>
<td>Short distance. Eg, computer to printer</td>
</tr>
</tbody>
</table>
Definition Of Serial Transmission

In Serial Transmission, data is sent bit by bit from one computer to another in bi-direction. Each bit has its clock pulse rate. Eight bits are transferred at a time having a start and stop bit (usually known as a Parity bit) i.e. 0 and 1 respectively. For transmitting data to a longer distance, data cables are used. It consists of D-shaped 9 pin cable that connects the data in series.

Serial Transmission has two subclasses synchronous and asynchronous. In asynchronous transmission, an extra bit is added to each byte so that the receiver is alert about the arrival of new data. Usually, 0 is a start bit, and 1 is the stop bit. In synchronous transmission, no extra bit is added rather the data transferred in the form of frames which contains multiple bytes.

Definition Of Parallel Transmission

In Parallel Transmission, various bits are sent together simultaneously with a single clock pulse. It is a fast way to transmit as it uses many input/output lines for transferring the data.
Parallel Transmission uses a 25 pin port having 17 signal lines and 8 ground lines. The 17 signal lines are further divided as

- 4 lines that initiate handshaking,
- 5 status lines used to communicate and notify errors and
- 8 to transfer data.

Question 28

[Ashwin George - 1641014]

Explain synchronous transmission with suitable diagram.

In synchronous transmission, the bit stream is combined into longer “frames,” which may contain multiple bytes. Each byte, however, is introduced onto the transmission link without a gap between it and the next one. It is left to the receiver to separate the bit stream into bytes for decoding purposes. In other words, data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes, or characters, it needs to reconstruct the information.
The above diagram shows divisions between bytes. In reality, those divisions do not exist; the sender puts its data onto the line as one long string. If the sender wishes to send data in separate bursts, the gaps between bursts must be filled with a special sequence of 0s and 1s that means idle. The receiver counts the bits as they arrive and groups them in 8-bit units.

Without gaps and start and stop bits, there is no built-in mechanism to help the receiving device adjust its bit synchronization midstream. Timing becomes very important, therefore, because the accuracy of the received information is completely dependent
on the ability of the receiving device to keep an accurate count of the bits as they come in.

The advantage of synchronous transmission is speed. With no extra bits or gaps to introduce at the sending end and remove at the receiving end, and, by extension, with fewer bits to move across the link, synchronous transmission is faster than asynchronous transmission. For this reason, it is more useful for high-speed applications such as the transmission of data from one computer to another. Byte synchronization is accomplished in the data-link layer.

Question 29  
[Christopher Mossa Bagorro - 1641018]
What is Multitransition: MLT-3 with clear flowchart and valid examples.

Question 30  
[Apisit Dhupatemiya - 1641012]
List the applications of guided and unguided media.

Guided media:

which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. A signal traveling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transports signals in the form of light.

Twisted-Pair Cable:

Unshielded Versus Shielded Twisted-Pair Cable:
Coaxial Cable Connectors:

Unguided Media:

Transport electromagnetic waves without using a physical conductor. 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.

Electromagnetic spectrum for wireless communication:
Question 31  
[Apisit Dhupatemiya - 1641012]  
**What is Manchester encoding scheme? Explain its types with valid examples.**

The idea of RZ (transition at the middle of the bit) and the idea of NRZ-L are combined into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization. Differential Manchester, on the other hand, combines the ideas of RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition; if the next bit is 1, there is none. Figure shows both Manchester and differential Manchester encoding. The Manchester scheme overcomes several problems associated with NRZ-L, and differential Manchester overcomes several problems associated with NRZ-I. First, there is no baseline wandering. There is no DC component because each bit has a positive and negative voltage contribution. The only drawback is the signal rate. The signal rate for Manchester and differential Manchester is double that for NRZ. The
reason is that there is always one transition at the middle of the bit and maybe one transition at the end of each bit. Figure shows both Manchester and differential Manchester encoding schemes. Note that Manchester and differential Manchester schemes are also called Biphase schemes.

**Question 32**  
[Ashutosh Singh - 1641013]  
Explain asynchronous transmission with suitable diagram.

**Asynchronous mode**  
Asynchronous mode is also known as start-stop mode. This mode is used when data to be transmitted is generated at random intervals. For example, when a user communicates with a computer using a keyboard, the time interval between two successive keystrokes is random. This means that the signal on the transmission line will be in idle state for a long time interval between characters. With this type of communication, the receiver must be able to resynchronize at the start of each new character received. To accomplish this, each transmitted character or byte is encapsulated between an additional start bit and one or more stop bits. This mode is mainly used for the transmission of characters between a keyboard and a computer. Asynchronous transmission can also be used for the transmission of a block of characters or bytes between two computers. The time interval between successive characters is a variable entity.
Question 33
[Anshul Agarwal - 1641011]
Differentiate between parallel and serial transmission.

Transmission Modes

Figure 4.31  Data transmission and modes

- Parallel Transmission
- Serial
  - Asynchronous
  - Synchronous
  - Isochronous

Asynchronous Transmission
Mechanism – Use n wires to send n bits at one time

Advantage

2. Speed – Increases by a factor of ‘n’ over serial transmission

Disadvantage

2. Cost – It requires ‘n’ communication lines just to transmit the data stream. Therefore it is expensive, hence limited to shorter distances.

Serial Transmission
Advantage – Cost effective than parallel transmission hence can be used for long distance transmission

Disadvantage – Slower than parallel transmission

3. **Asynchronous Transmission** – In this type, we send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte. There may be a gap between each byte. Asynchronous here means “asynchronous at the byte level,” but the bits are still synchronised; their durations are the same.
4. **Synchronous Transmission** – In this type, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits. The bit streams are combined into longer “frames” which may have multiple bytes.

Timing is very important because the accuracy of the received information is completely dependent on the ability of the receiving device to keep an accurate count of bits as they come in. **Advantage** – Speed, as there are no extra bits
Isochronous – In real time video or audio, in which uneven delays between frames are not acceptable, synchronous transmission fails. For this to be flawless there needs to be synchronisation in the entire bit stream. The isochronous transmission guarantees that the data arrive at a fixed-rate.