NETWORK FUNDAMENTALS

Theoretical bases for data communication

Data Representation

→ Data can be in any of the following forms:

- Text
- Numbers
- Images
- Audio
- Video

Terminology

→ The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.

→ Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.

→ The effectiveness of a data communications system depends on following four fundamental characteristics:

→ Delivery:

- The system must deliver data to the correct destination.
- Data must be received only by the intended device or user.

→ Accuracy:

- The system must deliver the data accurately.
- Data that have been altered in transmission and left uncorrected are unusable.

→ Timeliness:

- The system must deliver data in a timely manner.
- Data delivered late are useless.
- In the case of video and audio, timely delivery means delivering data as

they are produced, in the same order that they are produced, and without significant delay.

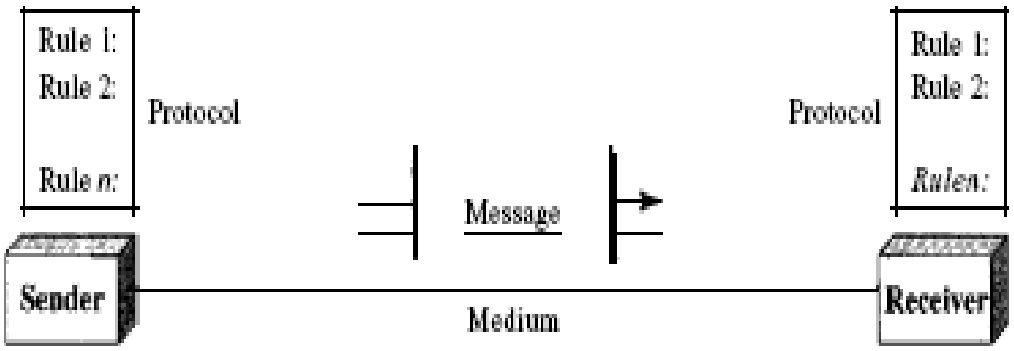
- This kind of delivery is called real-time transmission.

→ Jitter:

- Jitter refers to the variation in the packet arrival time.
- It is the uneven delay in the delivery of audio or video packets.
- For example, let us assume that video packets are sent every 3-ms.
- If some of the packets arrive with 3-ms delay and others with 4-ms delay, an uneven quality in the video is the result.

Components of data communication

→ A data communications system has five components as shown in the figure.



→ Message:

- The message is the information (data) to be communicated.
- Popular forms of information include text, numbers, pictures, audio, and video.

→ Sender:

- The sender is the device that sends the data message.
- It can be a computer, workstation, telephone handset, video camera, and so on.

→ Receiver:

- The receiver is the device that receives the message.
- It can be a computer, workstation, telephone handset, television, and so on.

→ Transmission medium:

- The transmission medium is the physical path by which a message travels

from sender to receiver.

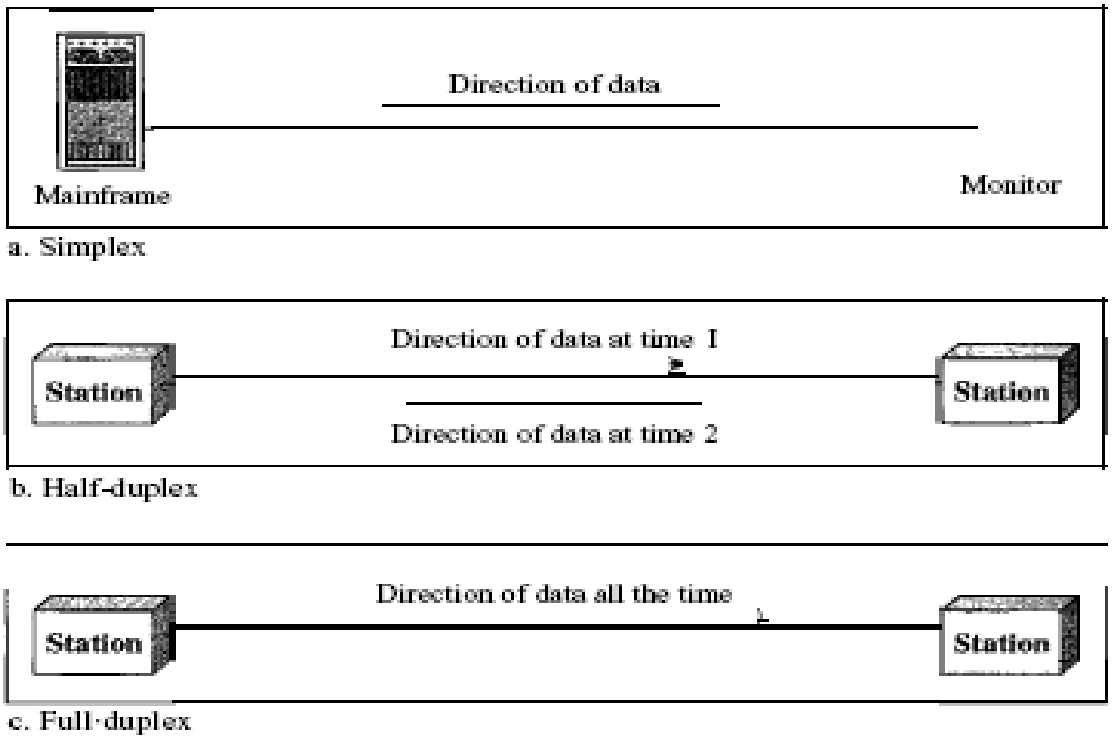
- Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.

→ Protocol:

- A protocol is a set of rules that govern data communications.
- It represents an agreement between the communicating devices.
- Without a protocol, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

Data Flow

→ Communication between two devices can be simplex, half-duplex, or full-duplex as shown in figure.



→ Simplex:

- In simplex mode, the communication is unidirectional, as on a one-way street.
- Only one of the two devices on a link can transmit; the other can only receive.

- Keyboards and traditional monitors are examples of simplex devices.
- The keyboard can only introduce input; the monitor can only accept output.
- The simplex mode can use the entire capacity of the channel to send data in one direction.

→ Half-Duplex:

- In half-duplex mode, both the stations can transmit and receive, but not at the same time.
- When one device is sending, the other can only receive, and vice versa.
- In a half-duplex transmission, 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.
- The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

→ Full-Duplex:

- In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously.
- In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction.
- This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals traveling in both directions.
- One common example of full-duplex communication is the telephone network.
- When two people are communicating by a telephone line, both can talk and listen at the same time.
- The full-duplex mode is used when communication in both directions is required all the time.
- The capacity of the channel, however, must be divided between the two directions.

Performance

→ Bandwidth in Bits per Seconds:

- The term bandwidth can also refer to the number of bits per second that a channel, a link, or even a network can transmit.
- For example, one can say the bandwidth of a Fast Ethernet network (or the links in this network) is a maximum of 100 Mbps. This means that this network can send 100 Mbps.

→ Throughput:

- The throughput is a measure of how fast we can actually send data through a network.
- Although, at first glance, bandwidth in bits per second and throughput seem the same, they are different.
- 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.
- In other words, the bandwidth is a potential measurement of a link; the throughput is an actual measurement of how fast we can send data.
- For example, we may have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps.
- This means that we cannot send more than 200 kbps through this link.

→ Latency (Delay)

- The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.
- The latency is made of four components: propagation time, transmission time, queuing time and processing delay.

  Latency = propagation time + transmission time+ queuing time + processing delay

  - Propagation Time
  - Propagation time measures the time required for a bit to travel from the source to the destination.
  - The propagation time is calculated by dividing the distance by the propagation speed.

    Propagation time = Distance / Propagation speed

  - The propagation speed of electromagnetic signals depends on the

medium and on the frequency of the signal.

- Transmission Time

- There is a time between the first bit leaving the sender and the last bit arriving at the receiver.
- The first bit leaves earlier and arrives earlier; the last bit leaves later and arrives later.
- The time required for transmission of a message depends on the size of the message and the bandwidth of the channel.

Transmission time =Message size / Bandwidth

- Queuing Time

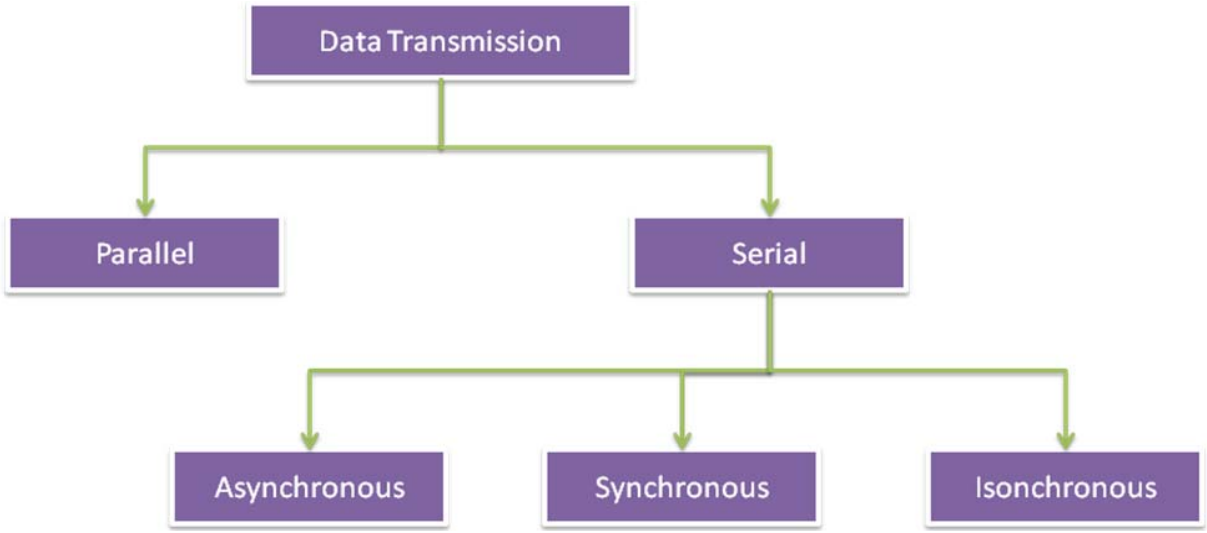
- The third component in latency is the queuing time, the time needed for each intermediate or end device to hold the message before it can be processed.
- The queuing time is not a fixed factor; it changes with the load imposed on the network.
- When there is heavy traffic on the network, the queuing time increases.
- An intermediate device, such as a router, queues the arrived messages and processes them one by one.
- If there are many messages, each message will have to wait.

Transmission modes

→ The transmission of binary data across a link can be accomplished in either of the following modes:

- Parallel mode (multiple bits are sent with each clock tick)
- 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



Parallel Transmission

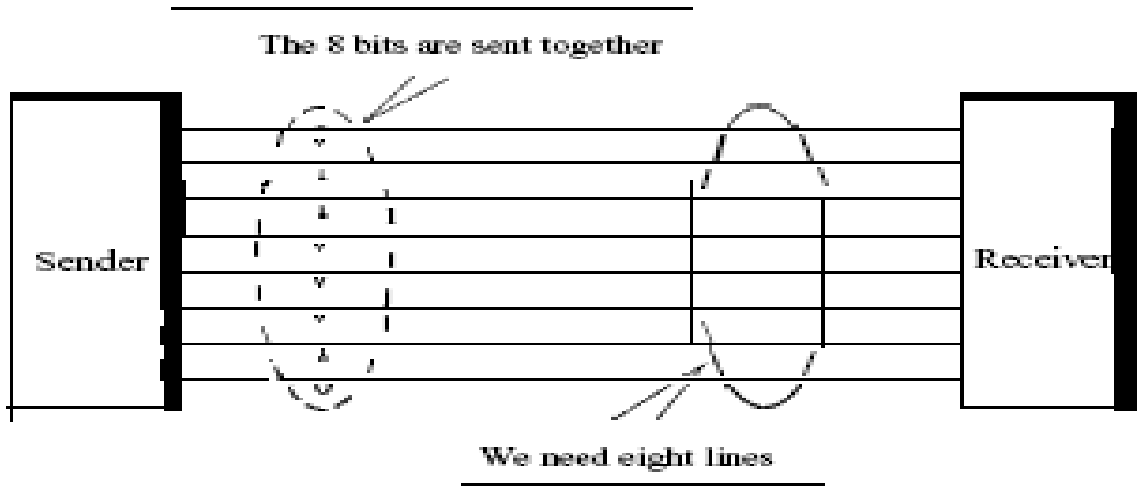
→ Binary data, consisting of 1s and 0s, may be organized into groups of n bits each.

→ 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.



→ Figure shows how parallel transmission works for n =8.

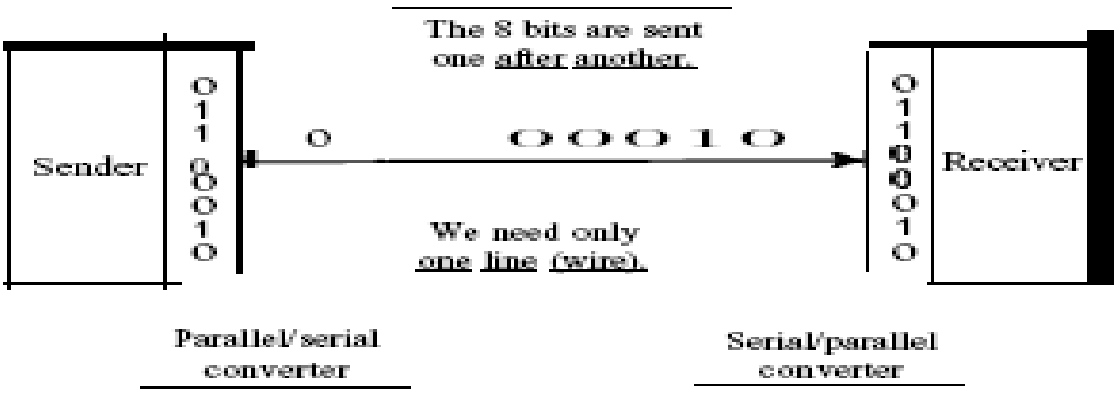
→ Typically, the eight wires are bundled in a cable with a connector at each end.

→ The advantage of parallel transmission is speed.
→ All else being equal, parallel transmission can increase the transfer speed by a factor of n over serial transmission.

→ But there is a significant disadvantage: cost.
→ Parallel transmission requires n communication lines (wires in the example) just to transmit the data stream.
→ Because this is expensive, parallel transmission is usually limited to short distances.

Serial Transmission

→ In serial transmission one bit follows another, so we need only one communication channel rather than n to transmit data between two communicating devices.



Transmission Media

- Information is represented in the form of signals that is passed into any medium.
- A transmission medium can be broadly defined as device that can transform information from source device to destination device.
- The transmission medium is usually free space, metallic cable or fiber optic cable.

→ **Classification of transmission media**

- **Conducted or guided media**
  - Uses a conductor such as a wire or a fiber optic cable to move the signal from sender to receiver.
  - Signal needs conductor and ground for data transmission.
- **Wireless or unguided media**
  - Uses radio waves of different frequencies and do not need a wire or cable conductor to transmit signals.

→ Guided Transmission Media

- Transmission capacity depends on the distance and on whether the medium is point-to-point or multipoint.

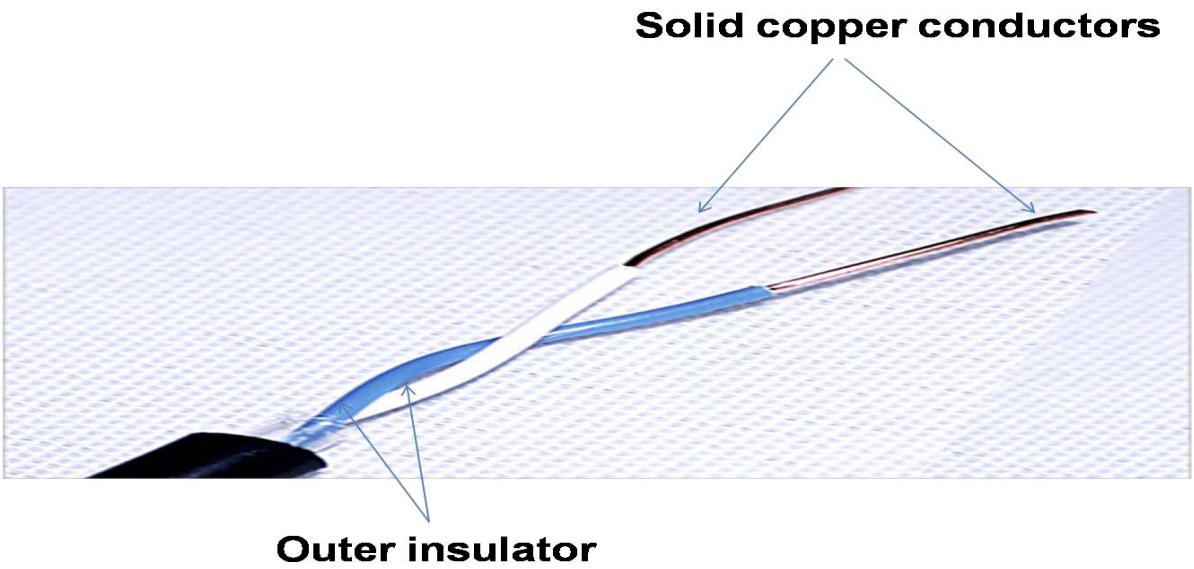
- **Three types of Guided Transmission media:**
  - Twisted pairs
  - Coaxial cables
  - Optical fiber

→ Twisted Pair Wires

- One of the oldest and still most common transmission media is twisted pair.
- A twisted pair consists of two insulated copper wires, typically about 1 mm thick.
- The wires are twisted together in a helical form, just like a DNA molecule.
- Twisting is done because two parallel wires constitute a fine antenna.
- When the wires are twisted, the waves from different twists cancel out, so the wire radiates less effectively.

→ Twisted pairs can run several kilometers without amplification, but for longer distances, repeaters are needed.

→ When many twisted pairs run in parallel for a substantial distance, such as all the wires coming from an apartment building to the telephone company office, they are bundled together and encased in a protective sheath.



→ The pairs in these bundles would interfere with one another if it were not for the twisting.
→ Twisted pairs can be used for transmitting either analog or digital signals.
→ The bandwidth depends on the thickness of the wire and the distance traveled, but several megabits/sec can be achieved for a few kilometers in many cases.
→ Due to their adequate performance and low cost, twisted pairs are widely used.

- Types of Twisted Pair
  - UTP (unshielded twisted pair)
  - STP (shielded twisted pair)

→ **UTP (unshielded twisted pair)**
  - UTP (unshielded twisted pair) cable is the most common type of **telecommunication medium** in use today.
  - Its **frequency range** is suitable for transmitting **both data and voice**.
  - Categories of Unshielded Twisted Pair

Type	Use
Category 1	Voice Only (Telephone Wire)
Category 2	Voice and Data transmission
Category 3	Data transmission to 10 Mbps
Category 4	Data transmission to 16 Mbps
Category 5	Data transmission to 100 Mbps

→ **Category 3 twisted pairs**

- Category 3 twisted pairs consist of two insulated wires gently twisted together.
- Four such pairs are typically grouped in a plastic sheath to protect the wires and keep them together.
- Prior to about 1988, most office buildings had one category 3 cable running from a central wiring closet on each floor into each office.
- This scheme allowed up to four regular telephones or two multiline telephones in each office to connect to the telephone company equipment in the wiring closet.

(a)

→ **Category 5 twisted pairs**

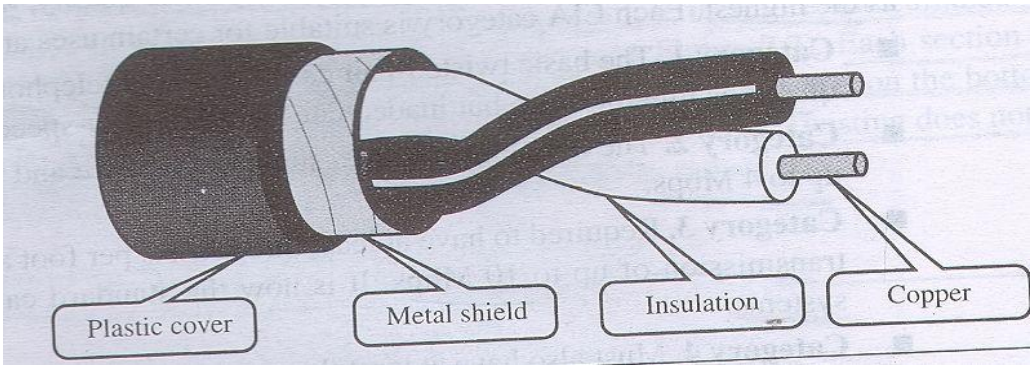
- Starting around 1988, the more advanced category 5 twisted pairs were introduced.
- They are similar to category 3 pairs, but with more twists per centimeter, which results in less crosstalk and a better-quality signal over longer distances, making them more suitable for high-speed computer communication.
- Up-and-coming categories are 6 and 7, which are capable of handling signals with bandwidths of 250 MHz and 600 MHz, respectively (versus a mere 16 MHz and 100 MHz for categories 3 and 5, respectively).

(b)

- All of these wiring types are often referred to as UTP (Unshielded Twisted Pair), to contrast them with the bulky, expensive, shielded twisted pair cables IBM introduced in the early 1980s, but which have not proven popular outside of IBM installations.

→ **STP (Shielded twisted pair)**

- STP cable has a metal foil covering that encases each pair of insulated conductors.
- The metal foil is again enclosed with a plastic cover.
- The metal casing prevents the penetration of electromagnetic noise.
- It also eliminates crosstalk.



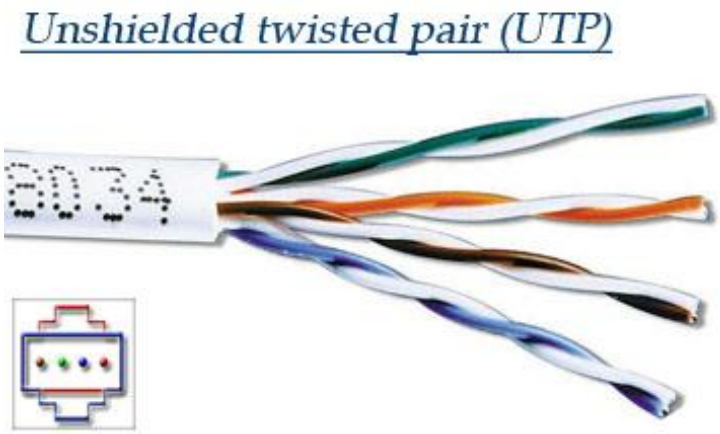
→ **Comparison of Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP)**

Unshielded Twisted Pair (UTP)	Shielded Twisted Pair (STP)

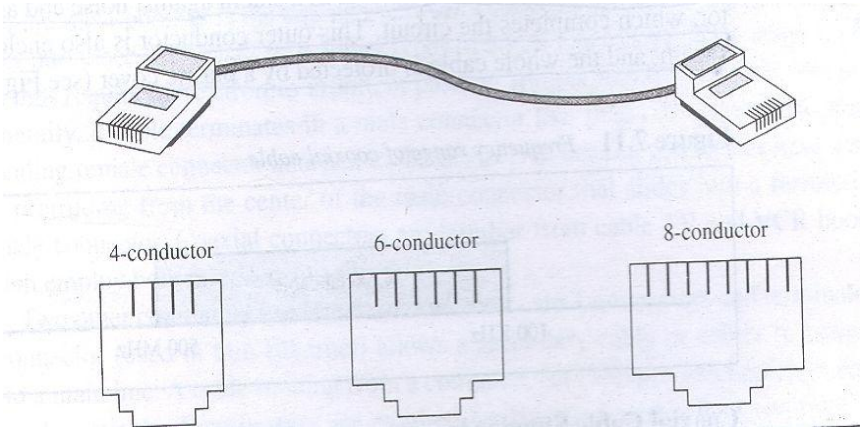
− Ordinary telephone wire
− Less expensive
− Weak immunity against noise and interference
− Suffers from external interference
	− An extra metallic sheath on each pair
	− Relatively more expensive
	− Provide better performance than UTP
	  − Increased Data rate
	  − Increased Bandwidth

→ **Unshielded Twisted Pair connector**

- The standard connector for UTP cabling is an RJ-45 connector.
- This is plastic connector that looks like a large telephone-style connector.
- RJ stands for Registered Jack.
- Each wire in a cable is attached to one conductor in the connector.
- The most frequently used of these plugs is an RJ-45 connector with eight conductors.



→ **UTP connector (RJ 45)**



→ Coaxial Cable

- Another common transmission medium is the coaxial cable (known as ''coax'').
- It has better shielding than twisted pairs, so it can span longer distances at higher speeds.