Transmission Media

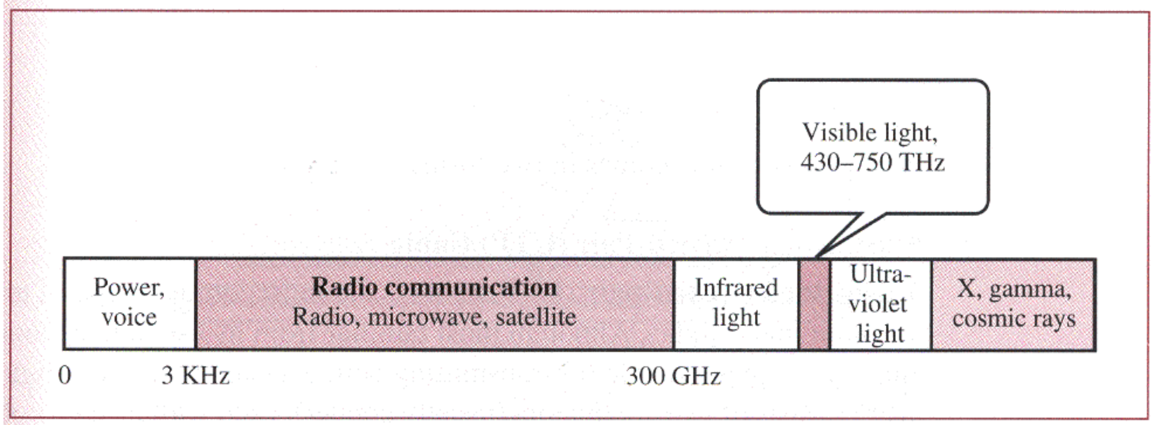
- The transmission medium is the physical path by which a message travels from sender to receiver.

- Computers and telecommunication devices use signals to represent data.
- These signals are transmitted from a device to another in the form of electromagnetic energy.

- Examples of Electromagnetic energy include power, radio waves, infrared light, visible light, ultraviolet light, and X and gamma rays.

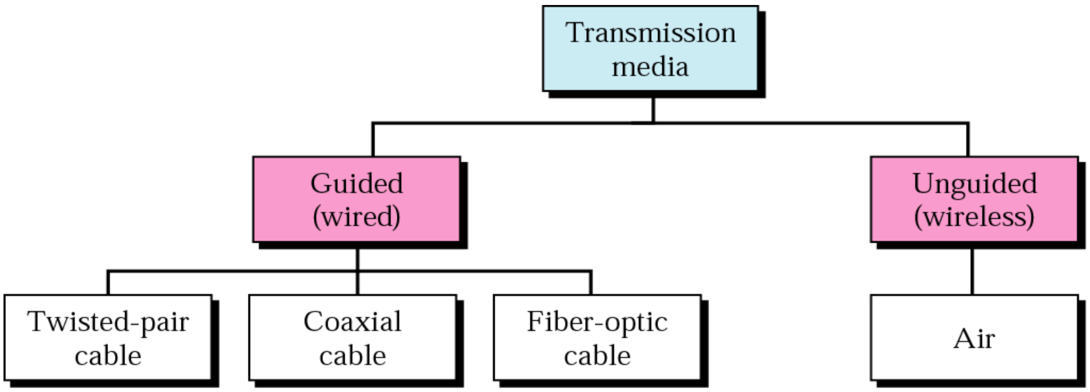
- All these electromagnetic signals constitute the **electromagnetic spectrum**

Figure 7.1 *Electromagnetic spectrum*



- Signals of low frequency (like voice signals) are generally transmitted as current over metal cables. It is not possible to transmit visible light over metal cables, for this class of signals is necessary to use a different media, for example fiber-optic cable.

Classes of transmission media



Transmission Media

- Guided media, which are those that provide a conduct from one device to another.
- Examples: twisted-pair, coaxial cable, optical fiber.
- Unguided media (or wireless communication) transport electromagnetic waves without using a physical conductor. Instead, signals are broadcast through air (or, in a few cases, water), and thus are available to anyone who has a device capable of receiving them.

Guided Media

There are three categories of guided media:

1. Twisted-pair cable
2. Coaxial cable
3. Fiber-optic cable

Twisted-pair cable

- Twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together.
- Twisted-pair cable comes in two forms: unshielded and shielded
- The twisting helps to reduce the interference (noise) and crosstalk.

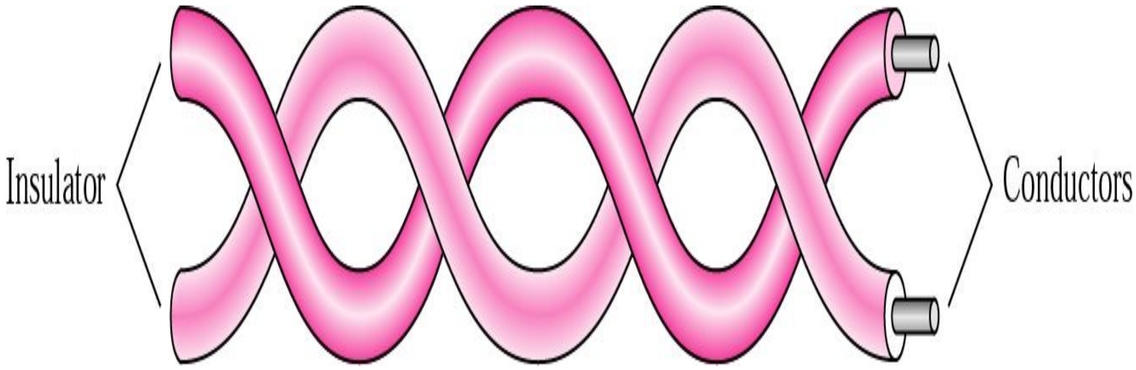


Figure 7.4 *Frequency range for twisted-pair cable*

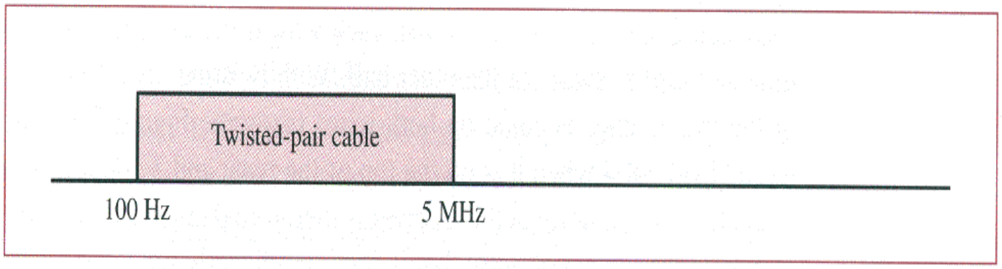
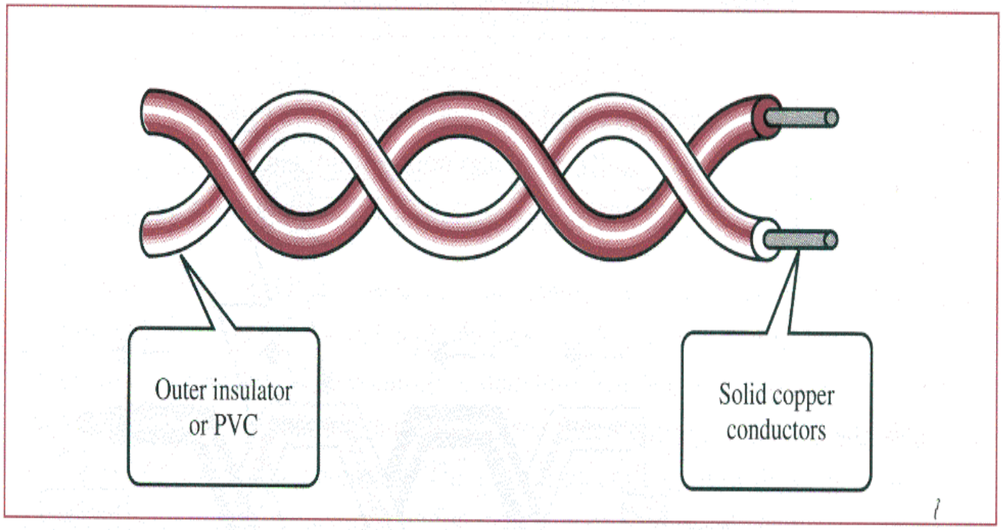
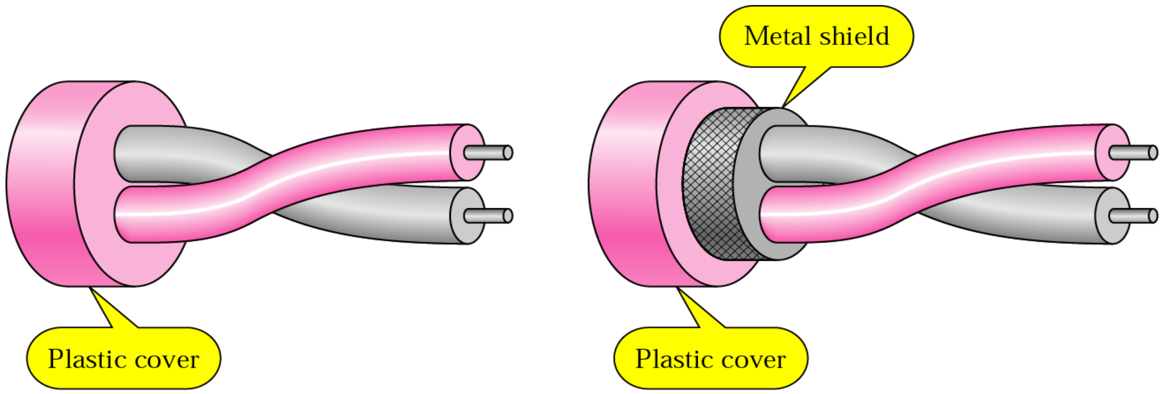


Figure 7.5 *Twisted-pair cable*



UTP and STP



a. UTP b. STP

Unshielded Twisted-pair (UTP) cable

- Any medium can transmit only a fixed range of frequencies!
- UTP cable is the most common type of telecommunication medium in use today.
- The range is suitable for transmitting both data and video.
- Advantages of UTP are its cost and ease of use. UTP is cheap, flexible, and easy to install.

The Electronic Industries Association (EIA) has developed standards to grade UTP.

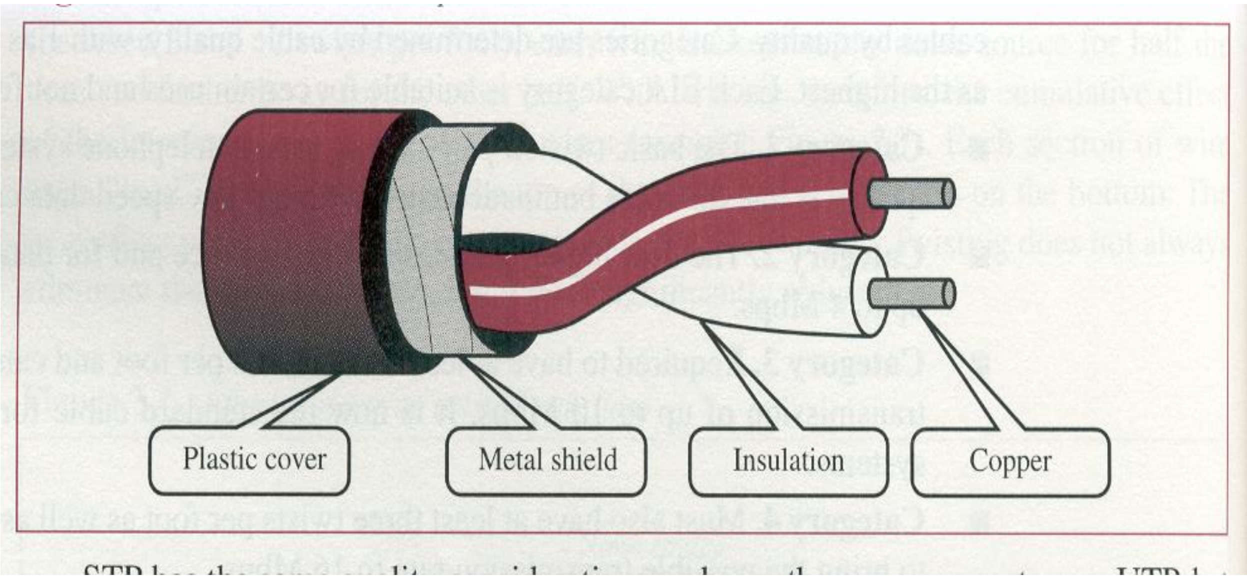
1. Category 1. The basic twisted-pair cabling used in telephone systems. This level of quality is fine for voice but inadequate for data transmission.
2. Category 2. This category is suitable for voice and data transmission of up to 2Mbps.
3. Category 3.This category is suitable for data transmission of up to 10 Mbps. It is now the standard cable for most telephone systems.
4. Category 4. This category is suitable for data transmission of up to 20 Mbps.
5. Category 5. This category is suitable for data transmission of up to 100 Mbps.

UTP connectors

The most common UTP connector is RJ45 (RJ stands for Registered Jack).

Shielded Twisted (STP) Cable

- STP cable has a metal foil or braided-mesh covering that enhances each pair of insulated conductors.
- The metal casing prevents the penetration of electromagnetic noise.
- Materials and manufacturing requirements make STP more expensive than UTP but less susceptible to noise.



APPLICATIONS

- Twisted-pair cables are used in telephones lines to provide voice and data channels.
- The DSL lines that are used by the telephone companies to provide high data rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.
- Local area networks, such as 10Base-T and 100Base-T, also used UTP cables

Coaxial Cable (or coax)

- Coaxial cable carries signals of higher frequency ranges than twisted-pair cable.

- Coaxial Cable standards:
  RG-8, RG-9, RG-11 are used in thick Ethernet
  RG-58 Used in thin Ethernet
  RG-59 Used for TV

Figure 7.11 *Frequency range of coaxial cable*

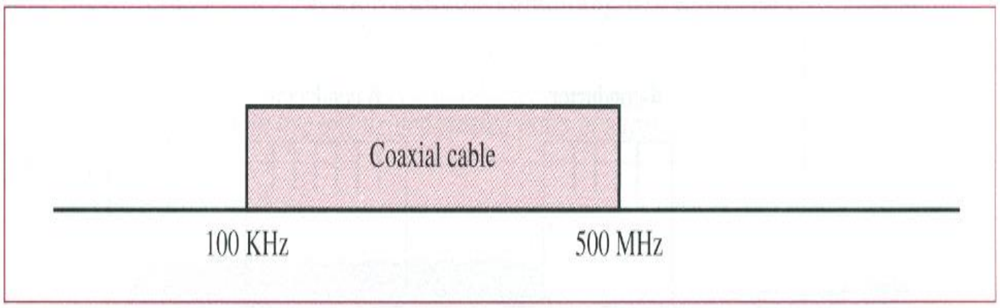
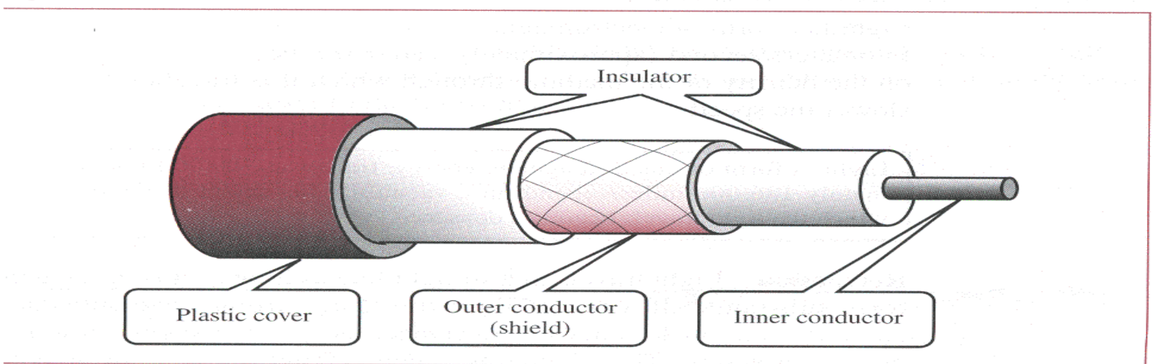
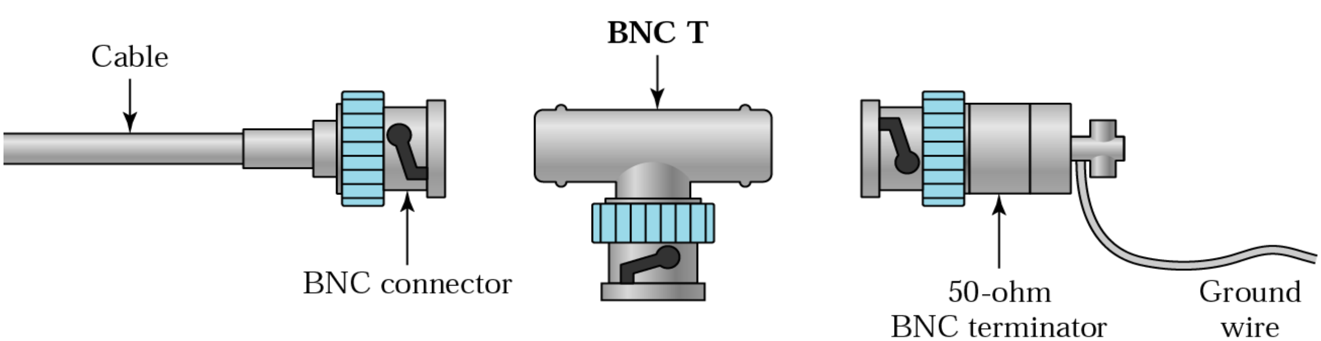


Figure 7.12 *Coaxial cable*



To connect coaxial cable to devices, it is necessary to use coaxial connectors. The most common type of connector is the Bayone-Neill-Concelman, or BNC, connectors. There are three types: the BNC connector, the BNC T connector, the BNC terminator. Applications include cable TV networks, and some traditional Ethernet LANs like 10Base-2, or 10-Base5.



Optical Fiber

- Metal cables transmit signals in the form of electric current.
- Optical fiber is made of glass or plastic and transmits signals in the form of **light**.
- Light, a form of electromagnetic energy, travels at 300,000 Kilometers/second (186,000 miles/second), in a vacuum.
- The speed of the light depends on the density of the medium through which it is traveling (the higher density, the slower the speed).

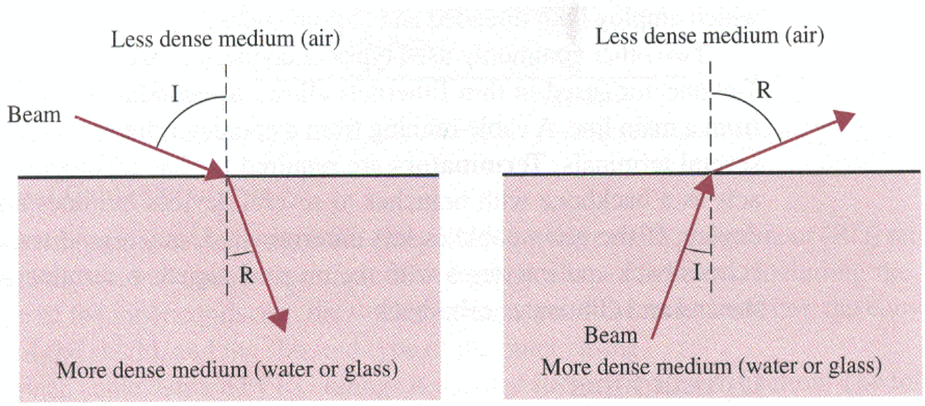
The Nature of the Light

- 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 (less or more dense) substance, its speed changes abruptly, causing the ray to change direction. This change is called refraction.

Refraction

Figure 7.13 *Refraction*



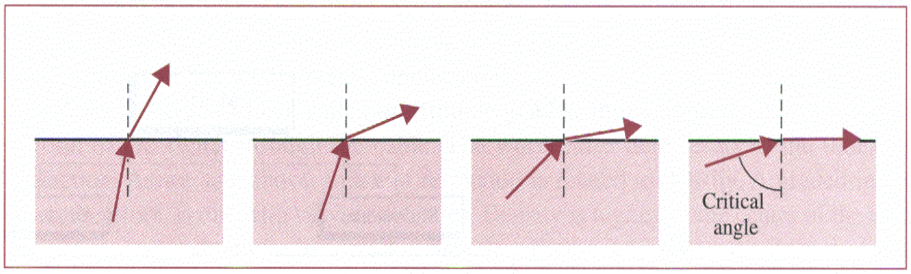
a. From less dense to more dense medium

b. From more dense to less dense medium

Critical angle

- If the angle of incidence increases, so does the angle of refraction.
- The **critical angle** is defined to be an angle of incidence for which the angle of refraction is 90 degrees.

Figure 7.14 *Critical angle*



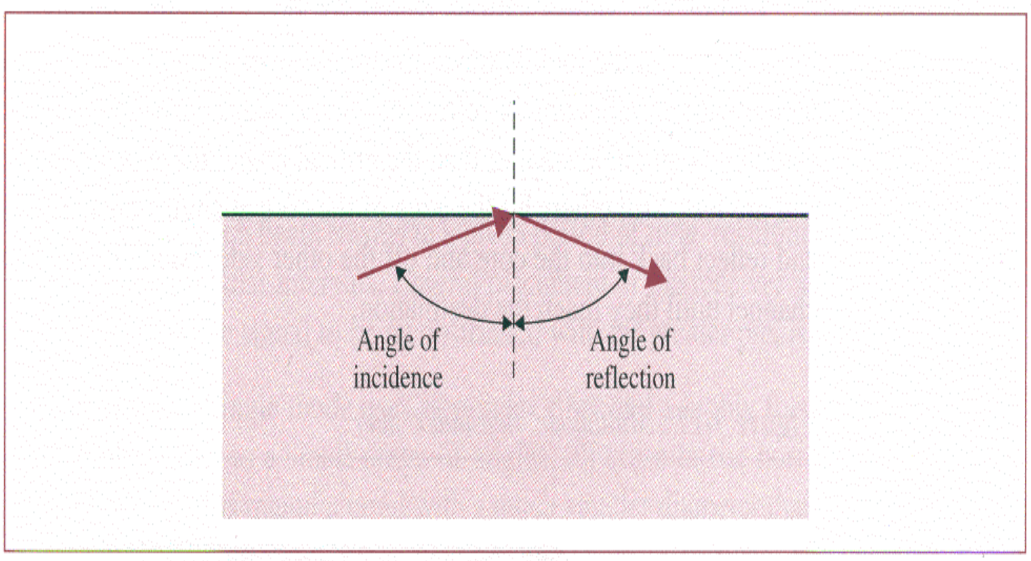
At some point in this process, the change in the incident angle results in a refracted

Reflection

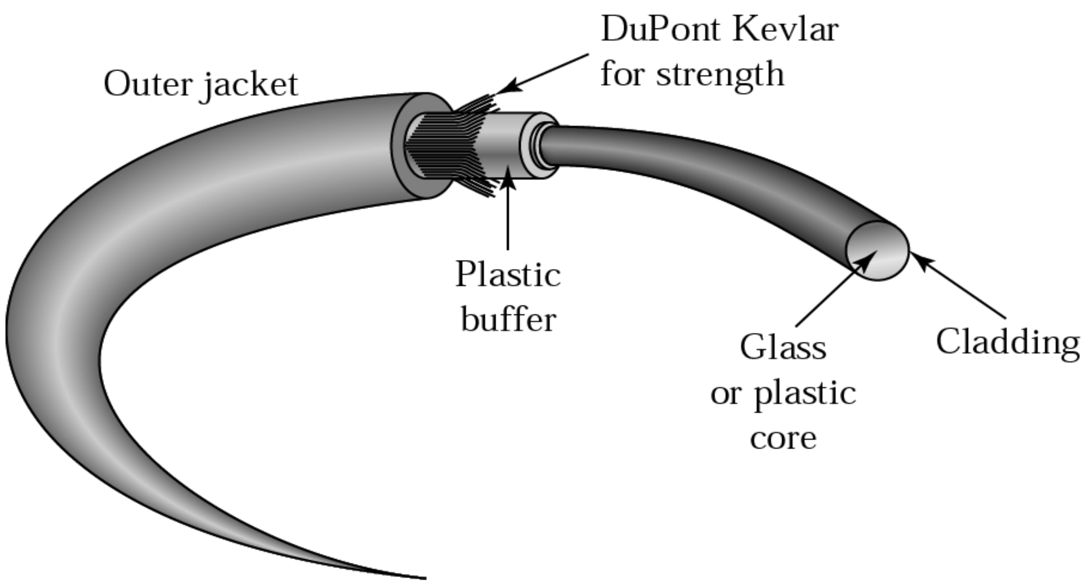
- When the angle of incidence becomes greater than the critical angle, a new phenomenon occurs called **reflection**.

- Light no longer passes into the less dense medium at all.

Figure 7.15 *Reflection*



Fiber construction

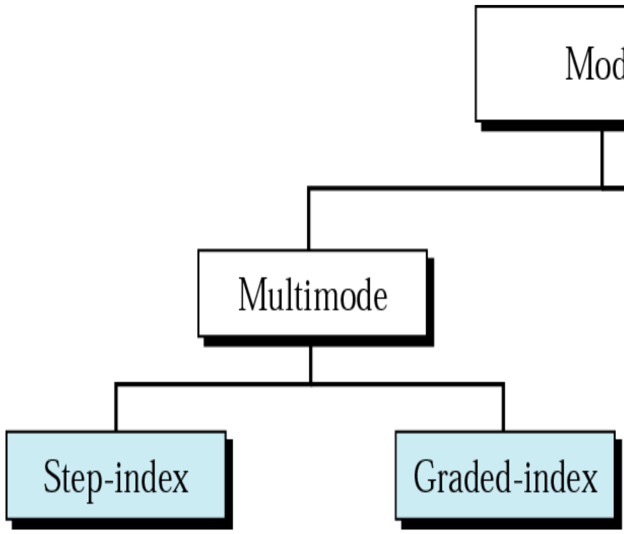


Types of Optical Fiber

- There are two basic types of fiber: multimode fiber and single-mode fiber.
- Multimode fiber is best designed for short transmission distances, and is suited for use in LAN systems and video surveillance.
- Single-mode fiber is best designed for longer transmission distances, making it suitable for long-distance telephony and multichannel television broadcast systems.

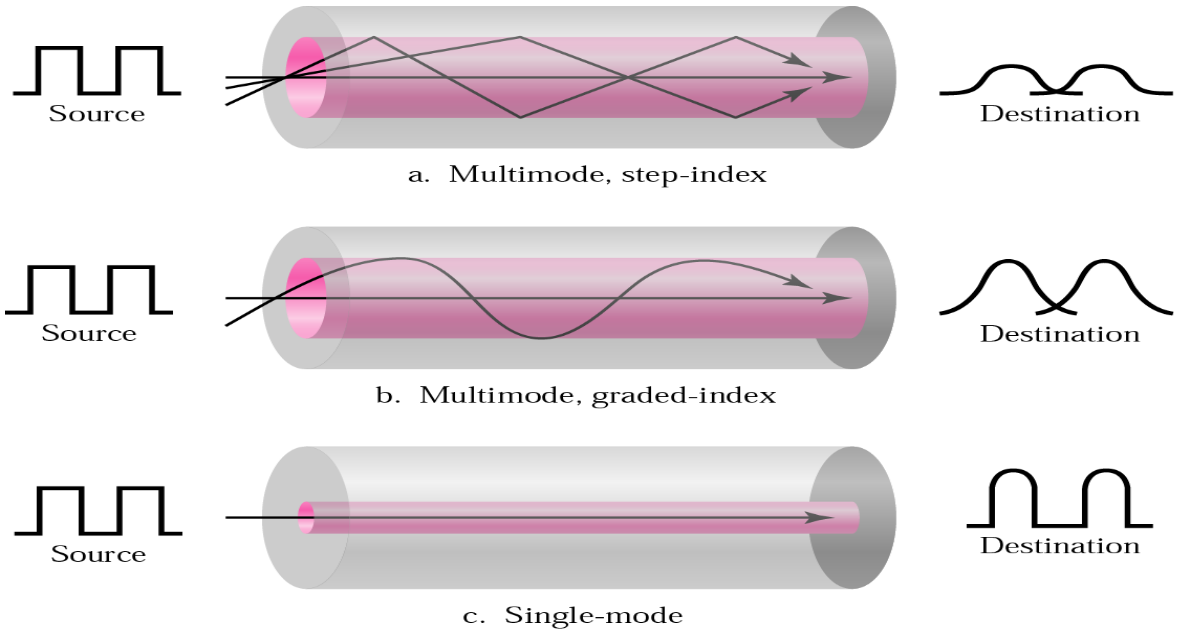
Propagation Modes (Types of Optical Fiber)

- Current technology supports two modes for propagating light along optical channels, each requiring fiber with different physical characteristics: Multimode and Single Mode.
- Multimode, in turn, can be implemented in two forms: step-index or graded index.



- **Multimode**: In this case multiple beams from a light source move through the core in different paths.
- 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 cladding. At the interface there is an abrupt change to a lower density that alters the angle of the beam's motion.
- In a **multimode graded-index fiber** the density is highest at the center of the core and decreases gradually to its lowest at the edge.

PROPAGATIONMODES



- 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.
- Fiber Sizes

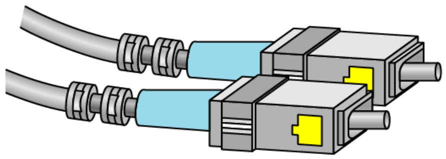
  Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding, both expressed in microns (micrometers).

Light sources for optical fibers

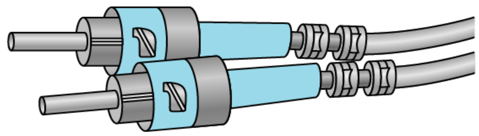
- The purpose of fiber-optic cable is to contain and direct a beam of light from source to target.
- The sending device must be equipped with a light source and the receiving device with photosensitive cell (called a photodiode) capable of translating the received light into an electrical signal.
- The light source can be either a light-emitting diode (LED) or an injection laser diode.

Fiber-optic cable connectors

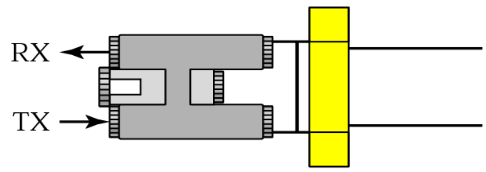
The subscriber channel (SC) connector is used in cable TV. It uses a push/pull locking system. The straight-tip (ST) connector is used for connecting cable to networking devices. MT-RJ is a new connector with the same size as RJ45.



SC connector



ST connector



MT-RJ connector

Advantages of Optical Fiber

- The major advantages offered by fiber-optic cable over twisted-pair and coaxial cable are noise resistance, less signal attenuation, and higher bandwidth.

- Noise Resistance: Because fiber-optic transmission uses light rather than electricity, noise is not a factor. External light, the only possible interference, is blocked from the channel by the outer jacket.

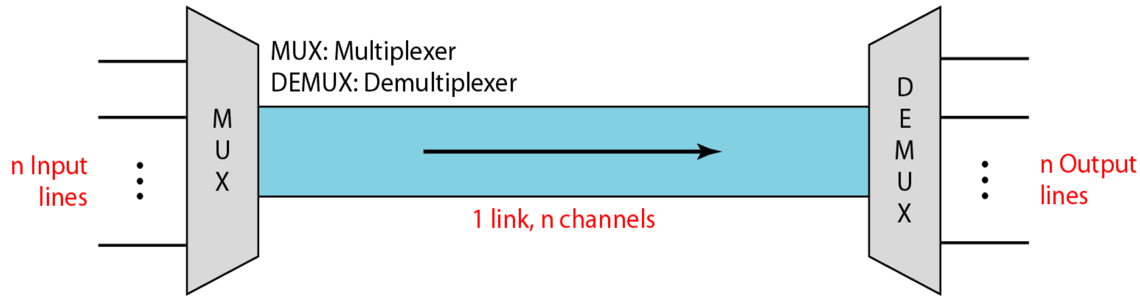
- **Less signal attenuation**
  Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for miles without requiring regeneration.
- **Higher bandwidth**
  Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.

Disadvantages of Optical Fiber

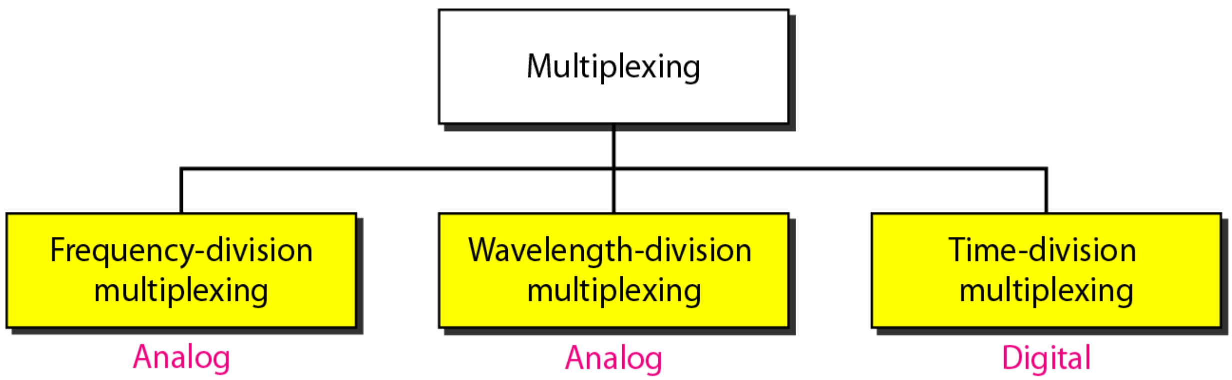
- The main disadvantages of fiber optics are **cost, installation/maintenance, and fragility**.
- Cost. Fiber-optic cable is expensive. Also, a laser light source can cost thousands of dollars, compared to hundreds of dollars for electrical signal generators.
- Installation/maintenance
- Fragility. Glass fiber is more easily broken than wire, making it less useful for applications where hardware portability is required.

MULTIPLEXING

Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. As data and telecommunications use increases, so does traffic. In real life, we have links with limited bandwidths. Bandwidth utilization is the wise use of available bandwidth to achieve specific goals. Efficiency can be achieved by multiplexing.



There are three basic multiplexing techniques: frequency-division multiplexing, wavelength-division multiplexing, and time-division multiplexing. The first two are techniques designed for analog signals, the third, for digital signals.

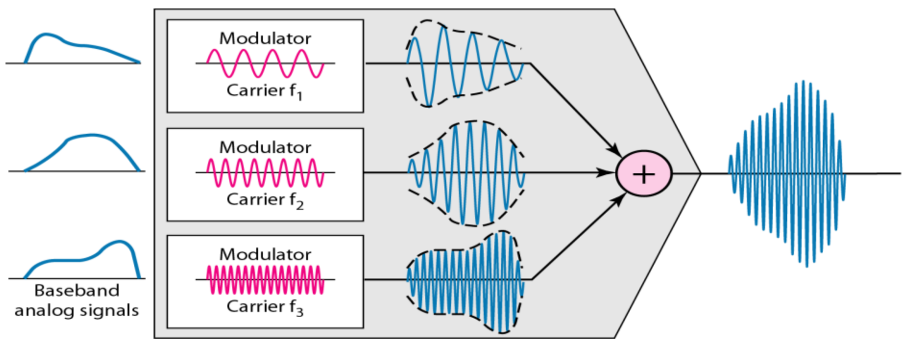


In a multiplexed system, n lines share the bandwidth of one link. The lines on the left direct their transmission streams to a multiplexer (MUX), which combines them into a single stream (many-to- one).

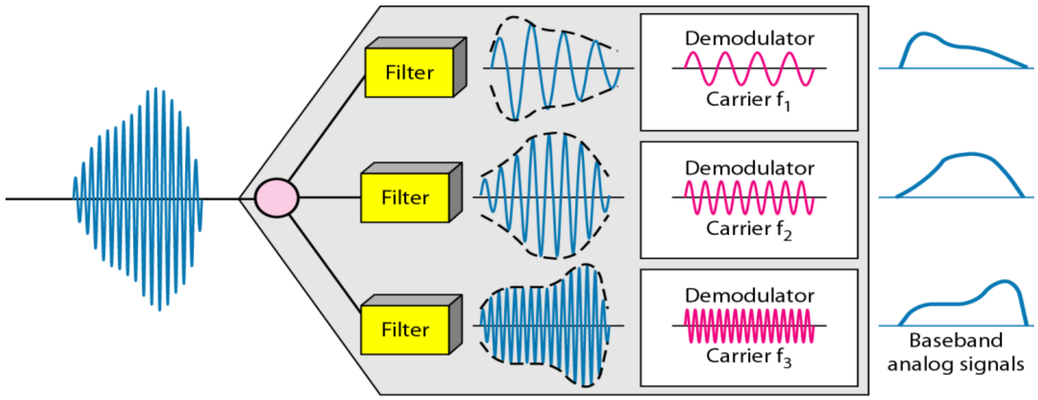
At the receiving end, that stream is fed into a demultiplexer (DEMUX), which separates the stream back into its component transmissions (one-to-many) and directs them to their corresponding lines.

In the figure, the word ***link*** refers to the physical path. The word ***channel*** refers to the portion of a link that carries a transmission between a given pair of lines. One link can have many (n) channels.

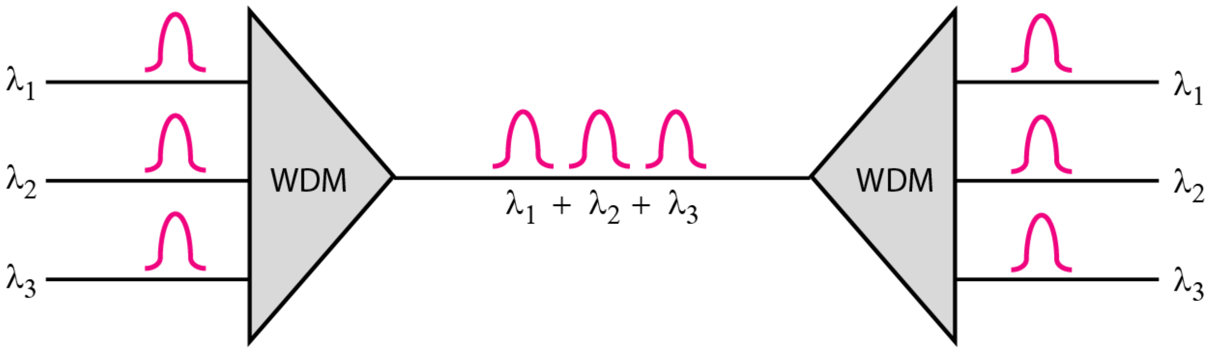
- **•Frequency-division multiplexing (FDM)** is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted. • In FDM, signals generated by each sending device modulate different carder frequencies. These modulated 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.
- In addition, carrier frequencies must not interfere with the original data frequencies.



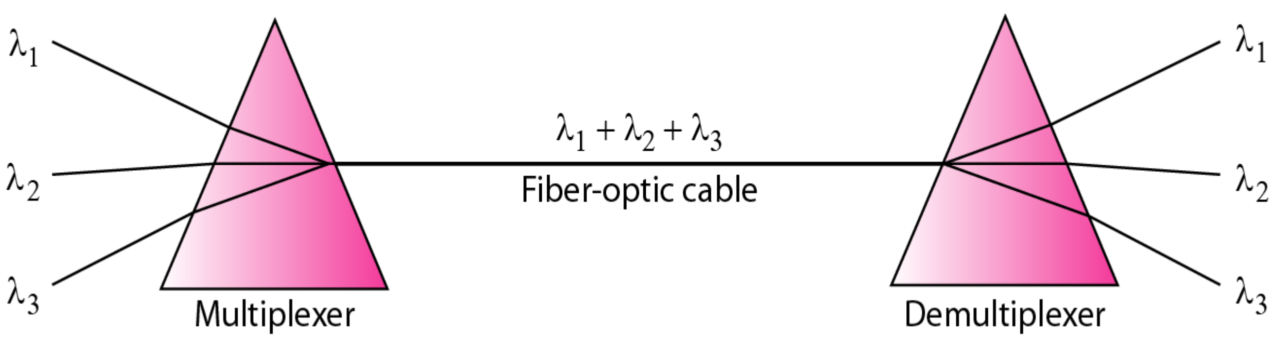
The de-multiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals. The individual signals are then passed to a demodulator that separates them from their carriers and passes them to the output lines.



Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable. The optical fiber data rate is higher than the data rate of metallic transmission cable. Using a fiber-optic cable for one single line wastes the available bandwidth. Multiplexing allows us to combine several lines into one. WDM is an analog multiplexing technique to combine optical signals. The combining and splitting of light sources are easily handled by a prism. Recall from basic physics that a prism bends a beam of light based on the angle of incidence and the frequency.

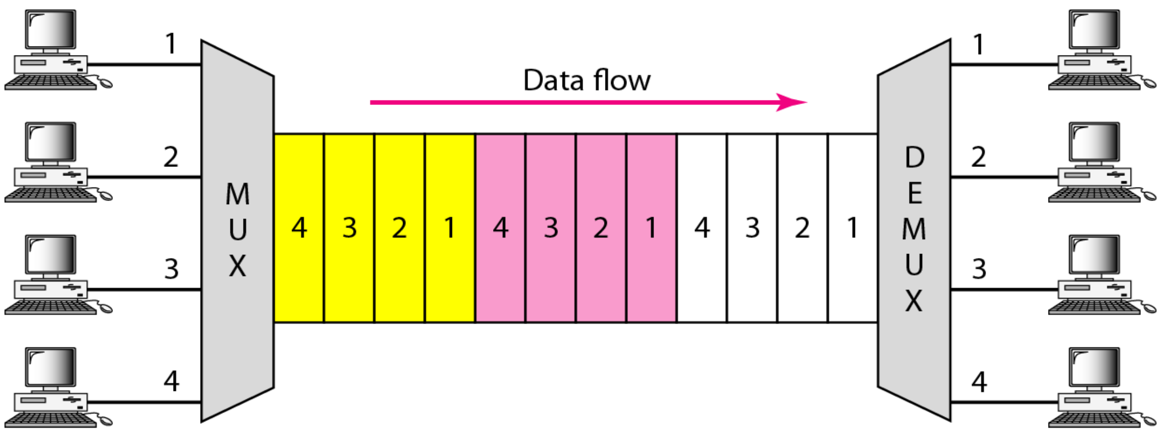


Using this technique, a multiplexer can be made to combine several input beams of light, each containing a narrow band of frequencies, into one output beam of a wider band of frequencies. A de-multiplexer can also be made to reverse the process.



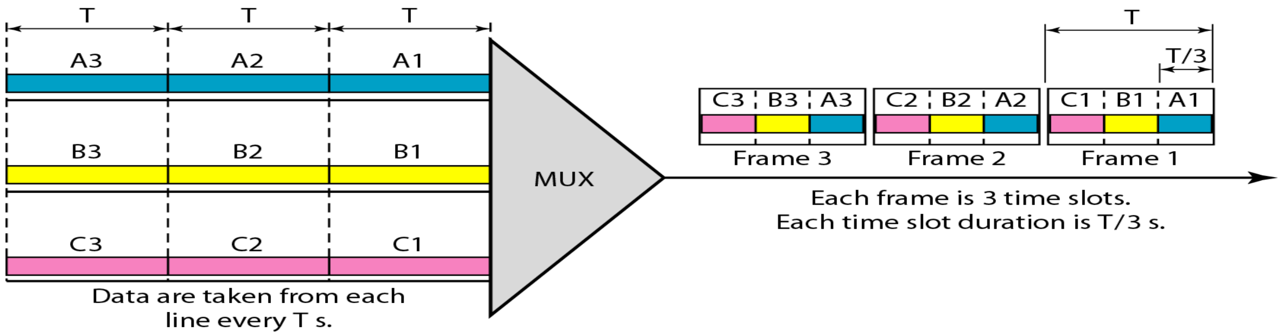
One application of WDM is the SONET network in which multiple optical fiber lines are multiplexed and de-multiplexed. A new method, called dense WDM (DWDM), can multiplex a very large number of channels by spacing channels very close to one another. It achieves even greater efficiency.

Time-Division Multiplexing : Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link. Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link. Note that the same link is used as in FDM; here, however, the link is shown sectioned by time rather than by frequency. In the figure, portions of signals 1, 2, 3, and 4 occupy the link sequentially. TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.



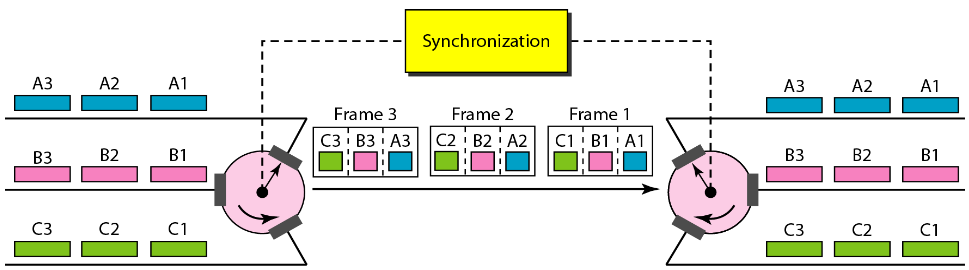
We can divide TDM into two different schemes*:* synchronous and statistical.
In synchronous TDM, each input connection has an allotment in the output even if it is not sending data.

Time Slots and Frames: In synchronous TDM, the data flow of each input connection is divided into units, where each input occupies one input time slot. A unit can be 1 bit, one character, or one block of data. Each input unit becomes one output unit and occupies one output time slot. However, the duration of an output time slot is n times shorter than the duration of an input time slot. If an input time slot is T s, the output time slot is T/n s, where n is the number of connections. In other words, a unit in the output connection has a shorter duration; it travels faster. In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.



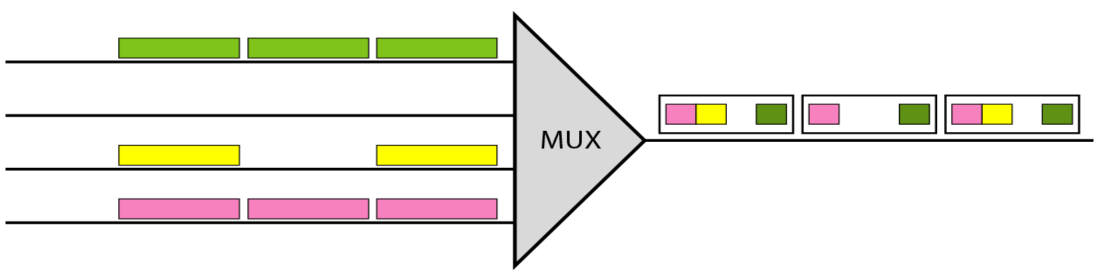
Interleaving

TDM can be visualized as two fast-rotating switches, one on the multiplexing side and the other on the demultiplexing side. The switches are synchronized and rotate at the same speed, but in opposite directions. On the multiplexing side, as the switch opens in front of a connection, that connection has the opportunity to send a unit onto the path. This process is called interleaving.



Empty Slots

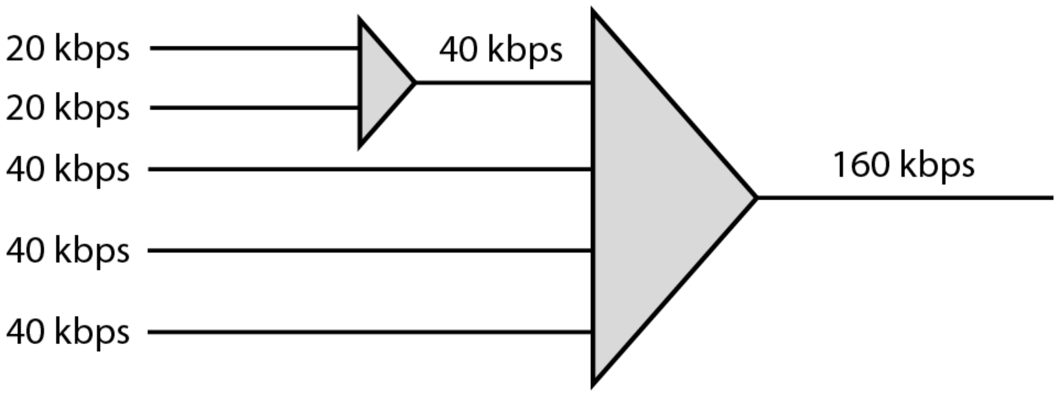
Synchronous TDM is not as efficient as it could be. If a source does not have data to send, the corresponding slot in the output frame is empty.



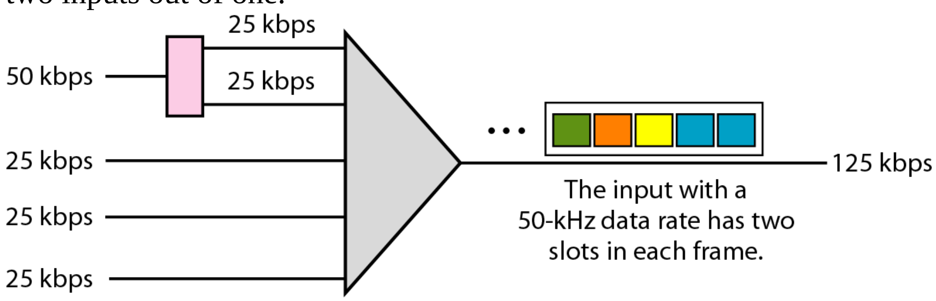
Data Rate Management

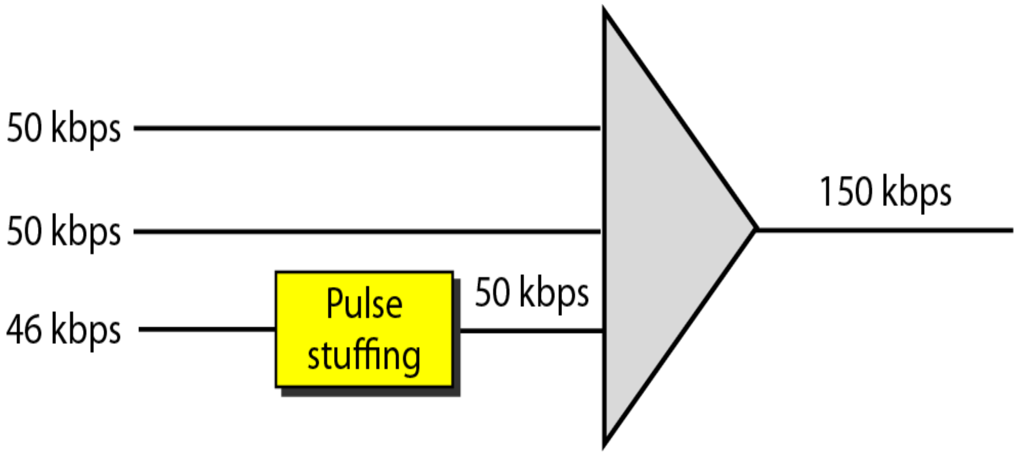
One problem with TDM is how to handle a disparity in the input data rates. In all our discussion so far, we assumed that the data rates of all input lines were the same. However, if data rates are not the same, three strategies, or a combination of them, can be used. We call these three strategies multilevel multiplexing, multiple-slot allocation, and pulse stuffing.

1. Multilevel multiplexing is a technique used when the data rate of an input line is a multiple of others. For example, in Figure, we have two inputs of 20 kbps and three inputs of 40 kbps. The first two input lines can be multiplexed together to provide a data rate equal to the last three. A second level of multiplexing can create an output of 160 kbps.



2.Multiple-Slot Allocation Sometimes it is more efficient to allot more than one slot in a frame to a single input line. For example, we might have an input line that has a data rate that is a multiple of another input. In Figure, the input line with a 50-kbps data rate can be given two slots in the output. We insert a serial-to-parallel converter in the line to make two inputs out of one.





3. Pulse Stuffing Sometimes the bit rates of sources are not multiple integers of each other. Therefore, neither of the above two techniques can be applied. One solution is to make the highest input data rate the dominant data rate and then add dummy bits to the input lines with lower rates. This will increase their rates. This technique is called pulse stuffing, bit padding, or bit stuffing. The input with a data rate of 46 is pulse-stuffed to increase the rate to 50 kbps. Now multiplexing can take place.

Frame Synchronizing : Synchronization between the multiplexer and demultiplexer is a major issue. If the. multiplexer and the demultiplexer are not synchronized, a bit belonging to one channel may be received by the wrong channel. For this reason, one or more synchronization bits are usually added to the beginning of each frame. These bits, called framing bits, follow a pattern, frame to frame, that allows the demultiplexer to synchronize with the incoming stream so that it can separate the time slots accurately. In most cases, this synchronization information consists of 1 bit per frame, alternating between 0 and 1.