Computer Network: Physical Layer

Objective of Lesson 8:

On Completion of this lesson, the students will be able to:

Classify the type of physical transmission media.

Explain Twisted-Pair Cable.

Explain Coaxial Cable.

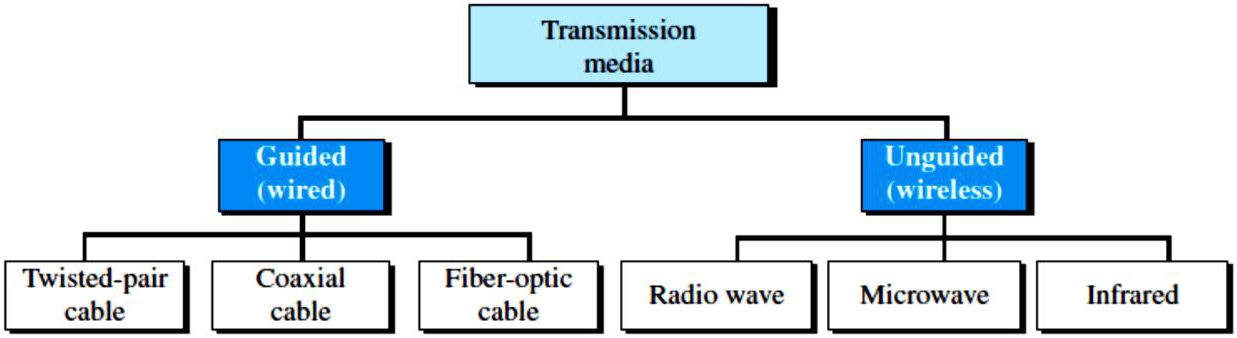
Discuss Fiber-Optic Cable.

One of the major functions of the physical layer is to ***move data*** in the form of electromagnetic signals across a transmission medium. Whether you are collecting numerical statistics from another computer, sending animated pictures from a design workstation, or causing a bell to ring at a distant control center, you are working with the transmission of data across network connections. Generally, the ***data usable to a person or application*** are not in a form that can be transmitted over a network. For example, a photograph must first be changed to a form that transmission media can accept. Transmission media work by conducting energy along a physical path.

Transmission Medium

A transmission medium can be broadly defined as anything that can carry information from a source to a destination. In the data communication, the transmission medium is usually ***free space, metallic cable, or fiber-optic cable***. The information is usually a signal that is the result of a conversion of data from form to another form. Transmission media can be divided into two broad categories: ***guided*** and ***unguided***. Guided media include ***twisted-pair cable***,

coaxial cable, and *fiber-optic* cable. Unguided medium is free space. See the following figures:



So we can see that there are various transmission media then how to select the appropriate one for any application, here some issues that should be considered:

The required bandwidth.

Transmission delay.

Cost & Ease of installation.

Ease of maintenance.

The available services and circumstances

Guided 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.

1.1. Magnetic Media

One of the most convenient way to transfer data from one computer to another, even before the birth of networking, was to save it on some storage media and transfer physical from one station to another. Though it may seem old-fashion way in today's world of high speed internet, but there are some circumstances in which we can use this media:

When the size of data is huge.

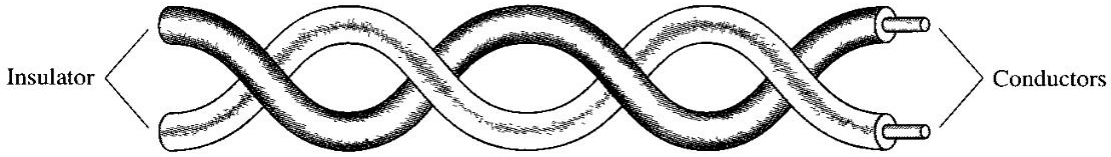
When the service is not presented or limited.

To transmission of data from disaster areas.

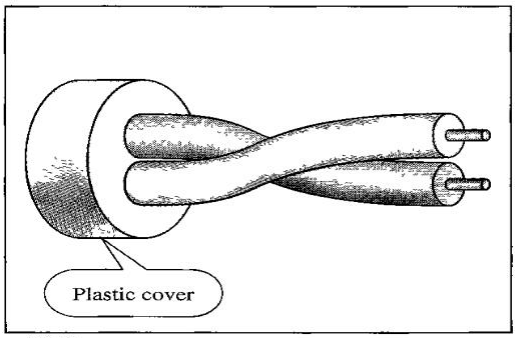
More security.

1.2. Twisted-Pair Cable:

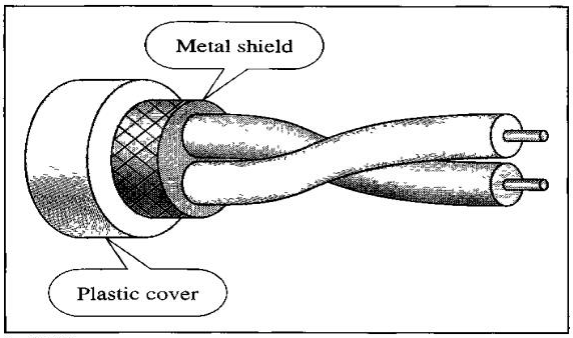
A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in the following figure:



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. There are two types of TP: Unshielded and Shielded Twisted-Pair Cable (UTP, STP)



a. UTP



b. STP

UTP Does not include shielding around its conductors. Typically contains four pairs of stranded or solid conductors. It is inexpensive and reliable. Supports distances of up to 100 meters (328 feet). Supports data transfer rates up to 1 Gbps.

STP Includes shielding, typically a foil wrapper, around its conductors to improve the cable's resistance to interference and noise. Typically

contains

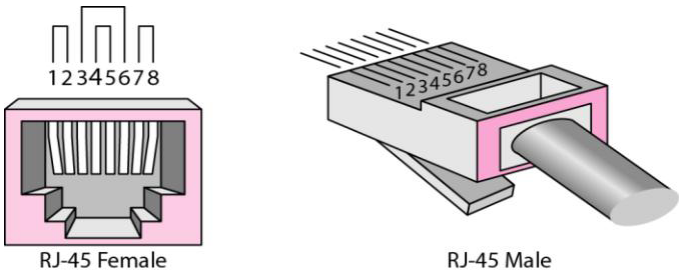
four pairs of stranded or solid conductors. Supports distances up to 100 meters (328 feet). More expensive than UTP. Most commonly used in Token Ring networking.

Twisted pair cable comes in different categories, which support different network speeds and technologies. These categories are summarized in the next table.

1.2.1. Connectors:

The most common UTP connector is RJ45 (RJ stands for registered jack), as shown in the following figure. The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs



1.2.2. **Applications:** it is used in:

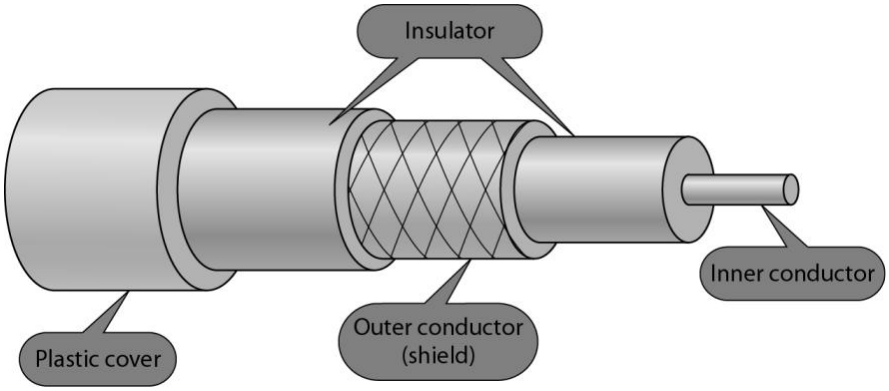
Telephone lines to provide voice and data channels.

It is used in DSL.

Local-area networks, such as 10Base-T and 100Base-T, also use twisted-pair cables.

1.3. **Coaxial Cable:**

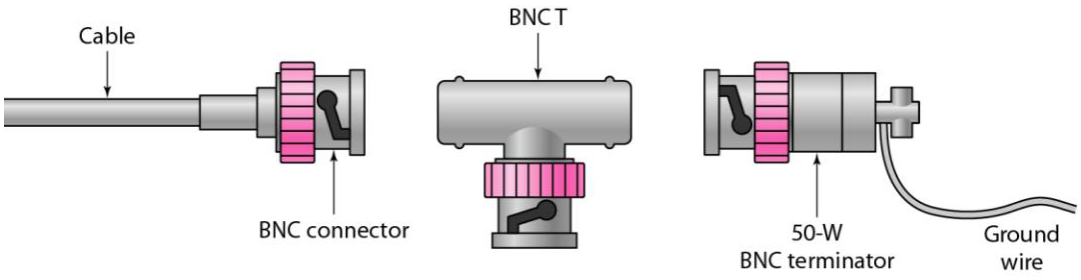
Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted pair cable. It has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two. The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit. This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover (see the following figure).



Coaxial cables are categorized by their radio government (RG) ratings. Each RG number denotes a unique set of physical specifications, including the wire gauge of the inner conductor, the thickness and type of the inner insulator, the construction of the shield, and the size and type of the outer casing.

Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

To connect coaxial cable to devices, we need coaxial connectors. The most common type of connector used today is the Bayone-Neill-Concelman (BNC), connector. There are three popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator as shown in the following figure:

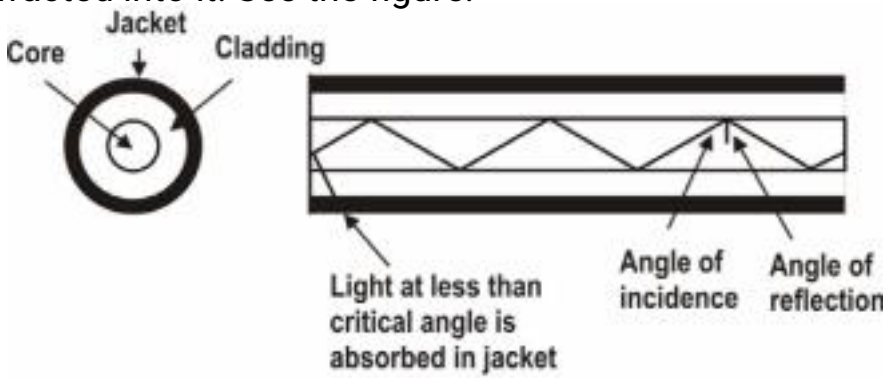


Applications:

Coaxial cable was widely used in analog telephone networks. Later it was used in digital telephone networks. Cable TV networks also use coaxial cables. Another common application of coaxial cable is in traditional Ethernet LANs.

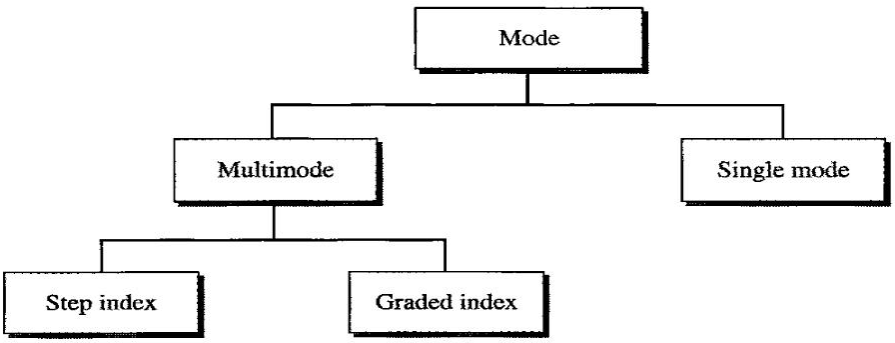
1.4. Fiber-Optic Cable:

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. 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. See the figure:



1.4.1. Propagation Modes

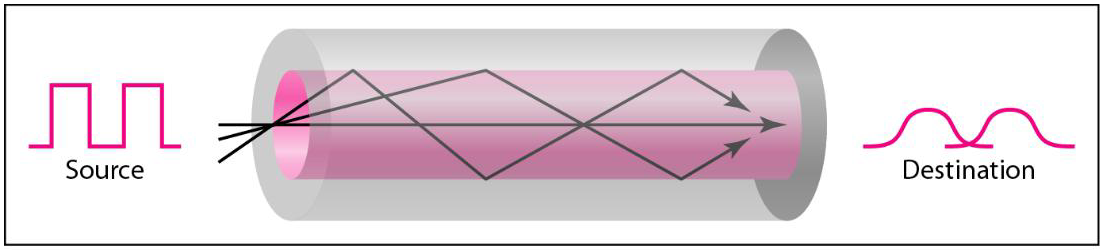
Current technology supports two modes (multimode and single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics. Multimode can be implemented in two forms: step -index or graded-index.



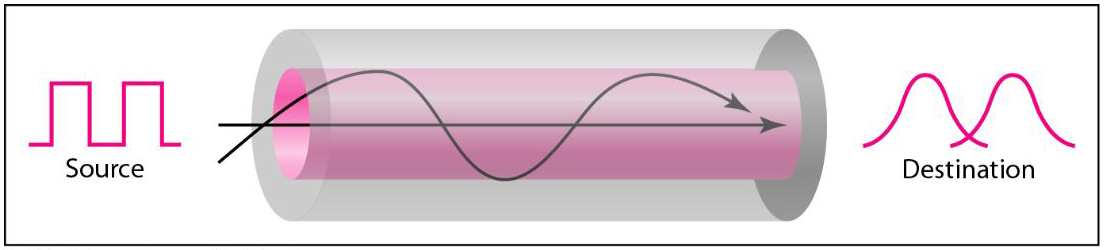
Multimode is so named because multiple beams from a light source move through the core in different paths.

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 the cladding. At the interface, there is an abrupt change due to a lower density; this alters the angle of the beam's motion. The term step index refers to the suddenness of this change, which contributes to the distortion of the signal as it passes through the fiber.

A second type of fiber, called **multimode graded-index fiber** in which Density is highest at the center of the core and decreases gradually to its lowest at the edge.

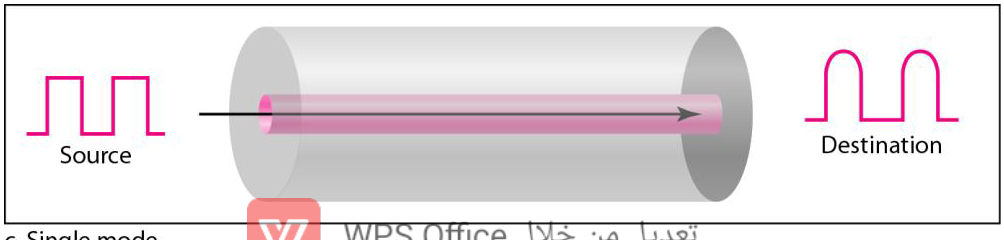


a. Multimode, step index



b. Multimode, graded index

Single-Mode Single-mode uses step-index fiber in which all the beams close to the horizontal (close enough to 90). In this case delays are negligible.



c. Single mode

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

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

1.4.2. Applications

Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective.
It is used with wavelength-division multiplexing (WDM-1600Gbps).
It is used in SONET network.
Some cable TV companies use a combination of optical fiber and coaxial cable.

1.4.3. **Advantages**:

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

1.4.4. **Disadvantages**:

Installation and maintenance.
Unidirectional light propagation.
More cost.

Unguided Media:

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.

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

There are some technical issues that differentiate between guided and unguided media as what follows:

The address of the point is not equivalent to the physical location.

Dynamic topology and restricted connectivity.

Medium boundaries are not well-defined.

Error-prone medium.

Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation, as shown in the following figure: