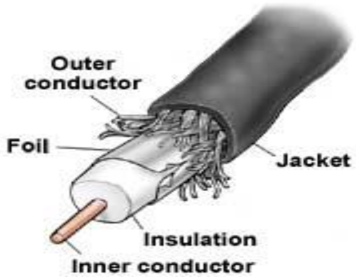
CHAPTER 2: PHYSICAL LAYER

1. Guide Transmission Media:

Coaxial Cable:

Coaxial cable is made of two conductors that share the same axis; the center is a copper wire that is insulated by a plastic coating and then wrapped with an outer conductor (usually a wire braid). This outer conductor around the insulation serves as electrical shielding for the signal being carried by the inner conductor. A tough insulating plastic tube outside the outer conductor provides physical and electrical protection. At one time, coaxial cable was the most widely used network cabling. However, with improvements and the lower cost of twisted-pair cables, it has lost its popularity.



There are two types of coaxial cable.

1. ThickNet
2. ThinNet

ThickNet:

ThickNet is about .38 inches in diameter. This makes it a better conductor, and it can carry a signal about 1640 feet (500 meters) before signal strength begins to suffer. The disadvantage of ThickNet over ThinNet is that it is more difficult to work with. The ThickNet version is also known as standard Ethernet cable.

ThinNet:

ThinNet is the easiest to use. It is about .25 inches in diameter, making it flexible and easy to work with (it is similar to the material commonly used for cable TV). ThinNet can carry a signal about 605 feet (185 meters) before signal strength begins to suffer.

Name	Description	Type	Segment	Speed
10Base2	ThinNet	Coaxial	185 meters	10 Mbps
10Base5	ThickNet	Coaxial	500 meters	10 Mbps

Coaxial cable can only be used with a BNC (bayonet-Neill-Concelman) connector. The following image will show you a BNC connector.

Twisted-Pair Cable:

Twisted-pair cable consists of two insulated strands of copper wire twisted around each other to form a pair. One or more twisted pairs are used in a twisted-pair cable. The purpose of twisting the wires is to eliminate electrical interference from other wires and outside sources such as motors. Twisting the wires cancels any electrical noise from the adjacent pair. The more twists per linear foot, the greater the effect.

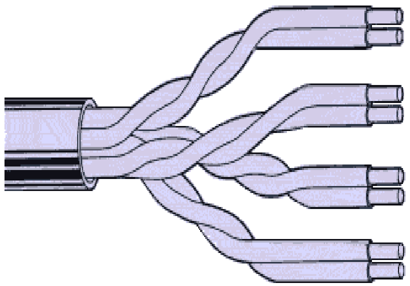


Fig: twisted pair cable

There are two types of twisted pair cable.

1. Shielded Twisted Pair (STP)
2. Unshielded Twisted Pair (UTP)

Shielded Twisted Pair (STP):

The only difference between STP and UTP is that STP has a foil or wire braid wrapped around the individual wires of the pairs. The shielding is designed to minimize EMI radiation and susceptibility to crosstalk. The STP cable uses a woven-copper braided jacket, which is a higher-quality, more protective jacket than UTP.

Unshielded Twisted Pair (UTP):

As the name implies, "unshielded twisted pair" (UTP) cabling is twisted pair cabling that contains no shielding. UTP cables can be divided further into following categories:

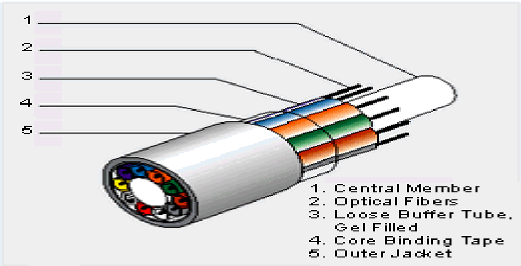
Category 1	Traditional telephone cable. Carries voice but not data
Category 2	Certified UTP for data transmission of up to 4 megabits per second (Mbps). It has four twisted pairs
Category 3	Certified UTP for data transmission of up to 10 Mbps. It has four twisted pairs
Category 4	Certified UTP for data transmission of up to 16 Mbps. It has four twisted pairs
Category 5	Certified for data transmission of up to 100 Mbps. It has four twisted pairs of copper wire
Category 6	Offers transmission speeds up to 155 Mbps
Category 7	Category 7 is a proposed standard that aims to support transmission at frequencies up to 600 MHz

Twisted-pair cable has several advantages over other types of cable (coaxial and fiberoptic): It is readily available, easy to install, and inexpensive. Among its disadvantages are its sensitivity to electromagnetic interference (EMI), its susceptibility to eavesdropping, its lack of support for communication at distances of greater than 100 feet, and its requirement of a hub (multiple network connection point) if it is to be used with more than two computers. Twisted pair cables use RJ45 connector.

Fig: RJ45 connector

Fiberoptic Cable:

Fiber optic cable is made of light-conducting glass or plastic fibers. It can carry data signals in the form of modulated pulses of light. The plastic-core cables are easier to install but do not carry signals as far as glass-core cables. Multiple fiber cores can be bundled in the center of the protective tubing.



When both material and installation costs are taken into account, fiberoptic cable can prove to be no more expensive than twisted-pair or coaxial cable. Fiber has some advantages over copper wire: It is immune to EMI and detection outside the cable and provides a reliable and secure transmission media. It also supports very high bandwidths (the amount of information the cable can carry), so it can handle thousands of times more data than twisted-pair or coaxial cable. Cable lengths can run from .25 to 2.0 kilometers depending on the fiberoptic cable and network. If you need to network multiple buildings, this should be the cable of choice. Fiberoptic cable systems require the use of fiber-compatible NICs.

Comparison:

Name	Description	Type	Segment	Speed
10BaseT	Common; being phased out for 100BaseT	UTP	.5 to 100 meters	10 Mbps
100BaseT	Common	Twisted-pair	.5 to 100 meters	100 Mbps

S.N.	Twisted Pair	Coaxial Cable	Fiber optics
1	Transmission signal is in electrical form over the metallic conductor.	Electrical form over the metallic conductor.	In the form of light over the glass fiber.
2	Noise immunity is low so there is high signal distortion.	Comparatively high noise immunity than twisted pair so less signal distortion.	Very less attenuation so that very less signal distortion.
3	Affected due to external magnetic field.	Less affected due to external magnetic field.	No affected due to external magnetic field.
4	Short circuit between the conductors is possible.	Short circuit between conductors is possible.	No problem of short circuit.
5	Very economical	Slightly higher in cost	Most expensive among all
6	Lowest data rate	Moderate data rate	Highest data rate upto Gbps
7	Signal power loss due to conduction and radiation	Signal power loss due to conduction and radiation	No power loss
8	Installation and maintenance of cable is very easy	Easy	difficult

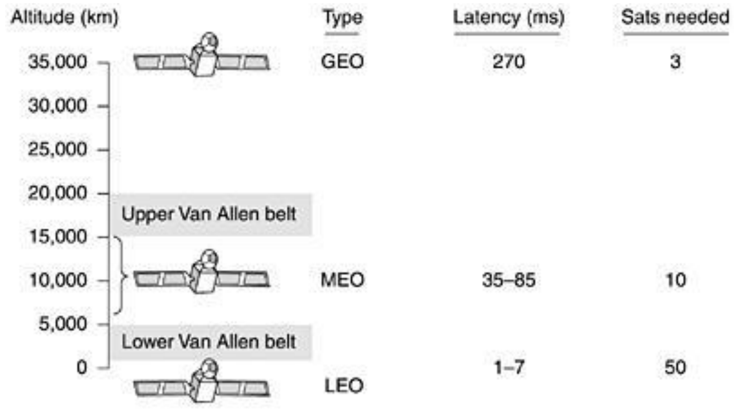
Satellite communication:

A satellite is small heavenly body that revolves around a planet. Ex: moon is the satellite of earth. This is the definition of natural satellite. For the communication purposes, artificial satellites have been developed that rotate around the earth. Artificial satellites (or just the satellites) are placed in the orbit through rocket. These satellites are used for variety of purposes such as military purpose, communication, weather forecast, research, etc. Based on the altitude of orbits, satellites are classified as:

- LEO (Low Earth Orbit): below 5000 km
- MEO (Medium Earth Orbit): 5000 to 15000 km
- GEO (GeoSynchronous Orbit): 35000 km
- HEO (High Earth Orbit): above 35000 km

Communication satellite generally has dozens of transponders. Each transponder can have a beam to cover larger area or a smaller area. The satellite stations within a beam area can send the frames to the satellite on uplink frequency. The satellite then receives and transmits the frames on the downlink frequency. The uplink and downlink frequencies are kept different. The communication satellites normally operate on C-band (4-8 Ghz), Ku-band (12-18 Ghz) or Ka-band (26.5-40 Ghz).
Satellite can transmit the signal from the earth station to a broader area, in different geographical terrain structure and remote areas without wire. So it is useful for satellite phones that can be used in any location within the globe. Communication satellites are used for television broadcast, telecommunication, internet, navigation (GPS) etc. Because satellite operates on higher frequencies, they provide higher data rate. However, for internet satellite are costlier than optical fibers.

Bands	Downlink (Ghz)	Uplink (Ghz)	Bandwidth (Mhz)
L	1.5	1.6	15
S	1.9	2.2	70
C	4.0	6	500
Ku	11	14	500
Ka	20	30	3500

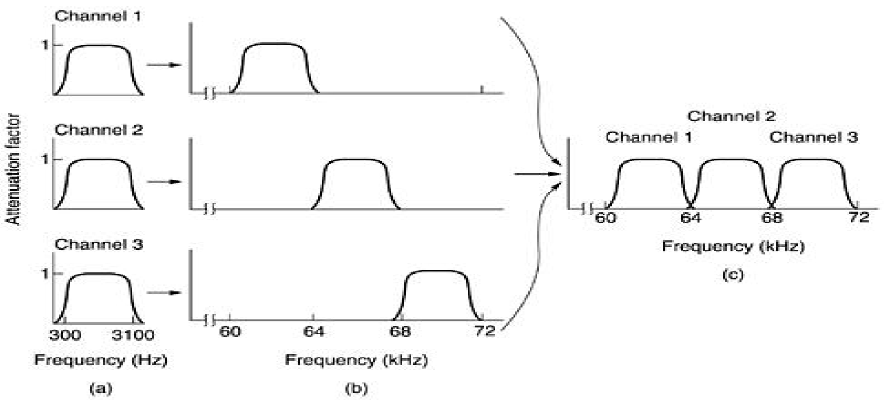


Multiplexing

The concept of multiplexing is developed in order to carry out many conversations over a single physical trunk. It can be divided into two main categories:

1. FDM (Frequency Division Multiplexing)

The frequency spectrum is divided into frequency bands, with each user having exclusive possession of some band. Figure below shows how three voice-grade telephone channels are multiplexed using FDM. When many channels are multiplexed together, 4000 Hz is allocated to each channel to keep them well separated. First the voice channels are raised in frequency, each by a different amount. Then they can be combined because no two channels now occupy the same portion of the spectrum. Notice that even though there are gaps (guard bands) between the channels, there is some overlap between adjacent channels because the filters do not have sharp edges. This overlap means that a strong spike at the edge of one channel will be felt in the adjacent one as non-thermal



noise.

Figure 2-31. Frequency division multiplexing. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

2. TDM (Time Division Multiplexing)

The users take turns (in a round robin fashion), each one periodically getting the entire bandwidth for a little burst of time. TDM can be handled entirely by digital electronics, so it has become far more widespread in recent years though it can be only used for digital data.

3. (WDM) Wavelength Division Multiplexing

For fiber optic channels, a variation of frequency division multiplexing is used. It is called **WDM**. The basic principle of WDM on fibers is depicted in figure below. Here four fibers come together at an optical combiner, each with its energy present at a different wavelength. The four beams are combined onto a single shared fiber for transmission to a distant destination. At the far end, the beam is split up over as many fibers as there were on the input side. Each output fiber contains a short, specially-constructed core that filters out all but one wavelength. The resulting signals can be routed to their destination or recombined in different ways for additional multiplexed transport.

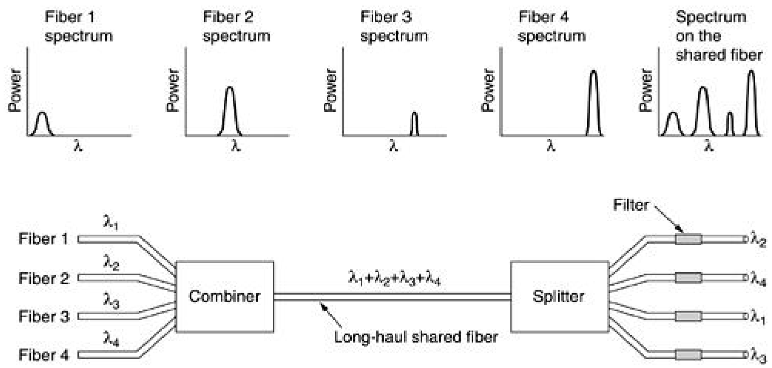


Fig: WDM

This is just frequency division multiplexing at very high frequencies. As long as each channel has its own frequency (i.e., wavelength) range and all the ranges are disjoint, they can be multiplexed together on the long-haul fiber.

Switching

There are three different types of switching:

- Circuit switching
- Message switching
- Packet switching

- Circuit switching: A physical connection is needed for the phone call to go through. This used to be done by a person at a switchboard. Now it is done automatically. Setting up the circuit can still take time, depending on how far the call is going and how many switches it passes through.

- Message switching: No physical path is set up between the sender and the receiver. The whole message (or block of data) is sent to the switching office. Once it has been received, it is inspected for errors and is then sent to the next switching office. This method is not used anymore.

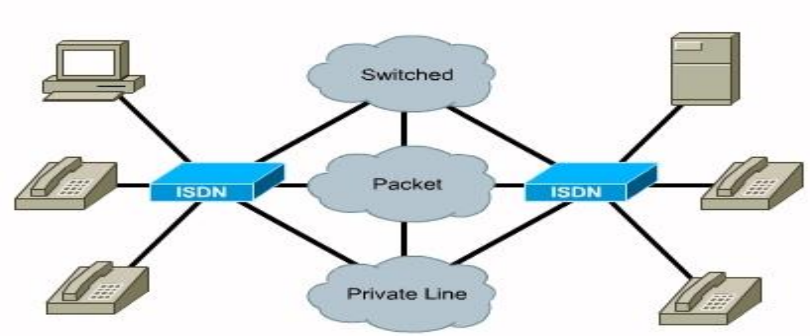
- Packet switching: There is no physical connection for packet switching. The data is broken up into the packets by the sender and they are sent to the switching office. The first packet can easily be sent to the next switching office before the second packet has arrived. This makes the packet switching useful for the busy networks.

Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

Fig: circuit vs packet switching

ISDN:

- ISDN is a set of standards which define an end to end Digital Network.
- Based on WAN technology.



- Uses digital signal
- Uses existing telephone wiring
- Charges are based on the duration of call (how long the WAN link was used).

- Alternate to using the leased lines
- Can transport many types of network traffic (voice, data, video, text, graphics, etc)
- Faster data transfer rate than modems
- faster call setup than modems

ISDN Components

- Terminal Equipment type 1 (TE1)
  - ✓ ISDN compatible device (Router with ISDN interface)
  - ✓ TE1s connect to the ISDN network through a four-wire, twisted pair digital link

- Terminal Equipment type 2 (TE2)
  - ✓ ISDN non-compatible devices
  - ✓ Will require a terminal adapter

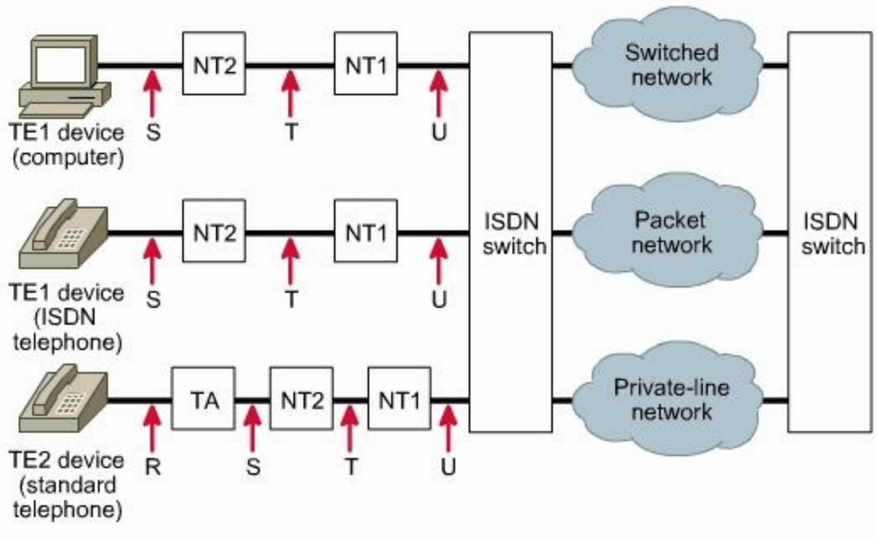
- Terminal adapter (TA)
  - ✓ Converts standard electrical signals into the form used by ISDN
  - ✓ Needed for connection with TE2 devices
  - ✓ The ISDN TA can be either a standalone device or a board inside the TE2
- Network Termination Type 1 (NT1)
  - ✓ Network-termination devices that connect the four-wire subscriber wiring to the conventional two-wire local loop

- Network termination type 2 (NT2)
  - ✓ Intelligent device that performs switching and concentrating
  - ✓ Provides multiple ISDN interfaces on an ISDN line. The NT2 may be as simple as a bridging device connected to an NT1 unit or it may be as complicated as a PBX (Private Branch Exchanges)

ISDN Reference Points

ISDN reference points define the logical interfaces between functional groupings, such as TAs and NT1s.

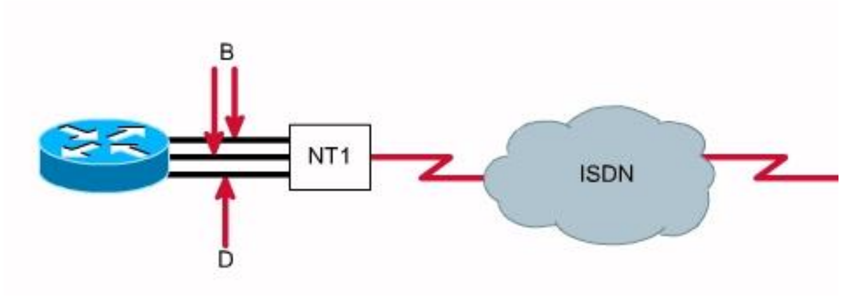
- R: point between non ISDN equipment and a TA.
- S: point between user terminals and NT2.
- T: point between NT1 and NT2 devices.
- U: point between NT1 devices and line-termination equipment in the carrier network.



ISDN services

BRI (Basic Rate Interface)

- Connection from ISDN office to the user location provides for access to three channels. The channels are two 62Kb B-channels and one 16Kb D-channel.
- The B-channel and the D-channel provide the user with access to the circuit switched network.



PRI (Primary Rate Interface)

- ISDN Primary Rate Interface service provides digital access via a T1 line. A T1 line provides a 1.544 bandwidth. This bandwidth is divided into 24 64Kb channels. The ISDN PRI service uses 23 B channel accesses and uses the 24th D channel for signaling purposes.