Transmission Media

In order to carry the data packets from one node to another on a network some sort of media must be employed. The most common types of media are:

- **Twisted Pair Copper Cable**
- **Coaxial Copper Cable**
- **Fibre Optic Cable**

Copper cables have been used to carry electricity and electrical signals from one place to another for many years. Since the 1960's Fibre Optic cables have been used to carry digital signals from A to B in the form of light. Which type of cable is used for a specific situation will depend on several factors

- Distance
- Environment
- Security
- How many signals

There are many variations of cable in existence but only the more popular types used on LANs will be covered here.

TWISTED PAIR CABLE

Twisted pair cables have been used for connecting telephones to Local Exchanges ever since telephones were invented, the size and thickness have changed but they are basically the same as they were in the early twentieth century.

A twisted pair cable consists of two insulated wires which are twisted round each other to form the twisted pair. The frequency of the twist down the cable coincides with the frequency of the electrical signals which will try to invade the cable from outside. The twist will introduce a cancelling effect at the frequency of these signals thus reducing Radio Frequency Interference (RFI) and Electro-Magnetic Interference (EMI). RFI and EMI are introduced on the cable because the copper wire would act as an efficient aerial at certain frequencies if it were two straight cables. The baseband signals being carried by the cable have sharp edges which can be severely distorted by the RFI, EMI, capacitance, resistance and inductance. Rounding the edges causes the receiving circuitry to think a "1" is a "0" and vice versa.

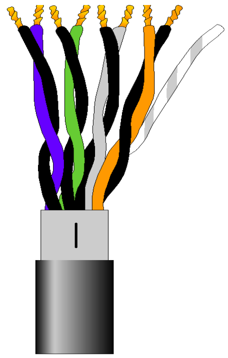
Two main types of twisted pair cable exist -Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP).
UNSHIELDED TWISTED PAIR

The number of actual twisted pair cables held in one sheath varies, that used for connecting Networks is generally 4 pairs (8 wires) but the cables laid in the road to feed telephones may have hundreds or thousands of pairs of cables. Each cable is identified by the main colour of the cable and a tracing colour. When there are hundreds of cables in a sheath there may be several tracer colours.

The type of cable used for networking have their pairs as the same colour but one will have a white cable with the same tracer colour as the main cable. i.e:

- Orange and white with a orange tracer
- Blue and white with a blue tracer

- Green and white with a green tracer
- Brown and white with a Brown tracer



Sometimes the white and colour tracer are reversed, i.e Orange with a white tracer. Some cables have one colour and either plain white or black. BT have a standard colour coding for their cables, and they are used in the order of the colours specified.

Originally twisted pair cabling was only used for applications which ran at less than 1Mbps, generally used for voice and RS232 or RS422 serial communication.Improving technological techniques, such as Ethernet Hubs and Switches, have allowed frequencies of between 10Mbps and 100Mbps to transmitted by twisted pair cables.

Twisted Pair cables are divided into different categories which vary in the number of twists per foot and quality, allowing the higher categories to transmit data at higher speeds, e.g.Category 3 cables have 2 twists per foot whereas Category 5 has 12.

Different categories are used for different applications:

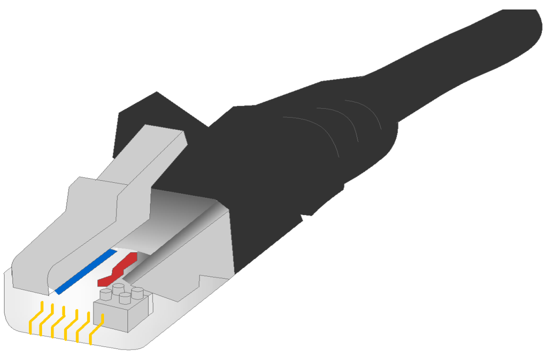
Category	Use
1	Less than 1Mbps. Voice and RS232
2	Up to 4Mbps. Token Ring and ISDN
3	Up to 10Mbps. Ethernet and Wang
4	Up to 10Mbps. 16Mbps Token Ring and ARCnet
5	Up to 100Mbps Twisted Pair Distributed Data Interface (Tpddi

The only one currently recommended for data is Category 5 (CAT5), which is used for integration of Telephone and LAN wiring (Voice and Data). It is used in a structured[1] manner which means that the wiring has to comply with standards such as the following:
Length of cable; How many cables in a bundle; No more than 0.5" of twist must be unravelled when making a connection; The radius of the curve if the cable is bent.
The full specifications for Category 5 would fill a large A4 manual and are really required only by those employed in installing the Structured cabling.

[1] Structured - A structured cabling system is one which can be pre-installed into a new building, or retrofitted to an existing building, and provide a flexible means of connecting devices.

The structured nature of CAT5 wiring utilises an RJ45 connection,shown on the right, which is a smaller version of the normal plug and socket used for connecting a BT phone. The wiring is connected to a Wall Plate or floor box at the users station and to a Patch Panel[1] in a Wiring Cabinet[2]. In a new building the wires from all the outlets on a single floor may be brought to a wiring cabinet on the individual floors. Inter-floor connections will also be made via cables between the cabinets on each floor. In this way an individual cable can be connected as either a data (network) or a voice (telephone) connection. The use of patch cables (small cables with an RJ45 plug on each end) can be used to provide the connections.

[2] Patch Panel - A unit which has a connection to accept the twisted pair cable and make the output an RJ45 Socket.
[3] Wiring Cabinet - Wiring Cabinets are large 6' cabinets which usually accept 19" wide units which screw to a vertical rack at each side. Most network equipment is made to fit into the standard 19" rack or have brackets supplied to do so. Cables are brought to the cabinet and connected to the patch panels. Smaller cabinets can be purchased if a small number of units are being purchased, the width is still the same.



Shielded Twisted Pair

STP has an extra metallic wrapper around the inner cables which will further reduce RFI and EMI, this sometimes surrounds all the pairs or could surround each individual pair this gives more bulk to the cable.

STP is available with two impedances, 100ohm and 150ohm impedance - the later is more expensive. The lower impedance gives the same performance as UTP but the higher impedance STP can deal with speeds up to 100Mbps.

Shielded Twisted Pair (STP) was originally used for Token Ring Networks and IBM have defined standards for twisted pair cables are defined as a Type x cable where x is a number. The most commonly used types are 1 and 3. The different types defined by IBM are given in the following table:

Type	Description
Type 1	Two STP Pairs for data transmission. Historically used for Token Ring. Each pair is shielded
Type 2	Six pairs of wire, two STP pairs for data and four pairs of UTP for voice
Type 3	Telephone grade UTP equivalent to EIA**[1]**/TIA**[2]** category 2 UTP cables Originally recommended for 4Mbps Token Ring but IBM now recommends Cat 3, 4 or 5 for both 4Mbps and 16Mbps LANs
Type 5	{Fibre Optic) IBM recommends 62.5/126 µm multimode optical fibre for installations
Type 6	Two pairs for data transmission - similar to Type 1
Type 8	Two shielded pairs housing in a flat plastic. Suitable for under carpet installation
Type 9	Thinner, low cost version of Type 1. Supported lower distances.

1] EIA - Electronic Industries Association
[2] TIA - Telecommunications Industries Association

Screened Twisted Pair

Screened Twisted Pair (ScTP) is the same as UTP but has an Aluminium foil surrounding the pairs in the same way as STP. It is thought that ScTP may become a replacement for Category 5 cable

COAXIAL CABLE

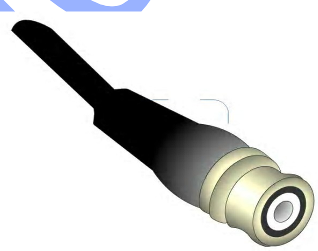
The first networks to be designed were cabled with Coaxial cable. It has two wires like Twisted pair but the design with an inner conductor and outer braid conductor enable it to have a higher Bandwidth and be capable of higher data rates.

Coaxial cables have three types which are suitable for data networks:

50 ohm- suitable for Ethernet Bus Networks.

75 ohm- Suitable for transferring baseband and broadband analogue signals such as Video

93 ohm- suitable for ARCnet networks.



Baseband Coaxial Cable

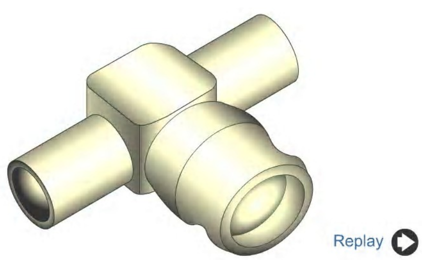
Coaxial cable is made up of a central inner core, which may be solid or consist of several thin wires, surrounded by an insulating material. Wrapped around this is a cylindrical conductor, which can be solid or a braided mesh outer conductor which is then wrapped in a plastic sheath.

With this type of Coaxial Cable a data rate of 1to 2Gbps can be achieved over lengths of 100Km. Coaxial cable was used extensively to connect telephone exchanges but is now gradually being replaced by fibre optic cables.

The thicker a coaxial cable is, the farther it can carry high frequency electrical signals. There are two thicknesses used in Ethernet bus networks and the different cables are called Thick and Thin Ethernet cable. Although different thicknesses they both have the same 50ohmimpedance.

The thick Ethernet cable was used in the original Ethernet bus networks and was sometimes referred to as "Yellow Wire" because of its base colour.

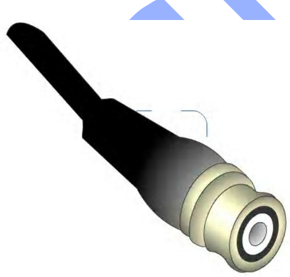
The thin coaxial cables are used with BNC connectors and creates networks which are referred to as "Thinnet" or "Cheapernet". Each cable has a "T" piece connecting to the Network Interface Card and the last cable each end has a Terminating resistor.



ARCnet[1] uses a 93ohm coaxial cable but still uses BNC connectors even though ARCnet utilises a star topology.

[1] ARCNET - A technology which is not used very often today and is not discussed in this course.

Broadband Coaxial Cable



The term Broadband comes from the telephone world, where it refers to any frequency wider than 4 kHz. This type of coaxial system uses an analogue 2signal on standard cable television cable. The cables can run for up to 100km at 300 MHz and often up to 400 MHz.

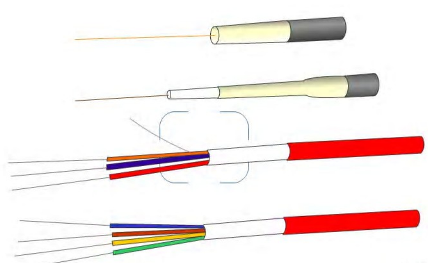
Broadband signals are often divided up into smaller channels of around 6 MHz each of which can contain a Television broadcast (6Mhz), a CD quality audio transmission (1.4Mhz) or a digital bit stream (3Mhz).

Broadband systems often use a tree topology and sometimes dual cables or frequencies for Transmit and Receive.

The main difference between Baseband and Broadband is that Broadband covers a very much larger geographical area than baseband but it requires amplifiers to increase the analogue signal level at regular intervals. Dual and single cable systems have been developed to overcome these problems.

The broadband cable is technically inferior to the Baseband but it does have the advantage of already being in place. The Netherlands has 90% of all homes fed by cable TV and the United States has 80%. Cable systems in the United Kingdom already offer telephone facilities as part of their packages but in the future the cable systems could become MANs for data transfer.

Fiber optic cable



In recent years Fibre Optic Cables have been used increasingly as a Transmission media for data.

Fibre Optic Cables are very thin (as thin as a human hair) strands of glass or plastic through which a laser light is passed from one end to the other.

The strands are measured in µm (millionths of a metre).

The thickness varies from 5 to 10µm for Single mode to 50 to 100µm for Multimode cables.

The cables can be purchased with just one single fibre optic strand inside, the top one in the diagram on the left, or with multiple strands, the bottom two.

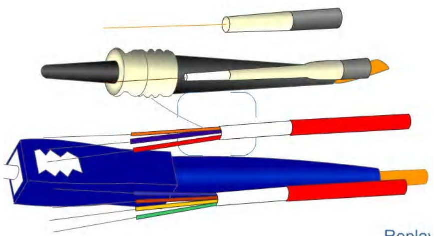
Using Fibre Optic cable is very expensive due its handling and the precision needed to attach the connector. Special tools, costing a lot of money, are used to attach the connector to the fibre strand. Two types of connector are shown on the right. The top one has a protective sleeve over the Fibre Optic Cable connection.

Fibre Optic cables can be joined together, spliced, in three ways but all three will introduce reflections at the join which can interfere with the signal:

- **By using connectors** - this loses approximately 10 to 20% of the light but it easy to reconfigure the systems.

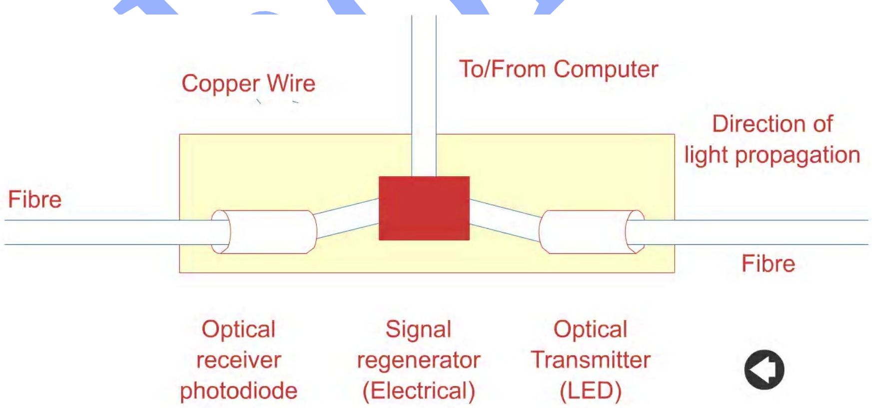
- **By splicing mechanically** - the fibre is very carefully cut, the two ends are then laid into a special sleeve and permanently clamped into place. Light is passed through the junction and adjustments made for minimum light loss. This method has about 10% light loss.

- **By fusing** - melting the two ends together to form a solid connection. This method has very low attenuation.



When using Fibre optic cables there must be units to transfer electrical signals to light signals and vice versa.

Two types of interface are used - Passive and Active. The Passive interface consists of two taps directly fused onto the fibre optic cable, one will contain a photodiode for reception and the other an LED or Laser diode for transmission. This system is extremely reliable as the light path is not broken even if one of the electrical components become faulty, the computer just goes off line. The Active interface has an electrical regenerator and will break the path if an electrical fault occurs. As most Fibre optic systems run on ring topology this will bring the ring down. The Active optical interface is shown below.



Fibre Optic cables have replaced a lot of the twisted pair cables being used to carry voice conversations because it is thin and light, e.g. two fibre optic cables will carry more capacity than one thousand twisted pair cables. if the cables are 1Km long the twisted pair will also weigh 8000Kg. Because photons (particles of light) are not charged they do not bump into each other thereby losing energy. EMI does not affect the signals running in a fibre optic cable as they are not electrical and they are more secure as the signals do not leak out either and cannot be picked up by an outside source.

Light source, transmission and reception

Two types of light source are used to generate the light used for transmission - LED and semiconductor laser.

Although very low power DO NOT to look down the fibre optic cable, as damage to the eye could result.

In recent years Fibre Optic Cables have been used increasingly as a Transmission media for data.

The two light sources are compared in the table below:

Item	LED	Semiconductor Laser
Data Rate	Low	High
Mode	Multimode	Single or Multimode
Distance	Short	Long
Lifetime	Long Life	Short Life
Temperature sensitivity	Minor	Substantial
Cost	Low Cost	Expensive

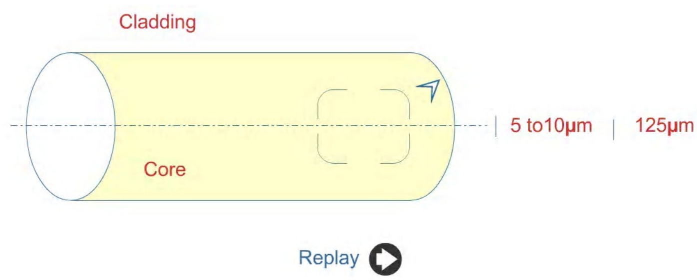
They can be tuned using either a Fabry-Perot or Mach-Zehnder interferometer. These are inserted between the fibre and the source. The Fabry-Perot interferometer has a resonant cavity which consists of two parallel mirrors. The light is perpendicular to the mirrors. The Mach-Zehnder interferometer separates the light into two beams, which travel slightly different distances, when recombined only certain wavelengths are in phase.

The system operates on pulses of light that are received by a photodiode, which transfers the light into pulses of electrical energy. Typically 1 pulse of light is equal to a "1" bit and the absence of light equals a "0" bit.

The system would be useless if the light leaked out, but the principle that when light passes from one medium to another, e.g. fused silica to air, the ray is refracted (bent) at the boundary. The amount of refraction depends on the medium being used. if the angle at which it is refracted back is correct then none of the light escapes and it continues along the fibre bouncing back and forth from the boundary.

Types of fibre optic cable

There are two types of fibre optic cable - Single mode and Multimode

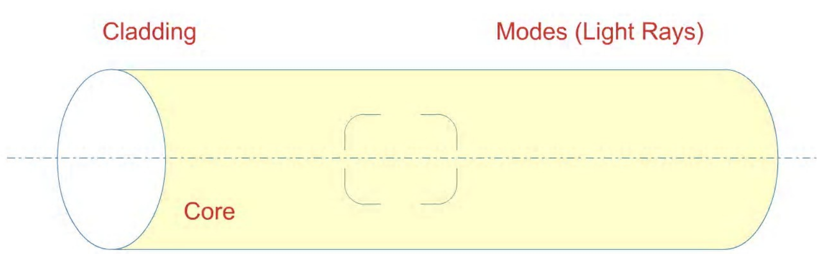


in recent years Fibre Optic Cables have been used increasingly as a Transmission media for data.

Each ray of light which travels through a fibre is called a Mode. By altering the diameter of the fibre two different transmission operating modes can be achieved - Single mode and Multimode.

The Multimode cable is thicker than the single and as such allows room for more than one light ray to pass through. Each ray that passes through will have a different angle of incidence1 and reflection as they are reflected off the cladding and therefore each ray will travel different distances, some will travel straight through the core. Because the ray travels at the same speed but each one can travel a different distance, the signal will spread over time and introduce data errors over long distances. This problem is known as dispersion. To reduce this problem there are two different types of fibre optic cable:
Step-index - This is a single fibre and cladding which does nothing to reduce dispersion.

Graded-index - This type of cable has a single fibre but several layers of transparent cladding. This causes the rays of light to reach the other end in a more consistent manner. Modes travelling down the centre of the core travel more slowly than those bouncing off the cladding thus this tends to equalise the time taken for each mode to go from one end to the other, thus the modes reach the other end more uniformly.



The most common Multimode fibre optic cable is 62.5/125 graded-index. The first figure is the core diameter and the second is the cladding diameter

The Single mode fibre optic cable utilises Step-index with only the core and the cladding. This makes the cable much thinner and more expensive to install. These fibres have their diameters sized to the wavelength they need to carry. A diameter of 8 may carry, for example, a wavelength of 1.3. As there is only one wavelength and a more coherent light source greater lengths of cable can be used.

Currently available Single Mode cables can transmit data at several Gbps over distances of 30Km. In the laboratory even higher speeds have been achieved over shorter distances.