Computer Networks
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Lecture - 4
Physical Medium – II

Good day. Today we will have the second lecture on the Physical Medium; in the last lecture we have seen the different ways these digital signals and analog signals, etc. can be used for communication, and how digital data or analog data can be encoded. Well, we are mostly interested in the digital form of data, how they can be encoded etc., and some of the general impairments of physical medium. In this lecture we are going to look at specific media, which are used in networking.

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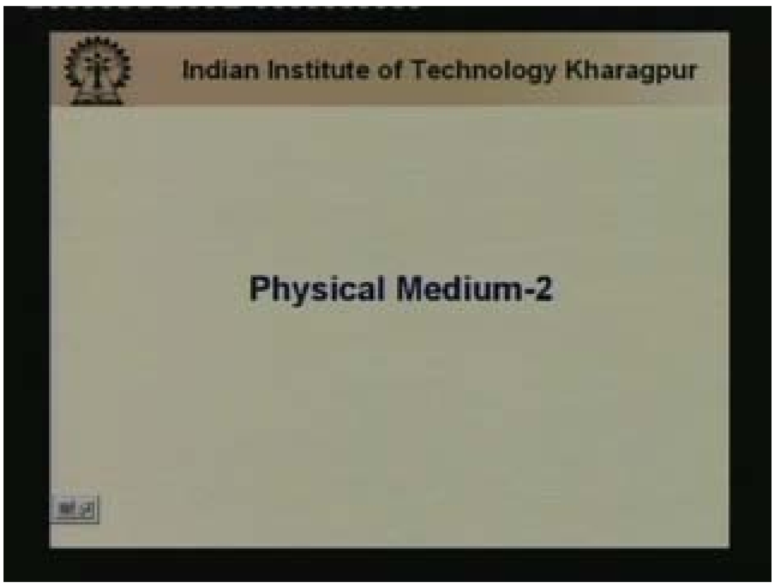

There are basically two types of media, which are used for communication: one is cable. They are actually two classes of cable. Now this cable could be copper cable or could be coaxial cable or twisted pair or shielded twisted pair. The twisted pairs are actually unshielded twisted pairs or UTP.

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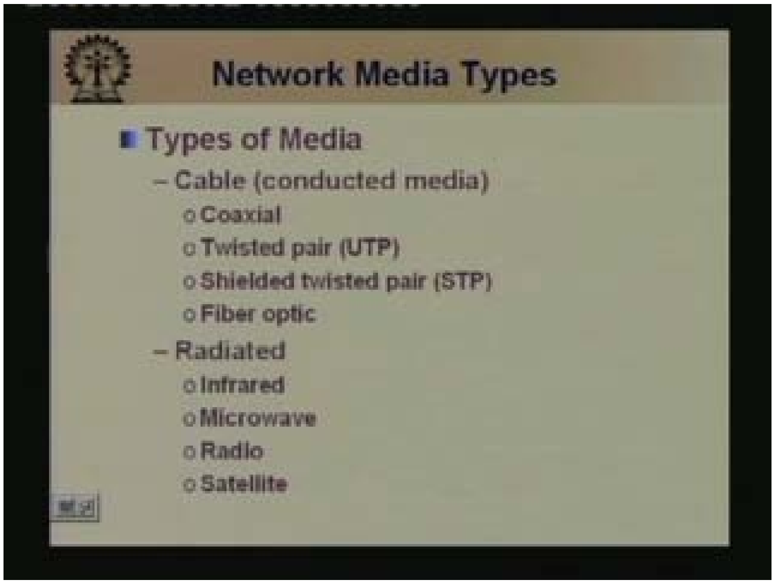

Sometimes we simply called them twisted pairs since they are more common; there are shielded twisted pairs also. Then, one of the most important cables these days is the fiber optic. These are the different types of cables that we use in networks. Similarly, we can also communicate without the use of any cable, by simple electromagnetic radiation and this radiation could be in different ranges of frequencies, like infrared or microwave or radio or satellite, etc. We will look at all these one by one.

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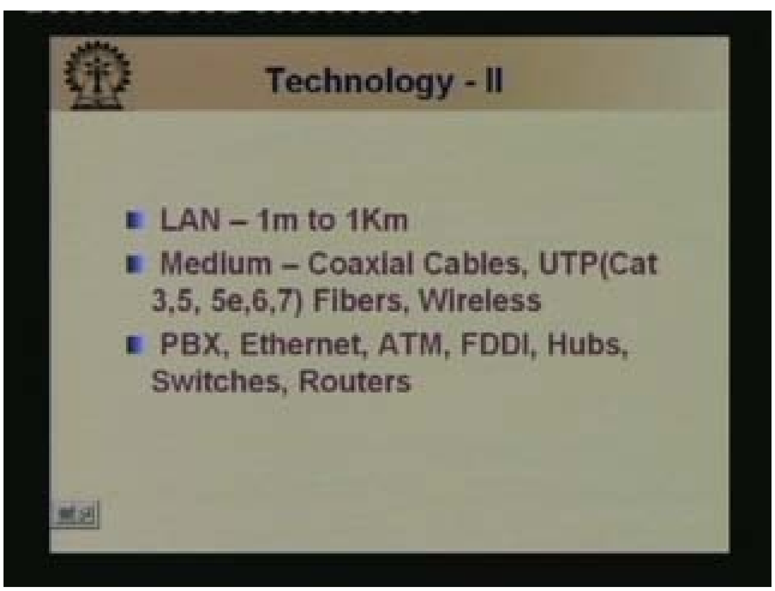

First let us look at the kind of media that we use in a LAN. LAN, as you remember, is a local area network that could vary from, let us say, 1 m to 1 km. So it is local strictly by its size; 1 m means two computers connected on the same table or connected side by side; it could be all the computers in one building and all the computers in several buildings; and so on. That is the kind of range that we have for LAN. The medium that we use for LAN could be coaxial cables, UTP, fibers, and wireless. Most of the types of cables that we talked about find their way in some niche or other in local area networks and, of course, UTP or unshielded twisted pairs are of different varieties or categories.

We could have Cat 3 cable, Cat 5 cable, Cat 5E cable, Cat 6 cable, Cat 7 cable and so on. You must have seen Cat 3 cable – if you have looked in your telephones that is the landline phones, they are connected by unshielded twisted pair cables of category 3. For computer networking, Cat 3 cables could also be used for LAN, although we usually prefer Cat 5 onwards. The kind of things that are on the network could be PBX; PBX is local telephone exchange that could also have some digital ports, etc. Ethernet is one technology, which is used in LAN; ATM is also used; FDDI is sometimes used. FDDI if you remember is fiber distributed, that is, the FDDI ring kind of structure. We have network boxes like hubs, switches, routers, etc. So these are the terms you would come across. Of course we would talk about some of these in more detail later on, but these are some of the technologies that come into LAN or local area networks.

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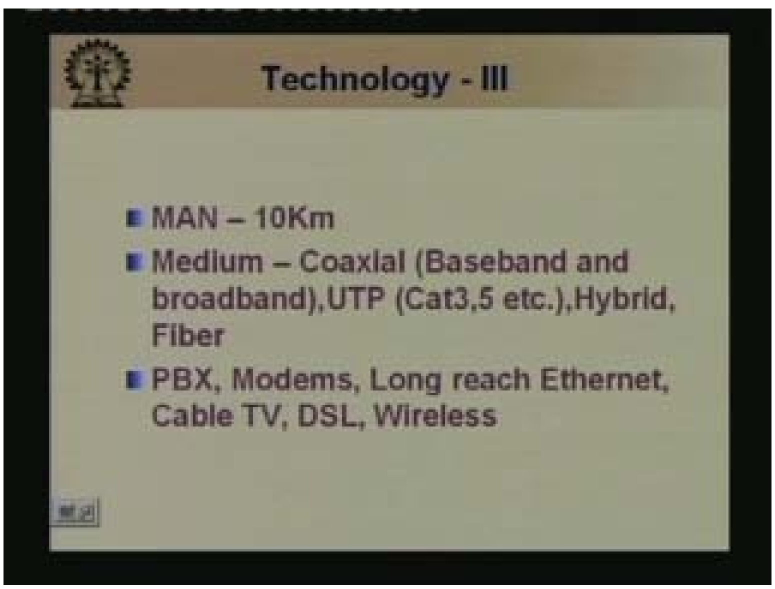

Then we come to slightly bigger networks, called MAN or Metropolitan Area Networks. There are some networks which are even smaller than a LAN; they are called Personal Area Networks. I may be wearing three or four computers and they are connected in network on my body. So we will come to PAN later on. Going on the other side of the spectrum that means, from LAN to bigger network, which is MAN, a metropolitan area network, typically one campus or one city may be several small towns, which are close together.

They would come under the purview of a MAN. MAN is a ballpark figure; it would extend may be about 10 kilometers – so it could be 5 kilometers, or it could be 20 kilometers or something in that range. The kind of medium that we use for metropolitan area networks is coaxial cables, both base band and broadband; we will come to what they are. Sometimes UTP are used but that is not a very preferred way of connecting. One way where UTP is definitely used is when you try to network through telephone lines. UTP could be a hybrid kind of system wherein some part of it could be coaxial and some part of it could be UTP and some part of it could be fiber. Fiber means fiber optic cables. The kind of technology that goes into a MAN would be PBX, different kinds of modems, for example if you are using a broadband coaxial cable you might use something that is known as a cable modem. Then you have this long-reach Ethernet that means Ethernet over may be some lines, cable TV DSL digital subscriber lines or it could be wireless. One issue which is important in MAN is the issue of access.

That means how do you reach to each individual user? Think of it as a town or a city; you really have to. In order to network the entire town you have to reach to each individual residence and reaching to each individual residence involves cost. If it is a small building like in a LAN you can take UTP cable to his room.

There are problems of taking UTP cables to each individual house; there could be electromagnetic disturbance and things like that but apart from that there is a question of cost so if you are trying to build so much copper into it that is quite costly. So to access users who are distributed over a somewhat wide area of several kilometers that is an issue in metropolitan area networks.

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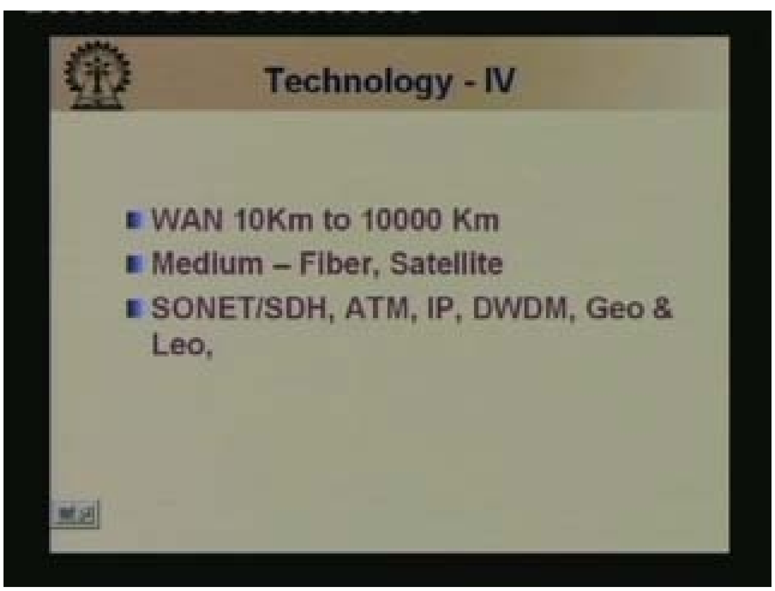

Finally, at the extreme of the spectrum, we have WAN, wide area network. So they may stretch from 10 kilometers to may be 10000 kilometers or almost to the other side of the globe. They involve very long distances.

The medium is usually fiber or satellite and the kind of technology used in WAN is SONET or SDH. It's almost similar technology ATM, IP – that is the internet protocol – DWDM, dense wavelength division multiplexing, Geo and Leo. Geo stands for geostationary satellite and Leo is low art orbiting satellite. So these are the kind of technologies that go into WAN. One issue in MAN is of course always cost and bandwidth, WAN bandwidth because as you can imagine that when you have to take some message across hundreds of thousands of kilometers away there is a lot of cost involved in it. So WAN bandwidth is usually costly and we try to make the maximum use of this bandwidth. Of course in recent time's lot of fiber has been laid internationally so the bandwidth problem is becoming less and less, but even then WAN bandwidth remains costly.

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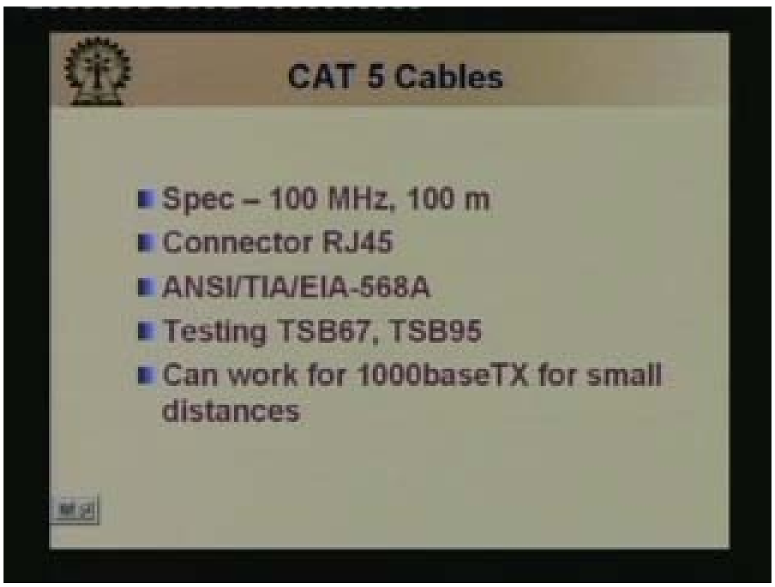

Now let us see some of the cable specifications that we use, first we take up this UTP cable of category 5 so CAT 5 UTP cables specification says about 100 MHz and these can stretch up to 100 meters. These are the figures which are normal, you can stretch things little bit this way or that way at times depending on your operating circumstances, etc. but this is normally the figure; so you can have some kind of idea from these. The CAT 5 cable looks like your standard telephone cable; the only thing is that they are made to a slightly better specification. The connector at the end of a CAT 5 cable has got a specific scientific number; this is called RJ 45. So we use RJ 45 connectors for connecting CAT 5 cables. There is a standard ANSI or TIA or EIA standard for how CAT 5 cable is to be used. What are the standard ways and how they are twisted, etc?

There are a number of wires inside the twisted pair of cables; so which wire stands for what, etc. I simply refer to the name of the standard here, which is EIA 568 A and then a cable has to be tested according to some standards; TSB 6795 is the standard for testing cables. CAT 5 cable is usually under these circumstances 100 MHz to say 100 meters.

If you are within the 100 meters, if you have done everything properly it is expected that it can work up to 100 mbps. The point is that if the distance is much less than that then naturally the same cable can work at a much higher speed. So inside the same room the CAT 5 cable may be used for 1000 mbps connection between computers or network nodes. There is some enhanced version of CAT 5 cable; I will not go into the details of this, which are given over here.

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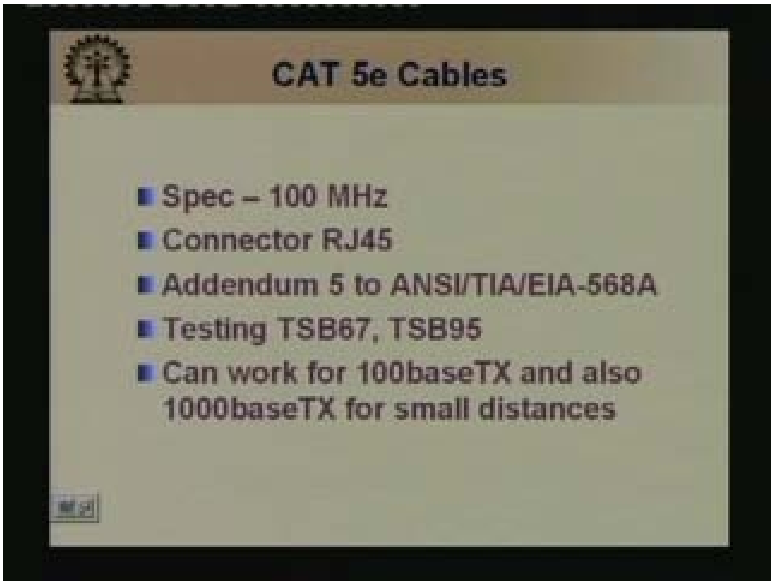

The specifications are almost the same; only thing is that this is slightly better in some way. And it can work for 1000 base TX for small distance. I said within a room if you are using CAT 5 e cable instead of simple CAT 5, you may be able to operate at 1000 mbps without much of a difficulty.

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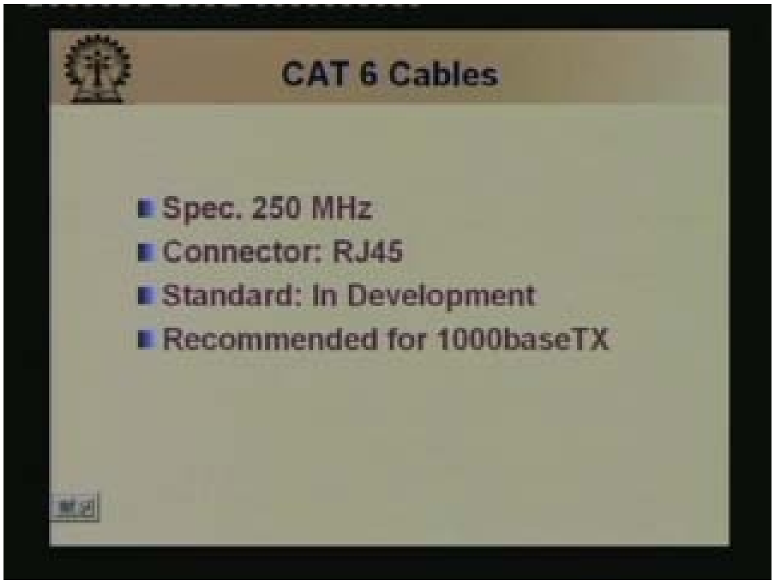

Then we have the CAT 6 cables, which is again slightly higher than CAT 5 cables here: the specification is 250 MHz this specification is much higher; so naturally CAT 6 cable would be somewhat costlier than CAT 5 or CAT 5 e cables. The same kind of connector is actually the recommended cable for operating at 1000 mbps. So here is a point. When networking started, people thought that 10 mbps is a fairly high speed. And soon people were using networks a lot and 10 mbps was not enough, so people went to 100 mbps. Now people are saying that 100 mbps is slow; so we want to go to 1000 mbps.

You see that in a comparatively short period of time, may be 15–20 years, our demand for bandwidth has grown a thousand-fold. When you are planning for an infrastructure, say copper infrastructure, in any organization or somewhere, then you should keep this in mind that whatever specification people are giving you today, after some time people may want to upgrade. What I mean to say is that if you put in CAT 6 kind of cables and use it for only 800 mbps today, then 1 or 2 years later you can use the same cable for 1000 mbps saving a lot of cost at that time; but of course, that would mean a higher upfront cost today. So that is always there.

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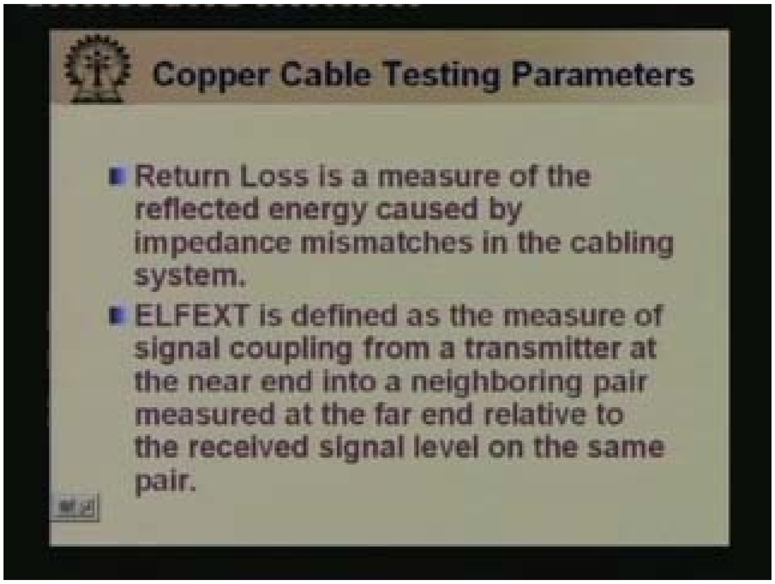

So for testing these kind of cables there are all kinds of testing parameters. I will not go to the details of these at all. This is a rather technical part. Return loss is a measure of the reflected energy caused by impedance mismatch in the cabling system. When you put a cabling system you can test it. And one of the things you might test for is return loss and another thing you might test is a cross talk as reflected from the other end. ELFEXT is defined as the measure of signal coupling from a transmitter at the near end into a neighboring pair measured at the far end, relative to the received signal level on the same pair. These kinds of testing parameters are there for testing copper cables. Similarly if we have put fiber optic cable somewhere, then fiber optic cables would have some other testing parameters. It’s a good idea to test the passive networking infrastructure, meaning all these cables and connections etc., and how they perform.

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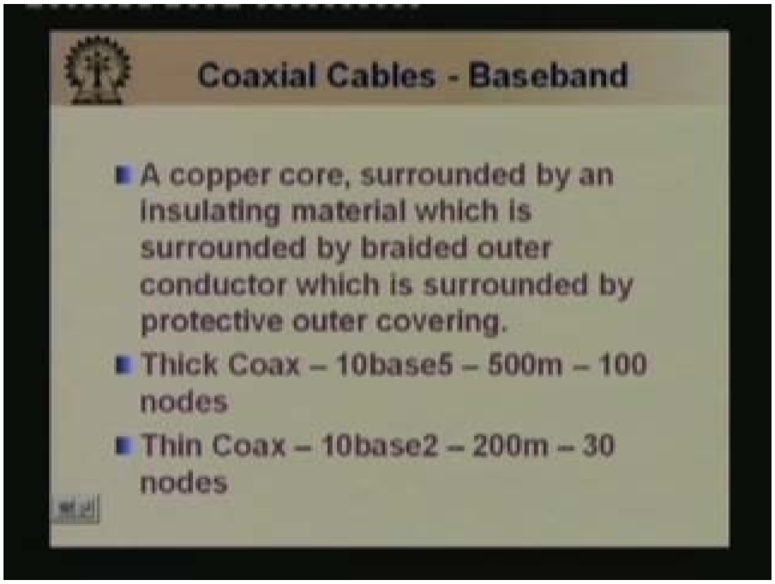

Now from unshielded twisted pair cables, we go to the base band coaxial cables. We have already mentioned about the base band coaxial cables. These are the cables we were talking about when we talked about the bus topology if you remember; so it is basically a shielded cable.

There is a copper cord surrounded by an insulating material, which is surrounded by braided outer conductor, which is surrounded again by a protective outer covering. So this is considerably thicker than a UTP. And then in the coaxial cables also there are two varieties, the so-called thick coaxial cable and thin coaxial cable. This technology is becoming obsolete now, but just for our knowledge, a thick coaxial cable is also presented as 10base5. This 10 represents that it works at 10 mbps and 5 represents that it can go up to 500 hundred meters. The thin coaxial cable is 10base2, so it works at 10 mbps and goes up to 200 meters. As I told you, nowadays almost everybody wants a 100 mbps to their desktop, in which case this thick and thin coaxial cables, that is the base band coaxial cables, are no longer of much use today.

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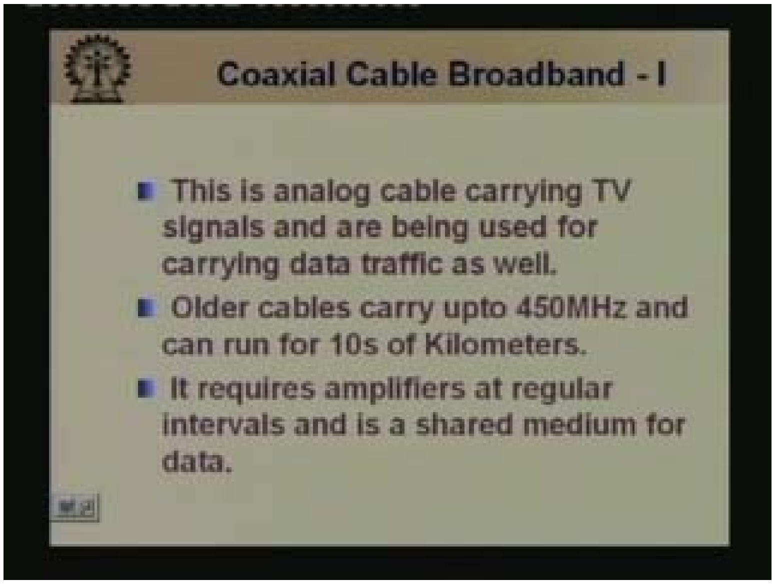

But another type of coaxial cable, which is very much in vogue and which is used even today, is the kind of cable that your cable operator puts. Many of you have seen that cable operator puts some kind of coaxial cable into your room, which goes into your TV. Now it is possible to use the same infrastructure for computer communications also, i.e., computer networking also. Remember,

I told you while discussing MAN that one of the most important issues in metropolitan area network is the issue of access; that is, how do you reach each individual subscriber at his or her home? This cable operator has reached lot of homes anyway. So naturally, people started thinking whether we can use these cables from the cable operators for network communication, and special kinds of modems were designed for that called cable modem. So we have a broadband cable infrastructure rather than the base band that we were talking about. This is quite often used and now they are being deployed in many cities for computer communication. This is, as I said, analog signal carrying TV signals and has been used for carrying data traffic. Older cables carry up to 450 MHz and the newer cables that have been put can go to a higher frequency, that means, higher bandwidth, and these cables use amplifiers at regular intervals.

Now these amplifiers in the old days were only one-way amplifiers because the way the cable operators wanted it is that they are broadcasting their signal from some central location and it just has to reach people's TV. But when you want to use this for computer communication the communication has to be two-way so the amplifier also has to be a two-way amplifier. So such small technicalities are there; it requires an amplifier at regular intervals and is a shared medium. Usually this medium is shared, that means, you and your neighbors – all your data is in the same medium.

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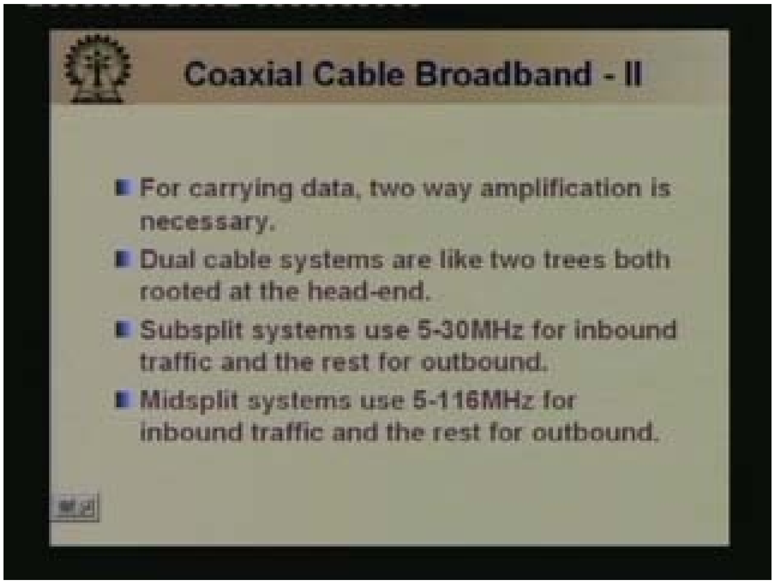

As I said, for carrying data, two-way amplification is necessary. Dual cable systems are like two trees, both rooted at the head-end; the head-end is where all the service providers' equipments etc. are placed. So there are all kinds of split systems, they use 5 to 30 MHz for inbound traffic and the rest for outbound traffic; mid-split system and there are all kinds of systems for using this for data communication. By the way, there is also some asymmetry that people have found in the network traffic for an average user in a city. One of the most popular uses of computer network nowadays is just going onto the internet, may be surfing it, may be getting some information, etc. But the amount of traffic in terms of query etc., which flows from the user to the computer, wherever it may be, is relatively small. Whereas you may be downloading large files, images, may be even songs, movies etc. Your bandwidth requirement – the upstream bandwidth requirement and the downstream bandwidth requirement are usually not the same; there is an asymmetry.

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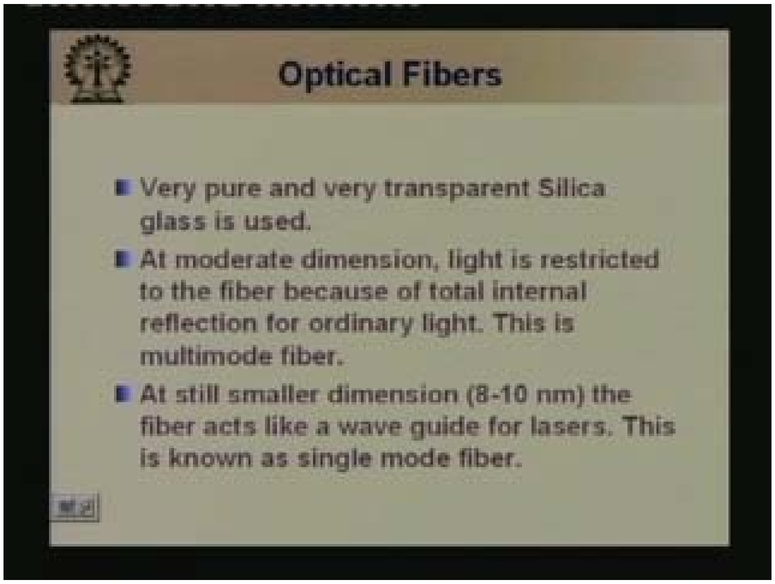

Now we come to another very important kind of cable, having looked at copper cable, namely, optical fibers. Optical fiber basically is made of glass, very pure and very transparent silica glass is used, which is very transparent in the sense that it can go up to tens of kilometers without too much of attenuation on the way. So think of a glass slab, which is several kilometers thick and you can see through it quiet easily, so that kind of transparency is required. So, naturally, there have to be some very strict standards for making this glass. But after all, it is simply a glass, which is drawn into fiber for giving us this optical fiber. At moderate dimensions, light is restricted to the fiber because of total internal reflection for ordinary light; this is called a multimode fiber. At still smaller dimensions, say something like 8 to 10 nanometers, the fiber acts like a wave guide for lasers. This is known as a single-mode fiber. Multimode fibers are used for local area networks whereas in all wide area networks and even in local area networks these days single-mode fibres are more preferred for carrying signals.

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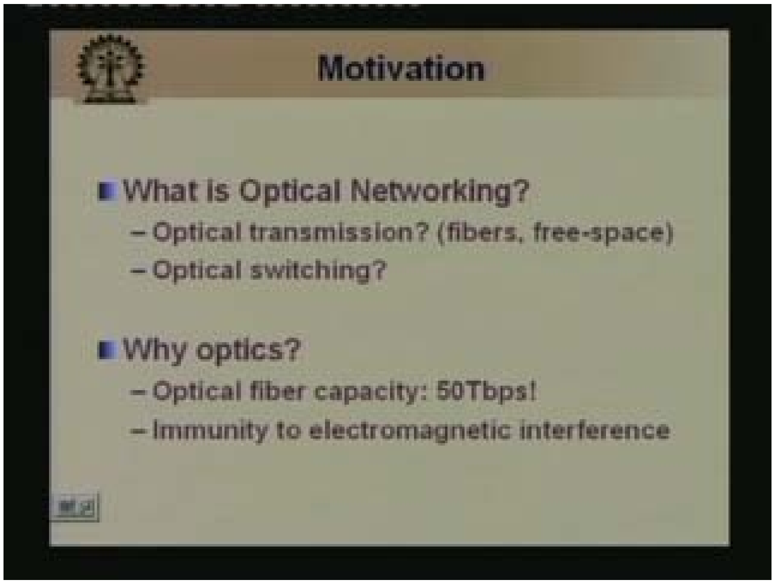

Finally what is optical networking? One thing is, naturally, optical transmission. By the way, optical transmission could be fibers or free space. Free space means suppose you direct a laser from the source to the destination on the free space, light will travel straight or it is expected at least to travel straight and then reach the receiver. So you do not need any fiber or anything at all but there is a problem. The first obvious problem is that the sender and the receiver have to be on the same line of sight without any hindrance in-between that is one point. And then there are other complications, which might come; in the sense that the intervening air may get hot and its refractive index may change.

So the light may actually bend, like they do in a mirage in a desert. That kind of things may happen, so it might miss the receiver altogether. So free space optic communication is not very much preferred. People prefer to put fiber optic cables wherever they can. These cables or free space we are talking about is for fiber optic transmission. Then there is the question of optical switching; can we provide the network level functionalities in the optical domain itself? This is a topic of research these days as this is quite promising. So maybe we will just look at this later on. Finally, why optics?

The point is that optical fiber capacity is huge, very huge – you see 50 terabits per second is mentioned over here. The point is that this has got an absolutely fantastic bandwidth, so if you can put a fiber optic connection between two endpoints your present as well as foreseeable future requirements will surely be met. So that is one good thing about optics. The other very good thing about optics is that it is immune to electromagnetic interference, if there is a lightning strike nearby, then it is not going to affect this very thin strand of glass that we have put, which is very good because if the same thing happened to a copper cable, there would be a surge and it could maybe burn some of your equipment. So this is another reason people favor fiber optics a lot.

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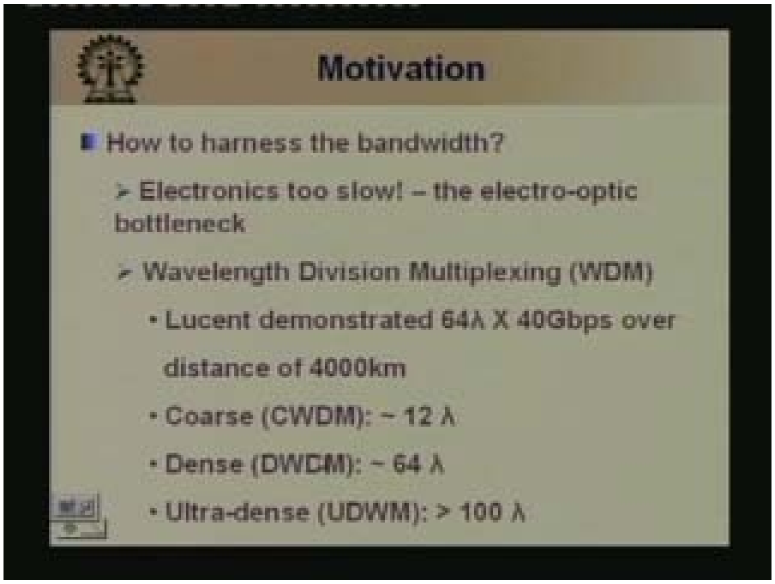

Now the point is that these 50 terabits per second bandwidth that we were talking about is only theoretical. Actually sometimes, I have been asked what the bandwidth of this fiber optic cable is. This really does not make much sense because the bandwidth of any fiber optic cable you would find would ultimately be dictated by the kind of boxes that you connect to it. The limitations would be there; the limitation is not inherent in the fiber. Fiber can take up a huge bandwidth as I just mentioned, but at the two ends you will have some optics and then you will have some electronics.

Now electronics cannot work at that kind of speed. A single piece of electronics suddenly cannot work at that kind of speed; so the overall speed at the bandwidth that you can get out of this fiber would depend on the kind of electronics that you put at the two ends. That is why there is a lot of interest these days in whether some of these electronics can be replaced by optics so that we can get much higher bandwidth. Now not content with just sending data through only one wavelength through this fiber, we have what is known as wavelength division multiplexing. That means different wavelengths of light carry different signals through the same fiber optic channel; that is called multiplexing.

We will come to WDM later on. With this WDM, you can get higher kind of bandwidth. Lucent, for example, demonstrated 64 lambdas; that means, 64 different wavelengths into 40 Gbps that is each of them operating at 40 gigabits per second over a distance of 4000 kilometers, so I think that is really great. There are two kinds of wavelength division multiplexing, namely, coarse wavelength division multiplexing, which is somewhat cheaper, and dense wavelength division multiplexing, which is used in WAN but is much more costly. So the number of wavelengths that we can use today varies from may be 8 or 12 to may be 64 or so. People are working on this ultra dense wavelength division multiplexing, which can carry us to may be 100 wavelengths in the same fiber.

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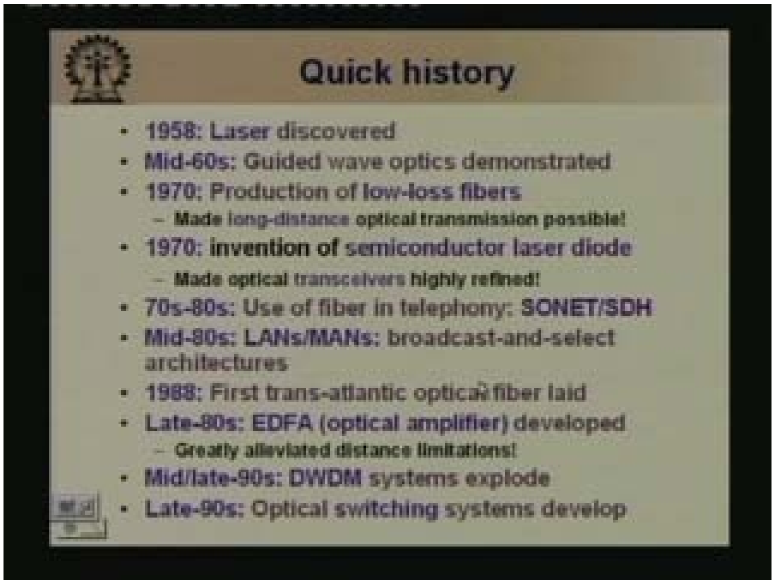

For a quick history, in 1958 laser was discovered. Then in the mid-60s guided wave optics was demonstrated, in 1970, we saw the production of low loss fibers. Because we want this low loss, we will be talking about this loss presently after sometime. So this made long-distance optical transmission possible. There was the invention of semi conductor laser diode, which was important. Then in 70s to 80s we used fiber in telephony in the form of SONET or SDH. Do not bother about what they are right now; we will be talking about them later on. In mid-80s, LANs and MAN were sort of being put in place and in late 80s;

We had a breakthrough in optically amplifying optical signals. So there is EDFA and RBM, dot fiber amplifier – we will be talking about that too in this lecture itself; and then in mid- to late 90s, this dense wavelength division multiplexing system started being put and in late 90s and in 21st century optical switching systems, different components of optical switching systems are been developed all the time. The point is that fiber optics has such a tremendous potential that there was a lot of interest in this and there is a lot of work going on in this area at the moment.

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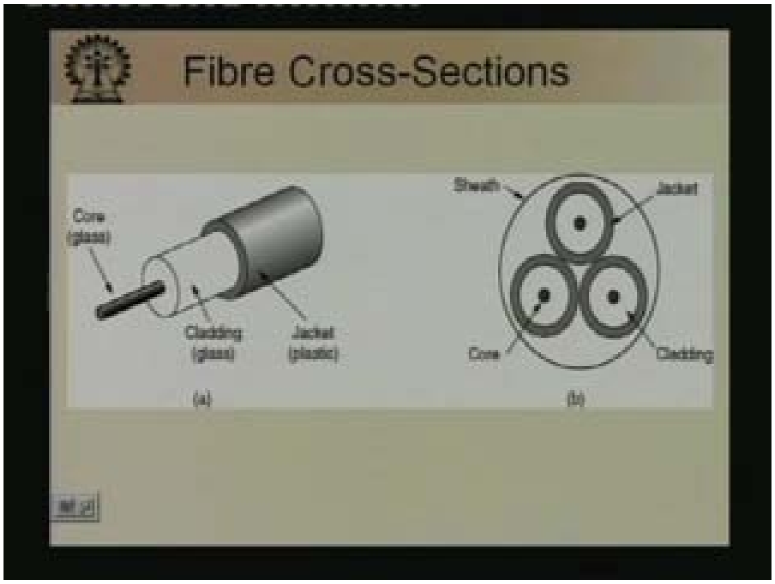

So here is some kind of a picture of a cross-section of a fiber optic cable. As you can see, when you see a fiber optic cable, you will see this fad jacket, which is just a productive jacket made of plastic, rubber; then inside it, there will be glass fiber. But what you see is actually not the fiber; that is also actually a cladding but that is made of glass. Inside this cladding there is this very fine core, which actually carries the signal. In one fiber optic cable like this, you will have several such individual fibers. So these are all individual fibers. What has been shown over here are the individual fibers and each of them will carry one; I have shown only 3 over here but it is typical to have something like 4 cores, 8 cores, 24 cores, 120 cores in one cable.

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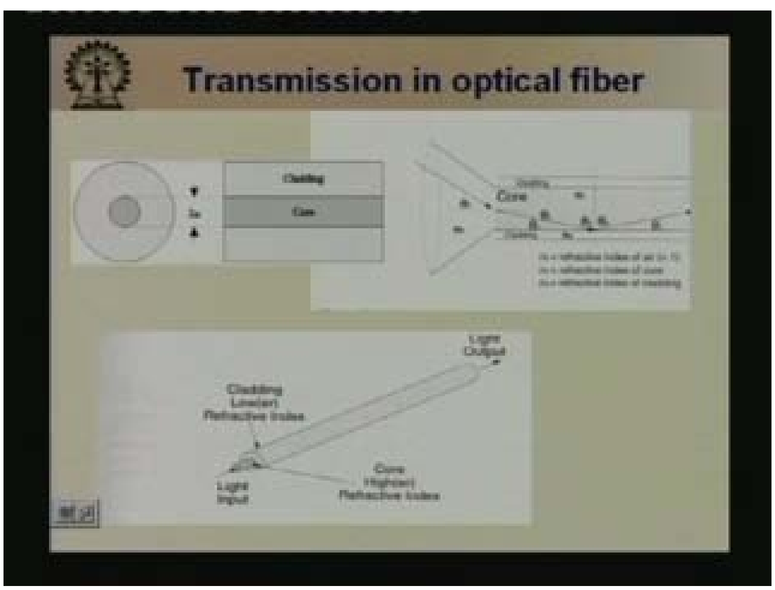

Let us look at this diagram of how it is. So if you take a cross section, there is cladding on two sides and core in-between. If you sort of cut it side ways, this is the kind of picture you get and what happens is that once the light comes into the core it sort of refracts like this and it impinges on this wall at a very wide angle of incidence. There is a difference in the refractive index between the core and the cladding. That is always maintained. So the point is that the core is at the higher refractive index and the cladding at lower refractive index. There is total internal reflection over here, so even if the fiber bends a little bit – although light usually would travel straight but through this total internal reflection it would follow this fiber – it can take small bends and come out of the other side of the fiber.

But of course there are limitations to how much you can bend. First of all, if you bend this core too sharply, this core will get damaged. So there are limitations on what is your bending radius, radius of curvature, etc. but in general to this total internal reflection the light will follow this core. So this is another picture – light is input from one end so this sort of follows the fiber and gets out of the other end.

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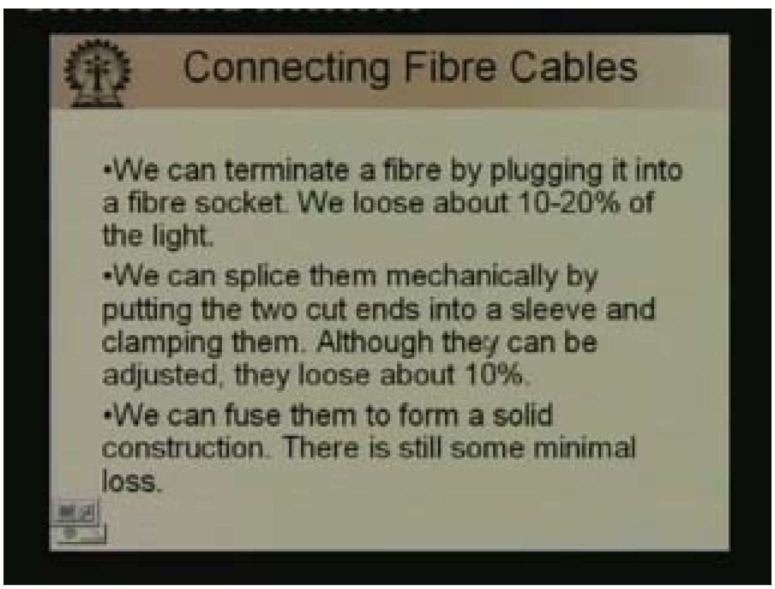

Well the light gets out, but how do you get it into something? That means, how do you connect these fiber cables, which are actually glass fibers, how do you connect them to other things? There are two ways of termination; we can terminate a fiber by plugging it into a fiber socket and then sort of clamping them together. We can splice them mechanically by putting the two cut ends into a sleeve and clamping them or we can fuse them to form a solid, which is a better method of connecting fibers. Even when you fuse them what will happen is there will be some kind of disturbance – that glass material will not be totally homogenous at the junction. So there will still be some loss but this loss is quite low if you are very careful in this splicing.

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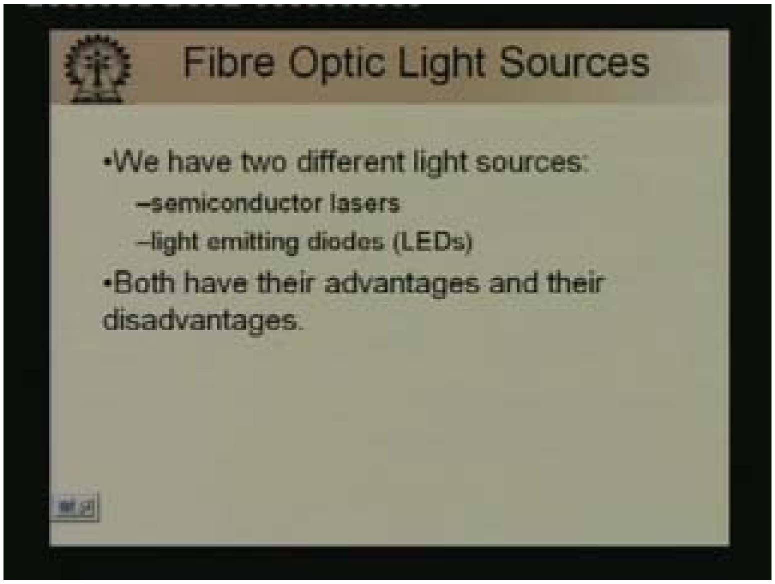

And what about light sources? We have two different light sources; they are called semiconductor lasers and light emitting diodes. Naturally, the first one gives out lasers whereas the other one, the simple LEDs, give non-coherent lights. So they are simple LEDs. Both have their advantages and disadvantages.

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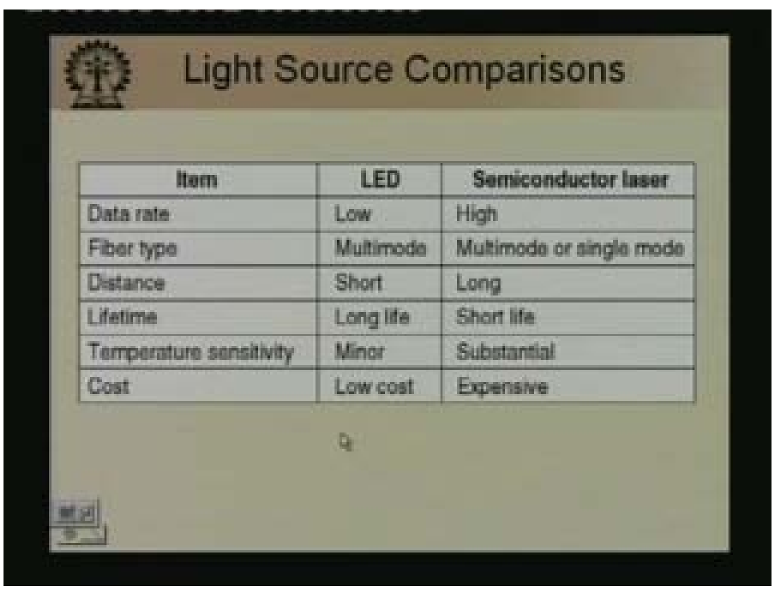
Light Source Comparisons

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

When you are using the semi-conductor laser – laser as you know is coherent light and simple LED gives you non-coherent light – so the data rate for lasers can be much higher with lasers and this is low fiber type. You can use multimode fibers over here and you can use single mode fibers. We prefer single mode fibers for lasers.

The distance that an LED can cover is short whereas the distance that single mode fibers, that means lasers, can travel through a single mode fiber is really long. So all our long-distance cables are actually single mode types and they carry laser. Since we are going to higher and higher speed all the time, we tend to prefer single mode fibers these days. Of course, LED has a very long life. So this is one area in which LED is definitely better whereas laser's lifetime seems to be short, although not very short. If proper care is taken, they will certainly run for several years. The temperature sensitivity for LED is minor so for semiconductor laser it is substantial, so its life source has to be maintained at a particular temperature. LED naturally is low cost and laser is more expensive. These are the pros and cons of the two sources. Let us took take a closer look at the kind of losses that we have in fiber. Remember, when we were discussing about electrical transmission through some copper medium –

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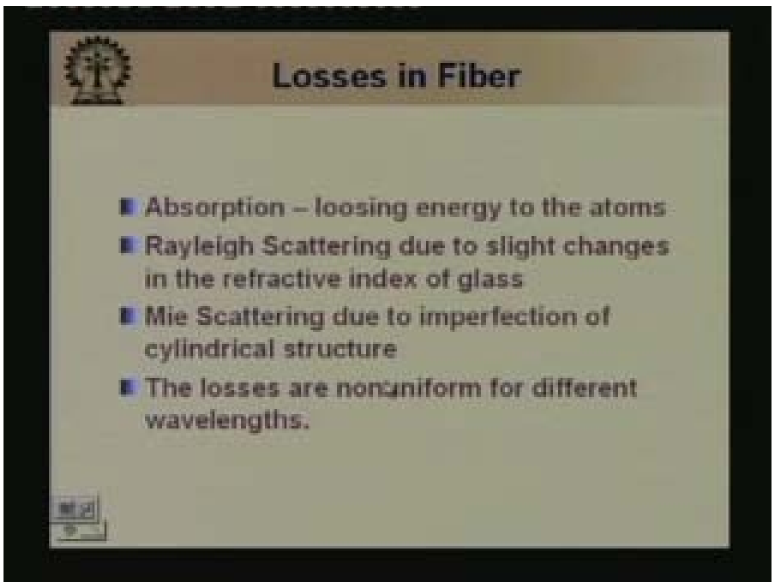

We were talking about it in the last class – there are several kinds of distortion to the signal. First of all, the signal strength tends to weaken as we go over a longer and longer distance; that is called attenuation. The same thing happens in the case of fiber also, in the sense that as we go further and further the signal will get weakened. You can look at this way that if the signal did not weaken, then we can look through a glass of any thickness. That is not true; the transparency of the glass, although it is very highly transparent, is not 100%.

That is why as it travels down the fiber its strength will become lower and not only that, it will also get its wave shape and also get somewhat distorted due to certain phenomena. For example, there is this phenomena of Rayleigh Scattering; that means due to slight changes in the refractive index of the glass some of the light will get scattered. Then there are other kinds of scattering called Mie Scattering due to the imperfection of the cylindrical structure. These losses are non uniform for different wavelengths.

That is why on the other end your signal will arrive first of all weakened, and secondly in a slightly distorted fashion.

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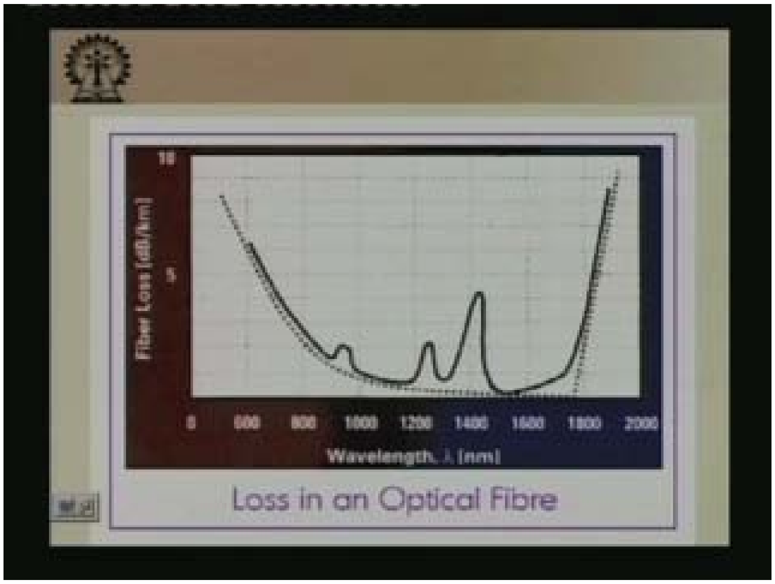

This figure, this famous figure, is the plot of the loss that will happen to a light signal at different wavelengths. As you can see, this loss in the fiber, given in DB per kilometer, is not uniform. You can see that it is not uniform across all the wavelengths. So there are some wavelengths, namely here, where the loss is very low. Then there are other wavelengths where the loss is quiet high. What we do is that we try to find some kind of windows, where the loss would be low and we can go to high distance. Because, remember that if the loss is low. We can go much longer without any amplification or repeated kind of action and that is good. I mean that would make the thing cheaper and of course we would be able to carry data for longer distance.

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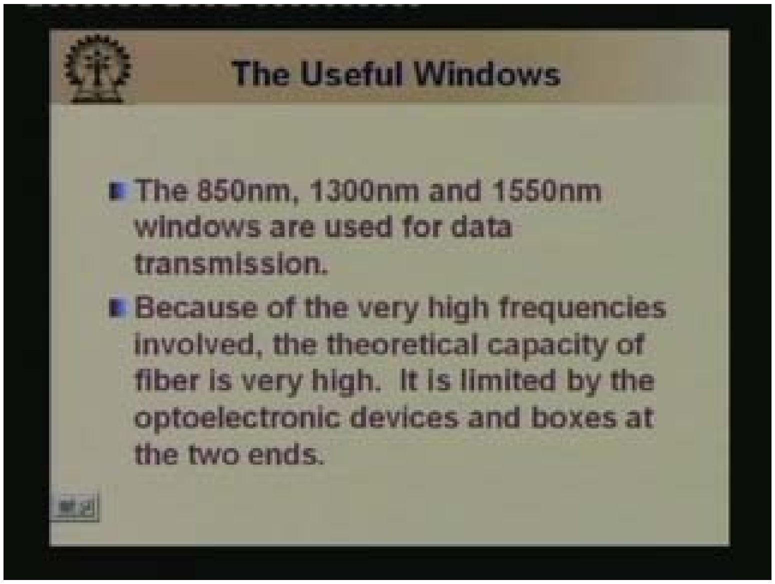

These are the three useful windows so to say: one is the 850 nanometer window, the other is the 1300 nanometer window, and another is the 1550 nanometer window. Around these wavelengths, if we send our signal, it will go a long way. So these are the three windows, which are used for data transmission. Because of the very high frequencies involved – you can look at the frequencies from these wavelengths, you can calculate and you will see that the frequencies are very high – it can potentially have a very huge bandwidth. So the theoretical capacity of the fiber is very high; it is limited by the optoelectronic devices and boxes at the two ends.

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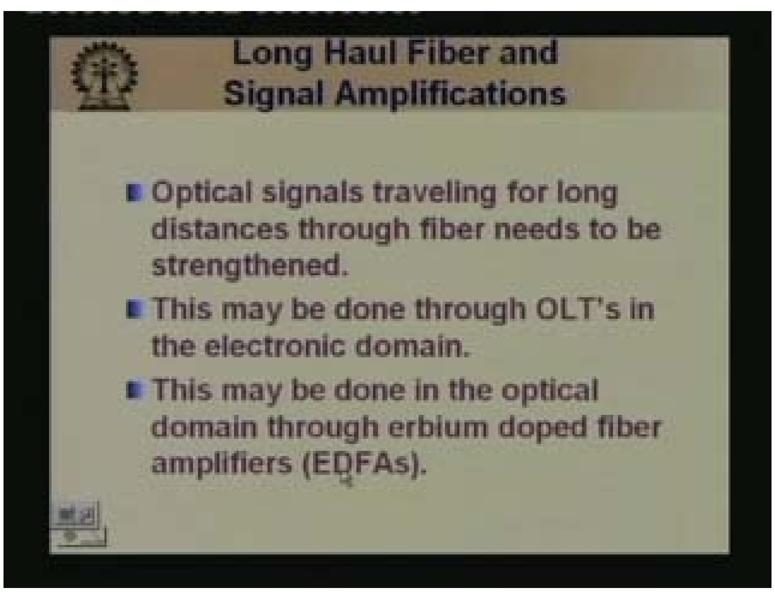

Now let us see if we want to take the fiber optic signal to a long distance; naturally, I mean whatever window you use after some distance depending on the kind of source you are using, the kind of frequency you are using, the quality of fiber you are using, it may be 5 kilometers or it may be 50 kilometers. But when you are going thousands of kilometers, at some point of time the signal will become very weak so you need some kind of repeater function. What is the repeater? The incoming signal may amplify or make the shape all right; so there are all kinds of repeaters. Repeaters are different gates; there are some repeaters, which simply amplify the signal. There are other repeaters, which can also make corrections to the shape of the incoming signal, etc. you need this repeater function in order to go to a very large distance.

So we will just take a look at this interesting phenomenon: how do you repeat optical signals? Optical signals traveling for long distances through fiber need to be strengthened. This may be done through OLTs; now what is an OLT? That is optical line transmitter, which takes the signal to the electronic domain and, of course, you can use a fresh source over there to make a nice and strong wave form and push it for the next leg of its journey. The important thing is that this may also be done in the optical domain and the advantage of doing it in the optical domain is that you are no longer restricted by the bandwidth limitations of electronics. So you can really operate at very high speed always in the optical domain and one way to do that is with erbium doped fiber amplifiers.

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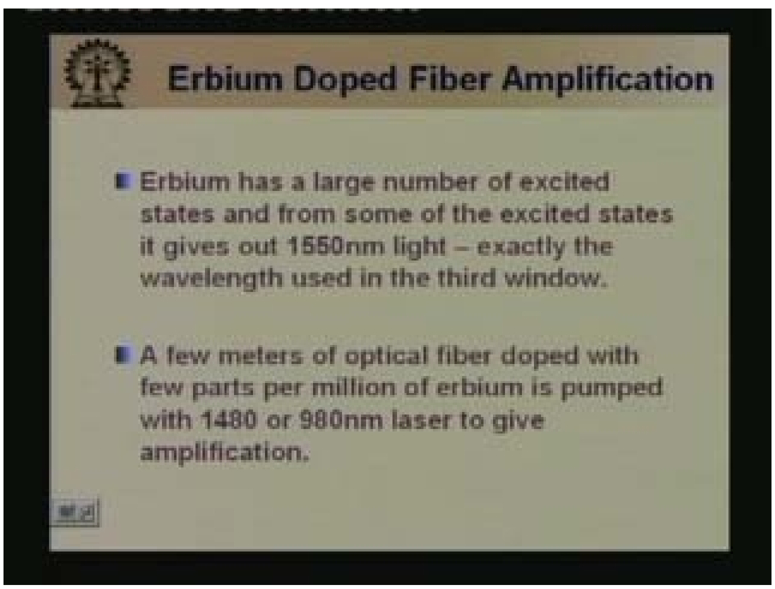

So erbium has a large number of excited states and from some of the excited states it gives out 1550 nanometer light, exactly the wavelength used in the third window in the glass. So a few meters of optical fiber are doped; that means a small quantity of this erbium is introduced in that; the glass is doped with the few parts per million of erbium and is pumped with 1480 or 980 nanometer laser, to give amplification. So what would happen if you look at this?

Suppose this is the ordinary fiber, which is carrying the signal, and there is some portion of it which is doped with erbium and a pump laser of certain frequency is fed into this.

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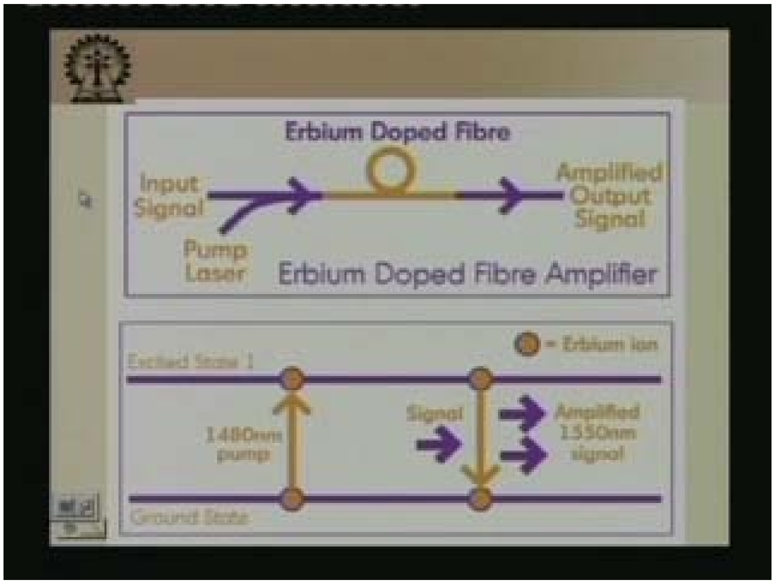

So what will happen is that the erbium atoms in this region will be in an excited state, so erbium will be in an excited state. When a signal photon comes, this sort of induces the erbium to come down to the ground state, giving an amplified signal. So this is a very simplified version of how erbium doped amplification is used.

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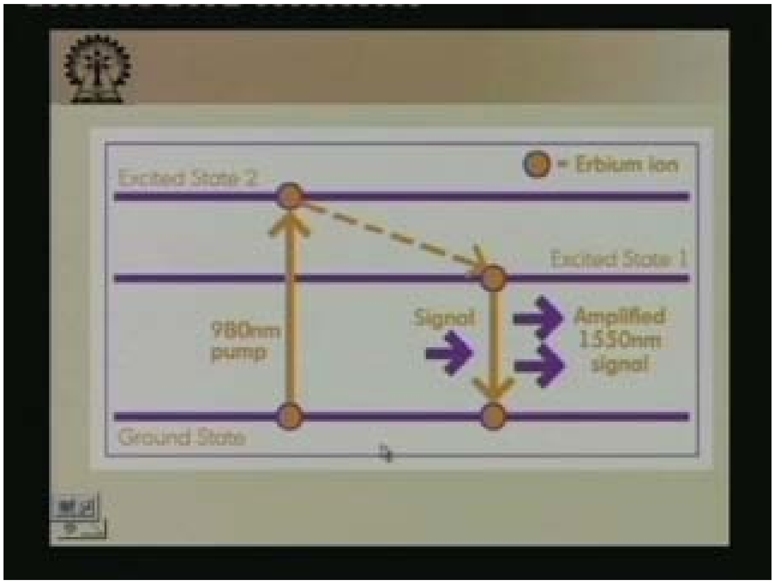

There are other kinds of this; depending on what kind of pump laser you are using, you may go to this kind of excited state or this kind of excited state from which you can go to excited state one and so on. But anyway, the basic idea remains the same.

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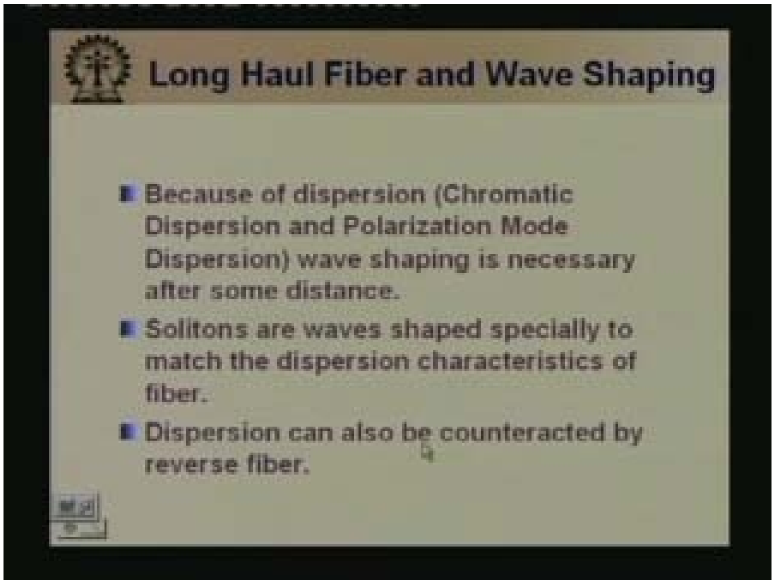

Because of dispersion, that is chromatic dispersion and polarization, mode dispersion wave shaping is necessary after some distance. There are other kinds of combination of wave forms known as solutions; these are waves shaped specially to match the dispersion characteristics of fiber so that a solution would not be distorted for a long distance. Distortion can also be counteracted by reverse fiber. So all kinds of technology are there; we do not have the time to go into the details of these, but this is a very up-coming and growing field.

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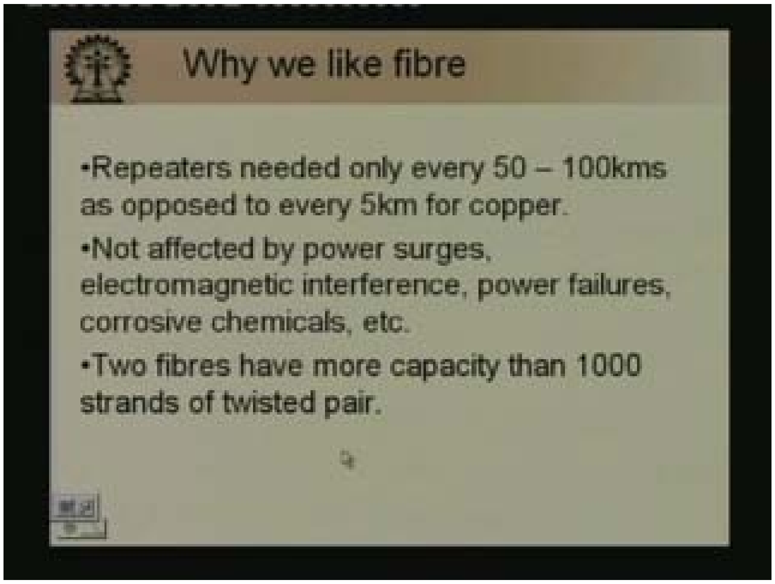

Once again, why do we like fiber? – because repeaters are needed only every 50 to 100 kilometers as opposed may be 2 to 5 kilometers for copper; not affected by power surges, electromagnetic interference, power failures, corrosive chemicals, etc.; communication in a fiber is usually simplex. That means there is the source on one end, receiver on the other end, so in one fiber the data is really going in one direction. So for two-way communication, we require a pair of fibers, but these two fibers have more capacity than 1000 strands of twisted pair, and that is really great.

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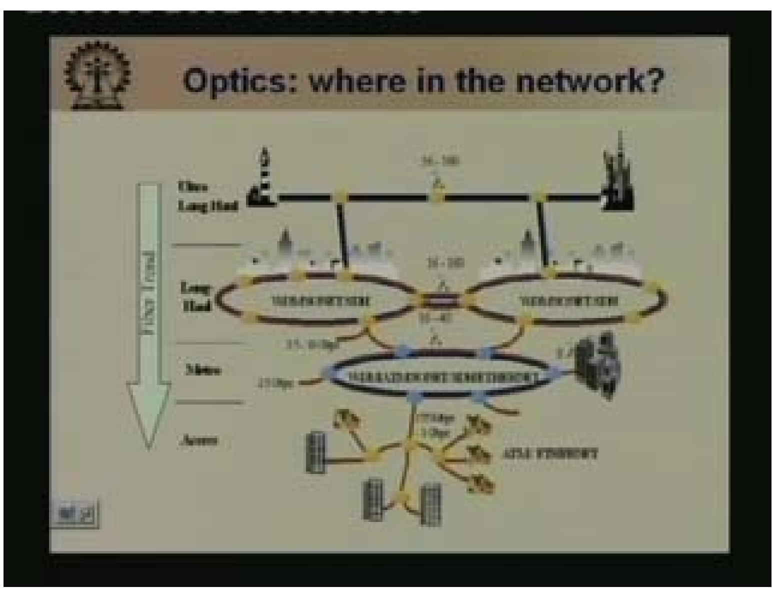

We will have just one quick look at where fibers are going? People are putting fiber at a feverish pitch now. One is the ultra long hall – ultra long haul means we have fiber for a distance of may be thousands of kilometers. Then in the long hall we have this WDM or SONET, SGAs etc., which is put by the telecom company or other communications companies. Then we have the WDM, ATM, SONET, ETHERNET, etc. in the metro, that means, within the same city, and now finally fiber is finding its way in the access side – that means to individual users also.

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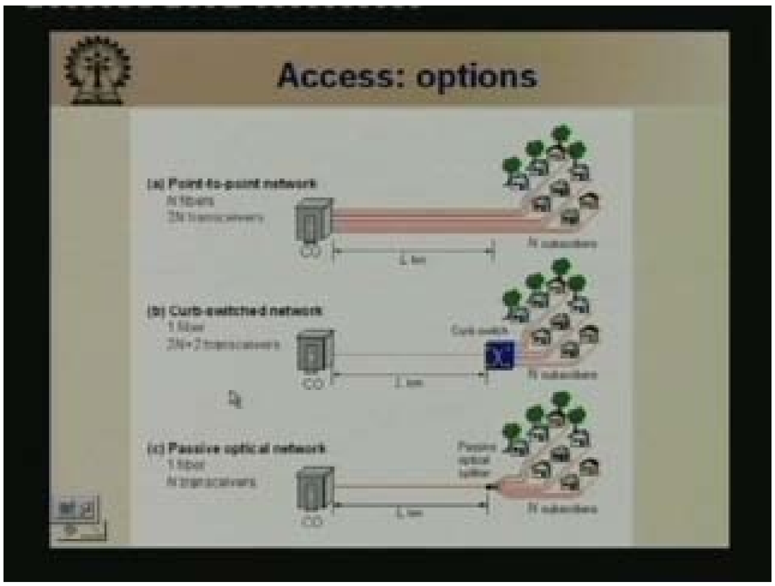

These are the different ways fibers can reach your home, which is the ultimate goal of networking. Either you can take individual fibers to homes or we can take them to a switch, which is placed in the neighborhood and from there individual fibers go to every home. There is also a concept of passive optical networking in that instead of keeping a switch out in the open, you put a passive sort of splitter, which splits the signal into so many parts. So PON, passive optical network, is another possibility.

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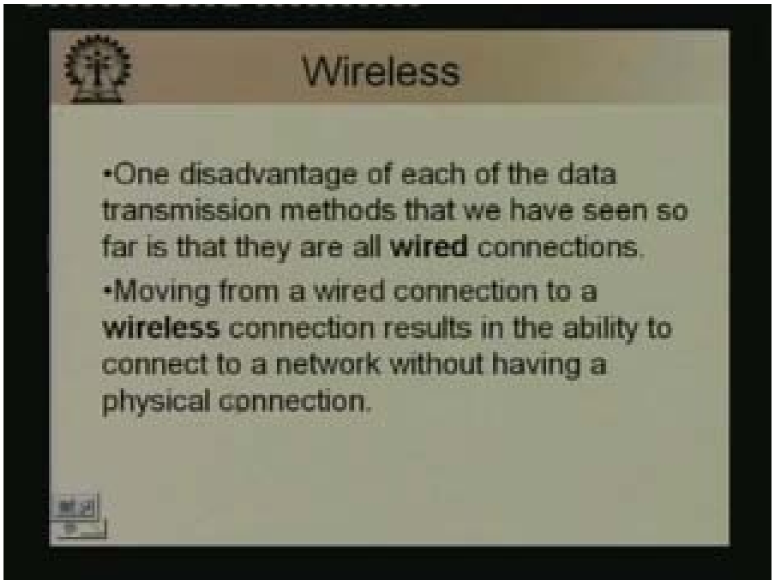

Let us come to the other most important physical medium, namely, wireless. One disadvantage of each of the data transmission methods that we have seen so far is that they are all wired connections. Moving from a wired connection to a wireless connection results in the ability to connect a network without having a physical connection. What is the great advantage of that? The greatest advantage of course is mobility. That means if you are connected in a wireless fashion, you can move around but still remain connected.

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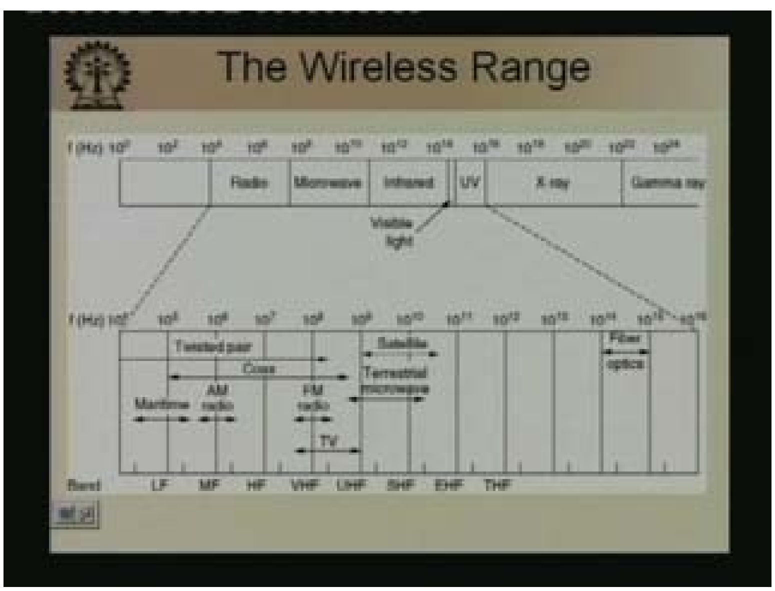

This entire electromagnetic spectrum is used for communication. This just shows a picture of that. On the low end we have the radio, followed by microwave, which is of a higher frequency, followed by infrared, which is of still higher frequency. Then we have the visible light; of course we talked about the fiber optics and this part has not been used for communication as yet, may be in future. These are the kind of frequencies we have. So the frequency range is tremendous – from 10^4 or may be 10^{14} or 10^{15} or so. We have these twisted pairs in this region, coaxial cables, maritime signaling, AM radio, FM radio, TV, terrestrial microwave, satellite, fiber optics. By the way, radio, and sometimes TV also, terrestrial microwave, satellite are all used for computer communication also.

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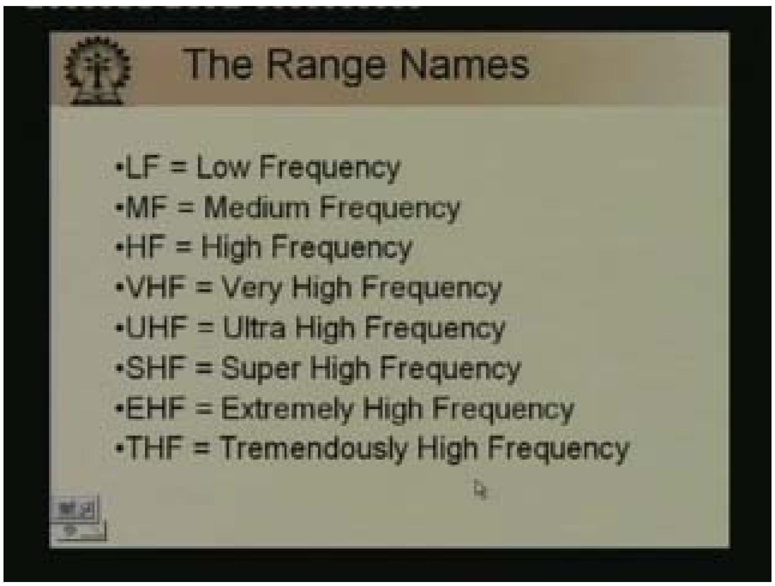

These are the different names for the different ranges: we have LF for low frequency, medium frequency, high frequency, very high frequency, ultra high frequency, super high frequency, extremely high frequency, and so on.

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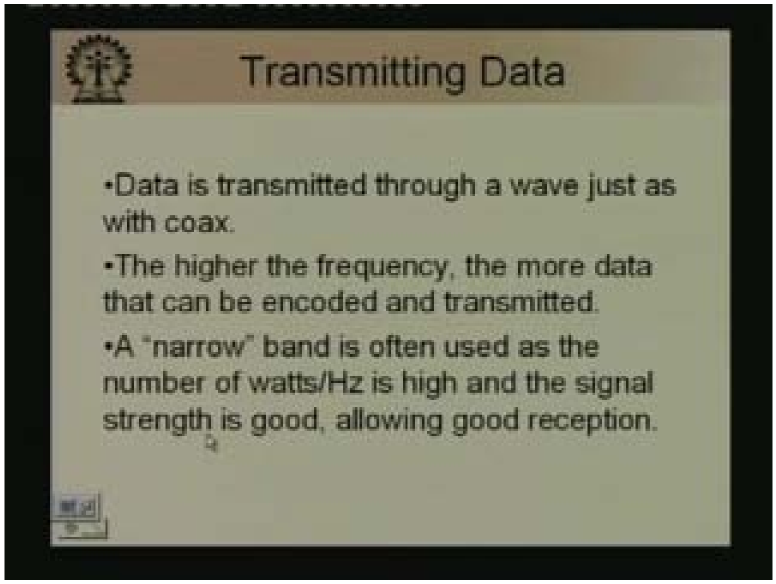

Transmitting data: data is transmitted through a wave just as with coax; that means the higher the frequency, the more the data that can be encoded and transmitted. Narrow band is often used as the number of watts/hertz is high, and there are different pros and cons at different frequency bands. We will just look at some of them.

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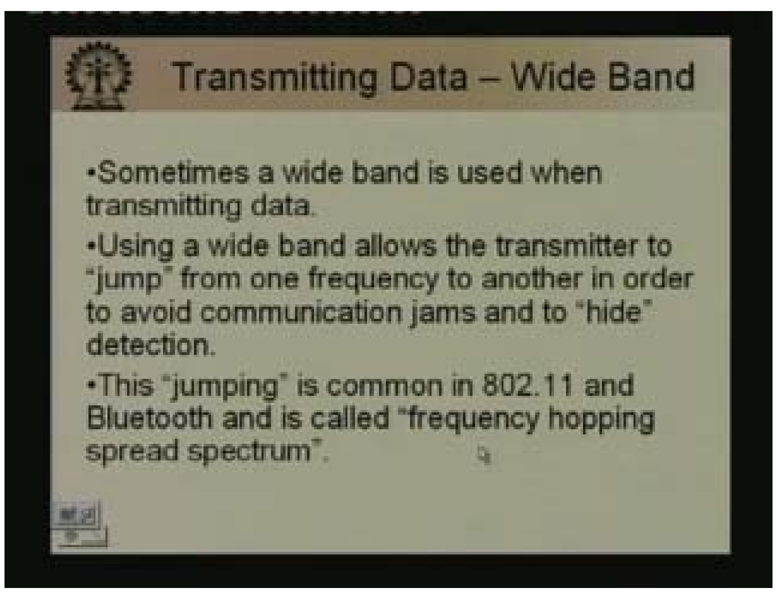

Sometimes a wide band is used; using a wide band allows the transmitter to jump from one frequency to another in order to avoid communication jams and to hide detection. That is just one example and this is nowadays used in IEEE 802.11, which is a wireless LAN standard. We will look at this later on.

Bluetooth is another wireless LAN standard to start at the low end of the spectrum, at the radio transmission, this is very easy to generate: travels long distances and it is Omni directional; that means you have an Omni directional antenna and you send your signal over there.

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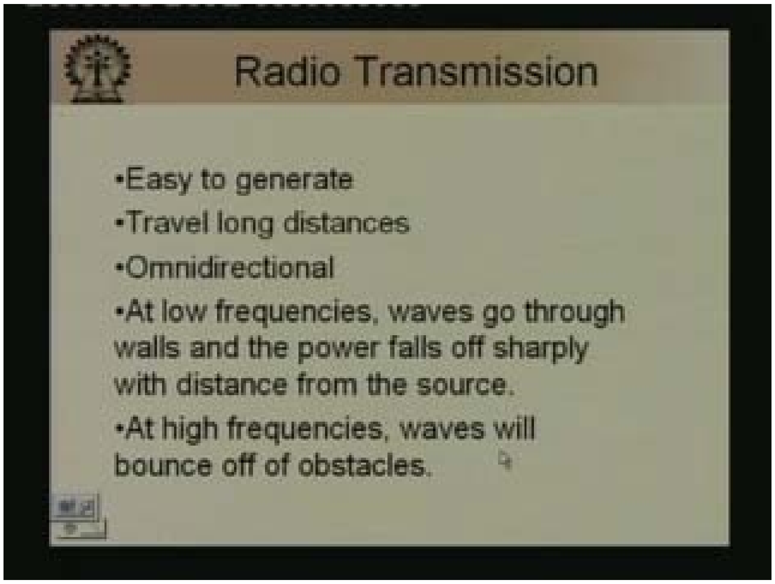

So it will travel in all directions and it will reach everybody around in a certain area. That will not happen if you are using a very high frequency like microwave; so at low frequencies, waves go to walls and power falls off sharply with distance from the source. At high frequencies waves will bounce off of obstacles.

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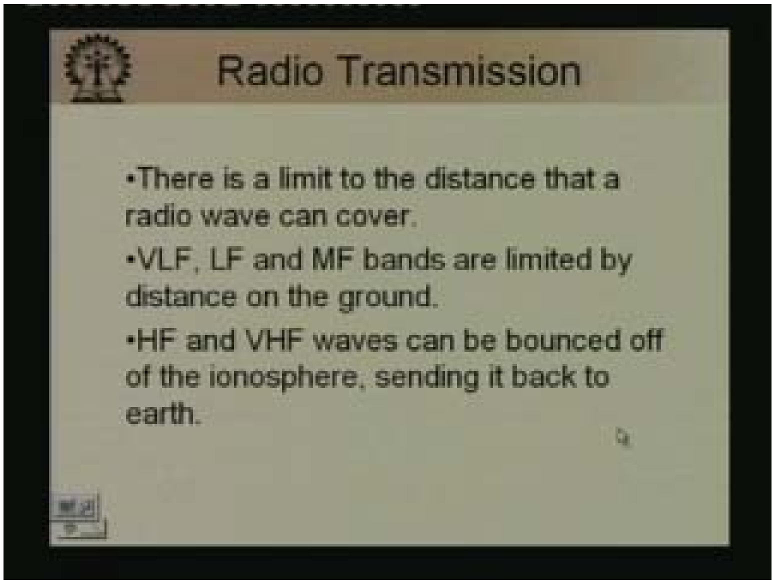

So there is a limit to the distance that a radio wave can cover. VLF, LF, and MF bands are limited by distance on the ground. High-frequency and very high-frequency waves can be bounced off the ionosphere, sending it back to earth, which is a very important thing.

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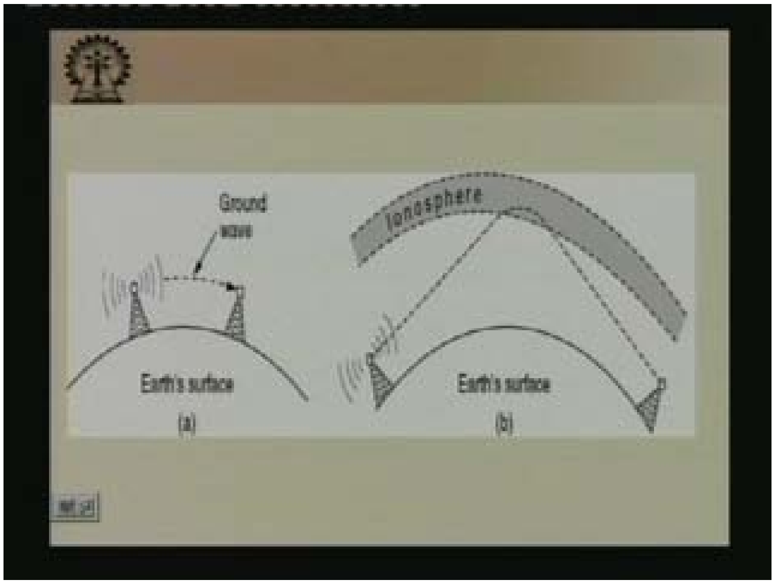

This is a picture of what might happen. In short-wave range – you know the short wave radio – you can listen to the radio transmission from USA. What is happening is that it is getting repeatedly reflected off the ionosphere and reaching the other end of the earth.

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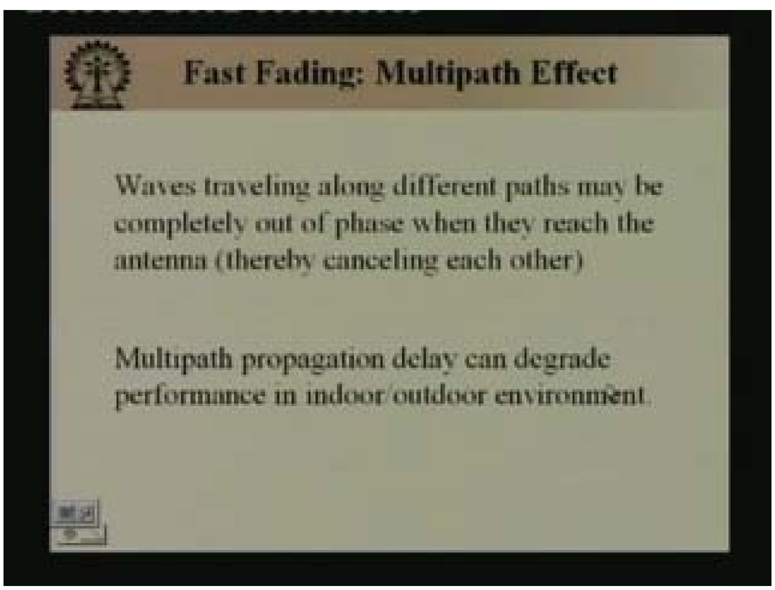

There are problems with this wireless communication; we will not go into all the details. First of all there will be selective kind of attenuation, and then there is a very irritating thing called multipath fading. So what happens is:

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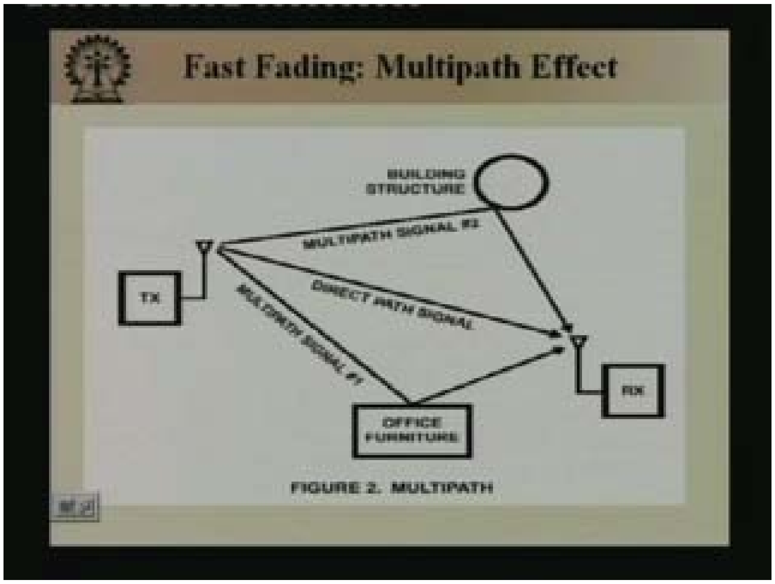

For example, something like this, your signal may reach directly or your signal may reach through a path after getting reflected somewhere and these two may be out of phase. So when they are out of phase, they will sort of cancel each other and you will have a very bad signal. These are the problems we encounter in mobile phones, etc. So you have to do something about these.

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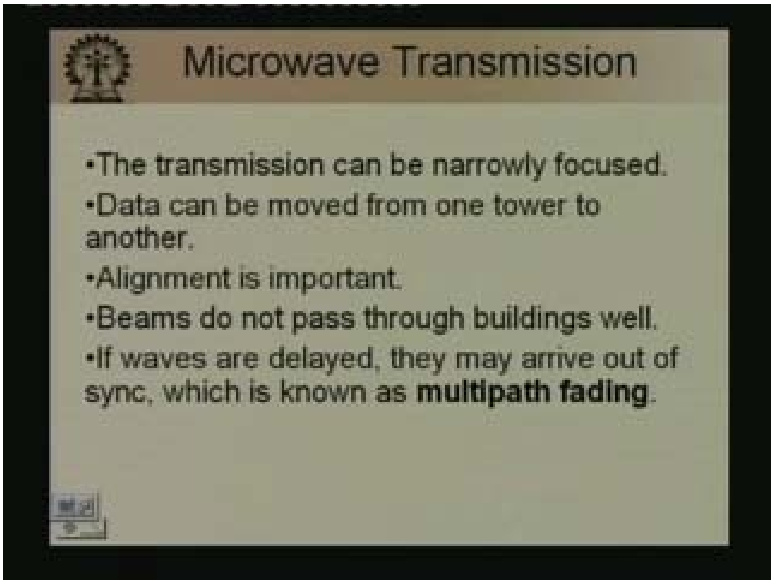

For microwave transmission, the transmission can be very narrowly focused. So data can be moved from one tower to another. You may have seen those microwave towers; so they are sort of in line of sight with each other. Alignment is important because this is a focused beam. If it is not aligned, your receiver will miss the signal altogether. Beams do not pass through buildings well. These are the disadvantages of microwave. If the waves are delayed, they may arrive out of sync, which is known as multipath fading.

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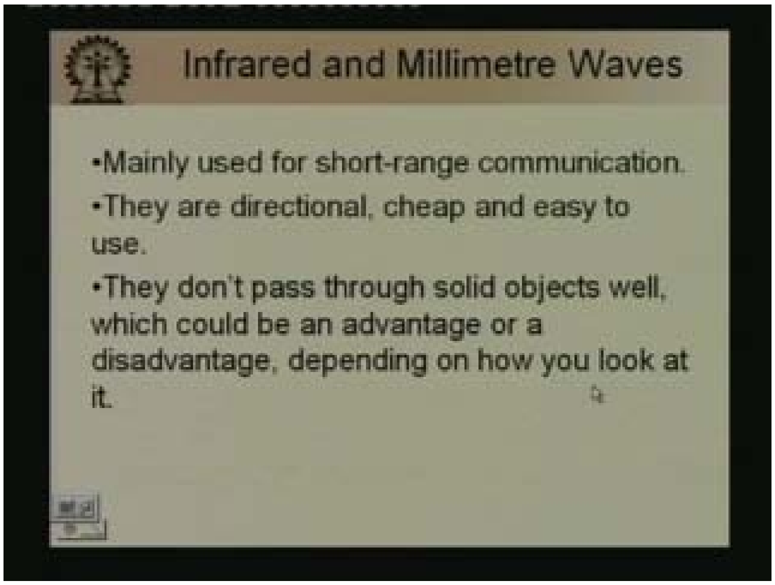

Finally, we have infrared and millimeter waves at the very high end of these; of course, we have talked about optical fiber. They are mainly used for short-range communication and they are strictly directional. As we are going more towards the light, it is becoming more and more directed, as light is very directed. So they are directional, cheap, and easy to use but they don't pass through solid objects. You cannot use them for a mobile phone, let us say, but you can use them for controlling your TV or for short-range connection to your computer from some handheld device, etc. So this can be an advantage or disadvantage – one way of looking at it is that since it does not go through walls, whatever you do in one room is going to not affect whatever you are doing in the other room. So that may be an advantage also. We tried to cover all the different ranges that we use in communication; we have the satellites. Also. As I mentioned, you have this geostationary satellites, which are nothing but repeaters on the sky.

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So we can sort of send the signal from earth to the satellite, where it will be amplified and sent it back to earth. These satellites could be geostationary or the satellites could be sort of low, earth orbiting satellites. So they are also used for communication over long distances.

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Note: The rest is part of Lec 5.

Faculty Name
Prof. Sujoy Ghosh
Lecture No. - 5
Multiplexing
(Sharing a Medium)

Today we will talk about Multiplexing.

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Multiplexing is about sharing a medium that means different users are sharing the same medium for communication at the same time.

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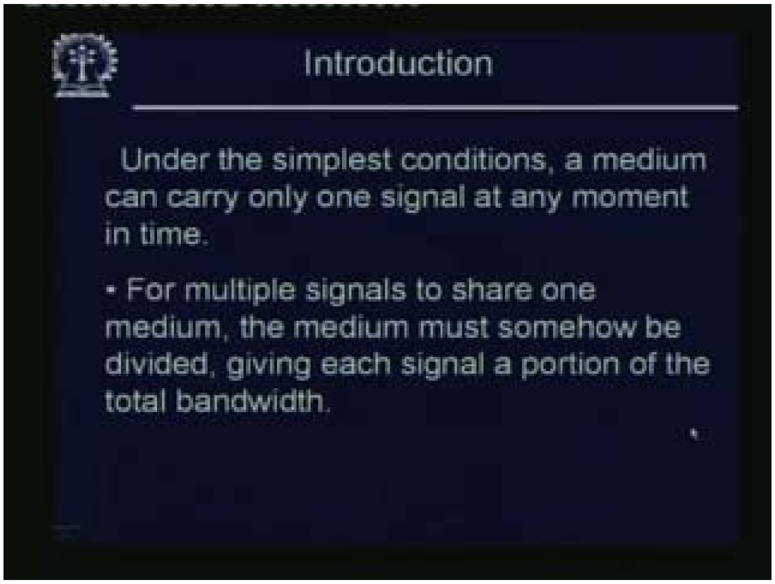

Another simplest condition a medium can carry one signal at any moment because if there are two signals over there they are going to interfere and then the signal will get garble but for multiple signals can share one medium the medium must somehow be divided giving each signal a portion of the total bandwidth if you remember that a particular frequency range around one particular frequency is called bandwidth and this band width is the most valuable resource so far as communication is concerned so what we tried to do is that we tried to use this bandwidth somehow to facilitate the communication between a number of pairs of senders and receivers so that is the idea of multiplexing.

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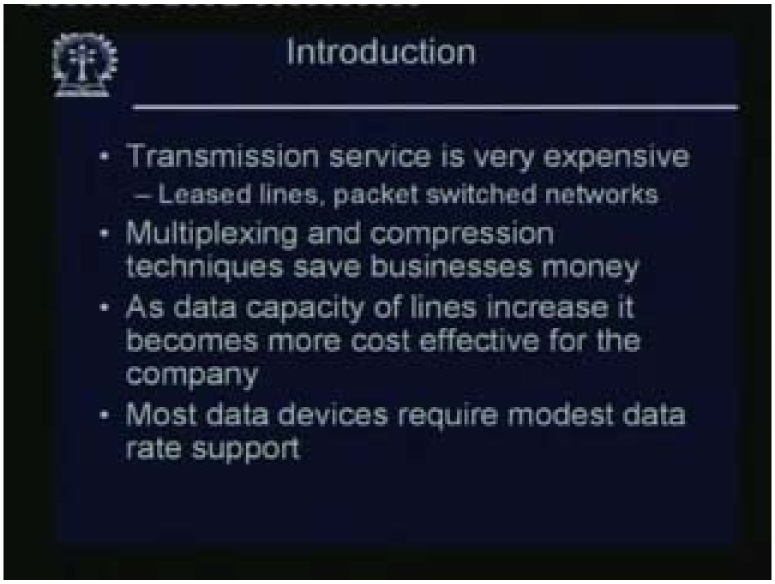

These line increases it becomes more cost effective for the company and most data devices individually they require modest amount of data but when the when a number of users their requirement are aggregated together the sum total may be quite substantial band width.

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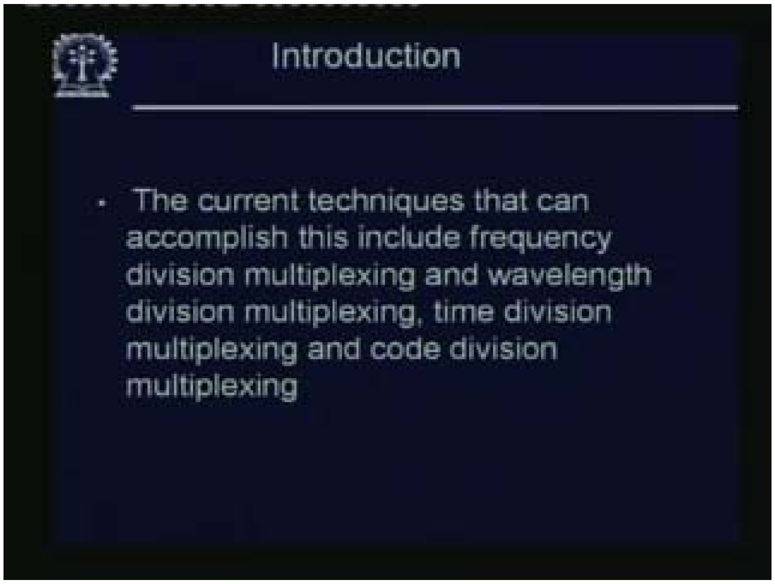

The current technique accomplish this includes frequency division multiplexing wavelength division multiplexing time division multiplexing and code division multiplexing. We will look at many of some of these at least.

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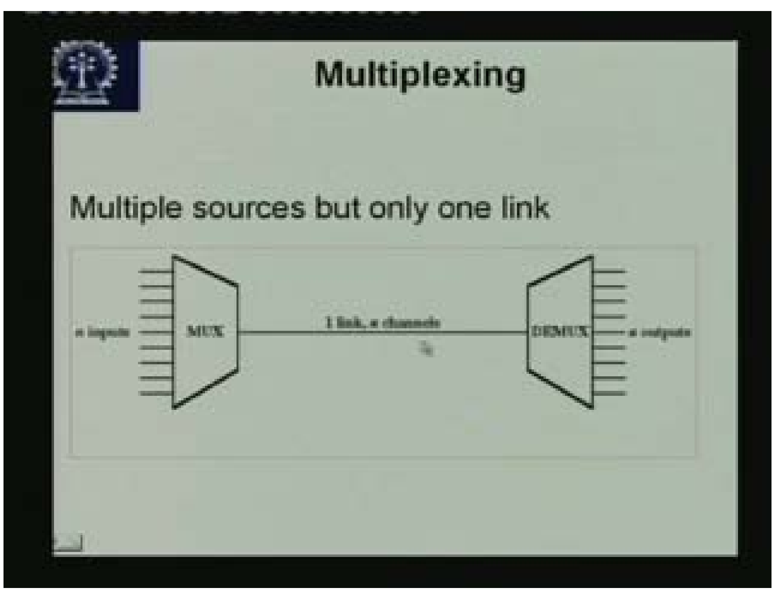

Let us see so this is the scheme of multiplexing you have one multiplexer and then you have n inputs on one side. So these n inputs are coming to the same multiplexer they are getting mixed up in some fashion. And they are being sent over the same physical link and on the other side depending on in which fashion you have put them together they started separated in two different lines. So these now these different lines in the right they can now go to different recipients. So just as on the left we have different senders and we have different receivers over here so the so a number of sender receiver pair is utilizing the same physical link in.

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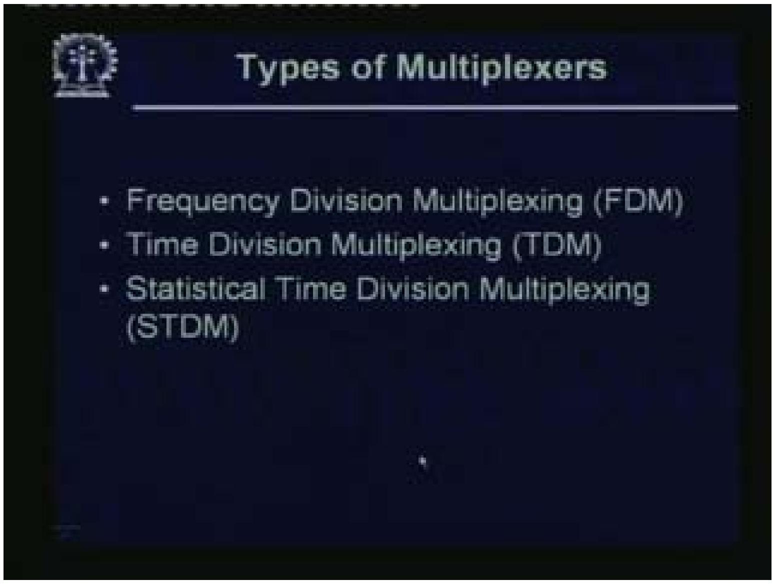

Now to for the types of multiplexer. As I mentioned that we have FDM that is the frequency division multiplexing, TDM that is the time division multiplexing, STDM that is the statistical time division multiplexing so we will look at these.

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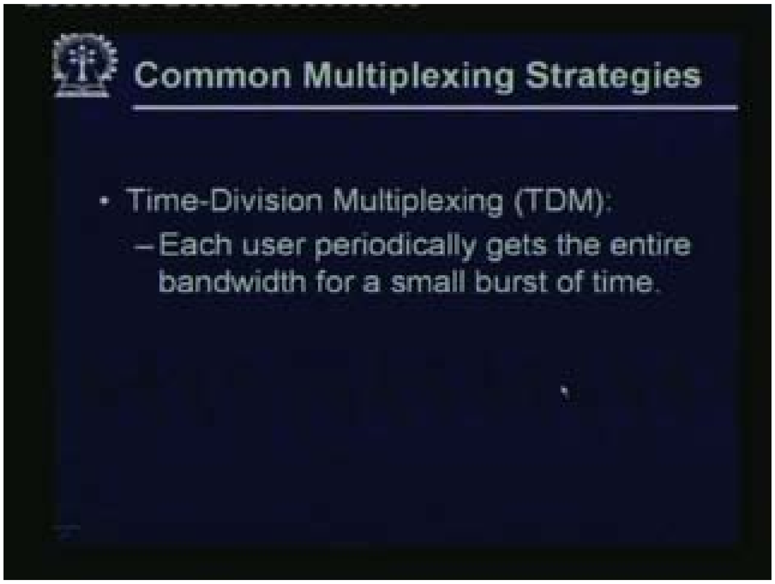

Just quickly before we go into get into the details of each of these time division multiplexing each user periodically gets the entire bandwidth. That means the entire channel is dedicated to one user but only for a short period of time. For a small burst of time after that it is somebody else so we will look at the details of this later.

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