Computer Networks
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Lecture - 5
Multiplexing
(Sharing a Medium)

Good day. Today we will talk about multiplexing. 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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Under the 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 garbled; but for multiple signals to share one medium, the medium must somehow be divided, giving each signal a portion of the total bandwidth. If you remember, a particular frequency range around one particular frequency is called bandwidth and this bandwidth is the most valuable resource so far as communication is concerned. We try to use this bandwidth to facilitate the communication between a number of pairs of senders and receivers. That is the idea of multiplexing. There are various reasons we want to use multiplexing, and the chief one is that transmission service is very expensive – leased line, packet switching networks, etc.

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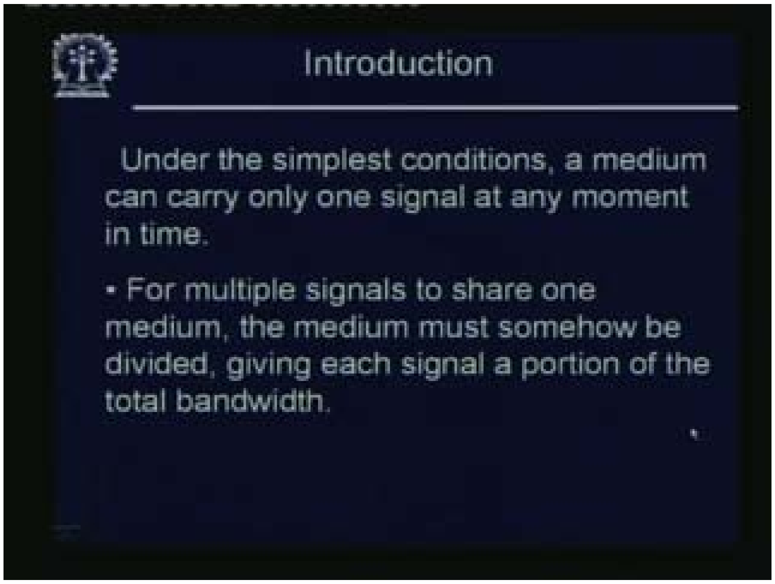

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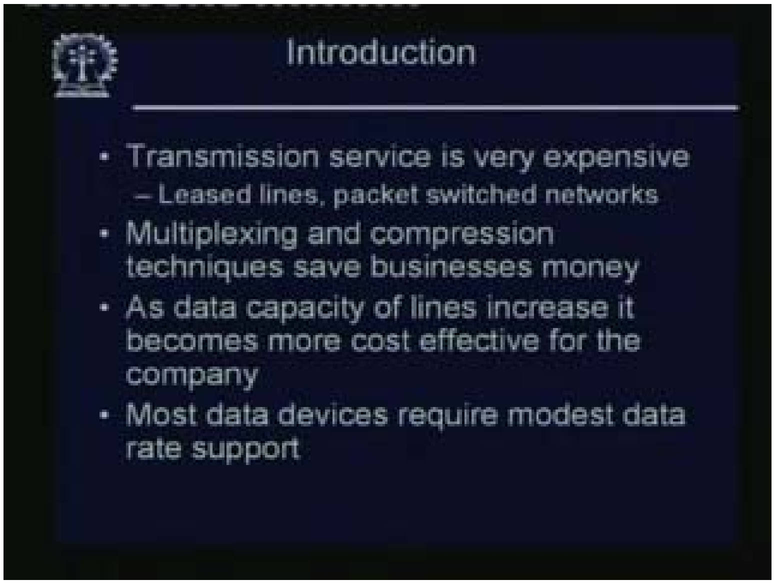

For example, lying of lines is in itself fairly expensive and a complex proposition and once you lay a line you like to utilize it to the maximum. If you can use that for the maximum amount of communication, multiplexing and compression techniques are the techniques, which we use for this purpose – it saves a lot of money for the business. When you can send a lot of data through the same line, the data capacity of the line increases, it becomes more cost-effective for the company; most data devices individually require modest amount of data but when there are a number of users, their requirements are aggregated together and the sum total may be of quite a substantial bandwidth.

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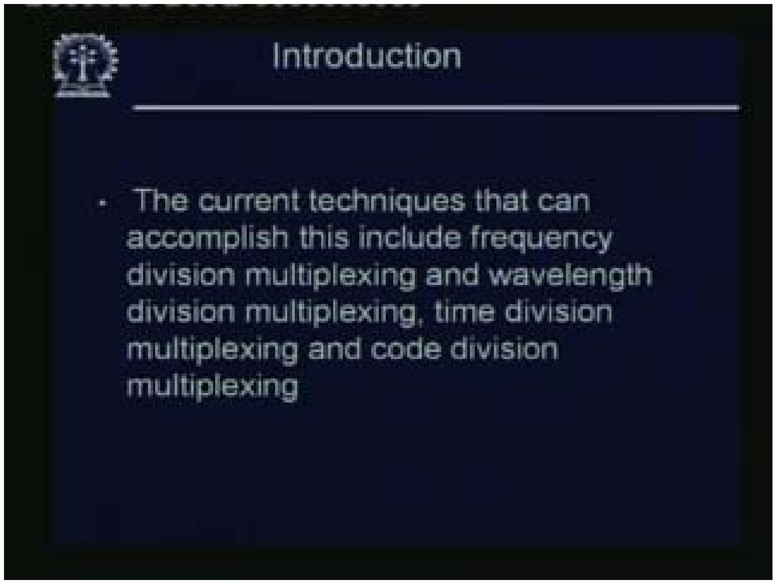

The current techniques that can accomplish this include: frequency division multiplexing, wavelength division multiplexing, time division multiplexing, and code division multiplexing. We will look at some of these, at least.

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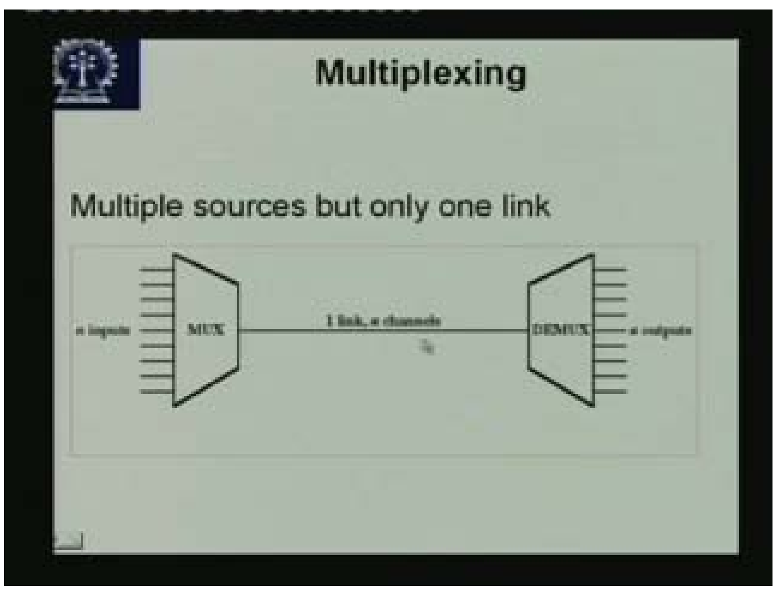

This is the scheme of multiplexing; you have one multiplexer and then you have n inputs on one side. These n inputs have come to the same multiplexer; they are getting mixed up in some fashion and they are being sent over the same physical link. And on the other side, depending on the fashion in which you have put them together, they have separated into different lines. These different lines on the right can now go to different recipients.

So just as on the left we have different senders and we have different receivers, a number of sender–receiver pairs are utilizing the same physical link in-between.

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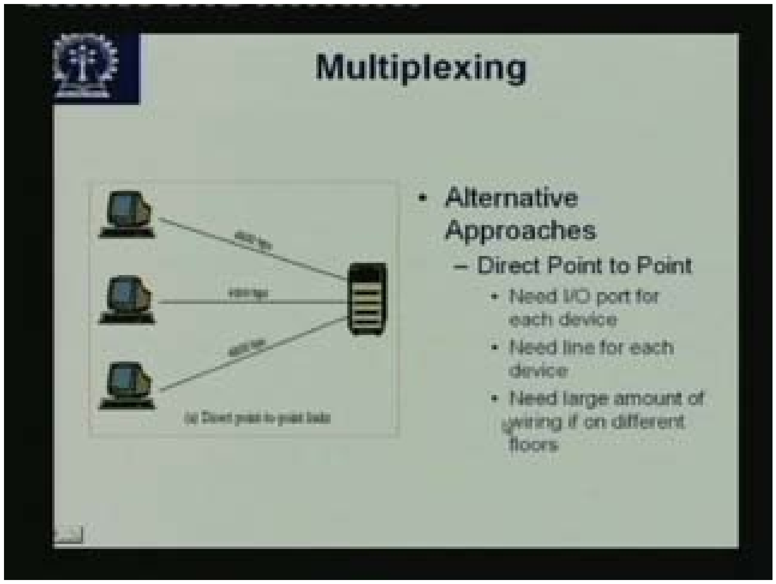

The alternative to multiplexing should be direct point-to-point connection; this has a number of problems. The first problem is that you need those lines that we were talking about, you need lines for each device, and you need a large amount of wiring, if they are on different floors. Another important point is that you need a lot of I by O ports on the computer side, which really is not feasible. You may have a few I by O ports, but you cannot have hundreds of I by O ports, it's really difficult to have hundreds of I by O ports there.

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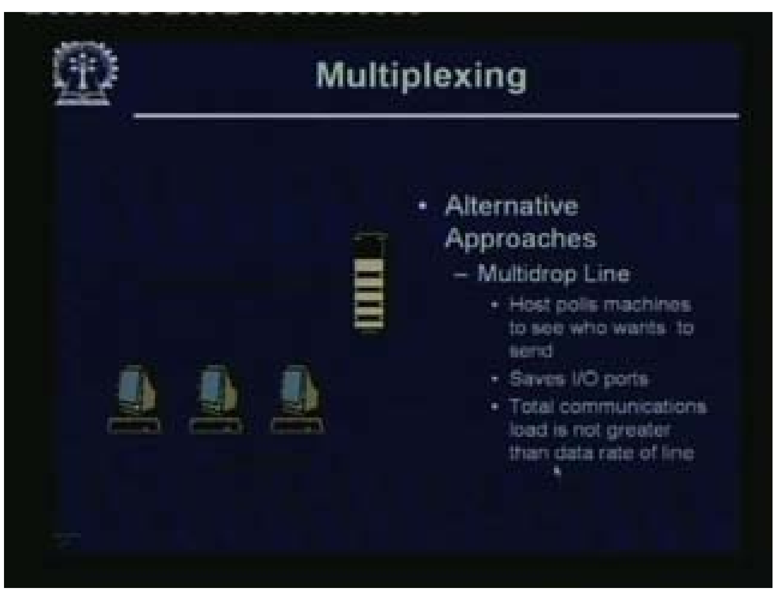

That is also another bottleneck that we wish to address. Another approach could be, a somewhat older approach, which is that of a multi-drop line. The host polls machines to see who wants to send and then uses the same lines, saves I by O port; the total communications load is not greater than the data rate of line.

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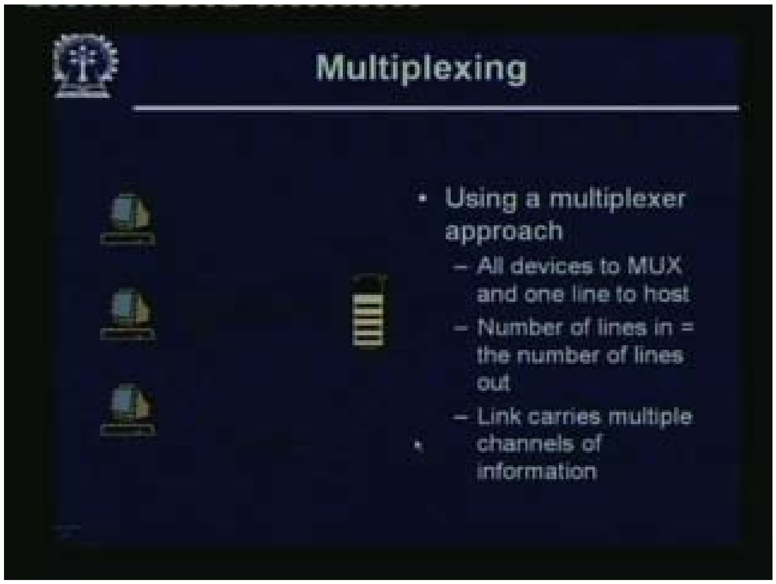

These are actually the simple approaches. Using a multiplexer approach, all the devices, their data is multiplexed on one side, sent through one line, and the number of lines in is equal to the number of lines out; the link carries multiple channels of information.

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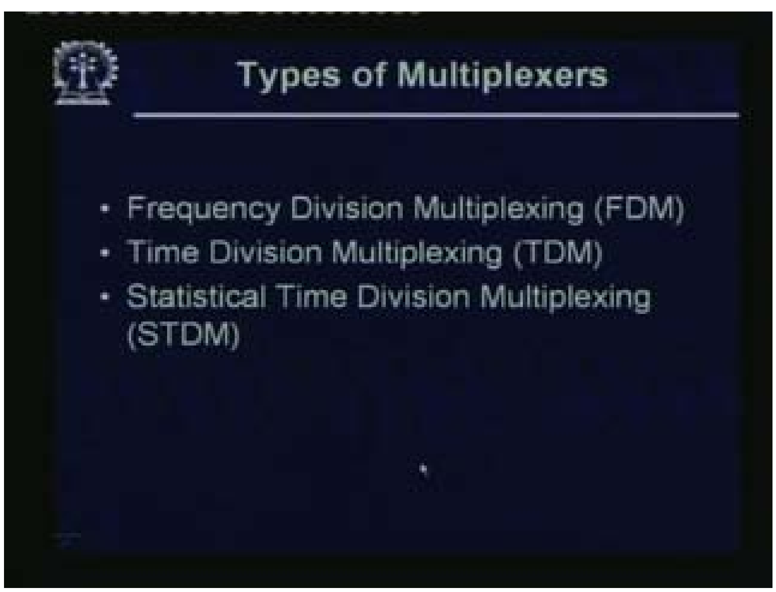

The types of multiplexer we have are: FDM, that is, frequency division multiplexing; TDM, that is, time division multiplexing; STDM, that is, statistical time division multiplexing. We will look at these.

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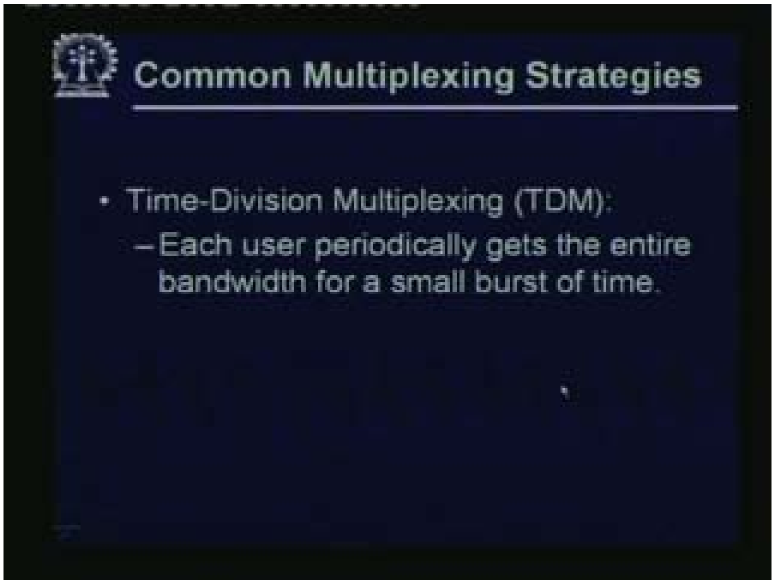

Just quickly before we get into the details of each of these, in time-division multiplexing, each user periodically gets the entire bandwidth. That means the entire channel is dedicated to one user but only for a short period of time, for a small burst of time. After that it is somebody else's time.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

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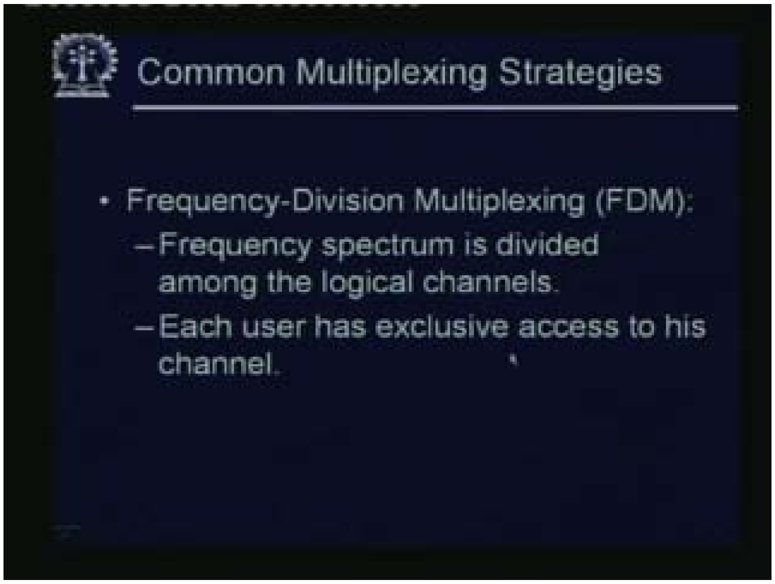

Another common approach is the frequency division multiplexing; here the frequency spectrum is divided among the logical channels. Here we have only one physical channel, but we want to have a number of logical channels, so the frequency spectrum of the channel is divided, each user has exclusive access to his channel.

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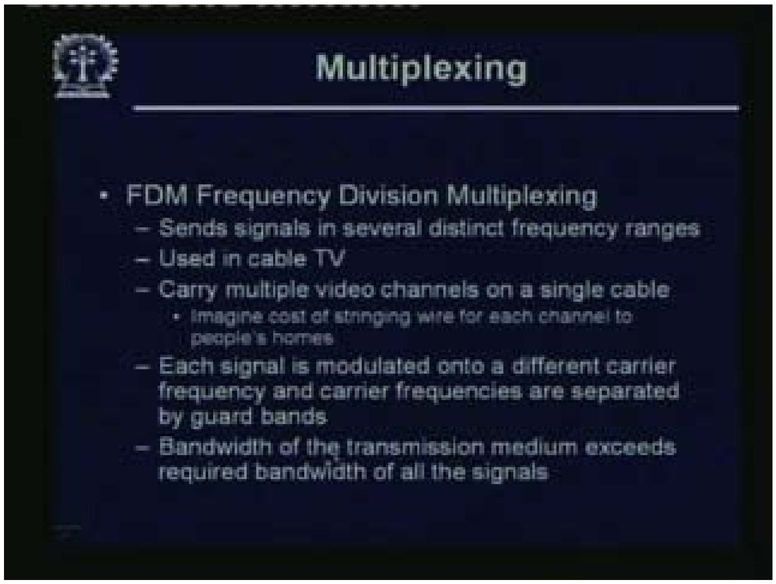

This FDM sends signals in several distinct frequency ranges: one of the oldest uses of frequency division multiplexing is in radio. For example, we have this electromagnetic field in our atmosphere, let us say, through which electromagnetic radiation can pass. Electromagnetic radiation can be of very large range of bandwidth, the whole range of bandwidth is there. Out of that, the so-called radio frequencies constitute one part of it, a fairly important part of it. This whole bandwidth of radio frequencies is divided into small channels and each channel is given to one particular station.

And on the receiver side, on the radio side, what we do is that we tune our radio, let us say, to one particular frequency, so that it receives signal from that particular station only; although a number of stations are all transmitting at the same time. This is an example of multiplexing. Another example of multiplexing, the same frequency division multiplexing, we see nowadays in the cable TV. The cable TV providers give one cable, one coaxial cable to the premise connected to the TV. That one coaxial cable apparently is carrying a number of channels, may be hundreds of channels these days. What is done once again is that, all the frequencies, which can travel down this cable, are broken into a number of logical channels and each channel is dedicated to one particular station. That is how we carry multiple video channels on a single cable. Of course I mean point-to-point is out of question. Imagine the cost of stringing wire for each channel; you’ll have a hundred cables coming into your building which is not really possible.

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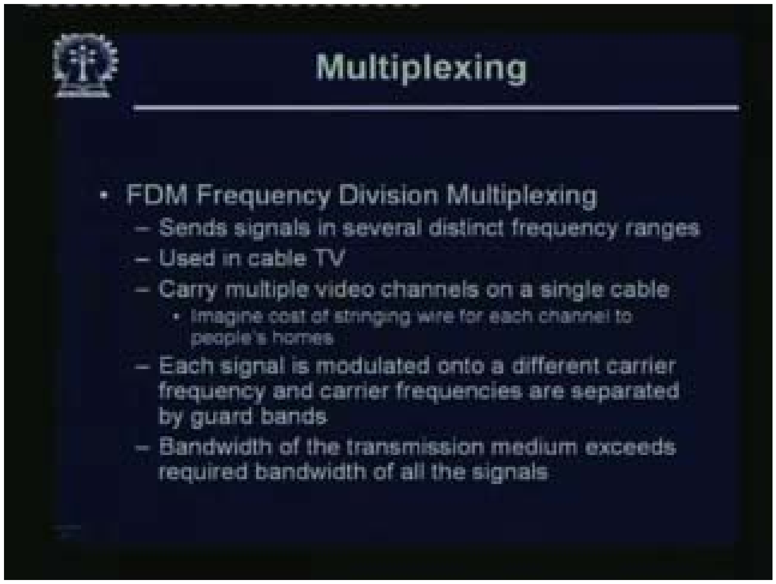

Each signal is modulated on to a different carrier frequency; carrier frequencies are separated by guard bands. This guard band is important because one particular channel, maybe a radio channel or a TV channel, the principle is the same everywhere. So, that uses some middle frequency, maybe some range of frequencies. The next station maybe a TV station or a radio station – whatever it is, that can occupy; first of all that has to be non-overlapping. The range of frequencies which is assigned to the second station has to be non-overlapping with the range of frequencies which is given to the first station and not only that, between these two there must be some separation in frequencies. Otherwise what will happen is these two signals are going to interfere with each other. So that is a guard band.

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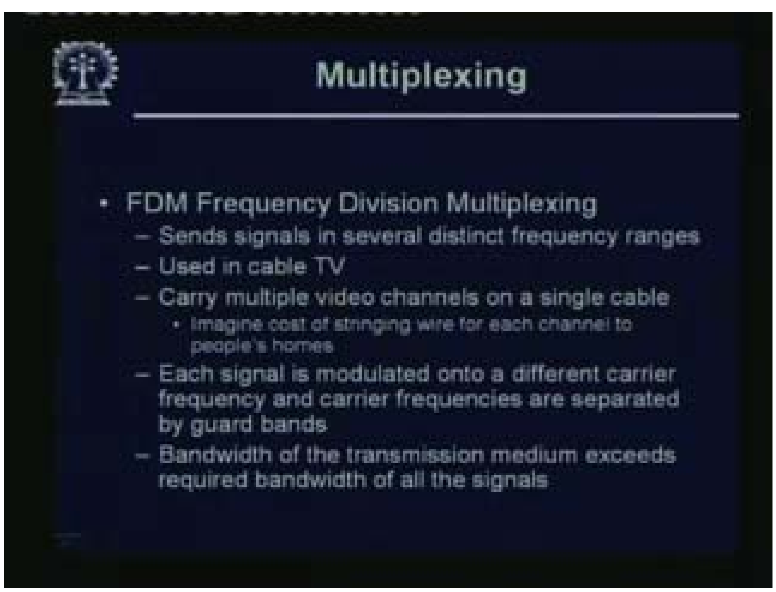

The bandwidth of the transmission medium exceeds required bandwidth of all signals because of these guard bands which have to come in-between.

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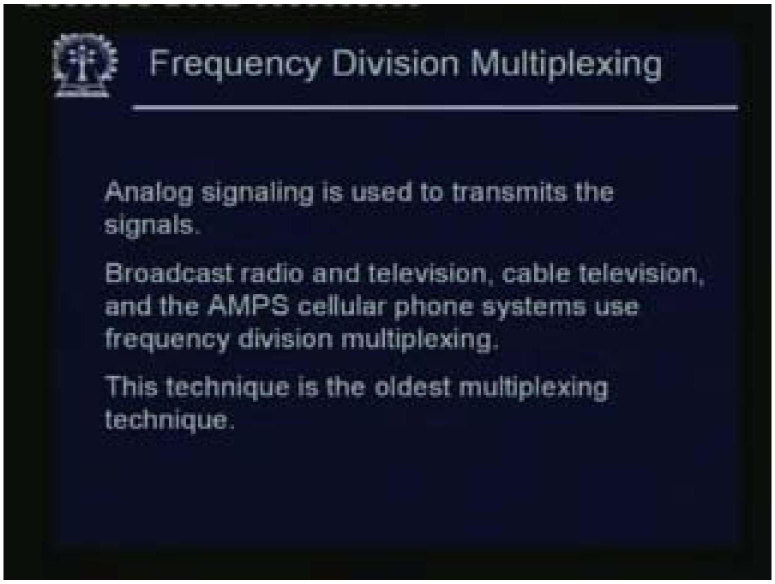

Usually for frequency division multiplexing, analog signaling is used to transmit signals. Broadcast radio and television, cable television and amps cellular phone system use frequency division multiplexing. Amps are an old cellular phone system that was there in USA. Nowadays of course, the kind of Cellular technology that we have in our country uses more complex multiplexing techniques; maybe I'll mention that later on.

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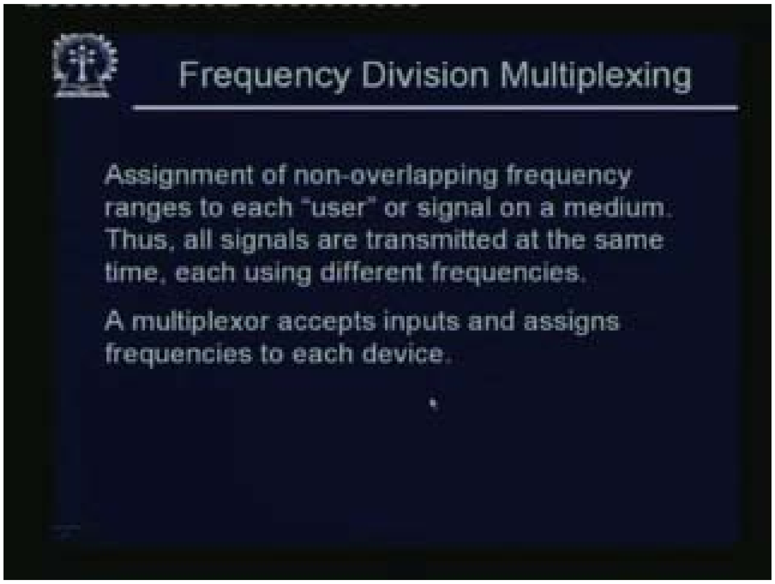

These systems all use frequency division multiplexing. This technique is the oldest of the multiplexing techniques. Assignment of non-overlapping frequency ranges to each user or signal on a medium –all signals are transmitted at the same time, each using different frequencies. A multiplexer accepts inputs and assigns frequencies to each device.

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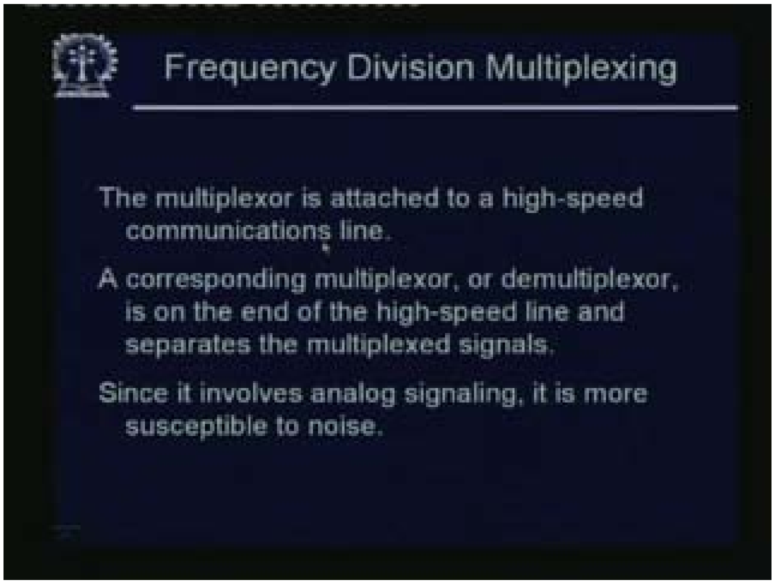

The multiplexer is attached to a high-speed communications line because all these frequency bands on individual users are going to adapt to a fat range of frequencies. The communication line must be able to handle this whole frequency range or in other words, the communication line has to be high speed. A corresponding multiplexer or demultiplexer is on the end of the high-speed line and separates the multiplexed signals, because on the other end you have to separate them out. Since it involves analog signaling, it is more susceptible to noise. Thus we have seen that the analog signals are more susceptible to noise. In digital signals we can sort of clean the noise more easily.

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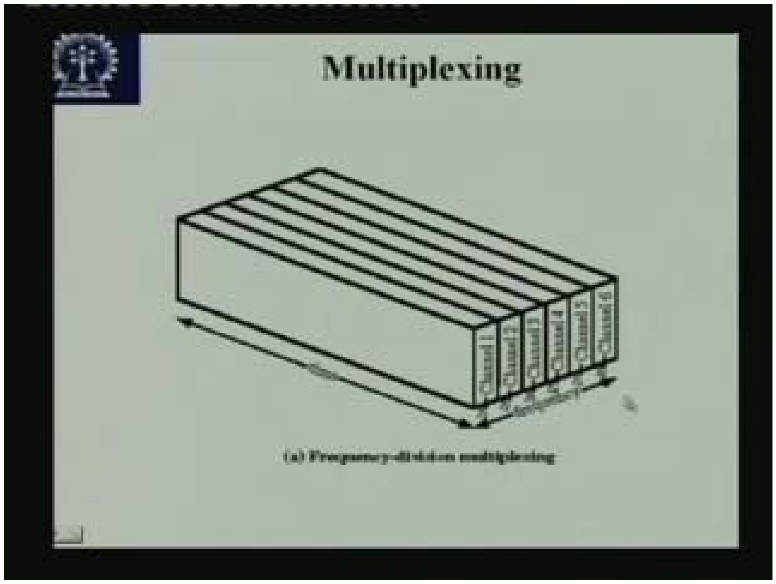

This is a diagram. If you note that for a particular user, suppose user 1, we give channel 1; along the time this channel 1 is entirely dedicated to user 1 for all time. Similarly channel 2, which is at a different frequency – frequency is on this side and time is on this side – once again user 2 gets to use this frequency for the whole time. This is the simplest kind of scheme, so that for this whole frequency band, frequency is being divided, which is why it is called frequency division multiplexing.

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As was mentioned, the frequency channel is divided into logical channels; each user hangs on to a particular frequency, the radio spectrum and a radio is examples of the media and the mechanism of extending information from the media.

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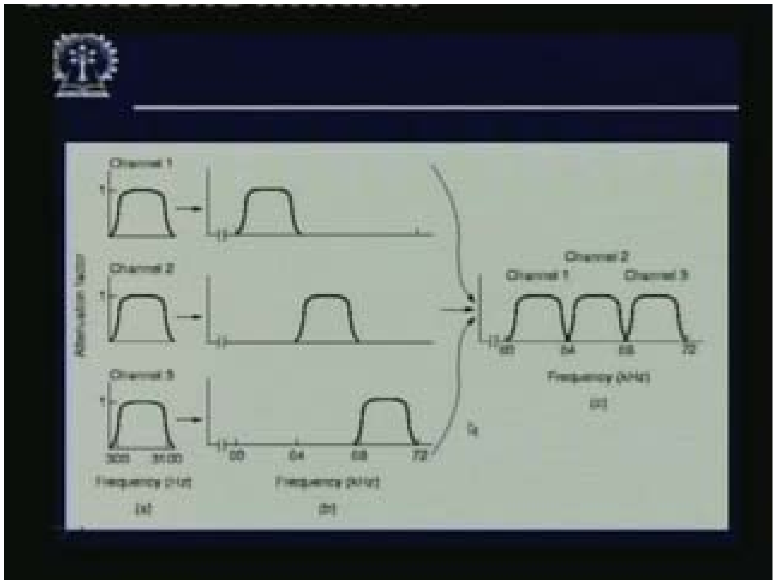

This is another picture of the same thing, see channel 1 and then channel 2, channel 3 – they all send some signals. If you plot them across the frequency versus the signal strength, you get a picture like this, so this is the first channel, this is the second channel and this is the third channel. In-between this part here is the so-called guard band. This frequency is not used by either of them. There is some overlapping due to noise and other issues; we will not get into that; due to that this is what it looks like; the frequency bands are all separated.

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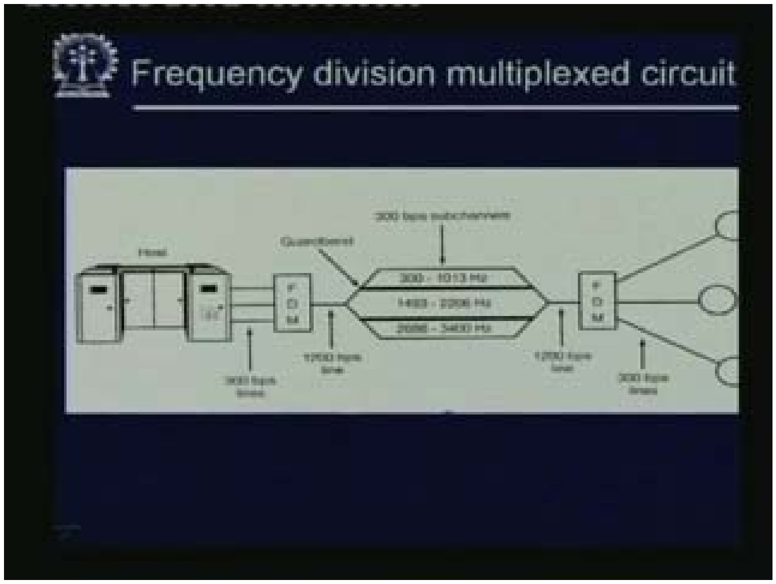

Here is another diagram which shows, let's say you have the host and a 300 bps line; a number of 300 bits per second lines are being multiplexed to 1200 bps line and then there are some guard bands: maybe 300 to 1013 Hz is one and then 1433 to 2206 Hz is another line; maybe 2686 to 3400 Hz is another line. These are the 300 bps sub-channels and you have the guard bands in-between. On the other side again you have this multiplexer–demultiplexer, which takes it to different users.

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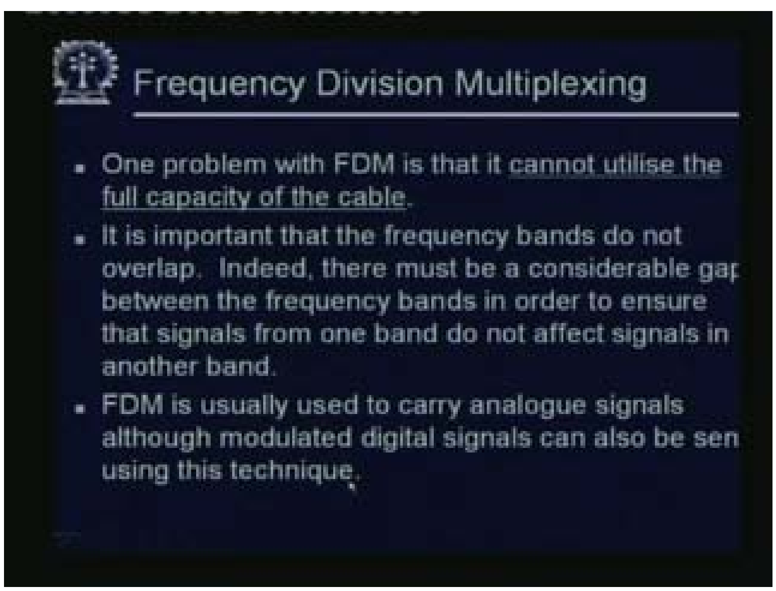

One problem with FDM is that it cannot utilize the full capacity of the cable. It is important that the frequency bands do not overlap so that is why you have to give the guard bands, so the full capacity of the cable is not utilized. The other disadvantage – we will summarize these advantages and disadvantages later on – is that it is sort of bit more prone to noise because we are dealing with analog signals. FDM is usually used to carry analog signals although modulated digital signals can also be sent using this technique.

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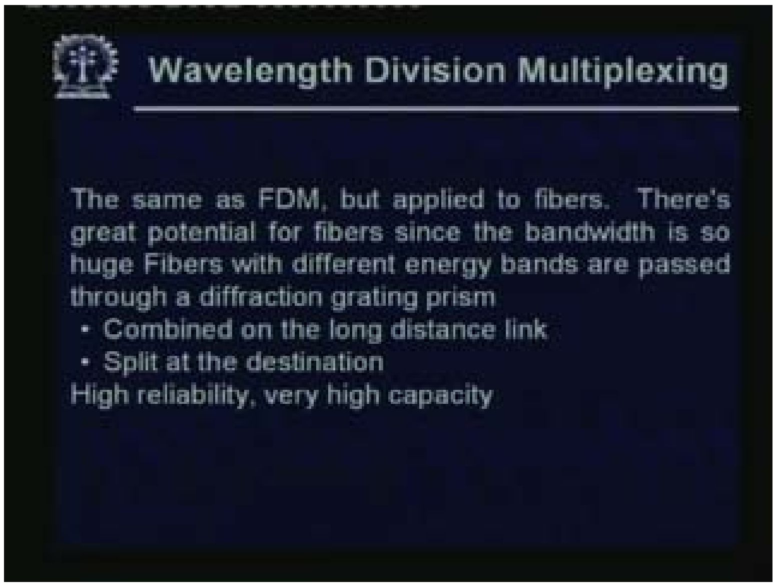

We have another type of multiplexing, which is wavelength division multiplexing. Wavelength division multiplexing is the same as the frequency division multiplexing. Only thing is that here the operating frequencies are much higher, actually they are in the optical range; that is why somehow it is given different name like wavelength division multiplexing, you know different wavelengths means different frequencies. If you are doing wavelength division it is same as doing frequency division and this is used in optical fibers. This is the same as FDM but applied to fibers.

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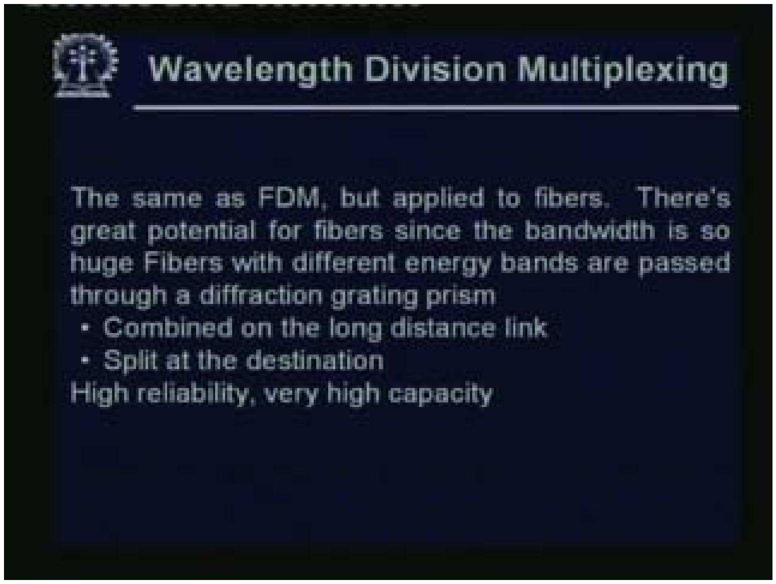

There's a great potential for fibers since the bandwidth is very huge. As I mentioned, the operating frequencies are very high, even a slight percentage deviation from the mean operating frequency gives you a very large bandwidth. So you can sort of compact or pack a lot of channels at those high frequencies. Fibers have a large bandwidth capacity and with different energy bands are passed through a diffraction grating prism combined on the long distant link and then split at the destination. This is got high reliability as well as high capacity, two very interesting properties.

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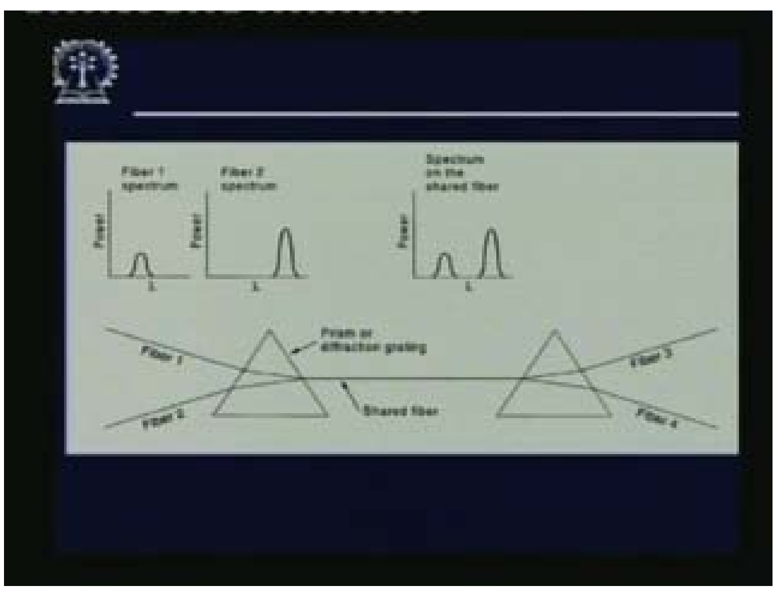

So multiplexing and demultiplexing for a wavelength division multiplexing is of course very simple. If you take a prism, you know if you send a white light through a prism it breaks up into all the different colours, because the refractive index of the prism varies with the frequency. So different frequency can come in, you can make the same light source also to say in this and on the other side you can use a prism to break it up. Of course I have shown a prism here for simplicity; usually something like a diffraction grating is used. So if you look at the fiber spectrum, if you plot the power versus the frequency so one fiber maybe giving at this frequency, another fiber maybe delivering power at this frequency. If you put them together simply then you get this power versus γ or power versus λ, kind of plot that you get Wavelength division multiplexing multiplexes multiple data streams onto a single fiber optic line.

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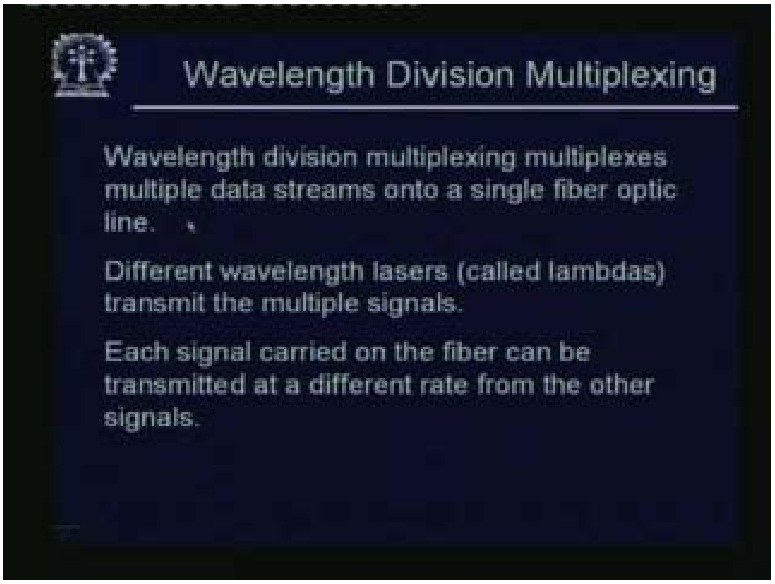

Different wavelength lasers called λs; traditionally λ is used for denoting a wavelength, some are quite extensively used in this optical communication domain. Different frequencies are called different λs and they transmit multiple signals. Each signal carried on the fiber can be transmitted at a different rate from the other signals. This is one very interesting thing of fiber that is, different colours although they may get mixed but finally again they will be separated. What rate of data, what protocol etc. are they carrying? The fiber system is really transparent to all that so that is a good thing – different systems can be put to the same fiber. As I mentioned that fiber have a very high capacity so you get to push in a lot of Channels into the same fiber. Dense wavelength division multiplexing also called DWDM. They may combine as many as 30, 40, 50, 60 or more channels these days into one fiber and each of these channels has a very high capacity; so DWDM channel has a very high capacity and it is improving all the time. People are finding ways of packing more λs into the same fiber and it is supposed to be quite scalable into the future; but of course if you want to pack those wavelengths in a very dense fashion, your equipment becomes somewhat costly.

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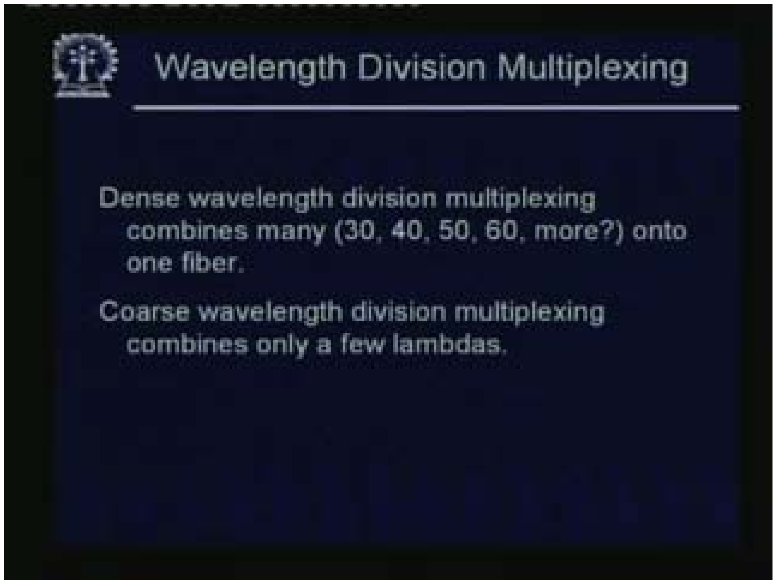

A cheaper alternative which has come up recently which are called CWDM so Dense Wavelength Division Multiplexing is called DWDM, cheaper version is called Coarse Wavelength Division Multiplexing or CWDM. In this CWDM the channels are more widely spaced on the spectrum. Multiplexer, demultiplexer, and all these costs go down and become cheaper alternatives but still you can push in a number of wavelengths into the same fiber. Now we come to the other very important multiplexing technique called Time Division Multiplexing.

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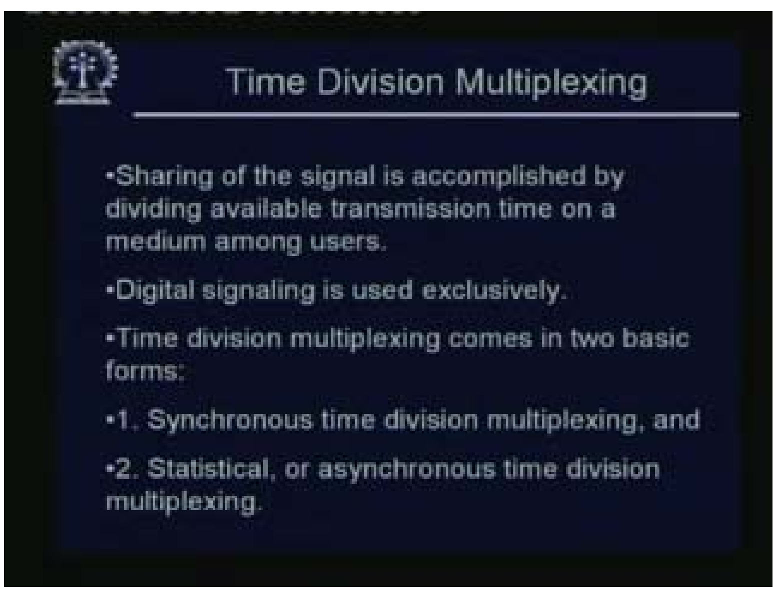

As a matter of fact this is extensively used in our computer communication or telecommunication. Time division multiplexing is very extensively used especially on the service provider side; we will look at these later on. Sharing of the signal is accomplished in time division multiplexing by dividing the available transmission time on a medium among users; so time is being divided. What is done is that, as I mentioned before, that each user gets a small burst of time in which at that time the entire channel and the entire bandwidth is at his disposal; but as soon as that short duration of time is over, then it is somebody else's turn to send and this maybe in a round-robin fashion after some time it will come back to the original user, so that he can send his next burst of data or voice or whatever it is.

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Usually we use digital signaling in time division multiplexing, almost always. Digital signaling is used almost exclusively. Time division multiplexing comes in two basic forms: one is synchronous time division multiplexing, the other is statistical or asynchronous time division multiplexing. We will look at synchronous time division multiplexing first and because that is the simpler scheme and then you will look at statistical multiplexing.

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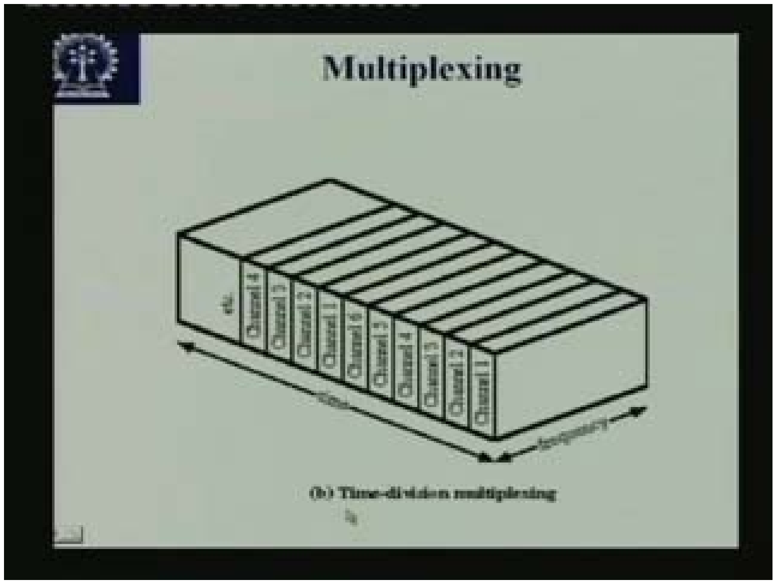

So the same multiplexing scheme now looks like this. If this is the frequency, the same plot if you remember in the previous diagram when we were doing TDM we were slicing this channel in this fashion. We are now slicing it in this fashion; that means time is divided; channel 1 channel 2, channel 3, channel 4, channel 5, channel 6; they get the entire frequency range for a small burst of time. And suppose only 6 channels are being multiplexed, after 6 again it will be the turn of channel 1. So channel 1 sends the first burst of data etc. using the entire frequency band during this time period and then during this time period. During this time channel 1 is not sending anything so it is quiescent. Time is getting divided in this fashion; this is why this is called time division multiplexing.

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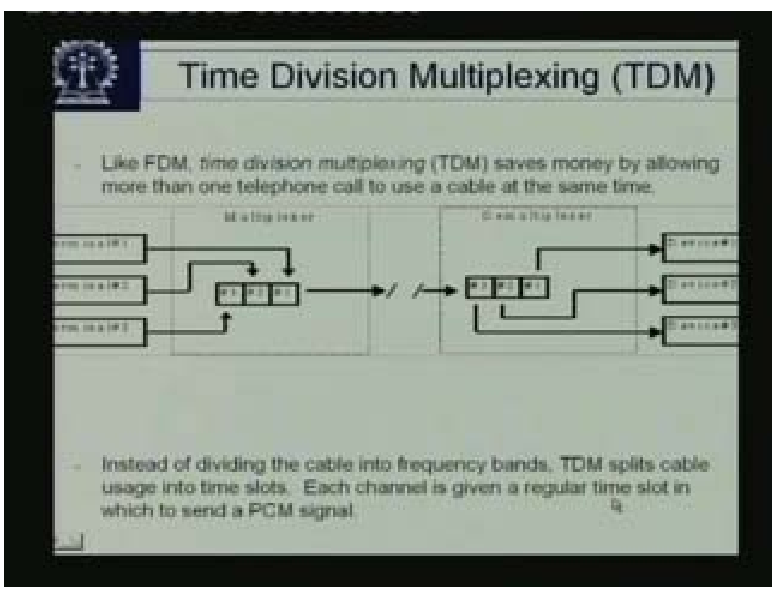

This is a schematic of a time division multiplexing system. Like FDM time division multiplexing saves money by allowing more than one telephone call to use a cable at the same time. You have terminal 1, terminal 2 and terminal 3. Terminal 1 is giving at this particular time then terminal 2 and this terminal 3. And over here on the other side this sequence and the way it goes that is known that has to be known; so whatever signal comes at one particular slot; this multiplexer knows that this must be for receiver number 1 and next slot is for receiver number 2 and next slot for receiver number 3. So on the receiver side; it just knows if it is this time slot, it is for a particular user. This is a synchronous division multiplexing because this clock and this clock have to be synchronized otherwise, there will be a problem. Instead of dividing the cable frequency bands, TDM splits cable usage into time slots. Each channel is given a regular time slot in which to send a PCM signal.

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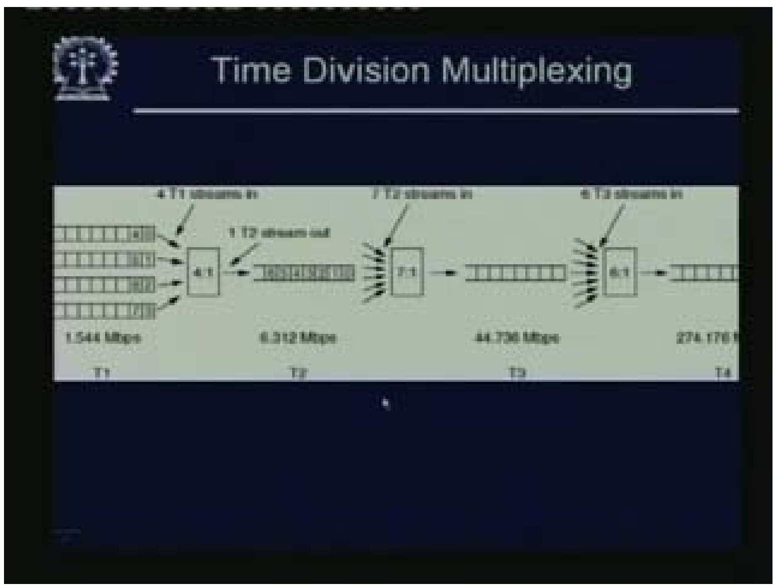

This is another view of the same time division multiplexing. Actually in actual practice, we will go into the details of this later on. Actually this time division multiplexing can be done in a hierarchy of manner. We will look at this hierarchy later on. If you remember from our digital signals discussion, that our voice, because it is up to say 4 kHz is our voice signal, because of Nyquist theorem, we require 8 kilo samples; that means double the rate that means 8,000 samples/second for capturing voice. And for each sample, it has to be converted. Each sample is an analog value; so that value has to be converted to a digital signal, an 8 bit digital signal, which is called PCM – pulse coded modulation.

That means there are 256 different levels that this is distributing, which is very fine. Our amplitude of voice if you divide it into 256 parts we are making a very fine distinction; that gives you 8 bits per sample 8,000 samples by second; that comes to 64,000 bits per by second. This is a very basic rate and this rate has got a name; we will go to these names later on. A number of such channels may be multiplexed together. This 64,000 bits by second is a very basic rate.

A number of such channels may be grouped together to form one particular higher level channel and different higher lever channels may again join together to make a hierarchy of channels, this is what is shown over here.

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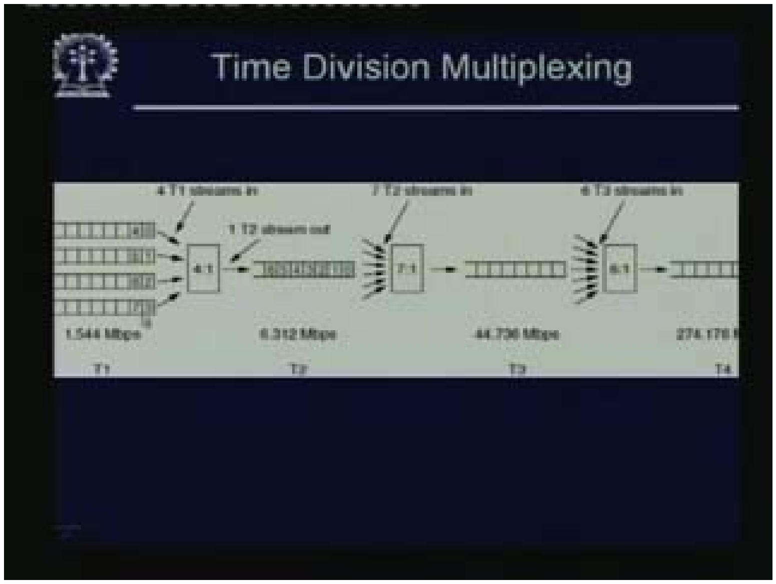

These T1 etc., don't bother about this figure at this moment because we will look at this later on. So T1 is one particular rate at which some of these signals come. There are worldwide standards actually there are two standards, we will talk about it later on.

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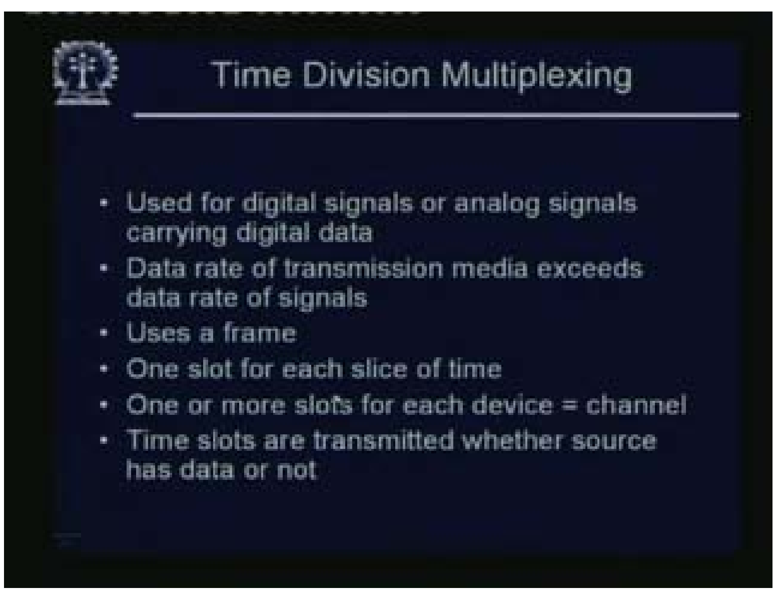

Standards of the rate at which these signals come; they sort of join together and form a stream of T2 stream and different T2 streams, different waves have different names like T1, T2, T3, etc., will form a T3 kind of frame and as you can see that the bandwidth is increasing all the time. The T1 rate is 1.544 Mb by second. Time division multiplexing used for digital signals or analog signals carrying digital data, data rate of transmission media exceeds data rate of signals; so this has to be there otherwise your TDM system will not work. Because in that small burst of time which is given to a particular user, in that burst of time that user should be able to send whatever digital data it had accumulated during that time, as well as the previous epoch during which it was quiescent; because at that time it was other people's turn. It may be a buffer or kind of thing where all these bits are getting accumulated and when it gets its small burst of time, during that burst of time it sends all the bits in that buffer, to make it empty.

And then it becomes quite again, so it will accumulate the bits again in the buffer and then again when it gets the next burst of time it will send all the bits. Thus data rate of transmission media has to exceed data rate of signals. It uses a frame; frame means a number of bits and bytes put together to form one particular unit at which to send it over; one slot for each slice of time. What would happen is that a slow device during his slot will send a lower number of bits; very high-speed device will send a large number of bits, but your slot will come periodically. One or more slots of each device is equal to channel and time slots are transmitted whether source has data or not. This is one particular problem with time division multiplexing. Think about this – that on the receiving side, receiver side is blind; it does not know this stream of bits which has come is for whom. The only way he knows that this is the time slot for receiver I, so he will send those bits to receiver I and so on in a round robin fashion.

What happens is, suppose the senders are S1, S2 to Sn, receivers are also S1, S2 to Sn; and then we have this. The SI will be sending to RI; what happens if SI has nothing to send at that point of time? During that time it is not possible for the multiplexer or the demultiplexer, in the normal scheme of things, to send somebody else maybe Sj's signal during that time although physically it would be possible; but then on the demultiplexing side it would cause a problem because the demultiplexer would not know whether this bit is for Ri or Rj. That is why even if Si has nothing to send, that slot will have to run empty; you cannot utilize it any further. This is the weakness of time division multiplexing which we try to sort of address in a different scheme, we will be talking about just now.

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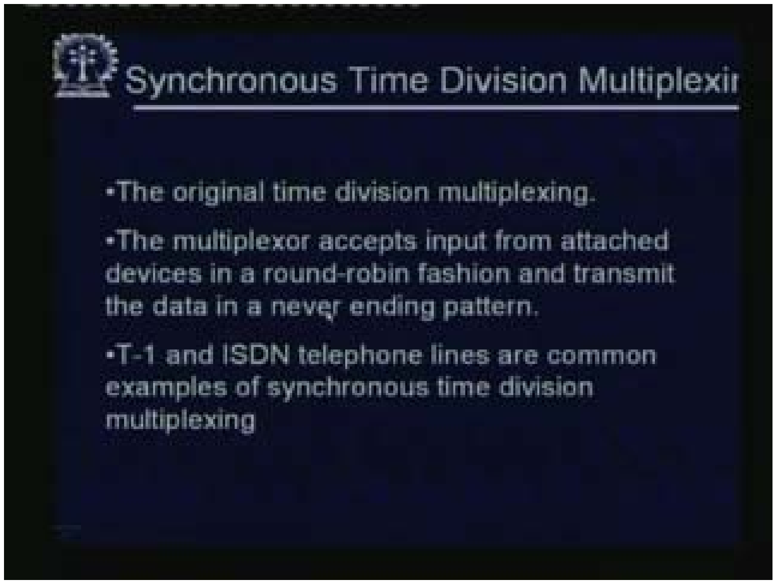

The synchronous time division multiplexing, remember that it is synchronous because the multiplexer and the demultiplexer has to agree about the slot of time; the original time division multiplexing, the multiplexer accepts input from attached devices in a round robin fashion and transmit. T1 and ISDN telephone lines are common examples of synchronous time division multiplexing.

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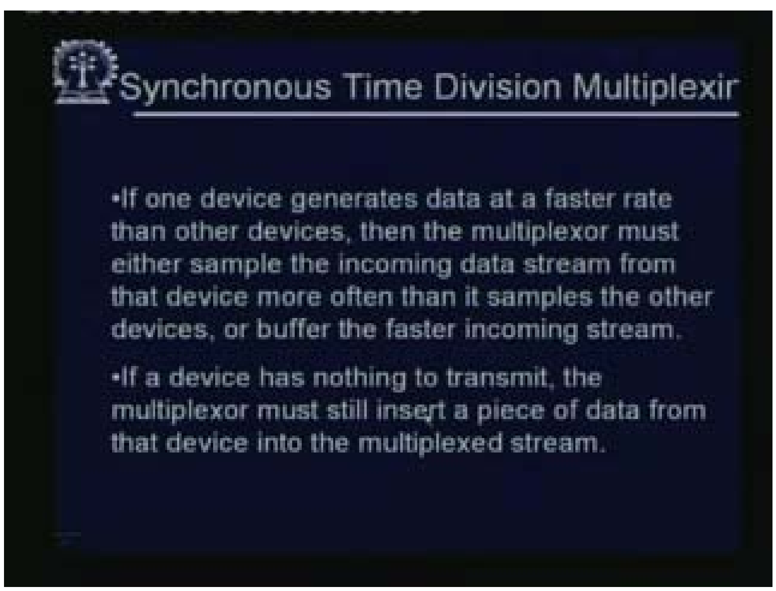

If one device generates data at a faster rate than other devices, then the multiplexer must either sample the incoming data stream from that device more often than it samples the other devices or buffer the faster incoming stream. If a device has nothing to transmit the multiplexer must still insert a piece of data from that device into the multiplexed stream, it may be a dummy data.

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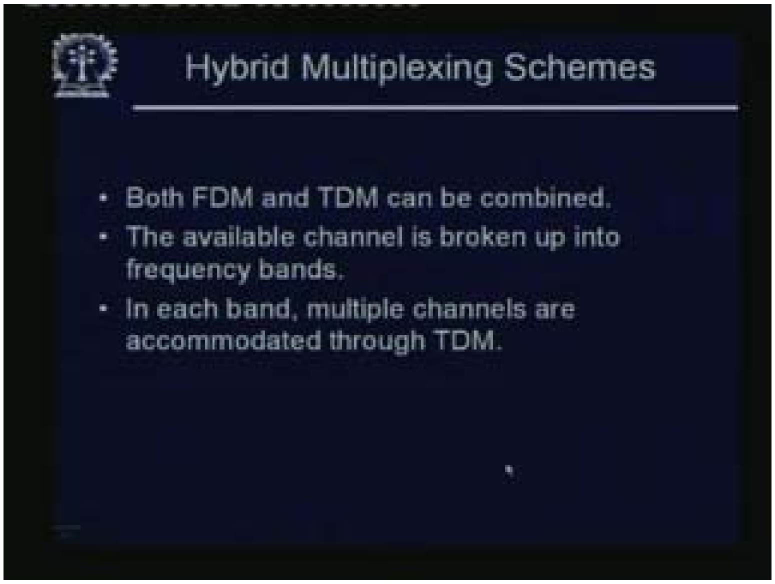

Before I talk about the other kind of TDM, which is the statistical time division multiplexing; I must mention that there are hybrids multiplexing schemes also. That means in the hybrid scheme, what you do is that you take a frequency band; it is like frequency division multiplexing, so you break up your entire available channels into a number of bands; but each of the bands instead of in the pure FDM, we are giving it to only one user but this band is allotted to may be a number of users who use TDM on this band. This is a combination of FDM and TDM, so such kind of hybrid multiplexing systems are quite widely used in these days and one good example is the cell phone communication that goes on; that may use hybrid kind of multiplexing systems.

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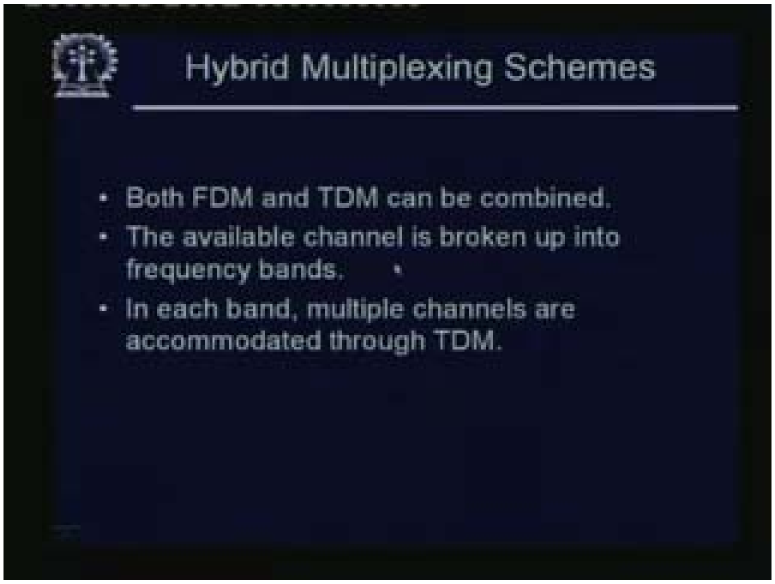

In hybrid multiplexing system, both FDM and TDM may be combined; the available channel is broken up into frequency bands; in each band multiple channels are accommodated through TDM.

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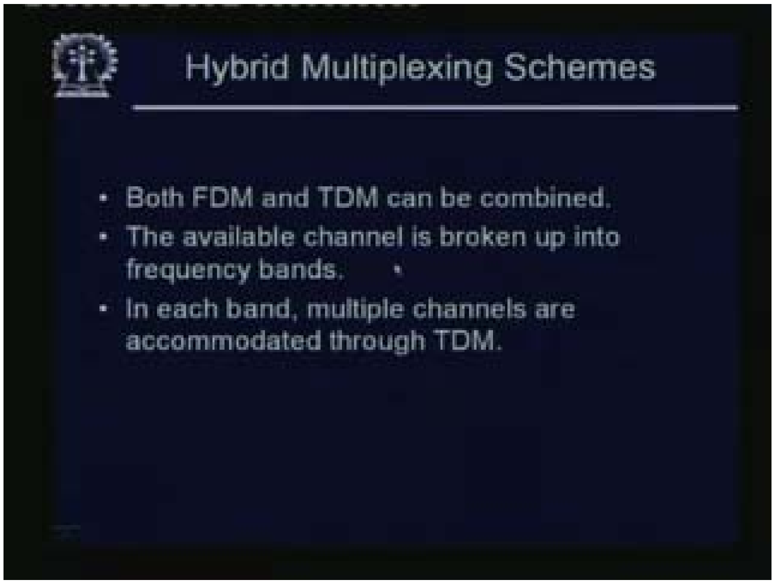

Now we talk about the other kind of time division multiplexing, namely, statistical multiplexing. This is time division but on demand rather than fixed, so we reschedule link on a per packet basis and packets from different sources are interweaved on the link. Remember that I mentioned the disadvantage of time division multiplexing is that even if the sender does not have to send anything, that time slot will go empty.

We cannot utilize it because otherwise on the demultiplexer side we will not be able to decipher who it is in the pure time division multiplexing. This is to be addressed in statistical time division multiplexing or STDM; what is done is that the packets are sent on demand; that means if somebody has to send and the channel is free, it will be sent.

Of course if everybody has to send, then you have to once again do some kind of scheduling in a round robin fashion in a simple vanilla case or you can do more fancy kind of scheduling. I am not going into that. So this utilizes the channel in a much more efficient manner; but you have a problem. We know what the problem is – the problem is on the demultiplexer side. On the demultiplexer side, one particular time slot being allotted to one particular sender or a receiver, that relationship is no longer there, and if that relationship is no longer there, how do we make out on the other side whether this is meant for whom? So you have to have that address inside that data stream. That means inside the data stream, there must be something which tells the receiver and the demultiplexer that this is meant for that receiver. So you have to have the address, at least the destination address in the packet so to say, now I am calling it a packet that whatever the burst of data sent in a particular time slot.

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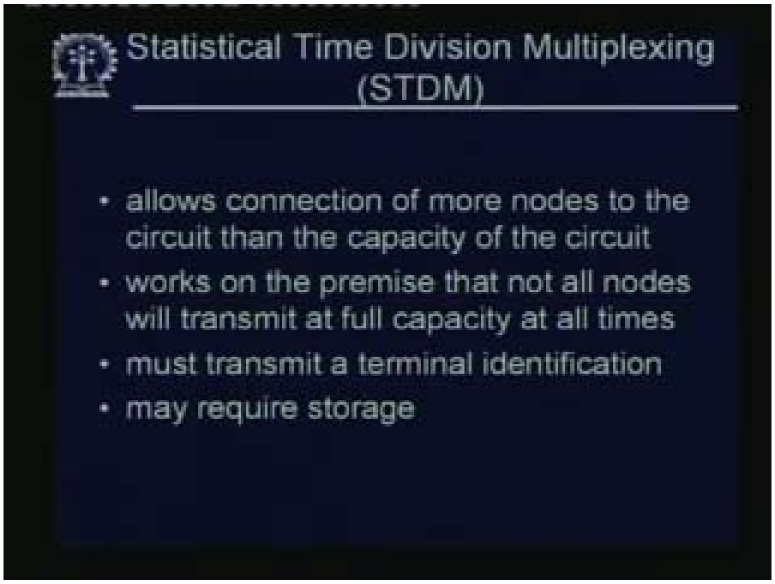

It allows connection of more nodes to the circuit than the capacity of the circuit. How is this possible? This is because usually our communication is always bursting, for example, when I am talking I may require 4 kHz, when I am making a sound; but then there are periods when I am quiescent that means I'm not talking at all .So overall if I can utilize that, maybe my effective rate of utilization of the channel will become more than 4 kHz; because one user is using 4 kHz. And this way in each of the channels, the same thing happens and much more dramatically, in the world of sending and receiving data. Data traffic is inherently bursting, which means that one computer is communicating with other computer, this will do so in bursts. It will want to send a lot of stuff; suddenly it has something to send, so it will want to send it fast in a burst.

Then for a long time it will be quiet, as there will be nothing because it will go there, maybe get processed over there, maybe some user sees it, sees that data, and things like that. So it is quiet for a long time, then again it sends another burst. And in-between this burst there is a lot of time. While the burst is there, I am using at a very high speed but then other people can share it, so that is why in some sense it allows connection of more nodes to the circuit than the capacity of the circuit.

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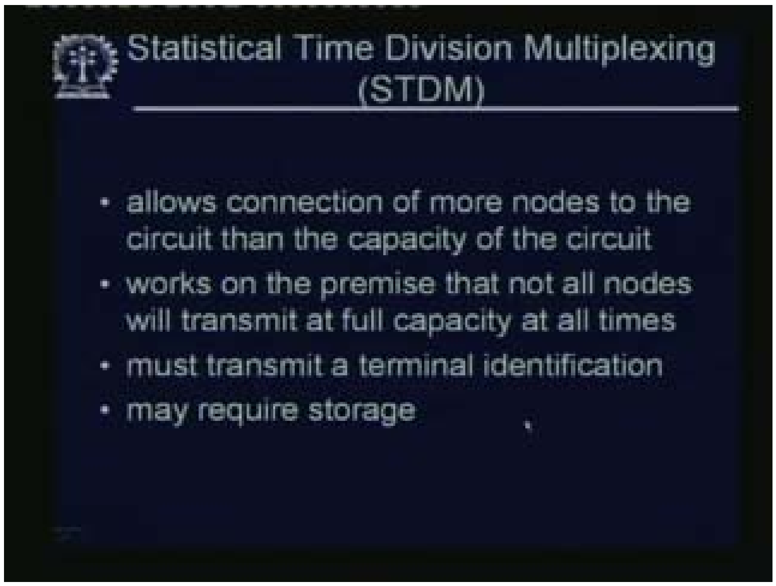

This works on the premise that not all nodes will transmit at full capacity at all times; must transmit a terminal identification, as I said the destination identification has to be there; and may require storage because two different sources may want to send at the same time and both of them land up hoping that the channel will be free. I am calling it a multiplexer at this point, at the multiplexer end you have to store them and then forward them over the channels, and then the channel becomes available.

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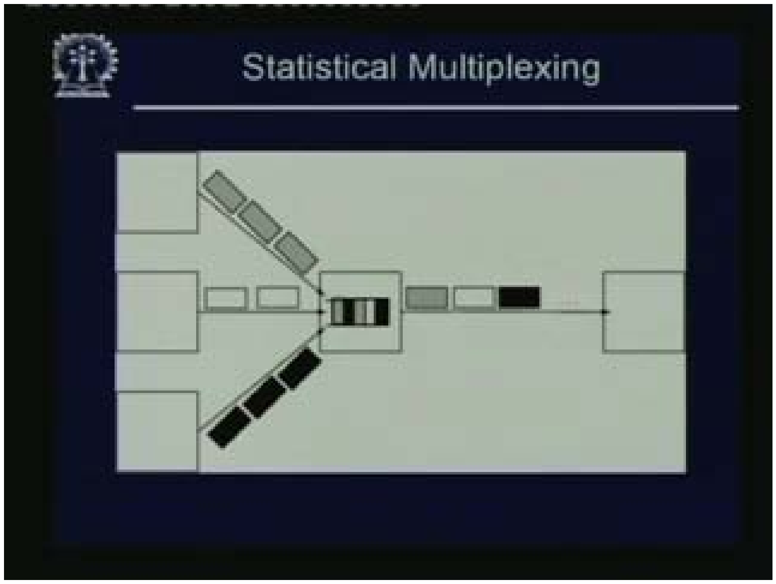

This is a picture of once again getting multiplexed – they are getting multiplexed as they come. This is the queue in-between and you have this buffer over here, this is the memory where the incoming packets are getting stored and they are making a queue so there are a number of packets here and from this queue one by one as they come, it is not necessary that they have to go in a strict round robin fashion; as they arrive they have are being pumped into this transmission channel. On this side, on the demultiplexing side, it will look at some receiver address which is contained within this packet or cell, whatever it is, and then send it to the proper receiver.

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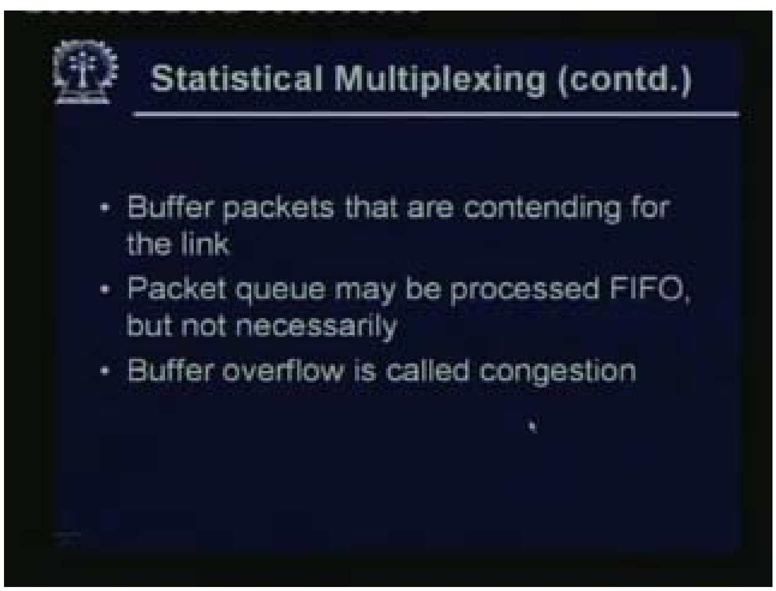

The buffer packets that are contending for the link, the packet queue may be processed first in and out, but as I said this is the most vanilla kind of scheme; there are other fancy schemes. For example you may have a high-priority queue for some of the users who may be paying more – that queue is processed first before the other queues and all kinds of possibilities are there. But of course since you have a buffer, it is theoretically possible and since your capacity of the link cannot handle if all the senders decide to send at the same time, which may happen, in which case it will be filling it in the buffer, but the buffer may also overflow, which means that there is a congestion in the network and then some data loss is there.

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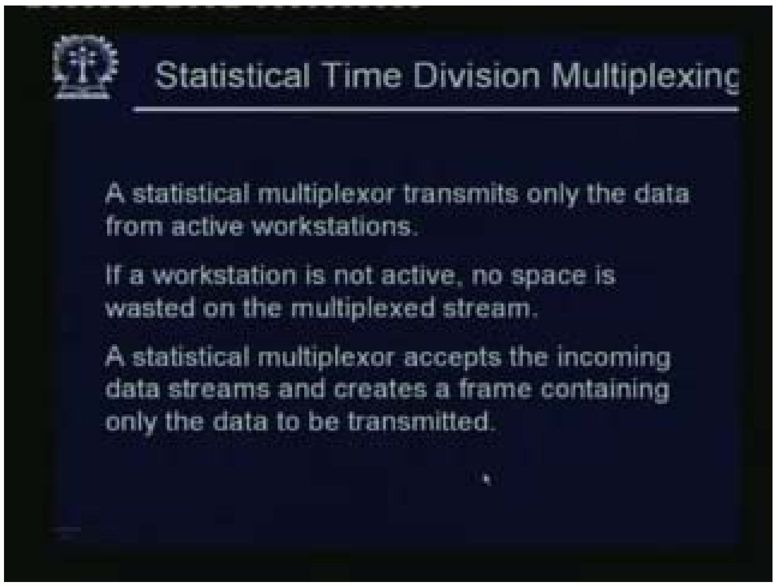

To summarize, a statistical multiplexer transmits only the data from active work stations. If a work station is not active, no space is wasted on the multiplexed stream; a statistical multiplexer accepts the incoming data streams and creates a frame containing only the data to be transmitted and also as I said this frame will also contain the some kind of destination address.

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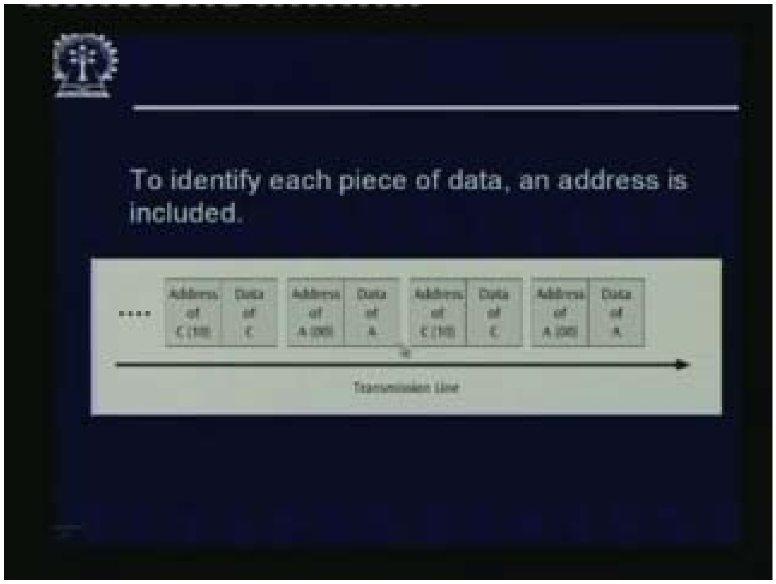

This is an example to identify each piece of data and the address is included. So the data of c as well as address of c, data of a as well as address of a – the address also has to go with the data. This of course is under the assumption that all these data packets and these addresses, together all these packet lengths are fixed, which is the case in some systems like ATM, etc. The size is fixed but the size may vary also, if the size varies then you will have to include the length of a also, that means this is the data of a; what is the total length of a or maybe the data part, if this part is fixed depending on the scheme then the address to which this is destined. All these are put in the form of a frame and then it is sent. Finally I would like to summarize the advantages and disadvantages of each of the schemes. By the way, in the beginning I mentioned something called code division multiplexing, which is a very interesting scheme.

We will talk about code division multiplexing when we talk about multiple accesses. There are actually two terms; one is multiplexing and the other is multiple accesses. Usually this is how we mean it but distinction is getting blurred these days; usually when you are multiplexing, the sources are sort of converged to the multiplexer in some sense. The sources are converged to the multiplexer in some sense and it goes to the demultiplexer where it diverges. There is a specific convergence which is there, that means a number of telephone lines are getting multiplexed; a number of telephone lines will come to the local telephone exchange. There these may be all destined for some other exchange, so all these lines will be multiplexed together so they are happening physically in one place. If the problem is this, then once again you have a shared medium but the users are distributed. In that case we call it a multiple access system.

CDMA is a multiple access system as well as you can in some sense call it a multiplexing system also. As I said this distinction is slowly getting blurred these days; for example, you are doing some kind of multiplexing when you come to cell phones. We are doing some hybrid kind of multiplexing; that means we have got a combination of FDM and TDM; i.e., we have some bands of frequencies which are being used by a number of users; but these users are not at the same place. They are carrying some wireless station.

That means they are carrying their mobile handsets and are at various locations. Even for the same base station, under the same base station, they are at various locations in that area so to say. Thus the distinction between multiplexing and multiple accesses is getting a little blurred these days. Anyway we will discuss code division multiplexing or multiple accesses when we talk about other kinds of multiple accesses. As you can guess, there is time division multiple access and then there is frequency division multiple access and then of course this code division multiple access is also there; so we will discuss it there.

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Coming back to the scheme that we discussed, namely, FDM, what are the advantages and good things about each of these schemes? FDM is of course simple and being simple means that it is cheap and is very popular, and as I mentioned this is the oldest multiplexing technique. Your radio uses this and lots of other systems use this. TDM is specifically for digital signals, so for digital signals TDM is very nice and then you can have a multiplexing hierarchy; that is another advantage of TDM. Why it is an advantage? Well the advantage is because of this: at different places we may require different levels of bandwidth and speed. Just think about this – suppose we have this telephone network, you may have a small exchange; the small exchange will naturally have a small number of users and only a few of those users will want to communicate or make an STD call or to communicate with some other telephone, which is under some other exchange.

So the few will have to be multiplexed together at the small exchange and it will be sent to the trunk exchange and from there it may go to another trunk exchange and so on and finally reach. At the trunk exchange what is happening is that once again various such connections from different local exchanges are coming and converging to the same trunk exchange. When this trunk exchange is communicating with another big trunk exchange, what is happening is that there are a lot of tributaries flowing into it; there are a lot of channels. So basically in the same signal, we are doing time division multiplexing.

That means the rate at which the receiver at this end is sending, that same rate has to be maintained throughout; but then instead of flowing in small tributaries, it is moved into a very fat channel. We require a multiplexing hierarchy. So such multiplexing hierarchies are easy to implement using time division multiplexing; we will see more of this when we talk about synchronous digital hierarchy later on.

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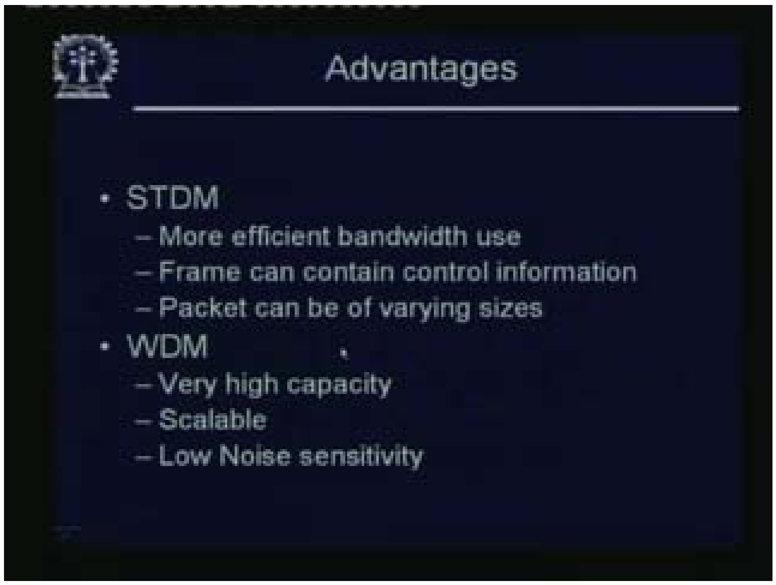

STDM's advantages: we are only talking about advantages. We will talk about disadvantages later on. In statistical time division multiplexing, this has certainly more efficient bandwidth use. It is much more efficient because as I mentioned, that especially data usage and usage in general may be very bursty and if it is bursty, then during the quiescent period, ordinary TDM is just wasting the channel whereas STDM is making full use of it.

So it has more efficient bandwidth use; that is a good thing about STDM. Another advantage of STDM is that the frame can contain control information; since you are putting a frame, may be with the address of the receiver or may be other kinds of control information can be put in the frame. And then, the packets can be of varying sizes. These are the advantages of STDM; not all STDM systems will allow this varying sizes; for example, ATM will not allow varying size cells. In ATM, the packets are called cells, they will have a fixed size but some systems may allow. WDM: we are writing it separately because although as I said this is some form of FDM, this works with a very high capacity, is scalable, and this has got low noise sensitivity.

That is another good thing about the communication in the optical domain. Suppose you are doing it in a electrical domain through a wire, may be, if there is some kind of electrical noise, somewhere some motor has started or very bad if there is some lightning somewhere nearby, lot of noise will get into it and this electrical wire will catch all this noise. Whereas an optical fiber is not going to catch any of these noises, it is very immune to noise, which is why it's got a very low noise sensitivity, which is very good and very high capacity and you can scale it to still higher capacity using DWDM.

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Just a quick look at the disadvantages: FDM, as I mentioned earlier, is susceptible to noise, wasted bandwidth, because of this guard band, etc., and of course one frequency is whatever the small band is being permanently given to one user and if his usage is very bursty, then a lot of bandwidth is wasted. Then, we have a limited frequency range. In TDM we have wasted bandwidth for the same reason.

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STDM takes care of that problem in a TDM but this is very expensive; traditionally we did not have any other alternative so we used STDM a lot when high speed was necessary especially in the service provider side, we used STDM. WDM is somewhat more costly than TDM and FDM but since this is a developing technology, this cost is coming down and that means the WDM cost is coming down but it is still somewhat more costly than TDM and FDM but may be less costly than STDM. We have looked at the different multiplexing techniques today; in the next lecture we will look at one kind of network, which is very widely used for data and all kinds of communication, namely, the telecom network, the telecommunication network. Because remember that although it is called telecommunication network and it was traditionally for people talking over telephones, for voice, etc., that is the network which carries most of the wide area data traffic today, and that is a very important. We will talk about it in the next lecture.

Preview of next lecture
Computers Networks
Prof: Sujoy Ghosh
Indian Institute of Technology
Indian Institute of Technology, Kharagpur
Lecture - 6
Telecom Networks

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Today we will talk about telecom networks, means the kind of network that is used by telephones and of course it is by host of other things as we will discuss. This telecom network is very important in the sense that first of all, it is one of the earliest networks that we had and that is one thing that is quite old and secondly, the telecom network even today is mostly used for a wide area communication. Comparatively, we have much fewer, I mean entirely or exclusive data networks. We will look at the evolution of telecom networks.

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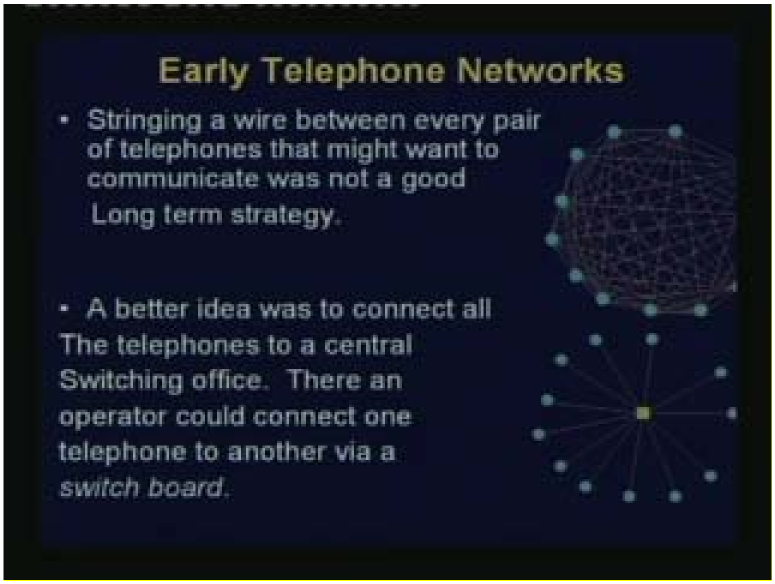

Well when Alexander Graham Bell developed the first telephone, it was a couple of telephone instruments connected by wire. Now if you are trying to connect more than one people that means more than one subscribers are there; taking this principle forward you will have to connect everybody to everybody else through a wire which of course becomes very unwieldy very soon; because connecting or stringing a wire between every pair of telephones, that might want to communicate was not a good long term strategy at all. As you can see that very soon we'll have veritable jungle of wires and of course it's costly and it is very difficult to manage.

At the subscriber end you cannot handle so many wires coming into your premise, so better idea was to connect all the telephones to a central switching office. There an operator could connect one telephone to another via switchboard. That is the next figure, you see that the number of wires have come down. As a matter of fact in the figure at the top if you have n subscribers; naturally you have n (n -1) by 2 links which is approximately n^2 kind of links. Whereas in the latter case you have only n links so the number of links as n becomes large, and you know today there are so many telephone subscribers so there is no question of connecting them individually, you have to connect them to a central switching office.

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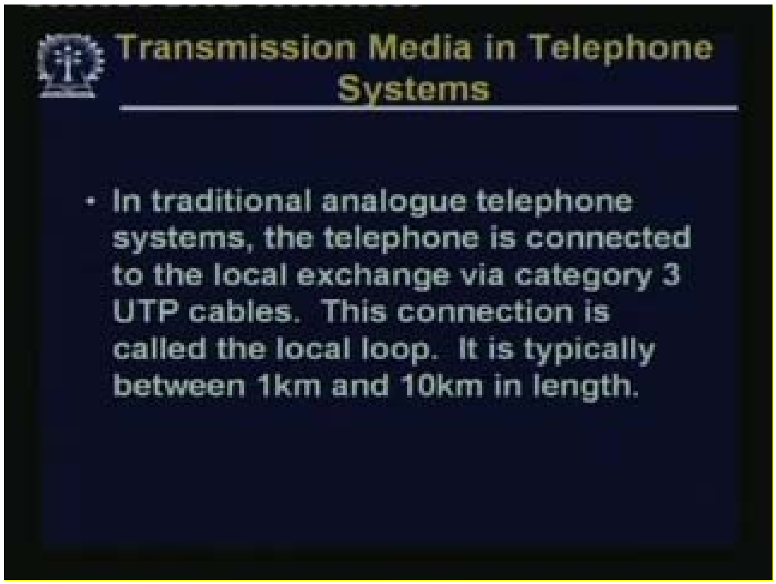

Even then once, again I mentioned this earlier in the lecturer, you must remember that it is not that we have a whole parallel network for data from computers etc. all over the globe, it is not there. The telecom network has been around for a long time. It had a long and very excellent history so that is why even today most of the wide area network traffic still rides on this telecom network. Originally it might have been a packet then it might be sort of made into some kind of a session for which there is some part of the connection is dedicated and all kinds of technology has come in but even today most of the wide area networks are based on the telecom networks and telecom. That is one side of the story, the other side of the story is that telecom networks the telecom people are actually in the process of routing some of the voice calls and may be some of the other kinds of calls into this packet kind of technology.

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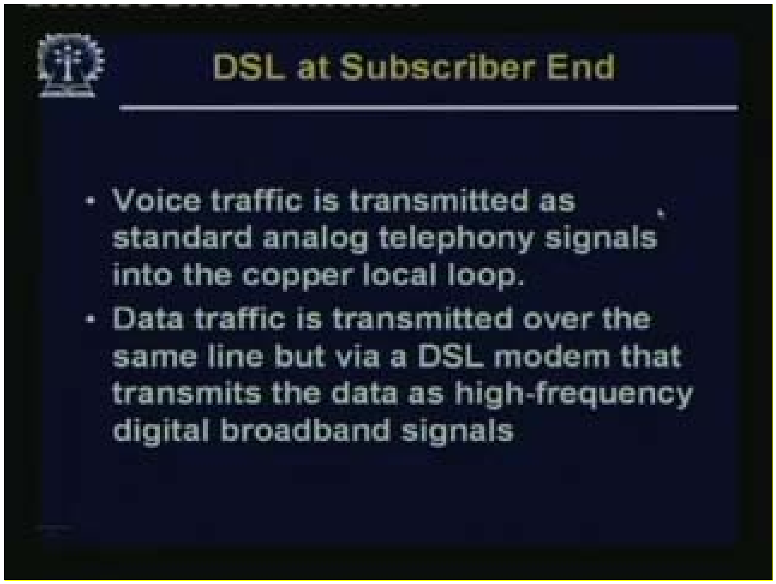

So DSL at subscriber end- voice traffic is transmitted as standard analog telephony signals; data traffic is transmitted over the same line via a DSL modem that transmits the data as high frequency digital broadband signals on the same line. If you have DSL modem you can have both your voice as well as data at the same time, unlike very ordinary analog lines.

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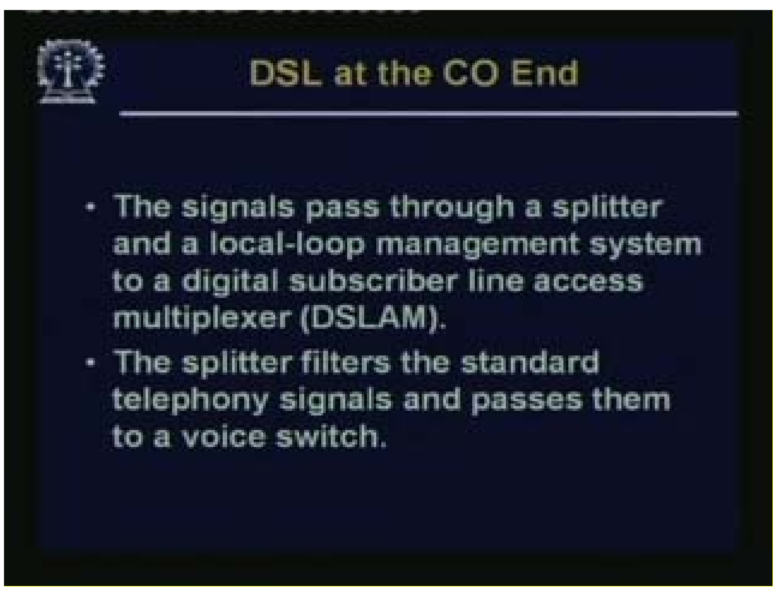

So DSL at the central office end, CO end, and the signal passes through a splitter as I have shown and a local loop management system. The subscriber line access multiplexer is there in this figure we have already seen.

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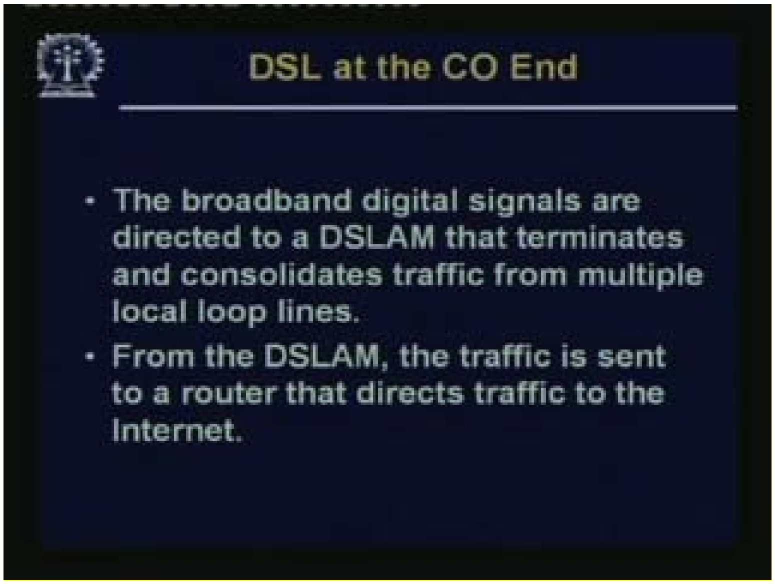

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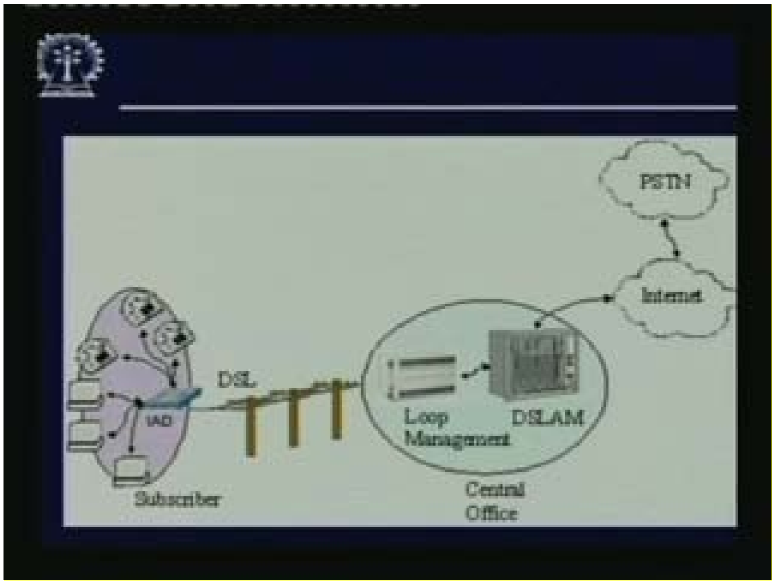

In this figure, we have DSLAM and the loop management over there, the broadband digital signals is directed to a DSLAM that terminates and coordinates traffic from multiple local loop lines.

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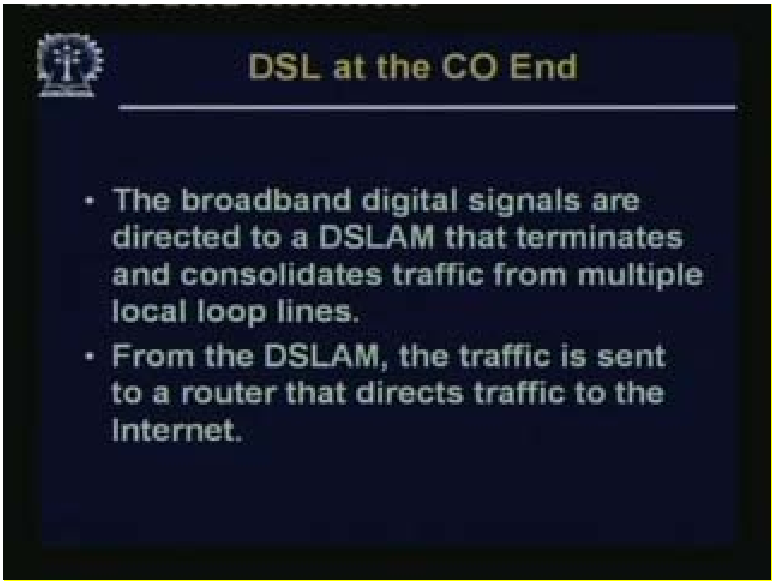

From the DSLAM, the traffic is sent to a router and then to the internet. And finally we have the loop management system, which may be in front of the splitter, or behind the splitter?

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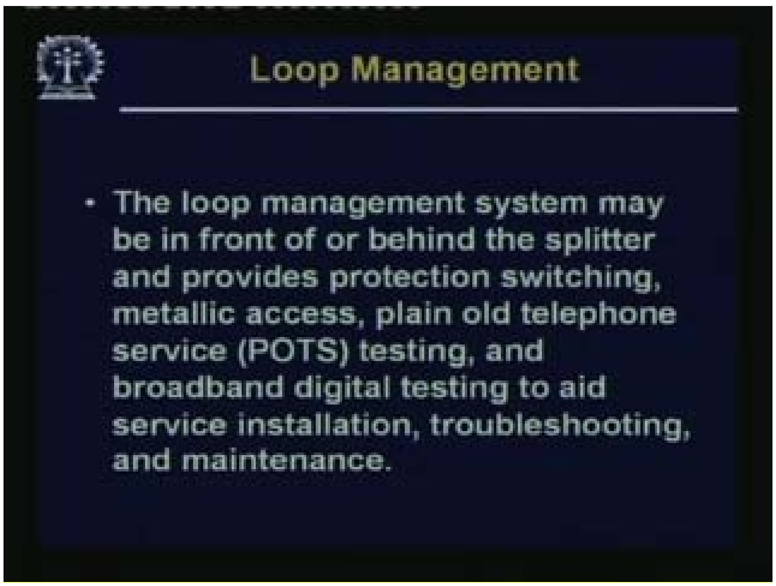

This comes to various functions like giving the connections and testing and all this service kind of testing are done through the local loop management.
Thank you.