Data Communications
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Lecture 18
Switching Techniques: Circuit Switching

Hello viewers welcome to today's lectures on switching techniques. So far we have assumed that two devices or equipment are directly communicating with each other and for that purpose whatever protocol and techniques are necessary we have discussed like the HDLC which we have discussed in detail. However, there are many situations where two equipments are not directly connected so in such a case they perform communication through a number of intermediate equipment or devices. So in such a situation the technique that is adopted is known as switching technique and the switching techniques can be broadly divided into two types; circuit switching and packet switching.

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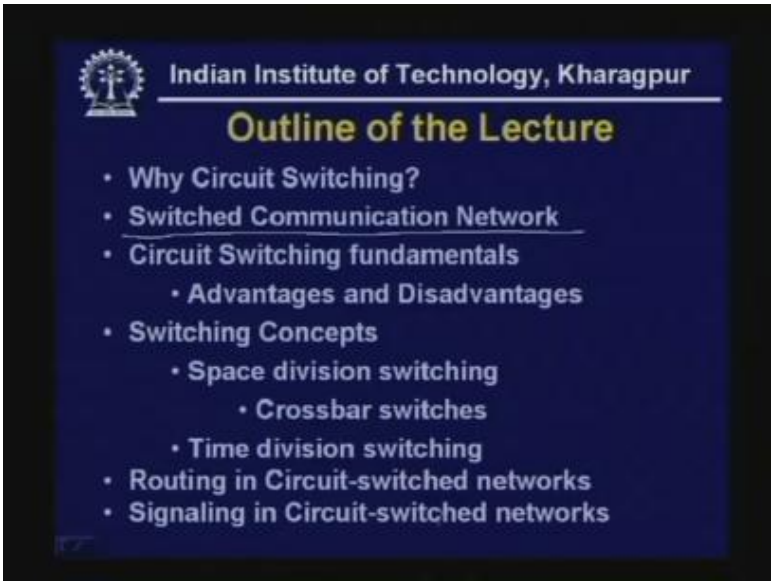

In today's lecture we shall discuss about circuit switching. This is the outline of the lecture. First we shall discuss why circuit switching, then in the context of circuit switching we shall introduce to you Switched Communication Network that is the model that is being used for communication. Then I shall discuss about the circuit switching fundamentals their advantages and disadvantages then various concepts of switching that is used in circuit switching such as space division switching and one application of that is crossbar switches and Time Division Switching. Of course both of them have combine having space and Time Division Switching. Then we shall discuss about how routing of signal takes place in circuit switched networks and finally we shall discuss signaling in circuit switched networks.

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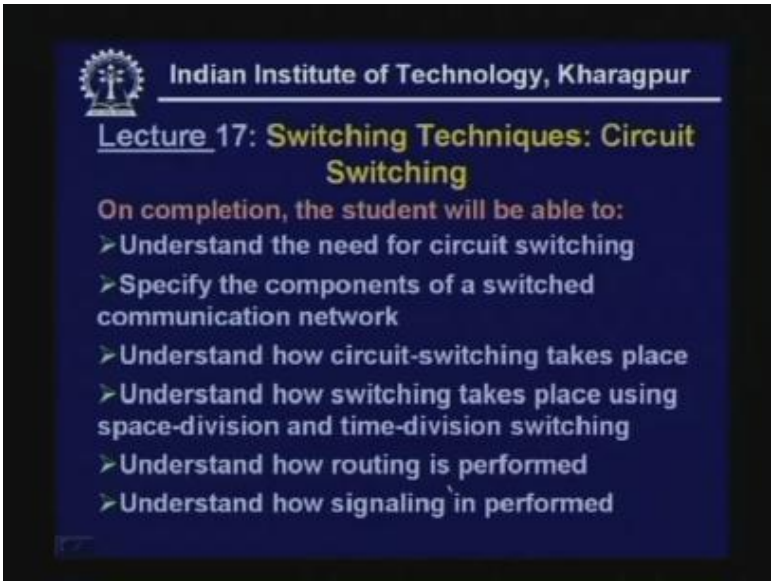

On completion of this lecture the student will be able to understand the need for circuit switching, specify the components of a switched communication network, understand how circuit switching takes place, understand how switching takes place using space division and Time Division Switching, understand how routing is performed and finally they will be able to understand how signaling is performed. So, let us consider the first question how two devices perform communication when there are many devices?

Suppose you have got a number of equipments or stations say A B C D so in such a case A wants to communicate with B C D may not be simultaneously but at a time A wants to communicate with B or A wants to communicate with C or A wants to communicate with D one possible alternative is to establish connection from A to B, A to C and also from A to D.

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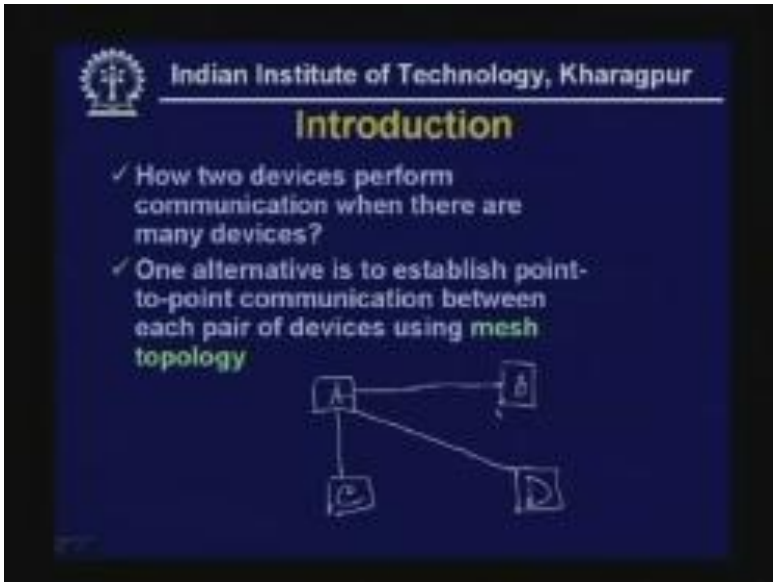

Similarly it is necessary to establish communication from B to C, B to D and finally C to D so we have to provide a number of links and it can be the shown that the total number of links required for n such stations is equal to n into n minus 1 by 2 so that number is very large. For example, here you have got four stations (Refer Slide Time: 5:10) so you will require 4 into 3 by 2 is equal to 6 so if you count you will find that total number of links is 6 that is 1 2 3 4 5 6 so you have got 1 2 3 4 5 and 6 so 6 links are necessary. Hence this is known as mesh topology. Obviously when you have got a large number of stations this kind of mesh topology is not practical. for example, if you have got hundred nodes then you will get 100 into 99 by 2 so many links that means 99 into 99 so many links will be necessary to establish a communication from any node to any node or any station to any station so this is not a good choice.

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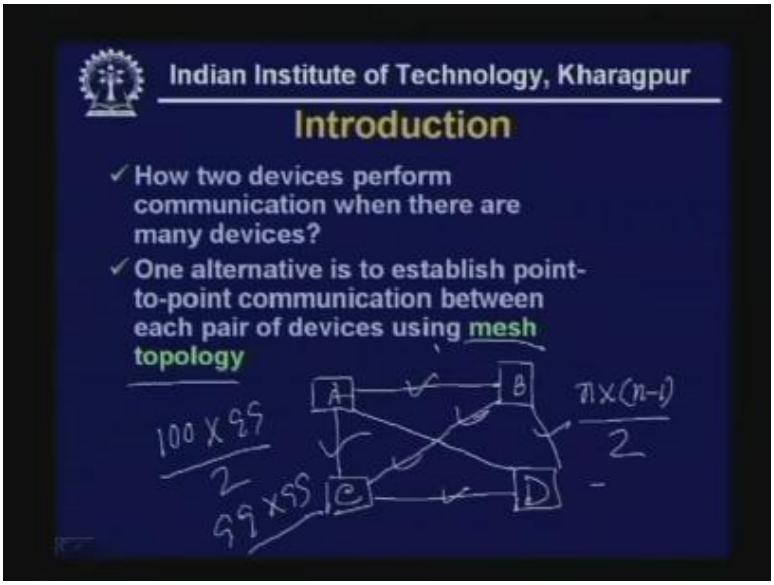

So what is the alternative? One alternative is to use switched communication network. So whenever you have got large number of devices then mesh topology is not practical so a better alternative is to use switching techniques leading to switched communication network.

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So let me introduce to you what we mean by switched communication network.

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In switched communication network we will find end devices namely essentially computers, peripherals, communication equipments such as cell phones, laptops PDAs and various other things and these are known as stations. The switching devices are called nodes. That means we are using some additional devices intermediate devices known as nodes and in such a situation some nodes connect to other nodes and some nodes are attached to stations. Let me show you the network.

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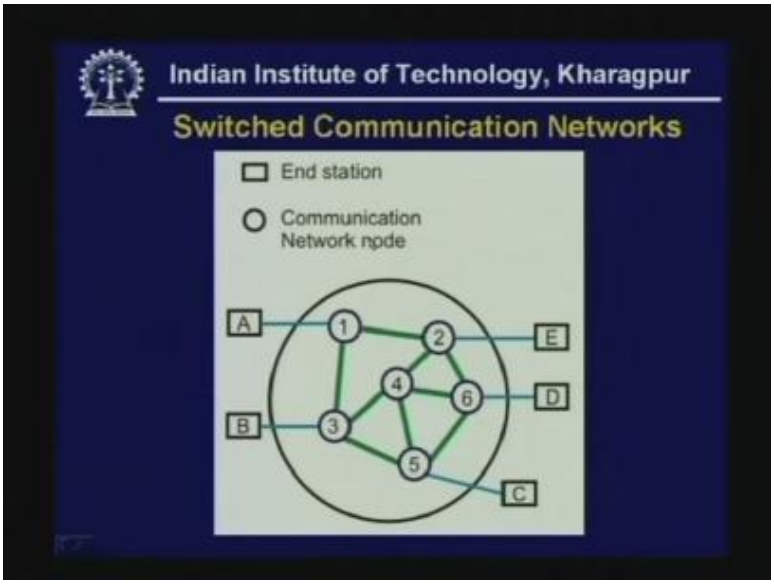

Here as you see these are the end stations A B C D E and on the other hand 1 2 3 4 5 6 are communication networks nodes so these are the nodes used as switches as

intermediate points for communication. How it is done? As you can see network topology is not regular so as shown earlier there is the mesh topology there are other topologies such as bass topology, ring topology, star topology etc. The bass topology is like this say we have got a bass and on to that we can connect all the stations this is your bass topology. So, in switched communication network you don't have bass topology you cannot use ring topology in which the stations are connected in the form a ring. So you can see that each station is connected to the neighbor neither is star like this so we find that in this case the topology is not regular. It uses FDM and TDM for node-to-node communication.

So here you find node-to-node communication as you can see shown in different colors from this station to node communication link. Here we find that this is narrower and this is wider. Actually this one to two or one to three these are node-to-node links and this links are of higher bandwidth. Since these links are with higher bandwidth and to make maximal use of the bandwidth we use FDM or TDM techniques. We have already discussed about the FDM and TDM techniques. We have also discussed how we can use the higher bandwidth of links so these links are used as FDM and TDM.

There exist multiple paths between a source destination pair for better network reliability. Here we find (Refer Slide Time: 9:25) it provides you a much higher reliability. for example, if A wants to communicate with C it can communicate through the nodes 1 3 and 5 but if suppose one of the link is down or one of the nodes is down in such a case if A can communicate through the node 1 2 6 and 4 or it can communicate through 1 2 4 5 so in this way several alternative routs are possible which increases the reliability of the network and that is one objective of the switched network communication so that it provides you higher reliability providing multiple paths.

Here another important feature is the switching nodes are not concerned with the contents of data. That means whatever data is being sent by a station that is being communicated by the node. In other words nodes can be considered as dumped devices. Whatever received is being transmitted to other node or to the destination station node. So either ways it is possible, a station will send to a node and the node will either send to another node or it will go to another station as it is shown here (Refer Slide time: 10:43) and in such a case the nodes do not modify the information or data. Their purpose is to provide a switching facility that will move data from node-to-node until they reach the destination. So their purpose essentially to communicate the data which is received from one end and sent to another end connecting to a node or a station. This is the basic model of the switched communication network and as I mentioned various switching techniques. These are circuit switching, message switching and packet switching so there are three alternatives.

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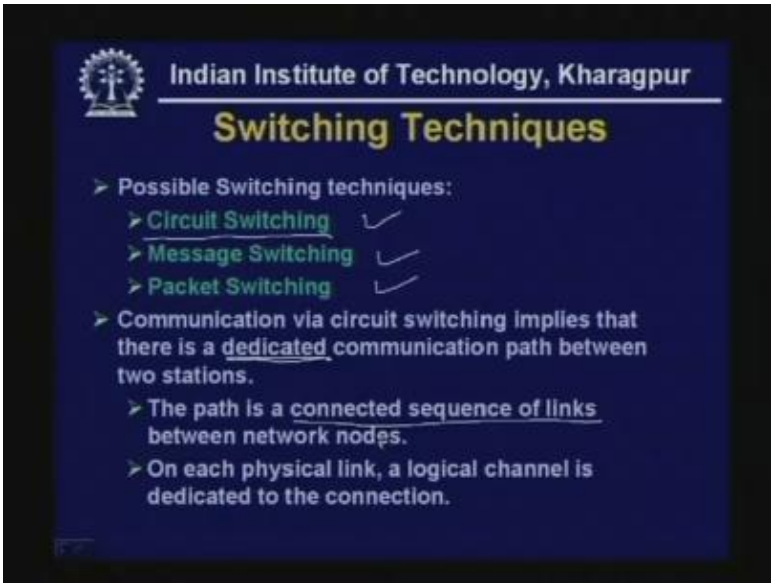

In this lecture as I mentioned we shall be concerned with circuit switching and in circuit switching the communication via circuit switching implies that there is a dedicated communication path. So I am high lighting this so it is dedicated and this dedicated is important because without setting up a dedicated no communication is possible in circuit switched network. So it is the dedicated communication path between two stations. The path is a connected sequence of links between network nodes. So it can be a connected sequence of links. That means it is not necessary that there will be a direct link direct path there may be a path to a number of nodes. So it can be a connected sequence of links between network nodes. And on each physical link a logical channel is dedicated to the connection. This is another important feature.

The circuit switching involves three important phases for communication. First one is known as circuit establishment, then data transfer and third is circuit disconnect. The circuit establishment phase is used to establish end to end connection before any transfer of data. So before any transfer of data is performed you have to set up a direct link and some segments of the circuit may be dedicated link while some other segments may be shared. So there are two alternatives it can be dedicated or it can be shared.

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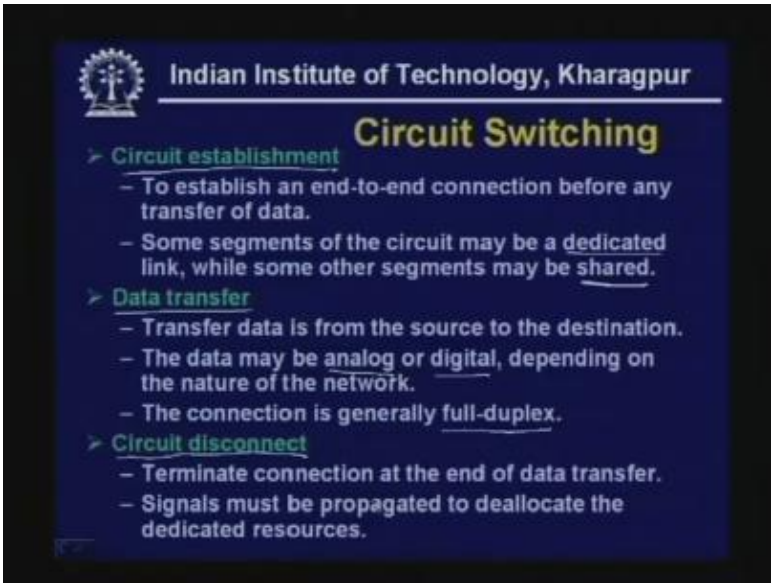

Then in data transfer the transfer data is from the source to the destination. Once the link is established whatever data is to be transferred is transferred from the source to destination through the dedicated link already established in that circuit establishment phase. then the data may be analog in nature or digital in nature either is possible depending on the nature of network and the connection is generally full-duplex.

As I mentioned whenever two stations are connected usually the communication is full-duplex in nature. And finally once the data transfer is complete, circuit disconnect is performed that terminates the connection at the end of data transfer; signals must be propagated to deallocate the dedicated resources. So whatever link was established the deallocation is done for that. Here it is shown how it is being performed.

So here the call request signal is going from A through node 1 to 2 then call request also goes from node 2 to node 4 then another call request goes from node 4 to node 5 for establishing connection from A to C. then once the call acknowledgement comes through the already established path that is after the call request comes data is sent from A to C through nodes 1 2 4 and 5 so this is how data is sent and after the data transfer is complete the acknowledgement signal sequence comes from the other end from station C to station A and the circuit disconnect is performed. This is how the data transfer takes place in circuit switching.

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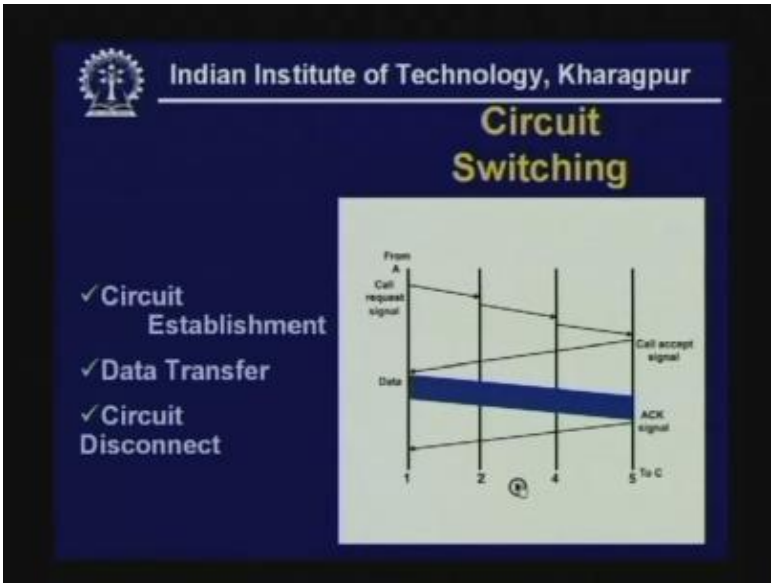

This circuit switching technique was originally developed for handling voice traffic but is now also used for data traffic.

As I mentioned this circuit switching concept was originally developed for public switch telephone network, for voice communication but now it is also used for data transfer. And as I already mentioned I am emphasizing that once the circuit is already established the network is transparent to the users. That means what data is being sent will be sent and information is transmitted at a fixed rate without no delay other than the required propagation through the communication medium. That means after the link is established there is no other delay in fault except the preposition time. Depending on the distance, depending on the medium that is being used there will be some propagation time but apart from the propagation time there is no other delay involved in this circuit switching technique. And as I mentioned best known example is the Public Switched Telephone Network that is being used in communication network so Public Switched Telephone Network (PSTN) is the best example of circuit switching technique.

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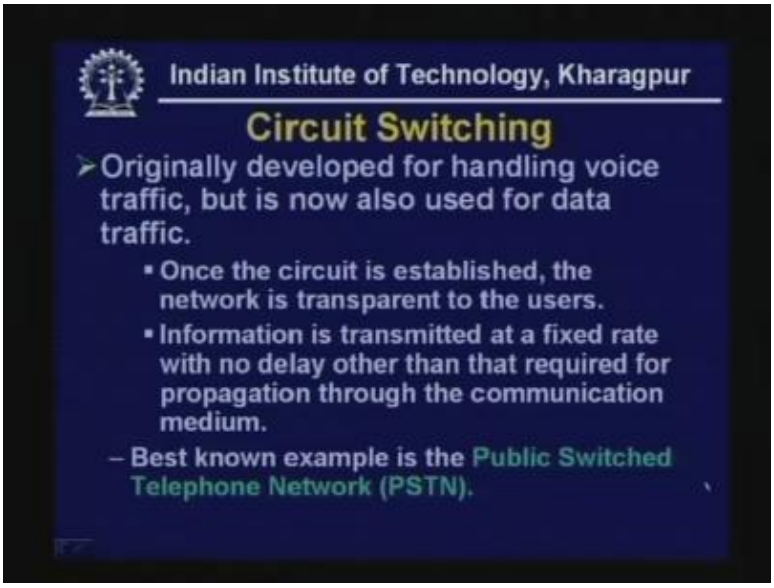

Now let us look at the advantages of this circuit switching technique. First it is fixed bandwidth and guaranteed capacity. That means there is an end-to-end link and since end-to-end link is there the bandwidth is fixed and it does not change.

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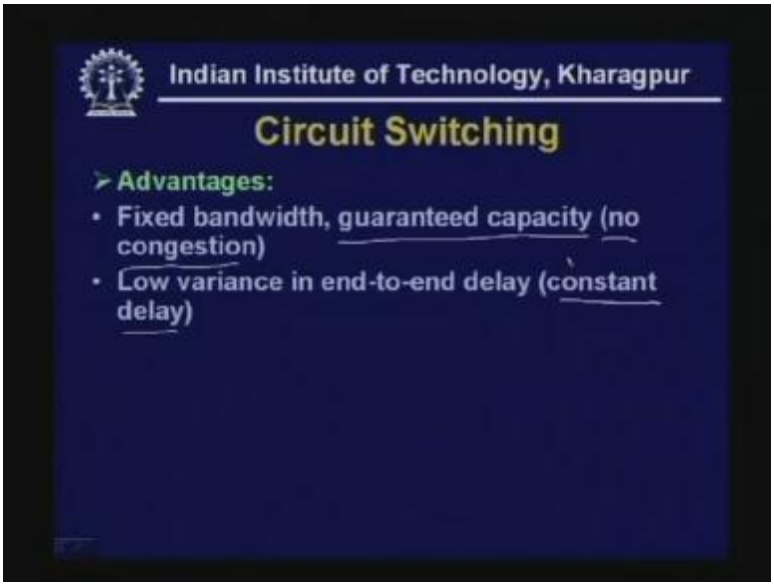

And here the advantage is it gets guaranteed capacity. That means after the establishment of the link is known then both the ends know what is the possible transfer rate and there is no possibility of congestion. Since the links are having dedicated link there is no possibility of sharing, there is no possibility of congestion. And the second important advantage is there is low variance in end-to-end delay, there is a constant delay. As I said

this delay is essentially the propagation time so there is no other delay involved in this communication.

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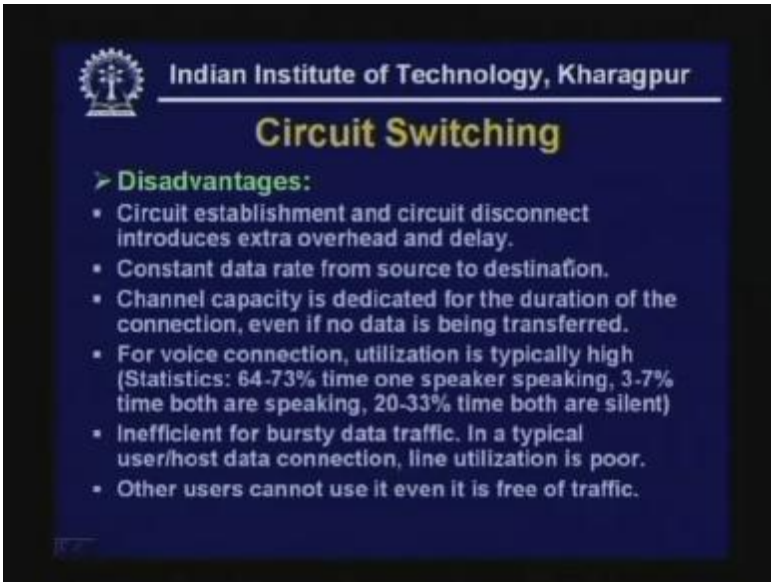

Now let us look at the disadvantages. In this world nothing is one sided there will be some disadvantage. The disadvantages are; the circuit establishment and circuit disconnect introduces extra overhead and delay. As I have shown before any data transfer is performed it is necessary to perform circuit establishment and at the end of transfer we have to perform disconnection. So, disconnection has to be done. Both of these will take some extra overhead and as a result it will involve some delay also particularly before any data transfer can be performed. It allows you constant data from source to destination and channel capacity is dedicated for the duration of the connection even if no data is transferred. That means after circuit establishment if data is not transferred obviously the bandwidth is wasted.

For example, you have a set of long distance call and after setting up the call if you don't talk even when you don't talk you pay for the link or bandwidth. This is one disadvantage. And it has been found that for voice connection although the utilization is high the statistics show that 64 to 73% time one speaker is speaking, 3 to 7% time both the speakers are speaking and 20 to 30% of the time both are silent.

Therefore as you can see even in voice communication the utilization is not very high it is only 64 to 73% but for data communication which is burst in nature this inefficiency can be very high. Particularly most of the time no data is generated and only sometimes a burst of data is generated in data communication. So, in a typical user host data connection the line utilization is very poor. And the irony is that whenever the user is not using the bandwidth that others cannot use. This is another important disadvantage of circuit switching.

Now let us focus on the function of the switching nodes which play a very important role in circuit switching.

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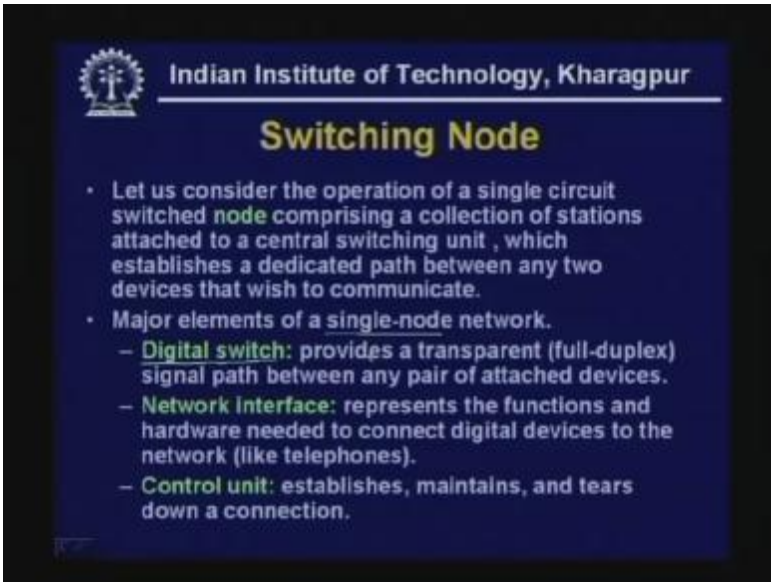

Let us consider the operation of a single circuit switch node comprising a collection of stations attached to a central switching unit which establishes a dedicated path between any two devices that wishes to communicate. A single node network or a particular node will have these three functions, it will have a digital switch which provides a transparent signal path between any pair of attached devices usually full-duplex, it will provide the network interface, it represents the functions and hardware needed to connect digital devices to the network like telephones so you have to interface your devices like computers, telephones and modems to the network and for that purpose some interface has been provided. And finally we require the control unit which maintains and tears down a connection.

Here is the block diagram or of a circuit switch node. One node is shown here.

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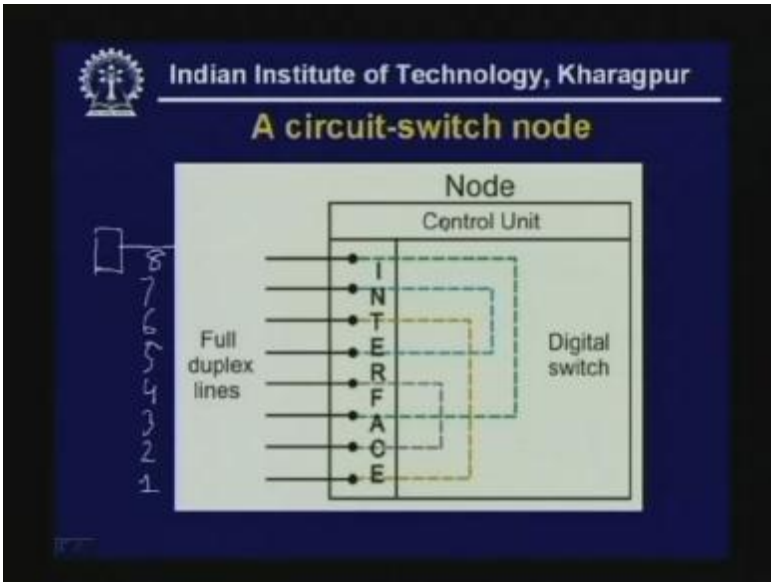

Here as you can see these are the lines through which the stations are connected so all the stations are connected through these links and through this interface so this interface is used for linking a number of stations and there is a control unit which performs the linking with the help of this digital switch. So the control unit controls this digital switch with the help of which the interface can be……., for example in this case there is a link between say 1 and this is 2, (refer Slide Time: 22:35) this is 3, this is 4, this is 5, this is 6, 7 and 8 you have eight lines and this 1 is connected to 6, 2 is connected to 4 and 3 is connected to 1 and then 5 is connected to 7 so this digital switch connects each pair with the help of the control unit. So this is the basic function that is being performed by circuit switch node.

Now switching can be done in a number of ways. One technique is known as space division switching. This was originally developed for the analog environment. You know that telephone network was originally used for voice communication and as a consequence it was developed for analog environment but subsequently it was carried over through digital domain as in nowadays. So, in a space division switch the signal paths are physically separated. Therefore physically separate paths are provided for each of these links or paths from one to another so it is divided in space essentially it is a crossbar matrix.

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Let us have a look at the cross bar matrix.

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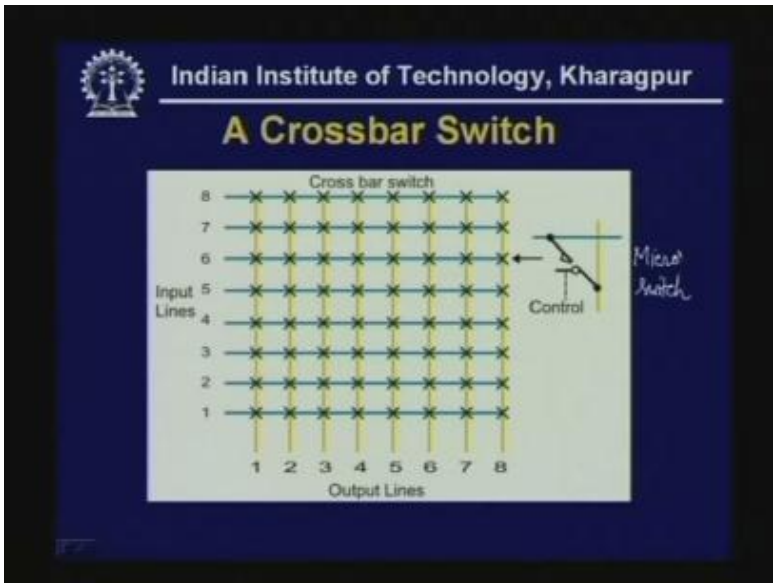

So here you see you have got inputs and outputs. These are input lines and the output lines and it is organized in the form of a two dimensional matrix and as you can see at the crossing of each particle on horizontal line there is a cross and essentially at each cross you have got an electromechanical switch or micro switch it is nothing but a micro switch. So with the help of a micro switch either a connection can be established between a vertical line with a horizontal line. for example here this is 6 and this is 8 so if this is closed that means if this cross here is closed this mirco switch is closed then a path is

established between 6 and 8 (Refer Slide time: 24:55). So at any junction if the switch is closed a path is established between the horizontal line and the vertical line connecting that particular cross. So you see this is how the cross bar switch operates. However, it uses **electromechanical lineage** or micro switches.

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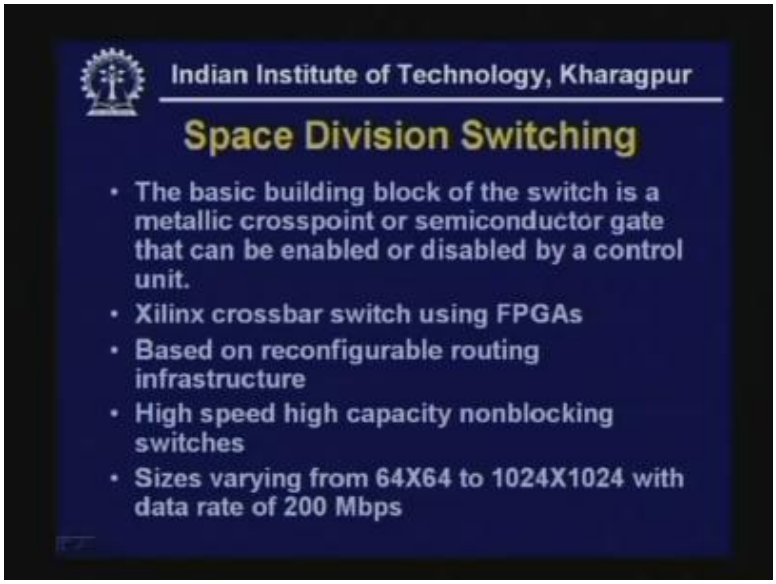

The basic building block of the switch is a metallic crosspoint or semiconductor gate that can be enabled or disable by a control unit. That means the control unit performs the function. as I have shown earlier there is a control unit and this control unit is controlling the digital switch and digital switch in case of space division switching is this cross bar. So this is how the cross bar switch works and originally these cross bar switches were having metallic crosspoint or semiconductor gates that can be enabled or disabled by the control unit.

Of course the early electromechanical switches were not very reliable they were bulky they used to consume lots of power. But with the advancement of VLSI technology nowadays the cross bar switches can be implemented with the help of semi conductor devices. For example, the Xilinx crossbar switch using Field Programmable Gate Arrays is available and it is based on reconfigurable routing infrastructure and in this Field Programmable Gate Arrays based switches you can have the high capacity non-blocking switches and it provides very high capacity varying from 64 by 64 or 1k by 1k so you can have a very big cross bar switch such as o1k by 1k which operates at a very high speed 200 Mbps. Obviously the data rate is quite high and nowadays possible by using this Field Programmable Gate Arrays and available from Xilinx.

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Let me introduce the concept of blocking and non-blocking before I discuss the other functions of the cross bar switch. An important characteristic of a circuit switch node is whether it is blocking or non-blocking.

A blocking network is one which may be unable to connect two stations because all possible paths between them are already in use. That means you may have number of paths. For example, I have shown eight inputs and eight outputs if you are not able to connect a particular pair because all the pairs are already used in such a case you call it blocking. On the other hand a non-blocking network permits all stations to be connected in pairs at once and grants all possible connection requests as long as the called party is free. That means as long as the called party is free the non-blocking switching allows connection between any pair of stations or inputs and outputs.

For a network which supports only voice traffics a blocking configuration may be acceptable since most phone calls are of short duration.

What I am trying to emphasize here is that a blocking network is acceptable in voice environment because most of the time people are not talking that means the usage is much less. On the other hand in data applications the connection remains active for hours. Usually whenever we are talking over a telephone we usually talk for a few minutes and then disconnect the call. On the other hand for data applications the connection may be active for hours and non-blocking configuration is desirable. What I am trying to tell is for voice application blocking network is acceptable or for data communication the non-blocking network is desirable.

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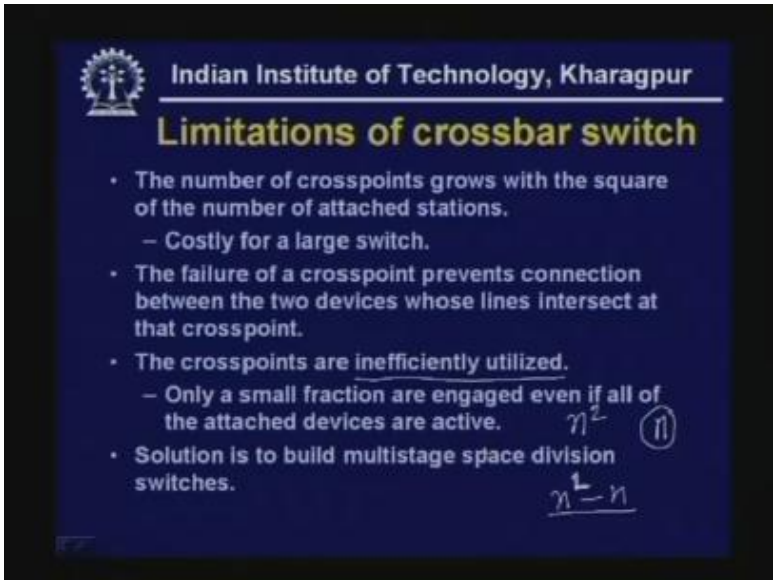

Now let us focus on the crossbar switch and what kind of limitations it has got. As you have seen the number of crosspoints switch grows with the square of the number of attached stations. Obviously as the number of inputs and outputs increase exponentially at the rate of square……. for example if you are having let us assume 1000 input or 1000 output or 1000 by 1000 switch so in such a case we will require one million crosspoints. That means a crosspoint is nothing but a electromechanical relay or an electronic switch and in this case for 1k by 1k switch you will require one million that means ten to the power six crosspoints so it is costly for a large switch. And another important disadvantage is that the failure of a crosspoint prevents connection between the two devices whose lines intersect at that crosspoint.

Let us go back to the diagram of the cross crossbar switch which will explain that.

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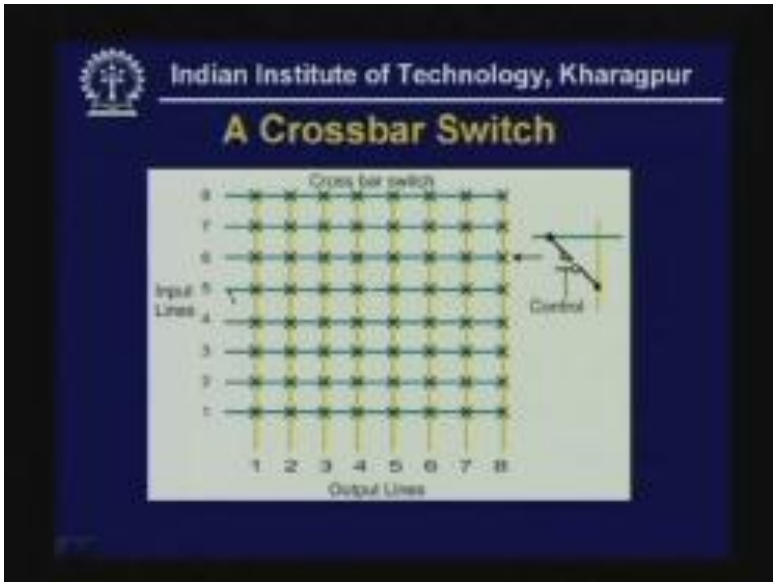

Suppose this particular crosspoint or the switch has become faulty, if this becomes faulty it is not possible to connect five with four so five and four cannot be connected if this becomes faulty. So even when four is not busy the connection cannot be established between four and five if there is failure fault here. That means the failure of a cross point prevents connection between the two devices whose lines intersect at the crosspoint.

Another important disadvantage is that the cross points are inefficiently utilized. What do you mean by that? We have seen that for a 1000 by 1000 network you will require one million crosspoints. But are the one million crosspoints used efficiently? Unfortunately no, even when it is used heavily may be 40 to 50 crosspoints are used but all the other crosspoints remain idle. So only a small fraction are engaged even if all of the attached devices are active that even when all the attached devices are active. That means whenever you are active that means you have got n square crosspoints but at a time when all pairs are connecting only n crosspoints remain busy so you see n square minus n crosspoints remains idle so that is a large number. What is the solution to this? What is the other alternative by which the efficiency can be increased? One better alternative is to use multistage switches.

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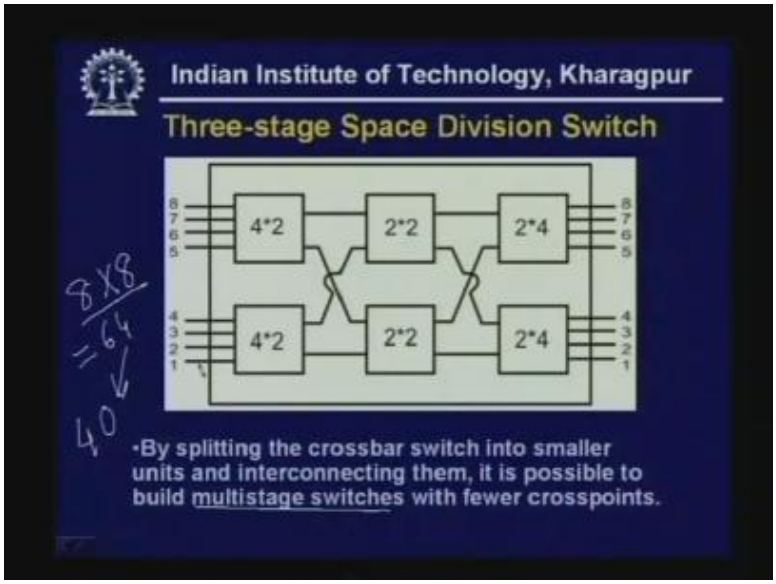

What is being done here is by splitting the cross bar switch into smaller units and interconnecting them it is possible to build multistage switches with fewer crosspoints. Here that example is shown which is nothing but a small 8 by 8 switch we have got eight inputs and eight outputs. Instead of a single stage crossbar switch here you have got three stage crossbar switches. As you can see here this is a 4 by 2 switch, this is a 2 by 2 switch these are all crossbar switches and they are internal linked in this way.

Now how many crosspoints are here? If it is a single phase you will require 64 cross points. So in this particular case as we shall see 4 into 2 is equal to 8 plus 8 is equal to 16 plus 4 is equal to 20 and another 20 so you will require 40 crosspoints so this is the reduction. If it is large crossbar switch and if you use multistage switches then the reduction is more significant. So in the previous example as I have explained the number of crosspoints needed reduces from 64 to 40.

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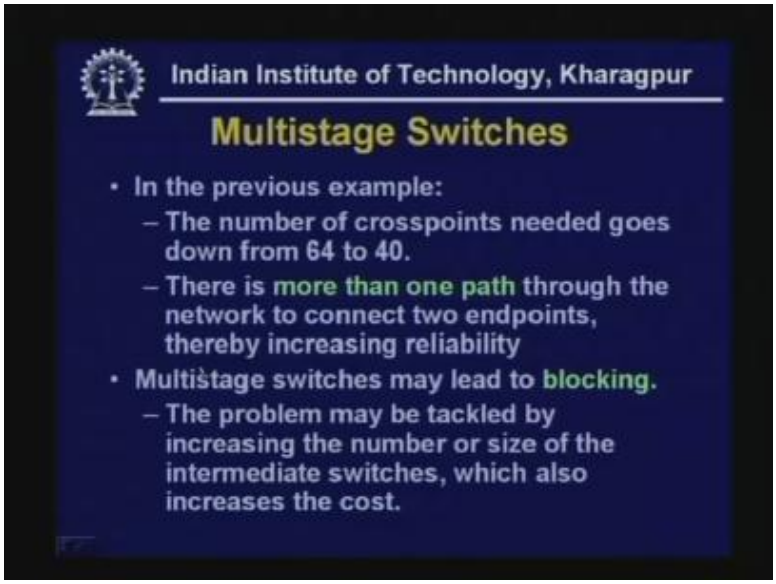

Another important advantage is that there is more than one path through the network to connect two endpoints and this increases the reliability. For example, in this case suppose one wants to communicate with five how connection can be done? One can be connected through in this path using this path (Refer Slide Time: 35:03) or it can be connected using this path so multiple paths are existing that increases the reliability. So if there is a failure in one path another path can be used for establishing the connection so this is an important advantage. Unfortunately there is a disadvantage because multistage switches may lead to blocking but this problem can be tackled by increasing the number or size of the intermediate switches which also increases the cost. That means although the probability of blocking is reduced it will remain in case of multistage switches. Let us see how it happens.

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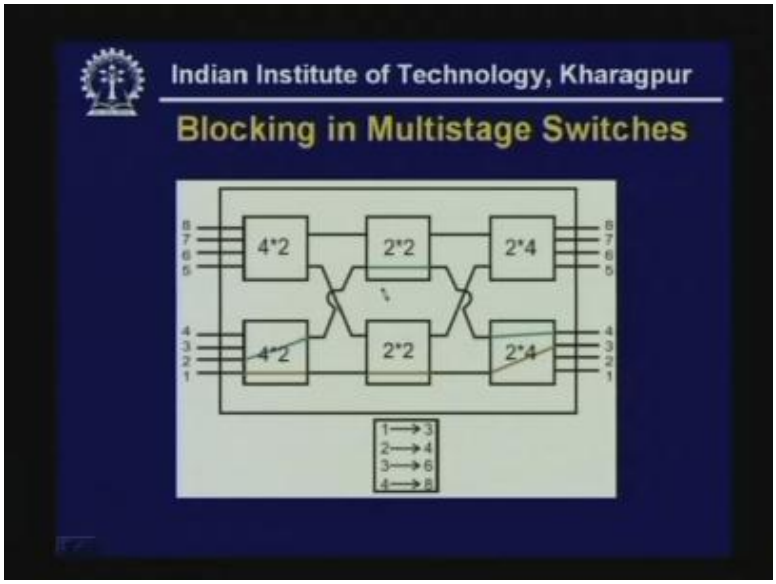

For example we would like to establish connection from 1 to three, two to four three to sox and four to eight which is shown here. So 1, 2, 3 connection is established here then 2 to 4 connection is established in this manner but now how the connection can be done for 3 to 6. Now we find that 3 and 4 cannot be connected to 6 and 8 the reason is from this switch (Refer Slide Time: 36:26) there is no other path available at this moment for connecting 3 and 4 to 6 and 8 because from this crossbar switch there are two outputs and both the outputs are now engaged for linking 1 to 3 and 2 to 4 and no other bars are available so it leads to blocking. So, whenever we are using multistage switches essentially it becomes blocking although it reduces the number of crosspoints. Now let us consider another implementation based on Time Division Switching.

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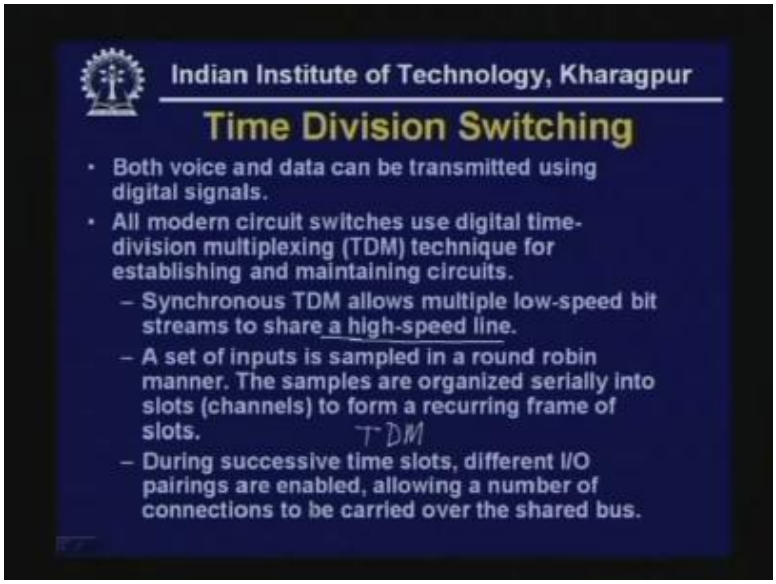

We have already discussed about TDM or Time Division Switching which is essentially based on Time Division Multiplexing and here both voice and data can be transferred using digital signals and all modern circuit switches use digital Time Division Multiplexing techniques for establishing and maintaining circuits and synchronous TDM allows multiple low speed bit streams to share a high speed line. We shall explain how exactly this is being done.

A set of inputs is sampled in a round robin manner; the samples are organized serially into slots to form a recurring frame of slots as we saw in TDM synchronous Time Division Multiplexing. Then during successive time slots different I by O pairings are enabled allowing a number of connections to be carried over the shared bus. Let us see how exactly it is being done.

To keep up with the input lines the data rate on the bus must be high enough so that the slots recur sufficiently frequently. That means we have to use high speed for Time Division Multiplexing switch. For example, for 100 full-duplex lines at the rate of 19.200 Kbps the data rate on the bus must be greater than 1.92 Mbps. So the source destination pairs corresponding to all active connections are stored in the control memory I shall explain how exactly this is being done thus these slots need not specify the source destination address because it is stored in the control memory.

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So here for example we have a simple TDM where the switching is not done.

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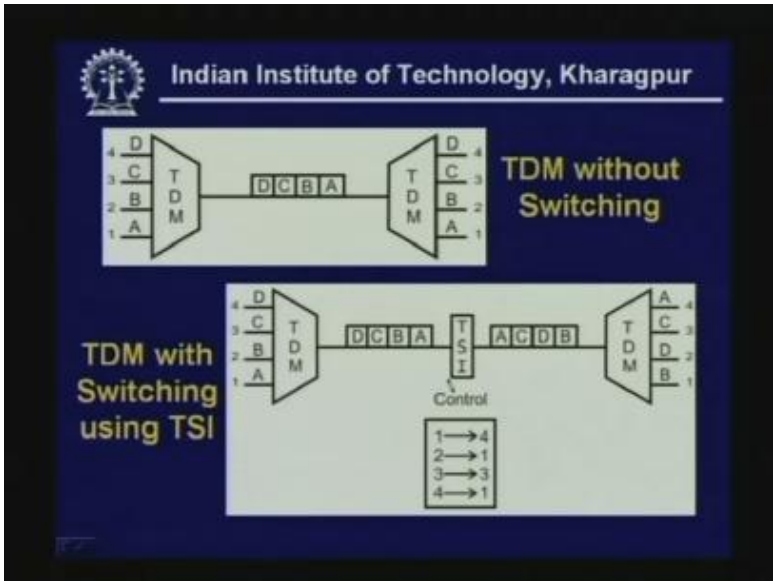

So in this case it is 1 2 3 4 where 1 is sending in data in slot A, 2 is sending in slot B, 3 is sending in slot C and 4 is sending slot D and slot A is again taken to 1 and slot B data goes to 2, slot C data goes to 3 and slot D data goes to….. this is the simple Time Division Multiplexing. Obviously this will not serve our purpose so we have to use something in between. The first thing that can be done is TSI. TSI stands for Time Slot Interchange.

What Time Slot Interchange does is it essentially does the interchange of the slot. for example, the connection is necessary from one to four so the data from 1 should go to 4 so this data is now in slot 4 then what comes from 2 goes to 1 so B goes to slot 1 data, then 3 to 3 here there is no change and from 4 it goes to 1 so B goes to 1 so it is 1 to 4, 2 to 1, 3 to 3 and you can see D to A so this is how it is being interchanged so this data now goes in the proper form. You can see here BDCA (Refer Slide Time: 40:45) so you see all the data is going in this manner. So you find that this data communication is taking place in this manner.

Now how exactly it is being done? It is being done in this manner.

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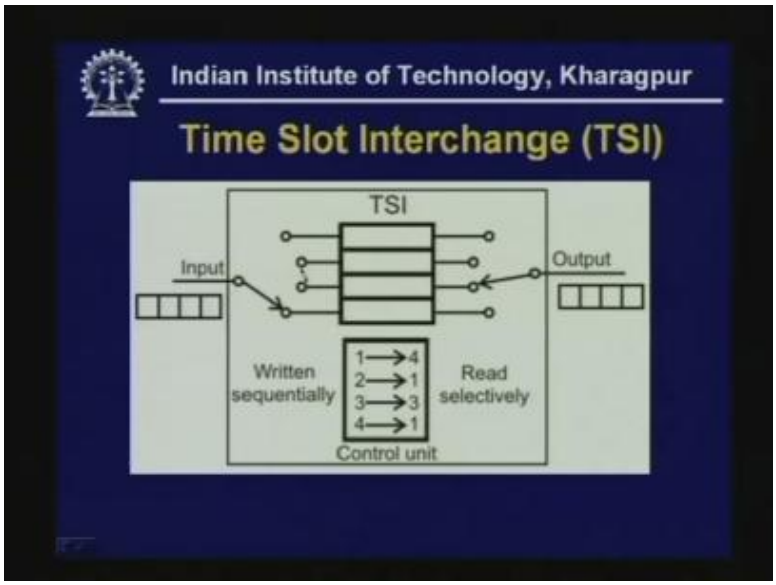

So here you can see the data is coming in slots then it is stored in some memory so in this memory the writing is done in a sequential manner that means 1 2 3 4 and then reading is done selectively. That means here the writing takes place sequentially and reading takes place sequentially that's how the Time Slot Interchange takes place and data goes from 1 to 4, 2 to 1, 3 to 3 and 4 to 1. This is how it takes place in Time Slot Interchange.

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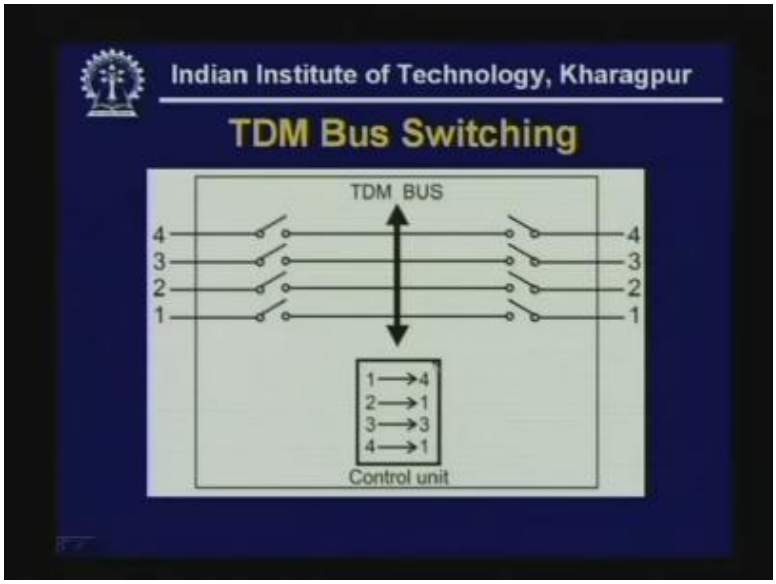

Another alternative is the TDN bus switching. So here we use a high speed bus and here the data comes at low speed and then is connected to a high speed bus. And for example at slow speed whenever this switch is closed then this switch is closed 1 to 4, whenever this switch 2 is closed then this 1 is closed and from the high speed bus the data goes from this input to the output. So, for example here whatever data rate is here on this bus it will be four times of that because it is doing the Time Division Multiplexing of data and it is being read on 1 2 3 and 4 in this fashion. So it is essentially some kind of Asynchronous Time Division Multiplexing that is being performed but however it is done in a different way. From a high speed bus with the help of the control unit the reading is taking place at different times. Therefore at different times it is coming from here 1 2 3 4 and here at different times it is being read by 1 2 3 4 in a different sequence. This is how the TDM bus switching operates.

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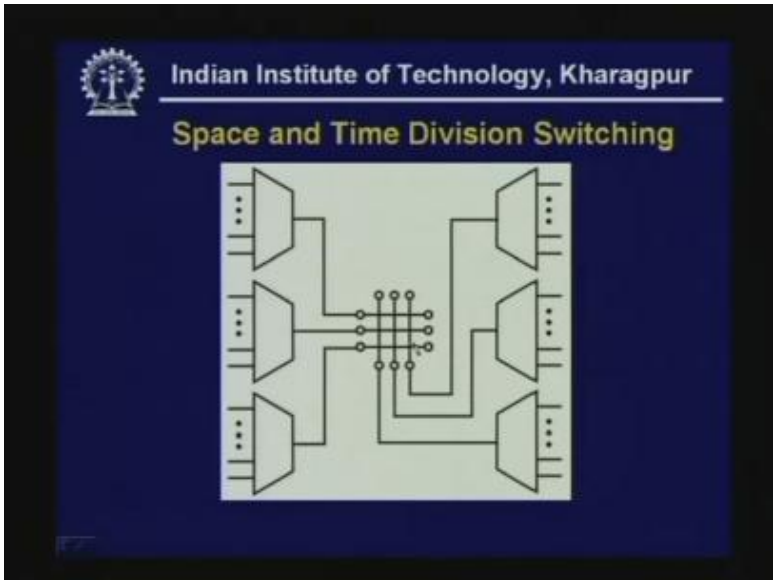

However, you can combine the space and Time Division Switching. we have already discussed the Space Division Switching and Time Division Switching and it can be combined here. So these are the typical TDM switches Time Division Switches and here it is Space Division Switches which is nothing but a crossbar. Therefore as you can see here this interchange can be done with the help of this crossbar switch.

Earlier we have seen the interchange was done with the help of memory or a first bus here the cross bars switch does the necessary interchange. That means from any one of the switch it will come here and then it can be taken to anyone of these multiplexes. So here it is a multiplexer and here it is a demulitplexer. So, from any one of these multiplexers it will come here and with the help of this cross bar switch it can be taken to one of the demultiplexer and as you can sequence it can go to anyone of these lines. This is how the space and time division switching are combined in implementing the circuit switch nodes. And as I mentioned the most important application of circuit switching is in telephone, the telephone network.

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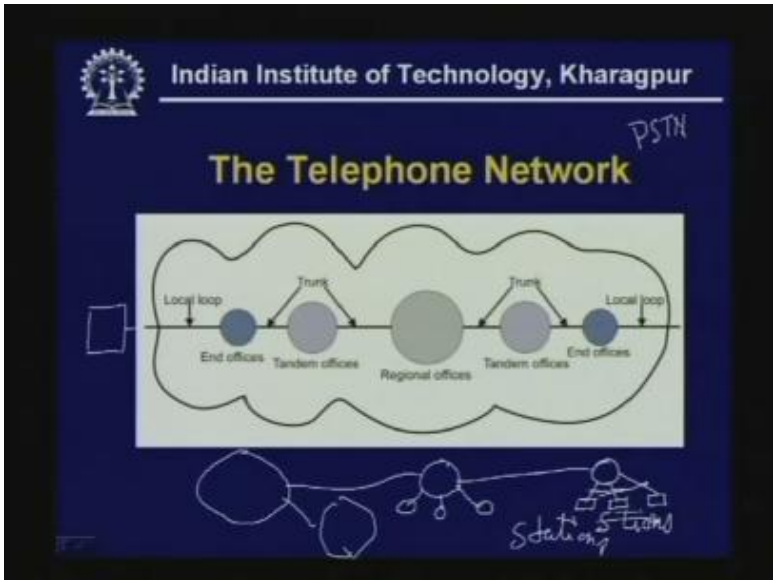

I have already discussed about the telephone network which is organized in a hierarchical manner. As you know you have got end offices and with the help of local loop these are connected to the end stations. So here you have the end stations which are connected through the local loop with the end offices and the end offices are connected to the Tandem offices and you have got trunk lines these are lines where we shall use the FDM or TDM techniques and then Tandem offices are connected to regional offices.

So there is some kind of hierarchy here. That means say one end office will connect to a number of stations so a number of stations will be connected. Similarly, a Tandem office will connect to a number of end offices. These are end offices (Refer Slide Time: 45:36) so these are stations or telephones you can say and this is your end office and these are all local loops and these offices are connected to the Tandem offices and the Tandem offices in turn are connected to the regional offices so several such Tandem offices are connected to regional offices. Therefore in this way there is a hierarchical network used in Public Service Telephone Network (PSTN).

Now let us consider the routing operation performed in circuit switch networks. As I mentioned in large circuit switch network connections often require a path through more than one switch that is the typical property of the switched communication network.

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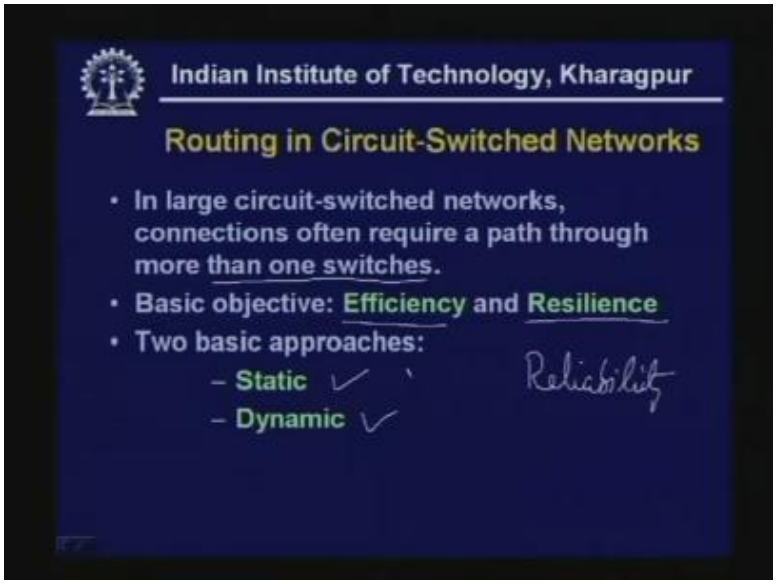

And here the basic objective is the efficiency and resilience. What do you really mean by efficiency? Here we would like to utilize the minimum number of switches. Obviously we would like to optimize on the hardware cost. On the other hand the resilience wants high reliability. High reliability means for example you may decide the switch capacity on the basis of average traffic. However, there are situations where the traffic will be above average. So traffic handling with the help of this network actually decides the resilience. Whenever there is some failure in the network even in such a situation the network should be able to handle with some degraded performance. If there is a catastrophic situation that occurs like flood or earthquake or something else then the traffic on the network suddenly increases or even when some exam results are out obviously it leads to lot of telephone calls. So network should be able handle that which requires resilience.

For routing purpose there are two basic approaches. One is known as static routing and other is known as dynamic routing. in static routing routing function in public switch telecommunication networks has been traditionally quite simple and static, normally it is very static in nature and as we have already seen the switches are organized as a tree structure. Since it is organized in a tree structure there is a fixed well defined path from one point to another point through a number of switches. However, to add some resilience to the network additional high usage trunks are added to cut across the tree structure to connect exchanges with high volumes of traffic between them.

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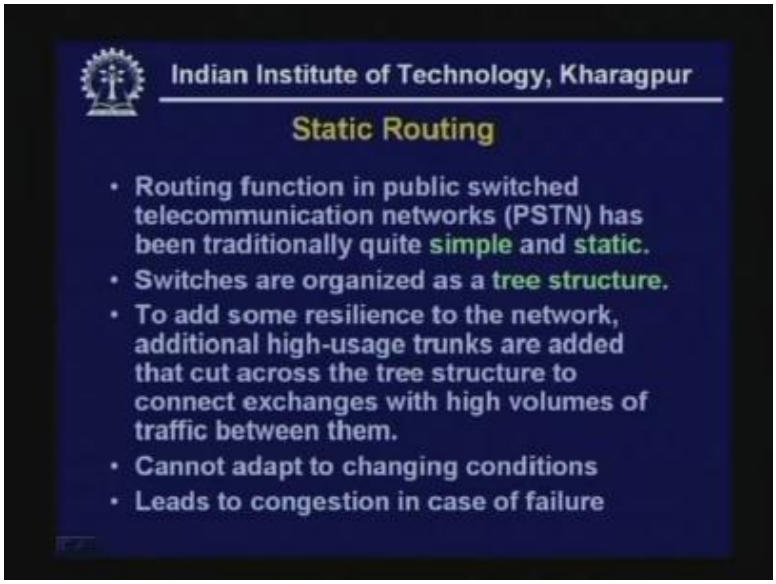

That means to have some resilience some additional high usage trunks added some redundancies are added so that in case of failure in case of heavy traffic this can be tackled. However, it cannot adapt to changing conditions. As I mentioned there may be some changing conditions because of some catastrophic situations or some special situations. So for these special situations this static routing cannot perform and obviously this leads to congestion in case of failure. Whenever there is some failure will lead to congestion. That means the connection cannot be established between two users.

To overcome the limitations and to cope with growing demands all providers presently use dynamic approach and routing decisions are influenced by current traffic conditions.

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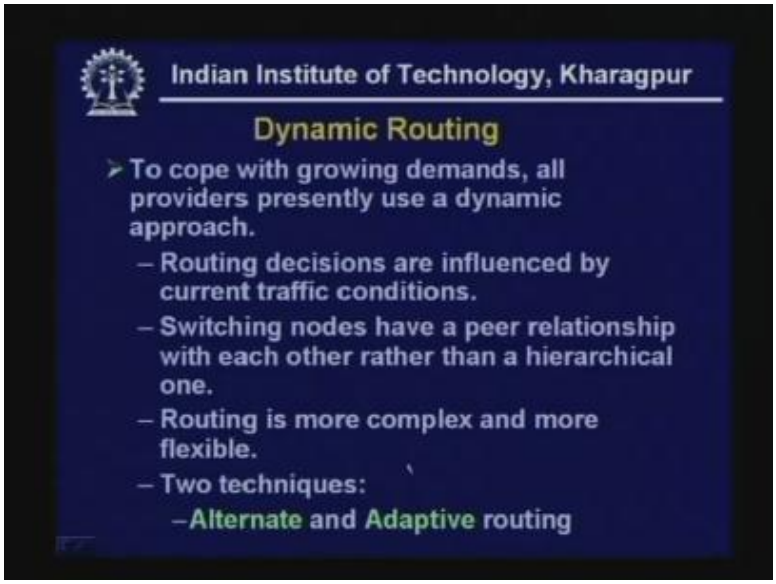

In dynamic routing it is not fixed and static it is based on the current traffic and conditions. So, switching nodes have a peer relationship with each other rather than a hierarchical one. That means in such a case it is not the hierarchical network. The nodes or switching nodes have peer relationship among all other nodes, they exchange information to find out traffic conditions and other things and as a result based on that the routing is done. Routing is more complex and more flexible and obviously it will be complex. Since it is not fixed it is based on the current conditions and it has to tackle the catastrophic or special situations. However, it has to be more flexible as well.

There are two basic techniques is used one is known as alternate routing another is known as adaptive routing. Let us see how they work. First let us consider the alternate routing approach. Here the possible routes between two end points are predetermined. So it is the responsibility of the originating switch to select the appropriate route for each call.

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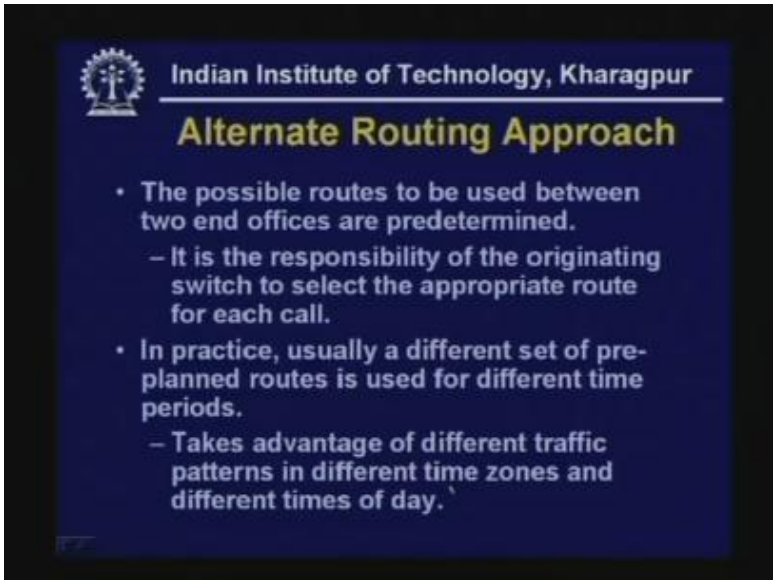

That means in this case based on busy traffic hours the routes are decided. For example, may be in the morning hours all people are going to office or schools and in the evening hours people are returning from offices or schools and based on that you know that traffic control is done, the route timings can be set in normal traffic control. Here also something similar thing can be done that is based on the statistics of history the direction of traffic can be decided at a particular time instance. In this case in practice usually a different set of preplanned routes are used for different time periods. For example, in morning period one route is established, in the evening period one route can be established or depending on the traffic condition and different paths and that can be based on history and statistics. So it takes advantage of different traffic patterns in different time zones and at different time of the day.

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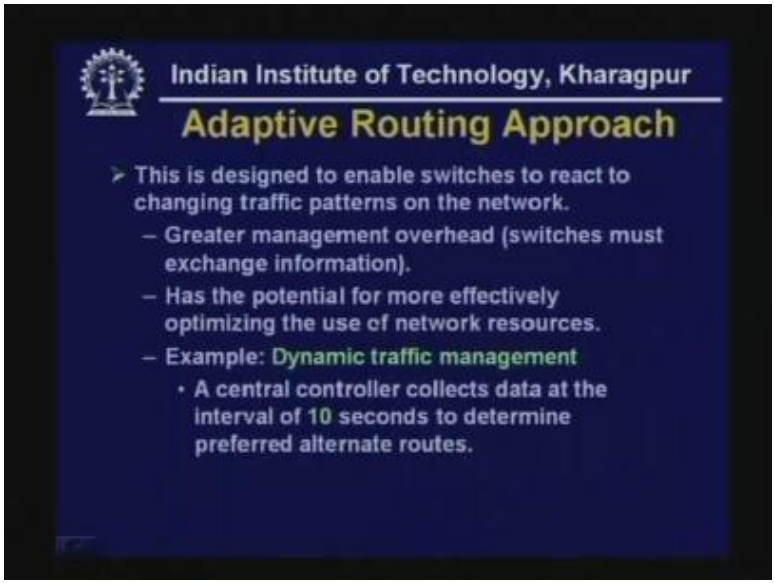

This is more appropriate in USA. For example, it has got different time zones and based on different time zones the office hours are different in different places so accordingly the routes can be set up in a predetermined manner and the routing can be done depending on the date and time and hour of the day.

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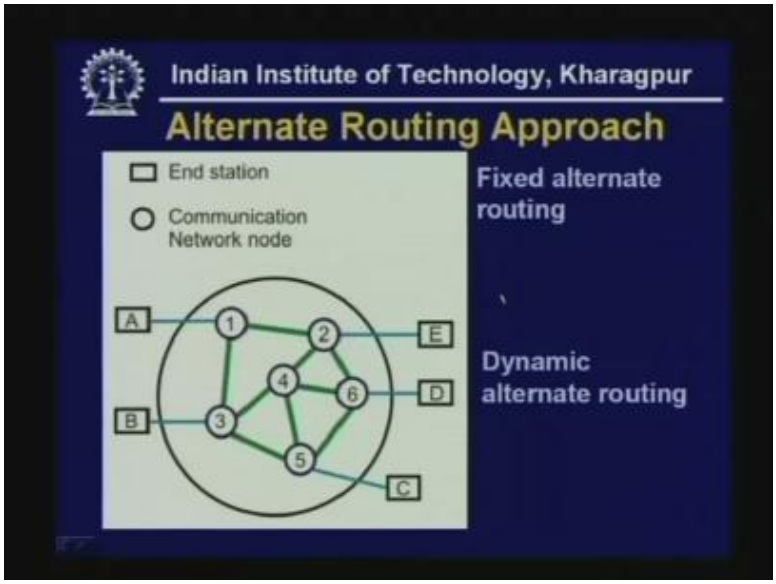

Then we have the alternate routing approach. In alternate routing approach several alternate routes are predetermined which are used for communication. For example, you can have a fixed alternate route, for example from A to D it can be that is from A to node 1 then to 2 then to 6 then it goes to D that means it is through the nodes 1 2 and 6 so this is fixed alternate routing. But it can be dynamic alternate routing. For example, another alternate route instead of 1 to 6 it can be 1, 3, 5 and 6 so this is the alternative. These alternative routes are available may be initially the shortest route is tried and if there is blocking then the alternate routes are explored in alternative approach.

On the other hand adaptive routing approach is designed to enable switches to react to changing traffic conditions on the network and it allows you better management overhead, switches must exchange information and it has potential for more effectively optimizing the use of network resources.

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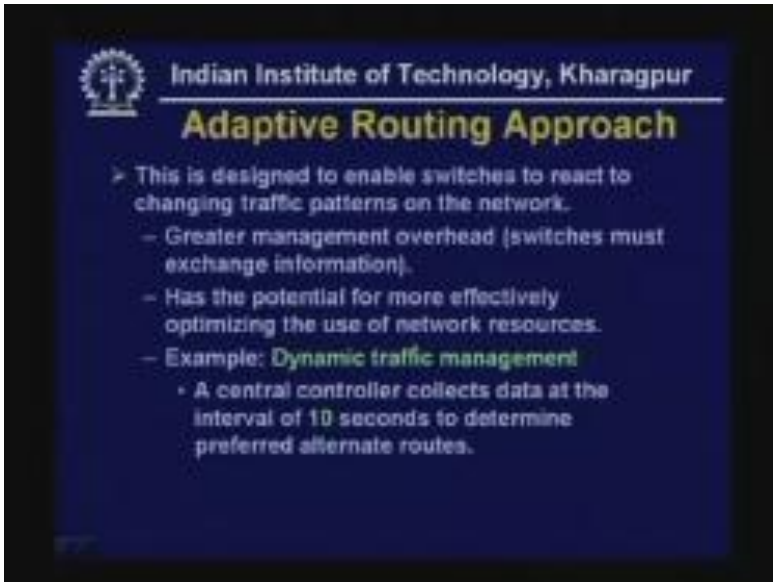

For example dynamic traffic management is being used by some telephone companies. A central controller collects data at the interval of ten seconds to determine preferred alternate routes. So it gathers statistics then the routes are decided. So apart from routing the nodes must send control signal to manage the network by which calls are established, maintained and terminated. So, to perform these functions; establishment, maintenance and termination various types of signals are to be generated.

For example, supervisory signals which essentially gives you the availability of sources then at risk for example at different stations a particular node has some telephone number that telephone number has to be sent so this is the address that has to be communicated and the call information as whether it is busy or something has happened or network management has to be done which is used for the purpose of maintenance and termination.

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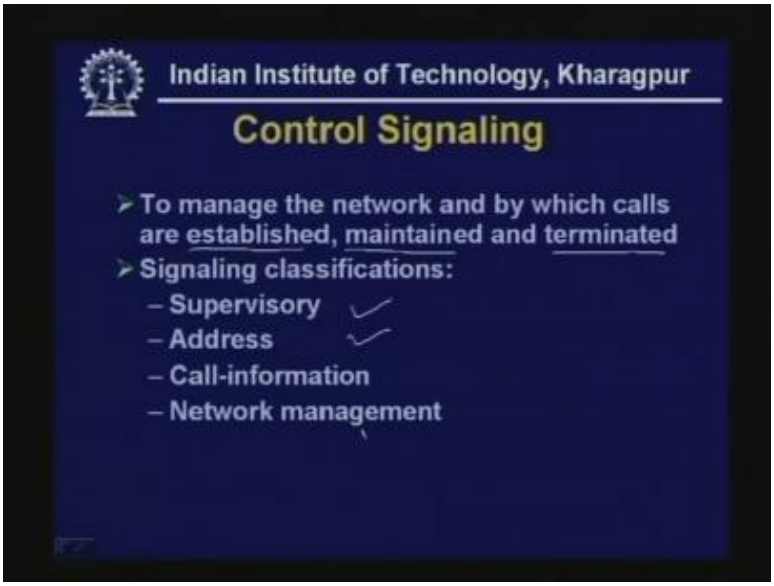

And signaling can be done in two different ways; inchannel, it can be in band or out of band and same band frequencies used by voice signals are used to transmit control signals and in out of band it uses different part of the frequency band but uses the same facilities as the voice signal.

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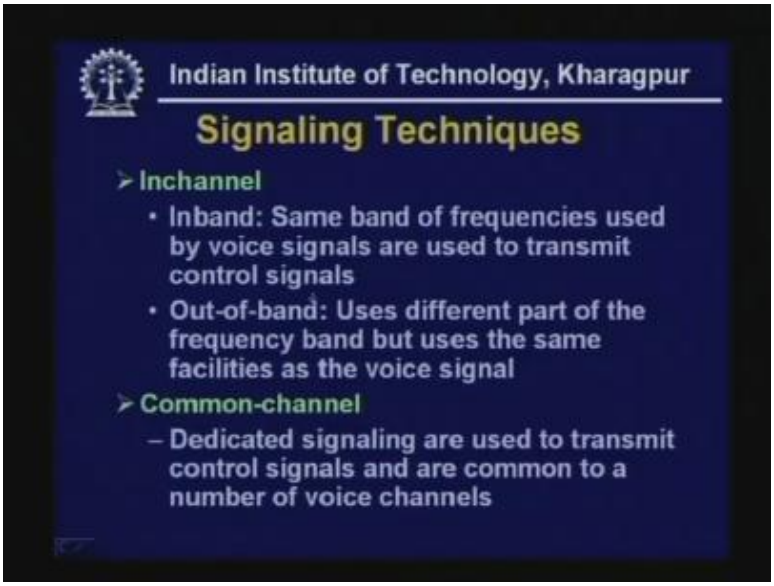

On the other hand the common channel is dedicated signaling are used to transmit control signals and are common to a number of voice channels. So we have discussed by the circuit switching technique and it is time now to give you review questions. Here are the five review questions.

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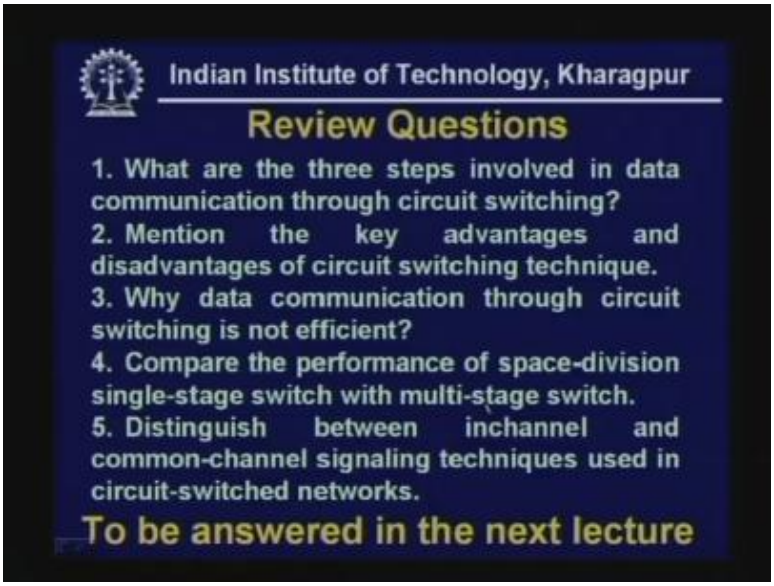

1) What are the three steps involved in data communication through circuit switching?
2) Mention the key advantages and disadvantages of circuit switching technique
3) Why data communication through circuit switching is not efficient?
4) Compare the performance of space division single stage switch with multistage switch
5) Distinguish between inchannel and common channel signaling techniques used in circuit switched networks.

Now I shall quickly give you the answers of the questions of the lecture minus 17.

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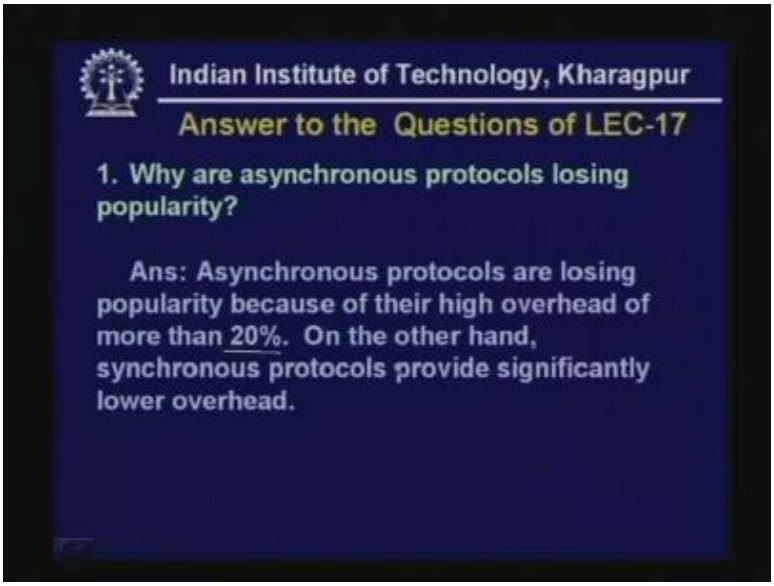

1) Why are asynchronous protocols losing popularity?

Asynchronous protocols are losing popularity because of their high overhead of more than twenty percent as we will explain in details on the other hand synchronous protocols provide significantly lower overhead that is why asynchronous protocols are losing popularity.

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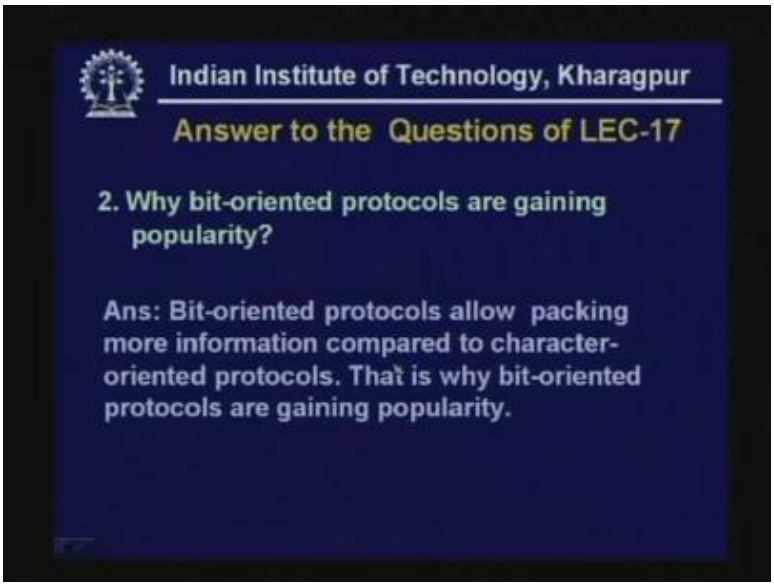

2) Why bit-oriented protocols are gaining popularity?

Bit-oriented protocols allow packing more information compared to character-oriented protocols that is why bit-oriented protocols are gaining popularity.

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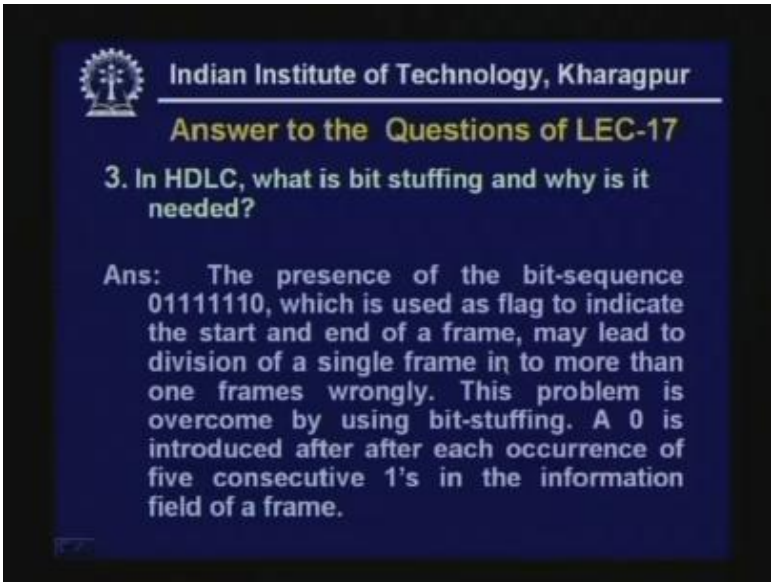

3) In HDLC what is bit stuffing and why is it needed?

The presence of the bit sequence 01111110 used as flag to indicate the start and end of a frame may lead to division of a single frame into more than one frame wrongly. This problem is overcome by using bit stuffing. A 0 is introduced after each occurrence of five consecutive ones in the information field of a frame.

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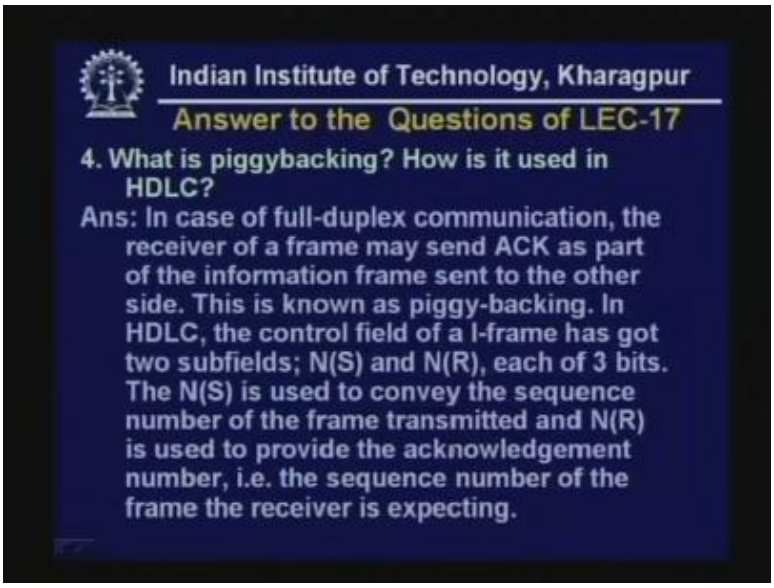

4) What is piggybacking and how it is being used in HDLC?

As i have mentioned the acknowledgement can be sent along with the information from the other end. That is being used in the piggybacking. So with this we come to the end of the lecture, thank you.