Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Digital Switching

Lecture – 01

by
Prof. Y. N. Singh
Dept. of Electrical Engineering
IIT Kanpur

So welcome to the mook for digital switching one this course actually I have been teaching in IIT Kanpur for a long time but I have split into two parts and that is why word digital switching move on and there will be also digital switching to sometimes later so here the emphasis is actually on describing the fundamentals basically the theoretical foundations which goes into digital switching systems, so for this lecture 1teh basically the objective is why require the switching systems okay.

And typically why you required a digital switching system and as I think most of must have already guessed it or must have discovered it this as to do with telephonic the hole or systems basically how the telephone exchange or current day packets switching systems are actually do operate. When we will go to digital switching two sometime later may be in another mook that we will talk about voice over IP systems, most likely it will be shift telephonic because that is what is now prevalent everywhere and we will be talking about the complete signaling of that and how actually you work with those thing .

And we will be skipping out industrial switching to on circuit switching systems are a telephone exchanges what we call them now so basically the way.

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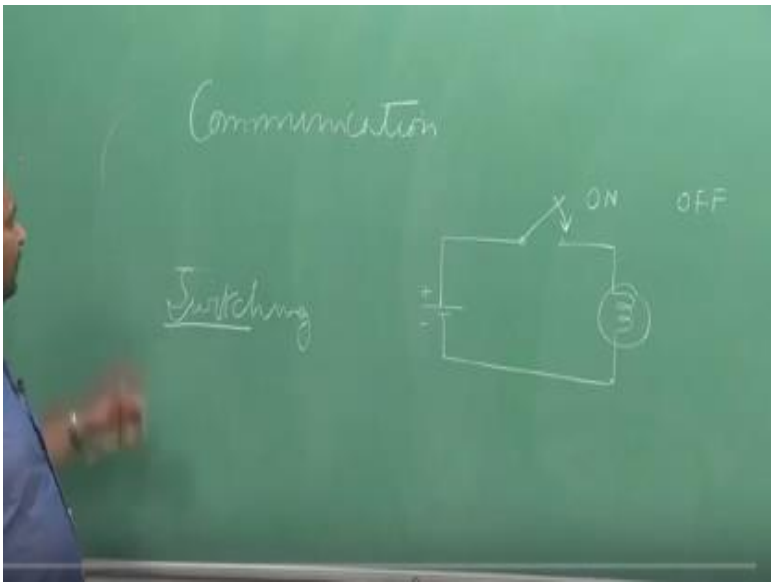

I will start is everything as start with communication so because humans do actually wont communicate communication provides edge if people communicates with each other they can coordinate and they are actually essentially the survival probability becomes better and that is how the communication becomes very important and it has been one of the main costive factors in the evaluation of human beings so columniation is one fundamental thing and the hole digital switching system is being derived basically out of it secondly I have been talking about word switching.

So how these two things are related if communication as to happen with actually I talk and everybody listens and that sis a good way of communication it is going to work but we are talking about telecommunications when people how are farer of can actually communicate with each other okay so how the switching comes into picture so let us switching fundamentally is.

Is has to do with the switch which actually means you are going to modify your state so you if you switch from one state to another state. State is for any system a state defines a condition in which will actually determine the input to output relationship so for me switching for example the most common switch which all of us come across is a electrical switch normally this how we

represent it and if you connect a power source so I have a connected a battery I can connect a electrical lamp and this switch can have two states ON and OFF.

And when you turn this ON and OFF that is what we call switching, but what you are switching here is a path for electrical power because of which the lamp will either glow or not glow so if I look into communication switching if can how switch the communication paths so if one person is speaking.

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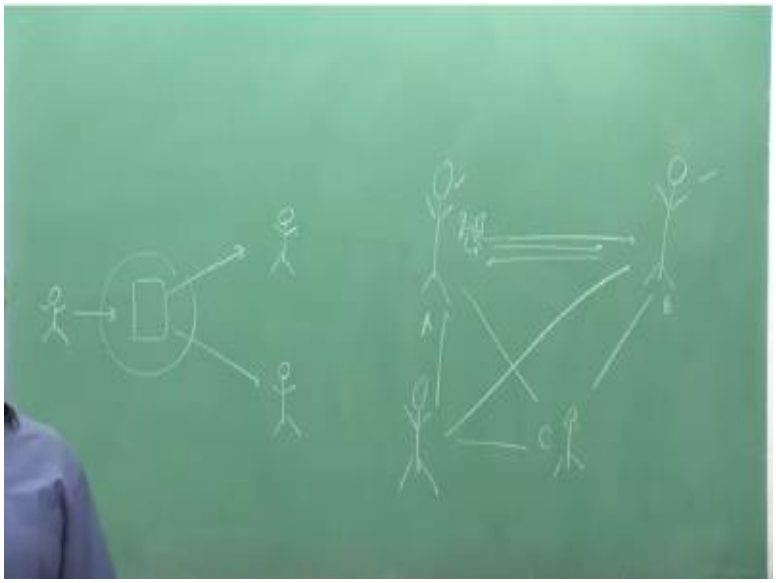

So this guy is speaking and I can actually have some mechanism by which this can either go to this person or this can either go to this person and now coming I am actually doing a similar action on a communication path and that is what the communication switching is all about and when these signals which are passing through this communication path are digital signals we call them digital switching so that is how we defined the digital switching systems so let us come to the networks the fundamentals of this we have to do with the communication so best thing if you what to set up the communication system so there is a person A and this person A would like to talk to person B.

So I am not talking about how the communication can be setup among multiple people and how the switching will come into picture so I can actually setup a communication link between them so this guy can actually have a microphone can actually have a speaker and these two combine together the voice can be recorded and played back so voice can go in this direction and voice can come in this direction so whatever this guy speaks is listened by this person and so on.

So I setup one link there is no switching required so whenever this guy wants to talk he will just talk other person will listen so 1 to 1 communication very good there is no issue in this so but if you want to actually have a communication systems to be built we need more number of users how should participate so power of communication only comes when you are able to communicate with anybody in the group okay so you have to have more number of people so if I had another person what we need.

We need to create more communication links if there more people you are coming in I need to create more communication paths you keep on doing it and you will be able to satisfy the communication requirements.

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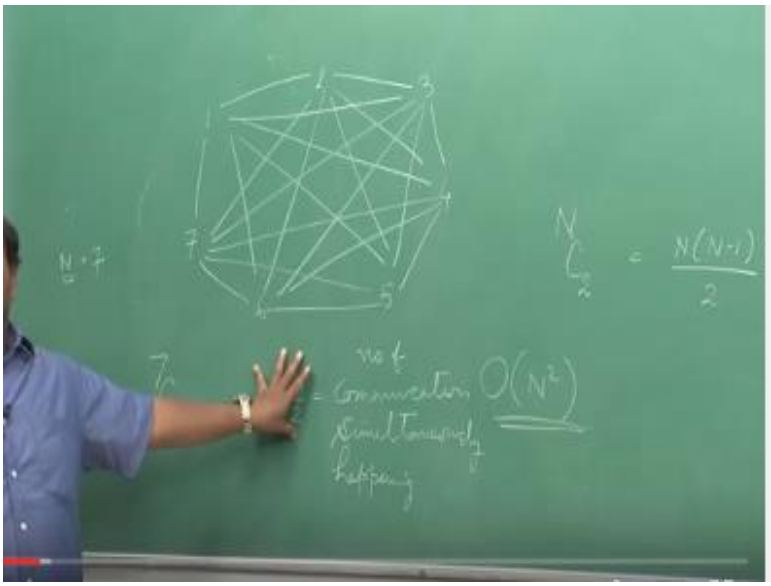

But outcome of this particular system is this mechanism is that if I have n number users participating I need to create large number of links how many number of them so I will create 3, 4,5, 6, 7 users I need to create how many links. So if you count these will be $^{7}C_{2}$ those many by directional links will be required for setting up a communication path between anybody to anybody so if the number of users is n here so n is in this case is 7 so I will requiring $^{N}C_{2}$ number of communication path to be created.

Which turns how to be N(N-1)/2 so number of links which will be required will have a complexity of $0(N^2)$ so as N grows the square the number of links required to setup a communication systems grows with N^2 but this is not good enough even if you are will to do this let us look at what is going to be utilization of every link at any point of time if it is a point to point communicating okay so one user is what to talk to other so he will setup a path so one link gets occupied but remember these two users will also get occupied haw are talking to each other.

So in general for every communication which is talking place there will be two user which gets consumed so for N^{th} number of nodes so there can be N/2 communications number of communications which are simultaneously which are happening so on a average what is the unitization of a link unitization of a link actually means when link is being used for communicated for communication to happen between person A to B the two end points if link is in use it is in use if it is not in use this unitization is not happening at that point of time.

So what is factional time for which utilization will happen on a average only N/2 links can be in use you cannot have more than that because all the users would be communicating in worst case and N/2 links in use number of links which are there is N (N-1)/ 2 so which actually means.

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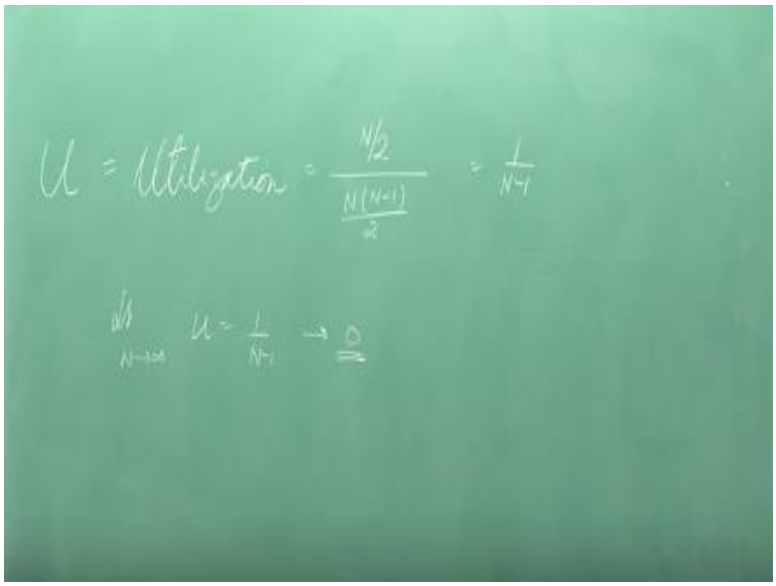

You will have a utilization U I call it utilization will be n/2 number of links which are occupied and total number of links which are there and this will be 1/N-1, now the problem here is if n grows because we have large number of population and I think we need to set up the communication part for everybody, everybody should be able to talk to anybody else that's the basically the objective. In limit when m goes to infinity your U which is 1/N-1 goes to zero is not a good design, see you are going to invest a huge amount of money in setting up the links and they are not going to be used.

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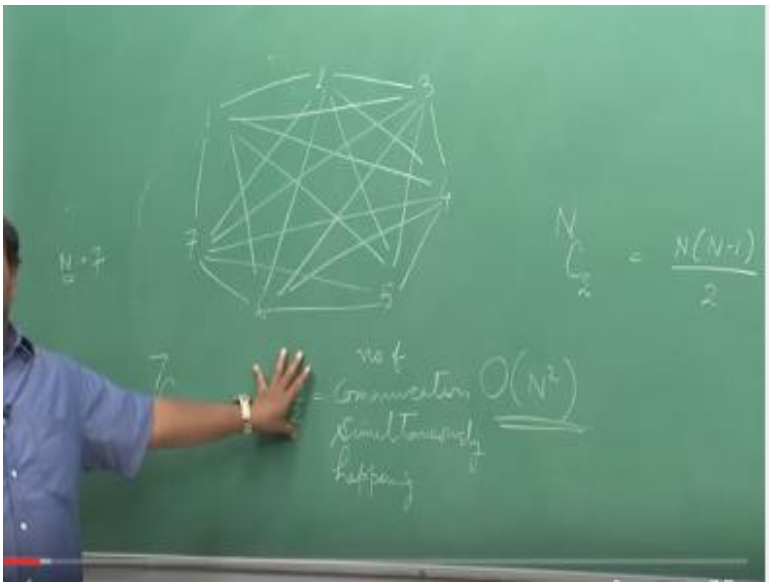

But you will say where the switching is happening; now switching is actually happening at the nodes. So when somebody wants to talk to, you actually select, you select which one of those gets connected to your audio player and audio recorder, okay. That particular system, so that is why you can make a voice call with this can be voice video or whatever you want but it is a communication path between two entities.

But utilization is extremely bad how to improve on this, okay. So let us see how we can do the improvement. Only good thing is network is passive most of the switching functionality is pushed to the nodes, now if I again actually accept another parading. I can be in far better situation, my worry is that I need to reduce this number of links, so one way of doping it is.

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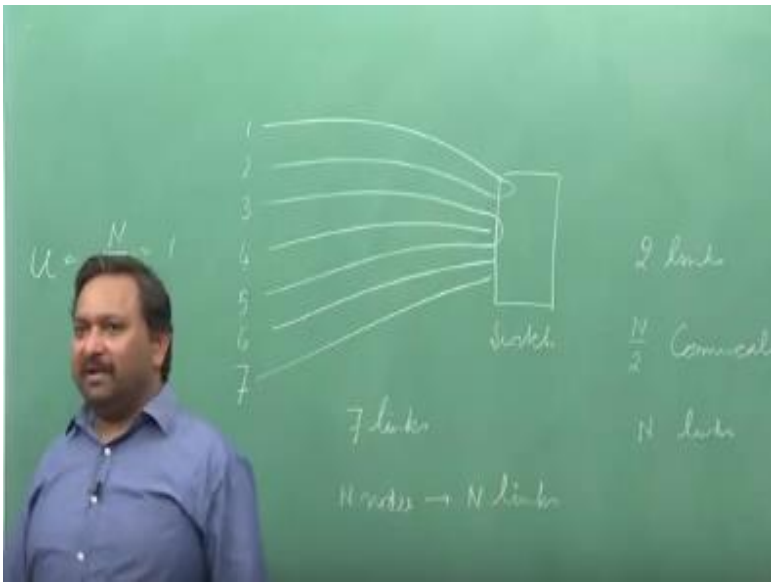

Let me have a small box so I am now adding more complexity this network was passive there was only links but now I am adding some component which is part of the network and I connect the users here and I connect them here, so how many links are required in this case I will come to this box what this box actually does, you require several links, so if there n nodes or n users you require n links.

Now this box is going to be something special, we will talk about how this box actually operates, okay. This is what we call actually a switch and currently it is a analog switch because the communication will be analog, if you start transmitting distance signals over it, it will become a distill switch in that case, so it actually means it can set a path between various nodes say one mode like to talk to two so it can set up a path between 1 to 2.

If 3 wants to talk to 5 it can create a path like this, so it can create path between pairs and it has the capability of doing this, so I am assuming and we will look into this how we will implement this particular box we call it a switch or in telecom paralysis we call it an exchange, okay. But the generic word is switch. So for every communication I require two links to be occupied and there can be utmost N/2 communications which can happen, okay.

So you will have total n links will be occupied in worst case if everybody is talking, so the pair wise all nodes are busy, so you will have n links occupied available links are n you utilization in this case will be N/N = 1. Even if N becomes very large it remains one, only issue is s by n academic grows this device should be able to connect to those many number of links and it should be able to create the connections between them.

That capability has to be built in, so now the complexity has been removed from the network has been actually moved to the network while simplifying the number of links, number of links have been reduced it is not having the complexity of ON^2 it is having an complexity of O (N) number off links are actually equal to N here but I am now may making something which is much more complex which is a switch.

And there are off course issues with this switch because the moment you implement this how the switch will how this device will know that which path has to be connected, so it means there has to be some mechanism by which this node can talk to this switch.

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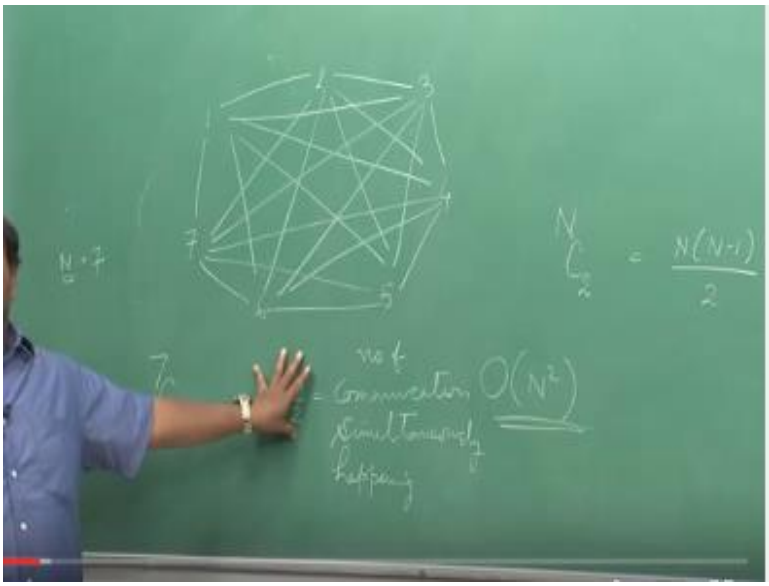

So in this case there was nothing like that you just want to talk to somebody choose that particular link and transmit, there was not signaling as such you are just directly making communication path only the end point you are doing selecting the various links actually and connecting it to the source of single device.

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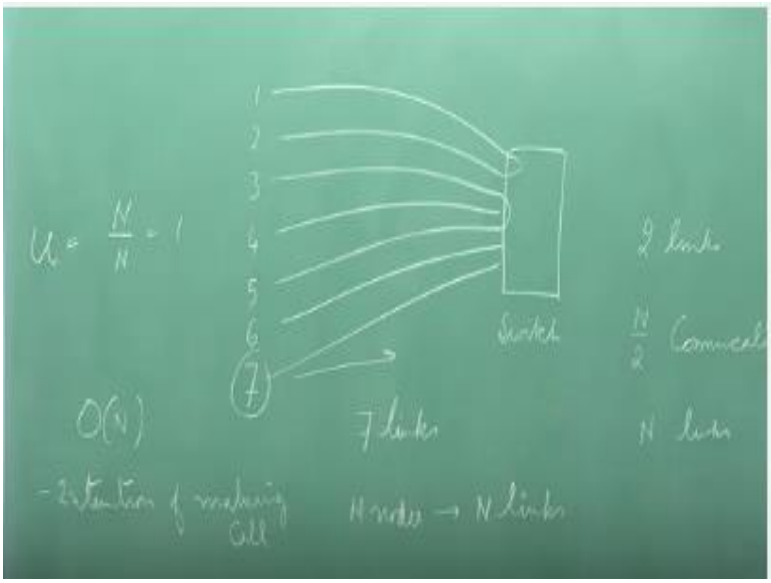

In this case we have introduce something called signaling I will talk about how signaling actually happens an example in the manual telephony and exactly same thing what happens in manual telephony. Will be replicated in electronics domain also so you have to first of all show for example to the switch your intension of making the call that is needed, switch has to tell you back dearest you can actually make a call verse that conformation happens you have to tell to whom I want to call, which number.

So once this information is there it will set up that particular path conform back and you will do the communication that is extra overhead now which comes, of course I will lead to the utilization so you are going to reduce the cost here because when you are going to lay this cable

from house to a next chain you are a switch you are going to incur certain cost, here the cost would have been among this when square.

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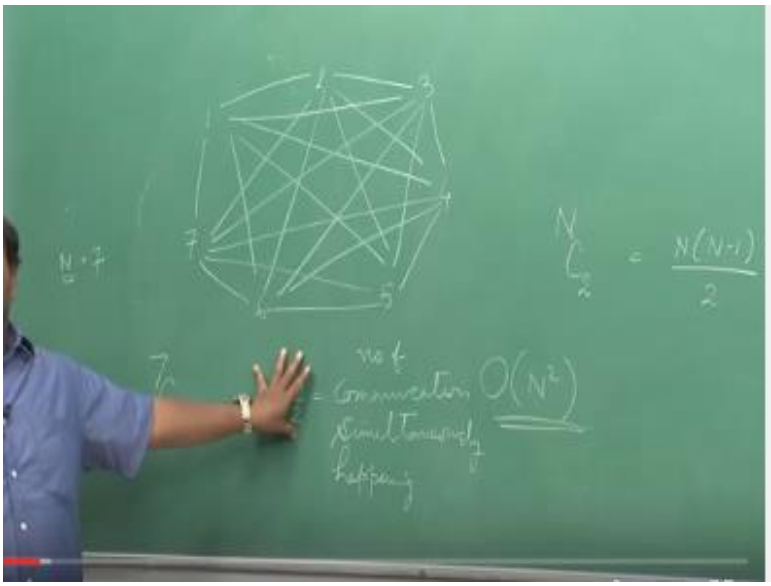

Utilization would have been very low almost zero which actually means the cost for user is going to be pretty large.

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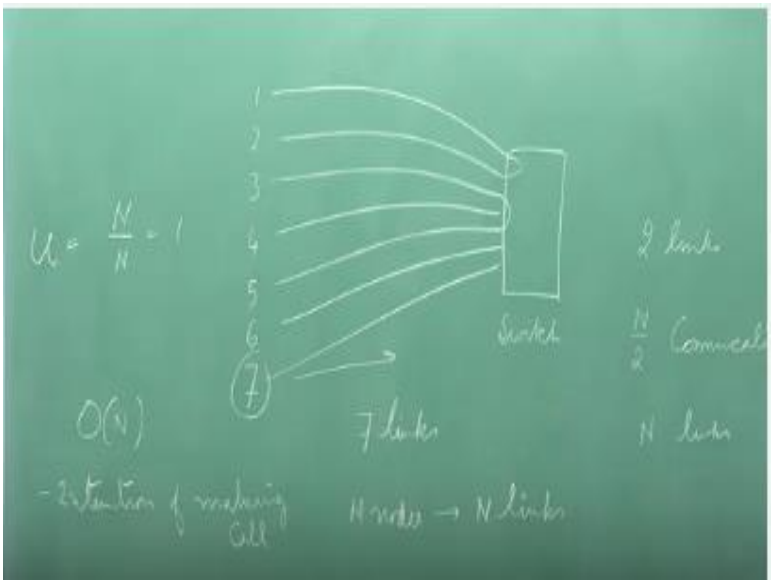

In this case the cost for user is almost fixed because this length is fixed if that is if there within a small locality, so you are going to now pay in by in this complication this implementation of this particular switch, okay. So this is realized almost long time back when telephony is started. But there is still an issue; I am assuming that it is a small locality the switch is there this cables run say few kilometers not more than that.

One, one and a half kind of thing kilometers which is fine but suppose if you have to take care of the whole city say whole country will this architecture still suffices angle to make one single switch where everybody one within the city or within the country or within the state will be connected to, now some of this link lengths will be extremely large and that is going to cost a lot, so implication of this is.

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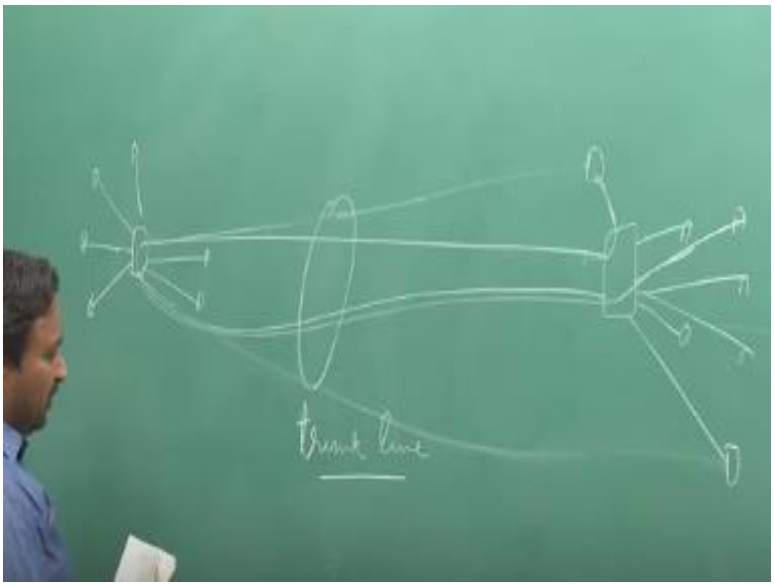

So if you have a switch some people are very far of some people are very close, the cost of this links are going to be pretty high there is another problem now how to solve this particular issue, I have got this particular topology. As this basically is a start complexity in the switch, number of links will grow as the number of users will grow linearly.

Same thing is happening here but the link distance is are pretty high, how to minimize on the cost? Because this will cost a lot, now let us see how we can minimize on the cost. Now as a user are you going to talk for 24 hours complete day all the time are you talking? Possibly not most likely you will making a call to a friend, talking for some time may be for half and hour at best one hour a day.

So people usually do not call to talk 24 hours if they 24 hours this link length is going to be justify but if you are only talking for $1/24^{th}$ of the day 24 hours are there for one hour a day so would for 23 hours you are still going to pay for the cost of this particular link his utilization is any way 1/24 if it is only half an hour a day it is 1/48 now can we do something these links are smaller in length. Their cause are small so I can afford to have lower utilization I can have utilization of $1/24^{th}$ because of this timely met so in this case I cannot.

So one of the way is to actually solve this problem is using something called remote concentrator units okay which is pretty popular if and exchange if you have to provide a connectivity to a remote village how to do that so village is a cluster so everybody might have phone but putting up an exchange their especially for that thing maybe a resource consuming thing it will actually cause something so idea is that wherever you have the locality lot of clusters so you sat of something called a concentrator unit.

Connect each one of them with the short link so even these guys will get connected so this link will not be there so all these are all shorter length but this is not a switch what it does is you are going to a so many small length a small length links you will create vary if show links all the way from here to here so there actually 1 2 3 4 5 6 7 users but you have only two links here so when somebody from here want to talk to this guy here is to talk to this remote concentrator unit which will set up a path.

All the way back to the switch and switch will set up a path between this device in fact now it is even possible because due to hardware thing that you can build up a even remote exchange notes so path can be set up directly here itself okay but what you have technically doing is now these two long length links are being shared across seven people earlier it was only one node so if all these seven used to be need to be connected here they were require we required seven very long link length links actually.

Now we do not so this are see in fact we can actually move further so this can be come in exchange if there too much of population is there why do not to use the remote concentrator unit can even deployed people and then I can actually have another locality were there many people so this is the natural extension and what I get now I erase these lines become trunk lines so trunk lines are the lines which will connect or inter connect the exchange is are the switches the lines which actually connect the subscribers of the users to the switch are known as subscriber access okay.

So subscriber's access part and this is known as the core part so normally the topology which will be there and now you can appreciate that this is has been done for cost activation.

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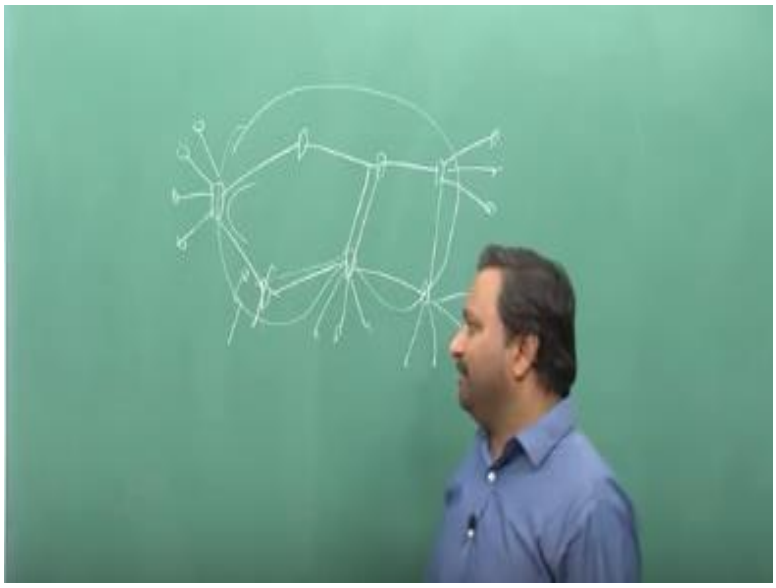

So normally you will have switches and there we multiple paths and then that will be users some switches will not have user so this kind of switches are known as access switches because people are connected to this, these are transit switch this switch is an access switch as well as it is actually permitting the calls to also pass through from one exchange to another exchange through this sets also trunk exchange is a trunk press subscriber exchange so this is not actually passing the calls.

Through it but it is only actually passing the calls from subscriber to the network then it is access exchange actually so you have a core network so this is what is becomes the core and the remaining part become the subscriber network so that is how we actually define the thing and important thing these trunk lines are mostly long distance once and they utilization factor are kept to a very high value so we only add more links are more capacity only when it is required so the cost per unit per second of.

Call on this is minimize in fact what happens now a days is this cost is much less compared to the cost of the subscriber line so from exchange to your home the line which is coming it is cost is much higher for per second call compared to a long distance STD link because their utilization is being maintained at a very high level of course you also create kind of inter connection so that even if a switch fails you can root calls from a other paths so trunk also provider liability okay so in fact technically if you look all these switches together.

All subscriber at are only at the adjust of this distributed system so this is a single gigantic distributed switch that is what is being created by using multiple of them okay so now the idea is that.

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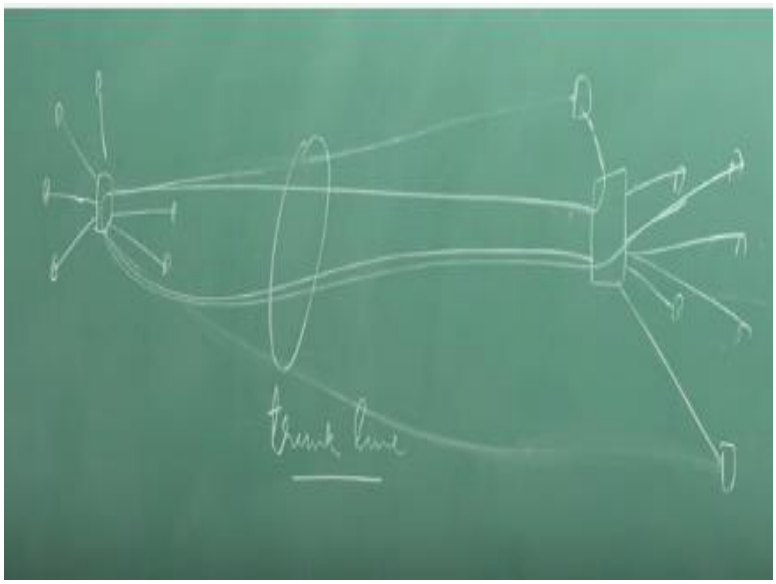

We will minimize on the cost as far as possible by actually using. Long distance link and maintaining the higher utilization for them and for the subscriber links these are short length links and their cost is going to be lower. So their utilization also can be lower so that is how the topology actually gets build so once this is clear let us come to the manual telephone okay so how the manual telephone you will look like so this will give us an idea about signaling.

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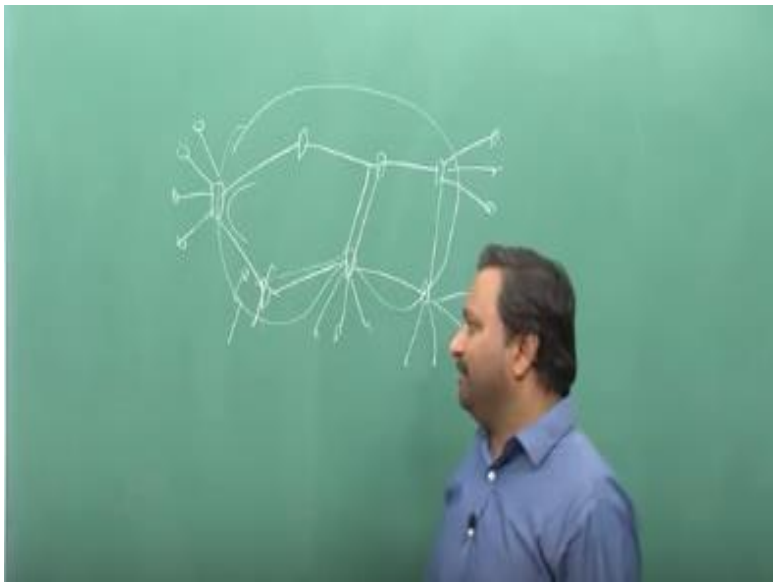

So in manual telephone in normally it will be humans which will be operating the exchange so I'm not going the intelligence in that switch so in the beginning itself people decided that we will actually have some humans operating then because they were no computers sophisticated computers are machines handling that and typically how this exchange will look like it will be nothing but there will be two boats so one where you will have the lights which will correspond to various users.

Which are directly connected to this particular switch and you will have connectors where actually jumper where can actually we insert and there will be human operator which will be operating this whole system so this will be connected to the phone instrument so currently I'm not talking about the trunk kind of thing I am talking about only one switch and all users connected to this but when will talk about signaling we will also consider the communication between exchanges.

Also so that is the case which I will take so in this case whenever you will the power mostly is being fed from the switch mostly through batteries so there is a cradle so when you left this

handset from the cradle the circuit actually or switch will operate here and electrical path gets completed which will get which will result into this bulb or indicator getting lighted up.

So this will remain there even when you are talking this slide will remain on until you are going to put the axis back to the cradle that was a basic fundamental mechanism and this is what is been use by the operator to figure out whether a user is busy or not busy okay so that is idea which actually has been used, so for example I call will be made in this case.

So user mostly will left the handset so when is the hand set is lifted the electrical circuit will completed which will result in to this slide coming up where is this light coming up the operator knows yes this gape probably once you make a call so one the operator comes observes this so there is a possibility that he or she might be busy in something else and she does not look at the light glowing up.

You may have to wait for long time before she talks back to you your call will not get through in this case okay so once this slide glows up she will actually put up a headset connect the wire to the point where the user is being connected the wire is being left and once this connection is made this user this actually can respond back so most likely it is a message welcome to so and so company and you would like to make it a call.

So all kind of welcome message will be coming up and of course you can see the similarity to the current telephone communication which happens. So one this happens you will this guy will tell I want to make a call, call to whom? Remember when the manual telephony was there was nothing like switch is here there is no numeric key pads of to dial the numbers. That interface came because of the automation.

So the person usually tells I want to talk to so and so gentlemen at this particular address, and this address will be known to the operator. Operator then will find out it will have a code book or a book which will be there using this it will find out to whom the call has to be made, okay so was it know that where is this there is this guy is this one what has to be done this guy is to inform that somebody wants to call you how that will better.

So normally there will be a extension on this board so we will have this special generators so I can have a some kind of a music so if the jack is connected to this you connected to your actually going to listed to the music that can be ready or they can be electrical power signal ringing current and osculating AC so she will actually put the inject this thing in the ringing current she will actually take a jumper kind of this ringing current and then connect to this subscriber.

The power signal will go there which can actually then drive an electro magnet which will cause the ringing to happen. Mean while this guy is actually can be because she in busy in making of the connection so this guy can be connected to the music source so that this guy is knows that my call is going through has of know so probably this will connect to a music source so this a music source actually this is a ringing current.

So ringing current is a power signal which can drive the bell on the other side of the phone okay so once that is done so this ringing will happen the user will not pick up the handset where is the user pickup the handset the light will glow here correspondingly, phone will still keep on ringing actually remember phone will still keep on ringing just removing the hand set will not stop it the operator will see the personnel acknowledge he has lifted the handset she will remove this jumper.

So ringing current is no more being apply it she can connect her head set here and talk to the person say so and so person is want to make a phone call to you now remember this is something what happen in her caller idée, so you get to know that who is calling you so once this person knows that to who is calling me and he is willing to accept the call he will conform, once the conformation happens this will once the conformation happens she will actually take out this connector and will create a jumper between these two.

And this music source will be disconnected and once the jumper is done the source and destination are connected together and they can now talk they can communicate the call has been set up but the moment the call is setup she has top actually take, remember there was a routing table or basically a table we says that which user is where so these are only number which are

there so which number may apps to which number okay or it has to be routed to some other city all that information is there in the routing table or address table.

She also I will have another register when the call is start she has to note down that who called to whom the call was made at what time the call is started and she has to keep on observing when the light goes off the call has being this mental when any one of them will put the handset back on the cradle the light will go off she has to figure out what is the closer time okay what is the closer time is known?

She will note down what is the closer time we call this record as call detail record, and this is what actually can be use at the end of the month to generate the bill for the customer, so but remember this is currently being done by human operator and he or she is prone to errors making errors she might of forward in to close the call she might have even forward into record the call itself the call was made.

So there will be a billing law is in that case which is happen she might actually do a misconnection okay she is not in the good mode she may not even look at the light and your call will not go through okay so now let us see if I extended to a multiple actions scenario because this is not the network, network is something like this.

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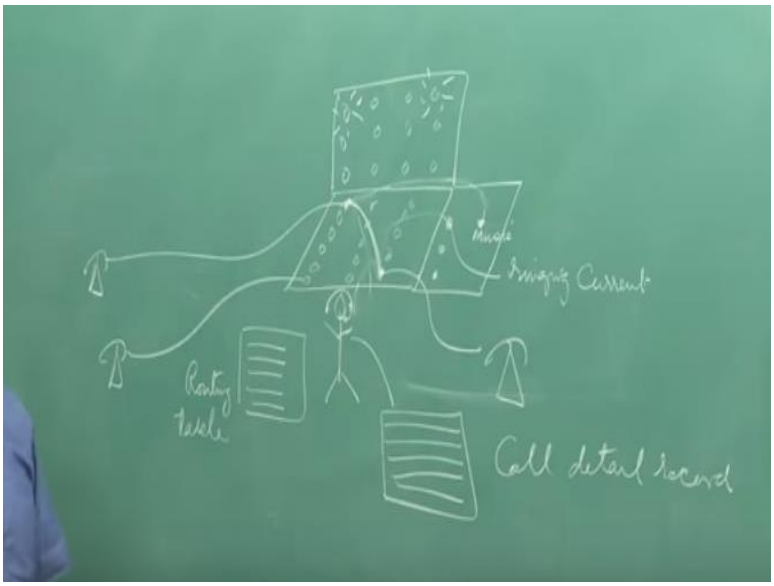

How will operate in this kind of scenario so it is a mire extension let us see how it is happens.

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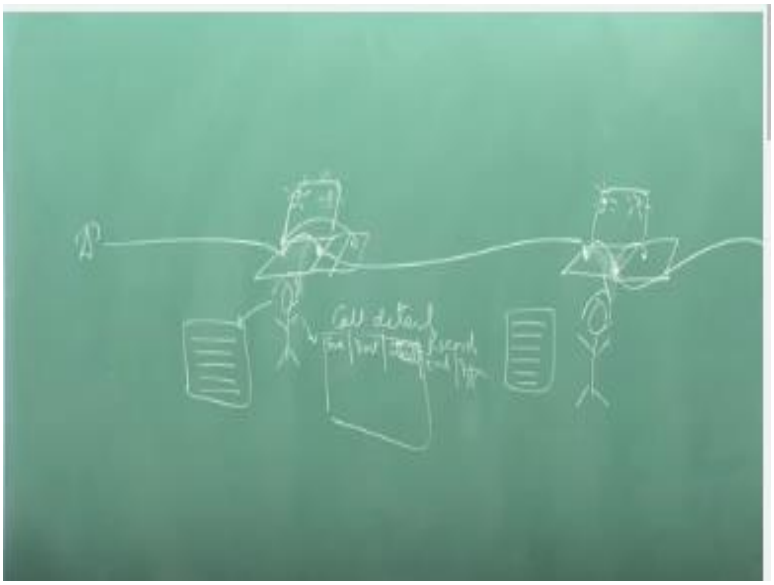

So if the user is here connects to one action this action is also connected to another action now that is the network and this can happen one after another but I am actually assuming the other side user is here itself now the two operators which are participated okay so similar procedure the source will lift the hand set the light will glows up once the light glows up the cradle handset is actually off the cradle.

So she or he will figure that this light glowing up connect the headset talk to the person welcome and then of course get the number same procedure what happened here and then of course where is that is being number has been received she can actually put the music source here this is disconnected she now looks refers to a book which is the routing table book this time the book does not tell that the destination is in the same city or connected to same switch.

It is connected to some other entity it some other place but she knows okay that place is connected to me the next guy so she will actually then put her head set in to the path for the other exchange and once that is done the light will glow here, so this operator now knows the trunk call which probably wants to be set up okay, first that is done so this connected.

Now this two operators can talk to each other and then he/she can transfer the destination formation all the way to this person and once that is done this line will be kept on hold actually ok this line is on because the other person as already put the connector here she has to look into the book and find out where the destination is.

Destination is at this point so what will be done is this will actually take out the set reconnect here so this light is off now so first this light is off this actually operator knows that call is being currently process of being set up so she has to wait till the slide comes back and then this will this user first of all before actually connecting this will actually connect the ringing source so you have this phone will ring.

Ringing current once the answered this is being lifted up the light will glow so she will stop the ringing current connect her headset here talk to the person and if that person acknowledges then a jumper is being connected here, the movement jumper is connected this light is ON .

The moment this light is on she knows that call is through ,in that case she will actually then disconnect her stuff and then put a jumper here the path is all through between source to destination so if they are more number of switches between the same procedure is requires severely followed.

And then of course once the call is starts we has to make the call detail records so call detail record again contain this was the person who called this call was the long distance because send another exchange and then of course it was started at this point of time and source and destination both are there and when the communication will stop either this will actually put the head set back to the creedal, or this will put and the lights will go OFF.

Once the lights actually goes OFF in that case she will make the closer entry of also so it is a source destination start and type of the call which is the trunk, this is being recorded in a register again we call it a call detail register, which will be used again to do the billing at the end of the month and of course since it is the type of call is being specified so bill for this will be different then the bill for the local call.

So that's how the calls used to get set up with a manual telephony exchanges in fact even now these are being used what in rudimentary fashion as a backup, but not in the commercial organization these are only within the organization as the ultimate loss result okay but mostly its automated nowadays.

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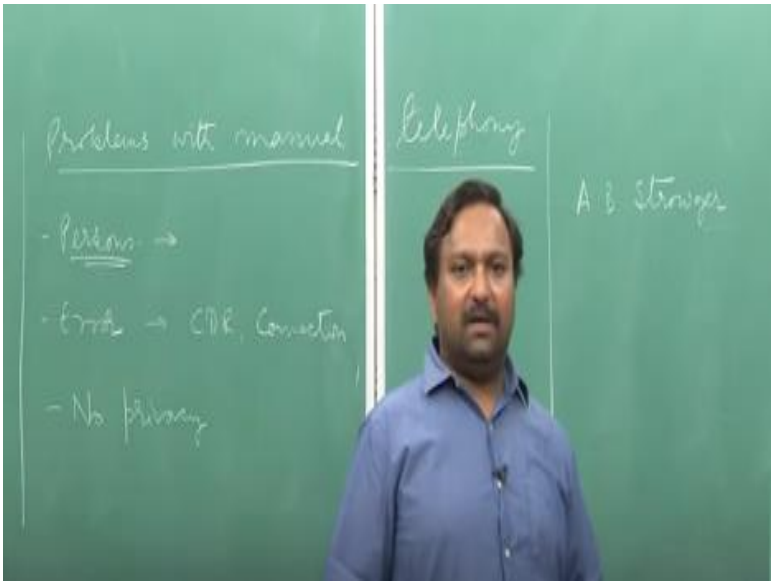

So in fact when you look at this whole scenario which i have explained you can see there was something equivalent of dial tone so welcome message being spoken by the operator that is equivalent to dial tone you dialing numbers that was like telling the address to the operator, she was putting on the music till the time she talk to the so on and further to other people that is, hunting tone that is a equivalent of that even now you get ending tone when the exchange is searching for the path .

When the call is through there is a ringing current which also was there it also happen now a days you do get a ringing tone ringing current actually and additionally you actually the sender

or the person who is calling here also being informed that there is a ringing is going on the other side, so you are able to set up the call perfectly.

And then of course the caller ID so all of these where existing in some other form but still there where problem in the manual telephone systems so what was those problems, so problems with telephony was where actually these that you required people that itself is a problem because, peoples their mood actually changes they can be angry they can be upset and they can forget the things.

So that was one fundamental problem itself we wanted something reliable there can be errors is error prone system errors in CDR, errors in connection and of course some time error on seeing the signals henceforth not responding okay it is not the equipment failure ,and of course the worse thing there is no privacy so if you want the privacy in this kind of systems when the communication has happen so you should actually talk in the coded language that's only privacy which you can maintain otherwise there is no privacy.

Operator can actually listen to whatever the communication which is happening and in fact this is what let to the automated, automatic telephonic exchanges and they goes by the name by ABS Strowgers okay, so ABS Strowgers was under writer and of course that time manual telephony was at a speak and he was also most of the time people use to call the underwriters and unfortunately where he was actually connected to an N exchange.

The operator there her husband was also the under writer and what is happened is all the business which was coming was being taken from the hands of the Strowgers to her husband and the Strowgers actually lost and that's when a I think decided that he need to solve the problem and of course with the help of other engineers he came off with the idea of Strowgers actually change.

So that was the first automatic exchange which came in to picture so in the next lecture we will actually look in to this Strowgers thing how actually the Strowgers build up the stuff and also look into how fundamentally the thing actually have evolved from this Strowgers to the cross bar so we will meet, I will actually continue in the next lecture.

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