Data Communications
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Lecture -23
X.25 and Frame Relay

Hello and welcome to today's lecture on X.25 and frame relay. In the last couple of lectures we have discussed about packet switching techniques and also discussed various issues related to packet switching such as routing, congestion control, flow control and so on.

In this lecture we shall discuss about two important examples of packet-switched network such as X.25 which is the oldest one and frame relay. Here is the outline of today's lecture. First we shall discuss the basic features of X.25 then consider the three layers of X.25 then we shall consider frame and packet formats of X.25. We will see that it operates in two layers data link as well as network layer.

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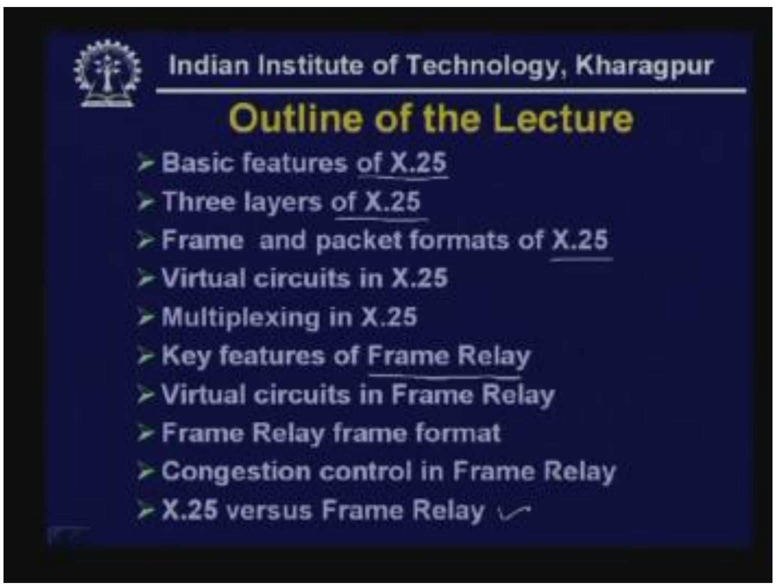

Then we shall consider the virtual circuits that is being used in X.25 for data communication and also we shall consider the multiplexing used in X.25. After that we shall focus our attention to frame relay by first introducing the key features of frame relay why frame relay instead of X.25 then we shall consider virtual circuits used in frame formats and we shall see the congestion control is very important in the context of frame relay and we shall discuss how congestion control is used in frame relay. Finally we shall conclude our lecture by comparing X.25 and frame relay.

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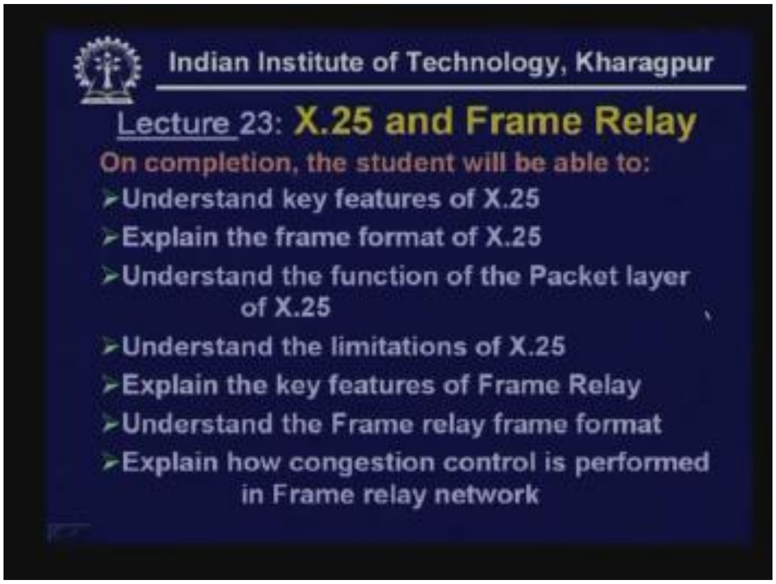

And on completion of this lecture the student will be able to understand the key features of X.25, explain the frame format of X.25, understand the function of packet layer of X.25 and they will also understand the limitations of X.25 and they will able to explain key features of frame relay and understand the frame relay frame format and explain how congestion control is performed in the frame relay network. So let us start with X.25. X.25 is a packet-switched network developed by ITU back in 1976. Of course subsequently several versions have come up several editions by enhancing the features of X.25 but it is the one of the oldest one developed in late 70s.

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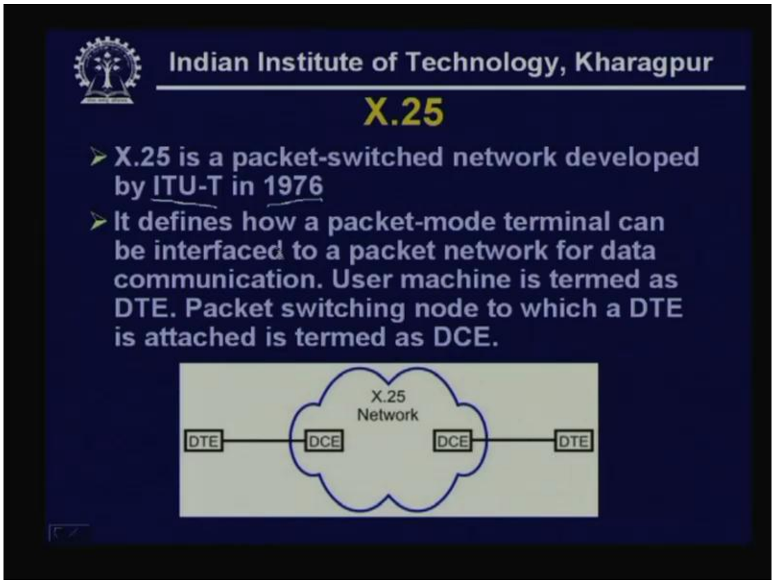

And this particular protocol defines how a packet mode terminal can be interfaced to a packet network for data communication. So here the user machine is termed as DTE as we already know so this is the terminal DTE Data Terminal Equipment (Refer Slide Time: 4:00) and packet switching node to which this data terminal equipment is connected is termed as DCE. We are already familiar with these two terms and as you can see DCE is part of the X.25 network and this particular specification explains in detail how DTE working in packet mode can interface with DCE and perform packet transmission. It has got three layers physical, frame and packet layers.

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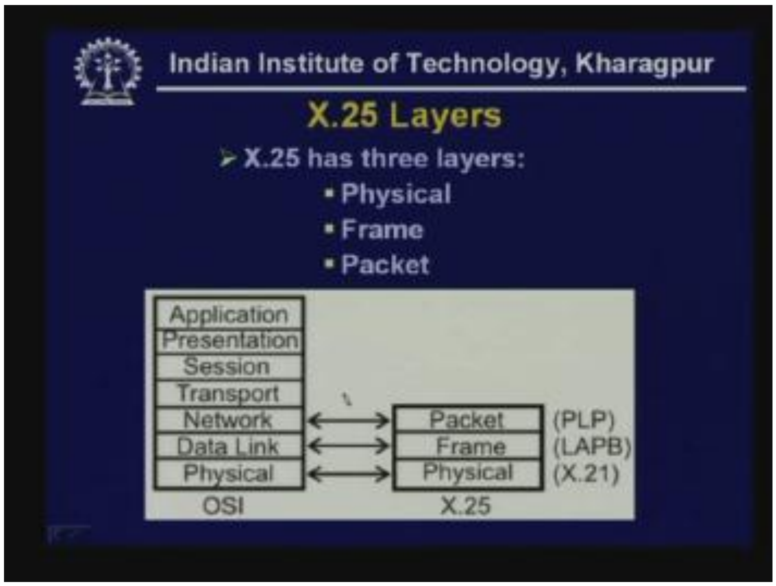

So if you are comparing it with the OSI model it essentially occupies the three lower layers, the physical data link and network layer. And, the physical layer in X.25 is essentially X.21 and then the frame layer uses a subset of HDLC which is known as LAPB, we already mentioned about it and then the packet layer PLP. These are the three layers. We shall consider the functions of these three layers in detail.

Physical layer: as I mentioned it deals with the physical interface between the attached station and the link that attaches that station to the packet switching node. This interface designs the physical, electrical, functional and procedural specification. The X.21 is the most commonly used physical layer in standard what has been recommended for used with X.21. However, in absence of X.21 other standards like RS-232 C can also be used which is analogue in nature and on the other hand X.25 is a digital interface. But this RS-232 C can also be used in place of X.21.

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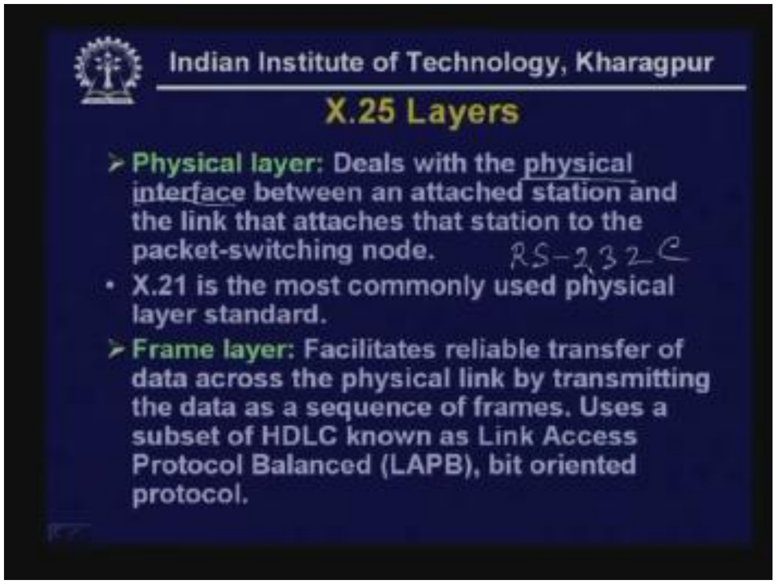

Coming to the frame layer it facilitates reliable transfer of data physically by transmitting the data as a sequence of frames. It uses a subset of HDLC known as Link Access Protocol Balanced (LAPB) it is a bit-oriented protocol as seen in HDLC.

Then the third layer is responsible for end-to-end connection between two DTEs and functions performed are establishing connection, transferring data, terminating a connection and it also performs error and flow control which is important in the context of DTEs. Then with the help of X.25 packet layer data is transmitted in packets over external virtual circuits. We have discussed different types of virtual circuits, here external virtual circuits are used to perform data communication using the X.25 network.

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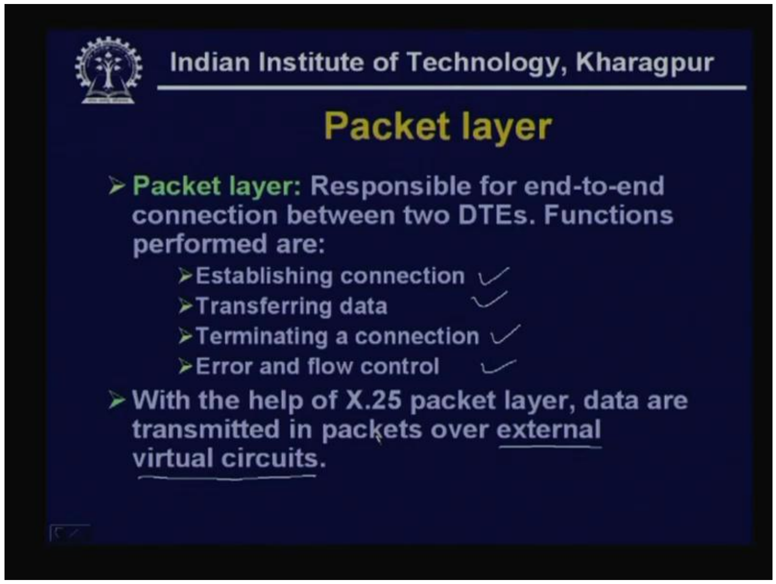

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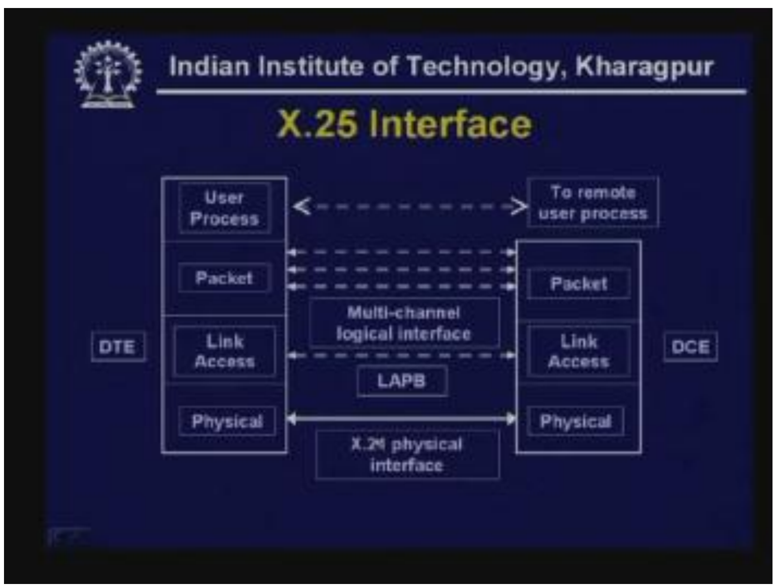

Here it shows the X.25 interface. As you can see this is the DTE this is the data terminal equipment, here is the data communication terminal equipment DCE which is essentially part of the X.25 network. So this interface specifies that X.25 physical interface. As I mentioned we can use RS-232 C in absence of X.21. Then LAPB is used as the logical interface between the link access layers which essentially works in the data link layer and it has got multi-channel logical interface which allows several virtual circuits to be established for communication of data in the packet layer. Then we have the user processors with which you can communicate to remote users by using this interface. So here it specifies the X.25 interface the interface between DTE and DCE. Let us look at the X.25 frame format.

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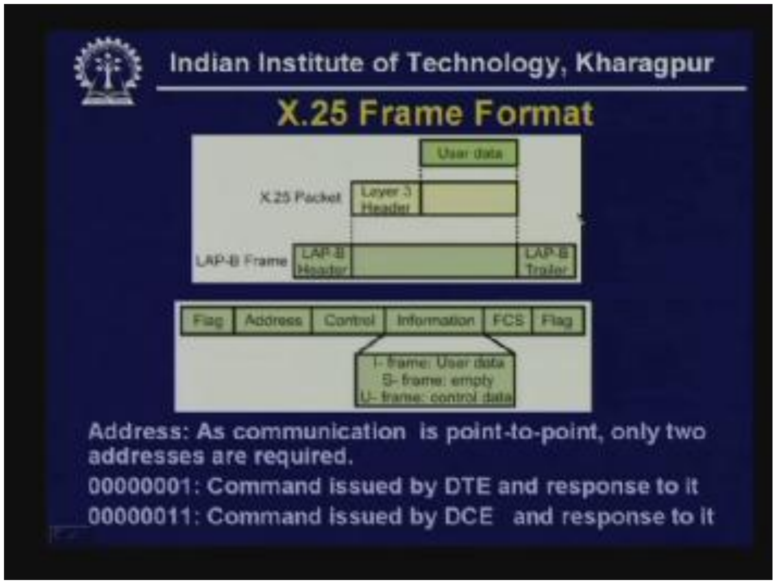

here the user data is used to form a packet in X.25 packet layer by putting header which we may call layer 3 header.as you can see layer three header is attached to user data to form a packet then the packet is passed on to the data link layer and the data link layer adds LAP-B header and LAP-B trailer and this is how a data link layer frame looks like.

A data link layer frame has this kind of format as we have already discussed in the context of HDLC. it has got flags at the beginning and at the end and then the address then the control and information. Then as you know there are three types of frames allowed in HDLC. One is information frame which is used for communication of user data, then S frame which is usually empty not used in the context X.25, then U frame which is used to pass on control information because it uses in-band signaling. In-band signaling is used with the help of these control frames.

One point you should notice that here it is essentially a point-to-point communication so you do not really require many addresses. Only two addresses are used. As you can see here 0000 and 0001 is used by the command issued by the DTE and response to it. That means whenever some comment goes from the DTE and some response to it is given with this address 0000 0001. On the other hand there is a common issued by the DCE and response to it given by the DTE that is given in the address 0000 0011. These two addresses are only used in the context of X.25 because it is a point-to-point communication and not a multipoint communication. However, as we shall see multiplexing can be done in data link layer. We shall consider about it in detail.

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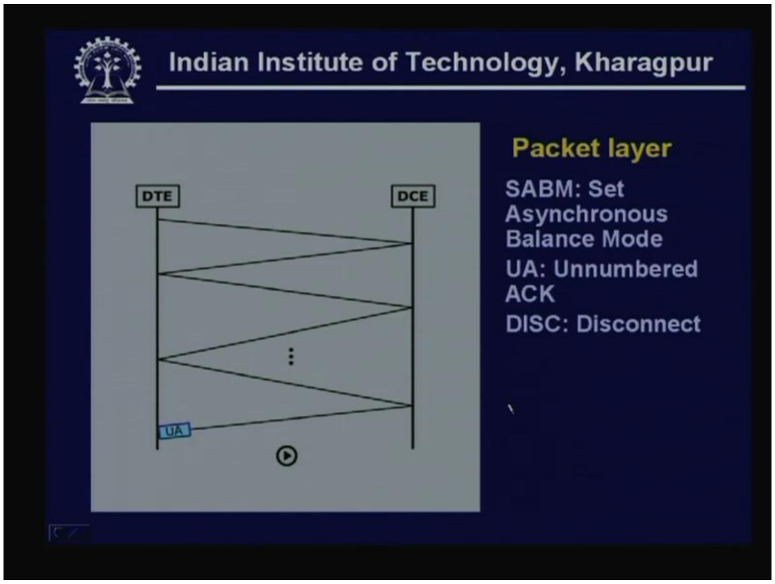

Here it shows how it works in the packet layer. here as you can see asynchronous packet mode is sent and unnumbered acknowledgement comes from the other end for setting up the link and then the data transfer can take place, information frame can go, here unnumbered acknowledgement comes from the other side and not only that but several such data can be transferred before it can be disconnected by sending a disconnect frame. Thus each time this kind of virtual circuit is created by using this protocol. The virtual circuits are created at the packet layer. It uses a virtual circuit identifier known as the Logical Channel Number. So the virtual circuit identifier is used to identify a particular virtual circuit.

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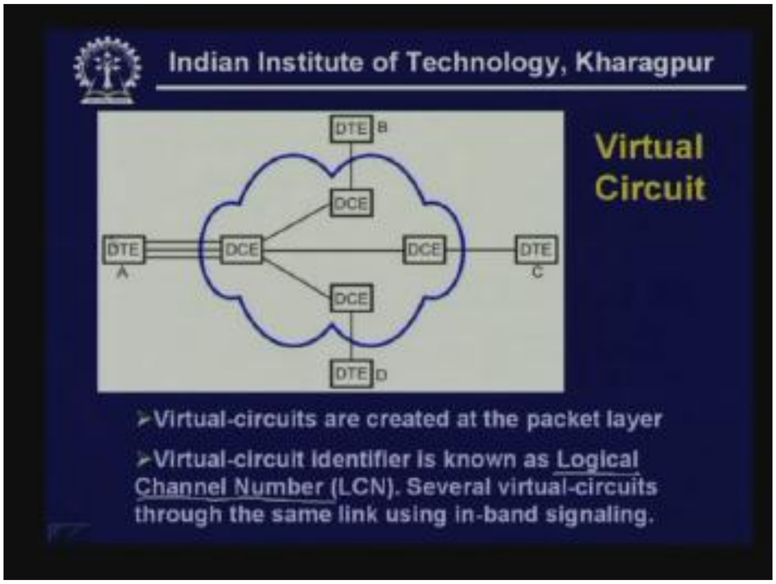

As you can see from this DTEA (Refer Slide Time: 12:21) there are several virtual circuits created. One is going to B, another is going to C and another is going to D simultaneously. And this particular link that is this DTE to DCE this link has three virtual circuits so through the same physical link you can create several virtual circuits which are identified by a Logical Channel Number or LCN. Also, several virtual circuits through the same link using in-band signaling can be created. So this is the fundamental idea of virtual circuit that is being used in packet layer of X.25.

Now there are two types of virtual circuits. That is also used in X.25. One is known as PVC or Permanent Virtual Circuit which is somewhat similar to leased line used in telephone network, that means line always exists there is no need dial to set up the link so it differs from the dial-up link. So always there is a connection whether you send data or not. Similarly here also the Private Virtual Circuit is fixed similar to leased line established by the network or providing this link. Data transfer occurs with virtual calls and packet transfer takes place one after the other and there is no need to have call set up or termination in case of type of Permanent Virtual Circuit.

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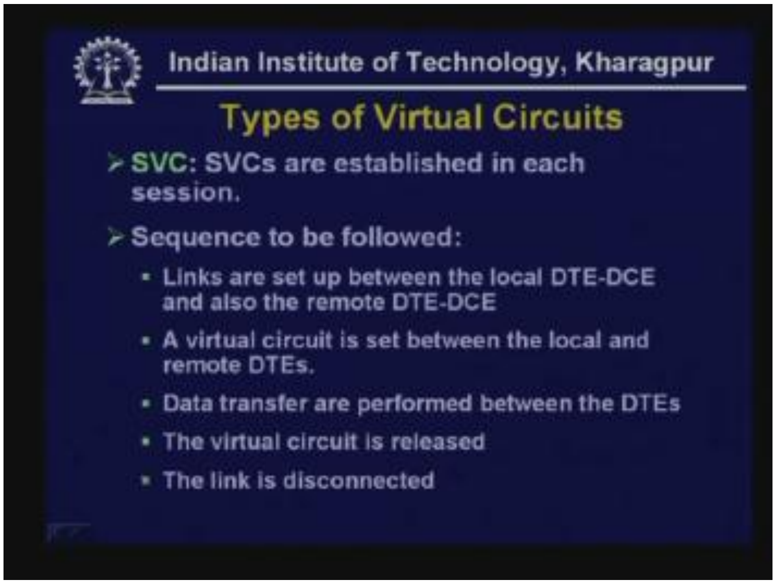

However, in case of Switched Virtual Circuit it is necessary to have link for each data transfer and the sequence of events to be followed are given here. First of all links are set up between the local DTE-DCE and the remote DTE-DCE. That means first a link is established between the local DTE and DCE and also between the remote DTE and DCE that is the first thing that is being done then a virtual circuit is set between the local and remote DTEs. So, after these two local and remote links are established between the DTE and DCE the virtual circuit is set between the local and remote DTEs then the data transfers are performed between the DTEs then the virtual circuit is released and the link is disconnected. This is the sequence that has to be followed for each session of data transfer using Switch Virtual Circuit in X.25.

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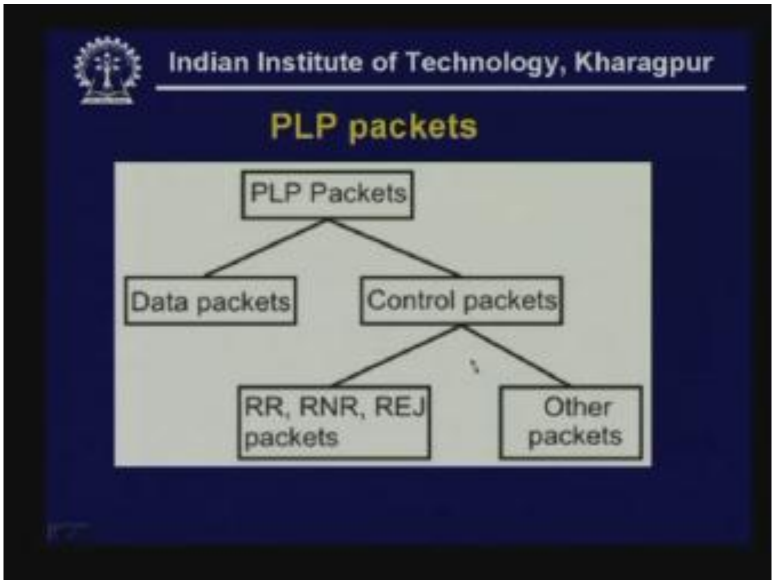

Now let us focus on the different types of packets used in the packet layer. As I mentioned the packet can be of different types; broadly it can be divided into two types; data packets and control packets. Data packets can be essentially used for sending the user data. For user data obviously there is some maximum limit on the size and that limit is used to form the data packets. On the other hand control packets can be used for various purposes. One purpose is to perform flow control and error control. This flow control and error control can be done with the help of packets like RR which stands for Receive Request, RNR stands for Receive Not Request and REJ stands for Reject Packets.

With the help of these three types of packets it is possible to perform flow control and error control but congestion control is not used in X.25. Essentially flow control and error control are performed.

Then the other packets are necessary essentially for in-band signaling. As I have mentioned you have to set up the virtual circuit, perform the data transfer, disconnect the link so all these links can be done with the help of these packets. And as we know the user data are broken into blocks of some maximum size and a 24-bit or 32-bit header is appended to each block to form a data packet. Then it uses sliding-window protocol, piggybacking for flow control. As I mentioned it performed flow control and Go-back-N protocol for error control. So it performs flow control and error control using sliding-window protocol and Go-back-N for error control.

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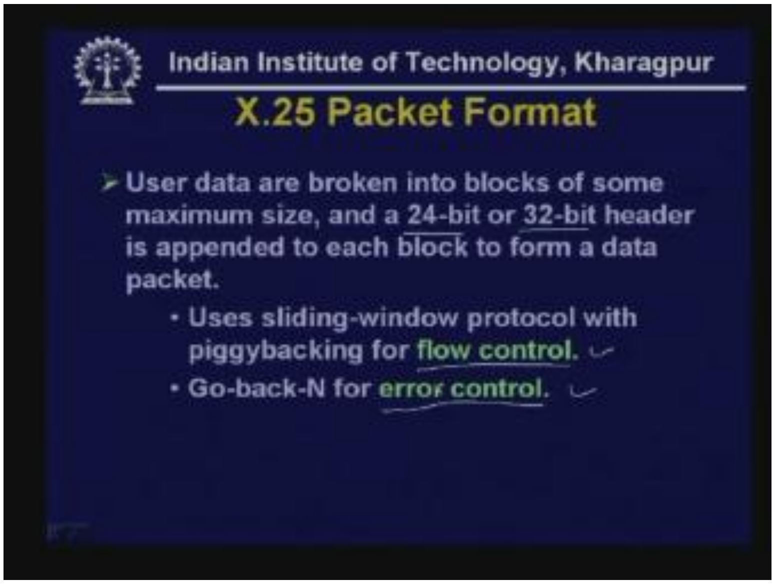

We have already discussed about these two approaches. Now we shall see how this is being implemented in X.25 network. X.25 also transmits control packets related to establishment maintenance and transmission of virtual circuits as I mentioned. Each control packet includes the virtual circuit number the packet type for example call request, call accepted, call confirm, interrupt, reset, restart etc. These are the various control packets that can be sent that can be communicated between the two DTEs and additional control information specific to a particular type of packet. So, in addition to this type of packet some additional information specific to that type may be added to the packet. Thus here is the packet format of X.25 system.

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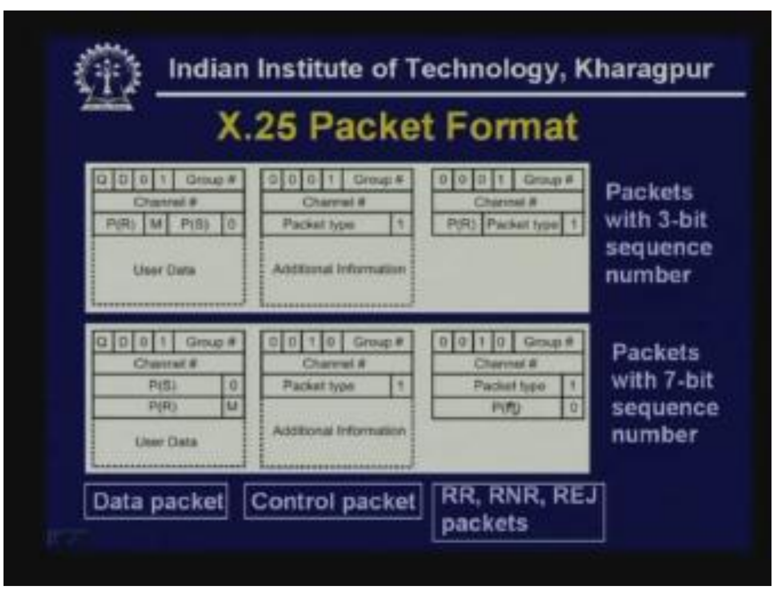

Here you see the packets are divided into two groups. First of all as I mentioned it is divided into three different types; data packet, control packet and RR RNR REJ packets so three different types. And as you can see here the data packet comprises either 3 byte here it is 3 byte and here it is 4 byte and that depends on whether we are using 3-bit sequence number or 7-bit sequence number. So whenever a 7-bit sequence number is used it is necessary to have a 4 byte header instead of 3 byte header. On the other hand whenever 3-bit sequence number is used that means you can have three bits for giving the sequence number or for acknowledgement in the user data or in control packets. So here let me explain different functions of different bits.

This Q bit (Refer Slide Time: 20:15) is actually not used by this layer, it is left to the user to use it properly for some function. On the other hand this D bit is used as an acknowledgement from the remote DTE. That means this bit as we know the acknowledgement or flow control and error control can be performed between in the data link layer as well in the packet layer. So whenever it is in the data link layer it is essentially node-to-node or hop-by-hop basis. On the other hand it is end-to-end flow and error control then it is essentially in the network layer and that is being specified by D. Whenever D is equal to 0 then it is essentially between two adjacent nodes or between the local DCE and DTE.

On the other hand whenever D is equal to 1 then it is used for end-to-end flow and error control so this bit designates that. And essentially this 0 1 or 1 0 is used to differentiate between the different sizes whether it uses 3-bit sequence or 7-bit sequence. Then 12-bit number which comprises of two parts group number and channel number together forms the Logical Channel Number LCN and Logical Channel Number is used to form a number of virtual circuits.

Then the PR and PS these two are used for acknowledgement and flow control. For example, PS is used by the sender, he uses this as the sequence number of the packet and that sequence number can be from 0 to 6 if he uses a 3-bit sequence or it can be 0 to 127 if he uses a 7-bit sequence number. The number cannot be 128 or 8 here. Hence this number is used as sequence number and PR is used essentially for acknowledgement in the piggyback form. That means it uses piggyback acknowledgement using that Go-back acknowledgement using sliding-window protocol. The window size can be 7 or 128 depending on the number of bits used in the PR and PS fields. That is why we will see that PS is not present in this RR, RNR and REJ packets.

When it is Received Request packet it specifies the number the receiver is waiting for or is looking for. that means it specifies the number or whenever it is RNR that means that packet has been corrupted and whenever it is rejected it is using the error control that packet has to be rejected by using the Go-back-N ARQ technique. These are the functions.

On the other hand whenever you are using a large sequence of packets that end-to-end acknowledgement can be done either at the end or for each of the packet. So it is a usual practice to send an end-to-end acknowledgement after the end sequence of the packet is being specified by M bit. Whenever this bit is equal to 0 1 then essentially it specifies that the end of sequence has occurred and end-to-end acknowledgement is sent.

On the other hand whenever it is 0 then you are using the sequence and for each of the packet acknowledgement is being sent. So we have seen the function of different fields of this packet layer. Now one point I should emphasize on is multiplexing that is being used in case X.25. This is one of the most important services provided by X.25.

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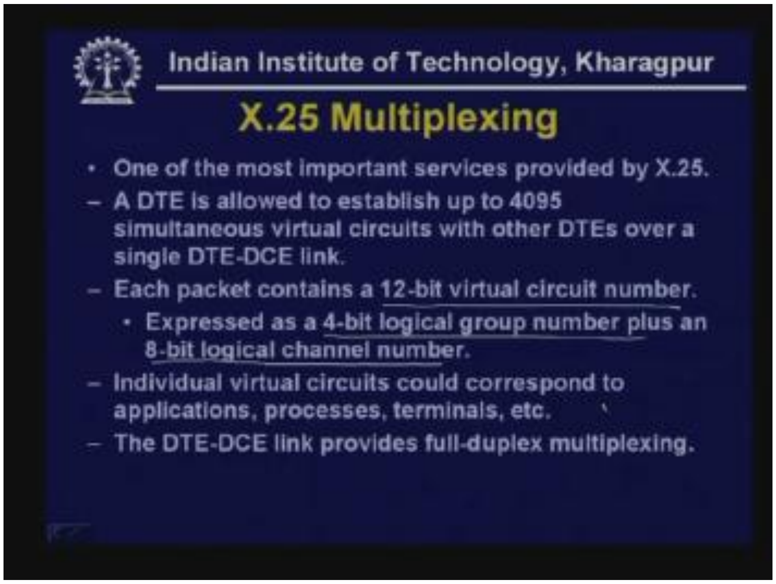

As we have seen DTE is allowed to have up to 4095 simultaneous virtual circuits with other DTEs over the single DTE-DCE link as we have already seen with the help of the 12 bits in the packet, this 12-bit group number and channel number and with the help of these bits up to 4095 virtual circuits can be created. Each packet contains a 12-bit virtual circuit number expressed as four bit logical group number plus an 8-bit Logical Channel Number as I have mentioned.

Individual virtual circuits could correspond to application, processes, terminals etc so you can divide them as per the application or processes or terminals. The DTE-DCE link provides full-duplex multiplexing. That means data communication can be done in both directions and not just in one direction through the same link by using in-band signaling.

So we have discussed in nutshell the various functions of X.25 and we have seen how it really works. Now X.25 was developed back in 1976 where the speed of the telephone network was not very high, only 64 kilobits were sent was the standard, only 64 kilobit it is not very high number in today's context moreover the links were very error prone, as a result it was necessary to have elaborate error control and flow control mechanism which however is not ready not really required in present day context that assured the development of a faster packet switched network known as frame relay. We shall discuss about it now.

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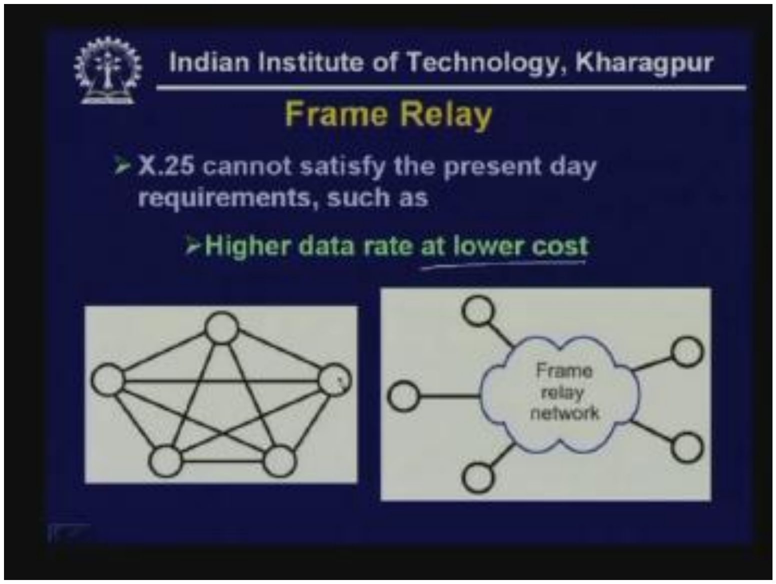

X.25 cannot satisfy the present day requirement such as higher data rate at lower cost. For example, if we use X.25 network since it is a point-to-point network communication if four stations want to communicate to each other we have to set up this kind of point-to-point link. So, if there are five nodes which wants to communicate with each other you will require ten different links. This can be avoided in frame relay network. So in a frame relay network as you can see each DTE is connected to a data communication network and the frame relay network does the remaining thing.

So here it is not point-to-point communication. Here (Refer Slide Time: 28:07) it works like a switched communication network, the nodes can communicate with each other and it does the switching. So, as a consequence it is much more efficient. Moreover that data rate is much higher in the case of frame relay. For example, compared to 64 Kbps used in X.25 the frame relay uses minimum of 1.544 Mbps. nowadays higher data rates can also be used but that was the minimum value with which it was started so speed is significantly higher.

Another important point is the X.25 does not support bursty nature of data. It establishes a point-to-point communication and the data flow has to be streamed or continuous. But unfortunately the present day context it is necessary to have bursty nature of data because the computer communication uses bursty nature of data.

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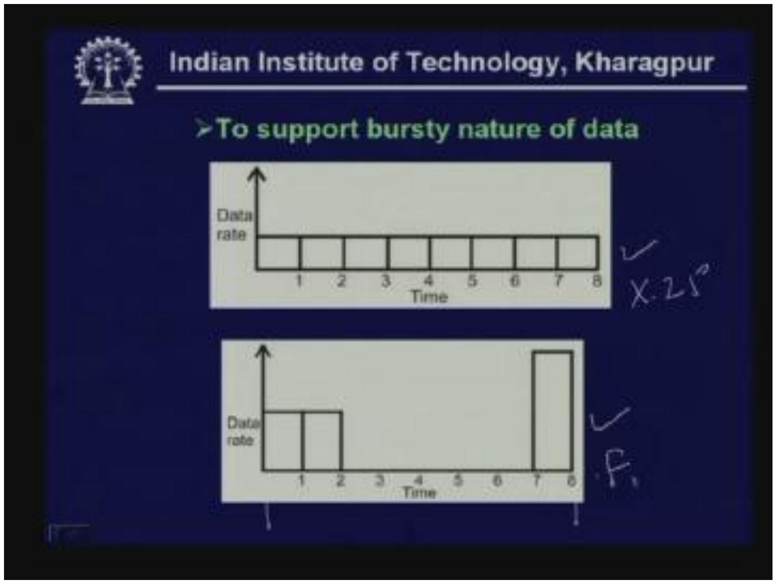

For example, this is the stream data flow and this is the bursty nature of data flow. And the frame relay has been designed to support the bursty nature of data. So the data can be sent in burst as you can see within some time say 8 may be millisecond the data is coming in say 3 bursts compared to stream data that is used in X.25 so here frame relay support this by buffering the data. And as we shall see, if the total value of data does not exceed some limit then the packets should be delivered without error.

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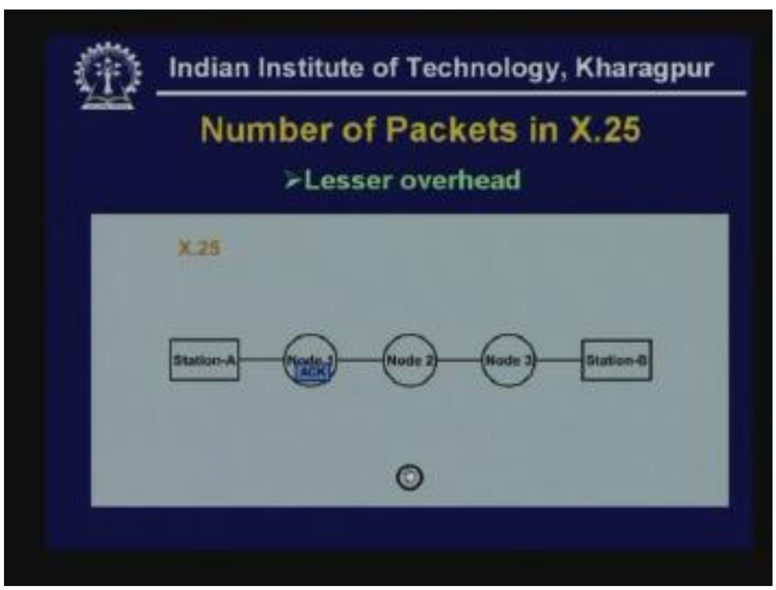

Third important factor is, as i mentioned in the era of X.25 network was not reliable. The links were error prone, slow and as a consequence it was necessary to perform flow control and error control not only between end-to-end but between each link as you can see here. So here as you can see the data is going from station A to node 1 and then acknowledgement comes which are used for flow control and error control then if it is correct then the data goes to the next hop and again acknowledgement is sent from that particular side. Similarly from node 2 to node 3 data goes and acknowledgement comes from node 3 to node 2 to perform flow control and error control then node 3 to station B data goes and acknowledgement comes. The story does not end there.

As we have seen there should be end-to-end flow and error control and that is being performed by sending acknowledgement from the DTE of the other side and again the same is repeated between each hop as you can see. Then the acknowledgement goes between each hop and the acknowledgement frame goes from node 2 to node 1 again acknowledgement of that comes node 1 to node 2 and finally acknowledgement reaches the DTE. So here it completes the end-to-end flow and error control.

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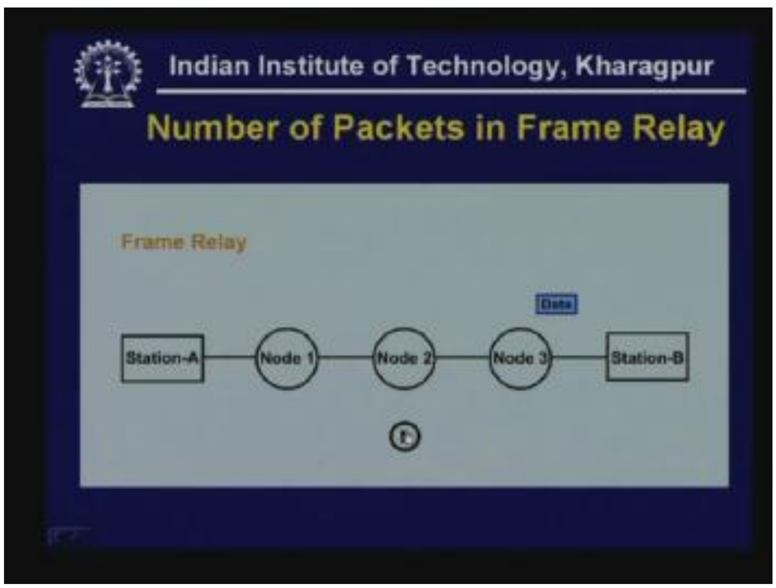

Therefore what you see is, to send a single packet how many packets have been transferred, it increases the load in the network although it makes it very reliable but increases the load significantly. So in the era of X.25 this was necessary because the links were not reliable. However, in the context of frame relay this is not necessary. So what was done was the flow and error control was completely removed not only the data link layer but also in the frame layer.

So as you can see the traffic significantly reduced here so data goes from a station A to node 1 and again data goes from one node 1 to node 2 and data goes from node 2 to node 3 and finally it is delivered to station B. So if any flow and error control is necessary that has to be supported by upper layers, the frame relay does not supported it because it is not necessary, the links are much more reliable and flow and error control may not be required and also the speed is high.

But as we shall see it will be necessary to perform congestion control because of higher speed. In frame relay also the virtual circuit is identified by a number called data link connection number. Here also it is based on virtual circuit, creation and there are two types of virtual circuits as we can see the Permanent Virtual Circuit and the DLCIs the Data Link Connection Identifiers are permanent and assigned by the network provider. So the network provider provides these DLCIs and there is a Permanent Virtual Circuit created from this station A to station B or DTE A to DTE B and this particular link (Refer Slide Time: 34:04) from A node 1 the DLCI is 75 and between these links DLCI is 85. So these numbers will be different for different links. On the other hand whenever the Switched Virtual Circuits are created the DLCIs are temporary. The data link connection identifiers are temporary and are assigned by the frame relay that means the network does the assignment during the connection phase.

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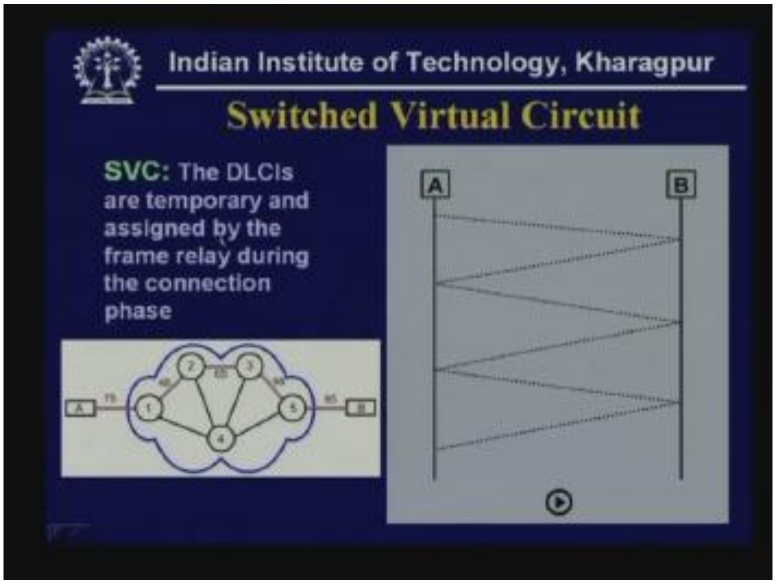

As you can see for communication from A to B these two DTEs the DLCI here is 75, here from 1 to 2 it is 48, from 2 to 3 it is 65, from 3 to 5 it is 98 and from 5 to B is 85. This is being set up in a dynamic manner as you can see. A set of phase is involved for setting up the virtual circuit and connection is established after that data transfer is performed, several packets can be communicated and finally the link is released as it is done in case of X.25. So this part (Refer Slide Time: 35:33) somewhat similar to X.25. Now let us see how the switching takes place within the network.

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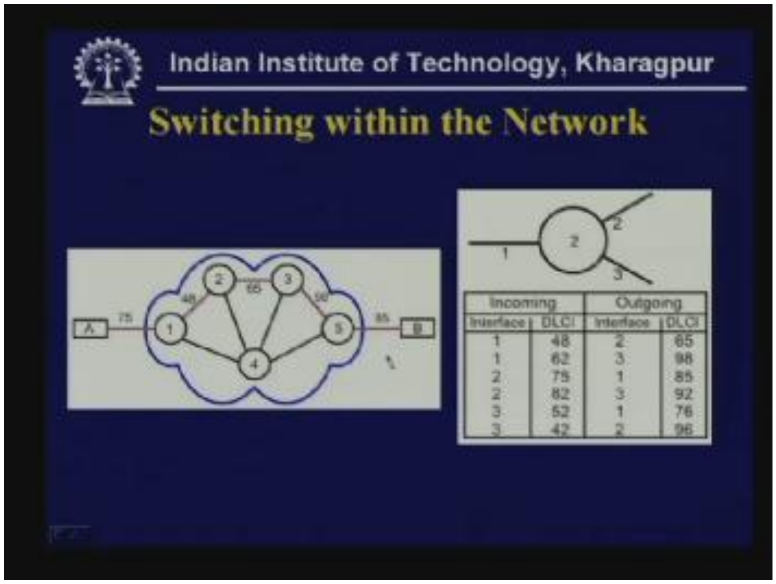

Here each node maintains some kind of table somewhat similar to the routing table. As you have seen in case of fixed routing the routing tables are stored in each node so a similar thing is done in this case also. Here you see (Refer Slide time: 36:04) this node 2 this node or the frame relay switch is shown in an expanded form and here you see the table that is being stored. That means it has got three interfaces coming from one, then another is two and another is three. This is the node or switch two. So, interface one this is the incoming so when it goes from one to two the DLCI is 48 and the outgoing DLCI is 65 and whenever it is going to three the DLCI is different that is 62 and the interface that goes is 3 DLCI is 98.

When it comes from the other direction that means comes from two to one when it goes in the reverse direction the DLCI numbers are different, that is how the full-duplex communication can be done. So here it is 75 and it is 85 similarly from 2 to 3 it is 82 and 92, from 3 to 1 this is 52 and 76 these are the DLCI numbers and from 3 to 2 is 42 and 96.

Therefore you can see how the DLCI numbers are used to do the switching and using this particular table the switching is done in case of this virtual circuit switch. So within the network each node performs this kind of switching. The frame relay operates in two layers compared to three layers used in X.25. So you can see here, this is the frame relay it got two layers physical and data link and the upper layers are provided by others may be by IP protocol.

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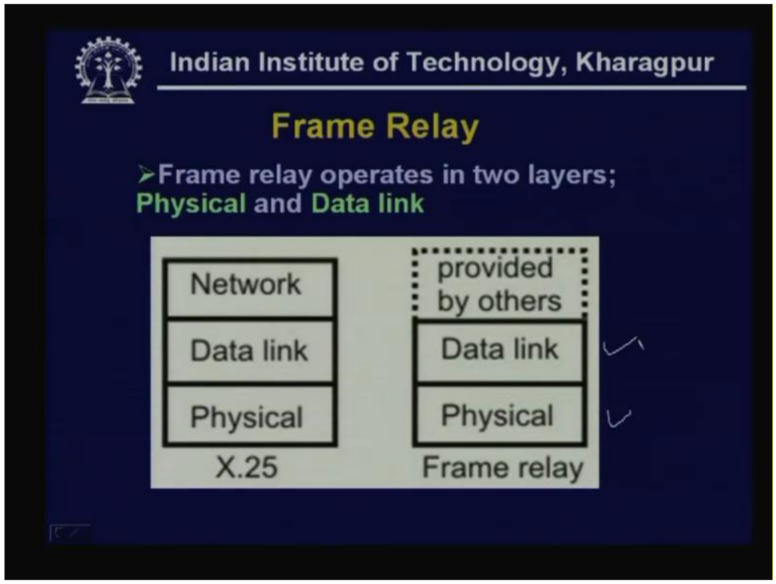

On the other hand X.25 also supports the network layers, it has got three layers as we have already discussed. With the help of these two layers the communication is performed. And the frame format used in frame relay is shown here.

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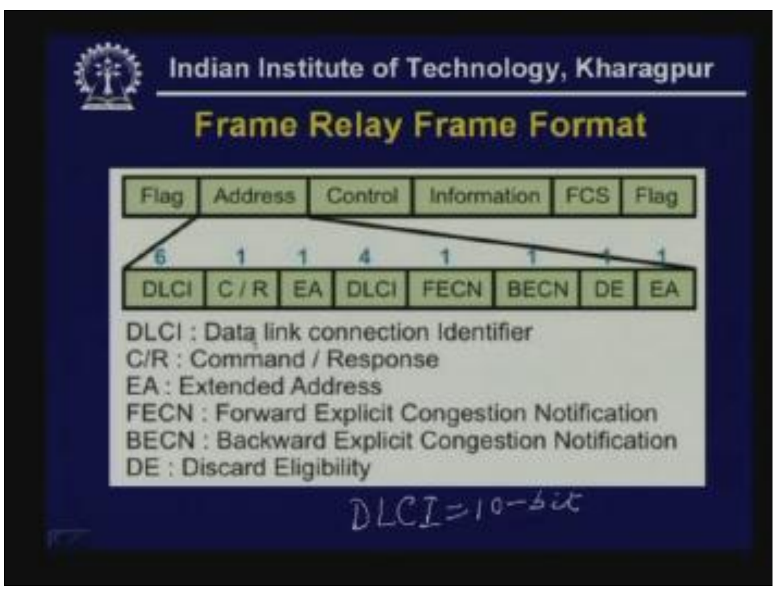

It has got flag at both ends then the address, control, information and frame check sequence. Here the DLCI comprises of ten bits so DLCI comprises of ten bits. So you can have up to 1k DLCI numbers. Then you have got another bit which says whether it is a command or response, this bit specifies whether a particular frame corresponds to command or a response then this EA stands for Extended Address. It is not necessary that the DLCI number has to be restricted to a 10-bit number but it can have more number of bits. In that case the EA bit is used; it is set to 1 whenever it has got a larger address. Then FECN, BECN and DE these are used in the context of congestion control. So although a frame relay does not perform flow control and error control it performs elaborate congestion control. Let us see later on about how it is done.

The congestion control that is performed is explained here. Because of higher data rate and no use of flow control frame relay network is prone to congestion. The basic reason for congestion is bursty nature of data and the frame relay has been designed to support bursty nature of data, the link speed is high so these two parameters has made it vulnerable to congestion and as a result it necessary to have to congestion control mechanism developed for frame relay. It is done in this manner.

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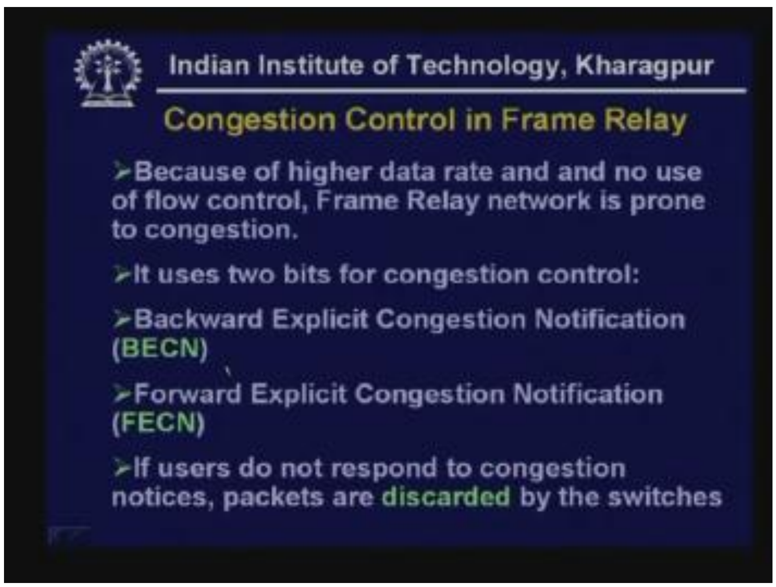

It uses two bits for congestion control. One is Backward Explicit Congestion Notification BECN bit and another is Forward Explicit Congestion Notification FECN. And also another bit is used; it uses another bit that is DE Discard Eligibility bit which is used for packet discarding. That means whenever other things do not work then this discarding is performed. Let us see how it is being done.

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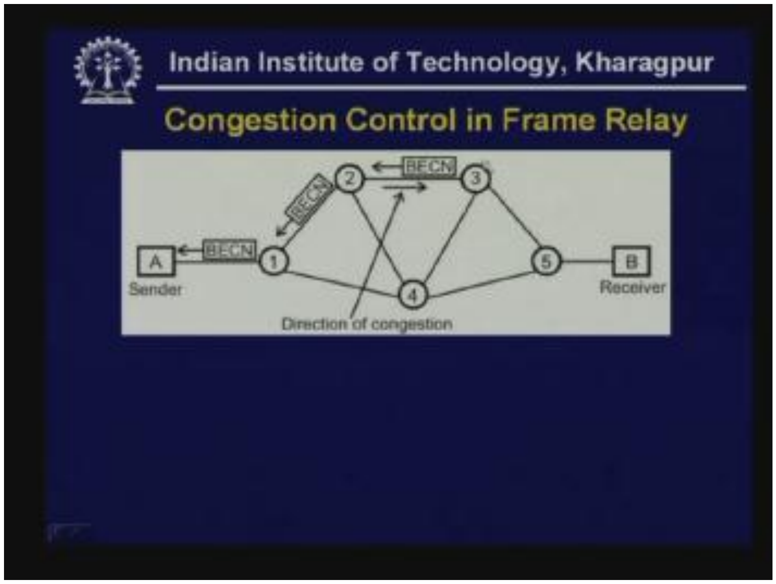

Thus the packet is going from this sender in this direction and it has been found that this part that is beyond three in this direction there is congestion. So this particular switch is identified by some means. This identifies whether congestion has taken place in the forward direction so each switch or node does. So whenever it identifies that congestion has occurred then it sends one explicit packet BECN to the source. So it goes towards the source and the sender in that case takes suitable measure which reduces the traffic reduces the rate of packet that is being introduced to the network to come out of congestion. This is the use of BECN bit (Refer Slide Time: 42:38) for controlling congestion. Then comes the efficient bit. So here you see there is this Forward Explicit Congestion Notification. This bit is used to inform the receiver.

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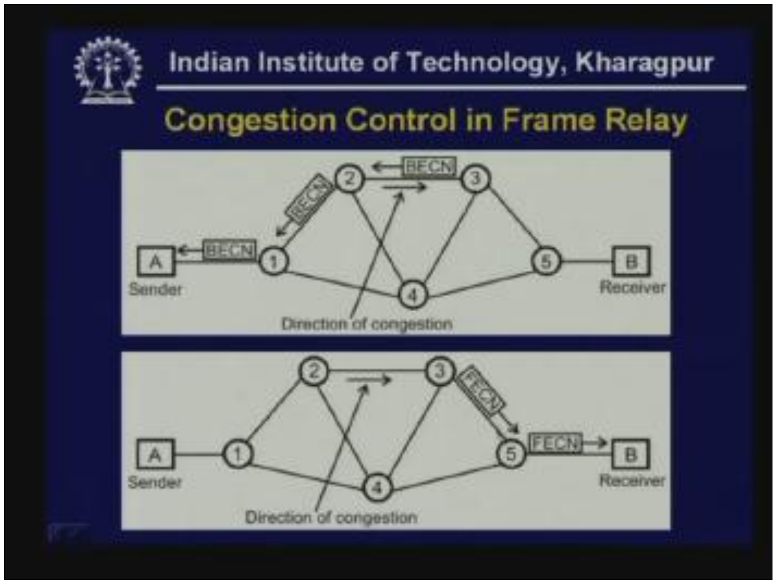

So, whenever there is congestion in this part of the network then this bit is set, this is the direction of congestion (Refer Slide Time: 43:14) in both cases as you can see, then the receiver is alerted about the congestion. Now it is up to the receiver to inform the sender by sending a packet that it is necessary to perform flow control so that it can come out of congestion. Therefore by using these two bits BECN FECN you have got four possibilities, when these two bits are 0 0 it means there is no congestion in either direction. Then whenever it is 0 1 or 1 0 there is congestion only one in one direction.

On the other hand whenever these two bits are 1 1 there is congestion in both directions. So, by using these two bits the congestion control can be done. However, whenever this does not work then this Discard Eligibility DE bit is used. How it is used? This bit gives the priority which means whenever it is set to 0 it is set to 0 for some packets and it is set to 1 for some packets.

That means whenever it is using this particular bit whenever it is set 1 it means they have lower priority where these packets can be discarded. So it essentially sets a priority in the packet. In case of congestion the packet has to be discarded and based on this bit the packets are discarded by the switches. And as you already know the packet discarding is a very important mechanism used for congestion control particularly when you have to come out of congestion.

Now you may be asking how do you find out that congestion has taken place or when to send FECN or BECN bits by a packet? For that purpose it is necessary to perform traffic control measurements. Each switch performs some kind of measurement on the network and based on that it will decide when to send FECN or BECN and for that purpose four attributes are used.

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First one is known as access rate. It is decided by the bandwidth of the channel that means it is the maximum rate of introduction of packet. For example, if the T_1 line is used then the maximum rate is 1.544 Mbps. That means if a particular node sends a packet at a rate faster than this then we can say that access rate has been violated.

The second parameter is committed burst size B_c which is the maximum number of bits in a predetermined period. It does not say that you have to send at this rate. It may be necessary, for example, in 5 millisecond or may be 5 seconds how many bytes can be introduced by a particular source node that is specified by this committed burst size. So may be this is the duration and within this duration it can be introduced in the form of bursts. And as long as the total size does not exceed the committed burst size it is guaranteed that the packets will be delivered without error.

Then the third parameter that is being used is Committed Information Rate. It defines the average number of bits per second that means it performs the averaging and finds out whether the average number of bits is essentially related to the access rate and this parameter is also specified in the beginning and if the average number of bits per second is not exceeded then it is guaranteed that the packets will be delivered without error. On the other hand it is exceeded then the switch will inform the sender that the Committed Information Rate has been exceeded.

Another parameter is excess burst size. This is the maximum number of bits in excess of the B_c where already the committed burst size is there. The network allows in addition to B_e some more before it decides to send FECN or BECN. That means in addition on top of BECN, suppose this is the limit of the BECN, so this is B_c and this is the B_e (Refer Slide Time: 48:28) so this much of excess is allowed by the frame relay network. But this is loosely bound on the sides but usually the committed burst size is more important than the excess burst size but in any case the burst size should not exceed this excess burst size.

Thus we have discussed how the traffic control is performed and how it is used to decide when to send the congestion control particularly by sending FECN and BECN. Now frame relay has been designed not only to support or send frame relay packets but it can also send packets coming from other networks.

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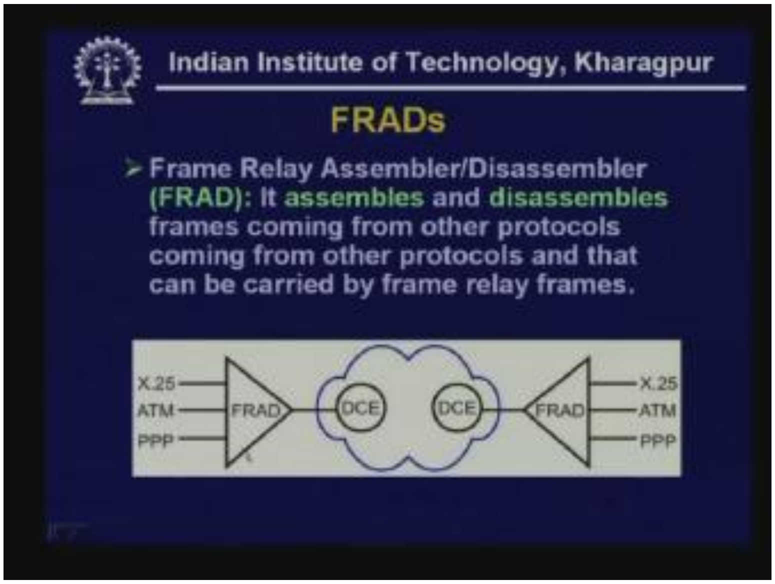

For example, X.25, ATM or PPP point-to-point so for that purpose special functionalities known as FRAD Frame Relay Assembler Disassembler is introduced because the frames of other types of standards or network like X.20 or ATM or PPP may not be the same as that of frame relay. So what the FRAD function does is, it disassembles the packets sends through the frame relay network, and then at the other end it performs the assembly. This is your frame relay network (Refer Slide Time: 50:00). Thus both assembly and disassembly are performed by two ends so that you can send packets coming from other protocols and that can be carried using the frame relay frames.

Thus the Frame Relay Assembler Disassembler assembles and disassembles frames coming from other protocols which can be carried by frame relay frames. This function **relate is** provided and which shows that it can be made compatible with X.25 ATM and other packet switched networks.

Before I conclude today's lectures it is time to compare the functionalities of X.25 and frame relay packet switched network. We shall compare the features.

First one is connection establishment. As we know in X.25 connection establishment is done by network layer. On the other hand it is not done by the frame relay it is done upper layers. Then the flow and error control is performed in X.25 both at data link as well as network layer hop-by-hop and end-to-end. On the other hand frame relay does not perform any flow and error control and for X.25 the data rate is fixed on the other hand frame relay supports bursty nature of data. The multiplexing performed by X.25 is in the network layer on the other hand frame relay performs the multiplexing in the data link laye. as we have seen it is done by using DLCI and here it is done by Logical Channel Number. Congestion control is not necessary in X.25 because of elaborate use of flow control and error whereas it is necessary in frame relay.

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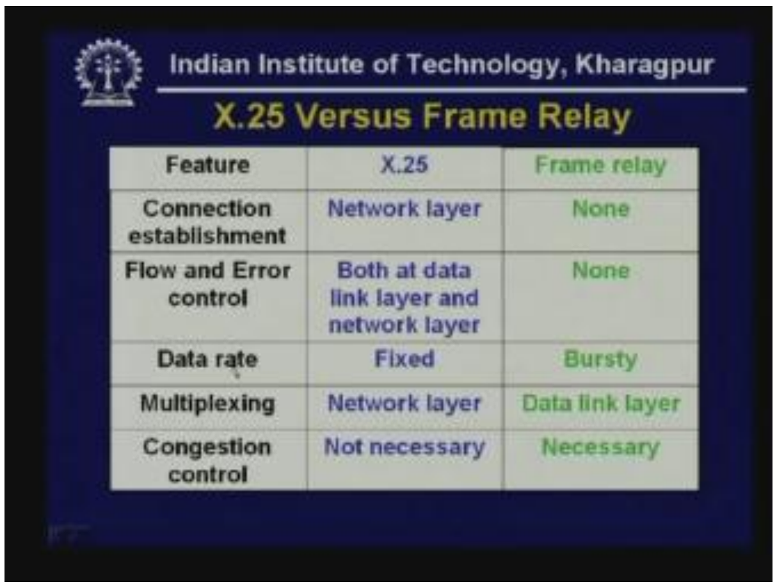

Feature	X.25	Frame relay
Connection establishment	Network layer	None
Flow and Error control	Both at data link layer and network layer	None
Data rate	Fixed	Bursty
Multiplexing	Network layer	Data link layer
Congestion control	Not necessary	Necessary

So it compare these two packet switched network we have discussed today. Now it is time to give you the review questions.

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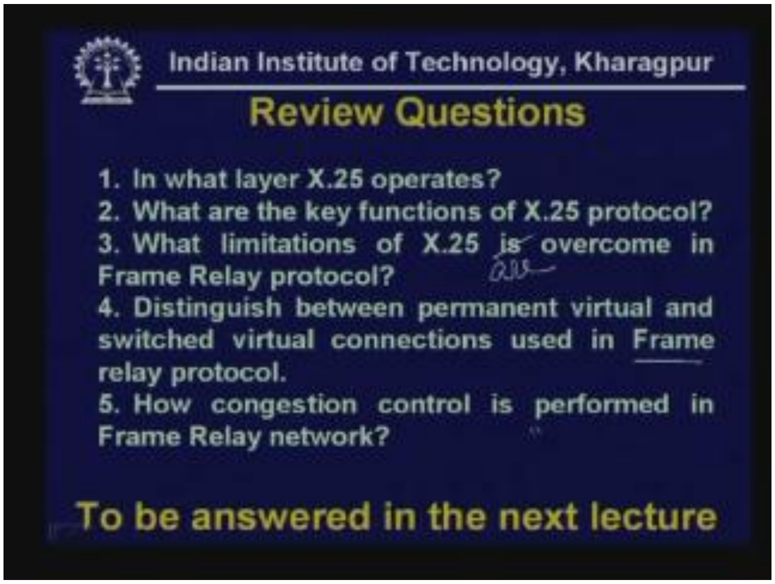

1) In what layer X.25 operates?
2) what are the key functions of X.25 protocol
3) What limitations of X.25 are overcome in frame relay protocol?
4) Distinguish between permanent virtual and switched virtual connections used in frame relay protocol
5) How congestion control is performed in frame relay network?

Now it is time to give the answers to the questions of lecture – 22.

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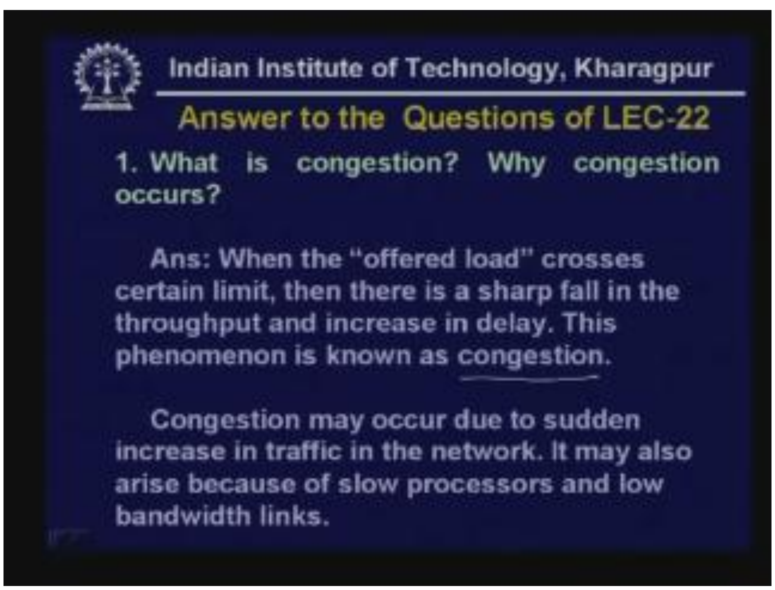

1) What is congestion? Why congestion occurs?

When the offered load crosses certain limit then there is sharp fall in the throughput and increase in delay. This phenomenon is known as congestion. As there is sudden increase in the load congestion arises. In that situation whenever link utilization exceeds beyond 80% then it is used as rule of thumb for identifying congestion. Congestion may occur due to certain increase in traffic in the network, it may also arise because of slow processors and slow bandwidth lengths.

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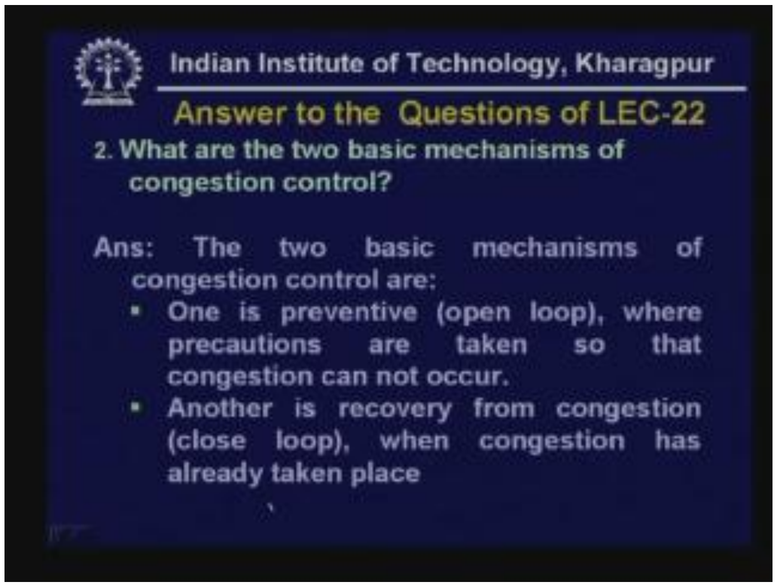

2) What are the two basic mechanisms of congestion control?

As we know there are two mechanisms of congestion control. One is preventive based on open loop technique such as the Leaky bucket algorithm or token bucket algorithm where precautions are taken so that congestion cannot occur in the first place. On the other hand another approach is based on the recovery from congestion by using close loop congestion control techniques when congestion has already taken place. We have discussed various techniques such as choke packet and so on.

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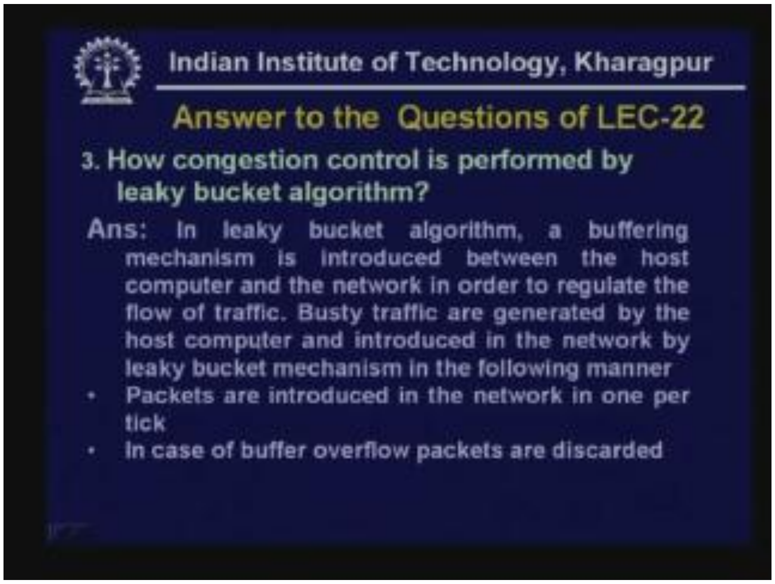

3) How congestion control is performed by Leaky bucket algorithm?

In Leaky bucket algorithm a buffering mechanism is introduced between the host computer and the network in order to regulate the flow of traffic. Bursty traffic is generated by the host computer and introduced in the network by Leaky bucket mechanism in the following manner. Packets are used in the network in one per tick. In case of buffer overflow packets are discarded.

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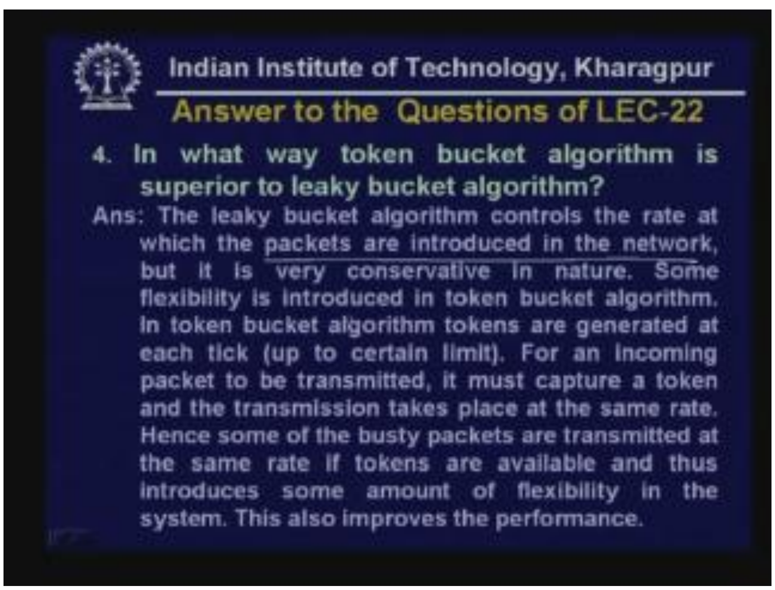

4) In what way token bucket algorithm is superior to Leaky bucket algorithm?

Leaky bucket algorithm controls the rate at which the packets have been introduced in the network, but it is very conservative in nature. Some flexibility is introduced in token bucket algorithm. In token bucket algorithm tokens are generated at each tick up to certain limit obviously based on the size of the counter. For an incoming packet to be transmitted it must capture a token and transmission takes place at the same rate. Hence some of the busty packets are transmitted at the same rate if tokens are available and thus introduce some amount of flexibility in the system, this also improves performance.

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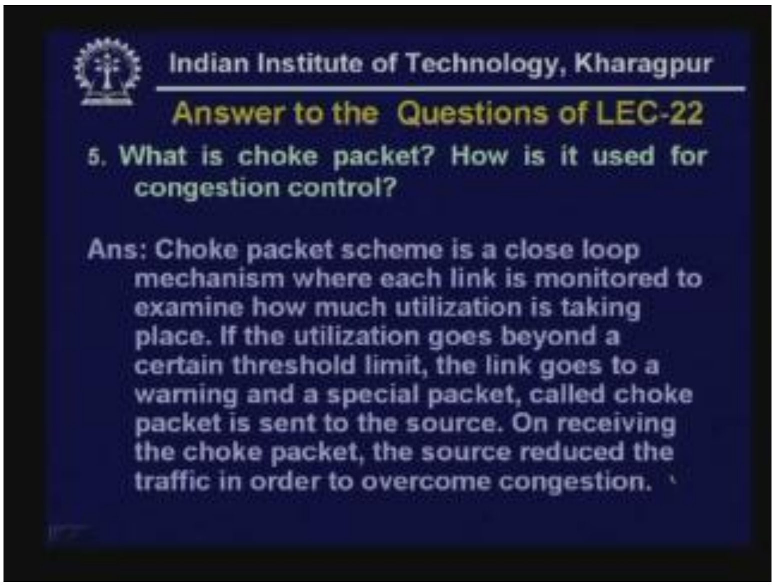

5) What is choke packet? How it is used for congestion control?

As we know choke packet scheme is a close loop mechanism where each link is monitored to examine how much utilization is taking place. If the utilization goes beyond a certain threshold limit the link goes to a warning state and special packet called choke packet is sent to the source. On receiving the choke packet the source reduces the traffic in order to overcome congestion.

With this we come to the end of today’s lecture. In the next lecture we shall discuss about another packet switch network that is ATM, thank you.