Data Communications
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Lecture - 24
ATM

Hello and welcome to today's lecture on ATM. in the last lecture we discussed about two important packet switched networks X.25 and frame relay. In this lecture we shall discuss about another very important packet switched network that is your ATM. In fact ATM is the most popular packet switched network today. Let us see the outline of today's talk.

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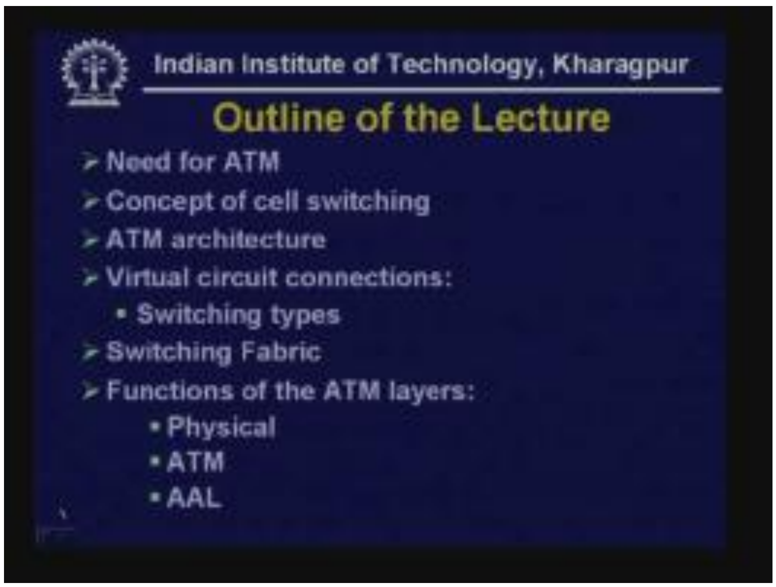

First I shall discuss about the need for ATM, what is the requirement for ATM then the one very important concept that is being used in ATM that is cell switching. I shall elaborate on the concept of cell switching then focus on ATM architecture. And as we shall see ATM is based on Virtual Circuit Connections. We shall discuss how virtual circuits are set up or what are the different types of virtual circuits used in ATM and also discuss about the switching type used in ATM. We shall also discuss about the physical layer device that is the switching fabric used in ATM. ATM has got three different layers; physical, ATM and AAL .we shall discuss about the functions of these three layers in detail.

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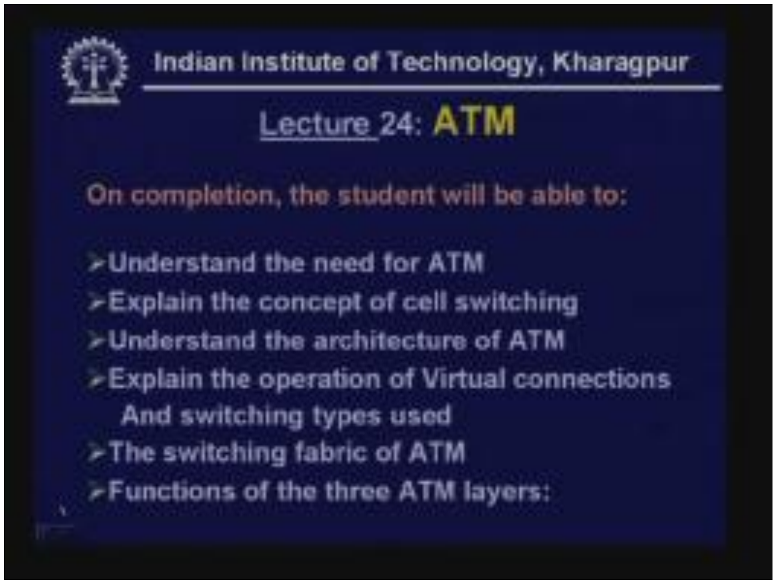

And on completion the students will be able to understand the need for ATM, they will be able to explain the concept of cell switching, they will understand the architecture of ATM, they will be able to explain the operation of virtual connections and switching type used in ATM and they will be able to explain the functions of switching fabric of ATM and again as I mentioned they will be able to explain the functions of the three ATM layers namely the physical, ATM and AAL.

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So let us start with, the need for ATM. if we look at the existing technologies you will find that it has got several limitations. First one is the different protocols uses different frame sizes. The size of the frames can be small, can be large, in other words the frame size is variable. And for complex network information carried in the header is extensive leading to inefficiency. That means the information carried in the header, header is quite big and it contains lots of information, and as we know the bigger the header it is essentially overhead on the network. So bigger header leads to higher overhead and this leads to inefficiency.

To reduce inefficiency the size of the data field is increased or it is made variable. Variety of frame sizes creates traffic and unpredictable and inconsistent data rate delivery. That means whenever the frame sizes are different it will make the data traffic unpredictable as, when a particular frame will reach, how long it will take, what will be the delay etc so it becomes unpredictable and as a result data rate delivery cannot be ensured. And as we know TDM is Time Division Multiplexing which is commonly used to make use of the broadband technology because the transmission media with higher bandwidth that is being used would like to make use of the broadband technology and for that purpose Time Division Multiplexing is commonly used.

ATM technology has been developed to overcome some of the limitations that I have already mentioned.

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And the most important design features of ATM are mentioned here. First of all it makes use of the high bandwidth transmission media which has lesser probability of error. Most of the earlier protocols for example X.25 when frame relay uses transmission media of lesser bandwidth for example twisted pair or coaxial cable. On the other hand ATM uses optical fiber. In other words, nowadays optical fiber is the most popular transmission media available today and as you know the optical fiber has got very high bandwidth and the probability of error is much reduced. That means the frames that are transmitted through the transmission media is less prone to error. So we have to exploit these two features in ATM that is one design goal. And we have the interfacing capability with existing systems. Obviously whenever we go for new technology having high bandwidth, low data rate, low error probability we have to also be able to use the interface with the existing system so that the data coming from the existing systems can be transported through ATM. And also it is necessary to have cost effective implementation.

As already discussed our telecom industry uses some hierarchies like T_1 T_2 T_3 and so on so the ATM should support these hierarchies and that was one of the design features. As we know most of the circuits are circuit switched. For example, our public telephone system is circuit switched. On the other hand, the circuit switch network has got a number of limitations that is why it is essential to have packet switched network, however, it should be connection oriented that means it must be based on virtual circuit switching concept to ensure accuracy and predictability which cannot be ensured by datagram techniques.

There is more functionality in hardware than in software for higher speed. Also, one of the design goals was that most of the functionalities will be implemented with the help of hardware rather than software so that it is fast and can be implemented with lower cost. Let us look at the limitations of the variable size frame multiplexing. here we see that in the present day technology the frames are variable sized, so whenever there is a big frame in front of a small frame, for example A is much bigger frame than B_1 or C_1 and because A takes quite a long time to go through the medium then B_1 will suffer much longer delay.

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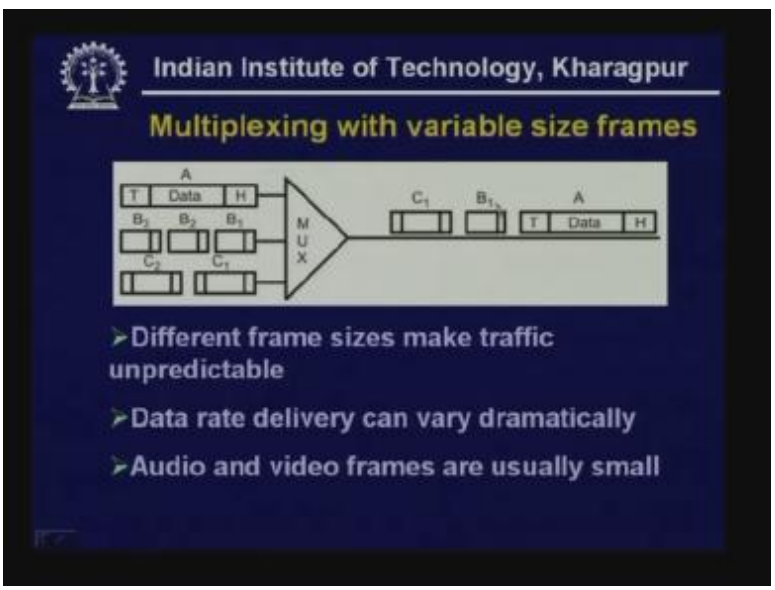

That means different frame sizes make traffic unpredictable and data rate delivery can vary dramatically. This cannot be tolerated by real time traffic for example video, voice whenever it is communicated these cannot be tolerated, for example audio and video frames. Moreover, as we shall see the frames used by audio and video are smaller in size so the present day technology X.25 or frame relay does not really exploit the very small size of audio and video frames so these limitations are overcome by using cell switching.

The cell is considered to be a fixed size block of information. It is not a variable size and usually the size is very small. For example, in ATM the size of the cell is only 53 bytes and all the frames are of the same size and the cell is used as the basic unit of data exchange.

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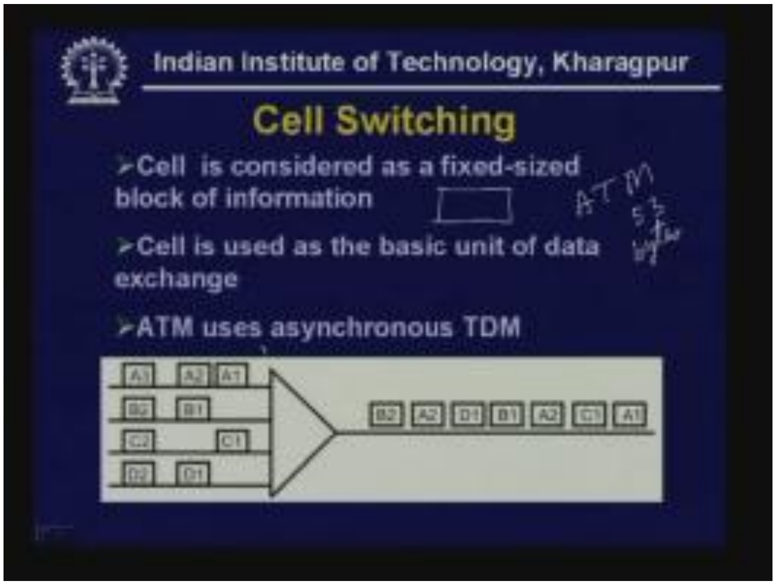

And also, ATM uses Asynchronous Time Division Multiplexing. We already discussed about the limitations of Synchronous Time Division Multiplexing and how Asynchronous Time Division Multiplexing overcomes the limitations and that is being used in ATM.

Here we see (Refer Slide Time: 10:27) these are the cells coming from different sources and because of Asynchronous Time Division Multiplexing the A_1 C_1 then A_2 do not have the fixed slot and as a consequence these cells will go in different order. This means for different frames there will be a different set of order because of asynchronous communication. However, because of high speed and smaller frame size the cells coming from different sources will reach the destination much more quickly. These are the advantages.

In spite of interleaving, none suffers long delay. As we have seen in the previous slide there is some interleaving A_1 then C_1 then A_2 B_1 then D_1 then A_2. For example A_1 and A2 are appearing somewhere here and in between we have got several other cells. Therefore in spite of these interleaving none suffers long delay because of high speed and also because of small cell size. The particular link cannot monopolize the medium and as a result none suffers long delay.

Cells reach different destinations in the form of continuous stream because of high speed and small size of cells. That means the data frames or video frames coming from different sources will reach the destination in the form of continuous stream of cells and they will reach quickly with much less delay and as a consequence it is possible to support this kind of real time traffic.

Switching and multiplexing by hardware at the cell level makes implementation inexpensive and faster. These are the basic advantages of cell switching. However, there are some limitations. For example, since the cell size is small the header has got 5 bytes and the payload is 48 bytes. So this is the size of a cell and as a consequence the overhead is 9.4% which is quite high so ATM has got high overhead in terms of header because of bigger header relative to the size of the cell. But the advantages are actually is more than the limitations that is being imposed by this large overhead.

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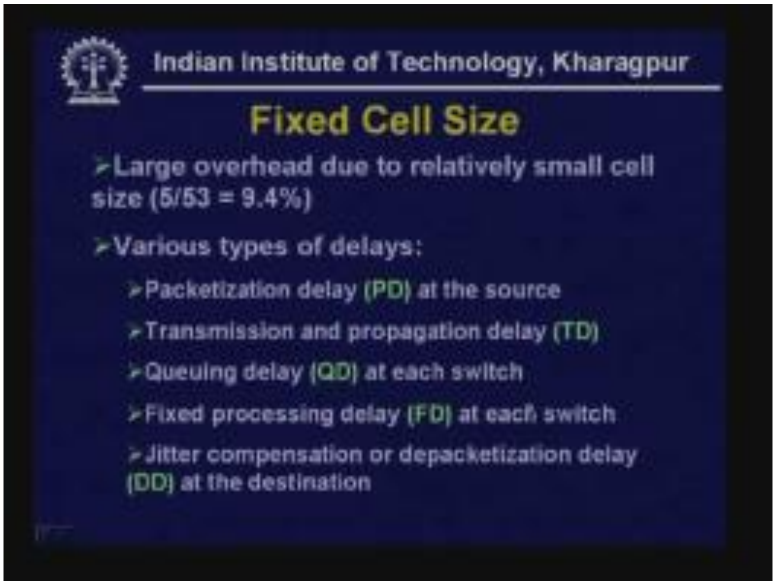

Also, it has got different types of delays. For example, packetization delay at the source for example data is coming from audio sources so they will be packetized in the form of cells. Since the audio data will arrive at a smaller rate there will be some delay in packetization, in making the packets, this is known as PD delay Packetization Delay at the source.

Then we have the transmission and propagation delay. Whenever you are sending over a long communication media if the distance is very long there will be some propagation delay and that propagation delay is usually relatively higher compared to the transmission delay because of smaller frame size. The transmission time will not be small because the speed is high, it is about 155 Mbps and as a result to transmit 54 bytes will not take much time, however, the propagation time can be quite long. Hence these two are added where the propagation time is more significant than the transmission time. This time is known as the TD or Transmission Delay although the propagation time is more significant.

Now we have the Queuing Delay QD at the each switch. Whenever the packets arrive at a switch several such packets may arrive from different sources simultaneously so as a result there will be some delay in serializing or queuing the packets which will lead to some delay known as QD. Then we come to fixed processing delay at each switch. The switches will take some time for the purpose of error checking lead to some delay.

and synchronization. This processing delay at the switch will Finally we have the Jitter compensation or Depacketization Delay at destination.

Since the packets are arriving with different delays it is necessary to buffer them. For example, when you are playing a audio cassette or any data or playing a video then it is necessary to buffer them then send them at continuous rate, this leads to Depacketization so that the jitter compensation can be done at the destination. Therefore whenever the packet passes through the ATM network different kinds of delays are suffered by it but these have to be taken into consideration in designing the network with the help of proper architecture and design.

Let us look at the ATM architecture.

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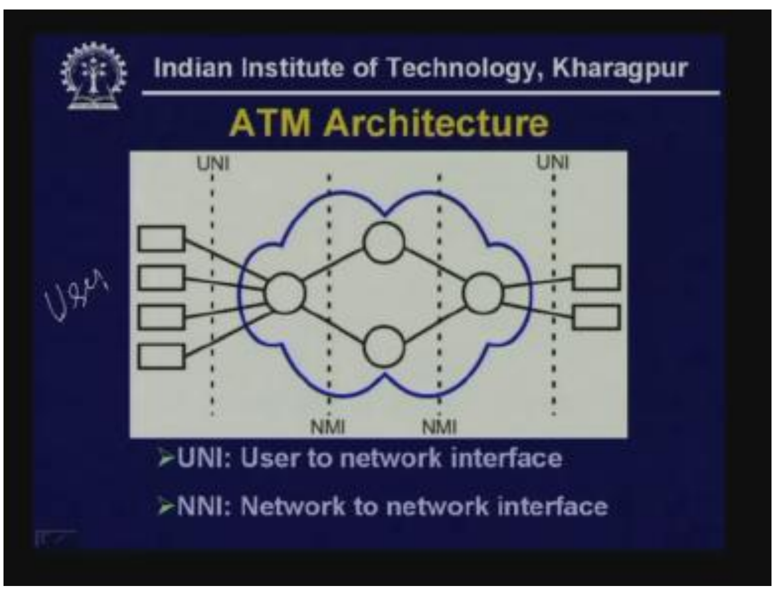

Here as you can see these are the user interfaces and this is your ATM network where you have a number of ATM switches (Refer Slide time: 16:31). This interface between the user and the switch is known as user to network interface so these are all user to network interfaces and here these are all user to network interfaces. On the other hand, the interfaces between a pair of switches are known as Network to network interface.

These interfaces are different because these UNI interfaces may be relatively slower in speed compared to the NNI interfaces, they can be relatively of much higher speed because of Time Division Multiplexing we use.

Thus two different types of interfaces are specified in ATM architecture; one is UNI between User to Network and another is NNI between switches in the ATM network.

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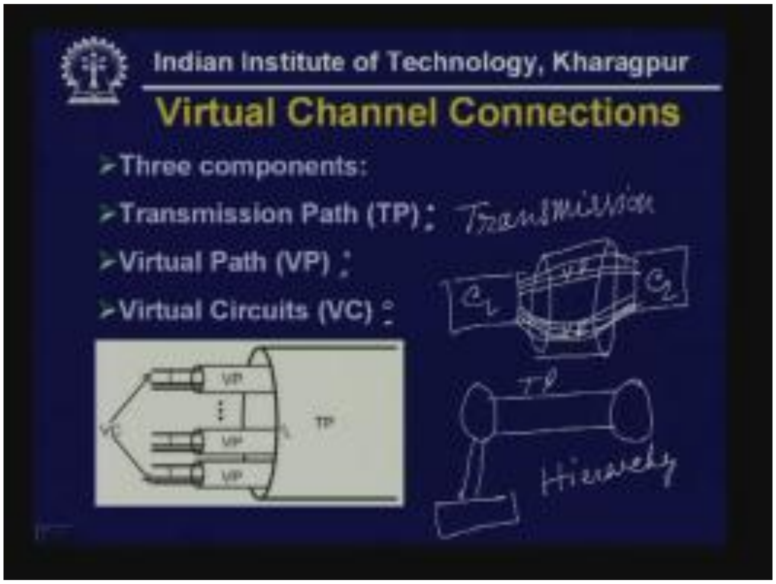

The communication takes place by using virtual circuits. There are three components involved in it. One is the Transmission Path. Transmission Path is essentially the transmission media, the physical media that is being used while doing the transmission. On the other hand the Virtual Path and virtual circuits are two components with the help of which the virtual connections are defined. And within each Transmission Path there are several Virtual Paths.

I can give the example of two cities connected by highways. So all the highways refers to the Virtual Path where you have got one city and where you have got another city. So there can be several highways linking them. Therefore this link shown here is the Transmission Path and within each Transmission Path you have got several Virtual Paths VPs, several VPs you can have. So this is your Transmission Path (Refer Slide Time: 18:50) and you have got several VPs inside. Essentially all the VPs together form the Transmission Path between the cities C1 and another city C2. Then within each Virtual Path you can have several virtual circuits.

For example, a highway can have several lanes, five lanes, eight lanes etc which form the virtual circuit within the Virtual Paths. So you find that this is the Transmission Path which is essentially the physical medium between two nodes or between a user and a node or switch and within this TP you will have several Virtual Paths and within each Virtual Path there will be a number of virtual circuits. So this kind of hierarchy is used for convenience. It will provide a number of advantages. These are the advantages of Virtual Paths.

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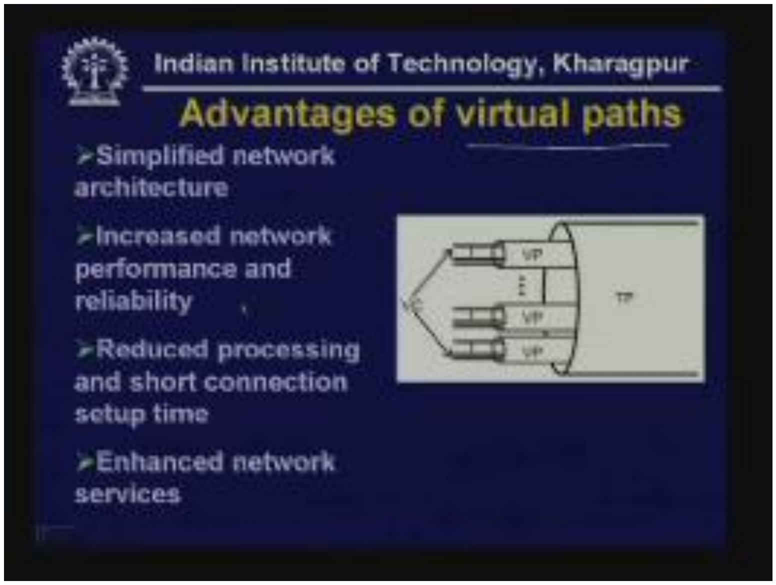

First of all it simplified network architecture, you can organize in a hierarchical manner. This leads to increased network performance and reliability and it reduces processing and short connection setup time. Because of this hierarchy connection setup time will be small and the processing time also will be less and also enhance network services. Hence these are the advantages provided by the Virtual Path Concepts.

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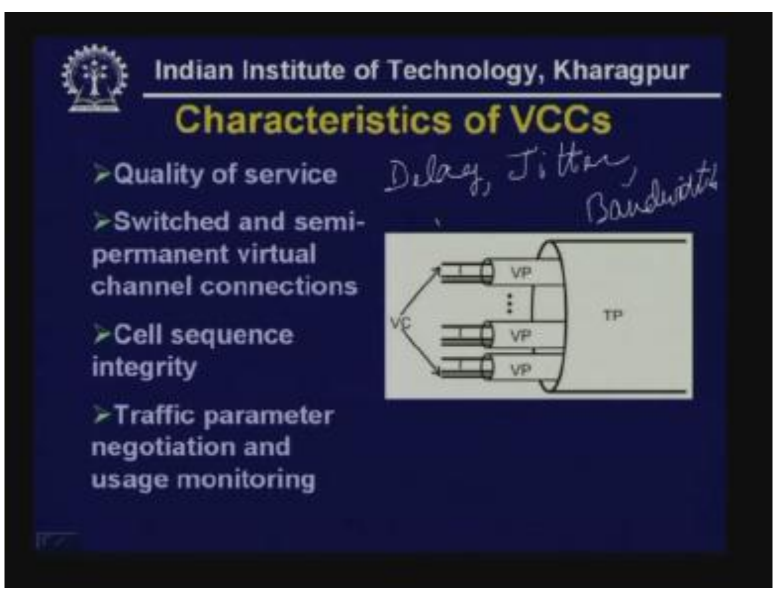

Now let us look at the characteristics of Virtual Circuit Connections. First of all it has to provide some quality of service such as delay, Jitter - variation in delay, bandwidth, burst size so these are the parameters that has to be specified, then the switched and semi-permanent virtual channel connections.

As we shall see we shall have Permanent Virtual Circuit as well as switched virtual circuit that is being supported by the ATM. Then we have this cell sequence integrity. Whenever the packets travel through the same virtual circuits the packets are delivered in order, as a consequence this cell sequence integrity is […. 21:33] and at the other end there will be no need to put them together in order. That means out of order delivery will not take place.

The traffic parameter negotiation and usage monitoring is also performed with the help of these Virtual Circuit Connections. These are the typical characteristics. The virtual connection is defined by a pair of numbers known as VPI and VCI. VPI stands for Virtual Path Identifiers and VCI stands for Virtual Circuit Identifiers. So, in case of UNI between the user and the network interface the VPI is 8-bit and VCI is 16-bit. On the other hand between two networks or switches the VPI is 12-bit and VCI is 16-bit.

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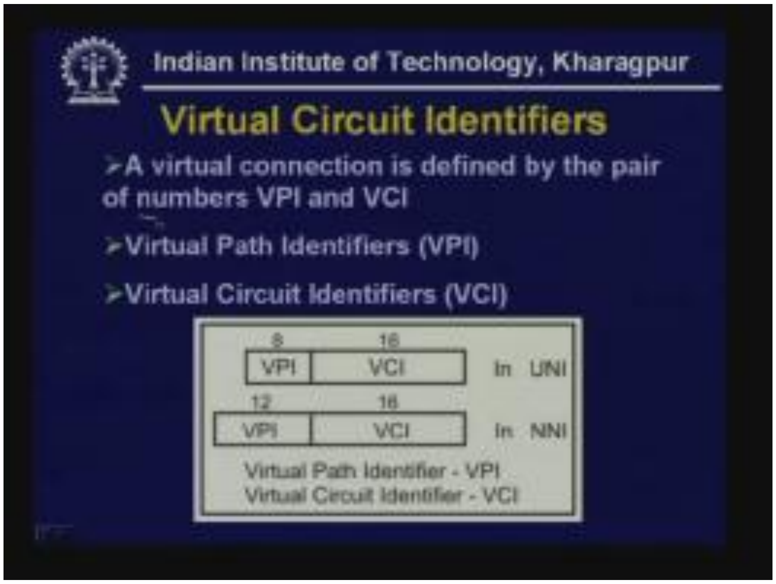

A particular Virtual Path is identified by 24-bit in case of user to network interface UNI and it has got 28-bit in case of network to network interface NNI. Hence that provides enormous number of virtual circuits to be created between user and network and also between two networks and obviously this number is much larger.

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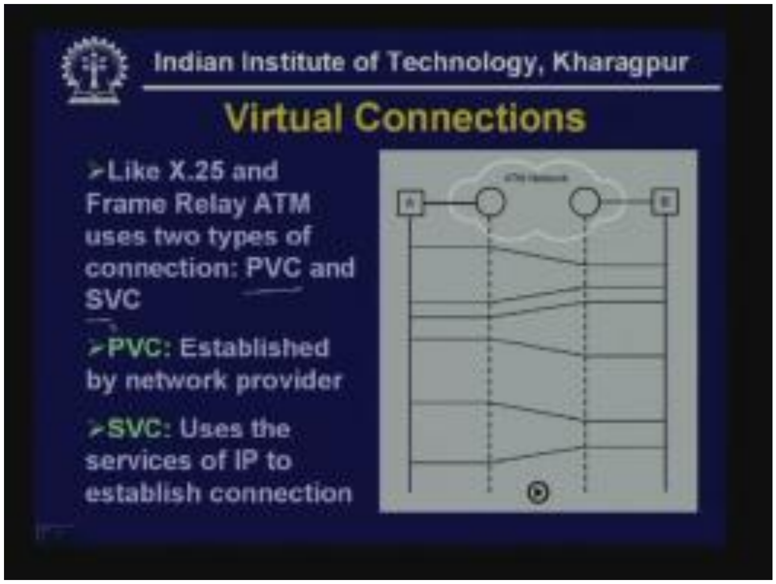

Like X.25 and frame relay ATM uses two types of connections; one is Permanent Virtual Circuit and another is Switched Virtual Circuit. In Permanent Virtual Circuit this is established by the network provider and the VPI and VCIs are all provided by the network provider in case of PVC.

On the other hand in case of Switched Virtual Circuits, actually the ATM has got no network layer so it has to take the help of one upper layer, for example, internet protocol is a network layer protocol, the ATM has to take the help of one network layer protocol to set up the connection to establish connection and at that time the VPI and VCIs are defined. Let use see how exactly it happens.

A set of packet goes from one side to the other side then the call processing message comes to this end, then this signal connect comes to one end and then connect technology signal goes to the other end. Therefore with this the connection is established and the VCI and VPI are all defined and then data transfer takes place as you can see. Data transfer is taking place from source to destination between two end users and as soon as data transmission is finished the connection is released and the release connection signal is sent and release comprehensive signal comes from the other end. Thus whenever a particular connection is setup in Switched Virtual Circuit this is how it takes place.

Now let us look at the switching types used in ATM.

As we know the switches are used to route cells from source to destination end points so it does routing and switching. There two types of switches used; one is known as VP and another is known as VPC. So routing is done using VPI for switching, the VCI remains the same.

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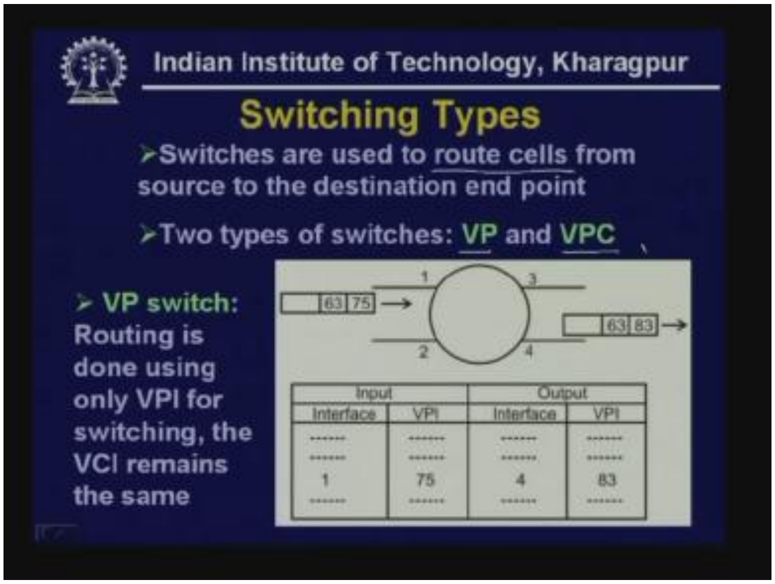

Usually between two switches the switching is usually in the form of VP switch normally. That means routing is done only by using the VPI but the VCI remains same. For example, this is one interface, this is another interface, (Refer Slide Time: 26:10) and this is ATM switch. The packet cell is coming to interface 1 and it is going towards interface 4. This is already setup. Now you see that the VCI part 63 is sent so it is not different but the only difference is the VPI part. So the VPI here is 75 at the put interface and the VPI is 83 at the output interface so the switching is done, it comes here and by looking at this table the VP switch identifies to which port it will be assigned to and what will be the VPI port provided to that so the cell is forwarded in this form with the help of these two numbers.

That means this cell header will have VPI VCI information and with the help of that routing or forwarding will take place.

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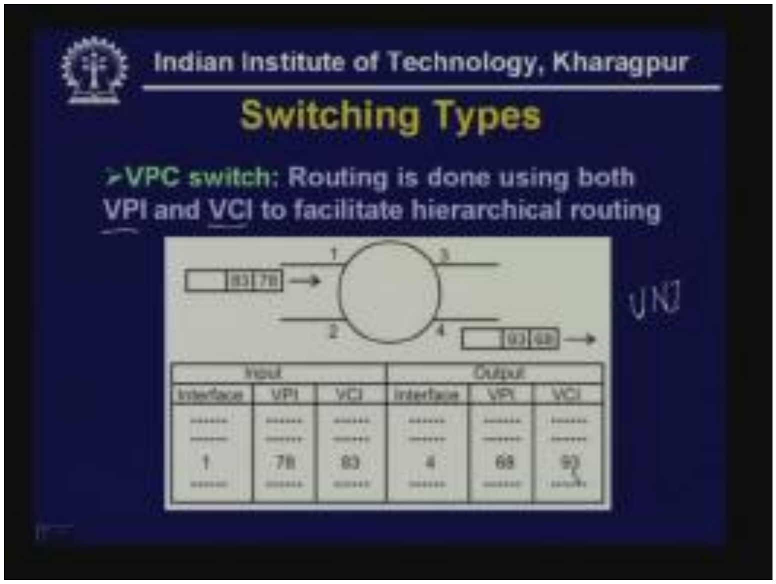

On the other hand in VPC, switch routing is done using both VPI and VCI and usually the UNI interface uses this kind of switching where both VCI and VPI is being used. This is the cell arriving at interface 1 with the VCI and VPI 78 and 83 where VCI is 83 and VPI is 78 and the output will be forwarded to interface 4 and when it is forwarded it assigns different VPI and VCI. So VCI is 83 and VPI is 78 and here VCI is 93 and VPI is 68. So it is being modified by this switch and then it is forwarded.

Therefore by looking at this kind of table the cell switching and multiplexing is being done with the help of switches. Now you may be asking that this has to be done by the hardware and we have to use some kind of switching fabric. One type of switching fabric that we have already discussed about is your Banyan tree. This is the Banyan tree that is shown, it has got 8 input and 8 output.

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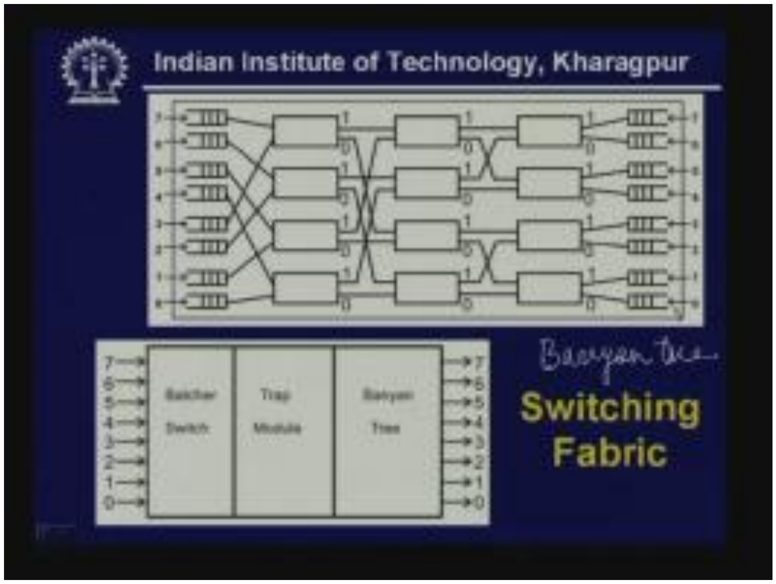

So eight input and eight output lines have been shown here. As you can see the cells are arriving here and it can go to any one of these lines. Actually these are output lines and these are the input lines (Refer Slide Time: 29:23). So whenever it comes to 1 it can go to any one of the output lines and it is being buffered. So these are being buffered here, you can see each line can have input and output, actually it can be full-duplex, it has to be full-duplex.

Here it is coming then through the zero interface it can go to any one of the interfaces and then switching is done with the help of these bits. So, on the inside it has got micro switches, these micro switches are used to do the switching. That means depending on this bit depending on 1 or 0 the input will go to this end or this end. Obviously at a time it will be able to switch one of the two inputs either to this or to this. So, if they want to go to the same output then there is collision. So, whenever the destinations are different even then the collision can occur. However, switching can be done in this way with the help of different bits. For example, if the destination is 6, let us assume that from 0 it has to go to 6, so from 0 this bit is 1 so it will go here in this path and the 6 is 1 1 0 so again it will go here then it is 0 so it will go here to this particular output line. In this way the switching is done, however the collision can occur.

Whenever it has got n inputs a Banyan tree switch will have $\log_2 n$ stages. So here the number is 8 so it will have three stages as you can see and in each stage there will be about n/2 micro switches. So n/2 is equal to 4 so we have four micro switches and three stages in this 8/8 switch.

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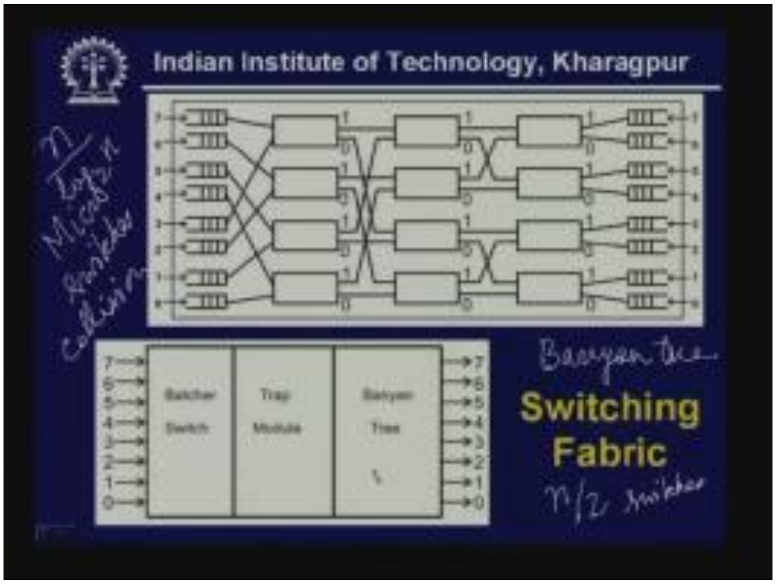

Unfortunately because of internal collision even for different destinations coming from input sources there can be internal collision. The internal collision can be avoided by using batcher banyan switch. It combines three different modules; one is the batchers switch. What the batcher switch does is whatever input it receives it does the re-shuffling in terms of the output link to which it is going. That means all the inputs are reshuffled based on the destination lines. This batchers switch does that.

Unfortunately there is a possibility that some of the cells coming from some of the inputs may have the same destination port/line so in such a case it cannot be sent simultaneously to the banyan tree, hence this is being overcome by using the trap module. The trap module will buffer them then partly one cell will be forwarded to the banyan tree. In this way the batcher banyan switch can perform the ATM switching and it overcomes the limitations of the simple banyan tree and this kind of switching can be used in implementing the ATM switches. Now let us look at the different layers used in ATM.

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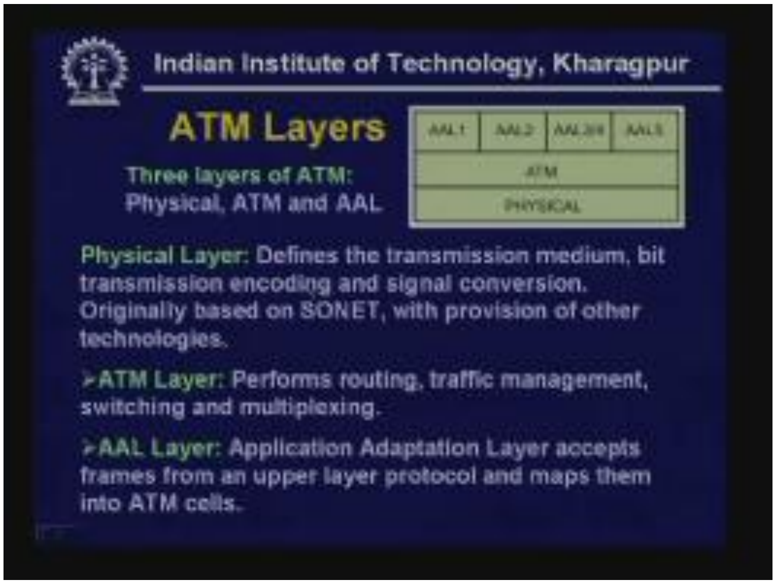

As I mentioned ATM has got three different layers; physical, ATM and AAL, AAL stands for Application Adaptation Layer. The physical layer defines the transmission medium, usually it is the optical fiber, bit transmission encoding and signal conversion. So it may be necessary to convert from electrical to optical and optical to electrical so the physical layer does that. This was originally based on SONET. We have already discussed about the Synchronous Optical NETwork. ATM was based on SONET and as we know in case of ATM the lowest rate is 155.52 Mbps which is the minimum bit-rate but it has got higher rates.

However, the ATM can not only use SONET but it has the provision for other technologies. That means it may also use the T1 lines if necessary, but it has been explicitly designed for SONET. Then the ATM layer performs important functions of routing, traffic management, switching and multiplexing. On the other hand the AAL Application Adaptation Layer accepts frames from an upper layer protocol and maps them into ATM cells.

That means the packets or frames coming from different applications may be of different sizes. The AAL layer does the mapping to the ATM cells. That means it will break them up, segment them and also it will do the combination. Let us see how it is being done. Here the functionality of nodes and stations are defined. As you can see here (Refer Slide time: 35:40) the functionality of the user stations has got three layer functionality; physical, ATM and AAL which is the Application Adaptation Layer. On the other hand the switches have got the functionality of two different layers known as the ATM and physical. Therefore all the switches have got ATM and physical layers within this ATM network and only the user interfaces has got three layers of functionality; physical, ATM and AAL.

Here it shows the functionality of different layers and how it actually happens.

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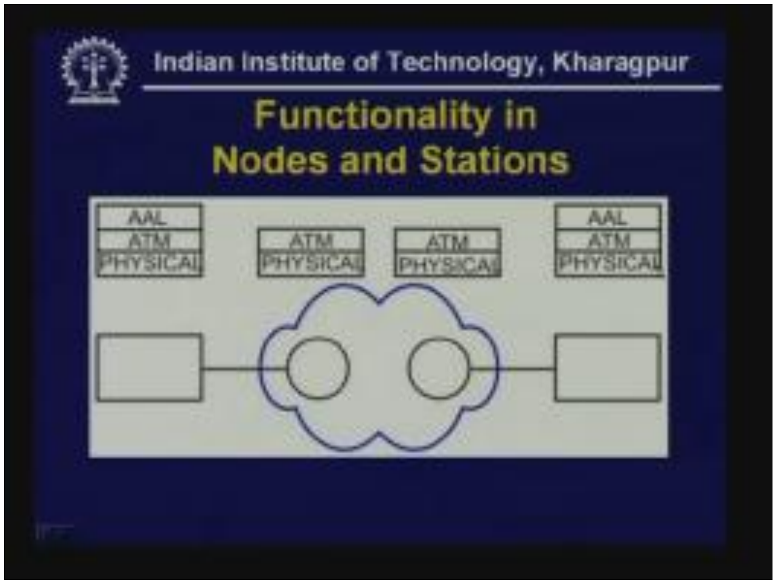

Here the information is coming from upper layer. The AAL layer does this segmentation of the frames in terms of 48 bytes so it breaks in terms of 48 bytes in the ATM layer puts the header converts into ATM cells and it introduces the 5 byte header so with that it gets converted into cells each of 53 bytes and then it passes through SONET layer.

The popular SONET layers are 12C and 3C which is commonly used for ATM and as we know the data rates are 155.52 and for 12C it is 622.08 Mbps. Of course as I mentioned T1 lines the DS 3 protocol can also be supported but primarily it uses these two. so here (Refer Slide Time: 37:33) it is explained with the help of 3C so STS minus 3C is the frame and in this frame as we know we have got the packet overhead header, SONET overhead header, line overhead header so these headers are there so we have 9 bytes here and here this is 1 byte for packet overhead and the remaining is used to packet the ATM cells.

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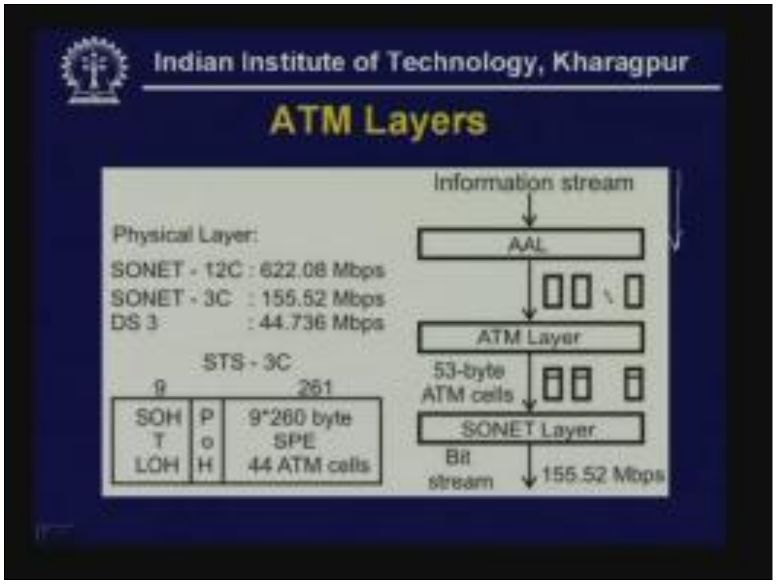

Therefore as you can see it is 9 into 260 byte this is the SPE this is the synchronous packet and in this the ATM cells are packed where we can pack 44 ATM cells. Here that 5 byte header added by the ATM cells is elaborated so it has got two different types of header for UNI user to network interface and network to network interface. The main difference is coming from this GFC. GFC is the Generic Flow Control. This Generic Flow Control was assumed to be between the users and here is your ATM network between the switches.

This flow control was assumed to be used between the user and the network and that is why 4 bits were left aside by the designer of ATM. However, this is not commonly used so you may consider this GFC as a flaw in the design. Now we have the VPI Virtual Path Identifier which is 8-bit between the user and the network layer for UNI. On the other hand it is 12-bit for the NNI interface.

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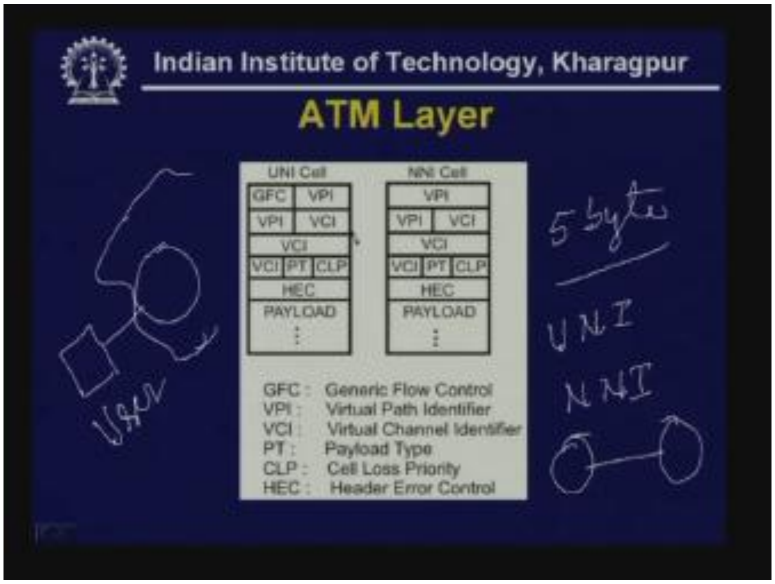

So whenever it is between two switches for that it can be 12-bit VPI and 16-bit VCI. So this VCI is 16-bit for both cases. Now, the Payload Type has got three bits, the Payload Type specifies what kind of payload a particular cell is carrying. The meaning is explained here.

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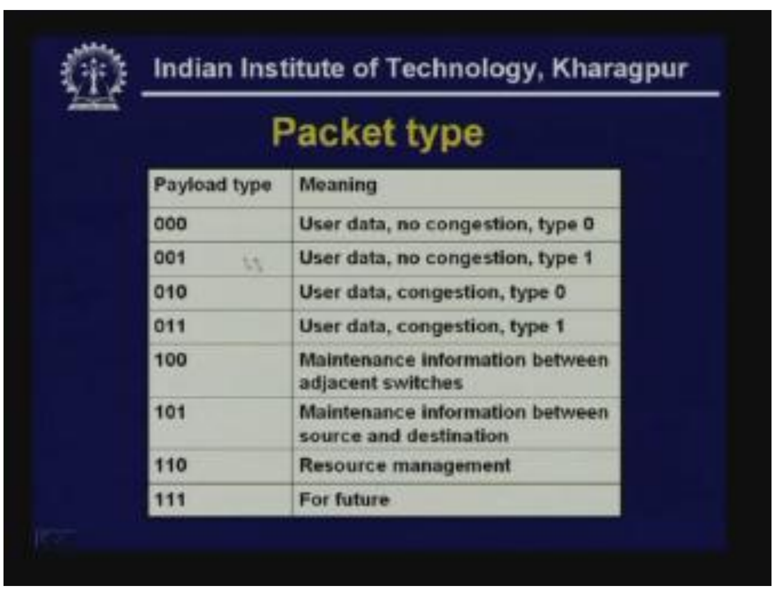

For example, if it is 000 the most significant bit specifies whether it is user or management data. So, if it is 0 then it is user data but again user data can be two types type 1 or type 0 depending on the least significant bit. And the middle bit is used to specify the congestion. So whenever it is 000 it is user data that means the cell corresponds to the user and there is no congestion in the network and it is a type 0 payload.

On the other hand whenever this bit is 1 this is user data and there is no congestion, and it is type 1. Whenever this bit is set to 1 user data, congestion has occurred in the network and it is type 0 and whenever it is 1 then this is type 1. When this is 100 it is maintenance information between adjacent switches. That means two switches can exchange some information and that management information is specified with the help of this Payload Type 100.

On the other hand this maintenance information can be between source and destination. In that case the Payload Type is 101. And this 110 the Payload Type is used for resource management and 111 has been left for future. So this is your Payload Type (Refer Slide Time: 41:52) and CLP essentially provides you cell loss priority, there is one bit specified for that cell loss priority and the cell loss priority is used for congestion control.

As we know whenever congestion occurs it may be necessary to discard packet and that is done with the help of this Payload Type bit. Whenever this Payload Type is 1 it means that the packet is of higher priority and whenever PT is equal to 0 the cell is of lower priority. That means when congestion occurs the cells with PT is equal to 0 it can be discarded and as long as cells with PT is equal to 0 are available only those cells are discarded. But the cells with PT is equal to 1 is not touched. However, whenever congestion is high, during then these cells may be discarded.

There is 8-bit Header Error Control, we shall discuss about it in more detail. this Header Error Control is a 8-bit field and the characteristic polynomial that is being used is shown here: X to the power 8 plus X square plus X plus 1.

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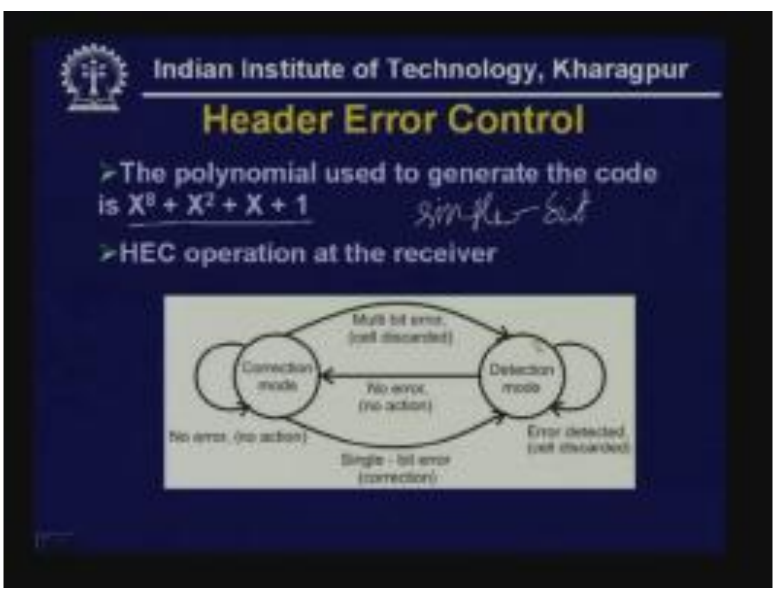

This is used for error detection and control correction. As we can see here normally when there is no error it is in correction mode and whenever there is error it goes to detection mode. So whenever you have got single bit error then it can be corrected. As you can see whenever there is single bit error it can be corrected then it goes to the detection mode. On the other hand whenever a multi-bit error is detected the cell is discarded because it cannot be corrected. That means each switch does the error checking, so it will have some overhead although it is done by hardware and whenever there is a single bit error it can be corrected because it uses 8-bit for error correction purpose and it does the error correction only for header part.

Here you have got 1 2 3 and 4 that means on this 32 bits or 4 bytes the error correction is done and the CRC check bits are kept here. HEC operation performed at the receiving end for error correction purpose and error detection purpose. Now the nodes make use of fixed cell sizes and HEC to determine the cell boundaries implicitly.

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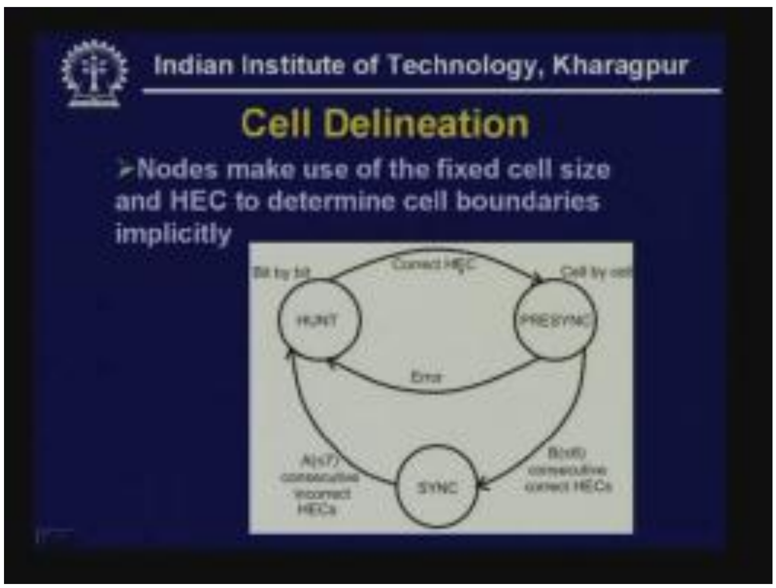

One important feature of cell switching is that there are no flag bits to identify the beginning or end of a cell. So, how the beginning or end of a cell can be identified is also being done with the help of this Header Error Control bits in an implicit manner with the help of cell boundaries.

The state transition diagram used for that purpose is shown here. Normally the switches are in hunt mode then bit by bit synchronization is done and whenever correct HEC header error correction is received then it does cell by cell checking. So it is in the pre-synchronization phase and whenever it receives several consecutive Header Error Controls correct HECs then it goes to synchronization mode. That means usually the value of B is not less than 6 but it is 5.

Hence if you keep it as 5 it means 5 cells are received correctly. that means header error corrections are corrected and then it goes to synchronization then each and every cell is now synchronized with the help of this header error correction and as the cells arrive with 53 byte and 53 byte once it gets synchronized then all these subsequences are synchronized.

However, whenever there is incorrect Header Error Controls it must have less than seven consecutive incorrect Header Error Control flags that are received then again it goes back to the hunt mode. So we find that the cell length delineation is performed the help of the Header Error Control bits and synchronization is done with the help of this particular field in an implicit manner.

Now ATM supports a number of service categories and these are divided in five different classes.

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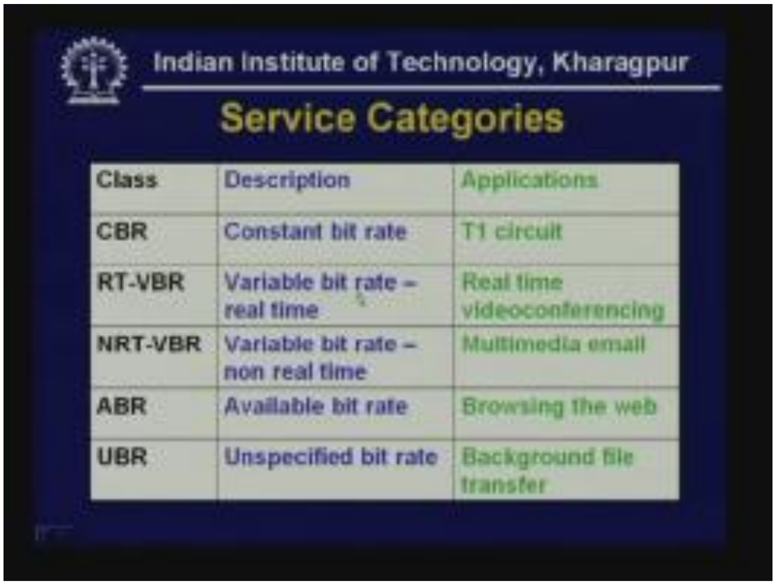

One is constant bit-rate. For example, it is coming from the telephone network T1 circuit so it comes in a constant bit-rate.

On the other hand the second type is variable bit-rate and it is real time videoconferencing. Or it may be video data and it is coming in a streamed form without any compilation then it is real time video or audio data. On the other hand whenever it is real time it is variable bit-rate non real time. For example, multimedia e-mail then it can be variable bit-rate non real time.

On the other hand available bit-rate browsing the web is the application. Some minimum bit-rate is specified. However, if higher bit-rate is available that is being used in the applications like browsing the web. Then we have the unspecified bit-rate so no specific bit-rate is specified and whatever bit-rate is available can be used. UBR is Unspecified Bit-rate which can be used for background file transfer and other purposes.

So real time videoconferencing is going on and in addition to that you can do background file transfer with Unspecified Bit-rate. Hence these are the different types of service categories identified by ATM designers and accordingly the AAL layer frames has originally got five different types but now it is divided into four different types.

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For example, AAL1 is for constant bit-rate stream, AAL2 is for short packets coming from video or audio applications, AAL3 or 4 for conventional packet switching and AAL5 for packets not requiring no sequencing and no error control. That means for simple applications when sequencing is not required and error control is not required this particular framing can be used.

And this AAL layer divided into two parts. One is the CS sublayer, sublayer that performs convergence known as the convergence sublayer, segmentation and reassembly sublayer. So these two functions are different and it has to perform segmentation and reassembly and also it has to perform the convergence. Now let us look at the four different types of AAL frames that are being used and find out how it is being done.

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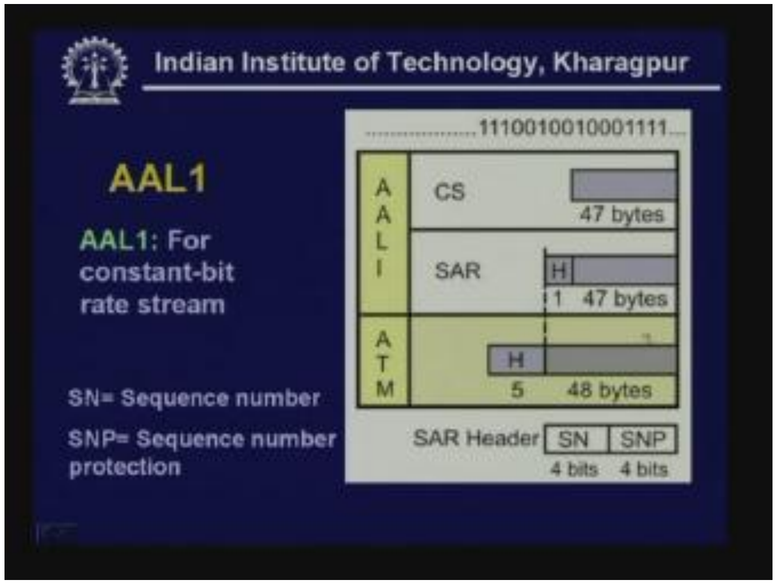

This is being used for constant bit-rate stream. The constant bit streams are coming and the CS layer divides it into 47 byte packet and the SAR sublayer the segmentation and reassembly sublayer puts a header which has got two fields namely SN and SNP Sequence Number and Sequence Number Protection that means for checking purposes. So these 8 bits are added then it goes to the ATM layer which forms that 55 bit cell with 5 byte header and then it is transmitted to the network.

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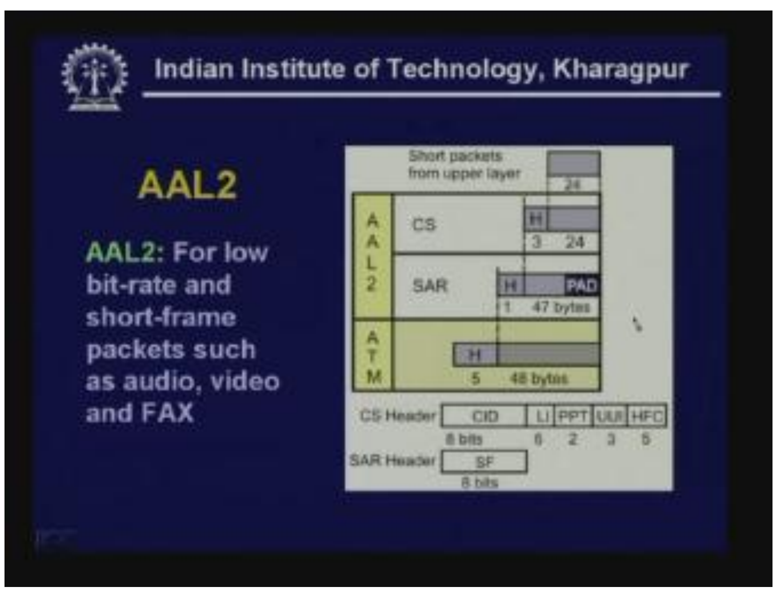

On the other hand in case of AAL2 which is used for low bit-rate and short-frame packet such as audio and video packets the packets are smaller in size which are 24 bytes so to make it 47 byte you have to add a pad. So here as you can see the segmentation and reassembly header is little different having different fields like LI, PPT, UUI and HFC. The SAR header is SF. Here the two headers are added, the CS layer puts the header the SAR layer puts a header so here it is 3 byte CS layer and it is 1 byte and remaining part is filled up with pad to make it 48 byte altogether which goes to the ATM layer and ATM layer puts the 5 byte header and sends it through the switch.

And here we have the AAL3 and 4 which are used both for conventional applications which can support both connection oriented and datagram type applications. here you see that the data packet up to 64 kilobytes can be supported and data is divided into packets by the AAL layer each with a header and trailer so header and trailer are added and this 44 byte payload are taken from the upper layer and then it forms the 48 byte cell which goes the ATM layer which forms the 53 byte cell and that is being transmitted through the network.

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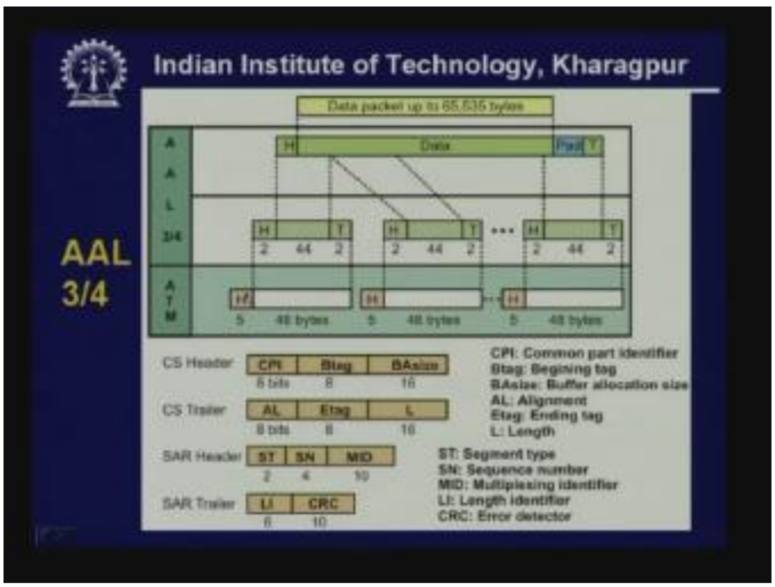

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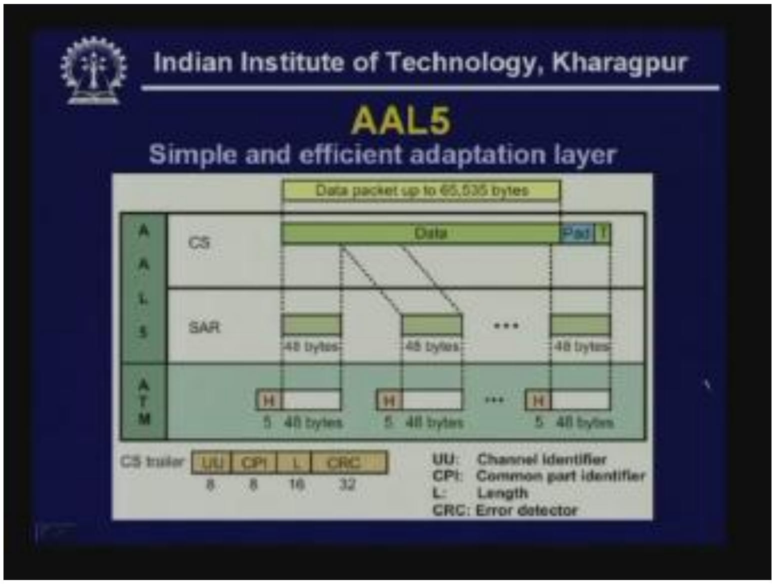

And then AAL5 is a simple and efficient adaptation layer. As you can see this is the frame format. Here also the data packets are up to 64 kilobytes and here there is no sequencing and other flow control is needed and that is why this is known as simple and efficient adaptation layer where there is no header or trailer no error control or sequencing is done. Error detection is also not performed and that goes to the ATM layer which forms the packetization then sends it. Let us see how congestion control is performed in ATM.

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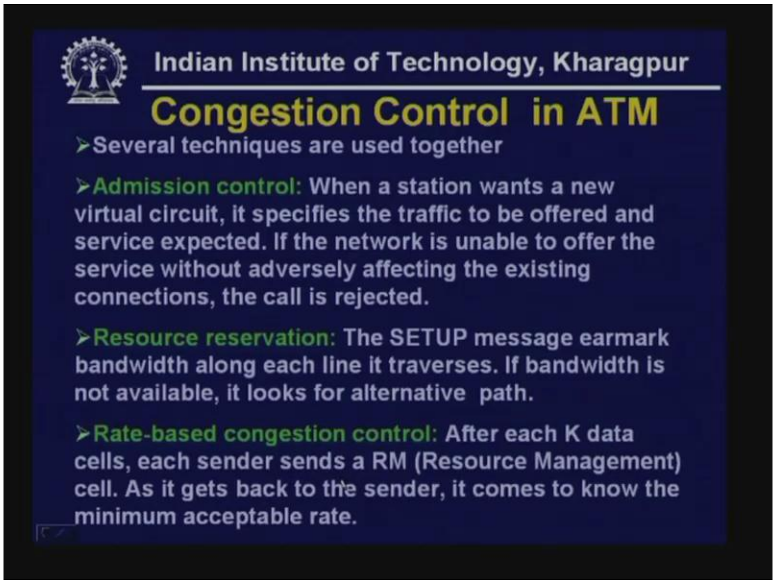

Since conventional congestion control schemes are inadequate for ATM because of the following reasons the majority of traffic is not amenable to flow control because it uses real time traffic where you cannot enforce flow control, feedback is relatively slow due to reduced cell transmission time because the propagation time is longer than transmission time, variety of applications supported by the ATM network. As I already mentioned five different types of packets are transmitted and it has a very high speed of switching and transmission because of that the conventional congestion control cannot be worth.

Congestion control is performed in three different ways; admission control, resource reservation and rate based congestion control.

Admission control: when a station wants a new virtual circuit it specifies the traffic to be offered and services expected. if the network is unable to offer the service without adversely affecting the existing connections, the cell call is rejected. So as we have seen a particular circuit may not be allowed to setup.

Resource reservation: A setup message is earmarked, better bandwidth along the line traverses and the bandwidth available is measured which is being used.

Rate based congestion control: this is performed where after each K data cells a sender sends a RM resource management cell and as it gets back to the sender after reaching the destination, it comes to know the minimum acceptable rate. Now it is time to give you the Review Questions.

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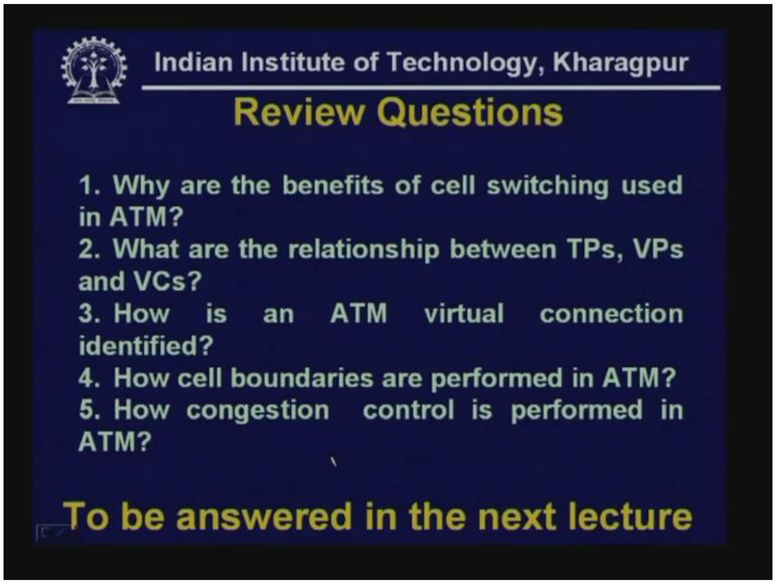

1) Why are the benefits of cell switching used in ATM? What are the benefits of cell switching used in ATM?
2) What are the relationship between TPs, VPs and VCs?
3) How is an ATM virtual connection identified?
4) How cell boundaries are performed in ATM
5) How congestion control is performed in ATM?

Here are the answers of lecture - 23.

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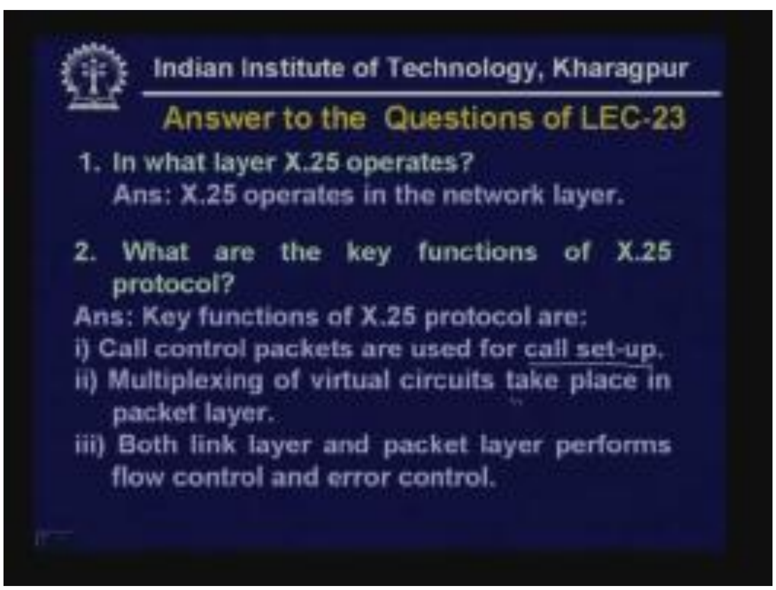

1) In what layer X.25 operates?

X.25 operates in the network layer.

2) What are the key functions of X.25 protocol?

Key functions of X.25 protocol are;
Call control packets are used for call set up. As we know multiplexing of virtual circuits take place in packet layer and both link layer and packet layer performs flow control and error control.

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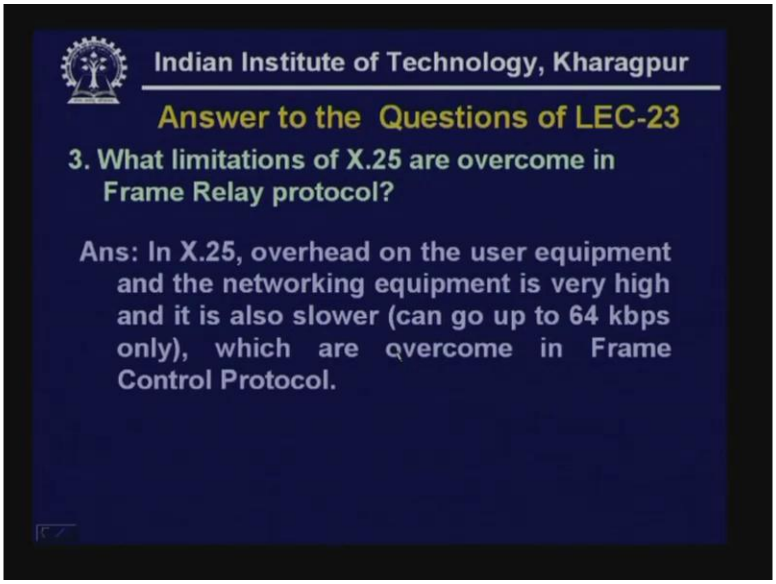

3) What limitation of X.25 are overcome in frame relay protocol?

In X.25 overhead on the user equipments and the networking equipments is very high it is also slower which are overcome in frame relay as we have seen that X.25 can go up to 64 Kbps and frame relay minimum rate is 1.544 Mbps so it is much faster and lesser overhead.

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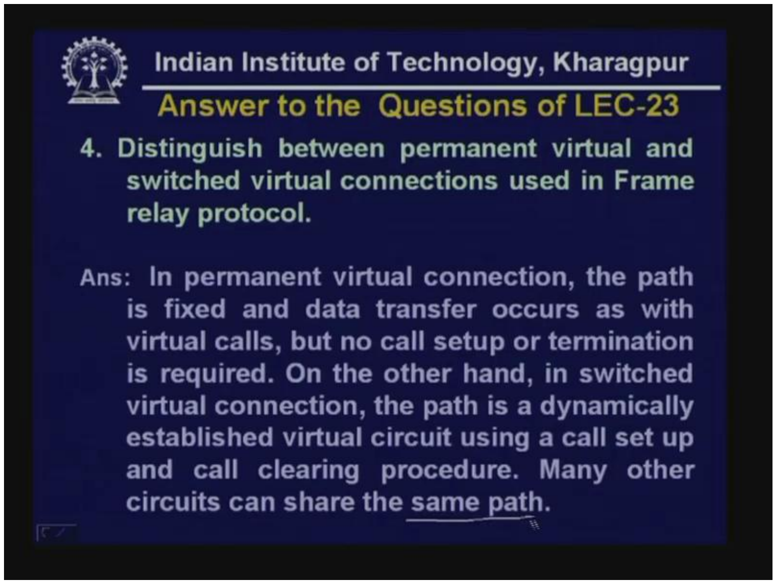

4) Distinguish between Permanent Virtual Circuit and switched virtual connection used in frame relay protocol?

In permanent virtual connection the path is fixed and data transfer occurs as with virtual calls but no call set up or termination is required. On the other hand in Switched Virtual Circuit connection the path is dynamically established virtual circuit using call setup and call clearing procedure and many other circuits can share the same path.

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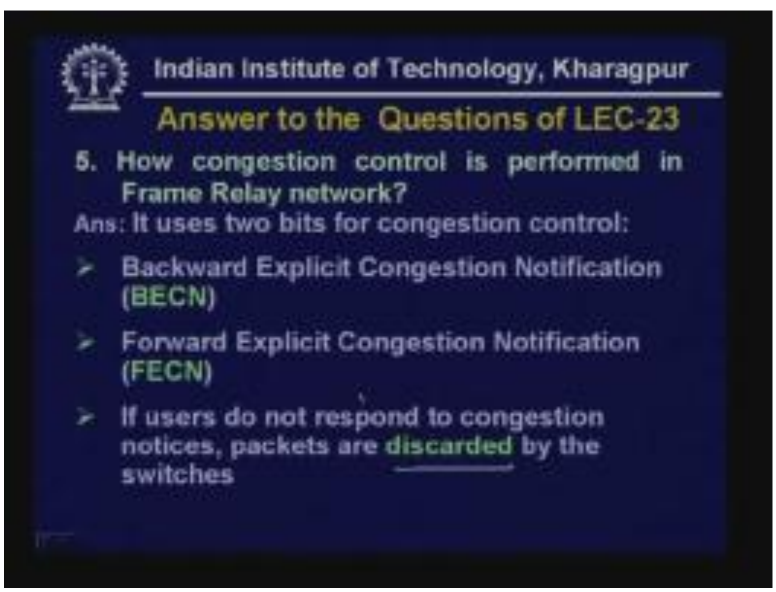

6) How congestion control is performed in frame relay network?

As discussed earlier, it uses two bits for congestion control backward explicit congestion notification and forward explicit congestion notification these two bits in addition to that it does the packet discarding if users do not response to congestion notices packets are discarded by the switches.

With this we come to the end of today's lecture on ATM and also the applications of packet switched network, X.25, frame relay and ATM, thank you.