Broadband Networks

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Lecture - 2

QoS in packet Switching & ATM

In the previous lecture we had discussed the basics of information transfer mode and we had seen that historically, the circuit switching was one of the first information transfer mode which was used for the telephone networks. Now, circuit switching is more efficient for the transport of real time services which require quality of service guarantees in terms of delays and loss. Essentially, the time division multiplexing in circuit switching offers almost no delays except for switching latencies and no packet losses. But on the other hand, circuit switching was found inefficient for the transport of bursty sources.

Then we saw that for the bursty sources, the transport mechanism that was developed was called as packet switching, while packet switching is efficient for the transport of bursty sources but it offers no quality of service guarantees. It is essentially a best effort switching technique where the network will make you know every attempt to transmit the packet. But it offers you know no quality of service guarantees in terms of the delays and the packet losses. ATM switching was or the fast packet switching as it was called; was developed by merging the concepts of both the circuit switching as well as the packet switching.

It has the advantages of circuit switching in the sense that it offers certain quality of service guarantees just like circuit switching. But at the same time, it has the advantages of packet switching, in the sense that it offers you the statistical multiplexing gain.

Now, how both these characteristics can be combined into our packet switching node with quality of service guarantees? That is how you can give the quality of service guarantees by at the same time by doing the statistical multiplexing?

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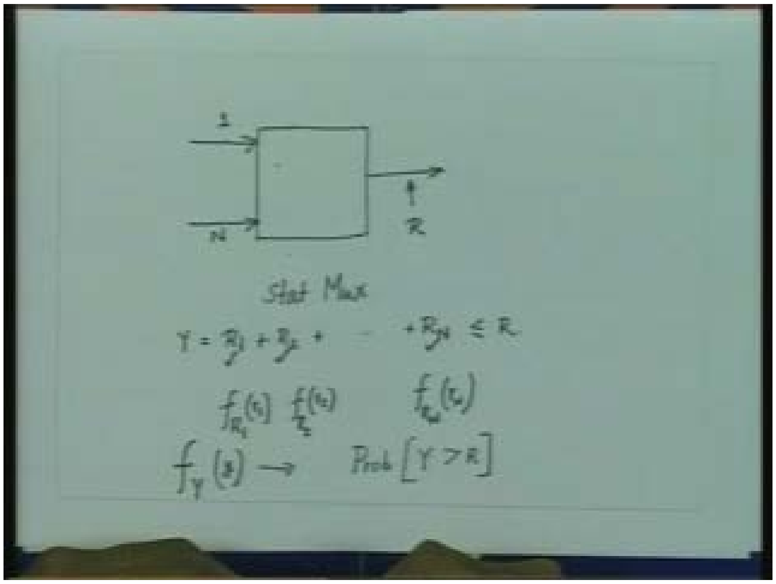

We had seen in the previous lecture with an example where we said that let us assume that there is a packet switch node which has say, 1 to N input ports and 1 to N output ports and now these input ports these traffic sources which are which are transmitting on 1 to this input port, so this is essentially a Stat Mux.

Now, each of these input sources may be having the data rates which are denoted by R_i, R_1 plus R_2 plus so on till, let us say you know R_N. Now, we want that these sources when they are multiplexed, they are combined; output transmission rate must be less than or equal to the output capacity which is R. Now, let us say that this Y which is the combined transmission rate of R_1 plus R_2 plus R_N; so, what we want is that the sum of these transmission rates must be less than or equal to the channel capacity or the link maximum bit rate of the link.

Now, we had seen in hypothetical admission control mechanism, where we assumed that each source knows its traffic characteristics in terms of its probability density function. So, each of these sources can specify its probability density function to the network.

Now, if the network knows the probability density functions of each of these R_i's. That is if the network knows the probability density functions of each of these R_i' s and let us denote them by f_{R1} (r_1) $f_{R2}(r_2)$ and f_{RN} (r_N), then we know that the network can compute the probability density function of Y which is $f_Y(y)$.

Now, if the network computes the probability density function of the output Y, then from this probability density function, the network can determine what is the probability that the combined output rate Y will become greater than R and whenever the combined output rate becomes greater than R, there will be a packet loss and if there is a limit on the tolerable packet loss, let us say delta, then we need to ensure that the probability that Y is greater than R is less than or equal to delta.

Now this is, as I pointed out that this is a hypothetical admission controlled mechanisms. Now, each traffic source invariably cannot specify its traffic characteristics through its probability density function. It may be possibly only for offline stored video sources, let us say, which can be characterized … and their probability density functions are known. But certainly, it may not be possible for the online traffic sources.

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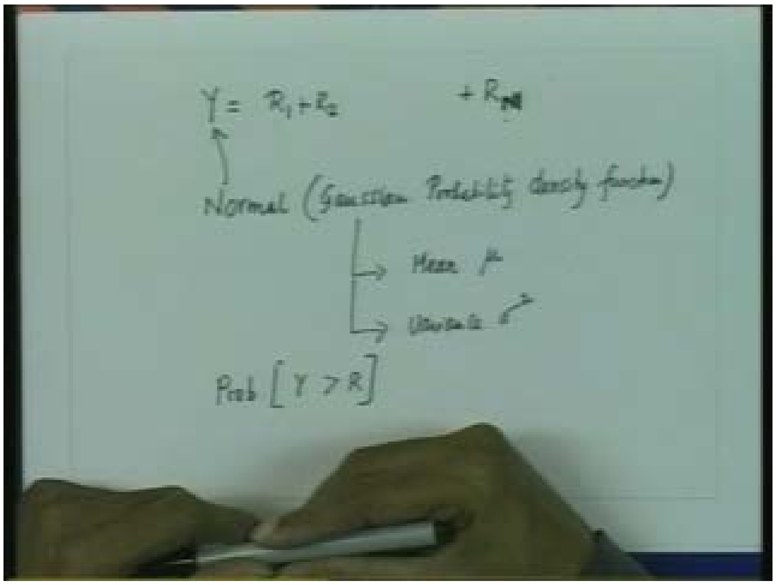

Now, one approach could be that if you assume, let us say that this Y is R_1 plus R_2 plus you know R_N or let us say you know R_M, now if you assume that if you do not know the density functions of each of these R_i's and if the sum of these traffic sources is very large, then we can also assume that that Y may have a probability density function which may look like a Gaussian probability density functions. So, we can assume that this could be a normal or Gaussian probability density function, provided, the number of sources we multiplexed is large.

Now, since the Gaussian probability density functions can be completely characterized by its mean, let us say, mu and variants which is sigma square; then in order to determine the probability that Y is greater than R, all we need to know is what is the mean of Y and what is the variance of Y and this can be done by making online measurements on the traffic sources. So, one of the simple admission control mechanism could be that the network first admits the users based on their peak rates. Let us say that there are no users in the network. The first user comes and specifies its peak rate. The network determines whether by admitting that user the packet loss requirements can be made. The user admits it.

Now, the second user comes, the network can do the admission control based on these peak rates. Now, as the sources start transmitting their data, the network can make an online measurement of the traffic sources and can estimate what are the mean and the variants of the combined output rate Y. By determining this mean and the variants, the network can determine that how many more number of users can be admitted into the network such that the probability that a combined output rate Y is greater than the maximum bit rate R is less than or equal to the specified tolerable limit which is delta.

Now obviously, these kinds of techniques are called measurement based admission controls. We will deal with them in more details later. But here, I just wanted to give you a glimpse of how on the one hand in the circuit switching technique, where the each connection each connection is given a certain time slot in a time frame and gets a reserved bandwidth on the one hand and therefore, he is offered complete quality of service guarantees that it is on one hand and on the other hand, in a packet switching network where there may not be any admission control, all the users are simply allowed to transmit and whenever the combined output rate increases the link rate, then the packets are buffered which is on other extreme.

We have seen that how we can combine a combination of these two techniques; that is the circuit switching and the packet switching at the same time and still offer you know quality of service guarantees.

Now remember, the hypothetical example that we just considered were each source specifies its probability density function and also specifies a certain tolerable packet loss. This will degenerate to some kind of a circuit switching technique if each source specifies that its packet loss requirements are zero packet loss, if it does not want any packet loss. Then in that case, the only way in which that can be ensured is by admitting the users based on their peak rates. That is their worst case scenario.

So, this kind of statistical multiplexing technique which offers quality of service guarantees and which we just discussed can degenerate to a circuit switching technique if the quality of service requirements are zero delay and zero loss. On other hand, it can degenerate to a packet switching technique where there are no constrains in terms of the quality of service requirements.

So, we have just seen how we can combine the advantages of the circuit switching technique as well as the packet switching techniques. Now remember, a statistical multiplexing which offers quality of service guarantees has to have some kind of an admission control mechanisms and an associated signaling procedures for that.

Now, before we briefly before we go into the details of how these admission control can be done in practice because as we have seen that the source cannot specify its probability density function; so, how we can do that in practice, we will just look at this and how the ATM has come up with this concept. But before that I just wanted to tell you some more differences between the circuit switching and the packet switching.

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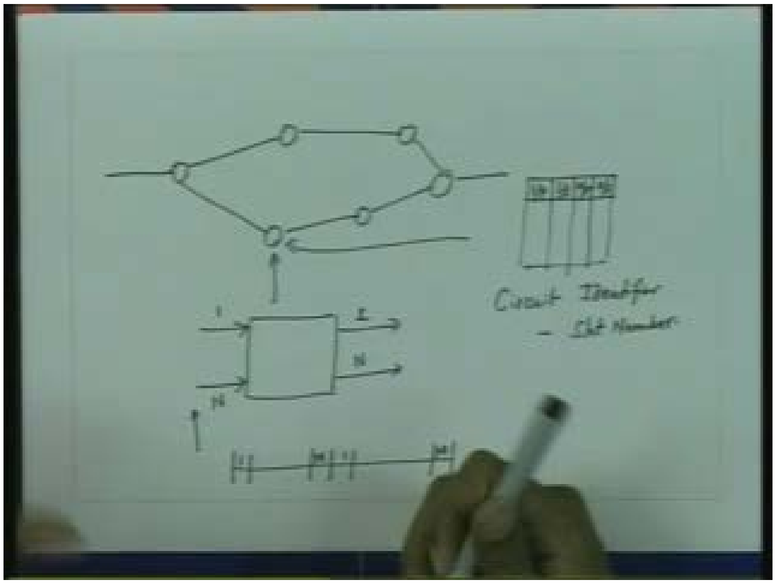

Now, consider for example a network of nodes which are essentially the circuit switch nodes. Now, if you look this as a network of circuit switch nodes and we have seen that each of these nodes could be a switch with 1 to n input ports and 1 to n output ports. On each of these links you have a TDM frame, where you may have 1 to M slots and these slots may get repeated.

Now here, you can see that a user number 1, let us say is given a slot number 1. Then that user is completely identified by its slot number. So, the circuit identifier in a circuit switching network is the slot number.

Now, each user has been given, let us say, a designated slot and he is allowed to transmit it bits in that slot of every frame. So, let us say, a user number 1 has been given slot number 1, then it transmit its bits in the slot number 1 of frame 1, then slot number 1 of frame 2 and so on.

Now, at the node, we have as you have seen; there is a signaling table and that signaling table will tell you what is the input port. So, this may be an entry of what is the input port, what is the input slot, what is the output port and what is the output slot and thus, the bits can be switched from one input ports to one output port.

So, in a circuit switching, a circuit identifier is essentially a slot number. Now, let us assume that this is a network of a packet switching node. Now, how the things will be done in a packet switching?

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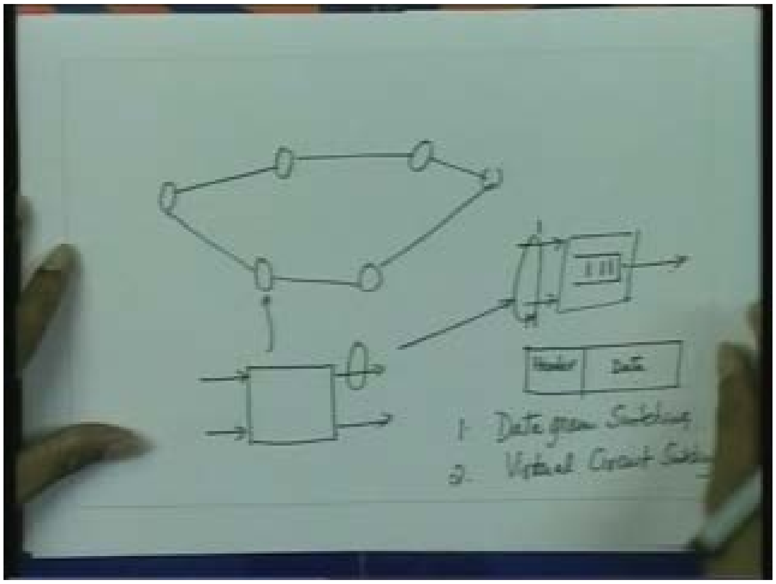

Now, let us say, again we have a network of node. But this time, this is not a, this is not a circuit switch node but this is a packet switch node. Now, in a packet switch node there could be still a switch of 1 to N input ports and 1 to N output ports. But on this link, now you have the statistical multiplexing instead of the time division multiplexing.

So, if you expand this link, we will say that there may be 1 to M flows and they are being statistically multiplexed here. Now seems, it may be possible that the combined output rate may increase this, you require some kind of a buffer.

Now movement, you require some kind of a buffer. The bits of each of these flows must be distinguishable. Now, how do you make a distinction? Typically, you will make a distinction by encapsulating this data with some kind of overhead bits which we call it to be a header. Now here, on this node, there will be a scheduler, right here which will look at the header and then it will schedule those packets.

Now, in packet switching, there are two ways in which the packets can be forwarded. One is we have the datagram switching or datagram routing, second is virtual circuit switching. Now, what is done in the datagram?

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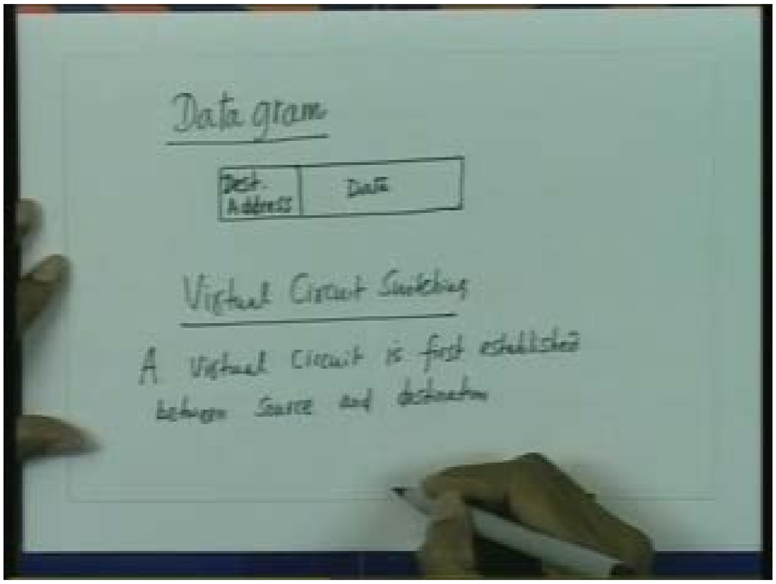

A datagram is quite similar to the concept of a postal switching or a postal routing where the post cards are routed. Each post card or each letter in the post office is required to have the destination address; so, quite similar to that. Here, in this packet where we have the data, here the header will have the destination address. The node, the packet switch node looks at the destination address and then determines where the packet needs to be forwarded by using some kind of a routing algorithm.

On the other hand, in virtual circuit switching, a virtual circuit is first established between the source and the destination before the data transfer can begin. So, a virtual circuit is first established between source and destination before the data transfer can begin. Now, this is very similar to the circuit switching where a physical circuit needs to be established between the source and the destination before you can transfer the data.

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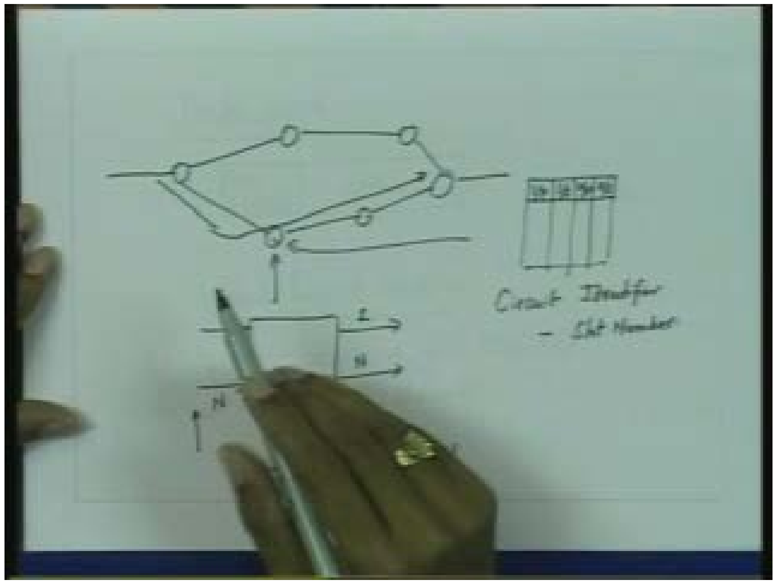

Now, in circuit switching; when you are establishing a physical circuit, remember that we need to see when you are establishing a circuit switching, when you are establishing a circuit between you knows this source to this destination, we need to see that the time slots are available on each of these nodes. Certain portion of the bandwidth therefore, must be available on each of these links between the source and the destination and if any of these time slots are occupied or in other words, if the bandwidth cannot be allocated; then the call is blocked.

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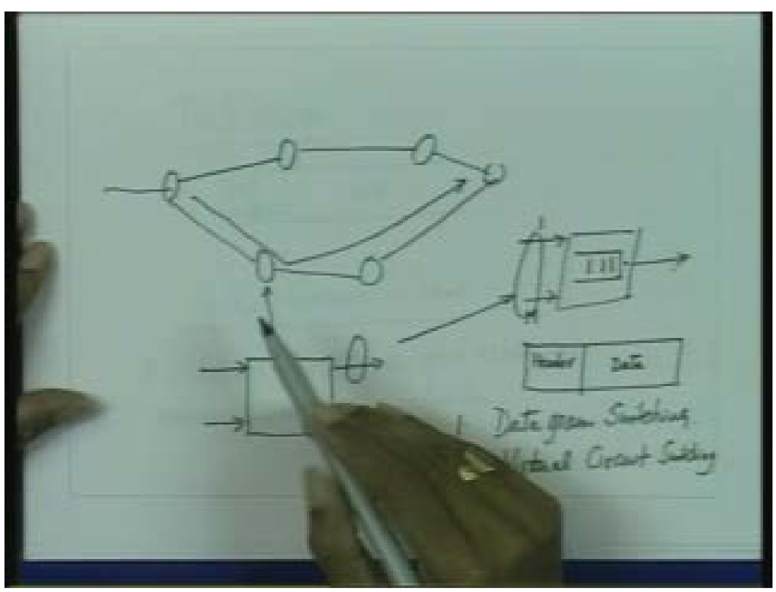

Now, on the other hand, if it is to be a virtual circuit packet switching; then we need to setup a virtual circuit quite similar to the circuit switching between the source and the destination. But the bandwidth may not be allotted permanently or the bandwidth may not be allotted to the circuit in any fixed manner. Essentially, virtual circuit is likely to exploit the capabilities of statistical multiplexing.

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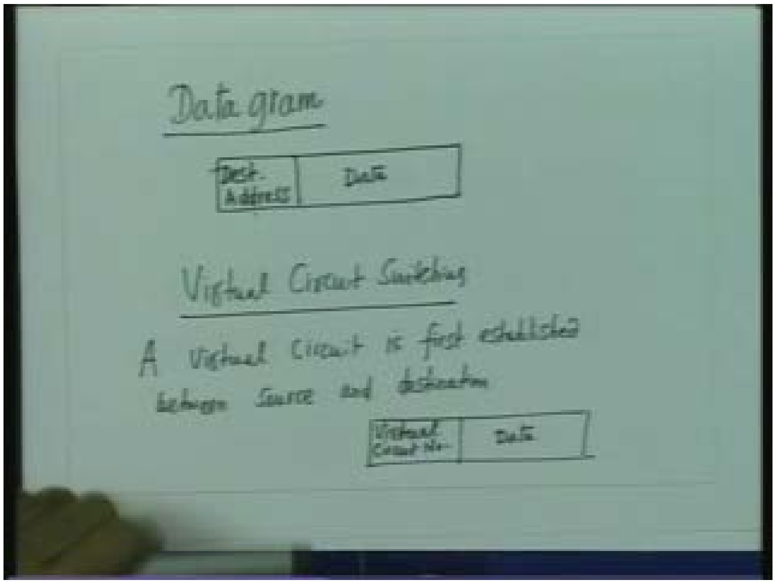

Now, whenever we do this, the virtual circuit; whenever the virtual circuit is first established between the source and the destination, then the packets need not contain the entire destination address but they may just have to contain the virtual circuit number.

Typically, the bits which are required for the virtual circuit number may be much less than the bits which are there for the destination address. Remember, destination address will refer to all possible addresses of all the possible nodes in the networks and therefore, the overhead bits which will be required to represent a destination address will be much larger.

On the other hand, the virtual circuit signifies essentially a flow between the source and the destinations and may be called only when the call needs to be established. Moreover, as we will see later that this virtual circuit number space can be reused also on some other links. So, as a result, typically, the overheads which was there in a virtual, in the representing a packet in a virtual circuit number is far less than in a data gram packet.

But of course, the disadvantage is that in a virtual circuit switching, a call must first be established or a virtual circuit must first be established between the source and the destination. Now, remember of course that a virtual circuit for virtual circuit a physical circuit must be there because after all you know when we transmit the packets, it will consume resources of the link but a circuit is called virtual because it consumes the resources only when the actual data is transmitted. Unlike in the circuit switching where the resources may be consumed by the particular connection even though it may not have some data to transmit.

Now, as we were just discussing a statistical multiplexing with quality of service guarantees in the context of ATM network, an ATM network essentially is a virtual circuit network. An ATM network happens to be a virtual circuit network. So, let us see what are the key features of the ATM network.

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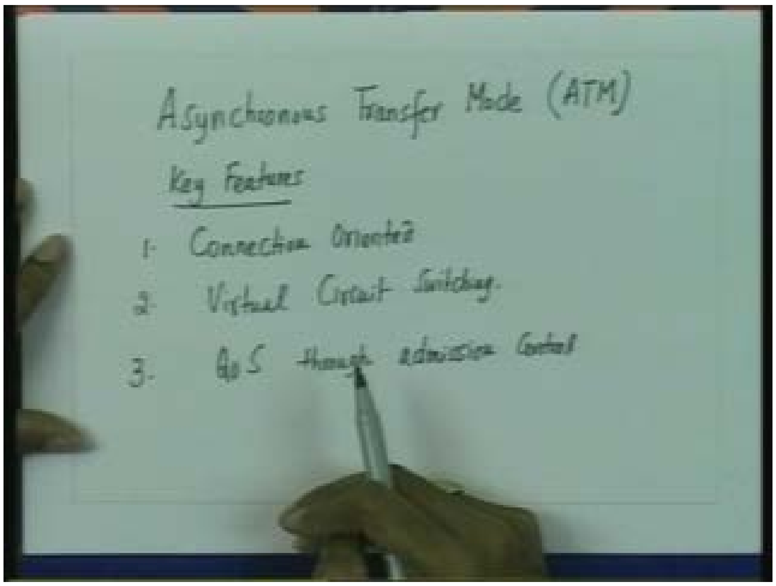

So, we will see asynchronous transfer mode which we call it to be ATM network. So, what are the key features that we have just studied? So, we say that it is connection oriented network. By connection oriented we mean that a connection must first be established between the source and the destination. Then its virtual circuit switching and third, it offers quality of service guarantees through admission control and signaling. These are the 3 key features of an ATM network or an asynchronous transfer mode which is essentially a packet switch network with quality of service guarantees. I would say, ATM was one of the earliest packet switching networks which offered quality of service guarantees.

Now remember; the node, the term - asynchronous here stands for asynchronous multiplexing. What we are saying that the multiplexing as a post to the synchronous multiplexing in the circuit switching, multiplexing in the ATM is asynchronous. Essentially, it is statistical in nature, exploits the statistical characterization of the traffic and at the same time it offers quality of service guarantees. There are some other features of the ATM networks also.

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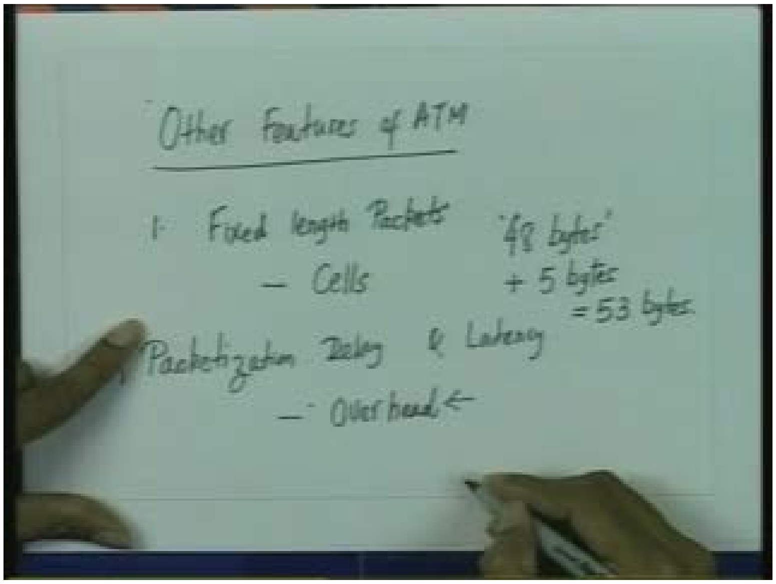

One of the features of ATM networks is that other features of ATM, one of the other features of the ATM was that it uses fixed length packets which are called cells. Now, why fixed length packets? The fixed length packet essentially simplifies switching and transmissions. That is why when the ATM network was first developed, it was thought that it may be better to have the fixed length packet in terms of the simplicity of the fixed length packets and the question then is what should be an appropriate length of the packet?

Since, ATM network was thought to provide quality of service guarantees for real time services, there is a tradeoff between what we called as the packetization delay and the latencies for transmissions.

Now, suppose there is an analog voice which we are digitizing it by sampling it; now, if you sample and put each sample into a packet, then of course our packetization delay will be minimum. But in that case, the overhead associated with each of these data will be proportionately larger.

So obviously, what we would try to do is that we would try to put many samples into one packet so that the overhead associated with a particular packet will be smaller. So, there is always a tradeoff between the packetization delay and the overhead.

Obviously, if you want to reduce the overheads, then your packetization delay increases, your packetization delay increases if you want to reduce the overhead in the latency; therefore for the real time service, it increases. Now therefore, from the point of view of latency, the packet size actually should be as small as possible. It also helps in you know therefore not having any echo cancellation mechanisms.

But on other hand, for the data transmission for statistical multiplexing efficiency, the packet length should be as large as possible. Finally, it was decided that a packet length of 48 bytes should be considered for the transport of an ATM pay load. We add 5 bytes of header here and an ATM cell comprises of 53 bytes. So, an ATM cell therefore consists of 48 bytes of pay load and 5 bytes of header. So essentially, we have 53 bytes of an ATM cell.

Now, as we have just seen that since ATM network is a virtual circuit switching network; obviously, these 5 bytes of the header must have some kind of virtual circuit identifier. We must have some kind of a virtual circuit identifier. Now, we will see that what kind of other fields are there in an ATM cell. Now, these virtual circuit identifier, as I was just mentioning, can also be reused. So, let us see you know how these virtual circuit identifier can be reused.

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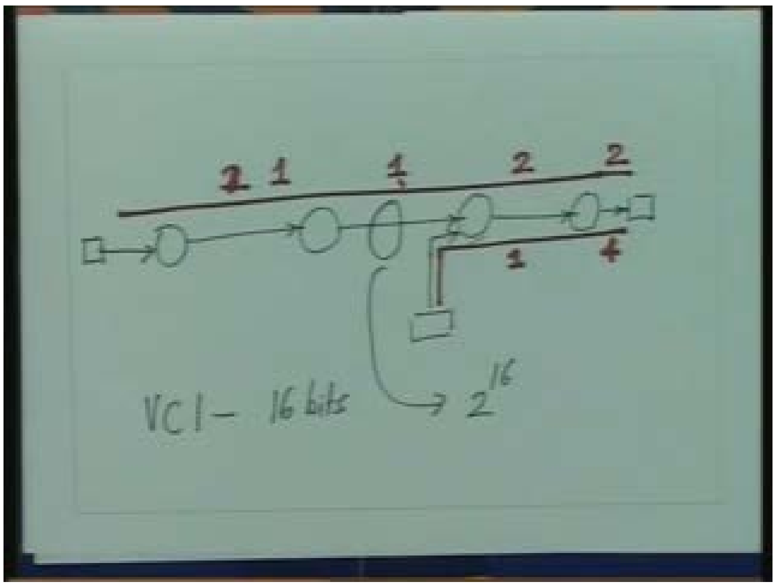

Now, let us see that you have an ATM network where you are establishing a virtual circuit from here to here and some of the calls could be added from here as well. If you want to establish a virtual circuit, suppose this call comes first and therefore this node has allotted for this particular call; so for this particular call, we can say that for this particular virtual circuit, you have allotted the virtual circuit number 1 here and if the one was not available here, this might have allotted it to be a virtual circuit number 4.

Similarly, the virtual circuit has to be established from here to here. Now, this virtual circuit might have been allotted. The virtual circuit number let us say, 2 on this, 2 may sorry, 1 on this, 1 may on this, but since 1 is already used by this virtual circuit, it could be let us say 2 on this and it could still be 2 on this length.

So, what we are trying to say is that this same virtual circuit may have a virtual circuit identifier number 1 here and a virtual circuit identifier number 2 here. So, this VCI is swapped from 1 to 2 on this length.

So in other words, we can reuse the virtual circuit identifier space you know you know on different links and we can we can ensure that by doing some kind of VCI swapping. Now, in ATM the virtual circuit identifier is 16 bits and therefore the total circuit virtual circuits that could be there is 2 raised to power 16.

Now, what it means is that total virtual circuit that could be carried on any link you know between these 2 nodes will be restricted to 2 raised to power 16. But that does not mean that the number of virtual circuit in the entire network would be limited by 2 raised to power 16. By using the principle of VCI swapping, we can increase the number of virtual circuits in the networks to several million except that a number of virtual circuits on a particular link will be restricted to 2 raised to power 16.

So, as we have seen the key features of ATM networks are that it is connection oriented at the lowest level - number 1, number 2 - it has virtual circuits witching and number 3 - it has statistical multiplexing with some kind of assured quality of service guarantees which will be done through some admission control and signaling mechanisms.

So, what does it mean? Since, it is quite similar to circuit switching in the sense that it is connection oriented at the lowest level; it is quite similar to packet switching in the sense that it is virtual circuit with statistical multiplexing. So, we can see that it has the features of both - circuit switching as well as packet switching.

Like packet switching, it has the transmission in the form of packets. However, these packets are fixed length packets. But like circuit switching, it has some admission control mechanism or a call setup face where it will be determined whether the assured quality of service guarantees can be given or not and if the assured quality of service guarantees cannot be given, the call is blocked in a way which is done very similar to the circuit switching. So, it has you know the features of both the things merged into one.

So now, let us see what is the format of the packet in an ATM network.

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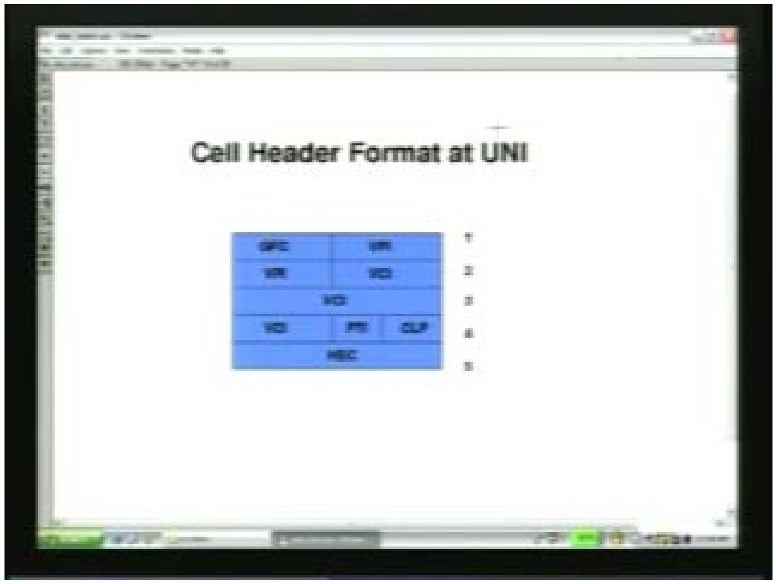

As we said that in ATM network, the cell, the packet consists of 5 bytes of headers. So, which you are seeing here, this is the 5 bytes of headers and we have 48 bytes of pay loads. So now, if you see here, VCI here which is 16 bit or 2 bytes of headers which is VCI. So, VCI stands for virtual circuit identifier VCI stands for virtual circuit identifier. Then we also have VPI. So, I will shortly tell you what is VPI. So, we will just see what are VPI and VCI.

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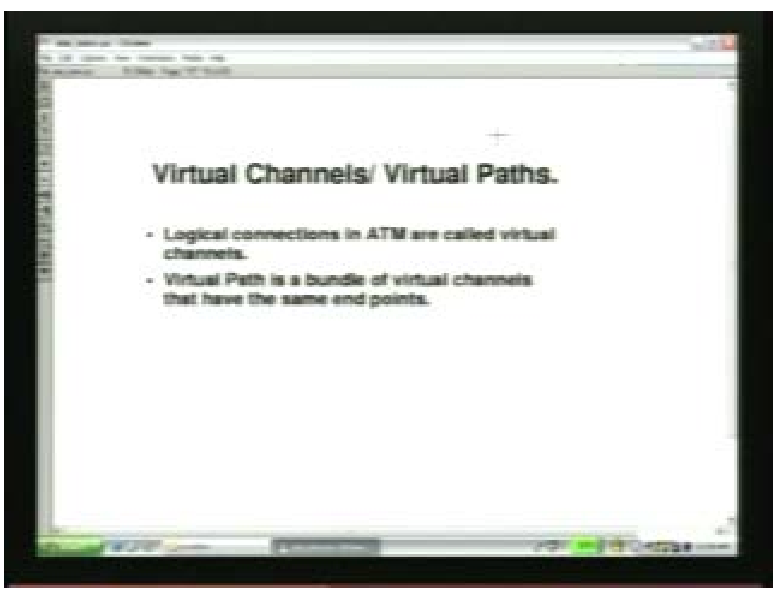

Now, the logical connections in ATM, they are called virtual channels and as we just saw; these virtual channels are identified by a 16 bit virtual circuit identifier or the VCI number. Virtual path, on the other hand is a bundle of virtual channels that have the same end points. So, virtual path is going to be a bundle of virtual channel that have the same end points and that is being identified by you know this VPI number.

So, if you see, in this 5 bytes of header, we have 16 bits of VCI; that is 2 bytes of VCI and 1 byte of VPI that is virtual path identifier. And, what is virtual path? Virtual path is a bundle of virtual circuits that have the same end point. Now, why do we why do we do this? If you see here, now let us look at here.

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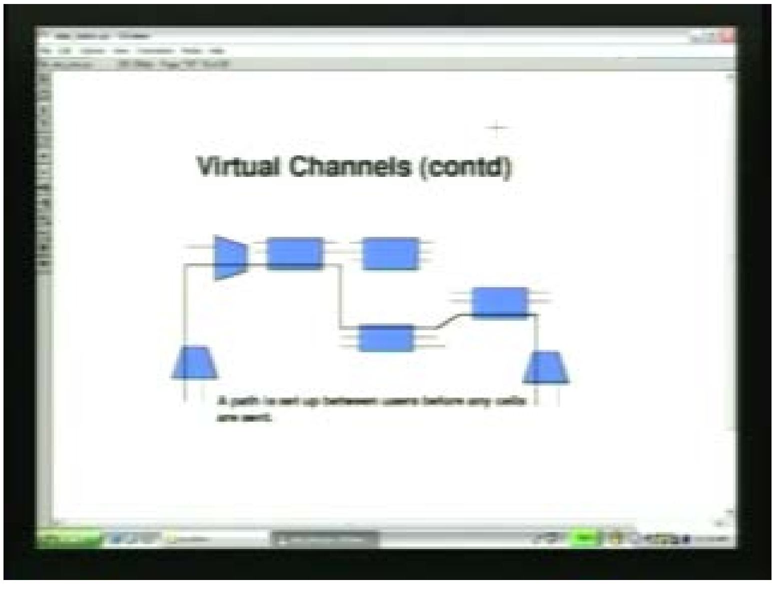

Now, if you see here that virtual channels; a path is setup before any cells. So, as we can see in this figure, a virtual circuit has been established before any cells or any cell transmissions takes place.

So, what happens is that the user first signals for some connections, the user first signals for a connection with certain QoS attributes and with certain traffic characteristics. Now, the network then by doing admission control at each of these nodes, determines whether the call can be accepted or not.

If the call can be accepted, then the network returns with a virtual circuit identifier number - VCI number and then this VCI number, the user has to use in each of a subsequent transmissions. So, this VCI number will be returned by the network if the call has been accepted and in the subsequent transmissions, the cells will be carrying these VCI numbers. Now, what is VPI?

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If you see VPI is as we have said is a bundle of virtual channels that have the same end points. Now, by doing this we actually have some kind of a simplified network architecture which will give you increased network performance. How? because, we can reduce the processing and short connection setup times.

What we can do is that we can setup a virtual path between the source and the destinations by over provisioning of some resources. Then subsequent virtual channels which have the same source and destination end points need not have to be provident every time when that virtual circuit needs to be established.

So, as a result you know what is done is that a VP you know, a virtual path may be established … with certain reserved bandwidth and whenever the requirement for a particular virtual channel comes up, then out of that bandwidth you know may be given to the virtual circuits as and when they keep coming. So obviously, this has the advantage that it has reduced short connection setup it has reduced connection setup time or short connection setup time. But at the same time, it has the disadvantage that we may have to have some kind of an over provisioning.

Now subsequently, if you are having virtual path identifier number, then the switching which is done at the individual switches that may be done by using virtual path identifier - VPI numbers only. That need not be done through the virtual circuit identifier or the VCI numbers. Now, this leads to some enhanced network performance and enhanced network services.

Now, we have seen here, this I pointed out here that this is the cell header format and typically in an ATM node, it is also called the cell header format at the UNI.

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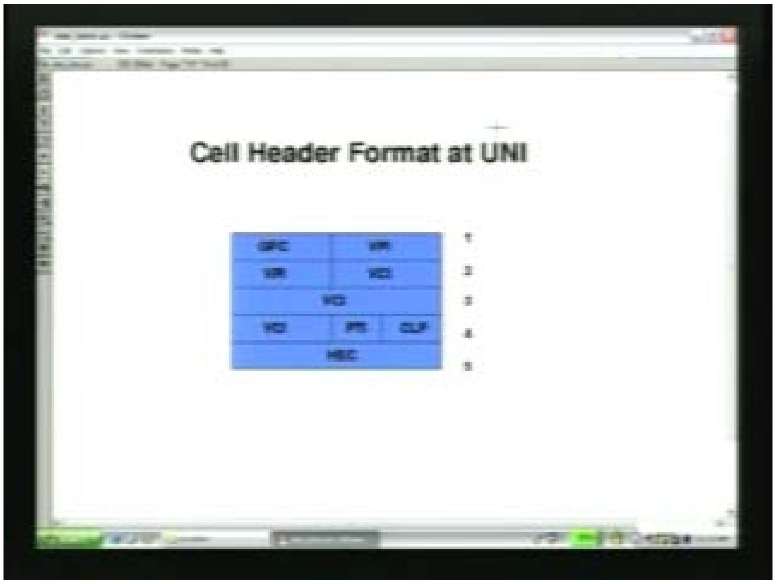

Now, UNI stands for user network interface and this is the interface that exist between an ATM user and it is and the network that is the the first connect point between the ATM attached node and the network.

On other hand, between 2 ATM network nodes, the interface is called NNI or network network interface. This is the UNI which is between an ATM user and the network and that is why it is called as the user network interface. Now, there are some other bits in the cells as you as you can see that there is a bit called pay load type identifier bit and there is a bit called clp. Now, payload type identifier will identify what is the kind of payload that is following these 5 bytes of header. So, these 48 bytes is a payload after this header and what is the kind of payload is signified by this pti bit in the header. There is another bit in this header which is the clp - the cell loss priority.

Now, this clp bit can be set to 0 if the cell has a higher priority. However, if it is set to one, then the cell does not have the priority. Now, in the event of congestion, those cells you know whose cell loss priority bits have been set to 1, they will be the first cells to be discarded. So, if a net, if a source is not confirming to its advertised traffic contract, then the network may take two actions; either the network may drop all those cells which are not confirming to the advertised traffic contract.

However, if a network has some bandwidth available, has some resources available, then it may take a lenient view and it may allow these cells to pass through. But it may put the cell loss priority bit to 1. As a result, what happens that if in the subsequent nodes; the resources are not available, then those cells whose clp bits have been set to 1, they will be the first to get discarded. So, this is the reason why the clp bits have been put.

The other bit if you see in this slide is we have HEC. Now, HEC stands for header error corrections. So, these are the, this HEC bits is essentially a CRC bits over the other 4 bytes of the headers. The other 4 bits are GFC or generic flow control. I will discuss about this generic flow control later on. So, this is the 5 bytes of headers which is attached to the data of an ATM user and this constitutes and 53 bytes of an ATM cell. Now, as we have seen that in an ATM or protocol stacks, so let me just show how an ATM protocol stack will look like.

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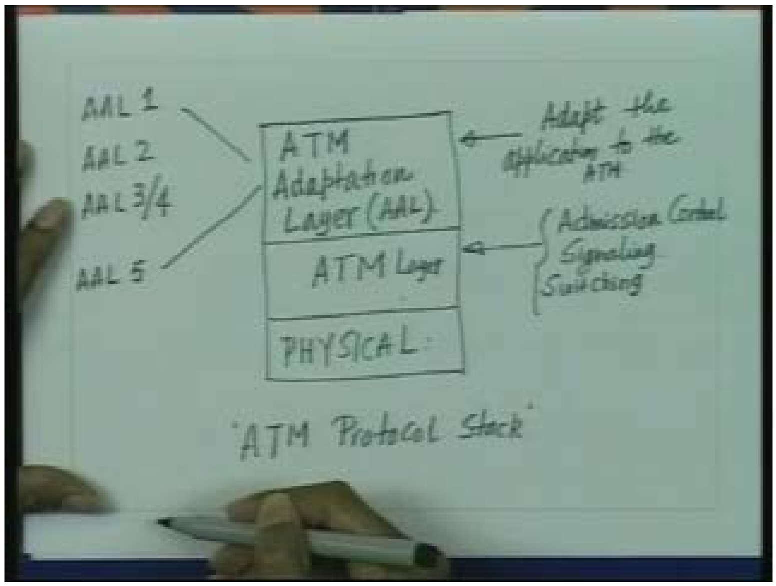

So, if you look at the ATM protocol stack, then of course, we have physical layer and we have the ATM layer. Now, the physical layer essentially is a media dependent. It could be copper or it could be optical fibers.

Now, what are the jobs of the ATM layer? The job of the atm layer as we have seen is admission control, signaling and switching. So, signaling for virtual circuit routing, switching that is switching the cells at each of the nodes and admission control for quality of service guarantee. So, all these jobs are done by the ATM layer. Then there is other layer which is called ATM adaptation layer or just called AAL. So, this is our ATM protocol stack.

Now, the function of the adaptation layer is really to adapt the applications to the ATM. Now, since the job of the ATM adaptation layer is to adapt applications or services to the ATM networks, there are as many adaptation layers as there could be services that are the application types that could run over the ATM networks.

So, we will see that there is an adaptation layer. 1 - there is an adaptation layer, 2 - there is an adaptation layer, 3 and 4, they have been now merged and one of the other popular adaptation layers is AAL 5. So, I will shortly explain what are the significances of these ATM adaptation layers for different services.

But before you know we go and into these various adaptation layers and the basics; one thing I would like to say is that ATM networks has classified the types of traffics that can be injected into an ATM networks as one of the 4 types and which I will just show you what are those types of the traffics which have been classified.

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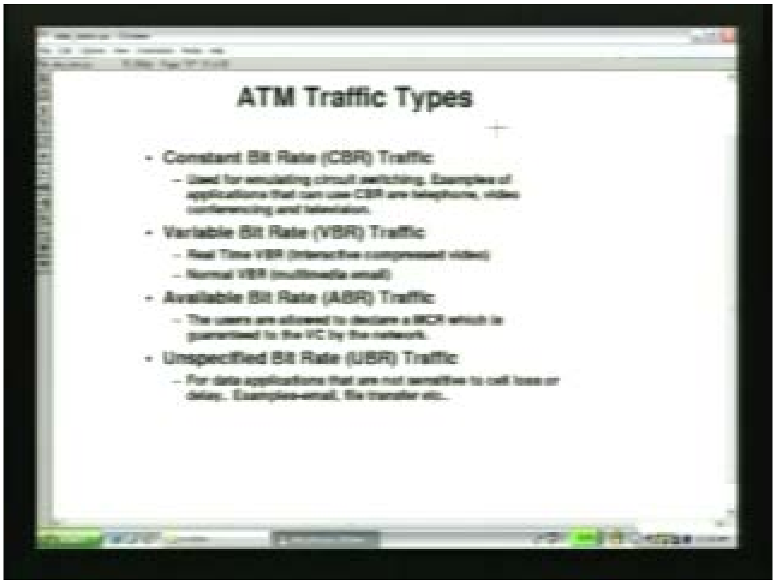

These are the ATM traffics types. One is constant bit rate traffic. Now, this constant bit rate traffic is used for emulating circuit switching. As the name stands, it is constant bit rate traffic. It is traffic with a periodic constant bit rate. Examples of these applications are TCM data coming from the telephone or a constant bit rate encoded video conferencing or television or video transmission details which are constant bit rate encoded, TCM encoded essentially.

Then the second traffic type is the variable bit rate traffics. Variable bit rate traffics can again be of two types: the real time VBR or the normal VBR or non real time VBR. Now, the variable bit rate, it is the variable bit rate traffics which is of the most significance in the ATM networks from the statistical multiplexing point of view.

What we say in the variable bit rate is that the real time source is encoded using some kind of a variable bit rate code by using some kind of compressing techniques and as a result, the data rate of the encoded stream varies in bit rate and therefore and it varies in bit rate, it bit rates bit rate fluctuates in a statistical fashion and therefore its traffic characteristics is more statistical in nature. So essentially, it is for the VBR kind of traffics where the statistical multiplexing comes into the pictures.

So, VBR traffic is a traffic whose bit rate fluctuates with time whose bit rate fluctuates with time essentially because of the compression which is used in encoding and it is also the traffic which requires the quality of service guarantees. So, all the talk we had done for the statistical multiplexing with quality of service guarantees essentially for the VBR kind of traffic.

On other hand, the CBI traffic, the constant bit rate traffic is also a real time traffic which requires quality of service guarantees. But since the transmission of the bit rates is constant in nature, it is periodic in nature; therefore, statistical multiplexing gains cannot be achieved for the constant bit rate traffic. So, for the constant bit rate traffic, the ATM network will degenerate essentially to some kind of a circuit switching techniques. So, it is it will be very similar to a circuit switching techniques and that is why we say that CBR traffic will require you know some kind of circuit emulations in the ATM networks.

There are other 2 traffics types which have been specified in the ATM networks which are called one is available bit rate traffics, another one is the unspecified bit rate or the UBR traffics. Now, available bit rate traffic is quite similar to the bursty traffic which is used in a normal packet switched networks in a normal packet switched networks. Now, this is the traffic which does not require any quality of service guarantee. The bit rate fluctuates much like VBR traffic. So, it is quite similar to the VBR in the sense that it is also bursty, but it does not require any quality of service guarantees.

So though, it will have statistical multiplexing, but since it does not require any quality of service guarantees; there may not be any need of admission control in this case. Now, when the VBR traffic was developed, if the VBR traffic has to co-exist with the traffic which also offers quality of service guarantees like VBR and where ABR traffic was developed and it if it has to co-exist with services like VBR and CBR kind of traffics; then it was thought that there may not be any bandwidth available for the ABR traffic if the network tries to be greedy. That is it tries to allocate the resources only for the VBR and the CBR traffic, then the ABR traffic that is the available bit rate traffic may actually starve of the bandwidth.

So then, it was decided that in the ABR traffic, the users are allowed to declare a certain minimum transmission rate, a minimum cell rate which is guaranteed. So, the ABR traffic in that sense now also falls into some kind of a Qos kind of traffic which is given a certain minimum cell rate. But, though it is for the bursty traffic; it is not real time real time traffic like voice and video.

Then, the fourth category of the traffic which was defined was called unspecified bit rate which is like data applications which are sensitive neither to the cell loss or the delay. So, it is very similar to the bursty traffic which is carried today in the internet world or in the otherwise packet switch world examples are like email applications or file transfers and so on.

So, these are the various traffic types which have been standardized in the ATM network world which actually signifies the kind of traffic characteristics which will be injected into an ATM network. So, as you can see that we have a spectrum of traffic sources, a constant bit rate traffic which is typically a traffic carried in the circuit switch world to an unspecified bit rate UBR or ABR kind of traffic which will be carried in a pure packet switch world which does not offer any quality of service guarantees.

So, we can see that the ATM provides a unified framework for carrying of these traffic types: on the one hand, on the one extreme - traffics which requires stringent quality of service guarantees, to the other extreme - the kind of traffic which does not require any quality of service guarantees.