Data Communication
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Lecture # 27
Medium Access Control- III

Hello and welcome to today's lecture on medium access control. This is the third lecture on this topic. In the first lecture we discussed about the contention based medium access control protocols like ALOHA, CSMA and CSMA/CD. In the second lecture we have discussed about the collision-free protocols where we have discussed the token ring and other protocols like round-robin protocols and reservation protocols. In this lecture we shall discuss about another very important approach based on channelization.

Here is the outline of the lecture.

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First I shall discuss about the basic concepts of channelization and I shall give an analogy based on cocktail party theory which gives you some idea how the channelization medium access control techniques work. Then we shall discuss the three important types of channelization based medium access control techniques such as frequency-division multiple access FDMA and time-division multiple access TDMA then code division multiple access CDMA. This code division multiple access CDMA is very complex and we shall discuss how it is used and particularly discuss different aspects of it like the transmitter and receiver, how the multiplexing and demultiplexing is done, then how the chip sequences which is used in CDMA as used here and how the chip sequences are generated with help of the Walsh table.

and on completion of this lecture the students will be able to explain the basic idea of channelization, they will be able to explain FDMA technique, they will be able to explain the TDMA technique time-division multiple access technique and understand the basic concepts of CDMA and they will be able to explain how multiplexing and demultiplexing occurs in CDMA and explain the orthogonal property of the chip sequences which are used in CDMA.

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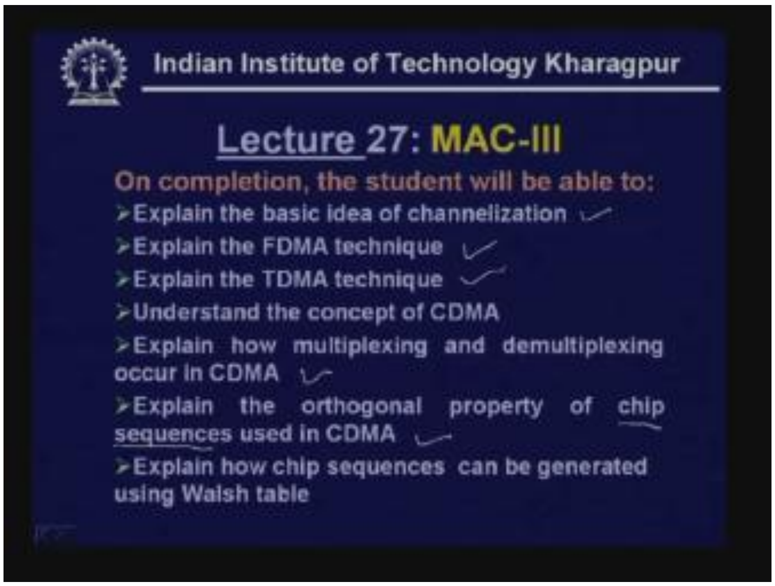

Finally they will be able to explain how chip sequences are generated with the help of Walsh table. Here is the basic overview of the medium access control techniques.

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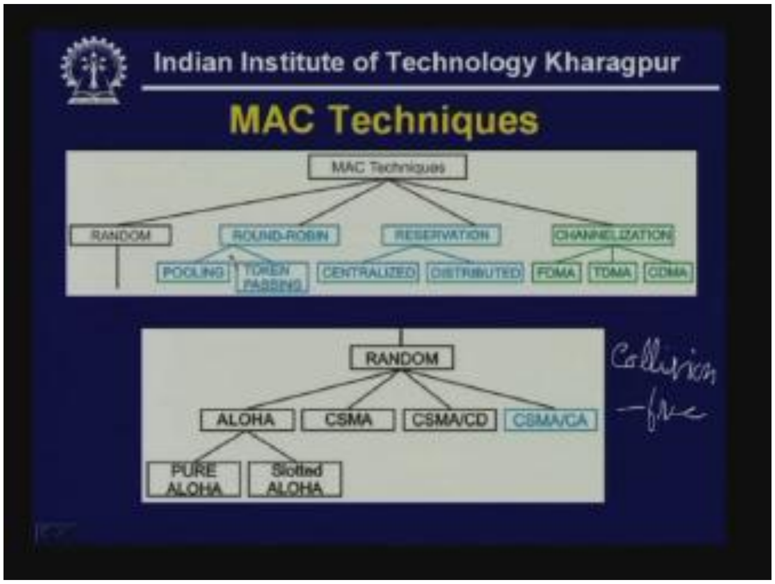

As I mentioned in the first lecture I discussed about the random access type protocols like ALOHA, CDMA and CDMA/CD and again the ALOHA has two different varieties pure ALOHA and slotted ALOHA and in the last lecture we have discussed about the collision-free protocols where the collision is avoided and there are a number of techniques such as CSMA/CA collision carrier sense multiple access with collision avoidance then there are two other basic approaches like round-robin where you have got two techniques polling and token passing which we have discussed in detail.

Then we have the reservation based protocol the two distinct categories of protocols which are based on centralized scheme and distributed scheme. All these things we have discussed in the last lecture. In this lecture as I mentioned we shall discuss about the channelization approach based on FDMA, TDMA and CDMA. Let us first try to understand what we really mean by channelization technique.

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It is essentially a multiple access method in which the available bandwidth of a link is shared in time, frequency or using codes. So there are three basic approaches. The bandwidth is shared in time, in frequency or using code by a number of stations. So these three alternatives that means sharing in time, sharing in frequency, sharing using code has led to three different approaches like FDMA where the bandwidth is divided into separate frequency bands and then different frequency bands are used by different stations.

Then we have TDMA where the bandwidth is timeshared that means at different instants of time different users or stations use the medium. On the other hand, in CDMA the data from all stations are transmitted simultaneously and are separated based on coding theory. So here we find that it is neither frequency shared nor timeshared but here it is based on coding theory so all are transmitting simultaneously in terms of frequency and time and they are separated by using coding theory.

The three basic approaches can be best explained with the help of a very simple cocktail party theory.

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Suppose a cocktail party is going on, say banquet dinner of a conference is going on and it is going on in a big area then there are three possible alternatives. In one case when all the people group in widely separated areas and talk within each group. That means in this case normally we have seen different people having different kinds of interest and groups in different locations where the cocktail party is going on, they talk among themselves and when all the people group in widely separated areas and talk within each group we call it FDMA. That means as if we have assigned different frequency bands to each of these groups and each of these groups are talking using different frequency bands. So this is your FDMA approach.

Another alternative is when all the people are in the middle of the room but they take turn in speaking. In the second situation some very important event is going on and all the people have gathered at a central place and each of them is taking turn in talking. So, in this case it is equivalent to TDMA or time-division multiple access. Here we have the basic approach, in terms of time the sharing is taking place.

Now the third approach is very interesting. When all the people are in a middle of the room but different pairs speak in different languages. It is not unusual that in an international conference when the banquet dinner is going on people from different countries will arrive there and obviously when they group together they may be speaking in different languages.

Let’s assume that all of them have gathered near the central area but small groups are talking in different languages, a group is talking in English, a group is talking in French, a group is talking in German, another group is talking in may be Bengali, another is Hindi, so you can see that each of these groups will start talking simultaneously; and since they are speaking different languages the group talking in English although they are hearing the voices of people speak in Hindi or French or German will not interfere with their discussion. So here simultaneously all of them are talking but they are not interfering with each other because they are talking in different languages. This is equivalent to CDMA or Code Division Multiple Access.

Here we shall see how all the people can talk simultaneously at the same time they will not interfere with each other or each of them can separately talk within their group. Hence, this is the analogy of the three channelization approaches based on cocktail party theory. Now let us first focus on the Frequency Division Multiplexing.

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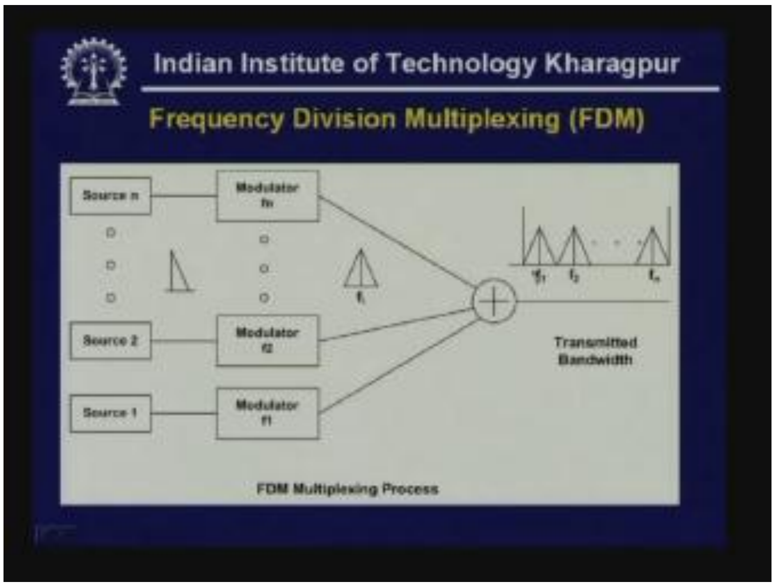

In Frequency Division Multiplexing we have already seen we have got a number of sources, you have got n sources as shown here and each of them is sending some data. The signals coming from each of these sources are modulated by using different carrier frequencies f1 f2 and fn and as a consequence we are creating signals in different frequency bands and they are combined together and the composite signal as you can see here (Refer Slide Time: 10:33) you have the centre frequency f1 which is the carrier frequency of the modulator one and f two and as you can see each of these signals coming from each of the sources are now channelized in terms of frequencies, that’s why it is called Frequency Division Multiplexing.

Here the overall bandwidth is divided into separate frequency band and each of the channels is using one of the channels to transmit. This is how Frequency Division Multiplexing occurs. We already know that you have to use guard bands in between the frequency bands of a pair of adjacent channels. So channel one and channel two are the adjacent channels so their carrier frequencies are f_{c1} and f_{c2}, you have to use some guard band between the two so that they are separated by strips of unused bandwidth to prevent inter-channel cross talk.

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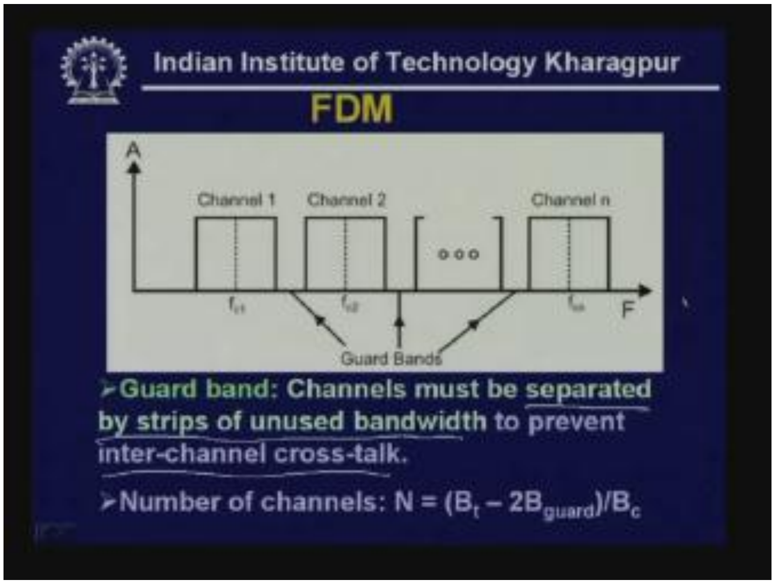

Whenever you perform frequency modulation the bandwidth increases and you have to overcome the cross talk so inter-channel cross-talk has to be avoided and to do that guard bands are used. So, whenever you have got a number of channels this particular equation shows what is the number of channels that can be used. That is, number of channels that can be used N is equal to B_t minus $2B_{guard}$ where B_t is the total bandwidth available and that is being divided into a number of channels, the bandwidth allocated to each channel is here and Bt the total bandwidth minus $2B_t/B$. This is how we get the total number of channels that is possible in case of Frequency Division Multiplexing.

Now you may be asking, what's the difference between Frequency Division Multiplexing and Frequency Division Multiple Access?

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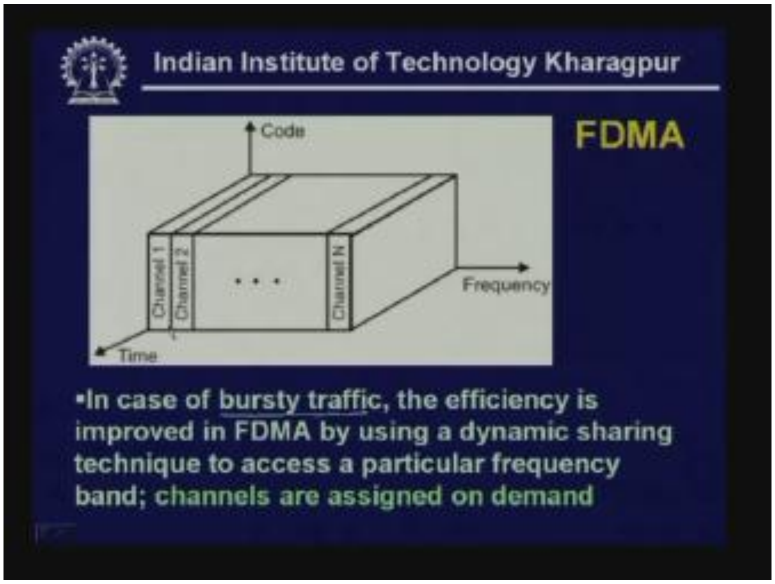

Here as you can see the signal sent by different channels have been shown in a three dimensional graph where the three dimensions are time, frequency and code. So as you can see the signals coming from different channels are only varying in terms of frequency here. However, in case of bursty traffic the efficiency is improved in FDMA by using a dynamic sharing technique to access a particular frequency band. Now, normally for each of these channels a frequency is statically allocated but if the traffic is burst that means all the channels do not have data to send all the time so in such a case there can be under utilization of the channels because a channel is statically or permanently allocated to a particular station or user.

Therefore, in such a case if the traffic is bursty that particular channel may not be used. So what can be done to improve the utilization? So, instead of statically allocating a particular channel to a particular station the channels can be assigned on demand. That means depending on the requirement of different stations or users a single channel can be allocated to different stations or users. So that makes FDMA Frequency Division Multiple Access. That means not only the overall bandwidth is divided into a number of channels but each channel can be allocated to a number of stations or users. So, if you have got N channels now since each channel can be shared by more than one user the total number of stations that can be provided a service can be greater than N if it is statically allocated than the total number of number of stations that can be used in service is equal to N.

However, since this is allocated or assigned dynamically on demand the total number of stations can be larger than the number of channels. Obviously this is possible only when the traffic is bursty in nature. If the traffic is streamed that means continuously sent then of course it cannot be done. This is the difference between Frequency Division Multiplexing and Frequency Division Multiple Access.

In case of Frequency Division Multiple Access as we have seen each channel can be used by different users based on the assignment done on demand. So this is your Frequency Division Multiple Access. Now let us focus on the Time Division Multiplexing.

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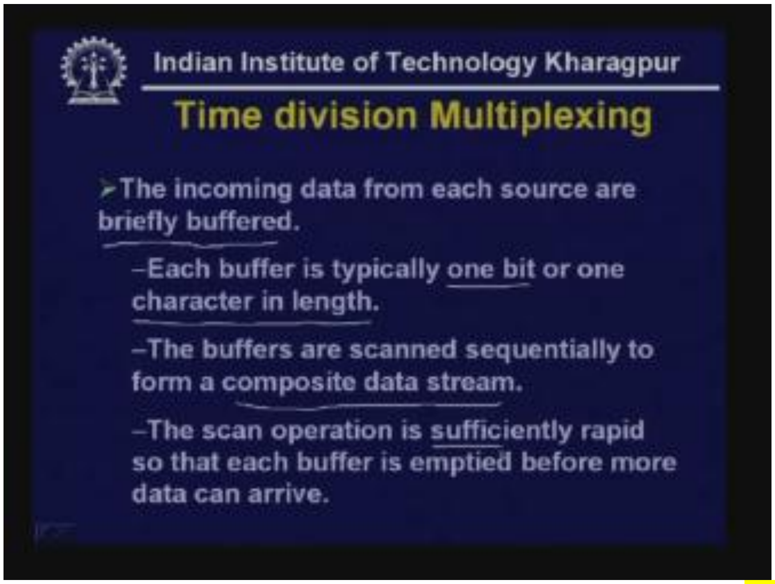

As you know the incoming data from each source are briefly buffered. We have already discussed the Time Division Multiplexing at length and we have seen that each buffer is typically either one bit or a character in length. The buffers are scanned sequentially to form a composite data stream and the scan operation is sufficiently rapid so scanning is done very fast so that each buffer is emptied before more data can arrive. Here it is shown how it is being done.

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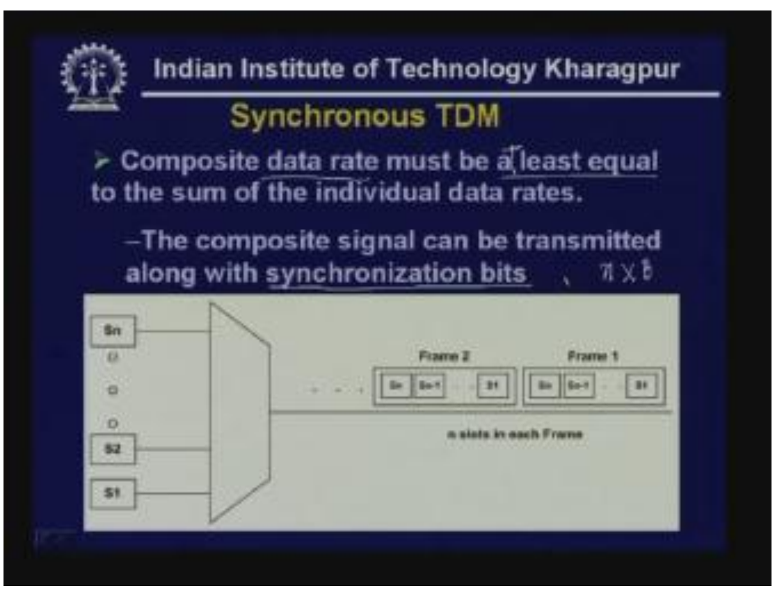

Here are the buffers coming from different sources and here you have got some kind of switch so a connection is established between S1 then S2 then in this way up to Sn but it is done very fast and some kind of framing is done and composite signal is framed where you have got data from S1 S2 up to Sn likewise it is repeated so again another frame comes up as S1 S2 and Sn.

Of course the composite data rate must be at least equal to the sum of the individual data rates. So if you sum up the individual data rates say you have got n channels, n into data rate is B then this has to be n into B that means here the rate will be at least n times of the individual data rates when you have got n stations or channels. Then the composite signal can be transmitted along with synchronization bit. Just like the guard bands are used in Frequency Division Multiplexing and guard band is essentially some kind of overhead similarly here the synchronization bits are overhead bits as you have seen in case of Time Division Multiplexing.

And here also the problem arises if these stations do not have data all the time. So here for example the first frame is filled up because there is data A B C D. On the other hand, in the second frame there is data from A B C but there is no data from D so it goes empty. Similarly, in frame 3 A B C D the C D has no data to send and this is the transmitter end and in the synchronous manner it is received at the other end and AA, BB, CC and DD are collected.

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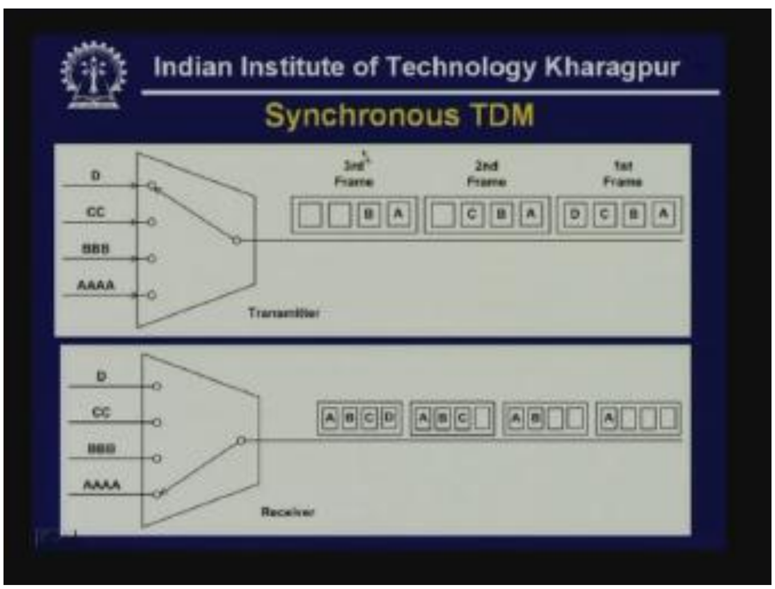

But as you know Synchronous Time Division Multiplexing leads to under utilization of the channel if the data is bursty in nature that’s why we developed another approach known as Asynchronous Time Division Multiplexing or ATM where instead of allocating a fixed slot for each of the channels these slots can be different. But in TDMA it is done in a little different way.

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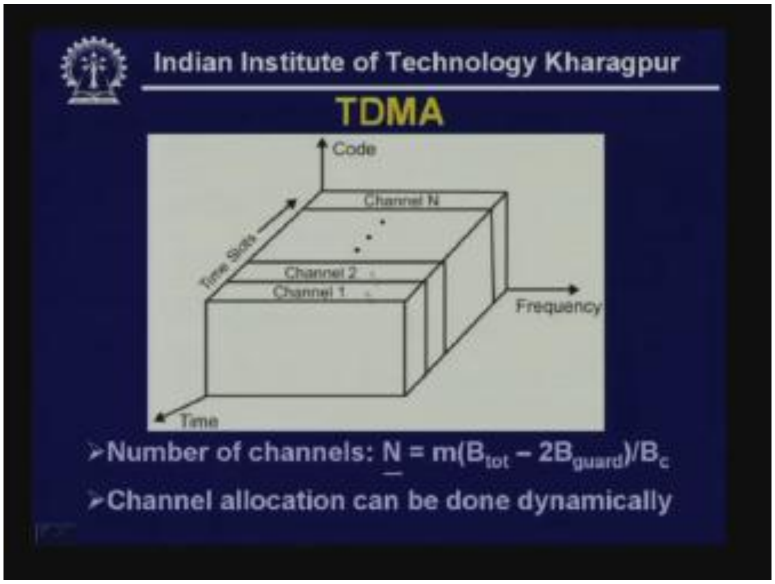

So, as you can see here the frequency and code remains same for each of the channels however the time slots are varying. In this case the number of channels is equal to N where m is number of bits for each of the stations multiplied by B total that is the total bandwidth available minus two into the guard bandwidth by B_c the bandwidth of each of the channels so you have got separate channels.

Now, just like in the case of frequency division multiplexing here also it is possible to assign the slots to different stations or users dynamically. So, channel allocation can be done dynamically. Whenever you do that for example this particular channel can be statically allocated to a single station or user in that case we call it Time Division Multiplexing.

On the other hand, if it is done dynamically based on demand then we call it time division multiple access. That means a particular channel can be shared by a number of stations or users. So, it is not only we are sending but we are dividing into different time slots but each of these time slots can be shared by more than one station or user. That is essentially known as TDMA or Time Division Multiple Access. We have discussed the two basic channelization approaches.

Now let us focus on the other one which is the most complex one the Code Division Multiple Access CDMA. In CDMA as you can see it is neither divided in terms of time nor divided in terms of frequency, each of the channels occupy the same frequency and time simultaneously. However, they are separated in terms of code so you have got channel 1, channel 2 and channel N using different codes. How exactly it is being done by using different codes will be explained very soon.

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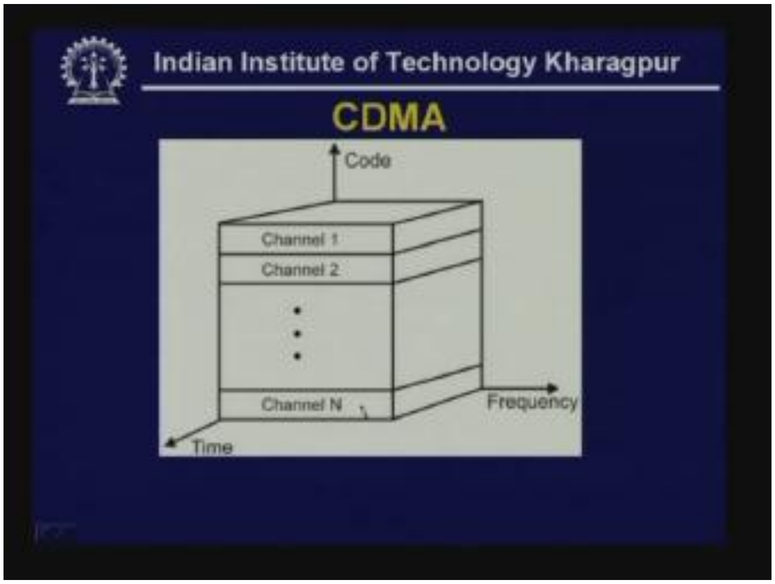

Here are the basic differences between TDMA, FDMA with CDMA.

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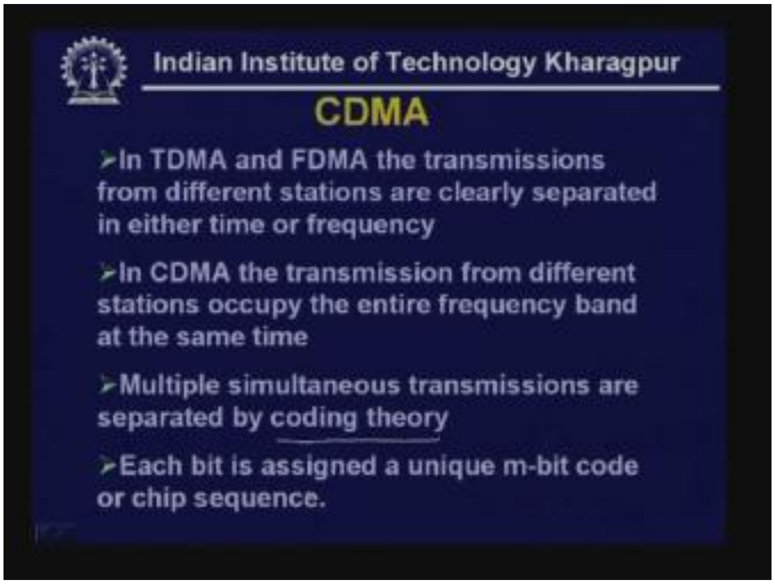

In TDMA and FDMA the transmissions from different stations are clearly separated either in time or frequency as you have seen. They are sent in different time slots or from different users where different frequencies are used. But in CDMA the transmission from different stations occupy the entire frequency band at the same time as you have seen in this particular diagram (Refer Slide Time: 22:37). All the channels are transmitted in the same time using the same frequency band. Now it is possible to have multiple simultaneous transmissions separated by coding theory. So we have to use some kind of coding theory so that it is possible to have multiple simultaneous transmissions which can be separated by coding theory.

What is being done is, each bit is assigned a unique m-bit code or chip sequence that is the basic idea. That means each bit of a channel is assigned a unique m-bit code or chip sequence. This diagram explains to you how multiplexing is being done.

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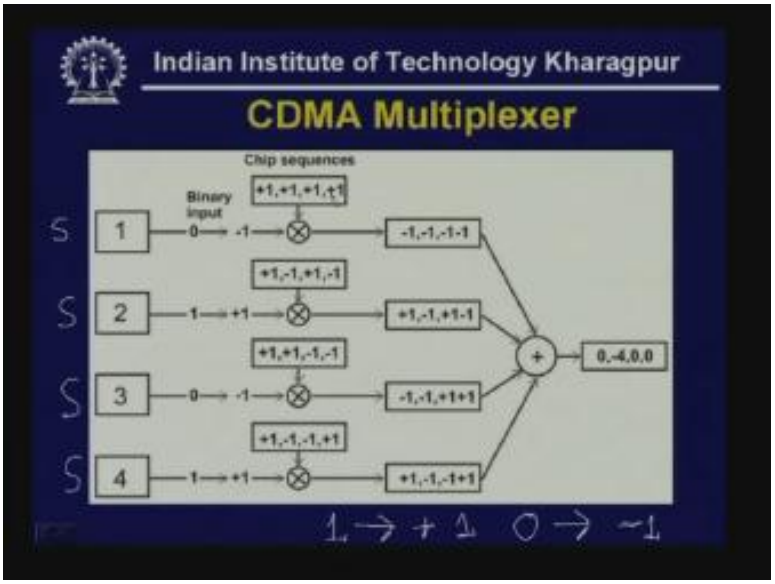

Here the binary data is coming from four different sources that is your station 1, station 2, station 3, station 4 so station 1 0 is coming, station 2 1 is coming, from station 3 0 it is coming, from station 4 1 it is coming and so on. Now for pedagogical purposes this 0 is represented by minus 1 and on the other hand, 1 is represented by plus 1. Hence you can see here 0 is represented by minus 1 and 1 is represented by plus 1 for pedagogical purposes.

Now each of these stations is having a unique chip sequence. So this chip sequence for channel 1 is plus 1, plus 1, plus 1, plus 1 essentially it is 1 1 1 1. On the other hand, for station 2 it is plus 1, minus 1, plus 1, minus 1 it is different from the chip sequence of channel 1 and then for channel 3 the chip sequence is plus 1, plus 1, minus 1, minus 1 again it is different either from station 2 and station 1 then finally you have got the chip sequence for station 4 which is plus 1, minus 1, minus 1, plus 1. As you can see all these four chip sequences are unique. Each of them is different from the other three and then this binary input is multiplied with the chip sequences so plus and minus leads to minus 1 so whenever it is multiplied with minus then plus 1, plus 1, plus 1, plus 1 becomes minus 1, minus 1 minus 1, minus 1 and minus 1.

On the other hand, for channel 2 it is multiplied with plus 1 it becomes plus 1 it remains same so plus 1, minus 1, plus 1 and minus 1 it remains same. Then minus 1 when it is multiplied it becomes plus 1, plus 1, minus 1, minus 1 the chip sequence becomes minus 1, minus 1, plus 1, plus 1 and from station 4 it is multiplied with plus 1 that is because the binary data is 1 so it becomes plus 1, minus 1, minus 1, plus 1 which in turn becomes plus 1, minus 1, minus 1, plus 1.

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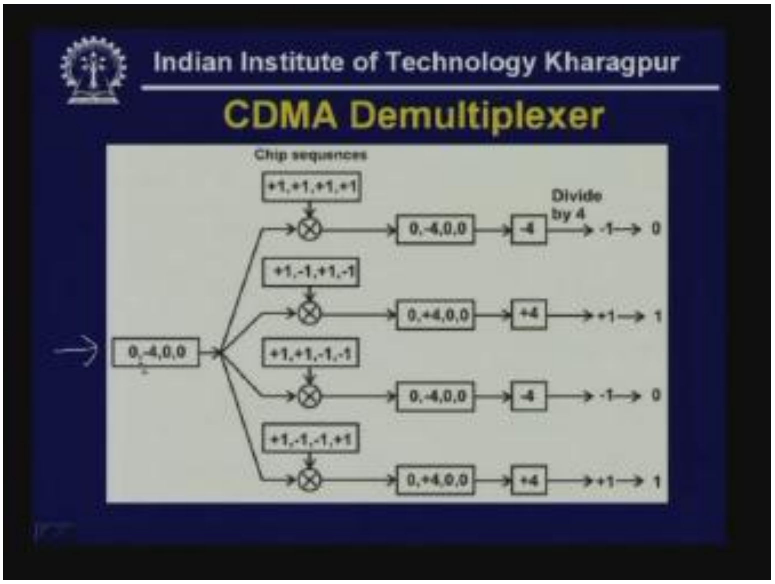

Now these are added bit by bit so here you see plus 1, minus 1, plus 1, minus 1 becomes 0. For the second bit minus 1, minus 1, minus 1 becomes minus 4, you have to add all the four then minus 1, plus 1, plus 1, minus 1 becomes 0 and minus 1, minus 1, plus 1, plus 1 becomes 0. Thus the composite signal corresponds to 0, minus 4, 0, 0 so this can be sent over the medium. This is sent and it is being received at the other end so here it comes from the medium and after it is received these same chip sequences (Refer Slide Time: 27:00) which were used for different channels are used for demultiplexing so it is multiplied with the same chip sequences.

Therefore, after multiplying with these chip sequences this is 0, minus 4, 0, 0 it becomes 0, minus 4, 0, 0 and this is 0, minus 4, 0, 0 multiplied with plus 1, minus 1, plus 1, minus 1 which becomes 0, plus 4, 0, 0 and similarly 0, minus 4, 0, 0 multiplied with plus 1, plus 1, minus 1, minus 1 becomes 0, minus 4, 0, 0 similarly 0, minus 4, 0, 0 multiplied with plus 1, minus 1, minus 1, plus 1 which is a chip sequence of channel 4, it becomes 0, plus 4, 0, 0.

Now, if you add together you have to perform the addition, here you are doing addition (Refer Slide Time: 27:55). So, if you add then you get minus 4, here if you add all the four you get plus 4, here if you add it becomes minus 4, here if you add all the four you get plus 4, here if you add it becomes minus 4, if you add 0, plus 4, 0, 0 you get plus 4 then you divide by 4 because you have got the total number of channels as 4 then you get minus 1 here, plus 1 here, minus 1 here and plus 1 here. Thus, after dividing by 4 you get minus 1, plus 1, minus 1, plus 1. So, as you know minus 1 is nothing but 0, plus 1 is nothing but 1 so whatever was transmitted that 0 1 0 1 is now recovered so all of them were sent simultaneously and the demultiplexer can be **separated out again by multiplexing with** chip sequence.

So in practice this is being done in this way so the binary information comes here which is the 0 or 1 and that is being multiplied with the help of random sequence. If R is the bit rate of data then this spreading factor is selected such that it occupies the entire frequency band of the medium.

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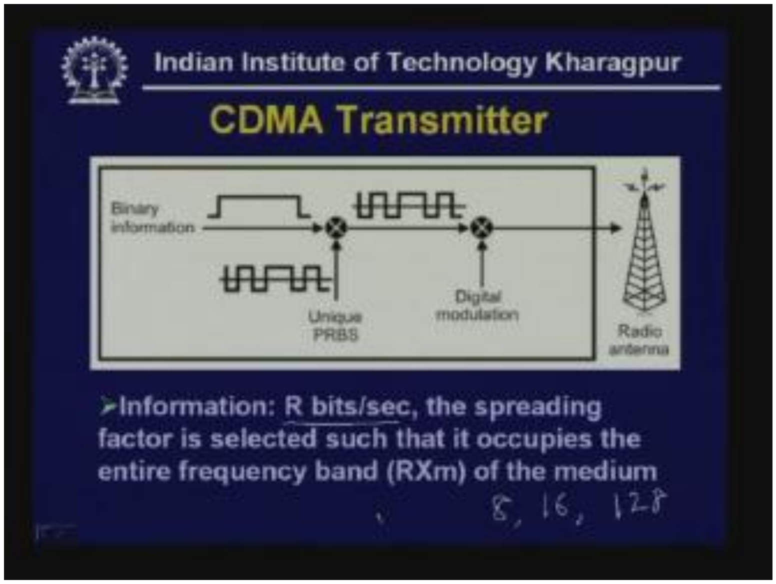

That means the number of bits in this chip sequence is chosen such that it occupies the entire bandwidth of the channel. So it can be 8, it can be 16 or it can be 128 depending on the bandwidth of the medium. Therefore, the signal that comes out becomes m times which is the number of bits in the chip sequence the data rate of the medium.

After multiplying this is the signal that is being generated and now you can perform digital modulation like QAM, QPSK this kind of modulation you can do then you can transmit by using an antenna. This is how the transmission is performed and as you can see the bandwidth here (Refer Slide Time: 30:15) is at times the bandwidth of each of the channels.

Now at the receiving end signals from all the transmitters are being received by this antenna then the composite signal is multiplied with the digital demodulator. Digital demodulator means that the decoding is being performed as seen in the case of digital modulation the demodulation is performed and after demodulation we get the composite signal and that is being multiplied with unique pseudo random binary sequence and after multiplying the same pseudo random binary sequence we get back the signal. Of course it will have some noise because of interference and other problems but you get back the binary information.

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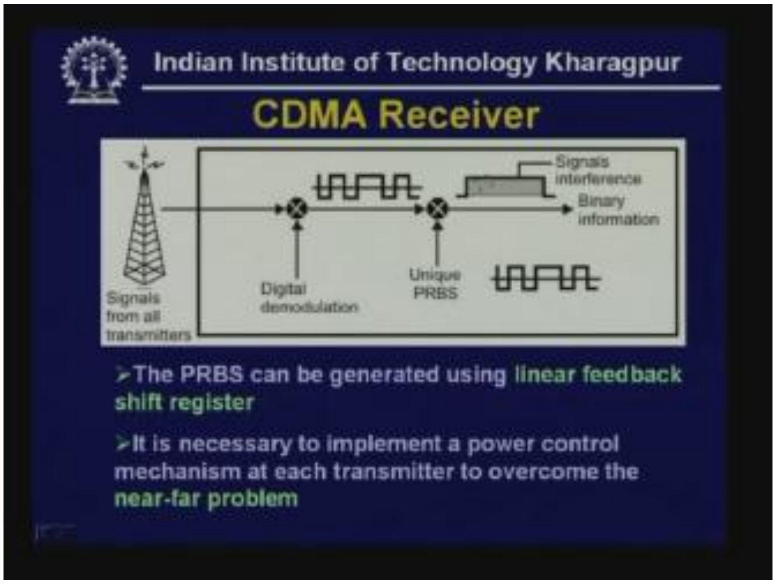

Now you may be asking how you generate these chip sequences. This is being done by using linear feedback shift register. You may recall that for error detection using cyclic redundancy code to generate that cyclic redundancy code and also to check it you use some linear feedback shift register to generate a random sequence. So, that kind of linear feedback shift register can also be used here to generate those unique pseudo random binary sequences. So, unique pseudo random binary sequences are used in transmitter as well as in receiver.

Of course there is one problem here. You have assumed that the signals coming from different stations have equal strength. That means this necessitates a power control mechanism at each transmitter to overcome the near-far problem.

Essentially the near-far problem arises because, if there is a receiver which is receiving signal from a number of transmitters depending on the distance if it is very near then the signal strength coming from that signal will be very high and the signal strength from the other signals will be low and as a result if the signal strength is very low that will be ignored so that will be considered as 0 and if the signal strengths are not equal then the noise will increase here, that is, the interference will increase. In other words the summation and then subsequent deduction is based on the assumption that they are of equal amplitude. That’s why some kind of power control mechanism is used at each of the transmitter to overcome the near-far problem as it is used in cellular telephone network. We shall discuss about it later on. Now let us discuss more about the chip sequences.

As I mentioned each station is assigned a unique m-bit code or chip sequence. Obviously these are not randomly chosen sequences. You don’t generate them in an arbitrary manner. If you generate them in an arbitrary manner then the property of orthogonality will not be satisfied so you have to satisfy the orthogonal property.

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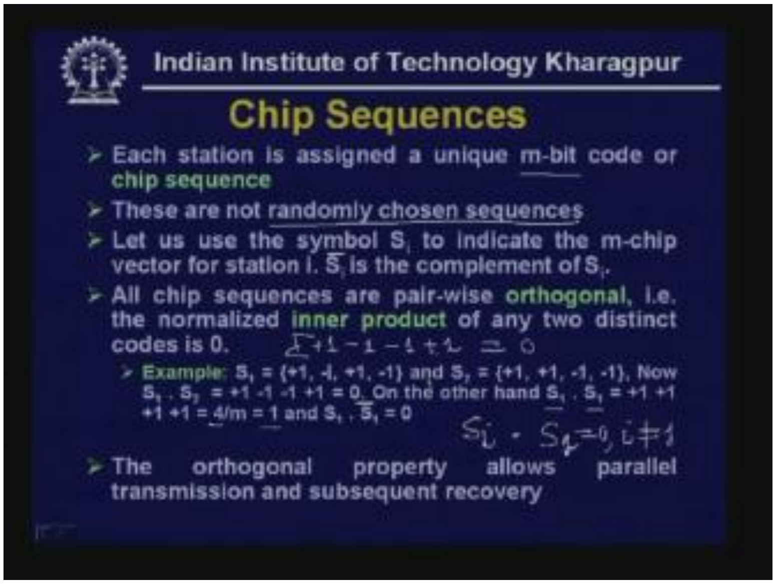

Let us use the symbol S_i to indicate the m-bit vector for station i and S_i bar is the component of S_i. Now all the chip sequences are pair-wise orthogonal. That is, the normalized inner product of any two distinct codes will be 0. So, for example, one code is plus 1, minus 1, this is your minus 1, plus 1, minus 1 and S2 is equal to plus 1, plus 1, minus 1, minus 1. If you take the inner product of these two that means you multiply plus 1 with plus 1 you will get plus 1, then plus 1 with minus 1 you get minus 1, then if you multiply with minus 1 with plus 1 you get minus 1 and minus 1 and minus 1 if you multiply you get plus 1, so if you add them this is the inner product, if you take the summation of these you will get 0.

That means if you choose any two distinct codes it will be 0. That means S_1 into S_2 it is 0, S_1 into S_3 will be 0, S_1 into S_4 will be 0, on the other hand, if you multiply the same code S_1 into S_1 if you do the multiplication plus 1 with plus 1 becomes plus 1, minus 1 with minus 1 will become plus 1, then minus 1 with minus 1 will become plus 1, plus 1 with plus 1 will become plus 1, if you add them it becomes 4 and if you divide it by the number of bits you get 1.

So we find that if you multiply S_1 with S_1 that means for the same chip sequences you get 1. On the other hand, if you multiply with the complement you get 0 again. That means if a code S_1 or S_i is multiplied with S_j where i is not equal to j then it is 0. And also whenever it is multiplied with its complement then again it is 0. This is the orthogonality property that is to be satisfied by the chip sequences and only then the multiplexing and demultiplexing is possible.

In other words transmission and subsequent recovery at the receiving end is possible only when this orthogonal property is satisfied. So, as I mentioned, the orthogonal property allows parallel transmission and subsequent recovery at the receiving end. I have already explained how exactly it is being done with the help of these two diagrams (Refer Slide

Time: 37: 02). Here you are doing the multiplexing and the chip sequences satisfy the orthogonal property. Then you can sum them together and transmit and then at the receiving end you can separate them out. This is how the chip sequences are to be designed.

Now let us take up several examples. Suppose the S_1 S_2 S_3 and S_4 are assigned to channel one A B C and D, now let's assume at a particular instant channel A B C D, so let's assume A is not transmitting, D is not transmitting, B is transmitting 0, C is transmitting 1. And another example say A is transmitting, B is not transmitting, C is transmitting 0 and D is not transmitting. Third example is C is not transmitting, A is transmitting 1, B is transmitting 0, C is not transmitting and D is not transmitting.

Now what will be the composite signal in the four cases? For B you have to multiply with this minus 1 so it becomes minus 1 minus 1 plus 1 plus 1. Then you have to add with that C which is plus 1 plus 1 minus 1 plus 1 so that is your plus 1 plus 1 minus 1 minus 1 (Refer Slide Time: 38:56) so if you add them it becomes, this is your 0 0, this is 0 and this is minus 1 here minus 1 minus 1 so it becomes plus 1 plus 1**….. t**here is a correction here (Refer Slide Time: 39:29**)** these two cannot be same S_1 S_2 S_3 and S_4.

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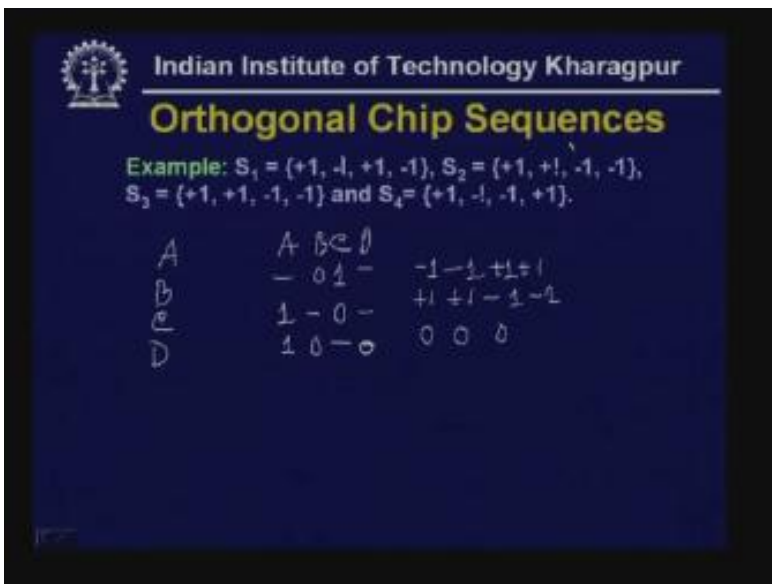

Let us look at the S_3 code. (Refer Slide Time: 39:34) S_3 is equal to plus 1 plus 1 minus 1 minus 1 and that was plus 1 minus 1 plus 1 minus 1, these codes are not proper so let me take up separate codes that is your S_1 is assigned to A that is your plus 1 plus 1 plus 1 plus 1 then S_2 is assigned to B that is your plus 1 minus 1 plus 1 minus 1 so in this way if you assign and if you perform the multiplication and addition you will see that whenever you are transmitting A and you are transmitting C or you are transmitting the A bar and C or if other stations are not transmitting even in that case also it will work.

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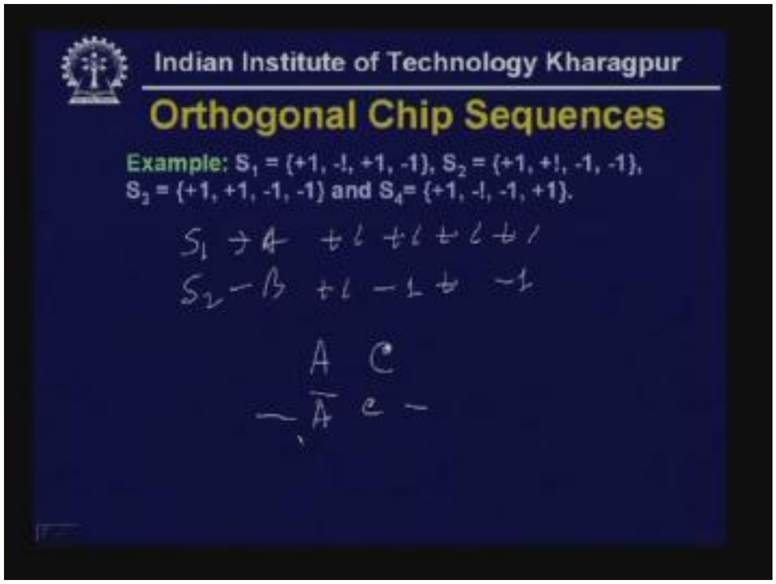

Whenever you have got some stations not sending even then it will work. That means in this case if some station is not sending data, consider this is not here (Refer Slide Time: 40:37) that means B is not sending, this is dash so in that case it will be 0 0 0 0 even then it will work. That means if it is 0 0 0 0 and if you do the summation you will find still at the receiving end you will be able to detect by proper addition.

Later on we shall take some more examples to illustrate. If you take orthogonal codes and take some stations transmitting some stations not transmitting still it will work. That means if you have got A B C D it is possible that two stations are not transmitting, one is sending 0 another is sending 0, another is sending one and all possible combinations are possible, so even in this situation it will be possible to multiplex and demultiplex at the other end.

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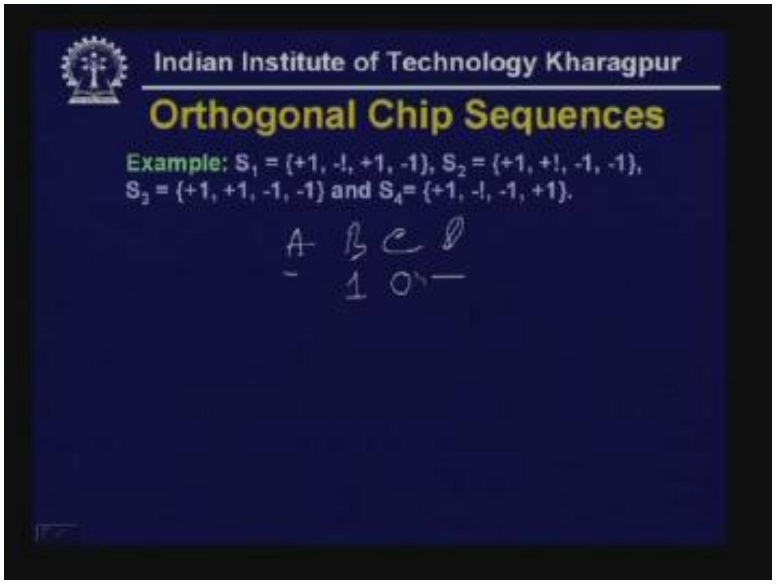

Now you may be asking how the chip sequences are generated. What is the technique used to generate the chip sequences? They have to be pair-wise orthogonal. That can be done by using Walsh table in an interactive manner. That means Walsh table can be used to generate orthogonal sequences in an interactive manner, how? The W_1 is plus 1 as you can see, it is a one dimensional matrix and W_2 is a two dimensional matrix with four entries, here you have got only one entry so 2N, 1, 2 and 4N can be generated, W_1 W_2 W_4 can be generated in this manner that if WN can be used to generate W_2N, so how do you generate? W_2N is generated from WN by putting WN, WN, WN and WN bar here to get W_2N.

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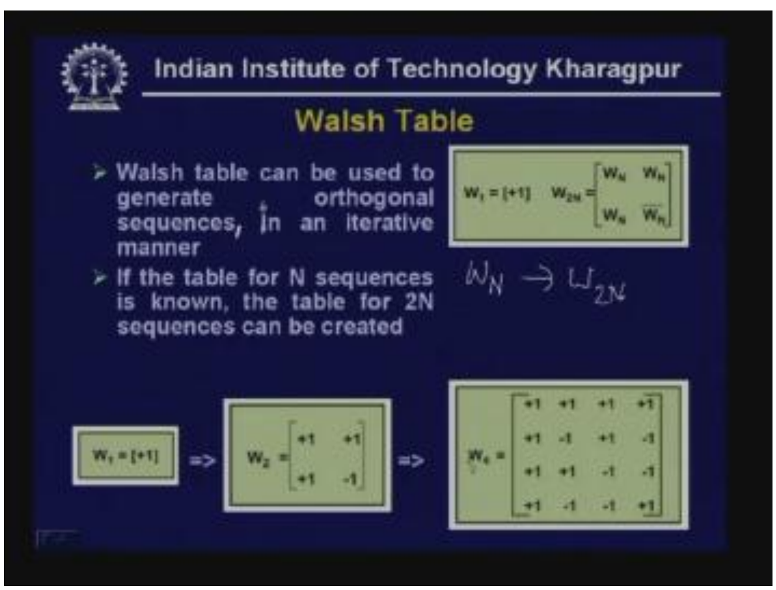

For example, W_1 is plus 1 and W_2 is here we have substituted W_1, W_1, W_1 and W_1 bar that means plus 1 plus 1 plus 1 and minus 1 then W_4 can be generated from W_2. This is how it is being done, let me show here. So you have to put this matrix (Refer Slide Time: 43:42) that means plus 1 plus 1 plus 1 minus 1 then here also you have to put plus 1 plus 1 plus 1 minus 1, here also you have to put WN so plus 1 plus 1 plus 1 minus 1 now here you have to put the complement of that, complement is minus 1 minus 1 minus 1 plus 1. This is exactly what you have got. Similarly, W8 can be generated which will be equal to W_4 W_4 W_4 W_4 bar.

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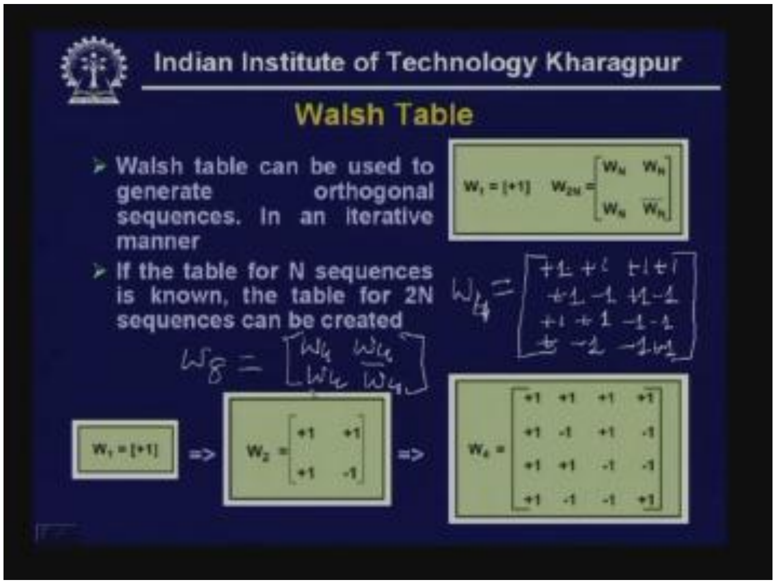

So in this way you can generate the next bit sequences in an interactive manner. So, if the table for n sequences is known the table for 2N sequences can be created and it can be proved that these sequences satisfy the orthogonal property. So this can be used for the purpose of CDMA and also the codes can be generated very easily and these sequences can be also generated by using linear feedback shift register as I have already told.

We have seen how the chip sequences can be generated in a very convenient manner by using Walsh table. We have discussed various medium access control techniques in three lectures. In the first lecture we discussed about the random techniques; ALOHA, CSMA, CSMA/CD and the next lecture was on collision-free protocols where we discussed various multiplexes with carrier avoidance, round-robin and reservation techniques and in today’s lecture we have discussed FDMA, TDMA and CDMA. Here we have seen that the signals can be transmitted in three different ways by using frequency in terms of time, frequency and code division multiplexing.

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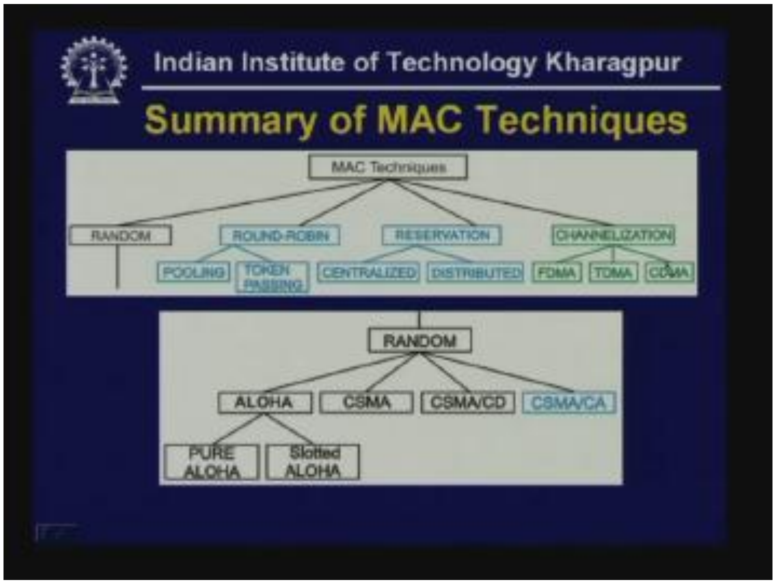

Now these medium access control techniques have many real life applications. In the next few lectures we shall discuss about the applications of these medium access control techniques used in broadcast communication and three important applications we shall consider. First one is the Local Area Networks (LAN), second one is the Satellite Networks, third is the Cellular telephone networks.

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In local area networks we shall consider three lectures. First one will be based on the IEEE802LANS and you will see there we have used CSMA/CD and token passing protocol. These two protocols are being used in IEEE802LANS which I shall discuss in the next lecture. We shall also discuss the high speed LANS where these medium access control techniques are used in high speed LANS based on CSMA/CD which are essentially first Ethernet, Gigabit Ethernet and also FDDI which is the Fiber Digital Distributed Interface which uses token passing protocol.

Therefore, in high speed LANS both CSMA/CD and token passing protocols are used and there will be another local area networks that is your wireless LAN where we shall find the use of CSMA/CA protocol. So CSMA/CA protocol will be used in wireless LAN. Then we shall consider the satellite networks and in satellite network we shall see that there is use of FDMA and TDMA Time Division Multiple Access and Frequency Division Multiple Access and primarily reservation techniques are used in these applications.

Finally we shall consider another lecture where we shall consider the use of TDMA this Cellular telephone network where the time division multiple access, frequency division multiple access and code division multiple access are used. We shall also see different standards like GSM and CDMA where these channelization approach of medium access control technique is used and we shall see how this TDMA, FDMA are used and also how CDMA is used in implementing in cellular telephone networks.

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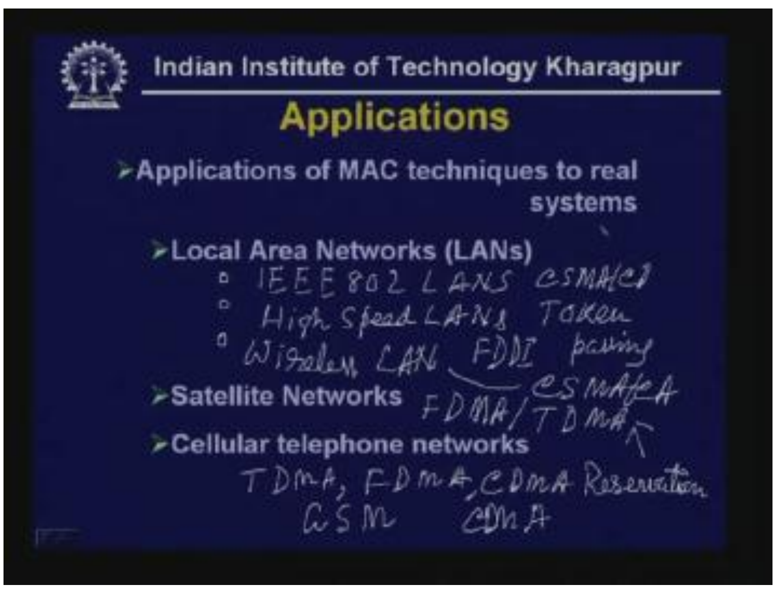

So in the next three lectures we shall discuss the applications of these medium access control techniques and we shall see how these medium access control techniques are used. Now this is time to give you the review questions.

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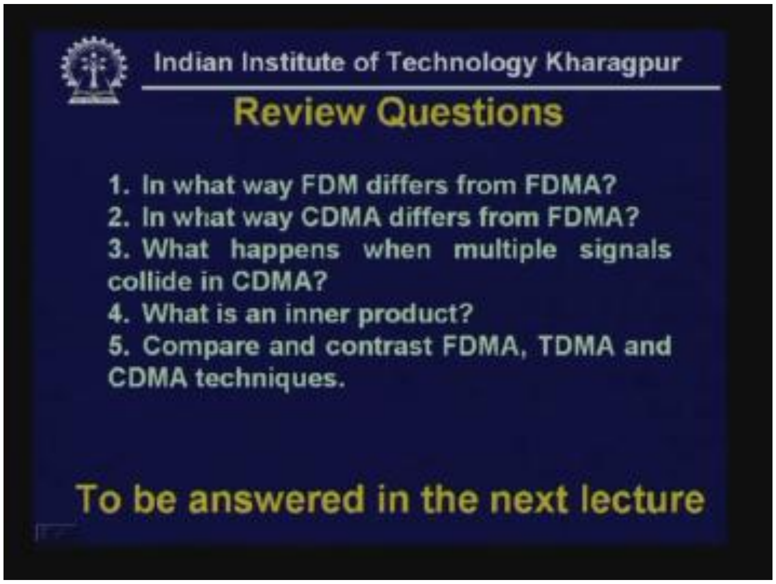

1) In what way Frequency Division Multiplexing differs from FDMA?
We have already discussed the FDM Frequency Division Multiplexing earlier. In this lecture we have discussed frequency division multiple access so the first question is based on that.

1) In what way FDM differs from FDMA?
2) In what way CDMA differs from FDMA?
3) What happens when multiple signals collide in CDMA?

We have seen that in CDMA the various transmissions coming from different sources are done simultaneously. So whenever collision occurs what happens in case of CDMA will be the third question.

4) What is an inner product in the context of CDMA?
5) Compare and contrast FDMA, TDMA and CDMA techniques which have been discussed in this lecture.

These are the five questions to be answered in the next lecture. Now let us consider the answers to the questions of lecture minus 26.

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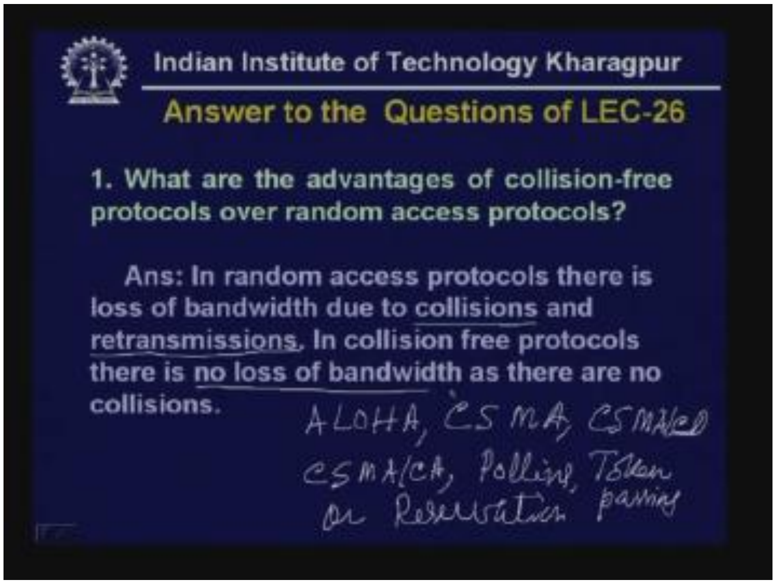

1) What are the advantages of collision-free protocols over random process protocols?
In random access protocols there is loss of bandwidth due to collisions and retransmissions. We have seen that in random access protocols based on ALOHA, CSMA and CSMA/CD there are collisions. And whenever there are collisions as you know it is necessary to do retransmissions and whenever the traffic increases the number of collisions keeps on increasing and that reduces the throughput. This is the drawback of this random access protocols. On the other hand, in collision-free protocols there is no loss of bandwidth as there are no collisions.

We have seen that in CSMA Carrier Sense Multiple Access Collision Avoidance or polling or in token passing or based on reservation, collision is completely avoided and as a result there is no loss of bandwidth due to collisions. That is the advantage of these protocols. Collision is completely avoided, there is no loss of bandwidth and as a consequence the collision free protocols are advantageous particularly when the traffic load is high. Then comes the second question.

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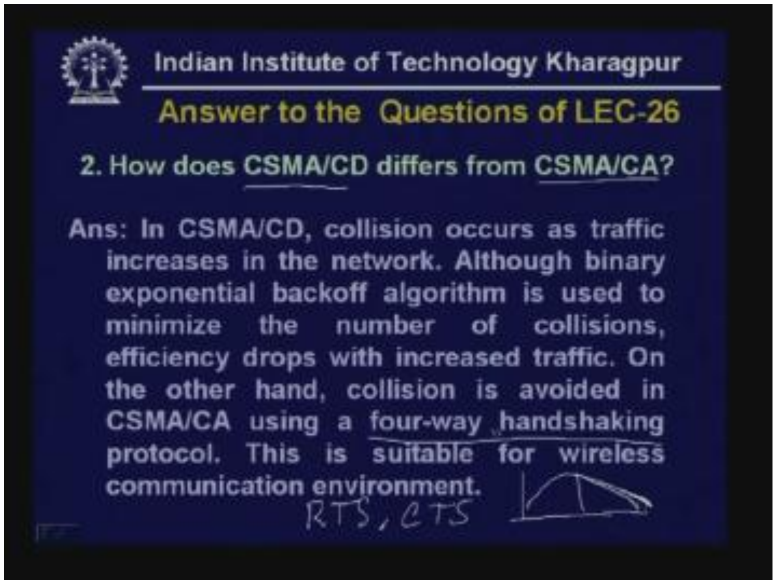

2) How does CSMA/CD differs from CSMA/CA?

In CSMA/CD collision occurs as traffic increases in the network. Although binary exponential backoff algorithm is used to minimize the number of collisions efficiency drops with increased traffic. We have seen that in case of CSMA/CD whenever collisions occur by using that binary exponential backoff the backoff average backoff time is doubled so that minimizes the number of collisions. But in spite of that as the traffic load increases the throughput decreases. As you have seen, particularly when the load is high like this (Refer Slide Time: 54:22) the traffic in this particular region, the number of collisions occur, the loss due to the number of collisions is more and as a result the throughput decreases.

On the other hand, collision is avoided in CSMA using four way handshaking protocol. The four way handshaking protocol is used by using Request to send, Clear to send and by listening this Clear to send the other stations backs off not sending their data so by this way the collision is avoided, this is particularly suitable in wireless environment where collision detection is difficult.

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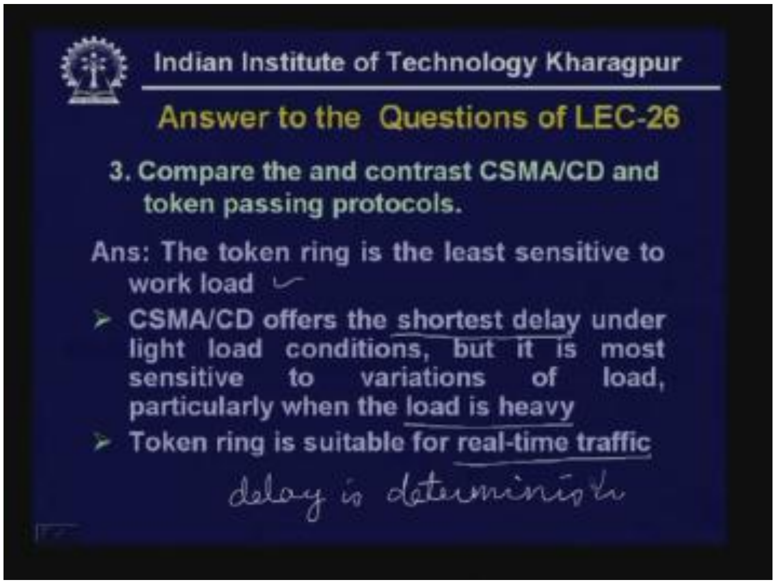

3) Compare and contrast CSMA/CD and token passing protocols.

The token ring is the least sensitive to work load. In token ring although when the network is lightly loaded the overhead is high but it is least sensitive to work load. As the load increases the throughput does not decrease. On the other hand, CSMA/CD offers the shortest delay under light load conditions but it is most sensitive to variations of load. That means when the load increases in CSMA/CD we know that delay increases significantly particularly when the load is heavy.

Another important difference is the token ring is suitable for real-time traffic because the delay is deterministic. What is the worst case time? It is deterministic. But in CSMA/CD it is non-deterministic, how much time it will take is not known. Therefore, as a consequence in case of CSMA/CD some packets may take very long time to deliver and there is a possibility that some unfortunate packets will not be delivered because in binary exponential backoff algorithm after fifteen collisions a packet is dropped so it is not guaranteed that a particular packet will be delivered so that's why because of the deterministic nature of token ring it is suitable for real-time traffic.

On the other hand, for the non real-time in the lightly loaded condition CSMA/CD protocol is better.

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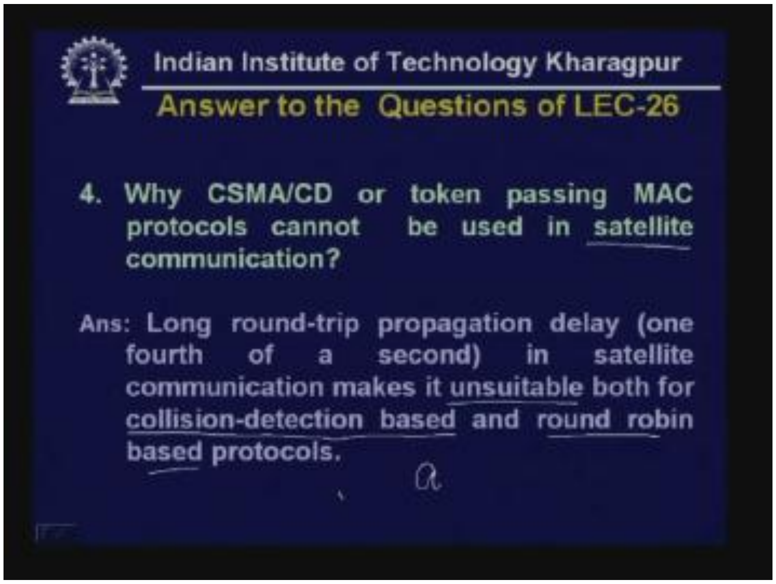

4) Why CSMA/CD or token passing medium access control protocols cannot be used in satellite communication?

As I told long round trip propagation delay in satellite communication makes it unsuitable for both collision-detection based and round-robin based protocols. Delay here is about quarter of a second so if collision is detected by a ground station that has happened quarter of a second earlier. In other words the value of ‘a’ which is the ratio of the propagation time by transmission time is very high so as a result the CSMA/CD based protocol is not suitable. Similarly, round-robin based protocols also are not suitable because it takes very long time to do polling or to pass the token, as a result these protocols cannot be used here.

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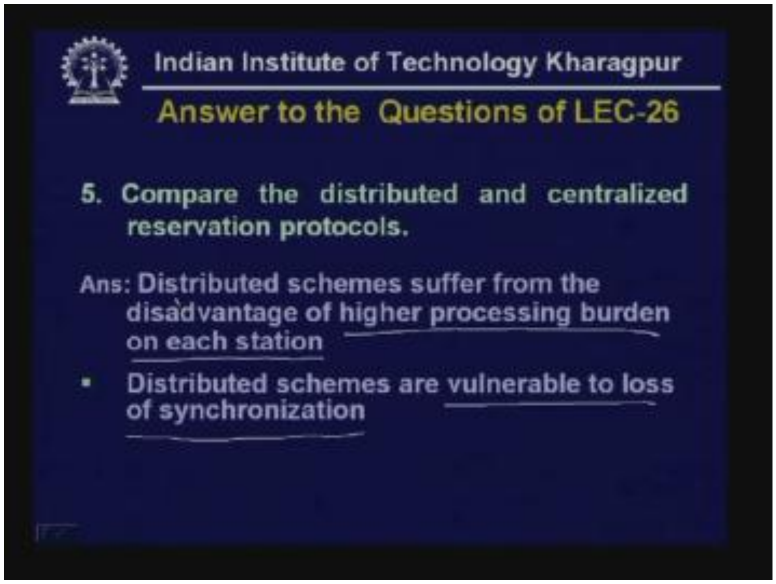

5) Compare the distributed and centralized reservation protocols.

As I have mentioned distributed schemes suffer from the disadvantage of higher processing burden on each station. So each station has the responsibility to perform that medium access control because it is done in a distributed manner. So, the processing requirement is high on these stations. Moreover, the distributed schemes are vulnerable to loss of synchronization because that synchronization is very much essential and in a distributed scheme it cannot be done. It can be very easily achieved in centralized schemes and that's why centralized schemes have some advantages. However, distributed scheme is preferred because if the centralized station fails then the medium access control cannot be done so it is much more reliable.

So friends, in this lecture we have discussed the channelization scheme of medium access control technique which concludes our discussion on medium access control technique and as I have mentioned the next three lectures we shall discuss the applications of the various other medium access control techniques. Thank you.