Spread Spectrum Communications and Jamming
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Lecture – 53
Introduction to CDMA

Hello students. In this module we will start discussing about the CDMA mobile radio network. In the last one, last module we have learnt about the different multiple access techniques so that are obtained in a mobile communication environment using spread spectrum communications. And we have heard about the term code division multiple access.

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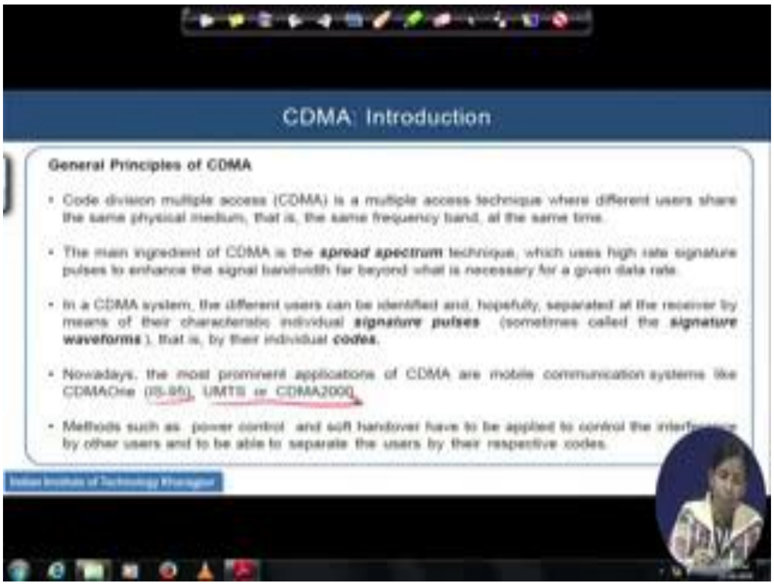

CDMA network is basically plotting that code division multiple access as a technology for the multiple access, so they providing the multiple access support among the different users. And we understand that all the users are simultaneously accessing the same wireless medium, using the same frequency and at the same time and they are differing from each other by the means of using the P-N sequence key of the code which are separating them out from each other.

The main ingredient of this CDMA is that spread spectrum technique and which uses the very high rate signature pulses to enhance the single bandwidth we understand, because that is a fundamental of a spread spectrum technique that you take your original data signal and you multiply it with your given key and you spread the bandwidth of the signal from the required bandwidth which is high bandwidth. And that is the way actually the processing gain will come into picture rather later in the receiver once you displayed the signal.

And in the CDMA systems we understand the different users we will be using different amount of the signature pulses. And we call them as well as the codes. And in our CDMA if you ask me what are the different CDMA networks available already deployed worldwide they are the some famous of the some of the names are IS-95 and UMTS or the CDMA 2000 and CDMA also. And so the different methods this are all these kinds of the networks we have discussed that all these different kinds of the methods will have different kinds of the power control and soft handover techniques that needs to be adapted inside them to be applied to control their different interference.

So, little bit about the interference by the multiple access techniques, we have learnt in the last module in the consecutive modules. So, we will learn how actually this interference is handled in a CDMA network by a different power control mechanisms and the soft handover techniques. Because interference may management or interference handling is a very very critical issue in deploying a CDMA network and successfully running a network and for successful operation of any CDMA network.

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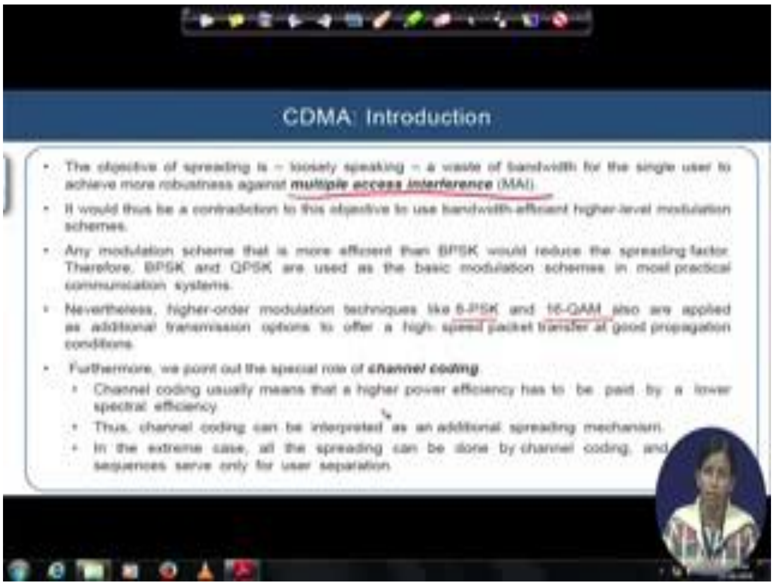

So, in a CDMA network the main objective of spreading new signals or loosely speaking you are wasting a part of the available bandwidth, because whenever we spread a signal we spread the bandwidth of the transmission and we spread the bandwidth intentionally than the minimum required bandwidth; bandwidth of that typical data rate to be private signal with that typical data rate to be transmitted.

So, whenever we are using the extra bandwidth the redundant bandwidth basically this is wastage of the bandwidth also to some extent if you can see, but that extra bandwidth gives a robustness against actually your multiple access interference as well as it gives you the robustness against the jammers. So, multiple access interference or MAI or which is the major controlling parameter of the performance of your system over a CDMA network. Please remember the term we call it as MAI and we will have a several techniques we consecutively discussing on the controlling of this MAI later on. And see it is a very contradictory part that you cannot design simultaneously or bandwidth efficient as well as a power efficient system simultaneously.

Here basically what we are talking about is that whenever we get a bandwidth we always talk about the bandwidth is a very useful resource and it always try to utilize the very good or bandwidth efficiency system design is the first moto as a system engineer if you start any telecommunication system design. He will see that always we try to save the bandwidth and that is why we go for a very efficient higher level modulation schemes to get employed and whenever we design such communication systems.

But whenever we use come to a CDMA networks we never talk about the bandwidth efficiency it is just a way because we understand that there is a redundant bandwidth involved in the transmission to (Refer Time: 05:36) the resonance against the or robustness against the multiple access interference. So, we never try to use a very high level modulation schemes rather we prefer to use BPSK or QPSK kind of the very basic modulation schemes for the CDMA network. We also utilize the modulation schemes like 18 PSK or 16 QAM later on we have apply to offer a little bit high speed packet transform. But beyond that actually very highly dense higher modulation schemes beyond 16 QAM that you will find on the other kind of the communication in your communication systems is not found in the CDMA.

Furthermost, we should mention here is that channel coding place a very important role in a communication systems. Basically the channel coding, the coding we use to provide a robustness of our transmit signal again the different deep fades that happens in the where the wireless channel. And channel coding usually means that the high power efficiency has to be paid by a lower lower spectral efficiency and channel coding can be interpreted as something as an additional spreading mechanism that you do. I mean you take into an every beat of your transmitted signal and you over encode it over the multiple a code beats. And then actually finally, it is a equivalently can be seen that it is another spreading mechanism. And while combining this channel coding channel coding applied on the CDMA network which in extreme case we can think something like this that all the spreading will be done by the channel coding for each and every signal. And then the P-N sequence can serve as the identity of the user to get the user separately.

So, channel coding combined with the spread spectrum with the spreading sequence we can think of like this. Channel coding will be helping you to provide resonance against a deep fade from the channel as well as he will provide you the basic spreading mechanism to spread over a bandwidth. And he will also provide you the; P-N sequence can be give the user separation.

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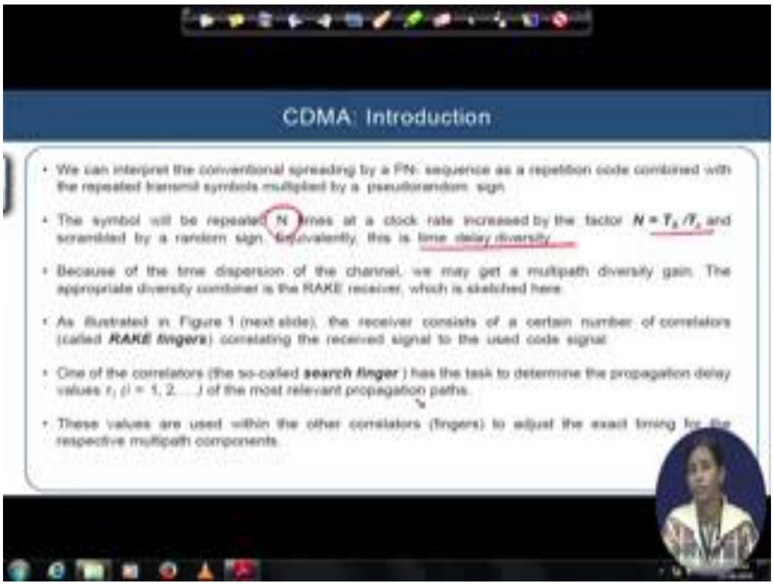

But, remember one thing that the conventional spreading by this P-N sequence as a repetition code combined with this repeated transmit symbols. And it can be multiplied by a pseudorandom sign. So, when conventional spreading is nothing but this, actually a P-N sequence has a repetition code and combined with the repeated transmit symbols.

So, the symbols so that will be repeated capital N times at a clock rate that can be that should be understood, because that rate the factor by means actually the clock rate is increased automatically because of spreading. It is given by your the processing gain T s by T c. And we will be scrambled that once again by some random sign. And once we do we do it this is basically the time delay diversity equivalent to that we were talking about.

So, it is over the time that you are repeating your signals and that is why we call it a time delay diversity; it is a time diversity that spreading is providing you. Because of this time dispersion of the channel we may get a multipath diversity gain that we have seen by the rake receivers. And because of this the rake receiver structure we will see quickly in the next that we have also earlier discussed a lot so that the this time delay diversity in order to maximize the diversity gain; that the typical kind of the receiver architecture that can capture this diversity gain is the rake receiver. Who consist of a series of the bank of the correlators. And correlators are designed such that we call the correlators as the search fingers also.

Correlators are designed in such a way that their task will be to determine the propagation delays corresponding to each and every relevant propagation path. And thus this propagation techniques expert the propagation paths if the correlators is identifying properly. He will be getting at the output actually the peaks corresponding to the delay of this each of the signals.

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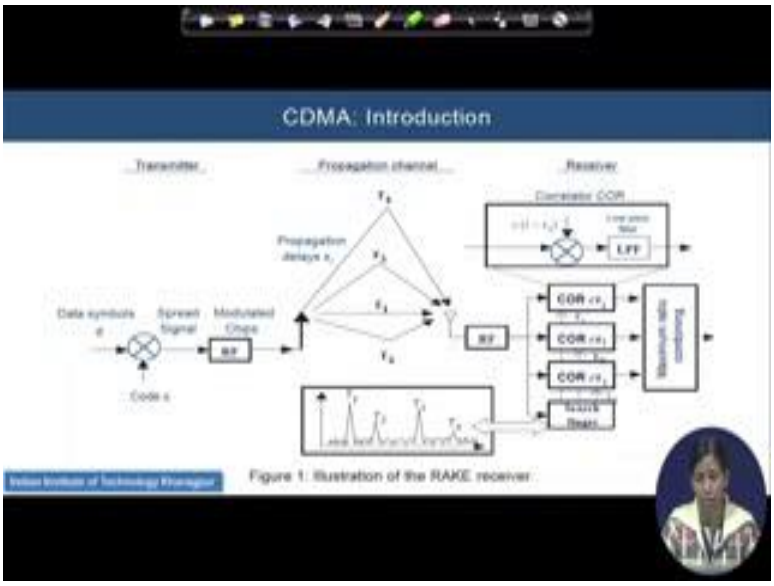

Let us see quickly the figure of this rake receiver it will be understood much more easily. In a transmitter you have data symbol, you have spread it with the code c. The spread signal after; I mean after the RF processing they are the modulated chips basically. And they are released in the by the antenna they are released in the wireless channel. And they will have a different propagation path associated with it, and let us assume we are having the four different path each of the paths are having the delays from tau 1 to tau 4.

And once actually you have received the signal in the RF let me see rake receiver architecture inside the RF is the bank of the correlators. Each of the correlators is having is capable of giving a matched actually, they are basically the match filters independently and they are having correlation peak with respect to the independent path delays.

So, I can at the output of the correlators all these correlators I can have a maximum ratio combining technique running at the output. And if I see actually what is a output coming at the end of the itself, you will be able to see that each of the rake correlator output is basically giving correlated signal peak at that corresponding delays; delays of their independent path. So, you can identify the different multiple paths and their corresponding delay of occurrence when the signals are occurring and (Refer Time: 11:58) in that corresponding to a typical path.

So, multiple paths can be detected according to their delay in receiver architecture (Refer Time: 12:06) architecture.

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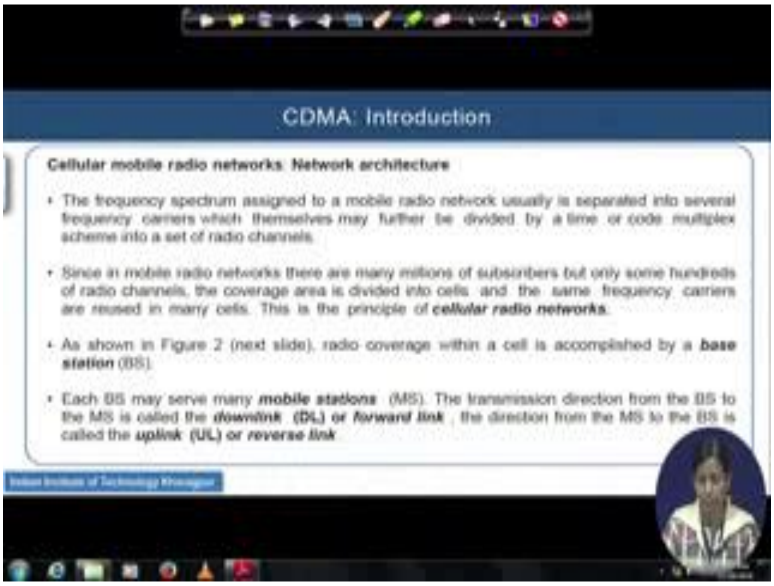

So, now with this understanding of rake receiver and code division multiple access technique let us now slowly enter into the network architecture, cellular mobile radio network architecture. Here we understand that the frequency spectrum assigned to a mobile radio network is separated into several frequency carriers which themselves may further be divided into either time over the time or over the codes for CDMA, and to generate a different radio channels. And since the mobile radio networks they are there are many millions of subscribers compare to the very few amount of the radio channels that we are getting. Hence to cover a very large area what we do is we divide the area coverage area of the wireless communication over the cells. And there are multiple such cells and each of the cells are having either the same frequency carriers or the frequency carriers within the cells can be reused also.

So, this is a very typical example of cellular radio network, we will see the situation in the next slide. And this radio coverage within the each and every cell is provided by a base station. And whenever we have the different users the way they are connected they may be connected by the multiple access techniques; that even multiple access techniques to the base station. And each base station they may have actually multiple mobile stations associated with them within that coverage zone. Whenever some communication will go on from the mobile station to the base station we will call it the uplink or the reverse link. And when some communication will be there from the base station towards the user side or the mobile station side we will call them downlink or the forward link.

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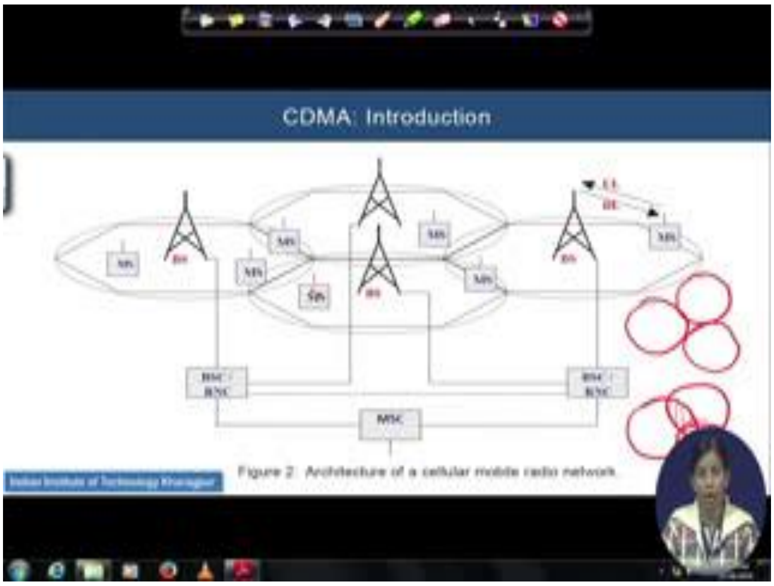

Let us see the structure: typical architecture of cellular radio network is shown here in this figure number 2. Given zone wireless is wireless communication zone is all covering area is divided into number of the smaller cells. The cell structure is not over, is not circular we prefer to go ahead with the regular hexagonal shape rather. This is because if we go ahead with the circular shaped cellular architecture then you will have some portions left unattended at all it will not be covered by any of the base stations. Or, otherwise the cells will be overlapped with each other to have a covering zone.

So, overlapping cell will have lot of problems related to the interference. And actually haggling the users, so we will be in the common areas. And to avoid all that the geographic area it is preferable to divide the geographic area by some hexagonal structure. Inside each and every hexagonal structure one one base stations is taking care of the communication system. As I told in the last slide that whenever some communication will be going on between mobile stations to the base station we call it uplink, and when the communication will come from the base stations to the mobile stations it will be downlink.

The multiple base stations they will be connected with each other via base station controller or sometime it is also a radio network controller. And multiple base station controllers will be connected in the via the mobile station controller. And remember one thing whenever actually you will be having call from ones cell to the next so it means the connect communication is required via the base station controller to the mobile station controller to that corresponding base station.

Also whenever we will talk about the handover; I mean suppose you are moving user and within the cell you if your use of this cell your associated with the cell this and suppose you with your mobile you are crossing the boundary of this cell and you are entering into the another cell, then your control should be handed over, your call should be handed over from one base station to the next base station. Usually, that handover is done by several ways it may be a soft handover or it may be a hard handover. So, we will discuss about that later.

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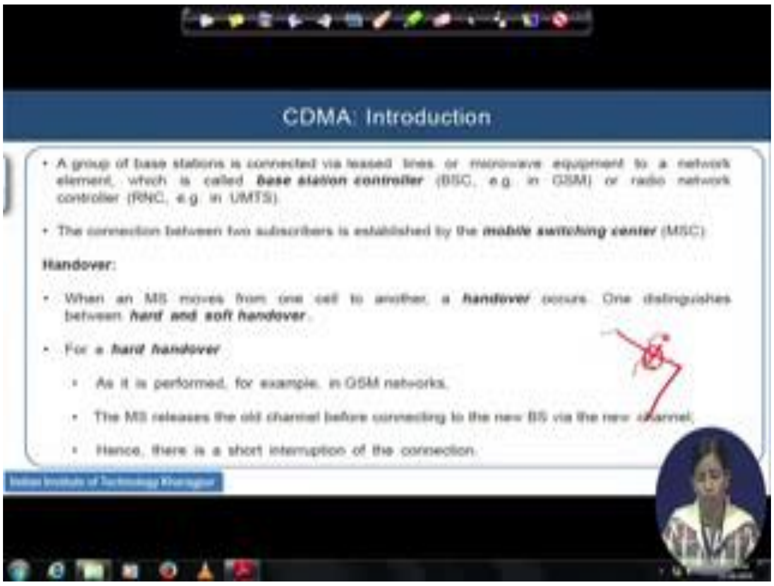

This hard handover as I was talking about; that hard handover is performed in the GSM networks the weight is done is, the whenever the mobile station is a reaches at the boundary of a any cell: suppose this is the boundary of the cell and mobile station is crossing the boundary he just leaves one channel and he is just joints the channel of which corresponds to the next cell and the base station it can be sub by the next base station.

So, whenever you are releasing one channel and then actually a opting some other channel in between some time is will be definitely there where you would not get any connection from any channel, because there is a interaction always associated with it. That is the main problem of your hard hand over.

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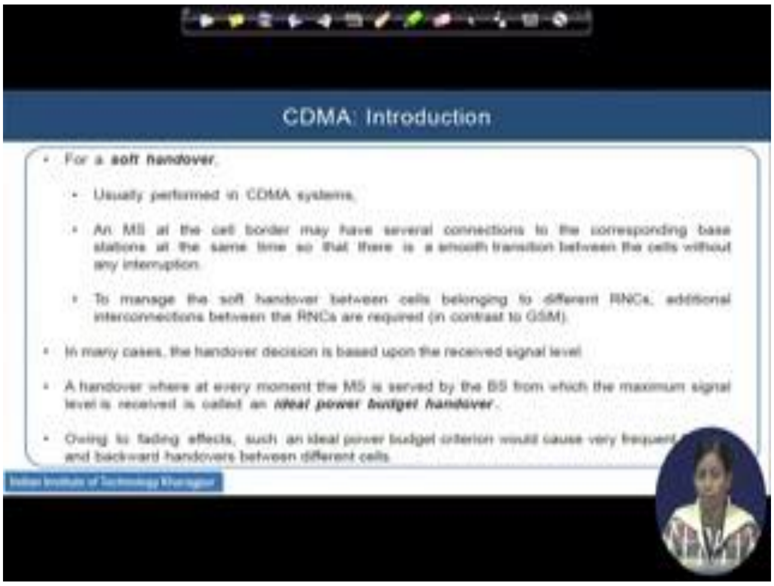

CDMA we do not prefer to go ahead with the hard hand over we prefer to go ahead with the soft handover where we have discussed about this earlier. The soft hand over means you are having actually particular mobile station is always getting screen or getting surprised by the numbers of the base stations.

So, that actually whenever some cell boarder will come with the smooth transition from the base station to the next base station can be easily happened without any interaction. And because of soft handover also there would not be actually call drop whenever you are crossing the cell boundaries. And we understand actually that whenever it needs to happen, at every moment the mobile station is served by a base station from the maximum signal level received, so we call it that ideal power budget handover.

So, how the handover will happen is based on basically every time the mobile station information in terms of the received signal power is getting updated at the base station. So, whenever it goes below some set certain level it actually the handover, it gets initiated. So, we call it the ideal power budget handover. But remember if you are going have with an ideal always follow the ideal power budget handover which can be a suddenly actually having a fluctuating figure because of the fluctuation happening inside the wireless channel, it may happen that channel has got a very deep fade for a certain period of the time you to reach your ideal power budget has gone down before a certain limit.

And if you do the handover based on the only ideal power budget, so several times back and forth back and forth kind of our backward and forward handovers can be is possible to happen. To avoid that no we prefer to stay actually with a multiprocessor certain period and we try to measure the level of the budgets the this received power level over certain period of the time and if the over the continuous period. If we find actually that the power is really very low becoming very low then only actually we initiate the handover to avoid the back and forth and over several times. This point we have discussed.

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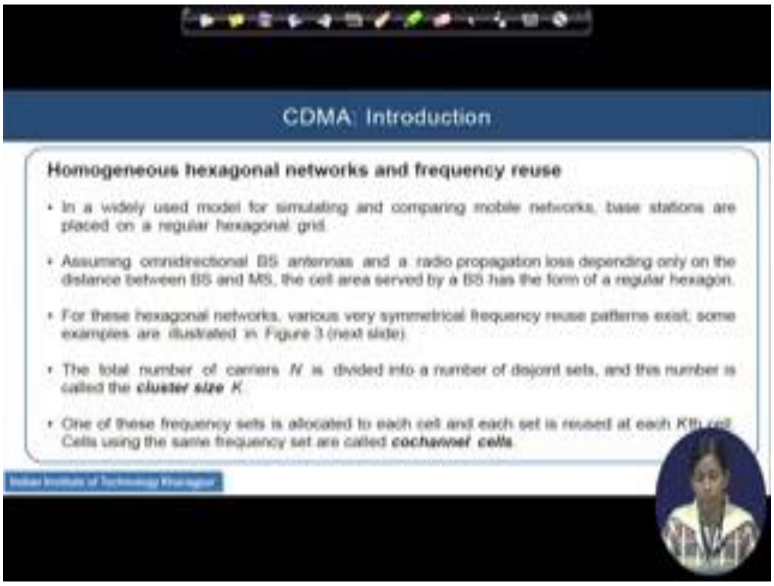

Now, there is a unique concert in the CDMA network which is called the frequency reuse and homogeneous hexagonal networks and the frequency reuse concept. With this is what you know it is a very widely used model for comparing the mobile networks and when base stations are placed over the regular hexagonal grid. Let us assume that the base stations are having omnidirectional antennas and radio propagation loss depending only on the distance between the base station and the mobile stations are happening, and there is no other loss at this moment. And let us see the hexagonal networks that later that we I am talking about. And what is the meaning of the frequency reuse I will explain with respect to that hexagonal structure.

Remember one thing, if I am having a total capital N number of the careers to be used for this hexagonal structure and that capital N careers are divided into say some numbers of the disjoint sets. And then this number is called the cluster size k. Remember whenever one cell will utilize the same frequency of the k-th cluster of the them they these two cells will be called the co channel cells; it is something like this.

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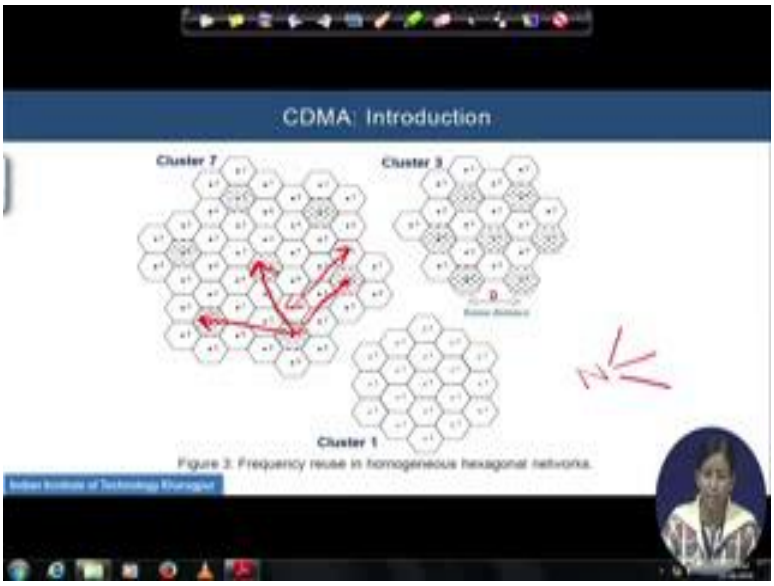

Let us first understand with a cluster 1. Cluster 1 means we are having this hexagonal structures of the cells. Now see actually is how that nicely and densely the whole areas is covered. When I am writing the number one in all the cells; that mean, it is a same set of the frequency user. Suppose capital N is the available number of the carriers, so these capitals N number of the carriers all the careers utilizing each and every cell. So, this is a cluster 1 kind of the architecture.

Apart from that, if I divide the capital N into suppose three different sets and one of this set is used in the cluster 1, second set of the users are used second set of the frequencies are used in cluster 2, and third set of the frequencies are used in say cluster three say then we which will be in another cell then actually it will be cluster three configuration. In such way once again actually wherever the some set the same set of the frequencies can be used in the other cells also.

But the minimum distance between those to cells we call is the reuse distance. And hence, your one going by the same ways suppose if I have a capital N number of the frequency channels and I have divided it in to seven number of the sets. So, I will have a structure like this, suppose you this is a say cell if we using the fast set of the user frequency set. This is your the second set, third set, four set, fifth set, six set, and the seven set. And now see actually this is the reuse distance of using the frequency set 1, this is the distance d of using the frequency set 2. For frequency set 1 this is another use user distance and huge distance capital D.

So, like that way actually the network can be formed. There are several plus points and advantages and disadvantages of using the increasing the cluster size or reducing the cluster size that we will see in the next slide.

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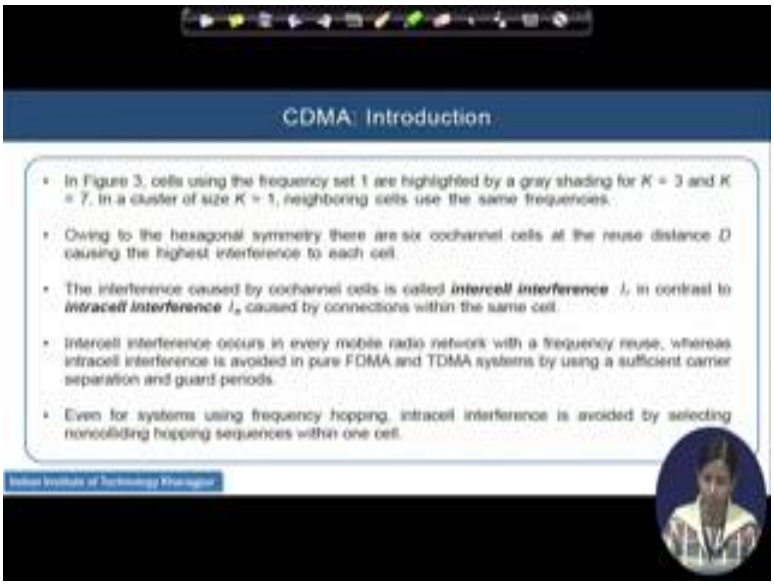

And remember one thing, inter free cell before you talking about the advantage it is advantage, we should know what is the meaning of in inter cell interference and what is the meaning of an intra cell interference. Inter cell interference is something that the interference that you that cell 1 is getting from the cell number 2 or cell number 7. Remember the frequencies that you are using they may be different. And it may happen actually that the course that because of the frequency overlapping and the dopplers (Refer Time: 24:57) and all the some part of the interferences are expected to come from the inter cells also.

Intra cell interference is something that within that frequency zone, within your own cell because of the nonorthogonality of the multiple sequences the codes are getting giving you the interference. So that is the source of your co channel inter or sorry it is not a co channel it is a intra cell interference that you are getting because of the nonorthogonality of the course. So, intra cell interference that is the coming equivalent to the multiple access interference, that is coming inside cell and intra cell interference is the interference that your neighbour cell is giving you. And inter cell inference occurs in every mobile radio network with the frequency reuse wherever the intra cell interference can be little bit avoided if you put your (Refer Time: 25:53), if you put the frequency revision multiple access if you put TDMA, on the CDMA like that.

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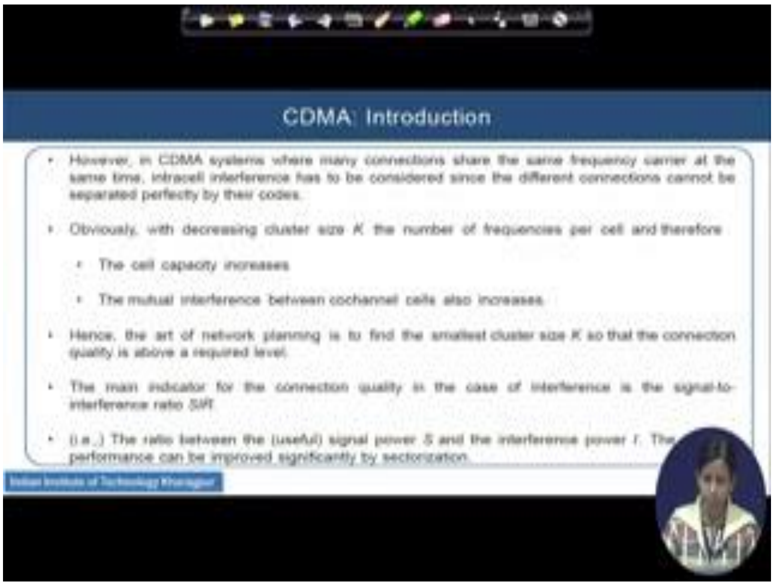

And that we have already seen that in a CDMA system there may be the connections share the same frequency carrier at the same time. And the intra cell interference has to be considered, because different connections cannot be separated perfectly by the code or by the time that is usual. And one thing it we should get clearly that if we decrease the cluster size capital K; I mean the number of the frequencies per cell. And the number of the frequencies per cell is decreasing and hence therefore the cell capacity; the particular cell capacity is increasing. That is this whenever the sale size is decreasing; that means, all available number of the frequencies you are utilizing for the single cell, hence its capacity increases.

But remember the mutual interference between the co channel cells they also keep on increasing, because if do not get the reuse distance larger or used distance is reducing.

So, the interference from the same cell or the say co channel cell they are suppose to increase. So, art of the network planning is will be to find out the smallest cluster size k so that you can enhance the capacity. But you have to handle the interference level in such several ways.

You do the clustering in such a way that it is reasonable amount of the signal to interference ratio you can promise with or you can have a very nice interference cancellation scheme associated in the receiver design.

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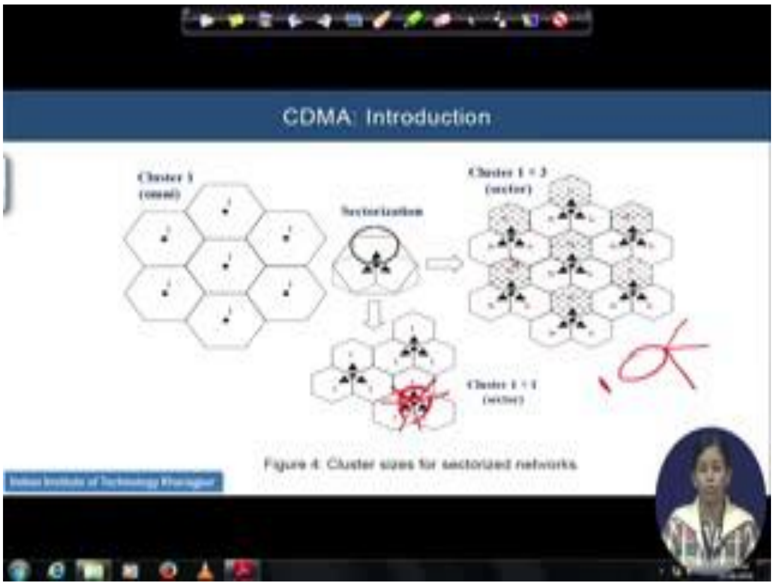

And, in order to handle this signal to interference ratio we can actually obtain another technique which we call sectorization. Sectorization is like this we have seen that if we reduce the number of the k; I am lower cluster size is always preferable to enhance the capacity. So, let is try with the cluster this cluster 1. Cluster 1 omnidirectional transmission going on; sectorization means what actually within each and every cell you can divide a cell by another further division within the cell is possible. And if one sector is something like this; so the cluster 1 and the sector one is something where actually all the users are using same number of the frequencies, but actually the sectorized antennas and getting used to focus the transmission within a typical sector.

So, antennas I am not omnidirectional anymore or antennas a design such a way suppose if it is 360 degree and divided by 3. So, 120 degree will be the maximum transmitting zone overviews or angular zone actually overviews a transmitted will you of each and every cell now will be transmitting. You can have this is called one cross one the full cluster structure we will call refer as one cross one. And if we have a sectoral like this at we have sectorized and also what we have done is we have set of frequencies; suppose the set of frequencies is 1, we have also divided the set of the frequencies in to three different parts and each of this part of the frequencies are allocated to each and every sector.

So, you have sectorize, you are using the sectorized antenna on the top of that you have also divided the frequencies over each of them.

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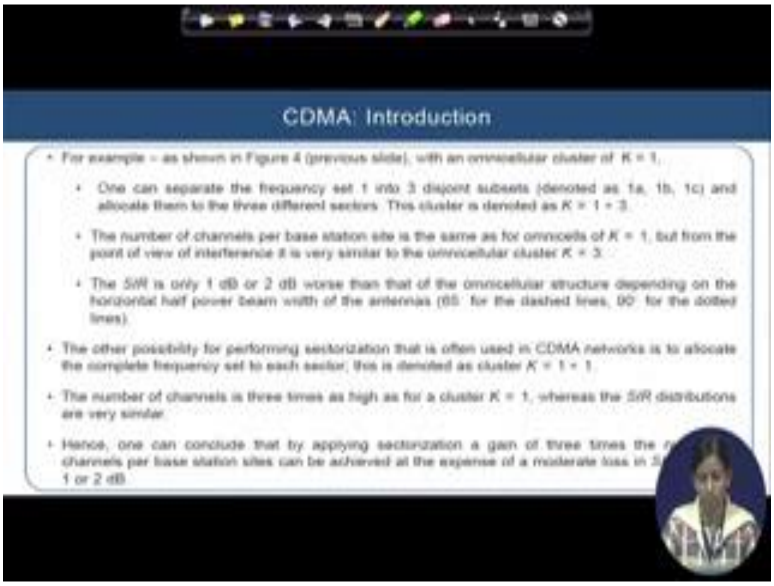

If this is the situation then we call it cluster 1 cross 3. Remember your cluster 1 cross 3 is equivalently similar to the cluster k-3 situation, should be equal to k-3 situation. Hence, that one will improve the signal to interference will be degraded in such situation, because k-3 gives your higher amount of the interference compares to the cluster 1 and that interference will be increase by 1 dB to 2 dB compare to the omnidirectional 1. And so we can conclude with the fact that it is always preferable to go ahead with lower cluster size. And if you are lo lowering the cluster side if you improve the signal to interference further in a CDMA network please go ahead with the sectorized concept.

And sectorization also should be done in such a way that actually satisfies the condition of your required signal to interference ratio. So, do not go ahead with the higher number of the sectors to some extent, because higher number of the sectors on the top of that actually dividing the number of the frequencies or the channels also incurred you some amount of the additive interference, because it becomes equivalent to the higher cluster configuration.