Spread Spectrum Communications and Jamming
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Lecture – 55
Interference Handling by Soft Handover

Hello students, we were discussing the interference handling mechanism in CDMA networks in continuation of that. Today our discussion will be on interference handling by soft handover. Last class we have discussed the interference handling by power control mechanism. We will see actually how this second mechanism also be very helpful and how does it help us to handle the interference in the practical networks.

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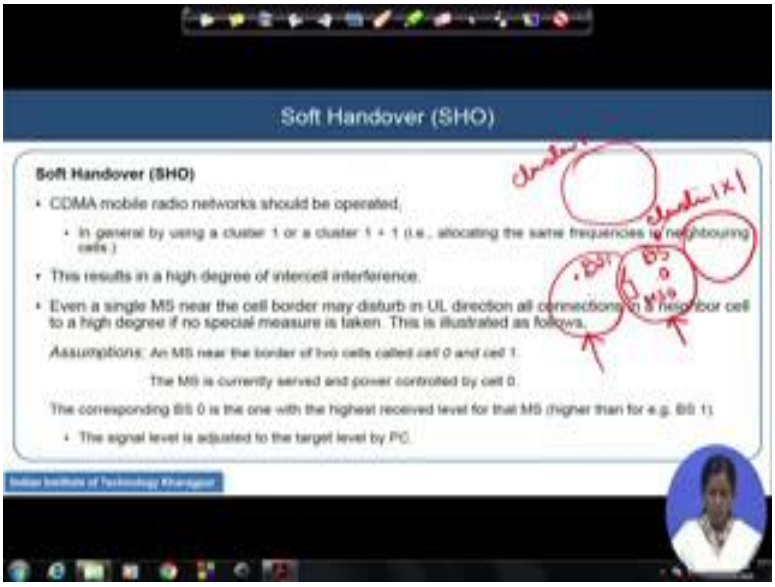

So, in a CDMA network we understand that already this conclusion we got from the last discussion on the power control mechanism, that we will deploy the network, the CDMA network in a single cluster mode. We call it a cluster 1 or we sometimes call it is a cluster 1 cross 1 means single cluster and single frequency and if we are not using cluster 1 cross 1 then, we will have the clusters where, actually the frequencies the cluster 1 cross 1 where actually the same frequencies are allotted in the multiple clusters.

So, cluster 1 cross 1 is an example here and cluster 1 is here. So, if this is the situation. So, in both the cases as a frequency that is getting used for transmission for all the mobile users are exactly the same then, there is a possibility that you will get high intra

cell as well as inter cell interference and even a single mobile station in such situation when I am in a neighbouring zone, when my all the neighbours are using the same centre frequency. Specially the mobile users who are located in the boundary of the cell or the cluster, they will actually play the major role in creating then controlling the total interference of the network.

Basically the users who of any cluster who are sitting in the boundary zone they will be creating interference to the immediately next neighbours clusters and neighbour cells and this may be something like this, can be explained something like this. Suppose this is a mobile base station. This is a cell number 0. So, it has a base station equal to 0 and this is a mobile station let me name it as mobile station 0.

Let us have another base station; base station 1 which is the base station of the neighbouring cell; cell 1. So, I have a cell 0 with a base station 0. I have a cell 1 with base station 1 and mobile station 0 is within the cell 0 and mobile station 0 is now located at the boundary of the cell 0. This is the situation. And also think of a situation that mobile station 0 was initially allocated to base station 0 and t is transmitting using the power control mechanism governed by the base station 0.

So, he is measuring his own distance from the base station 0 and then he is controlling the power for transmission according to the calculated distance and all the power control mechanisms that we have already discussed in the last module. And it may happen now see think a situation that currently though it is soft by this guy of this base station 0 and the highest received level of the power, if it was the enrolled to the base station 0 because whatever the power it was receiving from both the base stations instantaneously it was found that actually received power was more from the base station 0. So, it was allocated to the base station 0.

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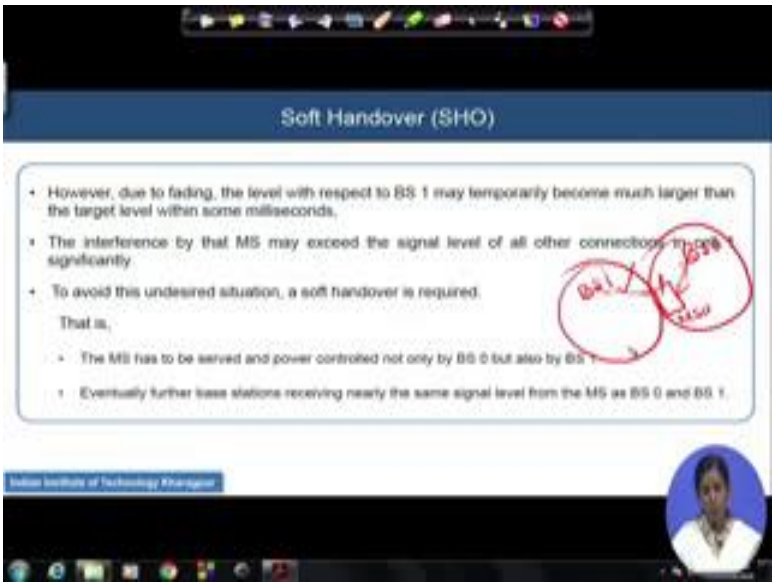

But now think a situation when this thing has happened. So, what we draw? We draw some figure like this. So, we had two cells; one is having the base station 0 another is having base station 1. Mobile station is close to the boundary of the cell 0. He was doing, transmitting actually by other power control mechanism and he is enrolled to base station 0. Why he was enrolled? We discussed that because he measured the received power level from both the base station and he found that the received power level is more from base station 0. So, he was enrolled to the base station 0.

Now, think of situation that because of the change of the fading condition change of the environment. Suddenly the channel between the base station 1 to this mobile station 0 it got better compared to the mobile station 0 to base station 0. So, I repeat the channel is now very good between base station 1 to mobile station 0 compared to the channel between mobile station 0 to base station 0. So, by means of channel is good we mean the fading is very less, fading is very very less. So, the power with which this mobile station is now transmitting, the power that it will that is received by base station 0 and the power received by base station 1. If I compare under the situation when the channel here is good compared to the channel between MS 0 to BS 0, you will suddenly see that the power that is getting received from MS zero to base station 1 is more compared to the power that is getting received by the MS 0 to BS 0.

It may happen because of the sudden change in the fading condition of the environment and because of that now what will happen? This power this mobile station 0 power will be working as an heavy interference on the overall the signals that the base station 1 is receiving from his own cell mobile users.

So, this situation is a completely unwanted one and may be because of very few milliseconds this phenomena has happened and after that the channel condition has got reversed and anyway again the mobile station 0 is found to be good to be associated with the base station 0 and again actually the interference power transmission is not, received power from the MS 0 is not such that the interference is high.

But because of that, but that may be actually most of the cases. But in between for those milliseconds time because of the good condition of the channel, the power received from the MS 0 to base station was becomes suddenly so high that it totally damaged to the communication within that cell one. So, this is possible and hence this is the reason why actually we are discussing this soft handover is required. The certain situation like this so demands that you should not give the command for the power control of the mobile users who are actually in the boundary of the both cells, by any one of the base stations. Its power control command should go from jointly from base station 1 as well as base station 0.

So, eventually what we are demanding is, it is something like that, the base station 1 and base station 0 should cooperate with each other to some extent and they will actually jointly at any particular time jointly they should actually instruct the mobile station to control the power. So, that the interference profile of say both the cells are maintained. It should not be actually going below beyond some certain threshold of the individual cells.

It may happen. Why we are talking about only two base stations? It may happen actually that the other neighbouring cells are having also the same kind of the phenomena. True it is because, but then we may actually come to the conclusion that out of all the neighbouring cells who are having this kind of the effect from mobile station 0, those two at least two of them who are having the significant effect from the power transmitted by mobile station 0 should take part actually in the decision process of this of mobile stations power control.

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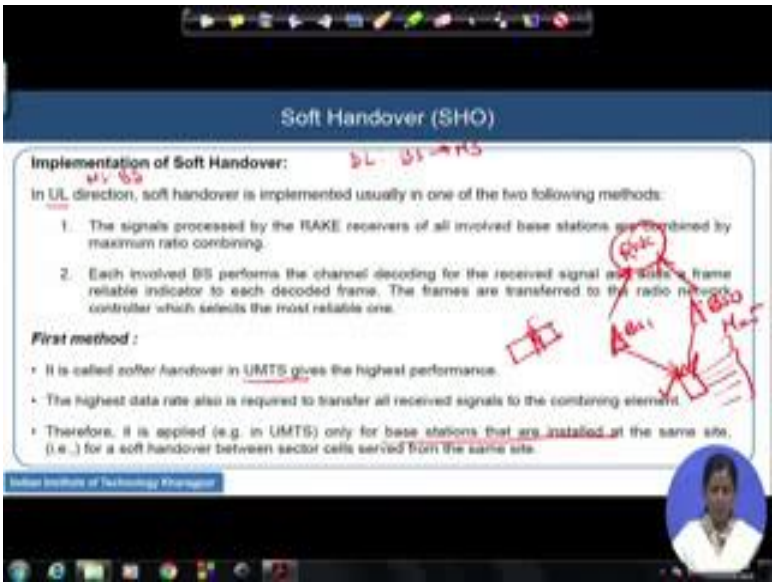

So, how do we implement this soft handover? We understand now that we are having two different kind of the communication direction. One is a uplink direction which is from the mobile station to the base station going on. Another is the downlink communication where, the base station to the mobile station communication will be going on. So, in the uplink direction soft handover is implemented basically by two types. So, the two mechanisms are there; it is something like this.

So, this is suppose my base station 1 and this is my base station 0. So, if I am having, if it is a downlink direction and I am a mobile station whose power control is required to be controlled by both of them. I will receive signal from both the base stations and here I have a rake receiver architecture that already is discussed in the CDMA fundamentals. That we are having the rake receiver architecture where, inside the rake receiver architecture we will go by the maximum ratio combining techniques at the output of the rake receiver we will process both the signals from both the base stations and then we will go by the maximum ratio combining to take the final decision and go ahead with the power control mechanism.

Another technique is that each involved this base stations they perform the channel decoding for the received signals and adds a frame to what they will do that in the downlink again. Each of this base station will perform the channel decoding of the received signal in the uplink and adds a frame reliable which will tell that when they

decoded this typical frame or typical packet. So, what exactly was the reliability indicator? So, they will add actually one field in the in the frame format. So, which will tell that what is the reliability associated with this decoded frame.

So, both the frames will be transferred from this base station to the radio network controller. The both the base stations will decode the frame and they will send it there and the radio network controller will pick up whichever is having the higher reliable indicator. So, he will pick up the packet which is having a higher reliable indicator. So, like that it may go on remember actually this rake receiver concept this one is mostly used, this is called the soft handover in the UTMS and it has a highest performance in terms of the dB gain that is performed. The highest if I understand that the highest data rate is also to be considered to transfer all the received signals to the combining element and all then actually. Therefore, if with the highest data rate is also needs to be address at the same time. Then it will be applied only for the base stations and that are installed at the same site not the base stations of different all the sites.

So, to choose the base stations whose signals will be combined in the mobile stations as well as whose signals will be really relevant related to one mobile station inside the RNC that there is a call actually to choose the base stations to who will be considered for a typical mobile station of our consideration.

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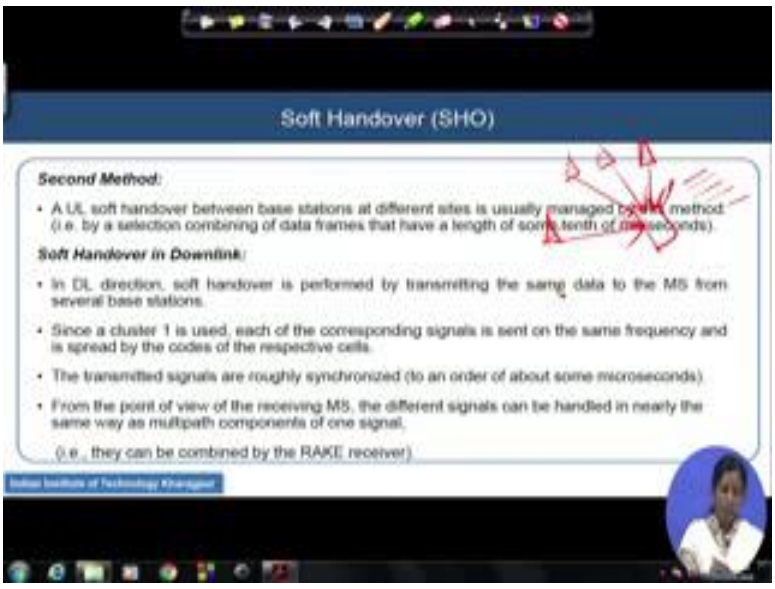

Thus, there a second method I mean where, actually this there is a second method where the base station performs the decoding option and all. So, the uplink software handover where actually in the UMTS sometimes we apply, that situation that uplink software handover and then connecting it to the RNC and taking a decision there and doing the selection combining in some extent of the data frames that is done.

So, that is all about the uplink soft handovers and all and power control mechanisms during your uplink is much more critical because we understand that the mobile users cannot be synchronized in the uplink direction. So, there is a much more critical that we have also discussed in the last module, when we were discussing the power control mechanism also.

So, uplink that is why we are so critical about the consideration of the uplink power control and is the difference handling in the uplink direction already and always. And sometimes actually the rake receiver that I told that it can do actually in the downlink direction, the rake receiver stuff can also be applied in the base stations because you may actually signal processed by the rake receivers of all involved base stations can be combined actually and so there is a central controller who will receive the signals from the multiple base stations and they in the RNC not the decoded one, but raw one and then he will do the, he will implement the rake receiver there and then he will implement all the stuff and maximum ratio of combining by maximum ratio combining he will take a decision.

Second method says that they will decode and they will put a indicator; channel indicator and then they will say and whichever is the having the best indication they will choose. So, the first one where actually from mobile station to the rake receiver concept is utilized is the most famous one in the UMTS that we have discussed. But soft handover in the downlink, in the downlink direction this soft handover is performed by a transmitting the same data to the mobile station from the multiple base stations.

Now think of a situation like this. Now we are having the multiple base stations; base station 0, 1, 3, 4, 5 and here is my mobile station. So, the mobile station will receive the signal from multiple one and the way actually the things were combined earlier in the RNC to form the rake receiver here inside the mobile receiver we may have the rake receiver architecture and here inside that mobile receiver can control, can have a rake

receiver architecture and he can actually take a decision by the maximum ratio combining.

Remember that if we are using the cluster 1 then, all the base stations will be using the same frequency. So, in that situation though the transmitted signals are not properly synchronized, they are roughly synchronized approximately within a micro seconds. From mobile sent point of view he can view actually all the signals coming as if actually it is a multi path signal coming to it. That is why actually equivalently by using the rake receiver architecture he can get the rid of the, he can actually get the final decision about the power control and they can hence is combining everything by the rake receiver.

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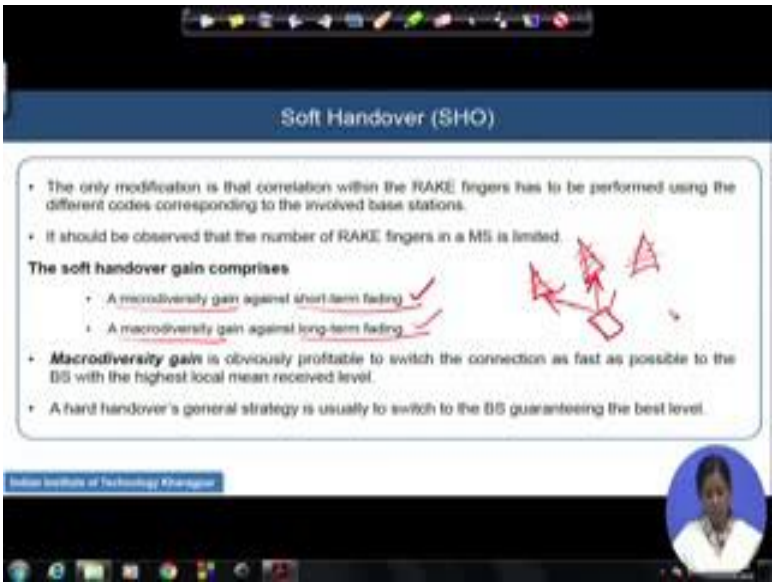

But only modification in the correlation architecture that we have to do here is, if we are not using the same frequency from all the base stations are not using the same frequency and they are utilizing the different frequency. So, in that case the same rake finger architecture can be rake receiver architecture can be utilized, but for the different fingers the correlation you have to choose a different kind of the codes of those base station cells and then you add the then you apply the maximum ratio combining. But remember actually that all the rake fingers that we deploy in the mobile station that should be limited and so fingers in the mobile station is also limited and that also limits the number of the input signals that you can combine and you can utilize for the processing

So, as this soft handover is now in place you will see that there are two different kind of the gains are involved in this soft handover process. The number one is the micro diversity gain and this gain comes from the fact of the short term fading. Another is the macro diversity gain this comes along the long term fading. So, we understood that this two fading we will actually, we are associated with the channel and this is over the short term duration the change of the channel that we are seeing. That we observe and this is over the long time duration if the changes that the channel take place and, but whatever be the changes in the channel this soft handover has the capacity to encompass both of them and provide the gain over both kind of the fading.

And this macro diversity gain this one is really profitable to switch the connection so as if you wish to get this gain no it should actually very fast. Finally, actually if you see the output of this rake receiver or the after the maximum ratio combining whatever the decision output you will see at the output of the output of the mobile station finally, your target will be to switch from one base station to the next base station to get the highest SNR, received SNR. But if I see the macro diversity gain it will be; obviously, profitable if you switch from the one to the next base station as fast as possible to get the highest gain. But remember the how fast it is this handover should happen there is a very big question.

So, based on what actually you will go ahead with this handover. Suppose you are getting controlled by two base station; base station 0 to 1 and suddenly you realize you have to switch between base station 1 and 2 say in that 0 should be discarded. So, will you switch on very fast actually once you realise or when and what is the threshold? Where is the decision point that will dictate you to switch from the one base station to the next?

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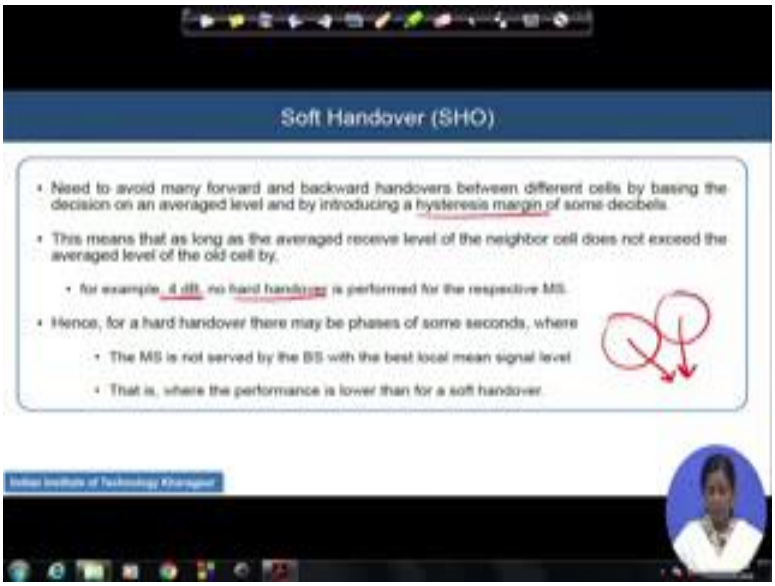

So, that is a very big question and we generally setup a strategy of this handover. So, we also need to understand. Though we understand that very fast switching is possible which is demanded, but we should understand that if you switch between the cells every on and off now. So, then there will be very hard actually, it continuously will be going forward and backward forward and backward kind off the handover.

Instead of doing that what we do is actually we keep on actually waiting the average level of the received SINR. So, over a certain period of the time sitting inside for a typical mobile station and we introduce a concept of the hysteresis margin of some decibels - I mean this is a typical decibels if you see that it is going below this level. The power of a typical cell is going below say certain level then only actually we will discard accepting the signal from that cell and we will actually incorporate a new cell base station to take part in the power control mechanism and hence that new cell that is getting added. So, power is handover is there from the base station 0 to that new base station say 2.

For example based on some practical data measure for example, this 4 dB may be a reasonable we people found that 4 dB is a reasonable threshold level of the old cell, if the average level of the old cell go below the 4 dB. These signals to noise for received signal to noise for from the old cell go below the 4 dB value then we hard handover process is initiated with respect to some mobile station. And remember that for a hard handover

that may have several phases, that may be phases some seconds actually where the mobile station is not served by the base station with the best local mean of the signal level and where the performance may be lower than the your soft handover process and all.

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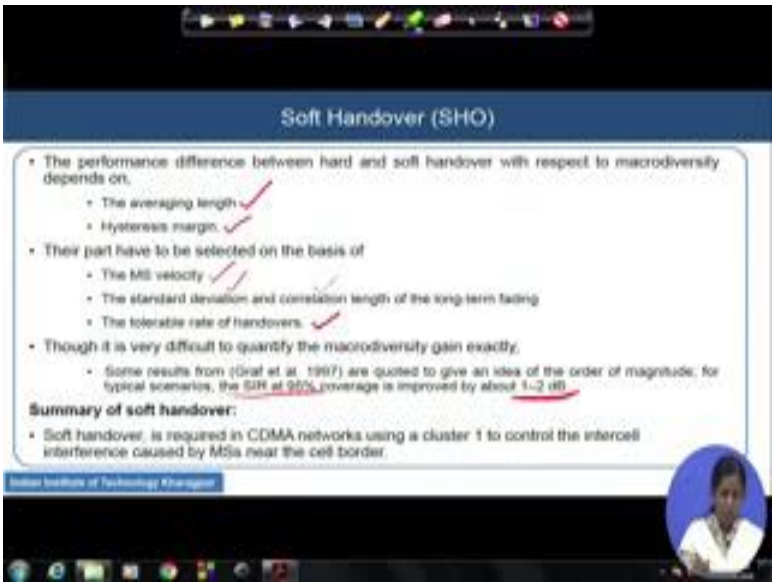

But we have to bare with all that only because instantaneous to and pro movement of any process handover process actually leads to lot of the control signal transmission over the network as well as actually it is a hazardous also for the mobile station to quickly switch from the (Refer Time: 22:05) quickly switch actually from one cell to the next.

So, there are lot of the control information as well as actually lot of data exchange is required whenever some handover happens, that is why we introduced in the last slide some hysteresis level. So, we have heard about two handovers now; the hard and the soft handover and with respect to the macro diversity it depends on this gain that you achieve from that and the performance between both of them. It depends largely on the averaging length over how much time actually you are everything from the current cell. And the hysteresis margin, the dB level gap that you have kept to decide the handover and both of this part they largely depend upon the three things; one is the mobile velocity, the standard deviation and the cross correlation length of the long term fading channel and the tolerable rate of the handovers. How fast handover you can tolerate in the network as well as in the mobile station?

So, is it allowed or not? So, based on that your handover will be going on, approximately is very difficult to quantify the how much macro diversity gain you can achieve for a typical kind of the long term fading, but still we got some practical data. And that practical data says that, approximately the order of the magnitude of the gain that you see is in the order of the 1.2 dB, the coverage can be improved by around 1.2 dB. If we go ahead by this micro diversity gain exactly we can get around 1.2 dB improvement in the coverage probability where, the SIR at 95 percent, at the SIR of 95 percent. These are some results recorded in practice and now if I come to the total, the summary of this soft handover, what we have gained? We understood that soft handover is unnecessarily required in the CDMA network with the cluster 1 architecture. Mainly to control the inter cell interference for the mobile stations who are residing in the cell border.

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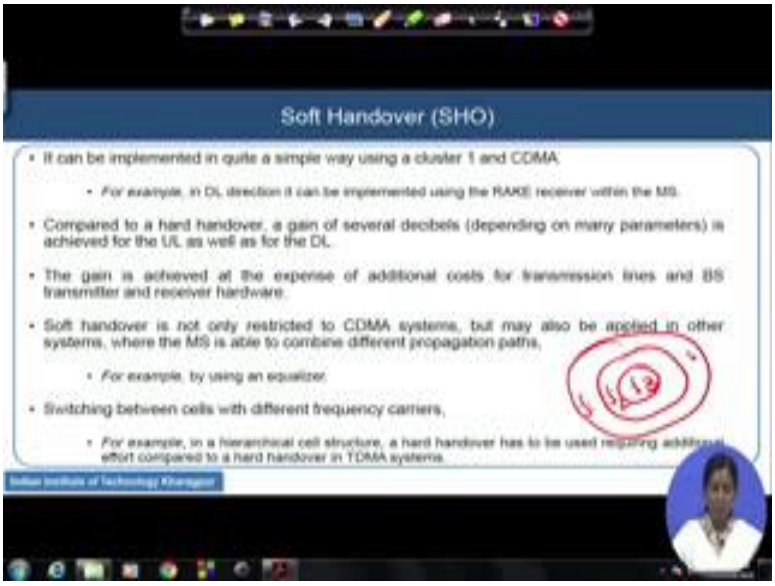

And we understood that it can be implemented in the downlink as well as in the uplink. And it is quite simple way that the way the cluster 1 and the CDMA in the downlink direction it will be applied. In the downlink it will be applied by the rake receiver architecture in the mobile stations. In the uplink we can apply each whether rake receiver architecture in the RNC or by applying, by decoding the received packet inside the base station and then further adding a channel indicator or reliability indicator value in each of the packets from the different mobile stations. And the RNC which is a radio network controller who sees actually all the packets received from the different base stations and

see what is the reliability indicator and chooses that packet who is having the highest reliability indicator in that.

And if I compare the soft handover with the hard handover, gain of several decibels though it is based on many parameters. The gain that you achieve by the soft handover it is much higher compare to the hard handover case. The gain is achieved though we are thinking that the gain will be achieved, but remember this soft handover is such that you are in your incorporating lot of the network resources. For example, multiple base stations you are involving to decide whether the handover is required or not. Whereas, in the hard handover only one mobile station he is taking care of the incoming signals and then taking the decision whether to go or not. So, he is doing the handover only by seeing or measuring the average level of the SIR of the old cell and whenever he is going down below certain level of certain dB level then only he is taking the part, he is taking the decision to handovers.

So, that is the hard handover, but soft handover is not like that it is not observing only the received power from the current cell and also the received power from the multiple cells are taking part into the process. So, though it is giving a higher gain, but it involves actually large resources in the network. The gain is achieved that is why with the additional cost for the transmission lines, additional cost for the transmission time also and the resource is from the network.

Soft handover is the process of the soft handover is not only recited to CDMA networks you can apply it on any other kind of the networks and even by (Refer Time: 27:15) simple example inside the equalizer also. And this switching between the cells with different frequency carriers if you are dealing with then, actually then there will be a hierarchical cell structure. For example, so this is the, there is the micro macro Femtocell concept where, the centre frequencies that are used in the different cells they may be actually different. In such kind of the situation the hard handover has to be used requiring some additional (Refer Time: 27:47) hard handover for this CDMA techniques that needs to be requiring some additional effort as compared to the hard handover in the TDMA networks because of the hierarchy of that different kind of the central frequency that we are using.

So, indeed that what we learnt here is that soft handover is a very essential part and preferable part for the CDMA networks, for the network deployment and especially for the users who are standing and who are there in the cell boundary and compare to the hard handover we prefer the soft handover because its gain achieved is much higher. But at the same time should remember that it involves large amount of the resources in the network, numbers of the base stations involved. So, numbers of the transmission processes involved and the other processing involved inside the base station as well as in the mobile station.