Spread Spectrum Communications and Jamming
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Lecture – 57
Multiuser Detection and Interference Cancellation

Hello students. Today we will discuss further techniques to cancel the interference in a CDMA network and in towards that direction, first we will discuss about the multi user detection concept, which we call a mud. And also we will discuss about the combine usage of the TDMA with CDMA, how to handle the interference, how TDMA in association with CDMA can help us to handle the interference in CDMA network. And at last, today we will discuss all the schemes that we have discussed in the last in this, all this four modules in the interference handling or the interference handling mechanisms in the CDMA networks. We will see actually the diagram of combined all the combined effects of the handling mechanisms effect as well as interference handling mechanisms of all the different kind of the techniques.

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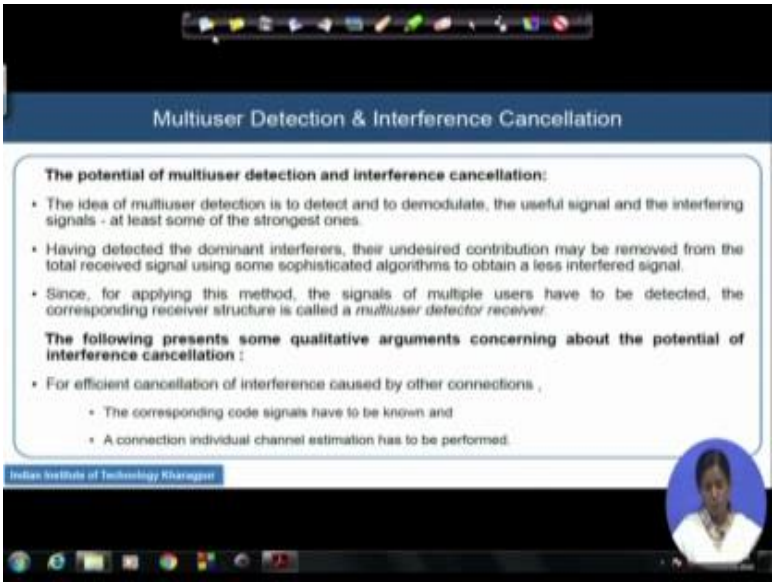

Let us start with a multi user detection concept. The potential that is involved the multi user detection and interference cancellation. So, multi user detection and cancellation says that idea is that we should be able to detect the multi user signal in the receiver and along with our useful signal. If we are able to detect the independent user signals apart

from our intendant signal then, we can also at least get an idea who is the stronger interference out of this along with the intendant signal. And if we can detect all those signals it will be very easy to subtract them from the incoming signal and get rid of them or at least gets a less effect of those interfering signals and so the whole process involves two thing; one is you detect the dominant interference and their undesired contributions actually now you subtract from the total signal you are receiving and lower down the interference.

So, detection is there and then the cancellation of those interference is there from the combined received signal. Hence the name and the receiver architecture that we actually are interested in or what is involved in such kind of the process is called the multi user detector receiver. So, first user detection of multiple user signals then, is the cancellation. So, detection hence the detection and cancellation and for efficient cancellation what we need to have here is, you can actually ask yourself also then you will get the answer that in order to get the detection we need to know the different codes of the a priori information about the code used for the different users right.

And also the connection individual channel estimation, inter channel connection between the different users and. So, the channel estimated value or the a priori information about the channel also needs to be needs to be known. Though these are the two important part that we should keep in our mind when we are dealing with the multi user detector receiver. One is the sum a priori information about the code signals of your multiple users where you are really affected in, where from you are getting the maximum reflection and maximum interference. The codes used for all of the users you have to know also the channel actually some apriori channel information between you and those users. Some channel estimation needs to be either performed or you have to have some a priori information on that.

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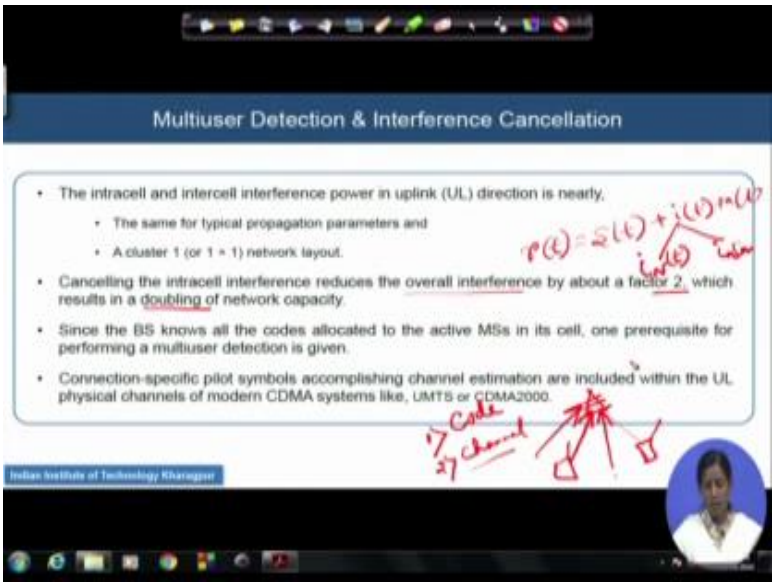

And continuously we are talking about two different kind of the interference; one is intra cell interference another is the inter cell interference to control the power in the uplink direction and also both not only in the uplink as well as in the downlink direction and in multi user detection and interference cancellation also we will be considering both kind of the interference and we will consider that the same the same for typical propagation parameters are known. And the cluster is of that 1 cross 1 network layout or cluster 1 kind of the network is utilized.

Now, if I can cancel the intra cell interference then, it will reduce the overall interferences by about a factor of 2 because we understand that when we receive a signal r t though we write actually it is a intendant signal plus this i t and plus n t. This i t is having basically two branches; one is the intra cell interference. So, I will write it as a i n say and another is inter cell interference so that is n t r say. So, this both of them are actually, there are if you can really actually reduce any one of them definitely it will improved. The total interference will be removed by a factor of 2 in that sense actually it is written, and if I can remove actually any one of them and reducing the interference by a factor of 2, definitely the capacity will be increased by two times.

And see actually then the very basic question is where from the information about the codes will come into picture? Very easy at least in the down link because base station to mobile station communication whenever is going on who is allotting the codes. Codes

are dynamically allotted in the network by the base stations. So, base station has a very good knowledge of who is using what kind of the codes and then whenever he is getting signals in the uplink. So, he understands actually from who are the neighbours of yours and what are the codes getting used by all those neighbours. So, he can actually start the cancellation he can extract the effect of each of them by subtracting, by multiplying the corresponding codes of those users and then actually taking care and finally, actually subtracting that value each of their value from the intendant signal.

Now, the connection specific some pilot symbols you can actually add because if the pilot symbols are different for the different users then, those pilot signals can help you to have the channel estimation there. So as I discussed in the last slide that the two important information's that you need to do for multi user detection is number one; is the code information and second thing is the channel information or the channel estimation you have to perform. In the uplink both are feasible it seems because a code is known to the base station he has given distributed the code and if I give the different channel training sequence for the preamble designed for the different users and then definitely actually using those different training sequences, the channel estimation is also possible.

Hence, it is seems that multi user detection and the cancellation is heavily possible in the uplink direction and this is really used also in the modern code division multiple access systems will like CDMA 2000 or UMTS.

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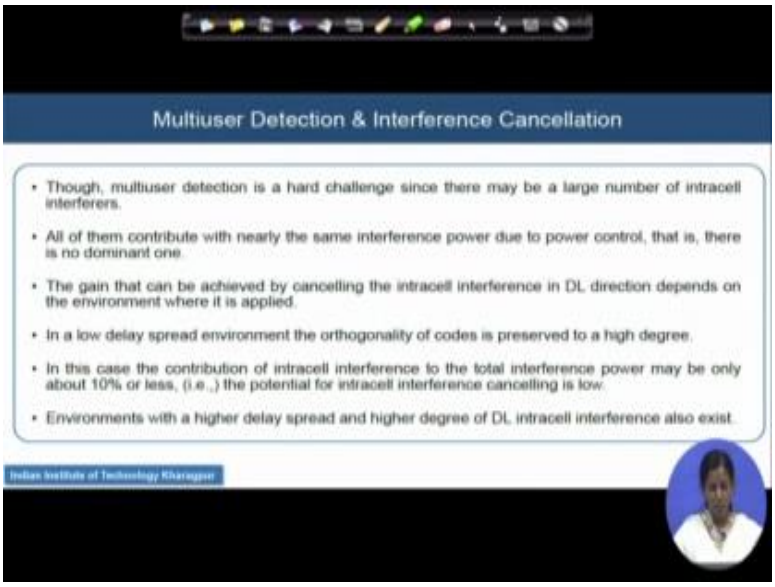

Though this multi user detection is hard challenge since there may be a large number of the intra cell interferers sometimes because it involves the huge signal processing of extracting, first each and individuals signal and then subtracting from the intendant signal and then actually coming up with it. So, it is a hard challenge, really hard challenge and actually all the codes we understand that though we know the codes they are not supposed to be in a perfect synchronization.

So, synchronization effect is also there. So, though the idea is seems to be implementable, but in a practical sense it is really hard to implement in view of all this issues. But all of them they contribute with nearly the, if I understand on the top of that, that all the users are transmitting by power control mechanism. So, we can understand that none of interferences are actually are exceeding compare to the other. So, almost the same level of the interference power approximately you are receiving at the receiver or at the base station and so the gain that can be achieved by cancelling the intra cell interference in the downlink direction basically depends on which environment that where it is applied. In the uplink the scenario is much more easier compare to the downlink and the downlink the cancellation of the inter cell interference will be largely depend upon where what the exactly the environment is about.

For example, if it is a slow fading environment and where the delay spread is also very low then the orthogonality of the codes that will prevail there would not be actually much loss in the orthogonality of the multiple codes and you can actually, it preserve the orthogonality to a very high degree. And in that situation in the downlink scenario you can apply this interference cancellation mechanism. In the case of this contribution of this intra cell interference to the total interference power may be only around to 10 percent in such a situation where there is a low spread environment and in that cases the cancellation actually does not actually mean lot of the signal processing involved in it, but also the gain from it also will be less because they are not creating really very much interference because the code itself is taking care of all the codes are orthogonal and orthogonality is prevailed from user to user. There is not a loss in that because the channel is a low delay spread channel.

So, it has not changed a lot. So, orthogonlity is almost maintained and that is why actually the interference is not that much around 10 percent contribution is coming from the intra cell interference and in that case you may avoid also the detection of that

process because improvement would not be much high. But if you are in a high delay spread channel and their higher degree of this downlink intra cell interference also exists and you have to really take care of devising the mechanism to detect and the detect and cancelling it.

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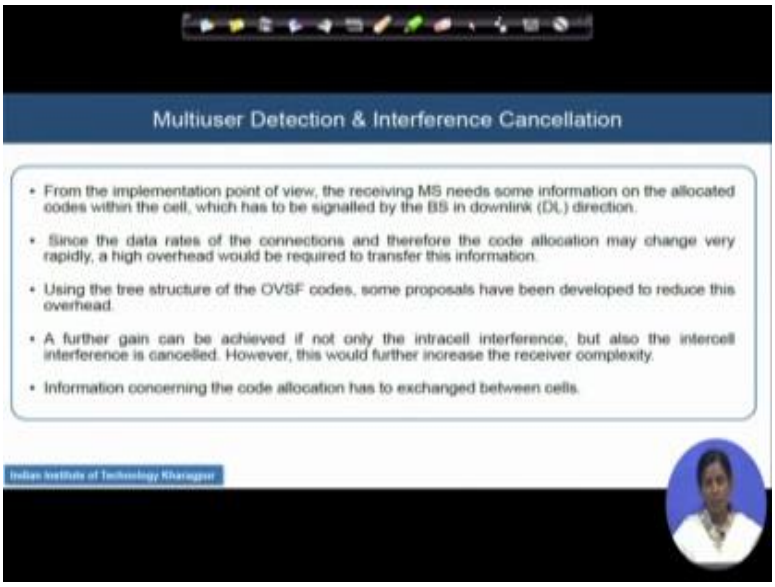

From the implementation point of view the receiving mobile station needs some information about the allocated codes and if it is in the downlink and hence the base station, actually the control signal when the base station is transmit into the receiver to the mobile station in the downlink, he should give the information about the approximate code information of his neighbours. And since the data rates of the connections and therefore, the code allocation may change and each and every movement. Think of a situation actually that each and every movement the user is changing his data rate requirement also and hence the code allocation is also varying based on the kind of the application he is doing and the kind of the data rate support he is asking.

So, in that situation the total overhead in the downlink, the total overhead of giving the code information from base station to the mobile station is really becoming very heavy and in such situation that the high overhead would be required to transfer this information so that extra overhead that is coming over the network sometimes may be tolerable, but if we think of a tree OVSF structure. So, some proposals can be developed actually there with minimal information given to the user to the mobile station and

having the information that the OVSF tree structure is used to provide the codes to the neighbours. He can actually make out what are the other codes already allotted to the neighbours.

The further gain can be achieved if not only intra cell interference, but also the inter cell interference will definitely and that actually the can give a huge gain to the performance, but remember with a heavy increment in the system complexity.

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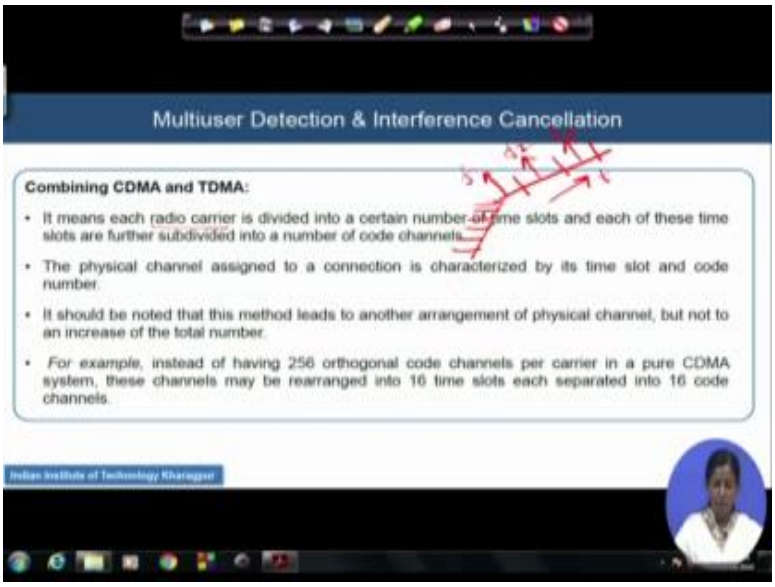

So, then next option people thought about is combination of CDMA and TDMA to handle the interference in a CDMA network. What is that? This combination means that each radio carrier I mean the FC is divided into certain number of the time slots and each of this time slots are further sub divided into a certain number of the code channels. So, what I am saying is, there is a time axis and each of this time beams it is divided over certain time beams. In each and every time beams there is a frequency allotted, carrier frequency allotted and inside that each carrier frequency I have the large number of the certain number of the channels. I mean the code channels allocated. So, for compared to the associated to this f 1 say 4 number of the, 5 number of the codes are available. Associated to this f 2 another 5 codes are available like that it is going on.

The physical channel assignment is to a connection is now characterized by two factors; one is what is your RF frequency? And what is you are actually the channel code? So, what is your RF channel? And what is your code channel? So, like that people specify

and it should be noted that this methods leads to some another arrangement of the physical channel, but it is not nothing, but actually you are adding something extra kind of. For example, if we use only a single frequency and suppose you are having a pure CDMA technique where 256 orthogonal, suppose code channels are they are per sub carrier like this and instead of that what you have arranged is you have 16 slots and 16 cross 16. So, total 256 codes you have divided now over the different time axis's like that it is.

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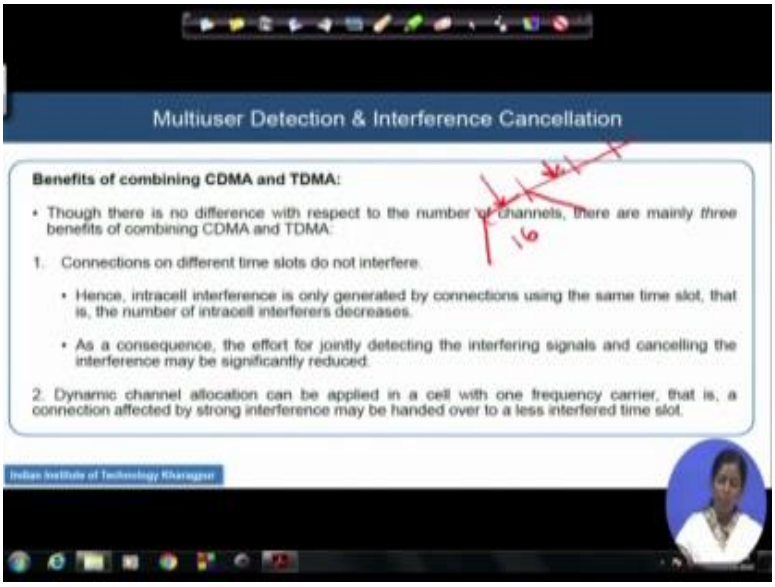

So, there are mainly three benefits if you do this communication of CDMA and TDMA. See the communication between the time slots they are independent. So, they do not interfere with each other at all. So, the intra cell interference is only generated from those users who are using within this time slot and if the same codes are getting used by another set of the users at different time slot. So, that will never create any interference to your intendant transmission, if you are sitting in the time slot number one.

So, the effort of jointly detecting the interfering signals and cancelling them that is still there, but its dimension has reduced. Earlier it was 256 and now it is only suppose 16. So, because only 16 number of the code channels are available part time period and earlier there was no time division. So, all the channels where available to (Refer Time: 16:36) code channels were available for all the time kind off. So, now, it is not the situation and. So, you can largely reduce the dimension of this multi user detection

approach and this dynamic channel allocation you can apply inside the cell, if you see that actually you can observe the condition of the channel over different time slots.

If you see now that there is a huge interference coming in this time slot for a typical user you will never schedule that user in this time slot. You use that you schedule that user in some different time slot where that interferer would not be there. So, large control of the interference by that mechanism also is possible in this situation.

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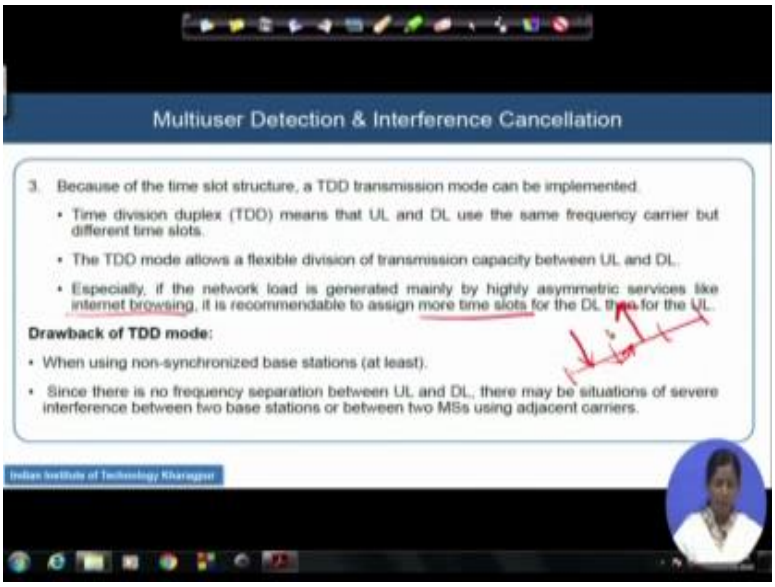

And another important part because we understand that there is a different time slot involved in the operation. So, TDD operation transmission mode can be implemented. TDD mode means downlink, when the downlink is going on uplink is not going on.

So, uplink will go on in the different time slot. So, any interference for the uplink channel to the downlink channel that is not possible and transmission capacity also it can be flexible, division of the transmission capacity between the uplink as well as in the downlink is possible and. So, high asymmetric services if the network load is generated suppose for internet browsing kind of, idea asymmetric kind of the services. So, in that situation it is recommendable to assign some more time slots for the downlink and then the uplink. So, variable adjustment of the time slots is also possible based on the kind of the demand, kind of the application currently going on and loading the traffic of the network.

But main drawback of this time division duplexing mode is what you know because when there is no synchronization between the base station at least. Since there is no frequency separation between the uplink and the downlink same frequency is used only the time is different if there is no synchronization. So, it may happen that actually when the downlink transmission is going on somebody has started doing the uplink also and then the downlink signal and the uplink signal can create interference to each other.

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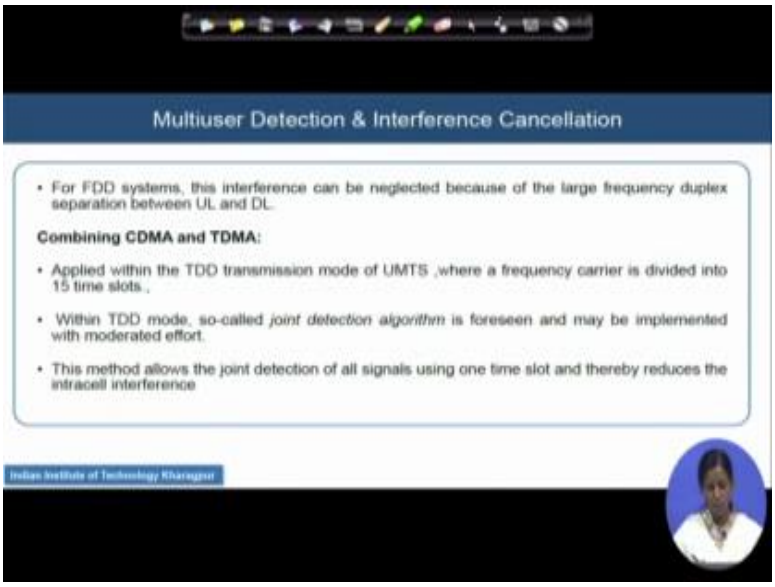

So, high level of synchronization is expected between the base stations in this situation. For everyday system this can be addressed and can be neglected because for the everyday system your uplink and downlink are completely having two different kinds of the frequencies for dedicated for. And remember this combination of the CDMA and TDMA we have applied already in the UMTS systems with the 15 time slots and within this TDD mode joint detection algorithm is running with the limited number of the code channels and this method also uses a joint detection of the signals using, one time slot and thereby reduces the. Means you can utilize actually the intra cell interference as well as the inter cell interference by having this joint detection algorithm in the CDMA system.

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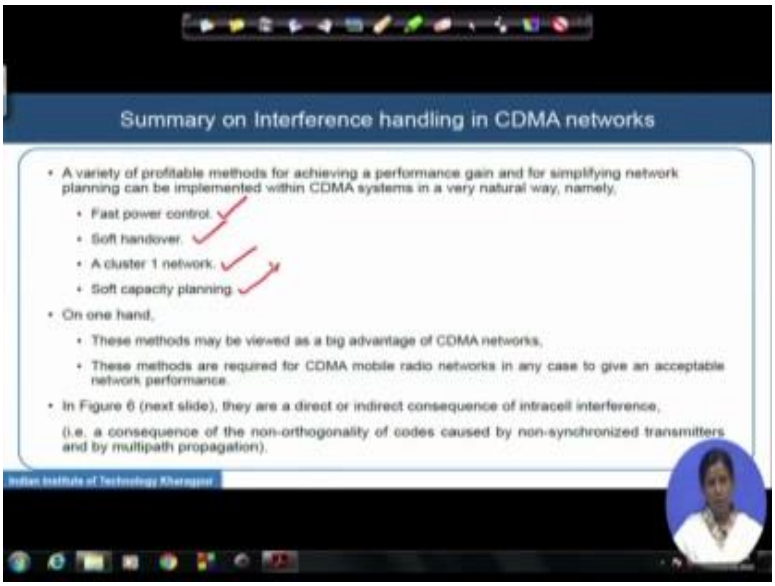

Now, if we are now ready to sum up all the interference handling mechanisms that are utilizing the CDMA network. We have discussed each of about each of them a lot. Number one is a fast power control mechanism, soft handover, we utilize the cluster 1 network where, single frequency is there and soft capacity, planning and is there. Apart from the multi user detection TDMA combined with CDMA, multi user detection receiver techniques, smart antenna techniques so all are also there in the list. And in one hand this methods may be viewed as a very big advantage of handling the CDMA network, but on the other hand the mobile networks on to give the acceptable performance also these all this any one of them at least more than one of them needs to be applied to get a successful performance in the network and in the next slide we will summarize more comprehensively.

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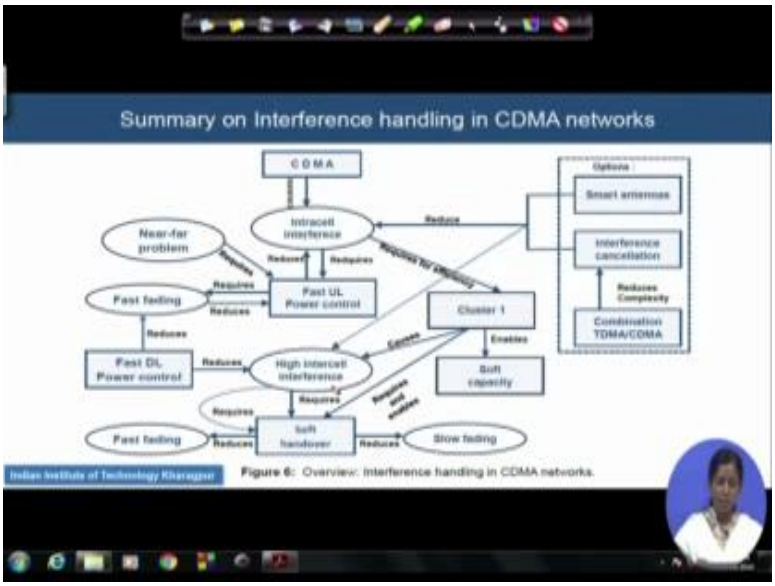

So, this is the overall interference handling mechanisms that we have till now discussed. Let us revisit in a CDMA network a network causes the intra cell interference. This intra cell interference is coming because the wireless channel and the multi paths are there in the wireless channel and also in the uplink direction, the users cannot be synchronized because of the channel actually the orthogonality of the codes cannot be guaranteed to be orthogonal because of the high delay spread involved as well as. So, you are getting the lot of intra cell interference at the receiver.

Once it is there so it requires some fast uplink power control. This intra cell interference actually also comes from the near far problem, which is the location dependant actually the power transmission because of which we saw that the power received from the nearest base station will be more than from the farthest base station and he is the nearest base station, nearest mobile station power is creating huge interference on the signal received from the farther mobile stations, far away mobile stations and once actually this kind of interference is there, there are the requirements actually. So, it requires the fast uplink power control and if I can do the power control it can reduce a inter cell interference.

Inter cell interference also requires for efficiency the cluster 1 kind of application, network deployment. And if you have a fast uplink power control I saw that I told you that the near far problem is also there. So, not only the intra cell interference is

demanding the fast uplink power control also the near far problem requires the fast uplink power control. And there is a fast fading involved in the wireless channel and if it is there fast fading is there and so for that to ready to take care of the effect of this fast fading one. So, the fast downlink power control will be required to control this fast fading, to handle this for this fast fading. The fast uplink power control also actually is related to this fast fading.

So, it also d b reduced if I can fast fading effect will reduced if we can apply the uplink power control. And now remember we talked about the cluster 1 kind of the deployment. The deployment of this cluster 1 enables the soft capacity and soft capacity it also actually requires the cluster 1 requires, the cluster 1 is essential to increase the efficiency of the network, but to have a efficient deployment of the cluster 1 you need the handover. Soft handover is the best one we have seen compared to the hard handover and, but cluster 1 I mean the with same frequency deployment of the all users, it causes the high inter cell interference also because you will have cluster 1 cross 1 means all the other neighbouring clusters will also be using the same frequency.

So, your high inter cell interference is expected to happen and to mitigate that you require the handover also soft handover also this high inter cell interference can also be reduced by the first downlink power control and. So, fast downlink power control is very good medicines for your fast fading as well as for the high interference, high inter cell interference. Soft handover reduces your fast fading and soft handover also reduces that can handle the slow fading. And now remember we have the several options to handle the intra cell interference like your combination of the TDMA, CDMA, interference cancellation scheme by multi user detector, receiver and we have learnt about the smart antenna techniques. So, all of them can combinely actually reduce a inter cell (Refer Time: 25:27) reduce the inter cell, intra cell interference.

See this combination of the TDMA, CDMA also helps to reduce the complexity of this mud architecture because we have seen that actually if I use TDMA then the number of the multiple users, that we need to take care of in the cancellation algorithm whose direction is required and hence cancellation will be required the number can be restricted, it can be reduced if I combine TDMA with CDMA. So, as a whole this is the complete picture of the CDMA network interference and it is a handling scheme that we have already discussed in the last four modules.

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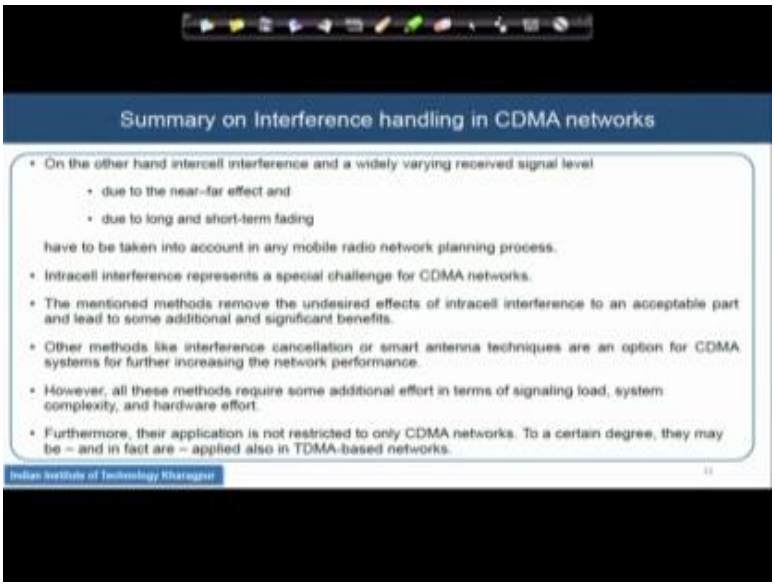

And this is basically the description of what you are we have discussed in the last few slides and there is nothing called that who is better than whom. Among all the interference cancellation scheme that we have discussed, but in general what we can say is that you are going to handle two different kind of the interferences called the intra cell, inter cell. You are having the problem of the near far and you are also having the problem from the wireless channel called the fast fading as well as the slow fading and these are the solutions available in your hand. For example, the fast uplink power control, soft handover using the cluster 1 concept, fast downlink power control and the combination of TDMA, CDMA, multi user detections, smart antenna. So, you do the combination of the different options to handle the interference of the network that is a suggestion. There is nothing to say that only one kind of the solution is applicable to one kind of the network.

So, depending upon the interference experiencing getting experienced in the uplink and downlink combination of these options can be implemented to improve the performance that is the message. And with this understanding we will be finishing off the interference handling mechanisms and the discussion of the interference handling schemes in the CDMA network here. And what we have totally understood is that based upon based on our several kind of the options available and different kinds of the problems handled and we have to actually get aware of the environment and the kind of the data rate that we are targeting and the kind of the applications for which we are targeting the CDMA network

and based on the budget, link budget that is prepared, based on the data rate as well as the coverage link and the data rate support and coverage link demanded then before deploying the CDMA network.

We have to take care about the different kind of the interferences that are possible to occur in such networks and get ready with some of the solutions with the existing different handling schemes already discussed.