Wireless Communications
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Lecture No. # 07
Improving Coverage and System Capacity

we will talk about improving coverage and increasing the system capacity in today's lecture. let us first look at the outline of today's talk.

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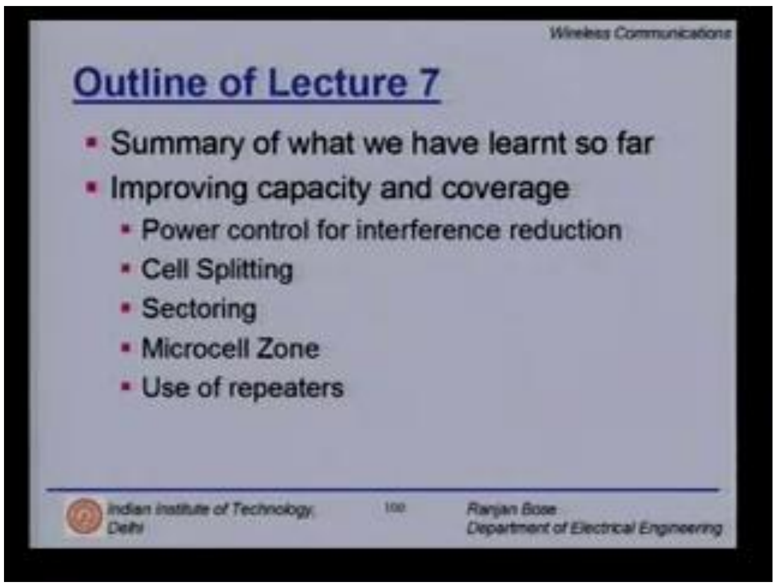

we will first begin by summarizing what we have already learnt in the last lecture. then we will talk about certain interesting aspects about coverage and capacity. both are of interest. we will look at specifically certain techniques namely the power control strategy, cell splitting, sectoring microcell zoning and the use of repeaters. all of them can be used in order to increase capacity and coverage. we will also look at certain examples to see how calculations are done. first let us summarize what we did last time.

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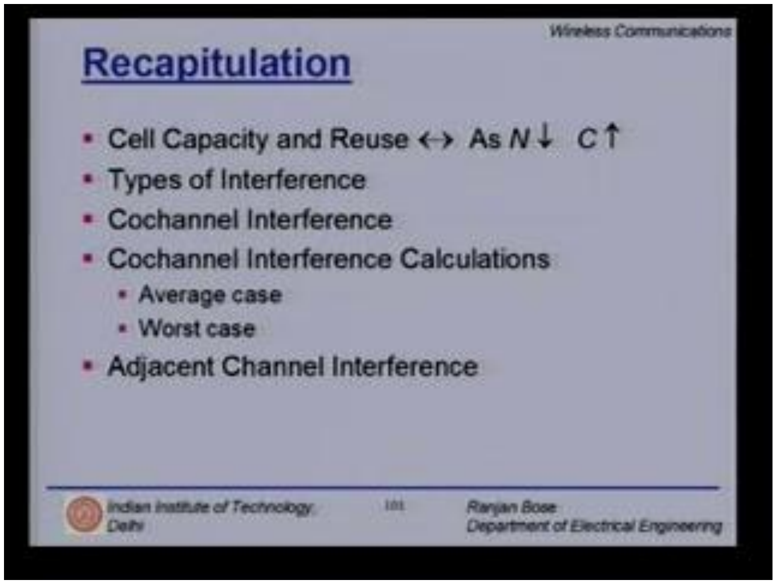

we noted that the cell capacity and reuse are interlinked. in fact, as the cluster size N goes down, the capacity goes up. we then looked at different kinds of interferences. we specifically looked at cochannel interference and adjacent channel interference. we looked at the cause for cochannel interference and then we looked at how to calculate certain kinds of cochannel interferences. we looked at average case as well as the worst case analysis. we realized last time that interference can cause problems and limit capacity of the system. finally we looked at adjacent channel interference & how it can be controlled by proper frequency separation. in today's talk, we would like to look at some strategies either to reduce interference or to increase capacity or to do both.

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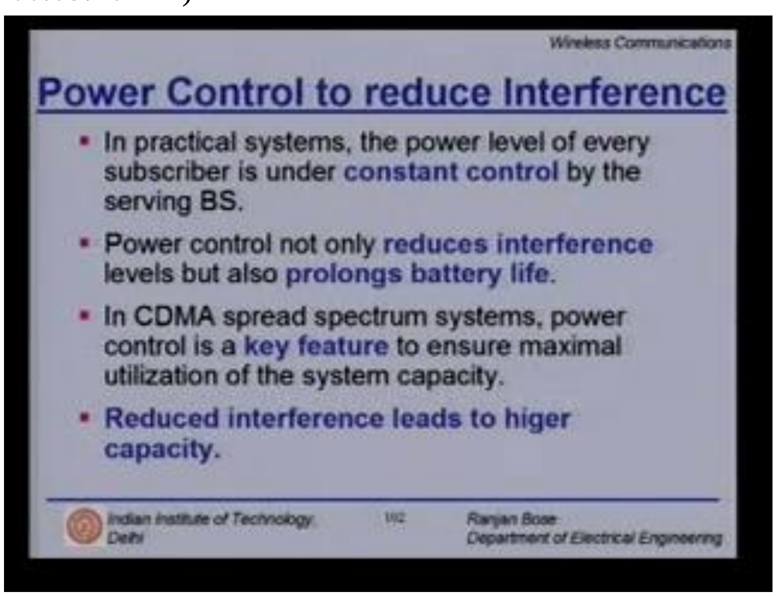

so the first technique is power control to reduce interference. in fact this is almost mandatory today if we do not carry out power control we have the problem of grounding the reasonable required signal by excessive interfering signals. we have no choice but we ensure that we do some kind of power control in order to keep interference under control. in practical systems, the power level of every subscriber is under constant monitoring and control by the serving base station. so as the mobile station is moving closer to the base station or moving away repeatedly, the power received is measured and being controlled. power control not only reduces interference but also prolongs battery life. so today, a competing handset manufacturer can publicize a longer battery life simply because the power control strategies are being implemented. in CDMA – "code division multiple access" spread spectrum systems, the power control is a key feature to ensure maximal utilization of system capacity. we know that in CDMA systems all the users are using the entire bandwidth at all times except they are all using different codes. that is, we are picking up interferences from other users all the time. if we are not ensuring power control we have the fear of grounding a faraway mobile station from an interfering user located closer to the base station. so reduced interference leads to higher capacity. when we talk about higher capacity issues today, we have to also see how interference can be reduced i thereby leading to increased capacity. capacity as we all know is the total number of users that can be supported in the system and translates directly to rupees.

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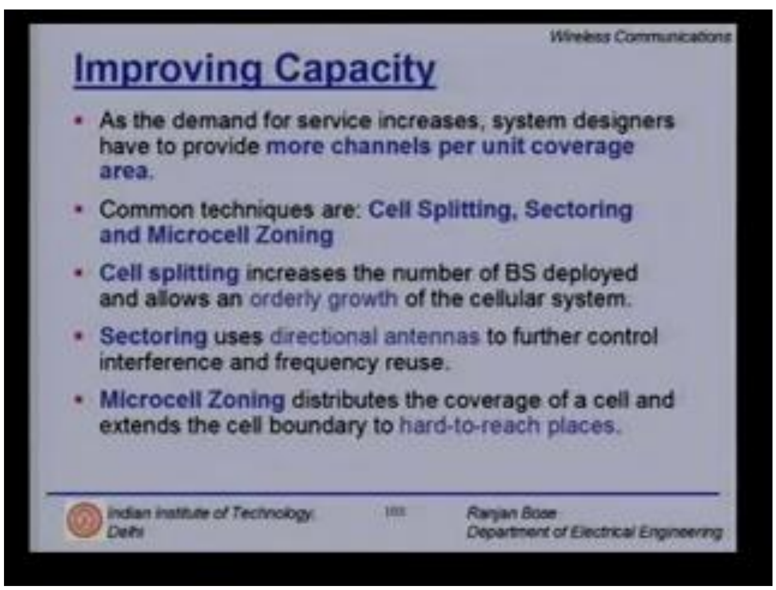

as the demand for service increases, system designers have to provide more channels per unit coverage area. so we are now talking about number of persons that can be supported per hertz of bandwidth per square kilometer. so we have introduced another factor per square kilometer. common techniques of improving capacity are cell splitting, sectoring and microcell zoning. we will look at cell splitting, sectoring and zoning in today's lecture. the process of cell splitting increases the number of base stations deployed and allows an orderly growth of the cellular system. we will see that cell splitting requires you to reduce the size of the cell as well as the transmitted power within each new cell. sectoring on the other hand uses directional antennas to further control the interference and frequency reuse. once i can control interference, i am in business. i can somehow increase the capacity of the overall system. microcell zoning is a relatively new technique which distributes the coverage of a cell and extends the cell boundary to hard-to-reach places. in fact, this hard-to-reach areas could be the basement of a building of valley area, tunnel or some other secluded area where i cannot really provide coverage. we will also look at the technique called using repeaters to cover hard-to-reach places. first let us look at what is meant by cell splitting and how it is done.

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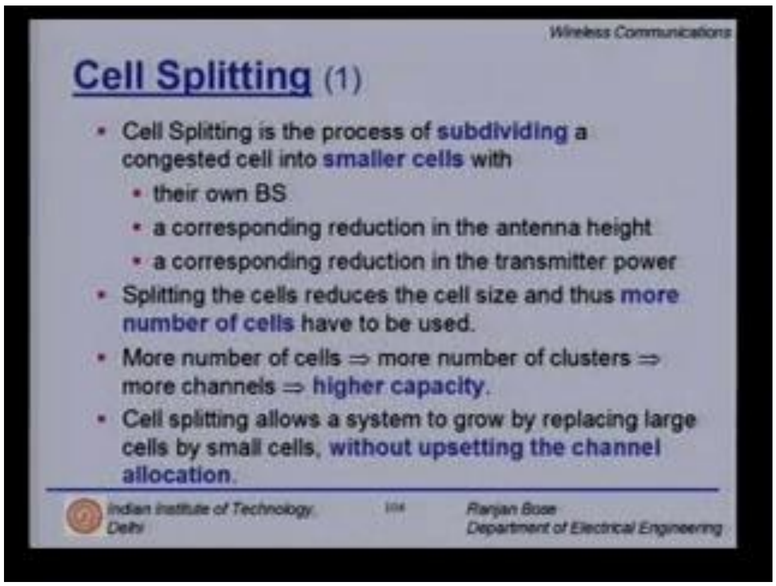

cell splitting is the process of subdividing congested cells into smaller cells .so we are working at cell level now. Suppose, after i have laid out the entire spectrum and distributed the different reuse frequencies, i find that certain cells are so congested that i cannot provide enough service to the customers. a lot of people in that cell are getting blocked calls. the channels are not available. but now too many base stations have been put. i cannot rock the boat. i cannot change the entire spectral allocation or the reuse pattern. i have only one choice. take those cells which are congested and try to do something called as ‘cell splitting’. so these smaller cells within the large cell have a very interesting characteristic. all of them have their own base stations. but these base stations are not so high. the antennas are shorter and they also transmit less power. please remember if you are having smaller cells, they are also closer in terms of reuse distance. i must correspondingly reduce the transmit power. also something to be remembered is, as we increase the base station’s height, we radiate to a longer distance. so we correspondingly have to reduce the height of the antennas. splitting the cell reduces the cell size. thus more number of cells have to be used. more number of cells implies more number of clusters, more number of clusters implies more number of channels because number of channels per cell is fixed and ultimately it leads to a higher capacity. cell splitting allows a system to grow by replacing large cells by smaller cells without upsetting the channel allocation. that is very important. frequency planning requires a lot of effort and resource allocation.

once it has been done, we cannot keep changing the frequency reuse pattern but the demand keeps on growing at different places at different rates. so cell splitting is a useful way to grow and ensure more number of users can actually be accommodated.

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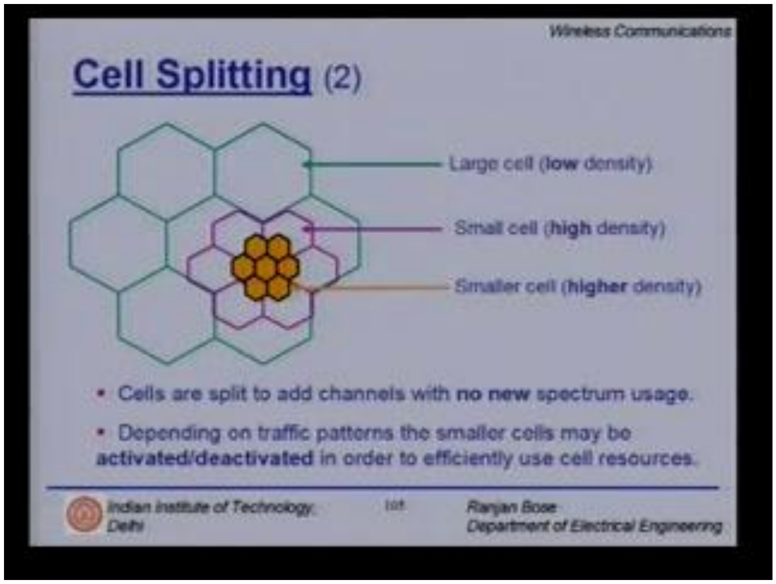

so let us look at an example. earlier we had these big cells because the demand was not so high. so large cell in low density areas. however some of the regions being supported by the cells have experienced an increase in the number of users. so as a first step, we split the cells. please note we have done the splitting partially. certain cells are being split into two or three cells. but these cells can only handle higher density. but in the event that more and more number of users have to be supported per cell, may be in the central cell, we try to subdivide the cells further by putting smaller and smaller base stations. so smaller cells would imply greater capacity. cells are split to add channels with no new spectrum usage. we have not requested for any additional bandwidth. the frequency is being reused. you can see that the reuse pattern is the same. depending on the traffic pattern, the smaller cells may be activated or deactivated in order to efficiently use cell resources. So we have a choice. we can either continue with the smaller cells or if the need goes down, then we deactivate the cells. we could also make this smaller cells in the morning time when peak office hours happen and then we come back and deactivate the cells once the demand is reduced.

The question being asked is: are we suggesting that the cell sizes are dynamic? the answer is no. we are not talking about the cell size being dynamic. we are not playing with the size of any cell. Particularly, we are splitting the cell. so either the cell is large or it is small but we did not play around with the boundaries of the cell, per say. we will also look at a more detailed example. .

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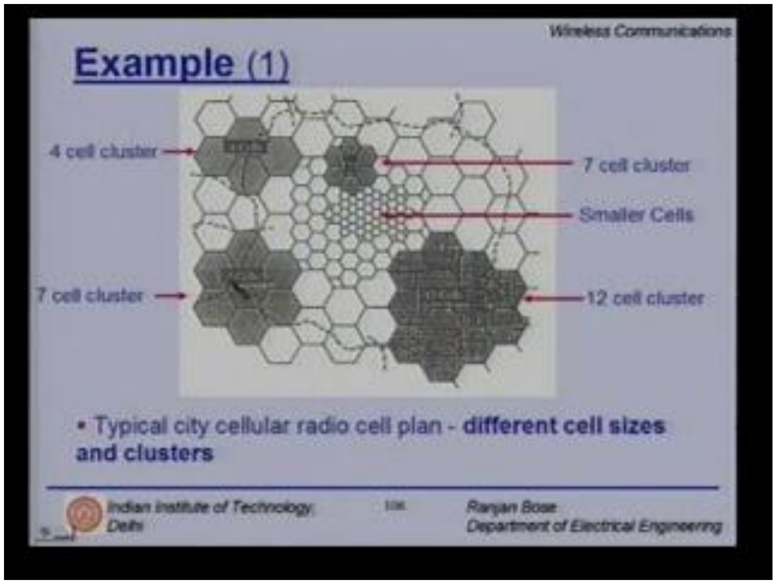

let us look at a certain geographical area. so if you can see a dotted random line, it represents an area to be covered by the service provider. now what has happened is, in this slide (Refer Slide Time: 13:33) you can see a variety of sizes. there huge cells. all hexagonal and then there are smaller cells and there is still smaller cells. Clearly, just by looking at the diagram, you can say that those areas which are being supported by big cells and even bigger cluster size like 12, here we are only supporting very low traffic density. it could be the outskirts of the city or a poorly populated area. a more densely populated area might use a reuse pattern of 7 but the cell size is the same. on the other hand a still more dense area would request us to reduce the cluster size. so we go down to four but maintaining the size of the cell. however at certain areas, i have to reduce the cell size in order to increase capacity. i'm still using 7. so i am using a combination of the cell size and the cluster size to accommodate and finally tune the required number of customers to be supported. there are certain regions where the cell splitting has led to much smaller cells and providing us with much higher capacity. so a typical city for example, like Delhi might have this. typical city cellular radio cell plan should have different cell sizes and clusters. it is fine-tuned to the demand.

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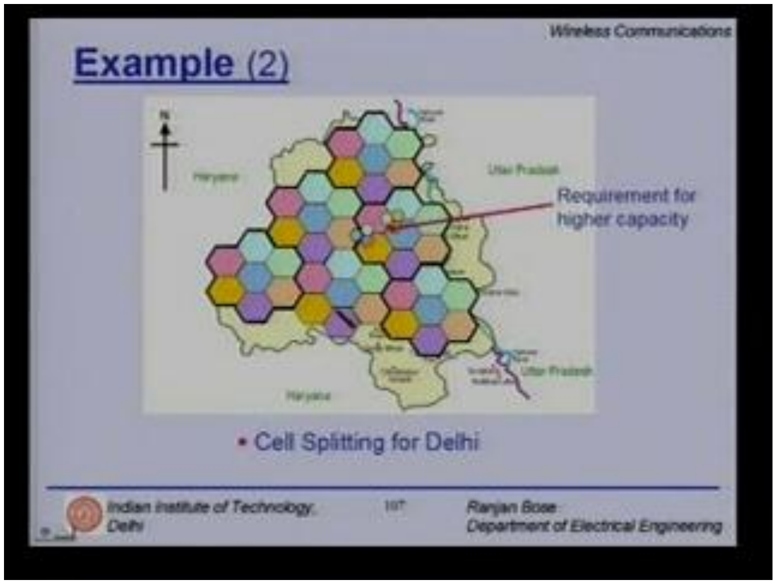

let us now consider the cell splitting for Delhi. what would happen if, after the city planners who have laid down the frequency reuse pattern, decide to increase the capacity in certain areas. so first let's look at the map of Delhi. we have Haryana on the left, UP on the right and the river is flowing through .Initially we start off with hexagonal cells as we are doing all the time and we are using a cluster size of 7. please note that there are different colors to represent the different frequency bands. 2 colors orange and yellow look almost same but they all represent different frequencies. now the idea is first to cover the entire region of interest by replicating the cells. so i replicate them. almost wherever desired i have left out some regions and i have been able to cover it up. But as life proceeds, it could be possible that there is a requirement. for example, the Connaught place area where i require higher capacity. more number of users have to be supported. so i start off by splitting the cells. if you see, i have put three cells which are smaller, have their own base station at a slightly lower height and much lower transmit power. what is to be observed is that consider this blue sub cell. it should be interfered with a bigger blue big cell because they are using the same frequency. clearly i must ensure the radiated power here. It should be less so that the users in these original cells do not feel a higher level of interference. what was the situation earlier? this blue cell had a cochannel blue cell located much farther apart. almost twice the distance than the new cell has cropped up. so something has to be done to proportionately reduce the power. it's not a bad deal because my cell is also smaller. so i need less power to cover the entire region of the cell. so it's not a contradictory requirement.

Conversation between student and professor: The question being asked is: we have put a small blue cell here as a result of the initial splitting process on top of a pink cell which is clearly using a different frequency band. they will continue to use different bands and at the boundary, different users either would belong to the blue cell or the pink cell. so the pink cell would not be serving any customers within the blue cell and this is the initial phase of splitting. ultimately it will split and the entire pink cell will be divided into blue, yellow & purple cells including a small pink cell. so this is the first step. if i am still not happy with the capacity upgradation, i continue splitting and i have more number of smaller cells here. so this is a technique being currently deployed in most modern cellular systems. here we have taken a simple example of how it can be done in Delhi. if you remember the last slide where we had an entire region having different cluster sizes and different cell sizes, if you continue the process, we'll end up getting a similar layout for Delhi. of course, i must emphasize that in real life cells are neither hexagonal nor they are non-overlapping. those are the two academic assumptions that we have made.

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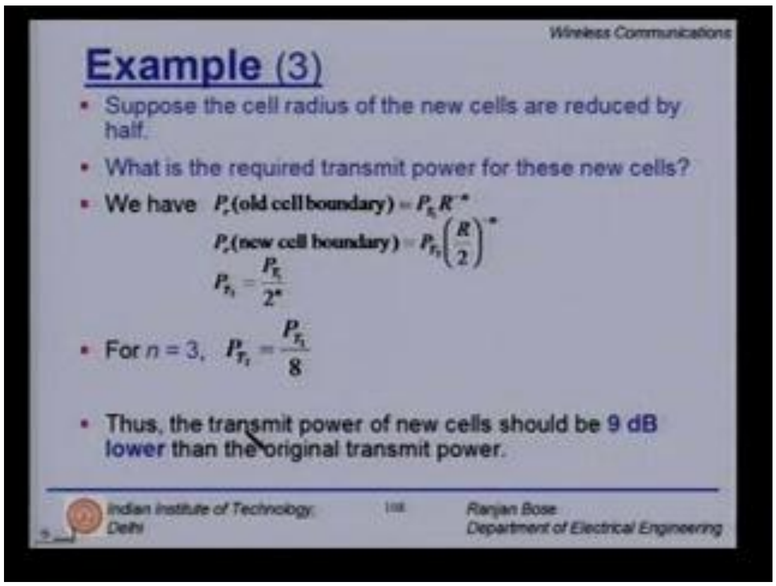

let's look at another example. suppose the cell radius of the new cells are to be reduced by half that is, the smaller cells in the previous example, the side is half the side of the original cell. The question being asked is: what is the required transmit powers for this new cell? clearly the transmit power must be lower. we have P r, the power received of the old cell equal to the transmitted power times the cell radius raised to power minus the path loss exponent. we have learnt that N 'the path loss exponent' can range from a value of 2 to 4. however in the new cell boundary, the received power is the power transmitted times R by 2 because the cell is half the size of the original cell raised to power minus n. so if we use these, the P transmitted to that is, of the new cell is P transmitted from the first original cell divided by 2 raised to power N where N is the path loss exponent. so this clearly tells us that how much lower the power of the new cell should be which is obtained by cell splitting . let us take a case where the path loss exponent is 3 for n =3, it's not a very dense concrete jungle it is normal urban area. here the P_{T_2} which is the transmit power required for the smaller cells should be the original P transmitted divided by 8. this translates to about 9 dB lower transmit power. so in this example we can see that it is fairly easy to calculate depending upon the size of the new cell and the path loss exponent. it is interesting to note that your answer would have changed if i had picked a different value of path loss exponent. so time and again, this n is figuring in our calculations telling us that if i am in a dense urban environment, automatically my interference gets mitigated to some extent. if i had choose n=4, i would have to lower my transmit power even further and probably it will be closed to 12 dB.

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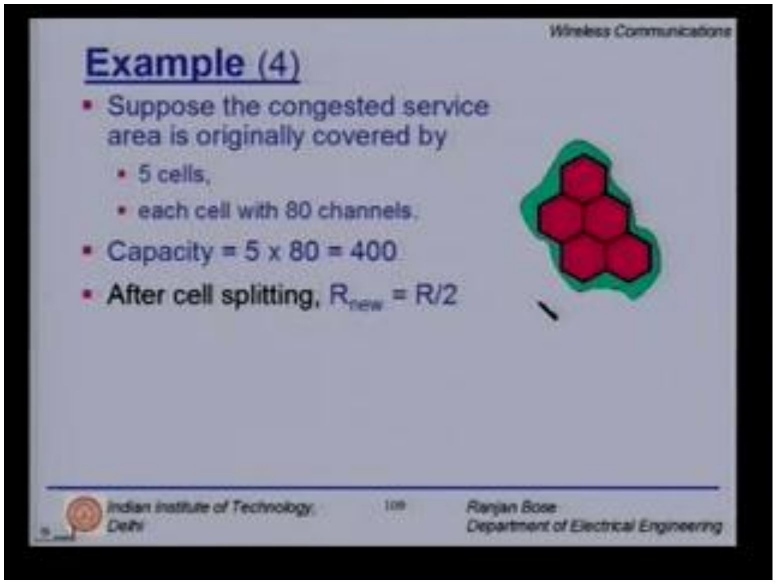

let’s look at another example. suppose the congested service area is originally covered by 5 cells and each of these cells has eighty channels. so what would i like to know? i would like to know that with cell splitting, what is the increase in capacity. how many more number of users can i support now? clearly we have not increased any more interference. we have ensured by loading the power of the transmitted antenna that the interference level is not increased. the quality of service is not hampered. the number of dropped calls, the cross talk etc have not changed. but what have we gained? we surely should have gained in terms of the capacity. let’s look at the situation. so we have area of interest. let’s pick up this irregular area which somehow was initially being served by 5 cells. but times have changed and i would like to remove congestion in this red cells by splitting the cells. so original capacity was just 5 into 80 = 400 for this cluster of 5 cells supporting a congested area. let us say that the new cell radius is half that of the original cell radius.

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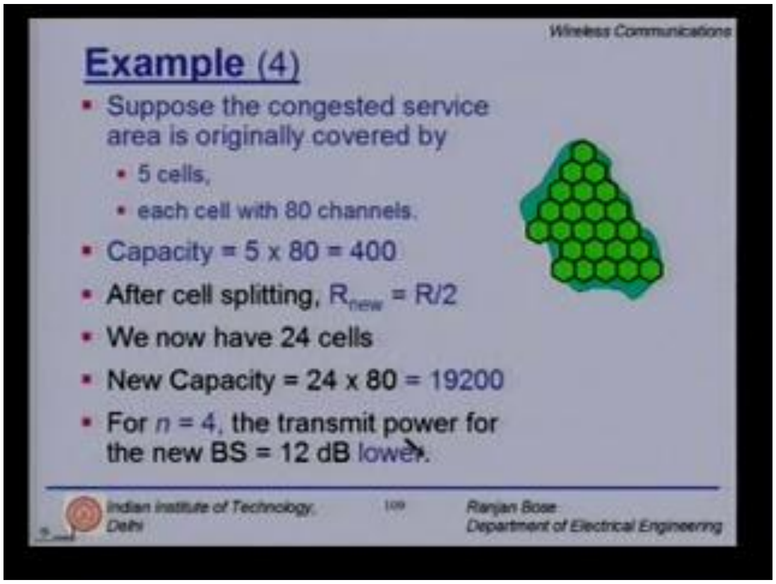

now in order to cover it, we have 24 cells. if you go back and forth you will see that this original area which was earlier covered by 5 cells require only 24 smaller cells plus it does a slightly better coverage. so if we go back, we see that this region covered by red is leaving out certain green areas here. but we can only put integral number of smaller cells. so the moment we put integral number, clearly we are covering all the red patches and at the same time covering a better area. we need 24 cells. all is not free because we have the need for 24 extra base stations. but the new capacity is 24 times 80 because still there 80 channels per cell the reused pattern is being respected. we are not playing around with that reused pattern. so 80 into 24 gives us 19200 users that can be supported. we have taken the care of the congestion issues. so cell splitting provides a powerful technique to handle more number of people without asking for a larger bandwidth. there is no free lunch. so what is the cost? the cost is in terms of the larger number of base stations and more hand off requirements. please remember hand off has to be done between every cell. if we had used a value of n =4 as opposed to n =3 in our previous case, the required transmit power for each new base station is 20 dB lower than the original base station. so yes. we are saving on power but then there are very many more number of cells. so cell splitting was the first technique that is used to increase capacity. but that is not the only technique. another popular method is called cell sectoring.

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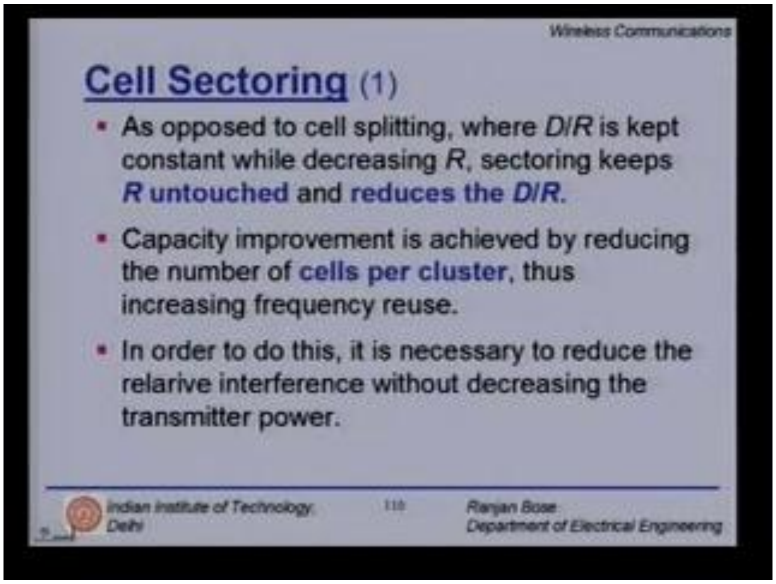

what is cell sectoring as opposed to cell splitting which we studied just now where D to R ratio is kept constant while decreasing R, sectoring keeps the R untouched. we are not going to play with the size of the cell but it reduces the D to R. now there is an impact. if we increase D to R, it reduces interference. if we decrease D to R, it increases interference. looks like we are in the going the wrong way. let us see what happens. the capacity improvement is achieved by reducing the number of cells per cluster, thus increasing frequency reuse. clearly this will lead to a high interference. so sectoring must do something to take care of this extra interference that is being generated. so the philosophy is fairly simple. i am not going to touch the size of the cells but i am going to somehow selectively progressively reduced the reuse distance. that'll increase my capacity. but that'll also increase my interference. now if i can do something about reducing the interference i am all okay. in order to do this, it is necessary to reduce the relative interference without decreasing the transmitted power. i am not playing with the transmit power. we earlier realized that i can do nothing about the interference by playing with the transmitted power.

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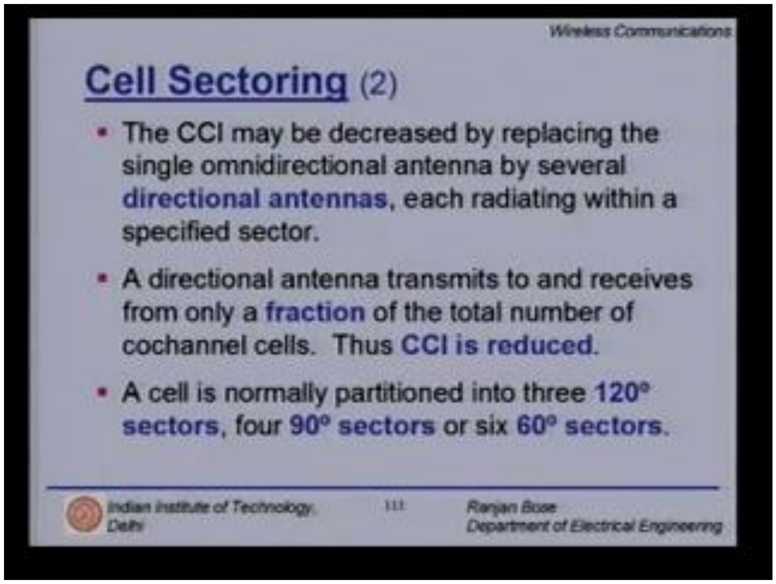

so how does cells sectoring work ? the cochannel interference which has been generated because i have reduced the reused distance may be decreased by replacing the single omnidirectional antenna by several directional antennas each radiating within a specified sector. so that's the key. the name cell sectoring comes from the fact that i am going to radiate now. not in all directions. i am not going to use an omnidirectional antenna but i am going to use a sector antenna. a directional antenna which only radiates in the part of the cell. will that reduce interference? surely i would from a very back of the envelope calculation cut down the interference by $1/6^{th}$. because if i my directional antenna is only 60 degree sector, i am not looking at the remainder of the angles. i am clearly cutting of interference from the remainder of the area. a directional antenna transmits to and receives from only a fraction of the total number of cochannel service that this clear. that is the basic philosophy. thus the cochannel interference is reduced. a cell is normally partitioned into sectors. these sectors could be 120 degree sectors. in that case, we'll only have 3 sectors per cell or you can divided into 4- 90degree sectors or you can divide it into 6- 60 sectors. as we increase the number of sectors, the amount of cochannel interference that i pick up goes down. so it is to our advantage that we have more and more sectors. however we will have to pay a stronger price. the price will come in terms of more number of sectored antennas and of course hand off. you are creating mini sector cells. so each time you go from one sector to another sector, there has to be a hand off. hand off comes at its own cost. we cannot have too many mobile stations handing off all the time.

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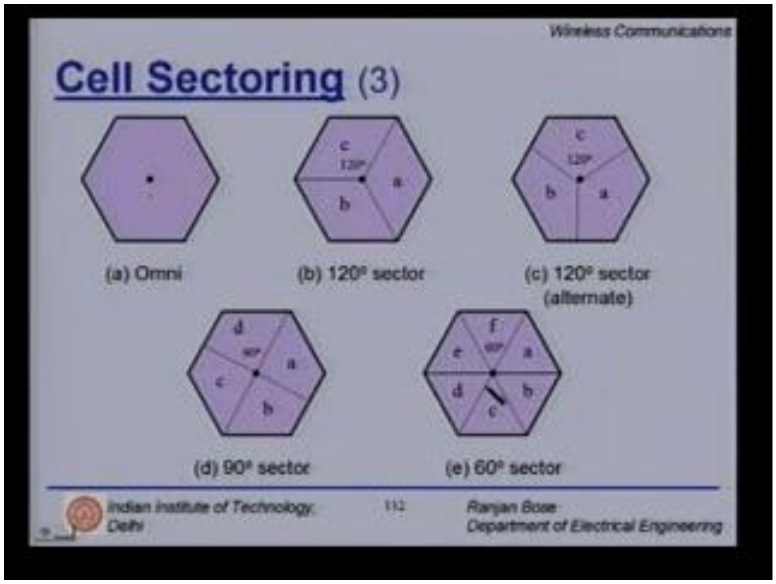

let's look at some typical geometries of cell sectoring. so one is our standard omnidirectional. we have not done any sectoring. we have one base station is free to radiate at all portions of the cell. but what we can do additionally is to take that hexagon and first subdivide into 3 sectors. on the same tower which earlier supported my base station, i now have 3 antennas and not 1. antenna 1 could be radiating in section a, antenna 2 could be radiating in sector b and antenna 3 could be radiating in sector c. there would be slight overlap between the sectors. the sector boundaries will not have a very clear distinction between a,b and c. there has to be some overlap. otherwise i cannot carry on successful hand offs. but in this case, we have used a sector of angle 120 degrees. the other possibility of using the same 120 degrees sector is to subdivide my cell in another fashion. so different geometries would require you to see whether you are most distant base station on an average is at what distance from the serving base station antenna. yet another method to sectorize the cell is to use 90 degree sector antennas. here i have a,b,c and d at 90 degrees. in your metropolitan area network IEEE 802.16, we also use 90 degree sector antenna as one of the possibilities. LMDS 'local to multi point distribution services' also uses 90 degree and 120 degrees sector antennas. so these methodologies are used in practice. another method is to have a 60 degree sector. so i divide the original cell into 6 sectors of 60 degrees each. normally anything below this is not preferred because too many sectors would require too many hand offs and too many antennas.

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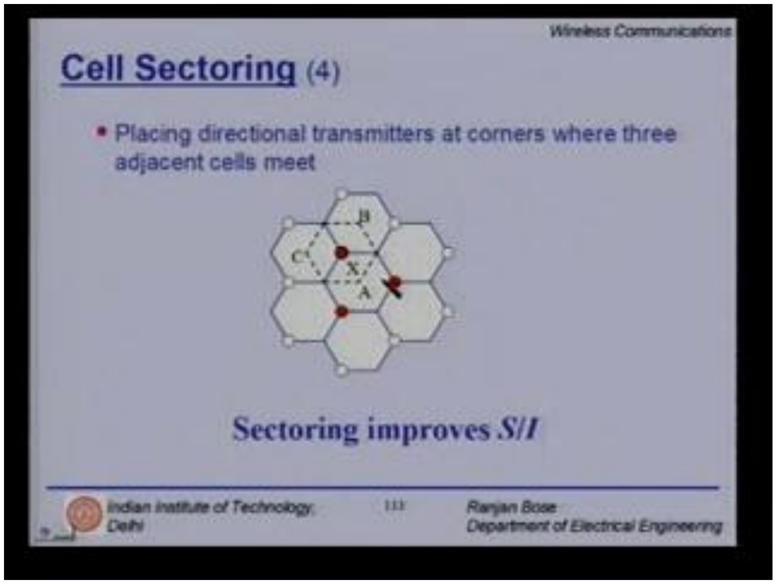

placing directional transmitters at corners where 3 adjacent cells meet is one way to do sectoring. let's look at an example. here this is the well-known seven cell reuse pattern. but i would like to now increase the capacity. to do so, i put a base station at a corner. this is different from what we have been talking about so far. Earlier, the base station was typically put at the centre of the hexagon. here i am putting at a corner. let's see what it can do. in an earlier example of cell splitting, we also started off with the cell edges and corners. this new sector base station can support 1,2 and 3 and i can use the similar philosophy for this sector antenna and this sector antenna (Refer Slide Time: 35:11). the same philosophy can be applied for all the remainder corner points. so i have not touched the size of the cell. please note the difference between cell splitting and cell sectoring. i have not touched the size of the cell and the transmit power. i have not touched the antenna height too. I have just place three directional antennas here. but every sector effectively can reuse the frequency bands and hence provide a greater coverage. so the reuse distance has gone down. Originally, i had A,B and C. now i have the coverage area X. the sectoring improves the signal to interference ratio simply because i have been able to cut off interference from 5 other cochannel cells because i am just looking at the 120 degree area.

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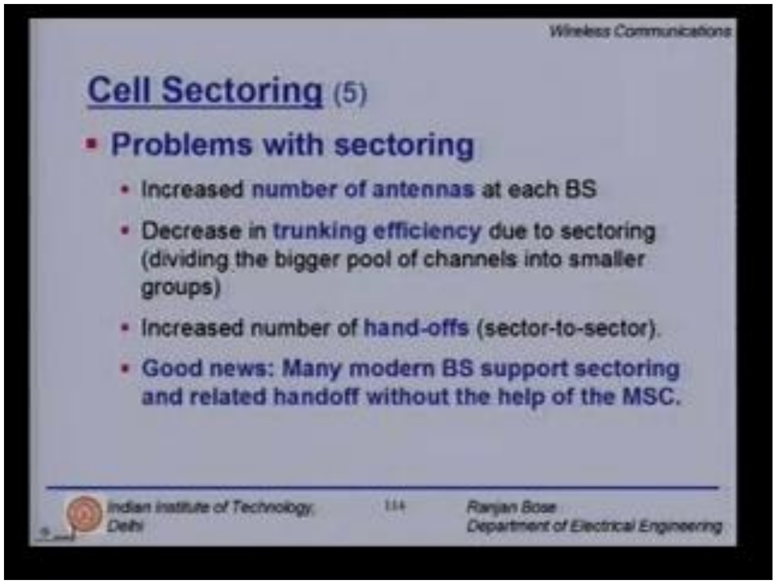

cell sectoring has certain problems. the first problem is the increase in the number of antennas at each base station. they are expensive. they have to be maintained. they consume power. there is a decrease in the trunking efficiency. remember in one of the earlier lectures we saw that if we have a pool of channels, you can have a much better efficiency as opposed to subdividing the pool of channels into groups and then using the groups individually. we had used the Erlang B formula and Erlang C formula to see that. this is called trunking efficiency. clearly when we subdivide a cell into sectors and we are not asking for extra bandwidth, we are cutting the pool in to smaller sub sections and each sector is using a part of the pie. So individual trunking efficiency goes down. then we have the additional problem of increased number of hand offs. each sector is being treated separately and when you move from one sector to another, you have to be handed off. but the good news is many modern base stations support sectoring and the related hand off without the help of the mobile switching centre. so sectoring can be handled locally and if you have such a base station, yes, you can go ahead and sector it. so sectoring provides an alternative to the cell splitting.

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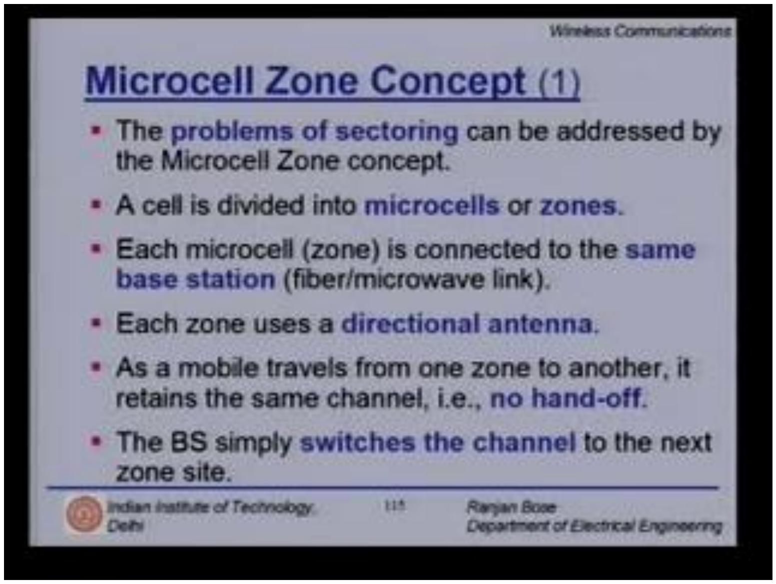

this new concept a third concept called micro cell zone concept which is different from both the cell splitting and sectoring. in fact it evolved to take care of the explicit problems of sectoring. the problems of sectoring can be effectively addressed by the concept of microcell zones. what do we do? in microcell zone we first divide a cell into microcells or zones. now please remember we are not doing any cell splitting. we are conceptually dividing a cell firstly into 3 or more sub zones called microcells. now what do we do? each microcell or zone is connected to the same base station by using either a fiber optic link or a microwave link. we are trying to do something in the middle. we are not doing cell splitting or sectoring exactly where we used directional antenna. let’s see whether we can extract good points of both and put them together. so we have conceptually divided a cell into zones but we have not put a single base station in every zone. otherwise it would become cell splitting. We only have one base station. each zone now uses a directional antenna. it’s a concept borrowed from the sectoring part. as a mobile travels from one zone to another, it retains the same channel because we were all the time communicating with only one base station. every zone is communicating with one common base station. so the channel assignment is done by the base station and it retains the channel and the mobile subscriber doesn’t have to hand off when going from one zone to another zone. the base station simply switches the channel to the next zone site.

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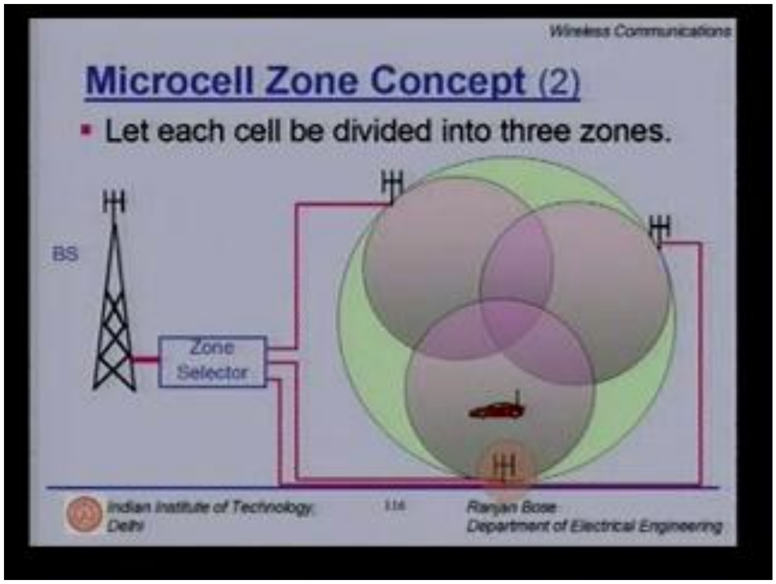

let us now look at a graphical example as to how things can be done. let us say we have the following cell which is congested and we have to do something about the congestion problem. we have deviated from our hexagonal geometry. for a change let us look at an omnidirectional antenna at the base station which was creating a circular cell. this cell has a base station. now i have not put the base station bang in the centre of the cell. it is slightly located apart from the cell. this base station is like any other base station. it has a tall tower it has an antenna and it is connected to the mobile switching centre. earlier this base station was supposed to handle the calls within the cell. we make an exception. we first subdivide the cell into 3 zones. let's put 3 overlapping zones. i am not using the hexagonal pattern. for the sake of illustration only circular patterns are being used. these are overlapping zones. we need this overlap to take care of the hand off if required. but that there is no hand off. so a smooth switching has to occur when a mobile station moves from one zone to the other zone. all of them do not have a base station. then what do they use? they have to be connected to the same original base station. clearly we need a logic, a zone selector which decides whether the base station is using zone 1, 2 or 3. how does a base station use a certain zone to radiate? it needs to put certain antenna. let us note a few things. Firstly, this antenna is directional. so it is only providing coverage on one side. depending upon on the radiation pattern of the antenna, i can define the coverage region and the transmitted power will also decide how big is this one (Refer Slide Time: 43:02). i have missed out certain regions in the original cell which can be taken care of by putting additional antennas. but i am not making the diagram too messy. i have got 3 zones & three antennas. but none of these antennas can do any thinking. they are passive radiators. now let us put a mobile station here. originally the mobile station happens to be in this particular zone (Refer Slide Time: 43:35). so it must communicate with the antenna located for this. the base station through the zone selector communicating to the mobile station is in this one. so it communicates and is establishing a call. however this is a mobile station. it has a luxury to move from one area within the cell to another. in that case if it goes from zone 1 to zone 2, there is no need to activate the transmitter which was originally present.

but now we have to start communicating with the other. but there is no hand off. This is because the same channel has been now rerouted and put into this one. that is the key. the same channel, if it was a frequency sub band 3, the same frequency sub band 3 is now being used but being radiated through the next zone. who does the thinking? the base station. the mobile switching centre doesn't even need to know this has happened. so i did not hand off. there was no problem of a dropped call. there was a big amount of overlap. i didn't even realize when i move from zone one to zone two. continuing this example, if i now decide to move to zone three, i must communicate not from the zone 2 antenna but through the zone selector, through zone 3. please note the antennas are using lesser transmit power. they are directional. there is no hand off. it merges the good points of cell splitting and cell sectoring. what will happen if this mobile station now chooses to move out of the cell on to the next cell? Well, in that case this base station would hand off the call to the next base station which probably would again have microcells zone concept. this scheme is particularly useful if you have to have base stations along the highway. so if you have a long corridor, you can have one after the other and you can keep on not handing off but switching the call. even if you are driving at high speed along the highway, you will not drop a call regardless of how fast you're travelling. the base station just keeps switching from one microcell to the other.

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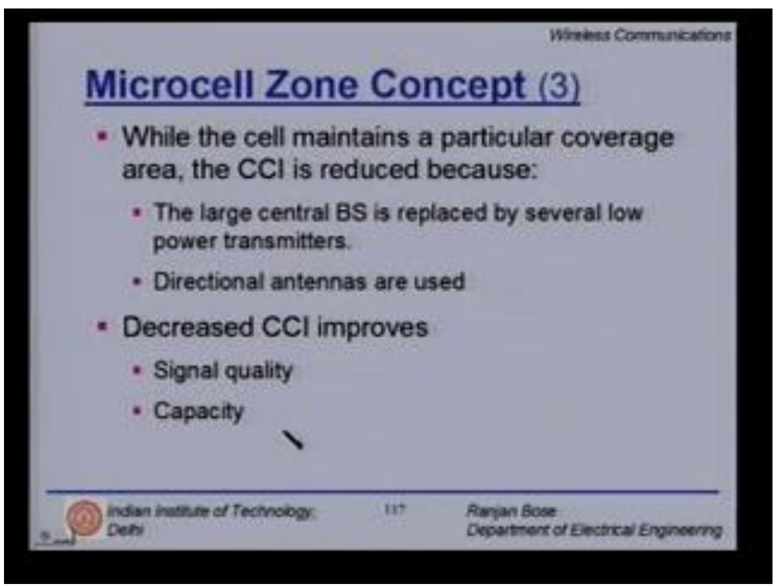

so if we continue the concept of microcell zones while the cell maintains a particular coverage area, the CCI is reduced because the large central base station is replaced by several low power transmitters. we have reduced the power. directional antennas are used. CCI 's are also reduced.

Conversation between student and professor: The question being asked is: can we modify and upgrade this microcell concept and ensure that the mobile station is actually receiving signals from not one but two base stations and so the transition could be smoother. the answer is yes. if you're ready to overlap enough, you can do this. so you're putting an additional layer of overlap to ensure that you would really never drop any calls. yes it is possible. but you have to deploy more resources. so as we were looking at the microcell zone concept,t the advantages are clear. the large central base station has been replaced by several low transmit antennas. directional antennas are being used. these are reducing the interference and this decreased level of cochannel interference improves both the signal quality as well as the capacity. so it’s a good concept to use.

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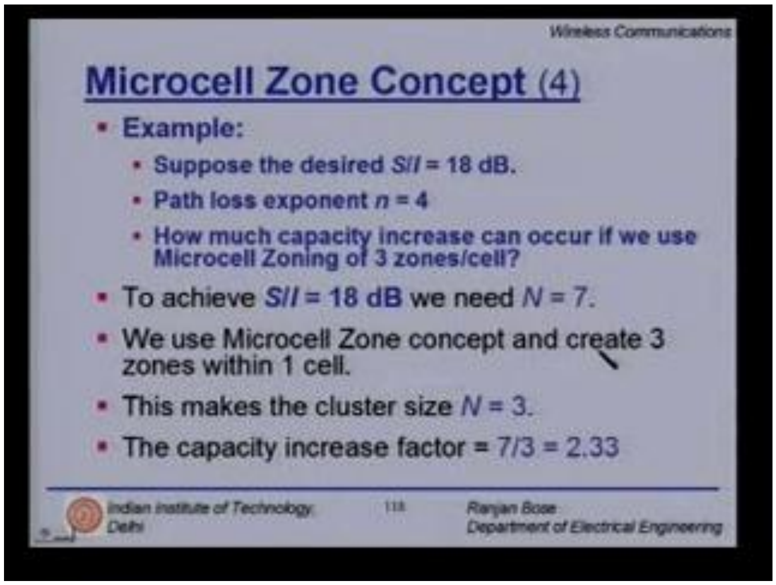

let us now look at another example. suppose the desired signal to interference ratio is 18 dB. we have played earlier with this number. the path loss exponent is n =4. so i am working in a dense urban area. the question that i have to answer is: how much capacity increase can occur if we use the microcell zoning concept wherein we use 3 zones per cell. so the question is: i would like to know the increase in capacity to achieve a signal to interference ratio of 18 dB, if we go back to our previous calculations, we require a cluster size of 7. we did this example earlier in fact if we use a cluster size of 7, you actually get signal to interference of 18.66 dB, slightly above our system requirement. so we are happy with the cluster size of 7. now since we are allowed to use microcell zoning, we create three zones within one cell. so what does it do in effect? in effect what we have done is we have reduced the cluster size. the cluster size is now 3 and if we use this value of 3, the capacity increase factor is nothing but 7 by 3 that is 2.33. if we had originally a 100 subscribers that we could support, now we can support 233 subscribers. without creating any extra interference problems i have been able to substantially jack up my system capacity. so microcell zone concept is good and can be used effectively. in the last slide, i would like to look at some of the other ad hoc means to increase the range extension.

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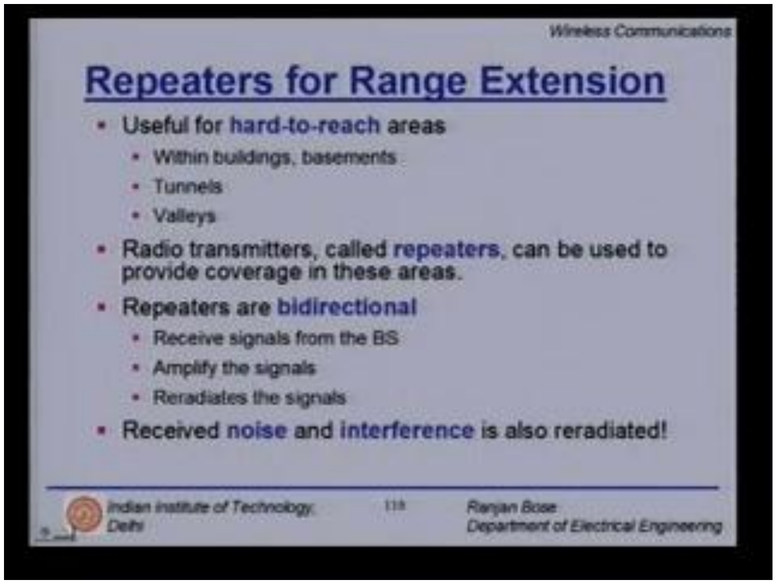

remember the microcell zoning concept could be used for hard-to-reach places but i still need an active base station. could i do something in a more cheap manner? i can use repeaters. these can be used for hard-to-reach areas such as within buildings, basements, tunnels, valleys or other secluded areas. so what are repeaters ? radio transmitters called repeaters can be used to provide coverage in all of these hard-to-reach areas. repeaters are by definition bidirectional. so what they do is they receive a signal from the base station. they amplify the signal and reradiate the signal. they reradiate in such a manner that the difficult-to reach areas are now covered. so the positioning of these repeaters is of interest. how do we effectively place the repeaters so that the hard to reach areas are now effectively radiated? suppose i didn’t have a line of sight or a good signal strength at some place behind a hill, i can put a repeater close by so that the hidden shadowed area is eliminated. the problem is that the received noise and inference is also reradiated. i have no means to filter that out. maybe i can think of a smart repeater. but then i can start putting too much of smartness into the repeaters and the costs will go up. it just senses, amplifies and reradiates. so repeaters can be effectively used to cover the areas which are normally not covered. i would like to summarize today’s lecture. let us see what we have learnt today.

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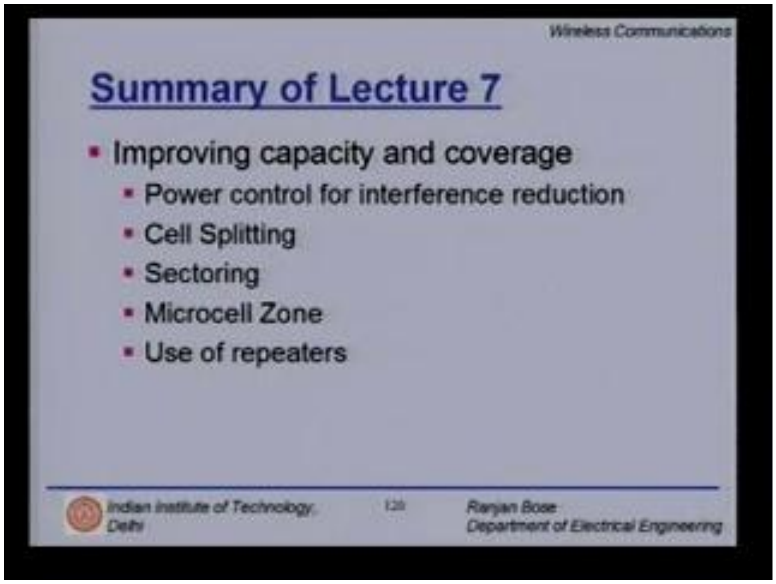

today’s lecture concerned capacity increase and coverage. we started off by looking at power control mechanisms for interference reduction and ultimately increase in system capacity. this is crucial for CDMA systems. we then looked at something called cell splitting to increase capacity wherein we divide the larger cell into smaller cells. another technique that was discussed is sectoring where we use effectively directional antennas. a new technique called microcell zoning was discussed which essentially combines the good properties of cell splitting and sectoring. finally we looked at an ad hoc technique called the use of the repeaters to reach out to the areas which are hard to eliminate using the regular base stations. we will conclude here and in the next time we would look at some propagation issues. thank you!