Introduction to Wireless and Cellular Communication
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Lecture – 05
Wireless Propagation and Cellular Concepts
Basic Cellular Terminology

Good morning, let us begin. This is lecture 5 picking up from where we left off in lecture 4. At the first few lectures have were intended to give you a bird's eye view of the cellular systems as they are known to us today, and also some of the features that are emerging part of the 4G and 5G systems. And also very importantly that there is a non-cellular component which we wanted you to be aware of and so we have touched upon that. Maybe just to sort of recap what were the key highlights, would you like to mention one or two things that you remember of what 5G stands for, what are the 5G elements that we will see that you have not seen in the earlier generations. Always connected which means large bandwidth that is because you have to connect all the users have to be connected so there has to be large bandwidth any other aspects of 5G.

Student: (Refer Time: 01:09) different size cells.

Different size cells, large number of basically what we refer to as heterogeneous network set nets I heard some.

Student: (Refer Time: 01:18).

New waveform designs, yes that is definitely part of 5G discussions as well. Densification, which is means that there will be a large number of small cells that is an important element. Massive MIMO is another element that we think we will play a role. What about the elements of non-cellular technology basically the ones that are going to compete for the smart grid, smart cities, smart transport.

Student: (Refer Time: 01:48) zigbee webs.

Zigbee webs; there is a whole range of technology. So, cellular is dominated by one standard in the non-cellular domain, there is a large number of technologies that are available each one is optimized slightly differently. So therefore, we can take advantage

of that and I heard one more comment anything about non non-cellular. Low power is a very very key they are they are competing with cellular because they want to be able to their devices to long last for long periods of time. And of course, there are technologies which are low data rate, but still are aiming for long range. So, those are the elements of what we have covered.

Today's lecture I would like to introduce some cellular terminology, so that when you hear or read articles or read some of the references it will be easy for you to relate to what we have already seen and discussed. These are basic terminology.

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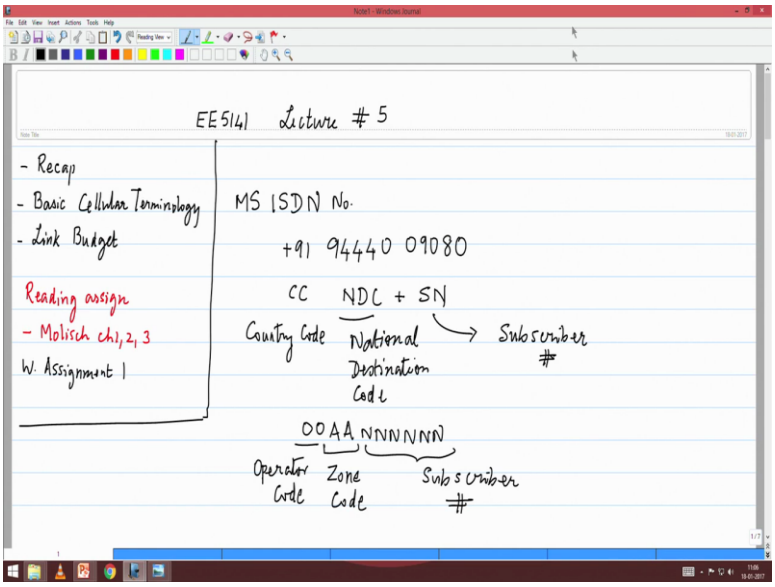

So, let me begin with your mobile number, and how to understand your mobile number. The mobile number that you have a 10 digit number along with the country code is referred to as the mobile station ISDN- Integrated Services Digital Network number; MS ISDN number. So, that is your 10 digit number which is include the country code will be 12 digits. So, typically the combination is what is important, what does your MS ISDN contain. It contains your country code, basically the country in which you are located. The second element is your national destination code- NDC stands for the National Destination Code.

So, that would mean your operator and your information about where you are normally which is your home location, national destination code. And the last one is actually your subscriber number. So, this is a good way to capture. This is all the information that you

need to actually reach a user, which country, which operator, which region and which subscriber in that region that you are interested in. So, the 10 digits it is interesting for us to break it up a little bit more.

In India we would look at it in the following fashion; these 10 digits would be characterized as OO AA and then six digits NNNNNN. This is the how the 10 digits would be constructed. OO stands for operator code; usually by looking at the first two digits you can tell who your operator is. So, that is my IIT number 94 we are part of BSNL. So, 94; obviously, stands for BSNL and definitely that would give us an indication of which operator. Second one is the operators have got zone course; basically together they have to tell you where I am, my home location. In India typically stands for the zone code. The area that you are located in. And the last six digits are the subscriber number.

So, at a high level we need to indicate what is the country code that is plus 91 for us, and within the 10 digits the national operator code the destination code and the subscriber number. And invariably this is what you will find as you are. So now, the important question is if you are an Airtel subscriber who has switched over to Vodafone for example, and you want to keep your mobile number. Now what happens, how does the network know because let us say I switch over to Vodafone our Airtel; Airtel is 98 in the Chennai region. But the network thinks I am a BSNL subscriber. So, that is an important element.

So, let me just sort of go back to our earlier presentation and then just ask you to tell you where in the network do I need to have additional information so that we can we can handle this problem. Basically we were talking about the problem of the mobile number portability; what happens when you have changed your number.

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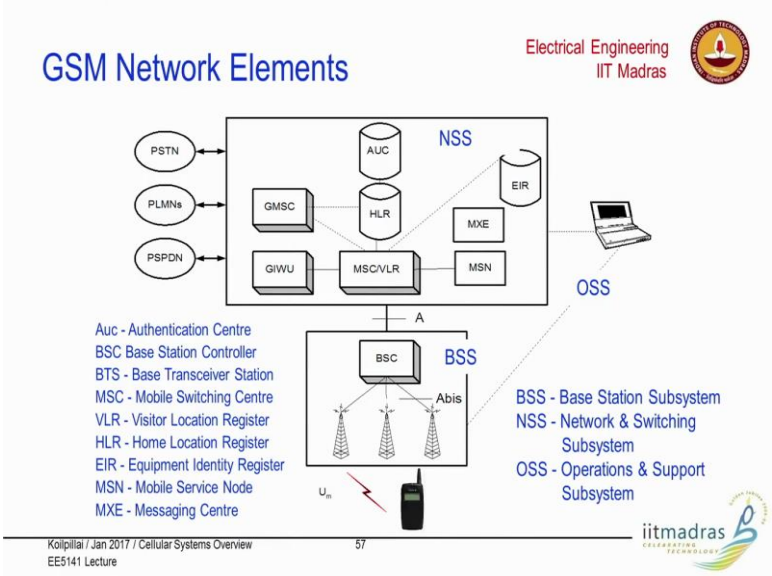

So, if this is the scenario I think the next slide is what we wanted.

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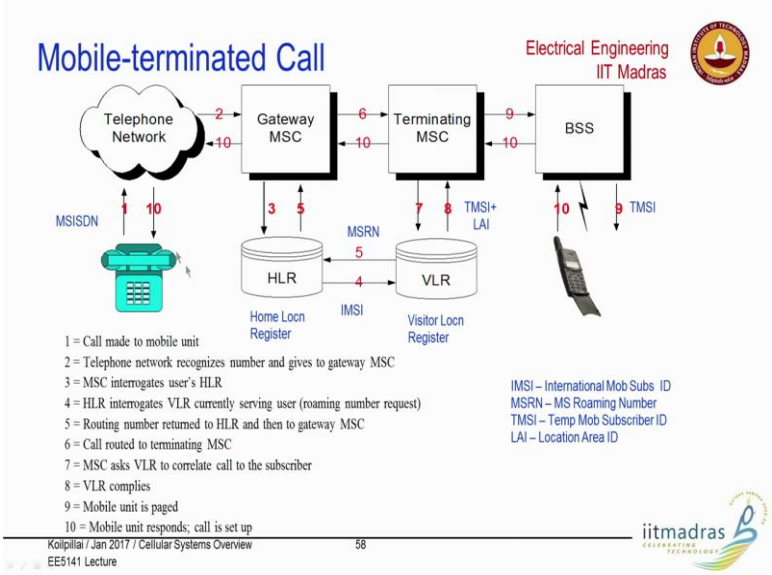

So, somebody is trying to reach me and they dialed 94. So, the network thinks I am a BSNL operator. So, basically will go to the BSNL home location register and BSNL; let us say I do not know this operator this user does not exist. So, there is a node that operators have created which is before you get to the gateway. Basically it is a database of all those who have ported their numbers.

So, basically if you have ported your number what is your current operators identity and that is that is very important for the network so that they can captures again whatever we have studied the base line and today's existing scenario you should be able to link.

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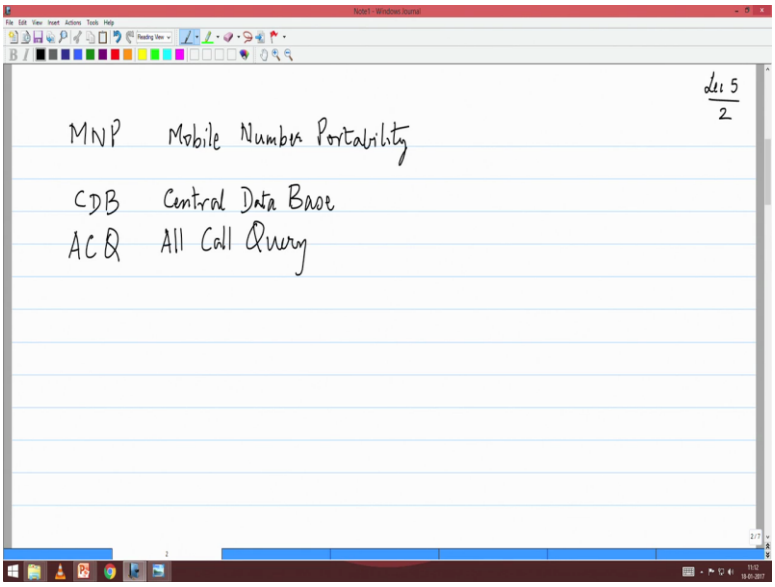

So, one of the key elements in today's discussion and our discussion what happens in the marketplace is mobile number portability. And now you know that it does not matter too much to the network, because the most of the time you are just the initial routing is when the mobile number is needed and that is done by means of a database. Mobile number portability; if you are not read about it or if you have not understood it you should definitely read it; very simple mechanism by which it is enabled.

So, what is the process in India? Your current service provider has to initiate the process. So, basically it is a donor initiated process, because your current net service provider is called the donor the new service provider is called the receiver; the donor has to initiate, the receiver cannot initiate because this is basically means that only if the user wants, but donor has to permit, but it has it is donor initiated. So, basically the information is that they must enter your information in a database- just called as central database. This is a number database of all those people who have ported their numbers. And the types of porting that we see today most of the time you are in the same region, but you want to change your operator. So, it will go back to a database in to the region, you are the home location register in the region. But there are people who may have moved to a different

region, but want to keep the same number; so they are also doing some kind of number portability, but it is within the same operator they do not want to change their number.

So, the other scenario is you have moved to a different region and you have moved to a different operator and you still want to keep your network; same mobile number. So, basically whatever is the configuration that is has to be captured in. And then there is a mechanism called call query; all call query basically the first thing that the network does is check with this database whether you have moved, if not it knows have to go to your own home, your home, your operators, your service providers home, location register, otherwise it will move to the home location register of your new service provider. So, this is called the all call query.

So, it is a very quick database check which tells it how to route the call; so basically one additional step in order to account for mobile number portability. So, today I am sure some of you would have done change your, moved your number. Again in principle it should not make a difference, because the mobile number portability just tells the network how to route a call or an SMS or a MMS that has been the received; so in principle. But there are authentication mechanisms which are slightly more stringent for a postpaid, because there the operator is sort of taking a risk that you will pay. In a prepaid they have nothing to lose, so they just basically will with authentication less.

So, maybe that is a good lead in to my question. Any one will you the further explanation any one has changed and how much time did it take; just give me one.

Student: 2 days.

2 days.

Student: (Refer Time: 10:37).

3 days: it says that it can take anywhere from 4 to 7 days, because basically they have to make sure that all your payments are all settled and your new service is initiated. So, there is a process of handshake between the existing operator and the new operator. Do you know that in Australia it takes 3 minutes, because that is all that it requires because it is just one change in the database and a handshake between the operators. But you know we are more cautious I guess it does it does take more time. But like I said it is a matter

of closing your accounts with one operator and moving over. In the case of prepaid you know maybe this you carry your balance forward I do not know how it works, but in the case of postpaid you have to settle your accounts make sure that you know they have to return your a deposit and things like that.

So, I think there is a little bit more processing that is needed for a postpaid, but from a technology perspective it does not know the difference whether you are a prepaid or a postpaid customer; all it knows is you have now you have a BSNL operator code, but you are actually Vodafone or a Reliance subscriber. So, interesting that whatever we study in the course actually is has got relevance. The MS ISDN very important that more or less defines who we are in the network, it is very very important that the mobile identity is not cloned and that is where the authentication comes in and a lot of interesting technology related discussions will happen. But again that is something that if you are interested in studying more about the security, in a cellular system that is something that means to be study.

Now I would like to go back and quickly discuss some additional terminology that is used, something that I believe every student who has studied wireless and cellular must be familiar with and therefore you are able to understand when you read technical articles, you are able to understand and appreciate. So, a first thing is let me refresh your memory or take you back to understand the two types of duplexing that we have in a cellular system.

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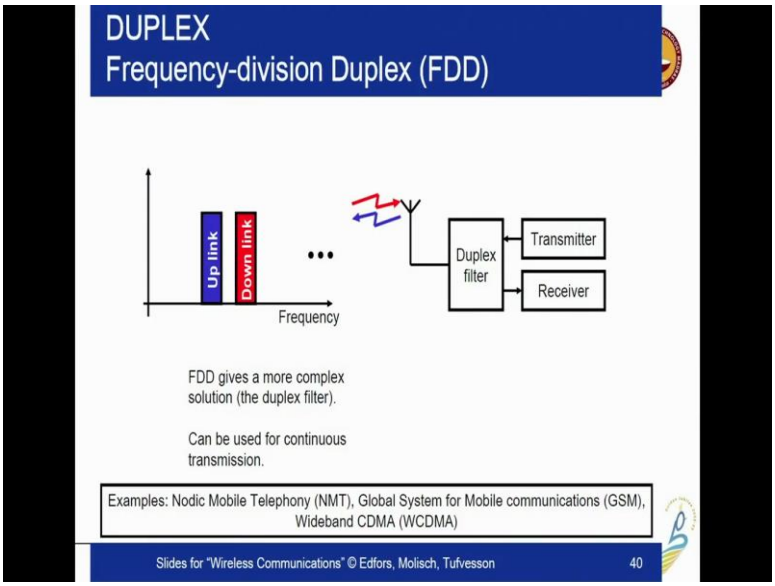

So, the first scenario is frequency division duplex. So, this is one operator. You are talking about how the transmission happens from the base station to the mobile; that is called the downlink; the mobile to the base station that is called the uplink. And typically they are differentiated in the case of a frequency division duplex by means of different frequencies. They are the uplink transmission happens at a different frequency from the downlink channel. Now let me keep that keep that picture in mind. We will come back to addressing a few more elements about it, but after we have discussed some aspects.

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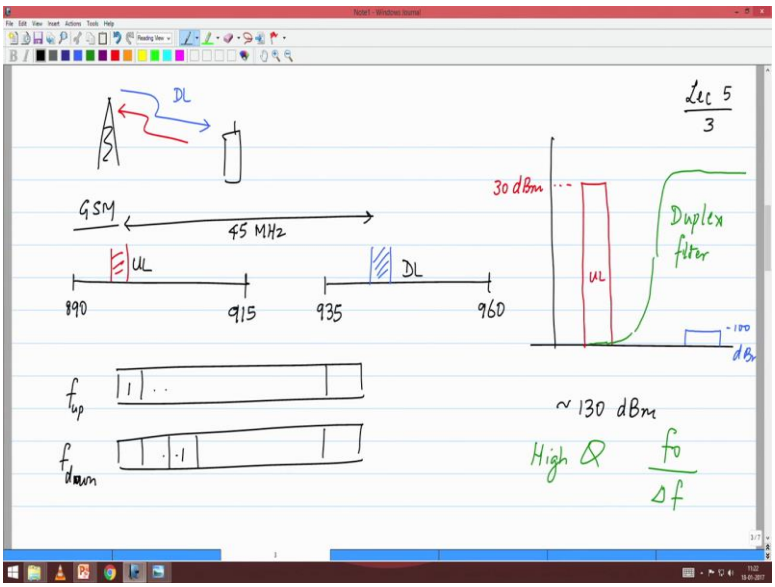

So, the concept is that I have a mobile and a base station: let me use blue for the downlink- this is the downlink, red for the uplink. Now just take a very practical case: India GSM second generation. Now how is the frequency allocation done for this? So, there is a band of frequencies which are specified as uplink frequencies, it starts at 890 all the numbers that I write will be megahertz, so please fill in the unit's- 890 to 915 and then after a gap there is a set of downlink frequencies which start at 935 and ends at 960 megahertz.

So, this is the how the GSM frequency band is located. And notice that each of them is 25 megahertz long, but GSM transmission actually occurs using a 200 kilohertz channel. So, let us say I was using this 200 kilohertz channel that was for my; sorry that is downlink I should erase that- downlink is here. Let us say I was using this 200 kilohertz channel the corresponding uplink will be here. There is spacing between the uplink and the downlink frequencies which if you notice is 45 megahertz.

And that is always preserved, whenever you get a uplink downlink channel pair you can you can verify that it has to be 45 megahertz. Apart notice that if you got something which is very close to the band is near 890 the uplink will be close to 935; again the 45 megahertz spacing is preserved. Now this is a very important element, though you may say you know there is a uplink there is a downlink there is a spacing between them. The reason for this is let me just highlight the following. Now let us look at the uplink transmission- the red transmission what is the power with which your handset transmits rough idea. You should know what is the power level ratio transmits 1 milliwatt.

Student: 1 milliwatt.

1 milliwatt cellular.

Student: (Refer Time: 16:10).

10 millwatts, 30 milliwatts- it is 1000 milliwatts; it is transmitting at 1 watt, 1 watt is your transmit power. So, the uplink transmission is at 1 watt. This is the uplink transmission and uplink at some channel which is lower. So, this is 1 milliwatt if you converted that into dBm that is 30 dBm; that is your transmit power. Now I am sure you have done at least one of the calculations that there in the slides approximately what is

your received signal power. It is very very low minus 100 dBm is actually something lower than that just for ease of discussion minus 100 dBm let us say.

So, the difference that you have between your transmit signal and your received signal is approximately 130 dBm; 10 on a dB scale means that it is a factor of 10 you can see that if it is 130 this is a orders of magnitude larger. Now the reason that they need to be separated in frequency first and foremost is that we do not want your uplink to in any way affect your downlink, because both are using the same antenna. The circuitry for the transmitter and receiver are physically close to each other in the transmitter. So, there is a possibility, that there is some RF leakage from the uplink portion to the downlink portion which means that your downlink will be completely wiped out.

And to make sure that this can never happen we introduced a filter which is a band pass filter which basically will eliminate all of the; after 915 megahertz up to 915 megahertz is stop band and beyond 935 is pass band. So, basically there is a band pass filter which will separate out. In addition to frequency separation there is a. So, this is an analog filter; it is sitting right at the front end of your receiver it makes sure that your receive chain is protected from the radiation that is happening in the transmit chain, and therefore not affected by the; so this is called a duplex filter.

Duplex filter, why because my uplink and downlink it is frequency division duplex I do not want my uplink to affect my downlink, so therefore I introduce a duplex filter which separates the high power uplink transmission rejects it and then allows only my low power received signal to pass through. Now, analog filters are always specified in terms of a Q factor. So, this will turn out to be a high Q factor filter. Why because the carrier frequency is large around 900 megahertz. And your delta s is your transition bandwidth, how sharp your filter has got supposed to be. And therefore, the 45 megahertz is given so that your Q can be manageable in terms of a component that is not too large. If you have a very high Q filter the component will become bulky, and therefore will make your device.

So, everything has a reason and this is an important element that you need to keep in mind. So, let me just for a moment go back to our slide and look at the information that is there. So, uplink downlink, right at the front there is a duplex filter that protects your receiver, so basically will prevent the transmit chain from affecting your receive chain.

So, this is a very important component that is there in a frequency division duplex system. And this is a bulky component so therefore we must be careful about the size and the design of that.

So, this is a important element. Now let us move over to a time division duplex system, a time division duplex system.

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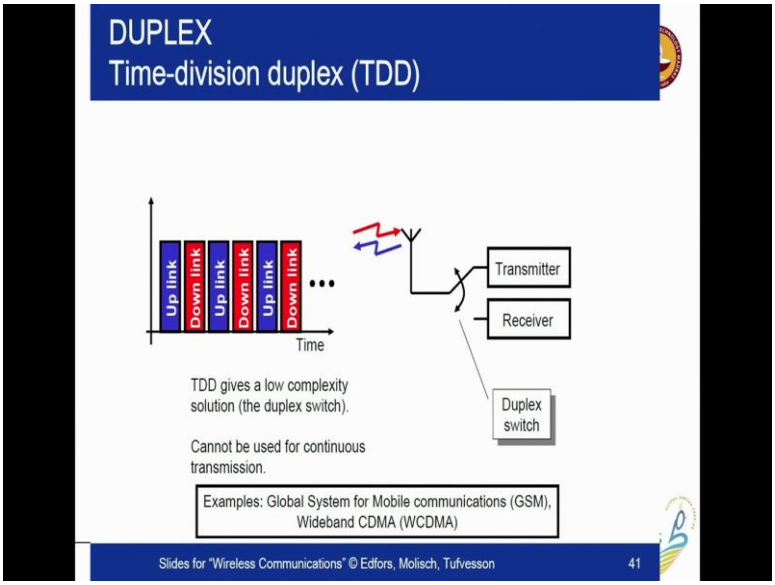

This is a time division duplex system; that means there is only one frequency there is no uplink downlink. At one point in time I transmit uplink from the mobile to the base station, then the base station transfer to me we go ping pong. So, notice that in such a case it is a switch that is sort of connecting the antenna to transmit and receive chain, there is no need for a duplex filter because transmitter and receiver are not on at the same time. In the context of cell phones we were very very conscious about the size. So, there was always discussion as to how do it take the advantages of the time division duplex and mix it with the advantage of a frequency division duplex. Frequency division duplex has got disadvantage, with all the uplink transmission is a non frequency all the downlink is on a different frequency.

So, here is how GSM has handled it. Again a simple innovation, but it is very important that you just are aware of that. So, remember that GSM is divide into 8 time slots right uplink. This is the error, this is happening on uplink frequency- f uplink then f downlink; this also has got 8 time slots. I do not want to have a duplex filter. But if the

transmissions on the uplink and the downlink happen at the same time then I cannot avoid the duplex filter.

So, the GSM design says that if this is time slot number 1 and you are given time slot number 1 then on the receive side the time slot number 1 actually comes offset in time. So, which means that though they are on different frequencies when it comes to your transmitter, your transmitter will transmit on a uplink frequency at a different times and then at the receive sense. So, basically it does some sort of a separation in time. So therefore, you strictly do not need a duplex filter. But of course, if you say that I want to go for high data rate and I want to use all 8 time slots, then of course you need a duplex filter. But the simple voice communication systems actually do not need and do not have a duplex filter, because GSM has allowed you to incorporate a TDD element into the design; I think it is a very clever way of avoiding a bulky component. But now let us quickly look at the other elements in terms of the terminology.

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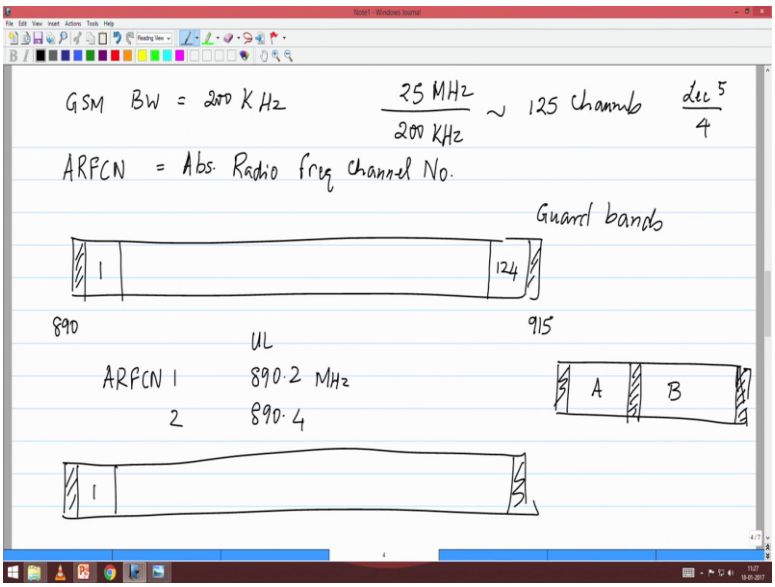

So, GSM the bandwidth is 200 kilohertz; is the bandwidth the channel bandwidth that is used is 200 kilo hertz. So, when you look at cellular literature and they talk about channels how are these channels defined and how are they understood. So, you will hear a acronym which is in fact most people will use it, but very few people remember the original one; it is called Absolute Radio Frequency Channel Number- everyone says ARFCN.

This is a very important one because this is how channel numbering is done across the world and anywhere you go if you say ARFCN 1 of GSM everybody knows what frequency you are talking about, so regardless of what the understanding is. So, basically it is a common definition. So, a quick check says if I have 25 megahertz in India and each of them is 200 kilo hertz I should get approximately 125 channels; I am right. So, basically the understanding is that I my GSM allocation in India should be going from ARFCN 1 ARFCN 125. So, again an important element that that is good to keep in mind it is a simple one. The first hundred kilo hertz and the last hundred kilo hertz are left as guard bands. And the reason is we do not know who is on the left or who is on the right, it is lower frequency or higher frequency. And you must have filters which will take them out of our own usage.

So, going to look at the uplink allocation; and the uplink allocation as I mentioned goes from 890 megahertz to 915 megahertz- that is our uplink allocation. So, if 890 is our starting point first hundred kilo hertz, so the first channel goes from 890.1to 890.3 and the middle of that is 890.2. So, ARFCN 1 is at 890.2 megahertz. So, this is ARFCN 1 and the middle point. And ARFCN 2 will be 890.4 like that you can sort of visualize how the different channel numbers increase.

So, the last of them because you have last 200 kilohertz is actually ARFCN 124 and that has got 914. Basically it is 200 kilohertz a short of 915 megahertz. So, basically that is your center frequency; so whatever is your frequency channel uplink. And now if you were to if you were to ask you to do the uplink map; uplink map should be exactly this is again guard bands on the uplink side ARFCN 1 uplink should correspond to exactly 45 megahertz away. So, again you should be able to map it on to these into these discussions, into the corresponding channels.

Now in India definitely we know that the entire band is not given to one operator they are given to different operators. So, if there are other operators how is the spectrum allocation done; maybe I will just draw it here for two operators guard band at the left end operator A is a spectrum allocation operator A will ask for we keep a guard band for his operation then that guard band. Actually acts as a protection between A and B, and then B will also have a guard band at the end to protect. So, basically between operators also there is a guard band that that can make sure that your frequencies do not disturb my

frequencies. So, again these are simple things, but I thought would be good for you to keep in mind. So, let us look at a few other parameters. So, that was GSM.

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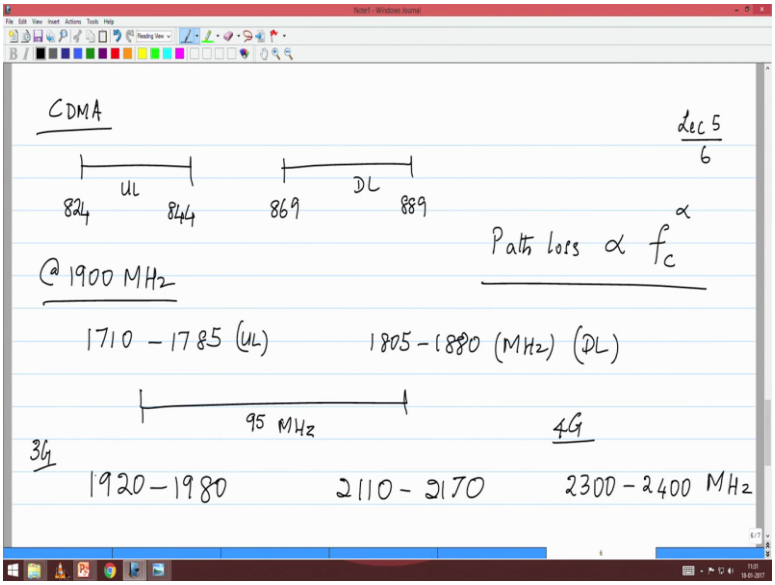

CDM is spectrum in India goes from 824 megahertz; goes from 824 to 844- 20 megahertz wide and then they corresponding uplink again maintaining the 45 megahertz spacing 869 to 889. So, this is again uplink downlink. Now you may wonder why always you know is does always have to be uplink first and the downlink. There is a reason for that: losses that are frequency dependent, so basically this is path loss is proportional to carrier frequency raised to some alpha.

Basically it is proportional to the carrier frequency. So, I need to allow for uplink transmission, I need to allow for downlink transmission who has more power? Base station has got more power; that means, downlink is not as vulnerable uplink is more vulnerable because I have to transmit with low power. Which frequency would give to the uplink give the one that has got lower losses? Because that is at a lower carrier frequency. So, again in all paired systems the uplink will be at a lower frequency than the downlink. Again, because of a very simple reason that path loss is proportional to carrier frequency raised to alpha, where alpha is an exponent we will talk about it; it is alpha is greater than two typically.

Now we go to the other cellular bands in India. So, there is cellular operation at 1900 megahertz or 1.9 gigahertz operation, the cellular band there is at 1710 megahertz to

1785 megahertz. So, you can see that there is 75 megahertz of spectrum available in that band. Again this is uplink the corresponding downlink happens at 1805 to 1880 megahertz, this is the downlink. Now what is your duplex spacing here? Duplex spacing- 95 megahertz. So, duplex spacing is 95 megahertz. Is it logical that you give 45 megahertz at 900 megahertz band and 95 megahertz at the 1900 band?

Student: Of course.

Yes, if you want to keep the same Q because the carrier frequency has double, so therefore you want to allow double the spacing, so that you can keep the same Q. Again sort of trivial observation, but it is consistent with our understanding that we have. So, this is all about the 2G bands. Let us quickly mention the 3G bands 3G bands there is a band at 1920 to 1980 and then correspondingly 2110 to 2170. So, this is all frequency division duplex. Notice there is an uplink frequency and there is a downlink frequency.

Now when we go to 4G a lot of the deployments in India are in the TDD band; that means, there is only one band that is available, there is no uplink or both uplink and downlink will happen on that band. And this is in the 2300 megahertz to 2400 megahertz. Notice that there is 100 megahertz of spectrum available, but approximately one half of it I mean half the time it will be used for uplink half the time for downlink and that is what is reflected for us in the chart which shows the difference between uplink downlink on an TDD system.

So, in this case the frequency is 100 megahertz available, but each operator will get 20 megahertz and then that 20 megahertz you have to use for both uplink and downlink, and a lot of the early deployments have been using 20 kilohertz bands a; sorry 20 megahertz bands for the uplink and downlink. 20 megahertz means it can support very high data rates and that is where you are seeing the high speeds in the 4G system. Very quickly any questions on TDD, FDD, duplex filter, uplink downlink, any of the points that we have mentioned so far?

Student: By 200 kilohertz (Refer Time: 31:59).

For the 2G system, because GSM was designed with a 200 kilohertz system and if you recall the 200 kilohertz system means that your board rate, your symbol rate is basically as is 200 times per second approximately. And if I went higher with the TDMA system

what will happen the time duration will reduce and my equalizer will become more complex. So, at the time of introduction of GSM people thought that up to 5 symbols of ISI would be manageable by the DSP that were available to us. So, they did not want to make the equalizer more complex so that is why they limited themselves to 200 kilohertz. If they had gone to one megahertz the equalizer would have been very complex and the receivers would have become very expensive. So, they wanted to be able to build handsets that are low cost and also complexity with the technology that was available at that time.

So, that was one of the limiting factors. Today we have the equalizer, so today we can go much higher, but having said that we do not do equalizers we go for o f d n which try to avoid an equalization; good, any other questions? Let us quickly move on to the next set of discussions. And one of the things that time permitting we will do in this course is make a visit to one of the cell towers. Whoever is interested we have a number of cell phone towers on campus it is always interesting for us to go and visit that. You would not see a cell tower quite like this, but this is what you would find in typical cellular deployment. And what I want you to notice is that of course why so many antennas sometimes there are small microwave antennas that are present parabolic dish antennas that are present those are for microwave backhaul.

So, but what is very common, what is very important for us to notice that notice there is a triangular structure at the top; right at the top there is a triangular structure. And on each side you see two antennas basically if I were to draw that there is a triangular structure you see two antennas: typically one is for transmit one is for receive.

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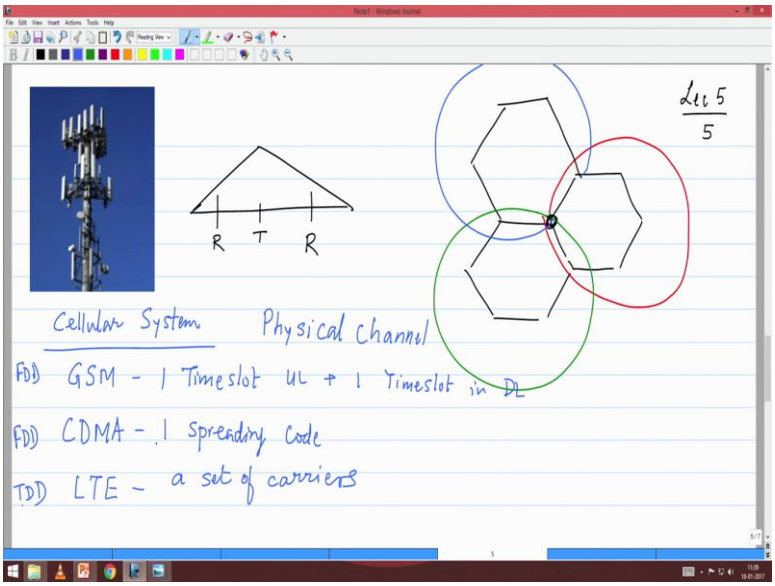

And so this is would be received transmit or in some cases what you will find is that this is the transmit antenna there are two receive antennas. And why not put receive this transmit why not?

Student: (Refer Time: 34:45).

This is for diversity. So, in case the signal received by antenna one is having a fade you want to make sure that you the at least the second one is got a better signal. So, you want to separate out separate them as much as possible. So, typically that would be the configuration.

So, on any cellular radiation you will find that there are multiple antennas and one is to make sure that. The other elements which I just wanted to point out the triangular or shape also tells us another important element that the radiation pattern of a cell phone tower is not 360 degrees it is actually only 120 degrees. So, if you were to look at this as your base station site let me see if I can draw what the radiation pattern will look like on that. So, it is only radiating over 120 degrees.

So, the second and third sectors as they called they are on different sectors, but this is how the radiation happens and why that hexagonal structure that just tells us how we visualize the planning of a cellular network this is a the most compact structure that without any gap. So, if you want to cover an entire geographical region you plan it using

a structure or a shape; that is with minimum shape with minimum number of them you can do it is called tessellation. We will talk about that in the next lecture that is part of the cellular design. So, we have talked about frequency division duplex, time division duplex, uplink downlink, basic structure of a cell phone tower, but I do wanted to add to you a few more things which are useful for us to keep in mind as we study our first understanding of the cellular system.

Now when we talk about cellular systems we always talk about channels, because a channel is the vehicle by which we carry information. So, here is basic information we talk about a channel. So, the first aspect that we talk about is a physical channel. When I talk about GSM I know it is a TDD sorry it is FDD, TDMA system. So, the channel that I am talking about for a GSM system is one time slot in the uplink and a corresponding time slot in the downlink; one time slot in the downlink. This combination establishes a physical channel in which information can flow from the mobile to the base station and from the base station to the mobile.

So, a physical channel in GSM is one time slot. In CDM it is one spreading sequence or is one spreading code. So, one spreading code notice it is also an FDD system. So therefore, I must allow for different spreading code on the uplink and a different spreading code on the downlink you will have to make sure that. So, this is a GSM is FDD, CDMA is FDD keep both those pictures in mind.

Now comes the LTE system. Now, what is physical channel? Physical channel basically represents a set of carriers. So, a set of carriers it can be one it can be more than one, but the single carrier will be very narrow so you may want to have a set of carriers. Now what about uplink downlink? Uplink has got a structure which has a set of carriers as the traffic channel; downlink will have a set of carriers as a set of the traffic. So, keep in mind that this is a slightly different system, this is TDD, but in essence the notion of a physical channel very important this is what is your base on which you build your entire system.

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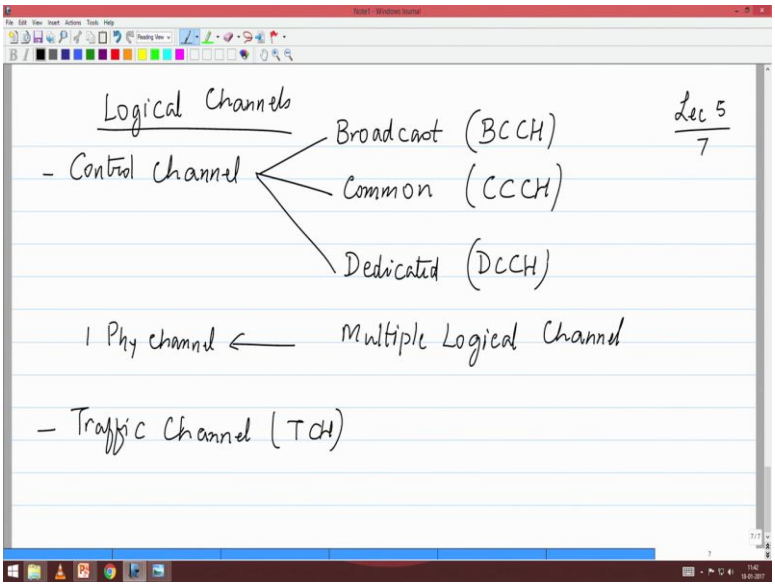

Now, in addition to the physical channel what is the information that is going over these physical channels? So, that is what we refer to in cellular jargon as logical channels. So, in GSM I can take one physical channel, I can send different types of information that we can use for the communication purposes. So, one of the most important logical channels that we have in any cellular system is called the control channel. Now what is the control channel actually carry first and foremost it carries broadcast information. It goes on transmitting saying this is my operator code I belong to BSNL this is my ID. If you are a BSNL user you can access me. Basically there is information that is being sent.

So, there is a broadcast control channel it is called BCCH broadcast: first C is for control second C h is for channel- broadcast control channel. Then, there is a second one which is called common control channel let us CCCH- common control channel. What is common control channel? Common control channel is paging information.

So, there is an incoming call for this particular subscriber or this set of subscribers that is common control channel. And then there is a third set which is called dedicated control channel- DCCH. This is saying that of user number 21, I want you to handover from this cell to another cell; that is control information that is meant only for one user. So, broadcast information is for everybody in the cell. Common control information everybody will hear it, but only one person is supposed to respond it, indicator it is

because it is a paging my information. Dedicated is something meant for only one user because it is very specific instructions given to one user.

So, there are different flavors of control information that is present. Now do you need three physical channels for this information? In the in the context of GSM they said well you know what GSM time slot is occurs very very frequently so I do not need three different physical channels, I will take all my control channels and I will time multiplex them into the. So, basically it will happen like this broadcast common common common then broadcast will come common common, basically there is a pattern that will repeat that will indicate how.

So, once you listen to the broadcast channel it will tell you what is the structure that of the common control. So, many logical channels can be multiplexed onto a single physical channel so that is important one. So, one physical channel can carry many logical channels; multiple logical channels and that is very important for us to know, because in the context of a cellular system logical channels is how we think, but when you actually transmit it is may not need physical channels for each of them. In fact, you can very efficiently transmit this information.

So, in addition to control what else is there is user data that is called traffic channel; traffic channel each user will need their own dedicated physical channels so whatever time you want to set up a traffic channel you have to set up a unique physical channel as well. So, control multiplex a lot of control into one physical channel the traffic each user gets a dedicated traffic channel. Now may be a good exercise at this point is to just say how are these things happening in a phone and what are some.

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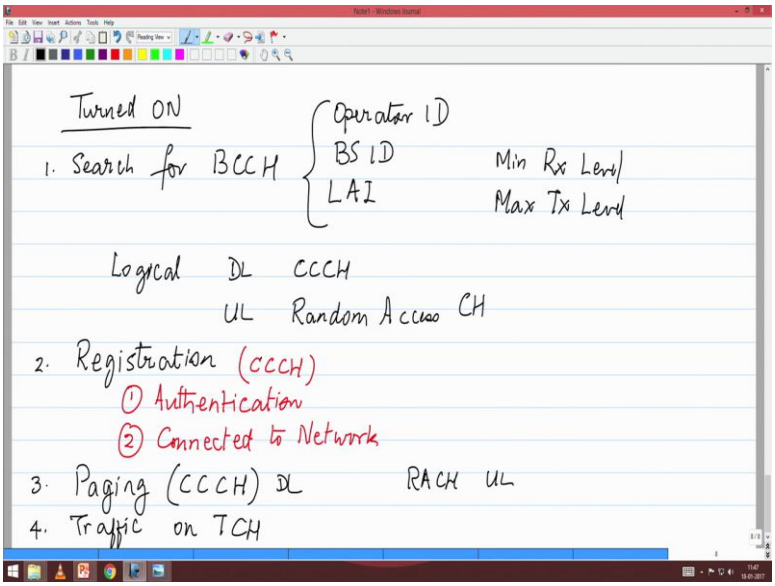

So, let us say that you have phone has turned on; you have just turned it on for whatever reason maybe turn out of power you forgot to recharge it is shut off. Now you have to charge it again you turned it on; what does the phone do? First thing it does it searches for BCCH, it remembers where it last found the BCCH it will try to go to the same frequency and try to find it, but if you have changed and different location the BCCH may or be on a different frequency, but it will search and it will find out.

Now what does it require from the BCCH, it takes the following information: what is the operator ID takes that information. It also looks for the base station identification, it looks for the location area identification- basically which a geographical area. Then it also has some other information like what is the Min Rx Level. What is what the mobile station is, what the base station is selling means? If you are receiving me at minus 1 or 2 dBm connect to me, if you are receiving me at minus 1 10 do not connect because the quality is not good try to find some other base station.

And there is another one there is a Max Tx level. Now, what is the Max Tx Level? Again very interesting; so if you notice there was a logical channel on the downlink which was called common control channel- CCCH and that was primarily for paging. Now what happens on the uplink? Paging means the network wants to tell you that there is a call coming in or there is a message for you which means that that is the information.

Now on the uplink should be the mobile trying to initiate a call right, I want to make a call. So, that is called a random access channel because multiple users may decide to send the request at the same time so that is called random access channel. So, that is the counterpart of the logical channel for the control common control on the downlink it is random access on the uplink again this is how the uplink. So, max tags transmit level is by the way if you are trying to make a random access do not use more than half watt, because you know this is a small cell do not blast at 1 watt because then everybody else will get disturbed.

So, the lots of very useful information that is going on the broadcast it quickly acquires the information checks the operator ID and says- yes it is the right operator I want to connect. Then comes the next step which is called registration. Once you have found a correct your own home operator and verified that you have you can receive the signal at a correct level, then you send a registration message. So, that also happens. By the way broadcast control channel is going one of the logical channels. Registration is done on the common control channel. That is basically on the random access channel you will send a message saying I want to connect with you and on return the base station will do a couple of things it will do authentication, it will verify that you are the correct user; there is a authentication mechanism.

Again if you look at any of the text books you will be able to find it. Basically it is challenge response systems ask you it gives you 128 bit sequences ask you to give a response. Basically you are supposed to scramble it with some secret code that you have the network will verify that it is a right code and basically it is like your one time password that it gives. So, it does something very very similar to that. Once you have successfully completed authentication connected to the network and that is when you will see your operator sign coming up BSNL or Airtel connected to network.

So, you remain in this situation, except if your location area identity changes suddenly, because you keep if you keep moving and then you have gone from to another location area then immediately you will send another registration message saying- I want to reregister on the network, otherwise you stay in this one. If there is a incoming call they will be paging happening. Paging also happens on the CCCH- that is what we mentioned that is on the downlink. And on the uplink you will say- yes I got the message I heard you. So, that will happen on the random access channel that is on the uplink the mobile

response. And then what the network assigns you is you start the traffic or start the voice call on a TCH. TCH is a physically separate channel. So, from the broadcast control channel you will be asked to move to another frequency another timeslot and then that becomes your channel on which the communication happens.

So, again this if it were a mobile initiated call it will only be step three you will send a request on the random access, the mobile the base station checks whether channels are available and then assigns you a traffic channel and then connects the call; so gain the use of the logical channels very important for us. So, having this basic background I believe we are now in a position to understand how the basic functions of a cellular system happen. And if you go back and look at this, now hopefully you can see that all of the logical channels and the physical channels are basically in what when the base station is communicating to the mobile; and that is where all the rest of it is all on fiber networks. These logical channels physical channels we talked about are in a wireless part which is between the mobile and the base station.

So, let me summarize what we have said today. We have talked about the FDD part- the reason for a duplex filter, the time division duplex where you have uplink and downlink on the same frequencies, and how GSM though it is and FDD system very cleverly avoids a duplex filter. And that is a good way to remember how is the information done. Physical channels are very important, using the physical channel we transmit multiple types of logical channels which help us communicate on between the base station and the mobile.

Any questions; please do read, the reading assignment has been posted Molisch chapter 3 is what we are going to pick up. Basically we are going to talk about we have covered all the basic cellular terminology, we will pick up with link budget in the next class. Basically it is just to visualize what a link budget is and how it is impacts a wireless system.

Thank you we will see you tomorrow.