Wireless communications
Prof. Dr. Ranjan Bose
Department of Electrical Engineering
Indian Institute of Technology, Delhi
Lecture No. # 03
The Modern Wireless Communication Systems

Today, let’s start with the modern wireless communication systems and find out why they work, what is the driving force, what are the technological innovations that have gotten into the modern wireless communication systems, how we can support more number of users and how we can offer better data rates & host of other services.

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First a quick look at the rate of growth of the current cellular subscribers in the world. As it’s clear from the diagram, there has been an exponential rise. The first point is a 1992 figure of about 23 million cellular subscribers and it grew steadily through the mid 90’s and it reached about 781 million by 2001. In 2002, it touched the historic 1billion mark. The tech gurus are predicting a growth which will take it to about 2billion in 2006. That’s where we are heading to. so this is the market to be in. It’s growing at about 30-40 % still.

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What makes this growth happen? What are the basic concepts involved in these cellular communication systems? One of the most important thing that makes this phenomenal growth is the multiple access methodology. We are not providing service to just one customer. We have to ensure that a number of customers can access the bandwidth and use it for voice communication as well as data communications. Multiple access schemes are generally used to allow many mobile users to share the finite amount of radio spectrum. We know that the radio spectrum is at premium. One of the most important cost comes from the licensing of the radio spectrum. Even if we have the money to get a big chunk of bandwidth, we have to use it carefully. The sharing of the spectrum is required to achieve high capacity by simultaneously allocating the bandwidth. Now they can be more than one way to do so.

Hence there are several multiple access schemes. Bandwidth here is being shown to be one of the resources that has to be shared we can make sure that the resources are shared in different manners. Even though we share the resource we have a constraint. The constraint is that we should not have severe performance degradation. What do we mean by performance degradation? For every application, we define something called ‘the quality of service’. It is different for different applications. For example, for voice communication we have constraints on the maximum delay allowable or the packet loss rate or the drop of call rate for data. Again the bit error rate is of importance. So these constraints do exist and even if we pack in more and more number of users, we must ensure that there is no severe performance degradation. One of the popular multiple access schemes is the frequency division multiple access popularly known as ‘FDMA’. Look at the diagram. On the y axis, we have the total bandwidth allocated.

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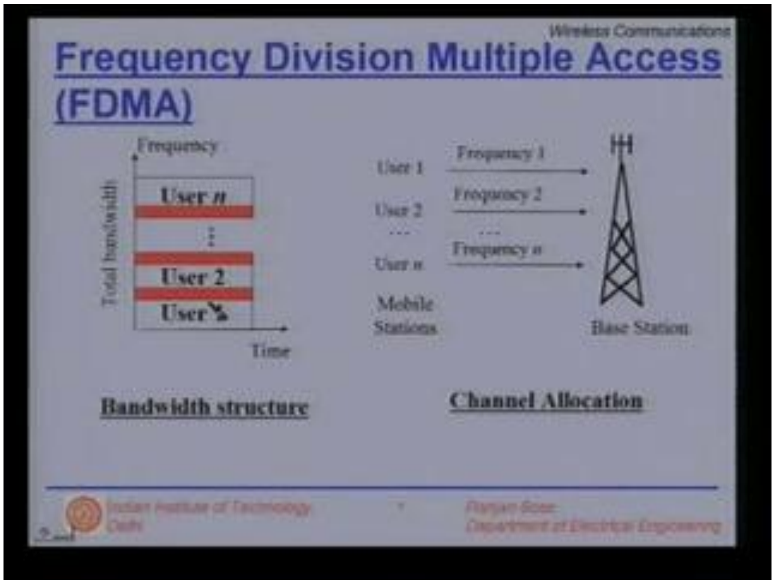

Again this is finite. On the x axis is the time. User 1 may be given one sub band followed by the user 2 and so and so forth up to user n. these bands are fixed. So if suppose user 1 switches on the mobile phone and we have to allocate one of the sub bands, we can give them sub band number 1. Suppose user 2 switches on the phone and has to be allocated a frequency for talking, we can give them another band but not necessarily the adjacent band. In fact, we should not give the adjacent band. At this moment in time, we are talking about allocating the sub bands. It's clear that the sub bands have been decided earlier but the allocation has to be done dynamically as and when the number of users switch on their phones and intend to talk. If we space users far apart along the y axis, it means they have less adjacent channel interference.

Clearly, we need to have ideal filters if such closely spaced frequency sub bands have to be used in practice. Let's look at an example of how this frequency division multiple access is used. Look at the base station. There are n users who are mobile stations. User 1 is allocated frequency 1, user 2 frequency 2 and so and so forth till frequency n. now please note all of the users are free to use their frequency bands throughout the time domain. All across the time duration they can use their entire frequency band without worrying. So they can talk, keep quiet, have long periods of silence, etc. it doesn't matter. They pay for the frequency band. As I mentioned before, such closely spaced frequency bands have the problem of energy from one band spilling over to the other band because of non- ideal filters. So we have to have some kind of a guard band. So in the red you have this guard bands. Who decides the width of the guard band? It depends on how sharp the filter cut offs are. If we have more expensive filters with sharp cut offs, we have narrower guard bands. Please note guard bands are not used to communicate data.

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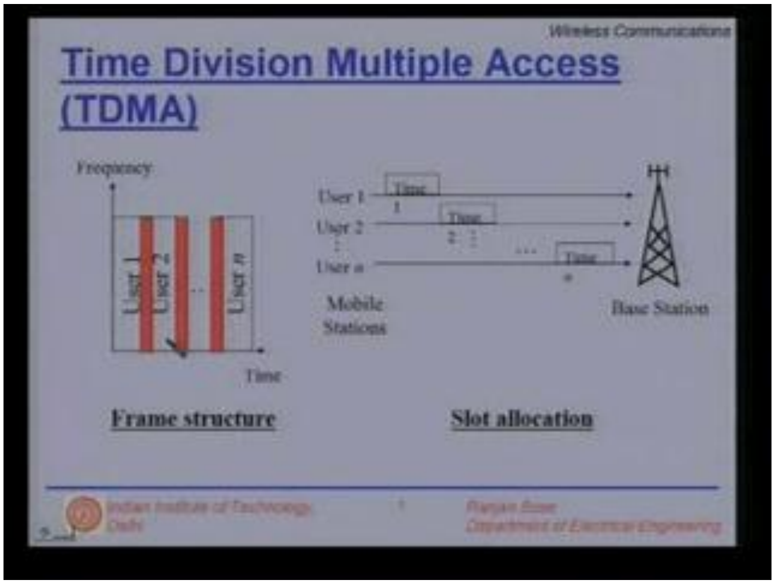

Another popular multiple access scheme is a time division multiple access. Here, again we have our popular frequency access as the y axis and time as the x axis. But we have sub divided the time axis amongst n users. in effect, we have n times slots where user 1 uses slot 1, user 2 slot 2 and so and so forth till the slot n. each user is speaking or communicating in its own time slot. After n time slots are over, time slot 1 will repeat followed by 2, 3 and so and so forth. Clearly this does not imply that your voice will appear broken at the receiver end. The reason is simple. When we communicate voice, we sample it first at slightly greater than the Nyquist sampling frequency. We use these time slots to send the digitized voice.

At the receiver end, we put back these sample points and reconstruct perfectly. So the voice will definitely not appear broken at the receiver end. Let’s look at how it happens in a real life situation. Here on the left are n users. These could be mobile phone users and they need to communicate with the base station. So, on the x axis is the time. So user 1 sends a small packet of information in time 1. Similarly user 2 sends in time 2 and so and so forth. Again they will repeat 1, 2, 3 up to n time slots as in the case of FDMA. For TDMA also we require to have some kind of a time broadband. Another important issue in TDMA is synchronization. If I am not well synchronized with the transmitter, I might be listening into somebody else’s time slot. In fact, I’ll get garbled data. So time synchronization is of importance.

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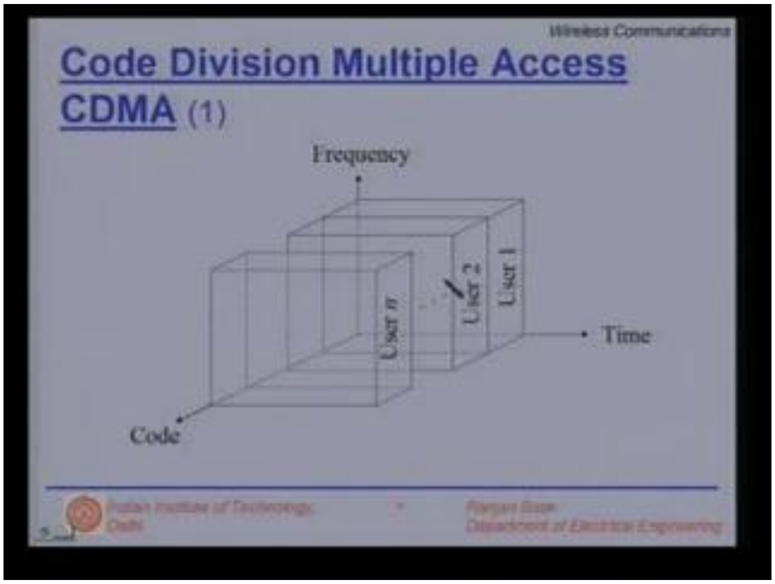

Let’s look at the third popular multiple access scheme called code division multiple access or the CDMA.

Conversation between student and professor: the question being asked is: what is the time band gap available in general? What determines how much or how broad should these red bands be? So the answer is it depends upon the allowable timing jitter in the system and the sensitivity to synchronization. That is, when I determine a time slot I have to get a synchronization at the receiver but there will be an error in there plus in the system, by definition there will be some timing jitters. So we have to account for all these things. These should not result in errors. Therefore what we have to do is, we have to plan for all these timing aberrations and then decide accordingly.

Coming back to CDMA or code division multiple access, we have the two popular axis; the frequency on the y axis and time on the x axis. If today, I wish to use a combination of TDMA and FDMA, I will ensure that these two axis are used and we can have check boxes throughout where we have a time slot and a frequency slot together. So every channel really consists of a particular time slot and a particular frequency sub band. In fact the popular GSM phones always use a combination of TDMA and FDMA. The CDMA or the code division multiple access adds one more dimension which is the code dimension. So every user is allowed all the time and all the frequency bands for communication but they share a particular code. So user 1 will be sharing code 1. It could be a spreading code for example, a Barker code or any other appropriate PN sequence. User 2 will have its own spreading code and so and so forth. User n will also have its own spreading code. Very soon we’ll look at an example to see why is it called a spreading code. But at this moment in time it is important to understand that each user can decode the signal using its own code. For example suppose in this room, we have ten people and each person uses a different language. So one person speaks in Hindi, one person speaks in Marathi, one person speaks in Tamil and so and so forth and I am the base station and I understand all these languages. So if all of the users keep talking in their own languages that is, their own codes and the base station who knows all the languages can understand what each speaker is saying. This is similar to what CDMA does. All the users are talking at the same time. So the impediment is as more and more users start speaking, we have more and more interference.

Conversation between student and professor: the question being asked is: is the interference, coming from the facts that along the code access, each of the users are not orthogonal? They are not separated. So the answer is yes. Truly speaking, when we have code 1, code 2 and code, n for different users, they must have a property. The property is it should be orthogonal in some sense. When I decode one user with its own code, I should be able to recover back my appropriate signal but if I use a wrong code, I should get noise like behavior. Since all codes are not ideal because we have to work with finite length codes, we do get a little bit of cross correlation. so the answer is we should find codes which have good auto correlation properties and very low cross correlation properties. That is, when you cross correlate code one with code two, then you should get a very low value.

Conversation between student and professor: the question being asked is: is there a limitation on the number of orthogonal codes that can be generated? Clearly, if we can generate a large number of orthogonal codes, then we can support a large number of users. The answer is if we do not have a restriction on the length of the sequence, these are called the PN sequences, then we can have a large number of codes. However in real life there will be a constraint on the length of the PN sequences and that inherently will put a constraint on the total number of good orthogonal codes available. Suppose we have n good orthogonal codes, then as and when users start using their codes and in our analogy more and more number of people in this room start speaking in their own languages, the general noise level in the room will go up. There is another problem. the person sitting in the first row in the class will appear to be speaking more loudly then the person speaking from the last row if they are using the same output power because for the base station, there is a fear that the person speaking from the first row drowns the voice of the person speaking from the last row. This is called the near-far problem. So CDMA essentially must have a form of power control. The users closer to the base station must reduce their power of transmission and the users far away should have a higher power emitted.

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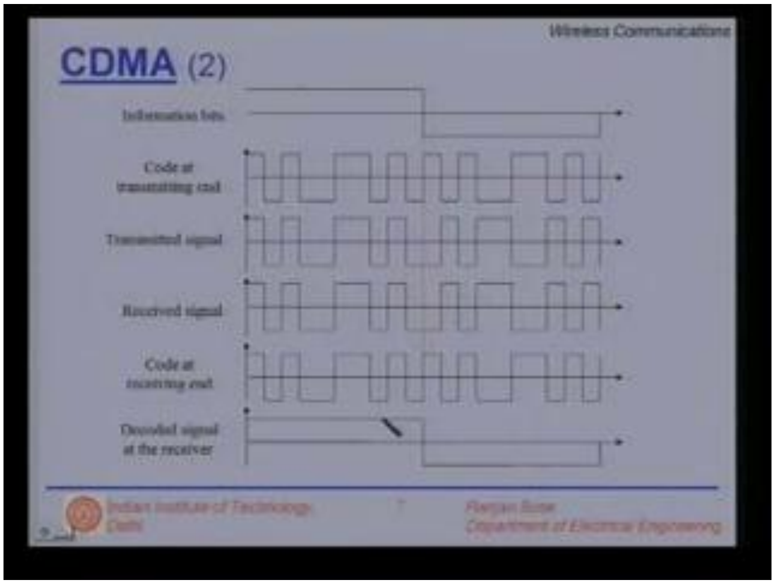

Let's look at an example. Let two information bits be represented as a 1 and a 0. Please note here 1 is represented as a value greater than 0 and 0 as a bit is represented with the value less than 0. Now let's look at one of the spreading codes. If you see, this is a code at the transmitting end. It is a pseudo random code. The chip sequences are much smaller in duration with respect to the bit sequence. So this is a bit interval and each small one is a chip interval. If we multiply the information bit with the spreading code, we obtain another wave form whose bandwidth will be larger than the bandwidth required for the transmission of the information bits simply because the chip interval is smaller and the frequency is larger for the information bits been transmitted. Hence in the frequency domain it spreads the sector. Hence they are called spreading codes. Now when we transmit this signal, hopefully what we receive will be a noisy replica. But in this idealized case we have shown the received signal identical to what we transmit. at the receiver end, we use the same spreading sequence as at the transmitting end and a direct multiplication leads us to recover the decoded signal.

Conversation between students and professor: the question being asked is: how does the receiver know which transmitting code is being used? Clearly, there is a need for certain control channels which communicate which code number is being used. Apart from the traffic channel, every mobile phone also has some control channels which help in synchronization, determining or conveying which code is being used. All these are done before the transmission of the actual data. Clearly if we do not know which code is being used, I will get garbage. Also, when I am receiving some signals, I am receiving signals from all other users as well. But my code will decode only information relevant to me and discard all the other extraneous information.

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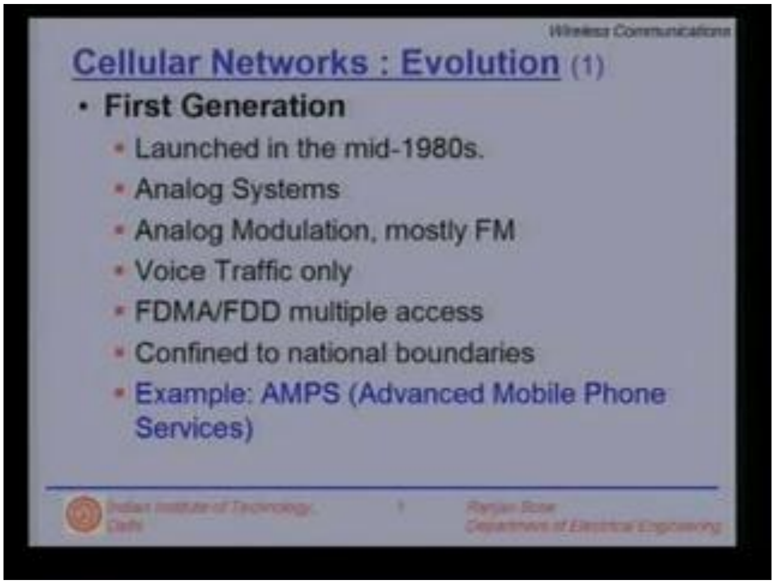

Now let us look at the evolution of cellular networks from the perspective of the multiple access schemes because at the end of the day, we have to support a large number of users. That's where the revenue is going to come from which will ultimately propel the growth. So we start with the first generation. It was launched in the mid 1980's. They were purely analog. They used analog modulation mostly frequency modulation (FM). They were intended primarily for voice traffic because at that time phones meant voice. They would use FDMA multiple access schemes, there had to be a multiple access. So they would just chop up the entire frequency band into sub bands and use analog transmission in each sub band. They were confined to national boundaries only. It's an important thing because if you confine your phone service to a local territory, you'll limit the number of users and customers. An example is the AMPS or the advanced mobile phones services popular in the US in the mid nineteen eighty1980's. As cellular networks evolved, the second generation came into being.

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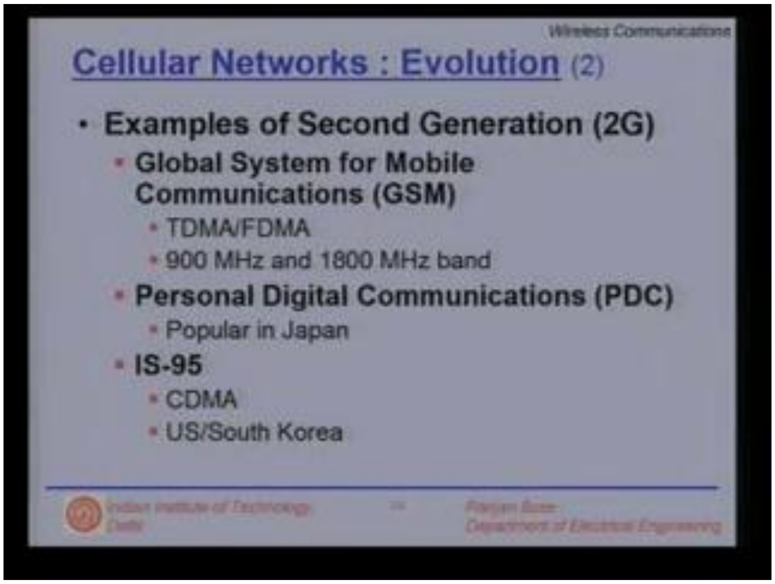

This was developed for voice communication again. At that time it was unthinkable that you will be using phones to communicate data. Why would anybody want to send data using the phone? That was the third process. Because nobody believed that you would be accessing the internet through the phone. Internet itself was in its earlier stages. But what was different is the second generation systems were digital. Digital in the sense that they used a digital modulation. GSM for example, it's a 2G phone system. It uses GMSK- the Gaussian minimum shift keyin.g it's a digital modulation technique. For multiple access they used TDMA FDMA and CDMA. They could provide data rates but of the order of about 10 kilobits per second. So even though they were designed for voice, there was a provision to handle data simply because they were digital schemes. But their objective was for voice communications. Clearly at the end of 2G systems, people realized that data traffic is gaining momentum. Something has to be done to improve the data carrying capability. But by that time, they had sold enough 2G mobile phones to completely change the standards immediately.

In fact in 2002, 66% of the mobile phones in the world were GSM. So they had to do something as an add-on. so they sat together and tried to evolve something called as a 2.5 G. In this slide, I have given some examples of second generation mobile phone systems. The first and the foremost is the GSM 'global system for mobile communications'. It uses a combination of TDMA and FDMA. It was initially started at 900 MHz. now you also have an 1800 MHz variant. Another popular 2G system which was popular only in Japan is the PDC or the 'personal digital communications'. It was very popular but the Japanese couldn't sell it elsewhere and therefore Japan is most excited to get into the 3G race. The third generation systems are not going to be confined to any global territory or national boundary. So Japan missed out on getting a big chunk of the 2G market. But it wants to get a head start in the 3G market. IS 95 was different. It was CDMA based the code division multiple access and Qualcomm the company which essentially propose CDMA was fueling this growth. It was popular in US and South Korea.

Conversation between Student and Professor:

So the question being asked is: what is the relevance or why 900 megahertz were used and today what is the frequency of transmission? 900 MHz has a very interesting reason to be used. If you conduct trials and see how far your signal propagates for a given power, it was found that 900 MHz was a very benevolent band. It would let the signal propagate much further. As you know air which is our channel is a band posture. So, 900 MHz up to 1800 MHz from a good band where I can easily transmit signals without suffering major attenuations. Also at that time those were the free bands available. 1800's came up because we wanted to send more and more data on it and actually there are two variants of 1800. So 1800 is a band which is being mentioned here but there are two bands around 1800 MHz which are actually being used. Today most of the phones that we buy are dual band and slowly the 900 MHz band is being phased out. If you see your phone, you have a visible antenna outside. But in many phones if you open the back cover, you will also see a patch antenna inside. So you actually have two antennas in many of the phones. One catering to 900 MHz and one catering to the 1800 MHz band. So, both are being used today.

Conversation between student and professor:

The question being asked is: is the 1800 MHz band clearly giving some advantage in terms of bandwidth? So the answer is yes. Any additional band of frequency centered around 1800 is clearly more than what was allocated for the 900 MHz and that is used for data transmission. Now we do not need high speed data because 2G was never meant for high speed data. In fact, when the add-ons to the 2.5 G came, we really are looking at the data transfer using add-on protocols which we are going to observe in the next slide. As cellular networks evolved, we have to overcome the impediments posed by the 2G systems.

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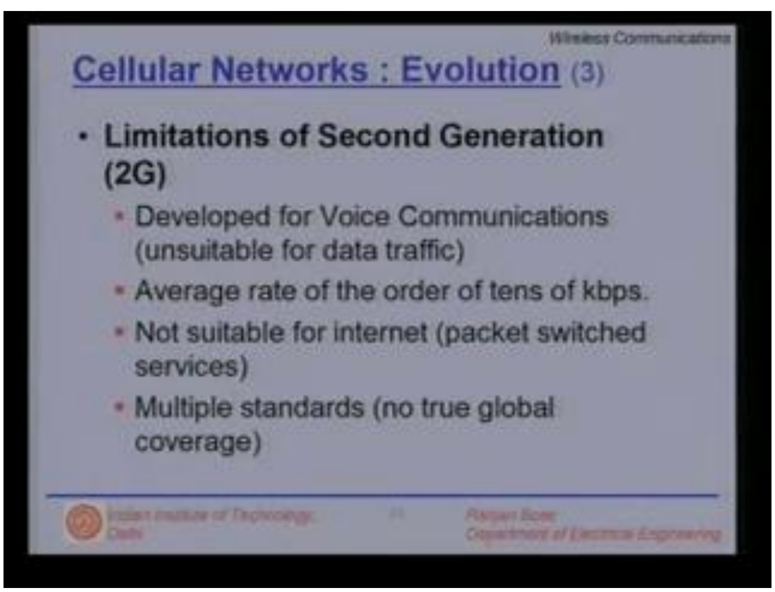

So what are the major impediments that we see today? First of all it was developed for voice communication and implicit statement unsuitable for data traffic, although data traffic could be carried out. The average data rates were the order of only tens of kilobits per second. It's not good to the customers who have become used to the luxury of high data rates. It is definitely not suitable for internet because the original GSM phone was a circuit switched system and not a packet switched service. But for internet we have to have some kind of a packet switched network. Then a general problem with all second generation systems was they were too many standards. Although GSM took the major chunk of the pie, still they were too many standards one in the US European standard, Japanese standard etc. so it was a mess. All these motivated toward the 2.5 G. it resulted as an effort to remove the impediments of the 2G systems.

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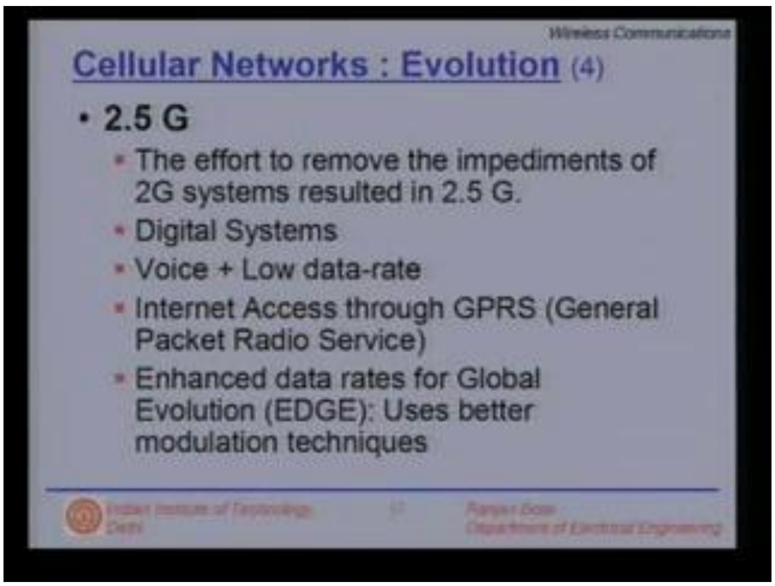

It is again a digital system. It is designed this time not only for voice but for low data rate traffic. So we make it explicit that it's going to be also for data traffic. Internet access can be done through general packet radio service or GPRS. So it is the first step of going towards 3G and then the step two called 'enhanced data rates for global evolution' or the EDGE which uses better digital modulation techniques to get that EDGE. So if you look at the steps you have a 2 G, then you can go to GPRS and then proceed on to EDGE and finally to the 3 G systems. That is the road map that has been laid out. Most of the GSM phones today in India are 2.5 G phones. The initial CDMA phones that have come out CDMA 2001 X EV DO are the tip of the ice berg for the 3G phones. They will write it as 3G enabled but truly all the parameters required for 3G are not being satisfied.

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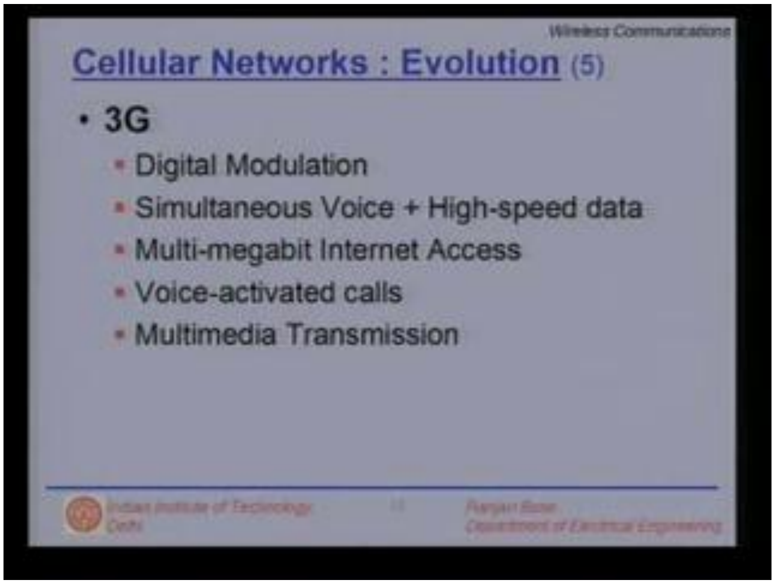

So look at the evolution of cellular networks. The 3G or the 3rd generation again requires you to use digital modulation. but apart from voice, we have high speed data. You have multi-mega bit internet access. So there's a thrust internet. I can check my emails while driving in my car at 80 km/hr. then the voice activated calls and your multimedia transmission are there. So I can download a movie clip and watch on my phone while walking around. So 3G puts constraints on how fast you go and how fast you can download the traffic. Clearly if you move much faster, the channel becomes more difficult to handle. The associated problem is fast fading Doppler effects which have to be taken care of. So whenever you talk about 3G and the quality of service you have to have an access, in which you tell how mobile you are. It's not just a mobile phone but how fast you are moving. Are you stationary? Are you a pedestrian traffic or are you in a vehicle? Is it a vehicular traffic? For all these things, you need to have a certain kind of quality of service. So 3G is still coming. Trials are being run. Initial three 3G phones have been released. But people have started talking about something more which is the 4G. One important thing about 3G is it is truly a world standard that is evolving. There are two standards which have been debated. One is the W-CDMA which is the wide band CDMA and the other is a CDMA 2000 standard. Both have a lot of similarity and basic differences. I guess both will be incorporated because a lot of money has been poured into the development of each of the W-CDMA and CDMA 2000 systems.

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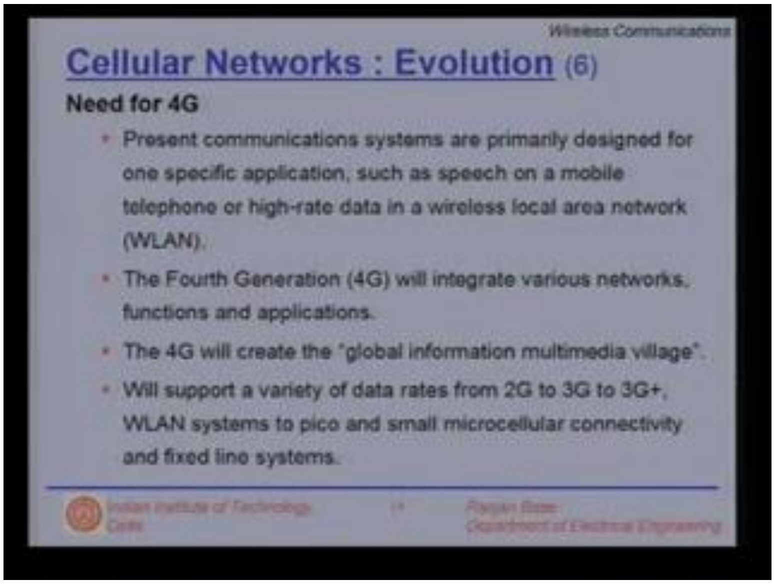

Let’s look at the need for 4G that is still several years down the road. So present communication systems are primarily designed for one specific application. for the first time 4G systems are looking from the applications point of view. So either it is a mobile phone for voice or high rate data for local area networks, 4G systems would like to combine all of this. 4G will integrate various networks, functions and applications. Today if I walk into a room which has a wireless local area network enabled through 802.11 B, I cannot interface my mobile phone with that. if I have a MMS clip or an SMS or a V card which I would like to print out on a printer which is connect to an 802.11 B wireless LAN, I have a problem. 4 G will solve that problem. I can walk into the room, configure my phone to send the printout to a printer connected to some other network, may be 802.11 B or an 802.15.3 UWB network and then I should be able to get my printout. The 4 G will truly create the global information multimedia village. The “anywhere” “any time” communication for all the applications should become possible. It should support a variety of data rates at variety of speeds. There will be various sizes of cells. Remember the cellular concept came from originally the mobile phone users where we had the city divided into cells. Each cell with a base station. Today we are talking about not just the macro cells but micro cells, Pico cells, home cells and even body area networks. So the other interesting feature about 4 G is that we will look at various sizes of cells. Each cell for a different application. Each application with a different quality of service and each application with a different data rate. 4G promises to combine all of these things but still it is in the future.

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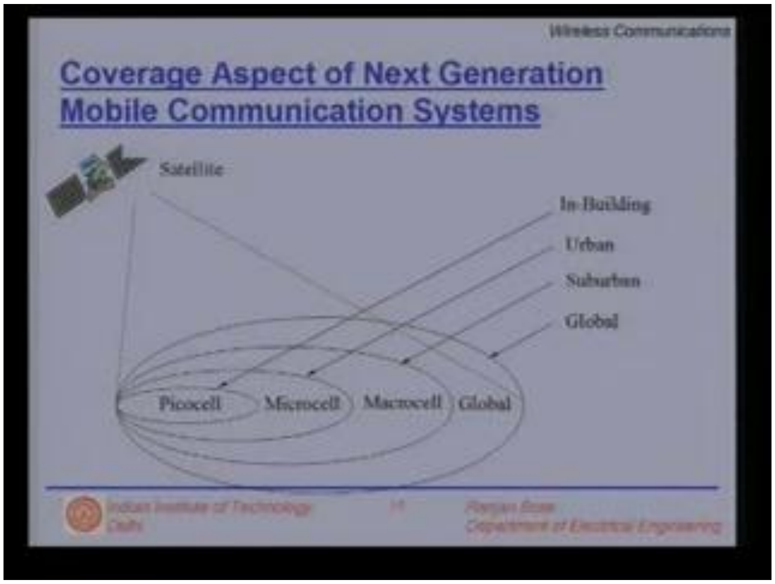

So when we talk about coverage, we talk about either the areas of coverage or how big the foot prints the cells are. In this slide, we'll have a perspective as to what kinds of coverage are being promised in the next generation mobile systems. We start up with the largest broadest coverage which is coming from the satellite. It is a kind of a global coverage. So we have a large foot print and there may not be just one satellite but a constellation satellites. They are going to give me a global coverage. As mentioned before, this low earth orbit satellites will not be geostationary and hence their foot prints will keep moving and once one footprint moves out, the foot print of another satellite. So these base stations are mobile in themselves. The subscribers may not be mobile. The next smaller distinction is the macro cell. We should take care of the suburban areas. So we are now talking about truly wide area networks. Remember 4G systems have to combine all these various kinds of applications. The next size is micro cell which takes care of the urban scenario. so IEEE 802.16, 'the Wi max' standard would probably fit into this picture and a 4G system should be able to easily communicate seamlessly with the Wi max systems as well. The next smaller is the Pico cell which is within the building. It could be my wireless desktop or a body area network. So these are the various coverage aspects.

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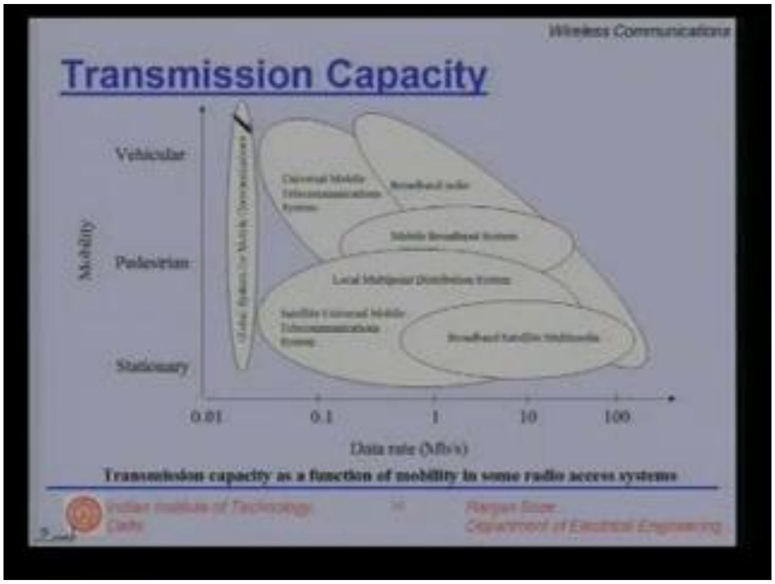

In this slide, we add the next axis which is the mobility part. On the y axis if you see, I have put stationary users, pedestrian applications and vehicular speeds. So stationary is 0 km/hr pedestrian is 3-4 km/hr and vehicular could be 60-80 km or even more. The higher end of vehicular is high speed trains. So people thought that you could go on a high speed train travelling at 200 km/hr and still download a movie on the laptop. So using these ellipses we have looked at the various applications. So the GSM forms this vertical ellipse here which is giving a low data rate.

Data rates are being expressed on the x axis but GSM actually covers stationary users, pedestrian users and vehicular users. On the extreme side is the broadband satellite multimedia. Here we are looking at from a 1 Mbps to 100 Mbps. but as you know we do not give enough mobility for satellite broadband users. here we have something called as a local to multipoint distribution system ‘LMDS’ which is the precursor of the Wi max IEEE 802.16 system which is going to give you metropolitan area network. It gives you limited mobility in terms of a pedestrian traffic, primarily stationary but look at the large bandwidth it covers. Further down the x axis but closer to the stationary limit will be your IEEE802.15.3 ‘the ultra-wide band’ standard. So this gives a perspective as to how the 4G systems are evolving. We have to move along the x axis that is, get higher and higher data rates. Now we would look at some terminologies useful for describing the 2G and the 2.5G systems which are currently in use. So in the next couple of slides let us look at some definitions.

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A mobile we all know is a radio terminal attached to a high speed mobile platform. Now this high speed is subjective but it could be a cell phone in our fast moving vehicle, a car or a train. Portable is different from mobile. It is also radio terminal that can be hand held and can be used by someone at walking speed or can be taken up from one portion of the room and kept in the other side of the room. A cordless phone is an example. Subscriber is a mobile or a portable user and this is the guy with the money and he pays for the service. Base stations are fixed antenna units with which the subscribers communicate. Base stations are connected to a commercial power source and a backbone network. Why are these called base stations?

Well, long time back when the circuits were big and the boxes that carry these circuits where even bigger and heavier, it was very difficult to put these heavy pieces of equipment high up on the antenna. Unfortunately all these base stations had to be put at the base of the tower on top of which the antenna was put. It was difficult to carry and maintain such heavy pieces of equipment at the top of the tower but you had to have a tower for a larger coverage area. so these boxes were kept at the base of these towers. Hence the name base station.

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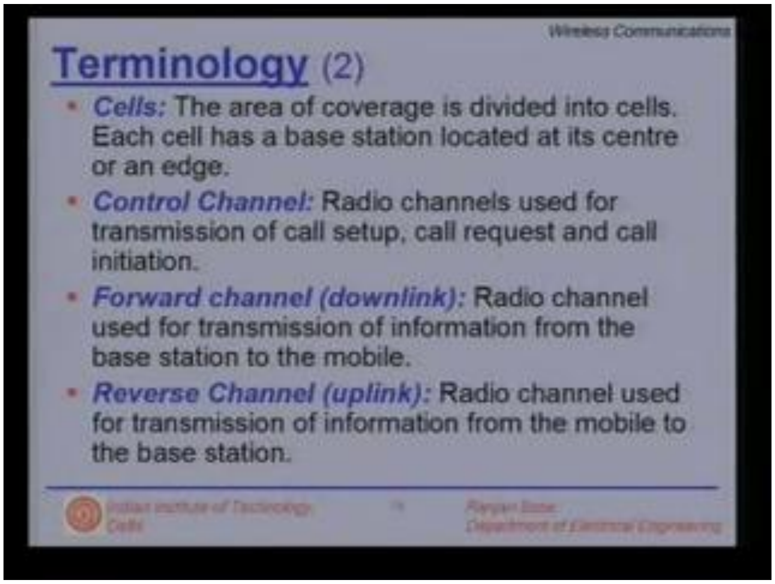

Let’s define cells. The area of coverage is usually divided into cells. Each cell has its own base station usually located at its center or sometimes at the edge. That’s a different configuration. so every cell has a base station and since the whole set is divided into cells, this is called a cellular communication. It’s not because we use pencil cells in your mobile phones. Next we have something called as ‘control channels’. These are radio channels used for call set up, call request and call initiation. These will essentially tell you how to synchronize, what to do with the power, should I reduce my power, etc. if it is a CDMA phone, should I use which synchronization code or which spreading code. We have forward channel also called the downlink. It represents the radio channel used for transmission of information from the base station to the mobile station. Usually the base station is on the top of a tower and it looks down upon the user. Hence the downlink. The uplink or the reverse channel is the radio channel used for transmission of information from the mobile to the base station.

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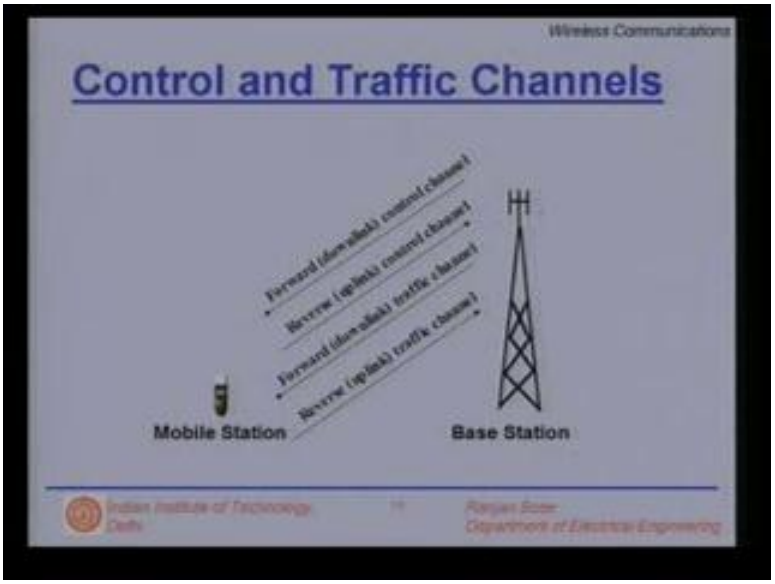

Let’s look at the control and the traffic channels. As mentioned before, control channels are useful for setting up the calls. Traffic channels are useful for actually sending the data. if you are given a certain bandwidth remember, part of that bandwidth is used for control applications and the remainder of the bandwidth is actually used for traffic. So look at the base station which needs to communicate with a mobile. So there could be a downlink or the forward channel which carries the traffic which is actually your voice or data. But to ensure that this traffic channel works perfectly, I need to set it up using a control channel. This is also a forward channel. The mobile station must also communicate by setting up a channel using a control channel called reverse control channel. This is called the uplink and once the channel is set up, you communicate the data using a traffic channel called the uplink traffic channel or the reverse link. that is all we need to know.

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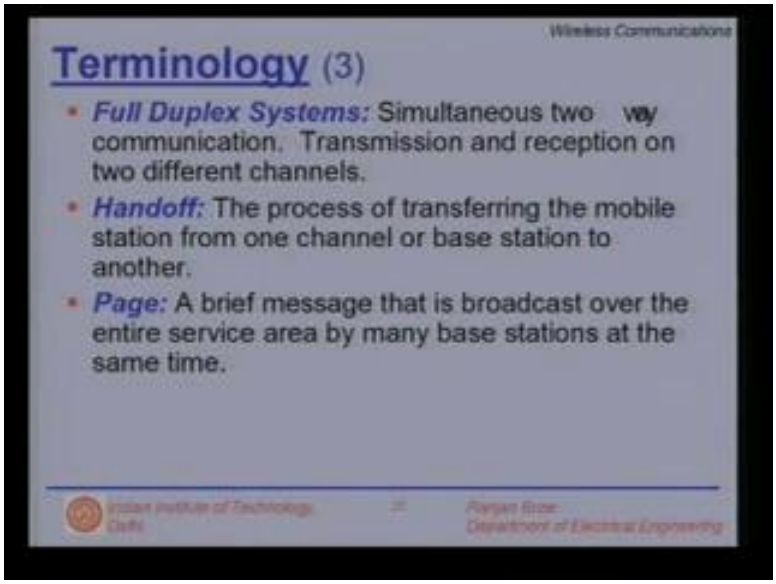

Let's look at some more terminologies. A full duplex system is one where simultaneously two way communications can take place. The transmission and reception take place on two different channels. Handoff is an integral part of all cellular communication systems. Since we have given the freedom to move around, you normally move from one cell to another. That is, you stop communicating with the original base station and then start your communication with the next base station. This process is called handoff. Care should be taken that you do not drop a call. Sometimes when you are moving, suddenly your phone call drops. You lose connectivity. That's because an unsuccessful handoff has taken place. This comes as a part of the quality of service. 'Page' is a brief message that is broadcast over the entire service area by many base stations at the same time primarily to locate where the mobile station is. Clearly when you initiate a call where you do not know where the mobile subscriber is present. You have to do a page. All the base stations have to simultaneously broadcast the information to locate where the users are.

Conversation between student and professor: the question being asked is: how does a base station know where, when and how to handover a call to the next base station? there are various strategies for handoff and today the most popular strategy is mobile assisted handoff – 'the MAHO' where the mobile users' handset has enough intelligence build into it to figure out that it is time to handoff and communicates with the base station and figures out the time to handoff. But how do you handoff? To handoff you should do a make before break. So make before break means at the same time you should be able to get signals from more than one base station. There are various handoff strategies which will be discussed at a later stage. But essentially today we use mobile assisted handoffs.

The question being asked is that what does it mean when we say that when we transfer from one channel to the other channel, usually what happens, when I move from one base station to the other base station of interest, we usually change channels because suppose I was allocated frequency band three in cell number one where I was initially having my conversation and I choose to move to cell number two another frequency band has to be made available. So not only do you change the cell, you have to also change the frequency band which is your channel. Suppose you were using CDMA phones and a handoff has to take place then you have to use a different spreading code. So a code also has to be changed. Not only the base station has to be changed but a different code has to be assigned. In general a quick phone call has to be setup and hence this handoff.

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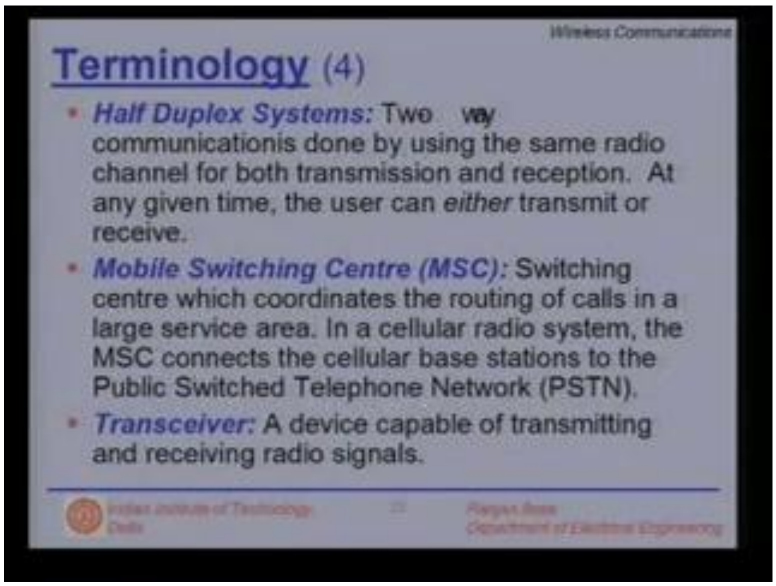

Continuing with the terminologies, half duplex systems use two way communications done by using both the radio channels for transmission and . At any given time the user can either transmit or receive. Mobile switching center are basically the brains behind the cellular switching networks. All of the base stations are connected to this mobile switching centers and these are themselves connected to the public switched telephone network. So the link of the mobile users to the outside world is in terms of the regular telephones. Public switched telephone networks is through the mobile switching center. You can have one or several mobile switching centers today depending upon how big your network is. Transceiver is a device capable of transmitting and receiving the radio signals.

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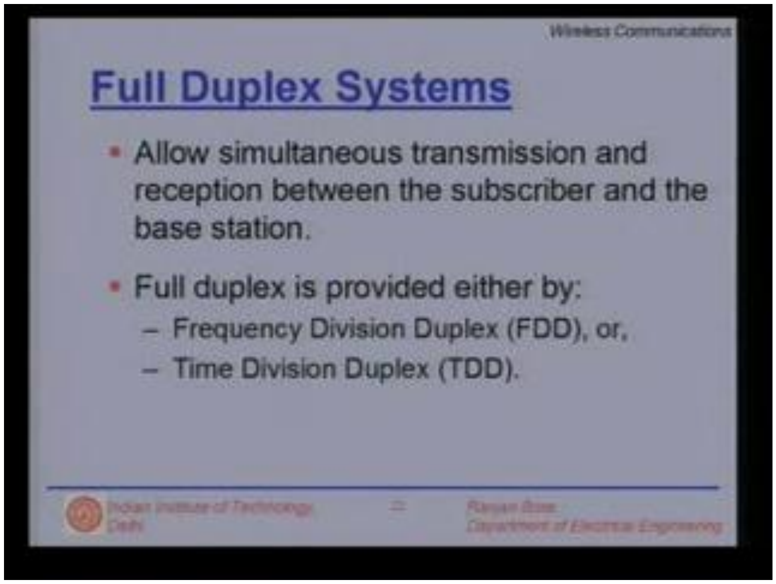

Full duplex systems allow simultaneous transmission and reception between the subscriber and the base station. Full duplex is provided either by FDD or the frequency division duplex or TDD the time division duplex. Please remember these full duplex and half duplex systems refer to only the communication between the mobile and the base station. It is for single user. It should not be confused with the multiple access schemes where it is decided how the channel is divided amongst several users. So a mobile system may use a combination of a multiple access scheme and a duplex systems. For example, I can have an FDMA /FDD or a TDMA / FDD or even FDMA/ TDD. So in FDMA /TDD, we have the big channel bandwidth divided into frequency bands for every user. But within his own band, the user is using TDD. So it becomes an FDMA/ TDD system.

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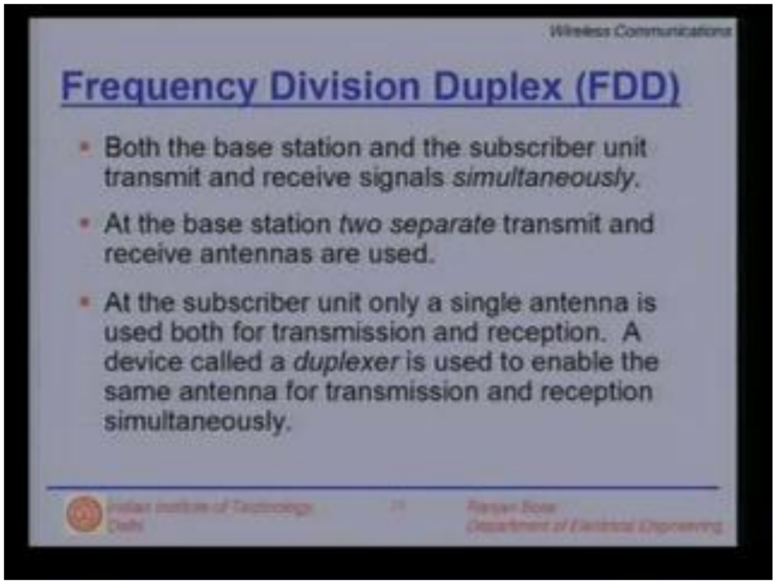

Student: what duplex technique do we use in CDMA systems?

Professor: in CDMA systems, we use TDD systems.

Continuing with FDD or frequency division duplex, both the base station and the subscriber unit transmit and receive signals simultaneously. At the base station, it’s possible to have two separate transmit and receive antennas. At the subscriber’s end, however only single antenna is used because we do not have the luxury of two antennas. We use a device called a duplexer to enable the same antenna for transmission and reception.

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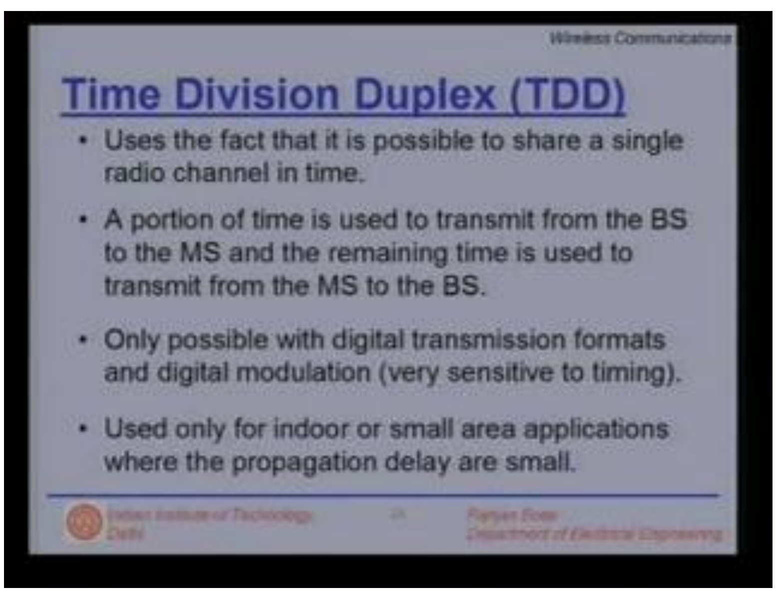

The TDD uses the fact that it is possible to share a single radio channel in time. A portion of time is used to transmit from the base station to the mobile station and the remainder time is used to transmit from the mobile station to the base station. So it's only possible with digital transmission formats and digital modulation because it is very sensitive to the timing. It's used only for small area applications where the delays are under constraint or you have an advance technique to keep the delays under control.

So we will conclude today's lecture at this point. We will go over to the paging systems from the next class.