Wireless Communications
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Lecture No. # 39
GSM and CDMA (Contd.)

Welcome to the next lecture on wireless communications. This is the second part of our lectures on GSM and CDMA. Today we will focus our attention on CDMA technologies. First the outline of today's talk.

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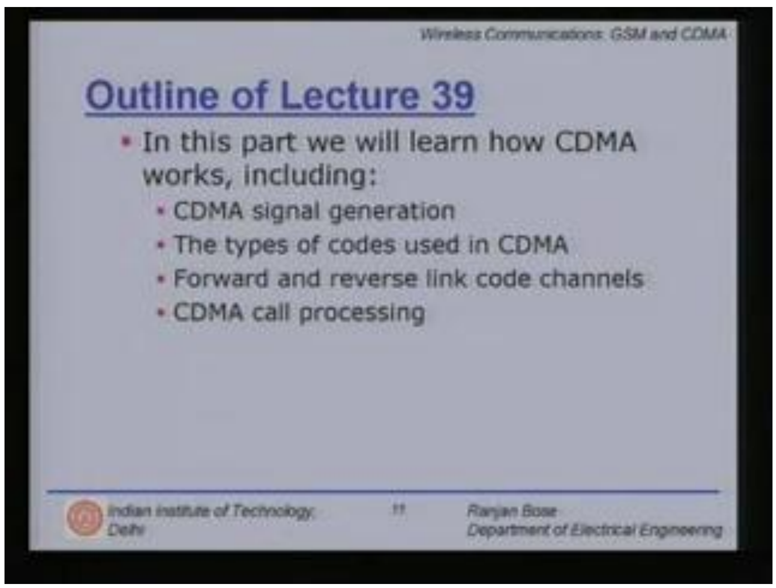

In this talk we'll learn about the CDMA signal generation, the types of codes used in CDMA, forward and reverse link code channels and finally CDMA call processing. So exactly what we want to learn in this part of the lectures is how CDMA systems work. CDMA of course stands for code division multiple access but it is much more than just a multiple access scheme, there is a lot inherent technologies embedded into it which we call together as CDMA.

So the words code and division are important parts of how CDMA works. CDMA uses codes to convert between analog voice signals and digital signals CDMA also uses codes to separate or even divide voice and control data into data streams called channels. So the basic idea is to have some kind of a spreading code which is usually generated using a PN sequence which converts the basic voice signals into digital signals and uses these codes to have separate channels.

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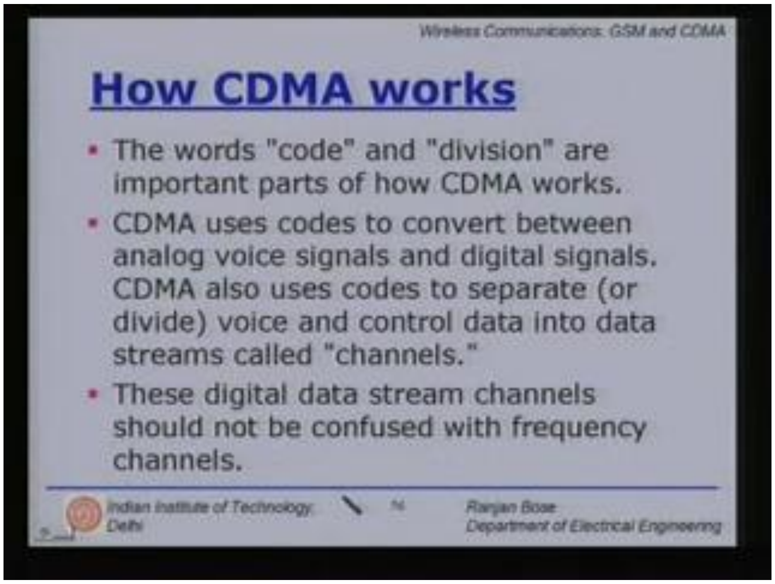

These digital stream data channels should not be confused with frequency channels this completely different, we have another dimension in space the code access. So let us now talk about generating a CDMA signal, there are five essential steps in generating a CDMA signal. First of all we have to go from our analog world to the digital world so we have to do an A to D conversion. Then an important step where a lot of emphasis is paid in CDMA systems as compare to GSM systems is the voice coder or the vocoding part. Then we move on to encoding and interleaving, channelizing of the signals and finally conversion of the digital signals into RF or radio frequency signals. So we will talk about all these five points from the prospective of CDMA systems, please note the use of codes is a key part of this process.

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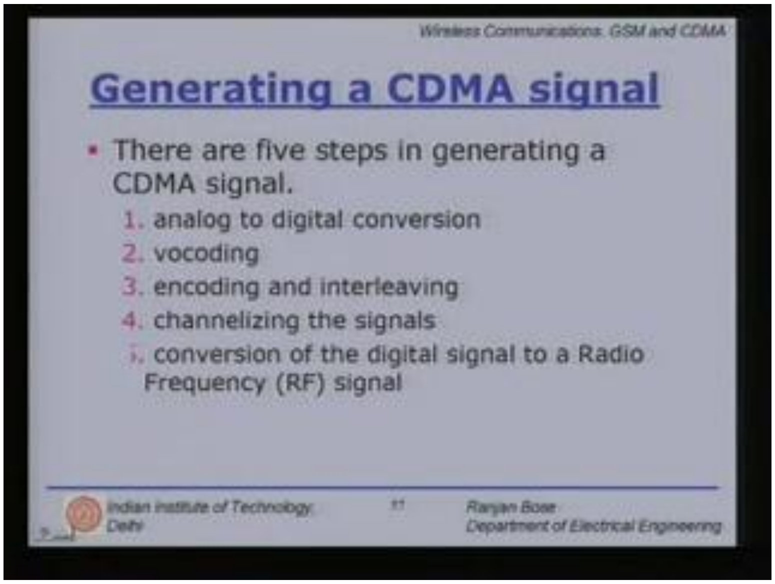

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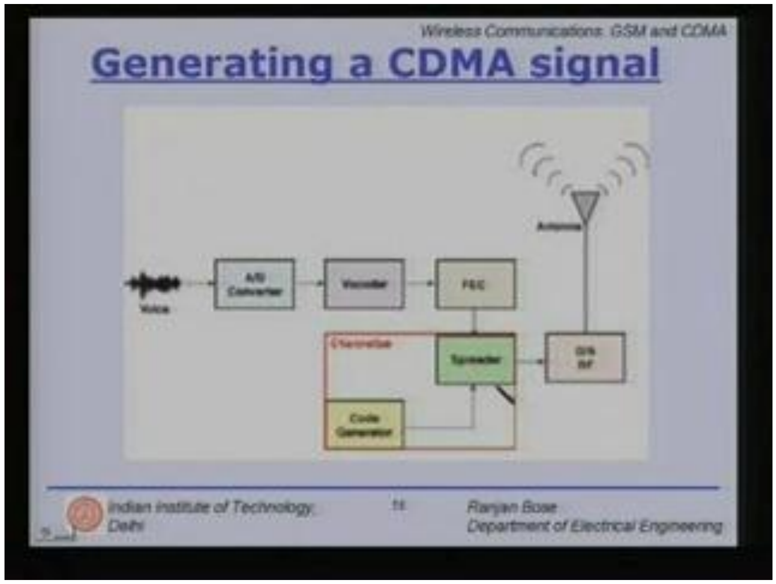

So here is a rough block diagram of how the CDMA transmitter part works. You have an analog voice as you can see and then you go through an A to D converter followed by a vocoder then a forward error correction then you have a channelizing block and then you have D to A converted into RF and radiate out. So this is the generalized block diagram of a CDMA system, how to generate a CDMA signals. We will focus individually into all of these blocks now. First the analog to digital conversion clearly the first step of CDMA signal generation is analog to digital conversion clearly called A to D conversion. Now CDMA uses a technique called the PCM or the pulse code modulation to accomplish this A to D conversion. It is a standard but PCM can have different number of bits per symbol and so we will talk about those also.

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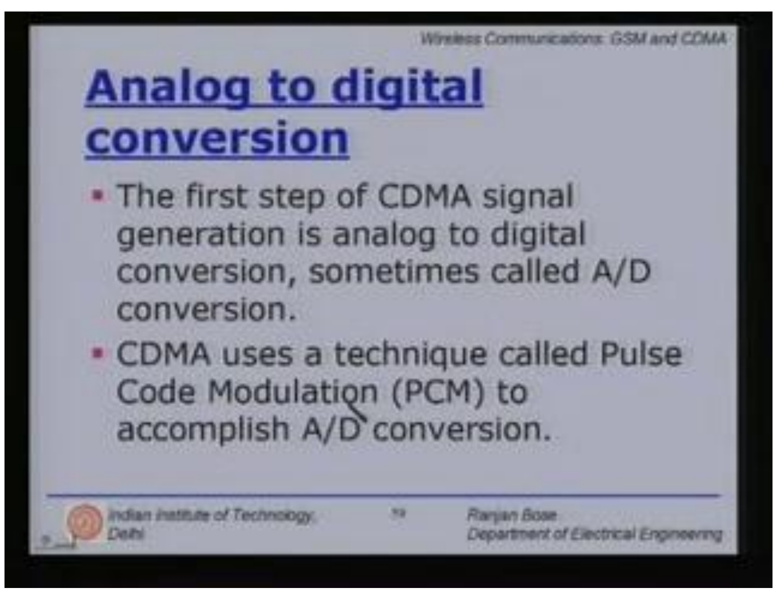

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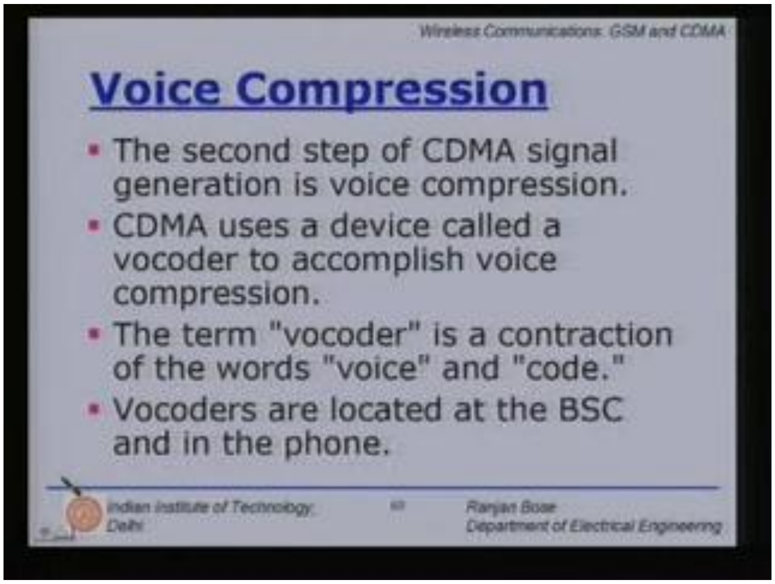

The second step of CDMA signal generation is voice compression. Now CDMA lays a lot of stress on this compression part. CDMA systems use a device called vocoders to accomplish voice compression. The vocoder term is a contraction of the word, voice and coder. Vocoders are actually located at the BSC and in the phone so these are the two places where the vocoders are located in CDMA systems. A slide on how compression is actually carried out so here is a diagram of your analog speech. So you talk for some time then there is a pause; it could be a pause between the words and then you talk for some more time and then there is another speech, there is a pause in this speech and then another section a burst of data.

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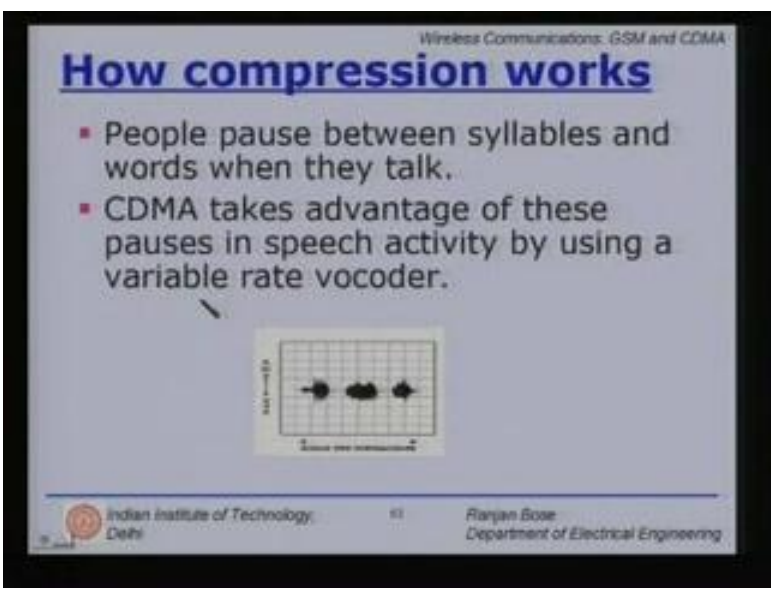

So this pause could be the pause between words or the speaker might be thinking. This is wasted bandwidth in GSM. We have to do something about it, in order to use this vacant parts and that's where the CDMA compression system kicks in. So people pause between syllables and words when they talk and they think while talking so they are natural pauses. CDMA systems takes advantage of these pauses in speech activity by using a variable rate vocoder this is important, so it's a variable rate.

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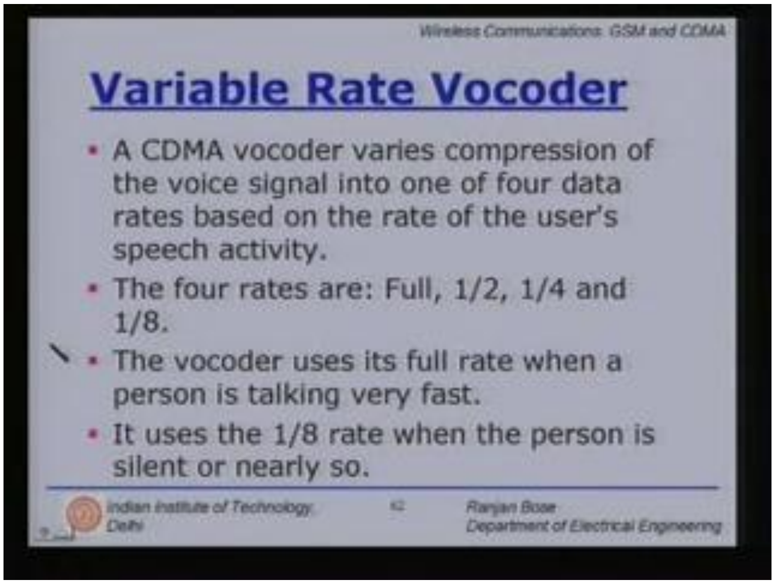

What is the variable rate vocoder? A CDMA vocoder varies the compression of the voice signal into one of the four data rates based on the rate of the user's speech activity. If the person is continuously talking then I will use a different kind of rate with there are lot of gaps in their speech then definitely I will have a much lower data rate. So it is matched to the speech activity of the speaker. The four rates are the full rate, half, one quarter and 1 by 8. So when a person is continually talking then you use the full rate vocoder and when there are deliberate gaps in the speech then you go by 1 by 8. The vocoder uses its full rate when the person is talking very fast, it uses 1 by 8 rate when the person is silent or nearly so.

Let us now cast a retention on the various types of vocoder so CDMA systems can use either an 8 kilobits per second or 13 kilo bytes per second vocoder. Recently the CDMA community adopted a new 8 kbps vocoder, this new vocoder is actually referred to as the EVRC or the extended variable rate coding. What it does is, it combines the quality of 13 kbps vocoding with the capacity of 8 kbps data rate. This is a more enhanced version the extended variable rate vocoding.

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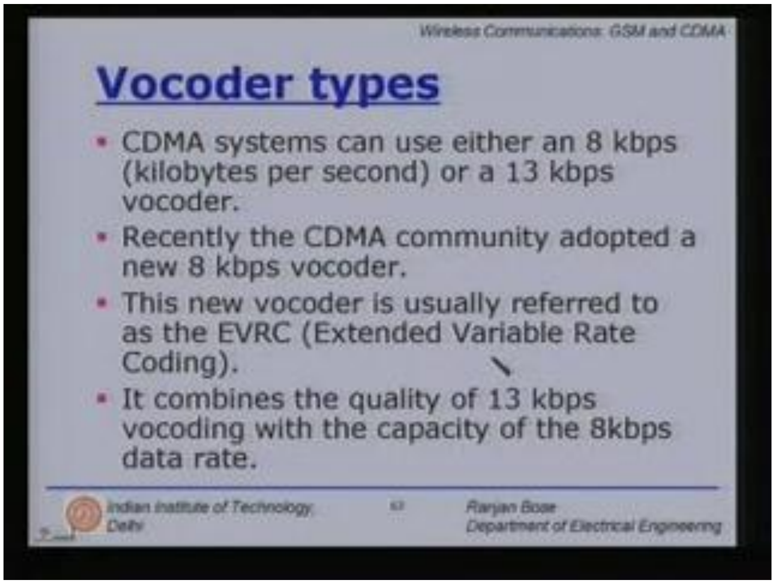

We now move to the next part of the CDMA signal generation part which is encoding and interleaving to take care of the randomness in the channel. Please remember we are dealing with a hostile environment channel where in there is multipath, there is shadowing and then there is additive white Gaussian noise. Encoders and interleavers are built into the BTS and the phones so they exist both at the base stations and the hand held phones. Clearly the purpose of encoding and interleaving is to build redundancy into the signal so that information lost in the transmission can hopefully be recovered back. In our previous lectures we have spend a lot of time talking about different kinds of channel coding and interleaving.

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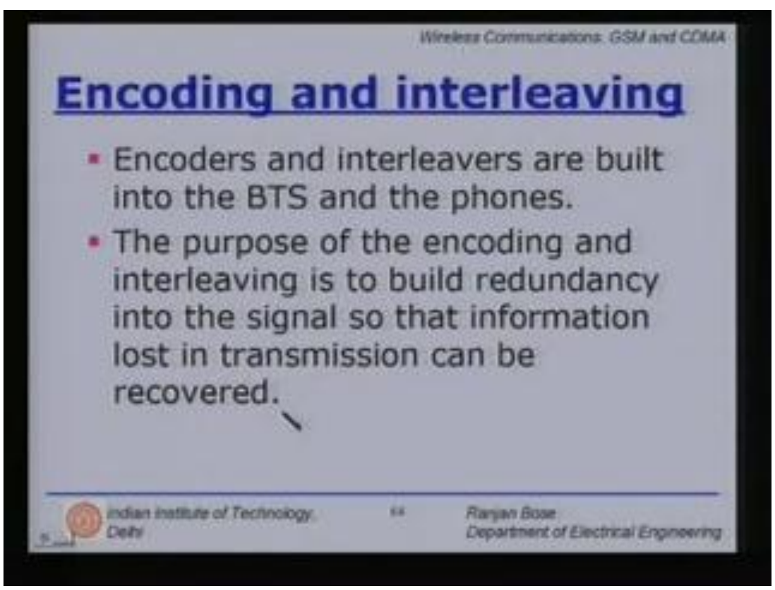

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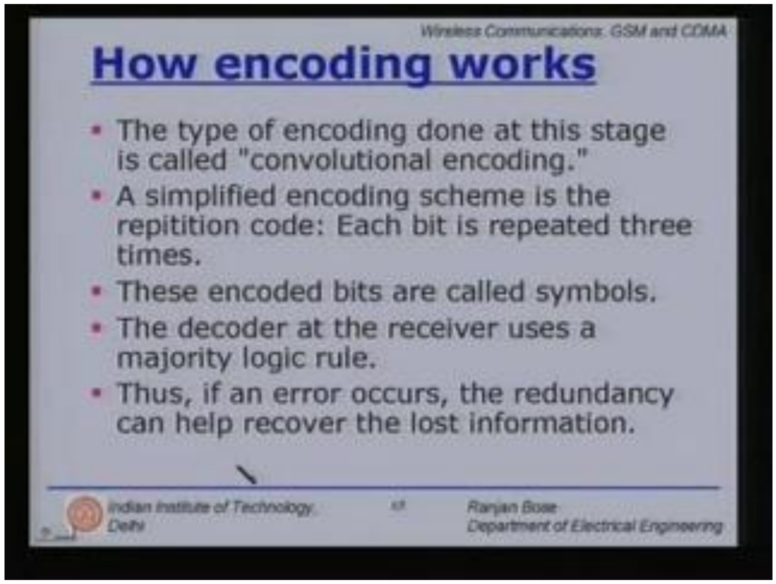

Just a very simple example to refresh our memory how a encoding work. The type of encoding done at this stage is the convolutional encoding. A simplified encoding scheme is the repetition code, this is just for illustration is not used; each bit can be repeated 3 times. Each encoded bit is called a symbol, the decoder at the receiver uses a majority logic if you are doing a repetition code. We have gone in details about linear block codes, cyclic codes and convolutional codes in our previous lectures. Thus if an error occurs the redundancy can help recover the lost information. Now we realized that in mobile channels when we undergo fades we tend to have burst errors. What are burst errors? Burst errors are sequence of bits in error, so it’s not random errors sprinkled all over the data stream they come in bunches and they are known as burst errors.

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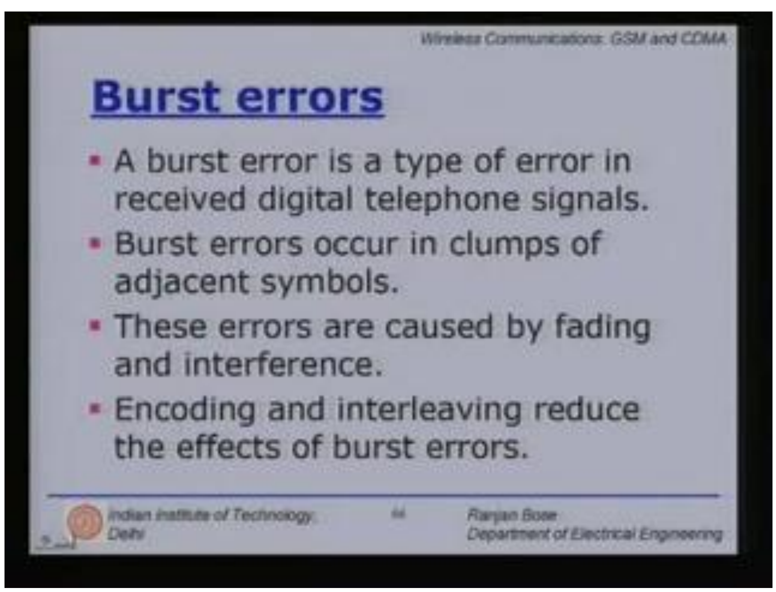

A burst error is a type of error in the received digital telephone signals. Burst errors occur in clumps of adjacent symbols. These errors are caused by fading and interference, suddenly if I move into an area where there is a deep null in the fading profile I encountered burst errors or if I move in region where suddenly there is a lot of interference coming from one of the interfering base stations I again lose lot of bits in a sequence. Encoding and interleaving reduce the effects of burst errors. CDMA systems employ strong burst error correcting techniques.

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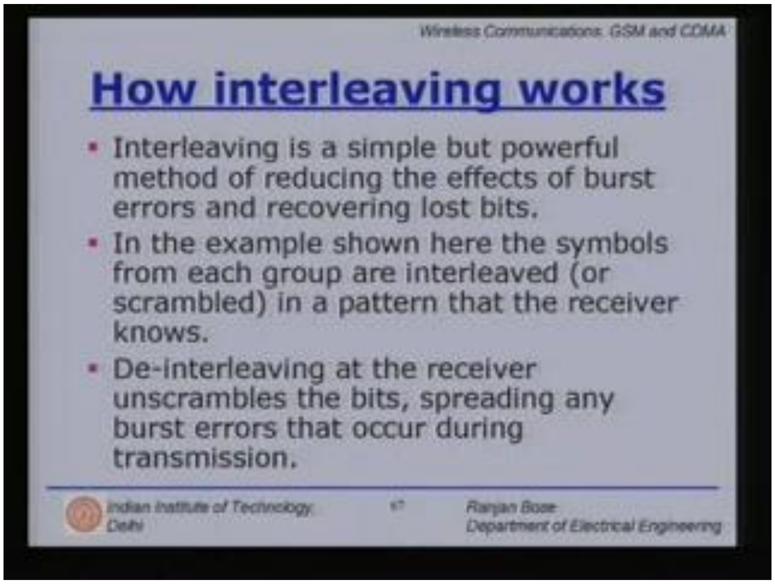

Now let us talk about interleaving. Interleaving is a simple yet powerful method of reducing the effects of burst errors and recovering lost bits. So in the example here, the symbols from each group are interleaved or scrambled in a pattern that the receiver knows. A very simple way is to have a lot of memory, you read in the data row wise into the memory and read out the data column wise. At the receiver side you put in the data column wise and read out row wise so that you undo the effect but what will happen is all the burst errors will then get distributed over the data sequence but that is just one of the simple ways.

Actually we can use any special kind of scrambling before sending the data and then unscrambled the data either receiver so as to distribute the burst errors. We can have various kinds of interleavers random interleaver, semi random interleaver, chaotic interleaver and a host of other kinds of scrambled. De-interleaving at the receiver, unscrambles the bits spreading any burst errors that occurs during the transmission. This is the general philosophy how interleaving works.

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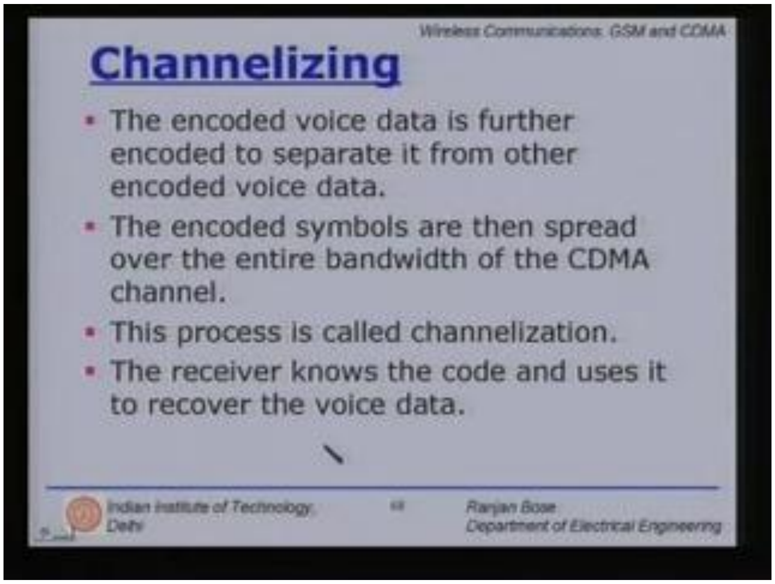

The next step in CDMA systems is channelizing. The encoded voice data is further encoded to separate it from other encoded voice data. The encoded symbols are then spread over the entire bandwidth of the CDMA channels. This process is called channelization. The receiver knows the code and uses it to recover the voice data so every channel uses its own PN sequence to spread the data and the receiver de-spread the data. So let us consider a simple example when there is a user 1 and user 2 and they use their own PN sequences codes here, code 1 and code 2 to send their own data but please note CDMA system is using the entire bandwidth all the time for both the users. So clearly they are interfering with each other, intentional interference but at the receiver if you use the code of user 1 to decode you de-spread your own signal but spread further the signal received from the interfering user thereby you obtain the useful data for yourself.
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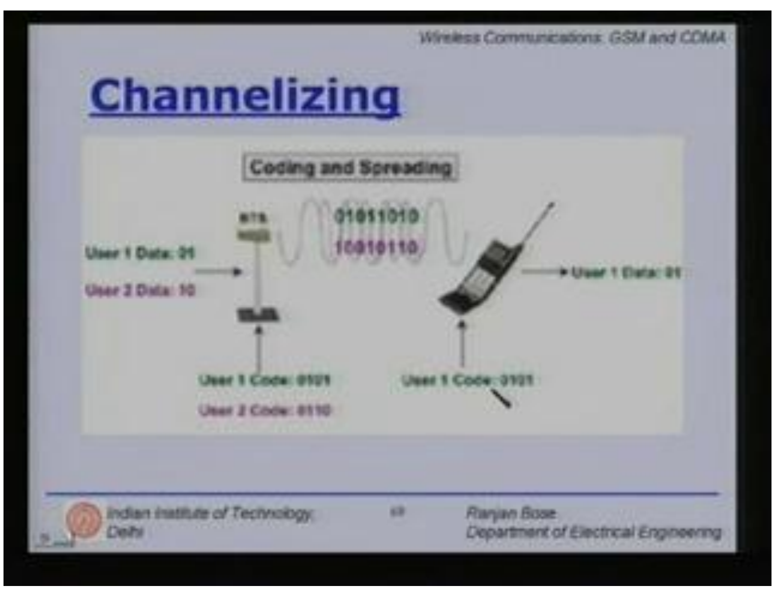

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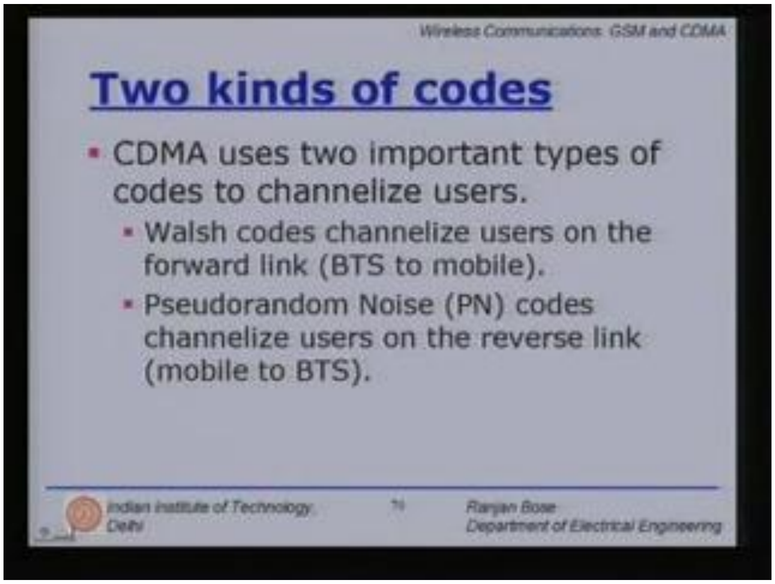

CDMA uses two important types of codes to channelize users, one is the Walsh code the other is the pseudorandom noise or PN codes. Walsh codes channelize users on the forward link that is base station to mobile. There you have the luxury of more power whereas PN codes channelize users on the reverse link that is from the mobile to the base station there we depend on the battery power and we do not have the luxury of unlimited power. Therefore you need to use two different kinds of codes based on the efficiency and performance. Walsh codes for the downlink or the forward link, PN codes for the uplink or the reverse link. Walsh codes provide a means to uniquely identify each user on the forward link. What is the property of Walsh codes? Thereby unique mathematically property that they are orthogonal. In other words Walsh codes are unique enough that the voice data can only be recovered by a receiver applying the same Walsh code.

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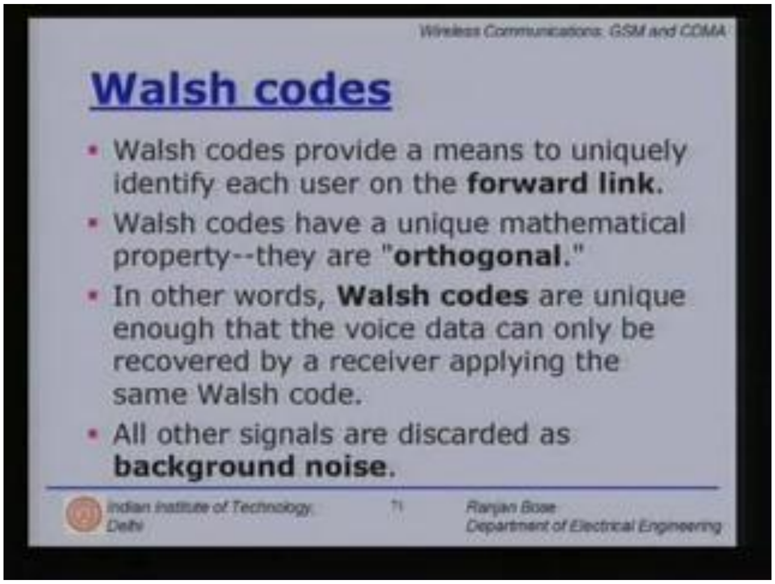

It has its almost close to orthogonal very good autocorrelation and cross correlation properties. The basic idea of any good code is that when you correlated with your own code that is auto correlated, you get a strong peak and when you cross correlated you get a very low value. So what happens is all the other signals are discarded as background noise. PN codes uniquely identify users on the reverse link. A PN code is one that appears to be random but actually it isn't hence the pseudo part. The PN codes used in CDMA yield about 4.4 trillion combinations of code. So what does it do apart from channelizing? It is making this system highly secure.

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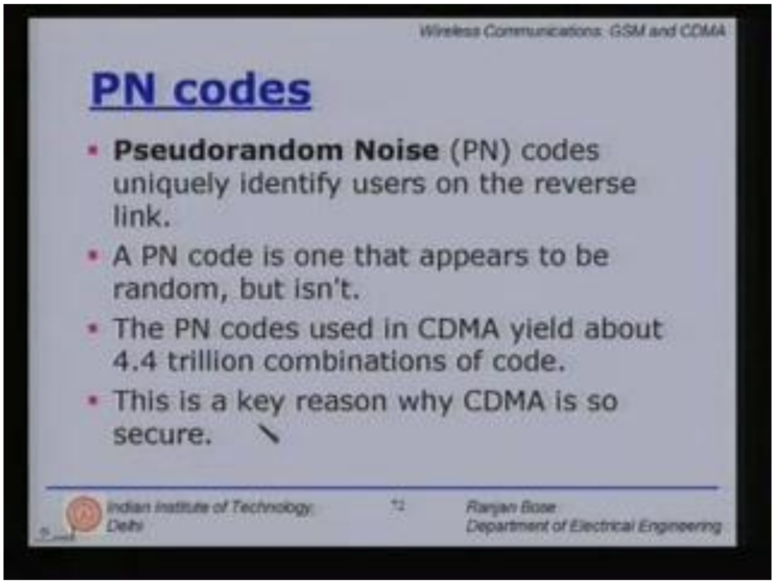

This is a key reason why CDMA is also very secure, inherent advantage of CDMA over your GSM technologies. In GSM we have to use stronger and stronger codes, authentication codes and other kind of cryptographic codes to ensure security. [Conversation between Student and Professor – Not audible ((00:18:39 min))] Question being asked is the PN code fixed for every mobile. The answer is we have a set of PN codes just like in GSM depending upon when you wish to make the call you assign the frequency and a time slot. Here there assigned a particular code when you wish to make a call. So if your phone is on but is in the standby mode then your code can be given to somebody else.

So a code is not fixed or logged, also when you move from one base station to another then you may have to switch between codes. My mobile is given a code during the transaction when I call my code is also transmit any signal to the receiver side. Question being asked is how is the communication set up between mobile and the base station as to which is the code being used. So in the hand shaking phase, before the call actually starts it is decided apart from the synchronization and power control issues on the control channels which PN code will be used and only that one will be used for the entire duration of the call with that particular base station. If you move to the other region in the hand off process your code may be changed. Sir; also why we are using vocoders at both mobile and the base station, base station only as to transmit information.

Question being asked is why are vocoders being used at both the base stations and mobile stations. Vocoders purpose is to compress so it doesn't matter speech for example, as so lot of inbuilt redundancy because of pauses. So that makes the use of vocoders justified. You are packing in a lot more information. [Conversation between Student and Professor – Not audible ((00:20:44 min))] Speeches coming from both the mobile; the speech communication is two way so it is required to use the vocoders. If there is a PSTN to a mobile call then also we need to use the vocoders to compress it, so it is built in to the standard. Question being asked is, do two different mobiles have different set of PN codes? The answer is two different base stations may have different sets of codes which will be assigned to the mobile and when the mobile goes from one base station to the other then there will be hand off of the codes. So you negotiate again, decide on the control channels which next PN sequence you are going to use and then continue your conversation.

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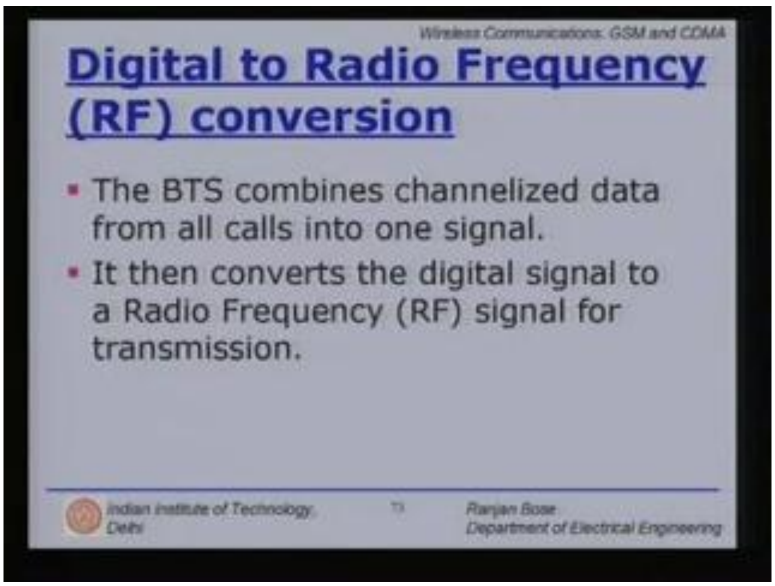

The final stage into generating the CDMA signal is the digital to radio frequency or RF conversion. The BTS combines channelized data from all calls into one signal, it then converts the digital signal to the RF signal for transmission.

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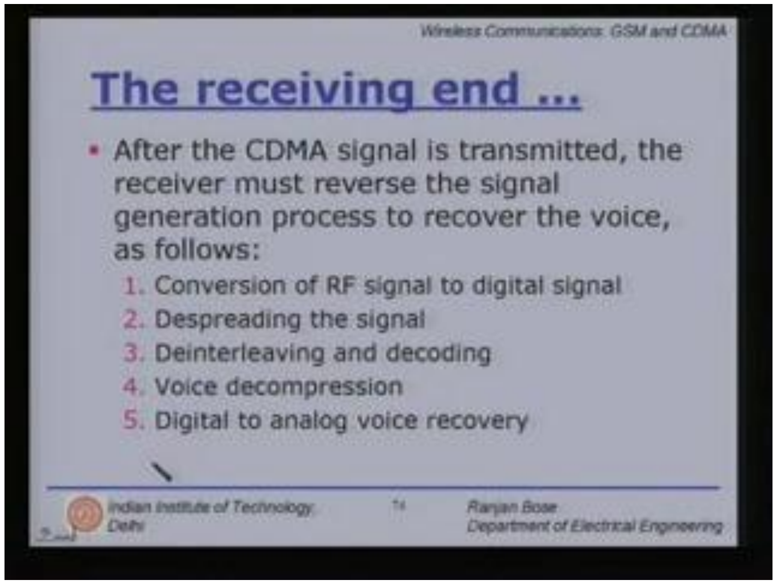

We now move to the receiving end, so from base station we go to the receiver, after the CDMA signal is transmitted the receiver must reverse the signal generation process to recover the voice as follows. Conversion of RF to digital signal, de-spread the signal, de-interleave and decode, voice decompression and finally digital to analog voice recovery just the reverse of the process. If all of them work well we hear the voice with clarity.

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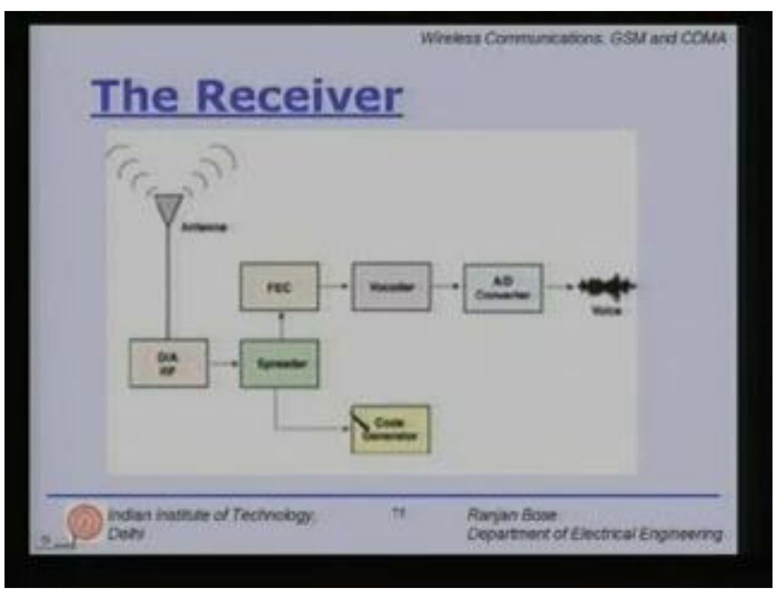

So the receiver block diagram looks like follows; there is an antenna and then there is a D to A RF. It goes to the de-spreader then you have the forward error correction module followed by the vocoder A to D and your recovered voice signal.

This is the rough block diagram of the CDMA receiver, of course you need to have a code generator in order to de-spread which code is being used is pre decided during the conversation. If I go from one base station to other then this code generator will switch from code one to code two.

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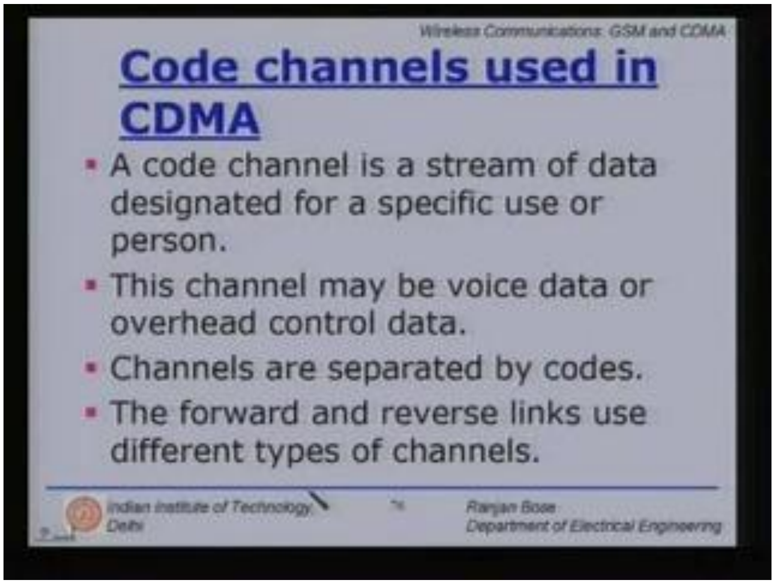

A code channel is a stream of data designated for a specific use or person. This channel may be voice data or overhead control data. Please note in CDMA also we need a lot of control channels as well as traffic channels. Channels are separated by codes hence this is a CDMA system, the forward and reverse links use different types of channels.

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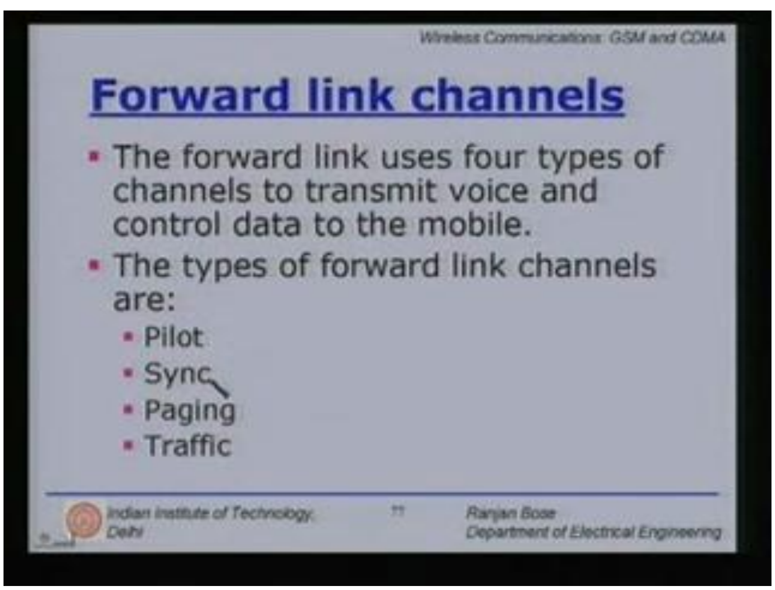

First the forward link channels, the forward link uses four types of channels to transmit voice and control data to the mobile. Please remember forward link implies base station to the mobile. The types of forward link channels are pilot, sync, paging and traffic. As a name suggest all four are meant for different purposes.

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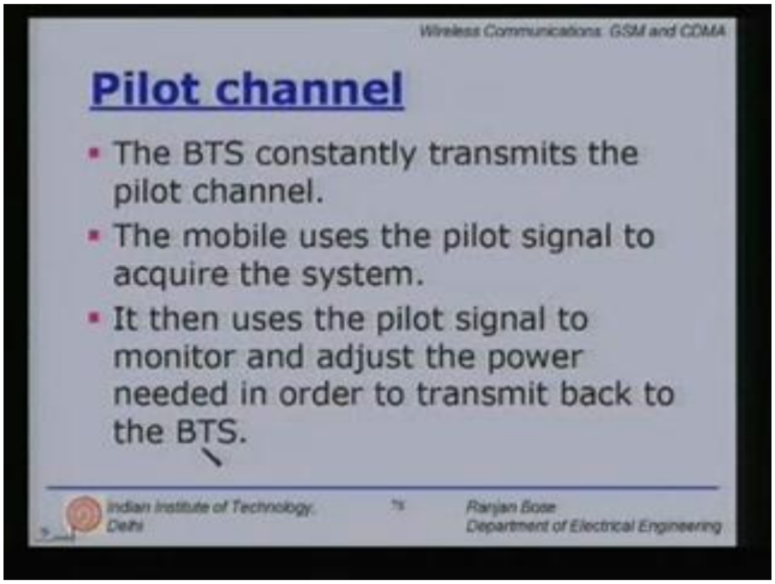

What does the pilot channel do? The BTS or base station constantly transmits the pilot channel. the mobile uses the pilot signals to acquire the system. It then uses the pilot signal to monitor and adjust the power needed in order to transmit back to the base station. Please note that CDMA systems rely heavily on power control. So the CDMA system can be compared within this room to a very simple example that all of the students in the room are talking in a different language. So English, French, German, Tamil, Hindi and I as the teacher I am able to understand all the languages. So each language forms a code and all of the users are talking at the same time. The base station which understands all the languages can uniquely decode each of the languages. So all the users which are the students in this class are using the entire bandwidth all the time but using their own code which is the specific language to talk.

Now what is important is the student sitting in the first row must speak softly otherwise they will drown the sound coming from those sitting at the back bench. The users which are closer to the base station must transmit at lower power, those at far away must use a higher power. Who will decide how much power to use? This has to be decided by some kind of a control channel and pilot channel is use to do that. So please remember this is the near far problem in CDMA system where there is a threat of our mobile close to the base station drowning the signals coming from a mobile far away from the base station. Hence power control is essential for the proper working of CDMA systems. Sir one more question, if the second hand receiver are using the code and during the hand over from one base station to the other, should the same base code is used or the other? The question being asked is while a conversation is going on suppose the mobile moves over to another base station and a hand over is started so is this same code maintained or not.

So the answer is most likely not because even though that code may be available in the next set, it may be already being use by some other user. So invariably you will be assigned a new code to talk while you are within the domain of the next base station so the code will change.

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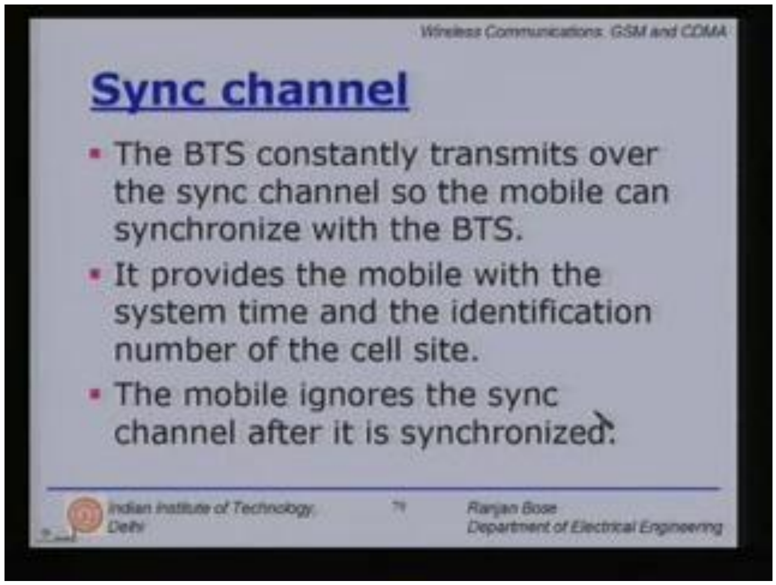

Sync channel, the BTS constantly transmits over the sync channel so that the mobile can synchronize with the base station. Please note the PN sequences are good only if your time reference is good. Even if you shift the PN sequence slightly with respect to the original PN sequence, the autocorrelation will go bad. So synchronization is of at most importance. It provides the mobile with the system time and the identification number of the cell site so it's primarily used for time synchronization. The mobile ignores the sync channel after it is synchronized. So it will transmits a set of known patterns by virtual of which you synchronize basically lock in.

Paging channel, the name suggest is used for paging a mobile. CDMA uses up to 7 paging channels. The paging channel transmits overhead information such as commands and pages to the mobile. The paging channel also sends commands and traffic channel assignment during call set up. So each time we are talking about handover, this call set up must be initiated. The mobile ignores the paging channel after a traffic channel is established. What do we mean by traffic channel? Once the voice communication starts, the paging channel is no longer required.

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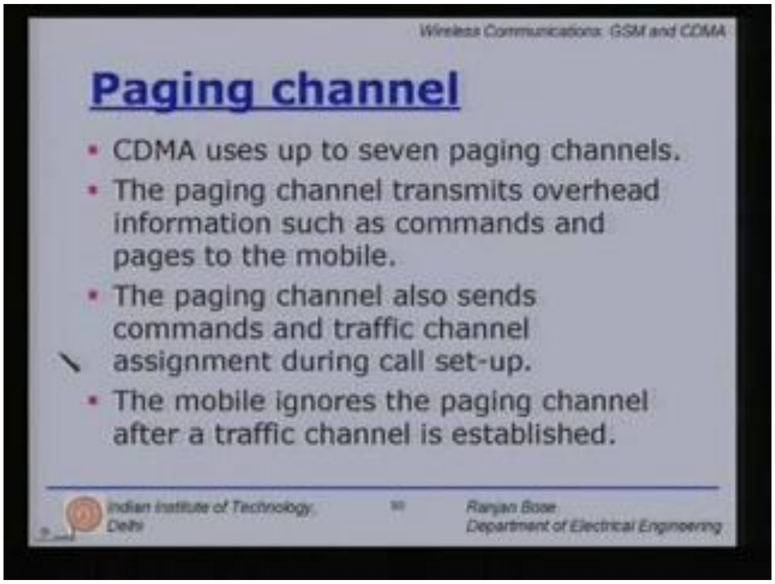

Forward link traffic channels, CDMA uses between 55 and 61 forward traffic channels to send both voice and overhead control data during a call. This 5 numbers come up because we need certain number of orthogonal codes if you increase the number of codes you have to increase the length of the codes to ensure that their proper orthogonality remains but there is an upper bound on the length of the code we can put for real time voice communications. So these numbers like 55 and 61 number of channels come out limited by the number of orthogonal codes that are available. Once the call is completed, the mobile tunes back in to the paging channels for commands and pages. So it is like a state diagram so either it is in a traffic mode or it is in the weight state tuned into the base station waiting for the commands.

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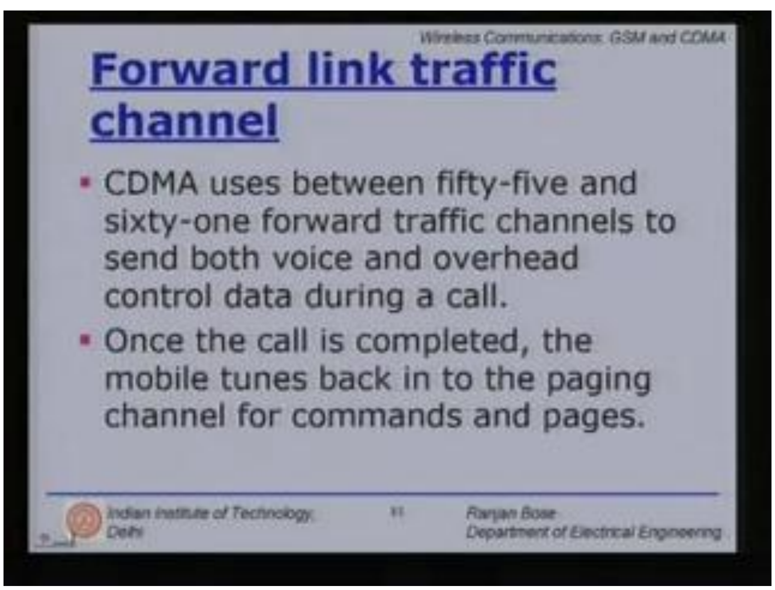

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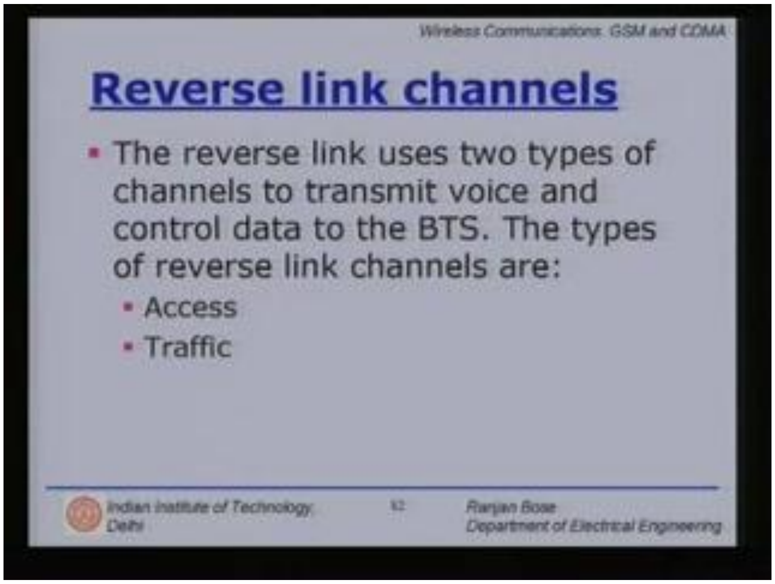

Let us talk about the reverse link channels. The channels provided from the mobile to the base station. The reverse link uses two types of channels to transmit voice and control data to the base station. The types of reverse link are access and traffic. Now what do we mean by access channel? The mobile uses the access channel when not assigned to a traffic channel. The mobile uses the access channel to do the following. First it has to register with the network so the moment you switch on the phone in any territory you have to register with the user with the network to tell okay I am there, I can be paged later on. Access channel is also used to originate calls, respond to pages and commands transmit overhead messages to the base station.

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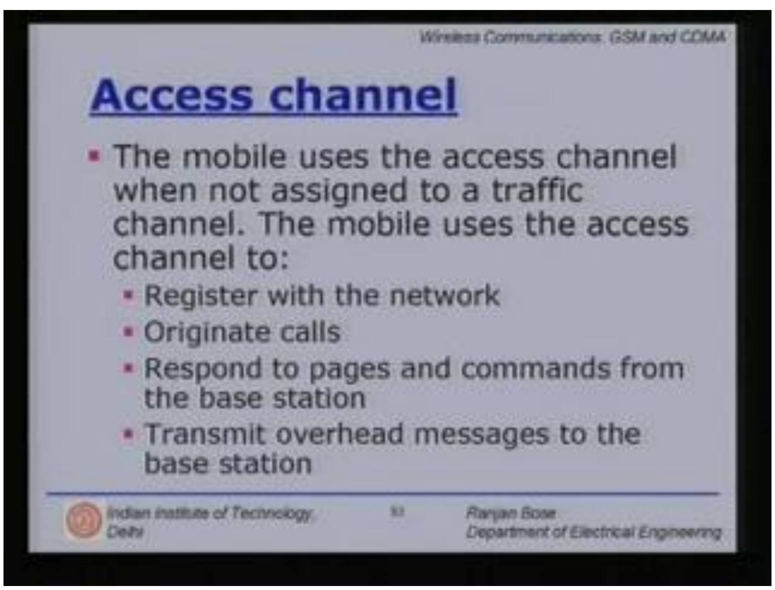

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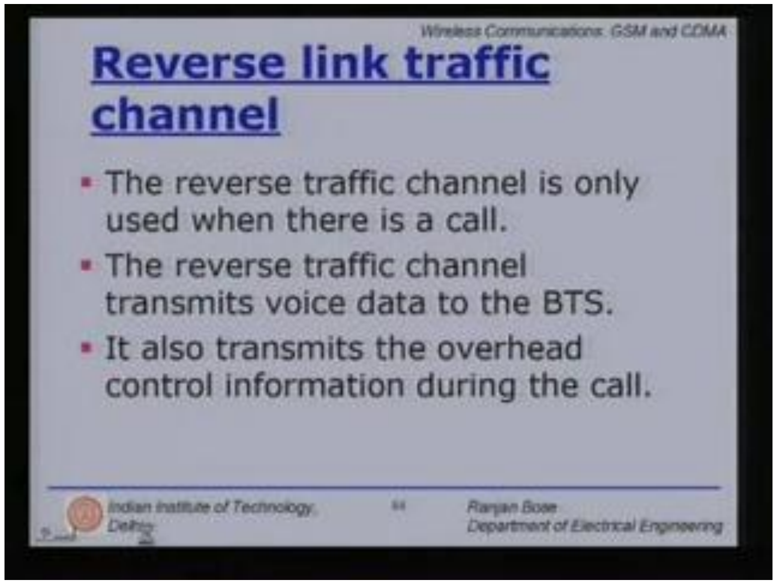

Now the reverse link traffic channel is used only when there is a call. The reverse traffic channel transmits voice data to the BTS; it also transmits the overhead control information during the call. Let us see how it works. There is an initialization and then there is an idle mode. It can go to the access mode if there is a call initiated; you go to the traffic mode and then go back to the idle mode once the voice communication is over. So this is the basic state diagram for the call processing at the mobile. So there are 4 stages or modes in the CDMA call processing initialization, idle, access and finally traffic mode.

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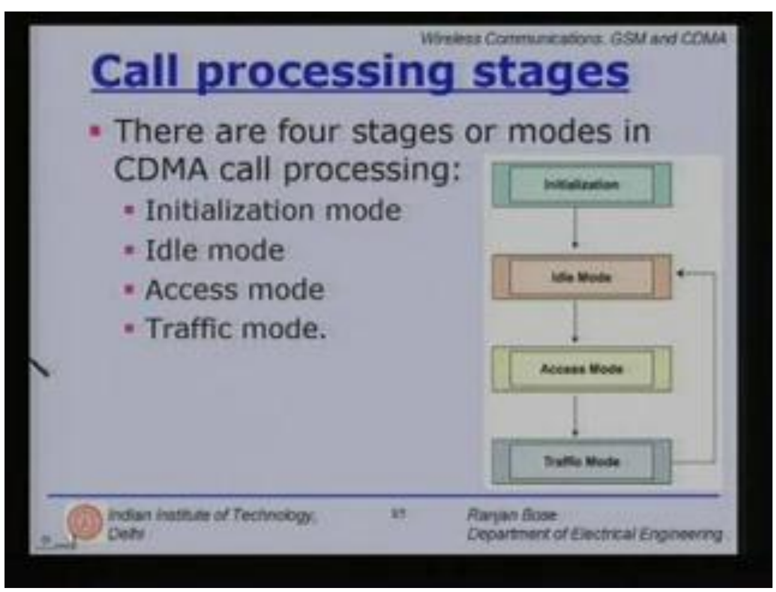

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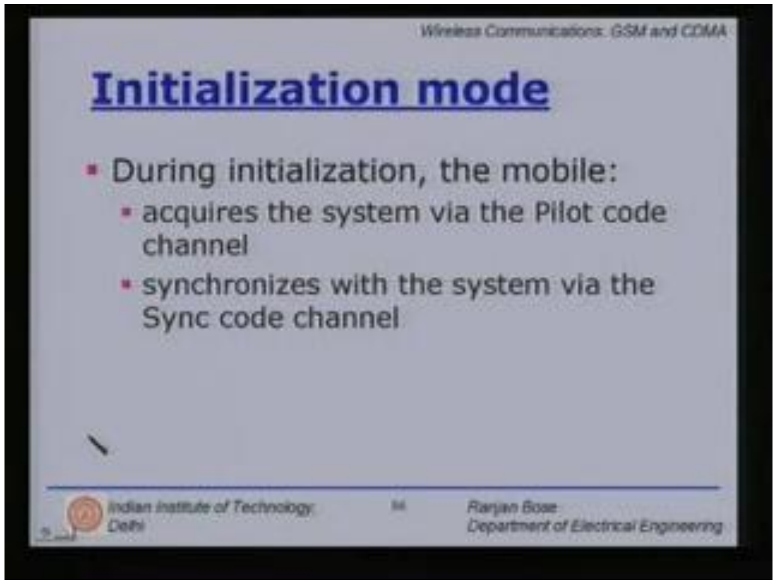

Let's talk about these modes; during initialization the mobile does the following. It acquires the system via the pilot code channel and then it synchronizes with the system via the sync code channel. Clearly you need to set your transmit power information correct and use time synchronization correct. Once these two are there, your all initialized rearing to go for any request for a voice communication. Needless to say these have to be updated periodically. The idle mode; this is when the mobile is not involved in a call but it must stay in communication with the base station and clearly it will expend some battery power. The mobile and the base station communicate over the access and the paging code channels and the mobile obtains overhead information via the paging code channel. At this time there is no voice communication taking place simply because there is no request for voice.

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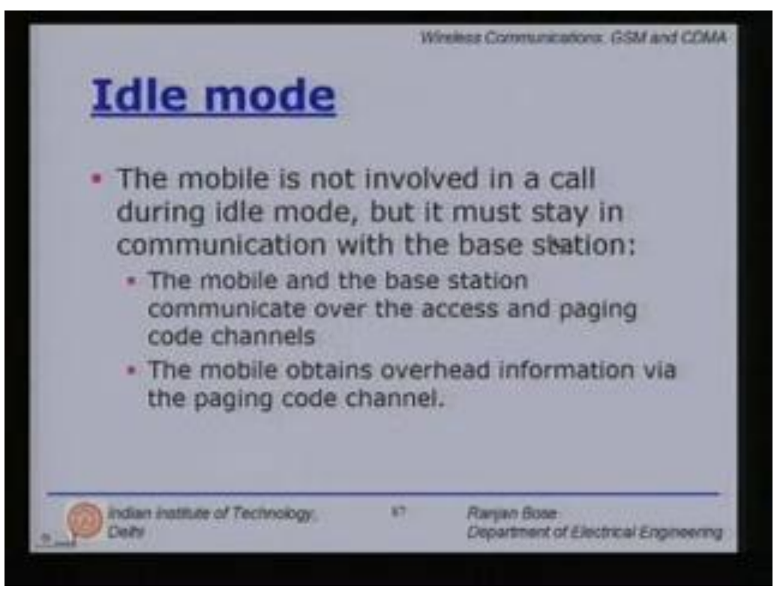

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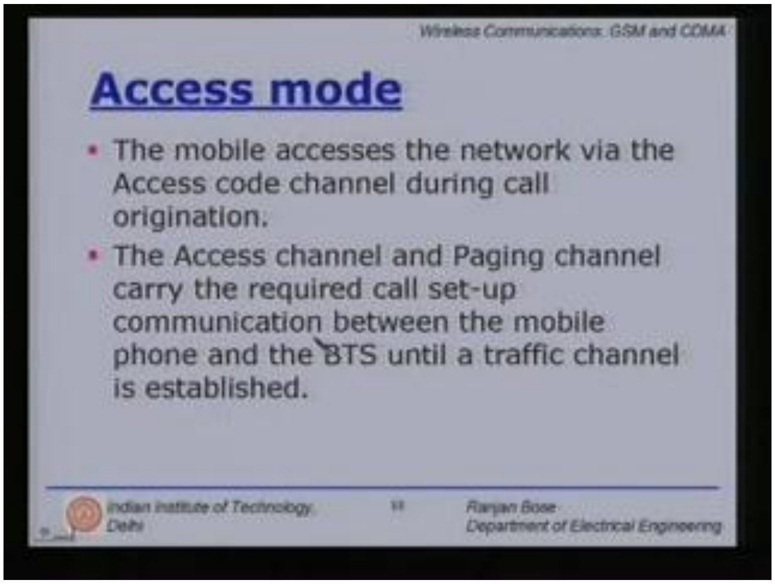

Now the access mode, the mobile accesses the network via the access code channel during call origination. The access channel and the paging channels carry the required call set up communication between the mobile phone and the BTS until a traffic channel is established. So you exchange information on what kind of code will be used. The power is already set up and once these basic requirements are put together we try to move to the next mode which will be actually the traffic mode. Sir in idle mode the base station will be assigning in PN code also to the model user like it means that all time the mobile user have the PN code.

The question being asked is in the access mode, does the base station assign the PN code? Answer is yes, during this mode only a mutual agreement is there as to which code will be used. So it has a set of codes but which one to use will be decided during this access. [Conversation between Student and Professor – Not audible ((00:35:27 min))] No, in idle mode the code is not decided. At that time we only talk about the power that are required to use and the time synchronization. Time synchronization is important even to carry out the communication regarding which PN sequence to use because all the communication is being done based on codes.

So timing and power are essential requirements for communication, not necessarily voice even control information. Therefore if you go to the idle mode and initialization mode here you must acquire the system and maintain the synchronization because communication is required even to communicate which PN sequence to use. [Conversation between Student and Professor – Not audible ((00:36:25 min))] Those are pre decided so the codes required for idle channel that is for communicating synchronizing, acquiring the system those are pre decided. So when you switch on your phone you already have them hardwired.

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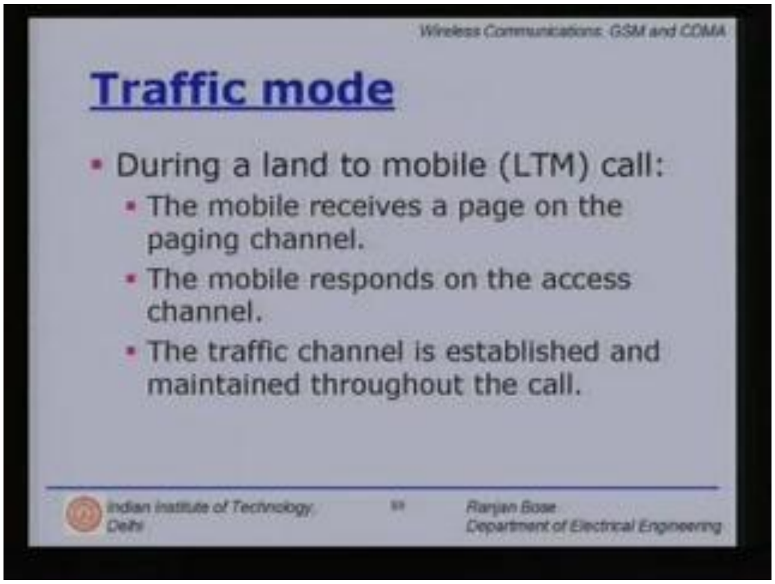

So we comeback to traffic mode so during a land to mobile call, the mobile receives a page on the paging channel, the mobile clearly responds on the access channel. The traffic channel is established and is maintained throughout the call, so the same PN sequence is maintained. During a mobile to landline call, the call is placed using the access channel. The base station responds on the paging channel and the traffic channel is established and maintained throughout the call.

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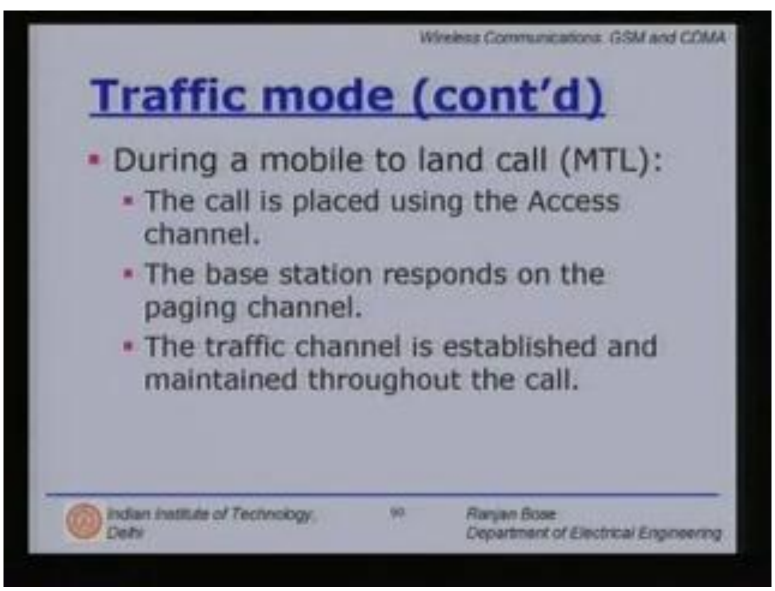

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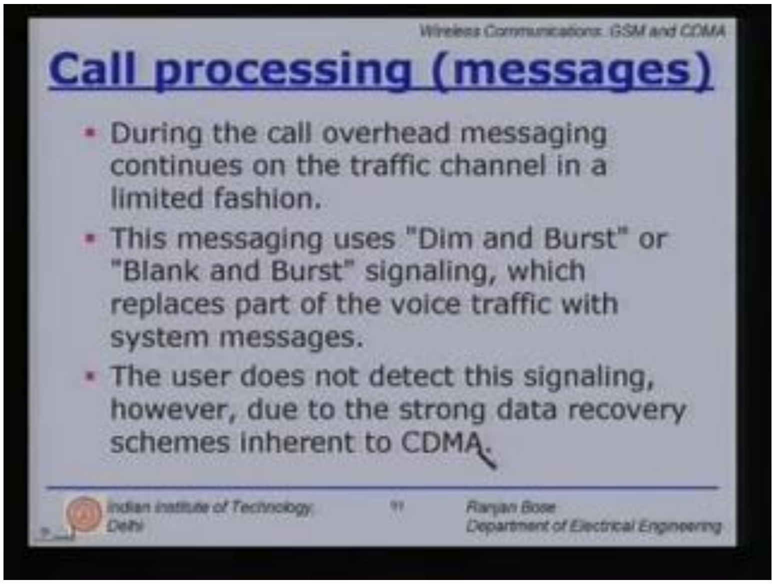

Call processing for messages; during the call overhead messaging continues on the traffic channel in a limited fashion. So please note even though your call has been made overhead messaging continues in parallel in a limited fashion. The message uses dim and burst or blank in burst signaling which replaces part of the voice traffic with system messages. The user does not detect this signaling however due to the strong data recovery schemes inherent in CDMA. As we discussed before CDMA has bifurcated and comes in two flavors today, the cdma 2000 which was originally proposed by Qualcomm and the WCDMA standard. So there has been an ongoing debate which finally has not been resolved and so we now have two 3 G standards.

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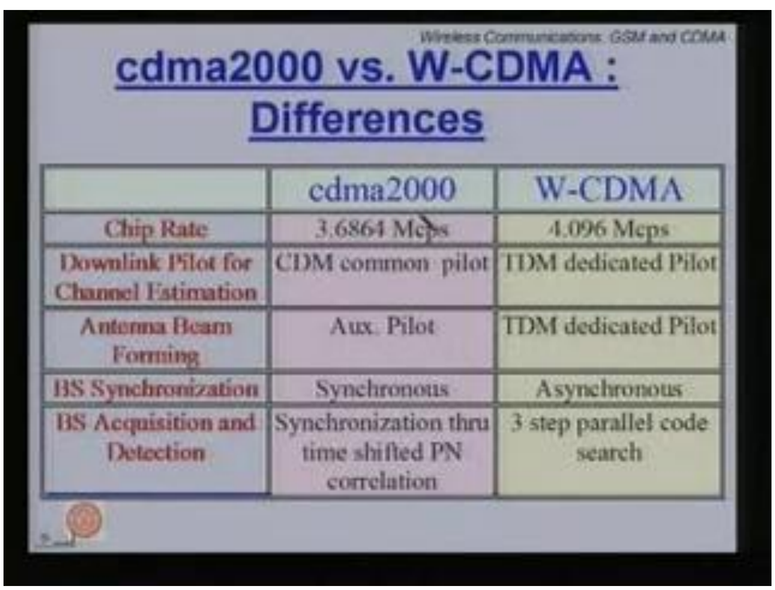

	cdma2000	W-CDMA
Chip Rate	3.6864 Mcps	4.096 Mcps
Downlink Pilot for Channel Estimation	CDM common pilot	TDM dedicated Pilot
Antenna Beam Forming	Aux. Pilot	TDM dedicated Pilot
BS Synchronization	Synchronous	Asynchronous
BS Acquisition and Detection	Synchronization thru time shifted PN correlation	3 step parallel code search

The cdma 2000 standard and the WCDMA, the cdma 2000 standard had to be different because Qualcomm owns about 200 key patents here which cannot be violated and it is also too expensive so WCDMA independent standard also exists. We will try to do is look at the differences and similarities between these two standards, very briefly. In India we are following cdma 2001 x. So in this table we have the various parameters for example look at the chip rate. Chip rate is defined as the minimum chip interval used in the spreading codes. Chip rate is much smaller than the bit rate, the smaller the chip rate the more the signal will be spread. Now cdma 2000 for example uses 3.68 mega chips per second whereas W-CDMA uses 4.096 mega chips per second.

There is no reason why they have to be different right, so these are minor differences. If you look at the down link pilot for channel estimation it is using CDM common pilot whereas WCDMA uses TDM dedicated pilot. Antenna beam forming you have the auxiliary pilot whereas here TDM dedicated pilot is used for antenna beam forming. What about a synchronization? In cdma 2000 we have synchronous whereas in WCDMA it is asynchronous mode of synchronization. Acquisition and detection of the base station here the synchronization is through time shifted PN sequence whereas in WCDMA you have an elaborate three step parallel code search method. So these are some differences which come out between cdma 2000 and WCDMA. This table has been put up just as an illustration of some of the differences which are there; you can have several slides just to delineate the differences between cdma 2000 and WCDMA.

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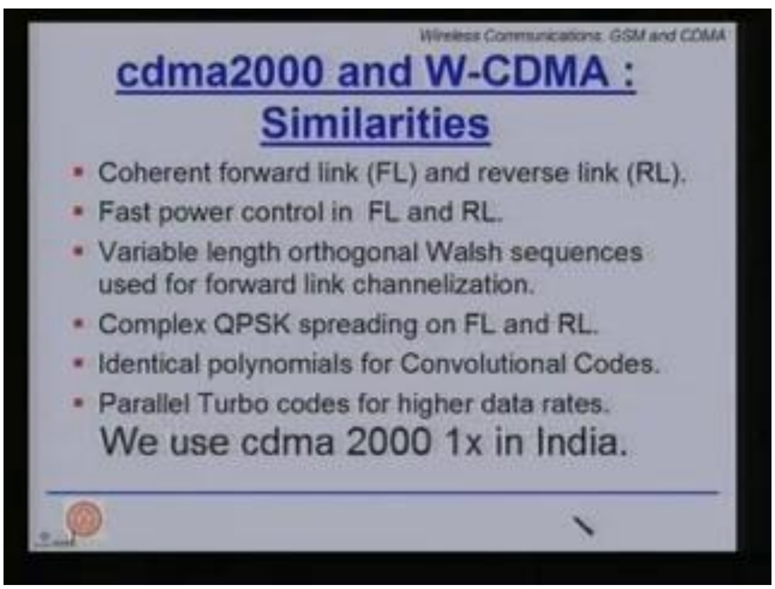

Of course there are lot of similarities also, so you have coherent forward link and reverse link in both, you need fast power control in forward link and reverse link. It’s an essential requirement of all CDMA systems. You have variable length orthogonal Walsh sequences used for forward link channelization. You have complex QPSK spreading on forward link and reverse link. These are identical for both systems, identical polynomials for convolutional codes or very similar polynomials for convolutional codes. Then you use parallel turbo codes for higher data rates. Of course has mentioned before we use cdma 2001 x EVDO in India.

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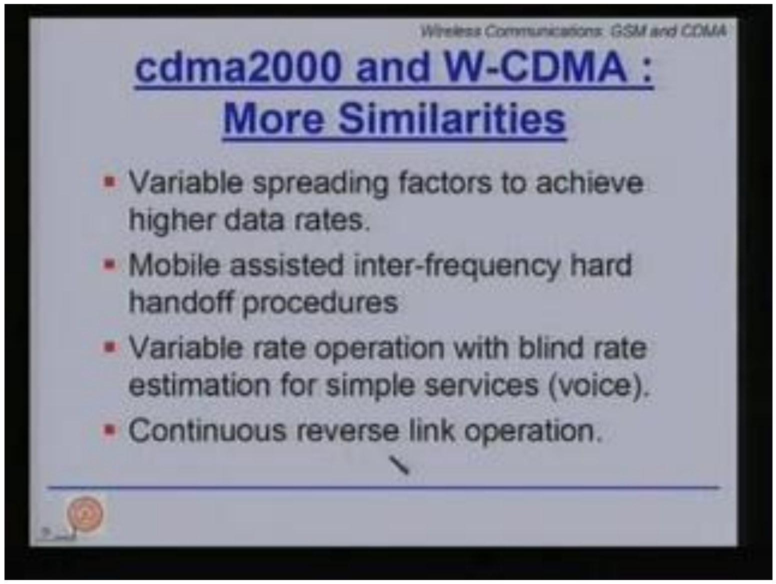

Some more similarities, variables spreading factors to achieve high data rates. Mobile assisted inter-frequency hard handoff procedures, variable rate operations with blind rate estimation for simple services like voice. So we have already talked about the variable rate operations in the vocoders before, continuous reverse link operation. Now let us have certain slides on error control codes from the prospective of this wireless standards. We have already had an in depth study of various error control coding techniques, this is revisiting from the perspective of wireless standards.

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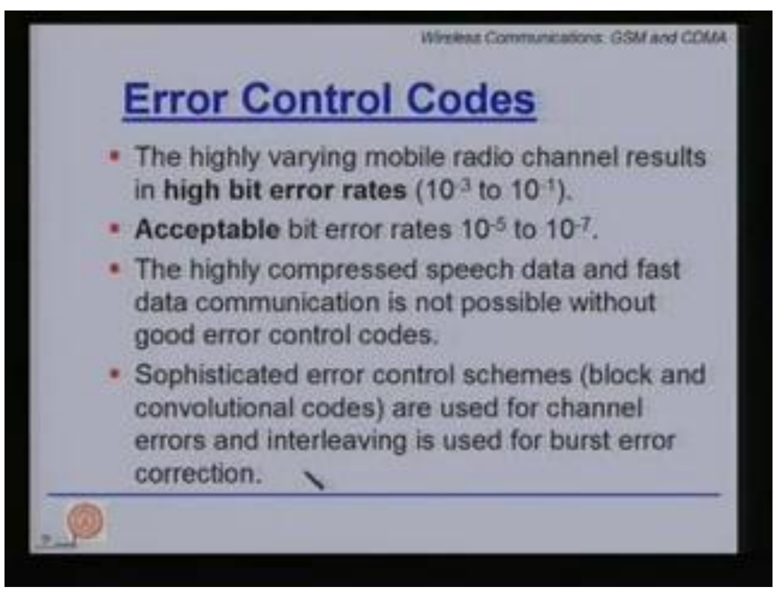

So clearly our mobile radio channels have high bit error rates as bad as 10^{-3} to 10^{-1} uncoded whereas the acceptable is between 10^{-5} and 10^{-7} bit error rates. Now in CDMA we have already compressed our data, we have already thrown out the redundancies. So we must make it robust to errors. The highly compressed speech data and fast data communication is not possible without very good error control codes, this is an absolute must. So sophisticated error control schemes both block and convolutional are used for channel errors and interleaving is used for burst error correction.

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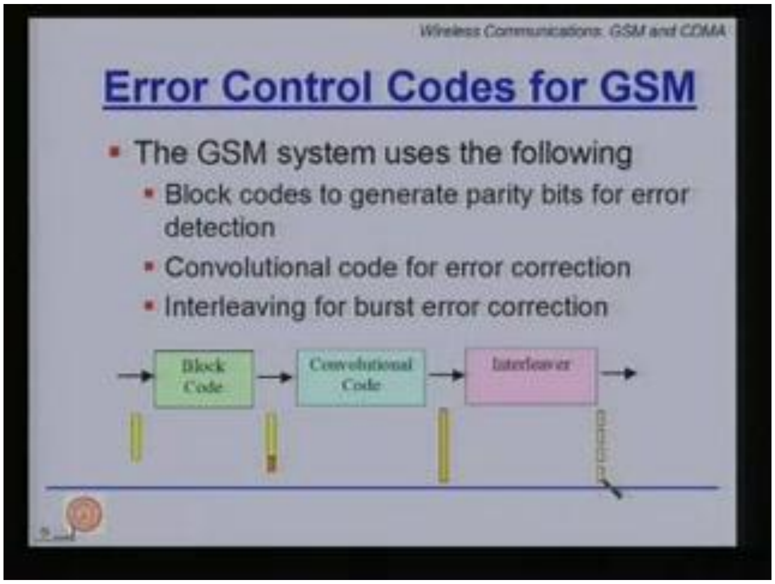

Error control codes for GSM, the GSM systems uses the following. It uses block codes to generates parity bits for error detection, convolutional codes for error correction and interleaving for burst error correction. So you start in a digital domain, you go to a block code you add a parity, convolutional code lengthens the sequence further and interleaving reads it and to rows and reads out in as columns and breaks up the date.

Speech data is classified into the following classes of varying importance are encoded accordingly, so there is a class I, class II and class III. Class I is the most important and constitute 50 bits out of the 260 in each speech frame. These describe the LPC filter coefficients and amplitude information. Similarly you have the class II definition which constitute 132 out of the 260 bits and carry information for long term prediction coefficient LTP whereas class III there are 78 out of the 260 bits and contain regular pulse excited RPE parameters.

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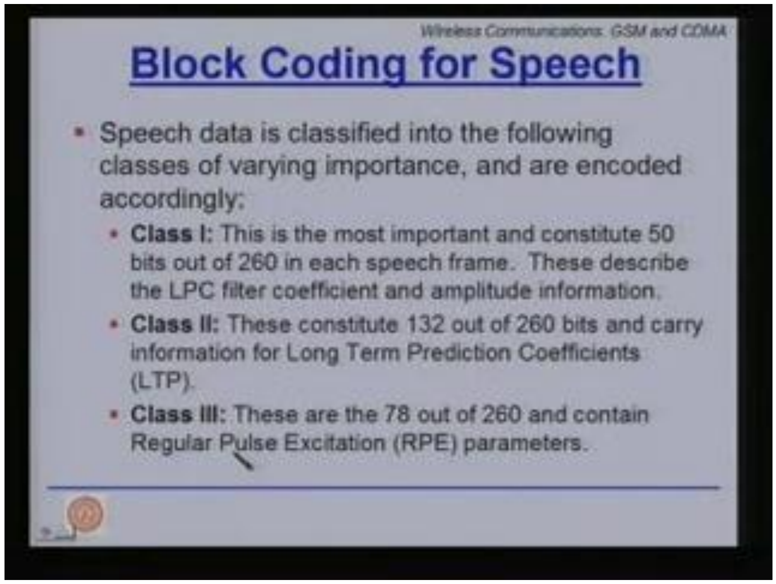

So these are some basic types of speech data classification. Speech data occurs on the TCH which is the traffic channel for the payload data in speech frames of 260 bits. So this 260 bits is coming on the speech frame, of these 182 bits are error protected and the remaining 78 are not. On the following cyclic redundancy check CRC code polynomial is used for GSM.

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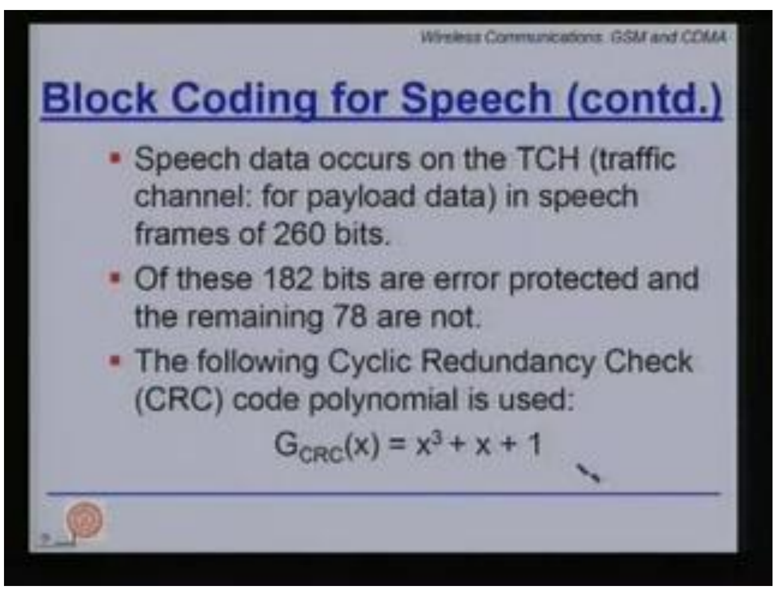

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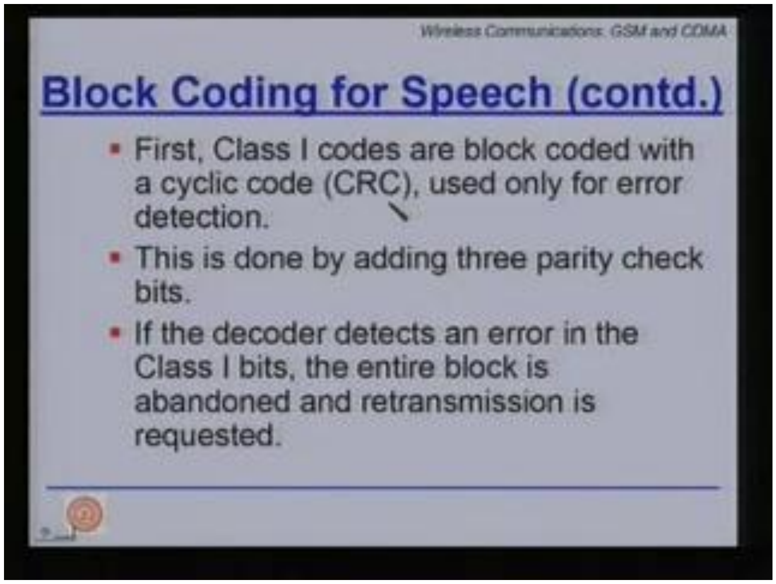

For class I codes we have block coding with a CRC used only for error detection, this is done by adding 3 parity check bits. If the decoder detects an error in class one bits, the entire block is abandoned and retransmission is requested. So it's a scheme where you request for retransmission of data once the error detection takes place. CRC we know is an important class of error detecting codes. The convolutional code is applied to both class I and class II bits including parity bits generated from class I bits. The convolutional code used has a rate 1 by 2 and the transmission errors can be compensated to a certain degree in speech decoder by extrapolation. The discarded of missing frames are extrapolated from the data from the last valid speech frame those detected without errors.

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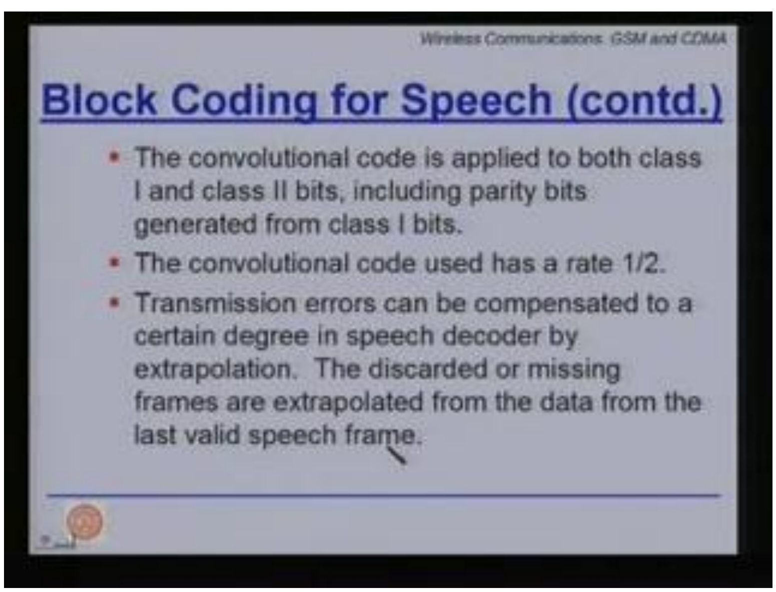

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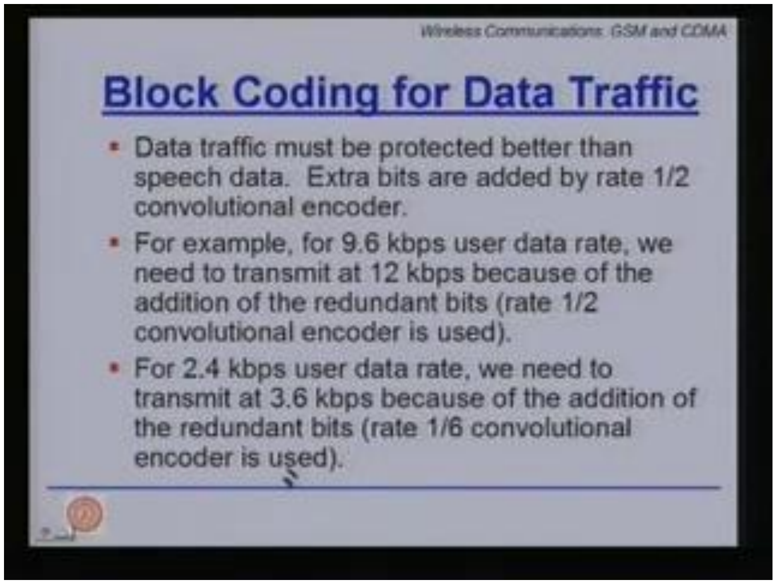

Now that was speech we have block coding for data traffic which is more sensitive to errors. Data traffic must be protected better than speech data because our ears are not so sensitive we can internally extrapolate and figure out the missing words, at most there will be a crackle in the sound we can still make out what's going on but in data if you make more than the possible errors that can be detected then we are in soup. Extra bits are added by rate half convolutional encoder. For example for 9.6 kilobits per second user data rate we need to transmit 12 kilobits per second because of the addition of redundant bits. Again for 2.4 kilobits per second user data we need to transmit 3.6 kilobits per second because of the redundant bits.

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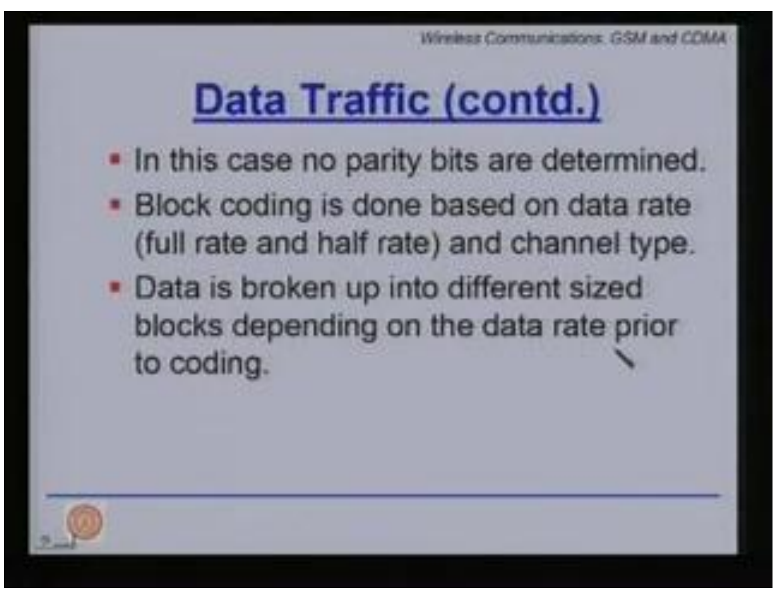

In this case no parity bits are determined, block coding is done based on data rate whether it's full rate or half rate as well as the channel type. So you have to do something to estimate how bad the channel is. Details broken up into different sized blocks depending upon the data rate prior to coding.
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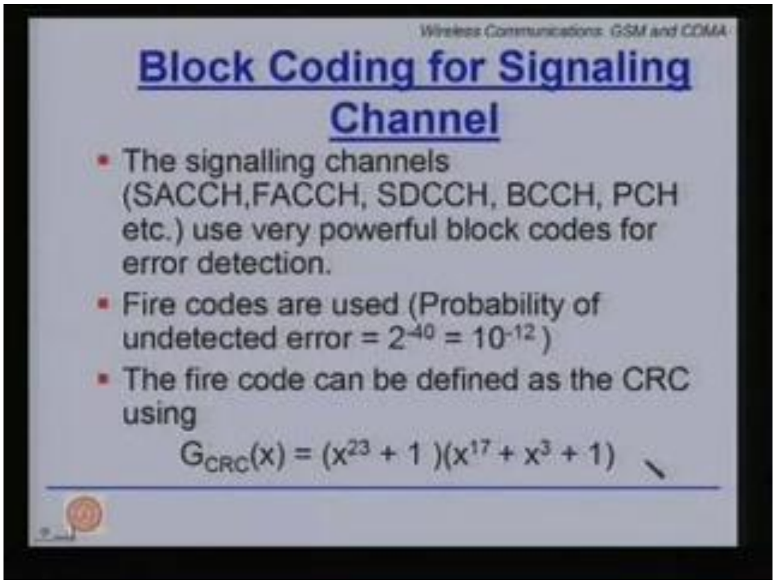

Block coding for signaling channel please note that we also have signaling channel and it's important to protect the data being sent over those signaling GSM channels. So these are the signaling channels which we have studied in the previous class. They must use very powerful block codes for error detection because if your signaling information goes prevail then your rest of the information will be useless. So it is important to protect the signaling channels.

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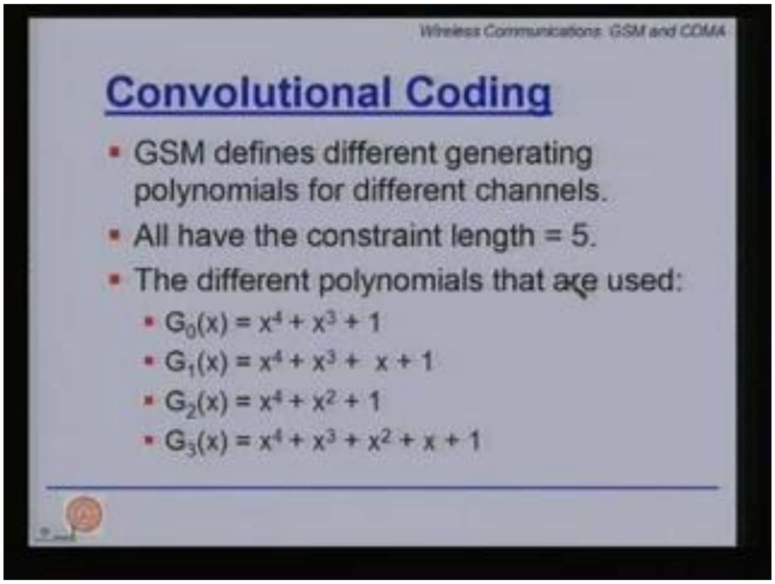

Fire codes are used so probability of undetected error is very high, it's a very strong codes in our series of lectures when we talked about cyclic codes, we studied fire codes in detail. So fire codes are used which will guarantee you probability of undetected error of 10^{-12}. Fire codes can be defined as the CRC using this following generator polynomial. GSM defines different generating polynomials for different channels. All have the constraint length 5 and here are 4 examples of the different kinds of generator polynomials use for different kinds of channels. So clearly by looking at the highest power of x which pertains to n-k, you can know what is the length n and k and also you can find out how many errors these can correct.

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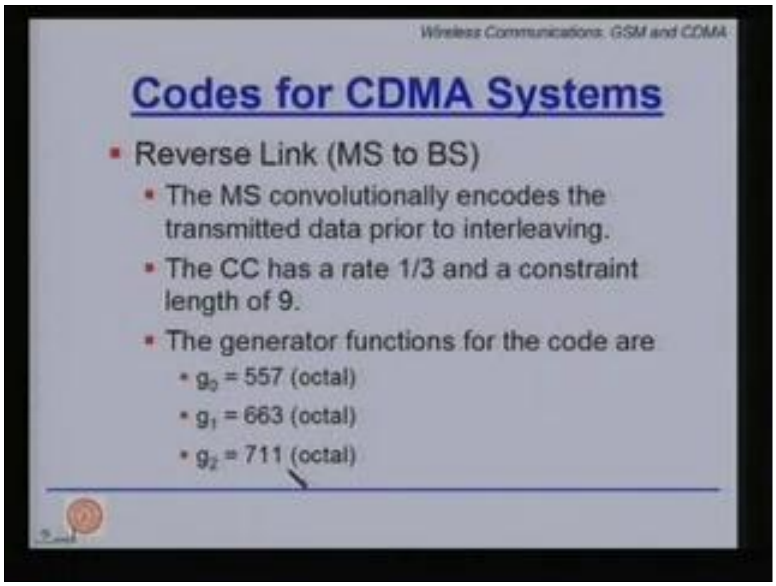

Those were the codes for GSM. Now let us discuss the codes used for CDMA systems. In the reverse link which is defined as the mobile station to base station and please note here we rely only on the battery power, so we cannot effort to have very strong signal power. The mobile station convolutionally encodes the transmitted data prior to interleaving. Interleaving is a must because convolutional encoding is also useful not for burst error but for random errors. So interleaving will make burst error look like random errors, the convolutional coder as a rate 1 by 3 which is a stronger code than the rate 1 by 2 encoders. We are putting in more redundancy. Now also note the constraint length of 9, clearly we are anticipating more errors in the reverse link channel and hence using a stronger code. Just for the sake of description the generator function for the codes are given in the octal format as follows.

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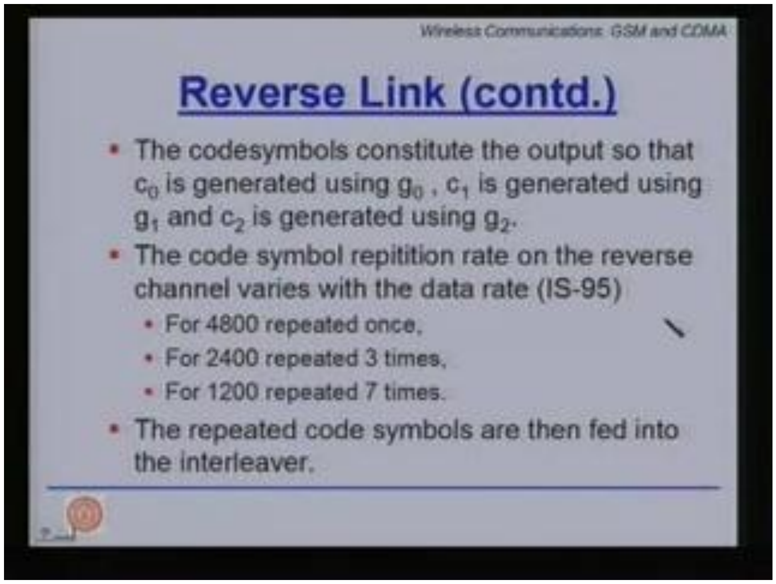

The codes symbols constitute the output so that C_0 generated using g_0, c_1 is using g_1 and c_2 generator using g_2. What are c_1, c_2 and c_0? They are the 3 output bits because your rate of the convolutional encoder is 1 by 3. So for every one bit that goes in 3 bits get out. The code symbol repetition rate on the reverse channel with the data rate for IS 95 are as follows. For 4800 bits per second it's repeated once, 2400 repeated 3 times, 1200 repeated 7 times. The repeated code symbols are then fed into the interleave. This is an example picked up from the first generation CDMA system which is IS 95.

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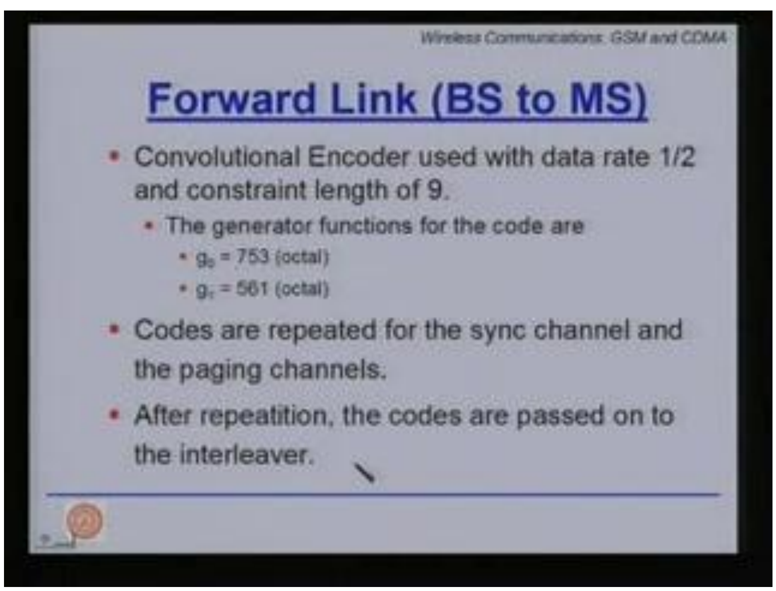

Let us talk about the base station to mobile station, the convolutional encoder used with data rate half. So it's a weaker convolutional encoder as compared to the rate 1 by 3 but the same constraint length. So for everyone bit that goes in 2 bits get out of the encoder and how are they defined, they are defined using this two generator functions in octal. Codes are repeated for sync channel and the paging channel, after repetition the codes are passed on to the interleaver.

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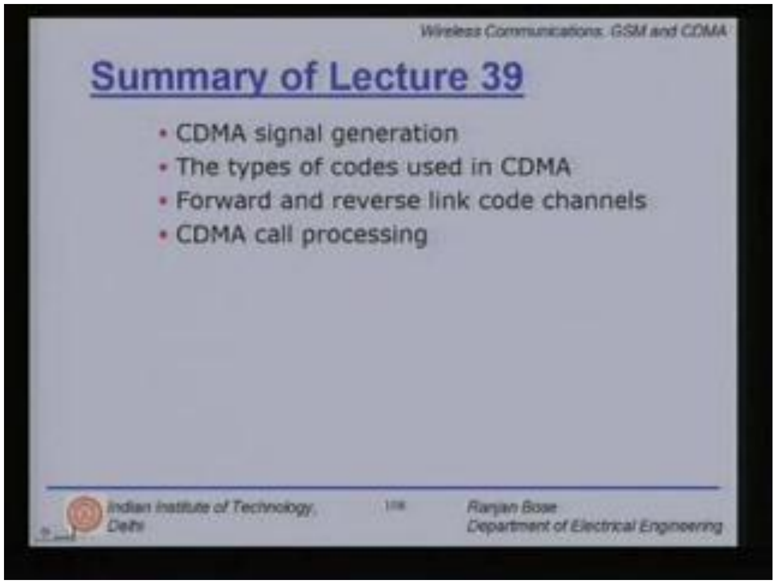

So let us now summarize what we have learnt in today's class. We started off with CDMA signal generation. Then we talked briefly about the types of codes that were used in CDMA systems. We then separately discussed the various forward and reverse link code channels, what are they used for, how are the different from each other and then we discussed CDMA call processing. Finally to put things in perspective we talked about error control codes and compared the error control codes used for GSM and CDMA technologies. We have seen that block codes, cyclic redundancy check codes and convolutional codes all are used in the various wireless standards because the wireless channel is a fairly hostile channel, it's a bad channel and it has to be protected. You also saw that we need to protect the traffic channels as well as the control channels. This brings us to the end of this two part lecture on GSM and CDMA technologies. We will conclude our lecture here.