**Spread Spectrum Communications and Jamming**
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**Lecture - 63**
**IS95 and CDMA - Part II**

Hello students, as a part of our understanding over the CDMA 2000 system, IS-95 and CDMA 2000 system and the specs, this is the second part of the discussion, where we will start with the error correcting coding.

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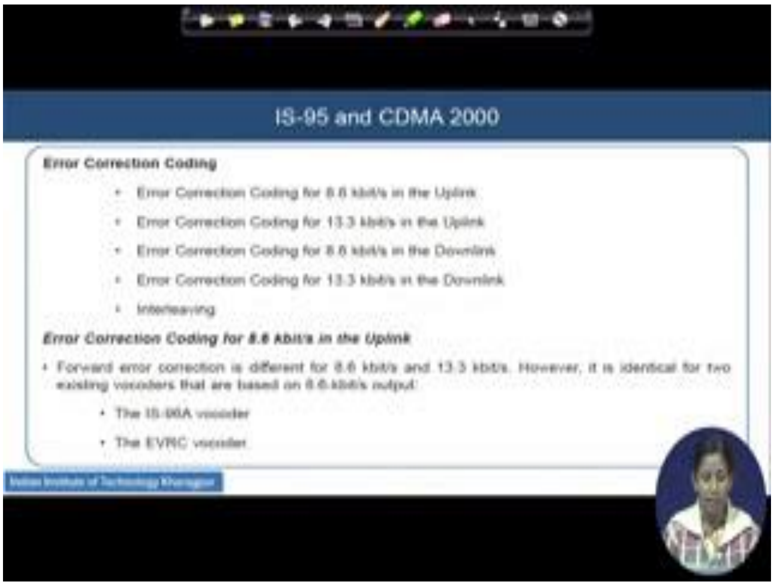


In the last module, we have discussed up to the variable rate speech coders, and here we will start with the error correction coding. So, we understood that basically two different kinds of the coding schemes are involved in an IS-95 transceiver; and in the transmitter side we utilize the speech coder as well as the error correcting coders. And speech coders are basically to modulate through code through code the signals through code the speech signal; and error correcting codes are deployed to correct or to take care of the de-fades of the wireless communication channel.

Let us see how many different kind of the error correcting codes are involved. We understand that there are two different code rates two different speed rates of the speech communication one is 8.6 kbps, another is 13.6. We have also uplink and downlink communication. So, we will see that the error correcting codes are there are four fold here; for 8.6 uplink, 13.3 uplink, 8.6 downlink and 13.3 downlink. And remember the after coding we provide the interleaving actually and only the corrected codes are not output not released in the air to get the maximum code gain the interleavers should be accompanied with the recurrently codes.

And here we have seen that we have two different kinds of the vocoders, I mean the voice coders one is IS-96A and then it was first developed; and the latest one was the enhanced variable rate coders which can support the 8.6 kilo bit per second as well as 13.3 kbps. And for 8.6 kbps now we will first discuss about the error control coding meant for which we understand that we have IS-96A vocoder as well as EVRC coder.

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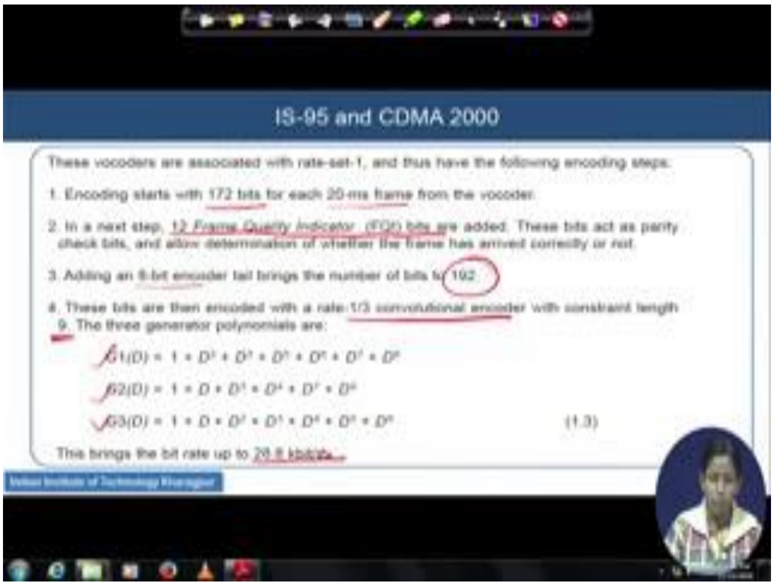


8.6 kbps is basically defines rate-set-1, and hence it will have the following steps for the encoding mechanism. Encoding process here starts with 172 bits. So, it takes 172 bits, because it corresponds to 20 milliseconds frame duration from the vocoders. And in the next step he adds a 12 length frame quality indicated bits. And these bits are basically to check you whether the frame is properly received, the frame is good or frame is bad, whether the further processing on this frame should be done or not. And it is received correctly or not that also will be a indication given by the FQI. And after this 12 bit FQI, we add 8 bit encoder tail bits we and so the total number 172 plus 12 plus 8 turns to be 192 bits per frame. And this bits and then encoded with rate 13 convolution encoder and a with a constraint length of 9.

So, we need the generator polynomials for this encoding, and these are the three generator polynomials defined in the spec for generation of this encoder or one-third convolution encoder. And once encoded this as it is a one-third convolution code; and after this encoding process, you will be reaching a bit rate up to 28.8 kilo bit per second.

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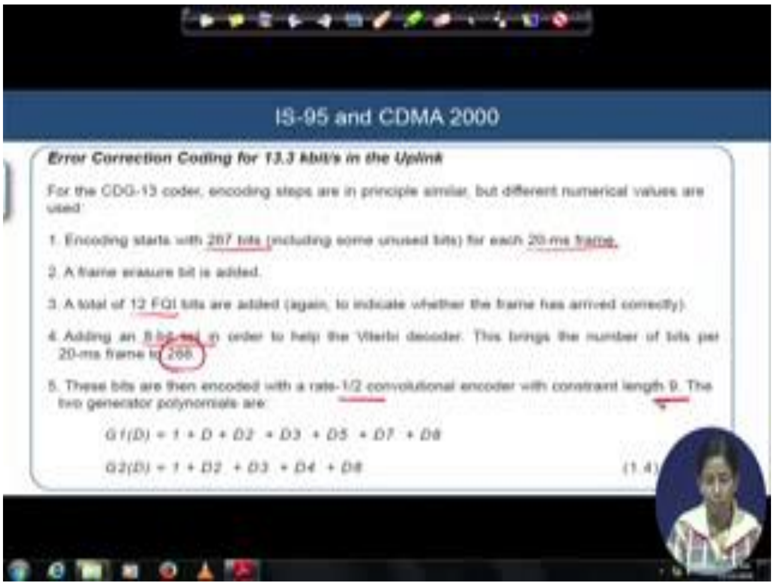


And once this is done, then let us see for the uplink. So, we discuss about the 8.6 kilo bit per second in the uplink, in that case how error correcting codes are done. Now, this is 13.3 kbps in the uplink, so encoding process is not same because we do not want the fundamental modulation and the data rate coding modulation rates to be changed. Now, modulated data be to be changed, so to get a different speed at different data rate for the coding for this speech translation in the uplink, we cannot actually incorporate the same kind of the error correction codes.

So, for 13.3, we need to proceed with the different coder also, here we proceed with the CDG 13 coder, and we start with the 267 number of the bits. So, number of the bits supportable in for higher communication is also high, and that is also corresponds to 20 milliseconds frame size. And we add a frame erasure bit after this. Then the similar to the earlier case 12 FQI, I mean frame quality indicator bits are there to detect whether the frame is received good situation or a bad situation. You add 8-bit tail to help the Viterbi decoder. And finally, you are ended up with the 20 milliseconds frame with the number of the bits equal to 288. And for this, here we in uplink for the high data rate we proceed with the half convolution code rate in the encoder and the constraint length is same.

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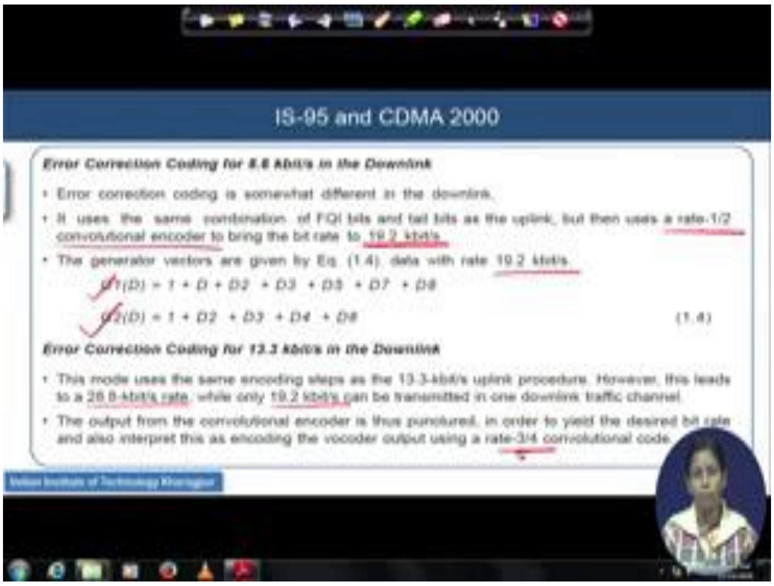


And these are the generator polynomials two generator polynomials are involved for the uplink 13.3 kbps. Let us see about the downlink for 8.6 downlink error correcting codes will be a somewhat different. It uses the same combination of this FQI bits and the tail bits to indicate whether the frame is received correctly or not and to help the Viterbi decoder in the receiver. But it uses a rate of convolution encoder instead of one-third convolution encoder to bring the data rate up to 19.2 instead of 28.8 that we have seen earlier. And so your generator polynomial needs to be different because that needs to be corresponding to the 19.2 kbps these are the two generating polynomials involved for this 8.6 kbps downlink.

The error correction coding that we are now using for the 13.3 kbps downlink let us see. This mode uses the same encoding steps are 13.3 kbps uplink, but it leads to 28.8 kbps, if I truly follow the uplink procedure while only 19.2 kbps is the maximum capacity for the downlink transmitted frame in the traffic channels. So, what we do here is in 13.3 kbps downlink, we first generate exactly by following the process of 13.3 kbps uplink that leads us to a 28.8 kbps date rate, and then we use the puncturing. Puncturing means actually some of the bits in between forcefully you turned out to be 0; and you put 0s, that 0s actually reduce the data rate. Basically it is equivalent to be or interpreted it can be to be are encoding of the vocoder signal output as a rate of 3 by 4, 3 by 4 convolution code. So, either you go ahead with a 3 by 4 convolution code, but we do not do that, we go ahead with the puncturing.

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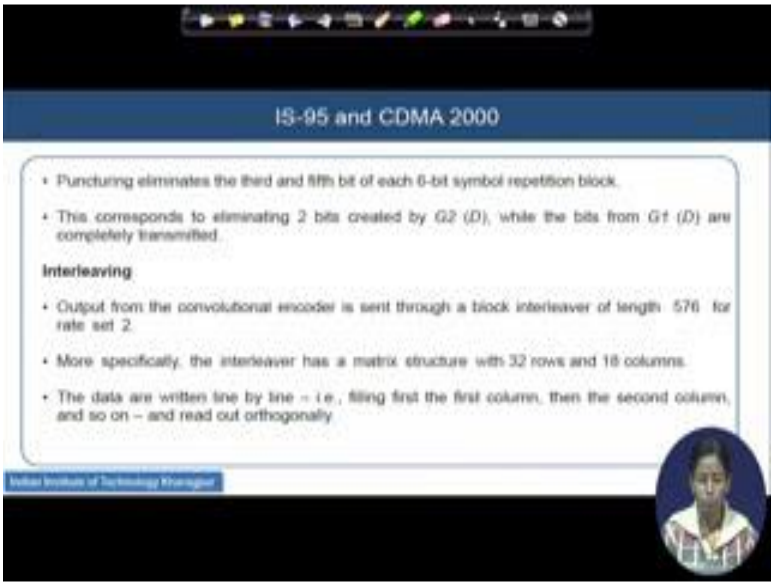


And every six here actually eliminates the third and the fifth bit of every 6-bit symbol repetition block and this basically the way we do is as the 2 bits we try to eliminate that is created by the generator polynomial poly polynomial two. And all the bits from the generated polynomial one kept intact. As I told that to get the maximum profit or maximum gain out of this gain from this encoding process, we have to use the interleavers and. So, the output of the convolution coder we feed inside interleaving which basically is a block interleaver, and which is having a length of 576 for rate set 2, which is rate set 2, 13.3 kbps set is a rate set 2. Interleaver is basically a matrix which randomizes the encoded output and here we use a matrix of 32 cross 18. And the data are written in the line filling the first column and then the second column then the third column and then so read out and they are read out orthogonally one by one.

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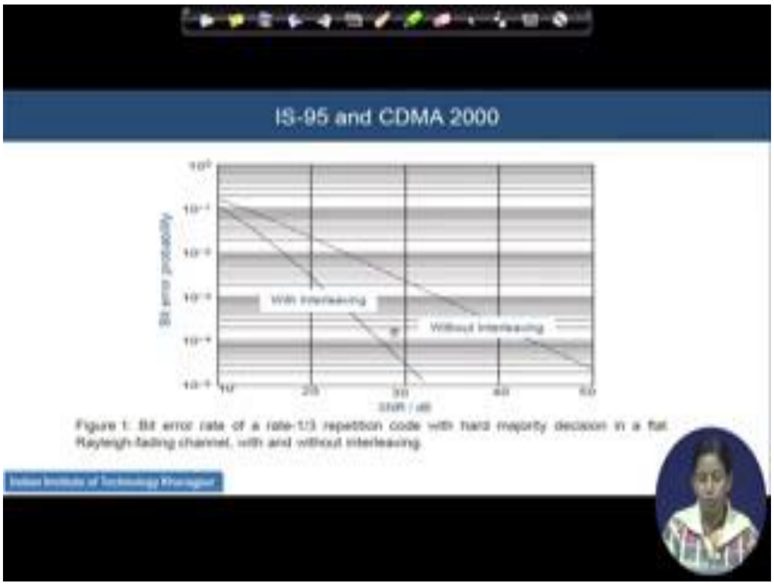


So, let us see actually if I do the encoding, but you do not provide any interleaving where the bit error probability can be and why do we how much do we say if you provide interleaving or randomize the output. See, the bit error probability suppose for 10 to the power minus 4 here we is the plot is plot is for rate one-third repetition code. And what a flat Rayleigh fading channel for this IS-95 system, we can see that for 10 to the power minus 4 bit error rate without interleaving, you need to provide an SNR which is expressed in dB, we need a provide an SNR around 42 dB and whereas with interleaving you can come down with a 28 dB kind of. So, the huge saving more than actually more than is to 13 or 14 dB because of the interleaving and randomization provided by interleaving.

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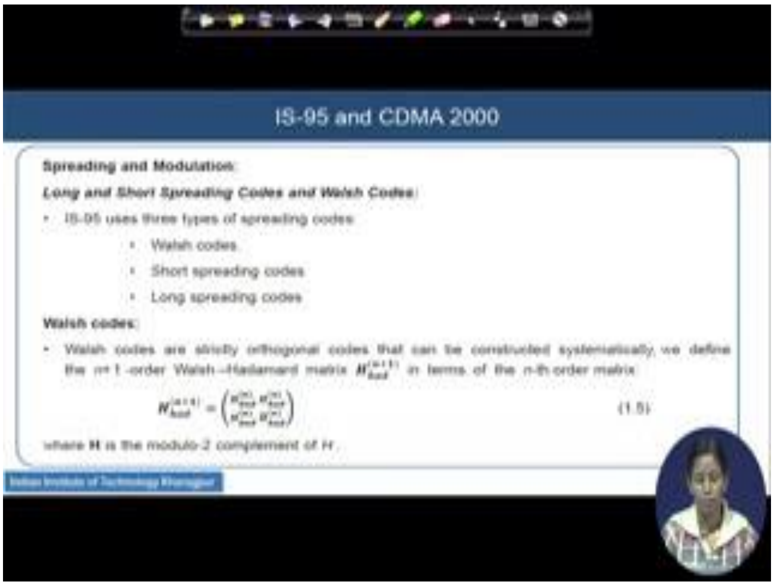


Now that is about your channel coding. Let us lo revisit the spreading and modulation. We understand that there are several tasks needs to be provided for several kind of the signal needs to be transmitted several data rate needs to be supported. So, spreading code can never be same for all this and IS-95 is basically using three different kinds of the spreading codes one is a long spreading codes, short code and the Walsh code

Let us first see what about the Walsh code, what is the typical Walsh code they used. Walsh code we understand that Walsh code can be generated by the Hadamard matrix we repeated from the for n plus n plus oneth order of Walsh Hadamard code can be generated from the nth Hadamard matrix written in this way, arranged in this way where this H bar is nothing but the modulo-2 complement of this matrix H.

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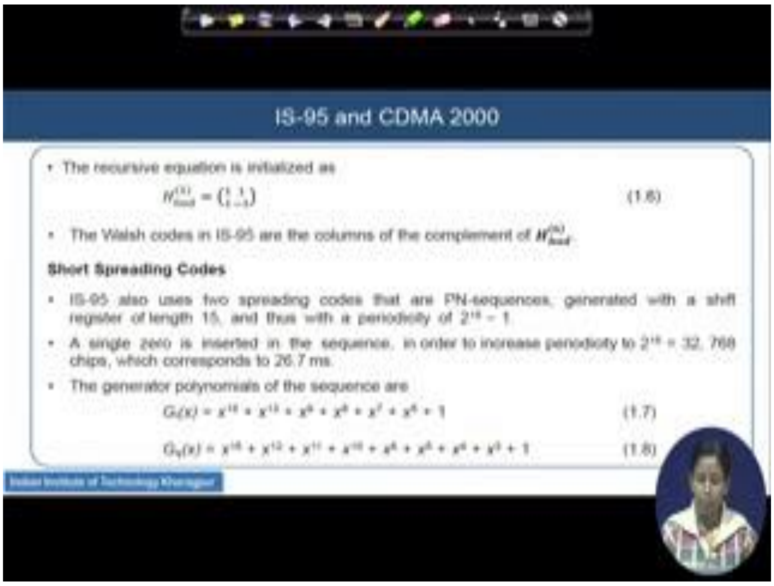


And here the recursive relation this we start with Hadamard matrix one, where the values are initialized like this shown in equation 1.6. And the Walsh code of IS-95 that will be the code by this actually feed first to generate the Walsh Hadamard code 6, then all the columns of this Walsh Hadamard code 6 are the Walsh codes that are used for spreading the traffic channel in the IS-95.

Short spreading codes are basically of the PN-sequence codes of length 15 and they are generated by the linear feedback shift registers, the way and the process that we have learnt already. And remember for we add a single zero in the sequence to increase the periodicity to 2 to the power 5, not 2 to the power 15 minus 1; to increase it to 2 to the power 15, we add sequence of zeros also, and which corresponds to totally 26.7 milliseconds for the transmission.

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These are the two generator sequence polynomial are the generator sequences generator polynomial to generate this PN-sequence of length 15. The long spreading codes they are also the PN-sequences only. So, PN-sequence of length 15 generates the short code here we will see the PN-sequence of length 42 will generate the long spreading codes. Here we do not add a sequence of 0 like the shot spreading codes. And finally, we end up with coding length of 2 to the power periodicity of 2 to the power 42 minus 1 which actually finally, equivalent to 40 days.

The generator polynomial for the same will be like this. And the output of this shift register is then modulo-2 added with the long code mask. So, here there is a concept of mask and this mask can be generated from the electronic serial number or it can be also generated from the encryption algorithm provided, we call it a private mask or the public mask based on where you are generating from, where you are generating the mask. But this key part is that this long code mask is different for the different channels. And hence you can easily differentiate between the access channel and paging channel and it can be also utilized for the BS identification access channel numbering; and it can be also utilized for the different kind of the synchronization paging channels and the traffic channels. Based on the type of the use that you are trying to utilize we go ahead with that.

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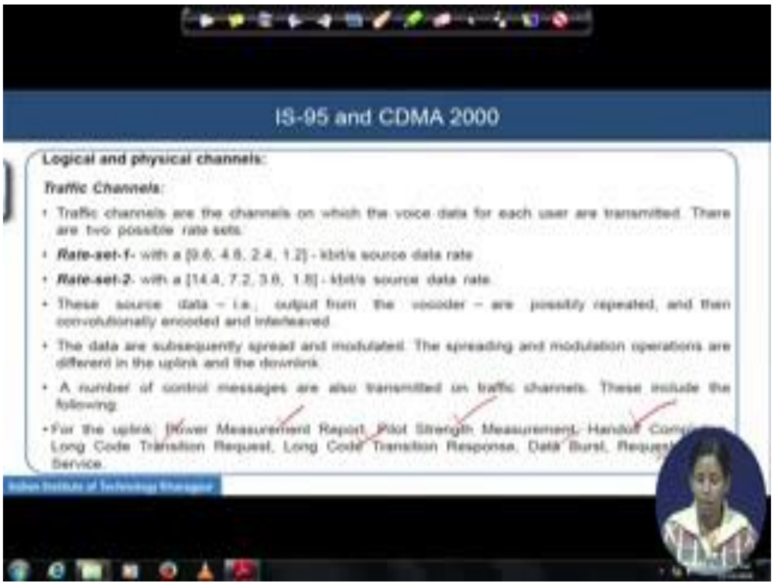


So, now this is the time to understand, what are the different logical and physical channels exist in IS-95 system. We will start with traffic channels, because traffic channels of the channels who carry mainly the voice data. And for each this is a most important communication requirement for IS-95 and there are two possible data set also required to be supported over the traffic channel we understand; one is the rate-set-1 another is the rate-set-2. See the limits of the rate-set-1, rate-set-1 should have support the data rates starting from 1.2 kbps to 9.6; whereas your rate-set-2 to support from 1.8 to 14.4. And these are the source data rate we understand from the output of the vocoder and they are possibly repeated, so they are convolutionaly encoded there interleaved and they are spread then they are modulated.

And spreading modulating operations are will be different from the downlink as well as uplink. And the control messages that are also transmitted on the traffic channel along with the voice data transmission, they are like this. For uplink actually the control channel information that we send is a power measurement report which is used for the power control in the downlink. Pilot strength measurement, handoff completion, long code transition request, long code transition response, data burst, and the request for the analogue services, these are all the important information the traffic channel information control messages that also flows through the traffic channel of IS-95.

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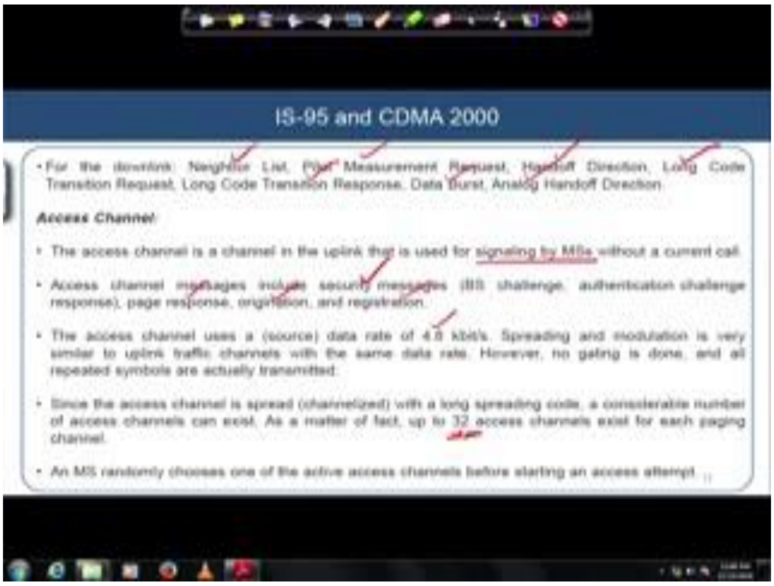


For downlink, such control messages will be the neighboring list, the pilot measurement request, handoff direction, long code transition, long code response, and data burst as well as your analog handoff direction, so this was about the traffic channel. Next comes the access channel. It is the channel that in the uplink direction which is used for signaling by the mobile stations without a current call. So, it is something before setting up a call how this signaling will be exchanged between the mobile station and the base station. The channel that is responsible for that will be the access channel. And he includes the information messages for example, the security message and in BS challenge, authentication challenge response all those, the page response the origination the registration information everything.

The access channel they uses the source data of 4.8 kbps. So, they also use the spreading and modulation very similar like to uplink, traffic channel mode, but remember there is no gating done here and all the repeated symbols are actually transmitted. And since the access channel is also spread with a long spreading code, and considerable number of the access channels can exist. In fact, this access channel that we get here is around a 32 numbers per paging channel. And mobile station can randomly choose any one of these access channel for the start of this transmission for start of his paging I should say.

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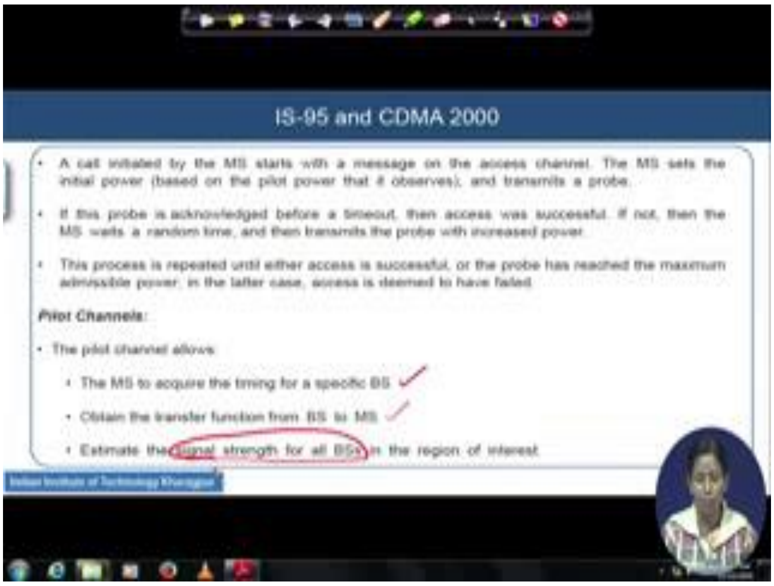


And the call initiated by this mobile station it starts with a message on the access channel itself then the mobile station sets the initial power according to the received signal power measured, and by its open-loop power control. And he transmits a probe, if this probe this probe maybe actually the request to connect then we call it to the address request and there was actually the request is done is acknowledged before the time out. And then the access will be successful. And this acknowledgment is required to come from the base station to the mobile.

And this process is repeated if the access is not successful and till the probe is reached the maximum admissible power. So, slowly actually we start increasing the power of the probe also in the successive attempt, so that at least with one such a certain power level of the transmission the acknowledgment should happen.

Next comes a pilot channels. What are the information that the pilot channels carry. Pilot channels allow the mobile station to acquire the timing information of the base station for a specific base station; it also obtains the transfer function from the base station to mobile station. It tries to estimate the signal strength of all the base station who are surrounding who are there in the environment who may be the interest of this mobile station closed to this mobile station and that may play a very important role when during the handoff.

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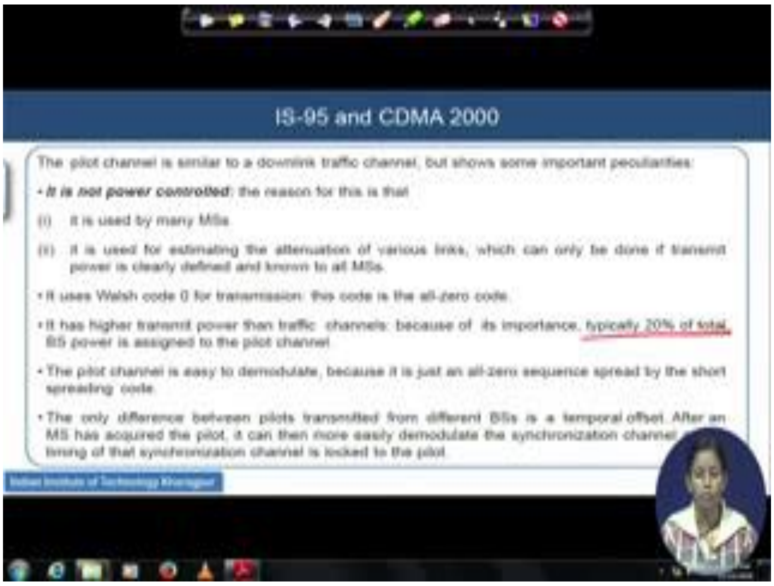


And pilot channel it is a very much similar to the downlink traffic channel, but it has some peculiar properties. Number one, it is not power controlled because reason is you do not know; what is the location of the mobile station, and this is a pilot that you are sending from the transmitter to the receiver. So, it should be used by lot of the mobile station, you cannot do any power control and we transmit preferably you translate with the very high power level, so that none of the mobile stations in the network misses this control information.

This guy uses I mean this pilot channels they use the Walsh code of zero for the transmission with this Walsh code zero means all zero sequence; and with a very high transmit power, once it is transmitted basically the high I told, but how much high is it is here is a measure. Typically the power maybe 20 percent of the total base station power assigned to the pilot channel. And pilot channel is such that it could be easily demodulated because you are spreading this all zero code with the short length spreading codes. And only difference between the pilot transmitted from the different base station will be what, they will be temporal offset, and mobile station requires to acquire all the pilots coming from the different base stations and from that extract the synchronization information about the network. And your timing information with any one of the base stations we are preferable base station where from you are receiving the maximum power.

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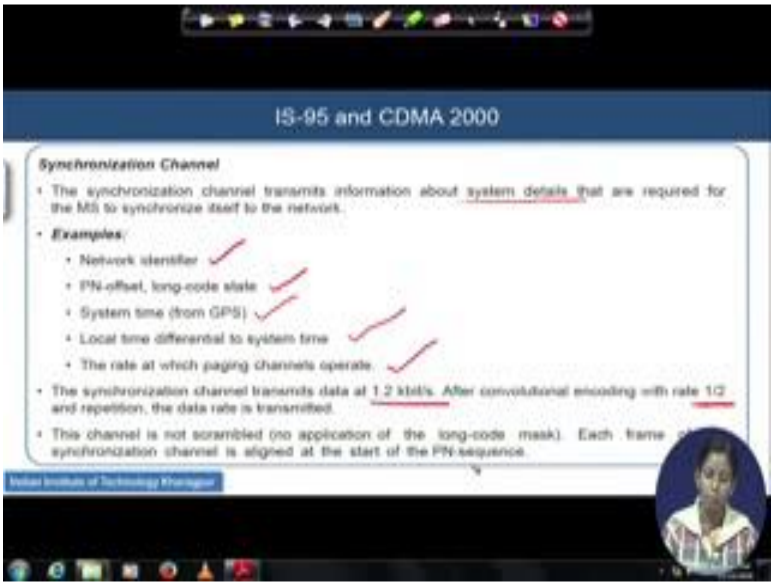


Next comes the synchronization channel. The synchronization channel it transmit some certain information about the system details, which is very important that pilot channels are basically to extract the timing information of the network, and this synchronization channel gives you the system details. It may be actually required for the mobile station to synchronize it with the whole network. What are those information, it may be a network identification information, the offset the long code PN offset between the mobile stations, between the base stations, the long code state, the GPS system time, local time and the difference of the local time with the GPS.

And rate at which the paging channels operate and as it is a very vital information, so we try to transmit it at a very low data rate and hence it is transmitted at 1.2 kbps, and after convolution it is coded. So, after convolution code coding with data rate of half and repetition, this synchronization data synchronization data is transmitted over the synchronization channel. Remember we never scramble this channel, because no application of the long spreading long code mask is there on this channel; and each frame of the synchronization channel is aligned at the start of the PN sequence.

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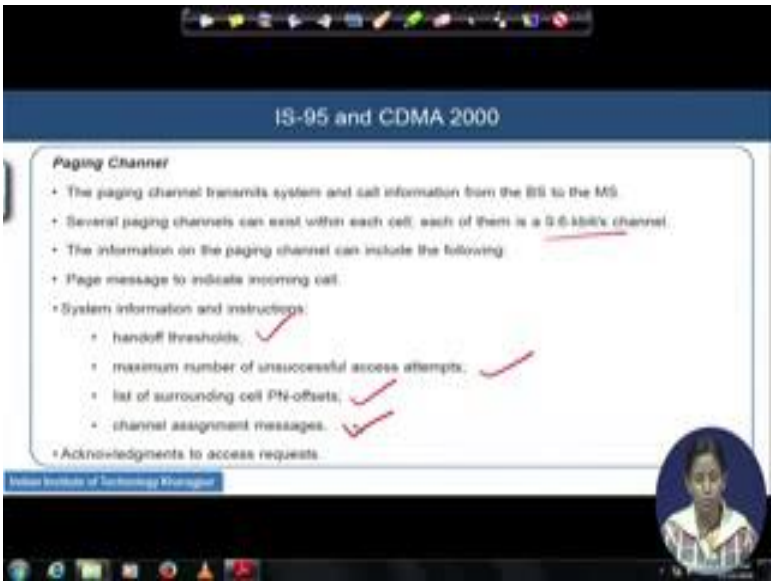


Here comes the second category of the channel named as paging channel. It transmits system and call information from the base station to the mobile station. The call information is the start time of the call end time of the call quality of the call. And whether it was a priority call or it is a medium call kind of the call; so all that actually needs to be transmitted through some channels which is paging channel. And several paging channels can exist in each of the cell and each of them is 9.6 kbps wide and 9.6 kbps supportable channel. So, the data rate was some maximum supportable by this paging channel is 9.6 kbps.

And the information on the paging channel can include the lot of stuff; it can be the paging message to indicate the incoming call. The system information and the instructions, what is system information, what is the handoff threshold the maximum number of unsuccessful access attempt list of surroundings cell PN offset; the channel assignment message. So, once you have such data rate such kind of the information data bank, you are from your measurements you have done in the earlier time being. So, that information you can now actually broadcast via the paging channel, so that it will help newly joined mobile users with the mobile user who newly joined the network to arrive himself and extra clot of the network related information will be revealed to him. And it also sends the acknowledgments to the access requests.

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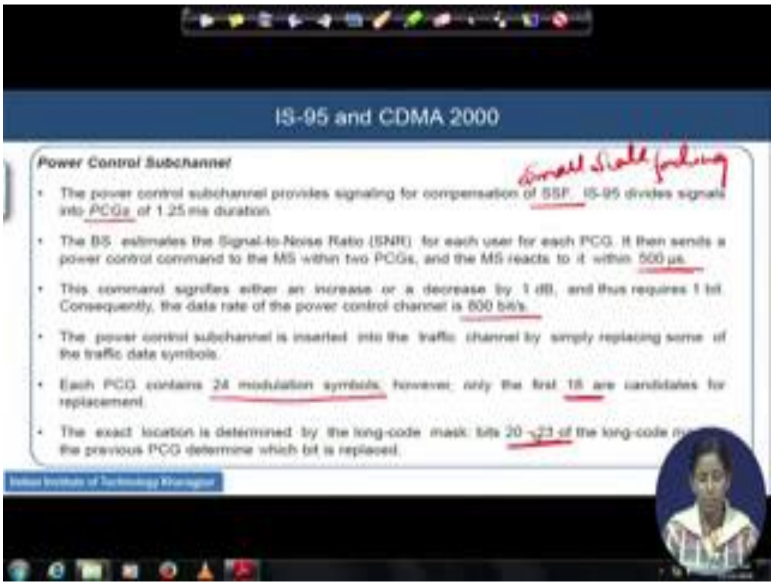


After that comes the power control sub channel. So, power control is a very important phenomena for a CDMA network we have understood. And to accomplish that operation, we understand that in the CDMA IS-95 mainly, it uses both the closed-loop as well as the open-loop. And for that if it is a closed-loop, then you need an inner-loop and as well as outer-loop to run. For that every moment, you need to send a feedback information from base station to mobile station; and to do that you need a dedicated channel for it the dedicated channel name is the power channel power control sub channel. And this power control sub channel is very, very important and they are actually responsible to compensate the effect of small scale fading here SSF stands for the small scale fading.

And in order to do the efficient control, the IS-95 divides the signals in a small group, we call the power control groups. And each power control group is having a width of 1.25 milliseconds duration. So, base station will estimate the standing a signal-to-noise ratio for each user for each power control group; and it then sends a power control command to the mobile station within two power control groups. And the mobile station reacts to within 500 microseconds. So, this command signifies either an increase or some decrease of the SNR value, and basically increases whatever it is increase or decrease it should be at the step of 1 dB in IS-95. And the data rate at which we transmit all these a feedback information and the command information and that will be at the rate of 800 bit per second.

We do not wish to lose any command or in instruction that is why the data rate is so low so that reliable communication is possible. The power control sub channel is inserted into the traffic channel by simply replacing them, some of the traffic channel replacing some of the traffic channel data symbols. And remember your PCG - the power control group it contains 24 modulation symbols and only first 16s are candidates for the replacement. The exact location this is determined by the long code mask; it bits a 20 to 23 of the long code mask in the previous PCG determine that which bit is to be replaced, that is all about the power control sub channel.

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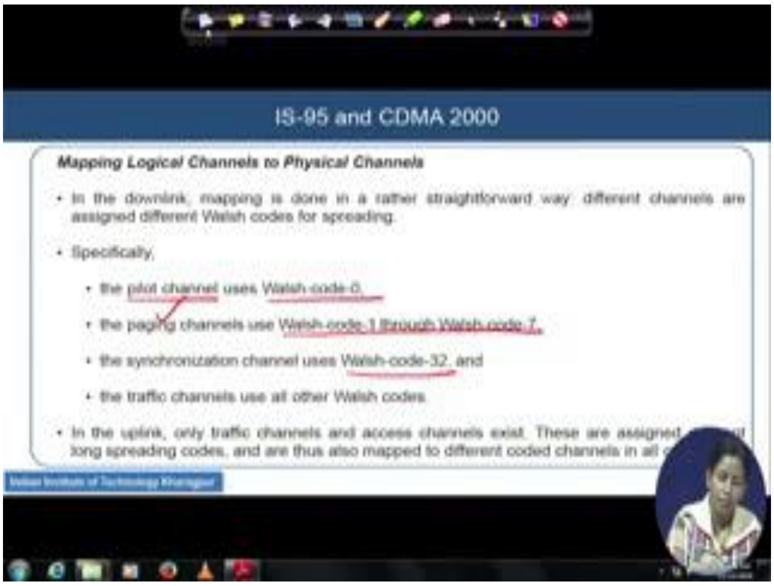


And then finally comes the mapping, the mapping of this logical channels to the physical channel all that we have done is are they are the logical channels. So, in order to map them in the physical channel in the downlink mapping done rather straightforward way different channels are assigned, the different amount of the different kind of the Walsh code for spreading. So, you can identify the different channels by means of the Walsh code associated to them. Specially the codes there are some example the codes that we use we use the Walsh-code-0 for the pilot channels that we have already discussed. We use Walsh-code-1 through Walsh-code-7, I mean Walsh-code-1 Walsh-code-2, 3, 4, 5, 6 and 7; all these are used for the paging channels.

Synchronization channel uses Walsh-code-32 and traffic channel uses any other Walsh code available. So, in the uplink only the traffic channel and the access channels exist, and these are the assigned different long spreading codes, and thus also mapped to different kind of the code channels in all the cases. So, but fundamentally the thing is that the way we will try to segregate the different channels in the practice in the receiver that whether it is a signal come related to the pilot channel or the paging channel or the synchronization channel or the traffic channel is coming up; some information definitely will come according to the Walsh code number, and some number will come in the frame format definitely. I am using that actually they that typical code Walsh code should be used to display the data to extract the signal corresponding from the different kind of the channels involved.

So, that is all about the CDMA 2000 preliminary understanding or some very basic understanding about the different kind of the coding techniques the coders, voice coders as well as error control coders, the different kind of some modulation, spreading, utilized and also having the concept of the channels, the mapping of the logical channels and physical channels.