Modern Digital Communication Techniques
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Lecture – 03
Introduction to Digital Communication System (Contd.)

Welcome to this lecture on Modern Digital Communication Techniques. In the last couple of lectures, we have seen the basics and fundamentals of the differences between the digital and analogue communication system and in the last lecture especially, we saw the critical aspects of a digital communication system or the fundamental aspects which one must get into and amongst the few things we did say that noise is one of the important aspects which should be handled. Today we continue a bit more in trying to explain to you a typical way of designing systems or typical way of layering architecturing, so that you can divide and conquer a big problem and divide into smaller problems and finally, solve each of the problems and finally, conquer the bigger problem, ok.

Today's digital communication systems are very complex systems. So, if you would see when it all started, one of the earliest communication systems if you would think of, if you do not think of a communication system rather a mode of communication, it would be smoke signals that was historic. They were in Africa. There would be drums, rolling drums or talking drums which could send messages across hundreds of kilometres through methods of relays. Well relays are relatively modern terminology, but that was the way it was being done. See if you look at today's technology where immediates of devices from smartphones to laptops to computers to all kinds of devices to sensors to machines, they are all connected almost in a single network compared to those days where it were very basic, but the need of communication was always there and because of that need, we have driven all the way and we are in a very advance stage of communication where almost anywhere we want we can set up the communication network. We can connect almost any device and we are also able to provide almost any time communication, we have gone into space.

So, if you look at these various domains of communication, one could ask that what has been the driving factor for all of these things and who has been doing all these activity.

So, there are been many different people who have been contributing and amongst them in the modern era, one of the pioneers centres was the maths centre at Bell lab. So, from there started many contributions of a modern wireless communications. Of course, we are not debating history about who was the first and who was the second and so on and so forth, but what we are talking about is the modern way of looking at things and the way of breaking down into things and solving each one.

So, this maths centre and when once we name, once we pick up this name, what it tells us is it builds up certain mathematical models of course and that is what we said in the beginning of the course.

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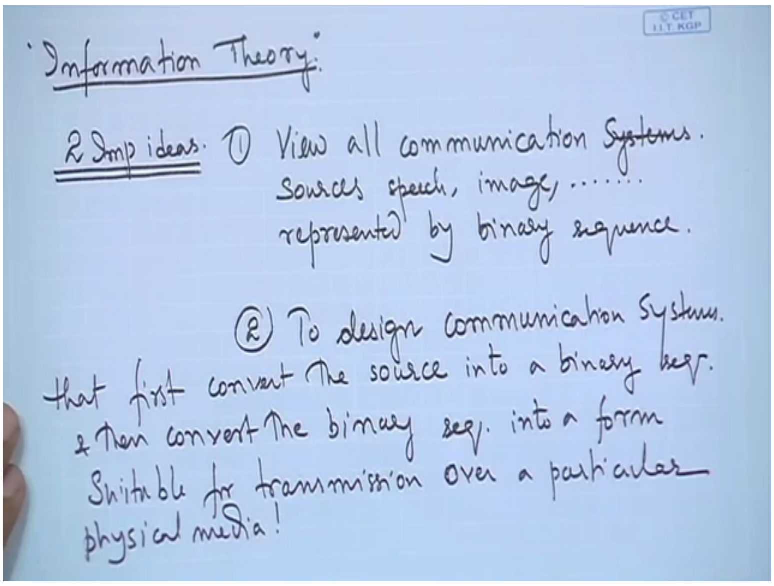

So, the way this structure, the system was very elegant and there on things became very nice. So, one of the things which this centre gave us was a information theory which is closely related subject. This particular name is for subjects of its own, its course of its own and huge amount of literature has been developed and if you look at digital communications, digital communications are modes of achieving things which are prescribed by this particular theory. So, when we study our particular subject Information theory would be scattered here and there and it will be the driving principle. So, just to keep in mind, information theory is one of the mother subjects of our particular domain and two important ideas.

If you look at two important ideas which helped us through all of these is one, if you summarise is to view all communication systems, all communication sources rather all communication sources be it speech, be it image, be it video or text whatever it is as represented by binary sequence. So, this is one of the important thing. It is said that whatever is the source can we imagine them to be giving out binary sequences. So, in the previous lectures, we have given some examples of what we have today. So, we have to think of when these were not existence, when things were pure analogue sources their images. So, if you could think of that time and at that time thinking of such an idea was quite revolutionary that you think of from this analogue sequence to directly binary sequence which could represent these things.

So, this is one important idea and the second was to design communication systems that first convert the source into a binary sequence and then, convert the binary sequence into a form that is suitable for transmission over a particular physical media.

Now, this is what we had explained in the previous discussion that almost intuitively we said that if you look at what things are today, they are in this form.

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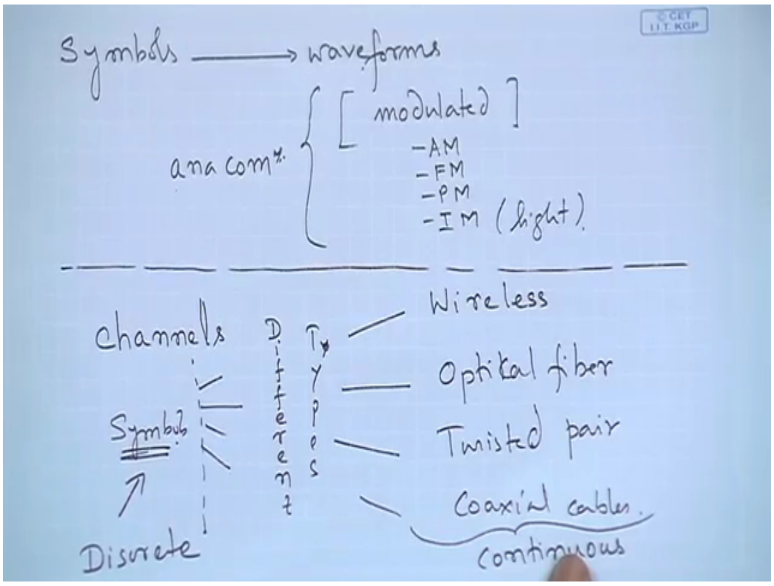

This is what we had explained in the last discussion, try to bring out in this particular picture. This particular description we said that there are symbols. So, they are discreet and this would be common, but this would go into different physical channels. So, that is what is mentioned over here. So, two important ideas; one is to view all communication sources as represented by binary sequences and then, to design communication systems that first convert the source into a binary sequence. Of course, that is there and then, convert the binary sequence into a form suitable for transmission.

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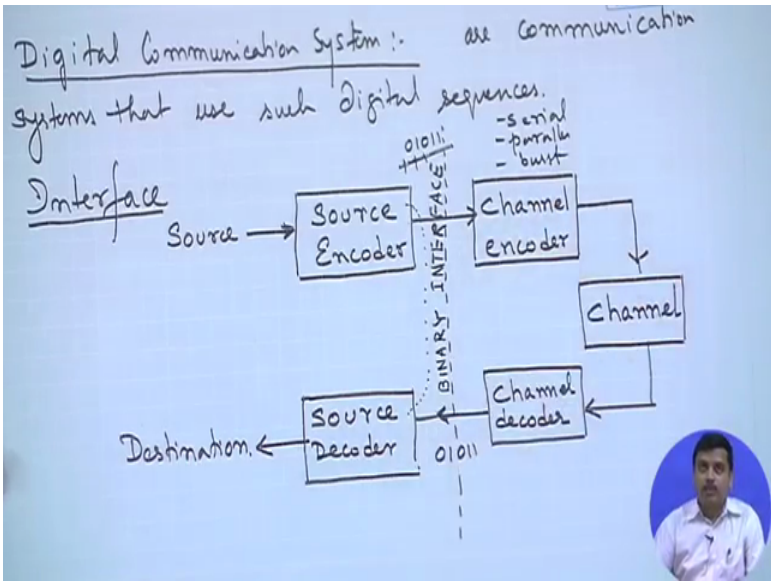

So, this is how you could carry on with your sequence of things and then, one would define, we define yesterday a digital communication system as, now we define digital communication system by definition. These are communication systems that use such digital sequences. So, now if we combine these two things, we more or less have a digital communication system description. That means, it say that first you convert source to binary sequence. Once you converted to a binary sequence, now you again convert it to some form which is matching with the physical media and then, you define digital communication as communication system which uses this binary sequences or this digital sequences.

Now, this digital sequences could be binary or they could be multi amplitude level as well. So, these are some of the important aspects which we should keep in mind as changes as one moves from analogue communication to digital communication system. The other important aspect that we would encounter in designing of things are interface. So, although in analogue communications you may have studied components and step by step development, but here we define interfaces and I will explain shortly that why do we do it and what is necessary and how does it help us.

So, if we think of a source, let here source followed by a source encoder and then, there is this channel encoder. Then, the signal goes out into the channel back at the receiver. There is this channel decoder and then, again this source decoder back here to the destination. So, this is a very broad diagram or a block diagram of a typical transmitter receiver structure that one can think of. Things can be simpler than this. So, if we look at this and what we have written before, there is one to one correspondence. So, there is sources to be converted and then, they have to be transpormed to physical form.

There was source here, you get binary interface. So, by what we mean is that here there are sequence of zeros and ones and then, these are converted in some form because of this physical channel and again decoded and its source decoding is done over here. So, if you have this interface, there are many advantage of having this particular interface amongst many different advantages. One clear thing we need to see over here is this source encoder. When it gives an output, it generates a sequence of zeros and ones. It does that it need not bother about what lies on that side. So, this is almost in capsulated, right.

We can think of as if there is communication system, source converts to sequence of zeros and ones and then, it goes into something which we can call integrated channel and then, this sends out again a sequence of zeros and ones. The job of the source decoder would be to take these inputs and generate the output at the destination. So, when we have this interface, we can define that the channel encoder takes a particular sequence of zeros and ones, not a particular takes sequence of zeros and ones in a particular rate. Rate means it talks about the time interval of generating zeros and ones and it generates outputs. So, some of the different contributions that can we taken from this is that source encoder need not bother about what the channel encoder does. It can do its job independent of the channel encoder.

Similarly, the channel encoder need not worry about what the source encoder does, only if it knows that there is this particular sequence or there is a sequence of zeros and ones. When we talk of binary interface, you say I am going to get zeros and ones. That is it and it will work on the sequence and produce a certain output, right. If this is again another binary channel, it is going to produce a binary output. If it is a wave form channel, it is going to produce wave form outputs and so on and so forth. So, these two need not worry about what each one does except knowing about details of this interface. Same goes over here is one part.

The second part would be that when one designs the source encoder and one designs the source decoder, at that point the decoder did not worry about what has happened here. It simply knows that I am going to get some binary sequence and I have to produce a particular kind of output. So, it can be designed with the idea that as if these signals are going into this, there could be errors. There may not be errors that dependence upon the particular type of model of the channel that we want to incorporate. So, this would be the dual of this particular box. So, they could be designed and implemented by group of people quite independent of this thing. In other words, if there is let us say speech source, you can define this speech encoder as well as the decoder and the output can be send through a wireless channel through a twisted pair or through coaxial or through optical fibre, where these things, these two parts can be meant common, where these parts will be different depending upon the situation, depending upon the type of channel.

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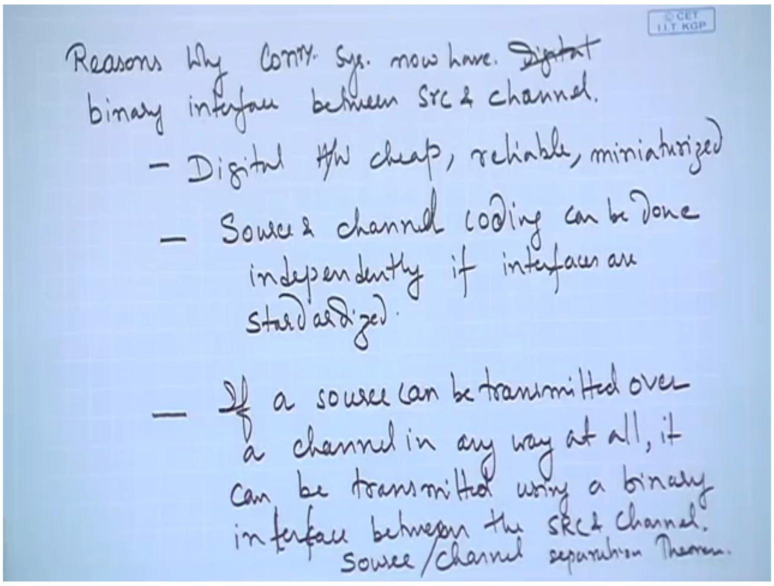

Continuing further, so we look at why or the reasons why communication systems now have a digital or a binary, you can say instead of say binary, simply say binary interface between a source and channel. Let us say why. So, a couple of things come up. One is digital hardware is cheap and it is reliable as well and it is miniaturised. That means, you can get very tiny form. This is one, this is another one of the big advantages. The second thing that as we have just said this source and channel coding can be done independently if interfaces are standardised. So, by standardise we mean if this is very well defined different channel, encoders can work on the same source encoder and vice versa. In this particular point, standardise means well defined, well explained, well expected by a lot of group of people.

The third which is one of the very interesting things we tuition out on what is said is that if a source can be transmitted over a channel in any way at all, so that means what we said that if a source can be transmitted to the receiver, that means it can be communicated at all. In that case, it can be transmitted using a binary interface between the source and the channel. So, this is also important statement which we made and that is based on the particular kind of description that we are going through. So, with this logic and justification, what is stated is that if at all data communication between the source and the destination, it can be done through binary interfaces. That means, if at all even communicate, you should be able to do it through binary interface and then, it reach to the point that if at all you communicate, you should do it through binary interface because there are several advantages, right.

So, this is the last thing which talks about it and in some places, you will find it also be mentioned as source channel separation theorem. It is not a theorem. It is just a statement in that sense say that the channel is different and source is different.

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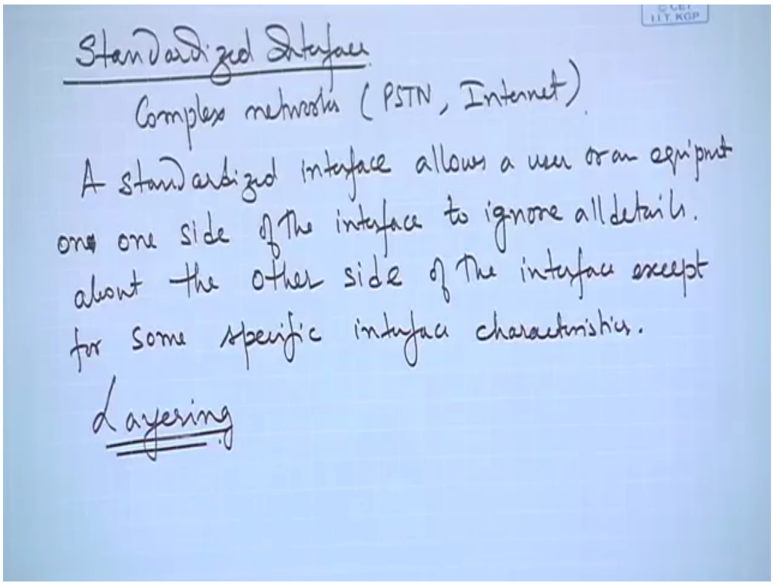

So, if nothing can go through, I can always send it through some binary mode. So, why this particular thing or standardises interfaces? Now, as we just mentioned in the beginning of this particular discussion that if we look at today's complex systems, let us say the communication system is pretty complex, the networks are pretty complex because there are many different things working together and if you look at even the PSTN, there is a public switched telephone network and that is also very complex for your signal from one point to go another point and the way signal travel.

Now, to maintain this kind of systems, to make it scalable, to manage it you need to break it down into parts and further for such complex systems. To work successfully, one should have some very simple fundamental theorems or philosophies or principles which make these things work. So, when you look at some very simple principles and theories which make these things worth, what you do is that you look for such very simple things and you build smaller things, you build up together and you make a bigger thing. Even if you have very very big system, where small things can come in at any place, you need to have a way of plug in things together. So, that is why we need to have these standardised interfaces because the things are very complex. You have complex networks like PSTN and then, you have the internet, right. In order to handle them in an easy way, you talk about complex complex, you talk about standardised interfaces

So, the standardised interface allows a user or an equipment on one side of the interface to ignore all details about the other side of the interface except for some specific interface characteristics. So, this model tells us what we have already explained here that standardised interface allows a user equipment on the one side of the interface to ignore all details about the other side of the interface except for some specific interface characteristics. So, if you look at this, when the source encoder is being designed or being implemented, it takes a source and produce a sequence of zeros and ones. That is it because it knows the next one is going to take this sequence of zeros and ones, right.

Well, when it connects to a particular channel encoder, when we say specific characteristics, that means that could be specific realization. It could be that this is the serial input. It could be parallel; it could be a burst. So, depending upon such specific interfaces is going to make outputs be available in such manner. If it burst, then there would be some words and there would be some controller pin. It could be activated and send a few bits. If it is parallel, again it would send the bits 1 2 3 4. Let us say 8 in a particular period of time periodic signals and if it is serial, it could continuously send the streams of zeroes and ones and somewhere between the two, there would be an initial synchronisation. There after things would be happening as it is. So, this needs to know the specific interface characteristics. So, once it knows the interface characteristics, that is it. So, that is what it says it does not need to know anything more what this channel encoder is going to do with this particular output. So, that is what is being send over here.

So, that is what we have already explained and the other important thing which we need to look at is the concept of layering. So, layering if we think of layering is as I have mentioned that you want to break it down into small parts. So, basically layering is about breaking into logical smaller parts, but not just breaking into random parts, but which are meaningful and as we go through, we will see different layers of communication system as we travel down through the course. So, we have already talked about one kind of broad level layering over here. We can look into further details.

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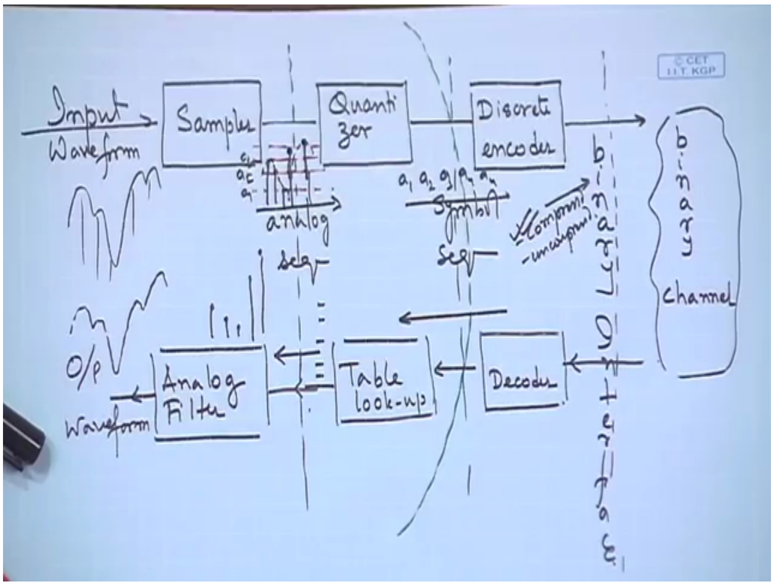

So, if we are taking about the source, so let there will be some input wave form and it would go through sampler in the same fashion as we have discussed. The higher level one is sampler is followed by quantizer. A quantizer is followed by the discreet encoder and a discreet encoder sends out signal to the binary interface which we have described before.

So, we have defined this binary interface before. So, we will write what we see there this whole thing that it sees could be thought of as a binary channel. This is a bit different compared to what we have discussed earlier. I will explain that there will be this discreet decoder what table look up, sorry the table look up comes over here followed by analogue filter and then, you have the output wave form, right. So, now if we see this earlier picture, if we come at this particular picture, I have briefly stated over here. So, now we are actually encountering that situation.

So, if I look at this situation at this point, we can say that the output is an analogue sequence because this is a sampler and it converts this analogue wave form. So, it will be sampled at specific point and the output that goes is 1 2 3, may be 4 5 as if this has been quantized, right. So, this is the kind of sequence that goes through this particular interface in this direction. Same would go out from this. I know there is slight difference that the levels that goes out could be a specific level because this is quantized version and then, the analogue filters. So, basically one could expect an output from here which is like this and then, this that job of the analogue filter would be to make it continue its kind of D to a conversion you can think of. So, its job would be to reconstruct this wave from right. So, that is how it is going to happen and if I look at here, what we are going to get is a symbol sequence. Why is it so? It is because these will pass through quantizer. A quantizer would mean that you are having different levels.

So, each level could be assigned a particular symbol. This could be lets say a1 a2 or a b c d, a3 and so on. So, what is going out is basically sequence of a1 a2 a3 maybe a4 and so on and so forth. The decoder is similarly going to give such sequences or levels which were there. Those sequences could be converted to signal levels and would be send out. So, this is the symbol sequence. The discreet encoder would map this particular symbol to a particular sequence which depends upon the types of encoder. Now, if you are not doing any special encoder, a very simple straight forward encoder would be PCMN encoder. That means, you would put 0 0 0 for the level 0 and 1 1 1 for the maximum voltage level.

If there are 3 bit quantizer and you say that this is uniformly quantized and whatever bit sequence comes out of it goes out of them encoder, whereas if you have a source compression technique which uses some of the probabilistic characteristic of this particular source because of this particular wave form, it is going to produce binary sequence which is not necessarily this same as corresponding to the levels of these particular symbols that we have. So, this could be binary sequences, could be compressed or could be uncompressed depending upon the type of application. Generally we have a compress sequence output at this particular point. So, now if we carefully look at this particular picture at hand, if we want to see the system at this point, if we want to see the sequence at this particular point, we can say that this whole thing is a channel which is a symbol sequence.

If I am going to see the system here, I can say this whole thing is a channel where the input is an analogue sequence, the output is an analogue sequence and if I put a boundary here, I would say the whole thing is a channel where analogue signal goes and analogue signal comes out, right and the analogue communication part of it would happen somewhere in this part.

So, all we try to see is that by virtue of breaking into different layers as we have defined and defining very specific standardise interfaces, one can break down the problem into smaller parts, handle that problem independent of what module is following it and just depending upon the type of specific interface that lies in between. So, for example this analogue, this sampler and analogue filter would work hand in hand. These two would work hand in hand and this two would work hand in hand.

We stop this particular lecture at this point. We continue further in the next lecture and finally, we will start talking about source encoder in later lectures and we will also cover these aspects in the upcoming lecture from now.

Thank you.