Communication Networks

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Module - 07
Data Networks
Lecture - 33
Broadband Access - Dail Up/ADSL

So, in the last lecture, we have already talked about this layered structure and then we have seen how each of the components in the network or even the end components or end users, how they actually handle those layers, ok. So, that is something with the help of means of successive addition and stripping off of headers. So, how they function, means function we have already understood.

So, what will be now starting up is something called the data link layer. But before going into the functionality, full functionality of the data link layer we would like to because the data link layer is mostly the access part of the network. So, we would like to see that what was the initiative initially for doing this access of the network for data.

Earlier we had access which was TDM access for voice communication. So, that was already there, that infrastructure was there how people have modified that infrastructure or put something, some functionality on top of that infrastructure to go towards connecting data into the network. So, this is something that we will be trying to study in this particular class, ok. So, let us try to see what is that we are targeting.

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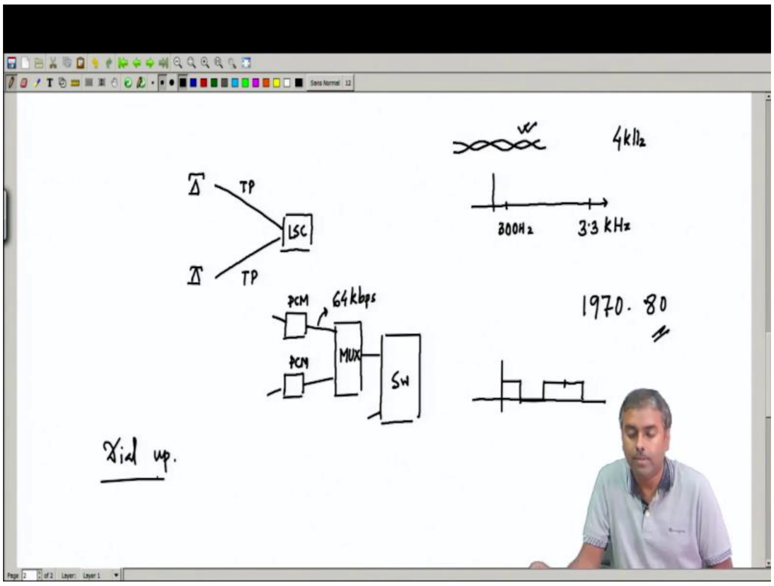

So, earlier what was happening? We had a telephony connectivity, ok from the home, and that telephony connectivity was going to from multiple homes in the same locality, was going to the local switching center, ok. And in between these were actually generally twisted pairs. So, those you might have seen them the black foiled copper wire actually twisted, and that used to be our telephony wires actually, ok. You will be seeing them as whoever has a landline in their home.

So, that used to be the method. These twisted pairs were capable of transferring data, not transferring data, and transferring voice. What was the band of a voice signal? So, it was generally from 300 hertz to 3.3 kilohertz that was the band, ok. So, it used to, mean this twisted pair was capable of at least handling up to 3.3 or 4 kilohertz. So, it is capable of it we used to say that it has a low pass effect, any kind of transmission line will have a low pass effect. So, it is band is limited up to 4 kilohertz, ok up to certain distance, ok.

So, this 4 kilohertz was the band restriction. So, beyond 4 kilohertz you cannot transmit anything. This was good enough because the voice signal was already the analog, actual analog voice if you transmit through electrical media. So, if you convert through a transducer from a voice signal to a corresponding electrical signal then it will always occupy up to 3.3 kilohertz. So, the 4 kilohertz band of this particular twisted pair was good enough.

So, everybody was supplied a twisted pair to their home and then a telephone receiver or transceiver, ok which was the transducer also. So, that used to be the case now suddenly that used to go to the local switching center. And what local switching center use to do? We all know; that this voice means whatever will be coming over here that will be first PCM encoded.

So, every voice will be PCM encoded, and then there might be some multiplexer and then there can be some switch, ok or it might, so the local switching center might have an overall switch where multiple such multiplexer also might be connected, ok. So, this used to be the fate of the voice.

So, voice was getting digitized at the local switching center. You transmit through the twisted pair analog voice that was first means PCM encoded; that means, digitized with 64 kbps data rate. So, that is where you get 64 kbps. After that, it is all the story of multiplexer switches, all kinds of switches, time switches, and space switches which we have discussed. So, this used to be the network, ok.

This network had already been there for more than 50 years, when data networks came into the picture around the 1970s and 80s, ok. So, 1970-80 around that time people started thinking about, ok maybe I need to also get connectivity, I have a computer, I need to connect my email server, I need to see the web page, I need to browse them and so on, lot of applications started coming in, ok.

So, after that YouTube came, all those video streaming services came into the picture, IPTV came into the picture, and then lots of services on facebook, twitter. So, all kinds of things started coming. So, this started becoming popular.

But, initially in the 1970s-80s people started thinking how do I get this data access from my computer at my home? So, then they thought there was one possibility that I start constructing another network, I start laying means again some cables to the home and then go to some switch. So, whichever way data networks operate, so entire things I do.

But this was a costly affair because already there is a twisted pair going to your home. Immediately replacing all of them and then putting some more connectivity towards getting this data connectivity, at that time data was not that popular and nobody wanted to actually pay this much service charge for this small data connectivity, occasionally you are seeing some means sending some email or just browsing the web for that you do not want that kind of infrastructure cost that, ok.

Again, another you have to take, you have to put a layer of cable towards your house, and then all the infrastructure has to be built up. So, nobody wanted to do that. They were starting to think can I give broadband connectivity or this data access through the existing infrastructure, this is where dial-up and the ADSL, ok digital sub or DSL, they used to call first ADSL was the advanced part, so digital subscriber line, ok. So, that started becoming popular.

So, what was that thing? That will start, first start to analyze because this is the historical way of delivering data and we have to learn from here because in networking so far this was the story that never you replace the earlier existing infrastructure. That is not cost-effective. Because you completely take out the earlier already existing infrastructure, and you put full infrastructure for everybody to connect that will be hugely costly for each user.

So, you do not want to do that. Rather, you do it gradually, or you do a kind of brownfield installation where already existing infrastructure you somehow reuse them, and that should be the technological challenge, that how do I reuse for my purpose and give the facility, give similar kind of facility, and slowly upgrade, ok.

So, all upgrades should be gradual and as backward compatible as you can. So, this was the target when people first started installing this broadband in the home. So, what they did was a very simple thing. So, they said, ok, this up to 4 kilohertz, it can support. Why cannot I use within that 4 kilohertz and do something, the data also will be carried over there. But, how the data will be carried data this is digital data, right?

So, it is like something like some 1 0 1 1 something like this. So, this is the data which is a baseband kind of data. It is not modulated. So, it cannot be going over that band, this 300 to the 3.3-kilohertz band, it cannot go over that. So, therefore, I would have to do something to facilitate this data transmission and that was the first initiative of this dial-up.

So, what was the initiative? Let us try to appreciate that part.

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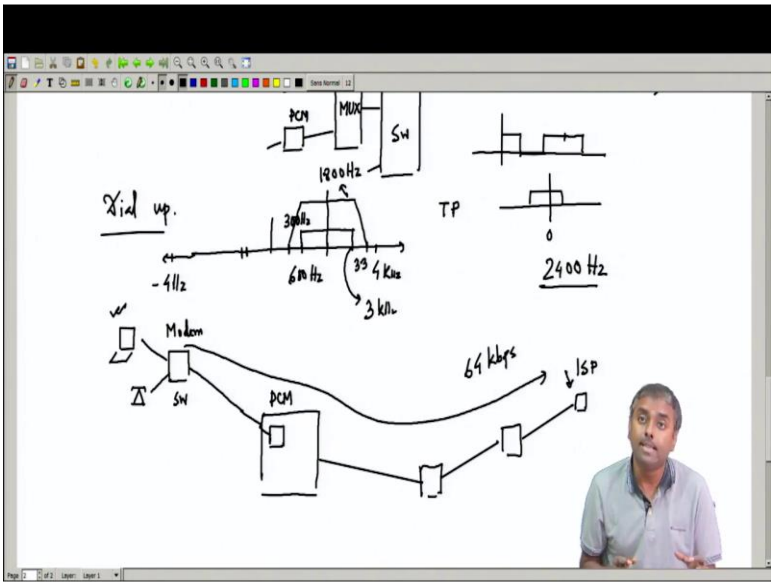

So, I already have seen that we have whenever we use twisted pair, I have a bandwidth of up to 4 kilohertz, right, 4 kilohertz. And if we take this Fourier representation, so minus 4 kilohertz, that is my band, right? And I can also say that it actually is like data, so it starts at 300 hertz.

So, what I can do is what they actually did; so, this band from 300 to let us say 3.3. So, in between from 600 to 3 kilohertz, 600 hertz to 3 kilohertz that particular band they have taken that this is where we will be doing data transmission.

What is the central frequency of that? That is this is the 1800 hertz. So, 1800 hertz is the central frequency, and whatever data we can put into that band. So, data is generally this kind of data that is baseband data that occupies the band from 0 to some frequency. So, I can give a small modulation and shift it towards this band. The modulation frequency will be 1800 hertz, ok. The overall band is 600 to 3 kilohertz which is 2400 hertz. Within this whatever I can put I will put as data.

So, digital data I will take. Now, I will modulate it with a central frequency of 1800 hertz which has a bandwidth of 2400. If I do that then this data will be exactly sitting in the voice band and I can then transmit it. But, if I do that what will happen to my voice? Now, I cannot communicate my voice because if I put voice and data together that will be colliding.

So, that is when people started thinking about dial-up. So, in dial up what you do, you instead of this telephone, you put a switch over here, [FL] basically the home network was modified. They used to put something called a modem. From the modem, you can connect your telephone device or you can connect your computer, but this modem has a switch.

So, it is also a switch, it decides which one to be connected to. If you are connecting your data, means connecting to the data network at that time voice connectivity is not possible because he will think that the link is already engaged. So, in dial-up, you used to actually dial a number and then you engage this one.

So, if you actually take means you connect a connectivity which is a TDM connectivity remember, you made a TDM connectivity, but that TDM connectivity at that time you are not using for voice transfer, but you are using it for your data transfer.

And you are fooling the system, you are putting them inside the same band. So, basically, it will go to your local subscriber loop, and the PCM encoder, we will think that this is also the voice signal because there is no difference. Whether it is modulated data or voice data it occupies the same frequency band. So, basically, he will take that, he will further sample it, and do the PCM encoding, as if it is the voice signal. So, you used to mean through this dialog connectivity you used to fool the whole system as if I am doing a TDM connectivity.

And what they used to do? They used to when they do this dial-up, they used to connect to whatever through this network. So, you have this telephony network, right, through that network the one at the other end that ISP, Internet Service Providers, phone number you used to connect or that has a particular number which was there, you always connect to that particular ISP understood. So, this is what used to happen.

So, you used to completely fool the whole system. Existing infrastructure was fooled as if you are doing almost like a circuit switch connectivity. So, he used to dial, this whenever you connect the data he used to dial this ISP. So, through the switches intermediate switches, he used to connect to this ISP and he used to give a PCM connectivity or 64 kbps through this entire circuit switch network.

In between it used to be a multiplexed switch, time switch, and space switch everything was happening, but inside he thought it was all voice data he was transferring, but actually it was not voice data. It is digital data that was in such a way that it looks like occupying the voice band only. So, that signal used to be transferred over here, ok?

So, this was the way they basically started using the same infrastructure for data connectivity. So, now, your machine will be generating data, and that data through this modem, you will be transferring, ok? Through this modem, you will be transferring. The method was the way I have explained. Now, we will explain what exactly the modem does. So, that we will also explain. And what kind of data rate you can get, so those things we will explain. But, this is how people used to do at that time.

So, in dial up what you can do? So, let us try to see.

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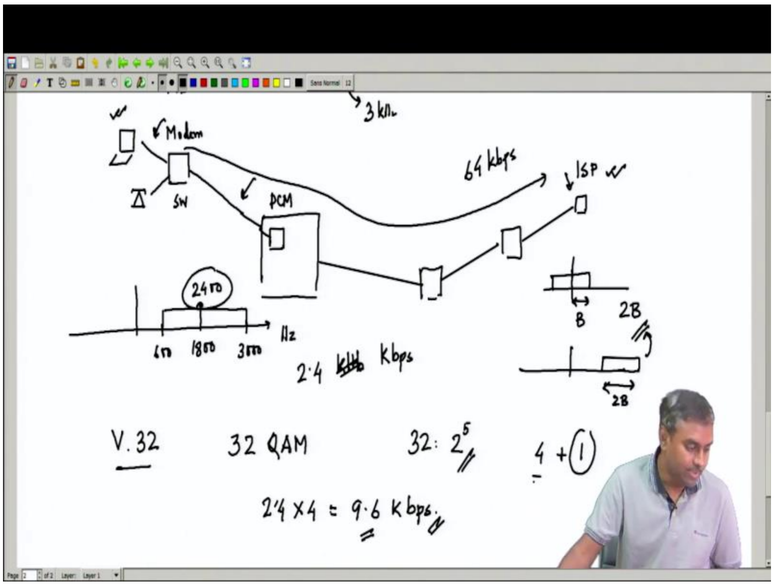

You have a band of 600 to 3 kilohertz, ok. So, this is an overall band of 2400 hertz and the center frequency was 1800, right? So, what kind of modulation you can use? People started thinking, ok, we might use all kinds of higher order modulation because only if 2400 we take that will be a very low data rate that we can transfer. Generally, the means of actual communication that you can do if you do baseband data transmission, so baseband data transmission if you do, so our understanding is every half hertz 1-bit you can transfer, ok.

So, whatever the bandwidth is, twice that bandwidth. So, basically, if this is B, it is linked to Nyquist sampling also in a way. But if it is B, you can actually 2B bits per second you can transmit with the very basic modulation, let us say BPSK or something like that, ok, or if you just transmit baseband data then we should not also call about BPSK. Just on a, if you try to transmit this is the highest bit rate that you can achieve with a B band, ok?

So, now, if you modulate it whenever you modulate this entire thing gets translated. So, basically now with the 2B band, you can actually transfer 2B, ok. So, if my bandwidth is 2400 with the very basic modulation scheme if I do BPSK, then 2400 bits per second only I will be able to transfer. So, 2.4 kilohertz is the maximum I, kilobits per second sorry not kilohertz, kilobits per second that is the highest data rate that I can get.

Now, I can go for higher modulation. So, initially let us try to think about these dial-up standards a a little bit. I will not go into the details of this, but the first standard that came was Vdot 32. Why 32? Because they wanted to actually transmit this data with a modulation of 32 QAM, ok. So, 32 QAM means 32 is 2 to the power 5, right, so that means, 5 bits per symbol.

So, if you do 32 QAM, the symbol rate will still be 2.4 kilo symbols per second, or the mod rate will be 2.4 kilowatt. But because per symbol you have 5 bits that you can represent or 32 representations are there, so 5 bits you can represent, so overall data rate will become 2.4 into 5 times that.

But, out of those 5 times because now you are doing a very high modulation, ok, so there is a chance of error. So, that is why you have to also do error control coding. So, out of these 5 bits actually 4 bits they have reserved for data transmission and 1 bit was for control. So, this was for this was a redundant bit where they used to use this trellis coding modulation to actually do error correction, ok.

So, that was the case, therefore, 4 bits effectively per symbol, you can transmit data, so that is why 2.4 into 4, ok. So, 9.6 kbps was the transmission rate. That was the V 32 modem where people could through this voice band they could achieve 9.6 kilobits per second. At that time that was quite high.

Today, when we think about, ok I need mbps data rate and all those things, of course, this was very rudimentary or preliminary. But, at that time that was sufficient because nobody wanted to do a whole infrastructure layout to get some data rate. So, they were happy with the very low minimum data rate they could get. And from there they wanted to at least see that the infrastructure does not have to be changed.

Over here the same thing has happened. So, what people used to do? Just supply a modem. What was modem will talk about that later. So, the modem does this, this 32 QAM modulation exactly putting in an 1800 a bit with a 2400 hertz bandwidth. So, that was done by the modem. So, this modulation and on the reverse direction demodulation, so that is why it is called modem.

Mod and demand, these two functionalities it used to do. And it used to also switch from telephone to this one. So, whenever it was going for data it used to also dial, but that was for the dial-up connection. So, it used to dial to the ISP number and then give connectivity through the network, this kind of 64 kbps data connectivity, but within that 64 kbps, he could transfer that 9.6 kbps data, ok.

Then, people started thinking if it is a 64 kbps link, why cannot we go up to 64 kbps? But, what was the restriction? Restriction was over here, this twisted pair sorry, over here, this twisted pair. Twisted pairs cannot take a huge data rate. So, people started coming up with going towards the Shannon capacity and started coming up with this kind of higher and higher modulation.

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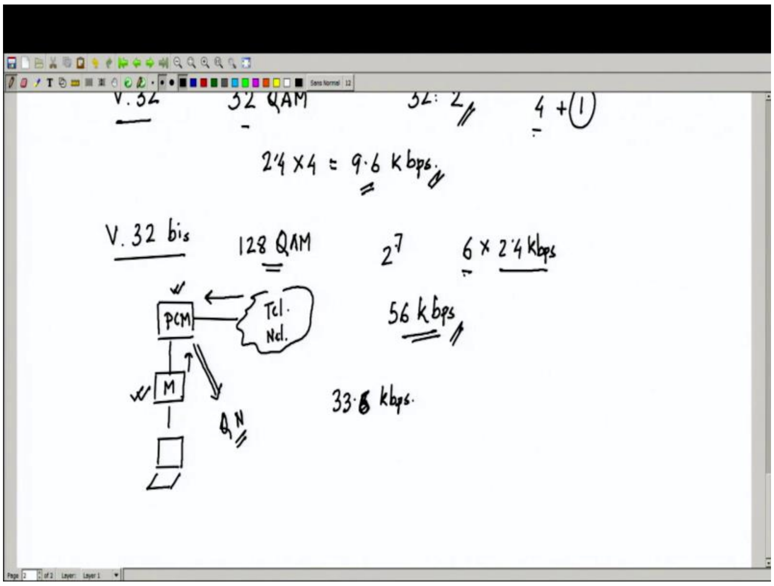

So, the next standard that came up over the years was V 32 bis. What did they do? They did nothing. So, instead of 32 QAM, they actually reached 128 QAM. So, just they enhance the constellation, ok.

So, you have 128 constellation points. Of course, it was a very congested constellation. So, the error rate was even higher, but they can enhance the design of the modem so that that error rate can be handled. So, enhancing the design means all noise cancellation and all those things they used to do, ok?

So, that modem 128 means 2 to the power 7. So, now, effectively 7 bits. Out of 7 bits, 1 bit was reserved for this error control coding. So, 6 bit, the 6 into 2.4 kbps because 2.4 kbps you can always get with the basic rate VPSK. Now, each symbol is effectively carrying 6 bits, so 6 into that. So, this was the next modulation and this was the next rate they could achieve; from 9.6, they actually increased one and a half times, ok. So, that was the next achievement that they could do, ok.

But, then they thought as I have told them, they had to push it towards this 56 kbps. The question was is it possible to go up to 56 kbps because sorry push it towards 64 kbps is it possible to go up to 64 kbps, ok? So, 64 kbps was not possible, ok because that is like 64 kbps is the data carrying link capacity, and you are pushing with a modulation, you are pushing towards that Shannon capacity gives a restriction to that. So, of course, you will have to add some redundant bits, and it will never go up to 64 kbps.

So, they, that is why they could reach up to 56 kbps, that was the standard modem. If you now think about the highest form of modem that was always termed as 56 kbps modem, ok with a very higher modulation scheme. You have to go beyond 128, much beyond that, ok. So, you can think about the constellation, you can think about how close those constellation points will be, and how small the error margin is. So, that will be happening.

So, now, up to 56 kbps they could reach, but there is a problem. The problem was that downstream they could reach up to 56, but upstream they could not reach this 56 kbps. What was the reasoning? Let us try to understand that part. I will just end this lecture with this particular reasoning why modem, once we started pushing towards higher and higher modulation, so that we can go up to 56 kbps and then that day you could see that through dial this is the highest modulation we could achieve. We cannot go beyond this. That is when the DSL came, then ADSL came, and all those things. We will talk about that also later on.

But, let us try to now understand that a dial-up connectivity can really go up to 56 kbps upstream, downstream it was possible. We will try to see what is the difference between upstream and downstream. So, let us try to see what generally happens over here. It comes from the system model. So, I have this kind of machine which gets connected to the modem. The modem does the dial-up connectivity, and then through the twisted pair it goes to the PCM encoder and this PCM encoder is the culprit. From the PCM encoder, of course, it goes to the telephony network, ok.

Now, this PCM encoder was the culprit because of what was happening. See I was fooling the system, and of course, the system will cause me some trouble. So, this is the trouble. Let us try to understand that. What I was trying to do? Through the modem digital data, I was encoding them in such a manner by modulation I was doing, making it in such a manner that he was thinking that it was a voice signal.

If it is a voice signal, what PCM encoder do? PCM encoder does sampling, 8 kilo samples. So, basically, I have digital data that is modulated, and through modulation, some kind of modulated signal will be going over there, that modulated signal I again sample and after sampling, I do A to D conversion. This is the culprit.

Whenever I do an A to D conversion, I will add a quantization noise. This noise will be coming irrespective of how well I make my modem. I can make my modem as good as possible, with all noise cancellation very nice, very high order modulation, all those things I can do, but this intermediate PCM encoder I do not have hand on that, I can only do things in my modem.

However, the PCM encoder will always add quantization noise. That will kill my data rate because whatever I do toward achieving Shannon's capacity I will not be able to achieve to towards that capacity. I will always be shortened by this quantization noise and that is something that is being introduced by the system because I have not changed the whole system.

I am leveraging the system as it is as if I am fooling him that I am transmitting you a voice, you do whatever you do with this voice signal. But, in between that is data, but I am actually fooling him that this is an analog signal and he is encoding it with a PCM encoder and he is introducing quantization noise. So, that is restricting me towards going up to Shannon’s capacity of 64 kbps of course, 64 is also not possible up to 56 kbps that is not possible. So, that was the restriction in the upstream I could not do these things.

So, what has happened? Finally, I could reach up to 33.3 kbps something around that data sorry, 33.6 kbps this much data, I could reach up to that because of the quantization noise of the PCM encoder. On the downstream, on the other hand, there is an advantage, because downstream of what is happening I am giving digital data on this site, ok. So, that digital data in the PCM, does the reverse thing, it encodes into voice. But at that time this quantization noise is not added because whatever data is coming accordingly he is encoding that.

So, I am getting exactly the same level of analog signal, and corresponding analog signal. And that if I now take it, whenever I am actually again decoding it as data, I am not getting that added quantization noise. So, that is why downstream I was not having any problem, with this PCM-introduced quantization noise. So, downstream I could reach up to 56 kbps. That was the reason as you can see; that technology was restricting that the upstream had a lower data rate and the downstream had a higher data rate.

So, that is when people started thinking that maybe always this should be the case because the applications also were oriented like that. In upstream, we used to transmit a very small amount of data at that time. We used to suppose web page browsing, we used to just put some things or type something the webpage link and all those things, then most of the things were coming downstream. I was actually downloading pages from the server. So, the downstream data was heavy which was going with this particular structure also.

So, that is why at that time downstream data was always heavy and people started thinking that all applications would be like that, but that is not the case. As you can now see all the applications are coming where upstream data are becoming heavier. You are like facebook, twitter, to YouTube, wherever you are uploading things more than you are downloading things, that is when upstream data also can be so it all depends on the application.

People used to think that day because of the technology restriction, that probably the data rate will be means lower in the upstream, but that is not the case. But anyway, as you now understand how broadband access initially was started, what the restrictions that, and what data rate we could achieve using that technology.

We will still be on that technology in the DSL part and ADSL part. We will just briefly in the next class, we will briefly discuss how we have we could still achieve a higher data rate using the same infrastructure, and then we will abandon that infrastructure and we will try to see for the next technological innovation that can give us a higher data rate, ok.

Thank you.