Communication Networks
Prof. Goutam Das
G. S. Sanyal School of Telecommunication
Indian Institute of Technology, Kharagpur

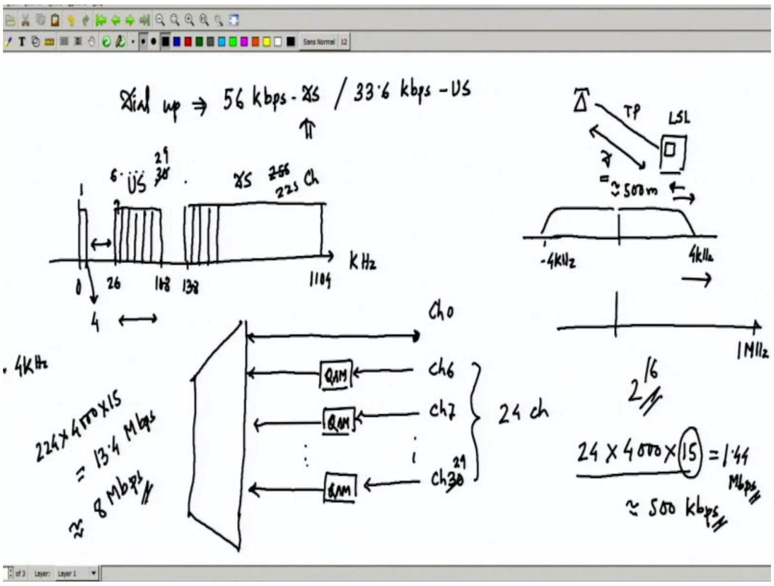
Module - 07
Data Networks
Lecture - 34
Broadband Access - DSL, Aloha

So, we have so far seen how broadband access could be facilitated by utilizing the existing infrastructure of TDM infrastructure. Now, we will try to see if we can because we have already seen that we could go up to just 56 kbps not more than that but the data rate or data rate requirement from the user side was ever increasing.

So, people started thinking that the limitation of 56 kbps beyond that we cannot go or we have to really come up with new infrastructure to really go beyond this data rate. So, that is where people started thinking still with the same infrastructure can we go further, a little bit further, what is the; what is the way of doing this? So, that is something we will try to see which is the digital subscriber loop or line.

So, that is something we will try to appreciate and then we will see how in the other context without using the same infrastructure we can come up with some more facilities for communicating data from one machine to another machine ok. So, what data networks how we can do? So, that is the aloha, slotted aloha, and all those things we will continue our discussion on that and we will try to see how that evolves into today's media access control protocol ok?

(Refer Slide Time: 01:55)



So let us try to see, what actually, what was the initiative to go towards, means a higher data rate compared to this 56 kbps that we have 56 kbps or this is downstream or 33.6 kbps upstream. So, that was the limitation of dial-up that is the maximum rate we can reach through dial-up. So, now, people started thinking can we beat this what might be the technology to beat this?

The first observation was see it was still a twisted pair so we remember that connectivity which was a twisted pair to the local subscriber loop and that was PCM encoded over here. So, this was the case and this was twisted pair, and twisted pair has we also know that it has a restriction, it is a low pass filter up to 4 kilohertz that is the restriction.

Now, people started investigating that ok if it is 4 kilohertz we cannot do anything. We have already seen that up to 4 kilohertz we can that is the maximum that we can achieve over here. Dial-up has already tried to achieve whatever maximum with all kinds of modulation schemes, error control coding, and everything they could see that this is the maximum we can go.

Then, people started thinking that is there a restriction that means this bandwidth can be pushed up by any means while using the same twisted pair because I do not want to change that up to the user every user already telephony line has already been installed.

Now, I cannot come up with new infrastructure or new wired connectivity. So, that I do not want to do, but can I do something else? What people could see is that this distance between the user to the local subscriber has an effect on that distance. So, they started thinking. They could see that if this distance has a kind of inverse effect as I increase the distance, the bandwidth or this cut-off frequency of this low pass filter of the channel gets reduced.

As I decrease the distance that might be enhanced and they could see if I allow that to be a few hundred meters. So, let us say 500 meters or something then this bandwidth can be enhanced up to almost 1 megahertz instead of 4 kilohertz this can go up to 1 megahertz, that is possible.

If the distance I take the order of 500 meters or so then they could start seeing that most of the homes from the digital subscriber loops are very close by and it was mostly within 500 meters because of the handling capacity of the digital subscriber loop it used to be a very small this one all the user used to be in the vicinity.

So, they could take that advantage they could see that ok, up to 500 meters I can really push this bandwidth to a much higher this one, and then what they started doing is something like this. So, they said ok let us take that band. So, this is in kilohertz ok?

So, this is 0, this point is 4, that means, 4 kilohertz that I will leave because now I have got a bigger band, I can go up to 1 megahertz. So, I left for the voice and then they started from around 26 to 108 they told me that is the band for upstream ok, and then from 138 up to 1104 or 1.1 megahertz, they put it for downstream ok.

And, all these channels means, all this band they have subdivided into channels of so over here they could put whatever band they have, they subdivided into a channel of four points some its roughly 4-kilo hertz, some 4.1-kilo hertz just to allow some guard band ok. So, they subdivided and they started encoding them as channel 1, channel 2, channel 3. So, basically, this was named channel 1 which was directly dedicated to voice.

After that few channels are wasted as you can see already. So, 4 more channels were wasted they did not allow anything. So, that the voice and data are completely properly separated from there they started counting channel 6. So, one then 4 channels are wasted after that 6 from their 4-kilohertz channel up to channel number 30 ok, and then from here again they have wasted a few more channels and then over here some more channels.

So, around 255 channels over here ok, over here that they could put. So, that is what they put in each channel of 4 kilohertz and in each channel, they started putting corresponding discrete multi-tone modulation. So, each channel has a central frequency. So, basically, they used to take data that data they used to modulate to that channel ok. So, it is like this what they used to do something like this. So, basically, channel 0 was for voice that is channel 0.

Channel 6 put a QAM modulation ok, QAM modulation at the central frequency of this one. So, from 26 to 30 so, 28 kilohertz taking that central frequency and a band of 4 kilohertz they used to modulate a QAM and they put it over here ok. Similarly channel 7 same thing and then sorry this should be on the same then they do multiplexing of this whole thing ok.

So, if I just see upstream. So, there are actually. So, if you see up to 30 maybe this should be yeah this should be 29 ok. So, there are 24 channels. So, 24 channels I can put 24 each one of them had this 4 kilo hertz band ok. So, 4-kilo hertz means 4-kilo simple samples in samples I can transmit and then whatever QAM you put. So, they put some kind of QAM where at least they could put 16 symbols.

So, 2 to the power 16 modulation scheme they have employed. Of the 16 symbols 15 were reserved for data transmission one was. So, 15 bits was the overall upstream transmission they could do ok which was as high as 1.44 megabits per second as you can see, that is quite high now, but of course, they could not go up to this 1.44 megabits per second.

Because of all these channels you are putting a very high modulation 2 to the power 16 kind of modulation that many QAM. So, this is very high modulation. So, some of the channels were very poor. So, they could not reach to that that kind of high modulation. So, some of the channels were absent whichever channel was having a problem.

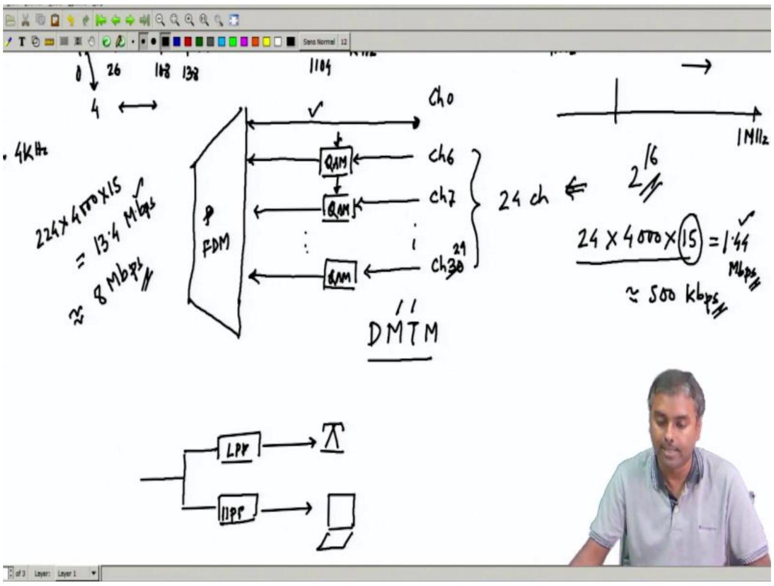
But, roughly up to 500 kbps, they could reach which was quite high. So, that was the technique of DSL that they started and downstream they have even more channels as you can see downstream was 225 channels. So, out of them basically, 1 channel they reserved and 224 channels, they have taken 1 channel reserved for some downstream other control communication.

So, 224 into 4000 because each of the channels is 4000 hertz so, into this and then 15 for their 2 to the power 16 QAM modulation. So, they could reach up to 13.4 Mbps, and again, roughly 8 Mbps they could always use it. So, they could reach up to the data rate of 8 Mbps sacrificing some of the channels because some of the channels might not be proper because of this high modulation they could not survive or the channel noise was so high that they could not actually put any data into that.

So, absent means making those channels absent you could reach up to a data rate of 8 Mbps downstream. So, that was the technique of ADSL. So, what ADSL did was nothing it was a simple engineering decision that distance bandwidth has some inverse proportionality. So, if I reduce the distance then I can enhance the bandwidth of the same twisted pair.

And, then they could actually be over here as you can see my voice channel still remains intact. So, earlier in dial if I transmitted data, I could not transmit the voice because those 2 were occupying the same band. So, one of them can be transmitted whereas, over here I have now the facility of duplexing these two things. So, my modem structure will be slightly modified as you can see, it will actually have whatever signal comes I segregate into two things and, I put a low pass filter and I put a high pass filter.

(Refer Slide Time: 14:06)



Of course, the low pass filter will be taking the voice and it will be put into my telephony and this will be going to my data part. So, now, because of this low pass filter, and high pass filter, I do not have a switch, both things can be simultaneously transmitted because, in the frequency domain, I have done frequency division multiplexing over here sorry. In the frequency domain, they occupy separate frequency channels.

So, I have no problem now, I can actually the modem to simultaneously facilitate both data and voice communication. So, that was the advantage of DSL or ADSL ok? So, what DSL did solved two problems, one is it could enhance the data rate and it could facilitate simultaneous transmission of data and voice. So, you could get whenever you take ADSL connectivity your modem will have 2 ports, one goes to your telephony, and one goes to wherever you will be putting ok.

So, it might be your computer with the R J 45 interface. So, whatever it is. So, it will have it collect the data will do this discrete multi-tone modulation. So, this is called discrete multi-tone because of what is happening. So, basically, he is taking this data if it is upstream data, he is segregating it into 24 channels each channel is separately modulated each one of them has a different center frequency. So, that is why it is called discrete multi-tone modulation.

So, multiple frequencies are modulating this is centered around 28 kilohertz, this is centered around 32 kilohertz, and so on. So, basically, they have separated this one. So, it is doing discrete multi-tone modulation it is not OFDM it is a discrete multi-tone modulation you have given a separate guard band between them. So that, you can separate them out. So, this multi-discrete multi-tone modulation you do and with an FDM multiplexer you aggregate all of them and transfer it ok.

So, this is what happens in your modem now the modem structure becomes a little more complicated instead of 1 QAM you have multiple QAM. So, of course, the user equipment and the modem equipment will be a little bit complicated little bit more extensive, but with that, you get a huge facility. Now, you can transmit your voice and data simultaneously you can get a huge data rate of 1.44 Mbps compared to 56 Kbps which was very low.

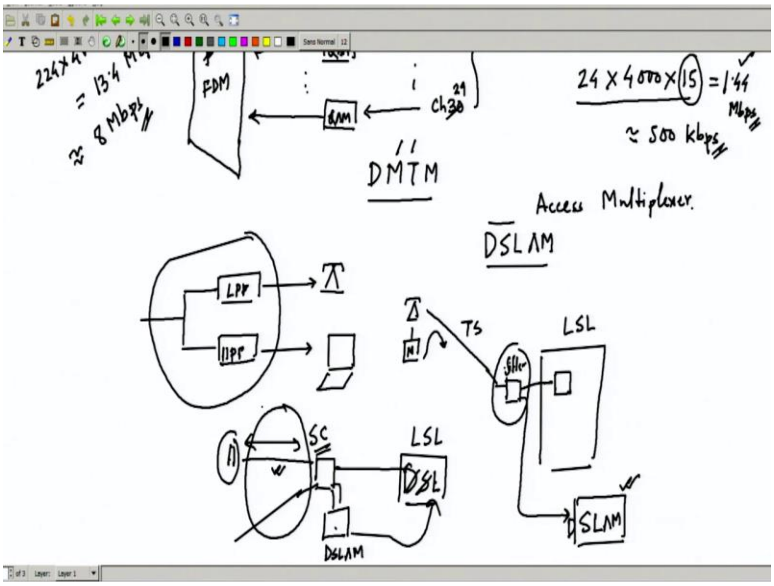
So, that is the facility you are now getting upstream downstream It is even higher 13.4 Mbps instead of just some 56 k Kbps that used to get. So, there is a huge increment of data rate that is one thing which has happened and of course, data and voice simultaneously you can transmit, but now let us try to see what is the disadvantage that has happened. So, of course, the design cost has been increased that is one thing.

The second thing is always you have to ensure that this distance between your local subscriber loop and your means home or the telephony connectivity that you have taken that has to be within some value. Otherwise, you cannot do this otherwise you need to put a booster or something which will amplify the signals. So, you can still get proper connectivity ok? So, this is one thing that has happened.

Now, let us try to see once I do this ADSL what happens to the other end of the communication part. What happens on the other end, is you directly do not put it into a PCM encoder now because now PCM encoder does not understand this. He will only take the voice, but the rest of the data is at higher modulation means a higher bandwidth. So, he cannot understand those things. So, there must be some separate local subscriber loop. So, that is another disadvantage.

Now, the local subscriber loop has to be modified, or an added component has to be installed in the local subscriber.

(Refer Slide Time: 18:48)



What is that, that is called DSLAM. So, this is called a DSL access multiplexer. So, what is this DSL access multiplexer? So, it is like this, basically from this telephony followed by a modem, of course, you will be launching it over here, but this is a twisted pair. So, over here before putting into your local subscriber loop and corresponding PCM modulator what you do, you segregate them out with a filter.

So, basically, this is a filter that separates it and will have similar kinds of things kind of structure the LPF and HPF. The low pass filter output goes over here, but the high pass filter output you take out and then you put it into your DSLAM. So, for every user you do this, the high pass filter part you take out and put it into your DSLAM, and then DSLAM actually encodes the whole data. So, basically what you have done is eventually you have shortened the network.

So, sometimes what people used to do this DSLAM they used to if the distance is too high than inside a street cabinet. So, suppose your home is there this is the digital subscriber loop, or sorry the local sorry it is not that is the local subscriber loop which is the local switching center where the PCM encoding is being done in between you put this filter device. This you supply to this one as it is, but over here this is the street cabinet actually.

So, in the street cabinet whichever homes are coming, so from you put this filter device and take all of them. So, filter device you take all of their output and put it into DSLAM. So, that way you shorten the distance this distance becomes shorter because at the DSLAM that modulation gets terminated whatever discrete multi-tone modulation you have implemented gets terminated.

So, therefore, the distance effective distance of those modulations that are at the higher frequency band is not generally supported by this twisted pair. So, you actually separate them out you put it in DSLAM, and from DLAM you start distributing it in whichever technique you have. So, from DSLAM you actually again you encode that data overall data into a higher modulation sorry higher multiplexed data stream and you put it into a local subscriber loop to take it further.

So, this is something you can always do ok. So, they will all be delivered to your ISP provider from that ISP provider his own network he will forward it to whichever server you are trying to connect to. So, then there will be corresponding routing and all other things that will be happening over there, but this is how at least you get a temporary solution where the last file still does not have to be deployed or redeployed.

So, DSL was that solution some intermediate solution as you can see dial-up there was a huge advantage because dial was taking the entire network as it is nothing had changed just put in a modem and you are ready with that, but dial-up having a problem because it has a lower data rate. Whenever you try to enhance the data rate what happens you come to this DSL technology, but this DSL technology requires a lower distance and it requires additional modulation which does not go through the original voice transmission.

So, that is why you had to install a new device called DSLAM the access multiplexer which has to be installed somewhere in between a straight cabinet probably where the distance of this twisted pair is within the 500 meters that you have already conjectured. So, that has to be happening and this additional device has to be installed where the modulation demodulation will be taking place. So, this device has to be additionally installed.

But, the advantage is you still have not considered replacing the last infrastructure which is the most costlier one. For every user you have to install that thing that you are not doing. DSLAM still is a centralized device that actually collects data from multiple users and then aggregates them. So, that cost gets shared among multiple users. So, that infrastructure you can still build, of course, DSL technology will have a higher cost compared to your dial-up technology.

Dial-up technology is just the modem cost, but over here modem plus this DSLAM whatever you are putting which is getting shared by multiple users that cost also has to be added to it and this has to be added in a street cabinet. So, they are also the proper I mean shielding and all those things have to be done. So, that is the added cost you use, but you still try to reuse some portion of the technology as much you can to enhance the data rate because your requirement was not being satisfied by dial-up.

So, now by doing this, you are getting this added supply of data rate. So, that is the advantage you have got. We will probably end our discussion over here because I do not want to go into the details of this there have been so many other modifications you had ADSL, and VDSL people tried to enhance this one. There was a standard called ISDN that was coming up, which is also to facilitate means data means to provide data rate very high towards your home using the telephony connectivity.

So, there were a lot of things that were happening in that aspect. So, we will probably in this course we will have this much liberty to discuss, could see how the network evolves that is a very important philosophy that always the installation has to be kind of brownfield. You cannot always do green field deployment from scratch whatever new technology I have learned let's implement that you will not be able to do that most of the time.

So, this is a very good example of how telephony networks slightly being bent towards facilitating data networks, that was the initial part of broadband access which is still being popular ADSL connectivity most of you are still using ADSL connectivity at your home. It is a very popular technology these days also for data connectivity, but now things are getting changed you are getting 5G connectivity you are getting probably fiber to the home connectivity.

So, all kinds of other aspects of connectivities are coming up. We will discuss them and we will continue our discussion on this layered architecture over here, this was a detour probably just to facilitate this particular new technology that we have seen over the years. We will now again go back to our root discussion of different layered architecture in the next class ok.

Thank you.